

## Basement Faults and Their Relationships to Salt Plugs in the Arabian Platform in Southern Iran

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### Abstract:

The Arabian Platform containing the Zagros Mountain Ranges (ZMR) is located to the northeast of the Arabian Shield. There are nearly 200 salt domes on the Arabian Platform. The structural analysis of landsat satellite data proves the existence of three groups of structural elements:

-those resulting from the folding of the ZMR?

-those resulting from the solution processes within the evaporitic formation, especially in the Hormuz Formation in the deeper underground?

-those resulting from the regional strike - slip faults of the basement.

Bending of anticlines in the competent cover rock, combined with minor strike-slip faults and horizontal displacements of parts of folded structures, strongly point to the presence of these basement faults. The salt plugs, which have pierced cover rocks of up to 10000m thick, are distributed on the Arabian Platform along regional basement faults. The area of diapir outcrops is bounded by the Oman Line to the east and by the Kazerun Fault to the west. The basement has been broken and thrust to the southern border of the ZMR. Pieces of the basement have been brought up to the surface on some of the salt domes. The fragments were transported by rotational ascent of the Hormuz Salt Formation to the present and former land surfaces. Sinistral and dextral basement faults are interpreted as antithetic and synthetic Riedel Shears which confine major blocks of the northeastern edge of the Arabian Plate, Oman Spur included. Considering the fold axes bending, the trend of the salt plugs and also the distribution of epicenters of the last 100 years, numerous new basement faults have been discovered by this investigation.

### Introduction

Although the salt domes in southern Iran, especially those around Bandar-Abbas which is called "salt dome province" have been a matter of investigations resulting in numerous publications since 1908, this paper has following innovations:

1. There have been vague ideas that the salt domes are outcropped along basement faults (Ahmadzadeh and others, 1990), basement faults already known have not been mapped correctly. Besides, most of them have been mapped in this paper for the first time (fig. 2).
2. Although there exists a map on which epicenters have been located until 1976 (Berberian, 1976), this paper shows the accurate location of epicenters of the complete last century and their relation to the basement faults.

Moreover, this paper displays the relation between basement faults and the bending of the folds and explains how the opening of the Red Sea and the Gulf of Aden have affected the trend of the old basement faults.

Previous works

The inland exposure of the Hormuz Series was first described by Pilgrim (1908, 1922, 1924), and Busk and Mayo (1918). The works of Richardson (1926, 1928) and Lees (1927,1931) marked the beginnings of modern studies of the Hormuz salt plugs, and subsequently 63 of them were mapped and described briefly by de Bockh et al in 1929. The first systematic study of these plugs was Harrison's great contribution, the results of which were published in 1930, 1931, and 1956. Kent (1958) investigated nine hitherto plugs and Later published the results of some of the most recent work on the south Iranian salt dome province (1970, 1979). These two articles are particularly significant, as they contain new information on the age of the salt and the structural setting of the plugs in relation to regional tectonics in the Persian Gulf basin. Useful contributions were made by Gansser (1960) and Ala (1974) who reviewed the geology of salt domes in various parts of Iran, including the Persian Gulf, and summarized the current ideas of their origin. Player (1969), N.I.O.C. (1977), Esfandiyari and Barzegar (1979), Stocklin and Nabavi (1975), Ahmadzadeh Heravi et al (1990), Farhoudi (1978), Farhoudi and Ghazizadeh (1993), and Farhoudi (1984) also published some of the most recent works on the South Iranian salt dome province (Fig.1).

