World Journal of Environmental Biosciences
Available Online at: **www.environmentaljournals.org**

Volume 15, Issue 1: 17-25

https://doi.org/10.51847/t6OJOsgtA9

ISSN 2277- 8047

Geological Determinism as a Conceptual Model for Solving Environmental and Engineering Problems

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ABSTRACT

The article examines geological processes and phenomena that have a significant impact on the life and activities of human society. In the course of research using a number of methods, it was established that geological processes were fundamental in relation to processes occurring on the Earth's surface and in its atmosphere. It is also substantiated that geographical determinism is a derivative of geological determinism. The leading role of geological determinism is determined by the dynamics of geological processes from ancient times to the present day and modern changes in the Earth's geology. The article analyzes in detail tectonic faults in East Africa, northeastern Turkey, and the southwestern United States, the shift of the Earth's magnetic poles, the magnetic anomaly in the South Atlantic Ocean, as well as the impact of human technical and technological activity on our planet. Particular attention is paid to three tectonic faults - African, Turkish, and Californian. The study showed that the African and Turkish faults are interconnected. The article emphasizes that geological processes have great importance for the formation of chemical substances and compounds in the bowels of the Earth. It is noted that the climate on Earth is largely determined by barocenters - the centers of cyclone formation. In order to minimize destructive natural and man-made consequences, humanity needs to solve engineering problems during the construction of technical facilities, taking into account current and potential geological processes and phenomena.

Keywords: *Geological determinism, Geological processes, Geological structure of the Earth, Earth's crust, Earthquake, Tectonic fault*

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Received: 02 December 2025
Accepted: 12 March 2026

INTRODUCTION

The question of which factor is the main one in the emergence and deepening of environmental problems, climate change on our planet, and determining the formation and development of technogenic civilization remains debatable. Evidence of this is the existence in philosophy and science of many different concepts, which are based on certain factors. The dominant factors are: God, gods (theological determinism), spirit, idea, Tao (idealistic determinism), mechanical movement, laws of mechanics (mechanistic determinism), natural environment

(geographical determinism), material production (materialistic determinism), biological nature of the person, his body (biological determinism), human psyche (psychological determinism), population, population growth, migration (demographic determinism), social phenomena, their universal interconnection and interdependence (social determinism), technology, technology (technological determinism).

Obviously, the main one among these determining factors is the natural environment. It is quite clear that without the necessary natural conditions of life, the appearance and existence of people on the Earth would be impossible. This is recognized by both science and religion, despite different ideas about the original starting point ("Big Bang" in modern science, "Creation" in monotheistic religions). In science, the sequence of stages in the development of nature is presented as follows (Koronovsky, 2023):

1) emergence of space (sky) with stars and planets;
2) appearance of water and land on Earth;
3) emergence of flora;
4) emergence of fauna;
5) Origin of man.

According to modern scientific concepts, one of the fundamental principles of cosmology is the anthropic principle, which fixes the connection between the large-scale properties of our Universe (Metagalaxy) and the existence of the person, an observer, in it. This principle, proposed by the English mathematician B. Carter, currently has two interpretations: "strong" and "weak". The strong anthropic principle goes like this: The Universe (and, therefore, the fundamental parameters on which it depends) must be such that, at some stage of evolution, the existence of observers is allowed in it. The weak anthropic principle is formulated as follows: there are different values of world constants in the Universe, but the observation of some of their values is more likely, since in the regions where the quantities take these values, the probability of the observer is higher (Wang *et al*., 2023).

The minimum necessary conditions for the life and development of the man, of all humanity, are the laws according to which everything is in motion in this material world, the quantitative values of constants and, of course, the Sun (star), the Earth (planet) and the Moon (satellite) located at a certain distance from each other, as well as a strong earth's magnetic field that protects water, earth, air, etc. from radiation. All these conditions exist on the Earth (Sorokhtin *et al*., 2010; Zakharov, 2022). It is no coincidence that the search for exoplanets in other stellar systems is carried out on the basis of similar conditions to our planet Earth (Zharkov, 2013; Deeg & Belmonte, 2018).

This understanding of the conditions for people's life and activity is most closely matched among the above dominant factors by geography, which is examined in detail within the framework of the concept of geographic determinism. Geographical determinism asserts that relief, climate, soil, flora and fauna, and other natural causes determine the process of social development, determine the nature of the socio-political system, the level of economic and technical development, the physical and psychological traits of people, their abilities, inclinations, temperament, and mentality. However, it proceeds from geological stability, the static nature of our planet, and therefore does not take into account the geological factor. In fact, geological processes have occurred and are still ongoing on the Earth, changing its internal structure and external appearance (Zhamoida, 2013).

