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NATURAL RESOURCES PROGRAM

SPACE APPLICATIONS PROGRAMS

TECHNICAL LETTER NASA-40

U.S. Geological Survey
Department of the Interior

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

Technical Letter
NASA-40
August 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 2 copies of:

TECHNICAL LETTER NASA-40

GEOLOGIC INTERPRETATION OF THE GEMINI V PHOTOGRAPH

OF THE SALT RANGE-POTWAR PLATEAU REGION,

WEST PAKISTAN*

by

William R. Hemphill**

and

Walter Danilchik***

Sincerely yours,

William A. Fischer
Research Coordinator
Earth Orbiter Program

*Work performed under NASA Contract No. R-146-09-020-~~013~~ 006
**U.S. Geological Survey, Washington, D.C.
***U.S. Geological Survey, Denver, Colorado

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TECHNICAL LETTER NASA-40

GEOLOGIC INTERPRETATION OF THE GEMINI V PHOTOGRAPH OF THE SALT RANGE-POTWAR PLATEAU REGION, WEST PAKISTAN*

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William R. Hemphill**

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These data are preliminary and should not be quoted without permission

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

006

*Work performed under NASA Contract No. R-146-09-020-~~013~~

**U.S. Geological Survey, Washington, D.C.

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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).

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INTRODUCTION

Purpose and Scope

Astronauts Cooper and Conrad, during their eight-day Gemini V mission in August 1965, took more than 290 color photographs of cultural and terrain features from orbital altitudes over North and South America, Africa, Asia, and Australia. The photographs were taken by means of a hand-held 70 mm Hasselblad camera, Model 500, equipped with a Zeiss Planar lens of 80 mm focal length and an f:2.8 aperture. The film was Kodak Ektachrome ASA 64. Most of the photographs were taken as "targets of opportunity" presented themselves, and other duties permitted. Because this was primarily a medical and hardware check-out flight, no attempt was made in pre-mission planning to select more than a few specific subject areas or to define lighting conditions or stereo specifications under which the photographs would be taken.

One of the orbital photographs obtained on the Gemini V mission is of the Salt Range and Potwar Plateau, a semi-arid region of West Pakistan (fig. 1) between the Indus and Jhelum Rivers. On first inspection by the authors the photograph seemed to be lacking of any interesting detail, but with closer examination the photographs became increasingly interesting, much because the photographs provided an opportunity to examine certain geologic features that have continuity on a great regional scale. The examination of the photograph has led the authors to believe that a systematic photographic coverage on the scale of this photograph of large desert areas underlain by folded rocks can be of great value not only for classifying and mapping (geologic and tectonic) the remote areas of the earth, but also for providing the continuity of structural information that is needed in formulating concepts of geotectonic processes--this is to say that regional geologic features do not respect political nor map boundaries. The authors have therefore selected this photograph for evaluation because they are familiar with adjacent areas where geologic and geographic features and conditions are similar to those in the area covered by the photograph with the intention of demonstrating the range of geologic features that can be interpreted from a solitary photograph with a minimum of foreknowledge. It must be emphasized that a full appreciation of the value of photography of this scale cannot be obtained from this random solitary photograph; a set of overlapping photographs covering the entire geologic province partly included in this photograph is certain to bring out geologic features not now comprehensible from one photograph.

The photograph (fig. 2) was taken on August 25, 1965 at 0436 hours Greenwich Mean Time (0924 hours Local Civil Time at longitude 72° E) during the 55th orbit. Field of view covers about 7000 square miles. The photograph was selected for evaluation because the authors have studied adjacent areas where geologic and geographic features and conditions are similar to those in the area covered by the photograph.

Geographic features and place names annotated on the photograph are taker from the United States Air Force Operational Navigation Chart G-6 (1963) and from Army Map Service Sheets NI-42 and 43 (1945). Geologic features identified from personal foreknowledge of the area are identified on the photograph by number (fig. 2). Geologic and geographic features that may be delineated or are judged interpretable by geologists with minimal knowledge of the area, are indicated by letter or geologic symbol. Annotation of geologic structural features, such as faults and folds, is restricted to the local area on the photograph where configuration of the terrain pointing to the existence of these features was observed directly.

