Distribution pattern of Ahwaz sandstone and Kalhur evaporate members of Asmari Formation in Dezful Embayment and Abadan plain, a basis for stratigraphic traps studies

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Abstract

Ahwaz sandstone and Kalhur evaporate members are two main constituents of the best reservoir unit of Zagros region, i.e. Asmari Formation. Poorly cemented to loose nature of the sandstone member and it's well textural maturity generate highly porous and permeable zones, whereas highly compacted nature of the evaporate member provide impermeable zones in the reservoirs. This paper aims to study the lithological characteristics of these members and their lateral and vertical distribution in two main zones of the Zagros, i.e. Dezful Embayment and Abadan Plain. The results are believed to provide significant information on discovery of the stratigraphic traps in the area. Inclusive results from ~ 200 drilled wells of 68 oilfields are used in this study. The established isopach, and isolith maps and correlation charts provide a good basis for locating the probable stratigrphic traps in the area. The sandstone member is well developed in central part of the northern Dezful Embayment (e.g. Ahwaz and Abe-Teymur fields) and Abadan Plain (Jufair, Kushk, Darquin, Azadegan and Omid fields). It is poorly developed in the southern Dezful Embayment, except for its NW (Aghajar, Kranj, Rag-e-Sefied, Tangu and Zagheh fields). Based on its distribution pattern in the area, the bordering fields around the central part of the northern Dezful Embayment and Abadan Plain are found more susceptible for development of the stratigraphic traps. The evaporate member is well developed in NW of the northern Dezful Embayment but is absent in southern Dezful Embayment, except Parsi and Karanj fields. Based on its distribution pattern in the studied area, the NW bordering fields between northern and southern Dezful Embayment have greater potential for stratigraphic traps development. Based on the outcomes of this study, the facies changes that resulted from Zagros folding and faulting and simultaneous basement fault movements seems the main causes for development of the combination traps.

Keywords: *Zagros, Dezful Embaymen, Abadan Plain, Asmari Formation, Ahwaz Sandstone, Kalhur Evaporate, Stratigraphic Traps.*

Introduction

The northwest-southeast trending Zagros mountain range is the most important hydrocarbon province of Iran. This mountain range is the result of the Arabian Plate subduction beneath the central Iran, completing with closure of the South Tethys and establishment of various tectonostratigraphic zones (Fig. 1). Tremendous folding and faulting of more than 11000m sediments of the Tethys basin (Alavi, 2007) along with widespread salt diapirism have provided a remarkable opportunity for development of significant hydrocarbon traps in the Zagros. The timing of the orogenic events associated with this closure significantly influenced the generation, migration and entrapment of petroleum in the traps. Dezful embayment and Abadan plain are two important zones of the Zagros range which include the most important oilfields of Iran. This is particularly important in the Dezful Embayment, which is one of the world's richest oil provinces, containing some 8% of global oil reserves in an area of only 60,000 km^2 (Bordenave & Hegre, 2006).

In the studied zones, the oil and associated gas occur in two carbonate reservoirs: the Sarvak Formation of Cenomanian to Turonian age, and the Oligocene to Early Miocene Asmari Formation. The Asmari Formation is the main hydrocarbon reservoir of these zones. This formation is composed of highly fractured carbonate facies, loose to poorly cemented terrigenous facies (dominantly sandstones), intercalations of shale and marl and some evaporate facies (anhydrite and gypsum). This formation overlies on top of the shale-dominated Pabdeh Formation (Eocene) and is overlain by the evaporate-dominated Gachsaran Formation (Upper Miocene). The sandstone facies of the formation (Ahwaz sandstone Member) are mostly developed in south Dezful Embayment, whereas the evaporate facies (Kalhur Member) in south Lorestan zones (Fig. 2).

The oil and associated gas are trapped in large "whaleback" anticlines which formed during the Neogene Zagros orogeny (Alavi, 2007; Bordenave

& Hegre, 2006, 2010). On the basis of its stratigraphic position, the sandstone member is divided into upper (Aquitanian to Burdigalian) and lower (late Oligocene to Chatian) parts (MacCord, 1974). The upper part, that shows greater lateral and spatial distribution in the area, is equivalent of Qhar Formation in Kuwait and Iraq countries (Adams, 1969). The Kalhur Member characterizes the base of the formation (basal anhydrite) in places and is composed of gypsum and anhydrite facies with intercalations of marl and claystone (James & Wynd, 1965). The great role of structural traps in petroleum geology of the region has overlooked the stratigraphic traps and other less important types. Since the stratigraphic traps are mostly the result of facies diversity in time and space (e.g. Gerard, 2009; Nikrouz *et al.,* 2017; Dolson *et al.,* 2017) this study aims to investigate such diversity in the Asmari Formation in a regional scale. The results are believed to provide a good basis for further detailed investigations on stratigaraphic traps in local and regional scales.