The modern Earth consists of several geological layers, distinguished by chemical properties. In the center is an inner, solid core with a radius of about 1,250 km, which is dominated by iron and nickel. Next is the outer, liquid core, about 2200 km thick. Above it is a mantle of silicates and oxides 2900 km thick, and even higher is a thin, approximately 35-40 km thick solid crust. It contains not only silicates and oxides, but also other chemical elements that aren't found in mantle rocks.

Since the Earth's crust is solid but lies on a liquid mantle, it is not stable or strong. It is shaken by earthquakes, volcanic eruptions, and other natural disasters. This creates additional challenges for solving environmental problems and engineering problems. In this regard, the purpose of this study is to identify the impact of geological processes and phenomena on the natural environment and the significance of geological conditions in the development of engineering activities, as well as the reverse influence of technogenic civilization on our planet Earth (Royzerman & Belov, 2006; Starostin, 2014; Amit & Choblet, 2021).

MATERIALS AND METHODS

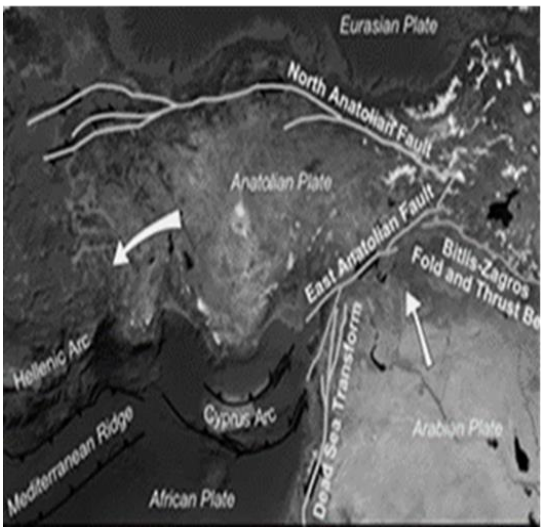
During the study, the dialectical method, methods of deduction and induction, analysis and synthesis, comparison, abstraction, generalization, and systematization were used. The use of the dialectical method made it possible to consider geological processes and phenomena in development. Using deductive and inductive methods, it was possible to consider geological processes and phenomena of a general and specific nature. The use of analysis and synthesis methods made it possible to analyze scientific data about geological processes and natural conditions and combine them within the framework of the concept of plutonism. The use of the abstraction method contributed to abstraction from unimportant properties and signs of geological processes and phenomena. Thanks to the methods of generalization and systematization, general conclusions were drawn, the results of the research were summarized, and an understanding of geological determinism was defined.

The main sources of theoretical research were such philosophical and scientific works as "Tao Te Ching" (Lao Tzu, 2023), "On Airs, Waters and Places" (Hippocrates, 1936); "On stones" (Theophrastus, 2016); "Periphesion" (John the Scot, 1976); "On the magnet, magnetick bodies also, and on the great magnet the earth" (Gilbert, 1956); "Principles of Philosophy" (Descartes, 1989); "On the Layers of the Earth", "The Word on the Birth of Metals from the Shaking of the Earth" (Lomonosov, 1949, 1950); "Universal Natural History and Theory of the Heavens" (Kant, 1963); "Theory of the Earth" (Hutton, 2011); "Guide to Geology" (Lyell, 1878); "The Origin of Continents and Oceans" (Wegener, 2011); "Paragenesis of chemical elements with the Earth's crust", "History of minerals of the Earth's crust" (Vernadsky, 1910, 1923–1927); "Living Earth: Composition and properties of matter in the interior of the Earth" (Yanitsky, 2005).