Geologic Setting

The Salt Range forms a steep, generally west-southwesterly trending scarp, where the average elevation rises abruptly from less than 1000 feet in the plain of the Jhelum River in the south to more than 2500 feet along the crest of the range. In the western part of the photograph the Salt Range curves northward toward the town of Kalabagh. Sedimentary rocks of Cambrian and Permian ages are exposed near the base of the scarp and rocks of Triassic, Jurassic, and Eocene ages crop out near the crest of the range.

The Potwar Plateau to the north of the Salt Range is underlain mainly by rocks of Pliocene age that belong to the Siwalik Group. These rocks are gently folded into a broad east trending syncline in the central part of the photograph but are relatively closely folded and faulted in the north.

STRUCTURAL FEATURES

Delineation of faults are largely based on sharp linear truncations of outcrop pattern and color. The fault zone northeast of Kalabagh, for example, shows clearly on the orbital photograph (fig. 2); studies in the field and on aerial photographs corroborate its existence and strongly suggest that the predominant movement is horizontal with the eastern block, comprising the Salt Range and Potwar Plateau, moving southward. If more of the mountainous region to the west of the Indus River could be seen, it is believed that this relationship would also be strongly suggested on the orbital photograph. Field studies have identified numerous east-trending high angle reverse faults north of the Indus and Soan Rivers that are not clearly expressed on the orbital photograph. These faults, individually, are less significant from a regional viewpoint than the strike-slip fault clearly shown north of Kalabagh.

Close inspection of the photograph indicates that many of the annotated linear features are expressed by a systematic alignment of short stream segments, particularly in the region north and northeast of Nammal Lake. Such alignments are commonly developed parallel to fractures in underlying bedrock, and although no exhaustive (or conclusive) study of fracture orientation has been made in this area, this explanation appears to be reasonable.

These linear features undoubtedly would be less apparent on conventional aerial photographs because of the limited areal coverage of single prints and the abundance of distracting detail resolved at larger scale. Some linear features in other parts of the photograph show up as abrupt linear breaks in color or outcrop pattern. Distinction between these linear features and those mapped as faults is arbitrary.

In some parts of the photograph, attitude of the strata may be inferred from outcrop pattern and topography as indicated by stream pattern. Strike and dip symbols indicating a gentle northward dip have been annotated near the crest of the Salt Range and in the southern part of the Potwar Plateau. North of the Soan River, beds are more tightly folded as is indicated by bedding traces and stream pattern. Although several fold axes may be clearly seen, direction of dip along the limbs of the fold can be easily misinterpreted because of the small scale of the orbital photograph. Discrimination between anticline and syncline axes in this region is based on observation of minute outcrop detail in the area of the fold axis with the aid of a magnifying glass. Interpretation of bedding attitude is also aided by foreknowledge that in this region anticlines are normally closed narrow structures whereas synclines are commonly open folds several miles across.

LITHOLOGIC INFORMATION

Surficial deposits such as alluvial fans, meander scars, and alluvial deposits along the Jhelum River may be readily identified on the orbital photograph (fig. 2) by the distinctive shape and position of these features with respect to present-day drainage systems. The predominant sedimentary rock type is revealed by numerous open folds, and continuous linearity of outcrop pattern and fold axes which are typical of terrain underlain by sedimentary rocks rather than of terrain underlain by metamorphic or igneous rocks. Conceivably, some of the dark-toned irregularly shaped areas (1 on Fig. 2) in the southeastern part of the photograph could be interpreted to be underlain by intrusive rocks; however, field studies have identified sedimentary rocks of Cambrian age in these areas. Dark-toned features in the interstream areas in the east-central part of the photograph (c on Fig. 2) could be interpreted as flat-lying lava flows now undergoing dissection. These features may be terrace and pediment deposits whose dark tone may be due to desert varnish deposited on boulders and cobbles that are known to comprise the surface of many older alluvial deposits in this region. On the other hand, they may be vegetated areas covered with scrub thorn, bush or hillslopes between alluvium-filled intermittent streams.

