Sedimentary Geology 366 (2018) 14–31

Contents lists available at ScienceDirect

Sedimentary Geology

journal homepage: www.elsevier.com/locate/sedgeo

The Totumo mud volcano and its near-shore marine sedimentological setting (North Colombia) — From sedimentary volcanism to epithermal mineralization

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ARTICLE INFO

Article history:
Received 5 October 2017
Received in revised form 29 January 2018
Accepted 30 January 2018
Available online 2 February 2018

Editor: Dr. B. Jones

Keywords:
Mud volcano
Heavy-light-clay minerals
Sedimentary mineralogy
Depositional environment
Northern Colombia

ABSTRACT

The Holocene mud volcano exposed at Totumo (younger than 4150 ± 50 yr BP) lines up together with some other landforms of its kind along the Caribbean Coast in northern Colombia. It currently vents a mud of the silicate-phosphate-bearing sulfur-sodium chloride type. The mud volcanoes evolved in an active continental margin setting of the South American Cordillera with high seismicity and affected by pervasive neotectonic structural disturbances. During the Neogene and Quaternary linear terrigenous shoreline sediments alternating with delta deposits evolved on this mobile crustal segment between the Andes and ancient Precambrian cratons. Meso- to microtidal sedimentary settings during transgression and progradation created meta- to instable sedimentary and petrophysical conditions (e.g. overpressure and gas-bearing bubble sands), favorable for the formation of mud volcanoes, whose lithofacies is subdivided into (1) footwall facies (detritus from metabasic, -pelitic source rocks), (2) mud volcano plus lateral facies (material from deep-seated hydrothermal sources, hydrocarbon plays, and brine reflux from the sea), (3) hanging wall facies, sand characterized by a strong longshore drift. The sedimentary volcanism in the area is characterized by different temperatures of formation: (1) pre-stage (<100 °C) and (2) recent stage (≈25 °C). Heavy (pyroxene, amphibole, epidote-clinozoisite, Fe-Ti silicates and oxides, garnet, alumosilicates, tourmaline, zircon, barite, Fe sulfides and -sulfates), light (Ca sulfates, calcite, quartz, feldspar) and clay minerals (kaolinite, mica, pyrophyllite, chlorite, vermiculite) are efficient tools to determine the source of mud, to subdivide the mud volcano system as to its facies and describe its physical-chemical regime as to the temperature of formation, pH and Eh values. The mud volcano system of Totumo bridges the gap between sedimentary "volcanism" and epithermal hot spring deposits of intermediate to high sulfidation and forms a useful "guide" to hydrocarbon accumulation.

1. Introduction

Mud volcanoes closely resemble in their outward appearance their cone-shaped namesakes known from the magmatic realm which spit hot ashes or create an apron of glowing lava flows on their slopes. Nothing like that may be deduced from the landforms under study, the eruptions of which are accompanied by slurries of solids, water and, in places, gases mostly at moderated temperatures as it is the case at Totumo, Colombia (Guliyev and Feizullayev, 1997; Aliyev et al., 2002; Dimitrov, 2002; Planke et al., 2003) (Fig. 1). Their initial stage, a water-dominated mud pool, locally, with gas seeps looks like a hot brine pool in the making (Fig. 1a, b). Phases of extrusion of slurry of water and mud alternating with phases of relative quiescence keep these cone-shaped landforms growing so as to attain up to 100 m and more in height and spread across areas intersected by deep-seated zones of structural weakness in the crust (Delisle et al., 2002) (Fig. 1 c, d). "El volcán de lodo del Totumo "(=mud volcano) is a small-scale replica of this large mud volcano found in Asia and offers good conditions to study this landform and its geological setting along the Caribbean Coast (Fig. 1c, e). For comparison, a set of extinct geyserites with gently dipping slopes covered with Fe oxide-hydrates near Mt. Hekla, Island, has been displayed in Fig. 1f as these fossil landforms closely resemble extinct mud volcanoes (Fig. 1d- in the background). So far, a great deal of research on mud volcanoes is centered on their genetic relation to earthquakes and seismicity or structural geology, in general, while their emissions have carefully been monitored and documented (Kopf, 2003; Milkov et al., 2003; Planke et al., 2003; Etiope et al., 2004; Baciu and Etiope, 2005; Davies et al., 2008; Mazzini et al., 2009; Ovsyuchenko et al., 2017). Mud volcanoes were emplaced in subaerial and in subaquatic environments (Delisle et al., 2002; Zitter et al., 2005; Kioka and Ashi, 2015). This may also be applied to the Totumo mud volcano which is located in a transition zone between the marine environment and its hinterland (Fig. 2a). Due to the scarcity of

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URL: https://hgeodill.de (H.G. Dill).

