Preliminary report on the birth of newly emerged Island and the nearby Chandragupta Mud Volcano, District Lasbella, Balochistan, Pakistan

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1.: Introduction

On the night between the 16 and 17th November 2010, an amazing phenomenon occurred offshore in the Arabian Sea near Hungol, District Lasbella, Balochistan, Pakistan. On the morning of 17^{th} November the local fishermen noticed that a new Island had appeared in the sea. Curiously enough, some wanted to have a closer look at the newly emerged Island. By doing so some of their boats were caught near the Island, luckily there was no casualty. They named it the “Sapt Island”, after the nearby Sapt village. As soon as we heard the news, we decided to visit the Island in order to investigate its characteristics and geological relationship. We visited the Sapt Island as well as the Chandragupta Mud Volcanoes. The Sapt Island is three kilometers away from the coast, however, due to unavailability of boats it could only be accessed from the locality of Kund Malair, which is about 26 km away, i.e. a three hours boat drive to the Sapt Island. This report presents the characteristics and geological relationships of the newly emerged Sapt Island along with the nearby Chandragupta Mud Volcano on the mentioned date of visit.

1.1: The newly emerged Sapt Island

The newly emerged Sapt Island, covered an area of 300 x 50 m and the highest point on the Island, was about 20 feet above sea level (Fig.1). On the Island we found ten small circular vents from which thick mud slurry was erupting episodically and violently (Fig. 2), along with highly inflammable methane gas, as noticed from its hydrocarbon smell and inflammable character. The Sapt Island comprises irregular mass of mud with numerous fissures and crakes. The mud is light greenish grey to very light grey, which contains very poorly sorted fragments mostly of sandstone ranging in sizes from boulders to cobbles (Fig.3). The sandstone fragments are mostly angular in nature. In some cases thick viscous slurry at the mouth of the vents formed huge mud bubbles, which violently burst in order to forcefully expels hydrocarbon gases. This phenomena sometimes caused to eject the viscous mud several meters high in the air (Fig: 4). We also found some dried-up vents, which may have been active at the early stage of eruption (Fig.5). It seems that the mud slurry had been gradually becoming more viscous so that it caused to choak some of the earlier vents. Videos of the event at early stages show that vents were much more active and the flow was less viscous having higher proportion of water. All these characters indicate that the Sapt Island is a mud volcano and emerged in response to the enhanced activity of the mud volcanism. Mud volcanoes commonly occur onshore as well off shore in the coastal belt of Makran. Some of the onshore mud volcanoes, such as the Chandragupta Mud Volcano, are present very close to the newly emerged Sapt Island.

1.2: What are Mud volcanoes?

Mud volcanoes are expressions of the expulsion of under compacted mud, fluids and gases from the rock formations in areas of high sedimentation rates and compressive tectonics, commonly in convergent margin settings. Mud volcanoes commonly occur onshore and offshore along the coastal belt of Makran. They show moderate variation in activity, which in some cases is concurrent with earthquake activity (Snead 1964, Wiedicke and others 2001, Delisle et al., 2004).

1.3: The onshore Chandragupta Mud Volcano

The Chandragupta Mud Volcano is present near the Hungol area of Makran and is perhaps one of the largest onshore mud volcanoes of the region. A cluster of three mud volcanoes, present adjacent to each other, is present 3.5 Km north of the coast and 16 Km southwest of the newly emerged Sapt Island. We visited all the three vents of the Chandragupta cluster and name them as Chandragupta-1, -2 and -3 (Figs. 6 and 7).

Chandragupta-1: It is a small oval shaped (67x 53 meter) lake-like feature 2.5 m below the ground level, which containes water with minor bubbling of gasses and weak extrusion of water-mud slurry in its centeral part (Fig. 8). Boundaries have curved walls, which are partly eroded and collapsed. The overall area covered by deposits of this mud volcanoe is 1000 x 700 m across, which seems to be the largest and oldest of the cluster. It seems that extrusion of mud has currently decreased, as compared to past periods, which caused to lower the water level within the crater and erosion of its older deposits.

Chandragupta -2: This Mud Volcano is located 15 km from the Coastal Highway (Fig. 9) and 4 km from the coast. It is reported to be the highest in the Makran region. It is circular-shaped with diameter of 20 m, which is filled with viscous and sticky mud-water slurry. The mud bubbles up and sometimes burst violently in order to emanate large amounts of hudrocarbon gasses. This phenomenon has been continuous, alegedly for hundreds of years, sometimes with enhanced proportion of mud. Height of this mud volcano has been gradually increasing with the passage of time, as mud-water slurry continued to overflow from its crater.

Chandragupta -3: This is the third mud volcano of the of Chandragupta cluster, which is adjacent to the Chundargup-2, however, it has dried-up and extinct. Its crater is oval shaped (14 x10 m) and height is 30 m above the ground level (Fig. 10).

