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The effectiveness of using modern engineering methods in earthquake prediction

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Abstract

An earthquake is characterized by natural actions and effects that causes damage and losses. It is characterized by a sudden release of energy waves which travels from the Earth's interior and the earthquakes characterized by the sudden movement of soil and perhaps from the breaking of rocks as a result of this high energy. Over the past five centuries, earthquakes have killed more than seven million people, Earthquake prediction began to take on a more scientific issues. Many scientists in different countries have applied different methods to make and form success means to determine the epicentral area, the magnitude, and the occurrence time of an impending earthquake.

Keywords: seismic electric signals, the F-S model, VAN method, Mahalanobis-Taguchi Method, Mahalanobis distance, Remote Sensing

Introduction

Aristotle was the first to define the different types of earthquakes and the first to note the connection of earthquakes with an interior earth action as a volcanic activity, his famous saying: “where the Earth shook once, it will shake again”(Lazaridou-Varotsos, 2013).

Geological and geophysical sciences developed during the last century resulting in new possibilities for geophysics to explore hidden parts of the Earth, these models were simple and had freedom parameters that made them fit the observations of large earthquakes that were available, such models were plates imitating the thickness of the brittle crust or half-space models sometimes layered with known variations in seismic velocity. Sometimes these models had microspores of fluids in the rock as part of their intrinsic and homogeneous rheology.

For pre-earthquake processes these models were far too simplistic. The buildup of stress and fracturing conditions for large earthquakes takes many years, while the release of the stress in earthquakes takes a few seconds.

Mistaken warnings ahead of earthquakes have the undesirable effect of adding to the anxiety and suffering caused by them(Stefansson, 2011).

The observations of large earthquakes did not have the necessary resolution to detect, and thus to model, such infinitesimal initiation features. It was necessary to increase sensitivity to be able to observe the weak pre-earthquake process(Stefansson, 2011).

Tectonic earthquakes are around 90% of total earthquakes. There are also the volcanic earthquakes associated with volcanic eruptions, and the collapse earthquakes that are small earthquakes in the underground caverns, there is a class of earthquake caused by human activity.

Earthquakes are characterized depending on their depth as:-

1- surface earthquakes that have a depth of up to 60 kilometers (the most).

2- earthquakes of intermediate depth, that occur at depths of between 61 and 160 km.

3- deep earthquakes that have much greater depths(Lazaridou-Varotsos, 2013).

The earthquake prediction assessment classified in time frame classes:-

1- Short term earthquake prediction: estimate is for the next days, weeks or several months.

2- Medium term prediction: estimate is for the next 5−10 years.

3- long-term prediction: estimate is for a decades .

when prediction is understood to mean dynamic prediction, deterministic 100%, positioning of a future large event in a sufficiently narrow space time window(Haken, 1983).

Improving ability to see into Earth, Faster, more cost-effective, more accurate, and less invasive techniques for characterizing the subsurface is perhaps the most important need in geo-engineering(National & Press, 2006).

It has been found that there is no correlation between the duration of preseismic signals SES and the magnitude of the subsequent earthquake, it is completely distinct from other precursory phenomena used in the past, that it had been suggested that the longer the duration of precursory phenomena, the greater the magnitude of the expected earthquake(Lazaridou-Varotsos, 2013).

The study problem

Earthquake prediction research has been conducted for over 100 years with no perfect successes.

Pre-earthquake processes are difficult and hard to detect; even with modern instruments it is difficult to observe them.

This research will answer the following questions:-

1- What is the main factors of earthquake development and generating process that could be detected physically and geologically ?

2- What is the most important and latest methods and tools in earthquake prediction?

3- What is the success rate of the current EQ prediction methods?

4- How we increase the EQ prediction success rate ?

What distinguishes this study from previous studies ?

In this study we highlight the most important and success method in earthquake prediction , with focusing in dealing with its development and attempt to reform an integrated model from this different methods to support our goal in increasing the success rate of earthquakes prediction and forecasting early.

The study content:

1.0 The most important earthquake prediction methods

1.1 VAN constitutes a short-term earthquake prediction method

It is technical method by using electrodes buried into the earth, and taking measurements to detect and interpret precursory electrical signals, these signals are termed seismic electric signals (SES), and come from the future focal area of an earthquake.

