



A new insight into the evolution of the Qatar Arch to recognize faults and a new gas field

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Abstract

Despite the previous interpretations of the evolutionary scenarios of the Qatar Arch, the present study aimed to present a new complementary scenario to lay out the probable effects of another basement fault, corresponding to the physical shape of the Arch. A remote sensing study was carried out based on geological and geophysical data interpretations, obtained from some national and international databases, including GIS-based global geology data of Harvard University, the free-air gravity anomaly data from the World Gravity Map (WGM), and the airborne geophysical project of the National Geosciences Database of Iran (NGDIR). Results revealed that offshore extrapolation of the Trans Arabian-Bostaneh Fault (TABF) lineament through the morphological boundary of Hauterivian–Barremian (HB) formations and the offshore extrapolation of the Kazerun fault could produce a new complementary model for the Qatar Arch evolution. Based on the particular shape of the Arch (i.e., narrowing and uplifting to the south influenced by the Kazerun basement fault and the rotation of TABF), we can propose that these faults crossed each other after the Barremian age, created a particular shape of the Qatar Arch, and influenced beneath the Fars hinterland. The obtained geophysical gravity data also showed a good match between structural units and faults with maximum values corresponding to the Qatar Arch and minimum values relating to the thick sediment field in the Fars region. In conclusion, the present study contributes to a new proposition about exploring the possible faults and a new gas field situated in the interior territory of Iran. All of these interpretations will provide a new insight to improve the extant knowledge in the geology and petroleum evolution of the study area, such as the Plate tectonic events and the creation of possible reservoirs in future.

Keywords Geology · Gravity · Barremian age · Kazerun Fault Zone (KFZ) · Trans Arabian-Bostaneh Fault (TABF) · Qatar Arch

Abbreviations

BAF Bastak fault
BSF Bostaneh fault

CGM Commission for the Geological Map of the World
Igeo Geo-accumulation index
GLF Gavbendi-Lar field
HB Hauterivian–Barremian
HZTF High Zagros thrust fault
KBF Kareh-Bas fault
KFZ Kazerun fault zone
NGDIR National Geosciences Database of Iran
NZF Nezamabad fault
RKB Rub-al-Khali Basement
RZF Razak fault
TABF Trans Arabian-Bostaneh fault
WGM World gravity map
ZFTB Zagros fold-thrust belt

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Introduction

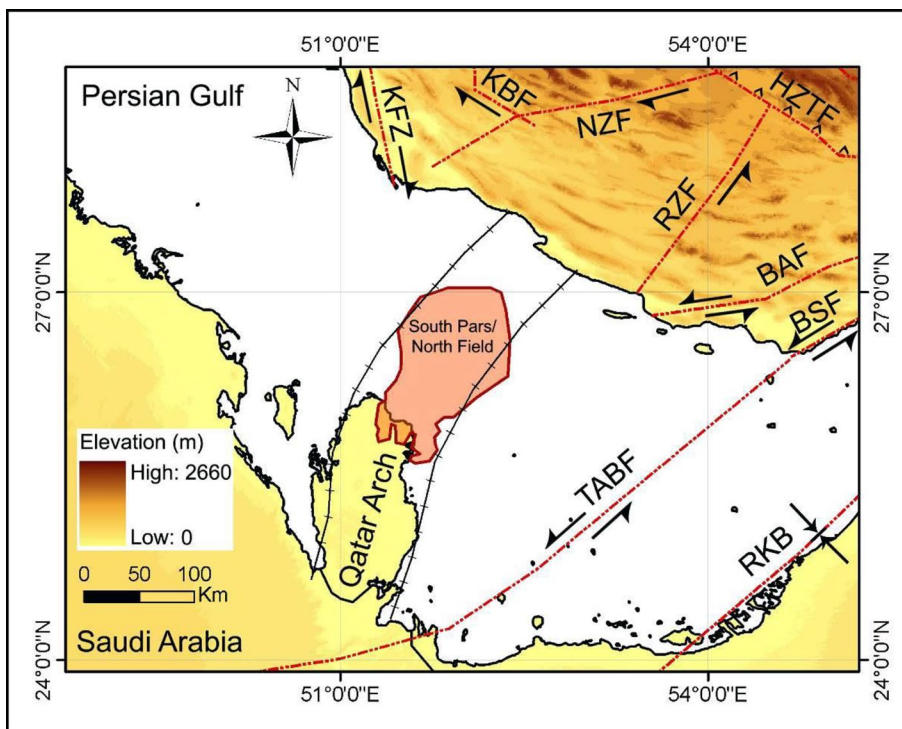
The largest gas field in the world was discovered in 1971 in Permian-Triassic carbonates located in the North Dome/South Pars zone (Alsharhan and Nairn 1997), which was recognized as the Qatar Arch or Qatar South-Fars Arch (Perotti et al. 2011). Within the Qatar Arch, from the south boundary of the Qatar peninsula to the Gavbendi region on the Iranian coast, some prolific gas fields are observed offshore (e.g., North Dome/ South Pars, North Pars, and Balal) and onshore, concentrated in the Upper Dalan and Kangan reservoirs (Bordenave and Hegre 2010). The structure of the Qatar Arch emerged at the end of the Triassic, warped the sedimentary cover of the Arabian Platform, and extended southward into the Qatar peninsula as well as northeastward to the Pars [Fars] region (near the Gavbendi city) (e.g., Bahroudi and Talbot 2003; Bordenave and Hegre 2010) (Fig. 1).

The Qatar Arch is a major regional anticline that runs through the central Persian Gulf and distorts the sedimentary cover of the Arabian Platform (Perotti et al. 2011). Many researchers (e.g., Talbot and Alavi 1996; Edgell 1996; Al-Husseini 2000; Konert et al. 2001) have studied tectonic aspects of this structure. These authors have considered the Qatar Arch as an Infra-Cambrian basement horst block, reshaped by the basement faults. Concerning the importance of this structure, other authors tried to complete its tectonic history (e.g., Perotti et al. 2011). Based on previous investigations (e.g., Konert et al. 2001;

Edgell 1996; Alsharhan and Nairn 1997) and recent seismic interpretations (e.g., Perotti et al. 2011; Perotti et al. 2016), the Qatar Arch has been shaped during several geological periods. Its structural evolution is related to the reactivation of Cambrian faults (Dizaji et al. 2013). Thick carbonate sequences covered the Arch along with evaporating and argillaceous intervals and its emerging started at the end of the Triassic until the Early Jurassic and again during the Cretaceous (Dizaji et al. 2013). The Arch was uplifted slightly in the Paleogene and Neogene periods (Murriss 1984; Dizaji et al. 2013; Dizaji and Bonab 2019).

Despite the previous interpretations of the evolutionary scenarios of the Qatar Arch, the main gap was the lack of an outstanding scenario to describe the reasons for the actual rotation of the Qatar Arch and its interactional effects in the surrounding regions. To fill this gap, our research aimed to present a new complementary scenario to lay out the probable effects of another basement fault, corresponding to the physical shape of the Arch. The main novelty of this paper depends on the exploration of some new faults and recognition of a new gas field situated in the hinterland region of Iran, which will provide a new insight to improve the extant knowledge in the geology and petroleum evolution of the study area (i.e., Qatar Arch and Persian Gulf), such as the Plate tectonic events and the creation of possible reservoirs in future.