2.: The geological set up of Makran:

The Makran region has been interpreted as an accretionary wedge, which stretches from the Kirther Belt of Pakistan in the east to the Straight of Hurmuz, Iran in the west. It developed by the subduction of oceanic crust of the Arabian Plate under the Afghan Block of Eurasian Plate and built up by the sediments scraped off the Arabian Plate. Subduction was probably initiated in Late Cretaceous to Early Paleocene (Platt et al., 1985, 1988) and accretion started about in Paleocene (Byrne et al., 1992). Two features make this accretionary wedge very interesting : 1) that the sediment thickness of the oceanic sediments is extremely high, and 2) the dip angle of subduction is extremely low. The 3000 m deep Oman Abyssal Plain is part of the Arabian Plate and is bounded in the north by the Makran subduction zone and accretionary prism. To the east the abyssal plain narrows due to convergence of the Murray Ridge and the Makran accretionary wedge and eventually disappears. Despite the northward subduction of the Arabian Plate below the Eurasian Plate at a convergence rate increasing eastward from 3.6 to 4.1 cm/yr (DeMets et al., 1990), there is no expression of a deep sea trench. This presumably is due to high sedimentary input from the Pakistan and Oman coasts and due to the small dip of the subducting plate of about 2-3^{o} (Harms et al., 1984; Flueh et al., 1997; Kopp et al., 2001). Sediment accretion and underplating of sediments (Platt et al., 1988) caused the uplift of the Makran coast at a rate of about 1.5 mm/yr (White, 1983) and a seaward migration of the shoreline.

The age of the 6 km thick oceanic crust below 7 km of sediments (White and Louden, 1982) of the Oman Abyssal Plain is unknown. A Jurassic (or older) crust is assumed by Whitmarsh (1979); a speculated Eocene crustal age seems more reasonable to Mountain and Prell (1990). Based on heat flow measurements Hutchinson et al. (1981) calculated a Cretaceous (70-100 Myr) age. No sea floor spreading magnetic lineations could be correlated in the Oman Abyssal Plain, indicating that the oceanic crust developed during a magnetic quiet period.

The onshore Makran accretionary wedge forms an arcuate belt of deformed mud-rich terrigenous Tertiary succession. Most of the 500 km broad accretionary wedge is exposed onshore Pakistan and Iran and has been investigated at its onshore and offshore parts (Byrne et al., 1992; Bannert et al., 1992; Fruehn et al., 1997; Harms et al., 1984; Kukowski et al., 2001; Platt et al., 1985, 1988; Quittmeyer and Kafka, 1984; von Rad et al., 2000; Kassi et al., 2003; Nicholson et al. 2003; Grigsby et al. 2004, 2009; Kassi et al. 2007, 2011). The onshore wedge of the Makran ranges contains Lower Oligocene? to mid-Miocene thick-bedded shale-dominant turbidite succession of the Hoshab and Panjgur formations, overlain by up to 2 km thich mudstone-rich succession of Middle to Upper Miocene Talar Formation and Chatti Mudstone, passing upwards and laterally into Late Miocene to Pliocene shelf sandstones (Parkini and Branguli Formation). The tightly folded and imbricated turbidites occur farther inland than the younger slope facies mudstones with broad synclines in the near shore areas.

There is evidence from sequence stratigraphic study of the Makran wedge and from the type of sediments in front of the wedge for two phases of imbrication (Platt et al., 1988). Convergence and formation of an early wedge probably initiated during Paleogene, which was followed by a second phase of thrusting from mid-Miocene to Pliocene, leading to the underthrusting of the older wedge and thickening and uplift of the accretionary complex. Since the Pliocene renewed frontal accretion and continuous underthrusting above a mid-level detachment has occurred.

3. The Mud Volcanoes of Makran

3.1: Onshore Mud Volcanoes

The onshore mud structures may form isolated conical volcanoes, fields of mud volcanoes or elongated ENE-WSW to E-W oriented ridges (Bannert et al., 1992). They occur in many localities along the coastal belt of Makran including those near Gawadar, Pasni, Chandragupta, Jebel-u-Ghurat and Ormara. In all cases they pierce the Upper Miocene Parkini Formation and the Pliocene Hinglaj, Talar and Chatti formations. Occurrence of the mud-related features seems to be aligned along tectonic structures, i.e. along thrust anticlines close to and along the Ornach-Nal Fault, where the Makran Accretionary Prism bends to the ENE, quantity of mud extrusions is higher and their distance from each other is smaller than further in the west. The dense occurrence of mud volcanoes in the east is in line with the eastward increasing plate convergence, frequent occurences of thrust anticlines and left-lateral strike-slip faults along the Ornach-Nal Fault. It has been suggested (Schluter et al., 2002) that development and distribution of the mud diapirs and volcanoes are largely controlled by thrusts or even back-thrusts that are observed offshore.

