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Environmental impact and sedimentary structures of mud volcanoes in southeast of the Caspian Sea basin, Golestan Province, Iran

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ABSTRACT

Mud volcanoes are defined as main elements of geological structures and ways through and within which buried argillaceous loose sediments and lithified rocks. The Gharniaregh Tappeh and Naftelijeh mud volcanoes are the most attractive geomorphological phenomena in continental which appear along the eastern coast of the Caspian Sea. The Naftelijeh mud volcano is more active than Gharniaregh–Tappeh, while the latter is saltier than the former, indicating its proximity to salt domes. The ejected materials from these mud volcanoes are often comprised slurry of fine solids silt and clay suspended in liquids, which may include water (frequently acidic or salty) and hydrocarbon fluids. The most part of the gases released are methane. Carbon dioxide and nitrogen are also emitted but in much lesser quantities. The complicated morphology of the volcanoes can be rough terrain, cone-shaped and buildings mentioned columnar shape. The morphology of the effects can be uneven terrain such as hills and buildings used in the column. Emissions caused significant environmental impact, including the loss of plants and vegetation destruction is quite evident in the region. Like all other natural phenomena, mud volcanism phenomenon can affect the environment both positively and negatively, which is discussed here. Catastrophic reduction of Paleo - Caspian size combined with the increasing scale of mud volcanic activity caused the oversaturation and intoxication of water by methane leading to the mass extinction of mollusks, fishes and other groups of sea inhabitants.

Key words: Caspian, Geomorphology, Gharniaregh Tappeh, Mud Volcanoes, Naftelijeh

INTRODUCTION

Mud volcanoes are geological structures formed as a result of the infiltration of clay materials to the earth's surface or seafloor. Sufficient water and gas are combined, making clay materials half-liquid and also pushing them up through the fractures of the crust for the outflow of muddy mass to the surface (Dimitrov, 2002). With the monitoring of place of volcanoes and using satellite data can be used to predict the new position possible mud volcanoe. There are many global studies of mud volcanoes that reveal aspects of their origin, mechanism of formation and paleo-activity (Fig. 1). The most widely used name for this natural phenomenon nowadays is "mud volcano". Furthermore, where they vary in size, the larger types are known as mud volcanoes, and the smaller mud cones. The term "salse" is applied to even smaller varieties than "cones", and they usually emit only argillaceous material without solid blocks. Still smaller occurrences are often designated, diminutive expressions such as " mini-volcano", "mini-salse," and finally "mini-gryphon" or simply "gas vent" (Guliyiev & Feizullayev, 1997; Jennerjahn, *et al.,* 2013). The South Caspian Basin (SCB) is giant oil and oil-gas-condensate fields and hydrocarbon appearances in the form of mud volcanoes are widely distributed here. In fact, mud volcanoes accompany all oil-gas fields in the area. From about 900 onshore mud volcanoes known on the Earth about one fourth are

within the western and eastern flanks of the SCB and more than 160 mud volcanoes are on the South Caspian sea bottom. The sources of the mud volcanoes are located at significant depths and are the natural channels of the matter redeployment in the sedimentary basin (Huseynov & Guliyev, 2004; Huseynov, 2004). Submarine release of waters from mud volcanoes and ejection of various components are crucial in the saline balance of marine and bottom sediment water. So, the annual release of salts into the sea increases average salinity of marine waters. Gases of the mud volcanoes have a hydrocarbon composition and consist mainly of methane, a small admixture of ethane, propane, butane, pentane and other non-hydrocarbon gases, such as CO_2, N, H_2S, Ar and He (Huseynov & Guliyev, 2004).

Petrography studies of rock-ejects show that the ''roots'' of the majority of the mud volcanoes of the SCB are related to the Cretaceous and Paleogene-Miocene deposits. Most mud volcanoes are located in the coastal areas of the Caspian Sea and Golestan Province. Mud volcanoes are an important source of information about subsurface sediments and conditions. Mud volcanoes differ from magmatic volcanoes on activity area astonish by their beauty, but their direct connection with oil and gas system attracts the greatest attention for study (Guliyev & Feizullayev, 1997). Those ones also exist on the floor of the sea and can form islands and banks that alter the topography and shape of the coastline and even trigger earthquakes. Mud volcanoes appear in various geological environments: On the active continental margins, inactive continental shelf and open seas. In this study, we map the location of the mud volcanoes and characterize them according to their height, shape and relation to sedimentary structures and biological effects. This study provides a description of offshore mud volcanoes in the Caspian Sea for the development of environmental research. The South Caspian Basin provides a unique possibility to study mud volcanism and fluid flow in an active pierced basin. Over 400 active mud volcanoes are present in this region, both on-shore and off-shore (Planke *et al.,* 2003). More mud volcano in this area located from offshore, because of the large of volume sedimentary deposits concentrated South Caspian basin. The erupted solid material is present as fall or flow deposits. Breccia flows are commonly emplaced during mud volcanic eruptions. These flows consist of angular boulders and clasts derived from the country rocks that are cut by the plumbing system, being embedded in a mud-dominated matrix.