Fig. 1 Structural elements around the Qatar Arch including faults and fields of Qatar Arch and South Pars/ North field boundaries, after findings of Bahroudi and Talbot (2003); Perotti et al. (2016)
Note Kazerun Fault Zone (KFZ), Kareh-Bas Fault (KBF), Nezamabad Fault (NZF), Razak Fault (RZF), Bastak Fault (BAF), Bostaneh Fault (BSF), High Zagros Thrust Fault (HZTF), Trans Arabian-Bostaneh Fault (TABF), Rub-al-Khali Basement (RKB)



Geological setting

The study area is a part of the Persian Gulf, including the subsurface of offshore Zagros, the Qatar Arch, and the South Pars/ North Field in the Persian Gulf Basin. The main lithology and period of the geological setting in the study area related to the Quaternary-aged alluvial deposits and losses, Neogene-aged conglomerate and sandstone, Paleogene-aged sediments, and Cretaceous limestone and shale (Fig. 2). For the study area, a long-term lithology chart and tectonic events can be drawn from Proterozoic to Cenozoic times (Perotti et al. 2011) (Fig. 3). On this basis, the tectonic phases of the study area can include passive margin, Alpine orogeny, Zagros subduction, and Zagros collision during the Arch development. Also, a brief stratigraphy chart from Jurassic to Tertiary including age, group, formation, thickness, lithological descriptions, and hydrocarbon plays can be produced in Fig. 4.

Qatar Arch has divided the Persian Gulf into the north and south basins, which the south basin being Rub-Al Khali in Arabian Plate (Edgell 1992; Ghazban 2009). The recent tectonic stage of the Persian Gulf has been influenced by the Arabian Plate, consisting of the late Mesozoic to present-day compressive phase with ophiolite obduction, the collision of the Arabian Plate with the Central Iranian continental block, and the creation of the Zagros Fold-Thrust Belt (ZFTB) (see Sharland et al. 2001; Konyuhov and Maleki 2006).

The Persian Gulf and Zagros Mountains have a similar sedimentary record and encompassing strata from the Precambrian to the recent period (Berberian and King 1981; Motiei 1993). The total thickness of these sequences in nearly un-deformed strata of the Persian Gulf region reached about 8–9 km and thinned to 4–5 km around the Qatar Arch at the end of the Precambrian (Konert et al. 2001; Perotti et al. 2011). In this regard, the thick Infra-Cambrian Hormuz salt bed acts as a detachment surface and creates widespread salt domes and salt plugs, while this layer is absent or thinned in Qatar Arch (Jahani et al. 2007). This fact is observable in the research of Perotti et al. (2011) (for instance, see Fig. 8).

According to Perotti et al. (2011), a lateral deep Hormuz salt and feeding the salt plugs and diapirs adjacent to the Arch are responsible for thinning the Hormuz salt bed. During the Paleozoic time, relatively uniform successions of shallow continental and mainly siliciclastic epicontinental sediments with uplift events were deposited on paleo-valleys formed either Precambrian basement or on the Hormuz basins (Jahani et al. 2007; Ghazban 2009). After deglaciation and significant sea-level rise during the Early Silurian, a widespread organic-rich shale, a lower shale member of the Sharawra Formation in Qatar, and Qusaiba in central Arabia was deposited. Graptolitic shale is considered the principal source rock for the Permian-Triassic reservoir of the North Dome/ South Pars gas fields (Alsharhan and Nairn 1997; Rahmani et al. 2010) and Paleozoic hydrocarbons in Saudi Arabia (Abu-Ali et al. 1991; Aoudeh and Al-Hajri 1995). Gas-bearing dolostone and limestone of Dalan (Permian)

Fig. 2 Geological survey of the study area, after the database of Harvard University (2021)

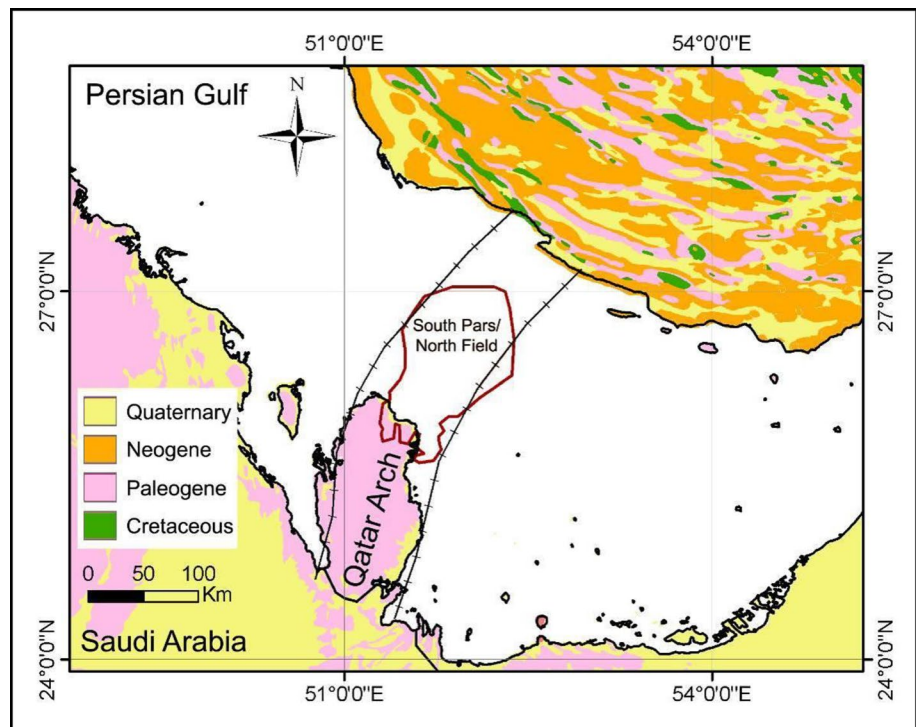
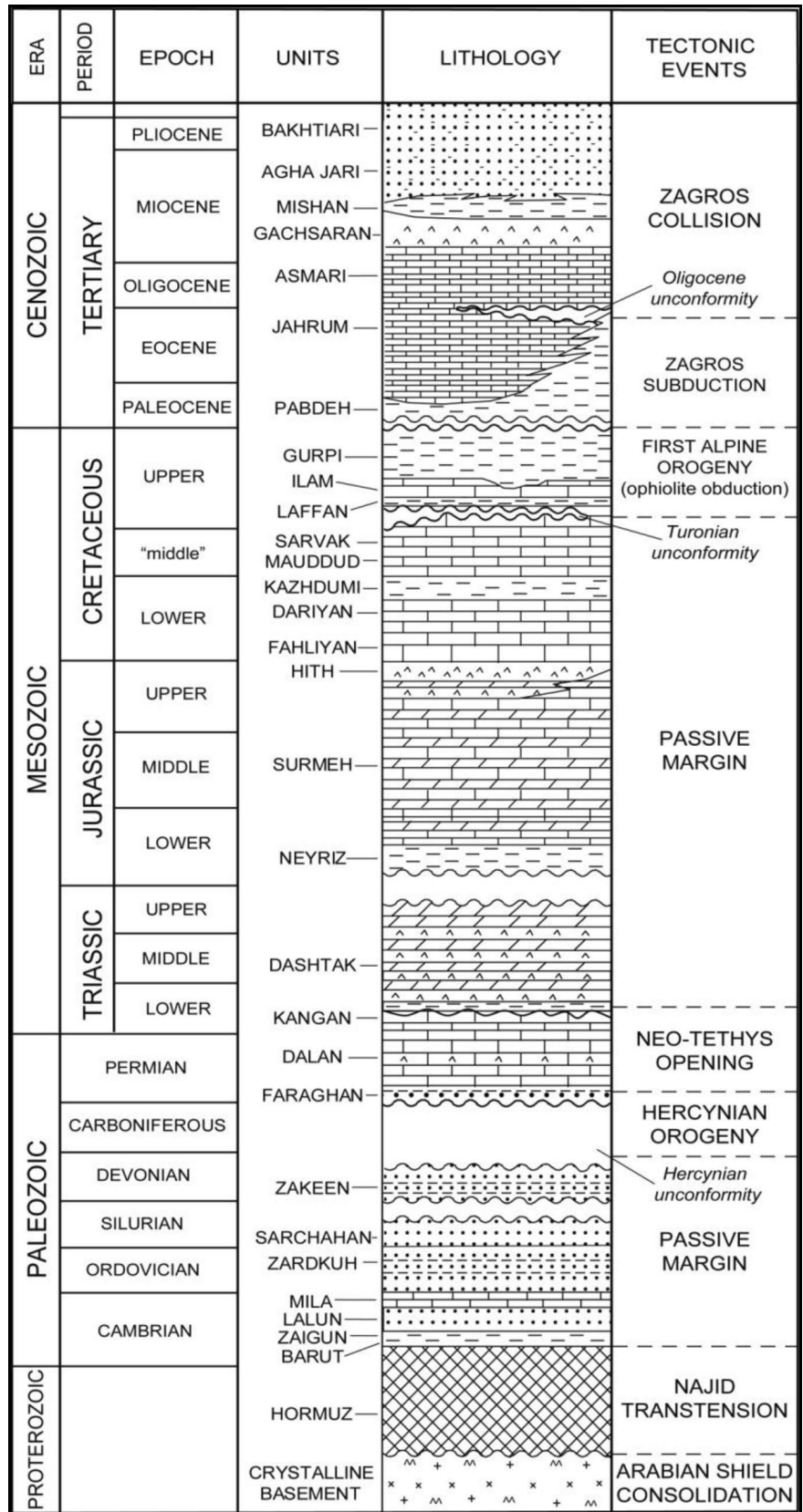


