WELCOME

The 33rd Virtual UNISEC-Global Meeting

Theme: Can Space Technology Mitigate Earthquake Damage

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Earthquake early warning precursors

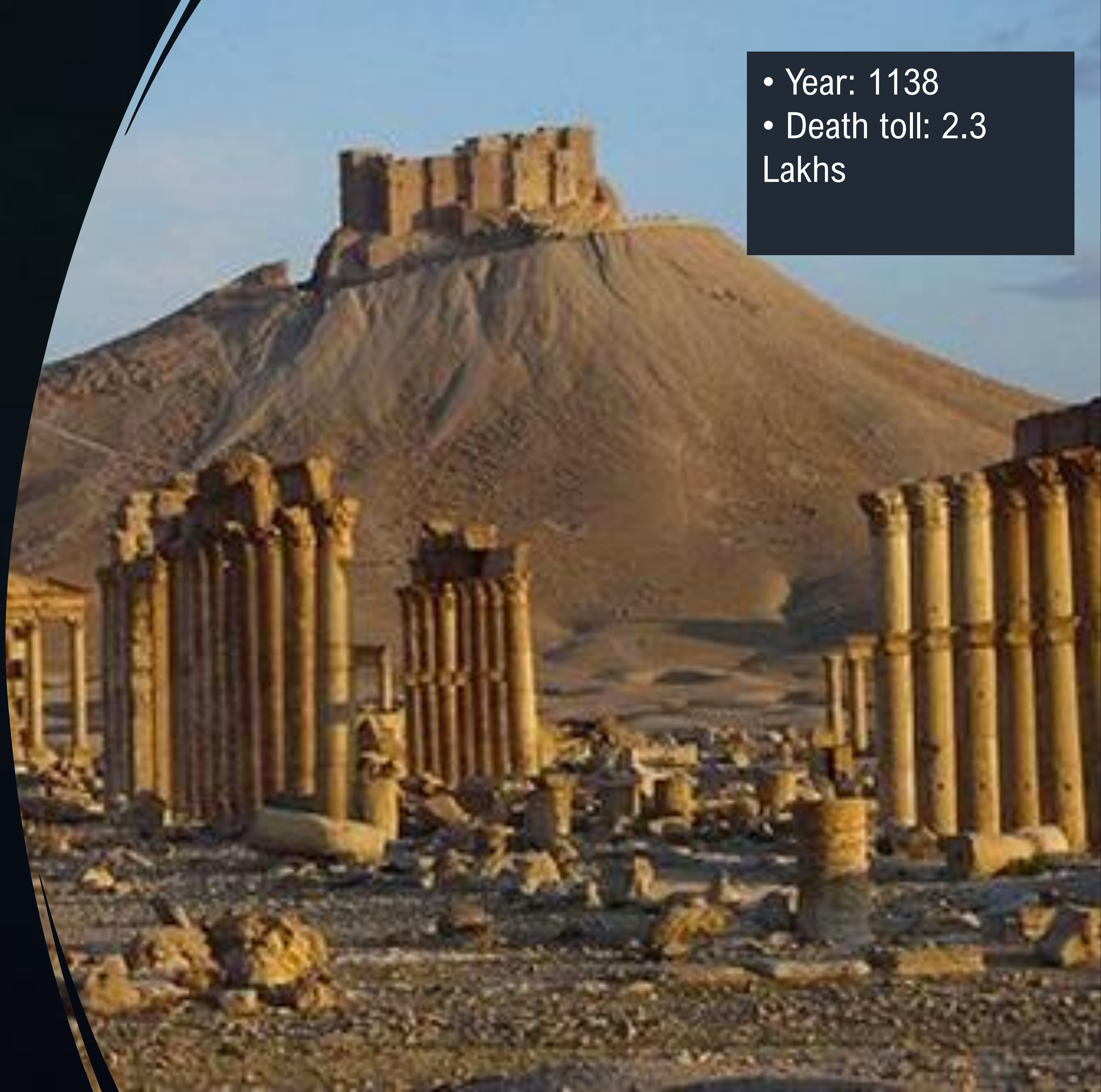
Dr. G.P.Ganapathy
Professor
Centre for Disaster Mitigation and Management
Vellore Institute of Technology (VIT)
Vellore 632014, Tamil Nadu, India
Email: seismogans@yahoo.com
gpganpathy@vit.ac.in

VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

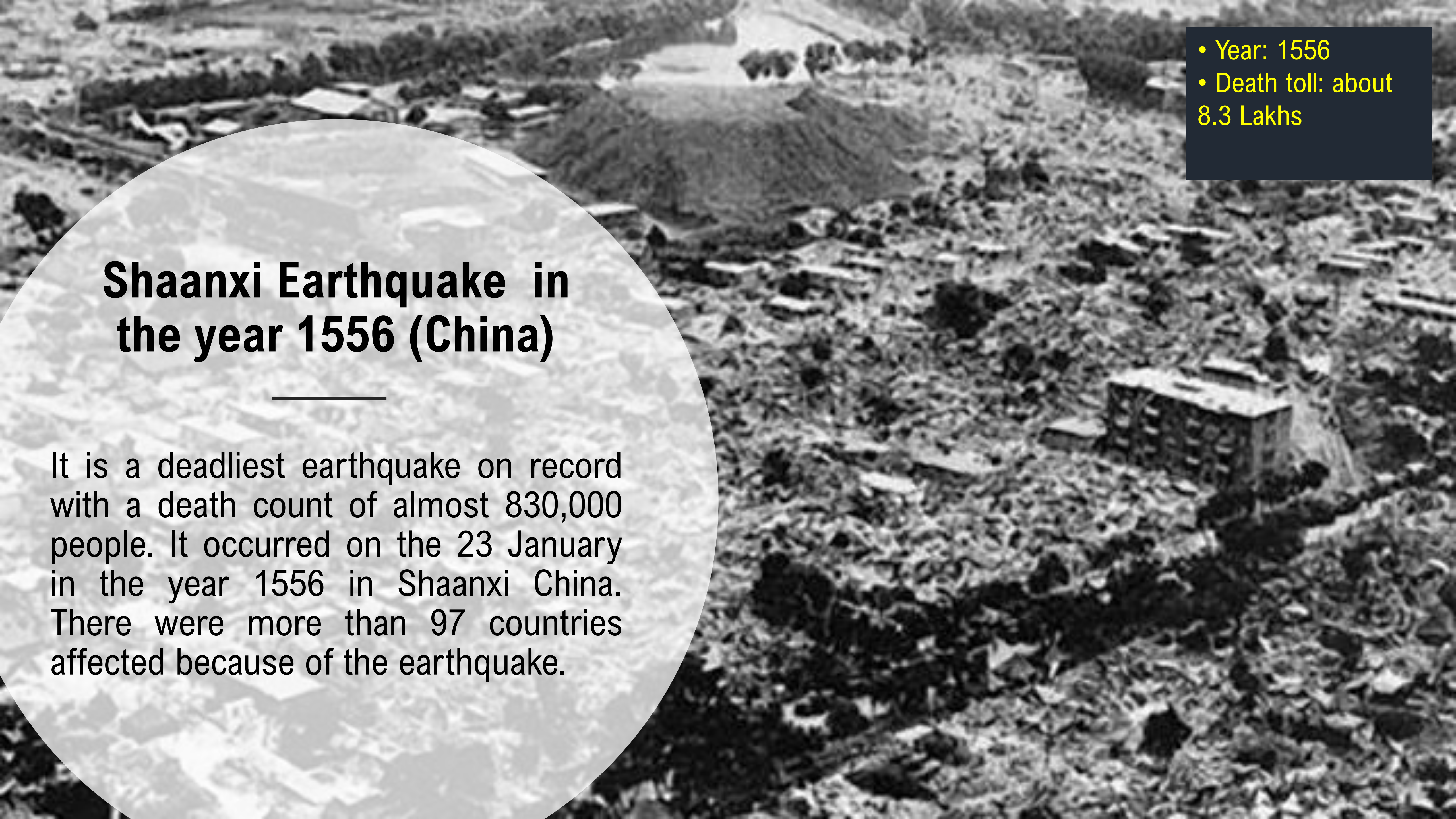
VIT – Recognised as Institution of Eminence (IoE) by Government of India

1138 Aleppo Earthquake (Syria)

Aleppo is situated northern portion of the Dead Sea and it separates the African plate from the Arabian Plate. The series of the earthquakes took place from October 1138 to the month of the June 1139. The area that was the hit the most was Harim. The earthquake caused deaths of around 230,000 people.



- Year: 1138
- Death toll: 2.3 Lakhs



- Year: 1556
- Death toll: about 8.3 Lakhs

Shaanxi Earthquake in the year 1556 (China)

It is a deadliest earthquake on record with a death count of almost 830,000 people. It occurred on the 23 January in the year 1556 in Shaanxi China. There were more than 97 countries affected because of the earthquake.

- Year: 1976
- Death toll: 2.42 Lakhs

1976 – Tangshan Earthquake (China)

The Tangshan earthquake is amongst the largest earthquakes ever taken place in the world. It took place in the Tangshan in the Hebei in China with the population of around one million inhabitants. It killed around 242,000 people.

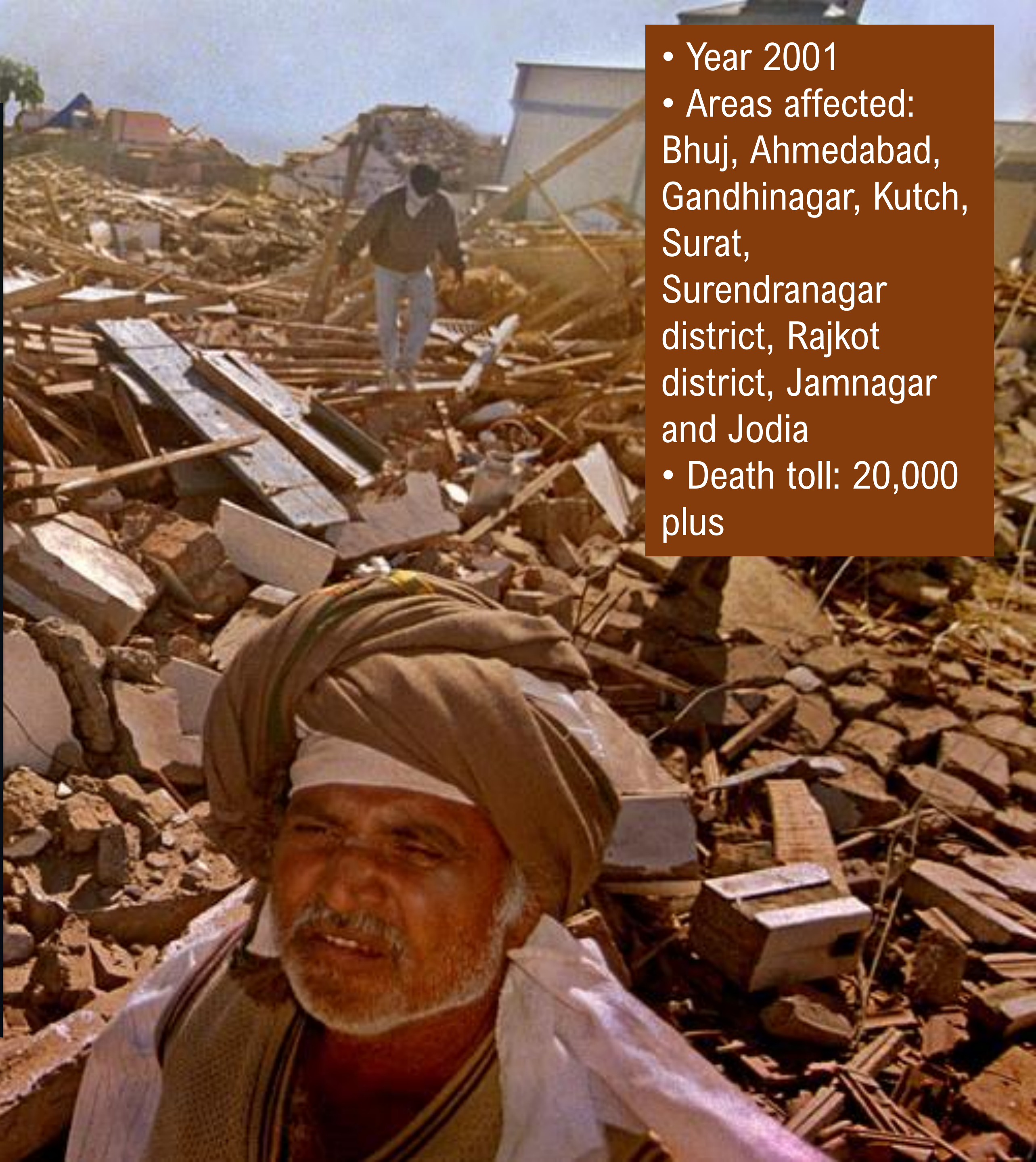
Latur Earthquake 1993

This was one of the deadliest earthquakes, which hit Latur in Maharashtra. The year was 1993. Almost 20,000 people died and around 30,000 were injured. The earthquake's intensity was measured 6.4 on the Richter scale. There was huge loss to property. Thousands of buildings were turned into rubble and more than 50 villages were destroyed.

- Year: 1993
- Areas affected: Districts of Latur and Osmanabad
- Death toll: 20,000 plus

Gujarat Earthquake 2001

Gujarat was affected by a massive earthquake on the morning of 26 January, 2001, the day on which India was celebrating its 51st Republic Day. The earthquake's intensity was in the range of 7.6 to 7.9 on the Richter Scale and lasted for 2 minutes. The impact was so great that almost 20,000 people lost their lives. It is estimated that around 167,000 were injured and nearly 400,000 were left homeless in this natural disaster.



- Year 2001
- Areas affected: Bhuj, Ahmedabad, Gandhinagar, Kutch, Surat, Surendranagar district, Rajkot district, Jamnagar and Jodia
- Death toll: 20,000 plus

The Indian Ocean Tsunami 2004

Following a major earthquake in 2004, there was a huge tsunami in the Indian Ocean, causing immense loss of life and property in India and the neighbouring countries – Sri Lanka and Indonesia. The earthquake had its epicenter in the ocean bed which led to this destructive tsunami. The magnitude was measured between 9.1 and 9.3 and it lasted for almost 10 minutes. According to reports, it was the third largest earthquake in the world ever recorded. The impact was equivalent to the energy of 23,000 Hiroshima-type atomic bombs. More than 2 lakh people were killed.

- Year: 2004
- Areas affected: Parts of southern India and Andaman Nicobar Islands, Sri Lanka, Indonesia etc.
- Death toll: 2 lakh plus

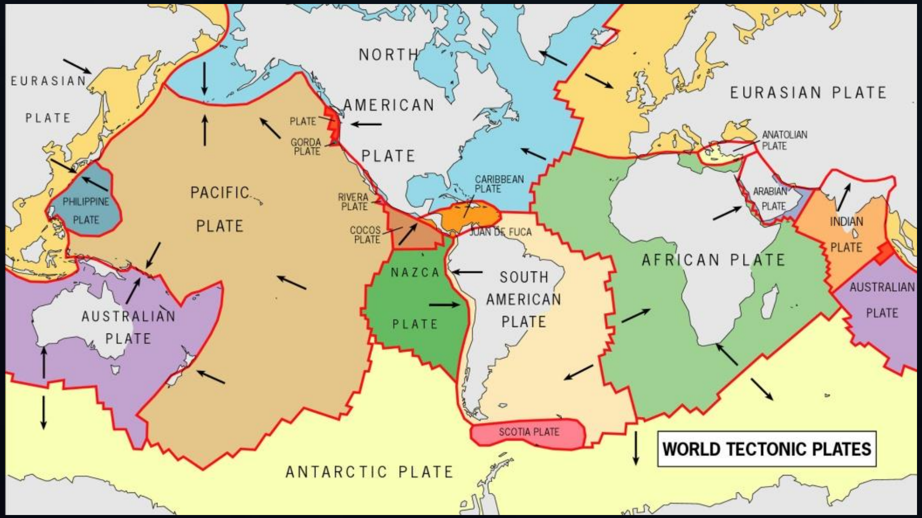
Earthquake

What is an earthquake and what causes them to happen?

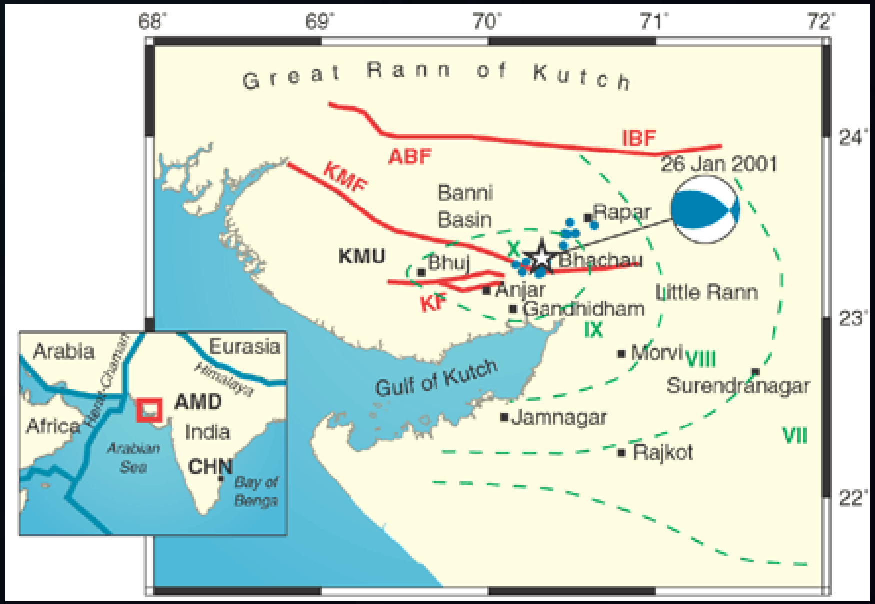
An earthquake is caused by a sudden slip on a fault. The tectonic plates are always slowly moving, but they get stuck at their edges due to friction. When the stress on the edge overcomes the friction, there is an earthquake that releases energy in waves that travel through the earth's crust and cause the shaking that we feel.

Type of Earthquakes?

Inter Plate Earthquakes



Intra Plate Earthquakes



Earthquake Impacts

Ground Shaking

Liquefaction

Faults

Land Subsidence

Induced Landslides

Tsunami

Some of the important Questions on Earthquake

Can we cause earthquakes? Is there any way to prevent earthquakes?

- Earthquakes induced by human activity have been documented at many locations in the United States and in many other countries around the world.

- Earthquakes can be induced by a wide range of causes including impoundment of reservoirs, surface and underground mining, withdrawal of fluids and gas from the subsurface, and injection of fluids into underground formations.

Foreshocks, aftershocks - what's the difference?

- Foreshocks are earthquakes that precede larger earthquakes in the same location. An earthquake cannot be identified as a foreshock until after a larger earthquake in the same area occurs.

- Aftershocks are smaller earthquakes that occur in the same general area during the days to years following a larger event or "mainshock."

- They occur within 1-2 fault lengths away and during the period of time before the background seismicity level has resumed.

What is the difference between aftershocks and swarms?

- Aftershocks are a sequence of earthquakes that happen after a larger mainshock on a fault. Aftershocks occur near the fault zone where the mainshock rupture occurred and are part of the "readjustment process" after the main slip on the fault.

- Aftershocks become less frequent with time, although they can continue for days, weeks, months, or even years for a very large mainshock.

- A swarm, on the other hand, is a sequence of mostly small earthquakes with no identifiable mainshock.

- Swarms are usually short-lived, but they can continue for days, weeks, or sometimes even months. They often recur at the same locations. Most swarms are associated with geothermal activity.

Why are we having so many earthquakes? Has naturally occurring earthquake activity been increasing? Does this mean a big one is going to hit? OR We haven't had any earthquakes in a long time; does this mean that the pressure is building up for a big one?

A temporary increase or decrease in seismicity is part of the normal fluctuation of earthquake rates. Neither an increase nor decrease worldwide is a positive indication that a large earthquake is imminent.

Some catalog contains an increasing number of earthquakes in recent years--not because there are more earthquakes, but because there are more seismic instruments and they are able to record more earthquakes.

The National Earthquake Information Center now locates about 20,000 earthquakes around the globe each yeaar, or approximately 55 per day. As a result of the improvements in communications and the increased interest in natural disasters, the public now learns about earthquakes more quickly than ever before.

Can some people sense that an earthquake is about to happen (earthquake sensitives)?

There is no scientific explanation for the symptoms some people claim to have preceding an earthquake, and more often than not there is no earthquake following the symptoms.

Can the ground open up during an earthquake?

Faults do not open up during an earthquake.

An earthquake occurs when two blocks of the earth’s crust slide past one another after having been stuck together in one place for a long time, because of friction on the fault, while the rest of the crust away from the edges has been slowly moving.

If a fault could open up, no earthquake would occur in the first place because there would be no friction locking the two blocks together.

Can large amounts of rain cause an increase in earthquakes?

Heavy precipitation or of drought might indirectly affect earthquake-prone faults. For example, patterns of precipitation can affect the weight of near-surface materials and of reservoirs.

Also the refilling of subsurface aquifers may cause the Earth's crust to expand (by a few millimeters) in some locations and contract in others, with the opposite occurring during dry periods.

These can cause small changes in the stresses on faults that--in principle--could slightly influence rates of seismicity.

Can we predict earthquakes?

An earthquake prediction must define 3 elements:

1)the date and time,

2)the location, and

3)the magnitude.

Can animals predict earthquakes?

- The earliest reference we have to unusual animal behavior prior to a significant earthquake is from Greece in 373 BC. Rats, snakes, and centipedes reportedly left their homes and headed for safety several days before a destructive earthquake.
- Anecdotal evidence abounds of animals, fish, birds, reptiles, and insects exhibiting strange behavior anywhere from weeks to seconds before an earthquake.
- However, consistent and reliable behavior prior to seismic events, and a mechanism explaining how it could work, still eludes us. Most, but not all, scientists pursuing this mystery are in China or Japan.

Earthquake Early Warning Precursors

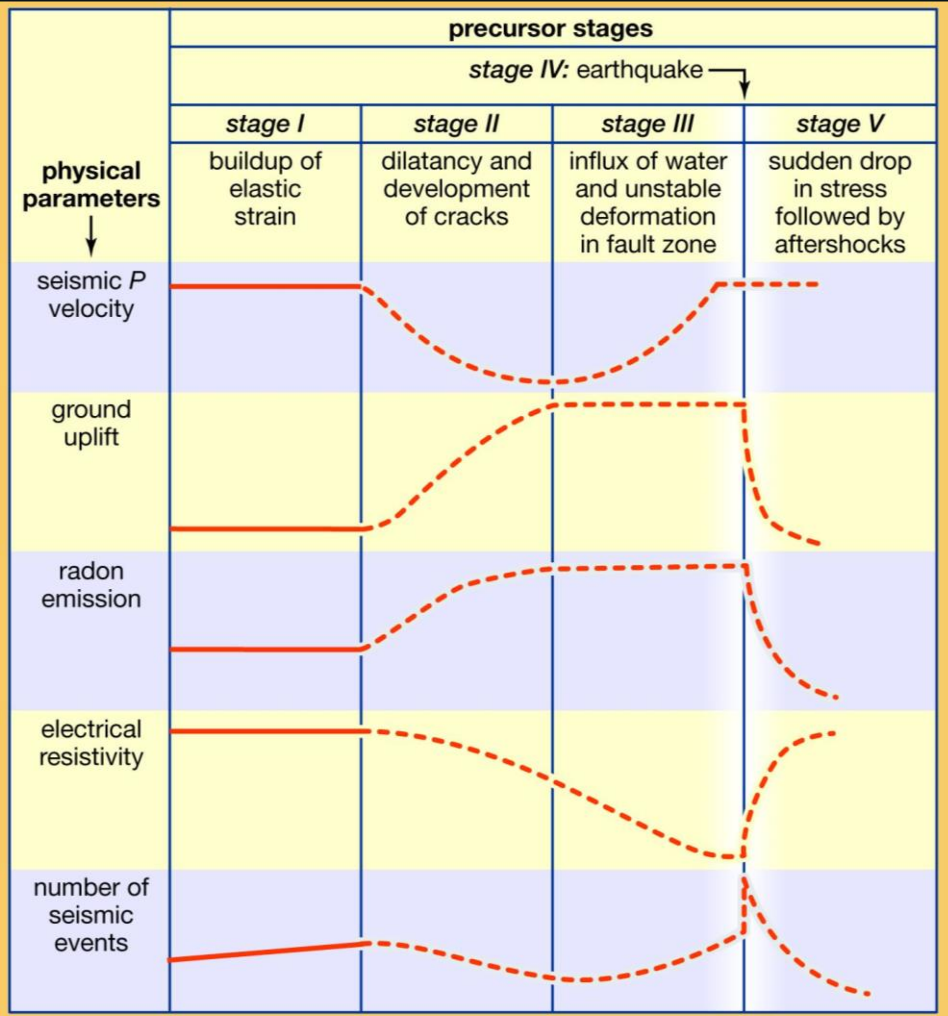
Studies Based on Earthquake Precursors

- There have been several recent efforts in earthquake parameter prediction based on recording and analyzing precursor signals before major earthquakes.

- The primary reason for earthquake activity is two or more of the earth's crustal plates that are steadily moving in different directions are locked together for a period of time, thus accumulating strain and elastic potential energy.

- The stored energy is released in the form of a major seismic event when some threshold is exceeded. In a majority of cases, this release of energy is a gradual process and is preceded by earthquake precursors.

Physical clues for earthquake prediction



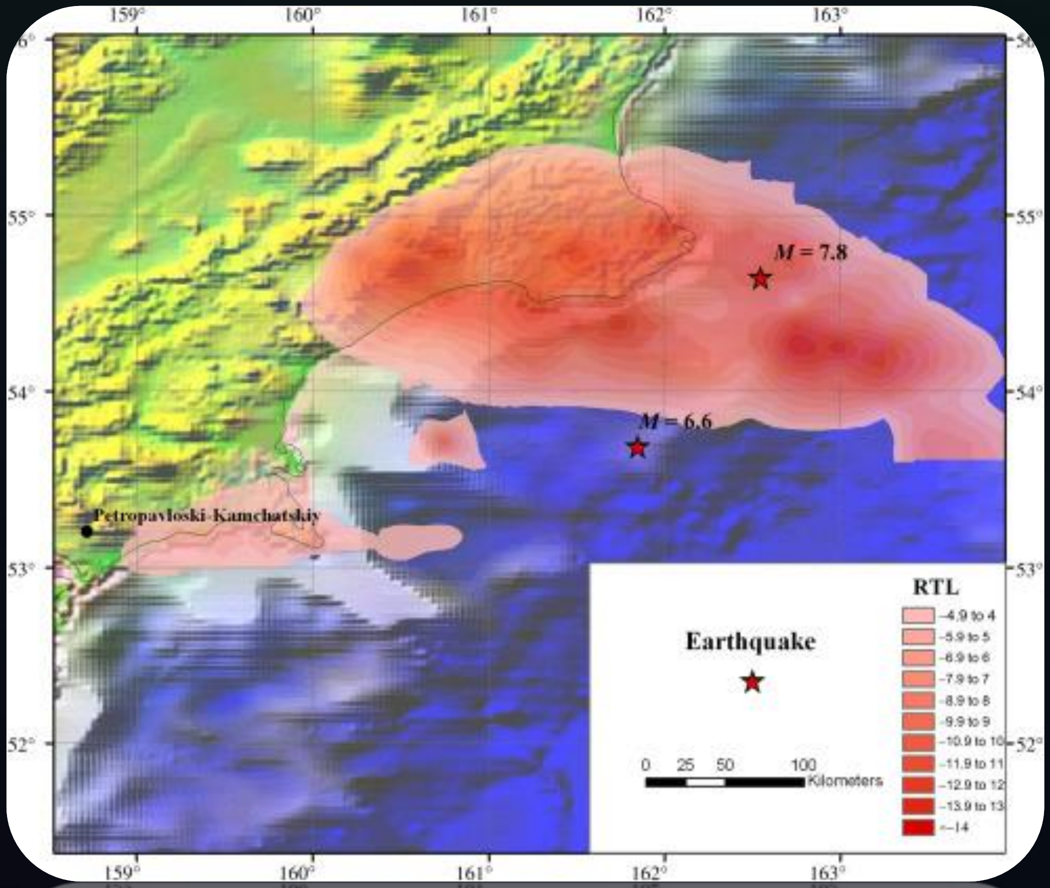
Source: *Predicting Earthquakes*, National Academy of Sciences, 1976

The theory of dilatancy (that is, an increase in volume) of rock prior to rupture once occupied a central position in discussions of premonitory phenomena of earthquakes, but it now receives less support.

It is based on the observation that many solids exhibit dilatancy during deformation.

For earthquake prediction the significance of dilatancy, if real, is in its effects on various measurable quantities of the Earth's crust, such as seismic velocities, electric resistivity, and ground and water levels.

