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# Rock Type Discrimination Using Enhanced Landsat Imagery

## Enhanced Landsat imagery was used successfully for medium-scale geologic mapping in Iran.

### Introduction

Since 1972 geoscientists around the world have been evaluating the utility of Landsat data for Earth resources inventory and subsequent management. Iranian scientists have been active in this field with investigations into the assessment of the utility of these data in a broad spectrum of disciplines.

The report that follows is the result of one such experiment in evaluating the capabilities of Landsat data, in the form of imagery, for investigation of geological phenomena, such as general rock type discrimination, using available enhancement techniques.

KEY WORDS: **Geological surveys; Images; Iran; Landsat; Mapping; Mapping photography; Rocks**
ABSTRACT: An experiment in evaluating the capabilities of Landsat imagery for investigation of rock type discrimination was carried out over an area in Central Iran. Results indicated that the Landsat imagery is of great value in general geological reconnaissance level investigation and in some cases, when enhanced, may be used for larger scale mapping purposes.
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### Study Area

An area of approximately 21,500 square kilometres covering the northern part of Fars Province, bounded by longitudes E-52° 30′, E-54° 30′ and latitudes of N-29°, N-30°, was chosen for the present study (Figure 1).

The main reasons for selection of this particular area were—

- The existence of superior recorded geological data such as geological maps and reports, making a geological mapping investigation feasible, and creating possibilities for correlation of these data with Landsat acquired data.
- Fair accessibility to the site, providing the capability of field checking "ground-truth" investigations.
- The availability of aerial photography coverage over the study area at a convenient scale of 1:20 000, thus making possible a multi-level analysis.

### Methods and Procedure

The bulk of the work presented here is based on the analysis of Landsat MSS image data with and without image enhancement techniques. Two Landsat data sets covering a single geographic area were selected for analysis (Plate 1). An approximate plot of the geographic area is shown on Figure 1. In standard Landsat nomenclature the scenes are referred to as E-1221-06293 and E-1221-06291.

The sequence of analytical steps utilized in this experiment can be summarized:

(1) Initial comparison of Landsat-1 MSS imagery with available geological maps.
(2) Recording of outstanding differences observed from the above correlation and preparation of Landsat-interpreted geological map (Plate 2).
(3) Confirmation of Landsat MSS data-based interpretation by implementation of a field-checking program.
(4) Preparation of 1:20 000 scale aerial-photo interpreted maps and correlation of aerial-photo interpretation with the outputs obtained from Landsat MSS image data interpretation.
(5) Lithological mapping evaluation, including discerning of recognizable spectral re-

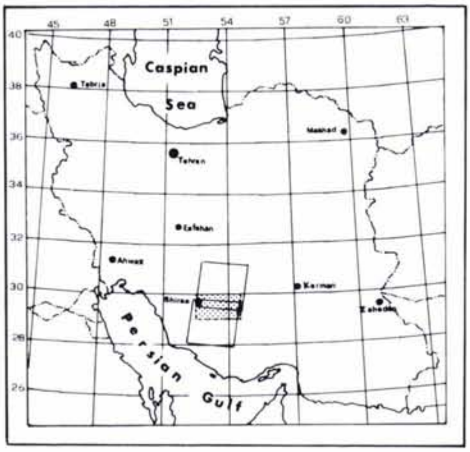



FIG. 1. Map showing the study area location and related Landsat coverage.

sponses for particular rock assemblages (if any), using enhancement techniques of Landsat data.

## RESULTS

Using the above-mentioned data sets, a preliminary Landsat visual data interpretation was carried out at a scale of 1:500 000, resulting in the 1:1,000,000 scale Landsat-interpreted geological map of the study area (Plate 2).

The interpretation was based primarily on morphological, drainage pattern, textural, and tonal variations. Upon comparison of this map with an existing geological map of the study area ((Plate 3) IOOC, 1969), it was immediately noted that, while some areas showed profound differences between the two maps (Plate 2, insets 1 and 2), there exists, however, a surprising and thus promising similarity between the Landsat-interpreted map and the existing geological map.

This leads the author to suggest that there exists a possibility of using Landsat data for reconnaisance level geological mapping with a reasonable degree of certainty, especially in areas where no previous geological record exists and thus where a quick interpretation would be very valuable.