Fig. 3 Lithological units and tectonic events of the study area in the Persian Gulf, after Perotti et al. (2011)



		Age	Group	Formation/Mbr.	Thick(m)	Description	Play	
Tertiary		Miocene-Pliocene	Fars	Mishan	273	Mainly Limestone, interbedded with Marl and Gypsum		
				Gachsaran		Limestone, Gypsum and Clay		
		L. Miocene-Oligocene		Asmari	46	Dolomitic Limestone to Limy Dolomite		
		Upper Eocene		Jahrum	480	Mainly Dolomite		
		L. Paleocene-L. Eocene	Aruma	Sachun Equiv.	25	Dolomite with Anhydritic interlayers,		
Upper	Santonian	Wasia		Ilam (Halul)	85	Dolomitic Limestone to limy Dolomite, Argillaceous Limestone		
	Campanian			Laffan	15	Shale, Marl and Argillaceous Limestone	■	
	Turonian-Cenomanian	Sarvak		Mauddud	53	Limestone, rarely clay and Argillaceous Limestone	●	
	Albian		Kazhdumi	43	Shale and Claystone, thin sandstone and siltstone in lower part	■ ▲		
Cretaceous	Lower	Aptian	Thamama	Dariyan	Upper	65	Limestone	●
					Hawar	23	Claystone, Marl and Argillaceous Limestone	■ ▲
				Lower	26	Limestone	●	
	Barremian-Hautervian	Gadvan		Upper	20	Claystone and Argillaceous Limestone	■ ▲	
				Khalij	15	Limestone	●	
	Neocomian			Lower		15	Claystone and Argillaceous Limestone	▲
					Fahliyan	175	Limestone, Chert	
Jurassic	Upper			Hith	80	Anhydrite with dolomite interbeds		
	Middle			Surmeh	93	Limestone, Dolomitic limestone, Anhydritic interbeds		
	Lower			Neyriz	30	Argillaceous Limestone and Dolomite		

■ Cap Rock ▲ Source Rock ● Reservoir - - - Unconformity

Fig. 4 Stratigraphy and petroleum situations in the South Pars field, after Rahmani et al. (2010)

and Kangan (Triassic) formations (Dehram Group) in Iran and equivalent Khuff Formation in Arabian countries were deposited in a very shallow and warm paleo-equatorial sea, following the middle Carboniferous Hercynian orogeny, middle Permian rifting, creation of Neotethys and the Gondwana breakup (Glennie 2000; Sharland et al. 2001; Alavi 2007). Triassic, Jurassic, and Cretaceous sediments were deposited on passive margins of Neotethys platforms, including carbonate sediments. Late Mesozoic to present-day carbonate and siliciclastic sediments and flysch members

represent the effects of subduction and collision of the Arabian Plate with Iranian continental blocks, resulting in the Qatar Arch and surrounding tectonics status (see Fig. 3).

Materials and Methods

The remote sensing analysis was carried out based on geological and geophysical data in this study. In this regard, the geological survey of the study area (around the Persian Gulf,

including the Qatar region and the southern coast of Iran) was extracted from GIS-based global geology data (Harvard University 2021). The gravity data were taken from the airborne geophysical project of the National Geosciences Database of Iran (NGDIR 2021). The free-air gravity anomaly data were taken from the World Gravity Map (WGM), released by the Commission for the Geological Map of the World (CGM 2021). The free-air gravity anomaly data can be considered on regional grids through the geo-structure and remote sensing studies (Daneshvar and Nejadsoleymani 2017).

Furthermore, the physical and geochemical information of sediment samplings of the Persian Gulf was reconsidered to produce the mean geo-accumulation index (Igeo) of heavy metal pollution (e.g., Cu, Fe, Mg, Ni, and Zn), after Rezaei et al. (2021). The Igeo index, to detect the geographical gradients in the study area, can be an effective indicator to quantify the intensity of heavy metals pollution and enrichment above background concentration levels (Jafarabadi et al. 2017, El Hamzaou et al. 2020).

