REMOTE SENSING FROM SPACE

ACQUISITION AND USE OF SPACE PHOTOGRAPHIC DATA
CASE STUDY : SYRIAN VOLCANIC AND WIND STREAKS PHENOMENA ,TLOOL AS-SAFA

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Satellite Remote Sensing is a widely used and potentially powerful tool in the mapping of large-scale volcanic phenomena. Landsat-5 Thematic Mapper,Radar SIR-A,Spot and MSS data have been used to map volcanic structure Southwest of Syria . TM provides nearly as much information as high-altitude aerial photograph , especially in areas with extensive lava cover . Radar and TM imagery have proved useful for detailed interpret - ation of volcanic structures . The brightness of the Radar returns from the lava surfaces shows significant local vaiation . Bright and dark returns represent rougher and smoother flows . These contrasts are less clear on the Landsat and Spot imagery. This paper presents the results of a Remote Sensing investigation based on various imagery .

1. Introduction

Remote Sensing from space is a widely used and potentially powerful tool in the mapping of large-scale geological structures. The Multispectral Scanner (MSS) (Sabins 1978; Lillesand & Kiefer 1979) onboard the Landsat satellite series is familiar to many geologists but, the poor resolution of the MSS has minimised its use. Beginning with Landsat-4,however,the Thematic Mapper (TM) (Longman 1984) instrument delivered data with improved resolution,thus allowing for better identification of both large-scale and small-scale structural features not previously detectable. The Landsat-5 was launched in March 1984 and is still operative,recording almost 150 scenes per day. The amount of data has increased considerably from MSS to TM,because of an increase in the number of spectral bands(4-7 channels),in radiometric resolution(64-256 digital levels)and in geometric resolution (80-30m). Compared to a MSS scene that contains ca.180 Mbits of information, a TM scene contains ca. 2000 Mbits and covers the same area.

Compared with the MSS instrument,TM has two additional channels in the reflected infrared area and one channel in the thermal infrared area. The thermal channel has a resolution of 120 x 120 m. The geometric resolution or pixel size of TM is 30 x 30 m. compared to 56 X 79 m(Sabins 1978,233) for MSS. A sun-synchronous orbit is used to insure repeatable illumination conditions. Repetitive coverage allows optimal cover conditions for geologic applications. Seasonal variations in solar illumiation were analyzed to select the best Landsat data for geologic applications. Landsat data are receiving from the Tracking Data Relay Satellite System(TDRSS). The TDRSS includes two tracking data relay satellites(one located at 41° west and the second at 171° west),and a ground station located at White Sands , New Maxico. Data received at White Sands are transmitted via DOMSAT to GSFC (fig.1).

On the 23rd of February 1986, Spot 1 was launched. Additional Frensh Earth Resources satellite SPOT-2 was launched in 1991 .

The advantages of SPOT are its improved spatial resolution and its stereo capability.

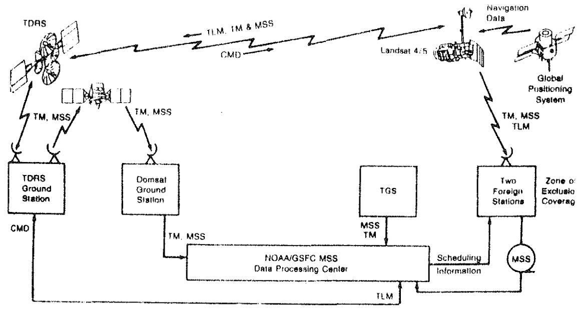


fig.(1)

This paper presents the results of a remote sensing investigation based on Landsat MSS and TM,SPOT,and SIR-A data. The study started in 1986 and has previously been described in two reports by M.Dalati(1988,1990 ,GORS Damascus,Syria). The aim of the study was to evaluate the benefit of Landsat , SPOT and SIR-A data in the mapping volcanic and wind streaks phenomena. In particular,the work aimed to compare TM data with older Landsat MSS data from the same area,and to compare SPOT data with SIR-A(Shuttle Image Radar-A)data,and to exemplify the utility of space photographs in establishing the origin and evalution of arid landscapes .