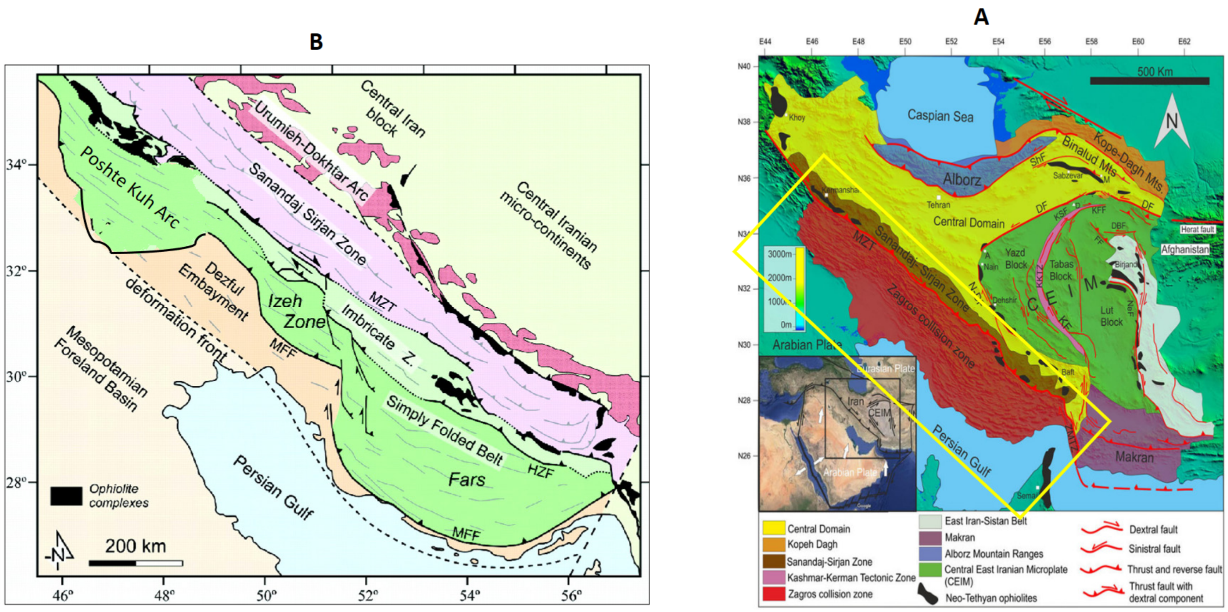

Figure 1. A: The main Tectonostratigraphic zones of Iran and position of the Zagros mountain range (After Tadayon *et al.*, 2018). B: The main structural zones of the Zagros and position of the studied zones (After Casini *et al*., 2011).

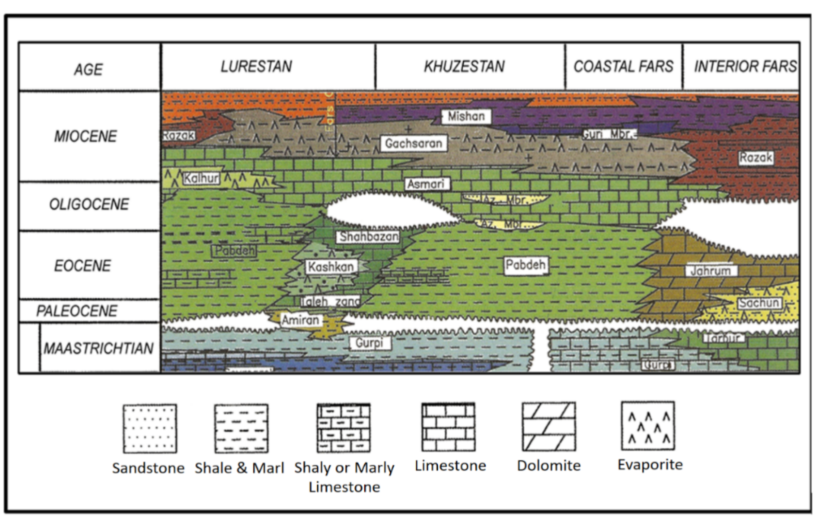

Figure 2. Stratigraphic position of the Asmari Formation and its two main members, i.e. Ahwaz sandstone and Kalhur evaporate in the Zagros range (After Motiei, 2001)

Methods and Materials:

All usual subsurface data (cores, cuttings and logs) from more than 200 wells of 68 oilfields are used for this study. In this regard ~ 1000 log data (Gamma Ray, Sonic, PEF, CNT, and FDC), ~ 200 porosity and permeability measurements and more than 800 thin sections from the cores were examined. Moreover, data from best outcrops of the formation in the Zagros region are included. Graphic well logs, palaeologs, petrographic results from cores and cutting, petrophysical data, and all geological reports on the Asmari Formation are included in this investigation. Combination of results from surface and subsurface data are used for establishing isolith and isopach maps of the studying members and the whole formation. To draw the isopach and isolith maps, the data were extracted from the petrophysical well logs and the Surfer software version 15 was used to plot and georeferencing these maps. All maps were edited by the Paintnet version 4. 0. 21 and the well correlation charts were made by the Strater version 5. Due to the lack of geophysical data in regional scale, the study is mainly focused on the logs and petrophysical data.

Results:

Results from structural studies in the region (Sepehr & Cosgrow, 2002, 2005) indicate the role of various faults on accommodation development of the Asmari Formation. These faults are related to three major fault zones, i.e. Izeh, Balarud and Hendijan, which are considered as the main structural controls on sedimentation (Figs. 3 and 4).
Sedimentation and deformation of the Phanerozoic sedimentary cover in the Zagros basin has been strongly influenced by the re-activation of the old tectonic texture in the basement (Bahroudi & Talbot, 2003).

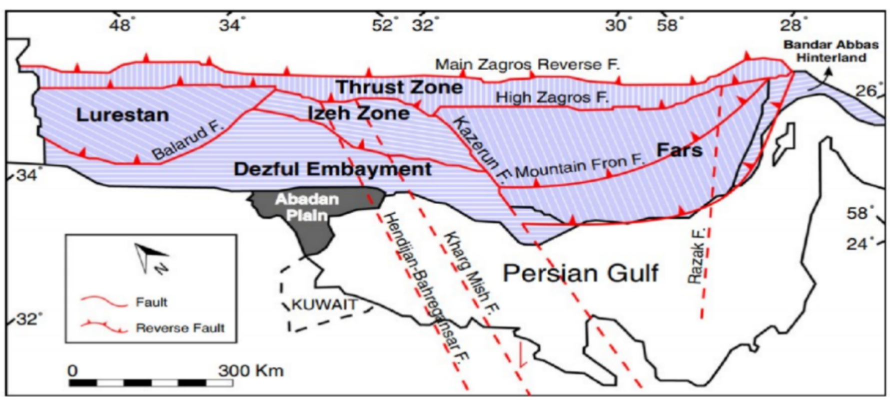

Figure 3. The main fault zones that are considered as structural controls on sedimentation of the Asmari Formation in the studied area (Sherkati & Letouzey 2004).

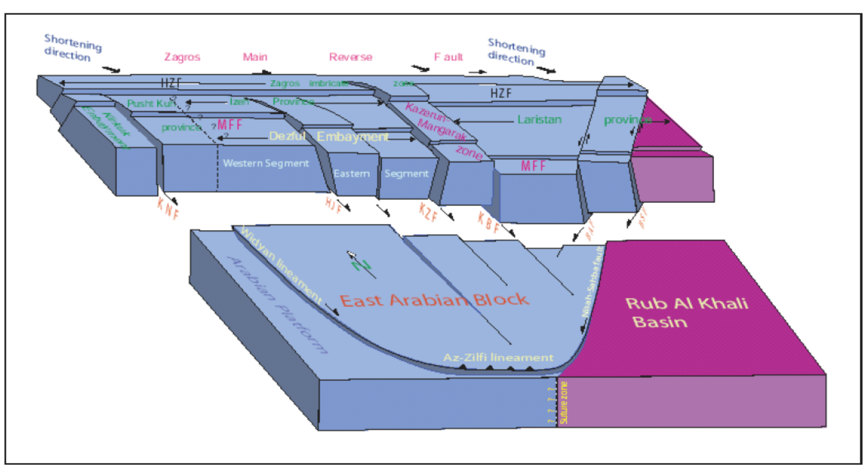

Figure 4. Morphology of the Zagros basement surface and Arabian plate based on data from structural and tectonic deformations in the area (Bahroudi & Talbot 2003). HZTF = Zagros Thrust Fault; MFF=Mountain Front Fault; BSF= Bostaneh Fault; BAF=Bastak Fault; KBF= Kareh Bas Fault; KZF = Kazerun Fault; HJF=Hendijan Fault; KNF=Khanqin Fault.