MATERIALS AND METHODS

Observation was performed at two mud volcanoes, Gharniaregh Tappeh and Naftelijeh during October 2012. Comprehensive plotting of the two mud volcanoes was done using a Garmin etrex GPS with a relative accuracy of four meters (Fig. 2). Water samples were collected from the volcanoes. Temper- atures were measured in-situ with a thermocouple thermometer. Mud and water were separated from each other by settling, filtered and analyzed at the School of Earth Sciences, University of Tehran.

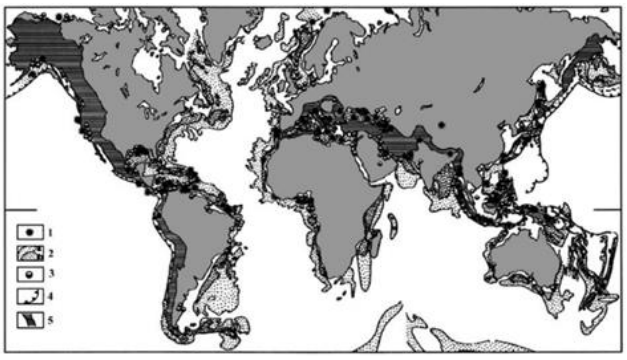


Fig 1. Global distribution of mud volcanoes (modified from Milkov, 2000).

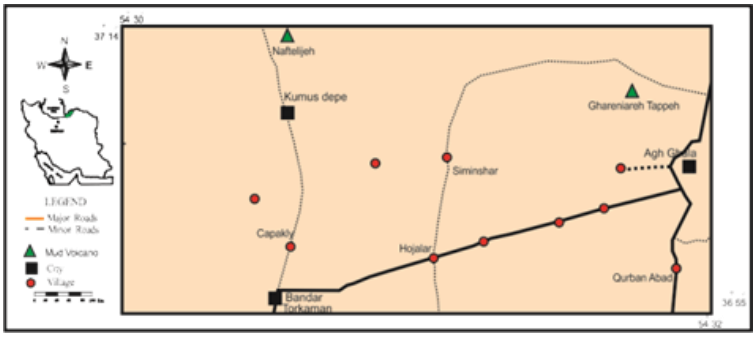


Fig 2. Position of Gharniaregh Tappeh and Naftelijeh mud volcanoes on the southeast of Caspian Sea coast.

Geologic setting of the South Caspian basin

Gharniaregh-Tappeh and Naftelijeh are located in Tertiary sequences of the coastal region. The geomorphology and degree of erosion at Gharniaregh-Tappeh and Naftelijeh suggest that it is older than the other mud volcanoes in the Province. Morphology of mud volcanoes also depends on the special weight of outflowing materials or mud and their eruption or jump sequence (Negaresh, 2004). The mud volcanoes in the world are of two types, hot and cold. The hot mud volcanoes are associated with the igneous volcanoes and the temperature of the extruded water and mud vary from 70° to 90°C, much higher than the ambient temperature (Negaresh, 2008). Cold mud volcanoes are sedimentary-tectonic in origin and are entirely unconnected with the igneous activity with water and mud at the same or lower than ambient temperature. These eruptions are associated with seismic activity, fracture formation, ground deformation, and emplacement of mud breccia flows. There are many of the sub-sea mud volcanoes in the Caspian Sea, which mainly formed at the depth of 10 to 800 meters and are eroded by waves and seabed currents (Yazdi, 2013).

It seems that the origin of mud volcanoes in the Southeast Caspian Sea (Higgins & Saunders, 1973) is tectonic-sedimentary and are formed by the subduction of oceanic crust of the under deposits continental. The number of spatial distribution mud volcanoes in the Southeast Caspian Sea is normal on a grand scale. As a result of continuing subduction an increased thickness of the Cheleken, Aghchagy l and Apsheron formation and Quaternary series in the South Caspian Sea. These formations mainly are calcareous, marl, clay and sand and consist of gastropod fossils Overlaying on each other conformity there are more mud volcanoes in southwest and southeast of the Caspian Sea.

Geology and geomorphology of the gharniaregh-tappeh and naftelijeh region

We use a morphological classification of the mud volcanoes, considering as characteristic the following features: (i) mud cone (ii) mud pool and (iii) mud lobe (Fig. 3).