Although specific rock types within a sequence of tilted and bevelled sedimentary rocks cannot be identified unequivocally from the photograph without supporting information obtained in ground studies, it may be pointed out that outcrop pattern and tone strongly suggest the regional continuity of some of the strata.

The beds exposed at 5, fig. 1, (identified on the basis of field evidence as Lower Siwalik), is an example where distinctive tone and outcrop pattern permits tracing of the unit for more than 50 miles. Light-toned beds at the base of the southern and western Salt Range (identified on the basis of field evidence as detritus and bedrock of the Zaluch Group of Permian age) also exemplify the use of small-scale photos in tracing the regional continuity of some outcrops.

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

The regional significance of some geologic features may be more readily recognized and interpreted from a single photograph taken from orbital altitude than on conventional aerial photographs of larger scale where hundreds of prints would be required to view the same area. The Gemini V photograph of the Salt Range-Potwar Plateau region of West Pakistan, covers 7000 square miles; with minimal geologic and geographic foreknowledge, structural features such as folds and faults may be delineated on the basis of rock outcrop pattern, color or tone, and drainage pattern. Some stratigraphic relationships may also be recognized but identification of specific rock type requires additional ground information, and generally is less conclusive or reliable than interpretation from larger-scale photographs.

Nearly all orbital photographs to date have been taken with conventional color films. Color rendition of certain features known or believed to be brightly colored on many of these photographs is poor, partly because excessive atmospheric scattering of shorter wavelengths in the visible spectrum imparts a blue cast to the color exposure and as a consequence, image contrast and color saturation at longer wavelengths in the green and red are reduced. For example, although red and brownish-red are diagnostic of rocks of the Siwalik Group which underlie the Potwar Plateau, these colors are poorly expressed on the Gemini V photograph of this region.

Further experimentation may demonstrate the usefulness of color infrared film (also known as "camouflage detection film" from its use by the military during World War II) in providing high color contrast between natural features photographed from orbital altitude. The long wavelength sensitivity of color infrared extends to about 8500Å and, properly filtered the film is insensitive to blue light (Tarkington and Sorem, 1963). It is believed that color infrared photography from orbital altitude would combine broad bandpass sensitivity with atmospheric penetration qualities that are superior to conventional color film. Although color rendition is distorted on color infrared photographs -- that is, features are imaged in colors other than their true natural colors -- this quality is not adjudged a shortcoming for interpretation of many geologic and terrain features, particularly inasmuch as the improvement of atmospheric penetration would also improve color contrast.

The limited number of color infrared photographs obtained on Gemini VII over the Gulf Coast of the United States and Brazil, are difficult to evaluate because of adverse lighting conditions, filtering problems, and inadequate exposure time.[1] In further orbital photography experiments with color infrared film, it would be desirable to photograph areas where bedrock is well exposed, such as arid regions in the southwestern United States, the west coast of South America, Saudi Arabia, and West Pakistan.

1/ Richard Underwood, Manned Spacecraft Center, Houston, Texas, personal communication.

Use of hand-held cameras will continue on later Gemini and Apollo flights. Brinkmann (1966) describes some features of precision 70 mm cameras of advanced design for use by astronauts in a space environment. There undoubtedly will be future opportunities to obtain orbital photographs of the Salt Range-Potwar Plateau region. Stereo coverage would greatly facilitate geologic interpretations, particularly of structural features of regional significance. Where hand-held cameras are used, photographs could be exposed in accordance with the principles of convergent photography introduced several years ago (Brucklacher, 1958; Theis, 1958) as a procedure to increase parallactic image displacement of features and effectively increase the vertical scale with respect to the horizontal scale of aerial photographs used in precision photogrammetric mapping. This approach would facilitate detection of relief differences which are small in comparison with orbital altitude.

