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A Preliminary Analysis of the Basic Principle and Research Value of Mud Volcano Formation

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ABSTRACT

The global plastic usage and production issue during the COVID-19 Pandemic requires strategic, solid controls. In this passage, under the COVID-19 background, we summarize the factors that cause increasing production and usage of plastic, highlight the effects of producing and using a large amount of plastic, and propose some ways to deaden the environmental problems caused by the mass production of plastic products under the epidemic. Several factors are pushing the production and usage of plastics, including changes in people's behavior, demand for protective equipment, and laws and regulations. These factors drive the production of plastic substances, bringing with them a series of serious environmental, economic, and human health problems. Thus, we propose three ways, including the government leadership, social participation, and individual responsibility, to de-escalate the detriment caused by the plastic matter.

KEYWORDS

Mud Volcanoes, Geological Processes, Tectonic Activity, Sedimentary Deposits, Environmental Impact.

1. INTRODUCTION

1.1. Overview of Mud Volcanoes

Mud volcanoes refer to various substances left behind after underground liquid or gas eruptions which usually appear in the form of mud or accumulate into a conical mud peak. These mud-like residues over time may also develop into mudstone areas. If the area still has underground natural gas escaping through fissures to the surface, the eruption material often contains water or other sediments. Mud volcanoes can be divided into onshore mud volcanoes and underwater mud volcanoes depending on their location.

1.2. Importance of Studying Mud Volcanoes

Mud volcanoes provide valuable insights into geological processes, energy exploration, environmental monitoring, and hazard assessment. They also aid in planetary science by offering clues about similar formations on other celestial bodies.

Figure 1. A close-up shot of a mud volcano

2. BASIC INFORMATION OF MUD VOLCANOES

2.1. Definition and Characteristics

Mud volcanoes resemble volcanoes in appearance and have almost identical internal structures. Mud volcanoes have a mud channel beneath their craters which is usually only a few dozen meters deep and a mud chamber below the channel. The principle of mud eruption is also like that of volcanoes. Underground mud is subjected to pressure breaks through the weak points in the surface rock layers and erupts onto the ground. During small-scale eruptions only bubbles rise with the mud slowly. During violent eruptions the mud will boil like water with bubbles rolling and spraying out large amounts of mud. If the outlet is small, it will only spurt out like a water pipe. Although there are many similarities between volcanoes and mud volcanoes, mud volcanoes are not a type of volcano.

Figure 2. The mud splashed from a mud volcano

2.2. Distribution of Mud Volcanoes

In addition to Antarctica, mud volcanoes can be found on every continent in the world, but the overall number is small. Mud volcanoes are often found along the margins of subduction and collision zones where the pressure of the rock layers is excessive. A large number of mud volcanoes are found in the central region of Azerbaijan, and they are also present in Borneo. Mud volcanoes are also found near oil fields in Jiangsu Province and Xinjiang Uygur Autonomous Region of China.

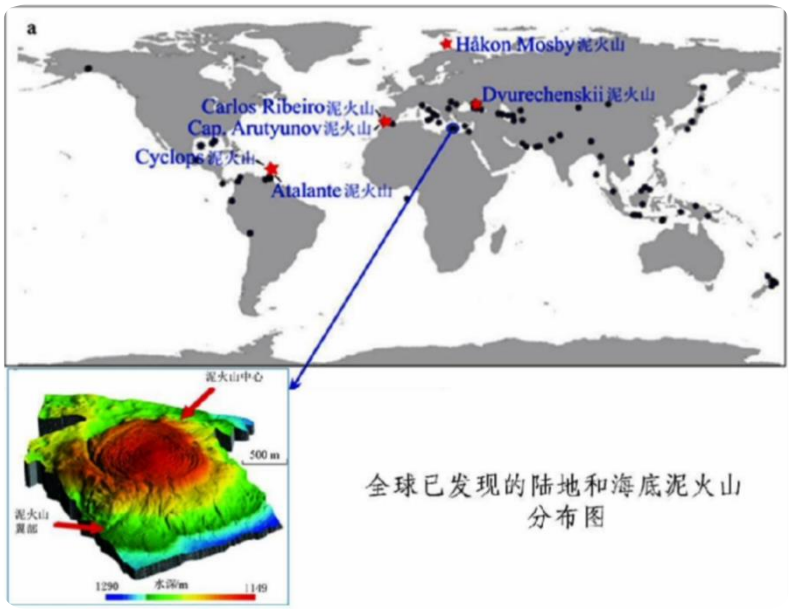

Figure 3. The mud volcanoes distribution diagram. The Chinese sentence means “Map of the global distribution of found terrestrial and submarine mud volcanoes”.