2.Area of investigation :

The area of investigation is located East and southeast of Damascus(fig.2)and includes an area of about 5000Km^2. Lava flows and volcanic cones occupy most of the area. The field of lava and volcanic cones extends southeast for about 450 km through Jordan to the Al Harrah region of northern Saudi Arabia. It is composed of basaltic and andesitic rocks,alteration rocks,fragments, bombs,breadcrust (fig.3),pyroclastic rocks and block lava,that are mostly Recent in age. Two of the major stages of eruption of Recent effusives are clearly distinguished B3Q4(Diret At-Tolool cover,Ard Ad-Dyoura) and B5Q4(As-Safa cover)-(fig.4). The cover. of the Recent basalts resulted from a number of natural outcrops. All the covers of Recent basalts(Alkali basaltoidos)-in the area-have nearly the same mineral composition. The petrographic composition of these rocks is quite common:Olivin,Titanougite,Labradolorite,Ilmenite,Magnetite, Volcanic glass,Apatit. The volcanic cones are composed of alternating slags,slags,Lava and Tuffs. All recent volcanoes have well formed and preserved volcanic cones. Very rarely,in the cones of the first stage,one can see slightly eroded craters. The height of the volcanoes ranges from 70 to 250 m,the diametre of the base ranging from 200 to 2,500 m. The craters are 70 to 600 m in diametre,and 30 to 70 m deep. The craters of the oldest volcanoes have a flat floor covered with loamy material .

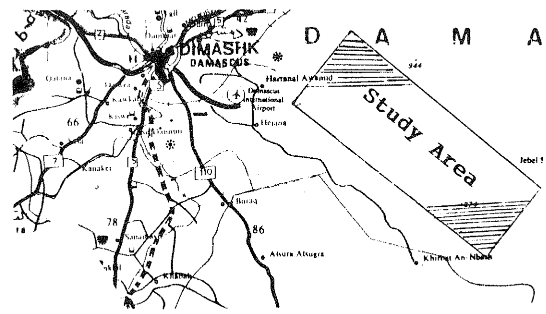


fig. (2)

The floors of the younger volcanoes are covered with lava blocks,whereas,the craters of the youngest volcanoes have clearly recognizable vent funnels.

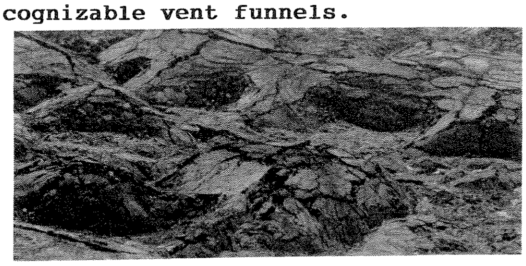


fig.3

The volcanic cones of all stages are composed of interbedded extremely coars-detrittal tuff breccias(the individual fragments being as large as 3-5m),slag lava , lava and tuff.The latter is poorly cemented forming layers 1 to 3.5m thick. The slopes and the terrain around the volcanoes contain scattered volcanic bombs and labilli. The slopes are often armored with the outflows of the latest lavas which sometimes break through volcanic cones, as in the case of the Tell Jaafar volcano(fig.5).

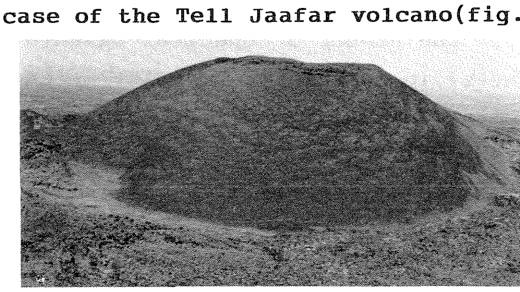


fig.5

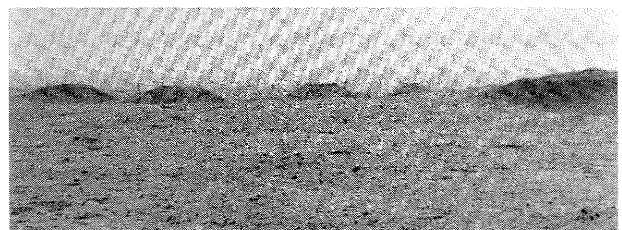
It has been noted ,that the centers of eruption are recognized at present as volcanic chains of a north-westerly strike,confined to fault zones. THe sources of eruption of the flows situated in the north of Diret At-Tlool are represented by two volcanic chains,each having 10 volcanic cones and consisting of two or three parallel volcanic chains(fig.6). The centers of eruption of the Diret flow are represented by five volcanic chains. The two biggest chains extend for 25 and 30 km and consist of 18 and 30 volcanoes,respectively. Sometimes the sources of eruption are single volcanoes. The thickness of each basalt flow of the recent age is not known. It seems that in the central parts of the flows it may exceed 100m because often in the walls of niches and caves the visible lava thickness attains 40-50 m . Without question it directly depends on the topography,sharply increasing in low areas. At the margins the thickness diminishes to dozens of metres.Often one observes here a peculiar kind of windows of the older lava flows.