It is believed that in some areas the expression of topographic relief on orbital photographs could be improved or observed more clearly by deliberately photographing the terrain at low sun angle. In the Potwar Plateau for example, rocks of the Siwalik Group commonly crop out as a series of parallel hogback and cuesta ridges, generally less than two or three hundred feet high. Shadow expression of relief that would be obtained on photographs at low sun angle would greatly assist in the recognition of outcrop pattern and structure. Shadow expression would be particularly valuable where topography is well adjusted to structure and where stereo coverage is not available.

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Figure 1. Index map of West Pakistan showing area covered by Gemini V orbital photography (fig. 2).

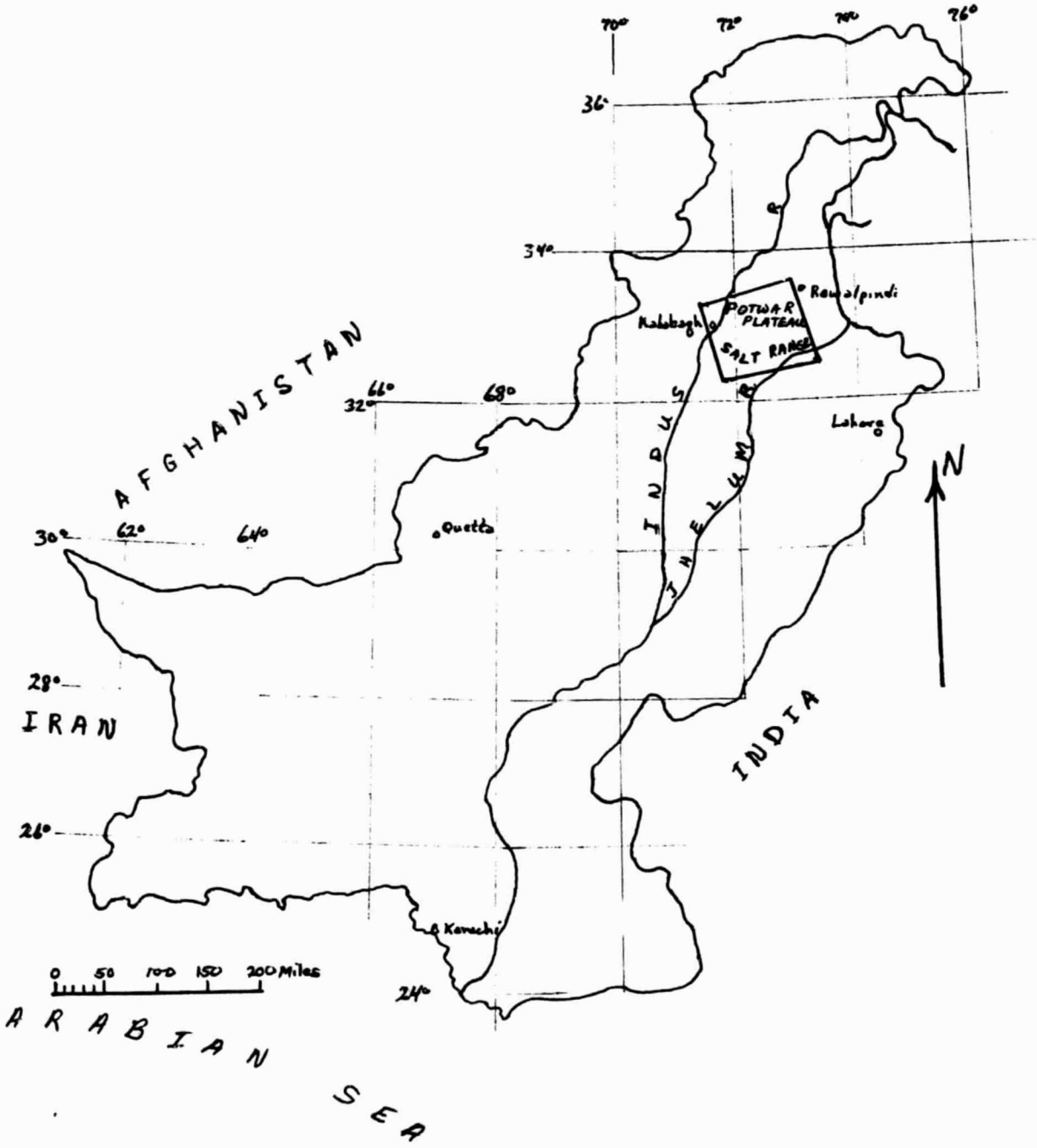


Figure 1. Index map of West Pakistan showing area covered by Gemini V orbital photography (fig. 2).

Figure 2. Gemini V photograph of the Salt Range and Potwar Plateau in north-central West Pakistan (Magazine 4, frame 19, orbit 55, exposed at 0924 hours Local Civil Time on August 25, 1965). Geographic features and place names are from World Aeronautical Charts NI 42 and 43 (1945).

Geologic features on the photograph, identified mainly on the basis of personal foreknowledge of the area, are labelled on the photograph by number and are described here as follows:

1. Reddish brown or generally dark toned areas underlain mainly by clastic rocks of Cambrian age. Outcrop is limited to the eastern Salt Range.