2.3. Differences and Similarities with Traditional Volcanoes

Mud volcanoes resemble volcanoes in appearance and have almost identical internal structures. However, they have a mud channel beneath their craters, usually only a few dozen meters deep, and a mud chamber below the channel. The principle of mud eruption is also like that of volcanoes. Underground mud is subjected to pressure, breaks through weak points in the surface rock layers, and erupts onto the ground.

2.4. Eruption Patterns

The frequency, duration, and intensity of mud volcano eruptions vary greatly. Some mud volcanoes are relatively inactive, erupting only occasionally over a long time, while others are very active, erupting frequently for several days or even weeks. The characteristics of mud volcano eruptions may also vary depending on the composition of the fluids and sediments being ejected. Some mud volcanoes primarily eject water and gas with little or no sediment, while others can eject large quantities of viscous mud.

Figure 4. The mud volcano as a whole

Figure 5. The crater of a mud volcano

3. FORMATION PRINCIPLES OF MUD VOLCANOES

3.1. Formation Mechanisms

Mud volcanoes form mainly in two ways. One is abnormal overpressure in the strata: because the rate of sedimentation is significantly higher than the rate of fluid expulsion, the water filling the rock pores cannot be expelled in time, gradually forming a strong pressure. When the stratum pressure exceeds the pressure of the overlying rock stratum, the mud will rise along the faults and fractures and finally erupt. The other is the causative structure: for example, lateral geological structures that compress the mud bottom (which can be considered as the “youthful” mud volcano) will cause the mud bottom to be exposed on the surface (or under the sea) and form a mud volcano.

3.2. Formation Conditions

After knowing how mud volcanoes form, we also need to understand the conditions under which mud volcanoes form. Usually, the formation conditions of mud volcanoes include the following:

- Fast deposition rate.
- Lateral compression of active continental margins.
- There are undersea or terrestrial faults that allow the mixture of gas and mud to rise.
- Sufficient geothermal energy for mud and gas ejection.
- There is mudstone layer which provides material source for eruption.
- There is sufficient underground mud fluid.