The basis of the tectonic zonation shown on the map(fig.7)is the difference in the age of the platform basement,character of dislocations of the platform sediments and history of formation and development of individual structural features.

In the south of the territory,along the Red Sea and Akaba gulf coast and also on the Sinai peninsula lies Arabian-Nubian schield with the Pre-Cambrian metamorphic rocks exposed at the surface. In the west of the territory,along the eastern Mediterranean coast,stretches a block-folded structure of the Great African faults that have a through character cutting different structural features of the platform including the margins disturbed by the Alpine folding .

The Arab depression which has the study area(Tlool As-Safa) is underlain by thick Neogene and Quaternary basalt flows.The depression is bounded by systems of north-Westerly faults that define its graben- like shape. The faults running along the sides of the depression are clearly marked by a volcanic chains (Tlool As-Safa).The deep character of the faults suggests a block structure of the basement below this area. The Arab depression lies between two uplifts ,the Jordan uplift(which is situated near the Dead sea)and the Rutbah anteklise which had been growing for a long time .
The Arab depression is bounded in the north by a system of regional faults and conjugated linearly elongated folds known as the Palmyrides.

The magnetic map shows anomalies are grouped into chains oriented north-westerly in accordance with the deep faults within the basement that control the position of volcanic vents.



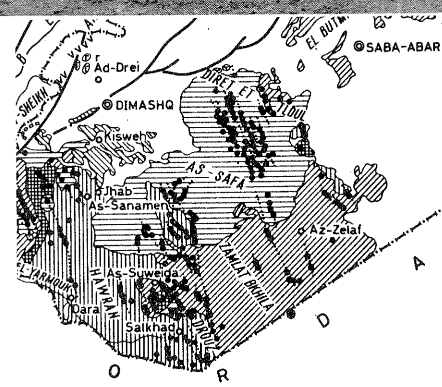


fig.(6)

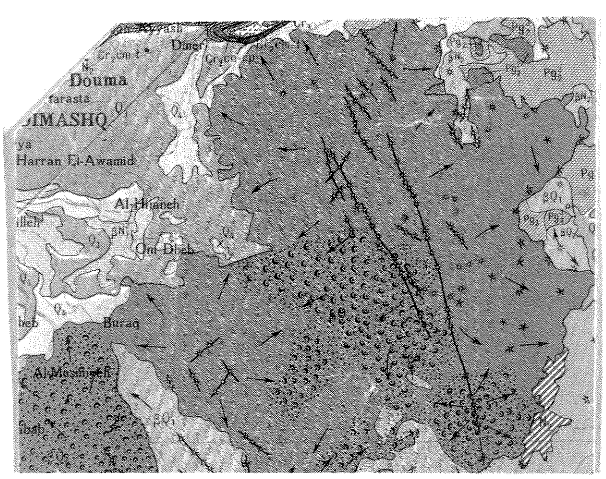


fig.(4),Geological map of the study area.

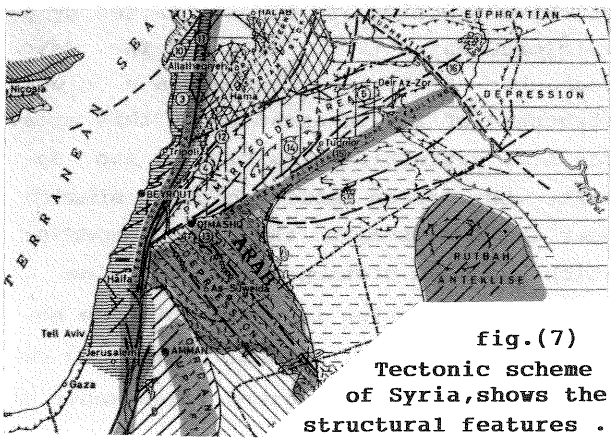


fig.(7) Tectonic scheme of Syria,shows the structural features .