The morphology on the Caspian Sea is cone and pool form, but on Oman Sea Coasts mud volcanoes are cone, lobe and pool form. Most of the mud volcanoes possess one or more mud cones which rise several meters high above the ground. Accordingly, several visits were made on Gharniaregh- Tappeh and Naftelijeh mud volcanos, to study their geomorphology and to collect water and mud samples.

From among materials forming diapirs, one can refer to sands, silt, and types of clay, in some cases rubble, clasts, abundant water, and hydrocarbon gases. The color of the mud exiting from Gharniaregh-Tappeh and Naftelijeh volcanoes are gray.

Gharniaregh Tappeh mud volcano

The geographical location of Gharniaregh Tappeh recorded using a GPS is 54° 23′ 50″ E and 37° 0′ 03″ N.

This mud volcano is located 15 kilometers northwest of Agh-Ghala (Fig. 1). It is

externally 700 meters in diameter and has a cavity inside roughly 5 to 10 meters deep (Figs. 4 and B). The Gharniaregh Tappeh described here is of the cold, sedimentary-tectonic type mud volcano. In this mud volcano there are actually two internal craters filled with water in between. The activity of this mud volcano in the Quaternary period focused from second vent and mainly muddy water form, and cementation of sediment in this period are very loose and porous sediments. Sometimes during eruptions, angular blocks of rock of various ages and sometimes reaching several centimeters in diameter and shell fragments may also be expelled (Figs. 5 A and B) and multistage of erupting outflow in the center of the crater of mud volcano (Fig. 5C).

Around the internal vent and surface, many grooves were created by erosion, which exhibit tracks alternating layers of salt, clay and silt (Fig. 5D). Sedimentary structures such as mud ball created by fast erosion on grooves in inter mud volcano (Figs. 5E and F).

The seismic study close to mud volcano of Gharniaregh Tappeh shows a hidden diapir, associated with a fault. At the vertical cross-sections C-C′ appear the new mud volcano and the cross-section C-C′ passes through both mud volcanos. For further determining, their lengths have been drawn as blue dotted lines in vertical cross-sections and the faults also are shown as black dotted lines (Fig. 6). It is completely clear that the new mud volcano has not reached the surface and the Gharniaregh Tappeh mud volcano has penetrated into the ground. Furthermore, these two mud volcanos are connected beneath the ground (Rezvandehy, 2006; Rezvandehy *et al.*, 2011). Source of the fluidized clayey mass does not lie below 3 - 4 km (Feyzullayev, 2012).

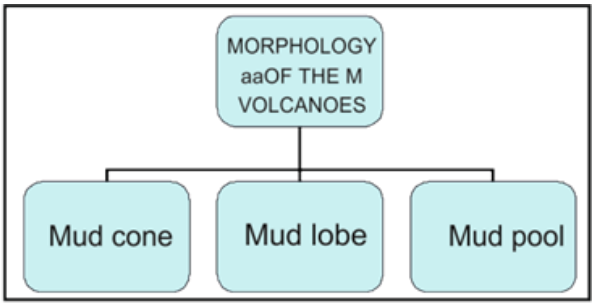
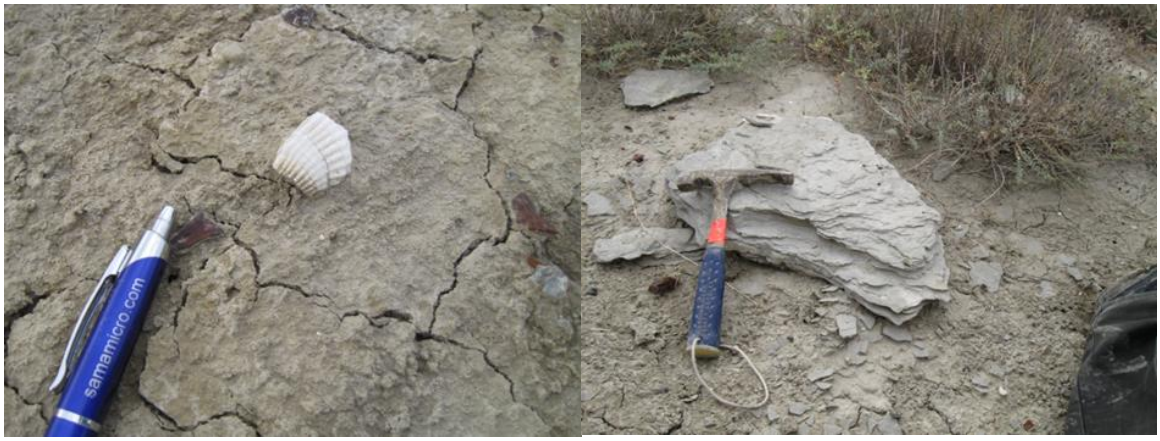


Fig. 3. Morphological features of the mud volcanoes on the Caspian Sea and Oman Sea Coast.