Geological setting

The ZMR in southern Iran, located on the Iranian side of the Arabian Platform, are one branch of the Alpine-Himalayan orogenic belt. The stratigraphy and sedimentology of the Zagros Thrust and Fold belt have been described by James and Wynd (1965), by Falcon (1974), and Farhoudi (1978).The Phanerozoic column is about 12000 m thick. Paleozoic sedimentation was mainly epicontinental; from Permian to Miocene time it consisted chiefly of carbonates. The Tethys Sea began to subducted under the Iranian Plat in the Late Cretaceous. Cessation (Ross and others, 1973) or slowing of subduction resulted in carbonate sedimentation in Early Cenozoic time (Farhoudi, 1978) as well as the deposition of 400m evaporitic materials in the Miocene. Orogenic movements began in the Middle or upper Miocene when sedimentation became clastic. The opening of the Red Sea intensified folding and uplift, which are still going on. Most of the salt diapirs are located in the southeastern part of Fars Province, especially near Bandar Abbas (Figure 1).The diapir field is bounded by the Oman

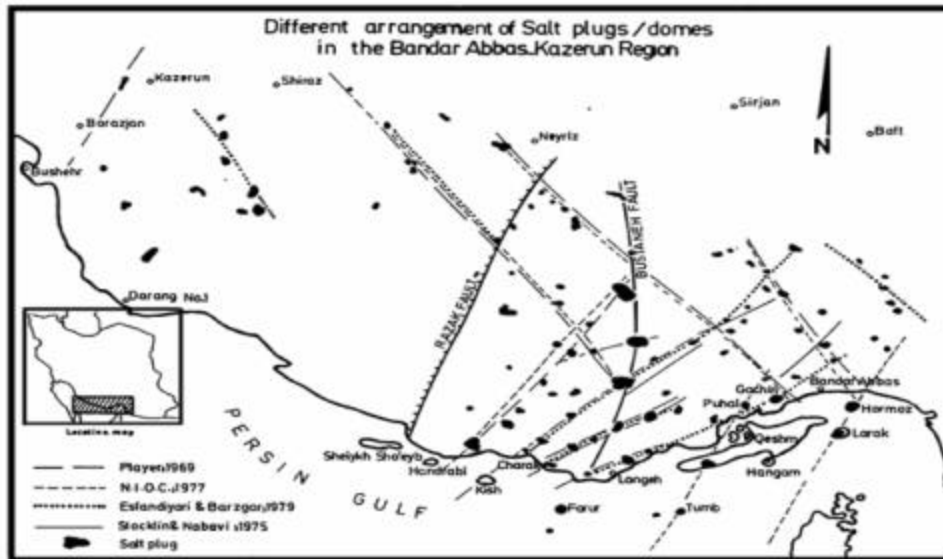


Figure 1.

Line to the east, the Kazerun Fault to the west, and the Main Zagros Thrust to the north. Only a few salt diapirs reach the surface northwest of the Kazerun Fault near the Main Zagros Thrust, they occur in great number in the form of small islands in the Persian Gulf, south of the boundary of the Zagros Folded Belt (Ala, 1974).

The presence of numerous salt domes, mainly of the Paleozoic Hormuz Formation, indicates active tectonics of the ZMR. Although salt domes have been reported in many places of the world, e.g. to the north of the Gulf of Mexico in the USA and in the northern part of Germany, most of them are not outcropped and have been detected by geophysical methods. In contrast to them salt domes in the

ZMR and in the Persian Gulf are not only high elevated domes, but in many cases the salt is flowing down the flanks as “Salt Glacier”.

Some of the salt domes are more than 1000 m higher than the surrounding area, e.g. Kangan salt dome. Some of them have been used as open cast mines. It’s more soluble than limestone and in contrast to the latter; it has plastic behavior and impede the flow of fluids. The Tertiary Gachsaran Formation, consisting mainly of salt, anhydrite and marl layers, acts as one of the best cap rocks of hydrocarbon in the Middle East.

The structure of the Zagros Thrust and Fold Belt consists of numerous, mostly northwest trending synclines and Anticlines. Steep flanks on most individual structures face southwest (Falcon, 1969). Dextral displacements have been reported on faults parallel to the Main Zagros Thrust between 33°-35°N (Tchalenko and Braud, 1974) and on the Kazerun Fault (Falcon, 1974). The near-basement salt and Miocene salt play a major role in the morphology and structure of the Zagros Thrust and Fold Belt. These salts cause disharmonic folding and do not permit sub-salt structures to continue upward.