The gas- and water-charged onshore mud volcanoes extrude methane and higher hydrocarbon derivates (Harms et al., 1982), which indicate a thermally mature source rock. It has been argued (Schluter et al., 2002) that older than Upper Miocene sediments must have been involved in the mud diapirs.

3.2: Offshore Mud Volcanoes

Detailed geological and high-resolution investigations in offshore Makran show small-scaled mud volcanoes in certain areas (Wiedicke et al., 2001). Schluter et al., (2002) shows a rising mud diapir, which most likely intruded along a thrust from the alegedly underlying mud rich succession. Their results support similar interpretations of Ross et al. (1986) and Ricateau and Riche (1980) from the western Gulf of Oman, where diapirs of Late Cretaceous clays above the oceanic crust of the Arabian Plate intruded Paleocene to Miocene clastics, which in turn are overlain by Upper Miocene and younger deltic succession.

The submarine part of the Makran accretionary prism is characterized by five to six thrust anticlines (accretionary ridges) that are separated by small, tilted synclines progressively filled with turbidites (Schluter et al., 2002). The south facing anticlines trend W-E to WSW-ENE and are cut by a complex channel system acting as gateways for the erosional detritus of the onshore exposed wedge. Also there is segmentation of the wedge along strike and the thrust anticlines showing lateral offsets, which is indicated by the occurrence of the NNW-SSE trending major sinistral strike-slip fault zones that can be traced from the coast across the wedge into the abyssal plain (Kukowski et al., 2001). Schluter et al., (2002) suggests that anticlinal cores are often characterized by a chaotic internal reflection pattern, which may either be due to the high angle bedding planes, which scatter seismic energy, or indicate mud material that intruded from the underlying succession.

The best indications for the existence of mud diapirs are drilling results from the wells Jalpari-1A and Dhak-2, which are situated above the doming structures and encounter overpressured muds at 2000 and 4450 m below sea level (Schluter et al., 2002). From the extrapolated results of well Jalpari-1A to the seismic profiles it has been concluded that the well stratified anticlinal cover is composed of the Plio-Pleistocene

Hinglaj, Chatti, Ormara and Jiwani Formations (Raza et al., 1990, Schluter et al., 2002). The stratified parts of the underlying anticlines occur at depths of the Upper to Middle Miocene Panjgur and Parkini Formations drilled at well Dhak-2, indicate a pre-Middle Miocene age for the chaotic mass underneath, which is interpreted to represent mud diapirs that derive mud from depths from the succession having a Cretaceous to Paleogene age. This interpretation is supported by Wiedicke et al. (2001), who sampled evolving mud diapiric structures further to the west for the offshore part of Makran.The presented model indicates a stepwise decoupling of the anticlinal thrust slices from the downgoing sediments along decollement zones within the mud-rich succession, thus creating an upward migration of imbricate decollements attached to mud diapirs.

4.: Origin and age of the mud volcano material

Biostratigraphic investigations on sediments of the Chandragup I, Jebel-u-Ghurat, Ormara and Gwadar mud volcanoes revealed mixed assemblages of foraminifers and nannoplanktons (Schluter et al., 2002). The fair to well preserved calcareous nannoplanktons range from Early Cretaceous to Recent in age. The coccoliths can be classified into the stratigraphic intervals of Recent/Pleistocene, Pliocene/Miocene, Oligocene/Paleocene, Late Cretaceous and Early Cretaceous (Delisle et al., 2004). The very well preserved to reworked benthic and planktonic foraminifera assemblages consist of Recent/Early Pliocene to Miocene shallow shelf faunas and Early Eocene/Late Paleocene slope faunas. Delisle et al. (2004) suggests that the pre-Neogene species are derived from source rock of the hinterland and the mud extrusions from the Upper Miocene Parkini mudstone sequence at depths of 2-3 km.

Schluter et al., (2002), however, argue that abundant Cretaceous and Late Paleocene/Early Eocene species of the mud extrusions cannot be ignored, particularly because reworking structures of the microfossils may have developed due to diapiric shale movements and extrusive processes of the overpressured muds. They favor the idea that at least part of the Makran mud volcanic material derives from the interpreted Upper Cretaceous to Paleogene hemipelagic succession of the downgoing Arabian Plate.

