

# APPLICATION OF REMOTE SENSING TO GEOLOGY AND HYDROLOGY FOR DAMASCUS AREA - SYRIA.

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## ABSTRACT

The excellent resolution of SPOT data allows the preparation of detailed geological and hydrological maps and studies. Thanks to SPOT's side-viewing, which helps to obtain stereoscopic images, the morphology is accurately reconstructed. This better knowledge of different geological units serves to improve significantly existing geological mapping and to provide new maps.

The part of the image SPOT-1 shown and analysed here lies in the region of Damascus and covers an area of 2100 km<sup>2</sup>. The city itself appears slightly to south of the NE corner of the scene, most of whose western edge lies in Lebanese Territory.

This paper includes analysis of two multiband images taken by SPOT satellite and a brief of geological and hydrological information for Damascus area.

## INTRODUCTION

The part of the image SPOT-1 shown and analysed here lies in the region of Damascus (Syria) and covers an area of 2100 km<sup>2</sup>.

The city itself appears slightly to the south of the NE corner of the scene, most of whose western edge lies in Lebanese territory. The analysis concerns two multiband images made 24 h apart on 12 and 13 March 1986.

The viewing direction of the right-hand image of the stereoscopic pair (13 March 1986) is 25°, and that of the left-hand image (12 March 1986) is 8°. Figure 1,a,b.

Several natural regions that occupy vast areas in Syria come in contact in this zone (Figure 2).

They are easily distinguished on the SPOT scene by the color and texture of the image:

- to the west, a mountainous zone with a confused relief, dark-colored and spotted with white by the snows of Mount Hermon, corresponds to the southern part of the Anti-Lebanon, (Figure 3).

- at the center, a more or less triangular area, with a better organized relief and lighter in color, represents the SW tip of the palmyra Range,



Figure 1,a SPOT image for Damascus area (right image).

- to the east appears the urban built-up area of Damascus, characterized by the bluish-grey color of the buildings, the web of roads and the red spots due to the dense vegetation of the gardens and orchards of the oasis, the Ghuta, (Figure 4).

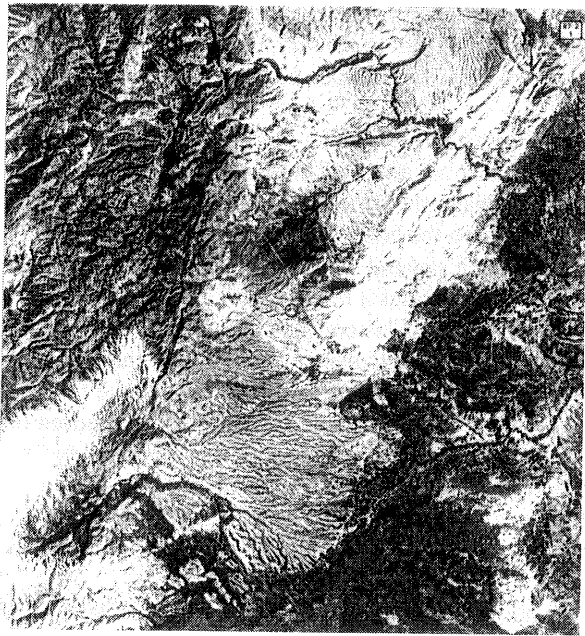


Figure 1,6 SPOT image for Damascus area (left image).

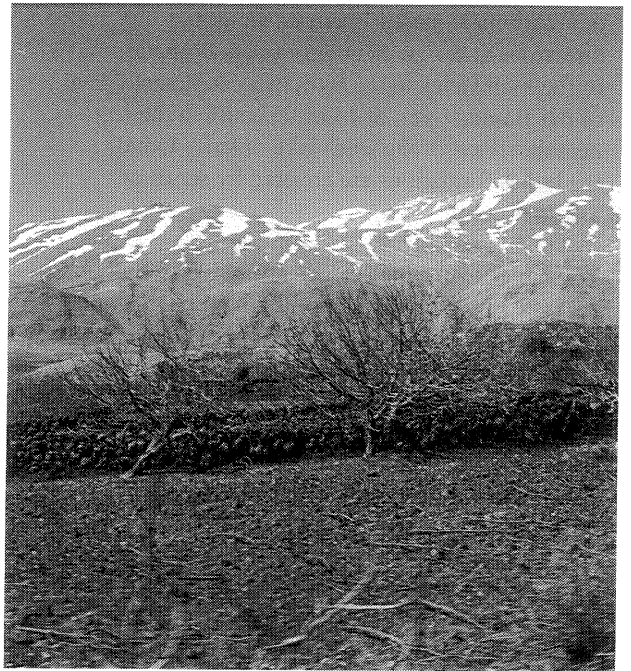


Figure 3, photograph of snow on Hermon mountain.

