AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

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BATCH 46

1. SUBJECT CLASSIFICATION
A. PRIMARY: TEMPORARY
B. SECONDARY:

2. TITLE AND SUBTITLE
Application of ERTS imagery to geology in Afghanistan

3. AUTHOR(S)
(101) Milton, D.J.

4. DOCUMENT DATE: 1975
5. NUMBER OF PAGES: 21 p.
6. ARC NUMBER: ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Geol. Sur.

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(In [IR] AF-3)

9. ABSTRACT

A report of a demonstration and training project conducted in Kabul, Afghanistan, in May and June, 1974. Objective of the project was to demonstrate application of ERTS-1 data to geologic mapping and analysis, and to train Afghan scientists to make such applications. ERTS-1 data were employed in an experiment in map editing. The greatest value of ERTS imagery in tectonic mapping is its broad coverage, which allows a synoptic overview. The 40 ERTS frames that cover the entire country display the tectonics of Afghanistan much better than it could be displayed by working with several hundred photomosiacs. As for mineral exploration, the USGS is engaged in an effort to detect iron oxides by computer processing of ERTS data tapes. Iron deposits of the Hajegak type would seem to be an obvious target. The basic geologic structure, the arid climate, the difficulties of field work in the more remote areas, and the current stage of geologic knowledge make Afghanistan an unusually favorable country for the use of ERTS in geology. The country provides problems that can be useful as test studies for advanced technology now under development in the USGS.

10. CONTROL NUMBER
PN-AAC-836

11. PRICE OF DOCUMENT

12. DESCRIPTORS

13. PROJECT NUMBER

14. CONTRACT NUMBER
PASA TA(IC) 02-72 GTS

15. TYPE OF DOCUMENT

AID 590-1 (6-74)

NASA TA(IC) 02-72 GTS
PN-AAC-836

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

(IR) AF-3

PROJECT REPORT
Afghanistan Investigations
(IR) AF-3

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Prepared on behalf of the
Government of Afghanistan and the
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This report is preliminary and has
not been edited or reviewed for
conformity with Geological Survey
standards or nomenclature

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FOR USE OF THE GOVERNMENTS OF AFGHANISTAN AND UNITED STATES ONLY

1975

APPLICATION OF ERTS IMAGERY TO GEOLOGY IN AFGHANISTAN

by

Daniel J. Milton

U. S. Geological Survey

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APPLICATION OF ERTS IMAGERY TO GEOLOGY IN AFGHANISTAN

By Daniel J. Milton

U. S. Geological Survey

INTRODUCTION

The writer was in Kabul from May 16 to June 27, 1974, in order to demonstrate applications of ERTS-1 data to geologic analysis and mapping in Afghanistan and to train Afghan scientists to make such applications in support of their routine activities. The project was undertaken by the U. S. Geological Survey (USGS) at the request of the Government of Afghanistan and the Office of Science and Technology, Agency for International Development, U. S. Department of State, under PASA TA(IC)02-72. Work was done in the Remote Sensing Office of the Afghan Cartographic Institute (ACI) which is in the process of being established under agreement with Mr. Robert Parr, U. S. Bureau of the Census, who will be the U. S. participant. Mr. Shuaib, a cartographer in ACI in charge of the Remote Sensing Office, and Mr. Said Maqsud and Mr. Mohammed Ali, geologists assigned as counterparts by the Department of Mines and Geology, participated in the project.

THE STUDY

ERTS imagery finds a role in a very wide range of geologic investigations; however, only in very special situations can it be the only tool. It will be most valuable to those who understand that it is one geological tool, among many, that has earned, and retains, its special values for geologic work. Field work is still essential to complete geologic studies; we were not, however, able to go into the field during this project.

Comparison of ERTS imagery with already prepared small-scale maps is a poor substitute for field examination. Nevertheless, it serves as a way of looking for the type of problems in which ERTS can be important in a more thorough investigation. Accordingly, the notes below, on points of interest in specific frames (fig. 1), are followed by some recommendations as to how ERTS imagery can be used in Afghanistan, both with the equipment locally available and with the special processing and computer technology under development in the USGS.

We had on hand in ACI positive prints and transparencies at a scale of 1:1,000,000. Two diazo printers were available, one supplied by this project and one by Mr. Robert Parr. (The Remote Sensing Office was equipped with an I^2S color-additive viewer, but it was put in operating condition only near the end of my stay.) The standard 1:1,000,000 scale photographs are conveniently the same scale as the Geological map of Afghanistan (Afghanistan Ministry of Mines and Industries and V/O "Technoexport," USSR, 1972). We were thus able to overlay diazo false-color composites directly on the map.

