International Symposium

HANOI GEOENGINEERING 2022

Innovative Geosciences, Circular Economy and Sustainability

ĐHQG Hà Nội
VIETNAM NATIONAL UNIVERSITY PRESS, HANOI

SECTIONS 3: SOLUTIONS FOR CIRCULAR ECONOMY AND SUSTAINABILITY MULTISECTOR COLLABORATION TO ADDRESS A WICKED

CHARACTERISTICS AND GENESIS OF MASS-TRANSPORT DEPOSITS IN UPPER PLIOCENE SEQUENCE, SONG HONG BASIN

Anh Ngoc Le[1], Oanh Thi Tran[2], Ngan Bui Thi[3], Muoi Duy Nguyen[3],
Hoa Minh Nguyen[3], Hang Thu Thi Nguyen[3], Man Quang Ha[4], Hung Dang Tran[4]
[1]Hanoi University of Mining and Geology, Hanoi, Vietnam; [2]PetroVietnam University,
Ba Ria - Vung Tau, Vietnam; [3]Hanoi University of Mining and Geology, Hanoi, Vietnam;
[4]PetroVietnam Exploration Production Corporation, Hanoi, Vietnam.
Corresponding author: lengocanh@humg.edu.vn

Abstract: The study area is located in the center of the Song Hong basin, covering an area of 3900 km^2. Mass-transport deposits have been observed widely based on the 2D seismic data. The internal deformation is mainly developed in the upper Pliocene sequence which is characterized as a highly faulted interval and changed to chaotic seismic facies towards the collapsed diapir and seaward. These chaostic seismic facies is interpreted as mass-transport deposits covering a widespread area of c. 1500 km^2 in the upper Pliocene interval. Faulting is also observed within the Pliocene sequence. The area of faulting covers almost half of the study area and the rest is dominated by the debris flow. The faults developed intensively as normal faults with an offset of c. 30 ms. They are possibly polygonal faults but need 3D seismic data to confirm. Deep faults are also interpreted close to the collapsed diapir and dipping toward the diapir. The occurrence of mass-transport deposits and associated high-density fault within the Pliocene sequence is possibly related to the late Miocene tectonic inversion. The dominant triggering mechanism for large-scale mass-transport deposits and faulting is tectonic inversion in late Miocene resulting in volcanic activities in this period.

Keywords: Mass-transport deposit; Song Hong basin; Upper Pliocene; Faults; Seismic.

1. INTRODUCTION

Mass movements of sediments formed kilometer-scale features (Figure 1) that represent major subaerial and subaqueous geohazards and can comprise significant depositional elements, characterizing marine slope and basin-floor systems (Posamentier et al., 2011). Recently, these types of deposits have taken more attention because of petroleum exploration in deep-water settings, which are characterized by extensive mass-transport deposition, cover up to 50% of the stratigraphic section (Posamentier and Walker, 2006; Posamentier et al., 2011). Mass-transport deposits play a significant role in hydrocarbon traps and reservoirs. On seismic data, mass-transport deposits can be distinguished by certain geomorphologic as well as stratigraphic characteristics (Posamentier and Walker, 2006; Posamentier et al., 2011). The term mass-transport deposit (also known as MTD) relates to several slope deformational processes, i.e., creep, slide, slump, and debris flow. These processes may form a process continuum and are intergradational. Many mass-transport deposits show evidence of several process mechanisms that were active at various points along their reach (Posamentier et al., 2011).

Mass-transport deposits have not been documented in the Song Hong basin (Figure 1). However, toward the south of the basin, the occurrence of MTDs has been documented in Qiongdongnan basin which is located to the south of the Song Hong basin. The MTDs are widely distributed in the late Miocene sedimentary strata, on the continental slope, and corresponding to the phase when the Red River Shear Zone reversed from left- to right-lateral slip (Wang et al., 2013). The objective of this paper is to first provide detailed descriptions of the seismic characteristics, distribution, and deformation of the MTDs in the central Song Hong basin.