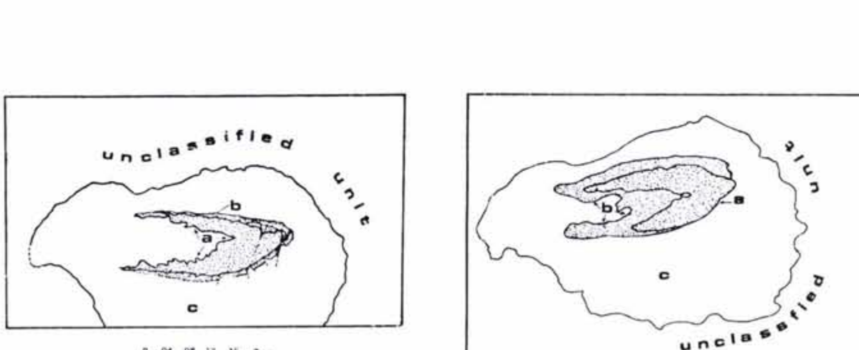
In doing so, one of the several anomalies observed between the Landsat image data interpretation and the existing geological map of an outcrop some 80 kilometres east of Shiraz, appearing on the Landsat imagery as one with similar charactristies to known conglomerates but mapped as a shale-limestone assemblage, was selected for more detailed investigations.

This suspicion of erroneous mapping was verified in the field, where the unit was found to be indeed, as suspected, a conglomeratic outcrop lying in a predominantly alluvial plain (Sarvestan Plain).

At this stage it was decided to map this outcrop in further detail using aerial photography. This part of the exercise was carried out for the purpose of creating a base for the evaluation of Landsat imagery, not just as a means of correcting existing maps, but as a tool for more detailed mapping of geological units.

The preparation of the photo-interpreted map of this unit, in which three zones were delineated as (a) Cliff-forming unit, (b) Slope-forming unit, and (c) Alluvium, was accomplished (Figure 2a).

From observations carried out in the field, three units are described in greater detail below:




(a) Aerial photointerpretation. (b) Landsat interpretation (enhanced).

FIG. 2. Comparison of geological mapping capabilities.

FIG. 3. Field appearance of cliff-forming unit.

Unit a—Cliff-forming portion, which is composed of cobble-size, well rounded, polygenic, massive-bedded conglomerate with a matrix of sands and gravels (Figure 3).

Unit b—Slope-forming portion, which is composed of boulder-sized, subrounded to rounded, polygenic, thick-bedded, boulder conglomerate by a materix of finer grains such as pebbles and granules (Figure 4).

Unit c—Predominantly derived from the upper ridge-forming and slope portion of the conglomerate mass. The aerial extent and boundary between alluvium of Sarvestan Conglomerate and the surrounding plain is clearly visible both on the ground and on the Landsat image (Plate 1).

In order to evaluate the capability of Landsat image data for detecting the above mapped zones, the image was exposed to several enhancement techniques using 70 mm format for color-additive enhancement and 240 mm format for density slicing enhancement.

As a result it was noted that, while the color additive techniques somewhat improved the delineation of the boundaries so clearly mapped using aerial photography, it was the density slicing technique, using an MSS black-and-white transparency, which produced the most accurate and promising results (Plate 4). As will be noted from the map produced from the slice, there exists a valuable correlation between the interpretation of the aerial photos at a scale 1:20 000 and the results of the 1: 1 000 000 enhancement (Figure 1).

Comparison of the map prepared by conventional aerial photo-geological interpretations with that produced by Landsat imagery enhancement clearly indicates the potential of the utility of Landsat imagery for larger-scale mapping of geological phenomena.

