USE OF THE GIS TO DELINEATE LINEAMENTS FROM LANDSAT IMAGES, DAMMAM DOME, EASTERN SAUDI ARABIA

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ABSTRACT

GIS can be used to define and delineate geological structures from satellite images. In this, study the GIS, ARCVIEW, was used to trace lineaments from LANDSAT images of the Dammam dome, eastern Saudi Arabia. The dome is an oval shape structural body trending NW and covering an area of 150 km2. It hosts the first oil producing oil well of Saudi Arabia, well No. 7. Lineaments were traced from the LANDSAT MSS images of normal and NE, NW, and NS Sun angle views. Data acquired from lineaments analysis are coincided and compatible with the field studies data of the major (regional) fractures. Those fractures are mostly related to the dome emplacement and they expose specific fractures pattern that represents the dome-shape body. Trends and pattern of the lineaments are also suggesting the same conclusions. Those lineaments may also represent a weakness zones (fractures or faults) within the Earth crust.
This study emphasises the importance of GIS and remote sensing utilization in structural geology studies.

INTRODUCTION

The GIS is used in many fields among them agriculture, land use, monitoring of desertification, forestry, wildlife management, archaeology, city planning, municipal applications, and geology. Application of GIS in geology is very broad and diverse. In geology, geological relationship can be determined through spatial characteristics. Based on this concept several data sets can be created and analyzed. Hence, the GIS can be used in geology in different fields among them; mineral and petroleum exploration, geological mapping and reconnaissance, environmental studies, and hydrogeological modelling.
In this study the GIS technology used to compare the relationship of doming of Dammam dome to the lineaments distribution pattern and to the regional fractures produced within the dome as a result of its emplacement. The Dammam dome is an oval shape structural body trending NW and covering an area of 150 km^2 (Figure 1). It encompasses three major cities Dhahran, Khobar, and part of Dammam. The dome is also characterized by gentle sloping topography in all directions with four stand out hills; Jabal Umm Er Rus, and the near by KFUPM Jabal (at the top of the dome), and Jabal Midar Ash Shamali and Jabal Midar Al-Janubi (east of the dome). Elevations of these hills are 150m, 100m, 125m and 92m respectively (Weijermars, 1999).

GEOLOGICAL SETTINGS OF DAMMAM DOME

The exposed rocks of the Dammam dome range in age from Palaeocene to middle Miocene (Figure 2). The rocks sequence from the base upwards consists of the following Formations; Rus Formation, Dammam Formation, Hadrukh Formation, Dam Formation and Quaternary coastal deposits, Sabkha plains and Aeolian sands.
At the core of Dammam dome both the lower and upper Rus Formations (Tleel, 1973) are present (Figure 2). The lower Rus is made up of alternation of marls and thin dolomitic limestone beds with abundant slumps and geodes. The upper part of the unit is vuggier weathered calcarenite with abundant mud balls. Jointing is more pronounced in the upper part of the lower Rus Formation due to the nature of the rock. The upper Rus Formation is mainly made up of fine-grained chalky limestone with few marls and clay layers at the top.

