CHAPTER III

SEISMIC: AN OVERVIEW

3.1 INTRODUCTION

In spite of the scientific and technological development, nature has demarcated to the scientific community to think or predict some natural phenomenon which can be considered as a natural warning. One of the natural warning is Earthquake which is the most damaging natural activity caused due to the sudden release of energy in the earth’s crust. Developing countries are more vulnerable to hazards because of their increasing rate of development and urban growth. The lack of proper disaster management leads to increase in risk in more densely populated areas. Most of the growth in civil structures and infrastructures will concentrate in the developing countries for the next few decades. The sole purpose of all mitigation processes in the world is to save human and property from the effects of natural disasters. The pre-planned mitigation activities help to save people and also reduce the effect of disasters.

Earthquakes can create disasters of high magnitudes when they hit highly populated areas. Damage and loss estimated to quantify potential, social and economical losses. Even it is complex process, loss of estimation will be useful tool for developing emergency preparedness and for promoting seismic risk mitigation. The advancement of techniques and tools used helps the urban planners, risk managers, emergency managers, decision makers to understand the impact of earthquakes and plan safety measures.

Earthquake disasters occur mainly due to the collapse of buildings and structures triggered by ground motions. It is, therefore, important to predict ground-shaking levels in order to determine appropriate building code provisions for earthquake-resistant design of structures. This involves extensive analyses and development of appropriate seismological models; namely, seismogenic sources, seismic site conditions, and ground motion predictions. The hazard products, viz. data and maps, constitute important tools for framing
public policies toward land-use planning, building regulations, insurance, and emergency preparedness.

3.2 SEISMOLOGY: DEFINITION

Seismology is the study of stress and changes in stress within the Earth and other planetary bodies, particularly earthquakes caused by slip and rupture along faults and by magmatic activity. The field is also concerned with earthquake risks and hazards, as well as the propagation of elastic waves through the surface of the Earth. Seismology is the scientific study of the seismic waves generated by earthquakes.

Seismic activity is defined as “the vibration of the ground due to the release of elastic energy from the breakage of rock within the earth or an explosion”. The phenomenon is commonly referred to as an earthquake, but while seismic waves can be either body waves or surface waves, an earthquake radiates seismic energy as both types of waves.

Most seismic activity is caused by the movement of tectonic plates. As these plates shift, rocks around the boundaries of the plates are deformed, which then causes elastic energy to be stored. When pressure leads to a fault segment slipping, the results can be extraordinary. Seismic activity has many other causes as well, including crustal loading, volcanic or hydrothermal activity, and the re-activation of very old faults.

Humans may also cause seismic activity through fluid injection, reservoir filling or demolitions. To record seismic wave motion, scientists measure seismic activity with a seismograph, which is a very sensitive instrument that very accurately reads the magnitude and location of the seismic activity being picked up.

While it may be very destructive, seismic activity is also responsible for many treasured landscapes and topographic locations that people enjoy for their beauty and unique features. Many national parks, for example, are in areas where large earthquakes or other plate tectonic activity occurred in the past.
Scientific and practical objectives of seismology:

- To learn about the structure of the earth and physics of earthquakes and
- To make the engineered human environment safer

### 3.3 DEVELOPMENT OF SEISMOLOGY

The American scientist John Winthrop (1714–79), often called the founder of seismology, was one of the first to make scientific studies of earthquakes. In 1857, R. Mallet, an Irish Engineer, travels to Italy to study damage caused by an earthquake near Naples. His work is generally considered to be the first serious attempt at observational seismology. His contributions,

- Earthquakes waves radiate from a central focus
- Earthquakes can be located by projecting these waves backward toward the source
- Observations should be established to monitor earthquakes

E. Wiechert developed the first seismometer with viscous damping, capable of producing a useful record for the entire duration of ground shaking. B.B. Galitzen developed the first electromagnetic seismograph in which a moving pendulum generates electric current in a coil and establishes a network of seismic stations across Russia. By analyzing seismic data from a 1909 earthquake near Zagreb (now in Croatia), the Austro-Hungarian meteorologist Andrija Mohorovičić discovered a boundary between the crust and mantle, now called the Mohorovičić discontinuity or Moho. Seismological studies were furthered by the U.S. seismologist Charles F. Richter, (1935) who invented the Richter scale to determine an earthquake's magnitude. Each successive point on the logarithmic scale represents an increase by a factor of 10 in wave amplitude. A modified Mercalli scale, originally developed by the Italian seismologist Giuseppe Mercalli, is also based on the earthquake's effects on the surface. The Worldwide Standardized Seismograph Network (WWSSN), consisting of well-calibrated short and long-period seismographs, is established in 1961.