Seismic Quiescence



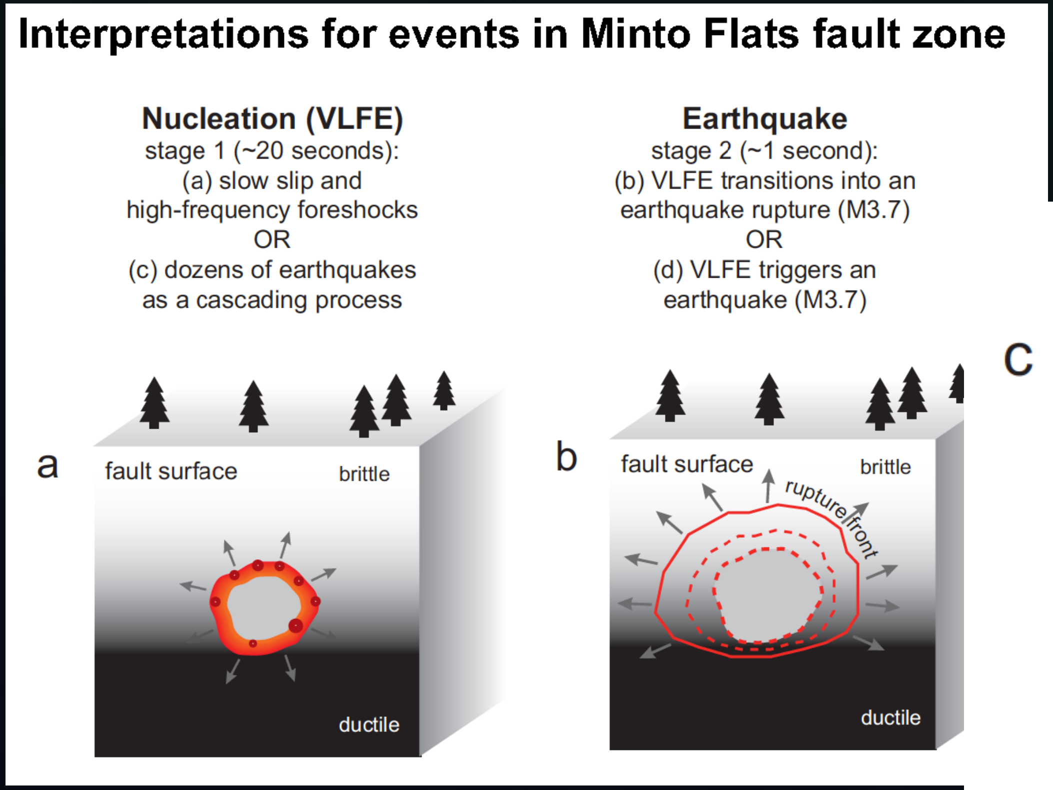
Seismic Quiescence is often referred to as the "calm before the storm" in earthquake science. It has been observed in several historical earthquake catalogs that the "normal" seismic activity in a region is suspended for a considerable time anomalous earthquake activity before the occurrence of a major earthquake.

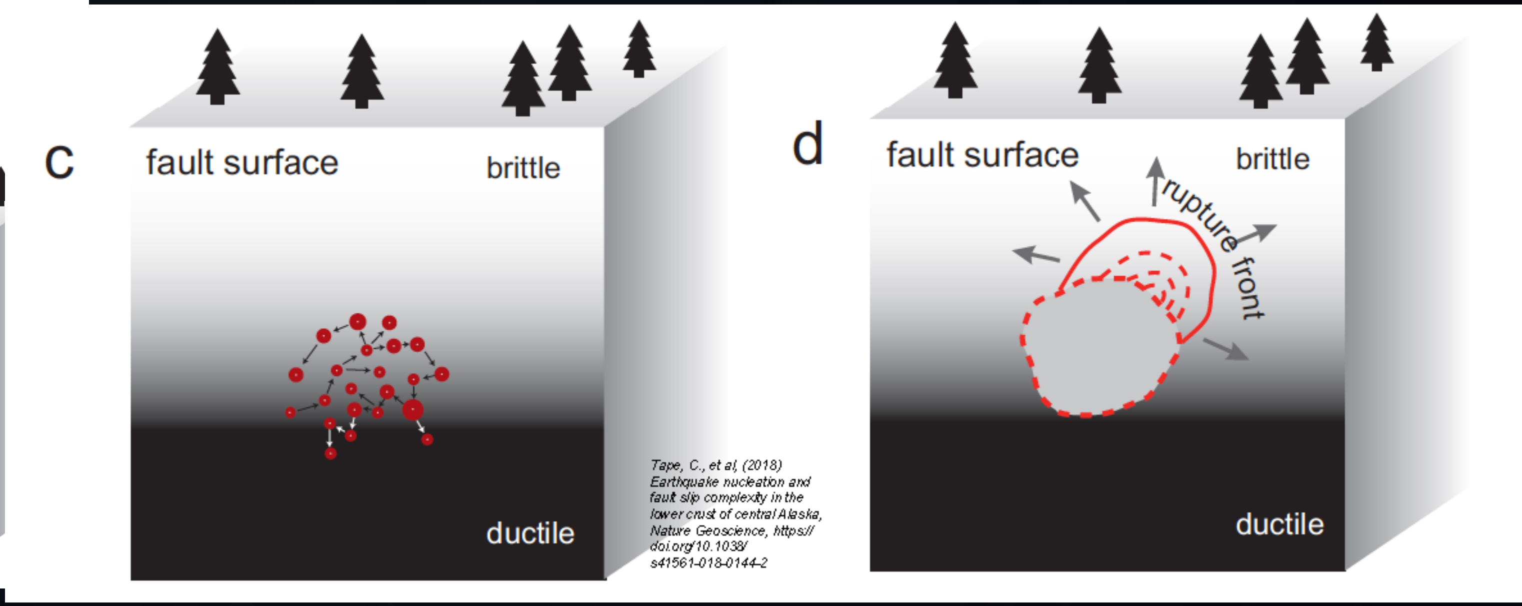
The map of seismic quiescence 1.7 years prior to the 1997 Kronotsky earthquake or Kamatchka earthquake of east Russia with $M_w = 7.8$ and main aftershock with $M_w = 6.6$.

RTL. The Region-Time-Length function (RTL) (Sobolev and Tyupkin, 1997, Sobolev and Tyupkin, 1996) measures the level of seismic activity at a given location (x,y) as a function of time t. It analyzes the number of earthquakes, their size, and their distance from (x,y) within a moving time window.

Seismic Foreshocks

A foreshock is an earthquake that occurs before a larger seismic event (the mainshock) and is related to it in both time and space. The designation of an earthquake as foreshock, mainshock or aftershock is only possible after the full sequence of events has happened.

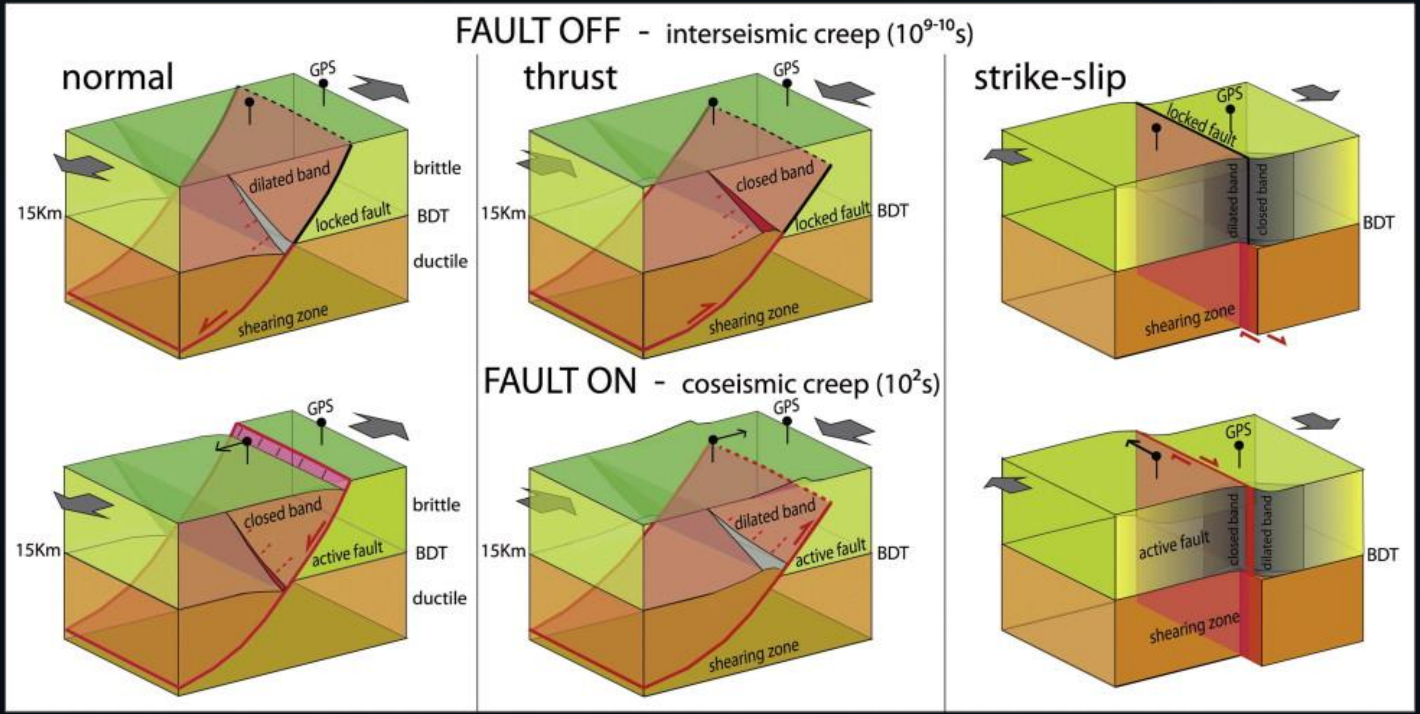




Seismologists have observed a process called nucleation, where the rate of slip along a fault ramps up gradually before an earthquake.

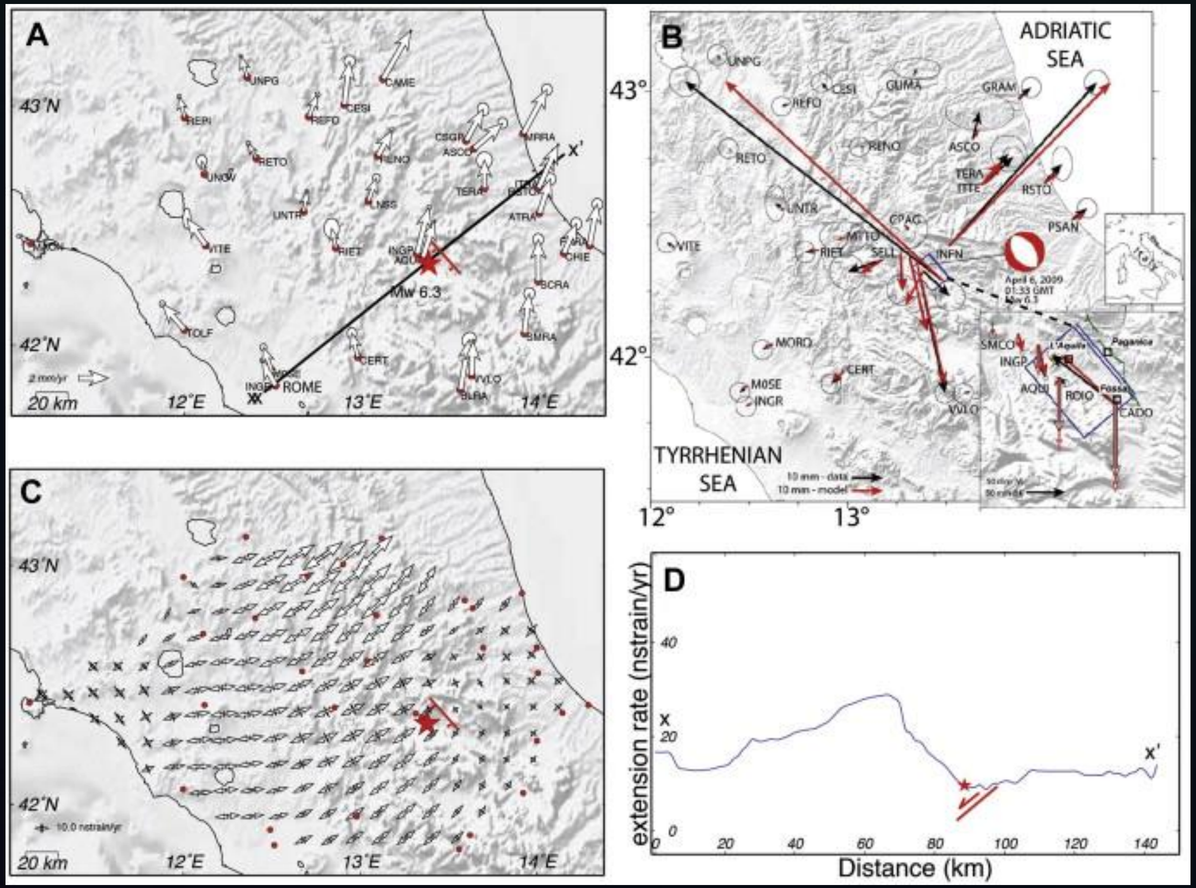
Alaska Earthquake Center seismologists, in collaboration with an international research team, recently identified a 2016 magnitude 3.7 Minto Flats earthquake that was preceded by an intensifying 12-hour sequence of foreshocks followed by a 22-second nucleation signal before rupturing as an earthquake. This discovery suggests that the rupturing process can begin hours or even days before an earthquake.

Fault Creep and Continuous Strain



- Large ground displacements in geological faults are not always abrupt occurrences during major earthquakes.
- Instead, many faults including segments of the much researched San Andreas Fault system exhibit continuous slow movement creep for a considerable time in the range of 10 days to a few years prior to major ground shaking.
- Scientists agree that fault creep is a result of continuous stress release in regions with high background seismicity rates.
- Modeling such an open physical system that continuously builds up and releases stress through slow deformation is the biggest challenge in earthquake prediction at such fault systems using fault creep measurements.

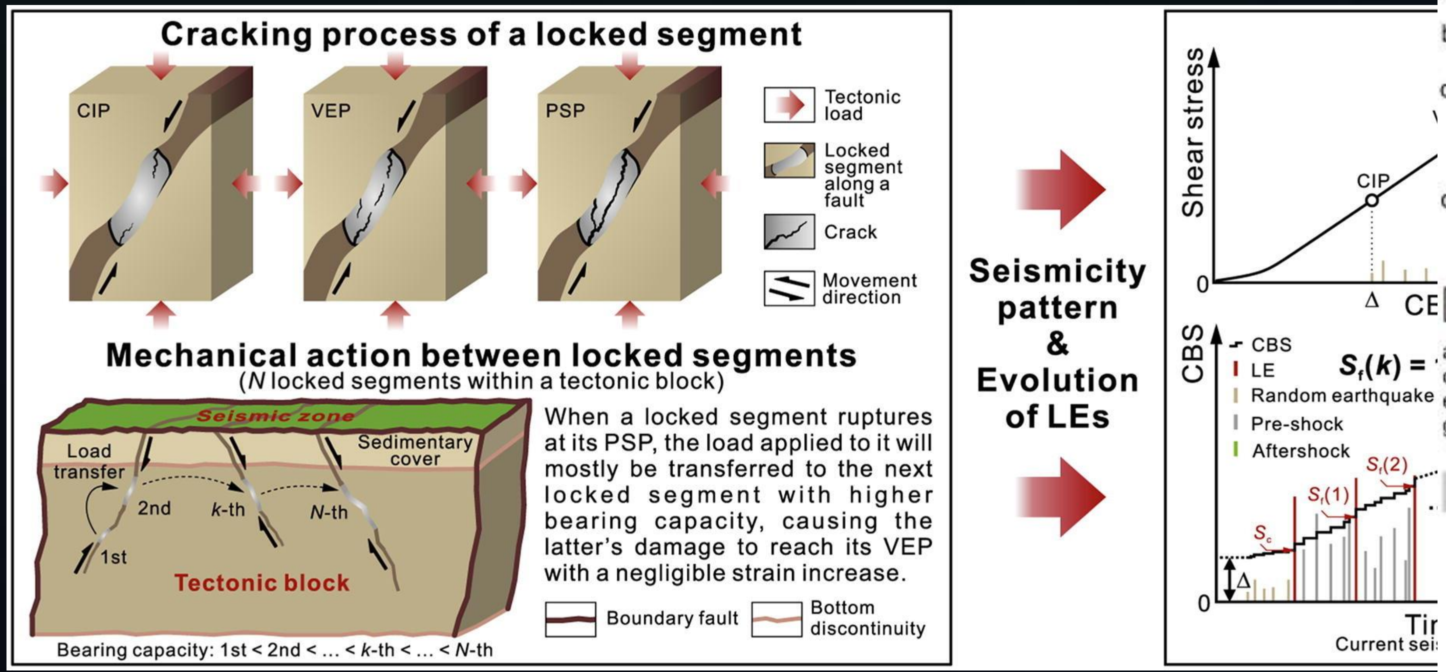
Fault Creep and Continuous Strain

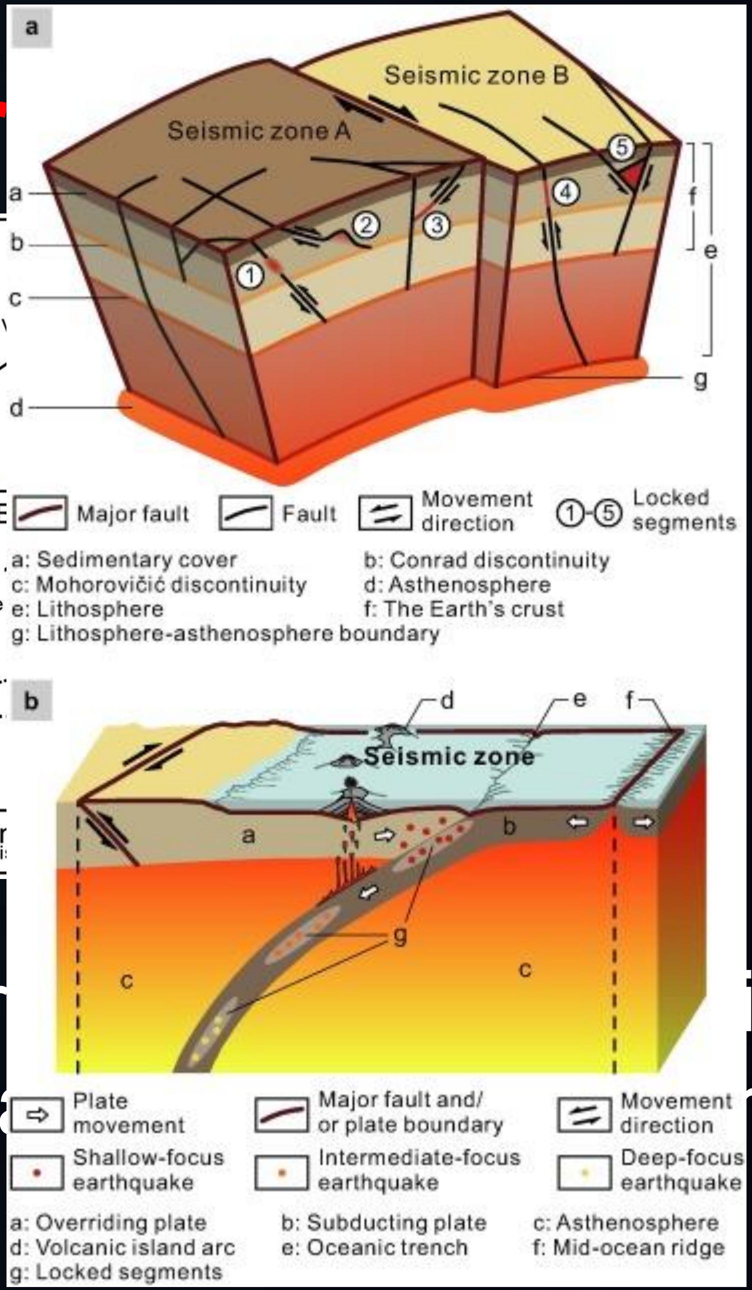


The strain rate principal axes on a regular grid based on the interseismic velocities based on the data before the 6th April, 2009, *M* 6.3 event.

The fault nucleated in an area of low interseismic strain rate (Doglioni et al., 2011). The higher strain rate to the north is interpreted as related to the postseismic relaxation of the 1997–1998 Umbria-Marche seismic sequence, where the faults did not return yet to a locked condition. The red line represents the main activated fault.

Seismicity Patter



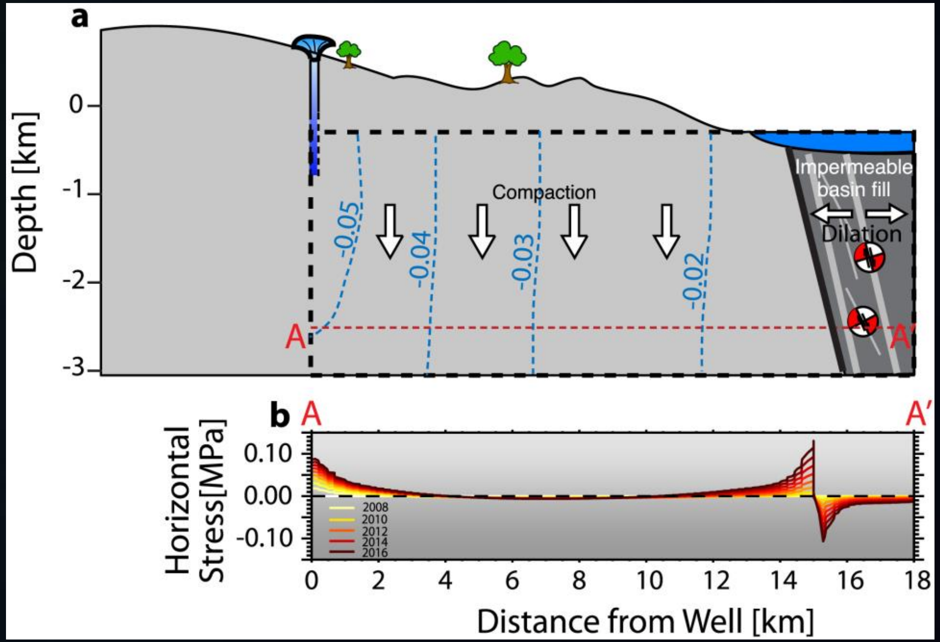


Increases in seismic activity in a particular … in the number or intensity of earthquakes, ca… rs to a major earthquake

Changes in Ground Water Level

Nadav Wetzler, 2019

Unusual fluctuations in groundwater levels, such as rapid changes or long-term variations, have been observed prior to some earthquakes. However, this precursor is still under investigation and not fully understood.



Groundwater levels in wells can oscillate up and down when seismic waves pass. The water level might remain higher or lower for a period of time after the seismic waves end, but sometimes a long-term offset of groundwater levels follows an earthquake. The largest recorded earthquake-induced offset in a well is a one meter rise.

Anomalous Geochemical Observations

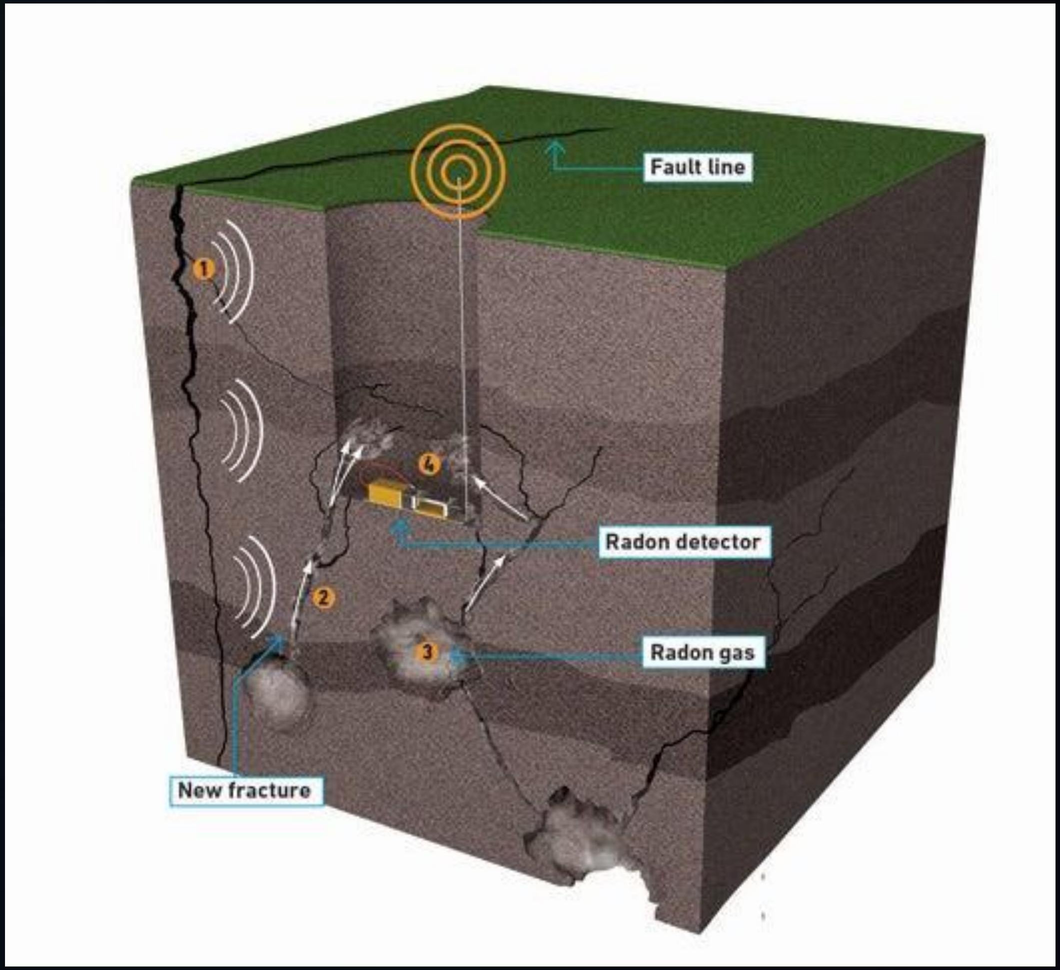
The most common is the apparent spike in soil radon concentration observed prior to large earthquakes.

Subsurface soil gas along active faults in central California has been continuously monitored to test whether its radon-isotope content shows any premonitory changes useful for earthquake prediction .

Changes in Radon Gas Emission

Radon gas is a naturally occurring radioactive gas that can be released from the Earth's crust.

Some studies have suggested that abnormal changes in radon gas emissions, either increasing or decreasing, may occur before earthquakes



Morgen Peck 2010

Electromagnetic Anamoloies

Anomalous changes in the Earth's electromagnetic field, such as variations in the ionosphere or electromagnetic waves, have been associated with seismic activity.

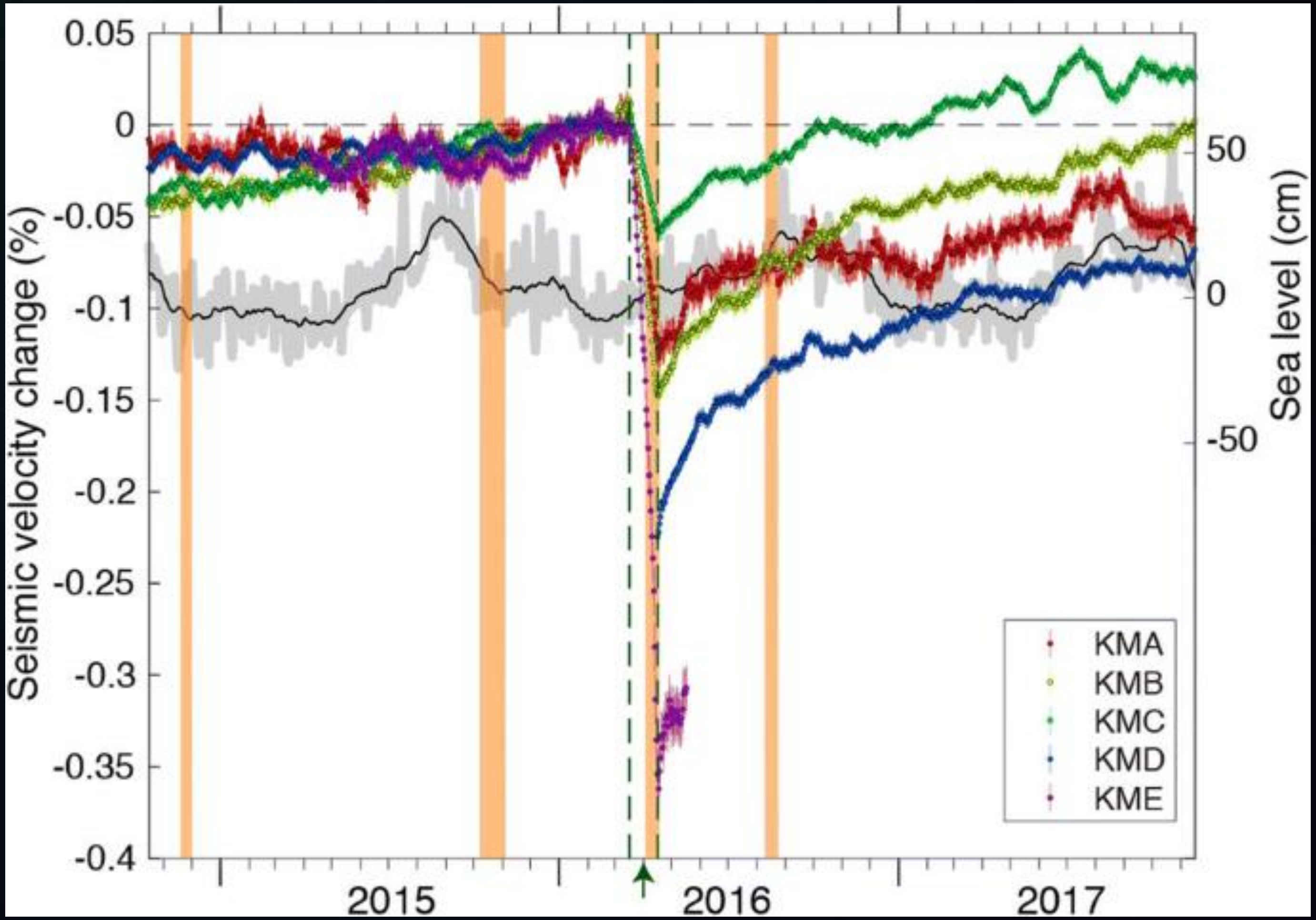
However, the link between electromagnetic anomalies and earthquakes is still not well understood.