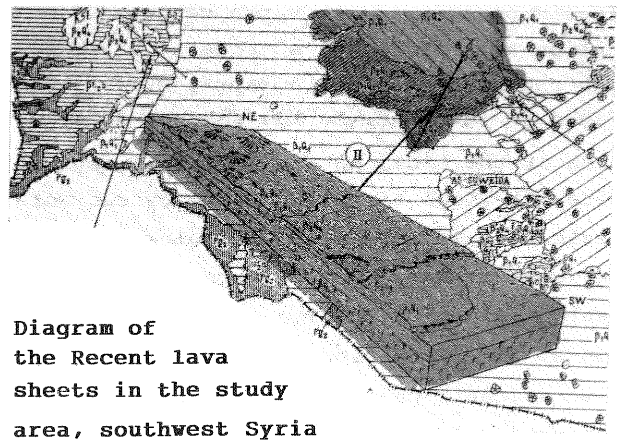


Diagram of the Recent lava sheets in the study area, southwest Syria

3.Interpretation of Remote Sensing data : Results of the Investigations, using space IMAGERY :

The investigations were carried out on the basis of multispectral data of the Landsat MSS,TM, and data of SPOT , black and white images, and data of SIR-A, black and white image,in addition to the data of Landsat RBV mosiac (Landsat-3,Return Beam Vidicon,RBV), which covers the study area or volcanic system(fig.8) in Tlool As-safa,East and Southeast of Damascus. It shows the volcanic chains of a north-westerly strike,confined to tectonic fissures and faults (faulting zones).There are traces of movement of basalt lava,typical of the flows stages is extensive development of niches and caves in which can see the internal structure of the flow. Chains of lava pits can be traced almost continuously along the edges of the lava flow. The pits are often separated by narrow commissures in the form of arches .

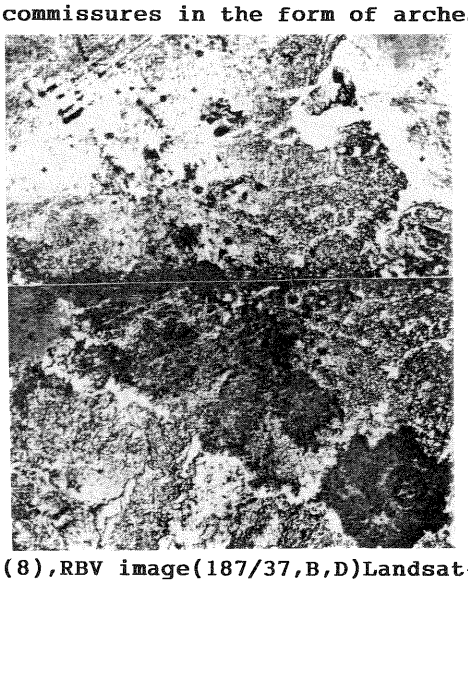


fig.(8),RBV image(187/37,B,D)Landsat-3 .

Recent basalt sheets are shown by a number of successive lava effusions. It can be easily seen in a number of fissures,extensive solid outcrops in a grey to black tone occupy all the flows of the stages which show an indistinct cellular pattern, coarse-cellular,distinctly cellular,patterned cellular,fine-cellular,whitish fine-wrinkled. Flows of the stages in some areas composed of block lavas present a very peculiar shape due to alternating dark and light bands radiating in all directions from the centers of eruption. The lighter bands show ; oriented accumulations of hummocks.

It appears on MSS Landsat Image(fig.9) the caldera,south of the study area,it is in a black color,in circular feature.