The area we studied mainly includes Dasht-i-Nawar, Ghazni, Zargunshar and Abe Estada in east-central Afghanistan (fig. 2). Two frames of the same area were used, one taken September 11, 1972, and one on December 5, 1972. The autumn scene gave a diazo color composite more informative for locating geologic boundaries; the winter scene shows tectonic features somewhat better. The difference in character between the mountains in the west and the plains in the east presented a problem to the photographer who prepared the positive

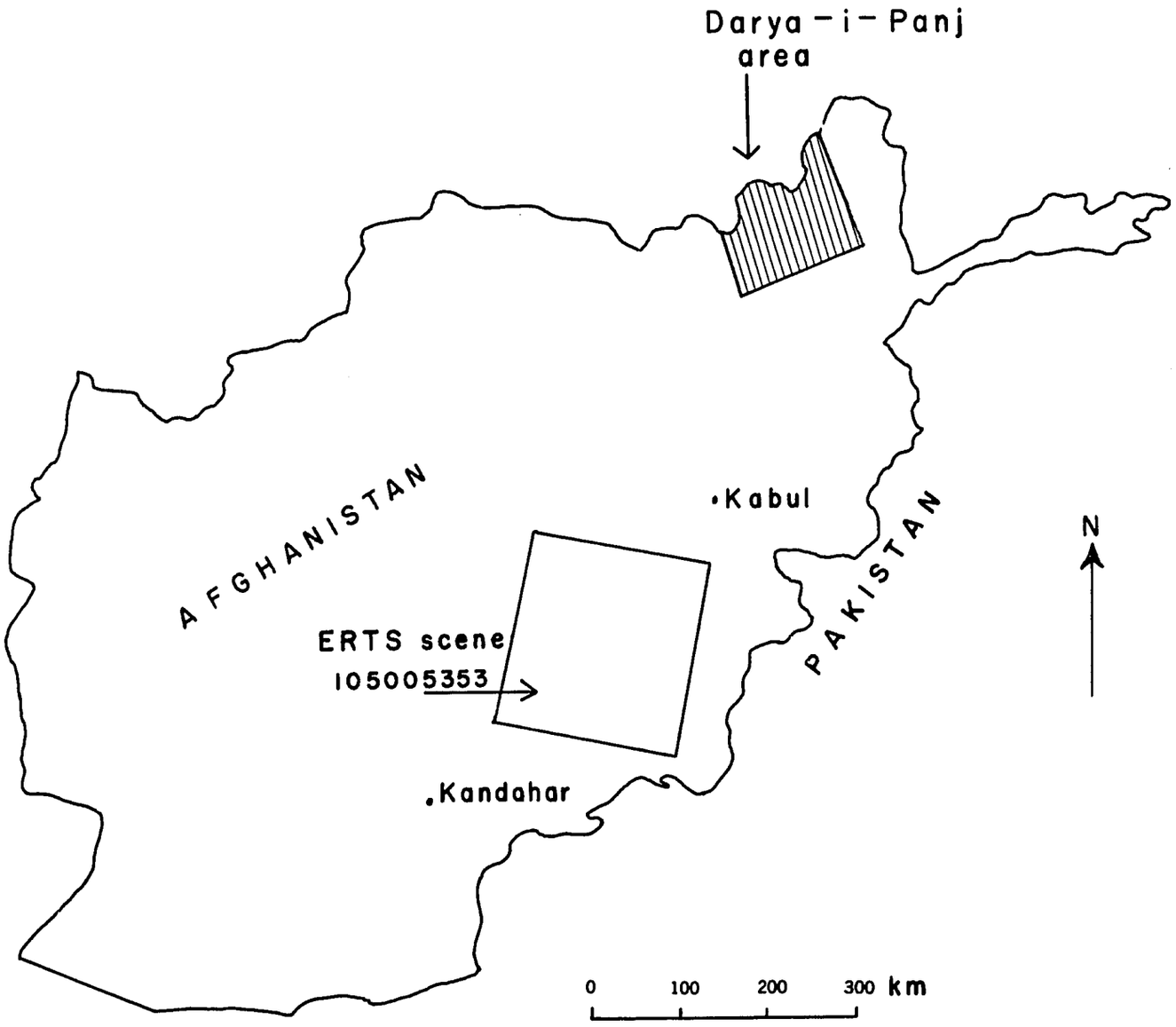

Figure 1. Index map of Afghanistan showing location of ERTS scene (see fig.2)

