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A COMPARISON OF GEMINI AND ERTS IMAGERY OBTAINED OVER SOUTHERN MOROCCO

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ABSTRACT

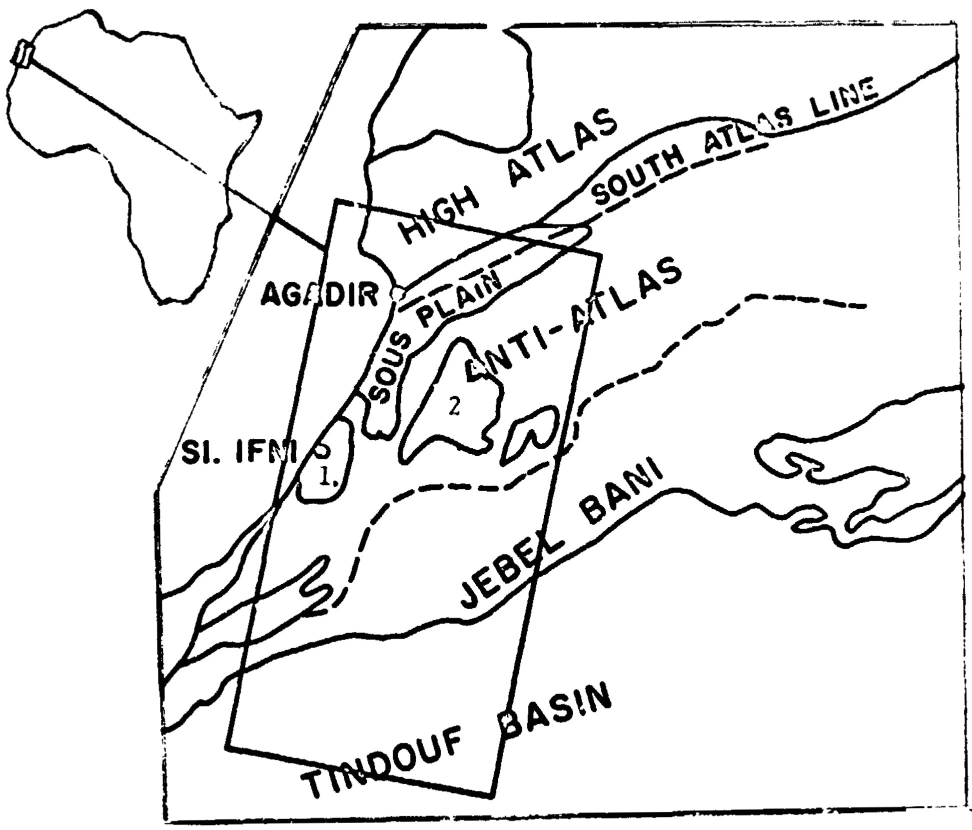
A mosaic constructed from three ERTS MSS band 5 images enlarged to 1:500,000 compares favorably with a similar scale geologic map of southern Morocco, and a near-similar scale Gemini 5 photo pair. A comparative plot of lineations and generalized geology on the three formats show that a significantly greater number of probable fractures are visible on the ERTS imagery than on the Gemini photography, and that both orbital formats show several times more lineaments than were previously mapped. A plot of mineral occurrences on the structural overlays indicates that definite structure-mineralization relationships exist; this finding is used to define underdeveloped areas which are prospective for mineralization.

More detailed mapping is possible using MSS imagery than on Gemini 5 photographs, and in addition, the ERTS format is not restricted to limited coverage.

Studies in the various earth science disciplines using data from orbiting spacecraft have been conducted for over a decade now. These investigations have utilized data from numerous satellite-instrument combinations. However, the most effective pre-ERTS studies have utilized photographs obtained for the S-05 Synoptic Terrain Photography Experiment, for which Dr. Paul Lowman of the Goddard Space Flight Center was Principal Investigator (Lowman, 1969). We are all now involved in conducting our separate discipline studies using ERTS data, so this would be a good time to see how this really does improve our resource evaluation capability.

One geologically interesting area where investigations have been conducted using both Gemini and ERTS imagery is northwest Africa, or more specifically, the southern-most part of Morocco (Figure 1).

This area as seen on ERTS imagery is shown on Figure 2. On the right is a photo mosaic constructed from 3 MSS band 5 frames enlarged to a scale of 1:500,000 on the original. This band was selected be-



MAJOR PRECAMBRIAN AREAS

1 **BA AMRAN**
2 **OULITE**

Figure 1. Location Map: ERTS-1 Coverage.

