OPEN ACCESS
Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) |ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Evaluations of Earthquakes in the Academic and Engineering Frameworks

Samir A Hamouda[1*], Naji S Amneenah[1]

[1]Department of Physics, University of Benghazi, Libya

DOI: 10.36348/sjet.2023.v08i05.002 | **Received:** 25.03.2023 | **Accepted:** 06.04.2023 | **Published:** 19.05.2023

***Corresponding author:** Samir A Hamouda
Department of Physics, University of Benghazi, Libya

Abstract

Earthquakes are among the hidden forces that threaten human life and the future of civilization. And with the technological progress and studies in space sciences, the Earth did not receive the attention of studies and researches, especially those related to earthquakes. This paper is presents a brief study of the magnetic and physical properties of the elemental compositions of the earth's crust as an attempt to find out the causes of earthquakes. Results of calculations have suggested that compressions and tensions on the earth crust due to the interaction of the earth magnetic field with the magnetic materials in the crust may be one of the main causes of earthquake events.

Keywords: Earthquakes, Earth layers, tectonic plates, magnetic susceptibility, Geomagnetic storms.

1. INTRODUCTION

Earthquakes are, one of the most destructive natural disasters faced by man. Earthquakes can result in landslides, ground shaking, fires, fissures, *structural damage to buildings,* tsunamis *and damage to highways and bridges*. The extent of destruction and suffering caused by an earthquake depends on: duration, magnitude, and intensity.

Statistical studies that were related to earthquake events have shown that an average of 60,000 lives was killed each year, (80,000 victims from 1994 to 2004), and (780,000 victims from 2001 to 2010) [1]. Such devastated earthquakes have also great negative impacts on economic grounds, causing massive possessions and industrial sector damage [1] gave some figures about the losses of earthquake events: as the 1989 Loma Prieta earthquake in California estimated at $6 billion, the 1995 Kobe earthquake in Japan estimated at $200 billion, the 2011 Tohoku earthquake in Japan followed by its great tsunami were estimated at $220 billion. Moreover, additional costs such as: lost productivity, lost income, lost tax revenue, as well as the cost of rebuilding all infrastructures must be taken into account [1]. However, the economic impact of a magnitude 7 or larger earthquake is expected to exceed €100 billion. The situation can only become more severe with the on-going growth and concentration of human populations in urban centers often found in seismic regions [1].

Despite all these human and material losses caused by earthquakes, there is a solid belief by experts that it is not possible to predict the occurrence of earthquakes. According to the United States Geological Survey, “Neither the USGS nor any other scientists have ever predicted a major earthquake. We do not know how, and we do not expect to know how any time in the foreseeable future” [2]. However, seismologists can only estimate where earthquakes may be likely to strike by calculating probabilities and forecasts [3].

From the introduction above and in the academic and engineering Frameworks it can be stated that earthquake prediction is one of the most urgent and challenging subjects for human beings. It was suggested by [4] that if short-term earthquake is realized, casualty is greatly reduced because with the prospective earthquake information, earthquake will not be a surprise attack to us [4]. However, recent sequence of highly destructive earthquakes around the world has heightened awareness of earthquake hazards and the inability of seismology as a discipline to derive information of increasing earthquake hazards in the weeks and days before major seismic events [4].

Since the interpretations of seismic events are based on conventional measurements of crustal movements (i.e., mechanical measurement), it was thought of great interest to look closely at the structure of earth in an attempt to understand its physical properties and mechanisms.

Citation: Samir A Hamouda, Naji S Amneenah (2023). Evaluations of Earthquakes in the Academic and Engineering Frameworks. *Saudi J Eng Technol, 8*(5): 91-97.

2. Structure of Earth

The Earth is made up of four main layers: the inner core, the outer core, the mantle and the crust, as shown in figure 1. Geologists believe that as the Earth cooled, the denser and heavier material sank into the center, and the lighter material rose upwards. As a result, the outermost layer is made of the lightest materials, such as rocks and granites, and the innermost layer consists of nickel and iron [5].