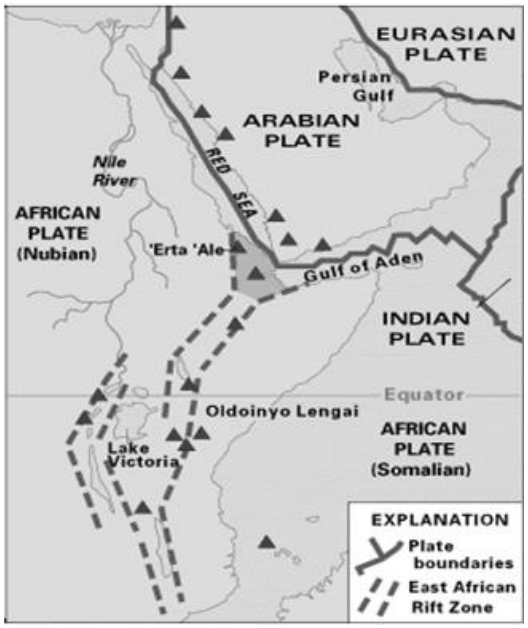
RESULTS AND DISCUSSION

In the ancient world, many philosophers and scientists gave preference to dynamics in their ideas about cosmic processes. But at the beginning of modern times, primarily with the transition from geocentrism to heliocentrism, dynamics gave way to statics. By the middle of the twentieth century, ideas had formed and spread that staticity and stability prevail on our planet, that the Earth is a cooled, tectonically inactive system, that it is at the final stage of its development, and that the current volcanic eruptions and earthquakes indicate its last convulsions. These ideas eventually took root in solving many practical, applied problems, in particular in engineering geology, which removed many restrictions in the design and construction of various technical facilities. The opinion has also established that all processes in space and on the Earth obey the Second Law of Thermodynamics, but the "thermal death of the Universe" will occur only in the very distant future.

However, in reality, it turned out that this is far from the case. The internal structure of the Earth, the processes occurring in the depths of our planet and breaking through to the surface in the form of earthquakes and volcanic eruptions, show that theorists and supporters of the concept of plutonism were largely right. The concept of plutonism, in contrast to the concept of neptunism, quite accurately explains the causes of movements in the earth's crust, tectonic faults, emergence of mountains, hot springs of water (geysers), etc. The dynamics have not disappeared anywhere. It has simply become slower compared to the early stages of the Earth's development. From time to time, it still makes itself known quite loudly. Modern tectonic faults in the Middle East **(Figure 1a)** and Eastern Africa **(Figure 1b)** are clear examples of this.



a)



b)

Figure 1. Map of faults in the Middle East a) and East Africa

The tectonic fault in the Middle East begins in Turkey at the Eurasian lithospheric plate and goes south along the border between the Anatolian and African lithospheric plates in the west and the Arabian lithospheric plate in the east to the Gulf of Aden. Further along the border between the African and Somali lithospheric plates is the East African Rift Valley, stretching from the Gulf of Aden to the Mozambique Strait at a distance of about 3,500 km, dividing Africa into two unequal parts: Nubian (larger) and Somali (smaller). A tectonic fault running through Ethiopia, Kenya, Tanzania, and Mozambique became evident when a fissure formed in southwestern Kenya, causing, in particular, part of the Nairobi-Narok highway to collapse (Engbers *et al*., 2020). Similar faults exist in other parts of the Earth, for example, in California (USA) between the Pacific and North American lithospheric plates and in the Krasnodar Territory (Russia) on the Eurasian lithospheric plate (Arroyo-Solórzano *et al*., 2021; Li *et al*., 2025). The lithospheric plates themselves are not monoliths. They can break, as is currently happening with the Indian or Australian (Indo-Australian) plate (Geggel, 2020).

Crossing California, the San Andreas Fault (1050 km) begins 160 kilometers north of San Francisco, passes directly under it, and in 40 kilometers north of Los Angeles, and ends at the Gulf of California **(Figure 2a)**. There are several other faults in the area, forming a dense network of potentially dangerous geological formations. Here, tectonic plates are in constant motion, and the growing tension between them is a result in an increase in destructive earthquakes **(Figure 2b)** (Romanyuk *et al*., 2012).

a)

b)

Figure 2. Map of the San Andreas Fault a) and photo of the San Andreas Fault b).