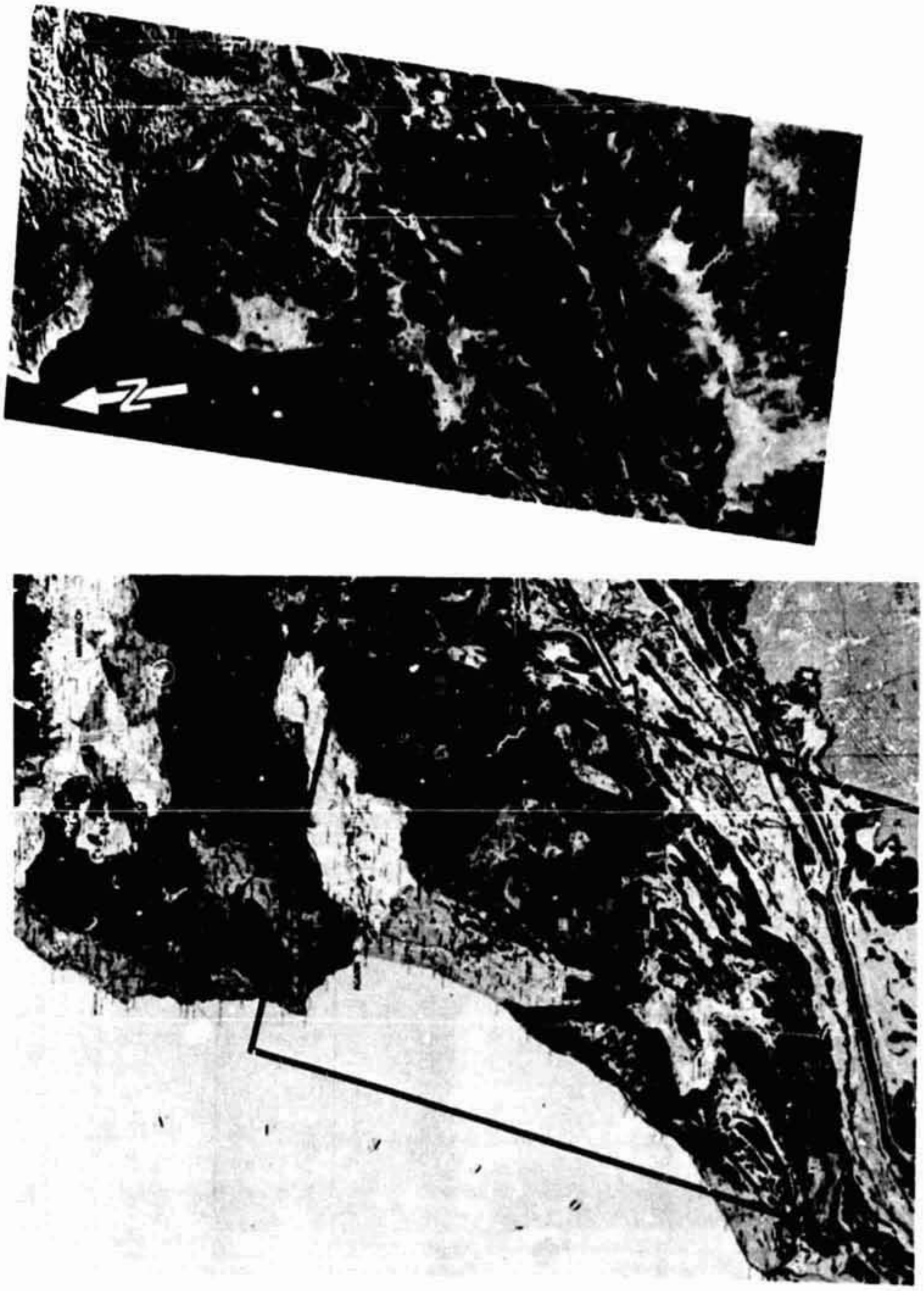


Figure 2. Geologic map and comparable scale ERTS MSS-5 mosaic.