2. Mostly limestone of the Zaluch Group, Permian age. Mainly detrital material along base of the south flank of the Salt Range where bedrock areas of rocks of the Zaluch Group are not readily distinguishable on the photograph from younger rocks. Light brown or white band on the photograph is remarkably persistant and may be traced northward nearly to the Indus River.

3. Limestone of Eocene age and Mesozoic sedimentary rocks.

4. Light-toned band may be an outcrop of limestone of Eocene age.

5. Mainly red and brown sandstone and siltstone near the base of the Siwalik Group of late Tertiary age.

6. Light-tone may be evidence of "water-logging", a process common to the Indus basin where leakage from irrigation canals saturate adjacent areas; subsequent evaporation leaves behind a saline concentrate which renders previously arable land unfit for cultivation.

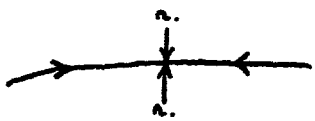
Geologic and geographic features that could be delineated and/or interpreted with minimal knowledge of the area are indicated by map symbol or letter.

Fault

Queried where existance is uncertain

Linear Feature

Alignments of short stream segments which are probably related to fracture in the underlying bedrock. Distinction between some linear features and faults is arbitrary.



Folds

Showing trace of axial plane and bearing and plunge of axis. Queried where attitude of limbs and plunge of axis is not clear.

Inferred strike and dip

Based on outcrop pattern and on topography as interpreted from stream position and drainage pattern.

a

Alluvial deposits

Floodplain of the Jhelum River.

Note meander scars.

b

Fan deposits

c

Older alluvium (?)

Possibly flat-lying terrace and pediment deposits or forestation occupying interstream areas now undergoing dissection.

