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# GROUND SURFACE DEFORMATION INDUCED BY SALT DIAPIRISM IN OIL FIELD ZONES: SOME EXAMPLES IN SE ZAGROS (IRAN)

Cyrus Liaghat, Laboratoire de Géodynamique des Chaînes Alpines, ESA CNRS # 5025, Chambéry, France, Currently at Griffin Dewatering Corporation, Houston, TX; THIERRY VILLEMIN and FRANCOIS JOUANNE, Laboratoire de Géodynamique des Chaînes Alpines, ESA CNRS # 5025, Chambéry, France

The Zagros belt of Iran, which is the result of the opening and closure of Neo-Tethys, consists mostly of a thick sedimentary sequence of limestone, sandstone and shale. These layers cover highly metamorphosed rocks of the Pre-Cambrian basement. These two major units (Sedimentary sequences and metamorphosed basement) have been detached by a thick series of Hormuz evaporites with estimated thickness of 3000 ft. It consists of pure salt, Gypsum, Marnes with anhydrite and Hematite, associated with volcanic rocks (Rhyolite and Dacites).

The Hormuz evaporites, which have risen to the surface because of low density of salt and also because of Zagros lateral movements, have cut through the overlying sedimentary rocks (5 to 7 miles thickness) and have appeared on the surface as Salt Plugs. A number of the salt Plugs had reached the surface by Triassic and others reached the surface in Mio-Pliocene. During this time, the movements of salt diapirs to the surface were accelerated because of lateral movement of Zagros folding. More than 200 salt plugs are present in Zagros South and Southeast and in the Persian Gulf region. Figure 1 illustrates salt plug distributions in Zagros South and Southeast.

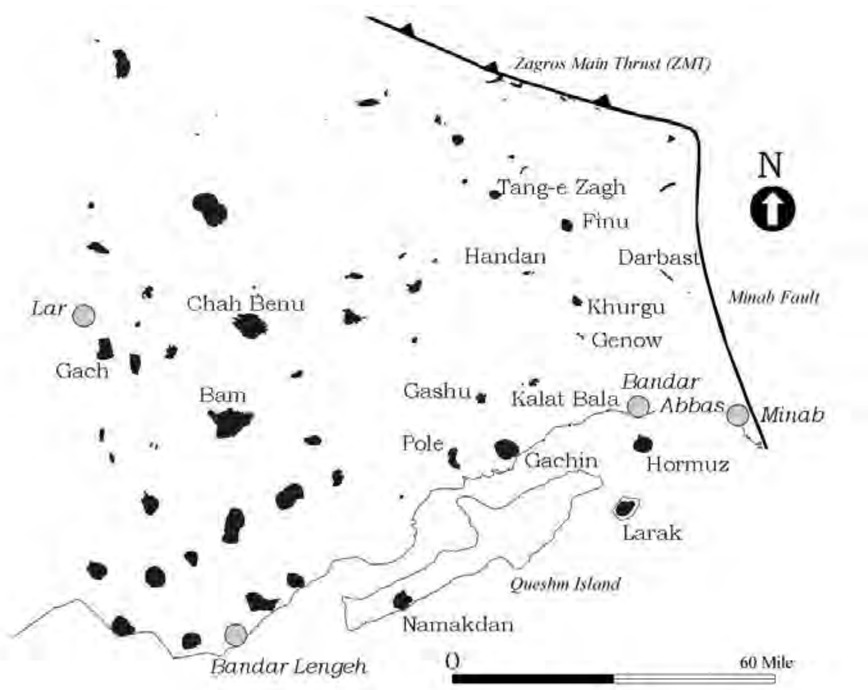


Figure 1: Hormuz salt plug distributions of Zagros South and Southeast. The location of each salt plug has been projected to this map by digitalizing of Zagros geological maps, printed by Geological Society of Iran and National Iranian Oil Company.

The diapirs generally are associated with anticlines, and in many areas pierce the structure at the plunging end or on the flanks. Diapirs outcrops in synclines also are present. In many areas the outcrop of diapirs make the spectacular white mountains of Salt, indicating that their rise has been faster than their solution near or at the surface.  At the surface, the salts flow laterally on the ground and make the Salt Glaciers (Figure 2).