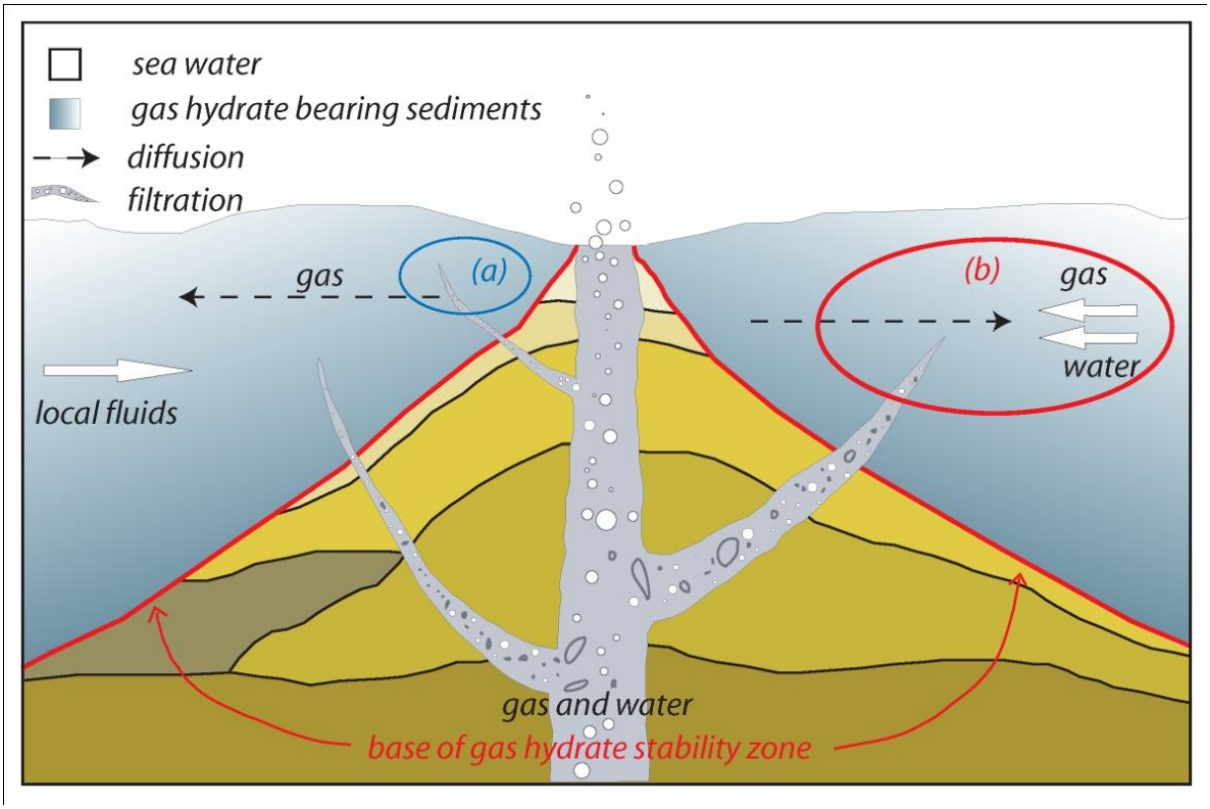

Figure 6. Volcanic edifice of mud volcanoes

3.3. Mud Volcano Systems

The term “mud volcano system” was coined by Stewart and Davies to describe mud volcanoes and a group of structures associated with feeder complexes that connect volcanoes to their source stratigraphic units. The system is driven by pressure and a fluid source that may or may not coexist with the mud source bed. Above the fluid source is the supply pipeline the detailed structure of which is largely unknown - it may consist of a complex system of fissures and dikes filled with mud that carry a fluid sediment mixture to the Earth’s surface where the fluid and sediment mixture then erupts to form a volcano. The pipe system of the mud volcano system is very limited. Some mud volcano systems are thought to consist of multiple mud chambers in different formations while other models suggest that mud volcano systems consist of large amounts of mud in the form of spherical diapirs.

4. IMPACT OF MUD VOLCANOES

4.1. Contributions to Human Exploration

Mud volcanoes aid human exploration. They are a powerful tool for geologists, biologists, and cosmic historians. They play an effective role in promoting the course of human exploration.

- Geological studies: Mud volcanoes provide valuable insights into the geological processes that take place deep beneath the Earth's surface. By studying mud volcanoes, scientists can better understand the formation and movement of subsurface fluids, the nature of tectonic activity in specific regions, and the composition and properties of the crust and mantle.

- Energy exploration: Mud volcanoes can be used as an indicator of the presence of hydrocarbons such as natural gas and oil, which are often associated with the formation of mud volcanoes. By studying mud volcanoes, geologists can identify potential sites for energy exploration and extraction.

- Environmental monitoring: Mud volcanoes can release large amounts of methane and other gases into the atmosphere, contributing to climate change. Monitoring and studying mud volcanoes can help scientists better understand the environmental impact of these emissions and develop strategies to mitigate their effects.

- Hazard assessment: Mud volcanoes can cause significant harm to nearby populations and infrastructure. By studying mud volcanoes, scientists can assess the risk of eruptions and other hazards and develop strategies to minimize the impact of mud volcano activity on human communities.

- Planetary Science: Mud volcanoes have also been found on other planets in the solar system, including Mars and Titan. By studying Earth's mud volcanoes, scientists can better understand the processes that shaped the solar system and other planetary bodies.

