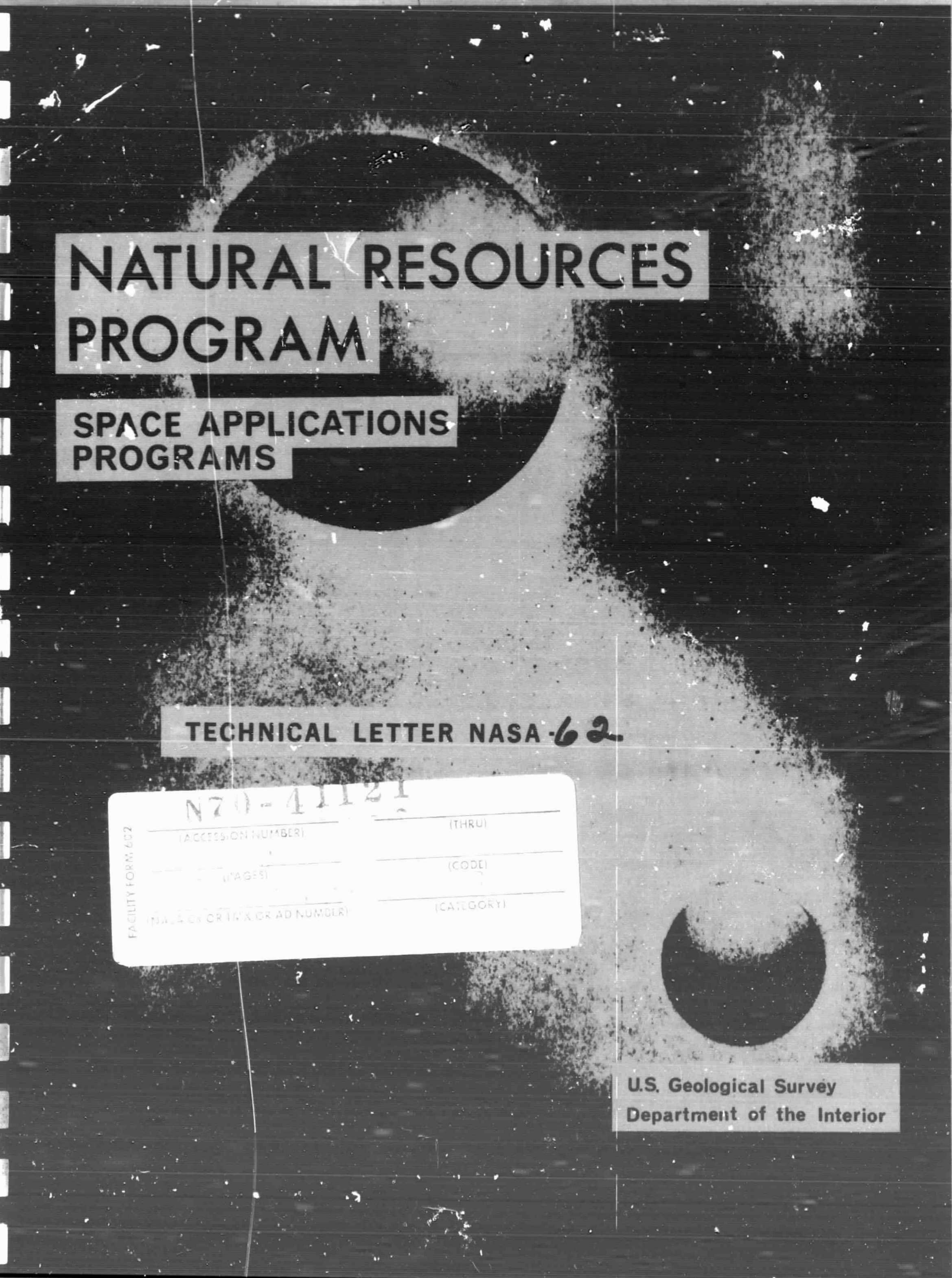

NATURAL RESOURCES PROGRAM

SPACE APPLICATIONS PROGRAMS

TECHNICAL LETTER NASA-62

U.S. Geological Survey
Department of the Interior

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Washington, D.C. 20242

Technical Letter
NASA-62
November 1966

Dr. Peter C. Badgley
Chief, Natural Resources Program
Office of Space Science and Applications
Code SAR, NASA Headquarters
Washington, D.C. 20546

Dear Peter:

Transmitted herewith are 3 copies of:

TECHNICAL LETTER NASA-62

RADAR IMAGES - METEOR CRATER, ARIZONA*

by

Gerald G. Schaber**

Sincerely yours,

William A. Fischer
Research Coordinator
Earth Orbiter Program

*Work performed under NASA Contract No. R-09-020-015
**U.S. Geological Survey, Flagstaff, Arizona

[redacted]

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TECHNICAL LETTER NASA-62

RADAR IMAGES - METEOR CRATER, ARIZONA*

by

Gerald G. Schaber**

November 1966

These data are preliminary and should not be quoted without permission

Prepared by the Geological Survey for the National Aeronautics and Space Administration (NASA)

*Work performed under NASA Contract No. R-09-020-015
**U.S. Geological Survey, Flagstaff, Arizona

Photo copies of illustrations are available for viewing at the following places:

Author(s); Discipline Coordinators; NASA Data Bank (Houston); Remote Sensing Evaluation and Coordination Staff (RESECS) and the U.S. Geological Survey Libraries (Denver, Menlo, Washington, Flagstaff).

TABLE OF CONTENTS

Radar Images - Meteor Crater, Arizona

by

Gerald G. Schaber

INTRODUCTION

Two overlapping strips of radar imagery, covering a total combined area of 460 square miles, centered on Meteor Crater, Arizona, were obtained on November 5, 1965, at the request of the U.S. Geological Survey. The system was a high frequeny (K-band), side-looking radar with a multipolarization capability. Two images were recorded simultaneously on each strip. Two separate combinations of transmit and receive polarizations were used for the two flight lines. In Run No. 8 (Figs. 1A and 1B), the upper image was produced from the horizontal component of a horizontally transmitted wave; the lower cross polarized image from the vertical component of a horizontally transmitted wave. In Run No. 14 (Figs. 2A and 2B) the upper image was produced from the vertical component of a vertically transmitted wave, the lower image was produced from the horizontal component of a vertically transmitted wave.

Meteor Crater has been, during the last few years, the focal point of many scientific investigations dealing with impact mechanics (Shoemaker, E.M., 1959), geophysics (Godson, R.H. et al, 1966) and remote sensing (Hemphill, W.R. and Vickers, Roger, 1966).

The obvious similarity of the Arizona feature with other, more eroded, terrestrial phenomena, as well as those on the Lunar and Martian surface, has prompted its use as a test site for remote sensing investigations.

GENERAL COMMENTS

Distortion - Distortion is present on both radar runs in the form of signal ripples parallel to the direction of flight of the aircraft. The ripples are extremely pronounced on the vertically (VV) polarized part of run No. 14 (Fig. 2A). The portion of the imagery nearest the flight line is considerably distorted, causing a foreshortening of surface features. As a result of such ground distortions, which are innate with the side-looking radar system, the scale of the image varies considerably in all directions. The scale of run No. 8 varies from 1:176,308 in a NE-SW direction to 1:186,644 (and three tenths) in a NE-SW direction. Run No. 14 varies from 1:191,595 SSE-NNW to 1:206,070 in a SSE-NNW line. The image scale is most nearly uniform, however, in the central portion of each strip parallel to the direction of flight.

Resolution of features - Cultural features such as railroad tracks, telephone line-right-of-ways and farmed patches show well on the radar images. However, the rather poor resolution of U.S. Highway 66 north of the crater is disappointing (Figs. 1 and 2). Secondary, paved roads are only very weakly visible or cannot be resolved at all.

Small topographic features are quite distinct. Steep bluffed, angular topographic features, such as stream canyons, are the most easily seen; very small, shallow washes and gulleys can be early distinguished owing to the topographic enhancement capability of the side-looking radar and the effect of moisture retention on the radar return signal, shown as dark areas in stream beds near the crater.

Linear structural features such as joints and faults are exceptionally well portrayed on the radar images.

Vegetation - The vegetation around Meteor Crater is very sparse, consisting of few scattered scrub junipers, pinyon pine, sage and upper Sonoran zone grasses. There is no visual evidence of vegetation on the radar images but backscattered signals may have been influenced by the moisture retention capability of grasses and other plants.

Polarized and cross polarized images - The cross polarized images of both strips exhibit less tonal contrast then the polarized or images of the same area. Moisture enhancement of the radar images is superior in the cross polarized images (Figs. 1B and 2B) of both strips and for this reason they contributed considerably more to the geologic interpretation than did the polarized images.

Method of study - The radar images were first studied using the pseudostereo affect that can be produced by use of both the polarized and cross polarized images. An overlay map showing distinctive features was then prepared from the images prior to field checking (Fig. 3). Available aerial photos, topographic, and geologic maps were scrutinized along with the radar images in the vicinity of the test site. Anomolous features recognized on the radar images were then field checked and interpreted. The polarized and cross polarized images were compared for their respective geologic value.

