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ERTS-1 IMAGE CONTRIBUTES TO UNDERSTANDING OF GEOLOGIC STRUCTURES RELATED TO MANAGUA EARTHQUAKE, 1972

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ABSTRACT

ERTS-1 imaged the western portion of Nicaragua on December 24, 1972, one day after the central part of the city of Managua was devastated by a major earthquake which measured 5.6 on the Richter scale. ERTS-1 images reveal four sets of lineaments (which may reflect fault systems) along any one of which movement could have taken place. One set, trending N 50° W, includes a line of active volcanoes that parallels the coast and constitutes the southwestern edge of the Nicaraguan Depression, a regional graben which cuts obliquely across the Central American isthmus. This trend is offset approximately 10km in a right lateral geometric sense just west of the city of Managua. A parallel lineament, north of Lake Managua, marks the northeast edge of the graben. A second set, trending due N-S to N 25° W, extends northward to northwestward from the mouth of the Rio Grande (Viejo) north of Lake Managua and can be projected southward across the lake to Managua. It is this set along which geometric offset of the volcanic lineament appears to have taken place. It is paralleled by a belt of young pit craters at the west edge of the city. A third set of linears trends approximately N 50°-60° E across the Nicaraguan trench. The fourth set, which is less conspicuous, is represented by only three identified members within Nicaragua. Two others, which are subparallel, are visible on the image in the area of Honduras, to the northwest. This set is notable for the fact that it extends from the coast entirely across the Nicaraguan Depression. Its trend is N 25°-45° E. Aerial photographs and field studies in the city of Managua by other U. S. Geological Survey personnel (Brown, Ward, and Plafker, in press) indicate that this fourth set is represented by four currently active, left-lateral, strike-slip faults and a narrow belt of aftershock epicenters. Instrumental data indicate that the aftershock earthquake foci are of shallow depth (<10.0 kilometers).

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1. INTRODUCTION

Managua, Nicaragua, was devastated by a series of 3 large earthquakes on December 23, 1972, the principal shock having a magnitude of 5.6 on the Richter scale. The loss of life has been estimated to exceed 11,000 persons and the damage to property valued at half a billion dollars (Brown, Ward and Plafker, 1973). Such destruction, as with the 1931 and 1968 earthquakes, was determined to be the result of two related causes: (1) The city of Managua is located on poorly consolidated sediments (scoria and ash) of volcanic origin; and (2) Many of the buildings are constructed of materials (masonry and tarquezal) that have little resistance to strong shaking. Direct displacement of structures situated along the course of active faults accounted for severe damage to buildings with better quake resistance (Brown and others, op. cit.).

On December 24, 1972, the Earth Resources Technology Satellite (ERTS-1), in orbit approximately 900 kilometers above the earth, acquired two multispectral images (NASA ERTS-1154-15385 and 15391) over Managua and adjacent areas to the west. These images were processed by NASA's Goddard Space Flight Center and forwarded to U. S. Geological Survey scientists for interpretation. Much of Managua was under scattered cloud cover, and therefore none of the damage could be defined. The area in the rest of the scene was cloud free, however; thus, it was possible to map a number of geologic features that may bear some relation to regional earthquake conditions and which contribute to general knowledge of the region.

The purpose of this preliminary report is to describe the evaluation of the ERTS-1 imagery and the results of rapid data interpretation (approximately 3 hours).

2. METHOD OF APPROACH

The authors have not visited Nicaragua and had access to only a very limited selection of library material when the interpretation was carried out in mid-January 1973. Positive 9" x 9" transparencies placed on a light table and an 8x magnifier were used to make mylar overlays. Diazo-foil, false color composites were made using a standard Ozalid printer.

The ERTS-1 imaging system is a 4-band multispectral scanner (MSS) in which the green (0.4-0.5μm), red (0.5-0.6μm), and two infrared bands (0.6-0.7μm and 0.8-1.1μm) can all be used to identify features. The following paragraphs attempt to explain their differences and contributions.

The green band (MSS-4) was somewhat affected by haze but clearly shows either sediment distribution or near-shore bottom features of water bodies or both (Figure 1). For example, two crater lakes on the Chiltepe peninsula of Lake Managua can be seen, but their tones are different. The lighter one is apparently more turbid than the darker. Marshland areas appear in tones lighter than water but darker than the surrounding land areas. Volcanic ash and lavas comprising volcanic cones and surrounding debris fields are darker than adjacent materials. Vegetative areas such as farmlands and cultural fields are difficult to define.