## THEORETICAL CONSIDERATIONS OF TONAL VARIATIONS IN CONGLOMERATES

As a result of the foregoing experiment, an attempt to analyse the reasons for the varia-

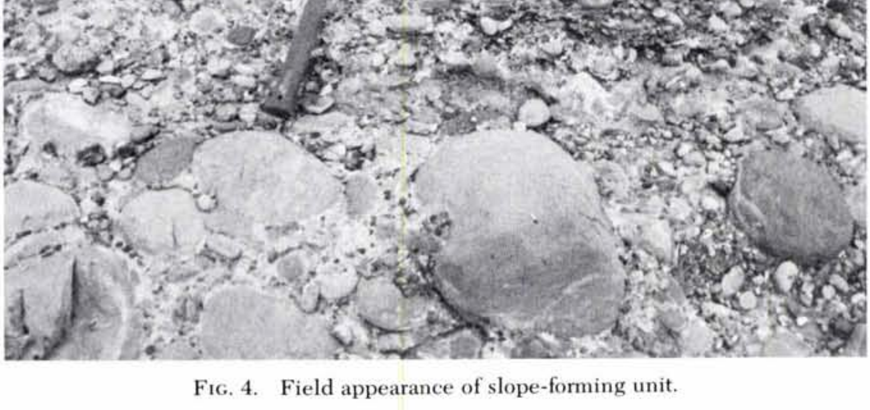


FIG. 4. Field appearance of slope-forming unit.

PLATE 1. Landsat-1 false color composite (bands 4, 5, and 7) mosaic of study area.

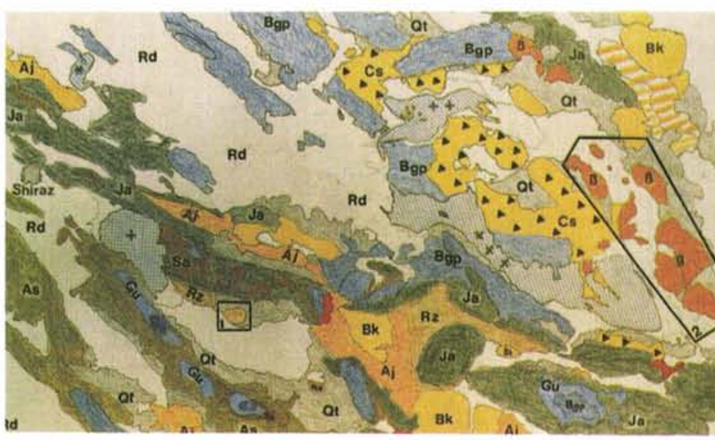



PLATE 2. Landsat-interpreted geological map of the study area. Original scale, 1:1 000 000.

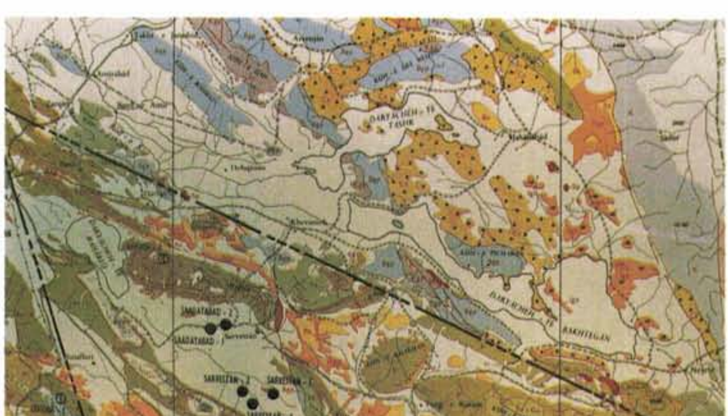


PLATE 3. Geological map of the study area (IOOC, 1969). Original scale, 1:1 000 000.