Special attention was paid to possible effects on the radar return of: (1) moisture content; (2) surface texture; (3) composition; (4) rock density and (5) effect of diverse vegetation types.

GEOLOGIC IMPLICATIONS

At the scale of the imagery (approximately 1:190,000) Meteor Crater is too small to allow any detailed geologic interpretation of the crater walls, rim, or ejecta blanket materials. Interpretation of the relationship of the crater and its rim materials with the surrounding geology, however, was attempted.

The most striking feature of both image strips is the excellent detail in which moisture-rich areas were defined (Figs. 4 and 5). These areas generally relate to alluvium-filled washes and to sandstone bedrock and debris from the Coconino, Toroweap and Moenkopi formations (Fig. 6).

Most of the washes that are so well defined on the radar images have topographic relief that was measured only in inches. Many of these same washes were identified only with difficulty on even the best available air photos taken at a much reduced scale.

Ground detail emphasized by moisture content decreases appreciably with lateral distance from the radar aircraft.

The area outlined on figure 4 illustrates the best correspondence of the radar imagery with the geologic map (Fig. 6). The dark gray zone running parallel to Canyon Diablo at "A" can be seen to relate to recent alluvium at the contact of the Kaibab dolomitic-limestone ("B") with the massive, lower, sandstone of the Moenkopi ("C").

The high radar backscatter seen in all meanders of Canyon Diablo (Figs. 1 and 2), regardless of the flight path of the radar aircraft, is evidence that a blocky, well jointed rock (the Kaibab dolomitic-limestone) is holding up the canyon walls. The limestone blocks, in this case, are acting like many dihedral and trihedral reflectors to return a strong signal to the radar aircraft 180° from the direction of transmission (Rydstrom, H. O., 1966, p. 7-8).

Widely spaced, northwest trending normal faults disrupt the nearly flat-lying Permian and Triassic strata three miles east and seven miles west of the crater (Figs. 1, 2 and 3). These faults are seen remarkably well on the radar imagery (especially on the cross polarized images) as a result of high backscatter from the aircraft-facing scarps as well as from concentration of moisture in sandy alluvium along the scarp.

Very little of geologic significance could be abstracted about the crater itself from the radar imagery. Several general statements can, however, be made:

(1) The crater has a square outline possibly indicating a well jointed or faulted surface bedrock.

(2) Joint patterns clearly visible at the crater's rim crest appear to trend along the northwest diagonal of the crater, the same as the trend of the normal faults in the surrounding area.

(3) Many small spots of high backscattering on the crater's outer rim slope are probably caused by large angular debris (sandstone and limestone blocks) thrown out of the crater. They are especially noticeable on the vertically polarized (VV) radar image (Fig. 2A).

(4) A halo of light gray can be seen surrounding the crater on strip 8 (Figs. 1A and 1B). This zone may represent the extent of present debris ejecta.

(5) A very dark gray spot visible in the center of the crater floor may be associated with moisture retained by a very fine pulverized sand and alluvium. The absence of many high backscattering spots within the crater itself indicates a lack of large debris blocks and a rather smooth crater floor possibly covered with fine talus and alluvial sediments.

SUMMARY

Preliminary studies of the polypolarized radar images of Meteor Crater indicate the following:

(1) The side-looking radar system enhances large to very small topographic features in a manner far superior to that of conventional aerial photography, which is dependent on the angle of solar illumination.

(2) Linear features such as faults and joints are very well recorded on the radar images.

(3) Differential moisture retention of various ground surface materials is exceptionally well displayed and has proven to be of significant value in geologic and geomorphic interpretations.

(4) Compositional and textural variations in rock types are poorly differentiated on the radar images.

(5) The cross polarized (HV) images are superior to the polarized (HH, VV), like images, with respect to moisture detection and separation of rock types.

(6) A major difficulty with the radar images of the crater is the small size of the image of the impact feature at the average scale of 1:190,000. There is essentially no resolution of the stratigraphic units within the crater walls.

(7) Image distortions and rather large scale variations are inherent in the side-looking radar system.

USGS Format I

Godson, R.H., Ackermann, H. and Watkins, J.S., 1966, Seismic Survey of Meteor Crater, Arizona, in Investigations of In Situ Physical Properties of Surface and Subsurface Site Materials by Engineering Techniques, Project Quarterly Report (Oct. 1, 1965 to December 31, 1965) U.S. Geological Survey, Branch of Astrogeology, Flagstaff, Arizona.