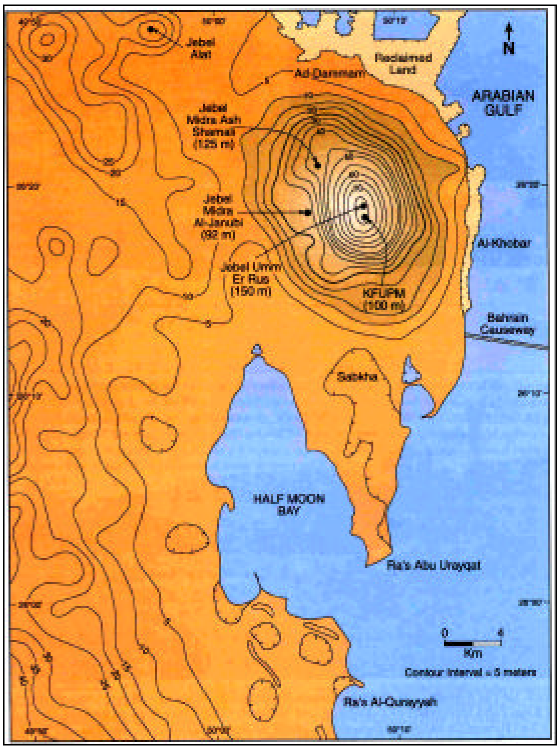

Figure 1: Location and topographic map of Dammam dome shows the dome structure

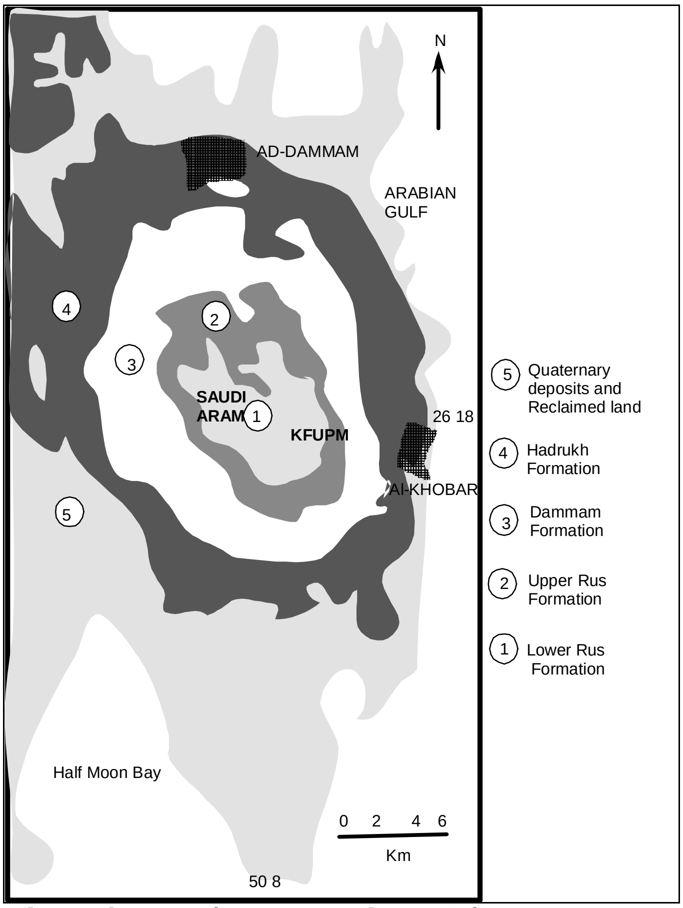

Figure 2: Simplified geological map of Dammam dome (after Weijermars, 1999; Stieneke et. al., 1958; Tleel, 1973; Roger, 1985)

The depositional environment of Rus Formation consists at the base of sabkha, which subjected episodically to shallow marine incursions and changes towards the top of the Formation into regressive facies, lagoonal associated with continental facies (Weijermars, 1999). The Rus Formation is overlayed conformably by Dammam Formation (Figure 2). Dammam Formation is subdivided into five members; Midra shale, Saila shale, Aveolina limestone, khobar and Alat members of dolomitic marl and dolomitic limestones. The four lower members of the Dammam Formation are present in a small ridge at the core of the Dammam dome (Weijermars, 1999). The Dammam Formation represents a transgressive facies sequence (Weijermars, 1999). The sabkha and sub tidal to continental lagoon facies were progressively transformed into an open shallow marine environment.

The Miocene Hadrukh Formation fringes the outer rim of the Dammam dome and comprises sandy marl at the base with intercalations of thin limestone beds, and sandstone. Towards the top the facies changes into calcareous sandstone and shales interbeded with minor amounts of marl and gypsum. The Hadrukh Formation represents continental to shallow marine facies (Power et al., 1966; Weijermars, 1999).

The Dam Formation unconformably overlies either Rus or Dammam rocks, depending upon location. At Jebel Midra Al – Janubi the Dam Formation comprises sandy conglomerate at the base overlain by stromatolitic limestone. The middle part of the sequence is dominated by clastic limestone, and intercalations of microcrystalline limestone with calcite geodes. In the top of the sequence consists of massive calcrudite, with ancient subaerial collapsed dissolution caves. This facies changes up into massive reef limestone.

The Dam Formation indicates a major marine transgression, and it shows shallow marine environment (Weijermars, 1999). Shallow subtidal to intertidal environment is also indicated at the type locality of Al-lidan escarpment (Irtem, 1996).

Quaternary coastal deposits, Sabkha plains and eolian sands are covering the low area at the peripyries of Dammam dome (Figure 2) and large alluvial fans of conglomerate and sand deposited within major wadies (Weijermars, 1999).