A new study published in Earth, Planets and Space sheds new light on the electromagnetic anomalies occurring before large earthquakes. The research supports the hypothesis that fault rupture progresses just before an earthquake, and the invading gas is charged and forms a large current, causing various electromagnetic anomalies.

Changes in Seismic Wave Velocity

Variations in the speed at which seismic waves travel through the Earth's crust have been detected before certain earthquakes.

These changes can be measured using seismometers and other geophysical instruments.

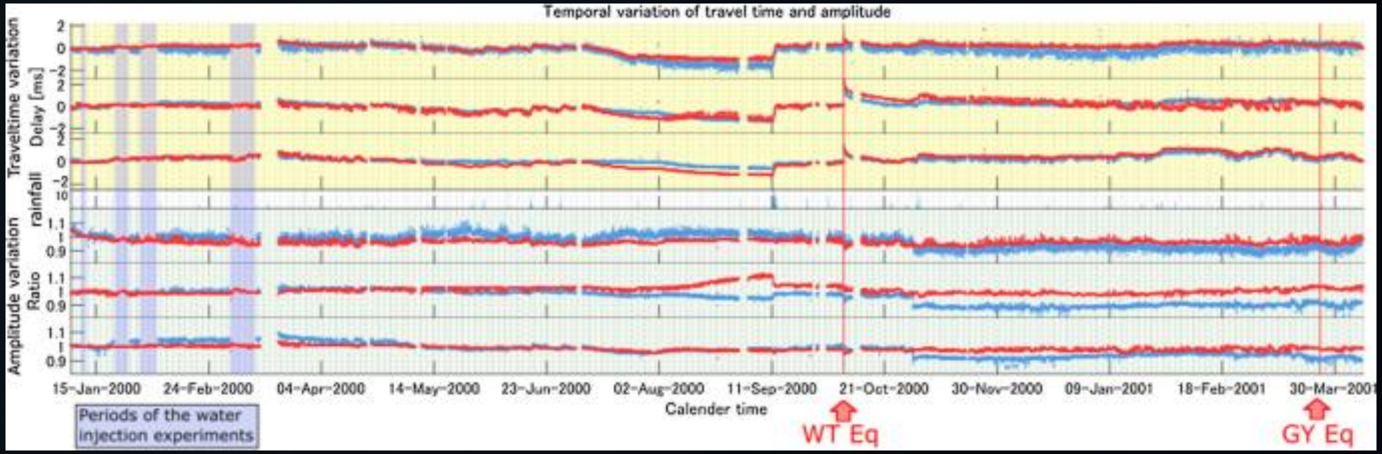


Ikeda, T., Tsuji,2018

Changes in Ground Vibration

Sensitive instruments can detect slight variations in ground vibration or oscillations before an earthquake.

These changes can occur over a wide range of frequencies and amplitudes.

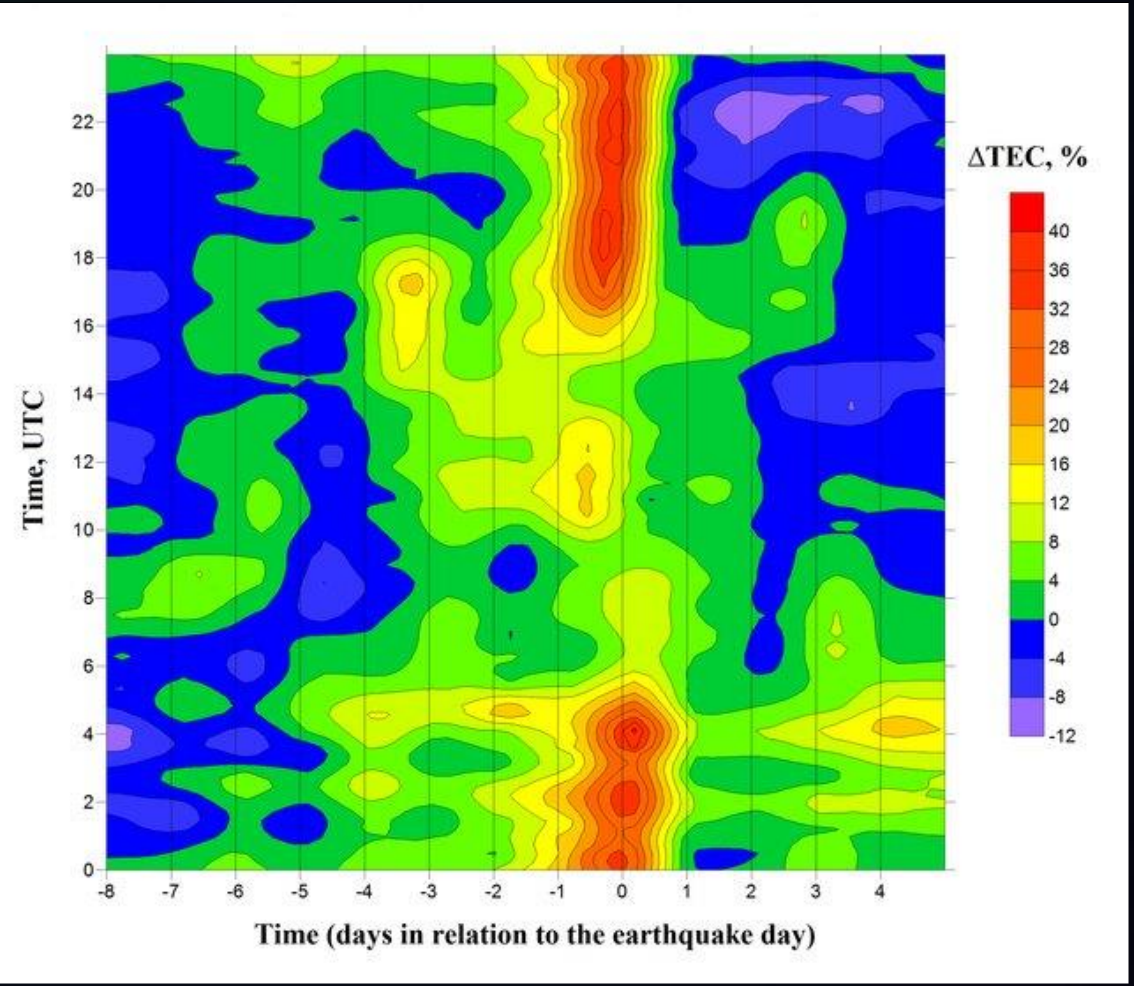


Suhei et al 2022

Geochemical Anomalies

Geochemical Anomalies: Changes in the chemical composition of soil, groundwater, or gases emitted from the Earth's crust have been associated with seismic activity.

This includes variations in the concentrations of certain gases or elements

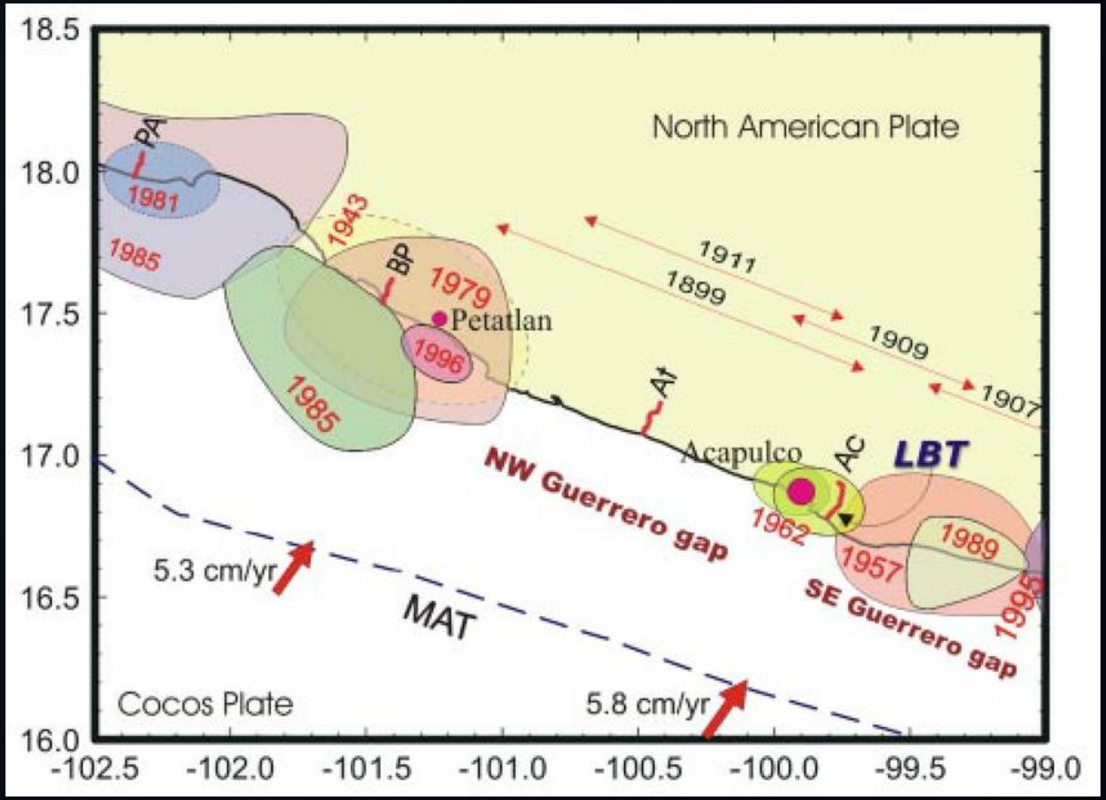


Ionospheric earthquake precursor mask for the Greek region: along the abscissa, the day before and the day after the earthquake are marked, zero marks the day of the earthquake; along the ordinate, the time from 0000 UTC to 2358 UTC is shown; tone scale shows the values of ΔTEC, % (Sergey and Dmritry , 2018

Seismic Gap

A seismic gap refers to an area along a fault line that has not experienced significant seismic activity for a long time.

The accumulation of stress in such regions can indicate an increased likelihood of an earthquake occurring in the future.

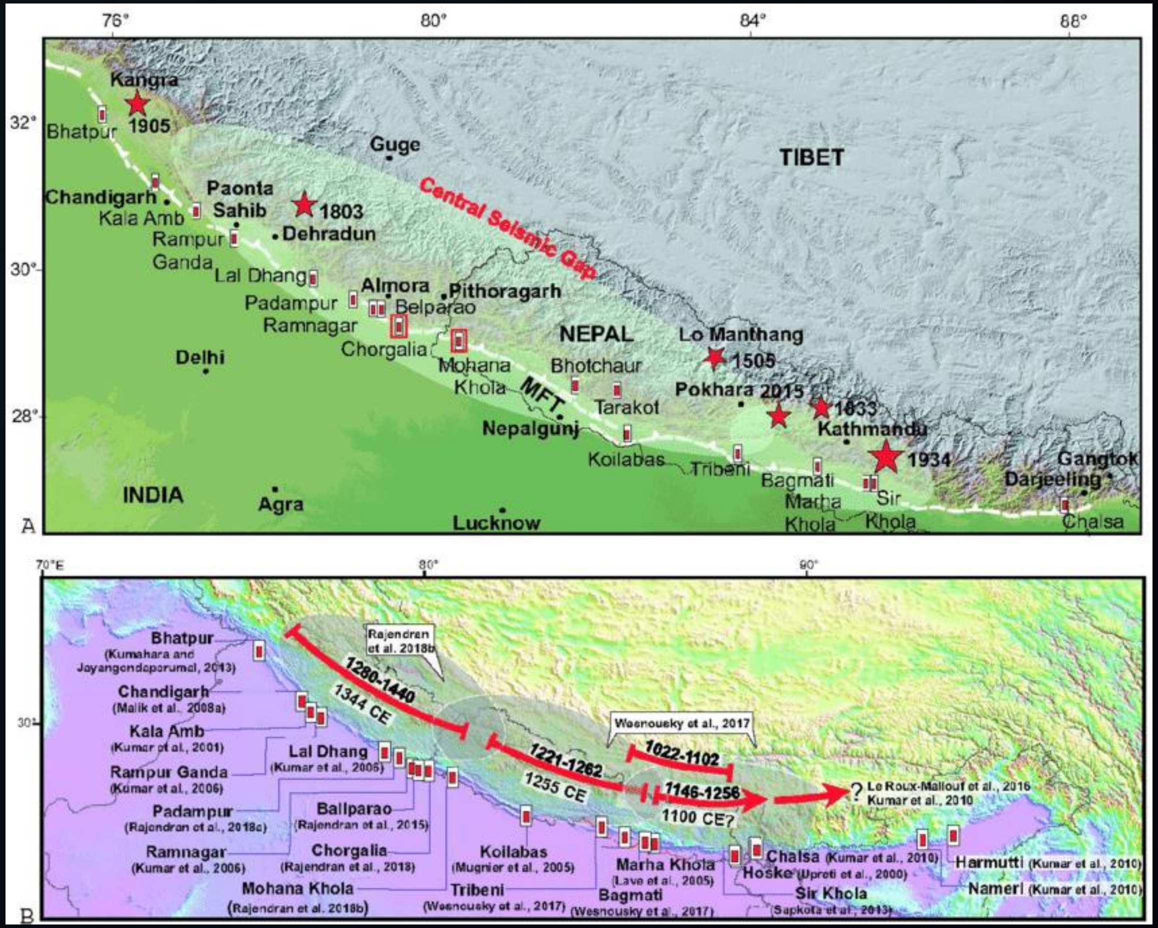


Vladimir Kostoglodov et al. 2002

Seismic Gap Migration

In addition to seismic gaps along fault lines, the migration of seismic activity within a region can be an important precursor.

If seismicity migrates along a fault segment, it may indicate an increased likelihood of a larger earthquake occurring in that area.



Rajendran and Kusala Rajendran 2005

Unusual Lights and Sounds

Rare observations of glowing or flashing lights, known as earthquake lights or seismic lights, have been reported in the sky before earthquakes.

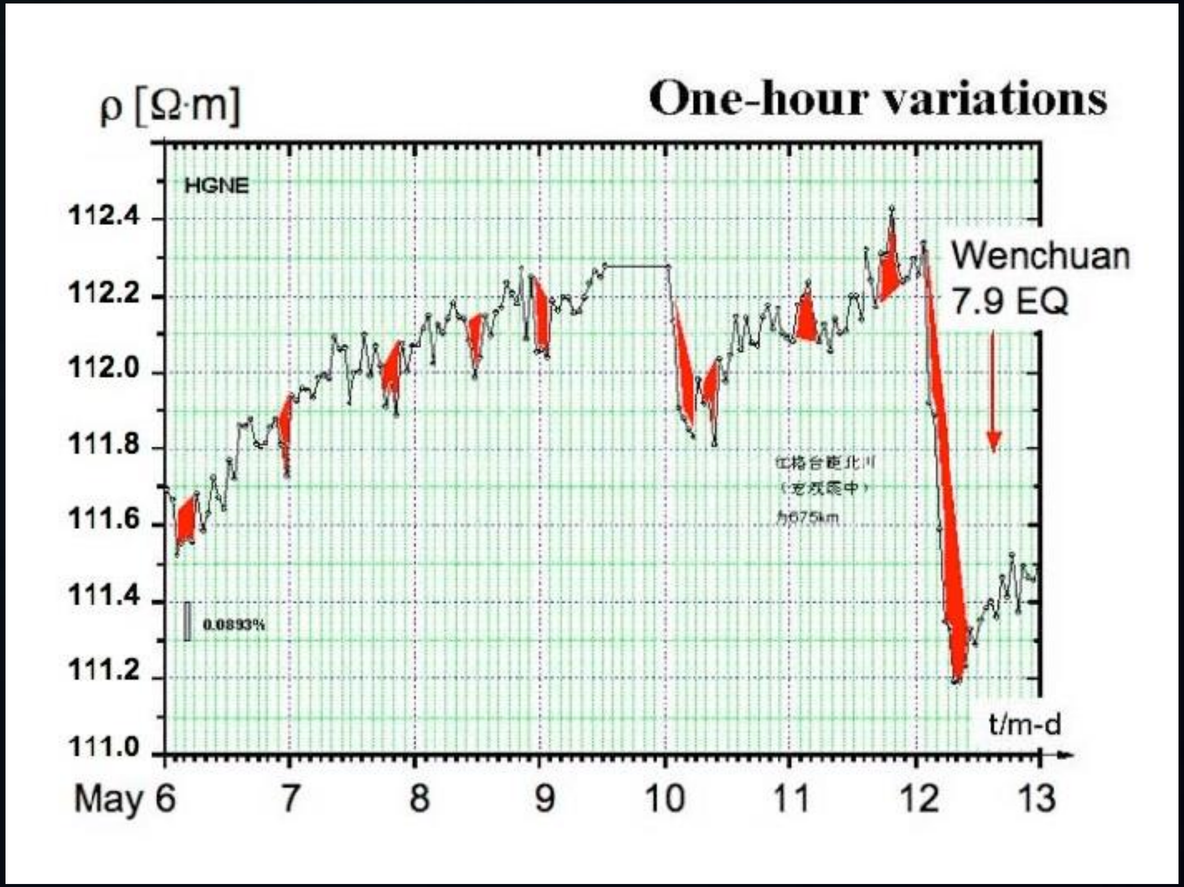
Similarly, unexplained sounds, such as rumbling or low-frequency noises, have been associated with seismic activity.

Earthquake lights captured over Mount Kimyo, Japan, in 1968
Courtesy : Bulletin of the Seismological Society of America

Changes in Ground Resistivity

Variations in the electrical resistivity of the Earth's subsurface can occur before earthquakes.

These changes can be measured using resistivity meters and are thought to be related to alterations in the pore fluids or mineral properties.

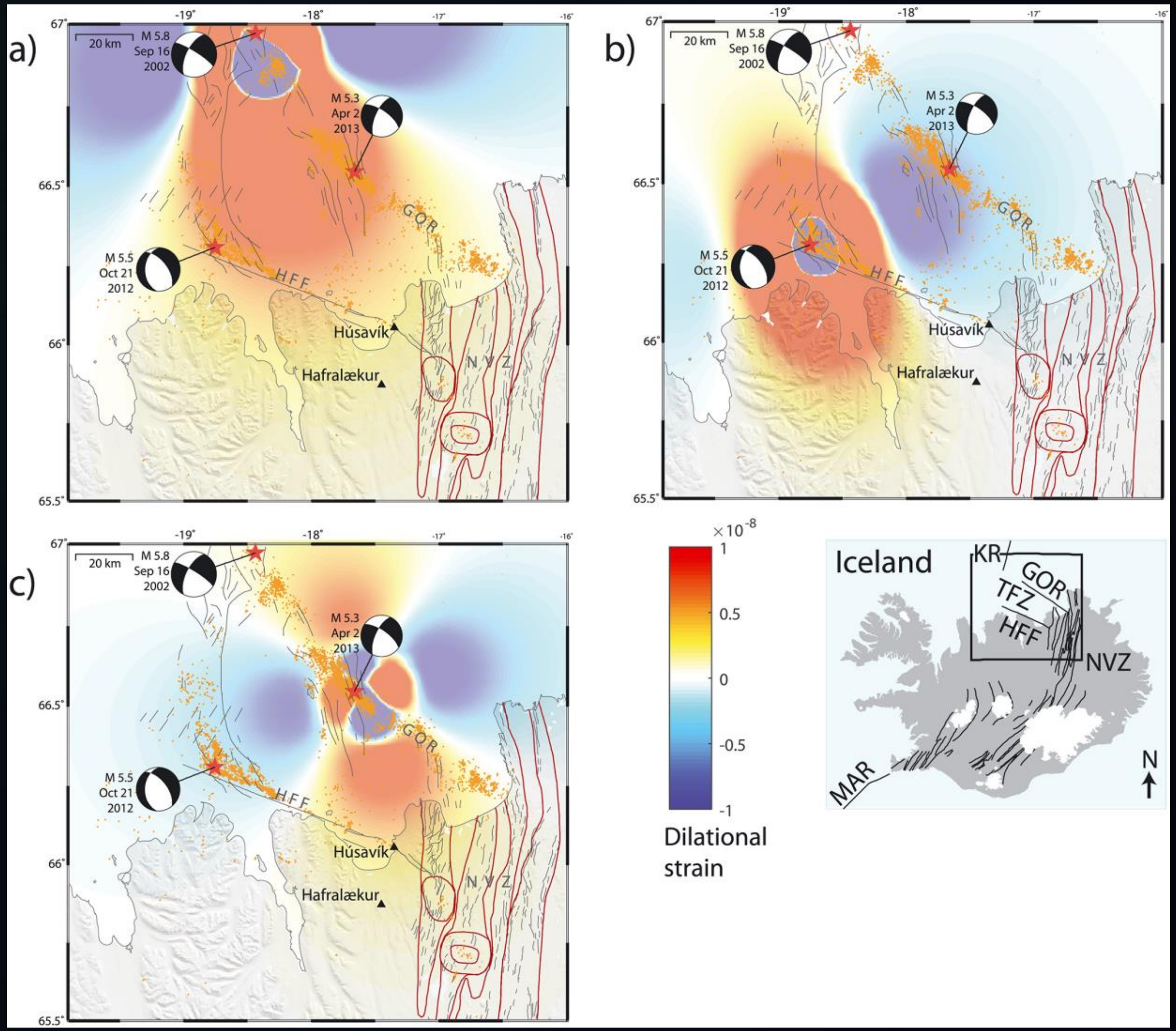


Changes in the electric resistivity of the soil prior to the M=7.9 Wenchuan earthquake (after (Zhao and Qian, 2009)).

Changes in Ground Water Chemistry

Shifts in the chemical composition of groundwater, such as changes in pH, temperature, or the presence of certain elements or gases, have been observed prior to some earthquakes.

These changes can be monitored through regular water sampling and analysis.

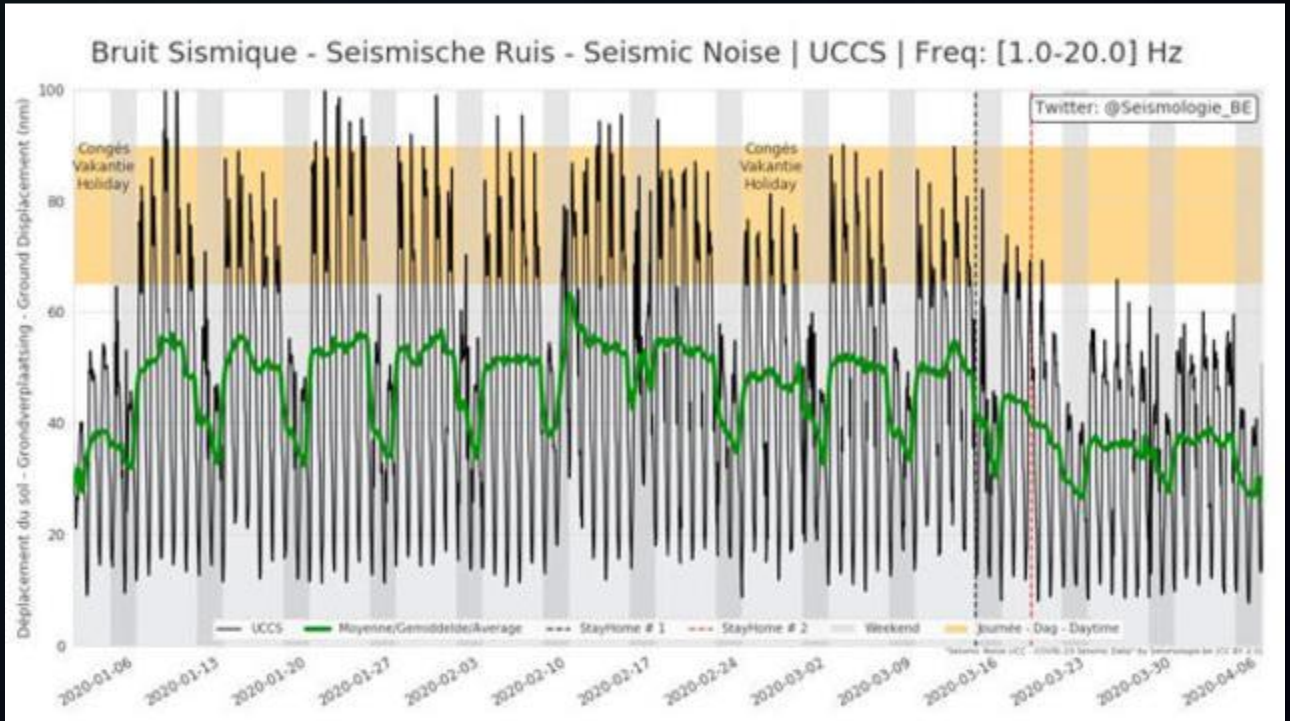


Skelton et.al 2019

Changes in Seismic Noise

Seismic noise refers to the background vibrations recorded by seismometers.

Unusual variations in seismic noise characteristics, such as changes in frequency content or amplitude, have been associated with impending earthquakes.

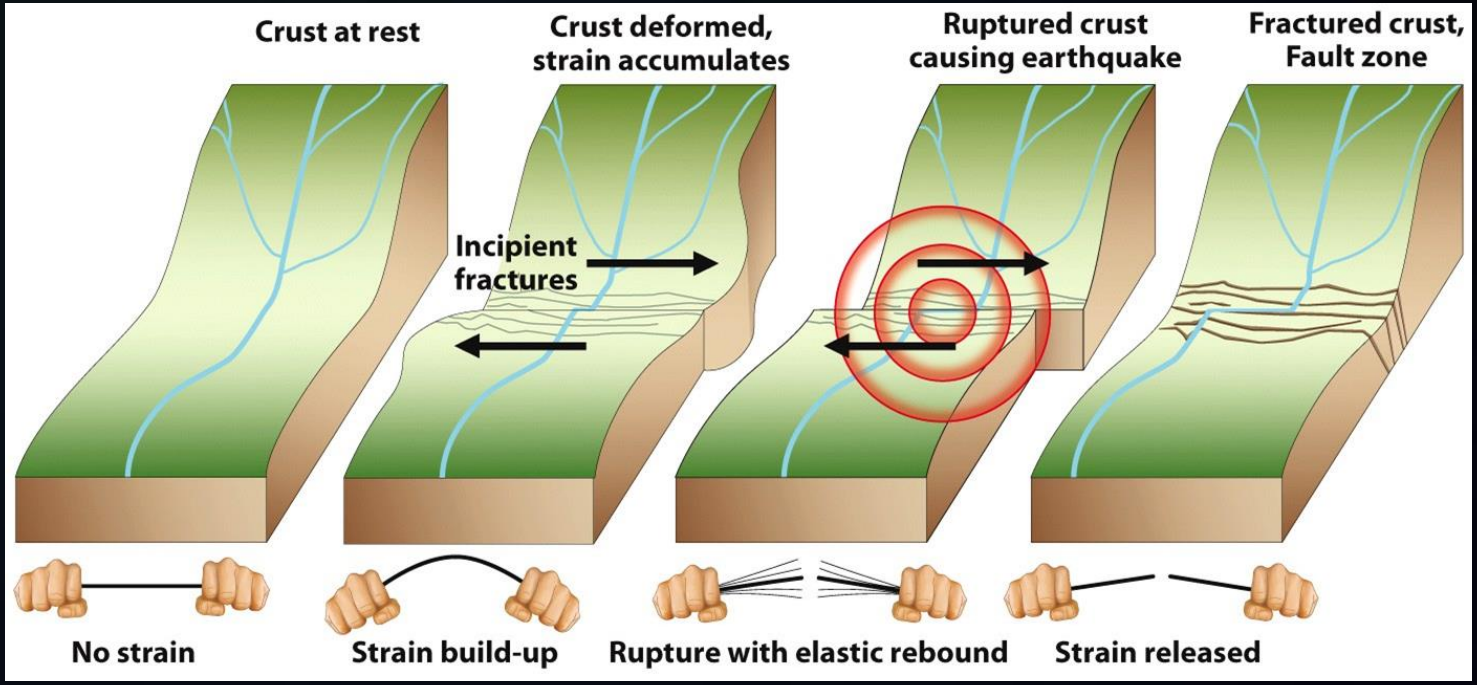


SOURCE: ROYAL OBSERVATORY OF BELGIUM

Changes in Ground Strain

Strain refers to the deformation or stretching of the Earth's crust due to tectonic forces.