Figure 2: Finu salt Glacier located in SE of Zagros.

Salt diapirism in Zagros has a very critical role in controlling the style of deformation and make the oil and gas trapped. Based on a statistical report, the 60% of recoverable oil reservoirs in the Persian Gulf basin have been formed by salt diapir movements. It shows the importance of salt diapirism activities in trapping oil and gas in this area and the necessity of studying salt diapirism phenomena in oil field explorations.

The study area is located on the SE side of Zagros folded belt, on the West side of Minab fault and a few miles South of Zagros Main Thrust (ZMT). The study area, which is limited at the East and West by longitudes 55°45'E and 56°45'E and at the North and South by latitudes 27°15'N and 28°00'N, located on the North of Bandar Abbas city. It consists of the wide flat valleys with a spots of high elevation mountains going up to 9000 msl.

A multiband Spot image and a couple of Panchromatic Spot images are available and give the opportunity to study in detail the structural and morphological anomalies around the salt plugs. The hydrographic networks are very sensitive to recent movements and surface deformation. Particular attention has been given during detailed study of Spot images because of high sensitivity of hydrographic networks to recent movements.

One of the most spectacular hydrographic anomalies which has been recognized by a detailed study of Spot images is located on the south flank of Kuh-e Darbast (Darbast Mountain in Farsi), on the East side of study area. As it is illustrated on the Figure 3, two drainage basins are getting close to a point of confluence and then diverge again. This anomaly is located between two active drainages and on a high elevation dead valley, which is a part of huge spent alluvium cone. At a few Hormuz outcrops close to divergence point, high rates of erosion and the inflation zone of this area are the evidences of the presence of underground Hormuz salt diapir in the core of this anticline. Three stages have been proposed for the evolution of this drainage basin by salt diapir movement (Figure 4).

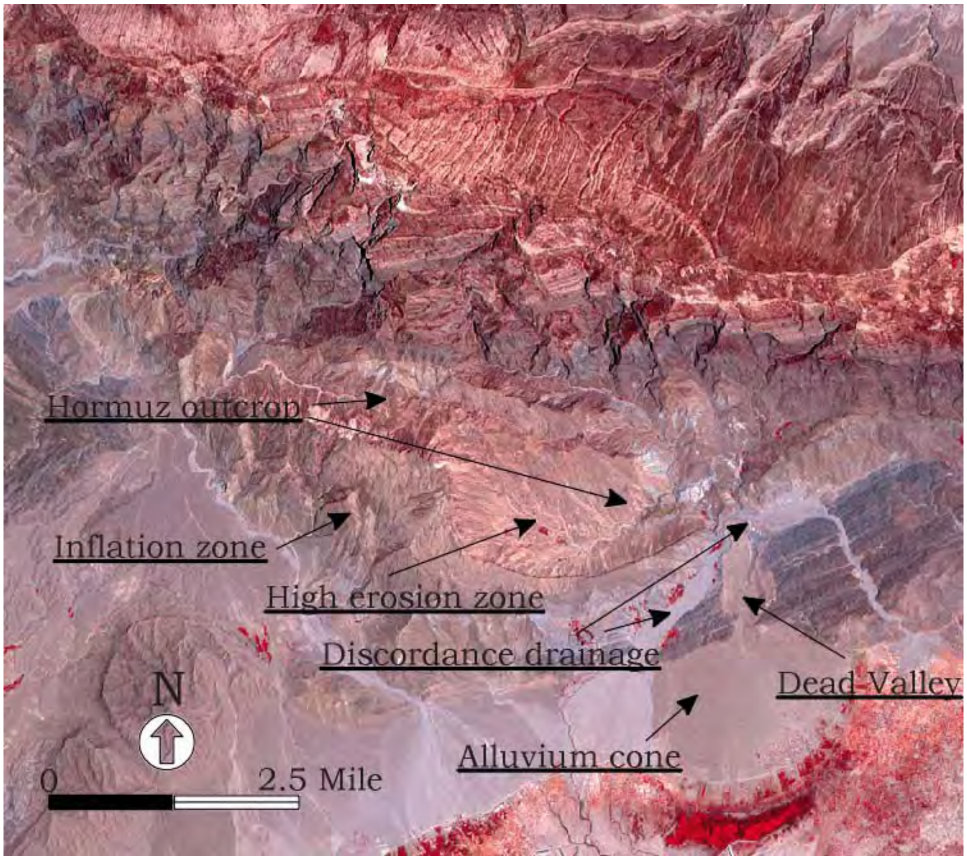


Figure 3: Spot image of Darbast Anticline.