4.2. Environmental Impact

Mud volcanoes can create unique habitats for a variety of plant and animal species, including some rare or endangered species. The mineral-rich mud spewed by mud volcanoes can also enrich the soil of the surrounding area, providing nutrients for plants and other living things. This could have important implications for the evolution of life on Earth. In addition to this, mud volcanoes can create unique habitats for a variety of plant and animal species, including some rare or endangered species. However, mud volcanoes emit harmful gases including methane and hydrogen sulfide, which can be harmful to humans and other living organisms at high concentrations. Mud volcanoes can cause erosion and land instability in some areas, especially on steep slopes or in areas with unstable geological structures. Mud volcanoes can also have a significant impact on human activity, especially when they are located near populated areas or infrastructure. Mudslides can damage buildings, roads, and other structures, and cause problems for agriculture and other land use activities.

4.3. Hazards to Human Activities

Mud volcano eruptions may pose a threat to nearby populations and infrastructure, especially when they occur in urban areas or near major transportation routes. Volcanic eruptions can cause serious damage to buildings and other structures and create dangerous conditions on roads and highways.

5. CASE STUDIES

5.1. Mud Volcanoes in Azerbaijan

Azerbaijan is known for its abundance of mud volcanoes, with more than 400 located throughout the country. Some of the most famous mud volcanoes in Azerbaijan include Yanardagh, Gobustan, and Dashgil. Yanardag, also known as the Burning Mountain, is one of the most famous mud volcanoes in Azerbaijan. It is located on the Absheron peninsula near the capital Baku and has been burning for centuries. The flames were caused by the igniting of natural gas that had seeped into the ground. Gobustan is another popular mud volcano site in Azerbaijan. Located about 60 kilometers southwest of Baku, it is home to numerous mud volcanoes as well as prehistoric rock art dating back to the Upper Paleolithic Period. Dashgil is another famous mud volcano site in Azerbaijan, located near the Caspian Sea. It is home to several large mud volcanoes as well as hot springs and mineral deposits.

The high concentration of mud volcanoes in Azerbaijan is due to the country's location on the border between the Eurasian plate and the Arabian Plate. The collision between these two plates created an area of intense tectonic activity that led to the formation of mud volcanoes and other geological features in the area. The unique geological environment of Azerbaijan plays an important role in the formation of mud volcanoes in the country.

Figure 7. Geographical location of Azerbaijan

The formation of mud volcanoes in Azerbaijan has several geographical features including:

- Tectonic activity: Azerbaijan lies at the intersection of several tectonic plates, including the Eurasian plate, the Arabian Plate, and the Anatolian Plate. The collision of these plates creates a complex system of faults and folds in the earth's crust, allowing fluids and gases to migrate upward and form mud volcanoes.

- Sedimentary basins: Azerbaijan is home to several large sedimentary basins, including the Caspian Basin and the Kura Basin. These basins are filled with sedimentary rock formations, including shale, sandstone, and limestone, rich in organic matter. The heating and compression of these rocks creates fluids and gases that contribute to the formation of mud volcanoes.

- Abundant water resources: Azerbaijan has a humid climate with plenty of rainfall and several large rivers. The presence of water helps lubricate faults and fissures in the earth's crust, making it easier for fluids and gases to migrate upward and form mud volcanoes.
- Hydrocarbon reserves: Azerbaijan has large reserves of oil and gas which are produced from deep underground reservoirs. The exploitation of these resources can create an imbalance in underground pressure which can lead to the formation of mud volcanoes.

Overall, the complex interaction of tectonic activity, sedimentary geology, water resources, and hydrocarbon reserves in Azerbaijan creates ideal conditions for the formation of mud volcanoes.

Figure 8. Mud volcano in Azerbaijan

5.2. Mud Volcanoes in California, USA

A mud volcano in Imperial County, California, was discovered in 1953 and after decades of immobility, it began to move in 2018. Geologists named the mud volcano "Slow One." It moved 18 meters in one day. Not far away are railroads, fiber optic lines, and oil pipelines, and Slow One is moving toward the tracks. As Slow One moves, it releases gas, water, and mud. Authorities dug a deep well near "Slow One" to vent the mud volcano and pump water on the other hand. Unexpectedly, there was too much water and pressure inside Slow One for the well to do anything. In addition, a 30-meter-long, 22-meter-deep wall made of boulders and steel bars was built to hold back the mud

volcano, but to no avail. In the future, “Slow One” may continue to move toward the county seat of Imperial County.

