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**USE OF ERTS-1 IMAGES IN THE SEARCH FOR PORPHYRY COPPER DEPOSITS
IN PAKISTANI BALUCHISTAN***

Robert G. Schmidt, *U.S. Geological Survey, Washington, D.C. 20244*

ABSTRACT

Geomorphic features related to a known porphyry copper deposit at Saindak, western Chagai District, Pakistan, are easily distinguished on ERTS-1 images. New geologic information from the images was used in conjunction with known geology to evaluate one previously known prospect area and to suggest two additional ones, but no new prospects were recognized on the basis of the images alone. The study also showed that Saindak-type deposits are not likely to be present in some extensive areas of the Chagai District.

The Saindak deposit is in an area of relatively easily eroded folded sedimentary and volcanic rocks. The deposit is characterized by an elongate zone of easily eroded sulfide-rich rock surrounded by a resistant rim of hornfels and propylitically altered rock. Both this rim and the central sulfide-rich valley are conspicuous features on the images. Swarms of dikes are probably useful for distinguishing real rims from other resistant rock types but there is no expression of them on the image, although they are easily seen on aerial photographs of the Saindak rim.

During field mapping, patches of strong red and yellow hue related to the mineral natrojarosite were noted in the central valley. Attempts to detect a color anomaly using simple false color composites were not successful.

The investigation showed that a rim like that at Saindak does not form if regional metamorphism has increased the resistance of the country rock to erosion, as in the Pakistan-Iran border region northwest of Saindak.

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INTRODUCTION

This investigation is based on the premise that the large low-grade copper sulfide orebody at Saindak in the Baluchistan desert (Figure 1) could be recognized on an ERTS-1 image, that other similar deposits may reasonably be expected in the region, and that ERTS-1 imagery offers a unique and convenient means of evaluating nearby areas for such deposits.

Mapping was undertaken at Saindak in 1962 because the locality was thought to have some economic mineral potential, and the complete results of this study were reported by Ahmed, Khan, and Schmiut (1972). In 1962, after discovery of the copper sulfide orebody, we noted several features of the deposit that lent themselves to optical remote sensing, and colored aerial photography was suggested as the most practical method (Schmidt, 1968, p. 60).

The discovery in 1967 of a major porphyry copper deposit at Sar Cheshmeh, near Kerman in Iran (Figure 1), and the subsequent discovery of several more deposits including those in the vicinity of Kuh-e-Hanza, to the southeast, as well as some to the northwest of Sar Cheshmeh has increased interest in this region as a potential source of minable copper. Examination of the deposit at Saindak was recently resumed by the Geological Survey of Pakistan (Khan, 1972).

All of the western part of Pakistan is covered by 1/253,440 photogeologic reconnaissance maps (Hunting Survey Corporation, Ltd., 1960), but probably less than 1 percent of the Chagai District has been mapped in detail. Mineral reconnaissance has been spotty and mainly for high-grade deposits; if a porphyry copper deposit had been noticed, it might have been passed over as too low grade for consideration at this time. Very little detailed topographic mapping is available for the region.

Studies on this project were made mostly on one bulk 9.5 inch positive transparency photographic image, ID 1125-05545. Comparisons were made with image ID 1143-05545 to determine that certain white patches were probably not snow cover. False color composites were prepared by printing multispectral scanner bands 4, 5 and 7 on yellow, magenta, and cyan transparent foils. Foils of various color densities were made and one set was then selected to give both optimum differentiation of geologic units and enhancement of the difference between eolian sand and other near-white geologic features. Areas of interest were examined in conjunction with photogeologic reconnaissance maps, and recognition of mapped geologic units on the image was generally easy. An excellent impression of relative topographic relief from the images, combined with the photogeologic maps, is a powerful interpretive tool. No study was made of the adjacent part of the image in Iran.