A team of researchers recently discovered an ancient relic hidden within Earth: a tectonic plate resting beneath the southern Indian Ocean. Scientists have found other
tectonic plates that sank below Eurasia and North America, but here Simmons et al. describe the unique structure of this newly discovered slab, which they named the Southeast Indian Slab (SEIS). The slab has at least one feature scientists have rarely seen before: It maintains its slab-like structure all the way from the upper mantle near Earth’s crust down to the region where the mantle meets the planet’s superheated core.

Researchers can make out structures beneath Earth’s crust by examining the speed at which seismic waves generated by earthquakes and similar Earth-shattering events—known as P and S waves—travel through Earth.

Once this tectonic slab was identified, the team looked at the region’s tectonic history over millions of years to determine where and when this plate was on the surface. Tectonic plates usually sink down into the mantle at a rate of about 1 centimeter per year or more; they don’t necessarily melt but instead bunch up at the base of the mantle and eventually assimilate or become undetectable as their temperature increases. However, if the researchers accurately estimated the timing of their newly discovered slab’s subduction, this slab must have stalled in a transition zone before descending deeper down into the mantle, allowing the slab to persist in the mantle longer than any other known plate.

### 3.4 SEISMIC WAVES

Earthquake generates seismic waves such as longitudinal waves, shear wave and surface wave. Out of these, surface and shear waves are destructive but these waves are slower than longitudinal waves. The longitudinal and shear waves are also known as P and S waves. Body waves propagate through the entire body, whereas surface waves travel along the surface of the medium. Seismic body waves include two different types according to the relative direction of disturbance with respect to direction of propagation: P- and S-waves. Seismic surface waves also include several different types, the Rayleigh wave being one. Velocities of P- and S-waves (Vp and Vs) are determined by several aspects of a material called elastic constants (or moduli). If a material’s shear modulus vanishes as with fluid, then only P-waves, not S-wave, can exist and this special type of
elastic wave is called acoustic waves. Velocities of surface waves are governed mainly by shear modulus of materials. Seismic waves used for the survey can be generated in two ways: actively or passively. They can be generated actively by using an impact source like a sledgehammer or passively by natural (for example, tidal motion and thunder) and cultural (for example, traffic) activities. A seismic survey of the former type is called the active method, whereas the latter is called the passive method. Most seismic surveys historically implemented have been the active type.

A seismic source—such as a sledgehammer—is used to generate seismic waves, sensed by receivers deployed along a preset geometry (called receiver array), and then recorded by a digital device called seismograph. Based on a typical propagation mechanism used in a seismic survey, seismic waves are grouped primarily into direct, reflected, refracted, and surface waves. There are three major types of seismic surveys: refraction, reflection, and surface-wave, depending on the specific type of waves being utilized. Each type of seismic survey utilizes a specific type of wave (for example, reflected waves for reflection survey) and its specific arrival pattern on a multichannel record. Seismic waves for the survey can be generated in two ways: actively or passively. They can be generated actively by using an impact source like a sledgehammer or passively by natural (for example, tidal motion and thunder) and cultural (for example, traffic) activities. Most of the seismic surveys historically implemented have been the active type. Seismic waves propagating within the vertical plane holding both source and receivers are also called inline waves, whereas those coming off the plane are called offline waves.

Seismic Hazard: In general terms, the seismic hazard defines the expected seismic ground motion at a site, phenomenon which may result in destructions and losses. Two major approaches – deterministic and probabilistic – are worldwide used at present for seismic hazard assessment.

The deterministic approach takes into account a single, particular earthquake, the event that is expected to produce the strongest level of shaking at the site. The outputs –
macro-seismic intensity, peak ground acceleration, peak ground velocity, peak ground displacement, response spectra - may be used directly in engineering applications.

In the **probabilistic approach**, initiated with the pioneering work of Cornell, the seismic hazard is estimated in terms of a ground motion parameter – macroseismic intensity, peak ground acceleration - and its annual probability of exceedance (or return period) at a site.