Results and discussion

Existing pieces of evidence

Talbot and Alavi (1996) have discussed the effects of north–south trending basement faults on the creation of the Qatar Arch. Based on this scenario, Qatar Arch has made an

emerging structure between Kazerun and Marzuk Transfer lineaments (Fig. 5). According to a simplified geological cross section of Qatar Arch, as another scenario generated by Perotti et al. (2011) (Fig. 6), two basement lineaments and uplift zone of the Arch have been described using seismic data and analog modeling (Alsharhan and Nairn 1997, Konert et al. 2001, Pollastro 2003). Corresponding the extension of the Qatar Arch (Bahroudi and Talbot 2003), Permo-Triassic reservoirs (Bordenave and Hegre 2010), the existing shape of the Arch (i.e., narrowed in the south and widened in the north), and the interaction of the basement faults, we can propose another complementary scenario. In this regard, the paleofacies and tectonic data should be reanalyzed in the study area in the first step.

Paleofacies and tectonic analyzes

In the first step, we should understand that the Trans Arabian Bostaneh Fault (TABF) is a basement fault, which has been extrapolated across the Persian Gulf. Through the reaction of TABF, Hauterivian–Barremian (HB) paleofacies data represent the creation of an intra-shelf basin around the Qatar Arch (Ziegler 2001). Glennie (2000) believed that the Barremian epoch is responsible for the start of Arabian Plate warping, distortion, and creation of intra-shelf basins over the Qatar Arch. A stratigraphic sequence study by Daneshvar et al. (2015) confirmed that the HB-aged Gadvan Formation (and its regional equivalent of the Kharabi Formation) abruptly deepened and inclined the southern part

Fig. 5 The emerging scenarios of Qatar structure between Kazerun and Marzuk Transfer lineaments and background data on the oil and gas reservoirs, after Talbot and Alavi (1996); Dizaji et al. (2013)

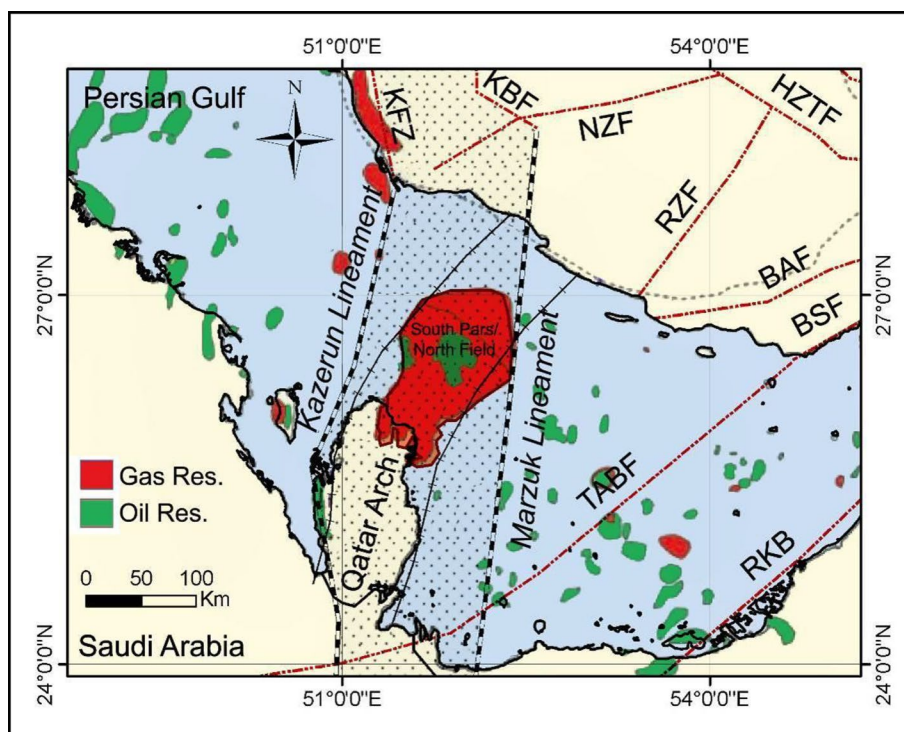
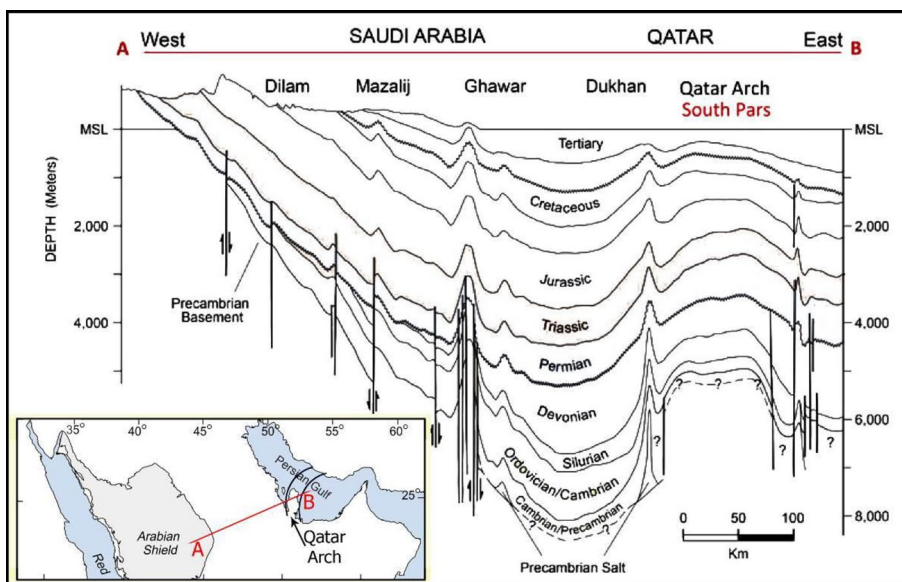


Fig. 6 Simplified geological cross section across Saudi Arabia and Qatar Arch, demonstrating the uplift zone of Qatar Arch, after Perotti et al. (2011)

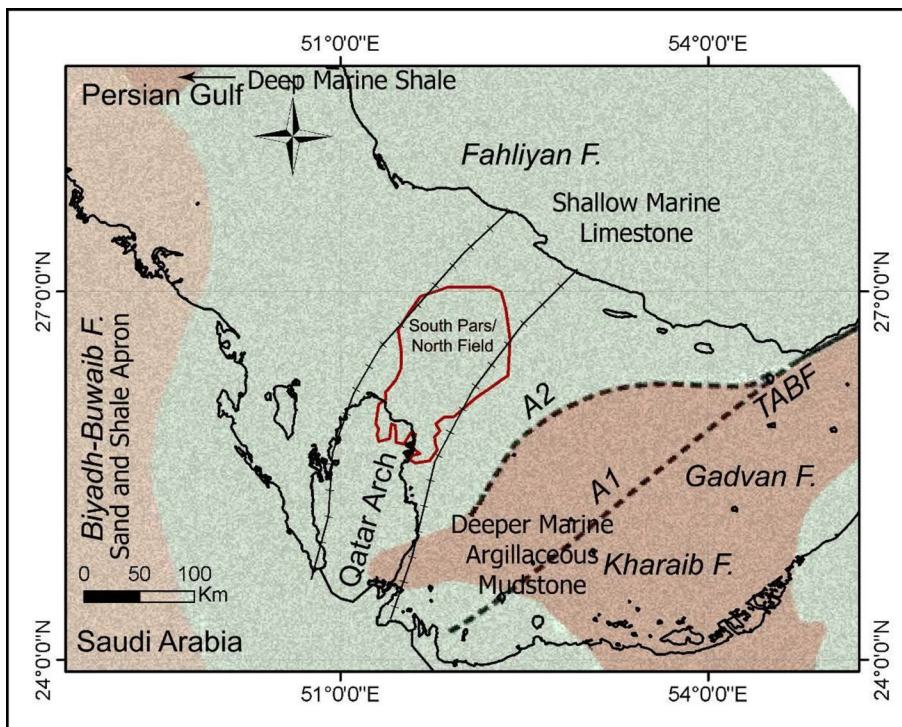


of the TABF. This variation can be featured through two lineaments of A1: linear extension of BSF (Bahroudi and Koyi 2004) and A2: morphological boundary of HB-aged formations (Daneshvar et al. 2015). In Fig. 7, the evolution of HB stages of the Qatar Arch, the HB paleofacies map, and the offshore extrapolations of TABF based on A1 and A2 lineaments were drawn in GIS.