A B

Fig. 4. A and B, Gharniaregh Tappeh mud volcano has a conical hill at the center of this hole and there is also another desolated hole at its top.



A B

C D

E **F**

Fig. 5. A, B, C, D, E and F: A and B: some shell fragments and block of rocks thrown away by the volcano during eruption; C: multistage of outflow of mud in center of crater; D: Mud ball sedimentary structures due to fast erosion on grooves; E and F: surface created many grooves by erosion.

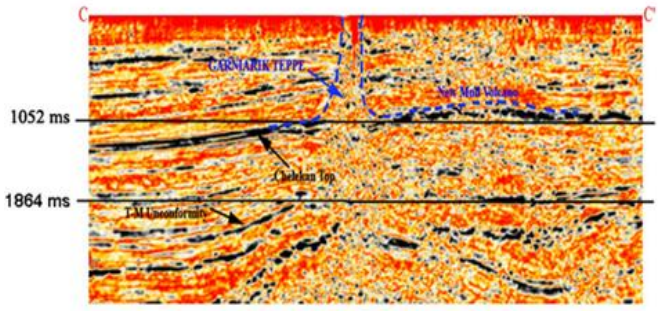


Fig 6. This figure vertical C-C′ cross-sections illustrates (the time line 1052 ms) the topography of the layers in Chelekan construction (modified by Rezvandehy *et al*., 2011).

Naftelijeh mud volcano

This mud volcano is located 15 kilometers from the northeast of Gomishan (Fig. 2) and recorded at 54° 23′ 50″ E and 37° 0′ 03″ N. It is 4 meters higher than the surrounding land, being 160 meters in diameter. Its crater is nearly 10 meters in diameter. Outflow mud of this mud volcano is flowing and gas bubbles exist in it. Around crater, mudcracks are visible (Fig. 7A). The observe of cyanobacteria lamination and horizon of redux in lobe of mudcracks are evident (Fig. 7B). It is surrounded by salt water with traces of petroleum substances. Due to the salty soil, scarce or anomalous vegetation occurs nearby the surrounding land. Halophyte plants grow on the margin of the mud volcano crater. The Naftelijeh mud volcano described here is of the cold, sedimentary-tectonic type.

Mechanisms of formation of mud volcanos

At a certain depth, where intense gas-generation (mainly methane) takes place due to the decomposition of buried organic matter, the instability of the system becomes yet more pronounced and reaches to a critical condition. With a sufficient density contrast between the overlying and underlying deposits, and with the interaction of tectonic processes, the overlying deposits may lose their integrity and the underlying argillaceous sequence may be forced upwards, resulting in the creation of a piercement structure (clay diapir) or a mud volcano (Guliyiev & Feizullayev, 1997). Mud volcanoes form either as clay diapirs that reach and pierce the ground-surface or as fluidized argillaceous sediments, along with structural weaknesses (conduits) within subsurface sediments/rocks (Fig. 7) (Milkov, 2000). Major factors causing formation of mud volcanos in

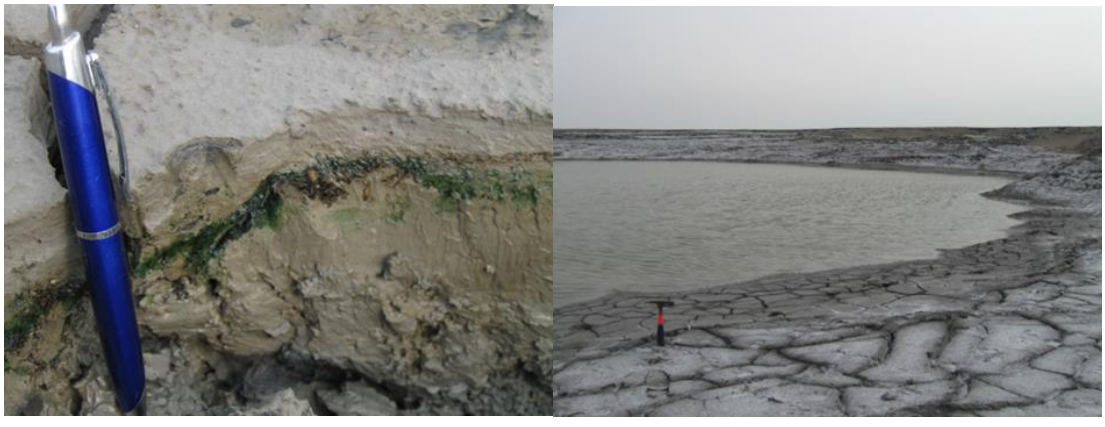
the South Caspian basin are Pliocene-Quaternary high sedimentation rates, super thick sedimentary cover and predominance of clayey rocks, low temperatures. It is suggested that mud volcanoes are formed by two basic mechanisms. The first mechanism is the formation of a mud volcano directly on top of a seafloor/surface-piercing shale diapir as a consequence of fluid migration along the body of the diapir. If the fluids do not migrate along the diapir, a mud volcano would not be formed and only a seafloor/surface- piercing shale diapir would occur. A mud volcano may or may not eventually develop on top of such a diaper (Fig. 8B). The second and maybe most common mechanism is the foundation of a mud volcano as a result of the rise of fluidized mud along faults and fractures. In this case, sediments with a high fluid content reach the seafloor and form a mud volcanic structure. This mud volcano may be connected to shale diapirs located at some depth below the seafloor.