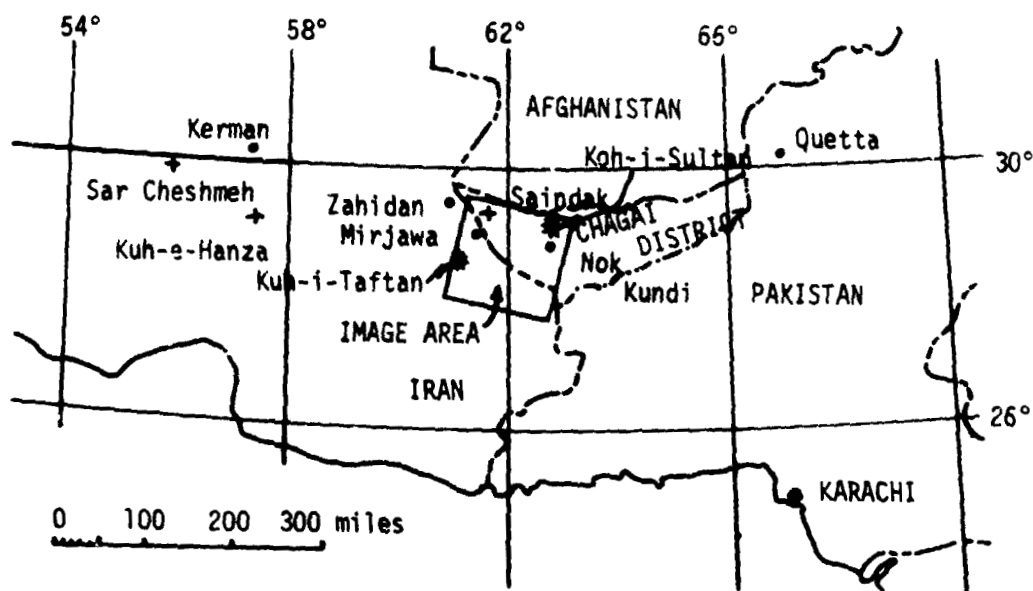


Figure 1: Index map of the Saindak area.

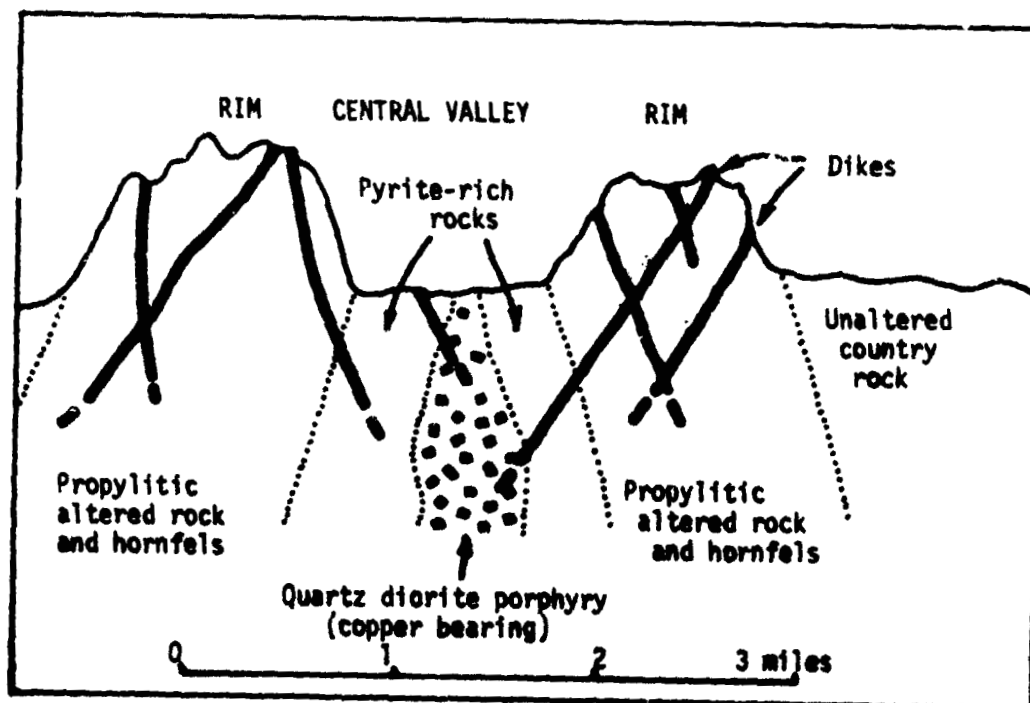


Figure 2: Hypothetical cross section of Saindak-type porphyry copper deposit. Vertical scale is exaggerated.