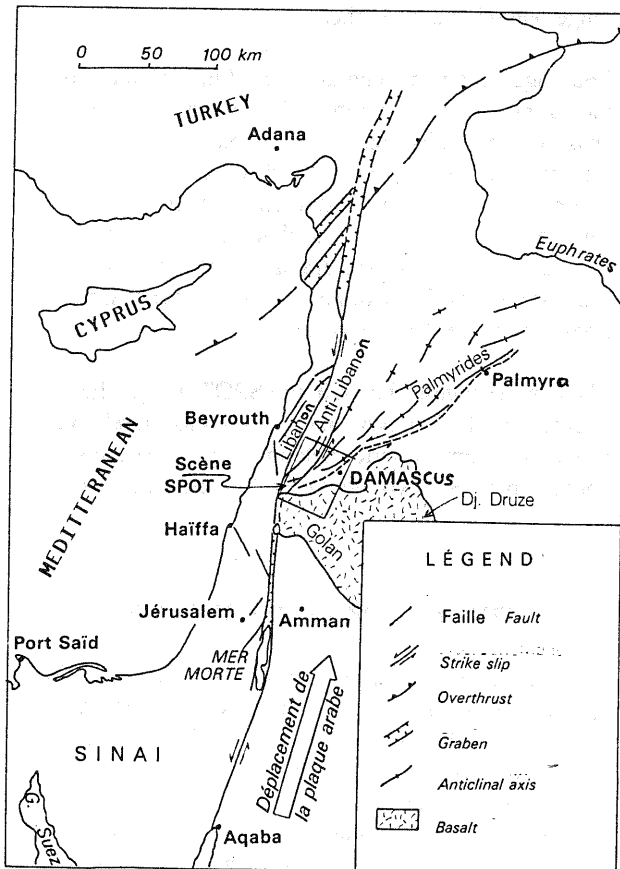


Figure 2, Middle East. Tectonic Diagram.

- to the south lies a zone dominated by nearly black dark grey colors: it corresponds to the northern edge of the Golan basaltic plateau, the northern margin of the Jabal ed Druz.

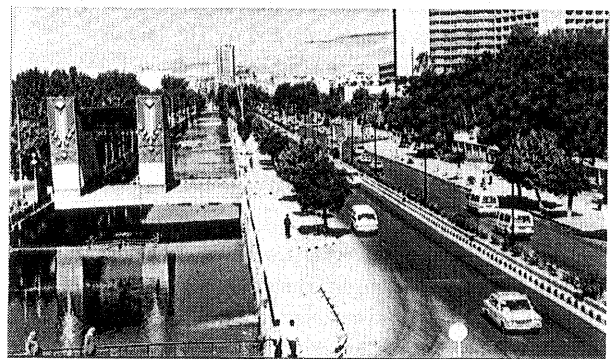


Figure 4, photograph of Damascus city.

## THE ANT-LEBANON RANGE

The Anti Lebanon occupies slightly less than the western third of the image, mainly in Lebanese territory.

It is dominated to the south by Mount Hermon at 2 814 m, still snow-covered. An alignment of sharp and rather high ridges, trending N30, emphasize the eastern margin, limit of the Palmyra Range. The drainage pattern appears fairly confused, without any very clearly guiding line, although flowing mainly eastward, drained by the Barada river and the Nahr al Awaj.

Microreliefs (on the scale of the image), well emphasized by the snow on the slopes of mount Hermon, are aligned in a nearly NS direction. Combined with the talweg lines trending N80 to N90, they form a guilloche pattern characteristic

of a carbonate massif fractured along two directions at 80°, with intense lapies formation. In the high valley in the form of a catchment basin of the Barada river, and further south in the neighborhood of the small lake of kafer Qouq, the lapies formations are covered by series of a lighter color.

