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Interpretation of Structural Lineaments Using Landsat-1 Images

A greater number of lineaments in the Zenden Fault region of southern Iran were observed on the Landsat images than were recorded on geologic and tectonic maps compiled from aerial photographs.

Abstract: *The study of Landsat images has proved to be very useful in delineating and interpreting the structural lineaments in the Zendan Fault region, southern Iran.*

Three hundred and thirty-nine major and minor lineaments were delineated using the Landsat-1 images. Density of the faults and lineaments mapped with Landsat images is double those mapped and reported by means of aerial photographs. The major lineaments, especially those that are parallel to the axial planes (such as the Minab Anticline), are high-angle reverse faults, thrusts, and underthrusts.

A horizontal compressional stress acting east-northeast is postulated by analyzing the dynamics of fracturing in the study area.

Introduction

The total lateral dissimilarity of the structure and the rock types east and west of the Zendan Fault, southern Iran prompted the interest and enthusiasm to carry out this investigation.

The writers' experience with the application of Landsat (Iranpanah, 1977) has proved that multispectral images allow quick and inexpensive reconnaissance of structural trends in vast areas of the Iranian Plateau. Accurate geographic base maps as well as tectonic maps may be prepared by using the images in conjunction with existing data.

The work presented here is based on analysis of two Landsat Multispectral Scanners (MSS) band 7 black-and-white images (Image 1: 1092-06123-701, 23 October 1972; and Image II: 1074-86114-502, 5 October 1972) (Figures 1 and 2), limited field reconnaissance, and review of the literature. The main stages of analysis involve preliminary correlation with available geologic data and recognition of new lineaments obtained from Landsat images (1:1,000,000) by means of a viewer equipped with a monitoring system.

Our study area covers approximately 5,000 km² (E-56° 30′ to E-58° longitude, and N25° 30′ to N28° latitude) in the southern part of Iran from east of Bandar Abbas to Djask.

Despite the apparent continuation of the Zagros Thrust Line across the entire Zagros Range and the Zendan Fault region (Stocklin and Nabavi, 1973), there is an abrupt change in lithology and structure from one side of the Zendan Fault to the other. The area of transition along the fault is approximately 50 km wide in an east-west di-

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Photogrammetric Engineering and Remote Sensing,
Vol. 46, No. 2, February 1980, pp. 225-229.

FIG. 1. Index map showing study area.

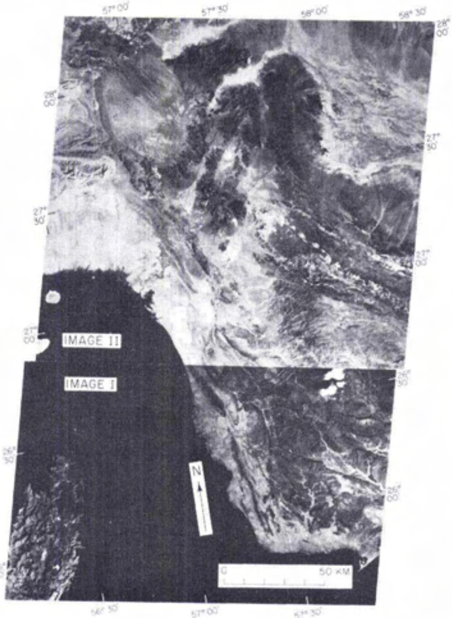

FIG. 2. Mosaic of the Landsat MMS 7 image #1092-06123-701, 23 October 1972 (Image I) and Landsat MSS 7 image #1074-86114-502, 5 October 1972 (Image II).