The superposition of hydrographic network digitalized on the Digital Elevation Models (DEM) of anticlines is another great tool to study topographic and hydrographic anomalies at the top of the suspected underground hidden diapirs. The Digital Elevation Models are currently used in most of the branches of Geosciences. They are a matricielle image Z (X,Y) where Z is a representative parameter of ground surface. Figure 5 shows the Digital Elevation Model calculated for one of the diapir sites in the research area.

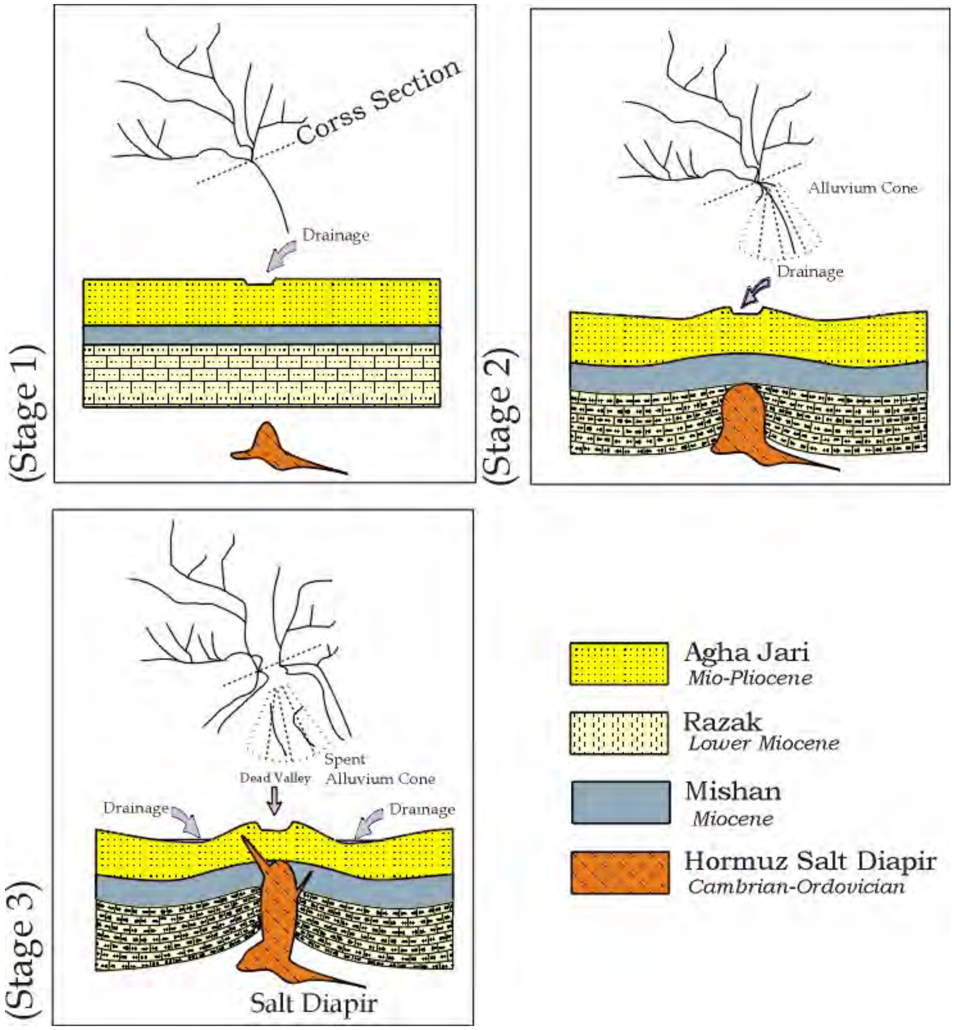


Figure 4: Three stages of drainage evolution at the top of the hidden salt diapir. First stage: the salt diapir rises to the surface. At this stage, the vertical movement of diapir does not have any affect on the surface layers. Second stage: diapir is getting close to the surface. It has already affected the surface layers and folded them. At this stage, the diapir pierces a few layers to reach the surface. Third stage: the advanced stage of