The old faults have been re-activated due to the creation of new faults that resulted from Zagros shortening in the sedimentary cover (Bahroudi & Talbot, 2003). Study of dispersion and mechanism of the faults in the region has shown their special role in decreasing the thickness of sediments above the basement (Haidari, 2008). The paleohighs of Kuhe Mish, Kuhe Bengestan, Pazanan and Haftkel are also stated significant factor in changing the whole or part of the sedimentary thickness and rotation/torsion of the structures in the area (Nazaraghaie, 1986). In this regard, local and regional structural deformations in the Zagros regions seem the main controls on stratigraphic and combined stratigraphic-structural traps development. Depth of boundary surfaces of the Asmari Formation in the studied wells is mapped for better analysis of the structural deformations during and after its deposition. The upper surface of the formation constantly occurs beneath the evaporate layers of the Gachsaran Formation. The greatest depth for upper surface of the formation is recorded in central part of the northern Dezful Embaymentn, from where the depth of the upper surface decreases toward northwest. In the Abadan Plain a gentle deepening of the upper surface depth from south-southeast to north-northwest is observed (Fig. 5).

The base of the Asmari formation frequently occurs on top of the Pabdeh and infrequently on top of the Jahrum (west and east of the southern Dezful Embayment and west of the Abadan Plain) and Shahbazan (NW of northern Dezful Embayment) formations (Fig. 6). Similar to the upper surface, depth of the lower surface in Dezful Embayment and Abadan Plain decreases toward the north and norteast.

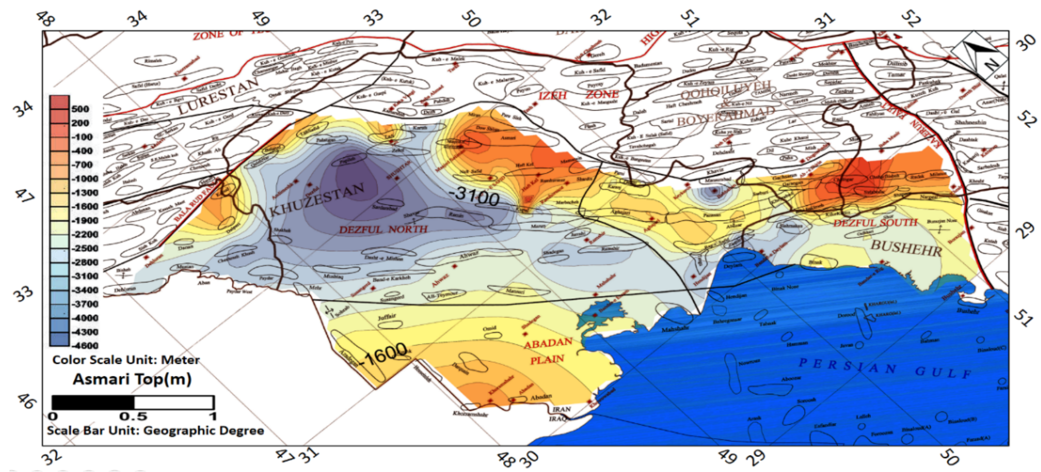

Figure 5. The UGC map of the Asmari top in Dezful Embayment and Abadan Plain.

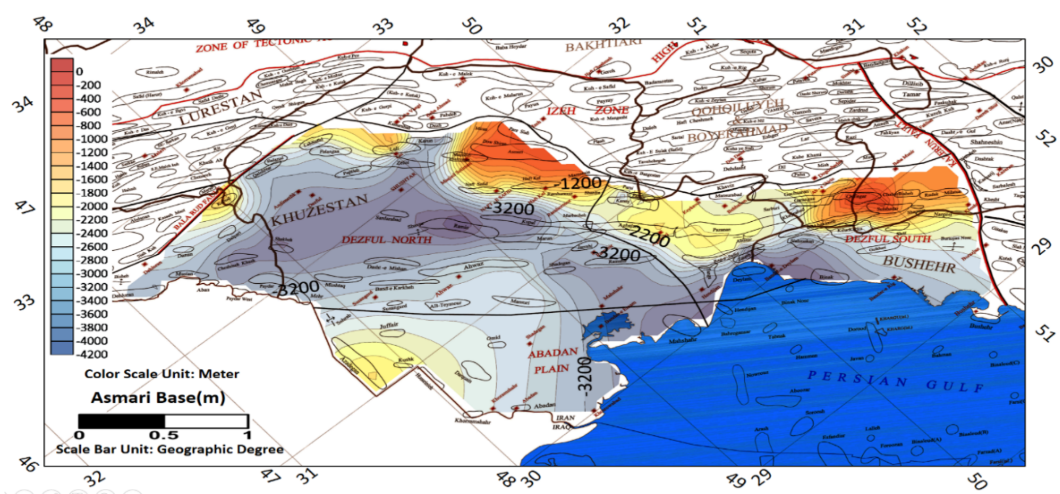

Figure 6. The UGC map of the Asmari base in Dezful Embayment and Abadan Plain.

The isopach map of the Asmari formation in the studied area is presented in Fig. 7. In general, the formation show smaller thickness where occurs on top of the Jahrum and Shahbazan formations (i.e. Abadan Plain and south part of the southern Dezful Embayment). This is partly related to the presence of an erosional unconformity in these places (Motiei, 1993).

The established isopach map for the Ahwaz Member (sandstone facies) shows its development mostly in the northern Dezful Embayment and Abadan Plain. This member is less common in the southern Dezful Embayment oilfields (Fig. 8). Correlation of this map with that of Asmari upper surface depth (Fig. 5) shows the greater thickness of the sandstone member in places with greater depth of the upper surface.

The established isopach map of the Kalhur Member (evaporite facies) shows its development largely in north part of the northern Dezful Embayment. This member is rarely observed in southern Dezful Embayment (Karanj and Parsi oilfields) and is absent in the Abadan Plain (Fig. 9).