The red band is clearer in overall appearance because haze has less effect in this region of the spectrum (Figure 2). The land surface tones are dark shades of gray due to the presence of vegetation. Cultural and soil features are clearly displayed. Water penetration is minimal, but sediment plumes in estuaries are clearly visible.

The two infrared bands are very similar in that edges of water bodies are sharply defined in black (Figure 3). Marshland and levees can be clearly delineated in these bands, and they are also excellent for determining the presence of water in small rivers, streams, and arroyos.

Surface tones of land areas are brighter in the infrared bands than in the green and red bands due to higher reflectance of vegetation which appear in shades of white to light gray (Figures 3 and 4). Cultivated croplands are brightest (exclusive of clouds and snow) and can easily be defined. Natural vegetation appears as light gray. These bands are most useful in defining tectonic features, such as volcanoes and lineaments. Cultural features, such as small towns and cities, stand out as dark patches somewhat similar in tone to volcanic cinder cones. Their rectangular to irregular box-like patterns, caused by road grids and lack of radial drainage, enables one to distinguish them unambiguously.

Soil tones are subtle shades of gray and therefore are difficult to distinguish from natural vegetation in the black and white renditions of the scene. They are, however, easily distinguished in color combined renditions (Figure 5). One great advantage of these bands is the fact that one can separate natural vegetation from shadowing produced by the angle of solar illumination; in the red and green bands, however, this is more difficult.

Because of the earthquake-related destruction of Managua, a preliminary geologic structure map was made to see if such information would assist ground studies concerned with the damage. The map (Figure 6) shows the result of about three hours of interpretation. These studies are continuing and more information is being extracted. Figure 7 was prepared in about 10 hours by Dr. J. N. Rinker.

The most obvious tectonic features visible in the scene are the Holocene volcanoes aligned parallel to the coast. This linear arrangement trends S 50° E directly toward the city of Managua. Many of the volcanoes are recognized by their dark tones and circular patterns. Many show drainage scars radiating from their central cone and lobate forms or serate edges at the termini of their flows at the margin of the volcanic debris. Several are marked by crater lakes which are seen as black spots in the near-infrared bands. Two that are clearly visible are Laguna de Apoyeque and Laguna de Jiloa on Punta Chiltepe, a peninsula on the southwest shore of Lake Managua within 10 kilometers of the city. Three other crater lakes, under clouds in the scene, lie just south of the city. One of these at the edge of the city, Laguna de Tiscapa, is a residential area which includes the Presidential Palace and the U. S. Embassy, an area where considerable damage to structures was reported.

Of next importance is a narrow belt of linear features that trends north to north-northwest (due N to N 25° W) on the north side of Lake Managua. A projection of these linears to the south, across the lake, intersects the volcano linear northwest of the city of Managua. The volcanic linear is offset approximately 10km, with the east block apparently displaced to the south. This displacement is not visible on the image, but is seen in the regional geologic map (Figure 8).

A third and fourth set of prominent linears strike north-northeastward and northeastward (N 25°-45° E and N 50°-60° E), respectively, crossing both the volcanic trend and the Nicaraguan Depression. Although it can not be seen in the ERTS-1 scene at Managua because of cloud cover, Mr. Leroy Anstead of IAGS, on duty in Managua at the time of the event, reported north-northeast trending earthcracks in the city. They were visible on the ground and in low-altitude (scale 1:5,000) aerial photography. This set has been mapped in detail by Brown, Ward, and Plafker (1973), and it is paralleled by a narrow band of earthquake aftershocks.

Strike-slip offset of a few to several tens of centimeters was measured in walls, sidewalk curbs, and roads that intersected these fractures. This trend had been mapped earlier both by Juan Kuan S. and Carlos Valle G. (written communication, undated) and on a radar mosaic of the country by Anstead (oral communication, 1973) and others for a length of over 100km. Inasmuch as this set is paralleled by three other lineaments seen on the ERTS image to the northwest, regional field investigations of this set would seem to be desirable from the standpoint of assessing regional earthquake hazards.

The authors had the opportunity to briefly study color infrared photography acquired from the NASA C-130 aircraft on or about December 28, 1972. The frame which covered the center of the city revealed the area of greatest damage to be white to light gray in tone, crudely elliptical in shape and covering about 70 blocks in area. The damage zone, trending east-west, is marked by collapsed roofs, walls, and extensive rubble in the streets. An extension of damage was seen in small areas to the north-northwest. Extensive damage also extended along this line, south of the probable epicenter of the main shock, to a small crater lake (Laguna de Tiscapa) next to which were the Presidential Palace and the U. S. Embassy. These were reported to be damaged beyond repair.