deformation. The salt diapir is close to the surface and has made an inflation zone on the surface. Hormuz salt diapir could reach the surface at this stage. The drainages have diverged because of uplifting the surface during the rise of the diapir.

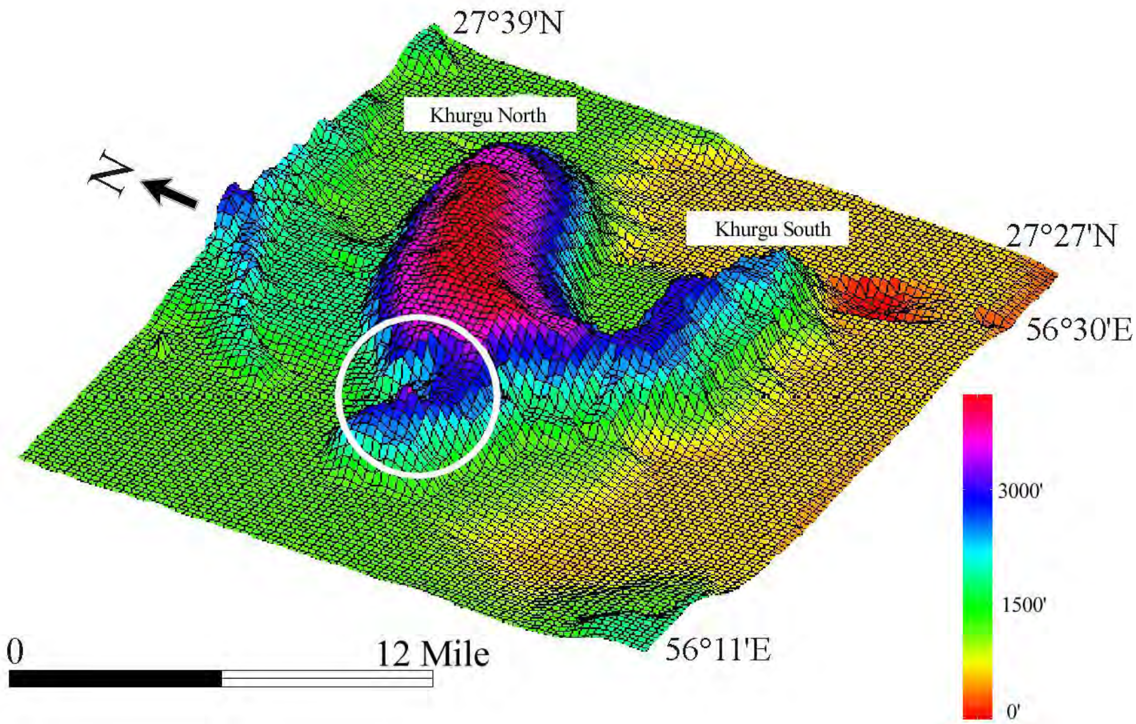


Figure 5: Digital Elevation Model of Kuh-e Khurgu. A white circle shows the Hormuz salt plug.

Any type of anomaly of hydrographic networks can be the result of a lot of natural endogen actions like lithology, structure, tectonic and exogenous actions like climatologic, vegetation and also human actions. A detailed study has been done on the models to be sure that the anomalies reported are structural. On the site of Khurgu, the DEM has shown a topographic anomaly on the west side of salt outcrop. This is the 900 ft settling of limestone layers made by eruption of Hormuz evaporites from the ground with the help of a normal fault on one side and a right-lateral strike slip fault on other side (Figure 6).