However the most of mud volcano are B, D and C in Fig. 8. In general, the source of mud does not exceed 3 - 4 km (Feyzullayev, 2012). Depths where the liquid, gaseous and solid products of mud volcanoes are obtained appear to be different.

The gases have the deepest roots (7 - 15 km) which are the main force information and activity of mud volcanoes (Feyzullayev, 2012).

Composition and main elements of sludge and waters out of mud volcanoes

More than 100 mineral associated with mud volcanism have been described, the majority of which are derived from the reworked rocks erupted from mud volcanoes. Minerals of mud volcanic origin reflect the complex multi-stage physico-chemical processes which take place as the volcanic waters and gases interact with the surrounding lithological succession penetrated by the mud volcano (Guliyiev & Feizullayev, 1997). About 90 minerals (most of illite and chlorite clay minerals) and more than 30 trace elements are present in mud-volcanic breccia. Solid ejected include oil-saturated terrigenous and carbonate rocks.The mineral composition of the two mud volcanoes is different from each other. Activity of Naftelijeh mud volcano is higher and sludge out of mud volcanoe has a brightly colored, while younger sediments have dark color due to the presence of water. The mineralogical analysis, X-ray powder diffraction (XRD) on bulk samples and <20 and < 2 µm fractions, has been undertaken in order to identify the constituent minerals of the sediments. On the basis of the results of the bulk mineralogical and its variability, a group of samples was selected in order to determine clay mineralogy. Suspensions of <20 and <2 µm fractions were separated by centrifuge. Oriented aggregates of <20 and <2 µm sizes over glass slides were analyzed by means of XRD on airdried, glycolated and heated samples (Moore & Reynolds, 1997; Martín-Puertas, *et al.,* 2007). The clay mineralogy of the <20 and <2 µm fractions of all the samples is characterised by illite, chlorite, kaolinite and smectite. The most abundant clay mineral at mud volcanoes is smectite and illite. In Table 1, the mineralogy of the bulk samples and the clay fraction can be seen. The major element composition of the expelled waters is controlled by the depositional environment (marine/non-marine, presence of evaporites), diagenetic processes (Carpenter & Miller 1969; Hanor 1994; Worden 1996), temperature and mixing. Elements like Cl, Br, I, and B may give important information both about fluid source, depth, and fluid–rock interactions (Kopf & Deyhle, 2002 ; Planke, *et al*., 2003). Mud volcanoes elemental composition is varied. This situation can be seen in the south of the Caspian Sea. The elemental composition of these two mud volcanoes shown in Table 2. As shown in this Table, Na^+ and Cl^- are dominant ions, elements, and this is due to the initial deposition from marine origin.



A B

Fig 7. A& B. Naftelijeh mud volcano:(A) ceynobactery lamination and horizon of redux in lobe of mudcracks and (B) a crater mudcracks .

Table. 1. XRD mineralogy of samples from Gharniaregh –Tappeh and Naftelijeh mud volcanoes.

	CM (clay minerals)	**Qz+Fd quartz and feldspars**	**Do (dolomite)**	**Ca (calcite)**
Gharniaregh – Tappeh	Smectite, illite, chlorite, kaolinite	quartz and feldspars	dolomite	calcite
Naftelijeh	Smectite, illite,	-	dolomite	calcite

Table 2. The water properties of Naftelijeh and Gharniaregh –Tappeh mud volcanoes (all values in ppm).

Elements	**Water sample No.1**	**water sample No.2**	**water sample No.3**	**water sample No.4**
Na	2250	2198	1911	1893
Ca	35	31	34	35
Mg	123	117	133	139
Li	2.2	2.0	1.6	1.5
K	75	71	55	51
Pb	0.013	0.015	0.009	0.011
Fe	0.17	0.26	2.8	2.6
I	<5	<5	<5	<5
Cl	159	163	148	142
Br	28	39	29	33
Zn	0.005	0.007	0.004	0.004

