Persian Gulf Fault: New Seismotectonic Element on Seabed

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Abstract

The Zagros zone is considered an important seismotectonic element for ages because of oil traps. The formation and destruction of these oil traps are primarily influenced by fold systems and their relationship with fault zones. In this research, the seismotectonic components of the northwest Persian Gulf were explored to identify their hidden structural patterns on seabed and their relations with petroleum reservoirs. Accordingly, the seismicity, seismic, and isodepth data of Hendijan, Bahregansar, and Norouz anticlines were used in the analysis. Result of the investigation determined the existence of Persian Gulf fault, a seabed fault in southwest Iran. In particular, the findings of this research explained the formation of Dezful Embayment and the focal mechanism of the Persian Gulf fault.

1. Introduction

In seismotectonics and hydrocarbon exploration, identifying hidden faults is exceedingly important [1]. In general, faults are prevented by the Hormoz salt layer to reach the surface during an earthquake [2]. Nevertheless, the majority of the faults in Zagros are latent [3, 4]. The orogenic belt of Zagros consists of 6 km to 15 km-thick sedimentary pile that lies on the Precambrian metamorphic basement [5]. Records indicate that the thick sediment layers on the bed of Persian Gulf induce the tectonic plates of the faults in Zagros to change [6, 7].

This study aims to recognize the basement lineament and its relation with other elements based on the geophysical evidence of Hendijan, Bahregansar, and Norouz anticlines and the seismicity data of the northwest of Persian Gulf [8, 9]. The structural element in this research is introduced as basement lineament for the first time. Such a lineament was subsequently explored in various studies and was named Hendijan–Bahregansar lineament with a right lateral strike-slip mechanism [10, 11]. Some parts of this structural element from Behbahan to Ramhormoz was assessed and called the Hendijan–Izeh fault. The subsurface evidence in Dezful Embayment justifies the effect of

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Hendijan–Izeh fault on the subsurface structures. Considering such proof, the structural changes, thermal anomalies, geochemical anomalies, and subsurface stratigraphy clutter in the three anticlines of Rag Sefid, Parsi, and Parsiah in the northwest of Persian Gulf are caused by the strike slip displacement of Hendijan–Izeh fault on the subsurface structures.

2. Study Area

The study area encompasses the northwest of Persian Gulf between the southern boundaries of Iran and Bahrain (Figure 1) and is in the middle section of the south part of Dezful Embayment and west of Kazeroon fault. In particular, the study area is situated between the longitude of 48 to 52 and latitude of 28 and 32.

3. Geomorphology

The Persian Gulf basin is entirely located on the continental shelf, whose edge and continental slope are situated in the Oman Sea. The longitudinal axis of this basin forms two separate morphological regions. The western part of the basin, including the major structure and some parts of the foreland of Arabian Precambrian Shield, materialized from the Amar tectonic collision and Najd Rift system [12]. Meanwhile, the relatively linear structure of the Arabian coast is isolated by the Qatar peninsula. Several impressions on the sea flow of this peninsula can be observed, and the sedimentation patterns along the east coast of Persian Gulf can be documented. A wide and shallow area, with a length of 20 km, can also be determined in the eastern part of Qatar peninsula. This area is covered with carbonate ridges, salt domes, and volcanic rocks.

4. Modeling the Synchronous Generator Infinite-bus Power System
The study area involves the outcrops of Quaternary and Neogene that consist of older rocks [13, 14]. The lower units of these ancient superficial deposits from bottom to top include Paleozoic, Mesozoic, and Cenozoic sediments with a thickness of 10 km. The presence of salt in the sequence of Tertiary with Paleozoic sedimentary cover [15] is the feature of the Zagros stratigraphy that influenced the seismotectonics of the area.

5. Methodology and Seismic data

The 2D seismic data recorded by a Western geophysical company (1967) from the Hendijan, Behregansar, and Norouz fields were collected. The seismic interpretation [16] suggests that a fault exists on the west side of the field and is expected to disconnect all formations within such a terrain. Moreover, this fault was identified to match the erosional area. Several ensuing lineaments were then identified on the seabed [12, 17]. The seismic data were gathered from 1999 to 2000 in Hendijan and Bahregansar fields by using a 2×2 km grid obtained from GGS and an Iranian national oil company (Figure 2).