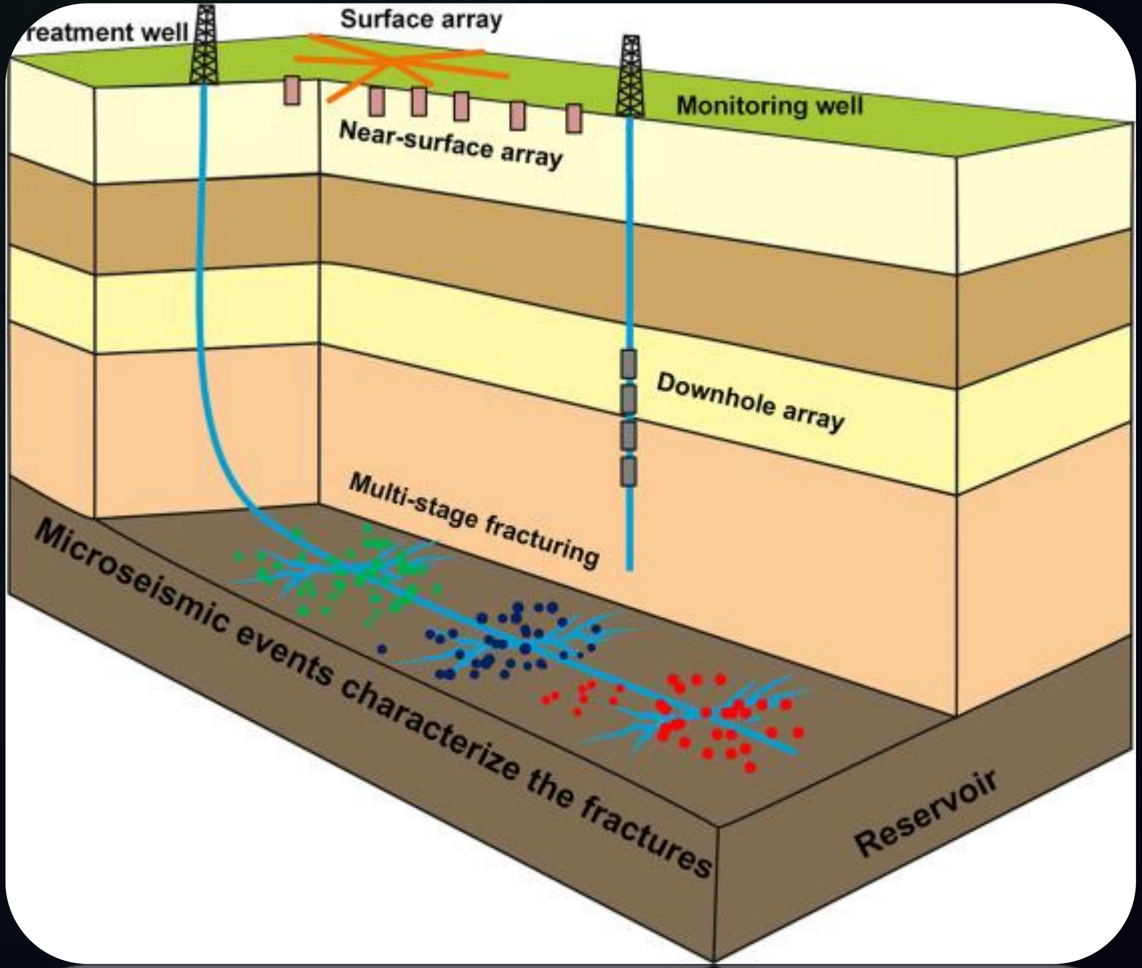
Monitoring changes in ground strain using strain meters or strain gauges can provide insights into stress accumulation and release, potentially indicating an impending earthquake.



Source : https://geophile.net/

Changes in Microseismic Activity

Microseismic events are very small earthquakes that are often imperceptible to humans but can be recorded by sensitive instruments.

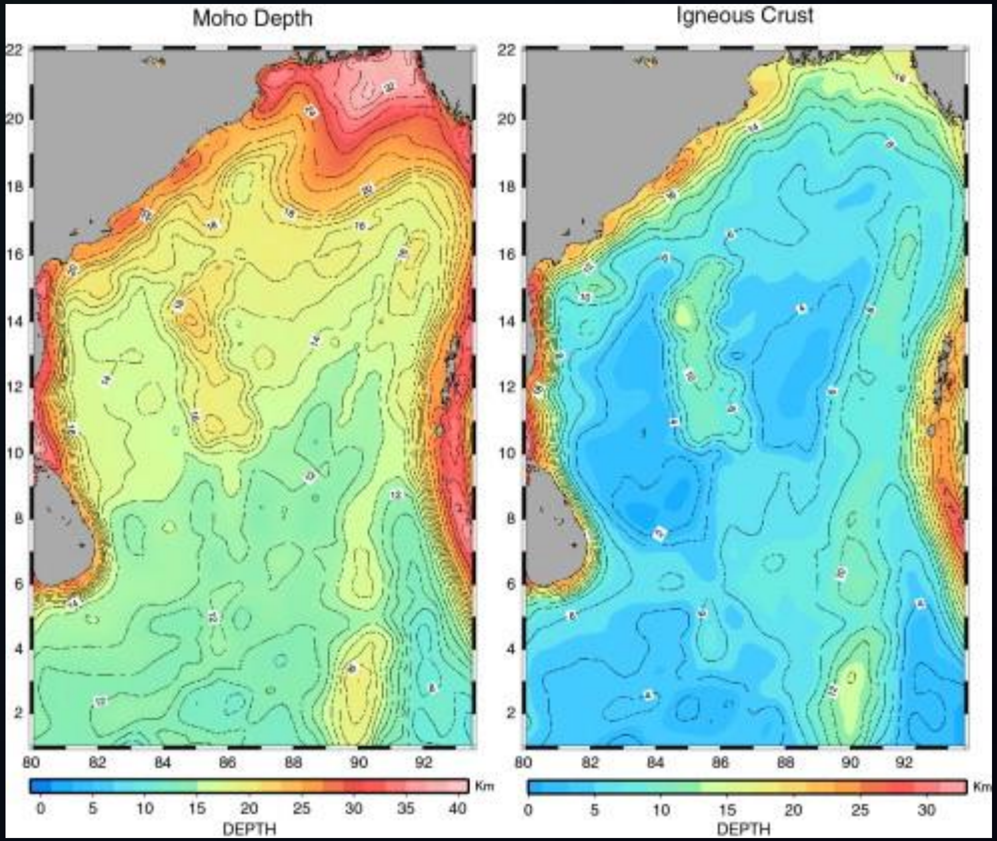


An increase in microseismic activity in a particular region can be an indication of heightened seismic stress.

Changes in Geological and Geophysical Parameters

Variations in geological and geophysical parameters, such as changes in crustal density, magnetism, or rock properties, have been proposed as potential earthquake precursors.

These parameters can be monitored through geophysical surveys and observations.

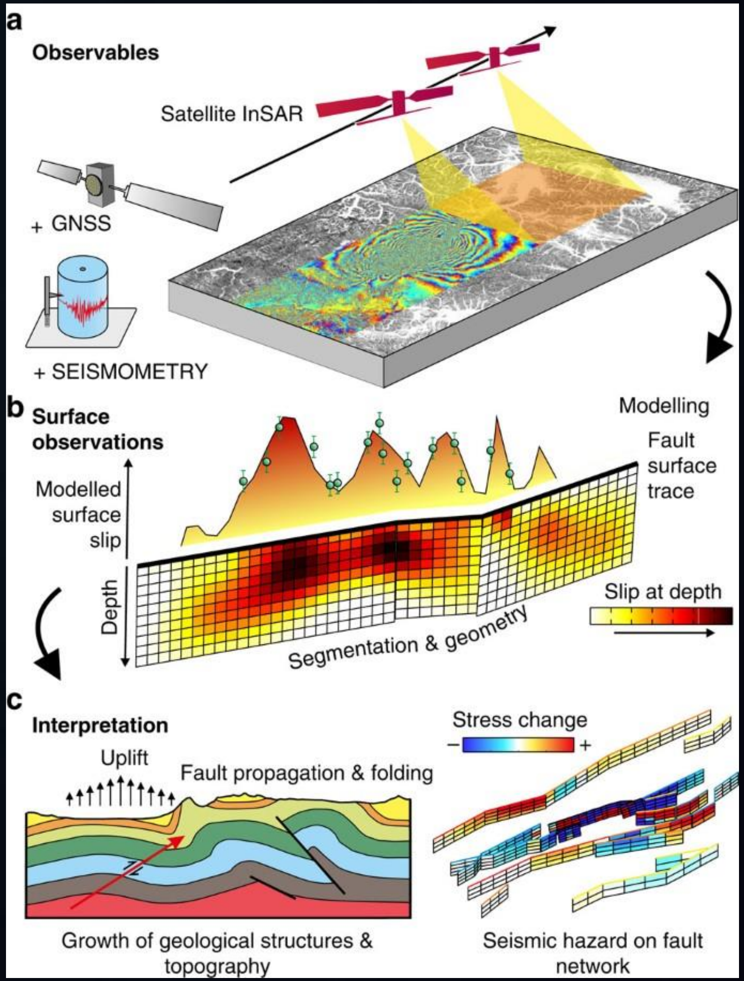


Bastia and Radhakrishna (2012)

Satellite-based Observations

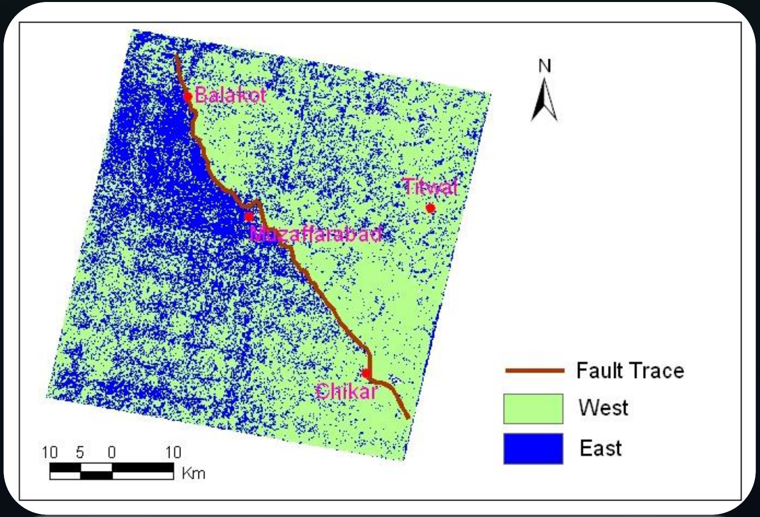
Remote sensing techniques using satellites can provide valuable information on pre-earthquake phenomena.

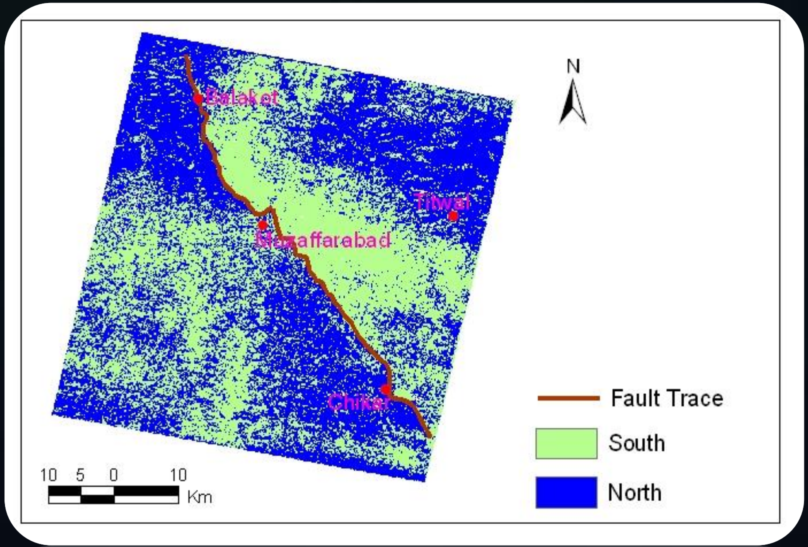
This includes monitoring changes in land surface temperature, vegetation health, or deformation patterns using satellite imagery.

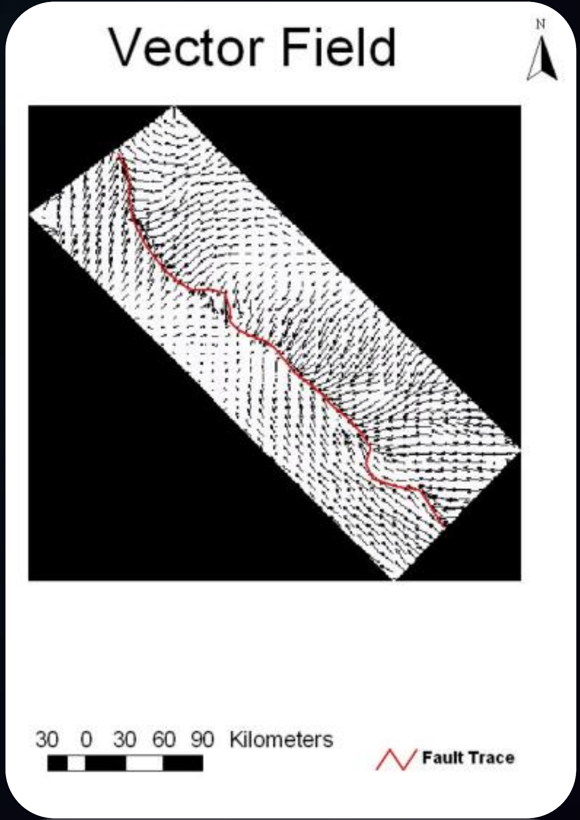


Eliot et.al 2017

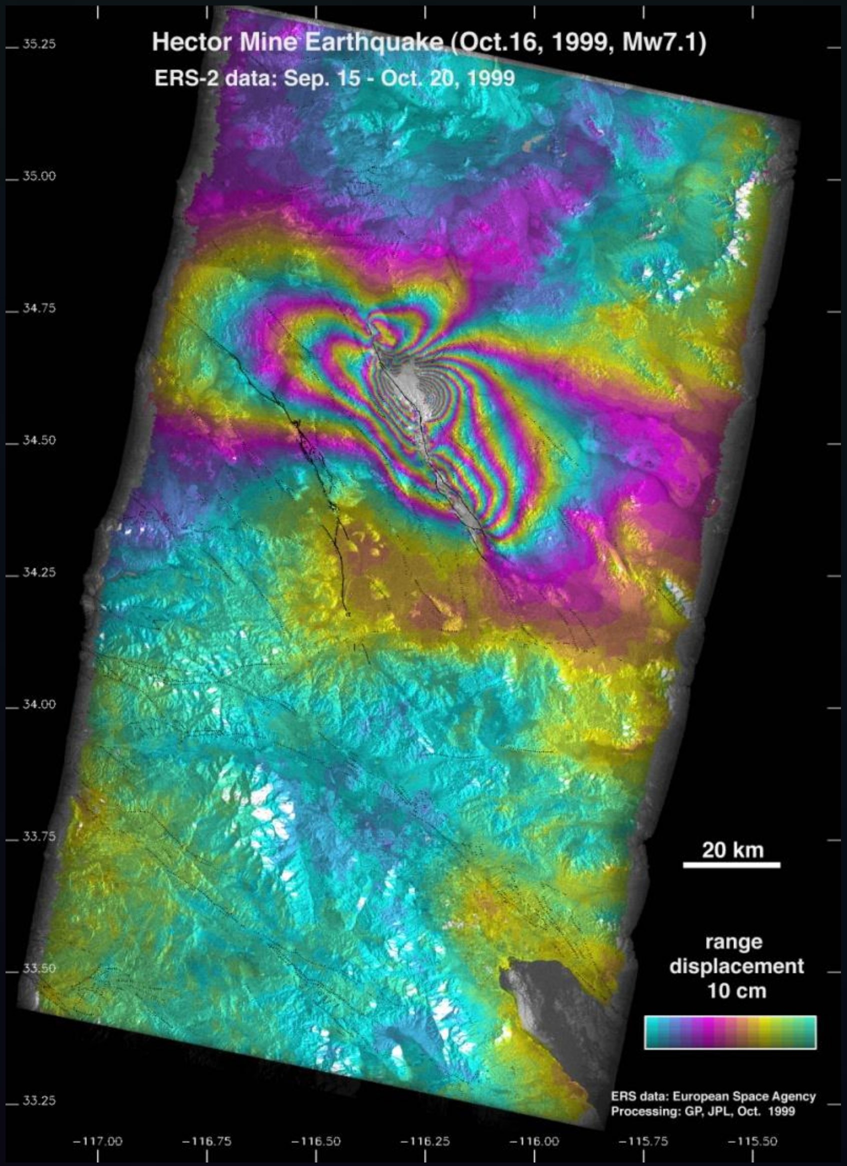
Causative Fault mapping using sub-pixel registration of ASTER images







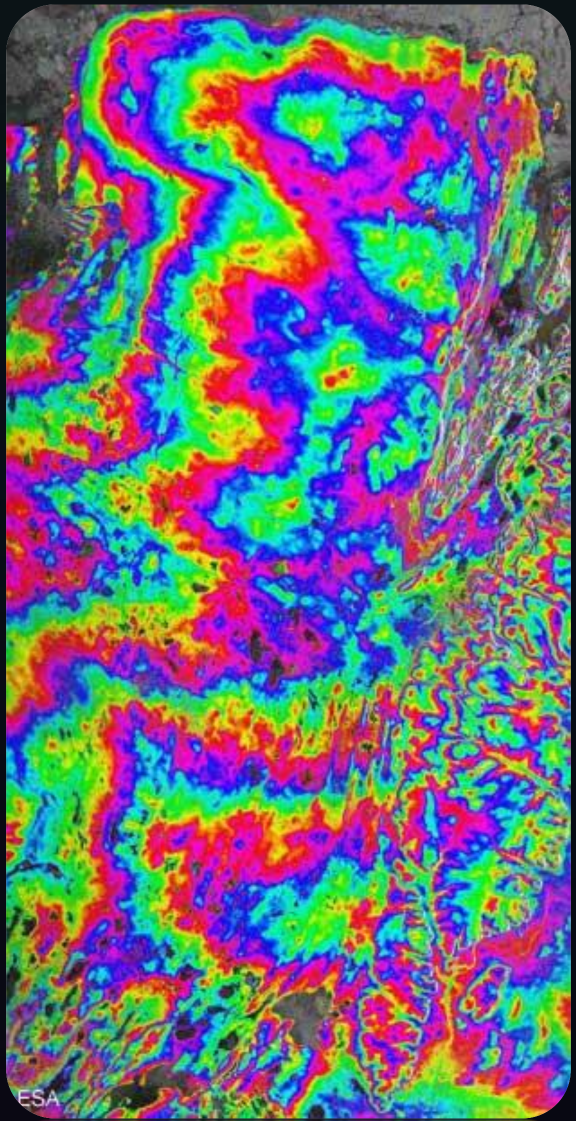
Causative Fault mapping using interferometric map



The image is an interferometric map of the Hector Mine earthquake area showing the ground displacement along the radar line of sight. One full color cycle represents 10 cm of range displacement. Gray areas are zones of low phase coherence that have been masked before unwrapping. Dotted lines depict California faults, after Jennings (1975), and thick, solid lines the Landers , 1992 surface rupture, after Sieh et al. (1993).

The radar data were acquired by the European Space Agency ERS-2 satellite on September 15 and October 20, 1999. The data used here cover frames 2907 and 2925 of descending track 127. The post-earthquake data were purchased from Eurimage and transfered from the Centre Canadien de Teledetection to JPL via FTP.

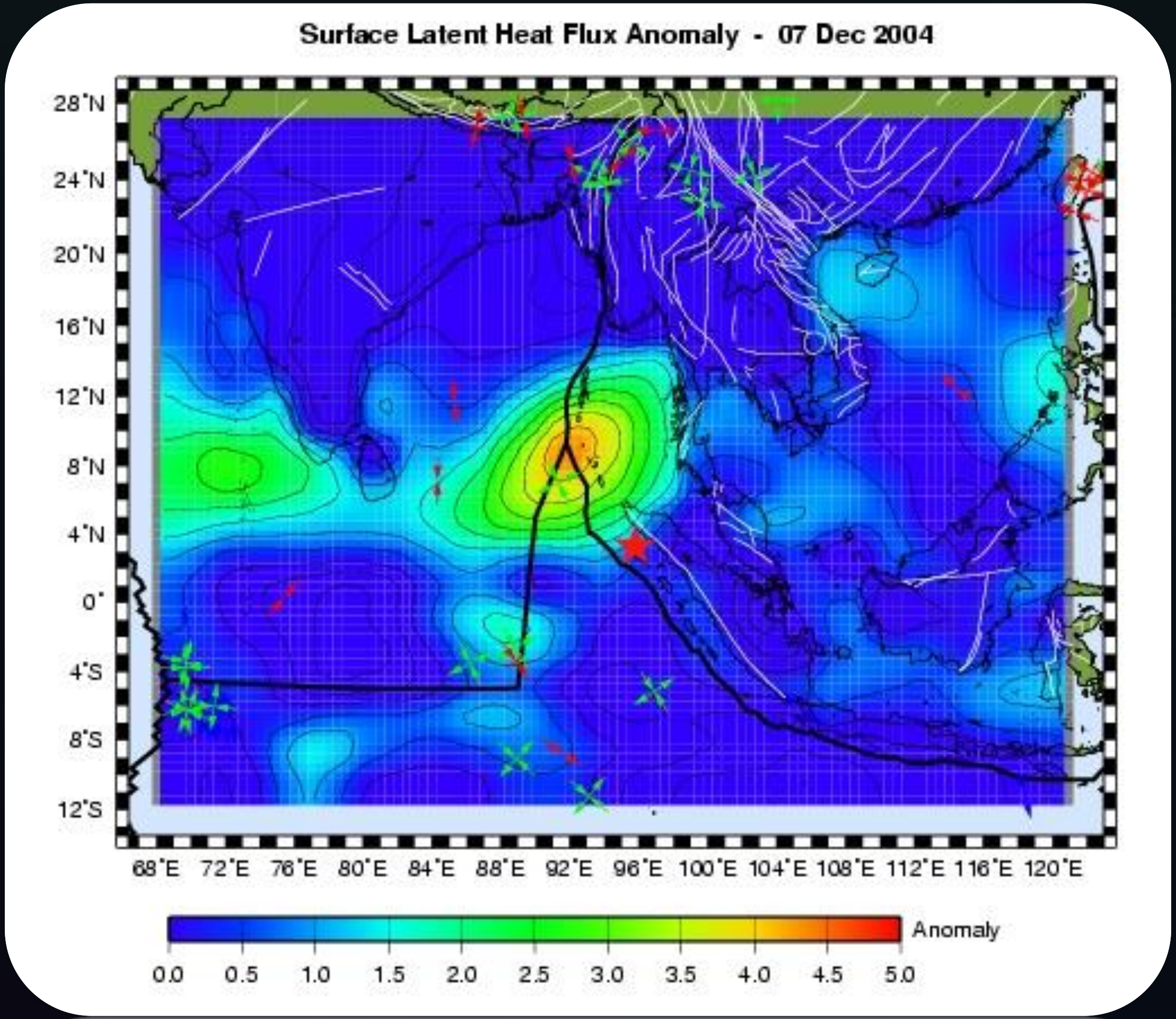
Causative Fault mapping using Radar Signals



Europe's Earth Remote Sensing spacecraft use radar signals that may offer clues in how best to spot earthquakes before they occur.

Each cycle of colors (for example, going from yellow to purple to turquoise and back to yellow again) represents a change in the ground-height, dependent on position of spacecraft above Earth.

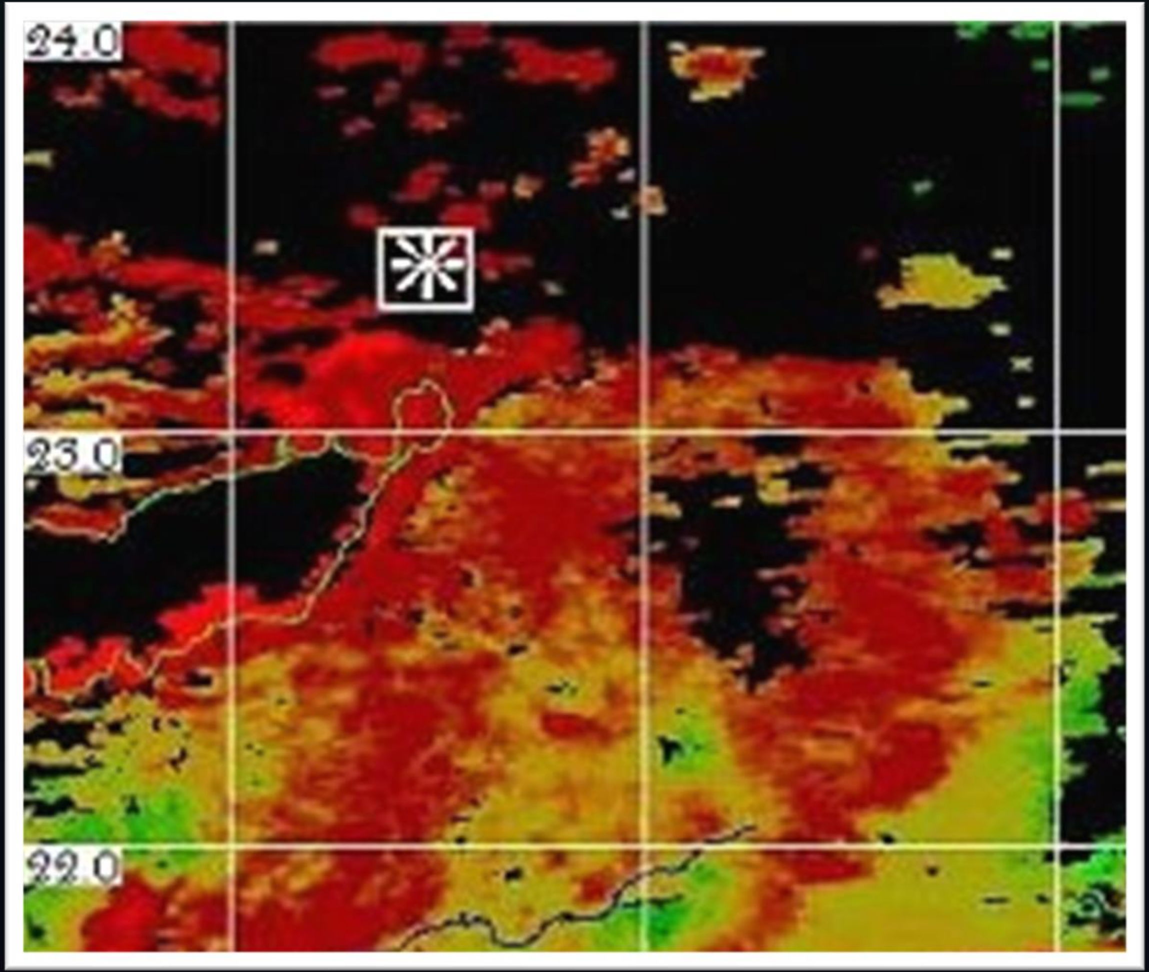
Causative Fault mapping using Surface Latent Heat Flux



Surface latent heat flux anomaly in the vicinity of the Sumatran earthquake several weeks before the earthquake occurred.

The CEOSR scientists believe surface latent heat flux may be the key to successful forecasting. The signs are promising. On Jan. 1, Cervone forecasted an earthquake off the coast of Japan. Eight days later, the earthquake, registering 5.3 on the Richter scale, occurred where he had predicted. His system has shown that the weaker the earthquake, the shorter the time span between when an anomaly is spotted and when the quake occurs. A massive quake has a much longer time span between the appearance of an anomaly and the actual quake, providing more time for preparation or evacuation.

Causative Fault mapping using Thermal Anomalies

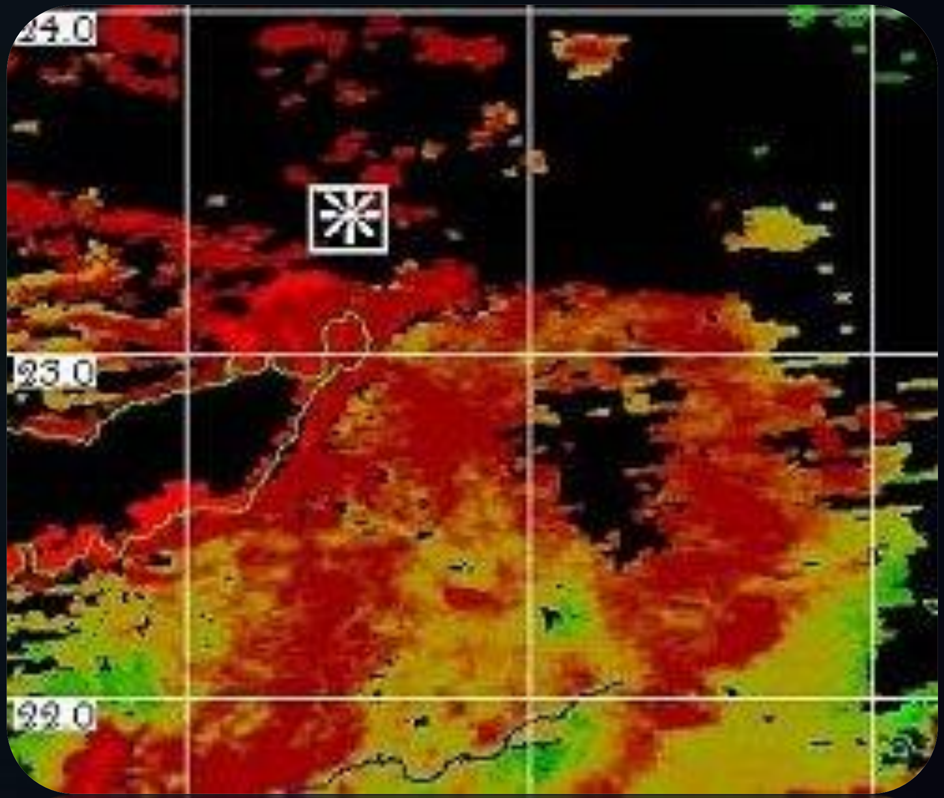


An infrared image of the region surrounding Gujarat, India, on January 21, 2001. Yellow-orange areas trace thermal anomalies that appeared days before the Jan. 26th quake. The boxed star denotes the quake's epicenter. Credit: MODIS onboard NASA's Terra satellite.