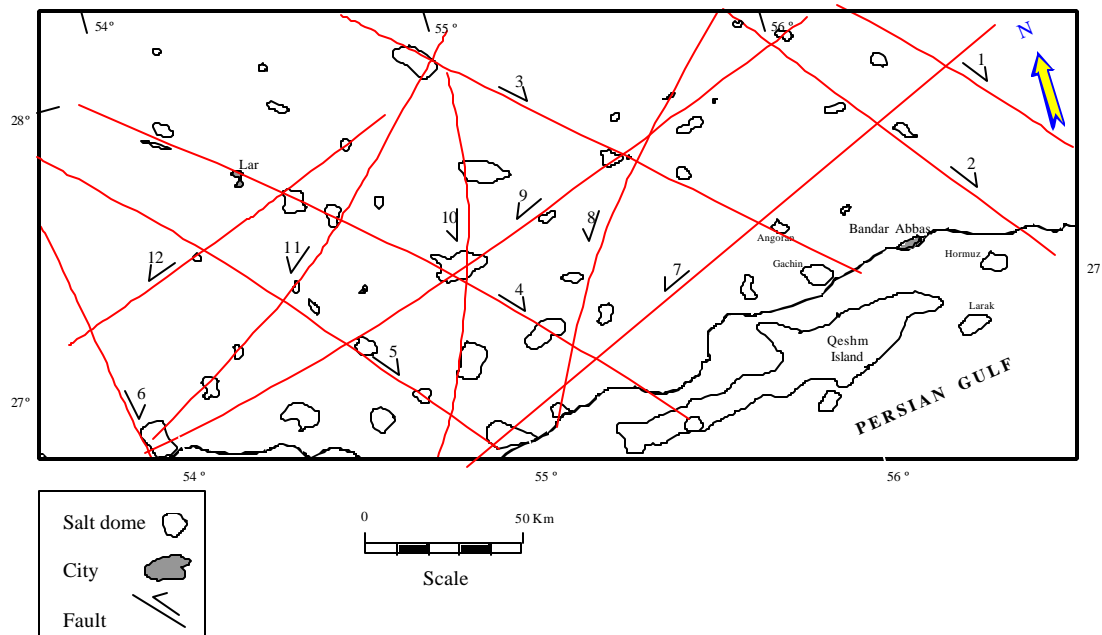
Earthquakes epicenters

The distribution of epicenters of the last century and the salt plugs of the area are studied. These earthquake epicenters are gathered tensely in special regions that probably show the development of basement faults in three directions (NW-SE, N-S, NE-SW). Most of these trends are conformed with the ones gained from the study of axis deviation of anticlines and synclines and with the trend of the salt plugs as well as that are shown in figure 2.

Discussion:

12 strike slip faults are recognized in the study area (Figure 2). Some of these faults could have important role in forming of pull a part basin for uplift of salt domes. They are as follows:

Figure 2. Trend of postulate basement faults in the study area



Fault No. 1: This dextral strike slip fault with 147° azimuth, deviated the axes of Forgun, Neyzeh and Kushkuh anticlines as well as displaced some features and caused linear outcropping of salt plugs specially in Kushkuh.

Fault No. 2: This dextral strike slip fault with 139° azimuth has caused deviation of the axes of Muran, Finu, Baz, Handun and Namak anticlines. The rotation of Muran anticline is an interesting feature of the previous activity of this fault. Several salt plugs are outcropped in this fault’s trend such as Handun and Namak salt plugs.

Fault No. 3: This strike slip fault with 135° azimuth causes deviation in the axes of Gachin, Gashu, Guniz, Muran, Bundasht, Shemilu and Shab anticlines. There are six salt plugs such as Anguran in the trend of this fault. Trust faults in Bundasht anticline, probably are formed by this fault.