EXPLANATION OF LETTER SYMBOLS FOR FIGURE 2

Q.....Undissected Quaternary deposits

Q_1.....Lower Quaternary deposits

N_1, N_2...Miocene

P_3.....Oligocene

P_2-P_3.....Eocene-Oligocene

P_{1-2}.....Paleocene-Eocene

K_2.....Cretaceous, upper division

K_1-RC....Cretaceous, Neocomian superstage

K_{1-2}.....Cretaceous, Barremian-Senonian

T_3r-J....Triassic-Jurassic, Raetian stage

T_1T_{3n}....Triassic, Lower division, Norian stage of upper division

C-P_1.....Carboniferous system, Permian system, lower division

D_3.....Devonian, upper division

S-D_2.....Silurian-Devonian, middle division

V-O.....Vendian complex, Ordovician

PR_3.....Proterozoic-middle subgroup

AR-PR_1...Proterozoic subgroup, Archean group, lower part

$\gamma, \gamma\delta, \delta, \delta\sigma$ Granite, granodiorite, diorite, ultrabasite
(Plus letter
age designation)

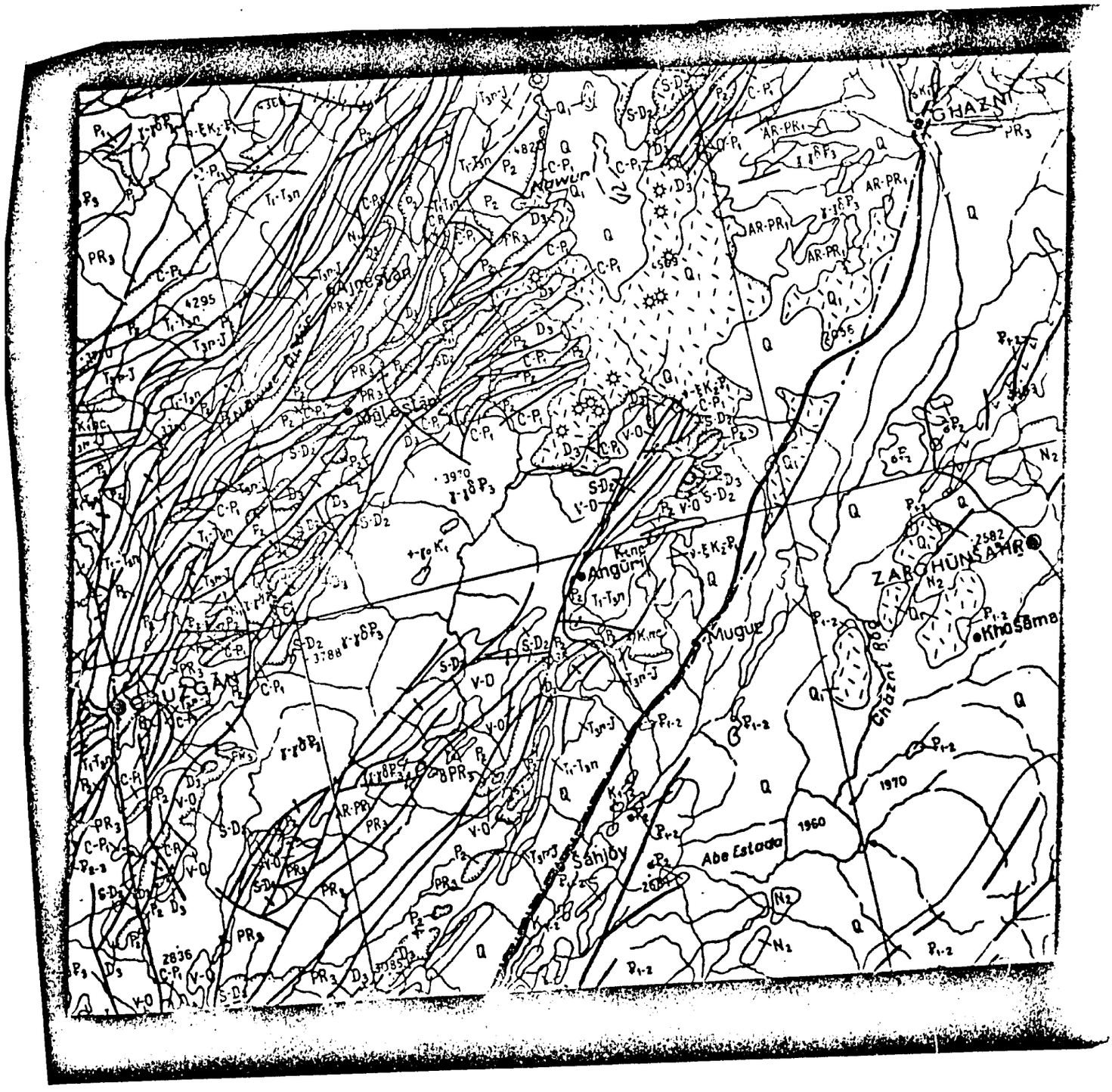
GHAZNI
Nawur
Ajnestan
Mūlestān
Angūri
Mugur
Šahjoy
Abe Estada
ZARGHŪNŠAHR
Khōšāma
Chāznī Rōd
UZGĀN
1960
1970