**Seismic Survey:** The seismic survey is one form of geophysical survey that aims at measuring the earth’s (geo-) properties by means of physical (-physics) principles such as magnetic, electric, gravitational, thermal, and elastic theories. It is based on the theory of elasticity and therefore tries to deduce elastic properties of materials by measuring their response to elastic disturbances called seismic (or elastic) waves.

**Seismic Data Acquisition:** Seismic data acquisition involves applying a seismic energy source, such as vibroseis truck or shot-hole dynamite at discrete surface location. The resulting energy is reflected back from interfaces where rock properties change.

By recording this reflected energy at an array of geophones placed in the ground surface, the results can be processed to produce an image of underground geological structures and a range of attributes that can be used to infer the physical rock properties. Surveys can be conducted along lines to produce a vertical profile (2D survey) or over an area to generate a 3D sub-surface volume.

**Seismic Migration:** **Seismic migration** is a data-processing technique that creates an image of earth structure from the data recorded by a seismic reflection survey. The oil and gas industry developed **seismic reflection** surveying methods between about 1970 and 1990. 40-ton shaker trucks send seismic waves into the ground, which echo from earth structures miles below. Miles-long arrays of thousands of sensors set in the ground, each like a 2-inch phonograph needle, pick up the echoing vibrations and send them to a recording truck along cables.
Industry has used simple reconstructions of these echoes, called \textit{stacked sections}, to locate buried oil reservoirs and pockets of natural gas. Stacked sections are most useful in areas where the rocks are relatively uniform and uncomplicated, such as the Gulf Coast. Where the rocks are more complex, such as in the Great Basin, seismic survey techniques have not been as successful in locating deposits of oil, gas, or geothermal hot water. More complex rocks scatter the echoing seismic waves in unexpected directions, and stacked sections show subsurface features in the wrong location, if they image them at all.

The term \textit{migration} comes about because, compared to stacked sections, the echoes ``migrate'' to their true subsurface position. Migration processing is only needed in geologically complex areas. This image shows features to a few miles depth below a producing geothermal power field in Dixie Valley, central Nevada. Advanced seismic migration processing of the data from previously recorded reflection surveys shows a possible reservoir of geothermal hot water caught within a complex of earthquake faults, about $2^{1/2}$ miles down. Although seismic migration was the only way to make a coherent subsurface image from the data in Dixie Valley, it does introduce some artifacts. Any interpretation of migrated images has to ignore these upward-curving ``false arcs''.

Above is a very similar type of echo-sounding, a medical ultrasound image taken of a baby in the womb. The data-gathering and processing techniques are almost exactly the same. In ultrasound, of course, all the echo sensors are in a probe just an inch wide, instead of miles long; and the image represents human structures just a few inches instead of miles deep. Note that the ultrasound image has the same kind of upward-curving ``false arcs'' as the migrated earth section.

3.5 \textbf{SEISMIC FORWARD MODELLING}

In \textit{seismic forward modelling} we take some kind of model of the earth, and then mathematically simulate seismic energy spreading through that model. The simulation algorithm itself is also a model - its an a mathematical approximation to how real seismic waves travel. How level of sophistication you need to have in the model (and the algorithm) depends on what you want to do.
The main uses in seismic exploration are:

a) **calibration** - taking geological information (for example from wells) and creating a "synthetic seismic" dataset so you can match the well data (in depth) to the seismic data (in two-way-time); this can then allow you to use "inversion" methods to estimate rock properties, and even identify if oil, gas or water is present in the pores.

b) **Algorithm benchmarking** - a number of synthetic seismic datasets based on forward modelling are available as "open" testbeds for seismic processing algorithms. They can be used to compare and refine different approaches or methods, or demonstrate a technique.

**Seismic Microzonation:** Seismic microzonation is a rigorous process involving several types of seismic, geophysical, geological and geotechnical investigations for advising seismic coefficient for the area, amplification due to soil for different heights of buildings and ground conditioning methods to safeguard against liquefaction. ISR has done seismic microzonation studies at Gandhidham-Kandla -Anjar area and is doing microzonation at Dholera SIR, Ahmedabad, Gandhinagar. Surat & Bharuch have been taken up in collaboration with Geological Survey of India. Now every year one new area will be taken up for seismic microzonation.