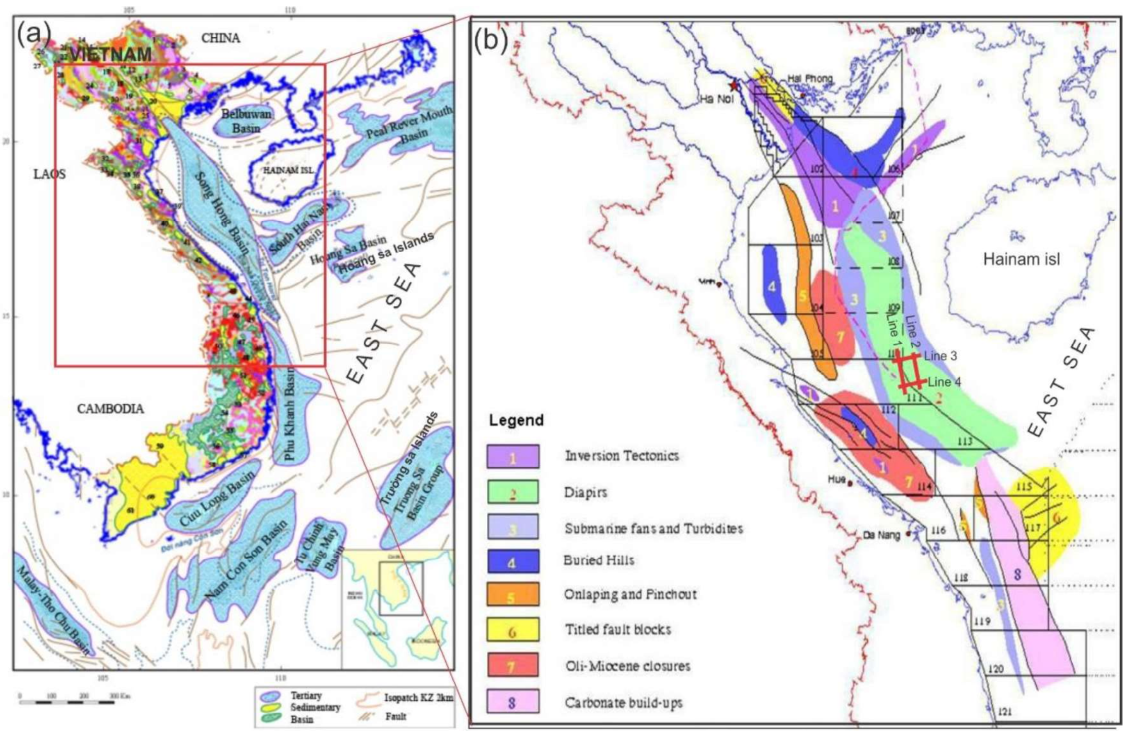

Figure 1. (a) Tertiary sedimentary basins in Vietnam; (b) Prospective plays in the Song Hong basin (Nguyen-Hiep, 2019). The study area is located in the center of the Song Hong basin, covering an area of 3900 km^2, with four 2D seismic lines (in red) which were numbered from 1 to 4. The study area lies in the area of diapirs which some are buried and some are exposed on the seafloor.

2. GEOLOGICAL SETTING

The study area is located in the central Song Hong basin covering an area of 3900 km^2 (Figure 1a). The Song Hong basin (Red River basin) is a large basin with compiling onshore and offshore parts, located within 105°30’-110°30’E longitude and 14°30’- 21°00’N latitude.

The basin is bordered by West Loi Chau basin to the NE, with SE Hainan basin and Hoang Sa basin to the SE, and Phu Khanh basin to the South. The central basin area extends from blocks 107-108 to blocks 114 -115 with water depth ranging from 20 to 90 m. This area is structurally complicated, the basement gently dips towards the depocenter where the thickness of the Tertiary section exceeds 14 km. Structures range from drape-over (covering the basement) in the West to shale diapirs in the basin center (Figure 1b).