Substantial amounts of fluids and methane may have been trapped because intact mud dominated formations in general release only minor quantities of their constituents due to low permeability and because the mud-rich succession was rapidly buried below the highly accumulating clastic material of the wedge. Mass balance calculations for the Makran wedge suggest that about 50% of the downgoing sediment is being underthrust beneath the wedge (Platt et al., 1988) providing the source of overpressured fluids and methane, which are very common in the submarine and onshore exposed Makran wedge (Kukowski et al., 2001; Delisle et al., 2004). According to the wedge and frontal imbrication model of Platt (1990) each thrust slice terminates at depths of the decollement, from which overpressured muds easily may have entered the fault planes giving rise to diapirism along the faults. Calculations from Brown (1990) show that this process can be accelerated by decompression due to faulting and thrusting of a rising mud mass from depths of 6 km and with a content of free methane of 1%, leading to a dramatic increase in porosity and decrease in density. At the Makran submarine wedge methane is indicated by sampling results (Wiedicke et al., 2001) and proven from onshore mud volcano analyses (von Rad et al., 2000; Delisle et al., 2004) apparently causing the rise and the intrusion and extrusion of fluids and muds.

5.: Acknowledgements:

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7.: Figures Captions:

Fig.1 *Distant view of the newly emerged Sapt Island Hungol Lasbella District Balochistan.*

Fig.2: Mud Volcano with in Island. There are 10 such mud volcano vents. In the background you can see the rest of Island have no regular morphology, indicating that the whole Island is not the product of Mud Volcano, but irregular mass of extrusive/ injected mass of land.

Fig.3 .Extrusive mud with incorporated angular pebbles, cobble can be seen.

Fig.4. Highly inflammable gas upcoming violently from the vents, which indicate Hydrocarbon reserves in region.

Fig:5. A dried and dead Volcano in Island

Fig:6. Satellite image showing location of newly emerged Sapt Island and the Chundergup active mud, about 22km from the Sapt Island.

Fig.7. Satellite image cluster of three Mud Volcanoes ,marked as Chandergup 1, 2 and 3.

Fig.8. Chundargup-1 Mud Volcano lake, which is near to the verge of dying. The edifice of the this volcano almost eroded and there is no more eruption and deposition of mud. At the end it became lake of water, and ultimately dryup in coming years.

Fig:9. The most prominent and active mud Volcano of Chandergup, visible from Makran coastal highway.

Fig.10. A view of Chundergup-3 from the top of Chudergup-2, and in 2nd photo the crater of Chudergup-3.

7.1 Figure:

Fig.2

Fig.2


Fig.3


Fig.4

Fig:5.


Chandergup Volcano
Sapt Island
Google

Fig:6.

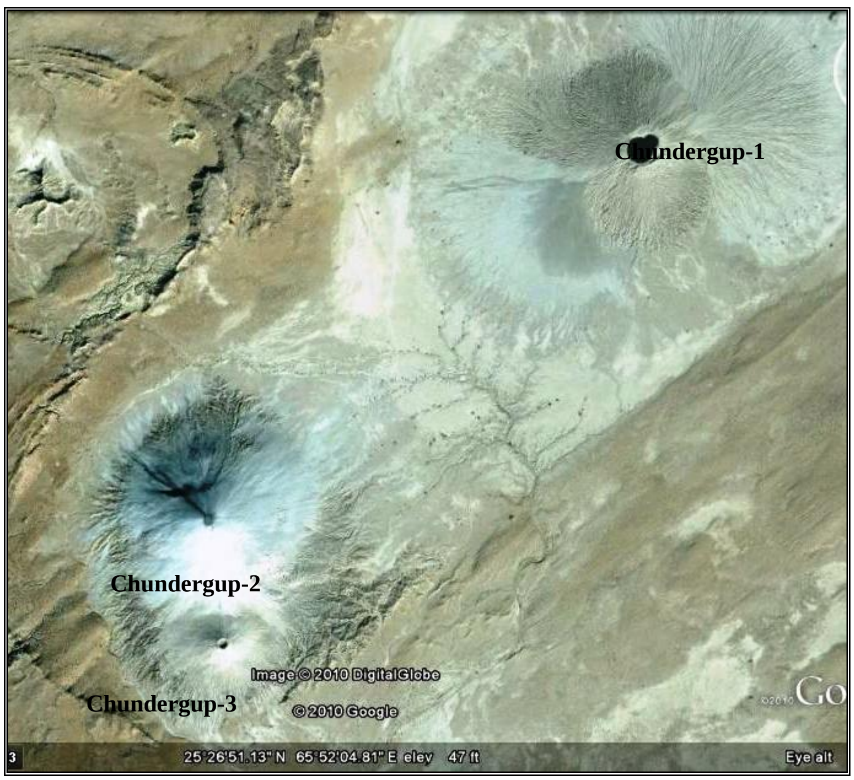
Chundergup-1
Chundergup-2
Chundergup-3
Image © 2010 DigitalGlobe
© 2010 Google
25°26'51.13" N 65°52'04.81" E elev 47 ft
Eye alt

Fig.7.

Fig.8.

Fig:9.

Fig.10.