**Tsunami Modeling:** Tsunami modeling of wave arrival time and amplitude in Arabian Sea from large earthquakes in Makran has been done and such information is given for coastal towns. A constant watch is kept for earthquakes along Makran coast for sounding tsunami alert. Near real time rupture modeling of earthquakes in Makran along with real time GPS modeling is being undertaken which will be helpful in estimating directivity and tsunami amplitude for effective tsunami warning.

**Geophysical Surveys:** Seismic, Gravity, Magnetotelluric, Resistivity, GPR and other Geophysical surveys are carried out for study of shallow and deep crustal structure and faults.

(i) **Study of Deep Crustal and lithospheric structures:** Imaging through seismic soundings, seismic tomography as well as by magneto telluric and gravity surveys.
(ii) **2D and 3D Seismic Surveys for Petroleum Exploration and Mapping of Basement Structures:** ISR gets done onshore and offshore 2D and 3D seismic surveys for petroleum exploration and determining the basement structures and faults. Large areas in the transition zone of Gujarat have tremendous petroleum prospects.

(iii) **3D Magnetotelluric Survey:** The method has been pioneered by ISR. It is found to be an effective method to find crustal structure and geological faults beneath the Deccan Basalts where other methods are not successful. This type of survey will be useful to tap vast petroleum reserves in Mesozoic rocks beneath the Deccan Traps and geothermal energy resources. The method could be essential for detecting any geological faults close to planned crucial plants like nuclear power plants or LNG Terminals close to postulated faults.

**Applications of Seismology:** One aspect of seismology is concerned with measuring the speeds at which seismic waves travel through the earth. Past earthquake studies have shown that P, or primary/compressional, waves travel fastest through the earth; S, or secondary/transverse, waves cannot pass through liquids, allowing scientists to discern the earth's many boundary layers known as the crust, mantle, and core. For example, the disappearance of S waves below 1,800 mi (2,900 km) shows that the outer core of the earth is liquid. Seismologists also prepare seismic risk maps for earthquake-prone countries; these indicate the degree of seismic danger. In addition, seismologists use earthquake data to determine plate boundaries (see plate tectonics); active earthquake areas generally coincide with plate margins, both destructive and growing, and transform faults.

An important commercial application of seismology is its use in prospecting for oil deposits. The first oil field to be discovered by this method was found in Texas in 1924. A portable seismograph is set up in the area to be investigated, and an explosive energy source is activated nearby; formerly, explosives such as dynamite were used to create the seismic waves, but they have been largely replaced by high-energy vibrators on land and air-gun arrays at sea. The waves generated are received by detectors known as geophones; on land, these are commonly placed in a fan-shaped pattern on the ground. From an
interpretation of the waves created by the energy source and recorded by the seismograph, the detection of geological structures in which oil may be trapped is possible.

Seismic methods are sometimes used to locate subsurface water and to detect the underlying structure of the oceanic and continental crust. With the development of underground testing of nuclear devices, seismographic stations for their detection were set up throughout the world. Under the Comprehensive Test Ban Treaty (signed 1996 but not yet in force) an international monitoring system has been set up which includes many seismic stations; the detailed data collected is also used by contributing nations for purposes other than monitoring nuclear tests.

**Marine Seismic Research:**
- To characterize the seafloor and sub-seafloor of the nation or other areas of interest
- To support analyses of seismic, tsunami, submarine slide or marine hazards
- To assess the distribution of mineral or unconventional natural gas resources in the offshore environment;
- To document the impact of climate and environmental change or events
- To document the processes related to the formation of and ongoing changes to continental shelves and margins
- To understand a variety of geological, geophysical and biological processes that affect the marine environment

**Data collected from marine seismic surveys:**
- The important in hypothesizing and subsequently demonstrating the validity of the theory of plate tectonics;
- The vital to making ocean drilling scientifically useful and environmentally safe;
- provide imaging of ocean faults which is the key to studies of earthquakes and landslide hazards;
- are essential to evaluate the potential for tsunami generation which in most cases, result from submarine slumping associated with earthquakes;
- Are used to define potential failure regions, slip planes, oversteepened slopes, creep, zones of potential overpressures and concentrations of gas hydrates or shallow free gas that may play a role in destabilization of sedimentary slopes.
- Are used to map sedimentary horizons, allowing correlations of sediment type and age across long distances and providing information on spatial and temporal disturbances of processes.
- It can be used to directly image magma chambers in volcanoes and mid-ocean ridges and repeat surveys can be used to image changes in magma reservoirs related to eruptions.
- It can be used to interpret processes of compaction, folding, dewatering and other processes in subduction zones that lead to uplift, earthquakes, slumping and other processes that will impact land and people.