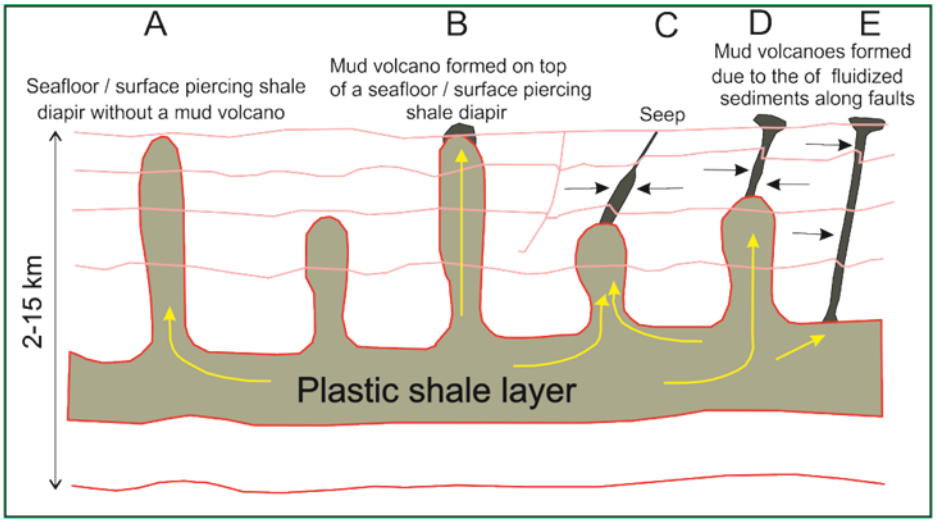


Fig 8. Basic mud volcano formation. A) Clay diaper, B) seafloor-piercing clay diapir - a mud volcano. C) Sea floor seepage. D, E) mud volcanoes formed due to rise of fluidized sediments along faults (adopted from Milkov, 2000).

Effects of biological parameters on mud volcano

Outflow materials from the mud volcanoes, including clay and silt and large amounts of methane and carbon dioxide created serious damage on regional ecosystem. The compositions of the gases emitted by mud volcanoes vary from region to region. However, most are dominated by methane, which generally accounts for over 85% of the total gas composition (Table 3). (Judd, 2005). Dimitrov (2002b) noted that in some petroleum-rich provinces, such as the Southern Caspian Basin, higher hydrocarbon gases are present. The most common gas, other than methane, is usually carbon dioxide. Nitrogen and hydrogen sulphide may be present in significant concentrations, but most often they are trace gases (Table 4).

Destruction of plants and aquatic ecosystems by mud volcanoes are negative impacts as environmentally. Excessive of carbon dioxide in place disturbs the food chain can also affect greenhouse gases. Mud volcanoes can cause both positive and negative effects on people and the environment.

Eruptions of mud volcanoes often associated with flames (Aliyev et al., 2002) represent an apparent geohazard for surrounding life forms and constructions. From the perspective of the petroleum industry, mud volcanoes are a major geohazard. The mud volcanoes are composed of relatively unconsolidated sediments, they produce numerous mud flows and may erupt, and they may host gas hydrates. These characteristics may lead to major slope instabilities.

Benefits of mud volcanoes

Mud volcanoes are used widely for medicinal purposes including treatment of arthritis and rheumatism, Geo-sites and exploration of hydrocarbon resources. Chemically, volcanic mud is composed primarily of silica. In addition, the mud has been found to contain quantities of curative properties (iodine, bromine, calcium, magnesium, organic acids and aromatic hydrocarbons - to name just a few). As the mud solution has no significant toxic substances, it has been recommended as a curative agent for mud baths .A) There is one other feature of mud volcanoes which is of great interest to researchers. This is their direct relationship with oil and gas fields. Mud volcanoes resemble super-deep exploration wells, providing valuable information on the formation and migration of oil and gas. Exploration of hydrocarbon reservoirs, mud volcanoes are interconnected with oil and gas, hydrocarbon reservoirs thus a sign of the

presence of oil. B) According to studies on elements in the mineral waters of mud volcano which is located in the Alpine folded belt has been shown that the high ranks of the elements such as iodine, sodium, calcium and bicarbonate. Some animals, such as elephants wallow in the mud out of the mud volcano and lick like dried mud. To lick the lack of elements such as sodium, calcium, iodine and other trace minerals your body needs can provide. C) The mud therapy is a bath of mud, commonly from mud volcano areas used in mud for improving skin diseases and muscular looks to ancient times. Rubbing the mud on skin or mud bath, is the most common mud therapy. D) Tourism development: mud volcanoes have beautiful scenery which can be interesting for tourists. E) Industrial applications of mud, from this mud can be used in pottery and ceramics industries of the characteristics of high temperature endurance, strength, etc. for the building as well as raw materials.