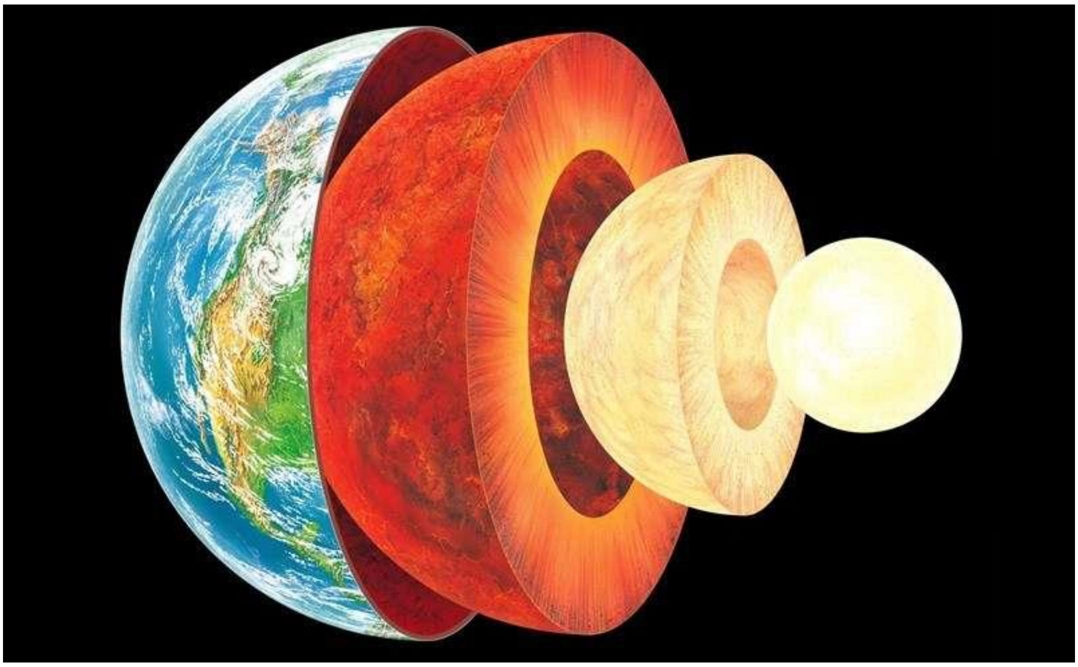

Figure 1: The main layers of Earth [6]

The inner core is the center and the hottest layer of the Earth. It is a solid and made up of iron and nickel with temperatures up to 6,000^{o}C. Due to its immense heat energy, the inner core is more like the engine room of the Earth. It has a radius of about 1,220 km and has pressures and temperatures so high that the metals are squeezed together and not able to move like a liquid but are forced to act as a solid [5]. The pressure is nearly 3.6 million (atm). The temperature of the inner core is far above the melting point of iron. However, unlike the outer core, the inner core is not liquid or even molten [7]. The inner core's intense pressure prevents the iron from melting [7]. The pressure and density are too great for the iron atoms to move into a liquid state.

The outer core is very hot. Its temperature is around 2200^{0}C to 5000 ^{0}C. It so hot that the metals inside are all liquid. The outer core is around 2900km under the crust and is approximately 2250km thick. It is composed of metals such as iron and nickel. The outer core surrounds the inner core [5]. The liquid metal of the outer core has very low viscosity, meaning it is easily deformed and malleable. It is the site of violent convection. Earth's magnetic field is created in the swirling outer core. Magnetism in the outer core is about 50 times stronger than it is on the surface [7]. The liquid iron in the outer core is an excellent electrical conductor, and creates the electrical currents that drive the magnetic field [7].

Generations of earth magnetic field is based on *Dynamo Theory, which implies that,* for a planet to have a geodynamo, it must rotate, it must have a fluid medium in its interior, the fluid must be able to conduct electricity, and it must have an internal energy supply that drives convection in the liquid [7]. However, variations in rotation, conductivity, and heat impact the magnetic field of a geodynamo [7]. The inner core rotates a little differently than the rest of the planet. It rotates eastward, like the surface, but it's a little faster, making an extra rotation about every 1,000 years [7].