These signals are essentially transient changes in the Earth's electric field, before the earthquake. So, VAN help in determination of the earthquake parameters: magnitude, epicentral area and time of an impending earthquake(Lazaridou-Varotsos, 2013).

1.2 Method of representative accelerograms

Description of method Records are chosen from databanks containing accelerograms that are appropriate for the considered site.

*** A new dynamic model involving upward**

*** migration of fluids from below**

*** the brittle crust :-**

Under some conditions, high values of pore fluid pressure can in response to plate motion strain effectively migrate from the brittle -ductile boundary at a depth of around 10km up towards the meteoric aquifer boundary at a depth of 3km to 4 km , by using this knowledge a dynamic model related to earthquake could be formed based on observation .

1- A NEW MODEL FOR UPWARD MIGRATION OF Earthquake Cloud Model

2- MAGMATIC FLUIDS : The model created was called the Fluid Strain Model (the F-S model).

3- Remote Sensing and using of Artificial intelligence (AI):-

Potential applications of remote sensing in geoengineering are related mainly to large-scale projects and regional activities and planning. Examples include hazard forecasting, monitoring regional subsidence, disaster response and recovery management, infrastructure planning, avalanches and regional instability(National & Press, 2006)

4- Synthetic aperture radar (SAR)

5- Light detection and ranging (LIDAR) is a new development in remote sensing that can SES anomaly detected before the impeding earthquake and the length of time window are signal type dependant (days to months)

6- GNSS Global Navigation Satellite System earthquake prediction tool

7- Mahalanobis-Taguchi Method using mapping and remote sensing services: a new method using Mahalanobis-Taguchi Method

1.3 The VAN method

VAN method : named afte P.Varotsos , K. Alexopoulos and K. Nomicos, this method measures low frequency electric signals, termed seismic electric signals (SES), by which P.Varotsos and several colleagues claimed to have successfully in earthquakes prediction in Greek.

prediction of earthquakes with this method is based on the detection, recording and evaluation of seismic electric signals or SES. These electrical signals have frequency component of 1 Hz or less and an amplitude, the logarithm of which scales with the earthquake magnitude

According to VAN proponents, SES are emitted by rocks under certain stresses caused by plate-tectonic forces.

*** There are three types of reported electric signal:-**

1- Electric signals that occur shortly before a major earthquake. Signals of this type were recorded 6.5 hours before the kope EQ (1995) in Japan,

2- Electric signals that occur some time before a major earthquake.

3- A gradual variation in the Earth's electric field some time before an earthquake.

*** Several hypotheses have been proposed to explain SES:-**

1- Stress-related phenomena: Seismic electric signals are perhaps attributed to the piezoelectric behavior of some minerals, especially quartz, or to effects related to the behavior of crystallographic defects under stress or strain. Series of SES may appear a few weeks to a few months before an earthquake when the mechanical stress reaches a critical value. The generation of electric signals by minerals under high stress leading to fracture has been confirmed with laboratory experiments.

2- Groundwater phenomena: Three mechanisms have been proposed relying on the presence of groundwater in generating SES.

The electro-kinetic effect is generated by the motion of groundwater during a change in pore pressure. The seismic dynamo effect is associated with the motion of ions in groundwater relative to the geomagnetic field as a seismic wave creates displacement, and this has been observed both for artificial and natural seismic events.

While the electro-kinetic effect may be consistent with signal detection tens or hundreds of kilometers away, the other mechanisms require a second mechanism to account for propagation:-

1- Signal transmission along faults: In one model, seismic electric signals propagate with relatively low attenuation along tectonic faults, due to the increased electrical conductivity caused either by the intrusion of ground water into the fault zone or by the ionic characteristics of the minerals.

2- Rock circuit: the presence of charge carriers and holes can be modeled as making an extensive circuit.

Seismic electric signals are detected at stations which consist of pairs of electrodes (NS and EW) inserted into the ground, with amplifiers and filters. The signals are then transmitted to the VAN scientists in many stations.

A radon ionization effect, caused by radon release and then subsequent ionization of materials in groundwater, may be active. The main isotope of radon is radioactive with a half-life of (3 ; 9) days, and the nuclear decay of radon may have an ionizing effect on air. Many publications have reported increased radon concentration in the vicinity of some active tectonic faults a few weeks prior to strong seismic events..

The VAN method has also been used in Japan, but in early attempts was difficult success comparable to that achieved in Greece .