Hemphill, W.R. and Vickers, R., 1966, Geological Studies of the Earth and Planetary Surfaces by Ultraviolet Absorption and Stimulated Luminescence, Technical Letter NASA-33 & 33A; U.S. Geological Survey.

Rydstrom, H.O., 1966, Interpreting Local Geology From Radar Imagery; Goodyear Aerospace Corporation; presented at the Fourth Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, April 13, 1966.

Shoemaker, E.M., 1959, Impact Mechanics at Meteor Crater, Arizona, Open file report, U.S. Geological Survey, Menlo Park, California.

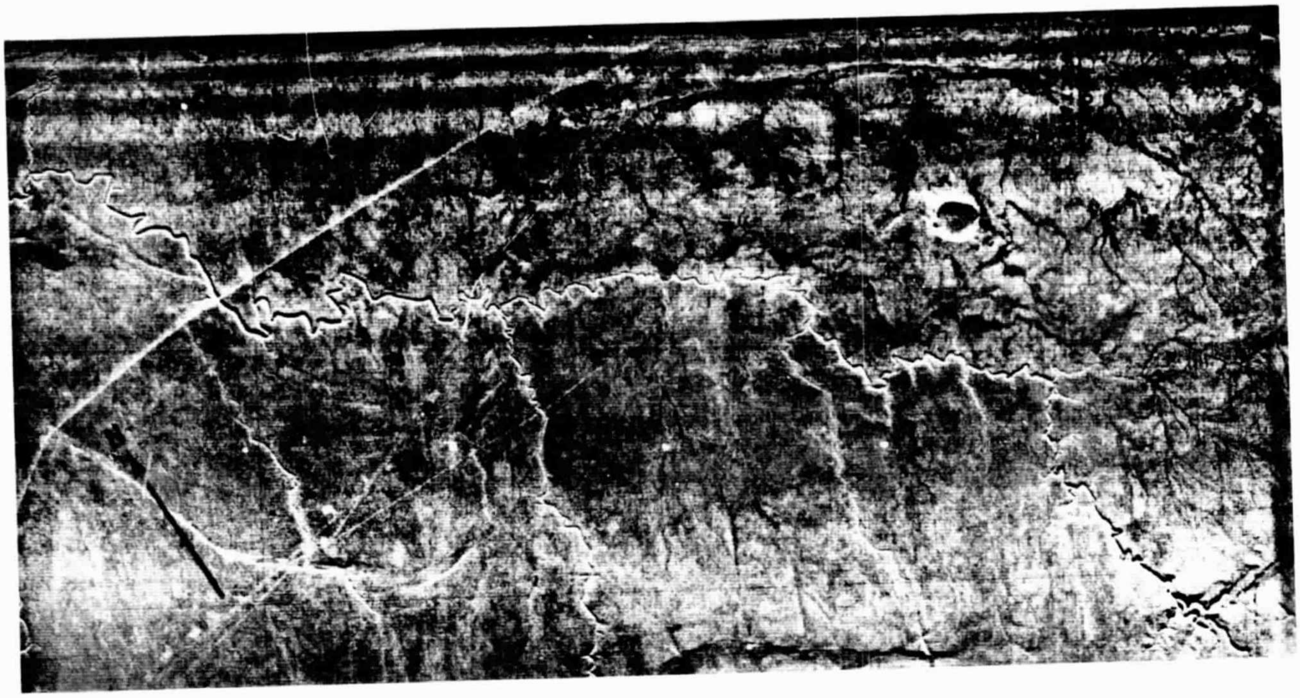

Figure 1A - Radar image run no. 8; polarized (HH) of Meteor Crater and vicinity, Arizona

Figure 1B - Radar image run no. 8; cross polarized (HV) of Meteor Crater and vicinity, Arizona