The mantle consists of very hot and dense rock. Its thickness is approximately 2,900 km. Its temperature varies between 870^{0}C at the upper part to 2200^{0}C near the bottom [5]. The mantle is mainly made up of semi-molten rock known as magma. The rock is hard in the upper part of the mantle, but at lower down the rock is softer and begins to melt [5]. Geologists believe that due to the greatest temperature differences from the bottom to the top of the mantle, gave the reason behind the plates of the Earth moving is the movement of the mantle [5].

The Earth's crust is the outer layer where we live. The thickness is around 0-60 km. It's a solid rock layer divided into two types: Continental crust covers the land and Oceanic crust covers water [5].

Continental Crust - buoyant (less dense than oceanic crust) and its thickness ranges from 10-70km.

Oceanic Crust – dense (sinks under continental crust) and its thickness is about 7 km, (see figure 2) [8].

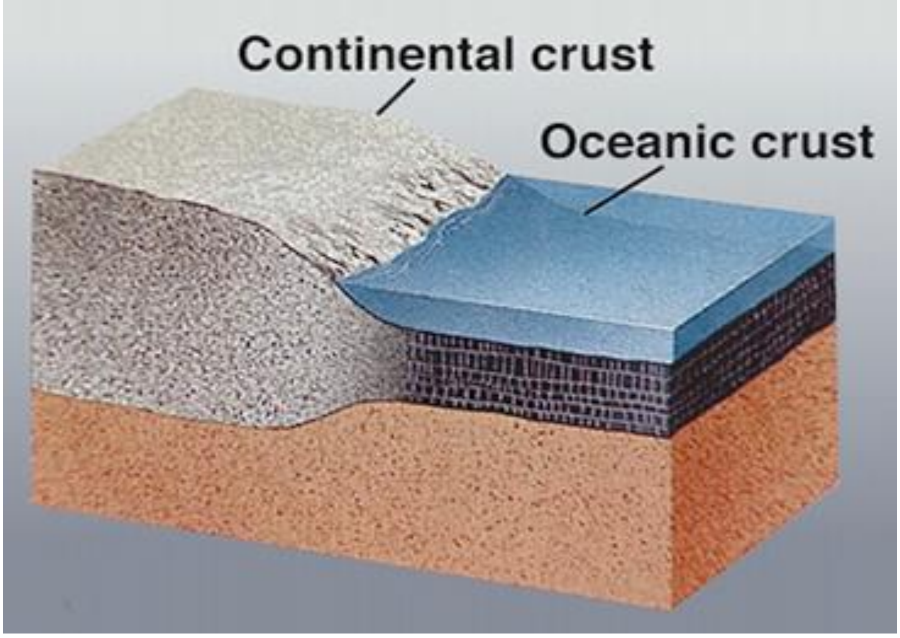

Figure 2: Earth's crust [8]

However, the Earth's crust is made up of seven major tectonic plates**:** African Plate, Antarctic Plate, Eurasian Plate, Australian Plate, North American Plate, Pacific Plate and South American Plate. Figure 3, shows the Earth's major tectonic plates [9].