Existence of deep marine “globigerina bioclast wackestone” and “sponge spicule radiolaria bioclast packstone” facies in the mentioned Barremian aged formations has

been observed in the western part of the Kazerun Fault Zone (KFZ) (Lassemi and Siah 2008), demonstrating the possible uplift in the east part of KFZ. Furthermore, Perotti et al. (2011, 2016) have interpreted the creation of an intra-shelf adjacent to the uplifted area based on two-dimensional seismic coverage images and the salt diapirism data. As mentioned by Hessami et al. (2001), TABF and other NE-SW trend faults caused the rotation of formerly north–south trending basement faults around the Zagros distortion (Bahroudi and Talbot 2003).

Fig. 7 Paleofacies evolution of HB stages around the Qatar Arch and offshore extrapolation of TABF, after Ziegler (2001) Note: Extrapolated lineament of A1 is after Bahroudi and Koyi (2004) and extrapolated morphological feature of A2 is after Daneshvar et al. (2015)



Complementary model of the Qatar Arch evolution

Based on the literature and the particular shape of the Arch (i.e., narrowing and uplifting to the south influenced by the Kazerun basement fault), we can propose a new complementary model for the Qatar Arch evolution by extending the offshore extrapolation of TABF lineament through the curved boundary of HB formations (Fig. 8). Based on this model, another warping scenario can be presented to the tectonic history of the Qatar Arch from the Barremian stage to the recent age.

Hessami et al. (2001) have noted that the rotation evidence of the blocks influenced by both left-lateral and right-lateral movements along the faults of Zagros basement resulted in anticlockwise rotation of blocks in the north (elongated NW-SE) and clockwise rotation of blocks in the south (elongated NE-SW) (Fig. 9). This scenario is caused on the convergence of the faults in the southern part of the Persian Gulf (Qatar Arch), which can be affirmed by the finding of Perotti et al. (2011) using the probable contour lines of top Permian. On this basis, the contour lines can resemble an uplifting condition with acceleration toward the southern Qatar Arch.

From the kinematic viewpoint, a complementary model can be defined step-by-step (Fig. 10). Following warping and distortion of the Arabian Plate and rotation of strike-slip TABF during Barremian (see Fig. 10b), the southern

part of TABF may be encountered KFZ, and interaction of these strike-slip faults (KFZ and TABF) has made a bulged arch (Hessami et al. 2001, Bahroudi and Talbot 2003, and Bahroudi and Koyi 2004).

TABF consists of two segments that probably join in the Strait of Hormuz: the Trans-Arabian lineament with a left-lateral strike-slip movement and the Bostaneh Fault (BSF), distinguished on the topographic map (see Fig. 1) (Bahroudi and Koyi 2004), satellite images, geological, and geophysical datasets. It seems that TABF offset left-laterally Zagros anticlines (Bahroudi and Talbot 2003). Besides, KFZ is the best-known active basement fault with a long history of reactivations, extending southward across the High Zagros Thrust Fault (HZTF) to the Persian Gulf and Arabia (Talbot and Alavi 1996).

As these two faults get away from each other to the northeast, the bulged Arch smoothly widens and flattens. Neglecting the effects of salt plugs, the widening of this Arch to the northeast could be represented by the top Permian contour map to the northeast (see Fig. 8). This complementary model can also explain the shortening of Cretaceous and Cenozoic sediments toward Qatar Arch on the geological cross section (see Fig. 6). In the other word, following the convergence of TABF, KFZ, and through the warping, and uplifting of the Arch, the sedimentary space has been decreased (i.e., the shorter thickness of the Cretaceous and Cenozoic sediments compared with the adjacent areas).

Fig. 8 A new complementary model for the Qatar Arch evolution. Note Offshore extrapolation of TABF and KFZ (red dashed curves), salt diapirs and domes (gray color centers), location of South Pars/ North Field, and probable contour line of top Permian (black dashed curves), after Perotti et al. (2011) using seismic data and analog modeling

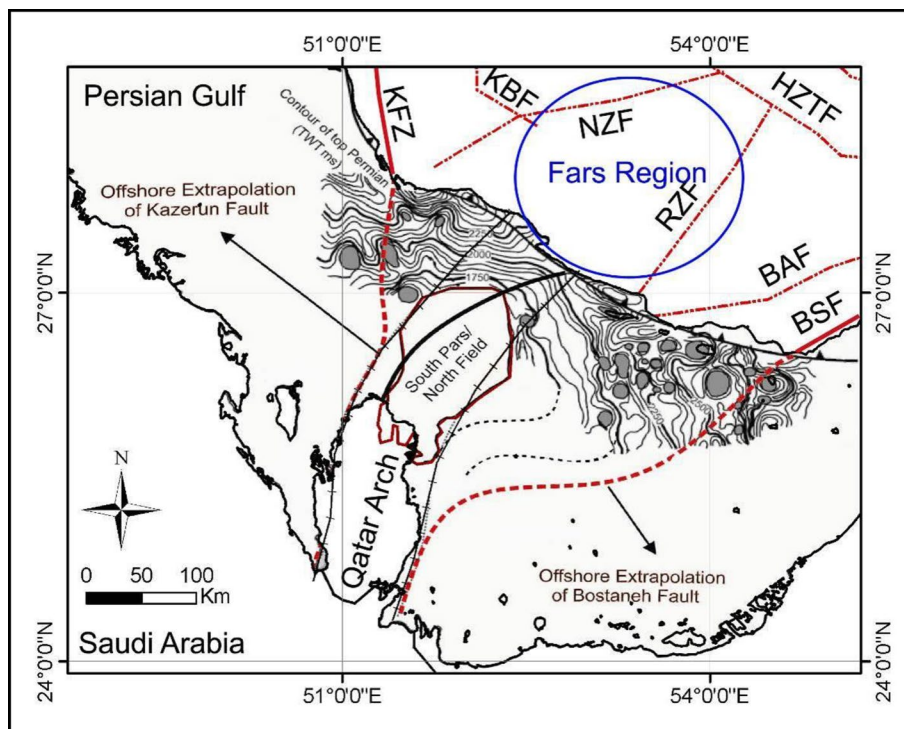


Fig. 9 Schematic map of the rotation of the structural features in the Zagros basement and the Persian Gulf after Hessesami et al. (2001) and authors' modifications Legend 1 is the plate-motion rate in cm/year, 2 is the main Zagros thrust, 3 is the Zagros front faults, 4 is the southern edge of the Zagros deforming zone, 5 is strike-slip faults