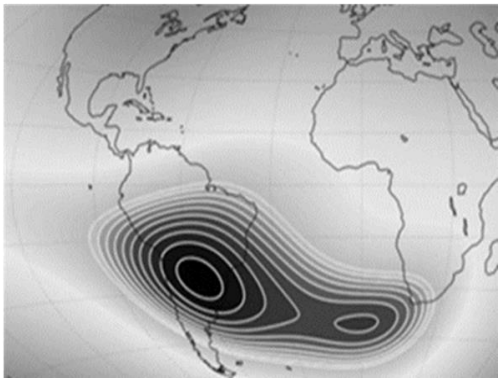
The growth of existing faults and the emergence of new ones on the Earth continue. One of the last major earthquakes, measuring 7.7 on the Richter scale, occurred in Myanmar on March 28, 2025. It was caused by the collision of the Indian and Eurasian lithospheric plates, and the movement of the Indian plate to the north (Ostroumova, 2025). The devastating earthquake and subsequent aftershocks created a large crack, which is clearly visible in eyewitness footage (Nimiya *et al*., 2021). Preliminary data indicate that the earthquake was a rare type known as a "supershear." This type of earthquake causes the earth's surface to rupture much faster than seismic waves. If this explanation is correct, the Sagaing fault, which runs from north to south across central Myanmar, could extend for more than 400 kilometers (250 miles) or more (Witze, 2025).

Based on the above, it can be stated that the Earth's dynamics are not constant and that the concept of plutonism is correct. This is confirmed by studies conducted by a group of scientists headed by I.N. Yanitsky. The essence of these studies is that earthquakes can also occur pointwise, in local spaces, as happened on the territory of the fourth power unit of the Chornobyl nuclear power plant on April 26, 1986 (Vasilyev *et al*., 2006) or, conversely, one or several buildings remain intact, and everything around is destroyed (Alhossan *et al*., 2024; Frost *et al*., 2024; Cuenca-Martínez *et al*., 2025; Mishra *et al*., 2025).

Another example of the uneven dynamics of geological processes and phenomena is the displacement of the Earth's magnetic poles (Frost *et al*., 2024; Ismail *et al*., 2025; Laaksonen & Virtanen, 2025; Peterson & Rogers, 2025; Torres *et al*., 2025). Thus, since 1831, when its exact geographical coordinates were first established (70°05' north latitude and 96°47' west longitude), it has moved towards Siberia by 2.3 thousand km **(Figure 3a)**. Moreover, if in 2000 it moved by 15 km, now the speed of displacement has increased to 55 km per year (Goshu, 2025). The location of the south magnetic pole is also changing. It is assumed that the continuation of the pole shift will lead to their change: the north pole will move to the south, and the south pole to the north. As modern research shows, the last drift of poles by 180 degrees began 789 thousand years ago and ended 786 thousand years ago. In addition, the Earth's magnetic field is undergoing changes not only in the displacement of poles, but also in its strength, decreasing by an average of 9% over the last two hundred years, and in the occurrence of anomalies. One such anomaly was recently discovered in the South Atlantic Ocean **(Figure 3b)**. Currently, it is divided into two parts: Brazilian and Cape Town (Brown *et al*., 2018).

Geological processes and phenomena that occur on the Earth, on the one hand, create and maintain gravitational and magnetic fields, the atmosphere, and ensure the abiogenic formation of minerals and the relative stability of the planet's surface, and on the other hand, cause earthquakes and volcanic eruptions, tsunamis, leading to local natural disasters. They are the dialectic of geological processes and phenomena that have a dominant impact on the Earth's surface and its atmosphere.

a)

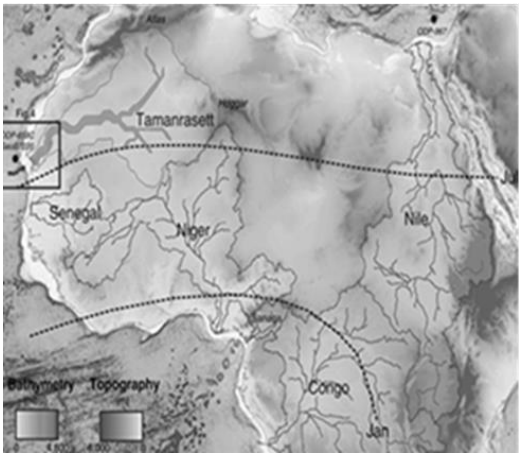


b)

Figure 3. North Magnetic Pole Displacement a) and magnetic anomaly in the South Atlantic Ocean b).

As an example, we can take the same water formed in the depths and pushed under pressure to the surface of the Earth (Danchin *et al*., 2024; Hillman, 2024; Alves *et al*., 2025; Chen *et al*., 2025; Romero & Campos, 2025). If, during the course of geological processes and phenomena, for some reason, little water begins to be "produced," this leads to the drying out and disappearance of rivers. Thus, in the Sahara, the largest desert on our planet, a sand-filled bed of the former Tamanrasset River was discovered **(Figure 4a)**. True, many believe that the reason for its disappearance is global warming (Skonieczny *et al*., 2015).