Figure 2. Black and white positive, bands 5 and 7, ERTS scene 1050-85353, taken in September 1972.

Contacts based on ERTS Contacts from 1972 map Note: latitudes are incorrect

transparencies; the gray scale provides intermediate contrast that is a compromise, not optimal for either area. For a serious, more detailed study, it might be worthwhile ordering specially processed material from the EROS Data Center, Sioux Falls, South Dakota, or to have it prepared in the USGS Flagstaff laboratory.

The area is one of highly varied geology: granitic and mafic bodies have intruded folded and faulted sedimentary and volcanic strata, which are in part metamorphosed. Overlying younger units include slightly folded and flat-lying sedimentary strata, volcanic material, and volcanic ejecta. The granite in general is lighter colored than the older sedimentary or metamorphic rocks in all bands, but particularly in band 7, with the result that many of the contacts of the batholiths and smaller intrusives can be clearly traced on the color composites. This is important not only for mapping, but for defining exploration targets in any search for contact-metasomatic or hydrothermal ore deposits. In general the contacts seen on ERTS imagery agree satisfactorily with the map, but there are some significant discrepancies. Most important is A on figure 2 where a dark belt of clearly stratified rocks striking N. 85° E. extends in a zone 20 km long and as much as 5 km wide into the area mapped as granite. The west end of the belt extends across zones mapped as Upper Devonian (D_3) and Carboniferous-Permian ($C-P_1$), and possibly includes an area mapped as Silurian-Devonian ($S-D_2$), so the stratigraphic assignment cannot be made from the available data. The almost east strike in this belt differs markedly from northeast trends that are dominant on the map in this area, but is only one of a number of east or east-northeast trends in the general area.

A strong east-northeast-trending lineament (B) extends westward past Duzgan, where the mapped faults have very different trends. Strong east (or slightly north of east) lineaments occur east of the batholith also. Other obvious very straight lineaments in this ERTS scene are interpreted to be late fractures of small displacement which would not be of great tectonic significance (although they could be important in locating ground water). However, at least one of these (C) is of some tectonic importance because it provides sharp contacts for granite bodies. What is shown on the geologic map as a single area of granite with irregular smoothly curved contacts appears on the ERTS image to be actually two bodies, the lineament providing a straight northern contact for one and southern contact for the other. A restudy of the area may indicate that these east trends add a significant complication to the general picture of northeast-southwest tectonic trends.

Some small areas characterized by light tones (especially in the infrared of band 7) and discordant contacts appear to be outliers of granite (fig. 2,D). Color and textural variations within the batholith presumably reflect petrographic variations. I have only outlined a couple of areas (E) (which are so dark that I suspect they may actually be metamorphic rocks), as I had no data to check against, but such variations should be useful in any study of the intrusives themselves. Tone differences also show up in the sedimentary and metamorphic rocks of the mountain zone. For example, in the extreme northwest part of the frame, a narrow slice of light-toned Permian stands out clearly against the darker Precambrian. Such differences could be very useful in mapping, but the area is geologically too complex for me to comment on without field examination.

The Quaternary volcanic rocks of the Nawur area in the north-central part of the frame are lighter in band 7 than in bands 4 and 5, so they appear brown in our false-color composite. The contacts are in many places surprisingly difficult to locate, however. Without field work, I could not determine whether this indicates real gradational contacts where a cover of volcanic ash feathers out, or whether the ERTS photographs (or our handling of them) are insufficient for distinction of units.