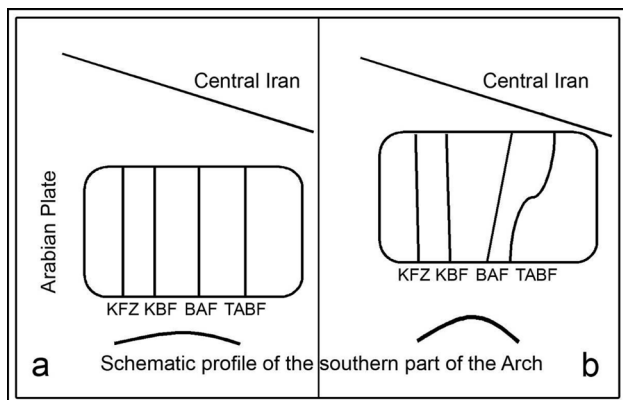
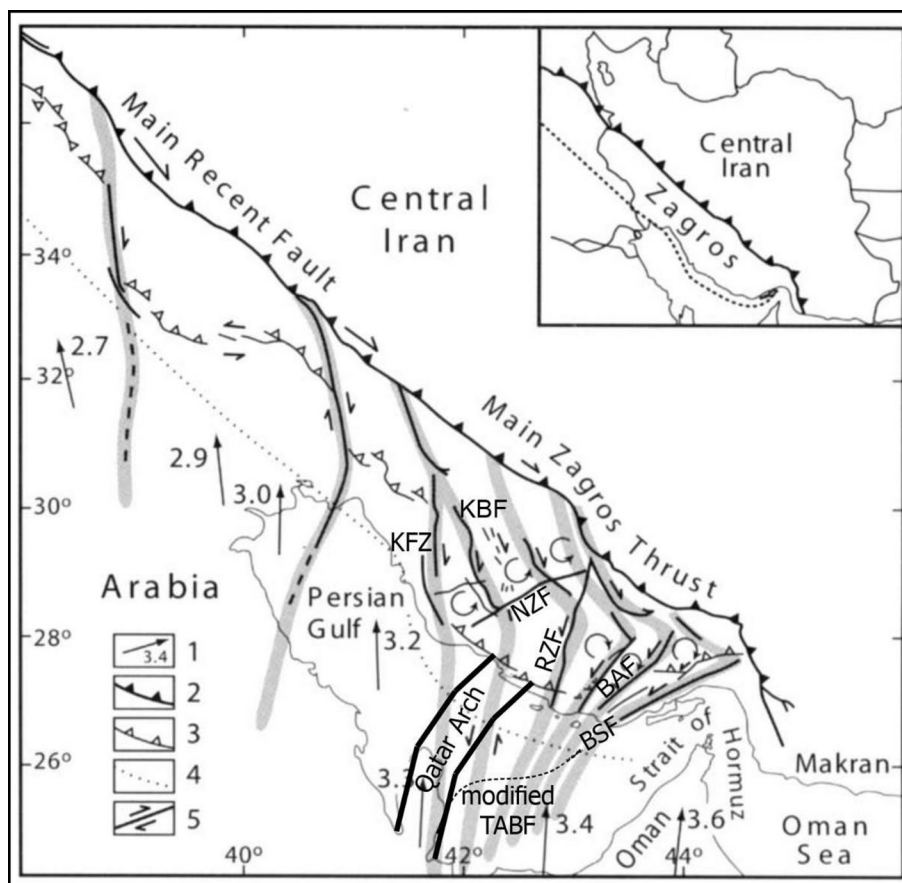


Fig. 10 Kinematic viewpoint of the complementary model as the step-by-step plot of the Arabian plate' pressure on the uplifting of the Qatar Arch, **a** at the end of Triassic-Barremian, and **b** at the start of the warping stage during Barremian

Exploration of a new field in the Fars region

There are some younger strike-slip faults, namely Nezamabad Fault (NZF), and Razak Fault (RZF), with a probable non-basement origin (see Fig. 1), with activation evidence from Oligocene to recent time (Bahroudi and Talbot 2003). Although these left-lateral strike-slip faults are attributed

to the reactivation of basement faults, we suggest that the southward effects of compressional forces on the Qatar Arch have made these faults during the subduction and crashing of the Arabian Plate at its northeastern margin.

This suggestion can be supported by the kinematic description of the faults' movement and anticlockwise and clockwise rotations of the blocks (see Figs. 9 and 10). Regarding relative movements, we believe that compressional forces are responsible for pushing the Qatar Arch and creating the faults of NZF and RZF. These faults are similar to faults developed during stress-strength tests on rock piles. The subduction and collision phases of the tectonic events are responsible for compressional stresses and forces (see Fig. 3).

Besides, in contrast to the Qatar Arch, the main reservoirs of the hinterland region between NZF and RZF, recognized as the Fars region (see Fig. 8), are generally still not explored. The adjusted parts around this region stretch from the KFZ to the Strait of Hormuz, and its southwest limit coincides approximately with the Persian Gulf coastline, are included the majority of the Hormuz salt extrusions and several gas fields (Sephehr and Cosgrove 2005). In the last step, we should aid the geophysical data to understand how major faults have subdivided this region.

According to the residual map of the Bouguer anomaly, subtracting from the regional gravity (after Jiménez-Munt et al. 2012), we can confirm that a positive anomaly is observable around the Qatar Arch (about +10 mGal). Contrarily, a negative residual map of the Bouguer anomaly (about -20 mGal) can be observed beneath the Fars region (north of Qatar Arch), demonstrating a notable crypto and great salt dome along with a new possible hydrocarbon field (Fig. 11).

This apparent contradiction between the existence of positive gravity anomaly of the Qatar Arch and the negative anomaly of the Fars region can also be detected in the free-air gravity anomaly data among the regional faults and basement lineaments (Fig. 12). In the previous works, some researchers have claimed that this gradient of gravity values probably related to the extent and distribution of the Hormuz evaporites over the Fars region (e.g., Edgell 1996; Jahani et al. 2007; Jiménez-Munt et al. 2012).

Al-Husseini (2000) has noted that many structures adjusted in the Qatar Arch are interpreted as Hormuz salt domes based on their oval shapes and corresponding negative gravity anomalies. Nevertheless, we detect a distinct arch in the Fars region, based on the high-resolution airborne geophysical data of the National Geosciences Database of Iran (NGDIR), precisely along with the extrapolation of the Qatar Arch (Fig. 13). On this basis, a distinct gravity anomaly (about -100 mGal) can confirm a possible new field between two possible new faults, namely the Khonj Fault and the Gerash Fault. We also suggest further exploration

to recognize Gavbendi-Lar Field (GLF). Therefore, we can draw the spatial distribution of mean Igeo hot spots in Fig. 14 (after Rezaei et al. 2021). This figure revealed a hot spot of Igeo value, exactly between the northern boundary of Qatar Arch and the southern boundary of Gavbendi offshore, disclosing the significant role of the GLF salt dome and the crypto faults of Khonj and Gerash in the conduction and accumulation of heavy metals to the sea sediments. The high concentration and geo-accumulation of heavy metals have been reported repetitively around the oil and gas reservoirs (Afkhani et al. 2013, Karbassi et al. 2015). In this regard, Dizaji and Bonab (2019) have represented the separation of several minor gas fields (such as Tabkak and Kangan) in the Fars region (north of the Qatar Arch), which belongs to the Dehram Reservoir. However, our result recommends a new major gas field (or salt dome), entitled Gavbendi-Lar Field (GLF), in the interior territory of Iran that is exactly along with the Qatar Arch (South Pars field) (Fig. 15).