Marine seismic research methods: A variety of methods and equipments are employed by marine seismic researchers when conducting seismic surveys. Research for understanding the nature of the Earth’s crust and dynamic processes often begins with seismic exploration. The opportunities for research using seafloor seismic data to understand the natural forces that shape and change our planet have never been greater than they are today. Seismic surveys use the principle of an active sound source (controlled) and receiver system.

Seismic acoustic sources used are: Airguns and Airgun arrays which was introduced first in 1960s, water guns- a pneumatic sound source, Sparkers - are electrical seismic sources that generate acoustic pulses by vaporizing seawater using high voltage electrical currents, Boomers – electromechanical sound sources that generate short and broadband acoustic pulses useful for high-resolution, shallow-penetration sediment profiling, chirp systems.

Seismographic Instruments: Instruments used to detect and record seismic disturbances are known as seismographs. Those in use today vary somewhat in design and function, but generally a heavy mass, either a pendulum or a large permanent magnet, is connected to a
mechanical or optical recording device. When earthquake tremors occur, the pendulum or the magnet, because of inertia, remains still as the earth moves beneath, with the relative motion between the earth and the instrument magnified mainly by electrical amplifying apparatus. The graphic record, called the seismogram, can be used to establish information about an earthquake, e.g., its severity and distance. By using three instruments, each set to respond to motions from a different direction (north-south horizontal, east-west horizontal, and vertical), both the distance and the direction of the earth movement can be determined. Three or more widely spaced seismographic stations are required to pinpoint the location of earthquakes in remote regions.

3.6 MONITORING FOR HAZARD ASSESSMENT

Each year, tens of thousands of small earthquakes occur throughout the United States, reflecting the brittle deformation of the North American plate along its edges and within its interior. Although not damaging, these smaller earthquakes provide a wealth of information that enables seismologists and engineers to better assess the distribution, frequency, and severity of seismic hazards throughout the country. Seismograph networks supply earthquake parameter and waveform data that are essential for the real-time evaluation of tectonic activity for public safety (e.g., volcanic eruptions, tsunamis, earthquake mainshocks and aftershocks), the development of earthquake hazard maps and seismic design criteria used in building codes and land-use planning decisions (e.g., characterization of seismic sources, ground failure, strong ground motion attenuation), and basic scientific and engineering research.

National and regional earthquake hazard maps published by the U.S. Geological Survey (USGS) and state geological surveys involve the collection and integration of seismograph network data with other geologic and geophysical data, including paleoearthquake chronologies, locations of active faults, determinations of threedimensional velocity and geologic structure, and wave propagation and attenuation parameters. These earthquake hazard data and maps help define the level of earthquake risk throughout the United States and provide input to risk management decisions at both
the national and local levels. Efforts to reduce the uncertainties in these data help to clarify the level of seismic hazard and risk and to identify the appropriate mitigation and response strategies for different parts of the country.

**Earthquake Monitoring:** Seismic monitoring provides a wealth of critical information for earthquake hazard assessment and for improved understanding of the earthquake process. The basic product of earthquake monitoring is the seismicity catalog, a listing of all earthquakes, explosions, and other seismic disturbances (both natural and manmade). Parametric data, such as earthquake origin times, locations, and magnitudes, are used to characterize the frequency and size of earthquakes in a particular region and help identify active faults. Earthquake catalogs play a key role in probabilistic seismic hazard assessment, especially in the eastern and central United States where there is generally insufficient detailed information on active faults and their tectonic causes (NRC, 1996).

Elsewhere in the United States, efforts are under way by the USGS, through the Advanced National Seismic System (ANSS) program, to provide uniform coverage in areas not currently monitored by regional networks. Regional network operators throughout the United States have begun to implement ShakeMap capabilities in cities such as Portland, Oregon; Reno, Nevada; and Salt Lake City, Utah. The benefit of this capability was demonstrated in Seattle, Washington, where the first deployment of ANSS instruments was made a few months prior to the 2001 Nisqually earthquake. In areas where sufficient instrumentation is still lacking, such as the central and northeastern United States, it is only possible to issue model rather than observational or empirical ShakeMaps.