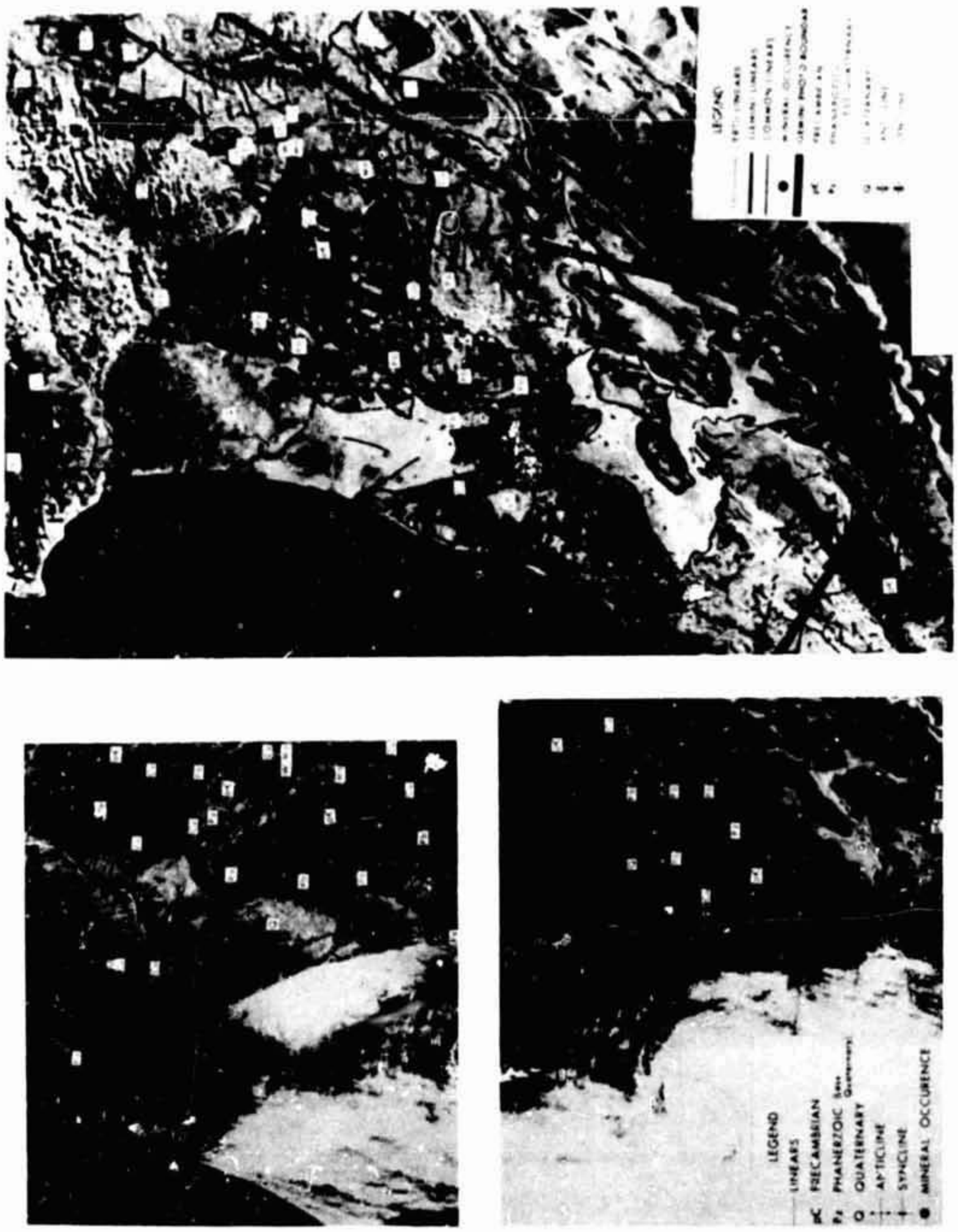


Figure 3. Gemini 5 and ERTS MSS-5 imagery with plotted lineations and mineral occurrences.

cause it exhibited the highest resolution in this area. The imagery was obtained November 3, 1972, and includes frames 1103-10411, 13 and 15. A similar scale geologic map (1956), includes the outlined area of the top 2 ERTS frames and is shown on the left side of Figure 2.

All the major geologic structures shown on the published map and described by Furon (1963, p. 78, 106-116) are clearly visible on the ERTS imagery. The east-northeast trending High Atlas mountains are separated from the geology to the south by the South Atlas line or Agadir fault. On the generalized geologic maps of Africa, it is shown as extending east-northeast from Agadir to the Mediterranean Sea, and is considered by De Sitter (1959, p. 179) as one of the great fundamental faults. Although a fault of the proper magnitude is not indicated on the geologic map, the major Agadir fracture probably lies below the Quaternary sediments of the Sous Plain and may account for the general straightness of the Wadi Sous. South of this major fault, the Sous Plain separates the High Atlas from the subdued Anti-Atlas mountains; this is the western-most link of a discontinuous chain of troughs trending parallel to the south Atlas line. The broadly uplifted, eroded domes of the Anti-Atlas mountains, extend northeastward from the Ifni Enclave, and are flanked on the southeast by the plunging foreland folds which form the Jebel Bani mountains. Further south, the margin of the Tindouf basin is outlined. Figure 3 shows the same area compared with Gemini 5 coverage taken in 1965.