The porosity variation of the Asmari formation in the studied area is prepared based on the total porosity values extracted from logs data (Fig. 10). Based on this map the porosity of the formation is significantly reduced to the northern and eastern parts of the Dezful embayment. Comparing of this map with those of facies distribution (Figs. 8 and 9) indicates a fair correlation with the sandstone abundance.

To investigate the spatial distribution of the two studied members and their constituent facies, lithological logs of the formation in various oilfields are determined through six W-E to SW-NE trending cross sections (Figs. 11-17). Representative wells from each field with the best comprehensive data are selected for this purpose.

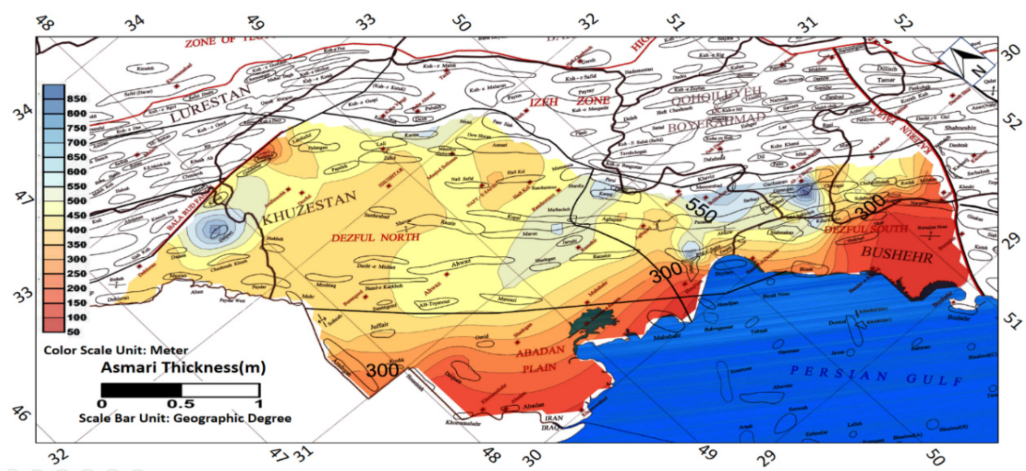

Figure 7. The isopach map of the Asmari Formation in Dezful Embayment and Abadan Plain.

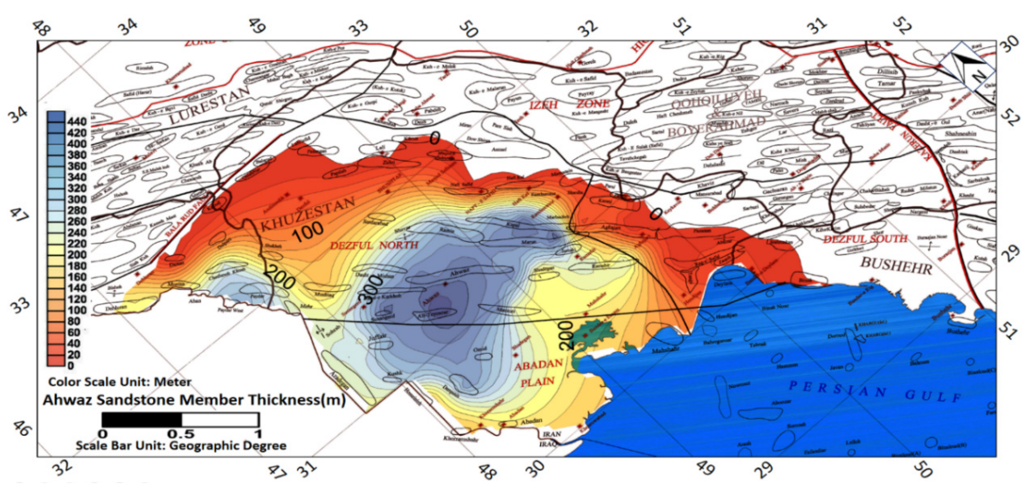

Figure 8. The isopach map of the Ahwaz sandstone Member in Dezful Embayment and Abadan Plain.

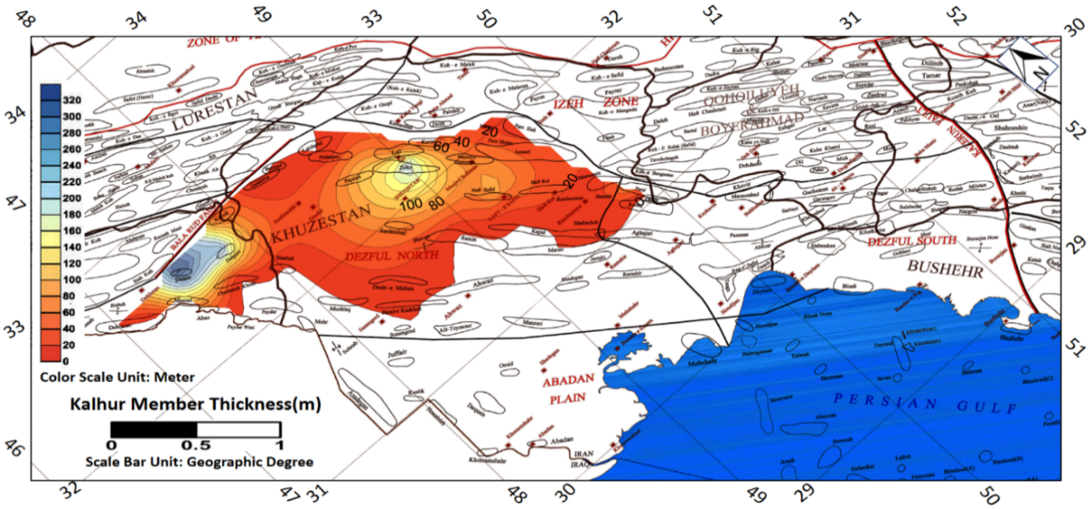

Figure 9. The isopach map of the Kalhur evaporate Member in Dezful Embayment and Abadan Plain.