The importance of selectivity of a sensitive station in VAN method:-

A very important property of these sensitive stations is their selectivity, which means that a sensitive station does not record SES from all seismic areas, but only from some of them.

*** The desired accuracy in a prediction:-**

Modern digital processing techniques required that the current stations network is ever to be expanded, might eases cross correlation methods which could, that help in confirming the existence of electromagnetic signals before upcoming earthquakes.(Lazaridou-Varotsos, 2013)

1.4 Method of representative accelerograms

Description of method Records are chosen from databanks containing accelerograms that are appropriate for the considered site. Selection is often made considering the magnitude and distance of EQ .(Douglas & Aochi, 2008).

Usually (if we record a single SES, it is followed by an earthquake within 11 days. If several electric signals are recorded within a short period of time(within 1−2 hours) , SES activity, then that activity is followed by several earthquakes, and the strongest of these earthquakes occurs after three weeks, during the fourth week after the recording of the SES activity (or 2−3 weeks later).(Lazaridou-Varotsos, 2013).

If the current SES amplitude is twice the amplitude of the past SES, the magnitude of the expected earthquake will exceed the past earthquake magnitude by one unit, that the signal strength decreases approximately inversely with the epicentral distance(Lazaridou-Varotsos, 2013).

2.0 MONITORING STRESSES TO PREDICT EARTHQUAKES

It is these rheological heterogeneities methods to estimate the stress field (especially seismic methods) do take account of such anomalies and try to correct for them. However, when trying to predict the site, time, and magnitude of earthquakes, scientists can make use of the anomalies instead. In fact, such anomalies based on their estimated effect on stress may form the basis for earthquake prediction(Stefansson, 2011).

Stresses in the crust that are significant for earthquake prediction can best be estimated on the basis of:-

1- measured deformation on the surface of the crust by making use of our knowledge of rheological properties in the crust and the upper mantle .

2- using information from micro-earthquakes with sources at the same depths as expected large earthquakes, either based on source mechanisms or ray path effects

3- the history of earthquake release there(Stefansson, 2011).

A new dynamic model involving upward migration of fluids from below the brittle crust.

Under some conditions, high pore fluid pressure can in response to plate motion strain effectively migrate from the brittle–ductile boundary at a depth of around 10km up towards the meteoric aquifer boundary at a depth of 3km to 4 km.

At seismogenic depths in the crust, fluids are near litho static pressure , values long enough for fracturing conditions to change, by high values of pore fluid pressure is meant pressures close to the litho static pressure (rock pressure) in contrast to the hydrostatic pressure prevailing in fluids at shallower depths than 3km to 4km. Water, which is compressible at the temperature and pressure at depth in the crust, that is the fluid used for modeling(Stefansson, 2011).

3.0 MODELS FOR UPWARD MIGRATION OF FLUIDS

3.1 Earthquake Cloud Model

When a huge rock is stressed by external forces, its weak parts break first and small earthquakes occur, based on the fact that large earthquake produces a large gap and small shocks generate small crevices, which reduce the cohesion of the rock. then, underground water percolates into the crevices. Its expansion, contraction and chemical effects further reduce the cohesion friction (Djamaluddin, 2005).

High temperature and water generates vapour ,the vapour erupts from an impending hypocentre to the surface by the crevices. It forms a cloud while encountering cold air. This kind of cloud, whose vapour is from an impending layers ,is an earthquake cloud.

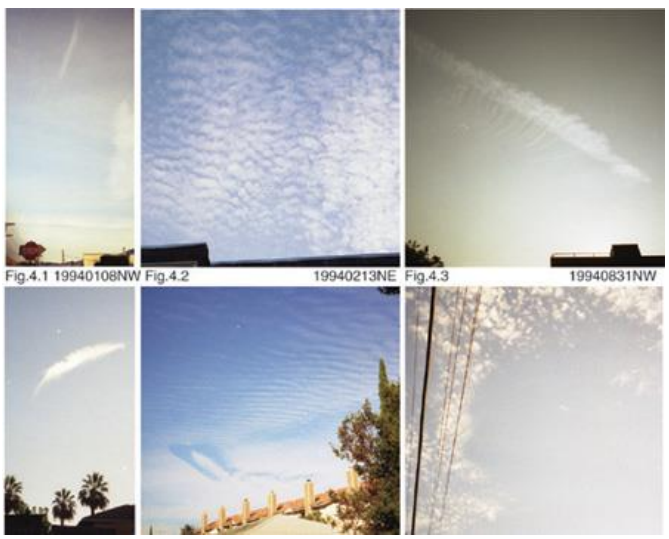

Figure 1. Various Shapes of Earthquake Clouds(Djamaluddin, 2005)

The earthquake cloud can be distinguished from weather clouds by the following characteristics : a sudden appearance and a special shape such as a line ,or a few parallel lines, a bind of parallel waves, a feather, a radiation or a lantern pattern ,while these properties do not occur together in weather clouds, the cloud can be used to predict earthquake magnitude(Djamaluddin, 2005).