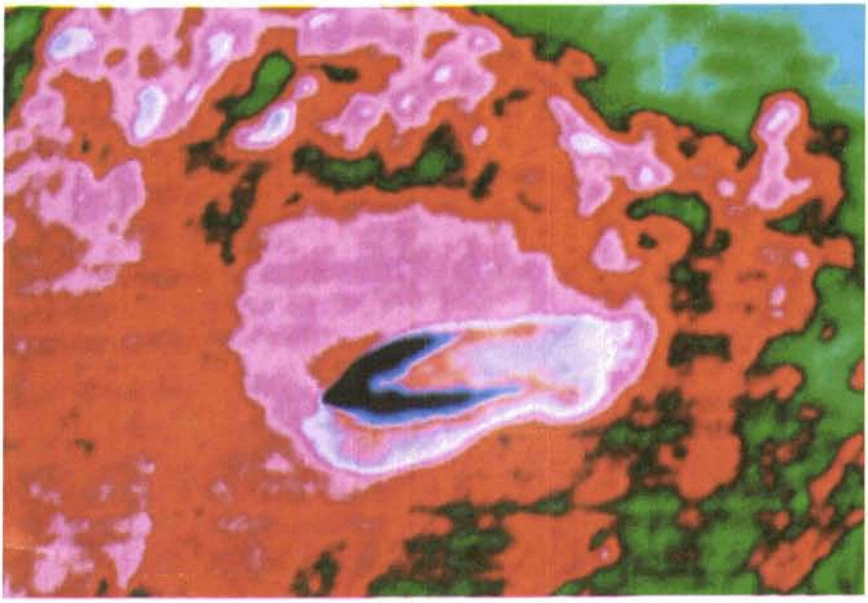


PLATE 4. Image enhancement (density slicing) of Sarvestan conglomerate, 1:1 000 000 scale Landsat MSS image, band 5, black-and-white transparency. Photo taken off analyzer's display unit.

tions observed in the tones of the unit, based on physical variations within the rock unit, and in particular, grain size consideration, is undertaken.

An explanation of this phenomenon may be that an incident ray of light falling on a rock unit composed of fine and coarse grained components will tend to reflect much more readily from the surface of the coarse-grained components than that of the fine unit (Figure 5).

As a result of this relatively larger scattering effect, the coarser grained layer will appear to have lighter tone than those of the fine grain layers.

In addition to the above grain size effect, a point also to be considered is the grain "sphericity" factor, which affects the reflectance of light from the grain surface. Thus, a unit with more spherical grains (such as a well rounded conglomerate) will most likely appear darker than a similar grain sized unit with non-spherical grains.

Furthermore, the surface texture of a unit naturally affects the reflectance of incident light from a surface. That is to say, with increasing roughness of a rock surface the amount of light reflected from that surface will correspondingly decrease.

In nature, however, the above clear-cut situations rarely occur. There is normally an interplay between the sphericity, grain size, and grain surface, and the final observed tone is therefore the result of the combination of the above-mentioned effects in conjunction with the effect of the actual nature of the rock unit.

Specifically, it can be seen that conglomerates in general will tend to appear to be

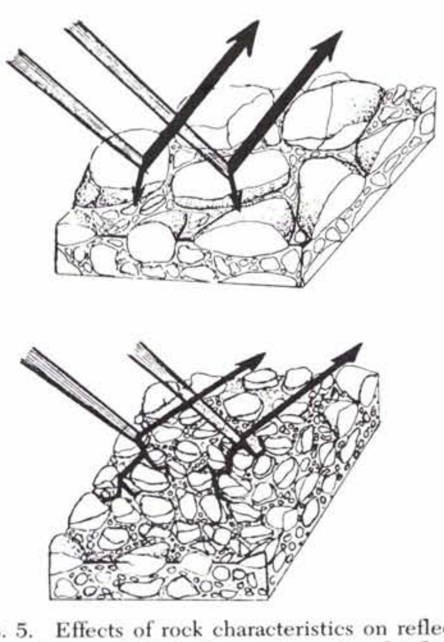


FIG. 5. Effects of rock characteristics on reflectance. Arrow width indicates intensity of reflection and/or absorption.

darker in tone than non-conglomeratic material. At the same time, within a conglomerate the finer materials will seem to be darker, probably due to greater absorption of the unit than the coarser material.

## Conclusions

- Landsat data can be effectively utilized for reconnaisance level geological mapping in regions of good exposure, and as such can be used to update and correct existing small-scale maps.
- With the use of special enhancement techniques, such as those described, the capability of Landsat imaging data for geological mapping at scales larger than those mentioned above exists, especially when the investigator is familiar with the geology of the region.
- The effectiveness of the density slicing enhancement technique in showing the variations within the conglomeratic mass indicates that, due to its sensitivity, this technique is well suited for delineation of tonally different areas that may not otherwise have been discernible.

## Acknowledgment

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2. Ordinarily *two* copies of the manuscript and two sets of illustrations should be submitted where the second set of illustrations need not be prime quality; EXCEPT that *five* copies of papers on Remote Sensing and Photointerpretation are needed, all with prime quality illustrations to facilitate the review process.
3. Each article should include an abstract, which is a *digest* of the article. An abstract should be 100 to 150 words in length.
4. Tables should be designed to fit into a width no more than five inches.
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