The domal uplift of the Anti-Atlas mountains was accompanied by a complex system of structural fracturing which can, in part, be recognized on the orbital imagery as a series of lineaments. These are particularly prominent across the Precambrian-Cambrian contacts. Most of the tranverse faults shown on the geologic map can be recognized and have been plotted on both the Gemini and ERTS imagery. In addition, numerous lineations, which are probably in large part also structural fractures, are clearly defined on the orbital formats, but do not show up on the published maps. Many of the published strike-slip faults, however, cannot be identified from orbital altitudes. In particular, the faulting developed in the saddle between the Ba Amran and Culite Precambrian domal areas cannot be recognized in contrast to the strike of the beds.

Lineations visible on the orbital imagery were plotted on acetate overlays, using near-1:500,000 image enlargements for the bases; this scale was selected to maintain maximum continuity with the published map. The 3 easily recognizable lithologic units were also outlined; these include dark massive Precambrian basement, light-toned Quaternary sediments and an all-inclusive Phanerozoic unit in between. Plots on the Gemini base are shown on the left, while on the right, is a composite overlay made on MSS band 5 imagery. All the linears visible on ERTS imagery were first plotted on the composite as thin black lines. This overlay was then compared with the Gemini overlay, and lineaments which were identified on both imagery types are shown here as lines of intermediate width. Finally, the lineaments which were seen on the Gemini photos and not observed on the MSS images were extrapolated and are designated by the widest lines. These plots show that the southern, more vertical Gemini photo compares quite favorably to the band-5 imagery in the areas of major domal uplift. Fractures mapped in the folded foreland area, however, are only marginally identifiable at best on the Gemini print, so were notgenerally delineated. The upper Gemini photo, however, is more oblique, and exhibits several linears which were not recognized on the ERTS data. Many of these approach the direction of the scan lines, so they may thereby be masked on the MSS image. The few remaining linears are somewhat aligned with the Gemini spacecraft tilt and have probably been enhanced by viewing down the lineament strike. The overlays without the base are shown on Figure 4.

To get a general numerical feel for the respective linears mapped, the lineaments for each of the three defined groupings were counted. In total there are 257 seen on the MSS imagery only, 38 seen on the Gemini image only, 115 that were delineated on both Gemini and ERTS. This indicates that about three times as many linears can be seen on ERTS imagery than are visible on the Gemini photos. This comparison, however, is probably too strongly weighted by inclusion of linears mapped in the southeast folded areas. If this group is discounted, a more realistic comparison emerges, with approximately 25 percent more linears seen on the ERTS pictures. There are several possible explanations for the increased lineament recognition capability: a. The imageries were obtained under different sun angle, (Gemini taken at 11:38 and ERTS during mid-morning, b. the viewing angle was different (vertical for ERTS and differing for each of the oblique Gemini photographs), c. there may be important seasonal differences (ERTS was taken November 3 while Gemini 5 was flown in August 22), or d. atmospheric differences may have influenced visibility on the different dates. The affect of each of these individual parameters is not certain. However, one thing that can be seen here empirically is the degradation of resolution in the direction of Gemini obliquity, as evidenced in the decrease of Gemini-mappable linears in the northeasterly direction.

After the linear plots were drawn, known mineral occurrences were superposed to determine possible relationships between mineral deposits and structure, and are shown on Figures 3 and 4 as large dots; a total of 25 ore deposits were located and plotted on the overlay. Of the 25, thirteen (13) fall on or very close to the Precambrian-Phanerozoic contact. This would be expected if one considers that mineralizing fluids related to the domal uplift will generally solidify in fractures near their genetic source, as described by Wisser (1960, p. 99). In addition, 7 of these 13 deposits appear to be on or near visible lineations on the ERTS imagery (only 5 of these 7 fractures were visible on the Gemini photos) and these are most commonly oriented in a east-northeasterly fault direction.