Figure 2. Northern California earthquake clouds(Djamaluddin, 2005)

3.2 MAGMATIC FLUIDS (the SISZ area example) The model created was called the Fluid–Strain Model (the F-S model).

The three features of the F-S model that make it the best available model to describe SISZ seismicity are:-

1- the availability of fluids at litho-static pressure below the brittle ductile boundary

2- Earth-realistic modeling revealing the possibility of upward migration of litho-static fluids in response to strain

3- good agreement with geophysical observations (Stefansson, 2011).

The model created was called the Fluid–Strain Model (the F-S model). It was a

which was encapsulated in it(Stefansson, 2011).

3.3 In SISZ, the model for upward fluid migration, with highly fractured rock would increase permeability, and if permeability is confined by some barrier below the hydrostatic boundary it could lead to high pore fluid pressures.

Faults start slipping under the presence of fluids and bring fault slip to an end, so small earthquakes are released , and high pore pressure, which helps to trigger small earthquakes, drops immediately when fracturing occurs and inhibits faults from growing larger).

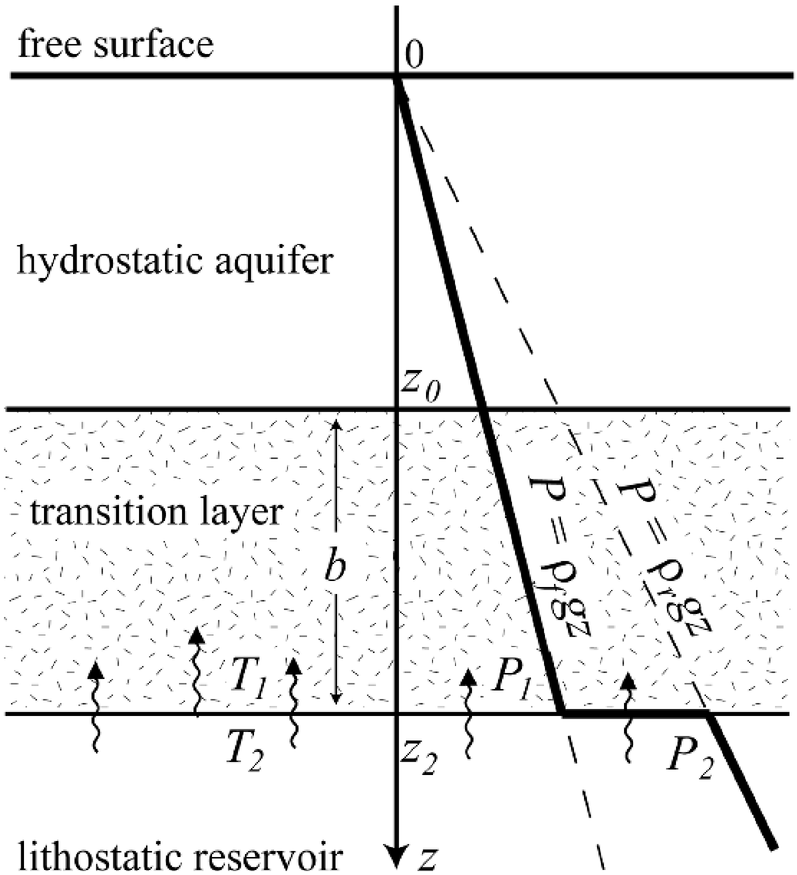

Figure 3. the transition layer is in contact with a hot fluid reservoir at lithostatic pressure