3. SUMMARY

The Managua earthquake of December 1972 constituted an early test of the ability of the ERTS-1 system to respond to a disaster situation. The alertness of the NASA satellite management team enabled the acquisition of data on the day following the event. Rapid image processing by the Goddard crew put data in the hands of geologists within 5 days of the event and copies of the initial interpretation were placed in the hands of the Nicaraguan Embassy within 2 weeks. The data obtained provided good background information on the surface geology and structure of the region.

Although cloud cover and smoke prohibited detailed studies of destruction within the city of Managua from ERTS-1, the destroyed area was large enough to have been detected in enlargements of ERTS-1 data at scales of 1:250,000 or 1:100,000 or in computer processing of the tapes. Repetitive data taken 18 days after the event would have been useful for comparative purposes. Pre-earthquake ERTS-1 imagery of Managua would also be extremely valuable in assessing changes associated with the earthquake.

4. REFERENCES

Brown, R. D., Jr., Ward, P. L., and Plafker, George, in press, Geologic and seismologic aspects of the Managua, Nicaragua, earthquakes of December 23, 1972: U. S. Geol. Survey Prof. Paper 838.

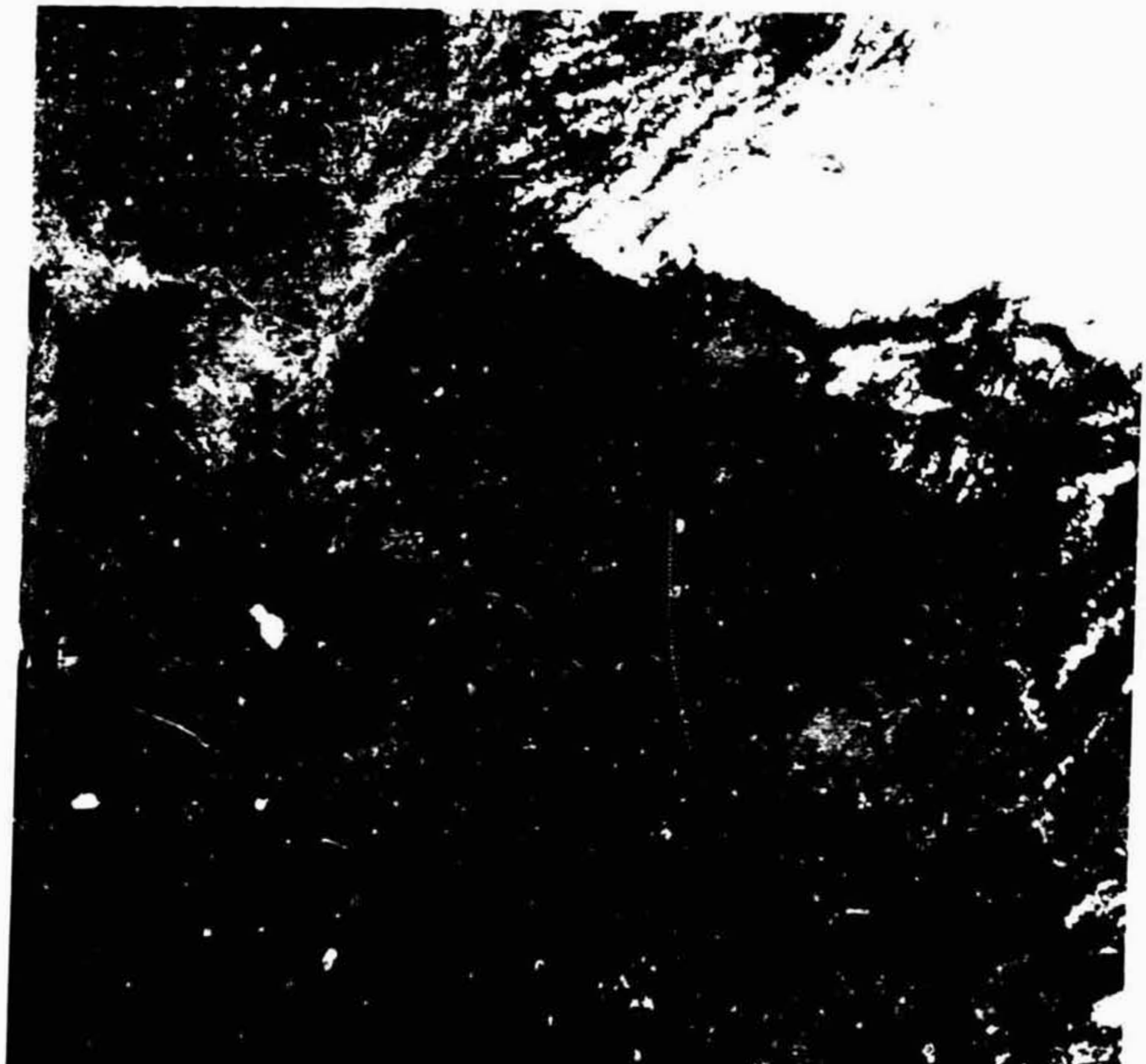

Figure 1. - Image of Nicaragua, Band 4 showing sediment plume in Bay of Fonseca

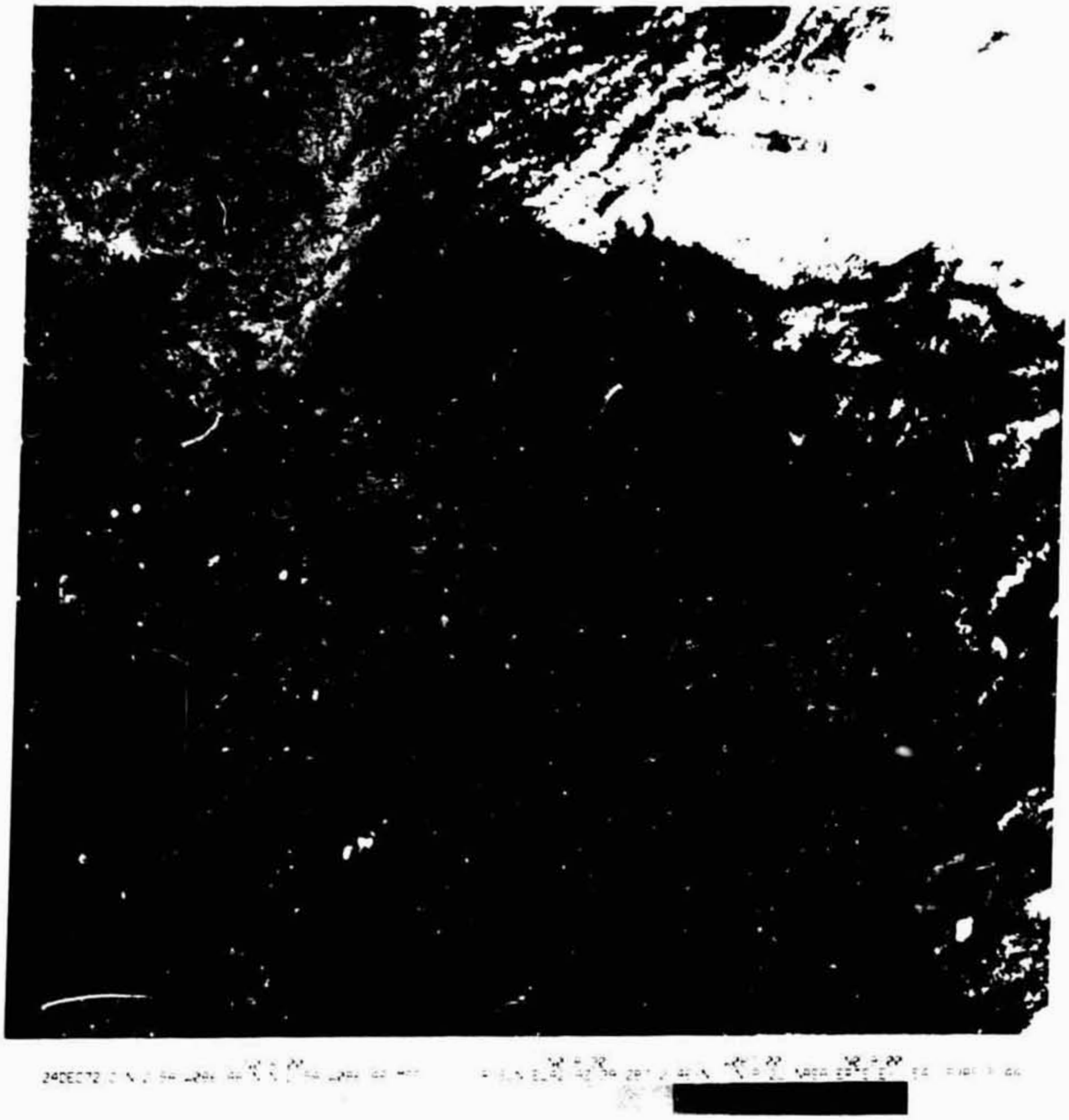

Figure 2. - ERTS-1 Image of Nicaragua, Band 5
showing cultural features

Figure 3. - ERTS-1 Image of Nicaragua, Band 6 showing distribution of volcanic centers and water bodies

Figure 4. - ERTS-1 Image of Nicaragua, Band 7 showing features described in Figure 3 but from which interpretation was made