Damages and losses of mud volcanoes

Mud volcanoes materials include water, clay, silt and gases such as methane, hydrocarbon derivatives, carbonic dioxide and dioxide sulfide. The sea level changes may have less effect on the mud volcanoes activity in the Caspian Sea area during the period of our life. Flowing of these materials in some parts of the world increased greenhouse gases, destruction of vegetation, aquatic ecosystem change, the loss of life and finances . Fortunately mud volcanoes occur away from populated centers and do not usually result in disastrous consequences. However, cases have been known where they have caused serious damage and loss of life. Unfortunately in deep marine environments, there is no way to reduce the risks of mud volcano . A) The destruction of vegetation: some of the mud volcanoes which are magmatic in origin are very rich in CO_2 emissions. Leaving these muds and covering by plants at various points are the cause of the loss of vegetation. B) The financial damage and loss of life, mud volcanoes are generally fatality, because the muds are mostly extracted from them to the extent that can be harmful to human societies. But with the influx of mud on farms, agricultural land and the fish and shrimp ponds can be a lot of damage.C) Methane mud volcanoes role in global climate change; methane is an important greenhouse gas. Oils emitted by mud volcanoes are the product of destruction of petroleum accumulations occurring beneath them Feyzullayev, 2012).

DISCUSSION

Mud volcanoes are not always volcanic in origin, but can be seen in the oil-rich regions, such as mud volcanoes in the South Caspian Sea. These occur both onshore and offshore, usually in areas having a high sedimentation rate, lateral tectonic compression and their combination. The Naftelijeh mud volcano is active than Gharniaregh–Tappeh, while –the latter is saltier than the former. The majority of the mud volcanoes are associated with the petroleum bearing structures.Volcanic activity has not greatly influenced reservoir pressure and oil production. More or less geologists believe that the thickness of clay sediment layers has fast sedimentation and water can not find opportunity to exit, resulted in more fluid state. In this case, high pressure water in silt- and clay-sized particles push gas and sediments upwards due to tectonic forces in the region. This area has high recent geodynamic activity: horizontal and vertical movements of Earth crust and shallow seismicity due to very rapid Pliocene-Quaternary subsidence and sedimentation rate within the South Caspian. The general morphology of the two mud volcanoes is foothills, covered with loess and fluvial sediments (Faslebahar, *et al*., 2009). The main geological peculiarities of the South Caspian basin, some of which are unique from the following points of view (Feyzullayev, 2012): 1) Very rapid Pliocene - Quaternary subsidence and sedimentation rate. Over 80% of these sediments consist of clayey rocks; 2) The thickness of the sedimentary cover (Mesozoic- Cenozoic) is 25 - 30 km and has no analogues in the world; 3) Characteristic of the

split-level structure of the sedimentary section in SCB, including the upper Paleogene-Quarternary complex presented mainly by plastic and decompacted rocks and the lower Mesozoic, consisting of the dense rocks; 4) Displacement of the onset of oil generation on considerable depths (oil to 4 - 5 km, gas to 7 km) (Fig. 9).

Most of sediments compaction changes over a wide range especially within 0 - 2 km, while at the depth of about below 3 km, rate of compaction is minimized and stabilized. This allows concluding that the sediments and, especially clays, undergo the greatest compaction (up to 60% - 70% of the initial volume) in the interval of 0 - 4 km depths during the subsidence of any basin. It means that clays reaching the depth of 3 - 4 km lose the large part of sediment waters. The loss of waters by the clay leads to decreasing amount of its plasticity and mobility, so the focus of the clayey diapir formation, most probably, occurs at the depth not lower than 4 km.

Bulk of clayey breccia erupted by the mud volcano is predominantly connected with this interval of depths.

Table 3. The chemical formulas of most of the greenhouse and the share of gas in global warming.

Methane	CO_2	Nitrogen	Higher Hydrocarbons
85.5%	9.5%	4.5%	0.5%

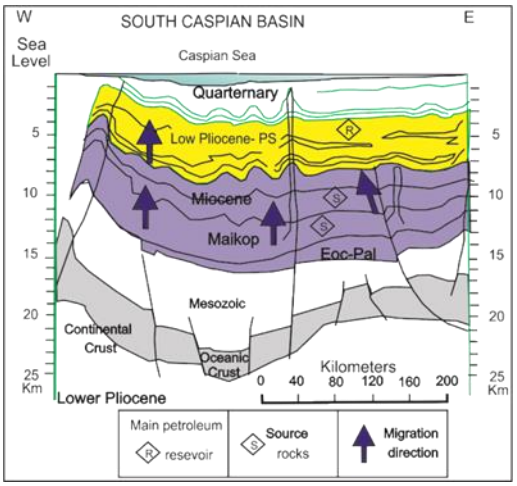


Fig 9. Regional geological profile along the Caspian Sea and location in the sedimentary (modified from Feyzullayev, 2012).