Conclusions

In the present study, we aimed to present a new complementary scenario to lay out the probable effects of another basement fault, corresponding to the physical shape of the Arch. For this purpose, some national and international datasets were analyzed using the GIS and remote sensing approaches. The results revealed that:

Fig. 11 Situation of the regional faults and basement lineaments in the residual map of Bouguer anomaly (contours in 10 mGal) resulting from subtracting the regional gravity, after Jiménez-Munt et al. (2012)

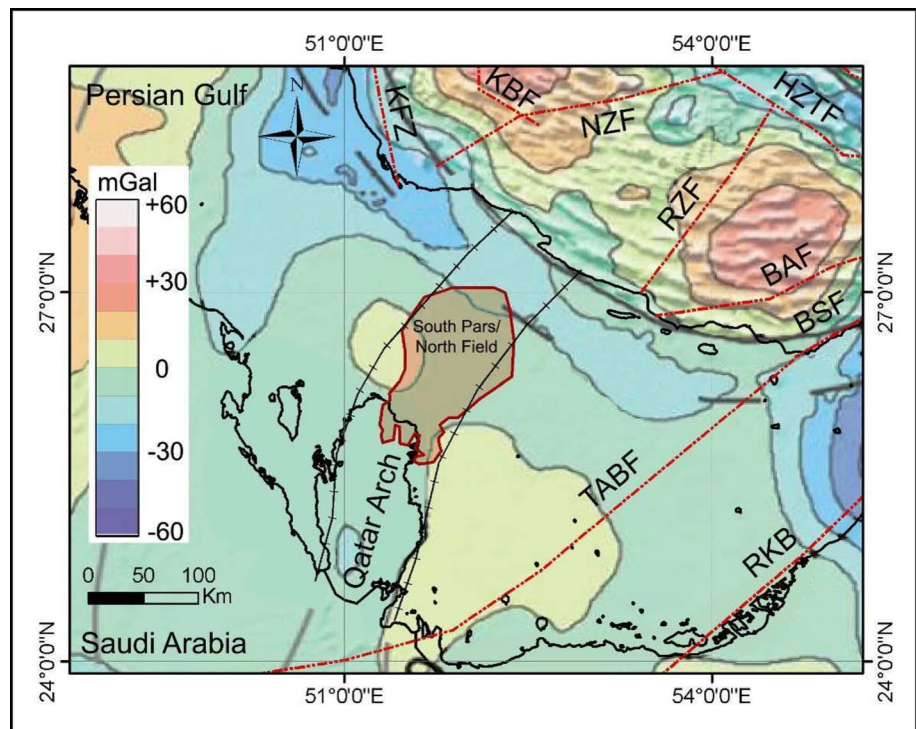


Fig. 12 Situation of the regional faults and basement lineaments in the free-air gravity anomaly data, after the CGM (2021)

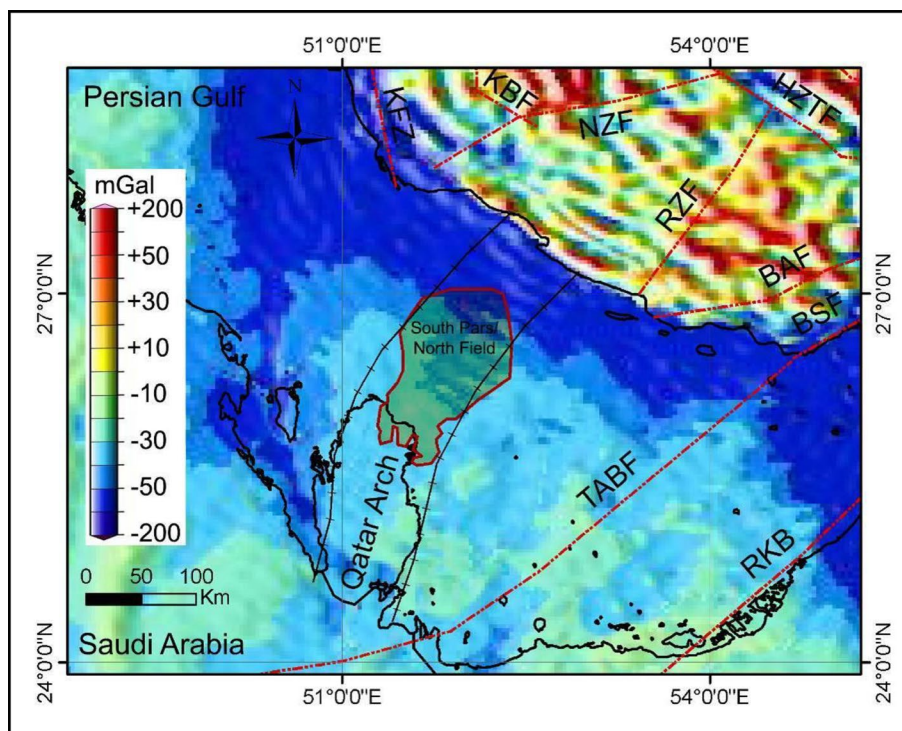
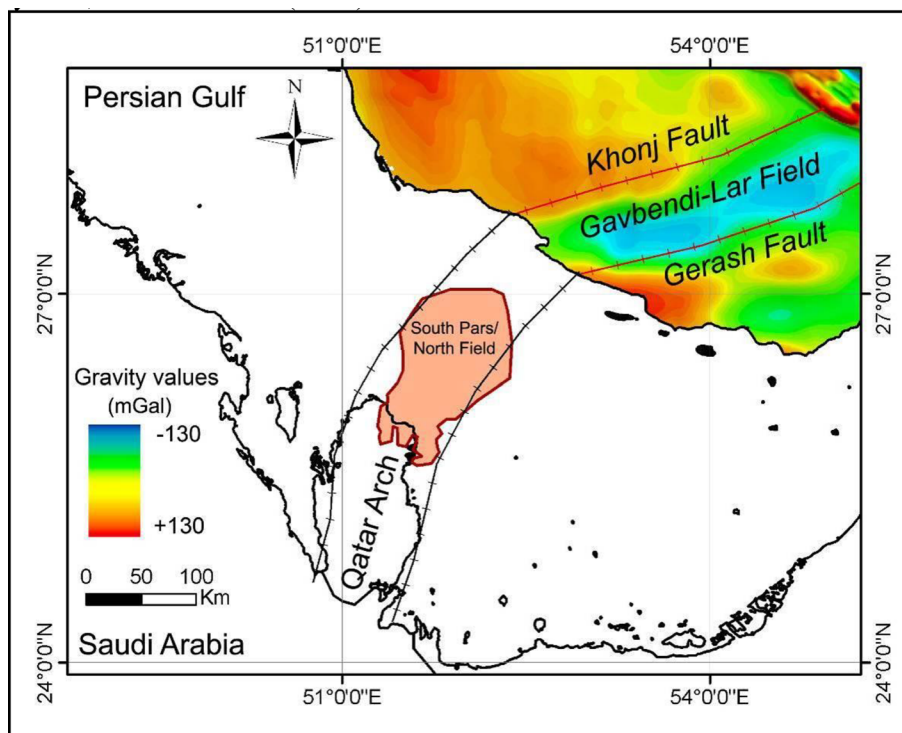