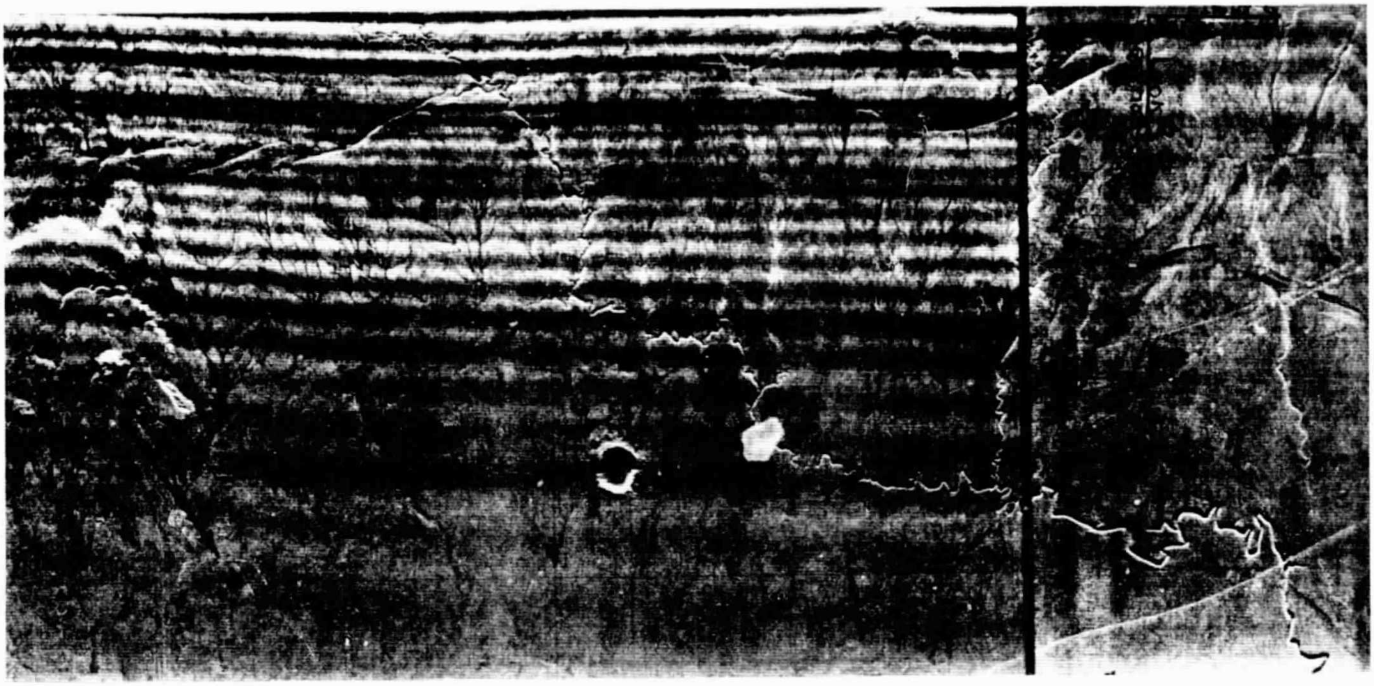

Figure 2A - Radar image run no. 14; vertically polarized (VV) return to right of black vertical stripe. Left of stripe, image is horizontally polarized (HH)