6. Isodepth data

The provided model of isodepth data from Hendijan, Bahregansar, and Norouz [18] is related to the upper part of Sarvak formation with a depth of 4 km on the seabed. The linear displacement in the southeast edges in these three anticlines was determined with the RMS software (Figure 3). Structural studies on the above data [19] show that a strike-slip fault with a N26E direction induced such a displacement to occur (Figure 4). The mechanism of these faults is strike-slip. Figure 5 reveals that the fault was identified in areas, in which the subsurface data are completely available. The same figure illustrates the other areas, from which the fault may be observed (dot lines). The rock unit is schematically shown in a 3D block diagram in the adjacent Hendijan and Bahregansar anticlines to provide a better view of its displacement. By accepting this model, Dorra, Hout, Khafji, and Safaniya reservoirs in Kuwait and Saudi Arabia seemed to be along these elements.
7. Seismic data

The epicenter of several earthquakes that transpired within the Persian Gulf seabed has not been attributed to specific faults. These recorded tremors occurred in 1962, 1976, 1993, 1996, and 2000 with a magnitude of Ms5.2, Mm 4.2, mb4.2, mb3.8, and Ms5.0, respectively (ISC). The epicenters of these upheavals are near the discussed structural element and show the seismic activity of the Persian Gulf fault. The mechanism of the fault for the earthquake that occurred on May 3, 2000 [20]
was identified as a left lateral strike-slip tectonic with reverse component. This fault exhibits a NE-SW trend with the dip of 80° from north to west, conforming to the discussed structural element.

8. Analysis and Discussion

All structures in the southwest of Zagros observed up to this day exhibit a strike-slip mechanism with a right lateral trend. Therefore, a fault with a left-lateral mechanism must be provided with a new model for the northwest of Persian Gulf [21, 22]. This model should justify the relation of the left-lateral interaction of Persian Gulf fault with its other structural elements. The Kazeroon fault and Dezful Embayment act as a strike-slip tensional basin, resulting in the subsidence of Dezful compared with other regions [22-24]. Balaroud fault plays a major role in controlling the forces from the displacement of west Zagros faults. In the southern part of this zone, the Persian Gulf fault has the same role. In particular, the Persian Gulf and Kazeroon faults act as a two strike-slip fault and transfer the force of Arabian plate toward the Zagros thrust fault. In this model (Figure 6), Dezful Embayment is assumed as a separate block surrounded by Persian Gulf, Kazeroon, and main Zagros thrust faults. Such an assumption is supported by seismotectonic evidence and basement lineaments. Accordingly, the distribution of the instrumental earthquakes in the southeast of Kazeroon fault and northwest of Persian Gulf is completely different. This observation verifies the change in magnetic lineaments and surface anticline at the confluence of the two faults. The mechanism of Persian Gulf fault confirms the sandbox model [1].

9. Structural analysis of anticlines in the study area

In the analysis, the Zagros folds in the northwest of Persian Gulf are categorized into three parts (A, B, C) based on their respective frequency and wave length. The boundaries of these parts are formed by the Persian Gulf, Kazeroon, and main Zagros faults (Figure 7). The effects of Kazeroon and Persian Gulf faults on the area folds in seabed and land are obvious.
10. Conclusion

By analyzing the geophysical and seismotectonic data in the study area, this research identified and introduced the seabed area of the Persian Gulf fault with a length of 97 km and a direction of N26E. Based on the seismic data and mechanism of the earthquake that occurred in 2000, the left lateral reverse strike-slip mechanism of tectonic plates can be attributed to this newly determined fault. Such a mechanism explains the formation of Dezful Embayment because of the performance of Kazeroon and Persian Gulf faults. According to the morphology of the seabed and relatively thick sedimentary cover in the region, the Persian Gulf fault along the seabed is hidden and should be considered in seismic studies and hydrocarbon exploration in this area.
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