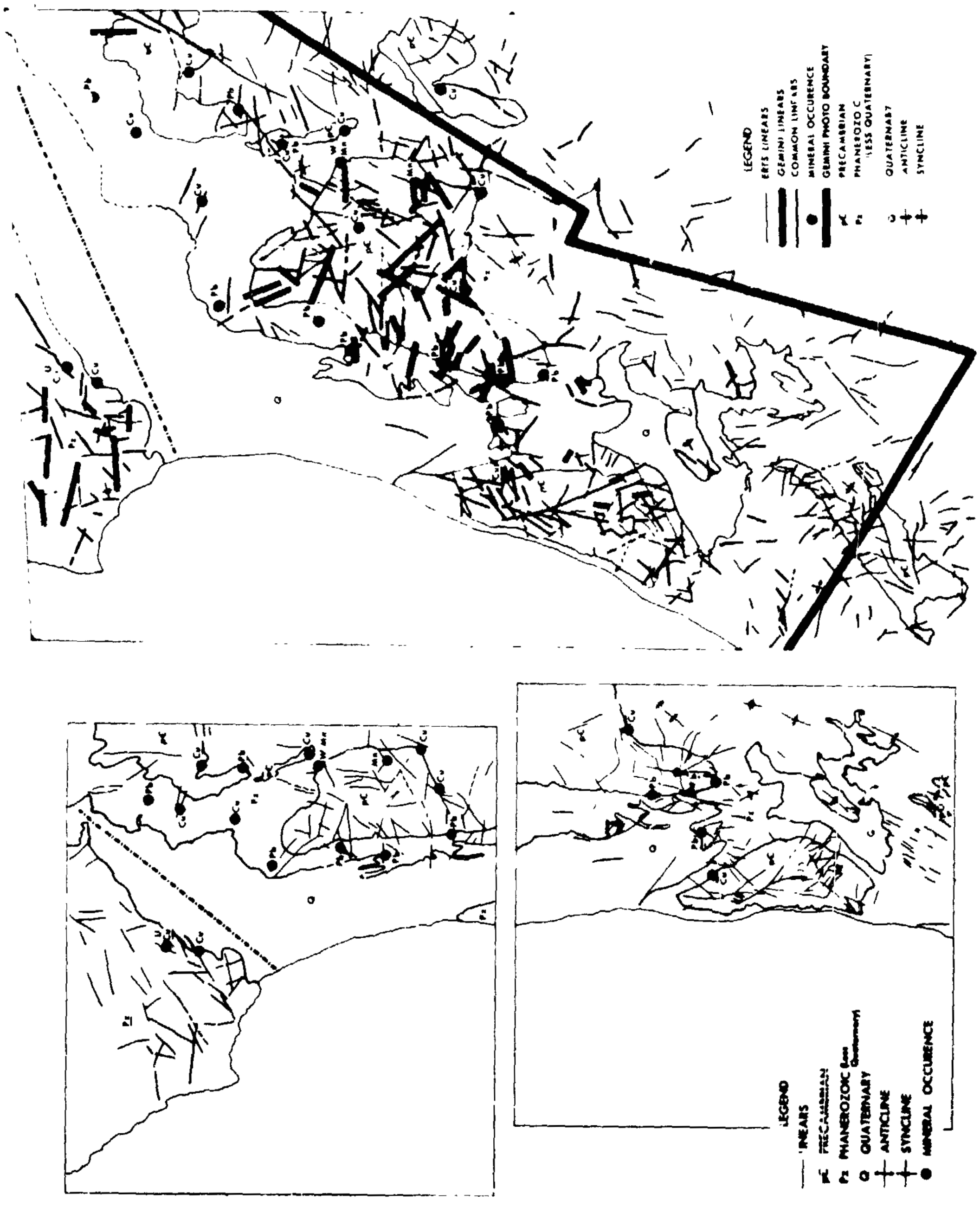


Figure 4. Lineations and mineral occurrences from Figure 3 without the photographic base.

Having once determined these general structure-mineralization relationships, it would be advantageous to use the synoptic view to identify other areas having similar relationships; the objective, of course, being to isolate additional areas which appear to be mineral prospective.

One such area which is strikingly evident is the Precambrian-Phanerozoic contact near the former Morocco-Ifni border. Ifni was only ceded to Morocco in 1969 so mineral exploration prior to that time was not practical along a poorly-defined political border. The area thus, is relatively virgin for prospecting. Of the total lithology contact area, those locations associated with east-northeast "Agadir-trend" faulting seem especially attractive, and should be investigated in the field.

This study, it should be stressed, does not claim ro replace currently used mapping and exploration techniques, but rather, it permits delineation of the more prospective areas, and thus can permit standard field techniques to be utilized in the most efficient manner.

In conclusion, both Gemini and ERTS imagery provide significant data for regional studies, and this can aid in the evaluation of mineral resources. In our immediate study area, however, the vertical ERTS format provides some additional detail which is not visible on the slightly oblique Gemini photos. In addition, it can be seen that the resource studies using photography obtained from previous manned orbital flights are limited to those relatively small areas where imagery is available, while ERTS imagery, on the other hand, has the capability of world wide coverage.

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