The basin formed through Paleogene rifting followed by Late Cenozoic thermal sagging (Rangin et al., 1995; Zhang et al., 2013; Fyhn et al., 2018). The basin has been experienced various Neogene phases of extension and inversion (Fyhn et al., 2018). Stratigraphy of the basin comprises the Pre-Tertiary basement, Paleogene, Neogene, and Pliocene-Quaternary sediments (Nguyen-Hiep, 2019) (Figure 2). In the offshore central part of the Song Hong basin, the Oligocene-Miocene transition is generally deeply buried and contorted by Miocene deformation (Fyhn et al., 2018).

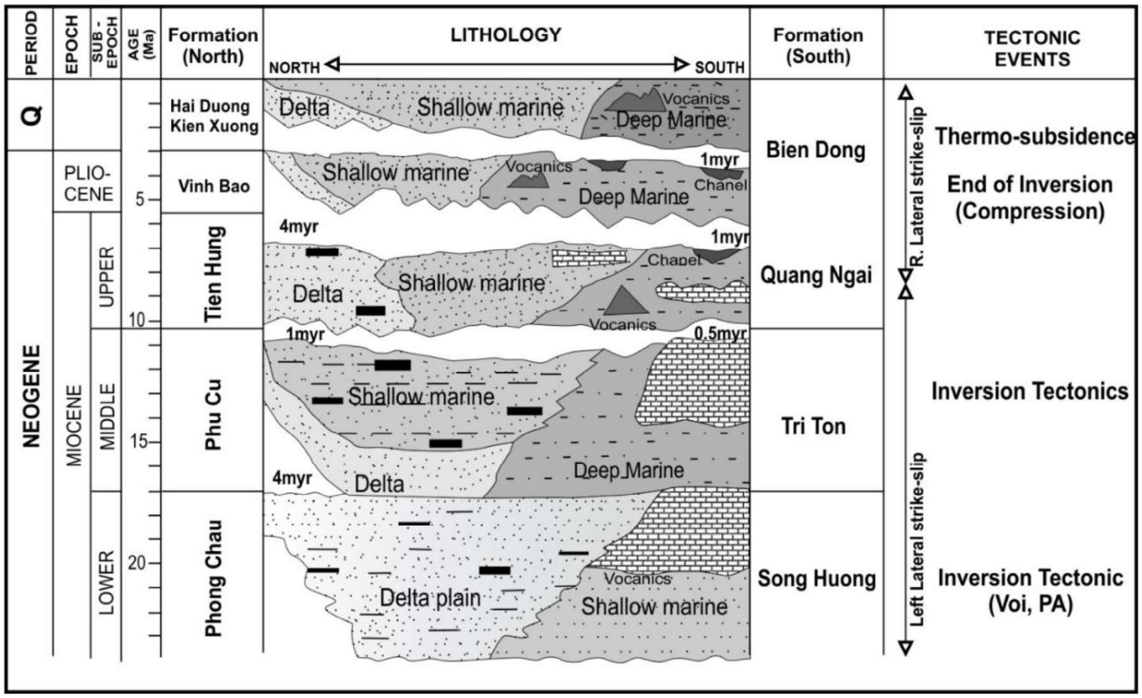

Figure 2. Stratigraphy chart of the Neogene - Q sequence of the Song Hong basin (Nguyen-Hiep, 2019).

3. MATERIALS AND METHODS

This study is based on c. 230 km 2D high-quality seismic data that was acquired in the center of the Song Hong basin. Each seismic line is about 60 km, located c. 130 km offshore, in the center of the Song Hong basin (Figure 1b). The study interval is down to 2s from the seabed. Age control is provided to the seismic stratigraphic through two drill sites closed to the study area in the block 111. Seismic interpretation has been carried on to analyse the seismic characteristics, distribution, and development of the MTDs. Two-way travel times are converted to depth using a seismic velocity of 2.000 m/s (from nearby well data) for the studied interval.

4. RESULTS AND DISCUSSION

The study area is located in the area of diapir occurrence, including active and passive diapirs (Figure 3). This study focused on the interval of Pliocene age which is bounded to the top by the unconformity S3 and at the base by unconformity S1 (Figure 4).