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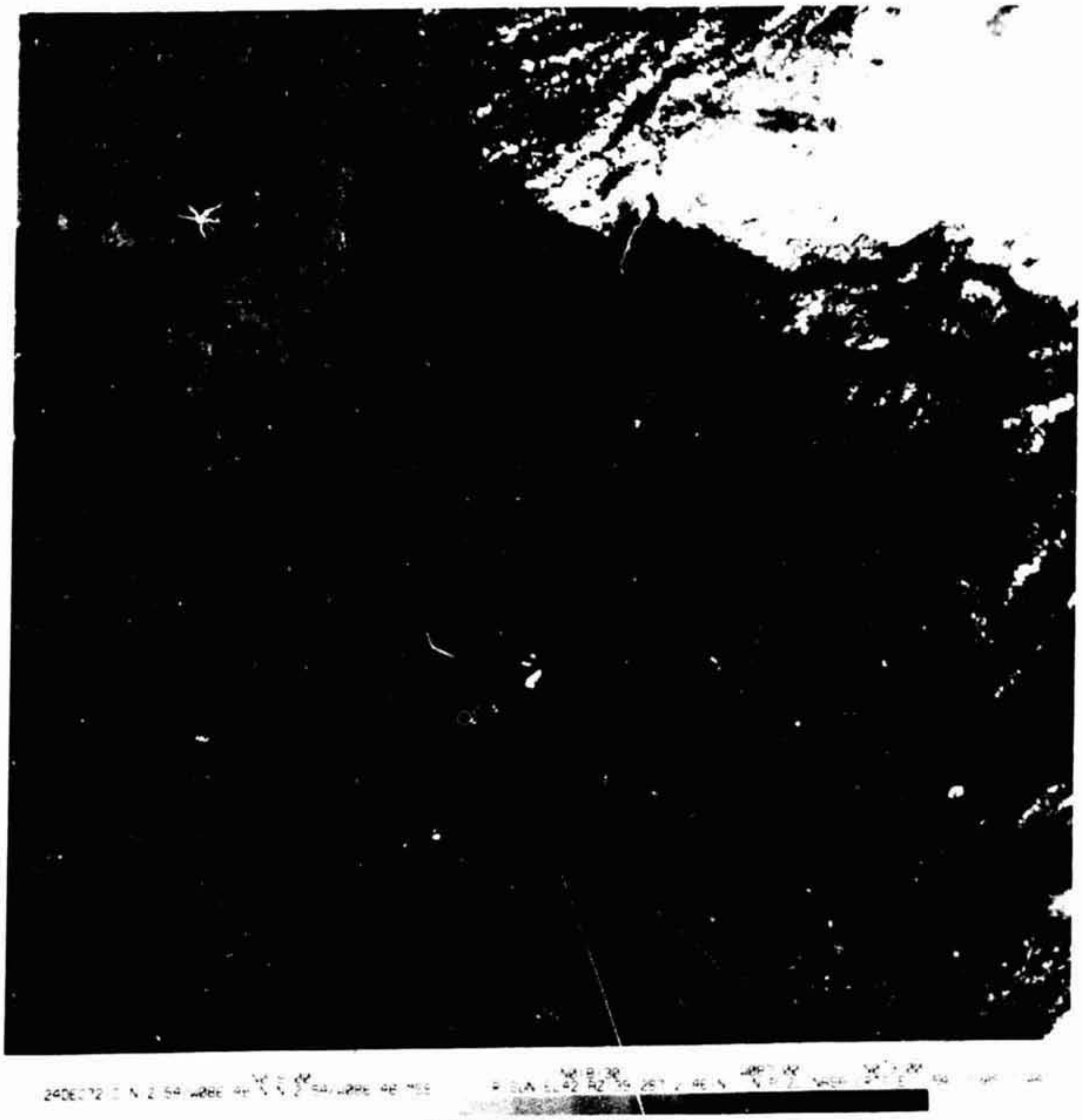
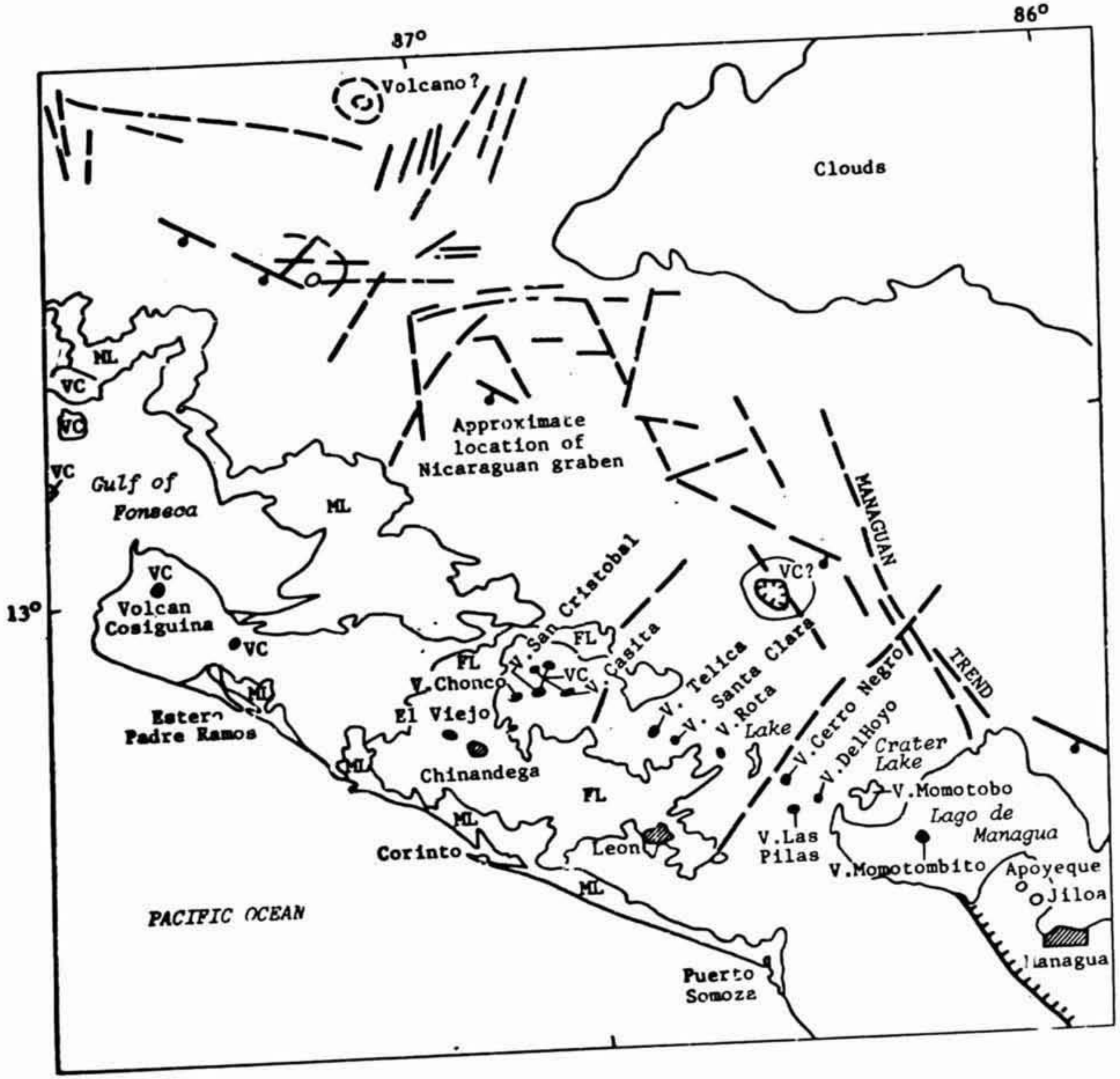


Images by National Aeronautics and Space Administration, 1972

FALSE COLOR COMPOSITE IMAGE

Figure 5 False color composite image of Bands 4, 5, 7



EXPLANATION

ML - Marshland

FL - Farmland

VC - Volcanic crater or crater lake

City or village

Edge of caldera

Lineament; possible fractures or faults

Approximate edge of Lake Nicaragua graben; ball indicates downthrown side

PRELIMINARY SKETCH MAP OF LINEAR AND VOLCANIC FEATURES IDENTIFIED IN ERTS-1 DATA OF NICARAGUA
24 DECEMBER 1972
By
W.D.CARTER, US GEOLOGICAL SURVEY
WASHINGTON, D.C.