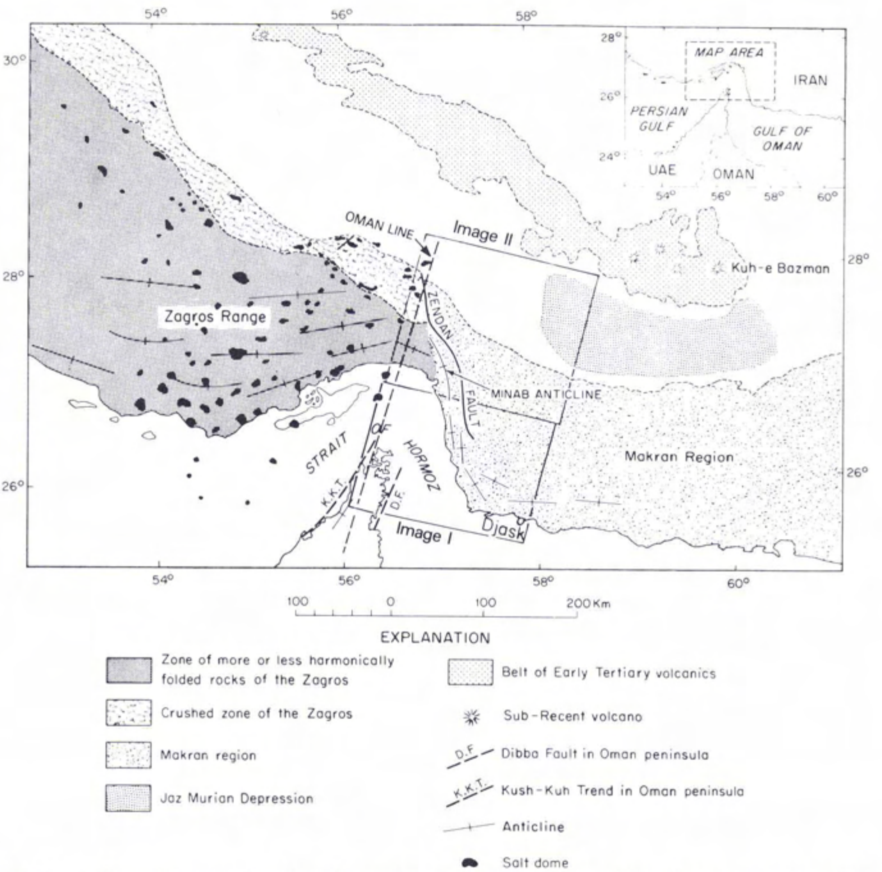

FIG. 3. Schematic map showing the major structural setting of the Zendan Fault and the adjacent areas (adopted from Huber, 1978).

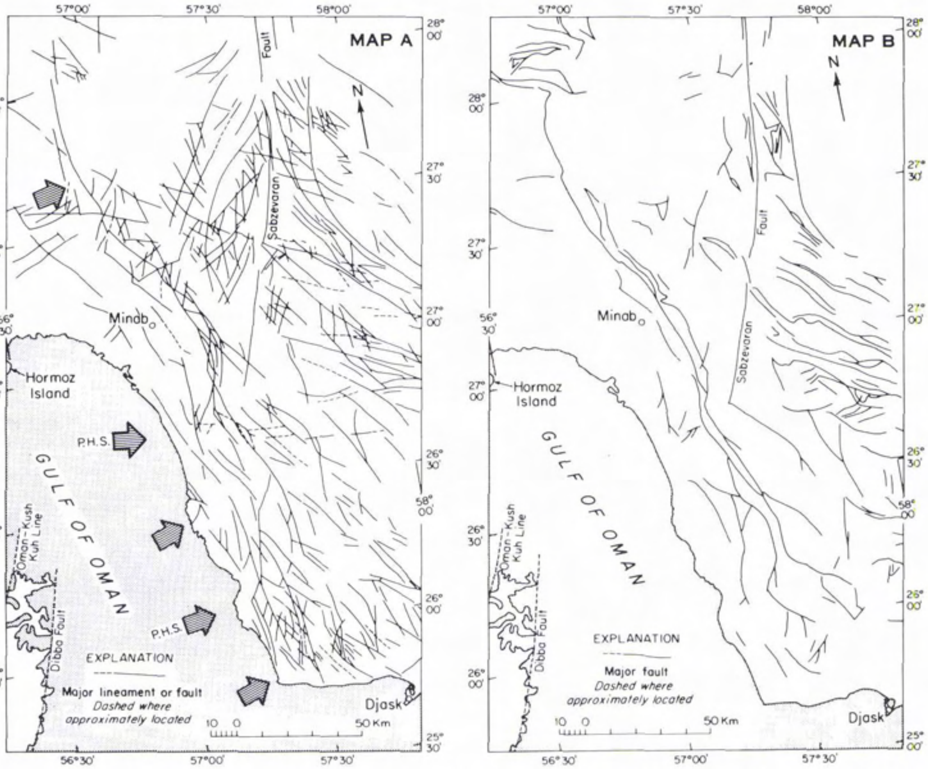

FIG. 4. A—Structural lineament map of the Zendan Fault area interpreted from Landsat images. B—Structural lineament map of the Zendan Fault area (adopted from Huber, 1978).

rection where the north-south striking anticlines such as the Minab Anticline (Figure 3) are present.