Figure 9. Location diagram of "Slow One"

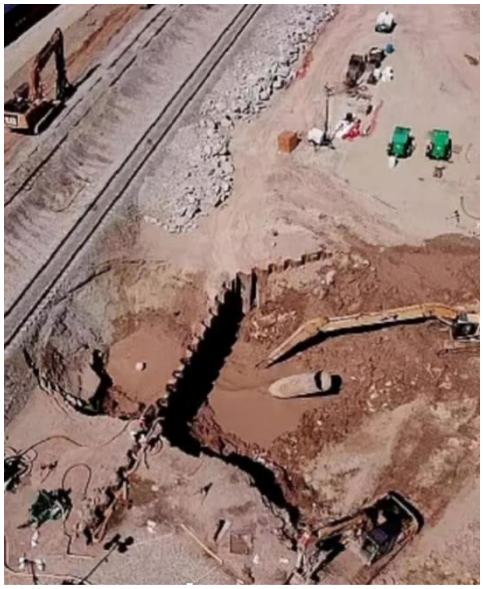

Figure 10. "Slow One"

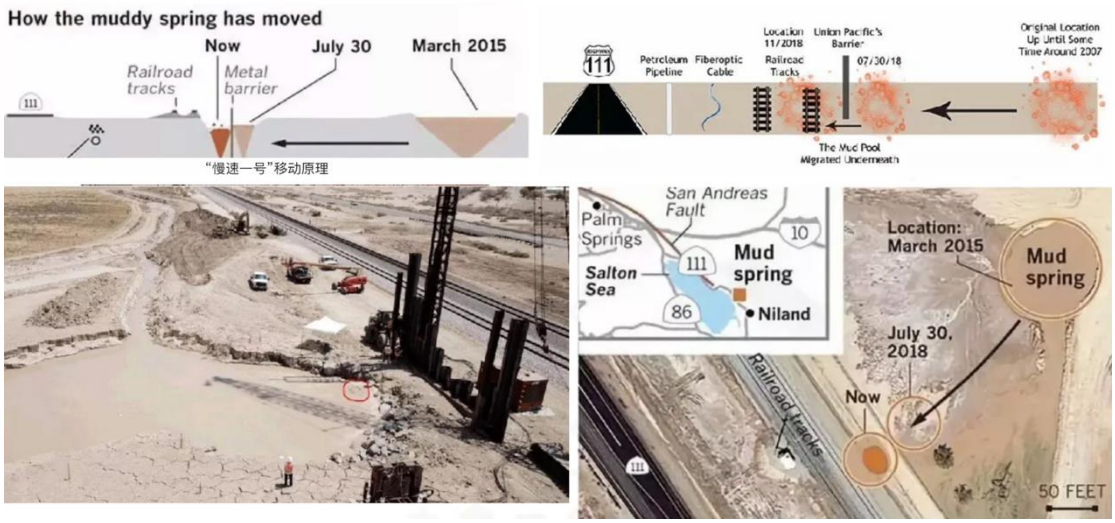

Figure 11. Moving mode of "Slow One"

As you can see, Slow One is like a time bomb, so how do we disarm this bomb?

First, important infrastructure such as cables and wires can be moved to areas that the "Slow One" cannot flow through or underground cables can be replaced on the ground. Secondly, Slow One is connected to the Salton Sea which is cooled by seawater and can accommodate mud materials. Finally, a bridge is built on the highway near the mud volcano to ensure that the bridge piers are far away from the movement area of the mud volcano to ensure traffic. As a reader, you can also think of other ways to solve this problem.

6. CONCLUSION

6.1. Summary of Key Points

Mud volcanoes offer valuable insights into geological processes and pose both opportunities and challenges. Their study is crucial for various fields, including geology, energy exploration, and environmental science. Mud volcanoes aid in geological studies, energy exploration, environmental monitoring, hazard assessment, and planetary science. They create unique habitats and have significant impacts on human activities and the environment.

6.2. Future Research Directions

Future research should focus on understanding the detailed structure of mud volcano systems, mitigating environmental impacts, and exploring the potential for using mud volcanoes in energy exploration and planetary science.

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