Geological processes and phenomena are not only the main source of water, but also the cause of powerful cyclones. Scientific research shows that there are barocenters on the Earth that are of geological origin and largely determine the climate on the planet (centers of cyclone formation) **(Figure 4b)**. Moreover, the formation of weather is practically independent of the topography, the intensity of solar heating, and the marine component (Kitaba *et al*., 2017). The processes occurring in the atmosphere are, in essence, derivatives of the processes occurring in the bowels of the Earth.



a)

b)

Figure 4. Dry bed of the Tamanrasset river a) and shown barocenters b): I - Mongolian; II – Greenlandic; III – Alpine; IV – Elbrus.

Geological processes and phenomena change water basins and river beds on the Earth, cause earthquakes and volcanic eruptions, floods and droughts, damage settlements and agricultural land, and destroy roads, bridges, and other infrastructure. Environmental damage from them sometimes reaches tens and sometimes hundreds of billions of US dollars. Since managing geological processes and phenomena in a positive way, as opposed to a negative one, is a very difficult matter, it is necessary to develop a reliable warning system and successfully overcome the destructive consequences using various technologies and technical means (Ashwin *et al*., 2024; Jin *et al*., 2024; Li *et al*., 2024; Owusu *et al*., 2024; Aksoy & Akaydin, 2025; Kunie *et al*., 2025; Watanabe & Mori, 2025).

The natural dynamics of geological processes and phenomena are also increasingly influenced by the technical and technological activities of mankind. This is very noticeable in the dynamics of seismic noise, high on weekdays and low on weekends. The pandemic caused by the coronavirus (COVID-19), which led to the introduction of quarantine in many countries around the world in the first half of 2020, became clear evidence of this. During the quarantine, a significant number of industrial enterprises, construction sites, and vehicles were stopped. As a result, the vertical movements of the earth's crust ("Earth tremor") decreased by ten to fifteen nanometers **(Figure 5)**. According to the Royal Observatory of Belgium, the level of seismic noise in this country in the second half of March 2020 fell by 50% in some places (Shen & Zhu, 2021; Mattern *et al*., 2025).

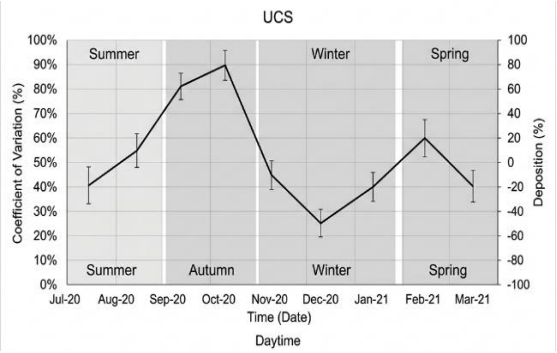


Figure 5. Dynamics of seismic noise.

Even local but excessively active technical people's activity has an impact on our entire planet. Thus, the construction of the world's largest hydrotechnical dam, "Three Gorges" in China, led to the fact that a colossal, monstrous mass was concentrated in one place - more than 65 million tons of reinforced concrete and almost 40 billion tons of water. As a result, the rotation of the entire planet slowed down by 0.06 microseconds, and the geographic pole shifted by 2 cm ("A huge Chinese structure slowed down the Earth's rotation and shifted the pole," 2025).

As we can see, over the past decades, humanity's impact on geological processes has noticeably increased. Geological movements in the Earth's crust are now caused not only by natural but also by artificial reasons. They include various types of explosions, both military and peaceful, mass flights of space rockets, airplanes and other aircrafts, active movement of rail and road transport, large-scale construction of huge facilities (cities, hydroelectric power stations, etc.), the unrestrained extraction of oil, gas, coal and other minerals, which results in voids being formed in the earth's crust that is either unfilled or

filled with something. This means that natural factors are largely ignored in the engineering process. Taking into account natural factors, it is impossible, for example, to build any large objects near tectonic plate shifts: megacities and cities, oil and gas pipelines, spaceports and airfields, sea and river ports, hydroelectric and nuclear power plants, mines and coal mines. These restrictions should be aimed at reducing negative environmental, financial, economic, and technological consequences.