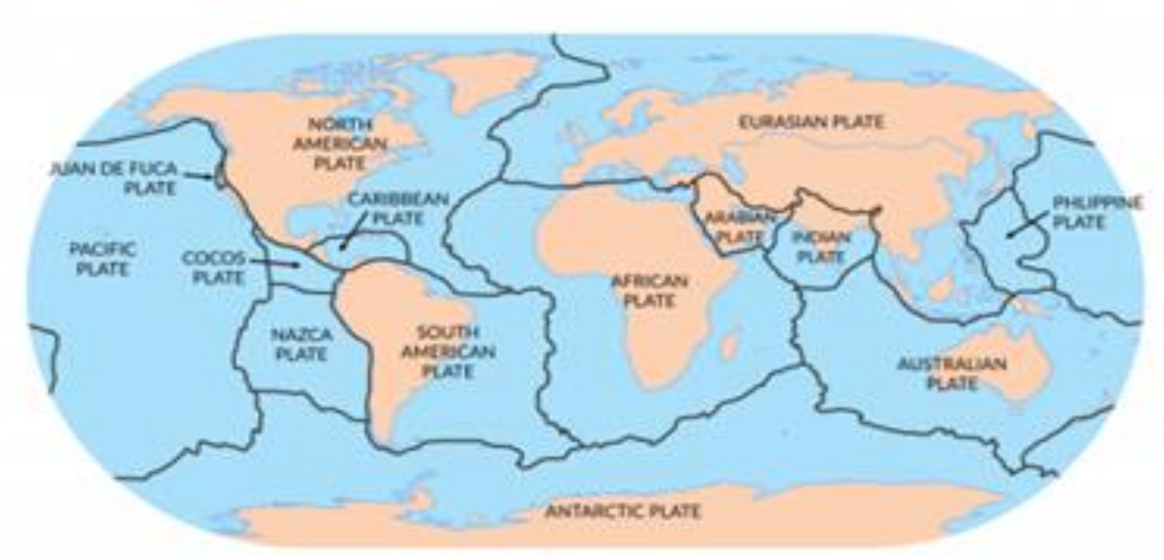

Figure 3: The Earth's major tectonic plates [9]

According to the theory of plate tectonics, the Earth's crust is made up of about a dozen plates on whose the continents and oceans rest. These plates are continually shifting because the substance beneath them is hot and soft mantle like a conveyor belt, driven by heat and other forces at work in the earth's core. The plates are moving about a 1cm to15 cm per year in different directions [10] (see figure4). Plates are made of rigid lithosphere. The lithosphere is made up of the crust and the upper part of the mantle. Below the lithosphere (which makes up the tectonic plates) is the asthenosphere [8].

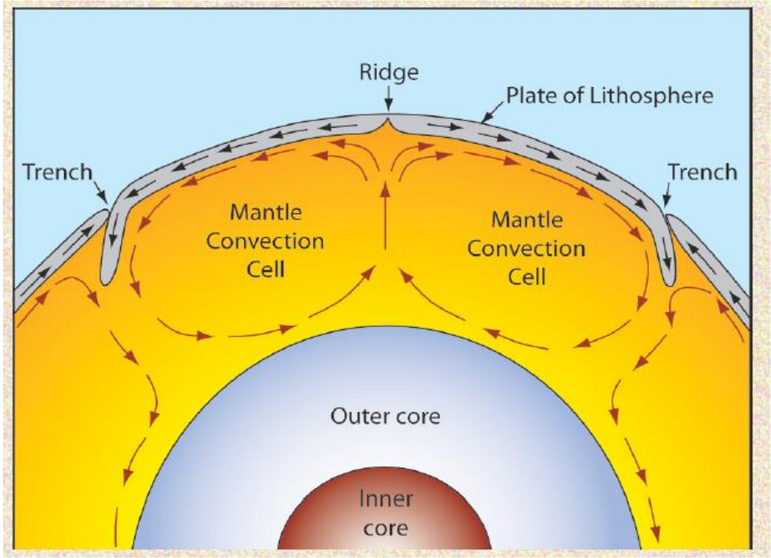

Figure 4: Plates are moved around by the underlying hot mantle convection cells [8]

The Earth's crust comprises about 95% igneous and metamorphic rocks, 4% shale, 0.75% sandstone, and 0.25% limestone [11]. The most common elements in the crust by weight are oxygen (46.6%), silicon (27.7%), aluminum (8.1%), iron (5.0%), calcium (3.6%), sodium (2.8%), potassium (2.6%), and magnesium (2.1%). These eight elements account for about 98.5 percent of the weight of the crust [12]. The weight of the crust is ($2.5\text{x}10^{22}$kg) [13]. It can be seen that oxygen is the most abundant element in rocks. It is an important part of most common minerals, such as quartz (SiO_2) and calcite ($CaCO_3$) [12].