The lapies formations can be attributed to the Jurassic mainly the limestone/dolomitic Dogger, which outcrops widely in the Mount Hermon dominating the Aarneh cirque, an anticlinal valley excavated in Liassic shale.

The depressions occupied by the light formations correspond to synclines filled by Uppermost Jurassic and Lower cretaceous shales and sandstones.

In some places are more or less well-drained depressions. They appear filled by dark-colored alluvial deposits punctuated by the red spots of crops.

To the NW of the scene, beyond the N50 feature which determines a ridge crossed by Damascus / Beirut road at a pass, a few hogbacks show a westward dip. In opposite side, the eastern ridgeline reveals eastward dips. The unit thus appears as a vast anticline, cut by faults. It looks like an axial horst plunging towards the NE, affected by gentle synclinal undulations and intersected by roughly N80° fractures. The torsion of the fractures which, from east to west, passes from N80° N60°, as the arrangement of the axis of Mount Hermon intersected by the eastern fault system, suggest that latter active at least partly in sinistral shear.

## THE PALMYRA RANGE

The area on the SPOT image associated with the Palmyra Range forms a light-colored salient whose southward-pointed apex is partly masked by dark volcanic outpourings and by a wide alluvial fan issued from Mount Hermon. Towards the north, it is crossed and partly drained by the Barada river. It appears to be formed of Cretaceous and Tertiary sedimentary largely consisting of alternating marl and limestone, imparting its lighter color than the Jurassic rocks of Anti-Lebanon, as well as its morphology. The clearly-visible layers sometimes forming hogbacks are numerous enough to allow a structural analysis, thanks to the stereoscopic view. They are deformed into a broad axial syncline (Sahl es Sahara, Mnineh) laying between two relatively narrow anticlinal chains (Yaafur - Dimas to the west, Jabal Kashin - Jabal ash-Sharqi to the east). The syncline appears occupied by unconformable formations, deeply cutting older rocks in places, as on either side of

the upstream cross valley of the Barada river, but clearly distorted by tectonics. They are of Continental Neogene age (undifferentiated Mio-pliocene system).

Anticlinal chains exhibit an average N30° trend on the western margin, and N50° on the eastern margin. In the western chain, the anticlines appear en echelon, slightly oblique to the border feature of the Anti-Lebanon, confirming a sinistral displacement along the fault. The eastern range forms a festoon with a convexity turned towards the SE. This convexity, combined with the asymmetry of dips, higher towards the SE than the NW suggests a tendency to thrust towards the SE. In greater detail, this range appears to be composed of relayed brachyanticlines, more or less separated by nearly east/west faults. Here this arrangement again suggests the existence of a sinistral strike-slip fault in the basement.

The north of the Barada river and of Wadi Halbun, the axial syncline is deformed by two plunging anticlinal axes, oriented nearly east/west, one originating in the eastern range, and the second in the western range, one relating the other.

The ridge alignment separating the Anti-Lebanon from the Palmyra range is complex. It appears to be highly broken up by faults oblique to the main fault. Interpretation is difficult in the absence of a stratigraphic attribution for the different compartments. Certain facts, such as the distribution of the formations in Jabal Berber, Jabal Mazara, and north of Yaafur, suggest the possibility of an overthrust of the Anti-Lebanon on the Palmyra range.

Thus, in the region shown in the SPOT image, the structure of the Palmyra range appears like a relatively plastic sedimentary series held in a sinistral strike-slip corridor between two more rigid blocks. (Figure 5).

## THE DAMASCUS DEPRESSION

Only its northwest margin is visible on the image. At the foot of the limiting escarpment of the Palmyra range, it shows the heads of two alluvial fans, one constructed by the Barada river, and the second by Wadi Halbun river.

The Barada fan is stopped at the south by tabular reliefs very gently dipping northward, they are broken into outliers, dark grey to black in color at the top, light grey to white at base. These are northernmost reliefs of the Jabal ed Druz, in the form of a basaltic table dissected by the erosion that causes the outcropping of its substratum consisting of plio-pleistocene lacustrine white marl (Figure 6).