Fig. 13 Recommendation of new faults and Gavbendi-Lar field based on the airborne geophysical data, after the NGDIR (2021)



- (1) The Trans Arabian-Bostaneh Fault (TABF) and Kazerun Fault Zone (KFZ) crossed each other after the Barremian age, created a particular shape of the Qatar Arch, and influenced beneath the Fars hinterland.
- (2) The southward effects of compressional forces on the Qatar Arch have made Nezamabad Fault (NZF) and Razak Fault (RZF) during the subduction and crashing of the Arabian Plate at its northeastern margin. This

Fig. 14 Location of the Gavbendi-Lar field and its relation with the interpolated Igeo values of heavy metal enrichments, after Rezaei et al. (2021)

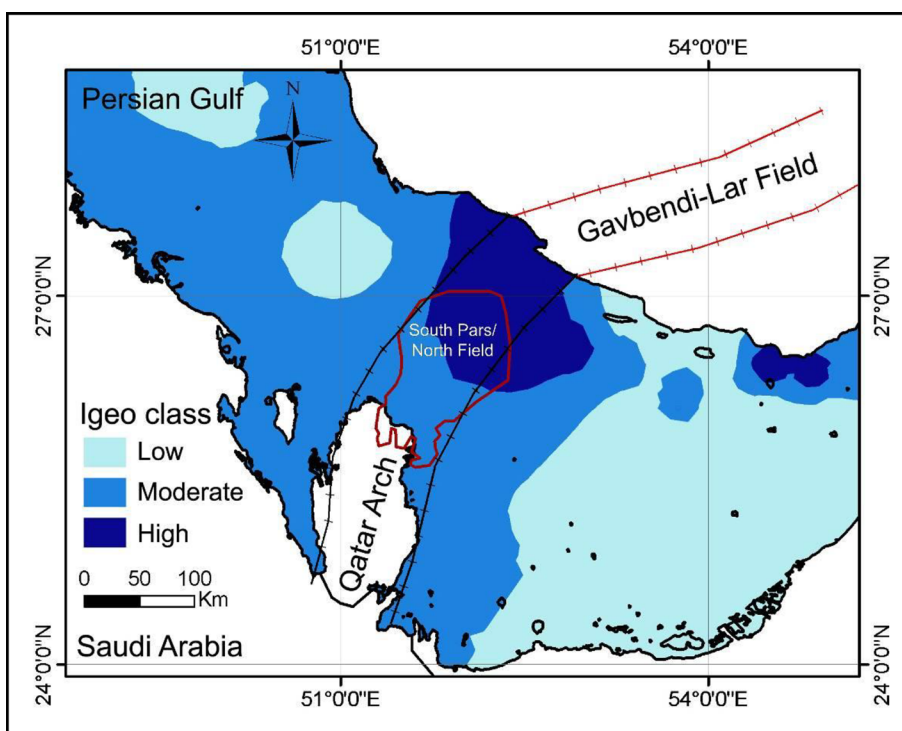
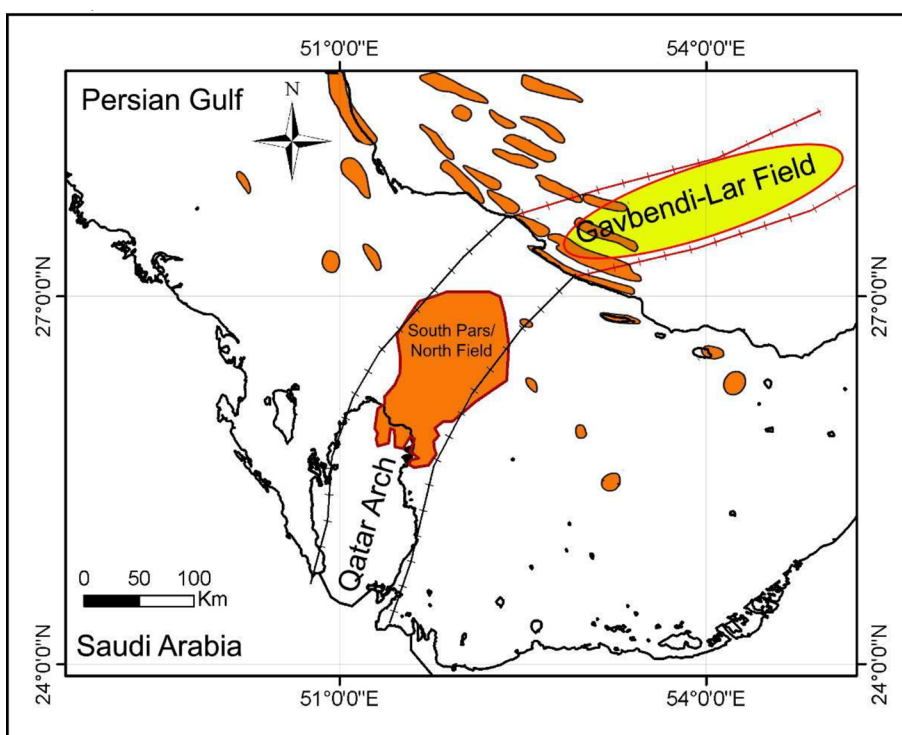


Fig. 15 Location of a possible new gas field of Gavbendi-Lar (yellow color patch) among the existing geographical separation of gas fields (orange color patches)



suggestion can be supported by the kinematic description of the faults' movement and anticlockwise and clockwise rotations of the blocks.

- (3) A distinct arch was detected in the Fars region, based on the high-resolution airborne geophysical data, pre-

cisely along with the extrapolation of the Qatar Arch. On this basis, a distinct gravity anomaly confirmed a possible new gas field of Gavbendi-Lar (GLF) between two possible new faults, namely the Khonj Fault and the Gerash Fault.

- (4) The obtained geophysical gravity data showed a good match between structural units and faults with maximum values corresponding to the Qatar Arch and minimum values relating to the thick sediment field in the GLF at the Fars region.
- (5) All of these interpretations will provide a new insight to improve the extant knowledge in the geology and petroleum evolution of the study area (i.e., Qatar Arch and Persian Gulf), such as the Plate tectonic events and the creation of possible reservoirs in future.

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Declarations

Conflict of interest The authors declare that they have no competing interests.

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Informed consent Informed consent was obtained from individual participant included in the study.

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