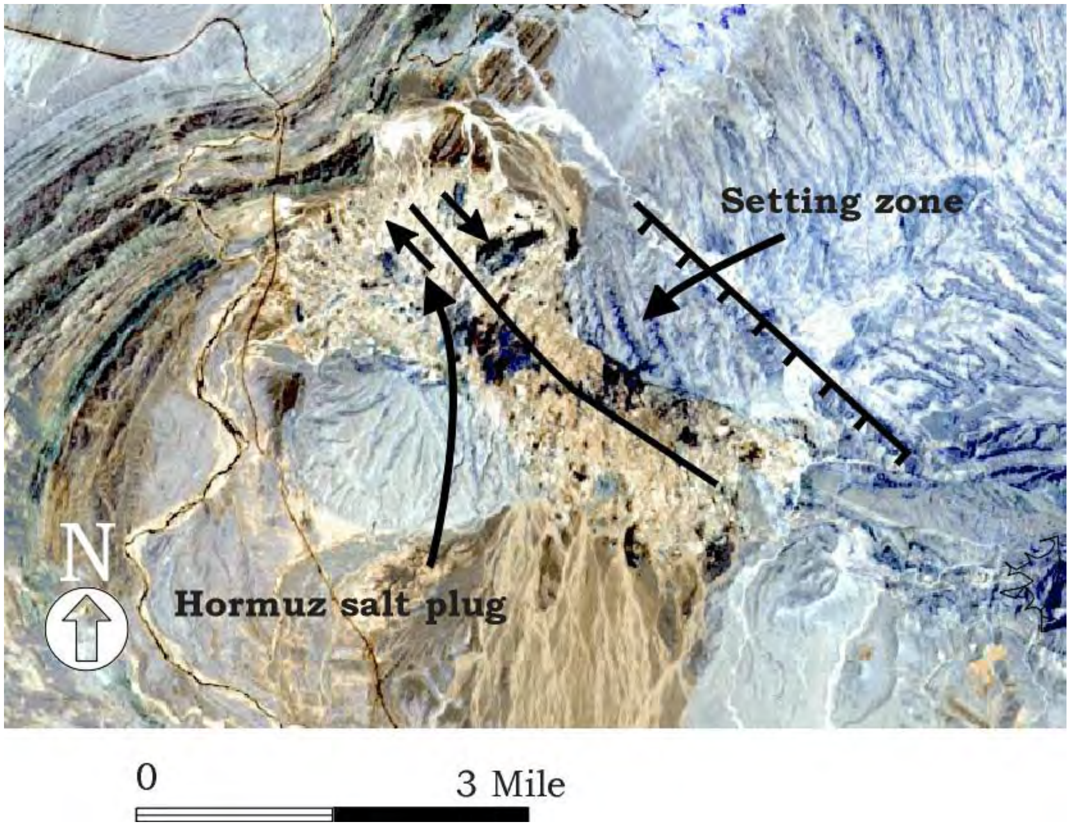


Figure 6: Spot image of Khurgu anticline. Setting zone is located on the East side of Hormuz outcrop.

On another site (Handan anticline), a shrink phenomenon has been recognized on the DEM and Spot images. It has been formed because of salt diapir eruption from the center of anticline and made an underground cavity in the core of anticline: like when the juice of an orange is taken out by a syringe (Figure 7).