Fault No. 4: This fault with 135° azimuth has caused right lateral offset of the axes of some of anticlines such as Kuh-e Kohneh, Pishavar, Gach, Burkh, Nakh and Champeh. There are seven salt plugs such as Kermostaj in Gach anticline, Bam and Namakdan in Qeshm island, which are outcropped in the direction of this fault. To the southeast, this fault may cross Tonbe Bozorg salt plug. In Kohneh anticline, it creates some minor faults parallel to itself and some of them to the axis of Kohneh anticline. Because of the activity of the minor faults, recognition of the anticlinal axis is very hard at this part of the anticline. This fault has created some minor faults parallel to itself by crossing Nakh anticline.

Fault No. 5: This dextral strike slip fault has caused deviation of the axes of Bostameh, Champeh, Herang, Nakh, Gavbast and Paskhand anticlines. It also displaced the axis of Nakh anticline and syncline, which is located between Gavbast and Nakh anticlines. This right lateral displacement is very clear in Asmary, Jahrom, Gachsaran and Guri Formation at the northwest limb of Nakh anticline. Exposure of salt domes at the east and northeast of Bastak could be related to this fault's activity. These are several salt plugs such as Kildun, which are outcropped at the direction of the fault in 140° azimuth. Kildun salt plug has a sharp fault boundary parallel to the fault direction. Cutting of Bakhtiari and Aghajari formations and forming sharp scraps in the salt plugs are also evidence of this fault activity. To the southeast, this fault may cross Tonbe Bozorg salt plug.

Fault No. 6 This strike slip fault in 167° azimuth crosses Chiru salt plug and causes a deviation the axis of some anticlines such as Chiru, Lavarestan, Gavbast (also, there is about 10 km right lateral offset in this anticline axis) and Bavash in right lateral sense of motion. Also, there is some minor faults parallel to the major fault (Fault No. 1) which is formed as the result of this fault activity. These minor faults specially could be seen in the Lavarestan, Gavbast and Bavash anticlines. Existence of erosion and collapse structures parallel to this fault trend, in Gavbast and Bavash anticlines could be related to this fault activity too. Minor faults trend and the pattern of erosion in Gavbast anticline, increase the possibility of a hidden salt plug in this area.

Fault No. 7: This fault with 80° azimuth, has caused deviation of the axes of Bostameh, Ashuru, Champeh, Khamir, Shab, Genow, Guniz, western end of Namak, eastern end of Handun, Neyzeh and eastern end of Furghun. Eight salt plugs outcropped in its trend.

Fault No. 8 This sinistral strike slip fault with 36° azimuth, has a concavity in its trend, to the east. It has deviated Muran, Shab, Ilicheh, Champeh and eastern end of shemilu anticline axis. Outcropping of several salt plugs such as Homeiran in the trend of this fault and creating minor faults special in Muran and Ilcheh anticlines, are considerable.

Fault No. 9 This fault with 76° azimuth, causes laterally displacement in the axes of Baz, Shab, Bam, Nakh, Herang, Namaki and Chiru anticlines and crosses in the southwestern part of it to Hendurabi island. Seven salt plugs are outcropped in its trend such as Bam and Shab salt plugs. This fault has created several minor faults special in Baz, Shab, Bam and namaki anticlines. It have deviated the axis of Shab anticline in 60° and has created some clear minor faults there and also outcropping of shab salt plug in this anticline could be related to this fault activity. Five kilometers displacement in the axis of Nakh anticline and creating several minor faults in circular form, maybe resulted to a hidden salt plug there.

Fault No. 10: This sinistral strike slip fault 14° azimuth is concave to the west. It has started in the north from the western end of Dasht-e Kanar and has deviated the axes of Qaleh Shur, eastern end of Chahal, anticlines. Seven salt plugs have outcropped in its trend. Fault controlled edge of a salt plug located in Herang anticline and the minor faults in Bam salt plug are some evidences for this fault activity. This fault may pass Farur Bozorg and Farur Kuchak islands.