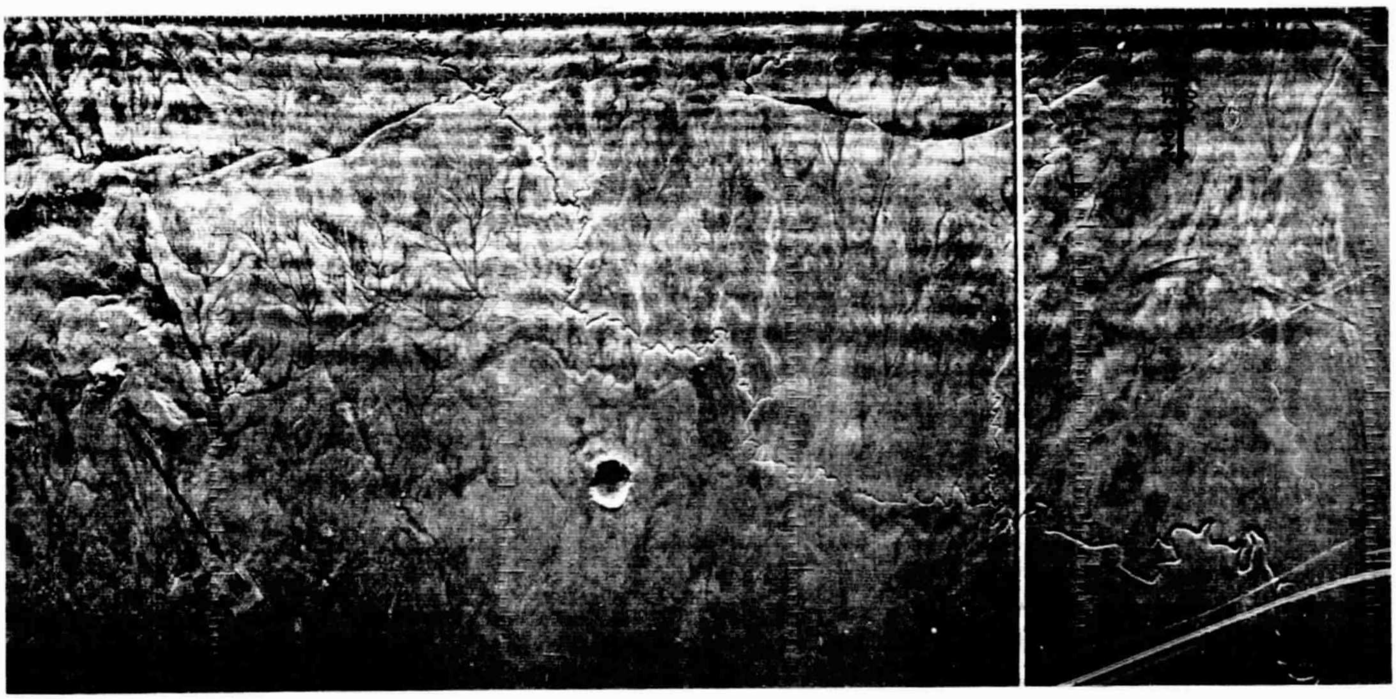

Figure 2B - Radar image run no. 14; cross polarized (VH) return to right of white vertical stripe. Left of stripe cross polarized image is HV