NASA EARTH RESOURCES TECHNOLOGY SATELLITE (ERTS-1) IMAGE
NORTHWEST OF MANAGUA, NICARAGUA—IMAGE AND FRACTURE PATTERNS, 1972

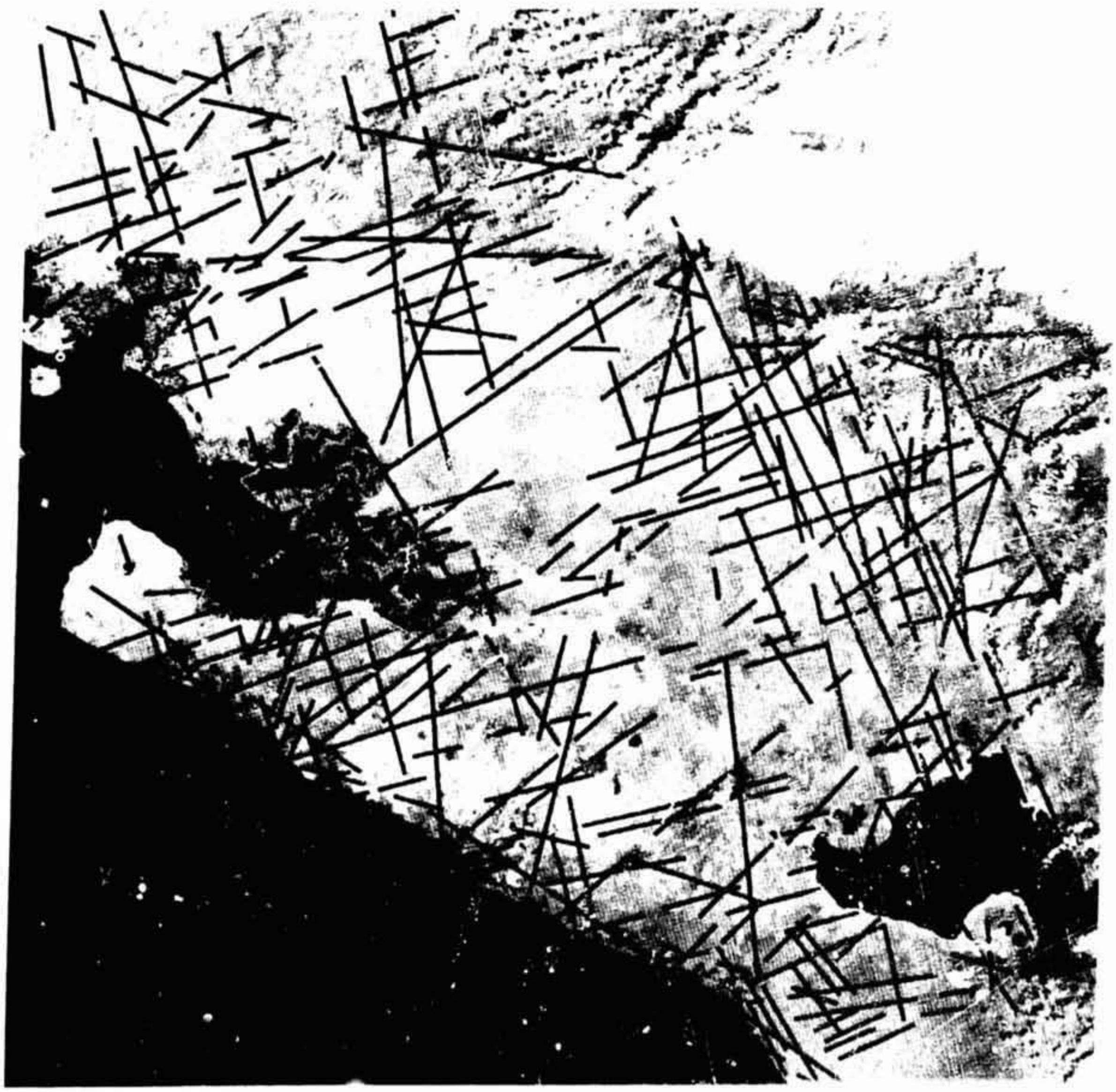


IMAGE SHOWING FRACTURE PATTERN ANALYSIS
By J. N. Rinker Defense Mapping Agency