The Zagros Range is mainly characterized by folded belts with great anticlinal structures, a narrow zone of intense disturbance (crushed zone), and a thrust line. Along the Zendan Fault they are separated sharply from the Makran region (Figure 3).

The Oman Line (Stocklin, 1968a) is believed to pass through the transitional zone (Zendan Fault area) that fixes the Iranian position of the much longer structural line (Figure 3). The line extends from the Ural Mountains to Madagascar.

The Makran region comprises the southern part of Iran and Pakistan from the Strait of Hormoz in the west (Figure 3) to near Karachi in the east. It is characterized mainly by east-west trending anticlines and synclines associated with longitudinal and transverse faults.

Orientation of the major faults and folds in the Makran region is completely different from that in Zagros Range. Even the orientation (N23°E) of the fold axes in the southern Zagros (relatively younger folds) varies greatly with the orientation (N90°E) of the fold axes to the north (older folds) (Figure 3). The east-west trending fold axes in the Zagros Range change abruptly into NNW-SSE trending folds striking N14°W just west of the Zendan Fault (Figure 3). The presence of more than 150 salt domes (Figure 3) (and their association with oil and gas reservoirs) in the Zagros Range and their absence from the Makran region, and the presence of chromite deposits only in the Makran region, have also been taken into consideration in selecting the Zendan Fault region for this investigation. The absence of the salt domes east of the Zendan Fault suggests that there probably was a Late Precambrian basement-high along the presently fractured zone of the Zendan Fault, a high that closed the sedimentary basin to the east where the Hormoz salt was accumulating in a north-south trending lagoon during proterozoic time (Figure 3).

As a result of this investigation many new structural lineaments have been postulated. The analyses of the dynamics of fracturing along the Zendan Fault region show that a principal horizontal stress (PHS) trending east and northeast was responsible for the development of the lineaments present in the area (Figure 5). Finally, better knowledge of the geology and the structural trends of the Zendan Fault region is important not only in understanding the regional development, but also for understanding the structure of southwest Asia as a whole.

Discussion of Analysis

The Landsat images highlight the extreme dissimilarity of structures and rock types east and west of the Zendan Fault (Figure 2). The Zendan Fault consists of sets of active high-angle reverse faults dipping east and sets of strike slip faults.

The Dibba Fault in the Oman Peninsula strikes N27°E and appears to be compatible with the trend to the south where the Ural-Oman-Madagascar Line is approximately located (Figure 3).

Regardless of the apparent anomalous geological relationship (lithological and environmental differences) between the Zagros and Makran regions (Shearman, 1976), the important factors that have been taken into consideration are the changes of structural trends such as faults and folds and the greater number of lineaments which have been interpreted from the Landsat images.

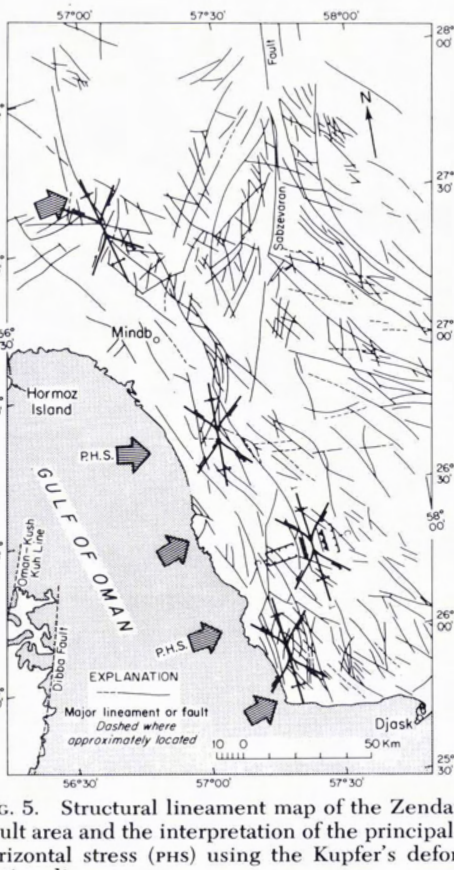

Fig. 5. Structural lineament map of the Zendan Fault area and the interpretation of the principale horizontal stress (PHS) using the Kupfer's deformation diagram.