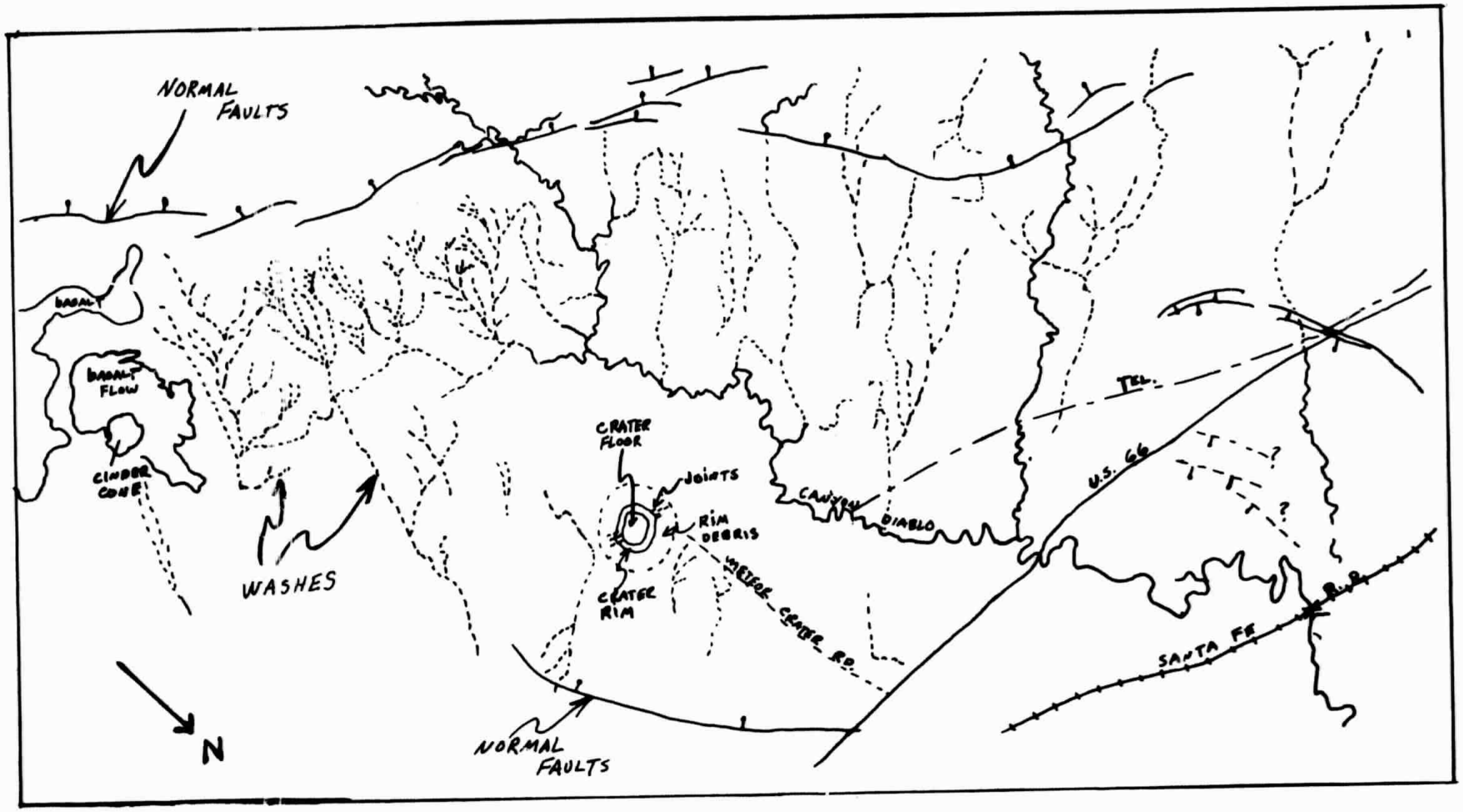

Figure 3 - Overlay showing significant features visible in radar imagery.
Scale 1:190,000 average

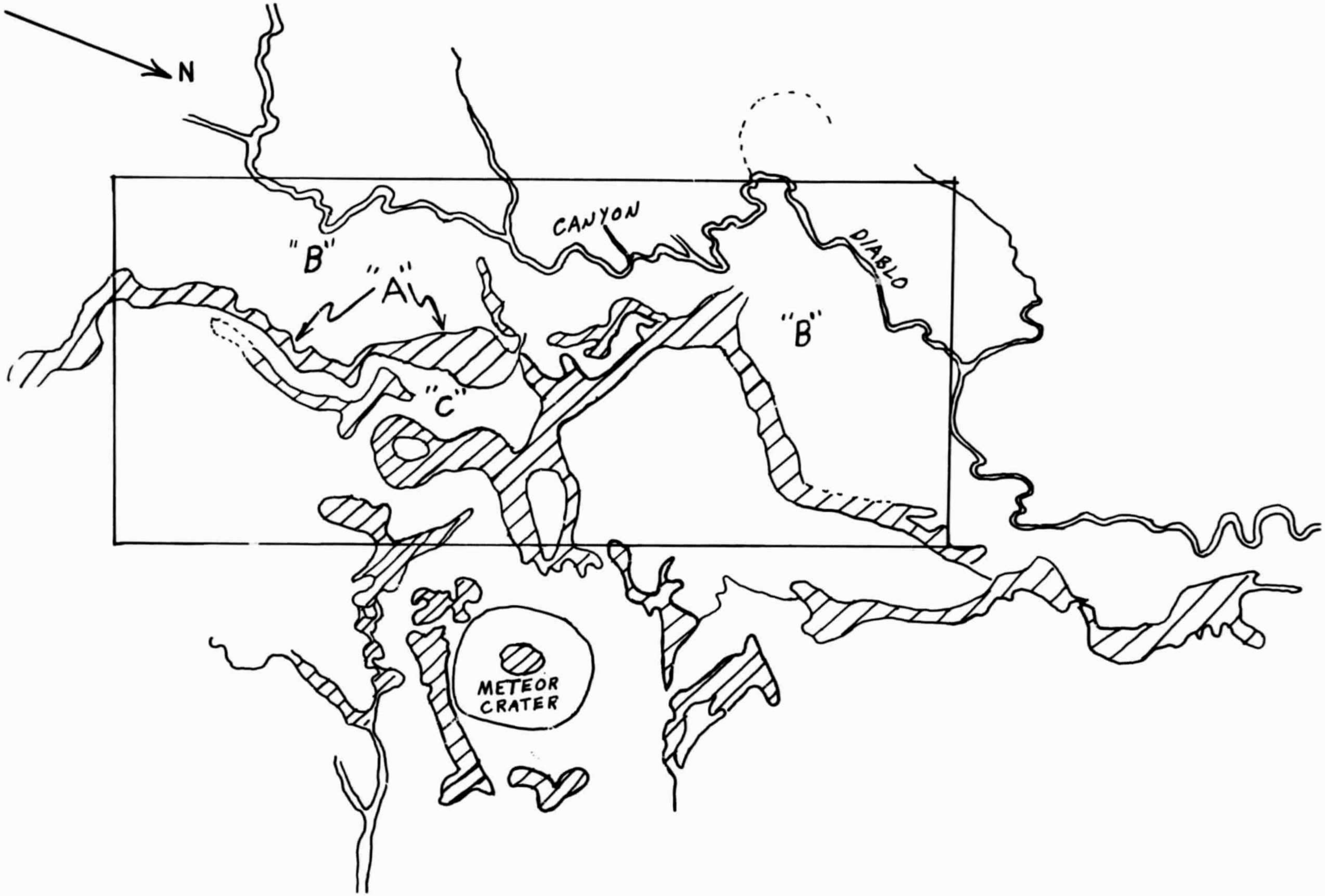

Figure 4 - Overlay map of enlarged scale 1:55,000 strip no. 8 (HV) radar image (Fig. 1B) showing relationship of moisture-rich zones (cross-hatched) with local geology (see Fig. 6) "A" - Recent alluvium; "B" - Kaibab dolomitic limestone; "C" - Lower Moenkopi sandstone