Table 4. An average composition chemical formula of the gases emitted by mud volcanoes (Judd, 2005).

Compound	Formula	Contribution (%)
Water vapor and clouds	H_2O	36–72%
Carbon dioxide	CO_2	9–26%
Methane	CH_4	4–9%
Ozone	O_3	3–7%

CONCLUSION

The expelled materials act as a tectonic window of underlying strata and the nature of both components, clasts and matrix, providing important information about the deeper units, when comparing with the regional geology. The mud volcanoes are reflected absolutely to be geomorphologic and show most beautiful and spectacular scenes.

Mud volcanoes are geological structures formed as a result of the giving out of argillaceous material on the earth surface or the sea beds. The gas released through mud volcanoes shows that they are one of the significant natural sources of atmospheric methane both in the calm and eruptive stages of development mud volcanoes.

However when submarine volcanic eruption occurs, the influence of mud volcanoes on the Caspian Sea ecology is very bad.

Noteworthy, during the spring eruption occurs of 2001 in the Caspian Sea the death of a huge mass of anchovy and macro-eyed sprats, which live at a depth of 50–100 m and more in an open deep part of the Sea, was observed (Katunin *et al*., 2002).

This large scale phenomenon during the period of the migration of sprats had no analogues in the last life of the Caspian Sea and has caused significant damage to industrial fishing (Huseynov & Guliyev, 2004).

The Caspian Sea, being an inland closed basin is very sensitive to climatic and tectonic events expressed in sea level fluctuations.

In regressive stages as a result of sea level fall and reduction of hydrostatic pressure the decomposition of gas hydrates and the releasing of great volumes of HC gases consisting mainly of methane are observed. Consequently, the dramatic sea level fall in the Lower Pliocene could provoke destabilization of gas hydrates and massive release of hydrocarbon gases to the water column that brought strong intoxication to marine water also (Huseynov & Guliyev, 2004).

Most important reasons triggering formation of diapirism / mud volcanism in the South Caspian basin are Pliocene-Quaternary high sedimentation rates and a good indicator of tectonic stress. Investigating the mud volcanoes from the Southeastern Caspian Sea, suggested a classification based on morphology, as follows: mud pool, mud cone, mud dome and mud caldera. Usually, the mud volcanoes eject several products, such as gas, mud, water, rock fragments and oil, but in these two mud volcanoes, most mud is ejected to the surface.

The mud volcanoes create a strange lunar landscape, due to the absence of vegetation around the cones. Vegetation is scarce because the soil is very salty, an environmental condition in which few plants can survive. However, this kind of environment is good for some rare species of plants.

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اثرات زیست محیطی و ساختمانهای‌های رسوبی گلفشان‌ها در حوضه جنوب شرقی دریای خزر، استان گلستان، ایران

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چکیده

گل فشان ها از عوارض ژئومورفولوژی و ساختارهای زمین شناسی است که توسط مجرائی با رسوبات مدفون رسی سست و سنگ‌های سخت شده در ارتباط است. گل فشان‌های قارنیارق تپه و نفتلیجه، از فعال ترین پدیده‌های ژئومورفولوژی درون قاره‌ای است که در امتداد ساحل شرقی دریای خزر مشاهده می‌شود. میزان فعالیت گلفشان نفتلیجه در مقایسه با گلفشان قارنیارق تپه بیشتر می‌باشد، و میزان شوری رسوبات آن در مقایسه با قارنیارق تپه کمتر است و این امر ناشی از نزدیکی آن به گنبدهای نمکی مدفون در منطقه می‌باشد. مواد خروجی این گل فشان‌ها اغلب دوغابی از ذرات جامد ریز در حد سیلت و رس معلق در مایعات است. بیشترین درصد گاز منتشر شده این دو گلفشان متان می‌باشد و مقادیر گازهای دی اکسید کربن و نیتروژن در در مرتبه کمتری قرار دارد. مورفولوژی گل فشان‌ها اغلب به شکل زمین‌های ناهموار مخروطی شکل و ساختمان ستونی شکل می‌باشد.گلفشان‌ها نیز مانند تمام پدیده‌های طبیعی، دارای اثرات مثبت و منفی زیست محیطی است که در این مطالعه مورد بحث قرار گرفته است. انتشار و گسترش مواد جامد و گازها توسط گلفشان ها تاثیرات زیست محیطی، از جمله از دست رفتن گیاهان و تخریب پوشش گیاهی را در منطقه سبب شده است. فعالیت‌های گسترده گلفشان‌های کف دریای خزر در گذشته و در حال حاضر باعث افزایش و فوق اشباع شدن آب از متان و این امر سبب مسمومیت آب در کف شده است. نتیجه این فعالیت منجر به انقراض دسته جمعی و کاهش سایر گروه‌های زیستی دریا در گذشته شده است.

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