Variations in network configurations with time, due to changes in instrumentation and sensitivities as well as changes in procedures for computing earthquake magnitudes and locations, introduce additional uncertainty. Improving the completeness and accuracy of these catalogs is a major objective of seismic hazard analysis, often depending on the occurrence of small earthquakes to identify the potential for damaging fault ruptures, and
of earthquake physics, which relies on catalogs as the basic space-time record of fault system behavior.

Digital waveform data, either weak or strong motion, are used to further improve earthquake locations, characterize seismic source and wave propagation effects, measure the state of stress in the brittle crust, and develop ground motion attenuation models.

**Monitoring in the Urban Environment:** For close to a century, standard seismological practice has been to site delicate instruments far from urban centers and other sources of noise. Studies of weak ground motions, faint vibrations from earthquakes occurring around the globe, led to important scientific advances during the twentieth century. Recent earthquakes, however, have dramatically demonstrated the vulnerability of the urban environment to earthquake-related damage. Unprecedented growth in urban areas during the last few decades has served to increase the level of earthquake risk faster than our efforts to reduce or mitigate it. Addressing seismic hazard and risk issues in the urban environment has required a change in the standard seismological practice, with the recognition that instruments have to be installed in cities to record ground motions where the earthquake damage is occurring. Recording on-scale ground motions close to active faulting (the near field) and within structures, and obtaining a better understanding of ground response in urban areas, have become critical elements in the national goal of reducing seismic risk.

**Tsunami Monitoring:** Tsunamis are oceanic gravity waves that may be caused by submarine earthquakes or other geologic processes such as volcanic eruptions or landslides. In the United States, tsunamis present a significant (although relatively infrequent) danger to coastal communities in California, Washington, Oregon, Alaska, Hawaii, and Puerto Rico. Seismic monitoring to detect large subduction zone earthquakes around the circum-Pacific and Caribbean regions provides valuable public safety information in advance of tsunami arrivals.
Distant tsunamis and locally generated tsunamis require responses at significantly different time scales. For local tsunamis, the ability to warn coastal communities of a potentially dangerous situation immediately after a large local earthquake is the key to public safety. Locally generated tsunamis can reach the shoreline quickly (within as little as 5 minutes), giving authorities limited time to issue any warnings or evacuations. The 1992 Mw 7.1 Cape Mendocino, California, earthquake generated a small 1-foot tsunami that reached Humboldt Bay 20 minutes after the earthquake occurred. Regional groups throughout the Pacific Northwest—such as the University of Washington, the Oregon Department of Geology and Mineral Industries, and the Bonneville Power Authority—recognize the significant local tsunami hazard posed by the Cascadia subduction zone and have begun installing strong motion instruments for real-time monitoring and warning for coastal communities.

Distant or tele-tsunamis generated from other parts of the circum-Pacific are monitored by the Pacific Tsunami Warning System, which was established in 1948 following the 1946 Aleutian (Unimak Island) tsunami. Tsunami waves travel at speeds of 800 km/h (or 0.2 km/s) at a water depth of 5,000 meters, far slower than seismic waves (3-8 km/s). This difference in wave speed makes it possible to issue tsunami warnings throughout the Pacific basin after an earthquake has been detected, but before the arrival of the tsunami. A Tsunami Watch Bulletin is released when an earthquake occurs with a magnitude of 6.75 or greater on the Richter scale. A Tsunami Warning Bulletin is released when information from tidal stations indicates that a potentially destructive tsunami exists.

**Volcano Monitoring:** Nearly every recorded volcanic eruption has been preceded by an increase in earthquake activity beneath or near the volcano. For this reason, seismic monitoring has become one of the most useful tools for eruption forecasting and monitoring. Systematic volcano monitoring enabled the accurate prediction, from hours to even a few weeks in advance, of nearly all the post-May 18, 1980, dome-building eruptions of Mount St. Helens. Real-time and near-real-time seismic monitoring capabilities at numerous volcanoes around the world provide a major advance for
identifying and guarding against volcano hazards. In addition to monitoring, the improved ability to locate earthquakes recorded by permanent seismic networks provides three-dimensional images of the magmatic plumbing systems beneath some volcanoes. The increasing use of broadband seismometers has facilitated the complete recording and comprehensive analysis of long-period seismic signals, which have preceded and accompanied a number of eruptions. A more quantitative understanding of long-period seismicity not only refines short-term forecasts of volcano hazards, but also improves our knowledge of magma transport and eruption dynamics.