One light-colored area (F) mapped as Paleozoic strata appears to be either granite or Quaternary volcanic rocks. Outlying patches of Quaternary volcanics in the valley near Zargunshar show very faintly on the ERTS frames. Better processing of the original transparency might help here. Geologically more significant is the patch of Quaternary volcanics mapped at (G). If this patch is bounded by a fault, as mapped, it indicates Quaternary deformation, which would not be expected in the area. ERTS imagery shows some small hills of apparently steeply dipping strata at the south end of the patch, suggesting that older rocks are exposed; if so the fault may cut these rather than the volcanics, and thus would be pre-Quaternary.

Several other ranges of northeast-trending hills (areas H) in the Ghazni Valley in areas mapped as Quaternary presumably are Paleogene sediments or volcanics. One of these is so large that one would guess that it was mapped by the geologist and accidentally omitted at some point during drafting of the map. The northernmost of these ranges is of a clearly different character from the mapped ultrabasites just southwest and actually shows up best on photographs taken when the ground is

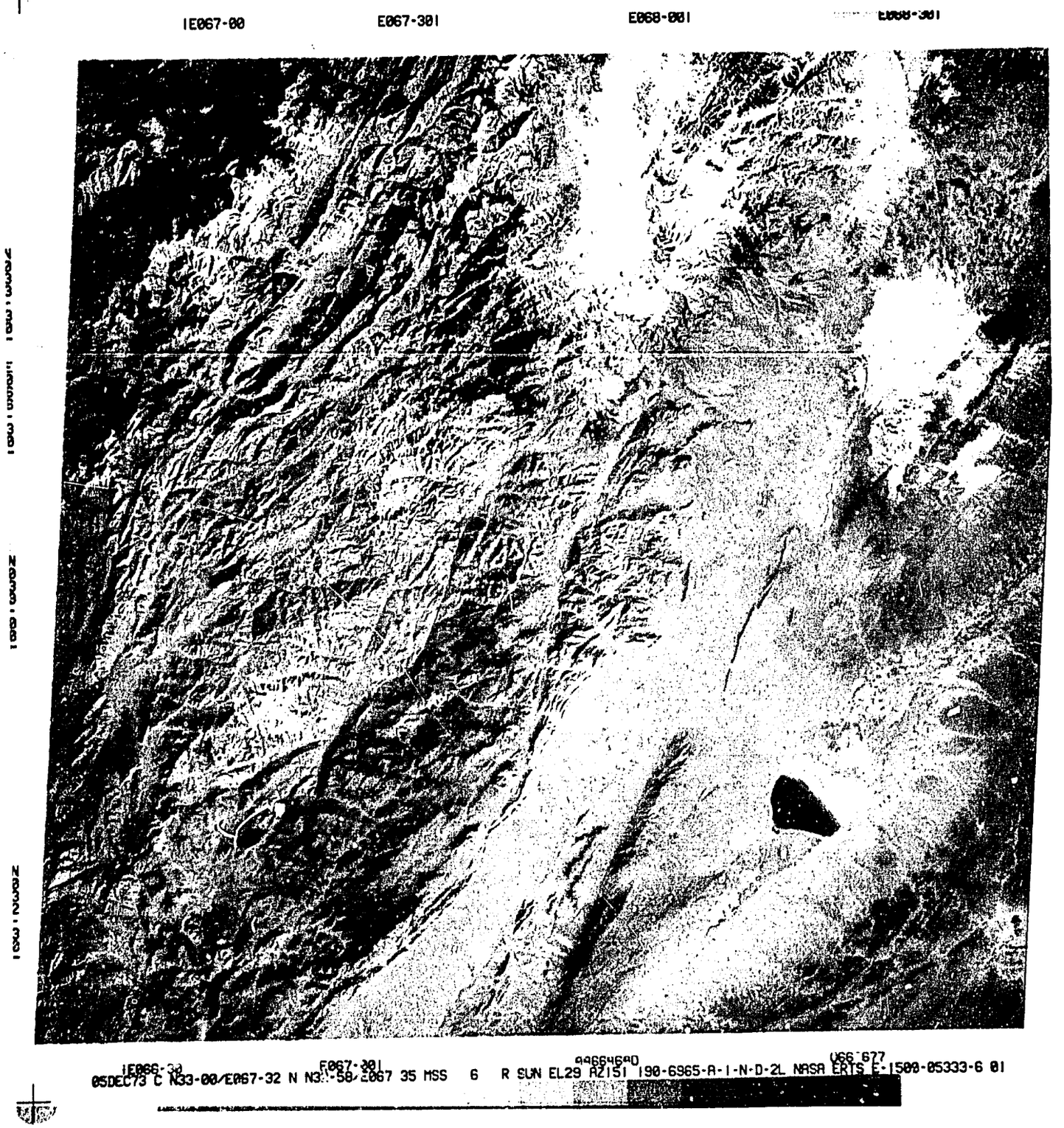

Figure 3. Black and white positive of band 6, ERTS scene 1500-05333-6 taken in December.

partly snow-covered (fig. 3). Another area in which the bedrock-alluvium contact is incorrectly mapped is at I, northwest of Abe Estada. This also may be only a drafting error, as one would expect the Paleogene to extend to the end of the fault. At J Paleozoic rocks apparently extend eastward beyond the Quarternary volcanics.

Such details may not be of major importance, and probably would escape most map editing, but the ERTS system allows rapid checking of small-scale maps by matching scales to provide overlays in a way that would be extremely difficult and tedious if large-scale aerial photographs were used. Two small patches of Pliocene sediments (N_2) are shown south of Abe Estada at K. The ERTS photos suggest much more N_2, in a different pattern extending up to the entire south edge of the lake. The dark tone, especially in band 7, suggests more N_2 on the southeast side of the valley also. This is confirmed by low ridges at L (best seen on the December photograph, fig. 3) which have a different tone from the nearby ridges of Paleocene. If the color can be trusted where such ridges are not visible (ground checking would be needed to determine this), there may be a belt of Neogene all along the base of the hills, as mapped in 1969 at 1:2,500,000 scale but eliminated on the 1:1,000,000-scale map (Afghanistan Ministry of Mines and Industries, and V/O Techno-export, USSR, 1972).

A second area in which we have compared ERTS images with the 1:1,000,000 scale map is to the north, toward the Darya-i-Panj northwest of Faydzabad (see fig. 1). Here Pliocene sediments unconformably overlie a variety of much older units. As these sediments are said to contain placer gold, their delineation should be a matter of economic importance.