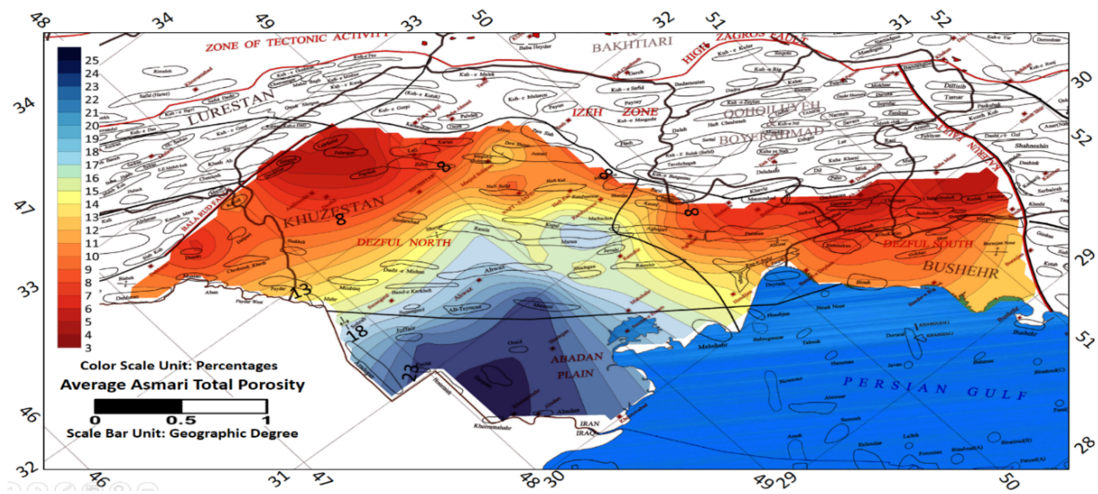

Figure 10. Total porosity variation of the Asmari Formation in the studied area.

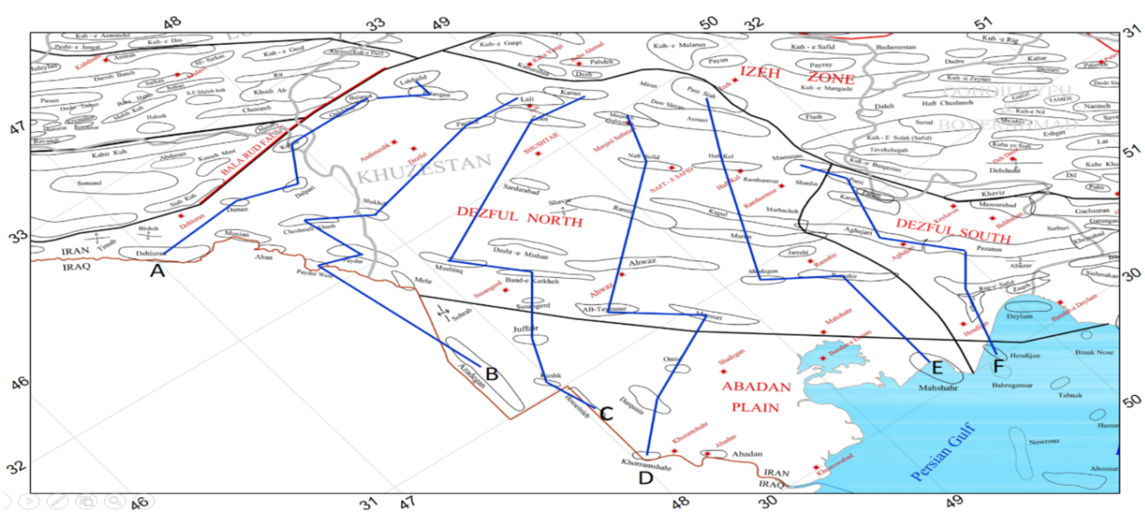

Figure 11. Position of the cross sections and oilfields from which data are used for construction of lithological logs.

The cross section A represents lithological logs from DH-1, DA-5, DP-3, KD-1, QR-1, BD-1, PL-1 and LS-1 wells (Fig. 12). Various substrate layer of the formation is seen in this section.

The cross section B with S-N then W-E trending represents sedimentological logs from AZN-76, PYW-3, PY-1, CK-6, SKH-2, PH-1 and LL-20 wells (Fig. 13). Various substrate layer of the formation is seen in this section.

The cross section C with S-N then W-E trending represents lithological logs from HOS-1, KSK-1, JF-5, SD-2, BKH-4, MQ-1, ZE-1 and KN-5 wells (Fig. 14). Various substrate layer of the formation is seen in this section.

The cross section D with nearly SW-NE trending represents Lithological logs from KM-1, DN-1, OD-1, MI-90, AT-48, AZ-449, RN-7, NS-43 and MIS-315 wells (Fig. 15). Various substrate layer of the formation is seen in this section.

The S-NE trending cross section E represents lithological logs from MR-1, RR-2, SG-26, MN-224, KL-27, HK-61 and PS-2 wells (Fig. 16). Various substrate layer of the formation is seen in this section.

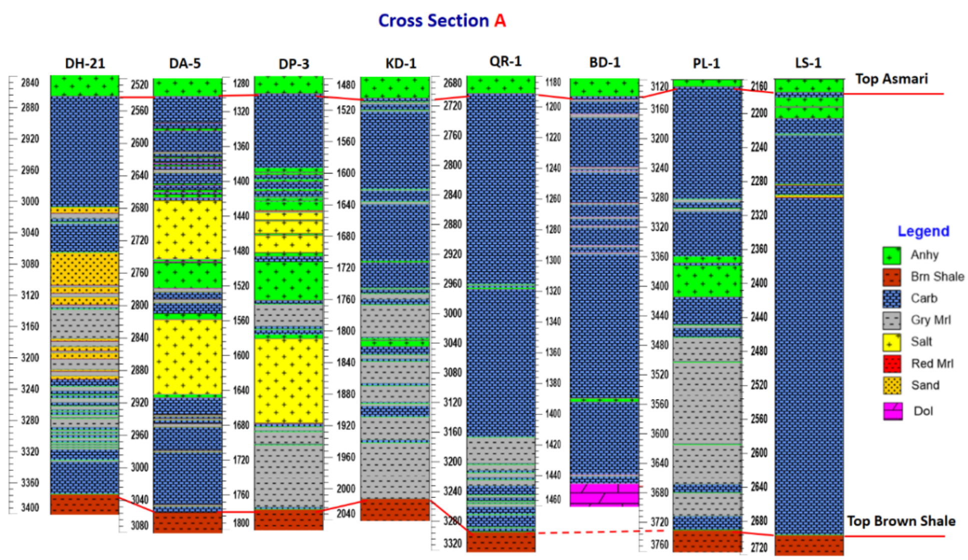

Figure 12. Lithological logs of the formation throughout the cross section A (see Fig. 11 for location). Brn. = Brown, Carb. = carbonate, Mrl. = Marl