NATURE AND GROWTH OF THE DOME

Dammam dome is a result of a subsurface salt diapirism that is related to Hormuz salt body. Hormuz salt started its initial growth in Jurassic and Cretaceous time in response to general tectonic extension that took place within the Arabian plate (Weijermars, 1999). The tectonic extension was further accelerated in Miocene time. Based on the elevation of Dam Formation of 150m over 20 Ma, Weijermars (1999) estimated the uplift rate of Dammam dome in Neogene time to be in the rate of 7.5m/ Ma. He also estimated an uplift rate of 7m / Ma in Oligocene from the maximum hiatus of 150m in stratigraphic section over 22 Ma. Furthermore, Weijermars, (1999) suggested a minor structural growth of Dammam dome during middle Eocene according to the Dammam formation thickness. The suggested modern uplift of the dome is at a rate of 5.6 to 7m /Ma (i.e. 0.56 to 0.75 mm per century).

FRACTURES WITHIN DAMMAM DOME

Based on their size, trend and extension fractures within Dammam dome were divided into three types; regional (major) fractures, local (minor) fractures and very small size -localized fractures. Mode of fracture, filling materials opening and spacing were noted for each type (Hariri and Abdullatif, 2004).

Field study indicated that two fractures Modes present within Dammam Mode I and Mode III.

No indication or presence of Mode II fractures within the Dammam dome. Mode I fracture is extension or tension fractures and characterized by lack of displacement in both the horizontal and vertical directions. Fracture opening in this type is perpendicular to the fracture planes. Mode III fractures are normal faults where movement is parallel to the fracture surface and in the vertical direction.

Field study indicated that regional fractures are the most prominent or dominant type of fractures present within Dammam dome. These fractures characterized by their large size, long extension (>500m) and systematic trends compared to the other two types. These characteristics made them the best candidate to be studied to determine their relationship of fractures to the tectonic (doming) and structural settings. In addition, those fractures are more important than the other local types concerning the engineering, environmental and hydrocarbon implications. Patterns and trends of those fractures were determined in several locations within the Dammam dome. The resulted pattern confirmed the relationship of those fractures to the doming in the area (Figure 3). Concentric and radial trends are characterizing the fracture pattern that is coincided with a pattern produced by an elliptical shape dome (Figure 4; Hariri, 1995).

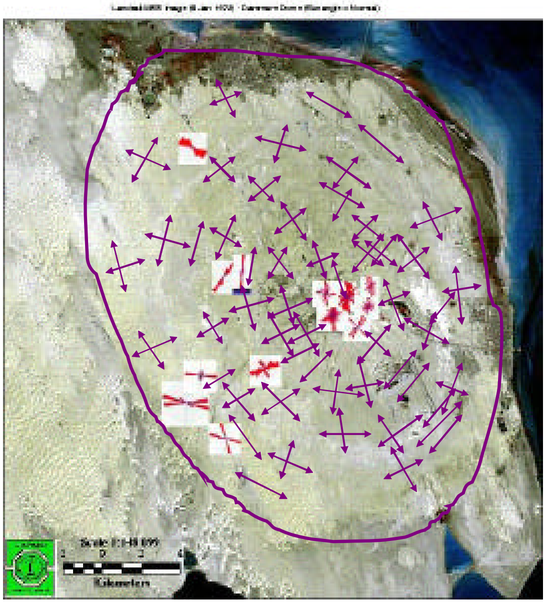

Figure 3: Rose diagrams of major fracture trends within the Dammam dome and the expected major trends (after Hariri and Abdullatif 2004)

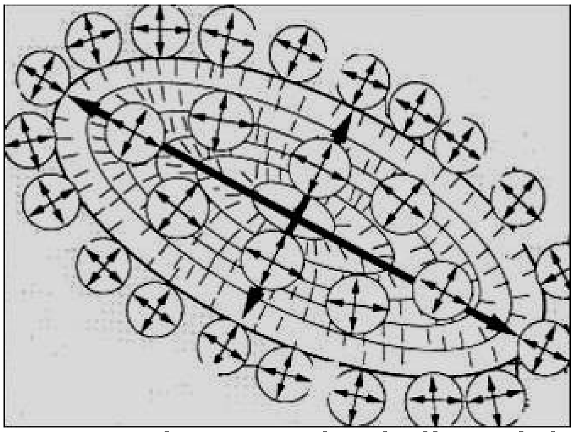

Figure 4: The propose fracture trends associated with elliptical shape dome (Hariri, 1995)

LINEAMENTS AND GIS STUDIES

Lineaments on aerial photos or Landsat images may be related to zones of weakness in the Earth crust and probably represent fracture traces (Sabins, 1997). The technique of observing and mapping lineaments from aerial photographs began as early as 1928, (Lattman 1958). Lineaments defined, in literature, as a mappable simple or composite rectilinear or slightly curvilinear feature differ distinctly from the patterns of adjacent features and possibly reflect a subsurface phenomenon (O'leary et al., 1976). Lineaments may be made up of geomorphic (relief) or tonal (contrast differences). They may include straight stream valleys, contrasting tone, straight ridges and alignment of vegetation (Roy et. al. 1993, Ross and Frohlich, 1993, Cepda, 1994, Hatcher, 1995 and Sabins, 1997). Lineaments study also provide general picture about the possible fracture presence within the dome.