REGIONAL GEOLOGY

The areas of interest in the Mirjawa range --the folded mountains along the Pakistan-Iran border (Hunting Survey Corporation, 1960, plate 1)-- and in the Nok Kundi region have somewhat different regional geology. The rocks of both areas are of Cretaceous to Quaternary age, with the proportion of the area covered by Cretaceous to Tertiary strata possibly considerably less than is shown on Hunting Survey Corporation, Ltd., maps (1960).

The Mirjawa range area, which includes the Saindak deposits, has mostly folded and much faulted sedimentary and volcanic-sedimentary strata with relatively small amounts of intrusive and extrusive igneous rock. The detailed description of the Saindak area (Ahmed, Khan, and Schmidt, 1972) is fairly representative of the geology of this border region. Cretaceous sedimentary rocks represent a wide variety of marine and continental depositional environments; lower Tertiary rocks are mostly shallow marine, and upper Tertiary-Quaternary strata are from continental sites.

Regional metamorphism, probably related to granitic intrusives 25 miles west of Saindak in Iran, has been noted on the ground a few miles west of Saindak, and at many places northwestward from Saindak along the Mirjawa range.

In the Nok Kundi region, a western section of the northern Chagai hills, folding and faulting are also present but without a strong linear pattern. Intrusive rocks are more abundant, several volcanic necks are conspicuous, and there are volcanic cones and probably plug domes, as well as the dormant or extinct volcano Koh-i-Sultan.

ECONOMIC GEOLOGY

At Saindak several small copper-bearing porphyritic quartz diorite stocks cut northward across the entire folded lower Tertiary stratigraphic section. The stocks are perhaps cupolas on a single unexposed granitic body 5 miles long and less than half a mile wide. The group of stocks or larger body are surrounded by zones of contact metamorphism and hydrothermal alteration, simplified in cross section in Figure 2. The stocks are enclosed in a sulfide-rich envelope that contains as much as 15 percent pyrite; the envelope in turn is surrounded by a zone of propylitic alteration in which pyroclastic rocks in particular are altered to a hard, dark epidote-rich hornfels. Because the intrusive trend cuts several formational units, the hornfels is derived from conglomeratic sandstone, siltstone, mudstone, and these same rocks with various proportions of incorporated pyroclastic material. Limestone in the zone of alteration has been changed to marble and tactite, some hematite rich and some sulfide rich. Many dikes cut

these alteration zones and are easily identified on aerial photographs, and within the limits of the alteration, veins containing sparse lead and copper minerals are common.

The sulfide-rich central core including both the intrusive porphyry stocks and the adjacent pyrite rich rock (of several primary sedimentary types) has been eroded out to form a light-toned valley (Figure 2). Desert soils associated with many porphyry deposits the world over have distinct red and orange color anomalies, and this is true at Saindak as well, where the mineral natrojarosite has been identified in the pigmented material. Windblown and alluvial grains considerably dilute or cover much of the colored soil in the central valley at Saindak, however. In plan this valley is encircled by a symmetrical rim of hills more rugged than the surrounding region. Large-volume low-grade porphyry copper ores can be a normal association of the sulfide-rich central zone, but only detailed field examination can determine this.

On the image (Figure 3) the linear central valley and surrounding rim of hills at Saindak are cut off at the north end, perhaps by a basin-range type border fault. Abundant dikes easily seen on aerial photographs, and perhaps helpful in identification of alteration centers, are too small for recognition at this scale. The interior valley is of light tone, but no color anomaly could be seen on the color composites that I made.