One would expect a contact of this type to be readily seen on ERTS imagery. Mr. Maqsud was still working on the problem at the end of my stay, but the preliminary pattern that we interpret from the ERTS photographs is very different from that shown on the published geologic map, so much so that, unlike the case of the Argandab granite, we are uncertain where to place an accurate contact to provide a basis for reinterpretation. In the northeast of the area of occurrence, what is probably Neogene rocks appears relatively lighter in band 7 and darker in bands 4 and 5 (hence browner on our composite) than most of the bedrock, but it is possible that some bedrock may have a similar appearance. Surely the area near the river just east of long 70° E. cut by deep northeast-southwest valleys is bedrock, and not Neogene, as mapped. I would think the same to hold for the apparently steeply dipping strata just northwest of the Darya-i-Kokca near 37°05' N. and 70°05' E. The wedge of Cretaceous, shown crossing the Darya-i-Kokca farther southeast, does not look different from the Neogene mapped on either side, nor is the fault shown as cutting the Neogene all the way to the Darya-i-Panj evident in the ERTS frames. A clear delineation of the Neogene sediments can very likely be obtained from ERTS, but further experimentation is needed and must be based directly on new field mapping or at least on large-scale maps on which contacts traced in the field are distinguished from photointerpreted contacts.

It is important to note that in every case we prepared color composites for a general look at the whole frame. For any specific problem involving distinction of rock types (and to a lesser extent for structural problems), more effective composites could be prepared. For example, in the Ghazni area (fig. 2), the composite stacks should be made in different ways, depending on whether the purpose is to outline the granite

bodies, the Quaternary volcanics, or the Neogene sediments. Much of the experimentation can be done with the equipment now available in the Afghan Cartographic Institute. The Color Additive Viewer allows a great number of combinations to be tried out rapidly before diazo prints are made. In some cases, transparencies with gray scales different from the standard Sioux Falls products may be advantageous, and could be ordered from Sioux Falls or prepared in the USGS Flagstaff facility. Beyond such simple improvements, there are a number of promising techniques that depend heavily on computer processing of data tapes and optical portrayal of the results, such as band ratioing and density slicing. The optical display is a vital part of these processes and requires special equipment. The computer system now installed in Kabul can print out a digital display of ERTS data from magnetic tapes (and in fact the Bureau of Census group prepared one during my stay), but in the absence of equipment for optical display, I can foresee little use in Afghan geologic studies.