Thermal Anamolies

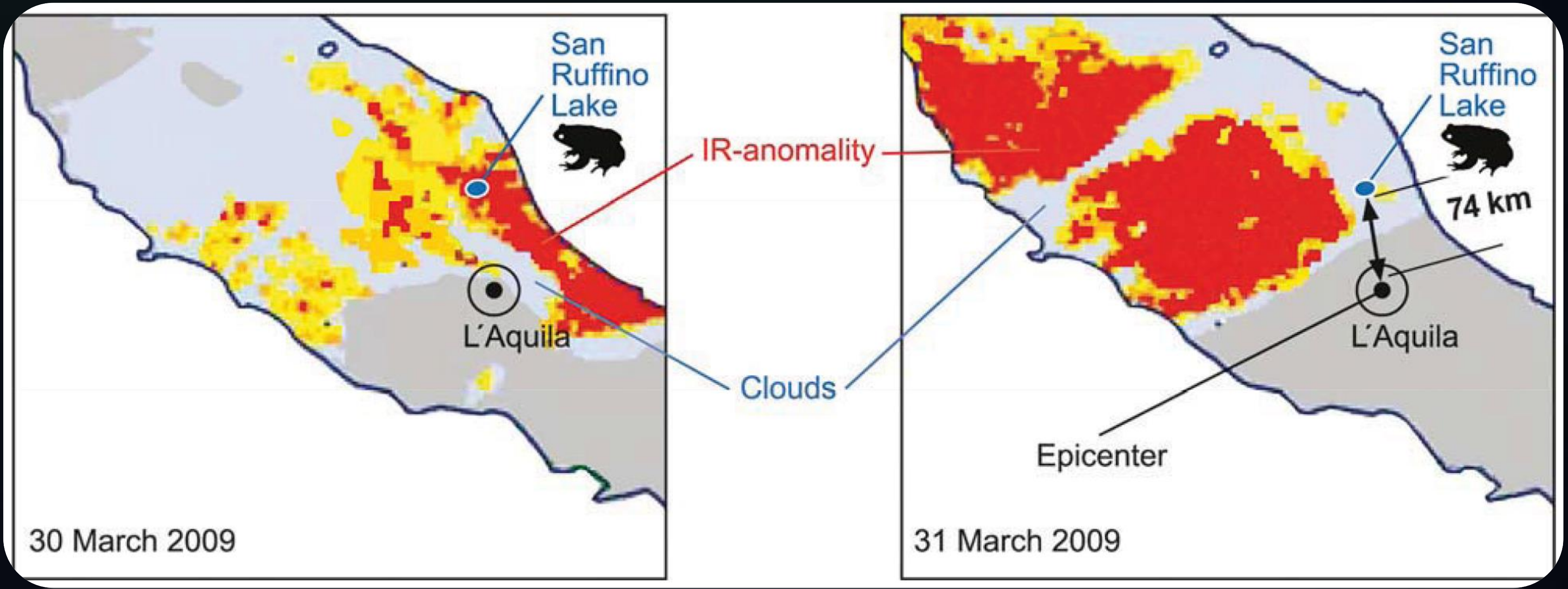
Unusual changes in temperature at or near the Earth's surface have been observed prior to some earthquakes.

These thermal anomalies can manifest as unexpected heating or cooling of the ground or bodies of water.



An infrared image of the region surrounding Gujarat, India, on January 21, 2001. Yellow-orange areas trace thermal anomalies that appeared days before the Jan. 26th quake. The boxed star denotes the quake's epicenter. Credit: MODIS onboard NASA's Terra satellite.

Satellite Information on Heat Anomalies and Heat Island Phenomena Preceding Earthquakes

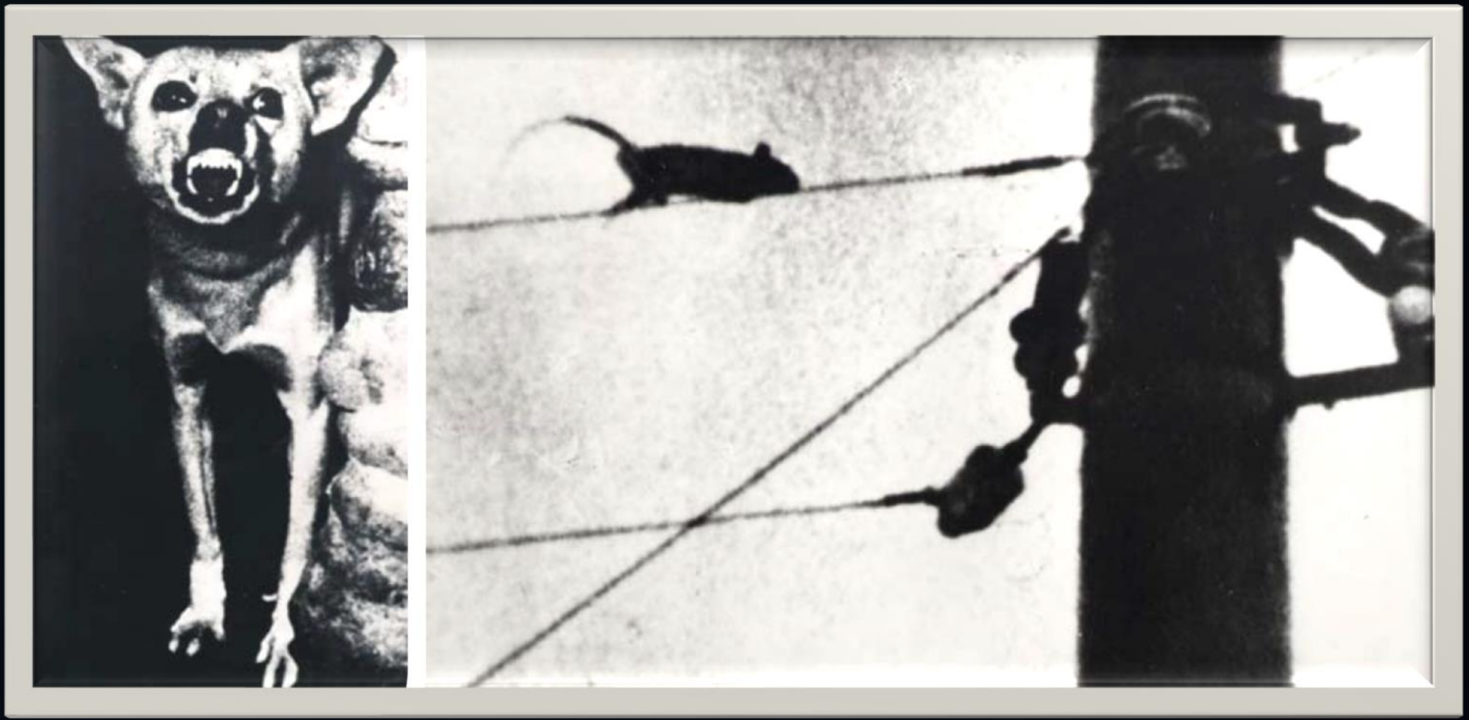


Infrared anomaly seen from a satellite (infrared anomaly distribution adapted from [48]) over central Italy before the Abruzzo earthquake. The left image was taken on 30 March, the right one on 31 March (the quake happened on 6 April, 3.32 A.M.). The arrows in the figures indicate the site of animal (toad) observation and the epicentre respectively (the infrared absorbing clouds are also indicated).

Abnormal Animal Behaviours

Abnormal Animal Behaviours

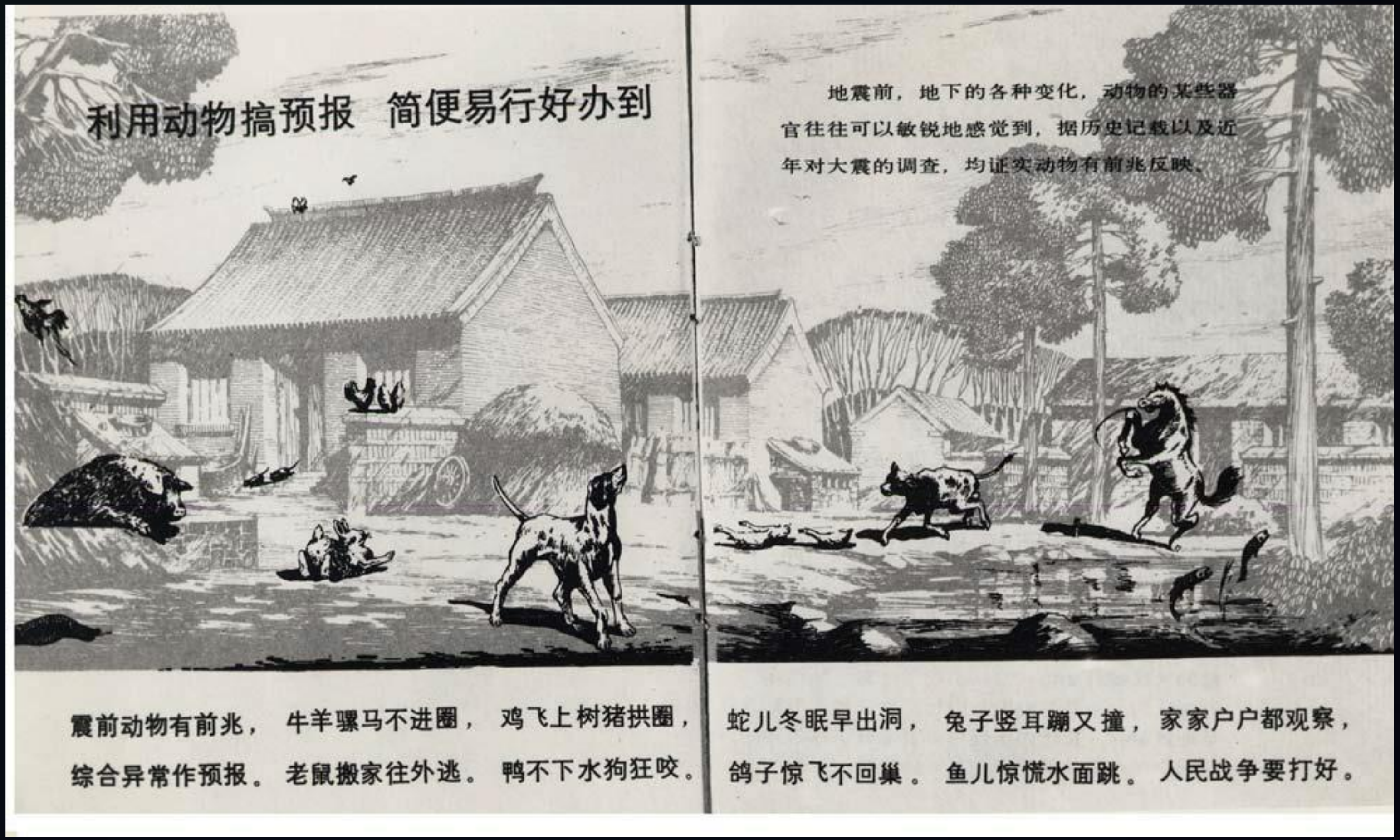
An Excited dog and of a fleeing rat, which were taken prior to the 7.2 Magnitude Sungfan-Pingwu earthquake from 1976.



Source : Helmut Tributsch, 2013

Abnormal Animal Behaviours

Chinese flyer, distributed to country people with the intention of explaining the behaviour of animals prior to earthquakes, which should be observed.



Source : Helmut Tributsch, 2013

Unusual Animal Migration

Some studies have indicated that certain animal species may alter their migration patterns before earthquakes.

This includes birds, fish, or marine mammals deviating from their regular migration routes or exhibiting changes in their timing.

Unusual Animal Grouping

Some observations suggest that animals may exhibit abnormal grouping behavior before earthquakes.

This includes the clustering of normally solitary species or the convergence of different animal species in specific areas.

Unusual Animal Behaviour

In addition to changes in animal behavior, there have been reports of unusual behavior in pets and domesticated animals before earthquakes. This includes dogs barking excessively, cats becoming agitated, or birds displaying unusual flight patterns.

Abnormal Animal Reproduction

Some studies have suggested that certain animal species may experience disruptions in their reproductive patterns before earthquakes.

This includes changes in breeding behavior, egg-laying patterns, or nesting habits.

Ground Deformation

Detectable changes in the Earth's surface, such as tilting, uplift, or subsidence, can be precursors to an earthquake.

These changes can be measured using various techniques, including GPS, satellite imagery, or ground-based instruments

Statistical occurrence of earthquakes

Statistical occurrence of earthquakes involves the postulation of trigger forces that initiate the rupture. Such forces have been attributed to severe weather conditions, volcanic activity activity, and tidal forces, for example.

Usually correlations are made between the physical phenomena assumed to provide the trigger and the repetition of earthquakes.

Inquiry must always be made to discover whether a causative link is actually present, but in no cases to the present has a trigger mechanism, at least for moderate to large earthquakes, been unequivocally found that satisfies the various necessary criteria.

Studies Based on Historical Data Analysis

Research in earthquake prediction based on the analysis of historic earthquake data dates as far back as 1939 and continues to be pursued today

Earthquake Magnitude Distribution and Prediction

- **Gutenberg-Richter Inverse Power Law Distribution**

(Many seismic catalogs have been found to loosely obey an inverse power law distribution such as the Gutenberg-Richter GR inverse power law distribution Gutenberg and Richter 1956)

Characteristic Earthquake Distribution

- The characteristic earthquake distribution is based on the gap theory of earthquake occurrence

Probabilistic Earthquake Distribution

- Probabilistic earthquake distribution, such as those based on the Gamma, Weibul and Poisson distributions, have also been investigated

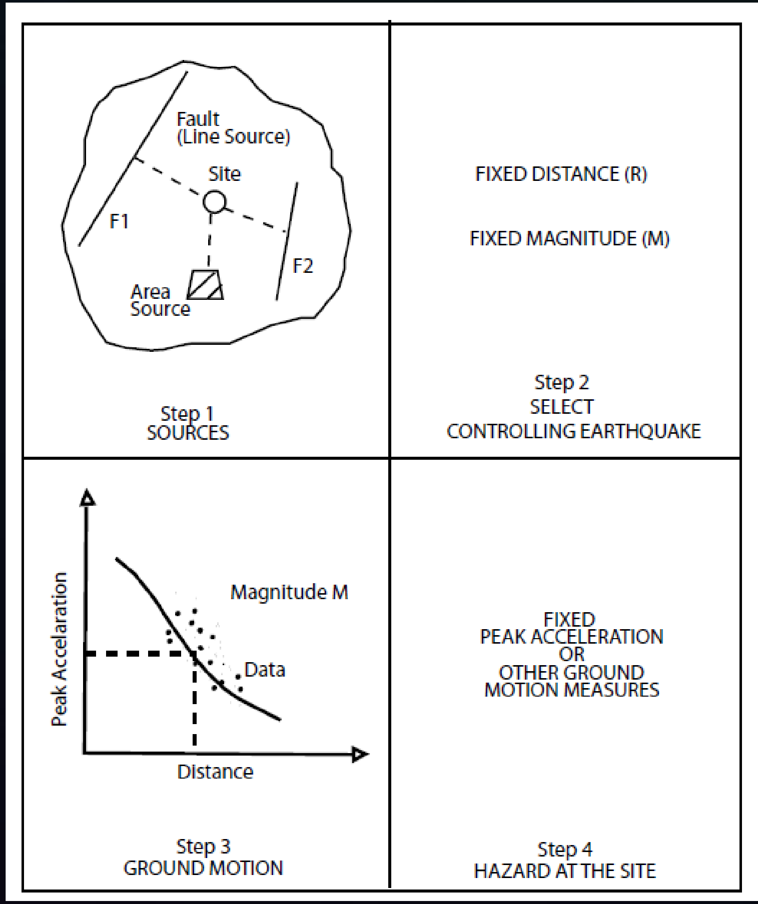
Time to Failure Model for Earthquake Prediction

- Another prediction model based on historical data analysis is the time to failure model for earthquake prediction (Bufe and Varnes 1993).
- The underlying idea is that the rate of progressive rupture or creep in a stressed material is inversely proportional to the remaining time to failure.
- From an earthquake occurrence perspective, this implies that the intervening time between foreshocks is consistently reduced as we get closer to the main shock. This model is also known as the accelerating seismic energy release model.

How to Mitigate Earthquakes

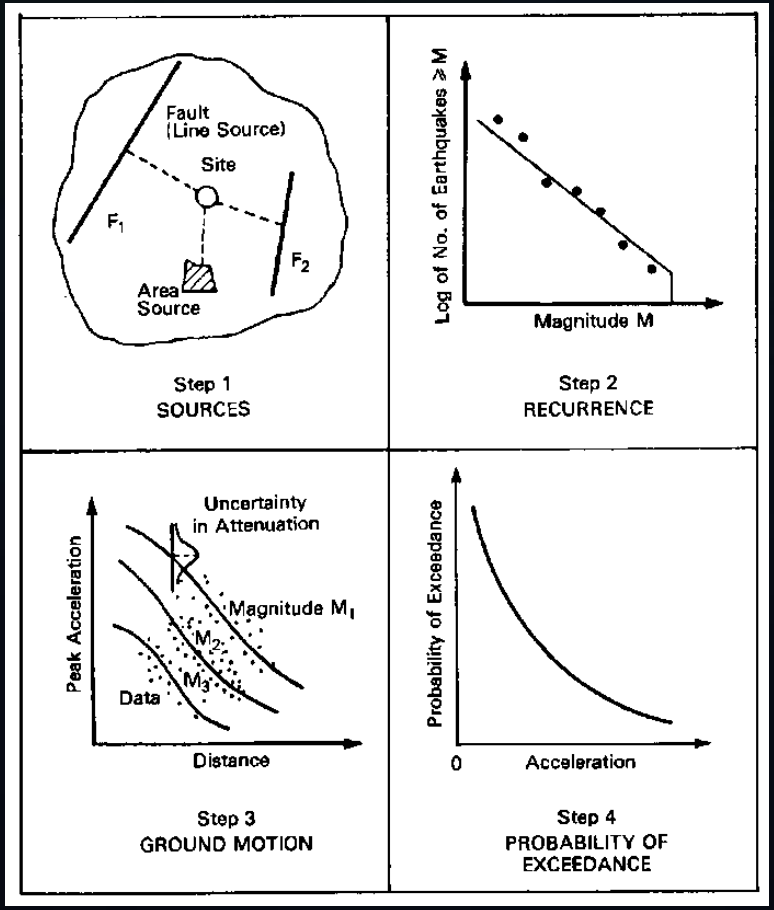
Hazard Assessment

Deterministic



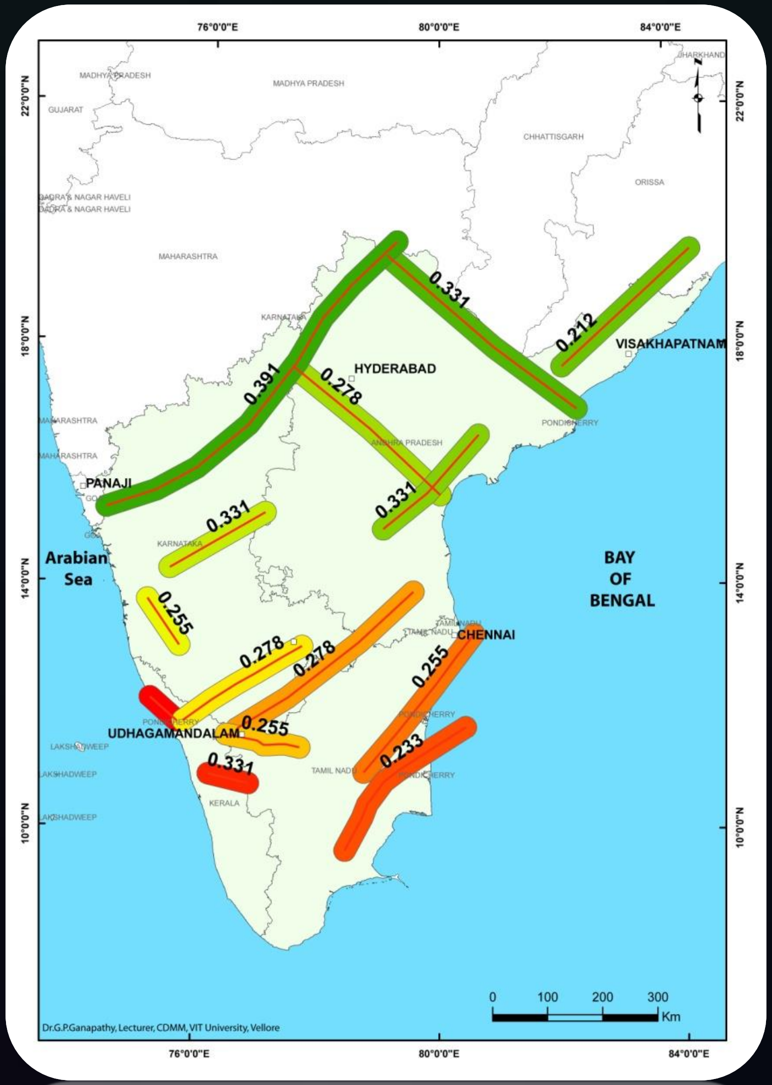
After Tera Corporation, 1978

Probabilistic



Probability of exceedance	*Return period (years)*	*Horizontal peak ground acceleration (g)*
50% probability of exceedance in 50 years	72	0.10
20% probability of exceedance in 50 years	224	0.11
10% probability of exceedance in 50 years	475	0.12
5% probability of exceedance in 50 years	975	0.18
2% probability of exceedance in 50 years	2475	0.23

Estimated Peak Ground Acceleration for each Potential Sources

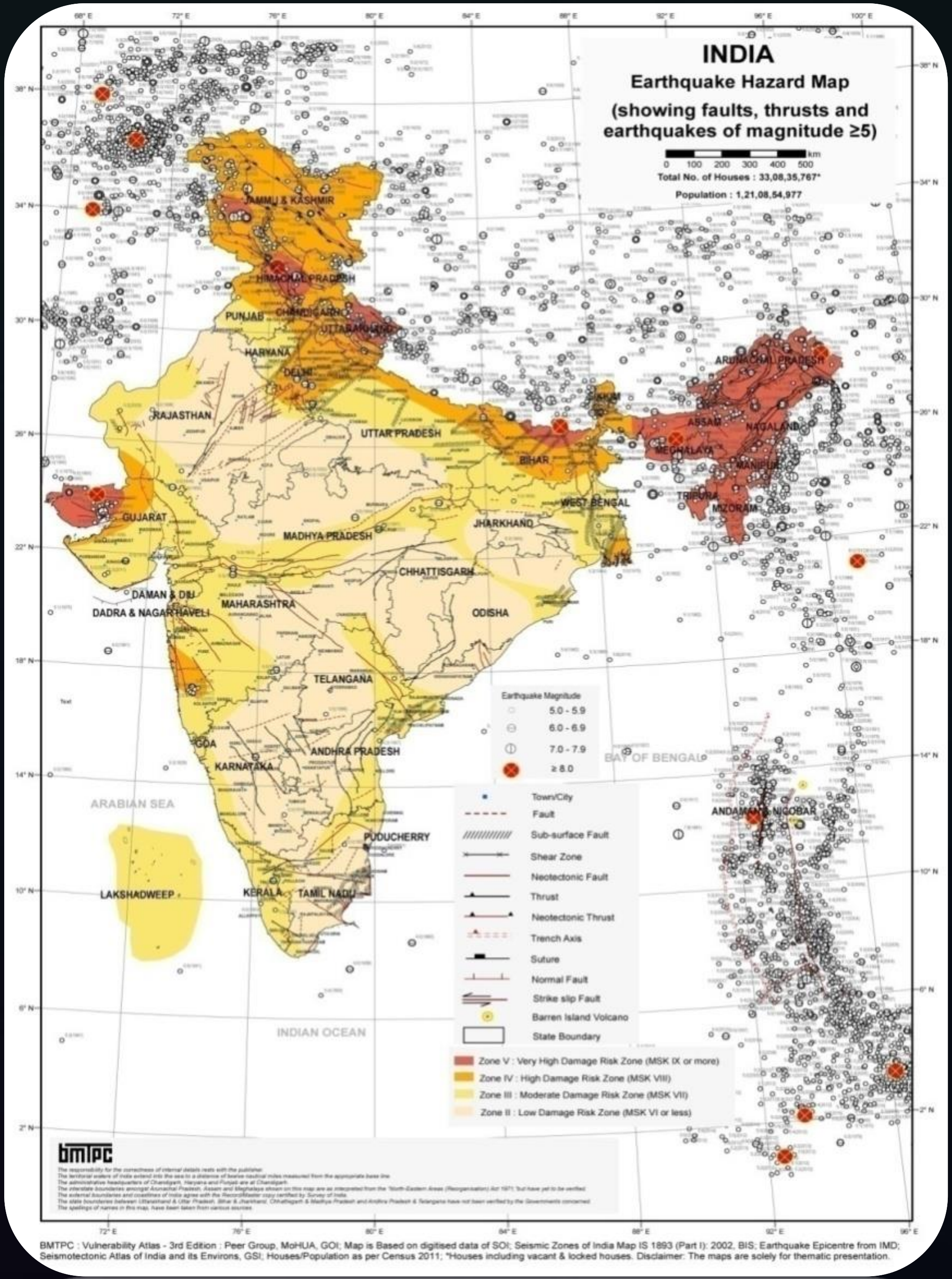


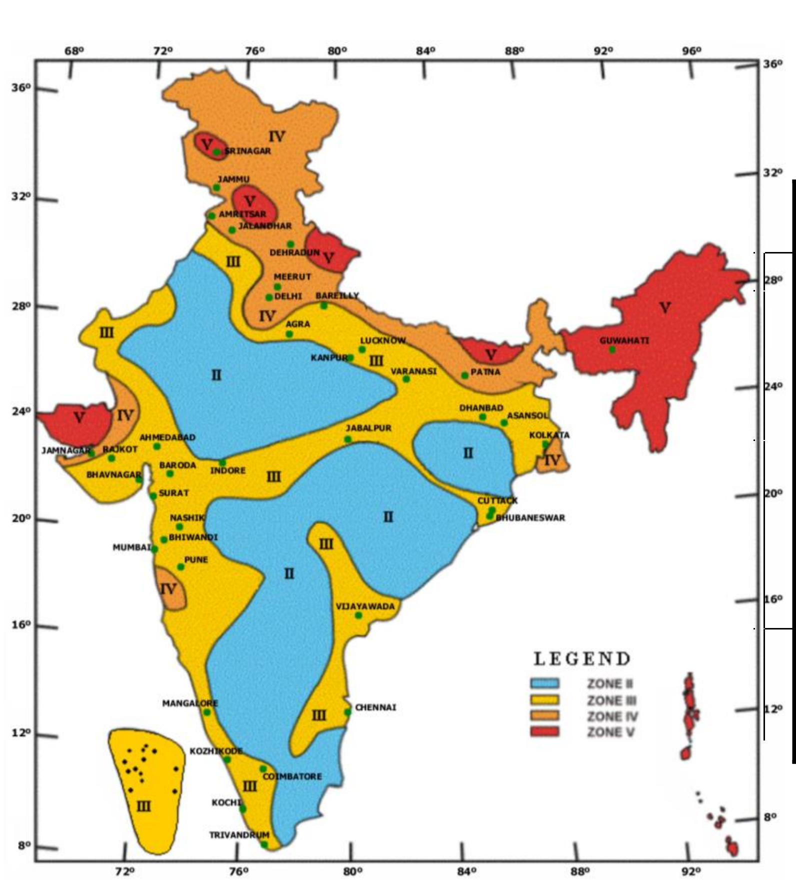
$$\ln y = c1 + c2(M-6) + c3(M-6)^2 - \ln R - c4\,R + \ln \in$$

Where y refer to Peak Ground acceleration (PGA) in g, M refer to magnitude and R refer to Hypocentral distance. Since PGA is known to be attributed nearly as a lognormal random variable ln y would normally distributed with the average of (ln ^{a}) being almost zero. Hence with e= l, coefficients for the southern region are (Iyengar and Raghukanth, 2004):

c1=1.7816; c2 = 0.9205; c3 = -0.0673; c4 = 0.0035; (ln $\in$) = 0.3136 (taken as zero)