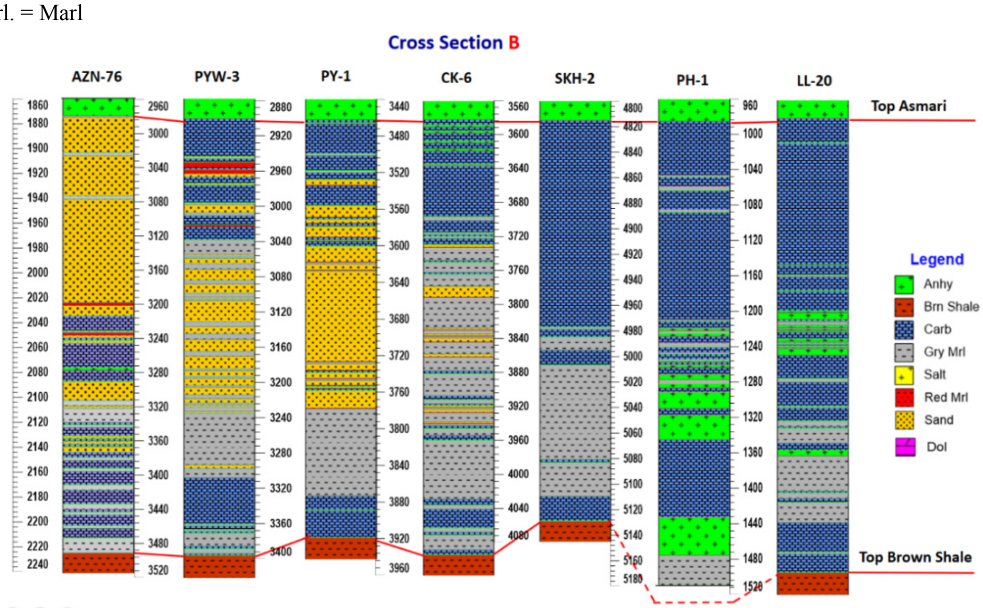

Figure 13. Lithological logs of the formation throughout the cross section B (see Fig. 11 for location). Symbols are similar to those of Fig. 12.

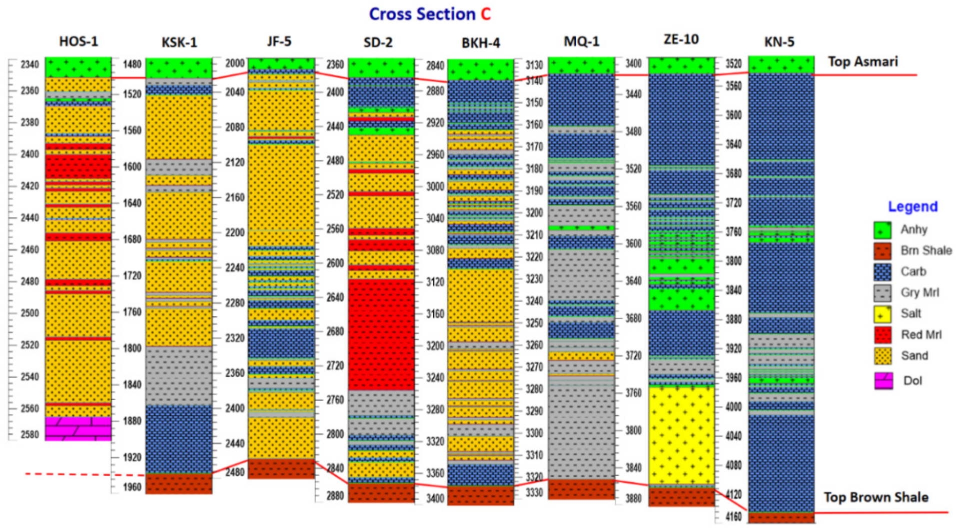

Figure 14. Lithological logs of the formation throughout the cross section C (see Fig. 11 for location). Symbols are similar to those of Fig. 12.

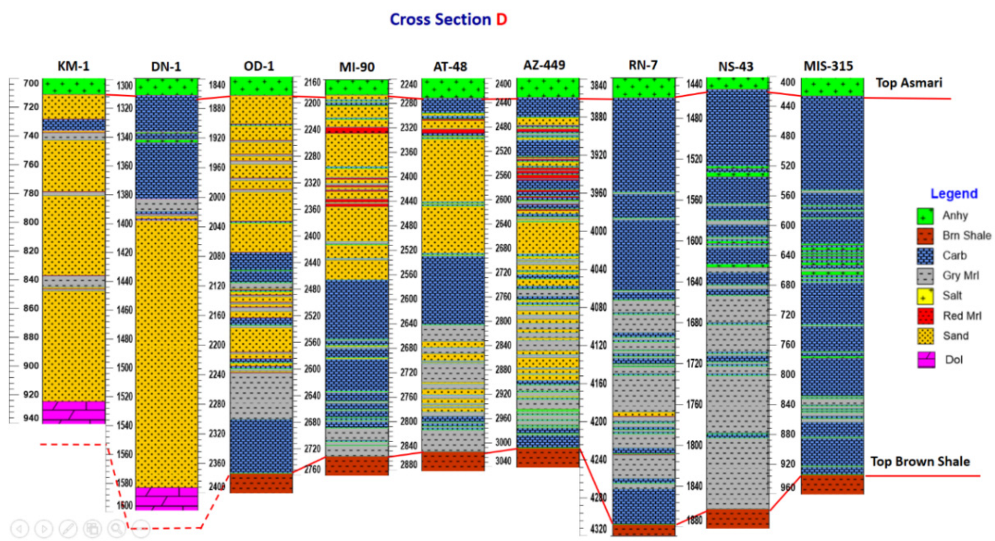

Figure 15. Lithological logs of the formation throughout the cross section D (see Fig. 11 for location). Symbols are similar to those of Fig. 12.

The cross section F with nearly SW-NE trending represents lithological logs from HE-6, TU-1, RS-186, PZ-124, AJ-187, KR-31, PR-4 and MA-10 wells (Fig. 17). Various substrate layer of the formation is seen in this section.