Based on the seismic characteristics, the Pliocene succession is divided into the upper part and lower part by the key surface S2. The lower part is dominated by low to high amplitude, parallel, continuous seismic reflections; the upper part is characterized by low to high amplitude seismic reflections which are highly faulted in the south and west and changed to chaotic and seismic transparency toward the collapsed diapir zone. While the upper part is characterized by highly faulted and chaotic seismic reflections (Figures 3 and 4), the lower part is much less deformed compared to the upper part (Figures and 5).

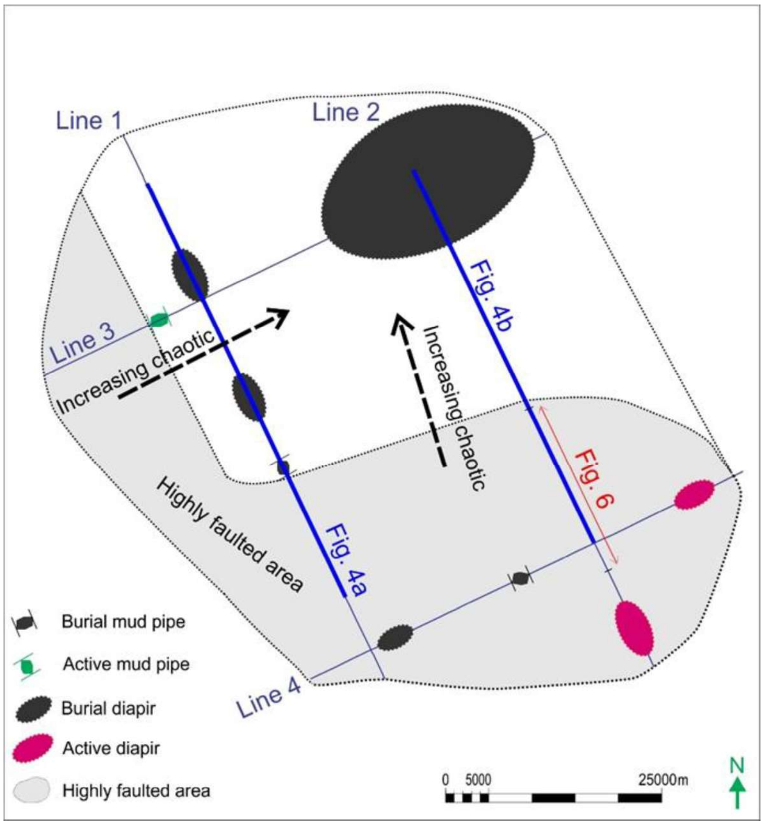

Figure 3. Map showing the study area with the distribution of the highly faulted and chaostic area in the upper Pliocene sequence.

The lower part thickness is c. 500 ms and is relatively consistent along seismic lines. This part is dominated by high to low amplitude, parallel, and continuous seismic reflections but is faulted in the area that is near to the largest collapsed diapir in this study area (Le, 2021b) (Figures 4b and 5b). This fault system is a series of normal faults dipping toward the collapsed diapir causing the related successions also dipping toward the diapir. The faults were penetrated from deeper sections and died out in the Pliocene sequence.

The upper part has a thickness of c. 200 ms. This unit is highly faulted in the southern area and almost abruptly changes to chaos seismic facies toward the collapsed diapir in the northeast (Figures 3 and 4). The highly faulted interval is illustrated in more detail in Figure 6. They are mostly normal faults, closely spaced, small offset of c. 30 ms and different dipping directions. The chaos facies is possibly related to the diapir evolution. Seismic line 1 and line 2 are c. 3 km apart. The upper part of both lines shows similar characteristics, the transition from highly faulted to chaos facies was marked by a collapsed structure which is wider in seismic line 1 and narrower in seismic line 2 (Figure 4).