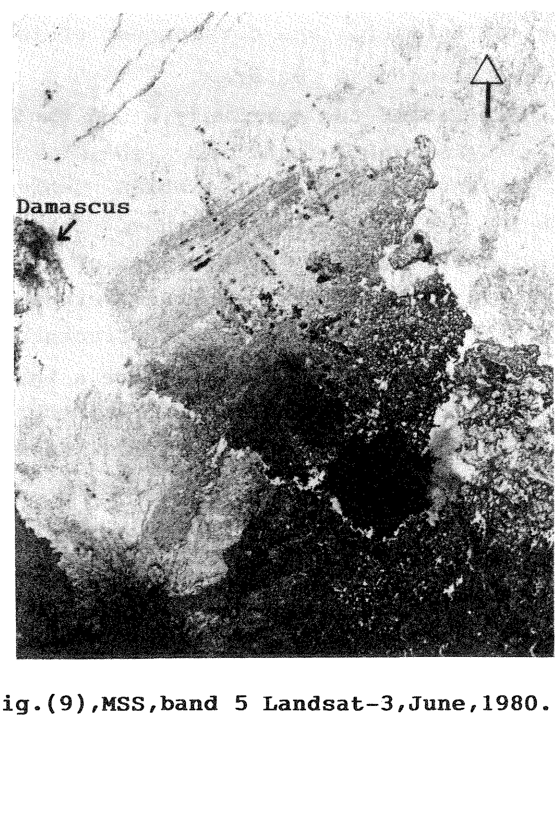
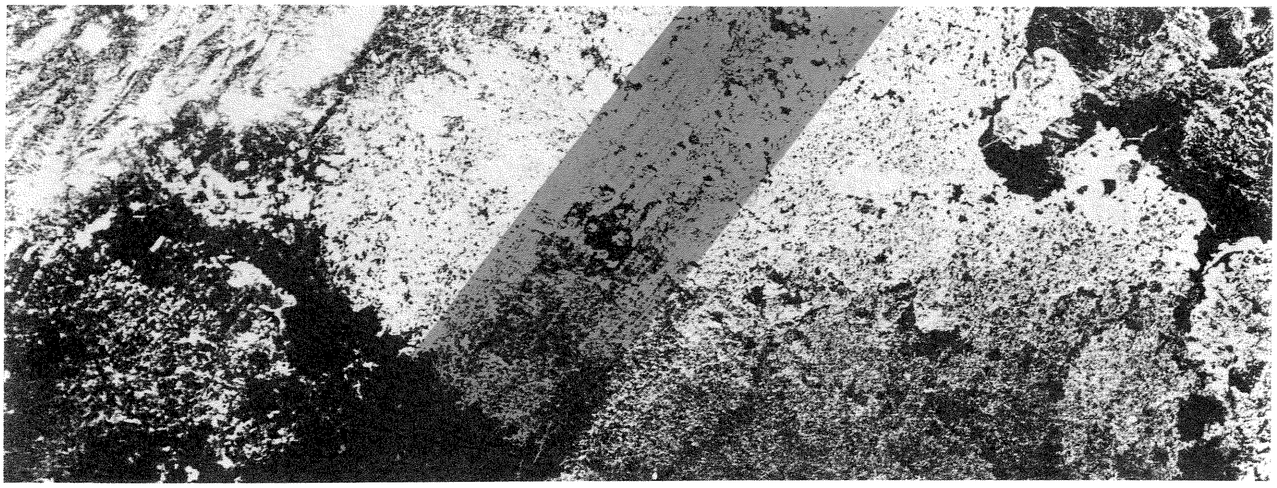


fig.(9),MSS,band 5 Landsat-3,June,1980.



(fig.14) SIR-A image -Radar image obtianed from space shuttle mission 1981,after NASA.

MSS image shows quite a number of volcanic cones are excellently preserved,morphological and structural features of the lava surfaces are clearly visible and distinct marginal swells are present. Effusions of recent lavas occurred repeatedly.Genetically they are associated with lines of deformations of the basement that are present at the surface as zones of subparallel faults of a north-westerly,or more rarely , north easterly strike,crowned with small chains of extinct volcanoes. In the south-western corner of the image ,it is noted the superposition of the lava sheet on the smoothed surface of effusives . The morphological elements of the sheet surface such as marginal ramparts, slump holes, swell cupolas , ets. are clearly seen. Accumulations of loose surface loams are seen at the margins of the caldera as white spots.

Reference to the different tones, gray to light gray,dark to black; it can be considered that some chains of volcanoes are formed of volcanic cones of different ages. The Tell As-Safa volcano (fig.10)is very peculiar . It is composed of slag-lavas and

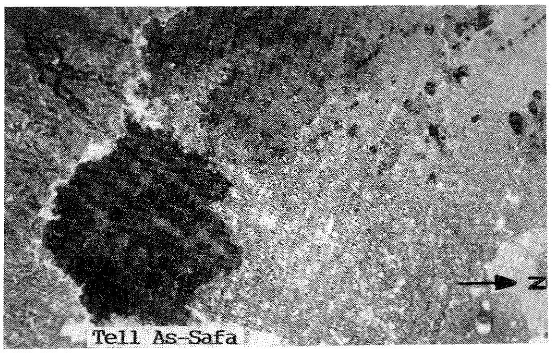


fig. 10

volcanic tuffs. In the lower part of the crater clearly pronounced vent is observed , where the eruptions occurred . The volcanic cone is encircled by a caldera about 900 m in diameter . It is an arch-like elevation formed of slag-lavas. This elevation is broken into four sectors by two trenches which appear to be of tectonic origin.The first trench runs northwestward while the second-nearly westward. In the centre of the volcano, where the trenches cross each other,two small slag cones with steep slopes are rising .

WIND STREAKS :

The characteristics of wind streaks associated with craters and hills , corresponding to obstacle heights of a few to several hundred meters, have been analyzed from MSS,TM Landsat images, SIR-A image(obtained from the American space Shuttle mission, 1981).