Discussion:

Tight association of the members distribution (in time and space) (Figs. 8 and 9) with dispersal pattern of the faults (Figs. 3 and 4) and depth of the surfaces boundaries (Figs. 5 and 6) indicate the major role of structural deformations (subsidence and uplift) on development of the studied members. This is in agreement with the findings of structural/tectonic studies in the area (e.g. Sepehr & Cosgrow, 2002, 2005). In other words the facies variation of the formation in the studied area was mostly affected from structural deformations, rather than eustatic controls. In this regard detailed structural analyses of the area would be vital in the study of stratigraphic traps.

Based on the provided maps the oilfields in the border of northern Dezful Embayment and Abadan Plain are more susceptible for development of the stratigraphic traps. Although based on available evidences, it seems that facies changes followed by Zagros folding and faulting caused creation of combination traps.

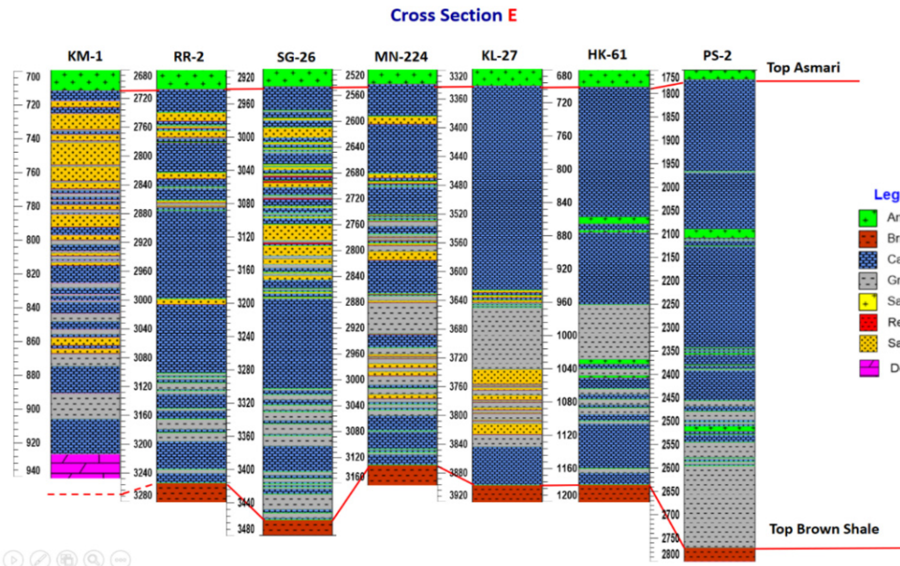

Figure 16. Lithological logs of the formation throughout the cross section E (see Fig. 11 for location). Symbols are similar to those of Fig. 12.

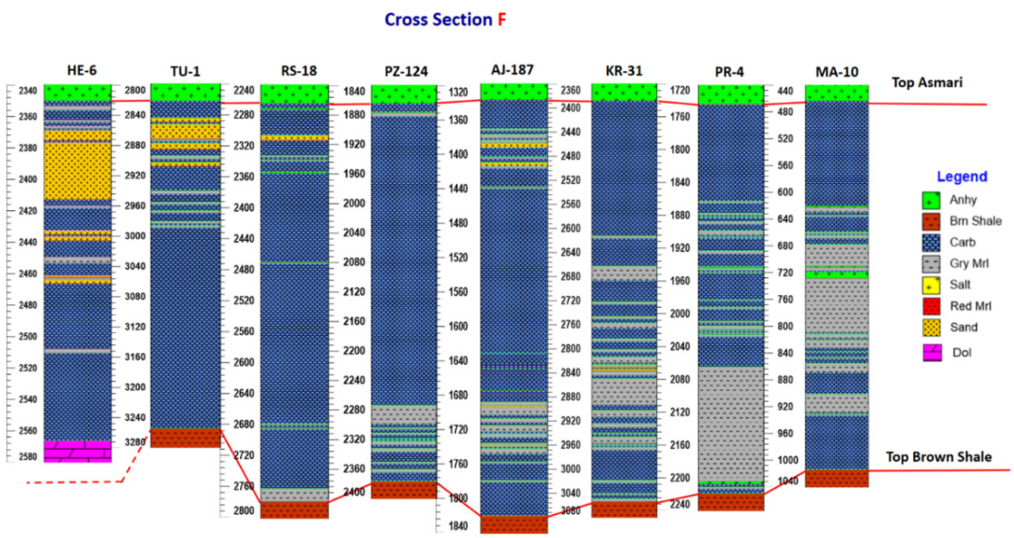

Figure 17. Lithological logs of the formation throughout the cross section (see Fig. 11 for location). Symbols are similar to those of Fig. 12.

Based on the Kalhur Member distribution pattern (Fig. 9), the fields in the northwest borders of the northern Dezful Embayment are more susceptible for development of the stratigraphic traps. This is due to the seal capacity of the member for stratigraphic traps. Where the Asmari Formation occurs on the Jahrum and or Shahbazan formations, e.g. Hendijan, Khorramshahr, Darquin, Hoseinieh and Balarud oil fields, crossing and storage of hydrocarbon is more simple than places where it occurs on top of the Pabdeh brown shales. This is well understood from porosity variations of the formation in the studied area (Fig. 10).

Results from distribution of the main facies in time (lithological logs) and space (described cross sections) provide further information on the best susceptible places for stratigraphic traps. Considering the facies distribution throughout cross section A (Fig. 12), the studied wells of Dehluran (abundant sandstone facies), Danan and Dalpari fields (abundant evaporate facies) have more potential for stratigraphic traps development. This is due to the presence of more porous facies (e.g. sandstones), greater structural deformation of the region and distribution pattern of the seal horizons (Evaporite facies). In cross section B, the studied wells of Paydar and Cheshmeh-Khosh fields have more potential for such a purpose, beacause of their sandstone facies components (Fig. 13). Compared with Payedar and Cheshmeh-Khosh, the greater amount of the carbonate facies in the Shakheh field and evaporate facies in the Papileh and Lali fields provides some potential for the stratigraphic traps in the last three fields. Facies distribution of the formation throughout the section C (Fig. 14) indicates the best potential for development of the stratigraphic traps in the Bande Karkheh (sandstone facies) and Moshtagh and Zeloi fields (evaporate facies).

On the basis of the facies distribution and their variety, the Ahwaz oilfield (for variety of sandstone facies) and Marun, Masjid Soleyman and Nafte-Sefid oilfields (for variety of carbonate and evaporite facies) have the best potential for stratigraphic traps development throughout the cross section D (Fig. 15). Facies distribution in the formation throughout the cross section E (Fig. 16) shows that the Kupal oilfield (for variety of sandstone facies) and Haft kel field (for variety of carbonate and evaporite facies) have the best potential for stratigraphic traps development. Similarly the best stratigraphic trap development is induced for Hendijan and Tangu oilfields throughout the cross section F, based on their constituent facies variety and abundance (Fig. 17). Due to the significant role of seismic data on the identification of stratigraphic traps, geophysical investigations including 3D seismic data collecting in the susceptible fields are highly recommended.