Fault No. 11: Deviation in eastern end of Gach anticline axis and also the axes of Burkh, eastern end of Gavbast, eastern end of Gezeh, Kuh-e namaki and Chiru anticline outcropping of seven salt plugs in the trend of this fault, creating of several minor faults specially in Burkh and Gavbast and Sharp cutting of Bakhtiari and Aghajari formations between Gavbast and Gezeh anticlines are some evidences for this sinistral fault with 50° azimuth, which is ended to the northeast to Dasht-e namak anticline.

Fault No. 12: This sinistral strike slip fault with 67° azimuth is started from the eastern end of Kurdeh anticline. It has deviated the axis of some anticlines such as Kurdeh, Gach, west of end of Burkh, Eastern end of Paskhand, Gavbast and Dehnow. Sharp cutting in the east of Kurdeh, linear edge of Kurdeh salt plug, displacement the axis of Gach anticline, clear deviation between Paskhand and Burkh anticlines and outcropping of a salt plug there, forming minor faults specially in Kurdeh, Gach and Dehnow anticlines and outcropping of six salt plugs are some evidences for the activity of this fault.

#### Conclusion

The displacement and bending of anticlines and synclines, the location of salt domes, concentration of earthquake epicenters and the truncation of structures indicate a close relationship between basement

faults, salt plugs and epicenters. By means of all these phenomena, the location and the trend of basement faults have been accurately mapped. These basement faults are strike-slip faults which are bounded by Oman line in the east and can be interpreted as the effect of the opening of the Red Sea and the Gulf of Aden (Figure 3).



Figure 3.

#### References

1. Ahmadzadeh Heravi, M., Houshmandzadeh, A. and Nabavi, M. H. (1990), New concepts of Hormuz formation's stratigraphy and the problem of salt diapirism in south Iran, Symposium on diapirism with special reference to Iran, V.1, P. 1-22.
2. Ala, M. A., 1974, Salt diapirism in southern Iran, A. A. P. G. Bull., V. 58, No. 9, P. 1758-1770.
3. Busk, H. G. and Mayu, H. T., 1918, Some notes on the geology of the Persian oil fields, G. Inst. Petrol. Tech., V. 5, P. 3-33.
4. De Bockh, H., Lees, G. M., and Richardson, F. D. S., 1929, Contribution to the stratigraphy and tectonics of the Iranian ranges, in J. W. Gregory, ed., The structure of Asia, London, Methuen, P. 58-176.
5. Esfandiyari and Barzegar, 1979, (In Nabavi, M. H. and Sabzehi 1987).
6. Falcon, N. L., 1969, Problems of the relationship between surface structure and deep displacements illustrated by the Zagros Range, in Time and place in orogeny, Geol. Soc. London Spec. Pub.3, P. 9-22.
7. Falcon, N. L., 1974, Southern Iran: Zagros Mountains, in Mesozoic-Cenozoic orogenic belts: Data for orogenic studies: Alpine-Himalayan orogens, Geol. Soc. London Spec. Pub.4, P. 199-211.