SUGGESTED FUTURE APPLICATIONS

Table 1 is a list of applications of ERTS to geology compiled by Short and Lowman (1973), on which are indicated those I consider should be of particular interest to Afghanistan.

The first and simplest category, map editing, is the one we have actually experimented with. As we have seen, much boundary and contact location can be done fairly successfully in the office, while stratigraphic discrimination requires a firm base of field control. I take "scale change corrections" to mean elimination of errors introduced during compilation of large-scale maps into a small-scale map. Although comparison with ERTS can be useful at many stages of map preparation (including preparation of base maps), for map editing in a strict sense, it is best

Table 1. Applications of ERTS imagery to Geology
(from Short and Lowman, 1973)

*Map Editing:

*Boundary and Contact Location
*Stratigraphic and/or "Remote Sensing" Unit Discrimination
Scale-change Corrections
Computer-processed "Materials" Units Maps

*Landforms Analysis:

Regional or Synoptic Classification and Mapping
Thematic Geomorphology (e. g., Desert, Glacial, Volcanic Terrains)

*Structural Geology:

*Synoptic Overviews of Tectonic Elements
*Appraisal of Structural Styles
Lineaments (and "Linears") Detection and Mapping
*Metamorphic and Intrusion Patterns
Recognition of Circular Features

*Lithologic Identification:

(*)Color-Brightness (Spectral Reflectance) Classification
(*)Ratio Techniques
*Photogeologic Approach

*Mineral-Exploration:

*Reconaissance Geologic Mapping
*Lineaments Trends (especially Intersections)
(*)Surface Coloration ("Blooms" and "Gossans")
(*)Band Ratio Color Renditions

Engineering and Environmental Geology:

Dynamic Geologic Processes (Sedimentation and Coastal Processes; Sea Ice; Active Glaciers; Permafrost Effects; Landslides and Mass Wasting; Shifting Sand Seas; Land Erosion)

Strip Mining; Surface Fractures - Mine Safety

Construction Materials

*Particularly applicable in Afghanistan
(*)Requires special technology

to work with the final publication scale or final compilation. If a second edition of the 1:1,000,000 map is planned, I suggest it would be well worthwhile to have a geologist systematically overlay diazo prints on the map to note possible discrepancies to be checked by the geologists responsible for each region. For the 1:500,000-scale maps in preparation, checking against ERTS imagery should be equally useful, but the actual mechanics must be somewhat different, because ERTS transparancies are not readily available at this scale. Depending on the complexity of the geology mapped, it may be possible to reduce portions of the map to 1:1,000,000, or to project transparencies of ERTS with the color additive viewer to match the scale. Alternatively, transparent map copy could be overlaid on 1:500,000-scale paper prints which are routinely available from Sioux Falls. Computer-processed maps listed by Short and Lowman are an experimental technique that have no particular significance to Afghanistan in the present stage of development.

Many investigations in landform analysis could be undertaken in Afghanistan. Among current USGS investigations, E. D. McKee's worldwide study of dune forms could be extended to Afghanistan. Of particular interest to myself because I have been concerned with what are probably analogous features on Mars, are the extensive areas in northwest Afghanistan that have apparently been eroded by the wind into huge yardangs. A field study of these geologic features would be immensely assisted by use of ERTS imagery, which shows a sharp regional distinction between terrain apparently eroded by the wind and terrain more normally eroded by water. Cirques on the higher mountains show up clearly, and a fairly good glacial map of Afghanistan could be made from ERTS with a limited amount of field

checking. Such geomorphological projects, however, are primarily of academic interest, and I would expect would depend on the initiative of individuals rather than on programs of the government of Afghanistan.

Structural geology (including economic applications) is the most important use of ERTS. Two of the problems listed by Short and Lowman (1973) are not of particular applicability in Afghanistan. Circular features are to be expected only in stable shield areas. Lineaments are important as a study in themselves in areas of simpler geology but in areas as geologically complex as Afghanistan, their importance diminishes to a minor role in the entire tectonic picture. Structural or tectonic mapping, to be complete, requires considerable field checking, which was not possible in this project period. However, some of the discussion above suggests tectonic problems that could be looked into. ERTS imagery would be particularly useful in checking the 1:1,000,000-scale tectonic map. Because tectonic mapping involves more generalization than geologic mapping, deletion of features that do not appear or are not prominent on ERTS images would be safer than changing contacts on a geologic map. In some areas, on the other hand, the details on the images suggest that more could usefully be added to the tectonic map. For example, the Paktya fold belt along the southeast border as shown on the 1:1,000,000 tectonic map seems to have been worked less thoroughly than other areas, and revision on that scale could use ERTS extensively. (Some of the Sioux Falls photo products in this area have low contrast and perhaps replacements should be specially ordered from the U. S.)