Conclusions:

Variation in thickness, lateral distribution and major facies content of the studied formation provide a good basis for choosing the fields with best stratigraphic traps potential. Such a study bids some places for further geophysical investigations and more detailed studies. Due to the role of unconformities on the stratigraphic traps development, analysis of the substrate formations (Pabdeh, Jahrum and Shahbazan formations) is very important in such a study. The lateral and spatial distribution of the two studied members and the whole formation fairly correlates with the depth of the Asmari upper surface. Such a correlation indicates the significant role of the structural deformations (bounding faults activity) during and after deposition of the Asmari Formation. In other words the distribution of the sandstone and evaporate members were a function of the basement subsidence/uplift, so structural controls. In this regard, in palaeo-environmental and sequence stratigraphic studies more emphasis should be taken on the medium to small scale cycles/sequences rather than medium to large scale ones. Combination of results from isopach maps, lithological logs (vertical distribution of facies), cross sections (lateral distribution of the facies) and their correlation with the porosity variation indicate the main entrance of the sandstones from southwest of the studied area.

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References

Adams, T. D., 1969. The Asmari Formation Of Lurestan And Khuzestan Provinces, IOOC Report, No. 1154 (Unpublished).

Alavi, M, 2007.Structures of the Zagros fold-thrust belt in Iran, American Journal of Science, 307: 1064–1095

Bahroudi, A. And Talbot, C.J., 2003. The Configuration of the Basement beneath the Zagros Basin. Journal of Petroleum Geology. 26: 257-282

Bordenave, M. L. And Hegre, J. A., 2006. The influence of tectonics on the entrapment of oil in Dezful embayment, Zagros fold belt, Iran. Journal of petroleum geology. 28(4): 339–368

Bordenave, M. L. And Hegre, J. A., 2010. Current distribution of oil and gas fields in the Zagros fold belt of Iran contiguous offshore as the result of the petroleum systems. Geological society, London, special publication. 330: 291-353

Casini, G., Gillespie, P. A., Verges, A., Romaire, I., Fernandez, N., Casciello, E., Saura, E., Mehl, C., Homke, S., Embry, J. C., Aghajari, L., And Hunt, D. W., 2011. Sub-seismic fractures in foreland fold and thrust belts: insight from the Lurestan Province, Zagros Mountains, Iran. Petroleum Geoscience. 17: 263–282

Dinh, C., Van, T., Quang, H., Van, C., Quoc, T., Van, X., 2017. Applying seismic stratigraphy analysis for assessing upper Oligocene stratigraphic traps in Southeastern Cuu Long Basin. Science and Technology Development Journal. 20: no.K4.

Dolson, J., He, Z. And Horn, B., 2017. Advances and Perspectives on Stratigraphic Trap Exploration-Making the Subtle Trap Obvious. Oral presentation given at AAPG 2017 Middle East Region Geosciences Technology Workshop, Stratigraphic Traps of the Middle East, Muscat, Oman.

Gerard, J., 2009. Stratigraphic Traps: Quantitative Approach Based upon A Producing Field Database, poster presentation at AAPG Annual Convention, Denver, Colorado, June 7–10

Haidari, Kh., 2008. Identification of the geological features of different Asmari reservoir sectors in Bibi-Hakimeh oil field with a special attention to the effects of building features. National Iranian south oil company, Report No. 6439.

James, G.A. and Wynd, J.G., 1965. Stratigraphic Nomenclature of Iranian Oil Consortium Agreement Area. American Association of Petroleum Geologists Bulletin. 49: 94–156

Mac Cord, D. R. 1974. Regional Geology Of The Asmari Of Ahwaz And Marun Areas(Unpublished).

Moradian, F., Baghbani, D., Allameh, M., 2017. Microbiostratigrapy of the Paleocene-Lower Eocene Sequences in the Bibi Hakimeh 2 Subsurface Section Located in the SW of Iran, Open Journal of Geology.7: 147–167

Maghsoudi, M. And Sherkati, S., 2000. Zagros Structure Index Map. National Iranian Oil Company, Exploration Directorate, Geology Division.

Motiei, H., 1993. Geology of Iran: Stratigraphy of Zagros. Geological Survey of Iran Publication, Tehran, 583.

Motiei, H., 2001. Simplified Table of Rock Units in Southwest Iran. Keyhan Exploration and Production Services, Tehran.

Nazaraghaei, A., 1986. The effect of Cenomanian – Turonian unconformity in Ragesafid and adjoining oil fields in relation to Hendijan paleohigh. National Iranian south oil company, Report No. 4006.

Nikrouz, R. Siabeghodsi, A. And Hassanalizadeh, P., 2017. Detection of stratigraphic trap of Sarvak formation using petrophysical logs and seismic attributes in one of the oil fields in the south west of Iran. Tehran University, Journal of the Earth and Space Physics. 43 (1): 1–5

Richardson, R. K., 1924. The Geology And Oil Measures Of South-West Persia, Reprinted From The Journal Of The Institution Of Petroleum Technologists. 10: 43.

Sepehr,, M, And Cosgrove, J. W., 2002. The major fault zones controlling the sedimentation,deformation and entrapment of hydrocarbon in the Zagros fold-thrust belt, Iran, AAPG Annual Meeting, Houston, Texas.

Sepehr,, M, And Cosgrove, J. W., 2005. Role of the Kazerun Fault Zone in the formation and deformation of the Zagros Fold-Thrust Belt, Iran, Tectonics, 24.

Sherkati, S. And Letouzey, J., 2004. Variation of Structural Style and Basin Evolution in the Central Zagros (Izeh Zone and Dezful Embayment) Iran. Marin and Petroleum Geology. 21: 535–554

Tadayon, M., Rossetti, F., Zattin, M. And Khodabakhshi, P., 2018. The long–term evolution of Dorouneh fault region (Central Iran): A key to understanding the spatio-temporal tectonic evolution in the hinterland of the Zagros convergence zone. Geological Society; Manchester Geological Association, Wiley.

Wynd, J.G., 1965. Biofacies Of the Iranian Oil Consortium Agreement Area. Iranian Oil Offshore Company Report 1082, (Unpublished).