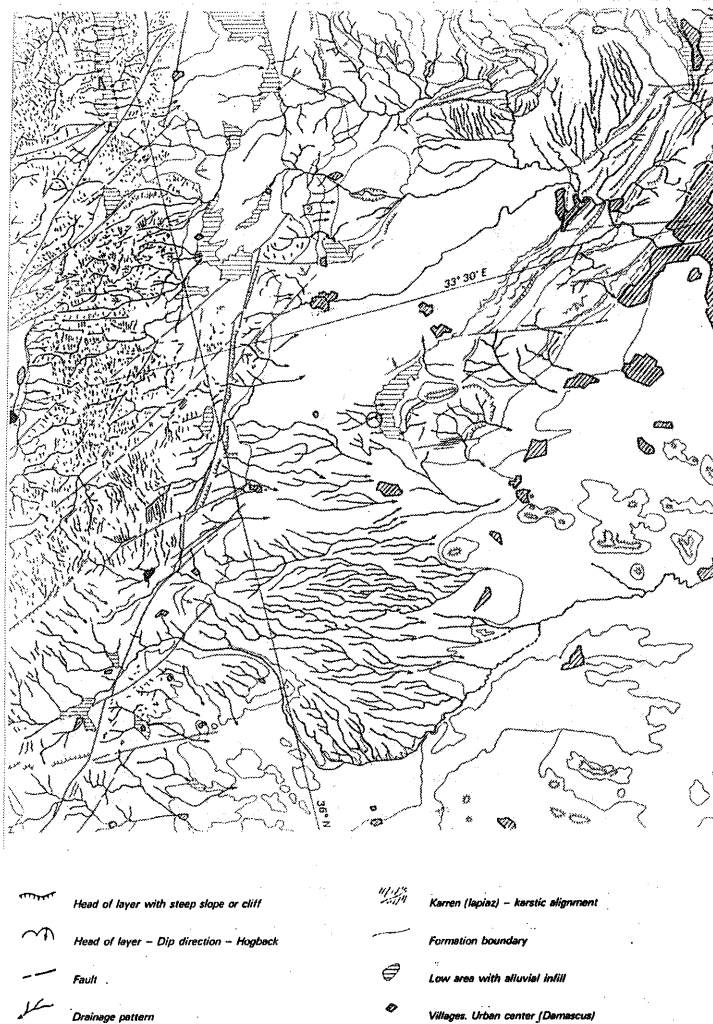


Figure 6. Hydrological interpretation of SPOT image for Damascus area.

### GOLAN PLATEAU

The image covers only the northernmost edge of this unit. It is characterized on the southern margin of the scene by a nearly uniformly dark color. It is a vast gently east sloping fan of volcanic materials flowing from the fracture which limits the Anti-Lebanon at the south of Mount Hermon.

Closer scrutiny helps to distinguish between two different units.

- a lower unit consisting of dark-colored formations which appear, particularly in the Hineh region, as interbedded in light-colored formations. It is pitted with red spots revealing crops. Its boundary with the Quaternary fills of the Awaj river is difficult to trace certainly,

- a lighter-colored upper unit forming an irregular east/west band, nearly 35 km long, with a width fluctuating between 1 and 6 km. This is a recent and nearly unweathered flow.

It supports virtually no crops, and, in its upstream part edge, it invades valleys associated with the present drainage pattern (south of Beit Jinn).

The different volcanic flows are interbedded in the continental formations of the Damascus basin. They belong to the same tectonic unit, the Arabian shelf.

### CONCLUSION

Geologically, the region covered by the scene recorded by SPOT 1 on 12 and 13 March 1986 in the Damascus region lies at the crossroads of three of the middle East's major structural units :

- the Anti-Lebanon Range,
- the Palmyra Range,
- the Arabian Shelf.

The boundaries between these units appears to be marked by sinistral slip faults. They tend to imply that the structure, although affected

by several tectonic phases, has mainly preserved the mark of a stress trending about N20, that occurred during Neogene times and could be still acting today, as shown by the volcanic extrusions of recent age (figure 8).