The greatest value of ERTS in tectonic mapping results from the broad coverage, allowing a synoptic overview. I was able to learn about the

tectonics of Afghanistan by using the 40 or so ERTS frames that cover the entire country in a way that would have been impossible if I had to handle the several hundred photomosaics. A far greater simplification would come from a single 1:1,000,000-scale mosaic of the entire country, which not only would be a thing of beauty in itself but would provide a firm base for any regional tectonic discussions. For this purpose, black and white would be about as useful as color. First attempts at preparing prints for such a mosaic in the Carotgraphic Institute were not promising. Sioux Falls prints that could be trimmed and fitted for such a mosaic would cost in the neighborhood of only $100. A dodged and controlled mosaic would have to be made in the United States at considerably greater expense. However it is done, I suggest that preparation of such a mosaic should have a high priority.

Lithologic identification from ERTS data (as opposed to extension of contacts of units whose lithology is determined in the field) is a technique just at the limits of the current state of the art. As such, at present it is probably of more concern to Americans developing remote-sensing systems than to Afghans mapping their country. The techniques are similar to those used in search for ore deposits and can be combined with that.

For Mineral exploration, knowledge of the basic regional geology is a prerequisite, as implied by Short and Lowman (1973) in their listing of "reconnaissance geologic mapping." "Lineament trends" could be expanded into a study of any structural guides to ore deposits. These are most useful where a number of ore deposits are already known, and some theory as to their control has been developed. Discovery and investigation of ore

deposits is just beginning in Afghanistan, so ERTS data would be used as an aid in the development of ideas rather than to apply an already existing theory.

The feasibility of direct search for ore deposits or their alteration haloes on ERTS images has received a great deal of attention. An example that has raised considerable interest in Afghanistan is Schmidt's (1973) search for porphyry copper in Pakistani Baluchistan. Such work is still very much at the stage of experimentation rather than at the stage of proven practical technique. Both photographic and computer-assisted processing techniques are employed, independently in some cases, together in others. Particular effort in the USGS is now being put on detection of iron oxides by computer processing of ERTS data tapes. Iron deposits of the Hajegak type would seem to be an obvious target for such an investigation. Detection of base-metal deposits is more complex, but descriptions of the Logar Valley copper deposits suggest that they are extensive enough that they might show on ERTS. Although computer processing is probably necessary ultimately, some results should be obtained with the simplest visual study of the images, with the facilities now available in Kabul.

Engineering and environmental geology includes a miscellany of ERTS uses. I am not aware of problems of current concern to Afghanistan that would fall into this category to which ERTS is particularly applicable, but if such arise, image interpretations for these purposes is generally straight forward. So far as ERTS serves to support tectonic studies, landform analysis, rock type distribution, geologic structural analysis, studies of surface water distribution and changes with time, it will serve engineering studies and environmental studies involving sites, areas and lineaments of sufficient size to be observed at ERTS scales and resolutions.

The basic geologic structure, the arid climate, the difficulties of field work in the more remote areas, and the current stage of geologic knowledge and mineral development make Afghanistan an unusually favorable country for the use of ERTS in geology. In particular, Afghanistan provides problems that can be useful as test studies for advanced technology now under development in the USGS. It is difficult, however, to preselect such projects; they are much more likely to develop out of studies that yield some results from fairly qualitative visual methods. If Mr. Said Maqsud and Mr. Mohammed Ali introduce other Afghan Survey geologists to ERTS, worthwhile results should be obtained in Kabul. Any cooperation in the future between the USGS and Afghan Surveys would be much more rewarding if it started with such specific investigations already in progress in Afghanistan. This would allow correspondence between the geologists involved and allow the American counterpart to evaluate special techniques that might be employed and to prepare materials in the U. S. Such projects could be regional investigations or general map editing along some of the lines suggested above. The exact nature is less important than that there be an active interest and committment to the investigation.

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GPO 894-621