3. MATERIALS AND METHODS

For Earth's continental Crust, it is important to understand the physical (electrical and magnetic) properties of curst elemental compositions. The magnetic field of Earth's outer core was measured to be 25 Gauss ($25\text{x}10^{-4}$ T) [15]. The electric current at the center of the outer core was calculated using Ampere's law and found to be $3.7\text{x}10^{8}$ Amp [15, 16]. Using Ampere's law again the average magnetic field in the center of earth crust (~ 35km below the earth surface) can be calculated. The average magnetic field at the center of earth crust was approximated to be ($2.5\text{x}10^{-5}$ T).

Table 1: Shows the chemical compositions by weight % of Earth's continental crust and oceanic crust

Elements	Earth's Continental Crust (weight %) [14]	Oceanic Crust[13]
SiO_2	58.21	50.1
Al_2O_3	15.28	15.7
$Fe4O_3$	3.52	8.3
FeO	3.73	-
MgO	3.51	10.3
CaO	5.09	11.8
Na_2O	4.83	2.21
K_2O	3.28	0.11
H_2O	1.26	-
TiO_2	0.84	-
ZrO_2	0.02	-
P_2O_5	0.20	0.10
MnO_2	0.07	-
Inclusive	0.16	-

The diamagnetic properties of materials are attributable to the magnetic susceptibility ($\chi<0$). The paramagnetic properties of materials are attributable to the magnetic susceptibility ($\chi>0$) and for ferromagnetic materials $\chi>>0$

For Paramagnetic and diamagnetic atoms the magnetic moment is given as [17]:

$$m = \xi B_{earth} \quad (1)$$

Where B_{earth} is the magnitude of earth magnetic field at internal location of earth. ξ (J/T^2) is the magnetizability and is given as,

$$\xi = \frac{\chi}{\rho_x u_0} \quad (2)$$

Where χ is the magnetic susceptibility, μ_0 is the magnetic permeability of vacuum ($4\pi\ \text{x}10^{-6}$ T.m/A), and ρx for each element x with y number of atoms is given as

$$\rho_x = \frac{N_A}{Y} \quad (3)$$

From figure5, the temperature value at 35 km depth in the earth crust was estimated at 450K. The thermal energy is given as:

$$E_{th} = k_B T \quad (4)$$

Where K_B is the Boltzmann's constant = 1.38 X 10^{-23} joules/K and T is the absolute temperature. Table2: lists the results of calculations due to equations 1- 5.

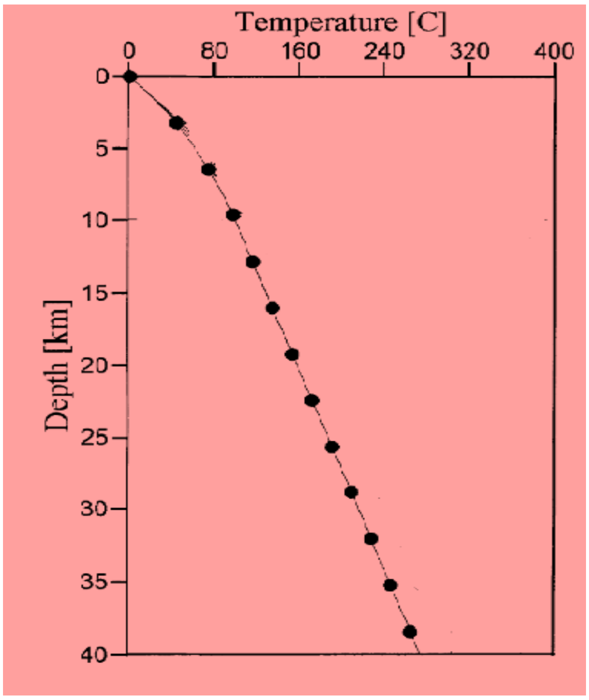

Figure 5: Temperature distribution with depth in the earth crust [18]

However, when the elemental compositions of earth crust shown in table2 are placed in a spatially inhomogeneous magnetic field, magnetic forces are exerted on them. The resulting magnetic forces are produced by the spatial derivative of energy. This magnetic force is expressed by [17]:

$$F = -\nabla E_{mag} = \xi B \frac{dB}{dx} \quad (5)$$

The spatial derivative of energy is a dimensional quantity expressed in units of Newton (N). Mathematically, it is the gradient of energy as a function of position. The negative gradient of energy is known as the force density. ∇B is estimated to be ($2.5\text{x}10^{-5}$T).