Seismic Hazard Zonation Map of India

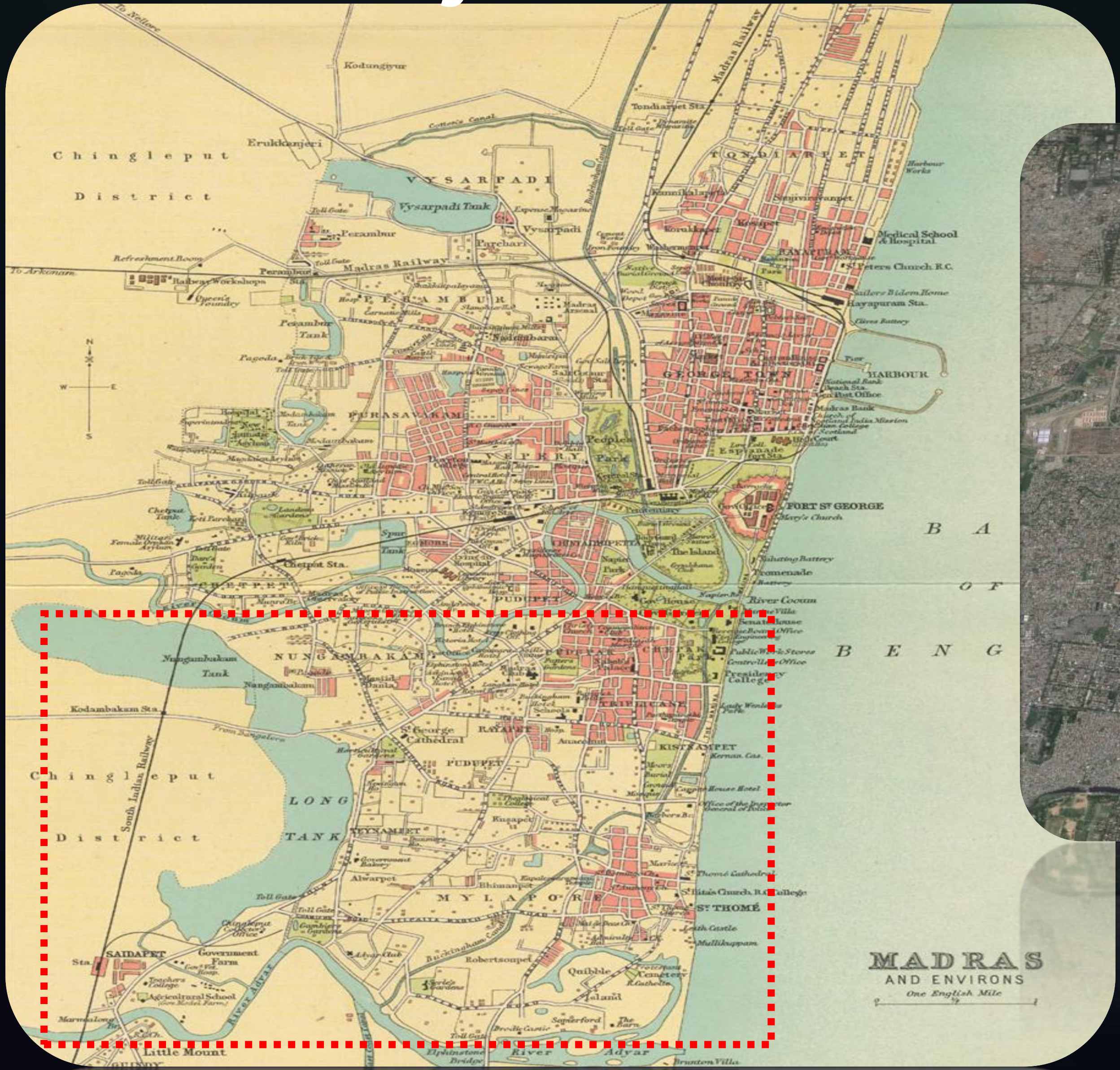




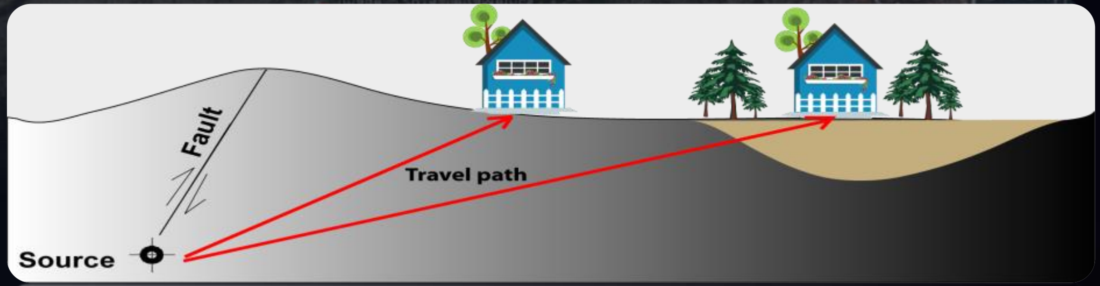
Source: IS 1893 (Part 1) : 2002 (BIS)

Zone	Magnitude
Zone V	Very High Risk Quakes of Magnitude ***8*** and greater
Zone IV	High Risk Quakes upto Magnitude ***7.9***
Zone III	Moderate Risk Quakes upto Magnitude ***6.9***
Zone II	Seismic Disturbances upto Magnitude ***4.9***

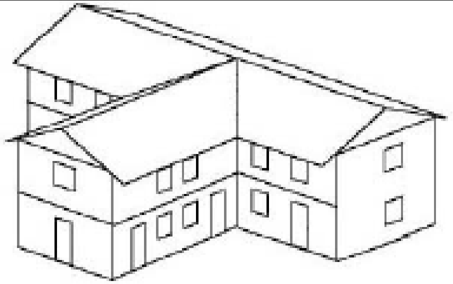
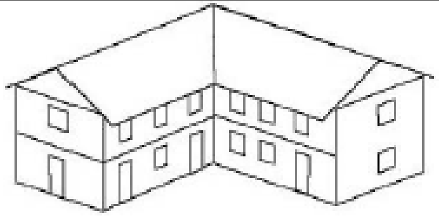
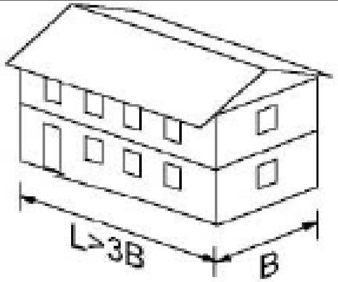
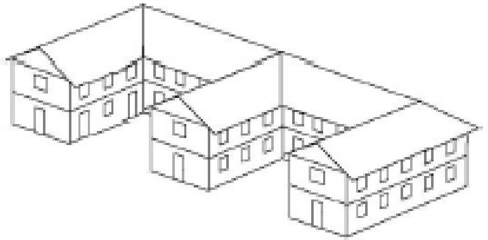
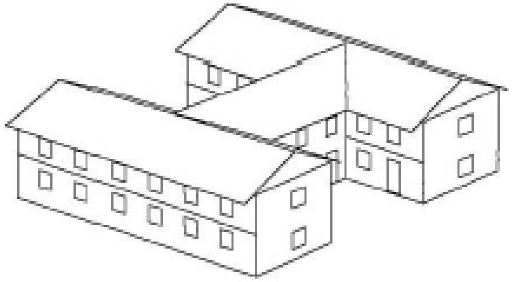
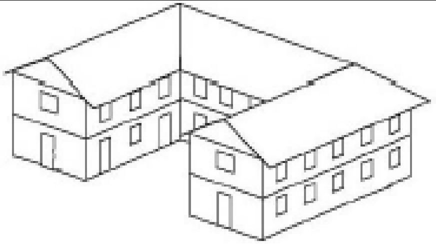
Chennai City 1909



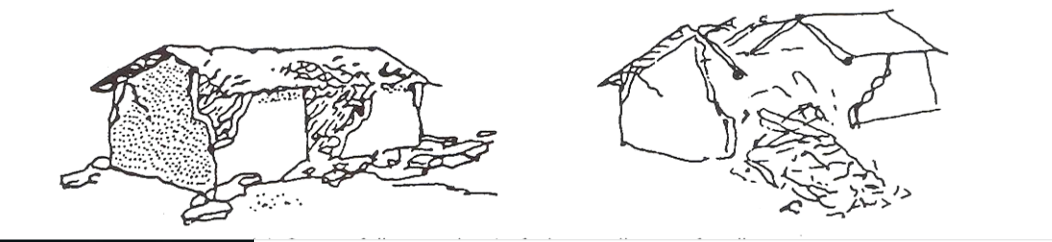
Chennai City 2021



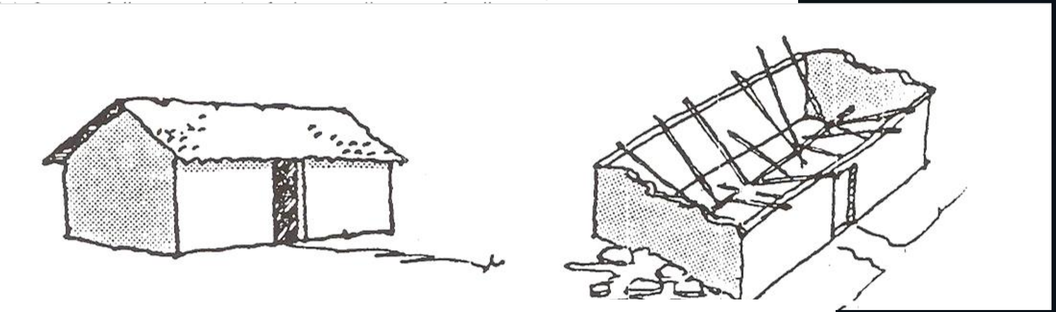
Examples of Some irregular building plan

		
T-Shaped Building	L-Shaped Building	Narrow Rectangular (L> 3B)
		
E-Shaped Building	H-Shaped Building	U-Shaped Building

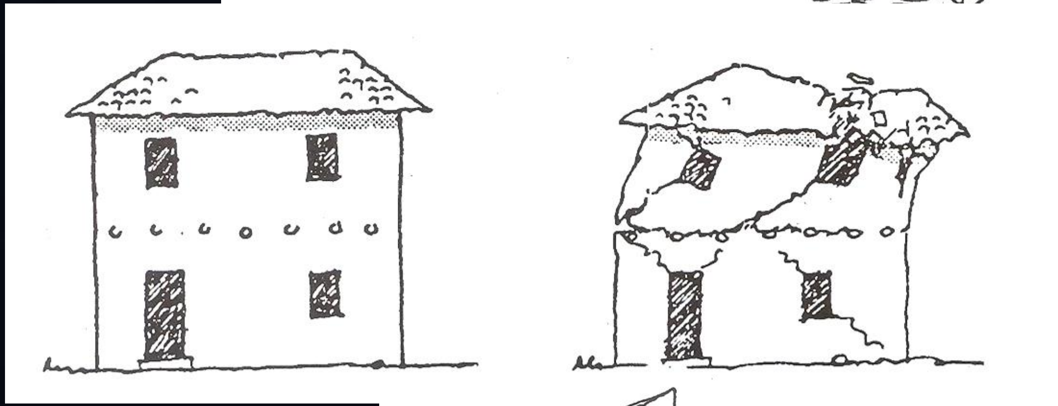
Typical damage and Collapse of earthen Buildings



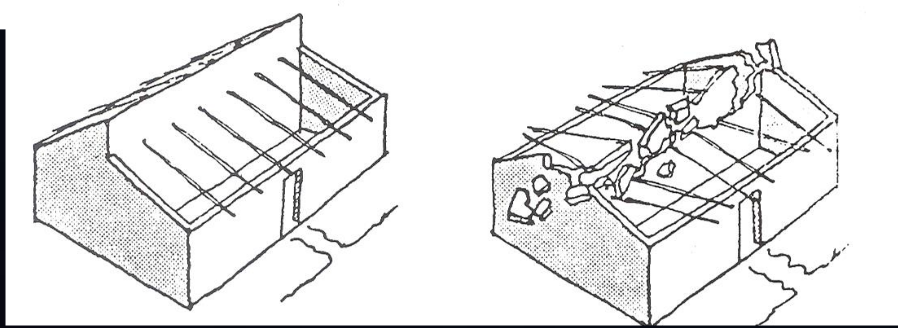
Corner failure and
out of plane
collapse of walls



Gables

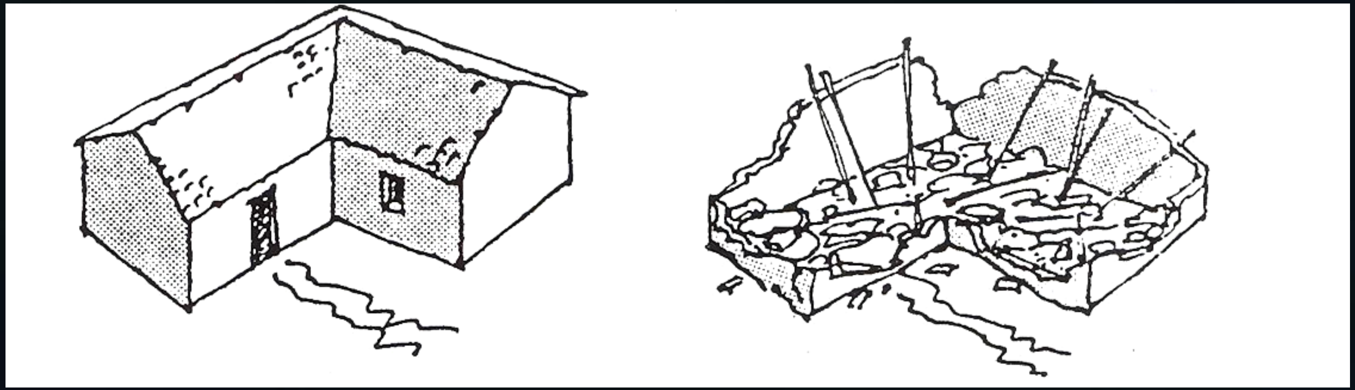


Two Storey
House damage



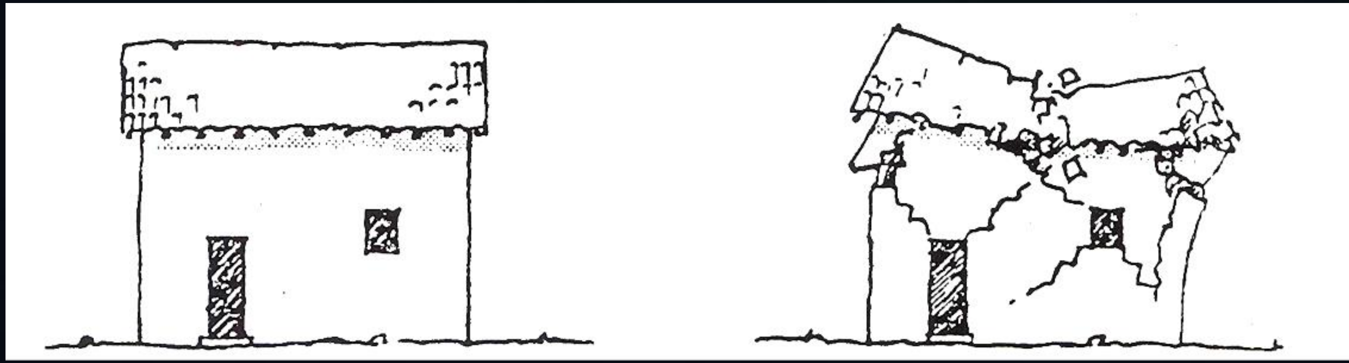
Split Level Roof

Typical damage and Collapse of earthen Buildings

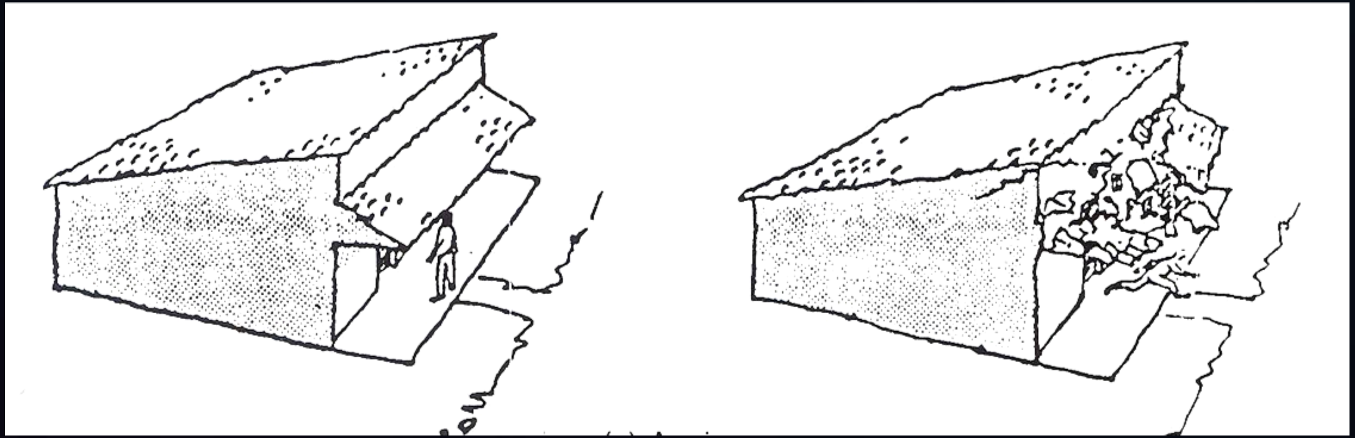


"L" Shaped

Buildings

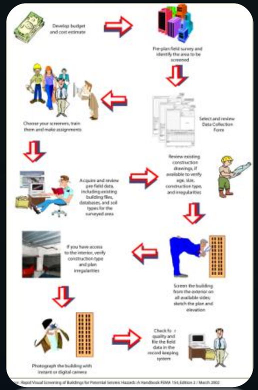


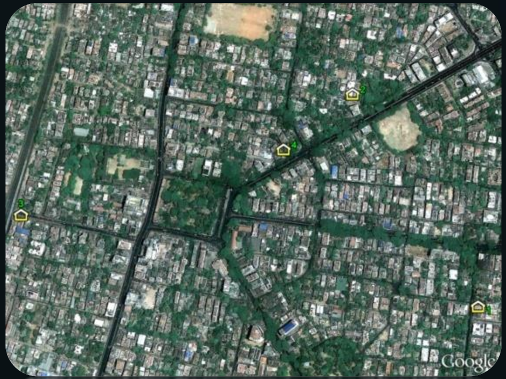
High Walled Houses

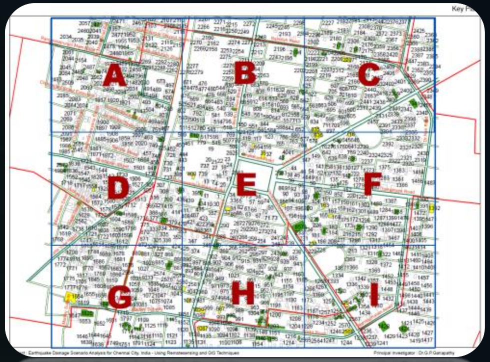


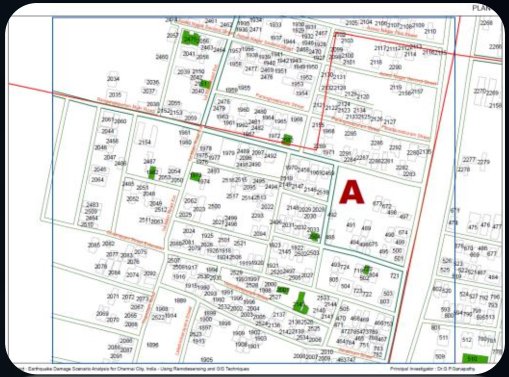
Awining

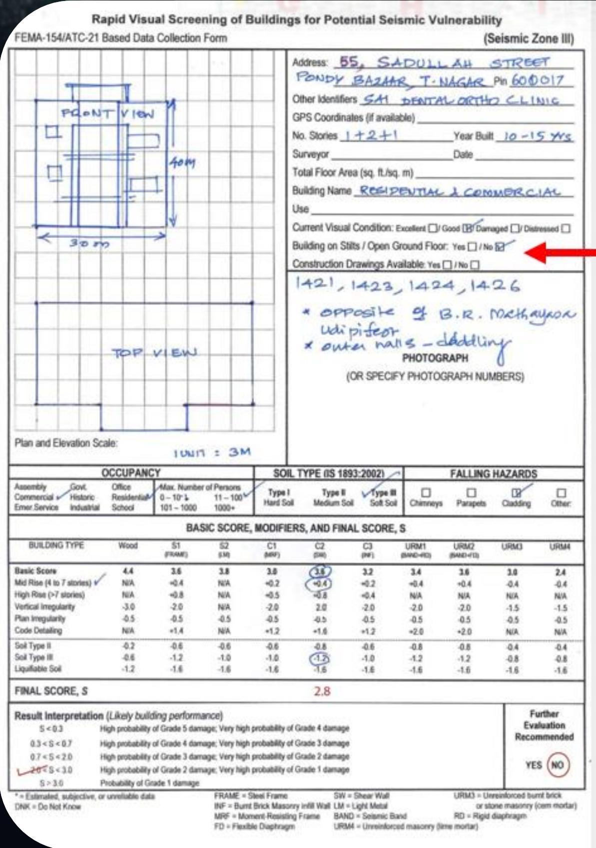
Rapid Visual Screening of buildings











Rapid Visual Screening of Buildings for Potential Seismic Vulnerability

FEMA-154/ATC-21 Based Data Collection Form (Seismic Zone III)

FRONT VIEW

40 m

30 m

TOP VIEW

Plan and Elevation Scale: 1 UNIT : 3M

Address: 55, SADULLAH STREET PONDY BAZAAR, T. NAGAR Pin 600017

Other Identifiers SM DENTAL ORTHO CLINIC

GPS Coordinates (if available)

No. Stories 1+2+1 Year Built 10-15 Yrs

Surveyor Date

Total Floor Area (sq. ft./sq. m)

Building Name RESIDENTIAL & COMMERCIAL

Use

Current Visual Condition: Excellent ☐ / Good ☑ / Damaged ☐ / Distressed ☐

Building on Stilts / Open Ground Floor: Yes ☐ / No ☑

Construction Drawings Available: Yes ☐ / No ☐

1421, 1423, 1424, 1426

* opposite of B.R. Mathayoor udipifeor
* outer walls - cladding

PHOTOGRAPH

(OR SPECIFY PHOTOGRAPH NUMBERS)

OCCUPANCY		SOIL TYPE (IS 1893:2002)	FALLING HAZARDS
Assembly, Govt., Office, Commercial ✓, Historic, Residential ✓, Emer. Service, Industrial, School	Max. Number of Persons: 0 – 10, 11 – 100 ✓, 101 – 1000, 1000+	Type I Hard Soil, Type II Medium Soil, Type III Soft Soil ✓	☐ Chimneys, ☐ Parapets, ☑ Cladding, ☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	Wood	S1 (FRAME)	S2 (LM)	C1 (MRF)	C2 (SW)	C3 (INF)	URM1 (BAND+RD)	URM2 (BAND+FD)	URM3	URM4
Basic Score	4.4	3.6	3.8	3.0	3.6	3.2	3.4	3.6	3.0	2.4
Mid Rise (4 to 7 stories) ✓	N/A	+0.4	N/A	+0.2	+0.4	+0.2	+0.4	+0.4	-0.4	-0.4
High Rise (>7 stories)	N/A	+0.8	N/A	+0.5	+0.8	+0.4	N/A	N/A	N/A	N/A
Vertical Irregularity	-3.0	-2.0	N/A	-2.0	2.0	-2.0	-2.0	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Code Detailing	N/A	+1.4	N/A	+1.2	+1.6	+1.2	+2.0	+2.0	N/A	N/A
Soil Type II	-0.2	-0.6	-0.6	-0.6	-0.8	-0.6	-0.8	-0.8	-0.4	-0.4
Soil Type III	-0.6	-1.2	-1.0	-1.0	-1.2	-1.0	-1.2	-1.2	-0.8	-0.8
Liquifiable Soil	-1.2	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

FINAL SCORE, *S* 2.8

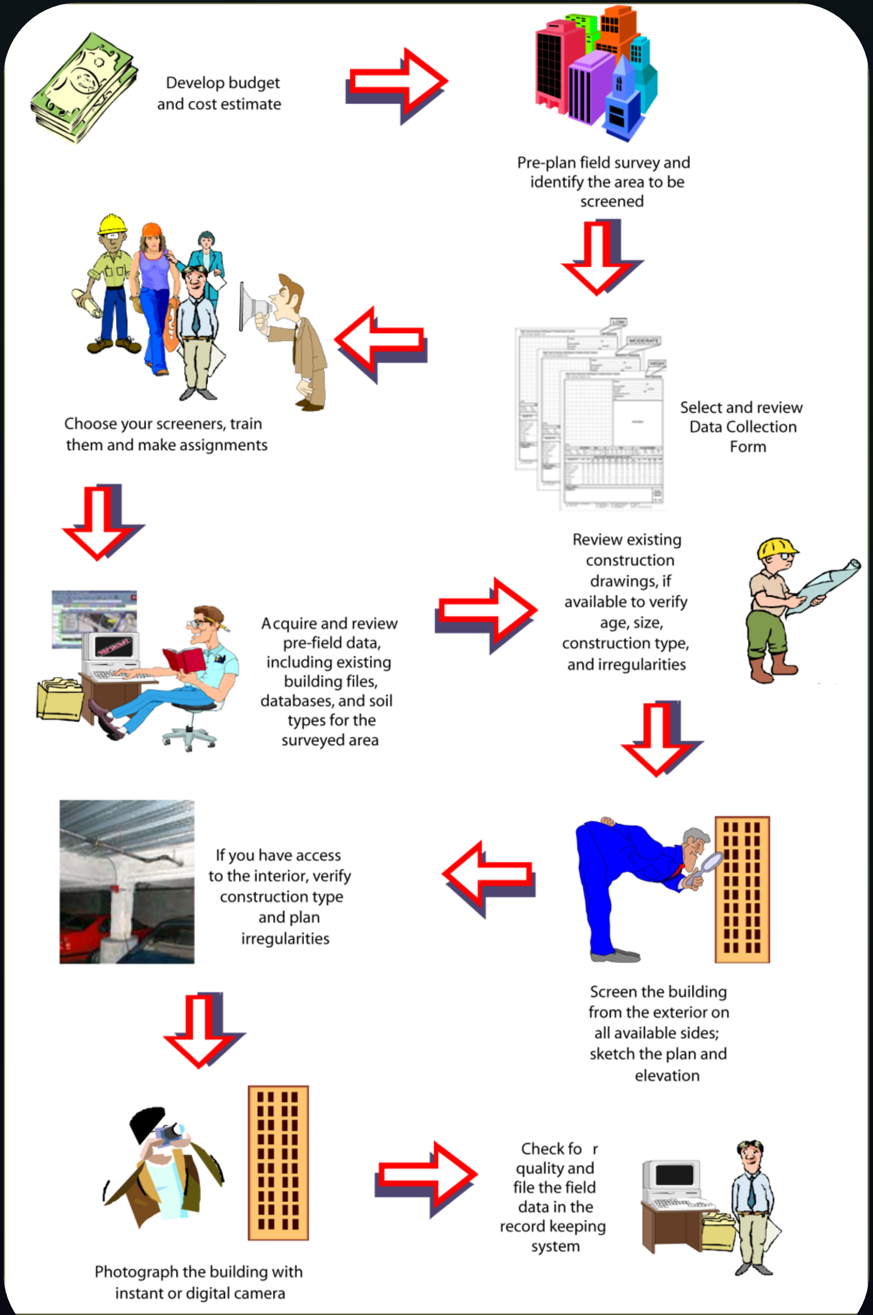
Result Interpretation (*Likely building performance*)

S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0 < S < 3.0 ✓	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S > 3.0	Probability of Grade 1 damage

Further Evaluation Recommended YES (NO)

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

FRAME = Steel Frame
INF = Burnt Brick Masonry infill Wall
MRF = Moment-Resisting Frame
FD = Flexible Diaphragm
SW = Shear Wall
LM = Light Metal
BAND = Seismic Band
URM4 = Unreinforced masonry (lime mortar)
URM3 = Unreinforced burnt brick or stone masonry (cem mortar)
RD = Rigid diaphragm



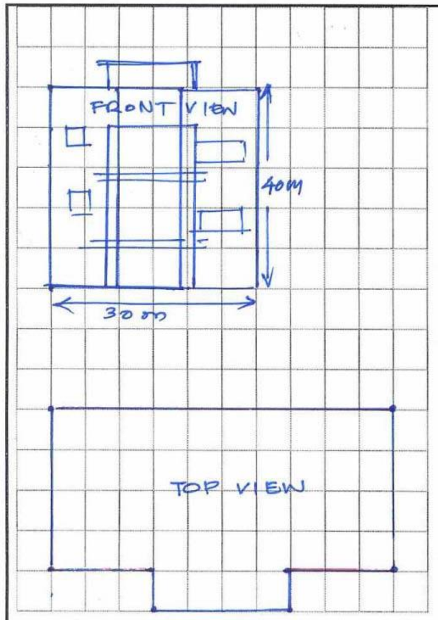
rce : Rapid Visual Screening of Buildings for Potential Seismic Hazards :A Handbook FEMA 154, Edition 2 / March 2002