In practical terms, in seismically dangerous areas, new buildings must meet all modern seismic resistance requirements, including the height of one to three floors. These requirements are currently met by beamless buildings that do not have beams. Their construction is much cheaper than that of beam houses. In addition, they are much more resistant to the rampage of the underground elements. Buildings with a large area of glass coverings are also promising. The fact is that earthquake-resistant glass is the most suitable material for construction in earthquake-prone areas, since it is lighter and stronger than concrete **(Figure 6a)**. Another type of house that can withstand seismic loads quite successfully is the timber-frame type. When constructing such buildings, the foundation is securely fastened with anchor bolts, and timber-frame elements ensure the strength and plasticity of the walls, and the stability of the roof and ceilings ("What kind of house can withstand an earthquake?", n.d.). Another complex technical object is the sea bridges, which are built in earthquake-prone areas with tectonic faults located underwater. A positive example is the seismically resistant Haiwen Bridge, which connects the Chinese cities of Haikou and Wenchang **(Figure 6b)**. It is 5.59 km long and crosses active tectonic faults – fractures in the earth's crust that have formed over the past tens of thousands of years (Wang *et al*., 2023). However, even with a minor widening of the tectonic fault by 0.8-2.5 cm per year, as is currently happening in East Africa, the construction of bridges and other structures is a technically challenging task, since the distance between the opposite sides of the faults is constantly increasing (Ahmed *et al*., 2025).

a)

b)

Figure 6. Building made of glass and metal a) and Haven sea bridge b)

For technical facilities to be stable, it is necessary to take into account the geological conditions of the area (tectonic faults, seismic zones, relief, soil, etc.) where they are planned to be built (Varivoda *et al*., 2022; Neftullayeva *et al*., 2023). In addition, technical objects must harmonize with the environment not only aesthetically (from the point of view of beauty, the beautiful), but also physically, chemically, and biologically (from the point of view of ecology, conservation of nature) (Kalaimurugan *et al*., 2022; Thangavel *et al*., 2025). In other words, technical objects must have a solid foundation under them. Otherwise, the technological process will accelerate the evolution of the geological structure of the Earth in a negative, destructive direction, activating its transformation, perhaps even into a lifeless planet like Mars (Zakharov *et al*., 2022; Wang *et al*., 2023).

Since there are many deserts and dried-up river-beds on the Earth's surface (the same Tamanrasset in the Sahara), areas where floods often occur (the Caucasus, Pamir, the Amur River basin, etc.), as well as the presence of the magnetic anomaly discussed above in the south Atlantic Ocean, require engineering and management to solve relevant environmental problems: providing humanity with fresh water, build-ing dams and dikes to prevent water disasters, and protecting all living things from cosmic radiation.

CONCLUSION

Based on known scientific data about the planets of the Solar System, as well as their satellites, according to the power of the geological processes and phenomena occurring, they can be divided into following four groups: 1) with high geological activity; 2) with moderate geological activity; 3) with low geological activity; 4) with the absence of geological activity (frozen, "dead"). Obviously, the present Earth belongs to the second group. It is thanks to the moderate nature of geological processes and phenomena that the Earth currently has the necessary and sufficient natural conditions for the existence of not only a protein form of life, but also a technically advanced civilization.

It is precisely from this geological stability of our planet that geographical determinism primarily comes. But in reality, this stability of the geographical environment is quite relative. It depends on the geological processes and phenomena that

occurred on the Earth in the past and continue to occur at present, although not so violently. Since geological processes determine the geographic environment, geographic determinism is a derivative of geological determinism.

If on the surface of the Earth and in its atmosphere, the main pollutants are various types of solid waste (industrial waste, household waste, etc.) and carbon dioxide, then the subsurface is a huge threat from voids resulting from mining. To solve environmental problems successfully, it seems necessary to make a transition to the active use of renewable energy sources. In the future, this will allow limited extraction of minerals and therefore reduce the formation of voids. In this case, the voids should be filled not with water, as is often done now, but with processed pollutants from nature, which requires the creation of new technologies and new equipment. To reduce the destructive consequences, humanity needs to take into account tectonic faults, seismic zones, active volcanoes, and other geological phenomena. This is the essence of geological determinism as a conceptual model for solving environmental, technical, and technological problems.

ACKNOWLEDGMENTS: None

CONFLICT OF INTEREST: None

FINANCIAL SUPPORT: None

ETHICS STATEMENT: None

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