4. RESULTS AND DISCUSSIONS

Table 2: Gives approximate values for the average magnetic energy (J/T) stored in the center of earth crust (35km below the surface of earth) to the thermal energy ratios

Elements	Mass Susceptibility $4\pi*10^{-6}$ m3 mol^{-1}	Magnetic	# of molecules	Restored energy($\frac{J}{T}$)	Force 10^9N
SiO_2	-29.6	Diamagnetic	8.7x1045	1.1x1020	73.0
Al_2O_3	-37.0	Diamagnetic	2.2x1043	3.3x1017	0.23
$Fe4O_3$	+3,586	Ferromagnetic	1.3x1042	1.9x1018	1.32
FeO	+7,200.0	Paramagnetic	4.6x1042	1.4x1019	9.3
MgO	-10.2	Diamagnetic	7.8x1042	3.2x1016	0.02
CaO	-15.0	Diamagnetic	1.3x1043	8.1x1016	0.06
Na_2O	-19.8	Diamagnetic	1.2x1043	9.8x1016	0.07
K_2O	+3,230	Paramagnetic	5.2x1042	6.9x1018	4.74
H_2O	-12.63	Diamagnetic	1.0x1043	5.2x1016	0.04
TiO_2	+5.9	Paramagnetic	1.6x1042	3.9x1015	2.67
ZrO_2	-13.8	Diamagnetic.	2.4x1040	1.3x1014	0.00009
P_2O_5	NA	Non-magnetic	NA	NA	NA
MnO_2	+2280	Paramagnetic	1.2x1041	1.1x1017	0.08

The data presented in table 2 show that the dynamics of the earth crust is still strongly influenced by the earth magnetic field due to the elemental compositions (Diamagnetic, Paramagnetic and Ferromagnetic materials) of earth crust. Generations of earth magnetic field is based on *Dynamo Theory, which implies that,* for a planet to have a geodynamo, it must rotate, it must have a fluid medium in its interior, the fluid must be able to conduct electricity, and it must have an internal energy supply that drives convection in the liquid [7]. However, variations in rotation, conductivity, and heat impact the magnetic field of a geodynamo [7]. The inner core rotates a little differently than the rest of the planet. It rotates eastward, like the surface, but it's a little faster, making an extra rotation about every 1,000 years [7].

Geomagnetic storms are created when the Earth's magnetic field captures ionized particles carried by the solar wind due to coronal mass ejections (CME) at the Sun. When a CME hits the Earth, the magnetosphere is compressed further [19] and a geomagnetic storm (variations of geomagnetic field) is formed. This geomagnetic storm can produce a ground-level geomagnetic field disturbance that could have the potential to impact on earth. One of the most important geomagnetic storm processes involves the intensification and flow of ionospheric currents known as electro jets. These electro jets are formed around the north and south magnetic poles at altitudes of about 100km and can have magnitudes of ~1 million amps, which is sufficient in intensity to cause widespread disturbances to the geomagnetic field [20].

The widespread disturbances to the geomagnetic field produce the gradient of stored magnetic energy as a function of position in the crust. The results presented in table2 revealed that the components of the earth's crust have magnetic properties. The interaction of these properties with the intensity of the Earth's magnetic field in different regions of crust, and the diversity of such interactions throughout the earth's crust makes the earth's crust consist of regions with attractive magnetic forces and others repulsive.

This implies that the interaction (repulsion and attraction) between the earth magnetic field and the magnetic materials in the earth crust is capable of producing vertical and horizontal (vibrations) compressions and tensions on the earth crust. These vibrational mechanisms taking place in the crust may be one of the main causes of earthquake events. It is noteworthy that the energy released from earthquake event with a magnitude of 8.5 is about $1.41x10^{17}$ joules which is far less than the magnitudes of stored magnetic energy in the crust (see table 2). Therefore, compressions and tensions (vibrations) on the earth crust could trigger a high energy release through the earth crust.