Rapid Visual Screening (RVS) of buildings

FEMA 154/Edition 2/ March 2002

Rapid Visual Screening of Buildings for Potential Seismic Vulnerability

FEMA-154/ATC-21 Based Data Collection Form (Seismic Zone III)



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Other Identifiers SAI DENTAL ORTHO CLINIC
GPS Coordinates (if available)
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Surveyor Date
Total Floor Area (sq. ft./sq. m)
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Use
Current Visual Condition: Excellent ☐ / Good ☑ / Damaged ☐ / Distressed ☐
Building on Stilts / Open Ground Floor: Yes ☐ / No ☑
Construction Drawings Available: Yes ☐ / No ☐

1421, 1423, 1424, 1426
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(OR SPECIFY PHOTOGRAPH NUMBERS)

OCCUPANCY					SOIL TYPE (IS 1893:2002)			FALLING HAZARDS			
Assembly	Govt.	Office	Max. Number of Persons								
Commercial ✓	Historic	Residential ✓	0 – 10	11 – 100 ✓	Type I Hard Soil	Type II Medium Soil	✓ Type III Soft Soil	☐ Chimneys	☐ Parapets	☑ Cladding	☐ Other:
Emer.Service	Industrial	School	101 – 1000	1000+							

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

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Vertical Irregularity	-3.0	-2.0	N/A	-2.0	2.0	-2.0	-2.0	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Code Detailing	N/A	+1.4	N/A	+1.2	+1.6	+1.2	+2.0	+2.0	N/A	N/A
Soil Type II	-0.2	-0.6	-0.6	-0.6	-0.8	-0.6	-0.8	-0.8	-0.4	-0.4
Soil Type III	-0.6	-1.2	-1.0	-1.0	-1.2	-1.0	-1.2	-1.2	-0.8	-0.8
Liquifiable Soil	-1.2	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6
FINAL SCORE, *S*					2.8					

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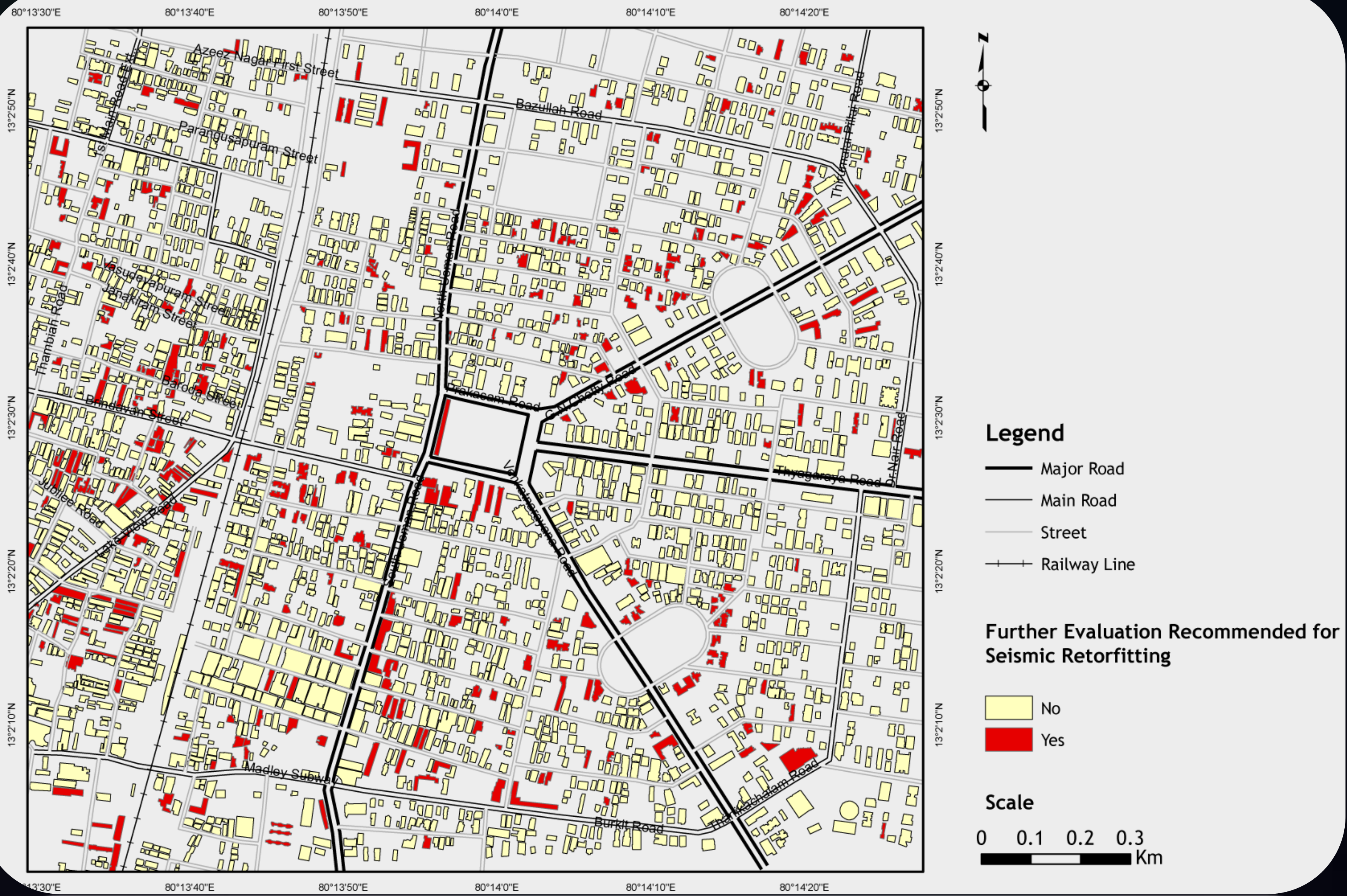
URM3 = Unreinforced burnt brick or stone masonry (cem mortar)
RD = Rigid diaphragm

Buildings Further Evaluation Recommended for Detailed Seismic Studies



Classification of damage to buildings

Classification of damage to masonry buildings	Classification of damage to reinforced concrete buildings
Grade 1: Negligible to slight damage (No structural damage, slight non-structural damage) Hair-line cracks in very few walls. Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases.	**Grade 1: Negligible to slight damage** (No structural damage, slight non-structural damage) Fine cracks in plaster over frame members or in walls at the base. Fine cracks in partitions and infills.
Grade 2: Moderate damage (Slight structural damage, moderate non-structural damage) Cracks in many walls. Fall of fairly large pieces of plaster. Partial collapse of chimneys and mumptys.	**Grade 2: Moderate damage** (Slight structural damage, moderate non-structural damage) Cracks in columns and beams of frames and in structural walls. Cracks in partition and infill walls; fall of brittle cladding and plaster. Falling mortar from the joints of wall panels.
Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage) Large and extensive cracks in most walls. Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls etc.).	**Grade 3: Substantial to heavy damage** (moderate structural damage, heavy non-structural damage) Cracks in columns and beam-column joints of frames at the base and at joints of coupled walls. Spalling of concrete cover, buckling of reinforced bars. Large cracks in partition and infill walls, failure of individual infill panels.
Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage) Serious failure of walls (gaps in walls); partial structural failure of roofs and floors.	**Grade 4: Very heavy damage** (heavy structural damage, very heavy non-structural damage) Large cracks in structural elements with compression failure of concrete and fracture of rebars; bond failure of beam reinforcing bars; tilting of columns. Collapse of a few columns or of a single upper floor.
Grade 5: Destruction (very heavy structural damage) Total or near total collapse of the building.	**Grade 5: Destruction** (very heavy structural damage) Collapse of ground floor parts (e.g. wings) of the building.

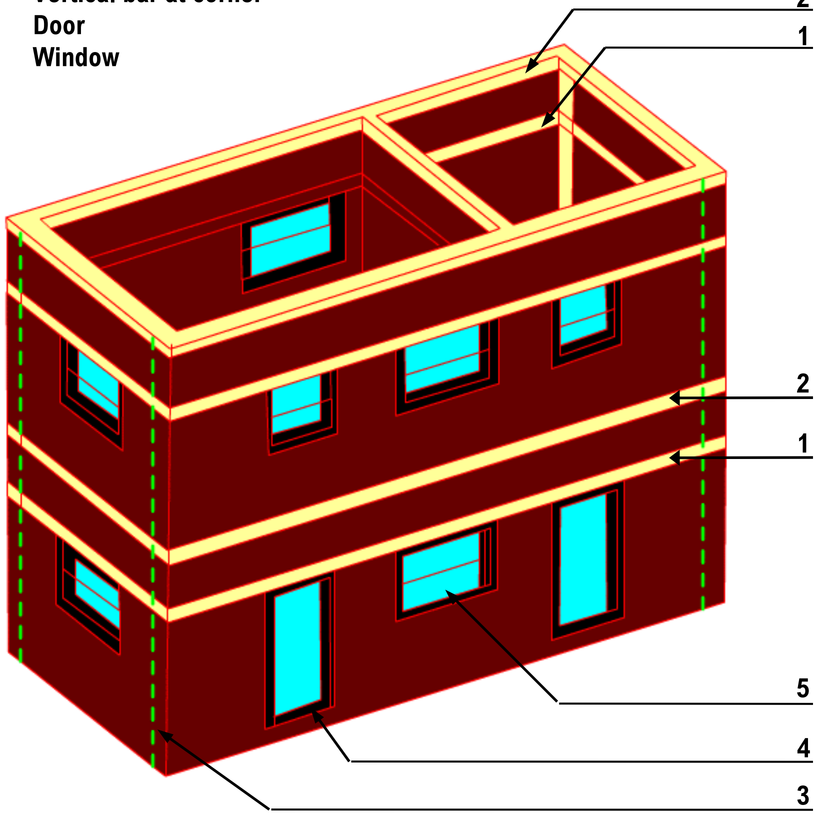
Expected damage level as function of RVS score

RVS Score	Damage Potential
S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0 < S < 3.0	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S > 3.0	Probability of Grade 1 damage

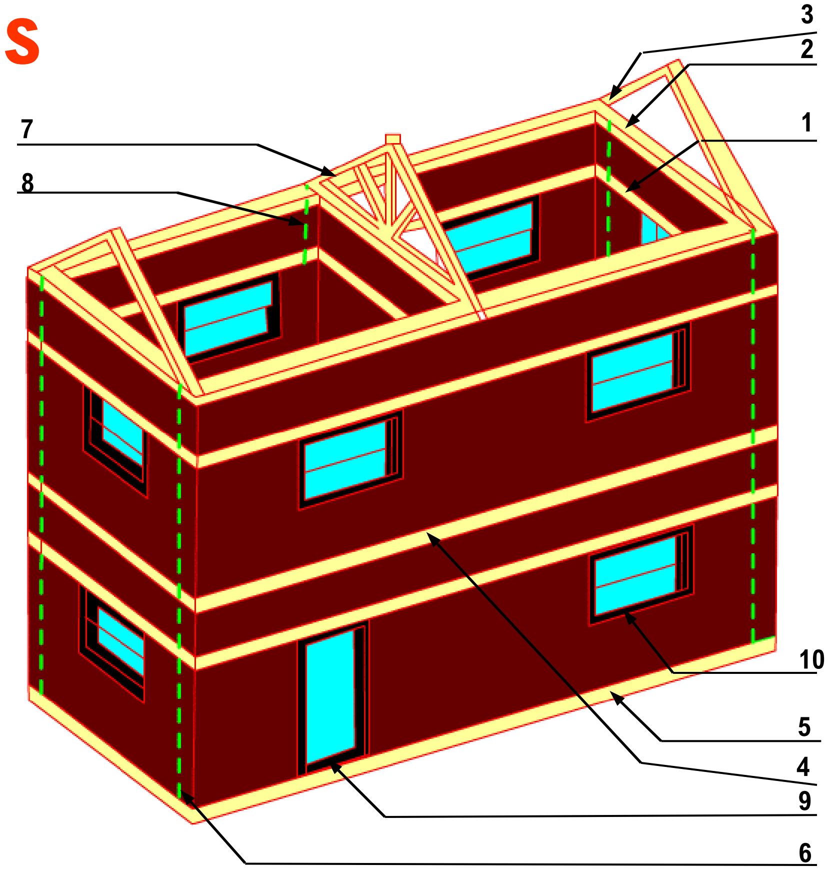
Seismic Building Codes

Legend

1. Lintel band
2. Roof/floor band
3. Vertical bar at corner
4. Door
5. Window



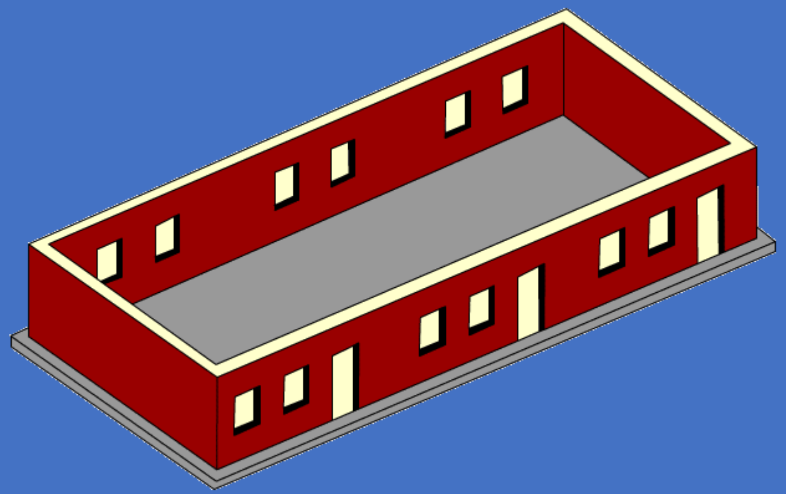
Overall arrangement of reinforcing in masonry double storey building



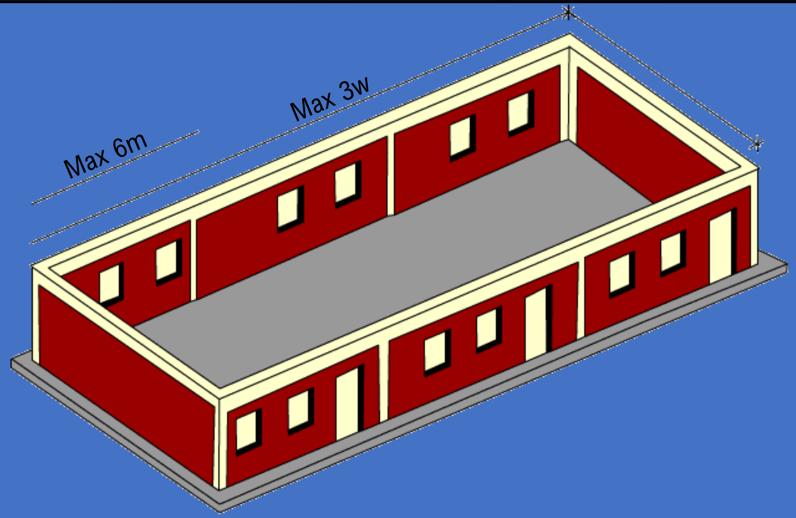
Legend

1. Lintel band
2. Eave level (Roof) band
3. Gable band
4. Floor band
5. Plinth band
6. Vertical bar
7. Rafter
8. Holding down bolt
9. Door
10. Window

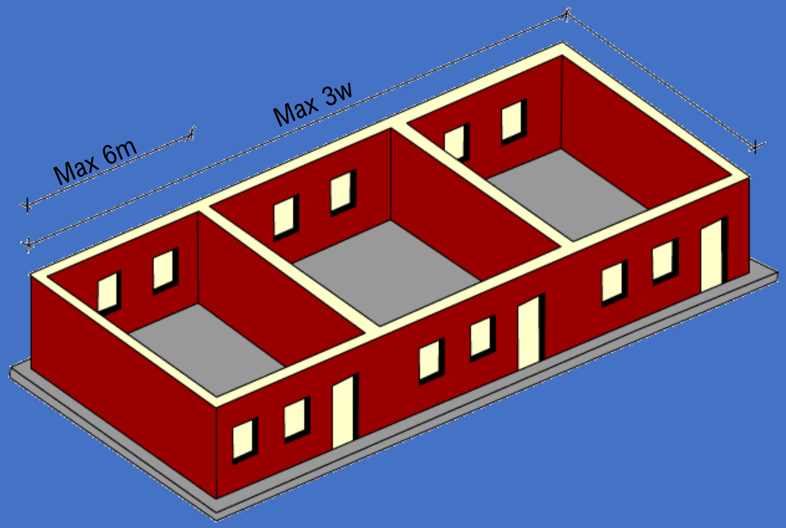
Overall arrangement of reinforcing in masonry double storey building having pitched roof



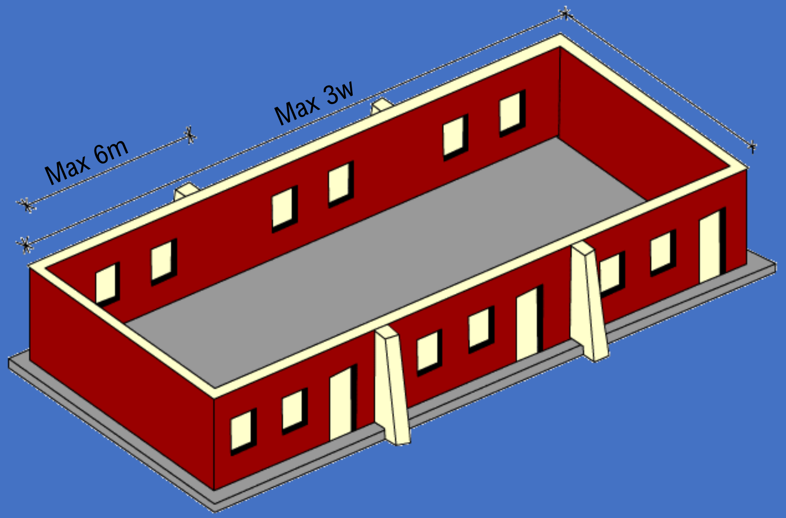
Unsatisfactory;long unsupported walls



Satisfactory; cellular enclosures



Satisfactory: long walls supported by R.C columns

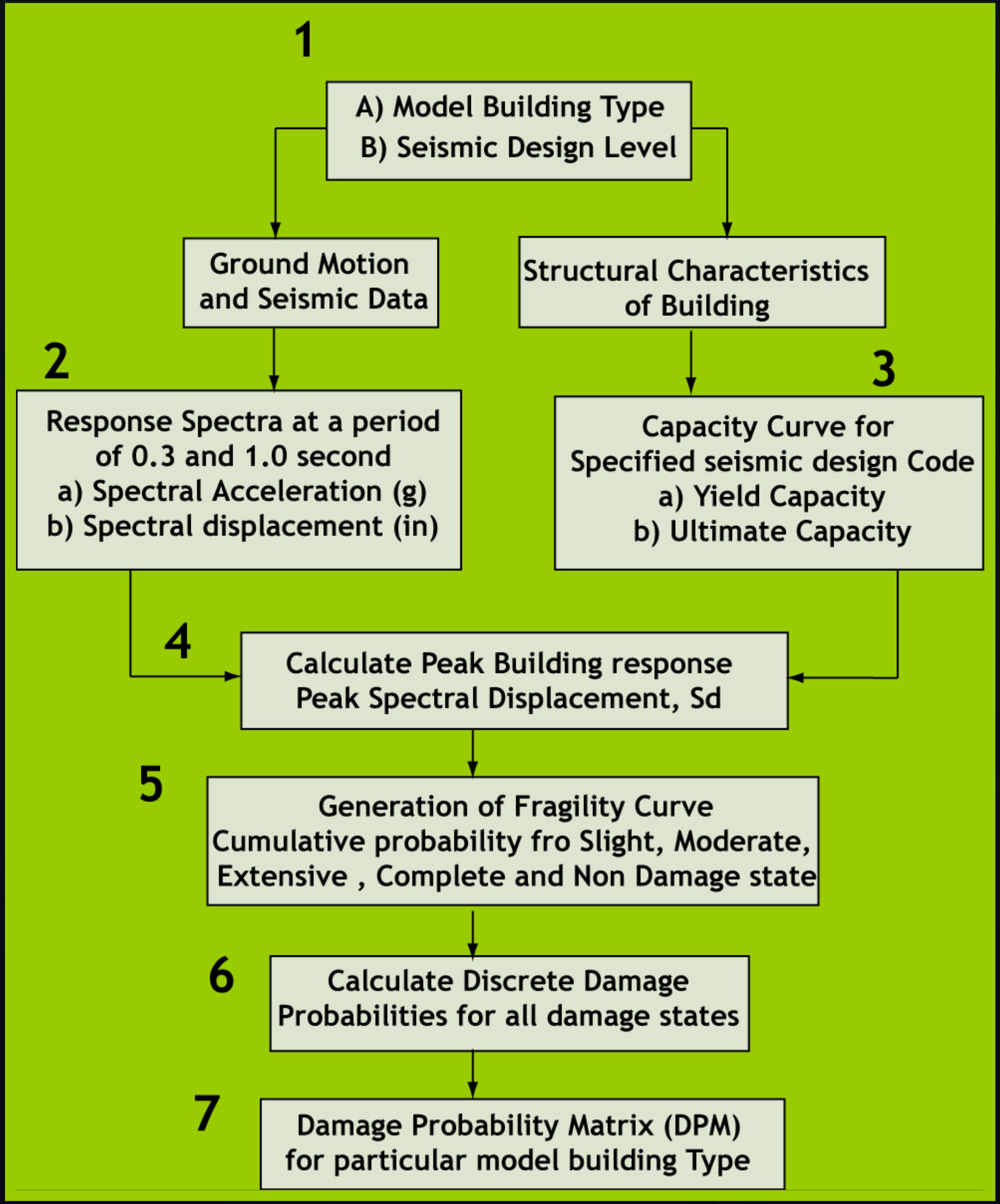


Satisfactory: long walls supported
by buttresses

Extra cost in providing seismic resistance

	Masonry	RCC Buildings
Zone III	1.5 – 2 %	2.6 – 3.2 %
Zone IV	3 – 4 %	3.2 – 4.0 %
Zone V	5 – 6 %	5.0 – 6.0 %