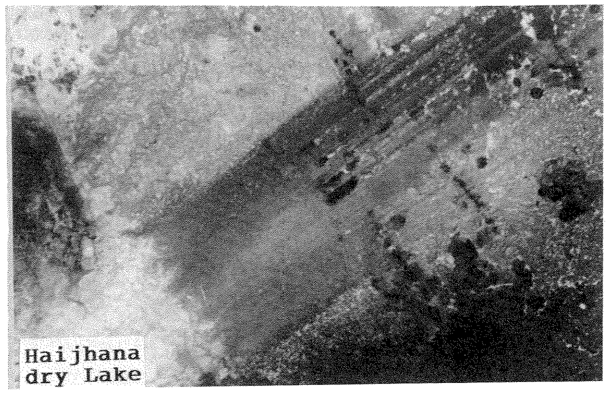


fig.11,part of MSS image B&W band 5 (1978) 28,Jun. shows the wind streaks .

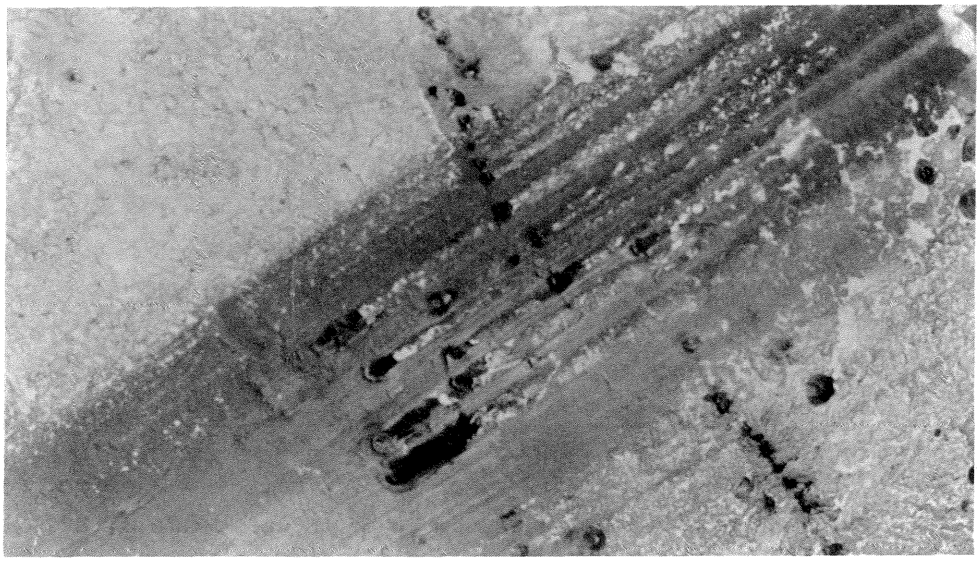


fig.(13), SPOT-1,HVR 1 , 121-283   09 ,July,1987,B&W,Resolution 10 m.

In the northwest of the MSS image (fig11), it is clearly noticed the wind streaks phenomena,and it shows that both bright depositional and dark erosional streaks were predominantly associated with bowl-shaped, and raised-rim craters.

Thematic Mapper(TM)Landsat-5 image shows the wind streaks(fig.12)phenomena in spindle-shaped, and in light-and dark-colored streaks in the lee of knobs . It is observed, from TM image wind streaks production as related to Obstacle type and size. A sharp drop-off in streak occurrence observed for smoll obstacles. On the SPOT image(feg.13) it shows the wind streaks, by far the most numerous and variable albedo features on the surface of the study area east of Damascus 60 kms. Streaks have been categorized as involving either the deposition or erosion of dust originally suspended in the atmosphere or the deflation of a deposit of wind transportable material. Bright depositional streaks have been interpreted as accumulations of bright dust(sands) have transported from the dry lake -Al-Haiganeh-west of the wind streaks phenomena and southeast of Damascus, these dust deposited downwind of topographic obstacles (hill or crater). Dark erosional streaks have been interpreted as resulting from erosion of volcanic-materials,tuff,and dust from a darker substrate.

The lava flows on the SIR-A image range from medium-to light-gray tones. They show a pronounced margin that can be traced(fig. 14). The abruptness of this margin reflects the contrast between the rough surfaces of the lava front, which appear bright,and the smooth, level surfaces of the material at the base of this front , which appear dark. The lava surface is extensively pitted in the area with dark returns coming from depressions that are probably floored with layers of wind-blown sand. SIR-A shows (in the northeast part) eolian depositions in parallel linear sand streaks that extend to the northeast. A dominant southwest wind could account for these phenomena.