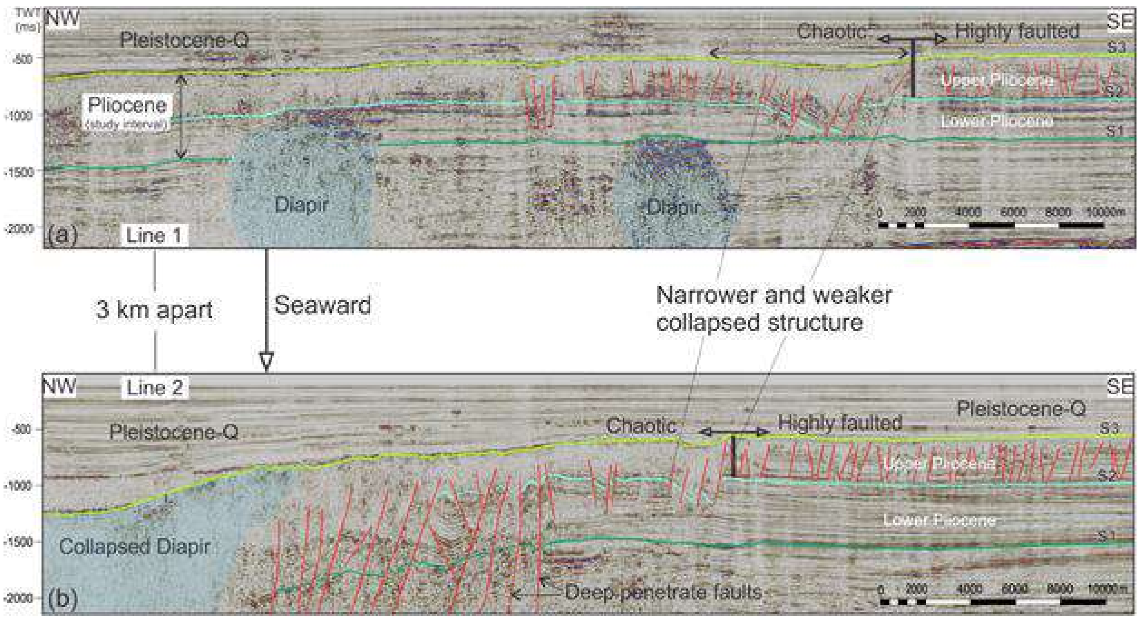

Figure 4. Seismic cross-section illustrating internal deformation of the Pliocene sequence. (a) Seismic line 1 shows a highly faulted upper Pliocene unit which is turned to chaotic facies toward the northwest. (b) Seismic line 2 across the collapsed diapir reveals the deeply penetrating faults dipping toward the collapsed diapir. Faults are all terminated below the reflection S3. See the location of seismic lines in figure 3.