For further examination of the fractures distribution and the suggested fracture pattern within Dammam dome lineaments were traced for the dome area, using Landsat MSS image (8 Jan 1973). Different Sun angle views were used for this purpose; NE, NW, NS and normal (Figure 5). The selection of the different Sun-angle is to enhance the lineaments exposure within the image; for example, the Sun-angle in the NE direction will enhance lineaments that trend NW.

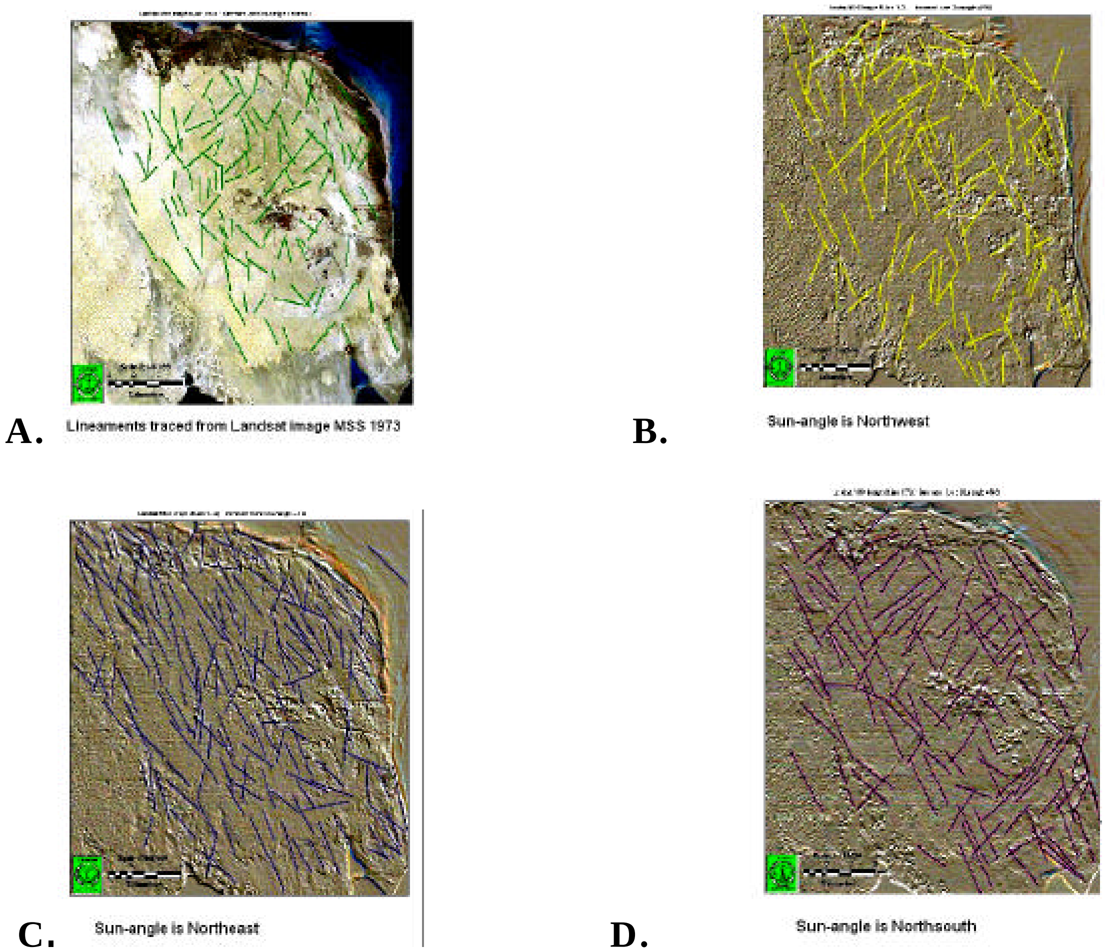

Figure 5: Four Landsat images MSS (1973) for Dammam dome showing the lineaments distribution within the dome area in different Sun-angle. A. normal colour image, B. Sun-angle is northwest, C. Sun-angle is northeast and D. Sun-angle is north- south direction