4.Conclusion

The SIR-A image shows an east-southeast alignment of the cones , which is evident thougt less clear on the Landsat image in the near-IR wavelength(fig.15). A south-southeast fracture pattern is clearly displayed on both the radar and the Landsat images. The brightness of the radar returns from the lava surfaces shows significant local variation. Very bright returns represent rougher and probably younger flows than the darker returns from smoother , probably older flows.These contrasts are less clear on the

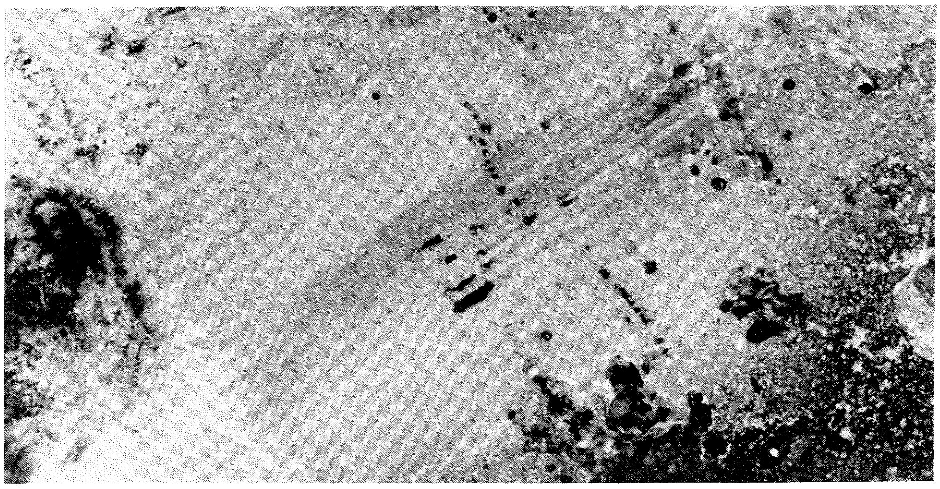


fig.(12),TM image color composite (bands 1+2+3) Landsat-5,July,1987.

Landsat image.

Due to the Radar penetration characteristic and because of the extreme dryness , the sand in some sits, could not be a radar reflective, and could be reflected by the solid layer of rock beneath the sand. This is a great deal of the Shuttle Imaging Radar (SIR)instrument on board the Space Shuttle Columbia on its flight in 1981.

Data from the TM-instrument onboard the Landsat-5 satellite has proved very useful for detailed interpretation of geological structures,volcanic and wind streaks phenomena. Compared with MSS-data, the TM-data gives more information about structures less than 5 km in length. This means that TM can provide considerably more information about wind streaks related to obstacles than MSS. The fact that TM has more spectral bands than MSS means that certain structural features are more easily detected than by conventional MSS-analysis. The MSS image resolution is so low that it is impossiple in many cases, to distinguish between valleys eroded along foliation zones and valleys developed along fractures or faults . Comparing the depositional and erosional streaks interpretation of MSS with that of TM , the TM gives substantially more information on streaks and the accumulations of dust , and the ability to distinguish depositional streaks from erosional streaks is greatly improved . The linear features derived from SPOT and TM scenes took roughly the same amount of time to determine.In general a comparative evaluation of TM , and SPOT data of the whole area clealy shows the

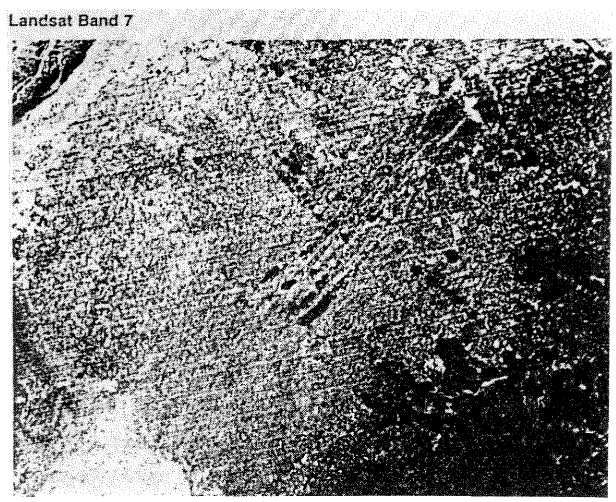


fig.(15),TM,band 7 ,Landsat-4 .

fig.(16),Spot-1,HRV,scale 1:50 000 .