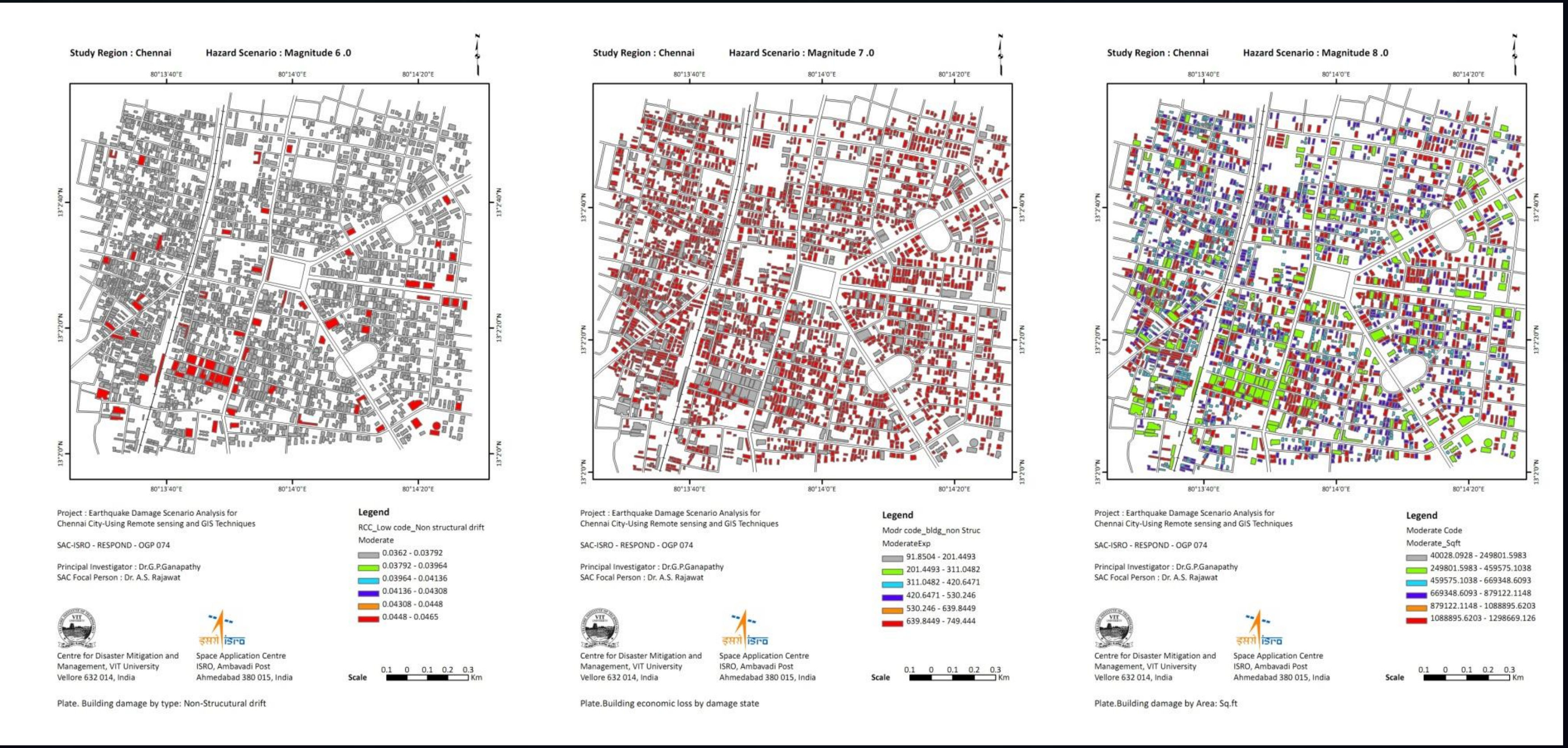
Non-Destructive Testing



Damage Scenario using Hazus Methodology

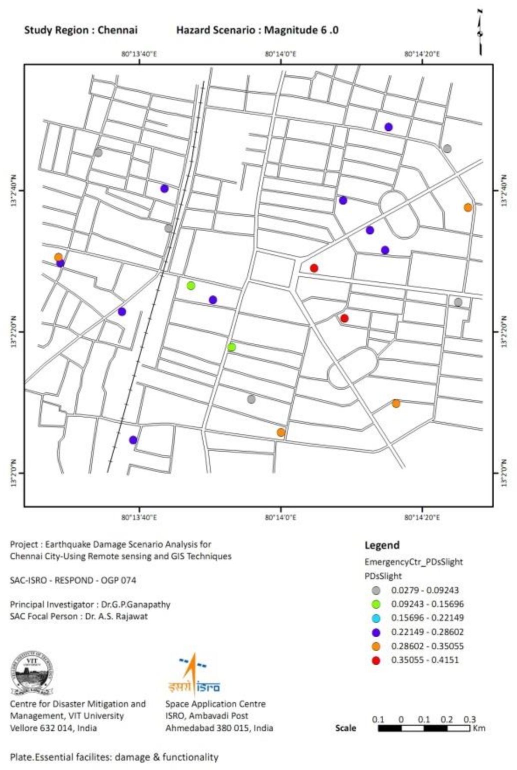
Moderate damage

M 6.0 M7.0 M8.0

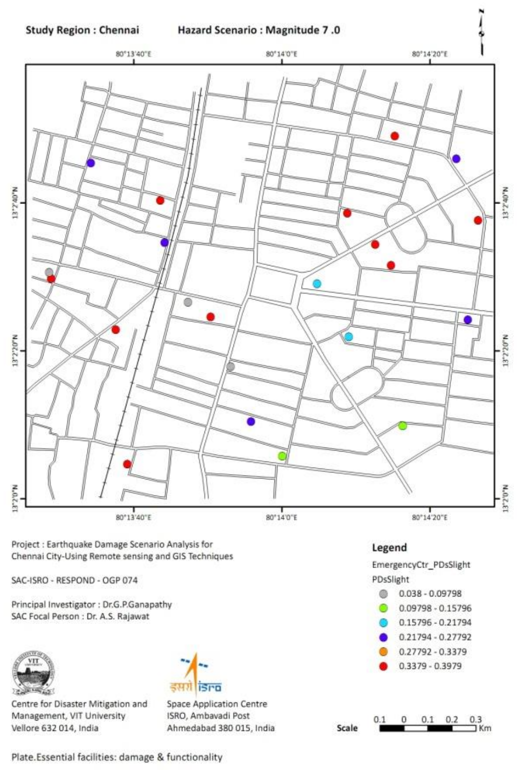


Emergency Centre Slight damage

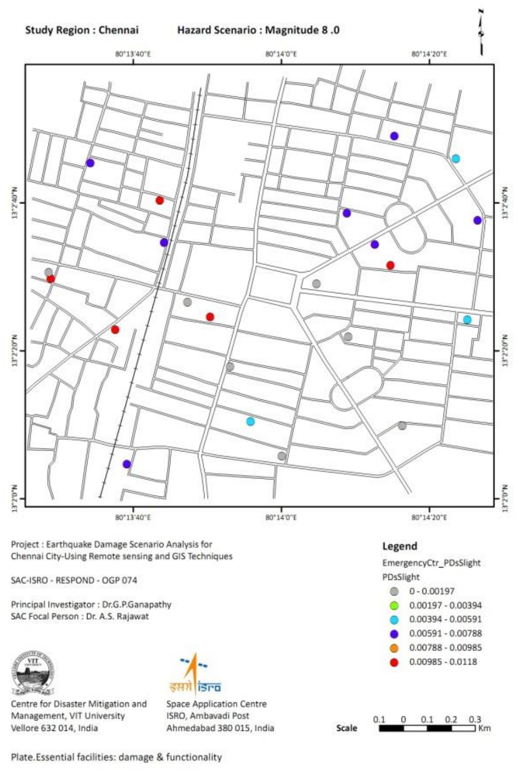
M 6.0

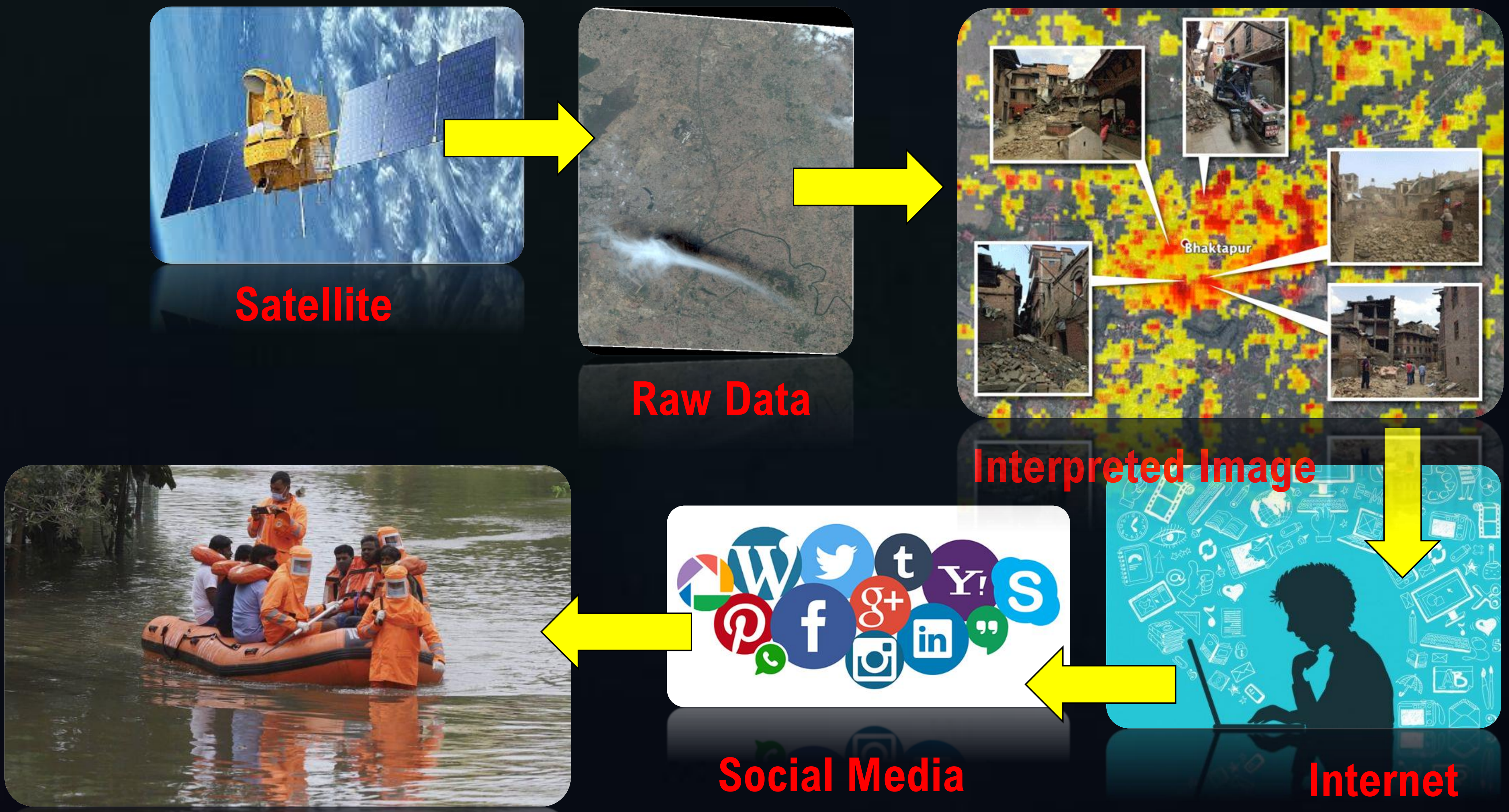


M7.0



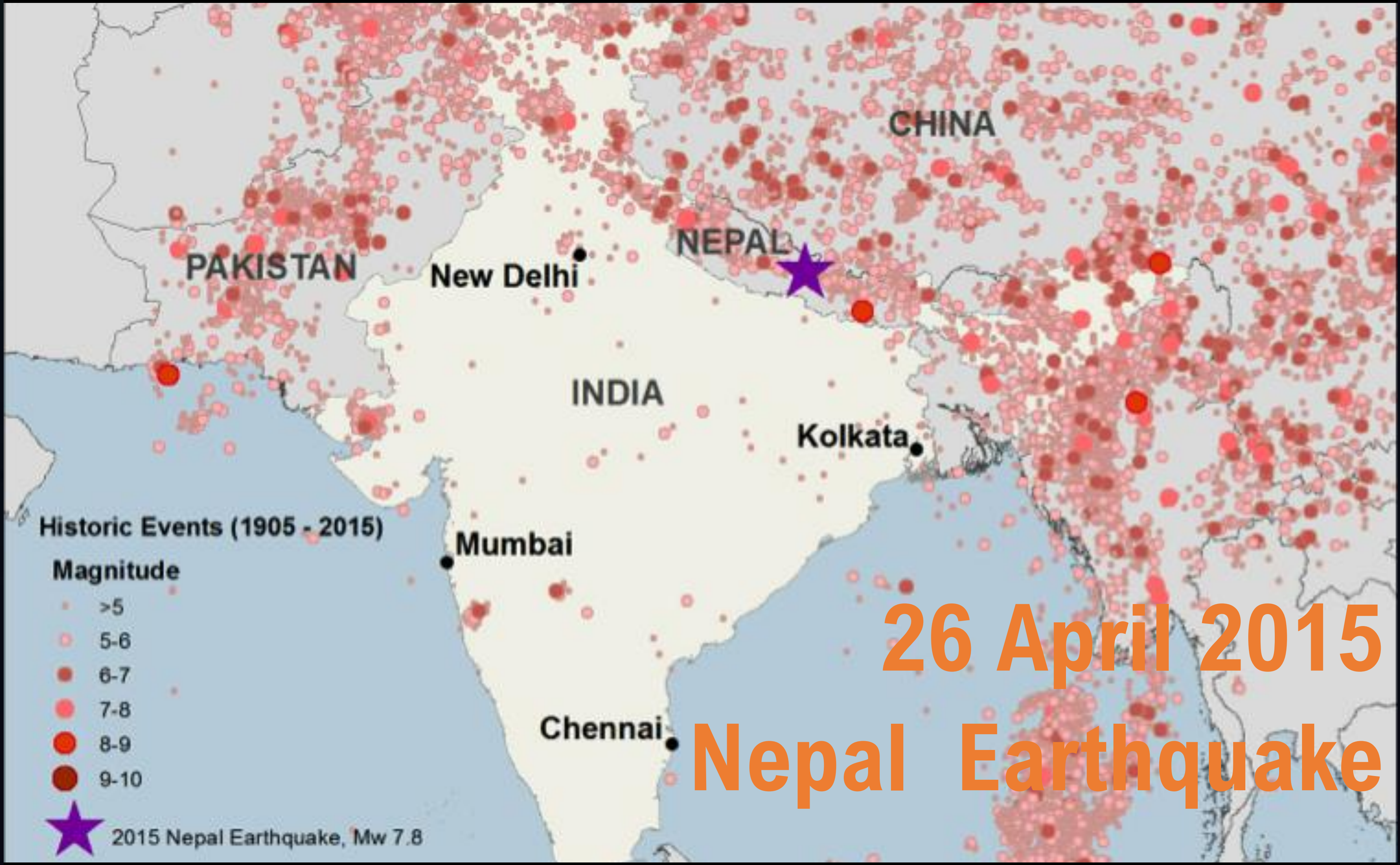
M8.0





- The satellite data is used effectively to quickly respond during disaster
- It is observed that the Social Media and other digital platforms are helps to quickly reach the ground level workers during disasters

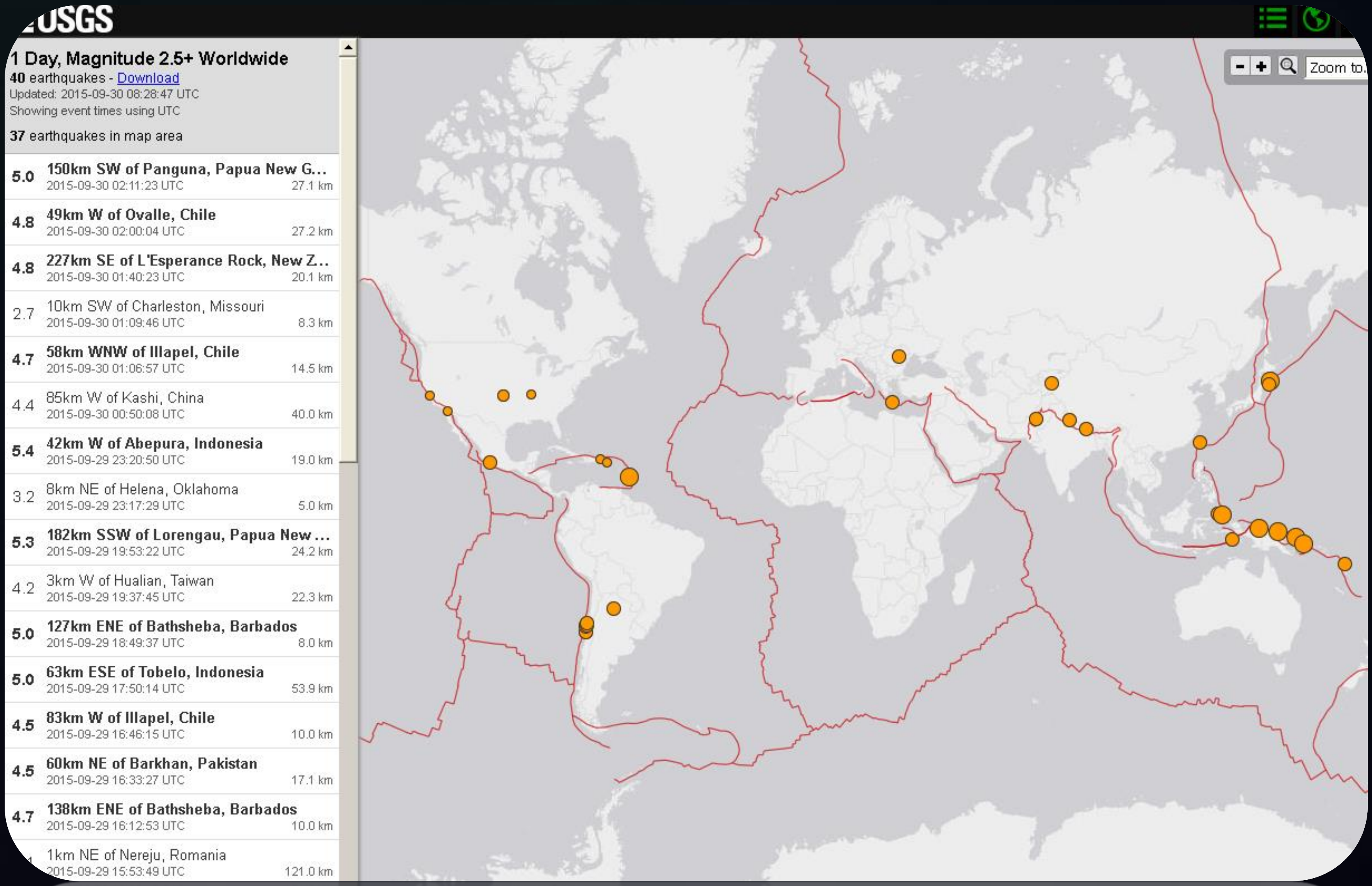
Quick response during earthquakes



2015 Nepal Earthquake

- Year: 2015
- 9000 people Killed and 22000 injured

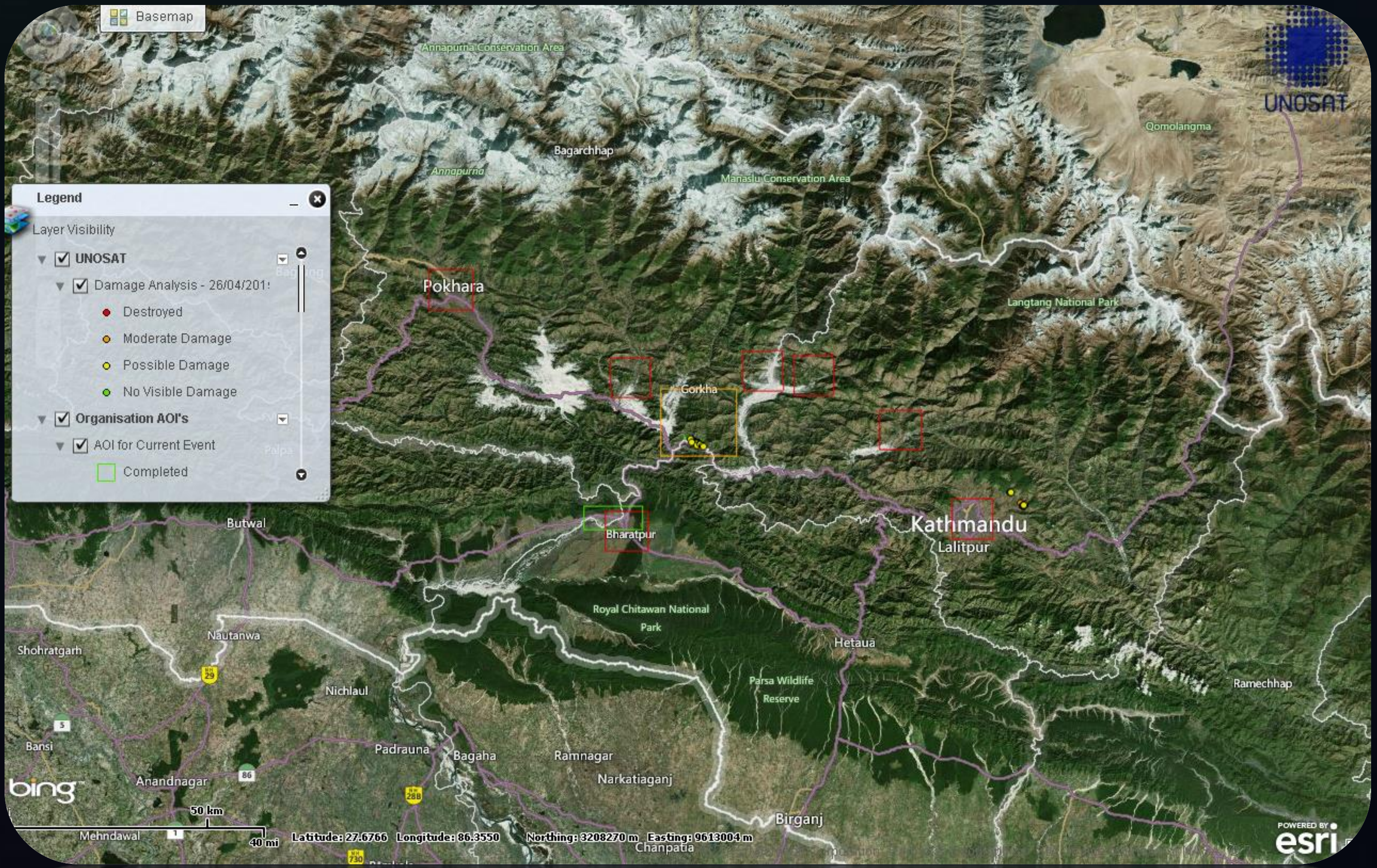
USGS Current Earthquake List



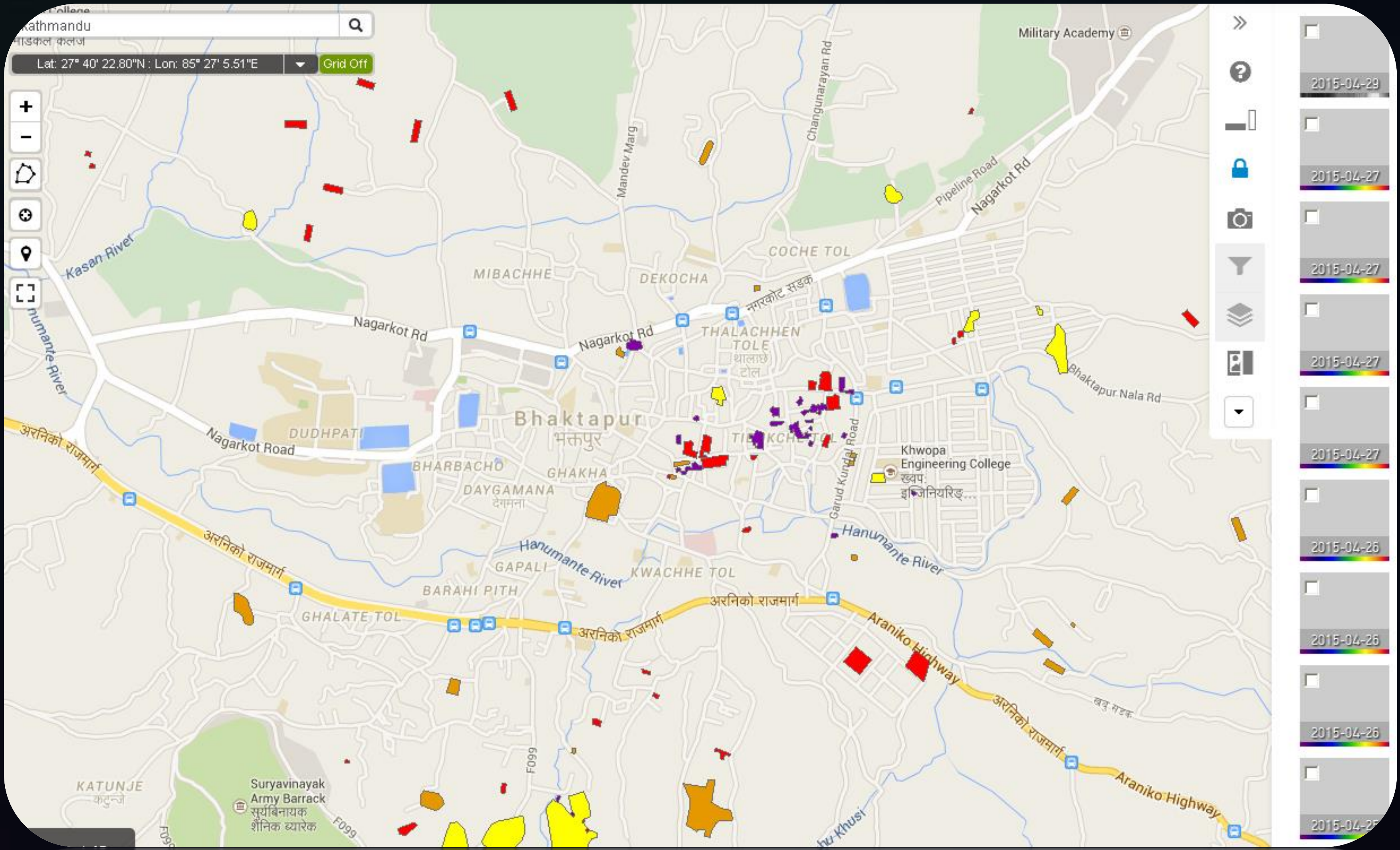
Damaged heritage structure

Rescue under Debris

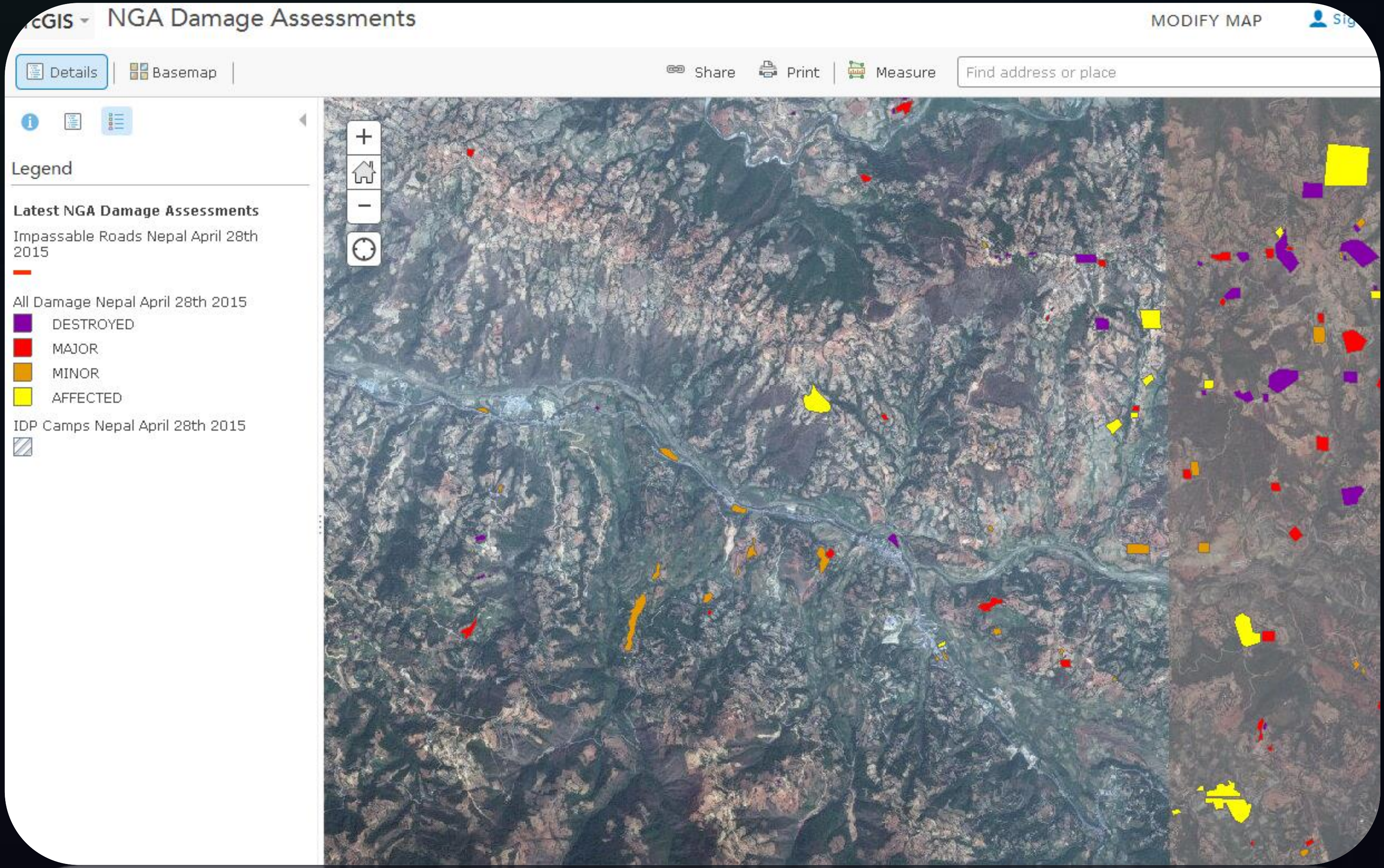
Rapid Damage Mapping



Rapid Damage Mapping



Rapid Damage Mapping



27th April 2015 Hanuman Dhoka Area

27 April 2015 Dharahara Tower

Most of the Dharahara Tower collapsed during the April 2015 earthquake.
Coordinates: 85.311924 E, 27.700568 N

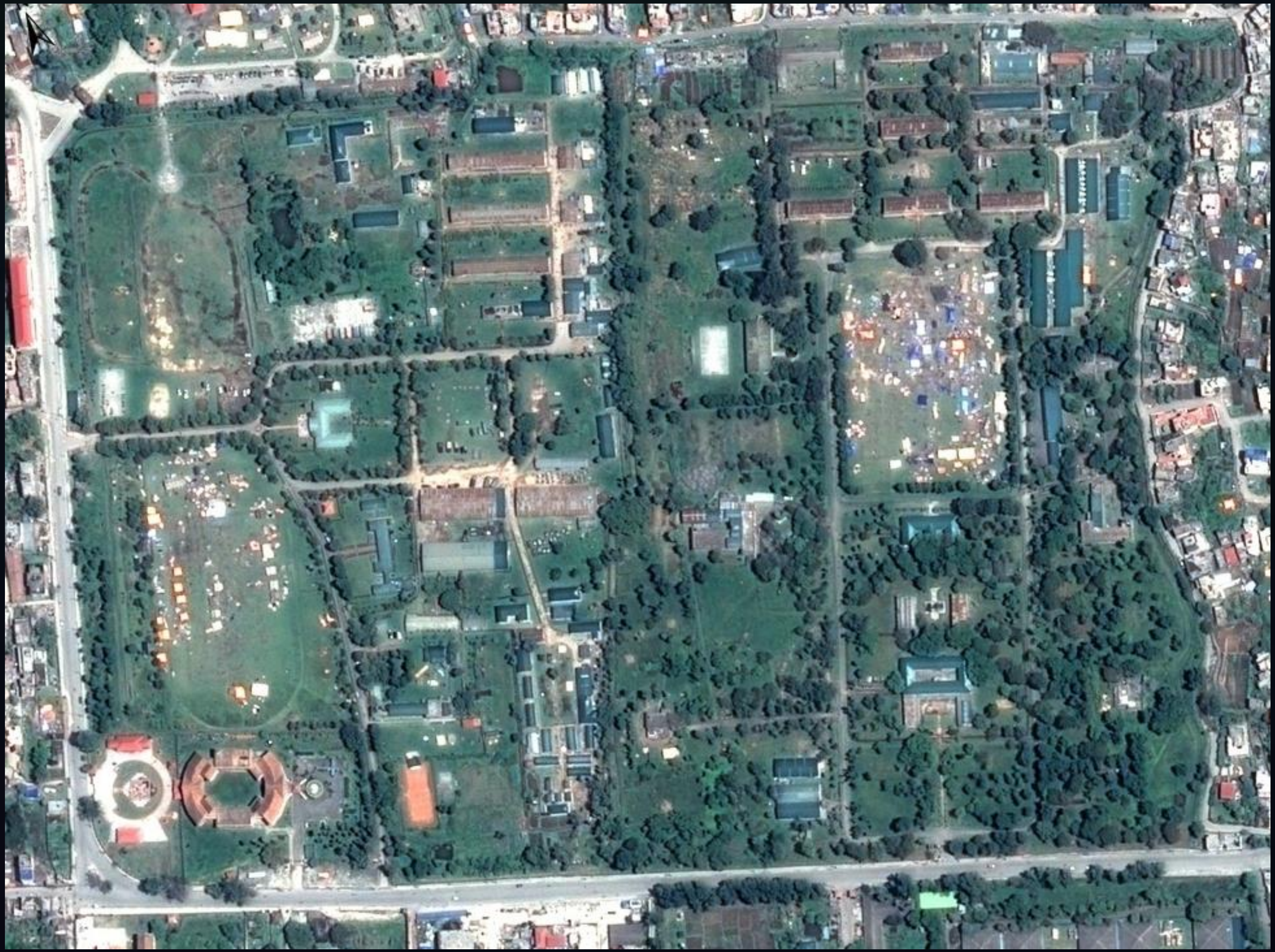
27 April 2015 Kathmandu

27 April 2015 Halchowk Stadium

Multipurpose stadium in Halchowk, Kathmandu.
Coordinates: 85.282523 E, 27.719544 N

Stadium used for rescue operations.
Coordinates: 85.282523 E, 27.719544 N

27 April 2015 Shelter



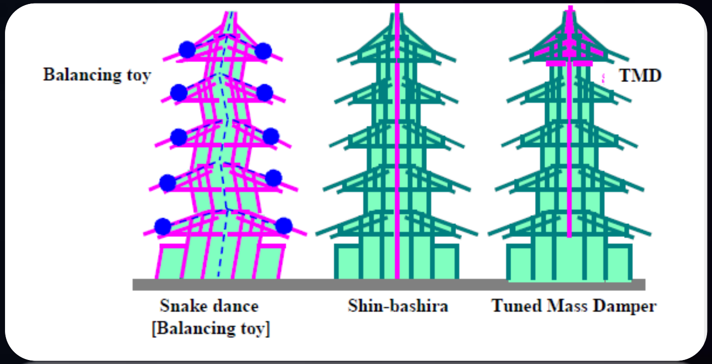
Transferring Traditional and Indigenous Knowledge

Earthquake Resistant

Traditional Architecture in Japan

HORYU-JI TEMPLE IN JAPAN

The architectural style of the five-story pagoda was introduced with Buddhism from India via China around the mid 6th century. During the years since then, about 1,300 years, many five-story pagodas encountered several huge scale earthquakes. There exist, however, no historical documents that report any toppling incidents of five-story pagodas except some damages in the ornamental element called kurin in Japanese in the top structure.



1000 Years old Kallanai Dam, Trichy, India

8 Billion Brains

16 Billion Hands

Destination - Disaster Risk Free World