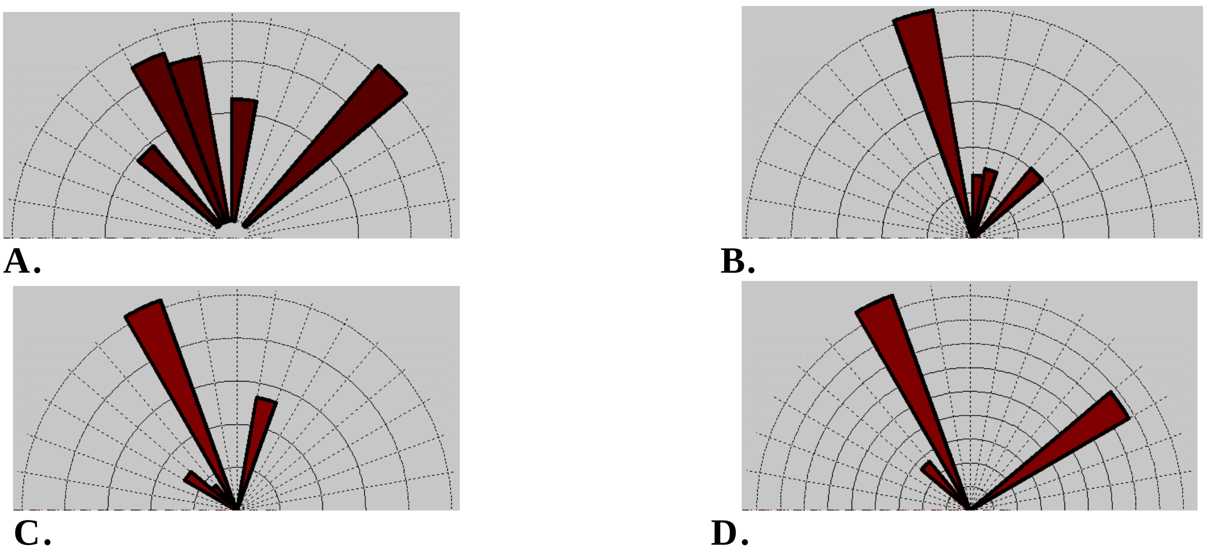

Figure 6: Rose diagram for lineament traces for Landsat image MSS1973 A. Color image, B. image with Sun-angle in the northwest C. image with Sun-angle in northeast direction and D. Sun-angle in the north-south direction

The four images of Dammam dome expose general compatible and concordant lineament trends (Figure 6). Major trends present, in all images, are almost northerly; north-northwest south -southeast, and north-northeast south-southwest. These trends were also noted in the field in several locations, for the regional fractures, particularly at the apex of the Dammam dome. Those trends are also present in the southwest, west and west-central parts (Figures 3 and 6). The east west, northwest southeast and northeast southwest trends are not very pronounced in the images as they present in the field study. This might be attributed to the fact that none of the images represents the Sun-angle in the east west or west east direction.
Pattern of lineament trends within Dammam dome, is also generally coincided with the suggested fracture pattern model (Figures 3 and 5). This general pattern may also indicate that the domination of lineament trends within the dome is particularly related to the dome emplacement.

CONCLUSION

Studies conducted on fractures and lineaments for Dammam dome area indicated that the oval shape dome structure has a great influence on the trend and pattern of those features. Moreover, major fractures and lineaments within the dome area are mostly related to the dome emplacement. Trends of lineaments traced from satellite images for Dammam dome are generally concordant and comparable with the trends of major fracture measured in the field. Those lineaments may represent fractures or weakness zones within the dome.
This study indicated that remote sensing and GIS techniques could be of great use to the geological studies. Moreover, lineaments and major structural features can better be observed and studied by using satellite images and or aerial photos. This might be attributed to the fact that the large size of those features makes them difficult to be noticed in the field.

ACKNOWLEDGMENTS

This study is part of a funded project sponsored by SABIC (Saudi Arabia Basic Industrial Corporation) (SABIC 2002-06). Therefore, our thanks and appreciations go to SABIC for this funding. The authors would also like to express their thanks and appreciations to the KFUPM (King Fahd University of Petroleum & Minerals) for the continuous support and for providing the facilities that helped in conducting this research. Thanks and appreciations are to Mr. Mushabab Al-Asiri, Mr. Fadhel Al-Khalifah, Mr. Fawaz Al-Khalid and Mr. Ahmad Al-Shaihab for their help and assistance in the field and lab works.

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