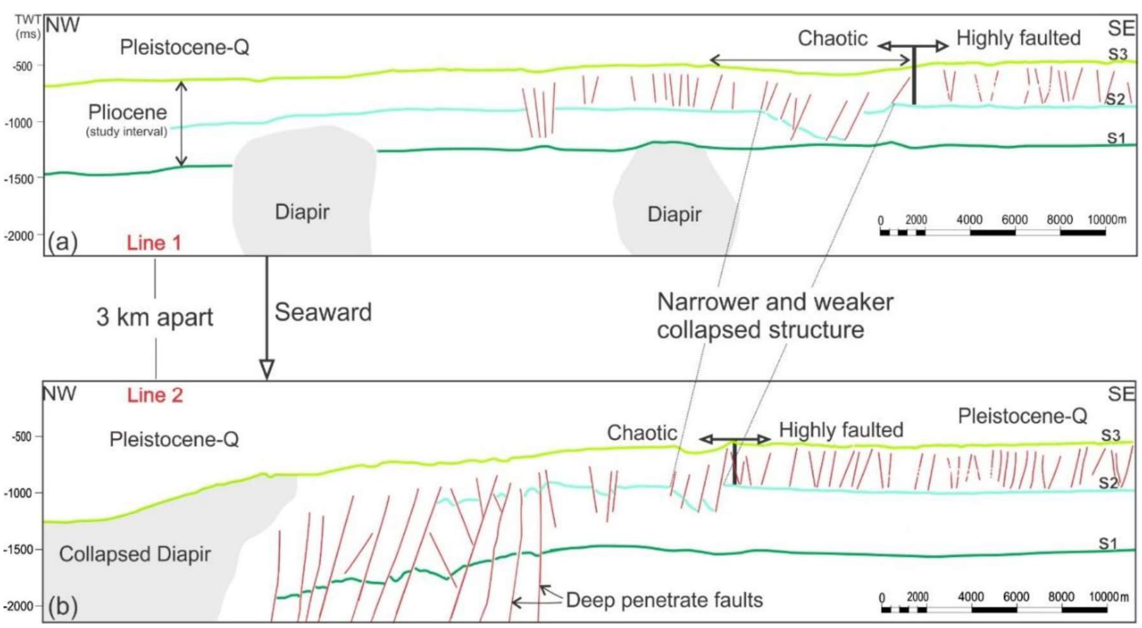

Figure 5. The schematic geological-geophysical cross section shows the internal deformation occurrence in the study area. The position of the cross section coincides with seismic line 1 (Figure 4a) and seismic line 2 (Figure 4b). See figure 3 for the locations.

Highly faulted in the upper Pliocene sequence which has similar characteristics with the layer-bound fault system termed as polygonal faults (Cartwright et al., 2007) and has been documented by (Nguyen-Hiep, 2019; Le, 2021a) in other basins of Vietnam. However, the 3D data is necessary to confirm the geometry of these faults on the map view as polygons.

The late Neogene rapid subsidence, rise of heat flow, depocenter shifting and volcanism probably reflect stretching associated with the change from left- to right-lateral motion on the Red River Shear Zone (Fyhn et al., 2018). Volcanism was energetic during Pliocene-recent in the Song Hong basin but relatively weak or quiet before the Pliocene (Wang et al., 2013; Le, 2021b). The increasing deformation towards the collapsed diapir proved the role of diapir activities in sedimentary deformation. Thus upper Pliocene deformation in the study area is supposed to be caused by volcanism resulting in a large area of mass-transport deposits and high-density faults.