d

Bedding traces

e

Drainage feature

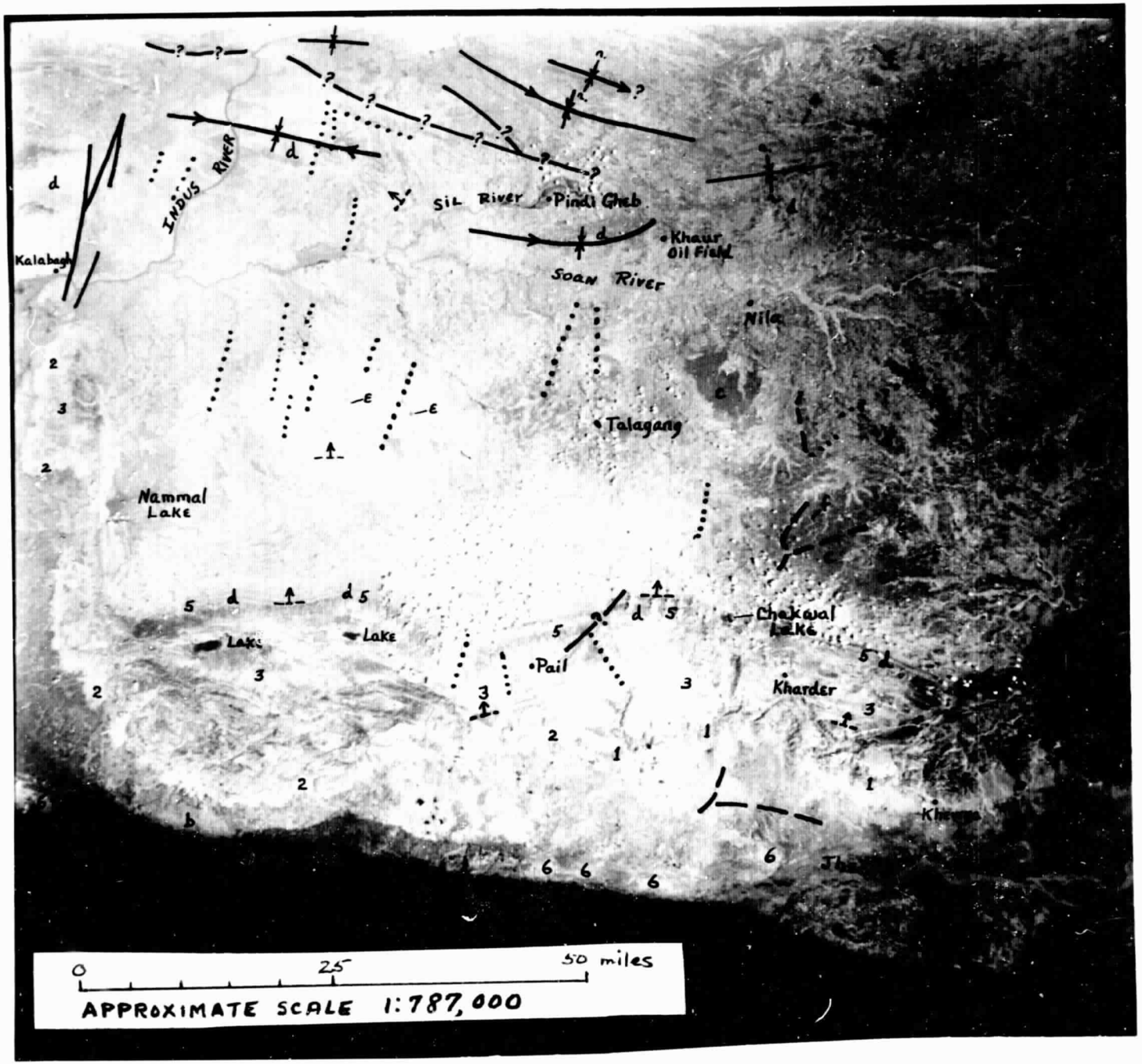
May be indicative of more luxuriant vegetation or cultivation adjacent to streams where local ponding by either natural or artificial means has increased moisture in the soil relative to surrounding interstream areas.

Transportation routes

Roads and railroads. Annotated only in places where evidence of their existence may be observed.

f

Unidentified cultural features may be aircraft emergency landing strips.


INDUS RIVER
SIL River
Pindi Gheb
Khaur Oil Field
SOAN RIVER
Kalabagh
Nila
Talagang
Nammal Lake
Lake
Lake
Pail
Chakwal Lake
Kharder
0
25
50 miles
APPROXIMATE SCALE 1:787,000