Figure 5 - Radar image from strip no. 14 (Fig. 2B, cross polarized) enlarged to 1:55,000 showing essentially the same area outlined on Fig. 4

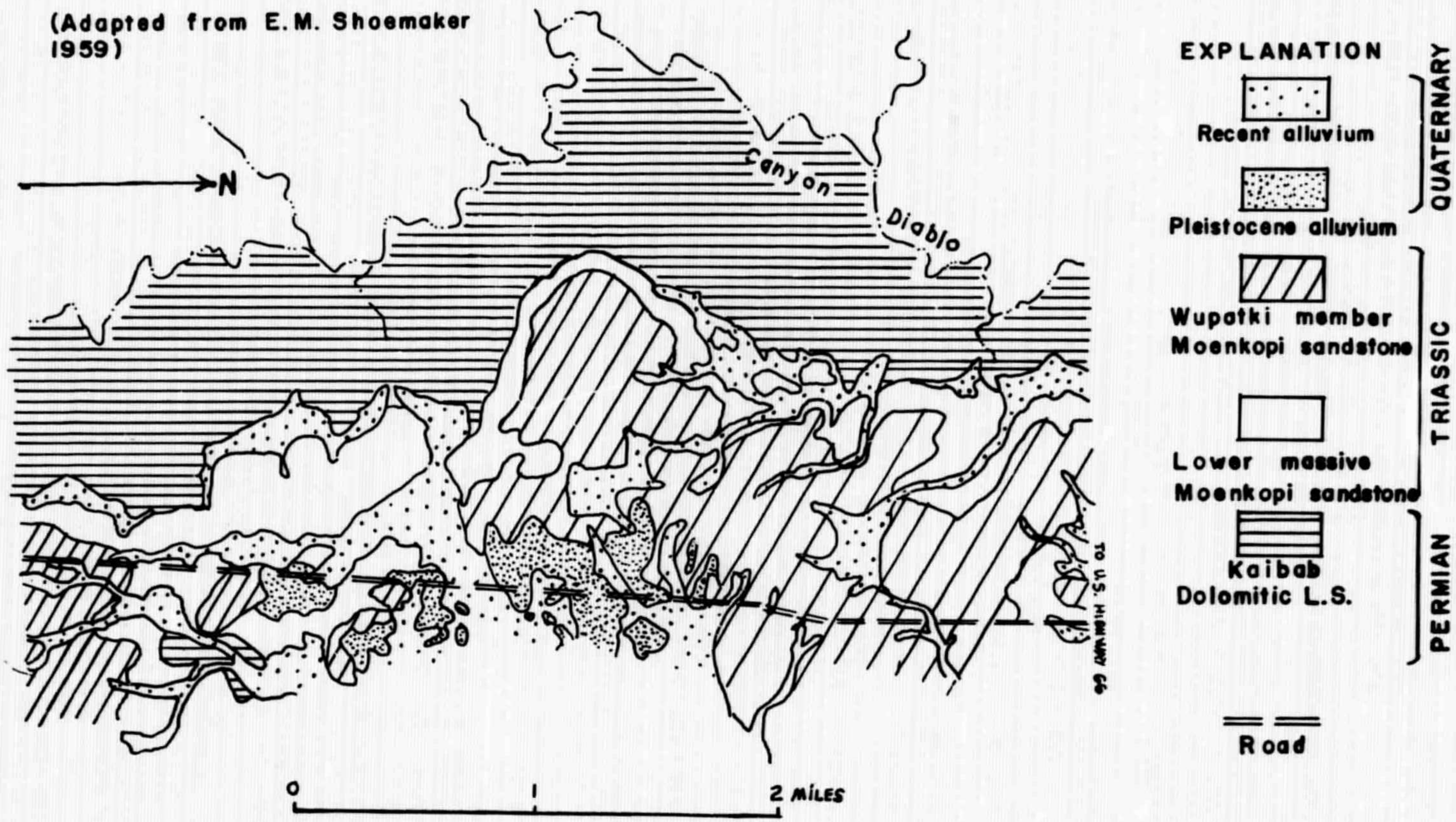

Figure 6 - Geologic map of area just west of Meteor Crater