Both the central valley and rim are displaced left-laterally by a major east-trending fault. The fault was mapped in 1961-62, but the displacement of the sulfide-rich zone was noted first in 1972 by Khan. Both the fault and the displacement of rim and central valley are easily identified on the ERTS-1 image.

The gradual increase in topographic relief westward from Saindak is caused by an increase in regional metamorphism, probably related to large granitic intrusives in Iran. The metamorphism was known in a very general way but had not been mapped: the affected area can easily be delimited on the image. This metamorphism is important because the increased resistance to erosion may preclude the formation of a rim of the Saindak-type in the border ranges northwest of Saindak.

EVALUATION OF PORPHYRY COPPER PROSPECTS USING ERTS-1 IMAGE DATA

Several possible prospect areas were evaluated using old data from reconnaissance maps, prospect descriptions, and personal experience together with new information from the image, and some adjustments of prospect priorities were made. Two new prospect areas resulted from using the old and new data together, although no new prospects were



Figure 3: Annotated northern part of ERTS-1 image ID 1125-05545, MSS band 7. Numbered localities are: 1/ Saindak copper porphyry prospect 2/ Amir Chah copper prospect 3/ new prospect near Mashki Chah 4/ new prospect near Koh-i-Dalil railway station 5/ volcano Kuh-i-Taftan 6/ volcano Koh-i-Sultan. The circles are eight miles in diameter.

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found on the basis of image data alone. The study showed that certain extensive areas are not likely to be mineral bearing and ground surveys there for copper porphyry deposits can be placed on a lowest priority basis.

Evaluation of old prospect areas:

Amir Chah locality - 29°08' to 11' N., 62°32' to 35' E. (Figure 3) -- Disseminated weak copper mineralization is present in a granodiorite(?) stock (Schmidt, 1968, p. 60), and there are small lean copper-bearing veins in hills a short distance to the west. The image shows that the central area of intrusive rock is topographically low and though partly mantled by dune sand, I think enough bedrock is exposed to indicate it has a light tone. Except rocks to the east which are younger volcanics, the surrounding dark more rugged areas, especially to the southwest and northwest, are interpreted to be hornfelsic zones of alteration, perhaps forming a fairly complete rim of hills; in contrast, hornfels was formerly known at only one locality on the northwest side. A hematite skarn with stains of malachite is also known on the northwest side (Hunting Survey Corporation, Ltd., 1960, p. 449.)

Although examination of the image did not add much new information, it helped reinforce my interpretation that the Amir Chah pluton may fit the general Saindak-type model, and this should be regarded as a fairly high priority prospect.

New potential prospects:

Mashki Chah locality -- 29°06' N., 62°24' to 28' E. (Figure 3) -- This is an area 6 miles north of Mashki Chah where a small intrusive is shown on the photogeologic map (Hunting Survey Corporation Ltd., map 22). Unfortunately this is also an area partly mantled by dune sand. The image shows that the intrusive forms a northeast-trending topographic depression, with a good suggestion of hornfelsic zones to the northwest and southeast. The whole feature is about the same size as the one at Saindak. This I regard as a relatively high priority prospect that deserves careful field inspection.

Koh-i-Dalil railway station area -- 28°53' N., 62°14' E. (Figure 3) -- This site was studied because the localized dike swarm suggests an intrusive center like that at Saindak. The only intrusive stocks mapped here are shown as diorites of the Tanki-sill type, but the image shows that the outcrop areas are not at all like the Tanki sills farther west, and are more likely to be quartz diorite type stocks. Slightly more rugged topography near the northernmost intrusive may be part of a hornfelsic rim. The entire feature occupies about the same area as that at Saindak. Because of its proximity to the highway and railway, this site deserves field examination prior to more remote localities.

Other possibilities in the Mirjawa Range -- Inspection of the image and photogeologic map indicate no other likely sites in the unmetamorphosed border range area besides Saindak and the Koh-i-Dalil railway station locality, and I would give other prospecting here a low priority. The metamorphosed area west and northwest of Saindak is not susceptible to this evaluation method and this study has not changed exploration priorities for porphyry-type copper deposits there.

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