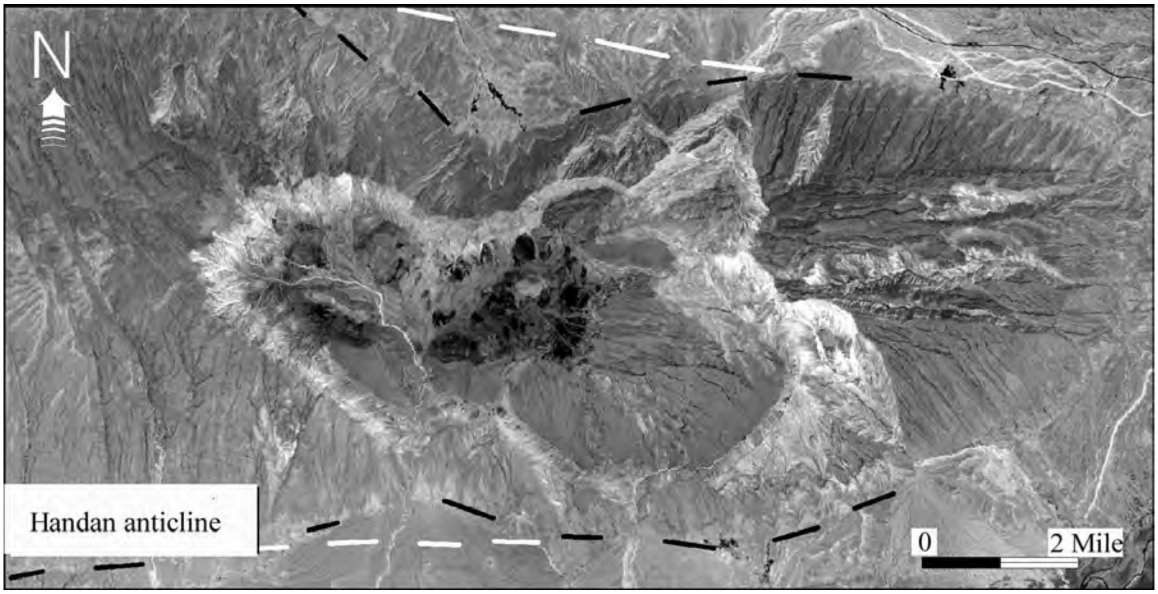


Figure 7: Spot image of Handan anticline. The black line shows the actual limit between Handan anticline and valley. The white line shows the same limit before shrinking the anticline. The dark spots in the center of anticline are Hormuz evaporite outcrops.

These are some of the phenomenon associated with salt diapirism activity in Zagros, which help to propose twelve new locations of hidden salt diapirs in Zagros (Figure 8). A detailed field investigation needs to confirm these hypotheses.

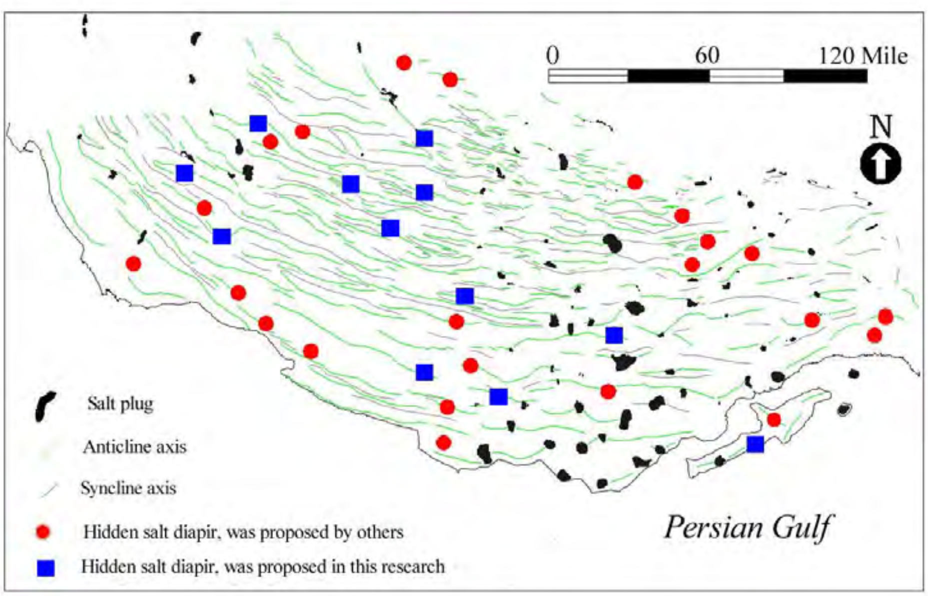


Figure 8: The distribution of Zagros salt plugs and the location of hidden diapirs.

The location of salt plugs has been projected to this map by digitalizing the geological maps of Zagros, printed by Geological Society of Iran and National Iranian Oil Company.