5. CONCLUSION

Our results have revealed that the accurate knowledge of the elemental compositions of earth crust, their distributions and their magnetic natures are essential for the understanding of the dynamics and processes that occur in tectonically stressed regions. The Spatial variations in earth magnetic field and the magnetic force $\xi \frac{BdB}{dx}$ are likely to produce significant stress differences in the Earth's crust. In such conditions, a weak magnetic field B is sufficient to generate a large magnetic force if a large magnetic field gradient dB/dz is produced. The interaction (repulsion and attraction) between the earth magnetic field and the magnetic materials in the earth crust is capable of producing the buildup and the relaxation of stresses which may have important consequences for the state of stress of the crust, its deformational behaviour and seismicity.

Perhaps the urgent conclusion of this study is to present ideas about the risks of natural disasters, the most important of which are earthquakes, and to come up with better construction and urban expansion policies. In this regard, at the present time, the two major approaches dealing with natural disaster curricula, the academic and engineering should be strengthened and working with each other closely.

REFERENCES

1. Freund, F., Ouillon, G., Scoville, J., & Sornette, D. (2021). Earthquake precursors in the light of peroxy defects theory: Critical review of systematic observations. *The European Physical Journal Special Topics*, *230*, 7-46. https://arxiv.org/ftp/arxiv/papers/1711/1711.01780.pdf
2. Can you predict earthquakes? | U.S. Geological Survey (usgs.gov)
3. Earthquake Prediction: Can Scientists Predict Earthquakes? | Caltech Science Exchange
4. Masashi, H. (2016). "Earthquake prediction with electromagnetic phenomena." *AIP Conference Proceedings*, *1709*, 020002, AIP Publishing LLC. https://doi.org/10.1063/1.4941201
5. The Layers Of Earth - The Three Layers Of The Earth, Inner Core, Outer Core (byjus.com)
6. Matt Williams. (2015). "What are the Earth's layers?"., phys.org. https://phys.org/news/2015-12-earth-layers.html
7. https://education.nationalgeographic.org/resource/core/
8. http://www.soest.hawaii.edu/GG/FACULTY/KJOHNSON/GG103/lectures/plates_Pacbasin.pdf
9. 7 Major Tectonic Plates: The World's Largest Plate Tectonics - Earth How
10. South Carolina Department of Education, (2005)," Plate Tectonics" Department of natural Resources, Geological survey. Slide 1 (sc.gov)
11. The Earth's Crust (uiuc.edu)

12. The World Economic Forum., (2021), “Visualizing the abundance of elements in the Earth’s crust”. Which elements make up most of the Earth's crust? | World Economic Forum (weforum.org)
13. ch001-p088756.indd (elsevier.com)
14. Clarke, F. W., & Washington, H. S. (1924). The Composition of the Earth′ s Crust, United States Geological Survey 127. https://pubs.usgs.gov/pp/0127/report.pdf
15. Earth's magnetic field (ua.es)
16. Paul, R., & Edwin, D. (2018). “Sensors for Mechatronics.” *ScienceDirect* (Second Edition)., Pages 145-182 https://doi.org/10.1016/B978-0-12-813810-6.00006-9
17. Markus Meister., (2016), “Physical limits to magneto genetics”., California Institute of Technology, Pasadena, CA 91125, United States. https://elifesciences.org/articles/17210
18. Singh, R. N., & Manglik, A. (2000). Identification of radiogenic heat source distribution in the crust: A variational approach. *Sadhana*, *25*, 111-118.
19. Estefania Blanch Llosa, (2007).,” Ionospheric effects of the 20 November 2003 geomagnetic storm observed from GPS, ground-based and satellite data”., The Ramon Llull University. https://www.fundaciongarciasineriz.es/wp-content/uploads/attachments/EBlanch_JGS.pdf
20. John Kappenman., (2010), “Geomagnetic Storms and Their Impacts on the U.S. Power Grid”., Metatech Corporation, Meta-R-319. https://irp.fas.org/eprint/geomag.pdf