8. Farhoudi, G., 1978, A Comparison of Zagros Geology to Island Arcs, *J. of Geology*, V.86, P. 325-334.
9. Farhoudi, G., 1984, Some morphotectonic aspect about the frequent earthquakes in the southern part of the Zagros mountains, Iran, 27<sup>th</sup> International Geological Congress, Moscow.
10. Farhoudi, G. and Ghazizadeh, M., 1993, Stages of karst geomorphology cycle in the Zagros Mountain Ranges, Iran, Proceeding of International Symposium of Water Resources in karst with special emphasis on arid and semi-arid zones, jointly organized by UNESCO and Iranian authorities, Shiraz, Iran.
11. Gansser, A., 1960, Uber Schlammvulkane und Salzdome, *Vierteljahresschr. Naturforsch. Ges. Zurich*, V. 105, P. 1-46.
12. Harrison, G. V., 1930, The geology of some salt plugs in Laristan, Southern Persia, *Q. j. Geol. Soc. London*, V. 86, P. 463-520.
13. Harrison, G. V., 1931, Salt Domes in Persia, in Symposium on Salt Domes, *J. Inst. Petrol. London*, V.17, P. 300-320.
14. Harrison, G. V., 1956, Comments on salt domes, *Geologieen Mijnbouw Gen. Verh., Geo. Ser.*, V.16, P. 131-138.
15. James, G. A. and Wynd, J. G., 1965, Stratigraphic nomenclature of Iranian oil consortium Agreement Area, *A. A. P. G. Bull.*, V.49, P. 2182-2245.
16. Kent, P. E., 1958, Recent studies of south Persian Salt plugs, *A. A. P. G. Bull.*, V.42, No. 12, P. 2951-2972.
17. Kent, P. E., 1970, The salt plugs of the Persian Gulf region, *Leicester Literary and Philos. Soc. Trans.*, V. 64, P. 56-88.
18. Kent, P. E., 1979, The mergent Hormuz salt plugs of Southern Iran, *J. Petroleum Geology*, V.2(2), P. 117-144.
19. Lees, G. M., 1927, Salzgletscher in persien, wien, *Mitt. Geol. Gesell.*, V.20, P. 29-34.
20. Lees, G. M., 1931, Salt-dome depositional and deformational problems, In symposium on salt domes, *J. Inst. Petrol. Tech. London*, V. 17, P. 259-280.
21. Lehner, E., 1944, The Persian salt formations, *India Natl. Acad. Sci. Proc.*, V.14, No.6, P. 249-258.
22. N.I.O.C. (National Iranian Oil Company), 1977, Tectonic map of Iran.
23. Nabavi, M. H., and Sabzehi, M., 1987, Geological and petrological studies on Gachin and Angoran salt plugs, Submitted to the Ministry of Industry, Report in Persian.
24. Pilgrim, G. E., 1908, The geology of the Persian Gulf and the adjoining portions of Persia and Arabia, *Mem. Geol. Survey India*, V.34, P.1-177.
25. Pilgrim, G. E., 1922, The Sulphur deposits of southern Persia, *India Geol. Survey Recs.*, V.53, P. 343-358.
26. Pilgrim, G. E., 1924, The Geology of parts of the Persian Provinces of Fars, Kerman and Laristan, *Mem. Geol. Survey India*, V.48, P. 1-118.
27. Player, R. A., 1969, Salt plug study, *N. I. O. C.*, Rep. 1146.
28. Richardson, R. K., 1926, Die Geologie und die Salzdome im sudwestlichen Teil des persischen Golfes, *Verhandl. Naturhist. Mediz. Verein. Heidelberg (NF)*, 15, 51 P.
29. Richardson, R. K., 1928, Weitere Bemerkungen zu der Geologie und den Salzaufbruchen am persischen Golf *Centralbl. Mineralogie, Geologie u. Palaontologie Abt. B.*, P. 45-49.
30. Ross, D. A. and others, 1973, Red Sea drillings, *Science*, V.179, P. 377-380.
31. Stocklin, J., 1974, Possible ancient continental margins in Iran, in Burk, C. A., and Drake, C. L., eds., *Geology of continental margins*, New York, Springer-Verlag, P. 873-888.
32. Stocklin, J. and Nabavi, M. H., 1975, Tectonic map of Iran, 1:2500000, *G. S. I.*
33. Tchalenko, J. S. and Braud, J., 1974, Seismicity and structure of the Zagros (Iran), The Main Recent Fault between 33° and 35° N, *London Philos. Trans., Ser. A.*, V. 277, P. 1-25.
34. Wolf, J. R., 1959, The geology of Hormuz Island at the entrance of the Persian Gulf, *Geologie Mijnbouw, n.s.*, V.21, P. 390-395.