The economic consequences of volcanism in the United States are wide and varied, ranging from the destruction associated with the May 1980 eruption of Mount St. Helens, Washington (~$1 billion in losses and 57 fatalities), to the impacts on air transportation from high-altitude ash clouds, to fluctuations in real estate values as a societal response to official warnings (e.g., Mammoth Mountain-Long Valley Caldera, California, earthquake swarms in the 1980s).

3.7 SEISMIC RESEARCH AND RESEARCH INSTITUTIONS IN INDIA

India has a history of pioneering seismological research in the solid earth science that resulted in the discovery of the core of the Earth. For the first time, identification of the surface wave and its distinction from the body wave on the recorded seismogram of the 12th June 1897 Shillong earthquake. Nowadays, frequent occurrences of macro to micro earthquakes in different parts of India and its adjoining regions posed challenges to Indian Seismological research community.

The seismological research in India dominated by studies on the, spatio-temporal aspects of seismogenesis and seismotectonics of the Himalaya and its adjoining regions; on tsunamigenic earthquake and earthquake pattern of the Andaman-Nicobar subduction region of India; on seismogenesis and seismotectonics of the Stable Continental Region of India; studies on site response, seismic microzonation, earthquake risk, vulnerability, disaster management and risk mitigation strategies of India; studies on earthquake
precursor and prediction of earthquakes in India; studies on seismological issues outside India.

The Earthquake Engineering and Vibration Research Centre is equipped with necessary facilities for providing testing, research and consultancy services in the areas of seismic and vibration qualification of instruments / equipment for nuclear power plants and other generating stations as well as manufacturers and utilities in the field of aerospace, railways and automobiles as per National and International Standards. In addition, this centre offers consultancy in checking the design adequacy of structures / bridge models for seismic qualification.

The Institute of Seismological Research (ISR) under the Science and Technology Department, Government of Gujarat is functioning from 2006. ISR is the premier institute in India fully dedicated to seismological research and is planned to be developed into a premier international institute in few years time.

The National Centre for Seismology (NCS) is established by Ministry of Earth Sciences as an attached office to address all earthquake related matters in the country under one umbrella of the Earth System Science Organization (ESSO). The Center is providing effective linkages / interface amongst various organizations / institutions working in the fields of Seismology and allied subjects for optimal use of infrastructure and resources. The broad and ultimate objective of the NCS is to provide earthquake (M:3.0 and above) related information to all user agencies in shortest possible time, earthquake hazard and risk related products of specific regions as mitigative measures for design and construction of earthquake resistant structures and land use planning towards minimizing damage to property and loss of lives due to earthquakes. NCS is also mandated to carry out research in pure and applied seismology and earthquake precursory phenomena, earthquake processes and modelling.

There are five divisions, namely, Earthquake Monitoring & Services, Earthquake Hazard & Risk Assessment, Geophysical Observation System, Earthquake Process & Modelling and Program Planning & Coordination to carry out various activities of NCS.
NCS is maintaining a National Seismological Network consisting of a total of 82 field observatories, including two telemetry clusters, one each around NCT Delhi (16 stations) and Northeast India (20 stations), for monitoring of seismic activities in and around the country on a 24x7 basis. NCS is carrying out active research on detail crust & upper mantle structure of sections of Indian shield Himalayan regions using various techniques, such as, receiver function techniques, surface wave dispersions, etc., estimation of expected ground motions for critical areas from future scenario earthquakes using various techniques and carrying out earthquake precursor observations, comprehensive analysis of the data sets. Additionally, scientists of NCS are actively involved in some of the on-going cutting-edge R&D projects being supported by the MoES, such as, ‘National Program on Earthquake Precursors’, ‘Deep drilling investigations in Koyna-Warna region of Maharashtra’, ‘Earthquake Early Warning System in Himalaya’, ‘Study of largest Geoid-low’, Volcanological studies in Andaman islands’, etc.

3.8 CONCLUSION

The present chapter has given an overview of seismology. Various aspects of seismic studies like objectives, need for the research in seismology, warning systems, seismic survey methods, international and national institutes in seismology, monitoring of tsunami and earthquake etc., were detailed in this chapter. The next chapter gives a detailed presentation of data analysis and interpretation with the help of tables and figures.
REFERENCES