A greater number of major and minor lineaments (339) can be observed on the Landsat images (Figure 4A) than on geologic and tectonic maps compiled from aerial photographs which show 170 major and minor faults (Figure 4B) (Stocklin and Nabavi, 1973; Huber, 1978). These new data could be used for improving the geologic and tectonic maps of the region.

In an area that lies at the junction of the two important crustal plate boundaries, the Iranian block to the east and northeast and the Arabian block to the west and southwest, one can expect that the divergent movements of these crustal blocks (Farhoudi and Karig, 1977) created a diverging forceful stress system. Although a number of the mapped lineaments are first and second order shears (Figure 4A), probably related to strike slip movements, other lineaments are associated with thrusts and some underthrusts.

The trend of the axial planes (such as Minab anticline) and the thrust faults are in agreement with the tension axis (TT) of the deformation diagram (Kupfer, 1968). The other lineaments are parallel to the left-lateral and right-lateral strike slip faults of the deformation diagram (Figure 5). It is believed that the major movement along the Zendan Fault was a horizontal compressional stress acting east-northeasterly (Figure 5).

An excellent correspondence between gravity and magnetic data and Landsat images was reported from Egypt, northwest of the Gulf of Suez (Bentz and Gutman, 1977). Similarly, we believe that a study of close association of lineaments with high gradients and magnetic anomalies in the Zendan Fault region will reveal the configuration of the magnetic basement. The interpretation of the lineaments along the Zendan Fault can then be complemented with the field data. These studies along with studies of other parts of Iran are now in progress.

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(Received 26 December 1978; revised and accepted 6 July 1979)

BOOK REVIEWS

Handbook of Non-Topographic Photogrammetry. Edited by H. M. Karara. American Society of Photogrammetry, Falls Church, Virginia, 1979. 158 × 233 mm. xiii + 206 pages. 99 illustrations including two in color. Price $15 to members of ASP and $20 to non-members.

The American Society of Photogrammetry has an enviable record of enlightened publication. The most recent addition to their list, the *Handbook of Non-topographic Photogrammetry,* is especially welcome since it represents the first attempt at a text on this subject in the English language and, as far as is known, the only comprehensive book since Otto Lacmann's *Die Photogrammetrie in ihrer Anwendung auf nicht-topographischen Gebieten* appeared in 1950. There is no doubt among photogrammetrists that a book on this topic is long overdue. Ironically, this notice is being written just as another text, for which your reviewer is responsible, has been passed to its publisher! Suffice to say that the emphasis is rather different and one person, at least, hopes that the two books will soon complement rather than compete with each other. The fact that publication of two such books has even been contemplated is, in itself, an indication of the immense growth of non-topographic photogrammetry within the last two decades.

The *Handbook* has been written by eight contributing authors under the editorial guidance of H. M. Karara. Despite the dust jacket statement that the reader will find the content to be representative of the subject's state "as of 1979," the editor's prefatory remarks honestly admit to text compilation in 1976. The three-year delay in publication is to be regretted. There are, nominally, nine chapters in the *Handbook.* Chapter 1 is a single page introduction which discusses the changes of title of the International Society for Photogrammetry commission which has responsibility for non-topographic photogrammetry. These changes reflect continued dissatisfaction with umbrella terms chosen to describe these many and varied applications of photogrammetry. The reader is then launched into the longest chapter in the book, which is concerned with close-range photogrammetry. By a process of exclusion of the content of six subsequent chapters, close-range photogrammetry is not concerned with terrestrial or underwater photogrammetry, X-radiography, scanning electron microscopy, holography, or moiré topography. Each of these topics merits a chapter in its own right, although their lengths vary from 5 pages to 21 pages. As well as being the longest, Chapter 2 is the best illustrated, with photographs and line drawings occupying 27 of the 65 pages. These are concerned with showing examples of cameras and plotting instruments, as well as applications in architecture, art and archaeology, industry, and crime. The text of Chapter 2 deals, unexpectedly and in the space of little more than two pages, with the direct linear transformation formulae for use with non-metric photography. This is the earliest mathematical content of the book (pages 35 to 37) and it will take the unsuspecting reader completely by surprise. It could even put the non-photogrammetrist off the subject altogether! Chapter 3, on terres-