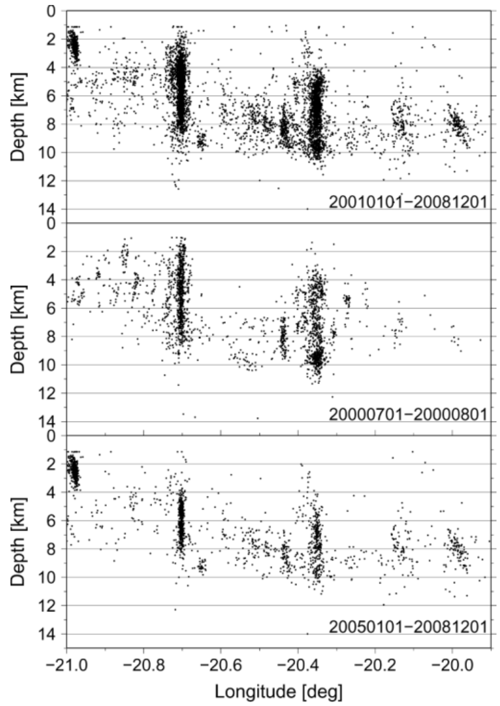

Figure 4. The clusters at longitude -20.37 degree and -20.71 degree are aftershocks of the large earthquakes of 2000 in SIZS area. The top image shows activity half a year after the earthquakes until the present. The middle image shows activity half a month after the earthquake and lasting one year. The bottom image shows activity since 2005.

Comparing the middle and the bottom images we can see that micro earthquake activity at the faults of the 2000 earthquakes reached certain shallower depths immediately after the earthquakes than during the last 4 years. The activity at the faults of the earthquakes 100 years ago is between depths of 7km and 10km only 2 kilometers above the brittle ductile boundary(Stefansson, 2011).

4.0 Remote Sensing and earthquake predication

topographic resolution that can be attained with current remote sensing technology is relevant to many geological and predictions applications:-

4.1 Synthetic aperture radar (SAR) uses tools mounted on space borne, airborne, or ground-based carriers to support high resolution images by repeating measurements at selected spatial intervals along a straight trajectory. Attainable resolution is from 10 m to 25 m for satellite based systems , while from 1 m to 3 m for airborne systems.

SAR data consists of a grid of complex amplitude and phase, two SAR images gathered at different times can be compared to produce interferograms that represent phase difference.

Space borne interferometric SAR can determine displacement in a few millimeters over hundreds of square miles.

Images gathered with synthetic aperture radar , with applications to ground subsidence and tectonic displacements.

4.2 Light detection and ranging (LIDAR) is an exciting new development in remote sensing that can provide very high resolution imagery of geologic features by measuring the time it takes for a laser pulse to travel from the source to a target and back to a sensor.

4.3 Self organizing spinodal (SOS) behavior : expresses the time evolution of seismicity in the earth's crust prior to a major earthquake, which is a consequence of the fault reaching its limit of stability, or spinodal.

We refer to this earthquake as the characteristic earthquake in a region(Francisco, 2013)

5.0 GNSS Global Navigation Satellite System earthquake early warning

The early warning module, called G-FAST, uses ground motion data measured by GNSS to estimate the magnitude and epicenter for large earthquakes , those magnitude 8 and greater, where one plate thrusts beneath another plate.

Using data collected by Chile’s more than 150 GNSS stations, Brendan Crowell of the University of Washington and his team tested G FAST’s performance against three large mega thrust earthquakes in the country: the 2010 magnitude 8.8 Maule, showed good results.(Monthly & On, 2018)

6.0 Mahalanobis -Taguchi Method

JESEA (Japan Earthquake Science Exploration Agency) has developed a new method using Mahalanobis-Taguchi Method (MT Method) which is one of artificial intelligence methods in this field.

The MT method has been developed by the late Dr. Genichi Taguchi who applied Mahalanobis distance (MD)

Every week new data should be checked whether or not the MD for normal feature space exceeds the threshold. The authors spent two years research on the application of the MT method for earthquake prediction which shows interesting result(Monthly & On, 2018).

The MT method varies depending on the selection of input parameters such as the number CORSs, the coverage area, range of time space, the features from XYZ coordinates.

The most important role is to determine the optimal input parameters to maximize the correlation between the MD and the occurrence earthquakes larger than Level 5.

After many validation tests, the authors have developed so called " µDEQ chart", where µD refers to the Malanobis's Distance and EQ refers to earthquake, which shows the risk factor of earthquake occurrence.

7.0 Prediction map with risk intensity

The authors succeeded to make a prediction map of Japan with risk intensity ranging from 1 to 5 for 30 separate areas with two reference CORSs(Monthly & On, 2018).