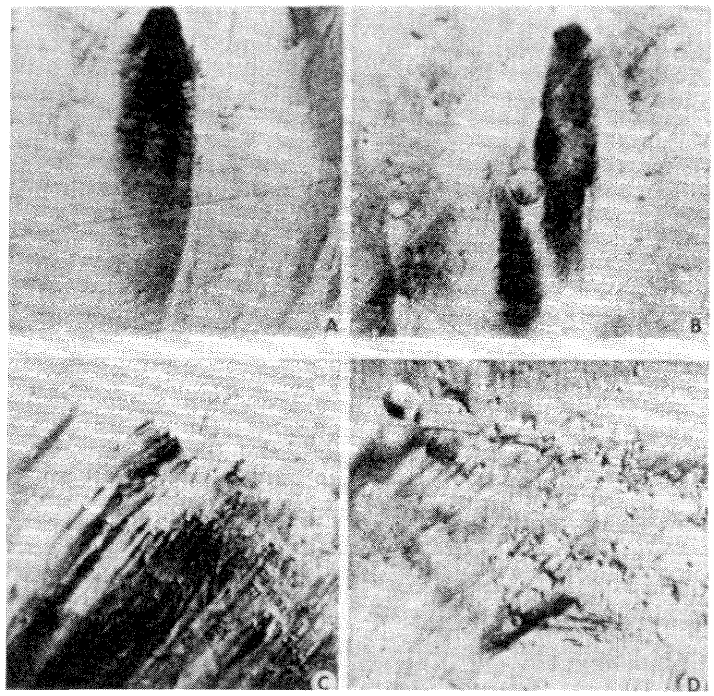


fig.17, Top: Spindle-shaped, sand-free zones in the lee of a hill in Libya (A),and of a crater in the Cerberus region of Mars(B).Bottom: Light-and dark-colored streaks in the lee of knobs in northwestern Sudan(C),and in a similarly rugged terrain on Mars(D) .

same higher content of information of the TM and SPOT data. On the other hand,the resolution offered by Spot HRV imagery, plus the fact that Spot steropairs are recorded directly in digital form , appears to offer a more satisfactory approach to this type of study. In addition, the SPOT multispectral mode offers additional data of considerable use to geologists(fig.16) .

Examples of several types of wind- streaks are shown in fig.17, spindle-shaped,sand - free zones in the lee of a hill in Libya (fig.17-A),and of a crater in the Cerberus region of Mars(fig.17-B),light-and dark - colored streaks in the lee of knobs in northwestern Sudan(fig.17-C) , and in a similarly rugged terrain on Mars (fig.17-D). Wind streaks have been observed by Mariner 6,7,and 9 and Viking Orbiter space-craft . Fig.(18) shows examples of dark and bright streaks,wind streaks related obstacles(crater and hill) .

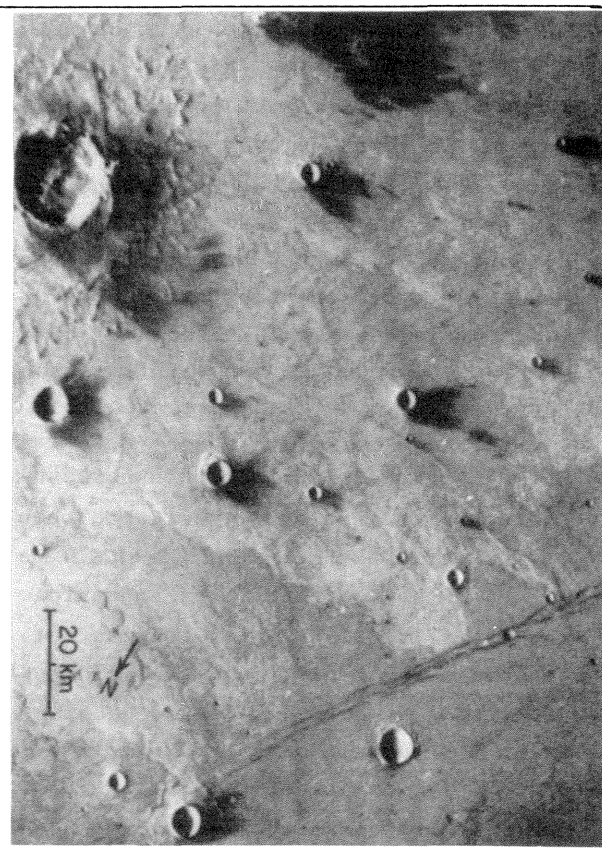


fig.(18)

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