https://doi.org/10.1016/j.sedgeo.2018.01.007
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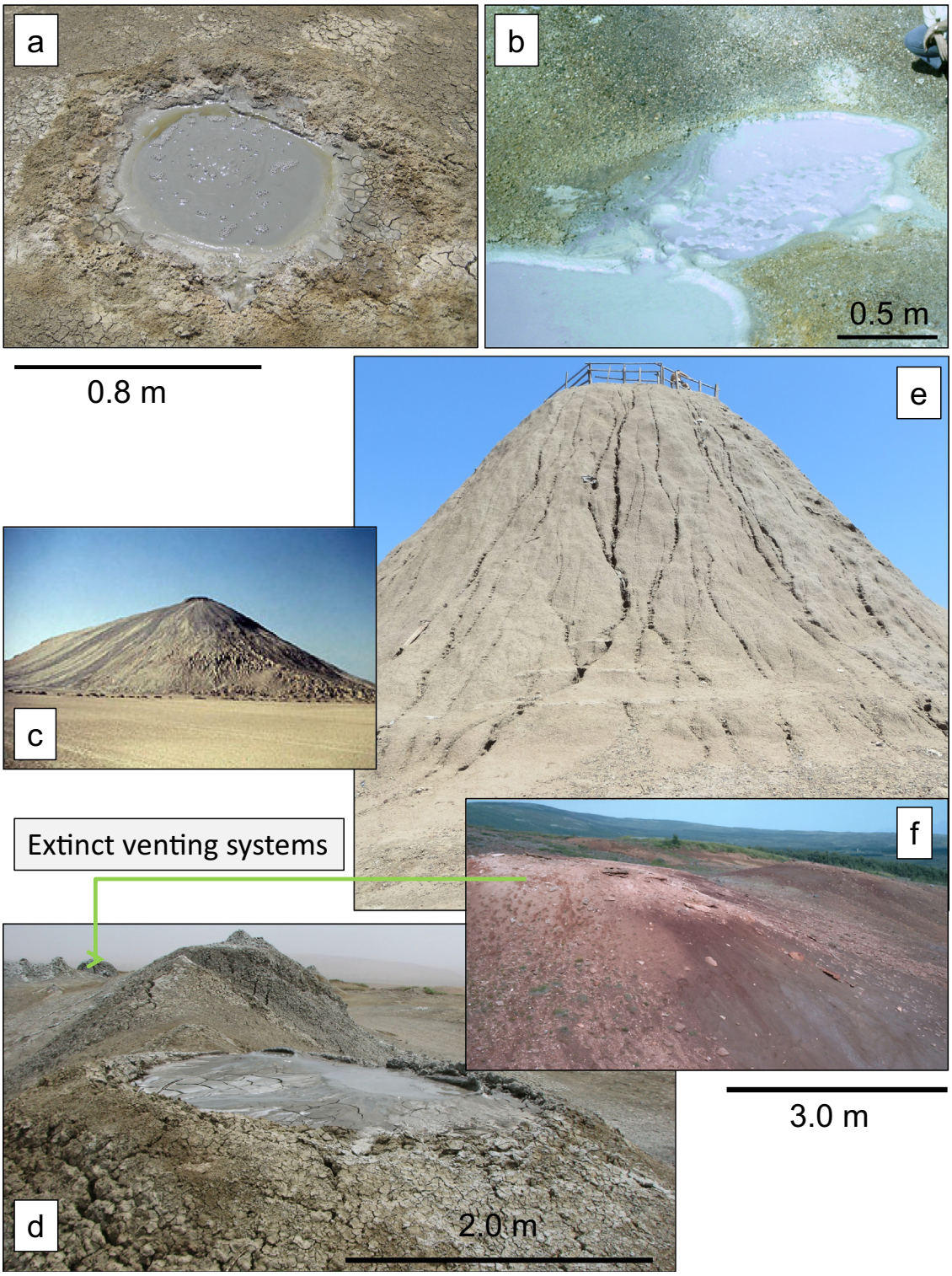

Fig. 1. From the mud pool to the mud volcano – from the hot brine pool to the extinct geyser. a) Water-dominated mud pool with sulfuric gas seeping out ("salse"). W of Baku, Azerbaijan. b) Slurry of water and sinter around an active hot brine pool near Mt. Hekla, Island. c) Mud volcano Chandragup I situated in the Makran Desert, Pakistan, with its cone attaining a height of the 100 m and its crater lake a depth of approx. 27 m (source: BGR).d) Dormant and "extinct" mud volcanoes lined up along a zone of structural weakness. W of Baku, Azerbaijan. e) "El volcán de lodo del Totumo" . See railing to secure bathers on top of the cone for scale. The mud volcano is intensively affected by gully erosion cutting through the steeply flanks of the mud volcano near Santa Catalina (Bolívar, NE Colombia). f) Extinct geyserites for comparison with their gently dipping slopes covered with reddish Fe oxide-hydrates near Mt. Hekla, Island.

sedimentological data concerning the formation of mud volcanoes, particularly in South America (mud volcanoes are known also from neighboring Venezuela, Trinidad and Tobago) in the current study emphasis is exclusively placed on the sedimentary petrography and the geomorphological setting of these special landforms. Talas et al. (2015) have recently published one of the few papers also addressing the sediment chemistry during their investigation but true sedimentological investigations have not been reported so far (Mazzini and Etiope, 2017). Heavy and clay minerals proved to be effective tools when it comes to decipher the subaerial evolution and to determine