Figure 5. µDEQ chart (kumamoto EQ ,Japan).

Result of the study

1- correlations between geo-electrical runs and seismic events in almost all cases examined, suggesting the existence of precursory geo-electrical patterns preceding earthquakes

2- A very important property of VAN method sensitive stations is their selectivity, which means that a sensitive station does not record SES from all seismic areas, but only from some of them

3- The earthquake cloud can be distinguished from weather clouds by many characteristics , that could help to predict earthquake by smart observation of this EQ clouds

4- Stresses in the crust that are significant for earthquake prediction

5- Light detection and ranging (LIDAR) is an exciting new development in remote sensing that can provide very high resolution imagery of geologic features

6- The importance for new innovation for Sensing, imaging, and geophysical techniques should ultimately enable reliable monitoring of ground movements.

7- The importance of rapid reconnaissance of ground failures following an earthquake; and Identification and mitigation of other conditions and situations leading to breakdown and loss of strength in earth materials that could result in loss of stability.

8- topographic resolution that can be attained with current remote sensing technology is relevant to many geological and predictions applications.

Suggestions

1- Modern digital processing techniques required that the current VAN method stations network is ever to be expanded, might eases cross correlation methods which could, that help in confirming the existence of electromagnetic signals before upcoming earthquakes.

2- New and improved geological and geophysical characterization tools are perhaps the most important need in improving our ability to identify and manage geo-hazards.

3- It is necessary to determine the optimal combination of input parameters to maximize the correlation between the risk factors resulted from the MT method and previous larger earthquakes.

4- The MT method will be feasible to achieve precise prediction of larger earthquakes if big CORS daily data of more than ten years are provided.

5- To apply the prediction methods to a large fraction of the world's earthquakes will require the development of satellite imagery and automatic image processing techniques that are focus on finding the hot vapour emerging at an impending epicenter, and it is possible that both the imagers and the techniques already exist, and need only be redirected to this target.

6- many communities are still at risk and continued research and development is needed , and there is also a need for development of hazard assessments and mitigation measures for developing countries that are less complicated and more easily understood and applied than those used in the modern countries.

Conclusion

Improving geophysical and remote sensing technology, more reliable and accurate instrumentation, enhanced data acquisition, processing, and storage and incorporation of the collected data into more information systems.

Understanding and predicting the long-term behavior of constructed facilities and earth structures, including time effects in disturbed ground. Properties and conditions change with time, because our ability to predict accurately what will happen over even short time frames is limited.

Applications of information technology, and communication systems for linking facilities and real-time integration of concurrent experimental, computational, and prototype analyses and observations.

Improved understanding and prediction of the behavior of geo-materials under extreme loadings and in extreme-loading is essential to hazard mitigation efforts. Understanding geo-materials behavior in extreme environments.

Mistaken warnings ahead of earthquakes have the undesirable effect of adding to the anxiety and suffering caused by them(Stefansson, 2011)

REFERENCES

Djamaluddin, T. (2005). Space-based Data: Between Pure Science and Down-to-Earth Application in Indonesia. United. *Nations Programme on Space Applications*, *16*(3).

Douglas, J., & Aochi, H. (2008). A survey of techniques for predicting earthquake ground motions for engineering purposes. *Surveys in Geophysics*, *29*(3), 187–220. https://doi.org/10.1007/s10712-008-9046-y

Francisco, A. R. L. (2013). *済無No Title No Title*. *Journal of Chemical Information and Modeling* (Vol. 53). https://doi.org/10.1017/CBO9781107415324.004

Haken, H. (1983). *Springer series in synergetics*. *Magnetic Phase Transitions*. https://doi.org/10.1007/978-3-642-12601-7

Lazaridou-Varotsos, M. S. (2013). *Earthquake prediction by seismic electric signals: The success of the VAN method over thirty years*. *Earthquake Prediction by Seismic Electric Signals: The Success of the VAN Method Over Thirty Years*. https://doi.org/10.1007/978-3-642-24406-3

Monthly, T. H. E., & On, M. (2018). Earthquake prediction method using artificial intelligence, *XIV*(3).

National, T. H. E., & Press, A. (2006). *Geological and Engineering in the New*.

Stefansson, R. (2011). *Advances in Earthquake Prediction; Research and Risk Mitigation*. *Springer Heidelberg Dordrecht London New York*.