Figure 7

Image showing more detailed fracture pattern analysis by J. N. Rinker, DMA

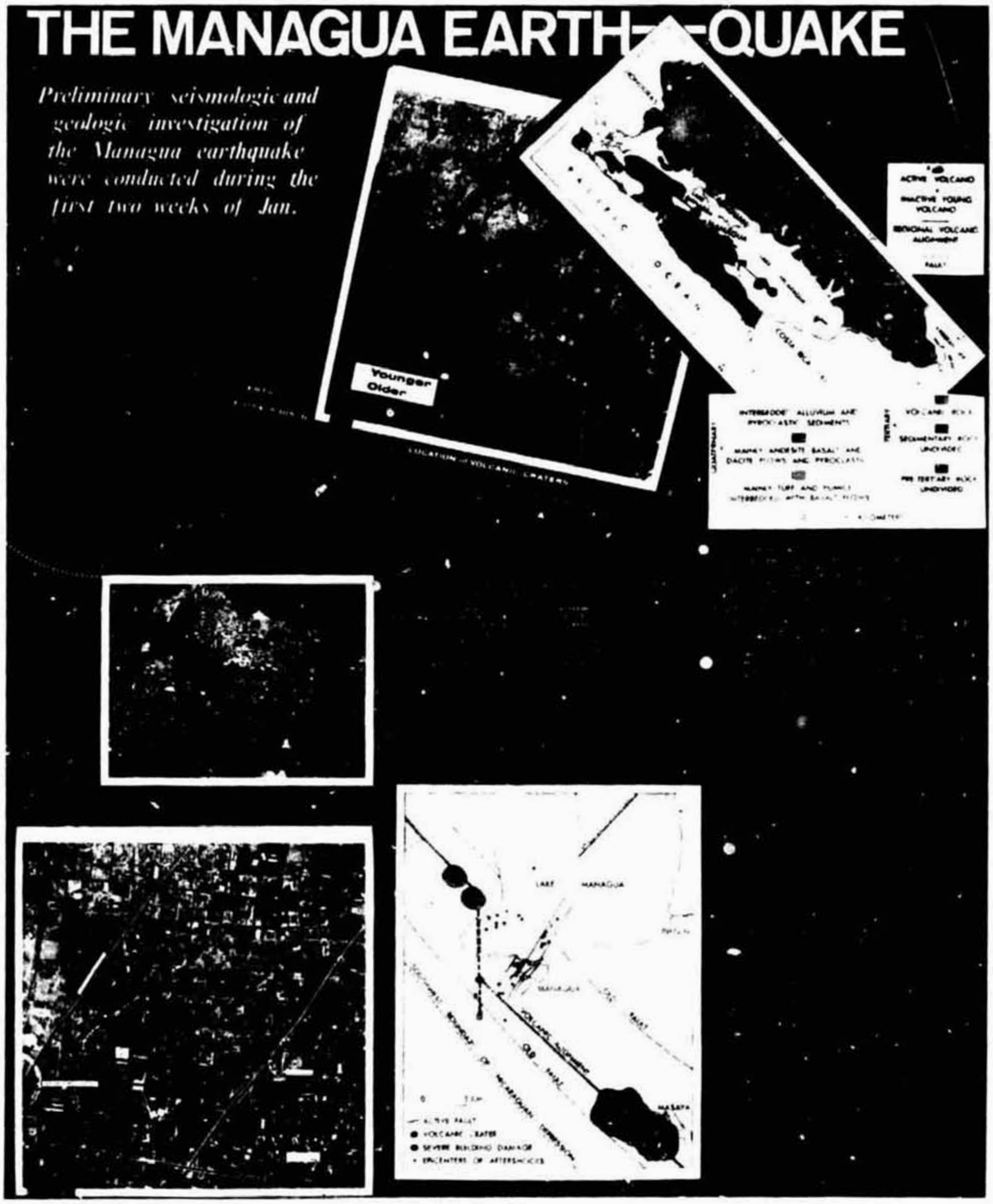


Figure 8

The Managua Earthquake summary showing preliminary seismologic and geologic investigation sources and products