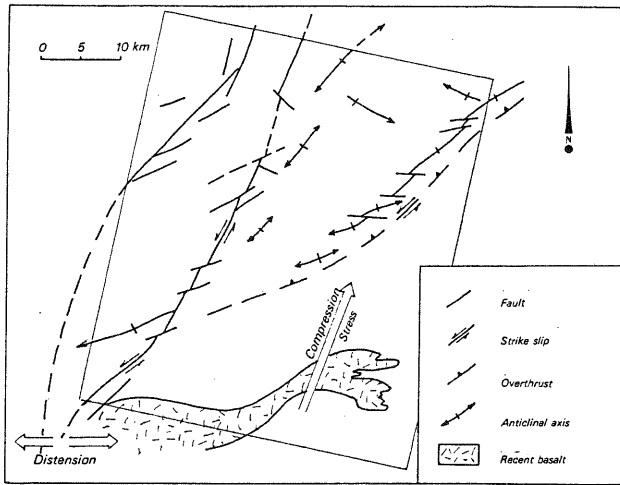


Figure 8, Damascus Tectonic Interpretation.

### OTHER OBSERVATION

In addition to the geological observation that it allows, the SPOT image offers a great deal of other information.

### VEGETATION AND CROPS

In the mountainous regions, the spontaneous vegetation appears to be very diffuse, and the crops are located in the valley floors ( Barada river) or in more or less closed alluvial depressions ( west of Jabal Mazar, Kafer Qouq, Aarneh).

In the Damascus region, the chief crops are those of the Ghuta of Damascus, irrigated by the water of the Barada river flowing from the Anti-Lebanon and those of the Awaj valley, irrigated by the waters flowing from Mount Hermon. (Figure 9).

### HUMAN ACTIVITY

The dominating element is the Damascus built-up area. The city was established 2 km from the outlet of Barada river crossing Jabal Qassiun, undoubtedly more than four thousand years ago.

It is clearly visible on the SPOT image. At this location, sheltered both from the northern winds by the Palmyra range and parching south winds by the reliefs of Jabal ed-Druz, the water of Barada river, caught in a cross valley and redistributed by a network of irrigation channels, has allowed the development of crops and gardens in a vast semi-circle overlooked by the citadel. Only part of it can

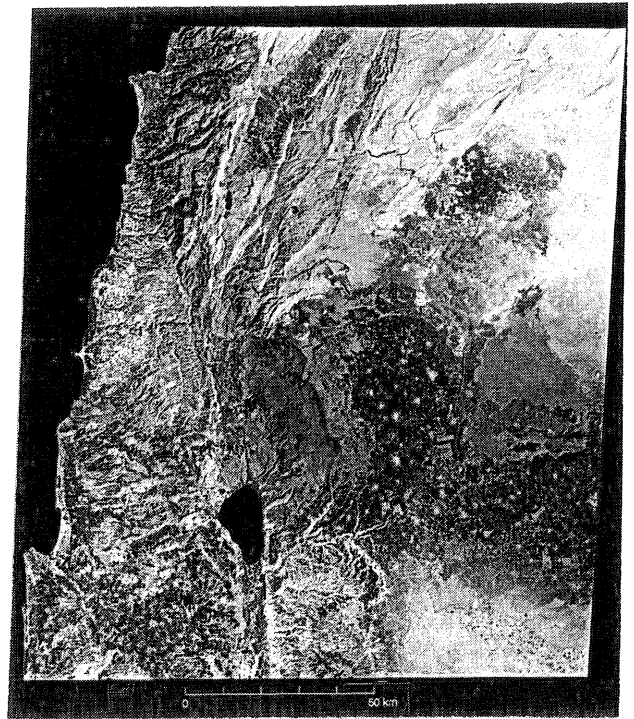


Figure 9, LANDSAT 5 image for southwest part of Syria.

be seen in the image published here, clearly distinguished by the extreme division of the parcelling arrangement.

The built-up area around the city has grown in a star along the main communications arteries.

Outside the urban zone of Damascus and its satellite towns, villages appear; they are more or less isolated far from the main highways (the only clearly visible communications).

The image also reveals abundant open-pit mining in the hills surrounding the plain of the Sahl esSahra (quarries, cement ?).

### THE CONTRIBUTION OF SPOT

On the whole, SPOT recording appears to be closer to conventional aerial photograph than LANDSAT on the same scale. The difference resides essentially in :

- a better definition of the image, allowing a finer perception of the details (drainage pattern, lapies texture of the Anti-Lebanon).

- the possibility of stereoscopic vision : many ambiguities can be cleared up on this account, allowing relatively through structural analysis.

The common advantage is the territorial extent of the scene, which although smaller in SPOT than in LANDSAT, remains out of all proportion to that of aerial

photographs, and serves to consider the problems on a regional scale.

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