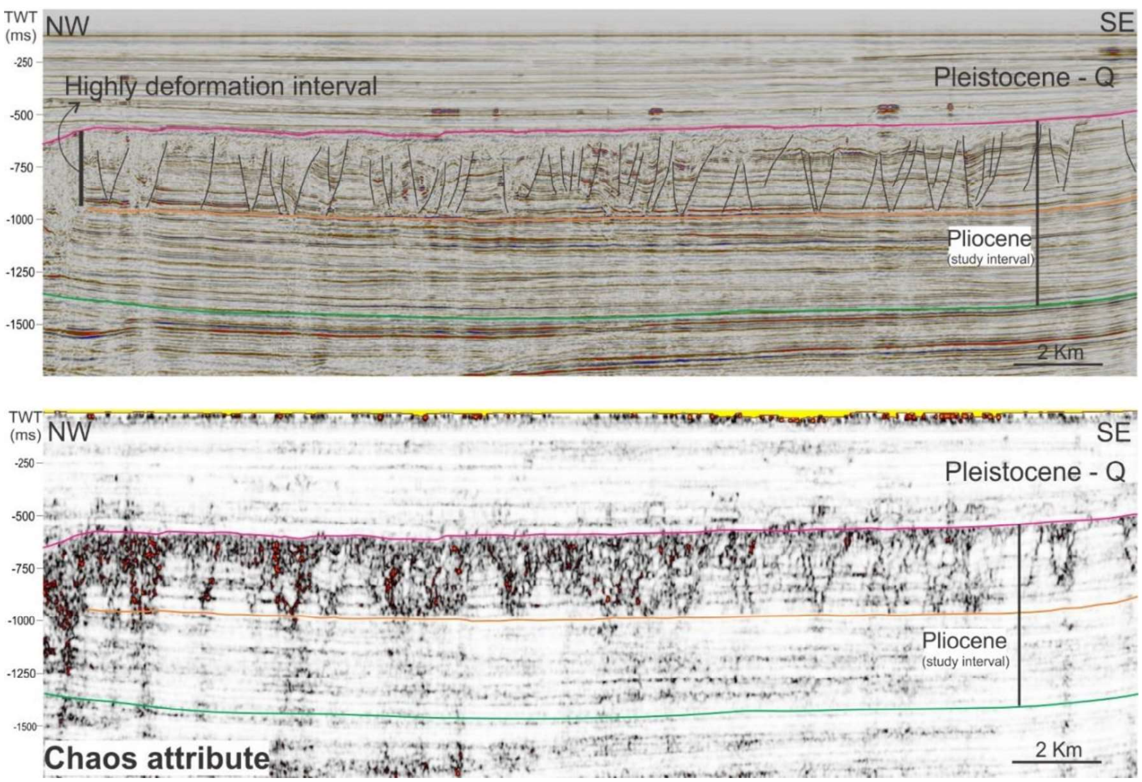

Figure 6. (a) A part of seismic line 2 trending Northwest - Southeast highlight the internal deformation of the upper Pliocene which is highly faulted, and (b) A chaos attribute facies of the seismic line in (a) reveals a number of faults detected in the upper Pliocene sequence. See the line location in figure 3.

5. CONCLUSIONS

Pliocene sequence in the central of Song Hong basin has been studied using 2D seismic data. Upper Pliocene reveals a large-scale internal deformation that is characterized as highly faulted interval to very chaotic seismic facies. The MTD unit show seismic facies characterized by a chaotic zone with discontinuous seismic reflections bounded by continuous strata of late Pliocene age This chaostic facies is interpreted to be MTDs which cover an area of c. 1500 km^2. We interpreted that the MTDs were formed by a prominent regional geological event, associated with the volcanism in Pliocene. There is a number of normal faults observed in upper Pliocene which are possibly the polygonal faults but will need 3D seismic data to confirm for this type of faults.

REFERENCES

1. Cartwright, J., Huuse, M., and Aplin, A. (2007). Seal bypass systems. *AAPG bulletin*, 91(8): 1141-1166.
2. Fyhn, M.B., Cuong, T.D., Hoang, B.H., Hovikoski, J., Olivarius, M., Tuan, N.Q., Tung, N.T., Huyen, N.T., Cuong, T.X., Nytoft, H.P. and Abatzis, I. (2018). "Linking Paleogene rifting and inversion in the northern Song Hong and Beibuwan basins, Vietnam, with left-lateral motion on the Ailao Shan-Red River shear zone". *Tectonics*, 37(8): 2559-2585.
3. Le, A. N. (2021a). "Characterization and Distribution of Cenozoic Polygonal Fault: Case Studies in West Africa and Vietnam Continental Margins". *The Iraqi Geological Journal*, 54(1E): 19-28.
4. Le, A. N. (2021b). "Seismic Characteristics of Mud Diapir in the Central of Song Hong Basin, offshore Vietnam". *The Iraqi Geological Journal*, 54(2A): 1-10.
5. Nguyen-Hiep (2019). *The Petroleum Geology and Resources of Vietnam*. Science and Technics Publishing House. 762p., Hanoi.
6. Posamentier, H. and Walker, R. (2006). "Deep-water turbidites and submarine fans: Special Publication Society for Sedimentary". *Geology*, 84: 399-250.
7. Posamentier, H. W., Martinsen, O. J., and Shipp, R. (2011). "The character and genesis of submarine mass-transport deposits: insights from outcrop and 3D seismic data". *Mass-transport deposits in deepwater settings*. Tulsa: SEPM, Special Publication, 96: 7-38.
8. Rangin, C., Klein, M., Roques, D., and Le Pichón, X. (1995). "The Red river fault system in the Tonkin Gulf, Vietnam". *Tectonophysics*, 243(3-4): 209-222.
9. Wang, D., Wu, S., Qin, Z., Spence, G., and Lü, F. (2013). "Seismic characteristics of the Huaguang mass transport deposits in the Qiongdongnan Basin, South China Sea: Implications for regional tectonic activity". *Marine Geology*, 346: 165-182.
10. Zhang, C., Wang, Z., Sun, Z., Sun, Z., Liu, J., and Wang, Z. (2013). "Structural differences between the western and eastern Qiongdongnan Basin: Evidence of Indochina block extrusion and South China Sea seafloor spreading". *Marine Geophysical Research*, 34(3-4): 309-323.