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RECONNAISSANCE OF THE GEOLOGY AND ORE MINERALIZATION IN PART OF THE CHAGAI DISTRICT, PAKISTAN

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RECONNAISSANCE OF THE GEOLOGY AND ORE MINERALIZATION IN PART OF THE CHAGAI DISTRICT, PAKISTAN, 1964

by

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U. S. Geological Survey

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RECONNAISSANCE OF THE GEOLOGY AND ORE MINERALIZATION IN PART OF THE CHAGAI DISTRICT, PAKISTAN, 1964

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ABSTRACT

The Chagai District of the Quetta Division is in the northwestern part of Pakistan.

Igneous activity during the Himalayan orogeny included the extrusion of horizontally layered andesites of the Cretaceous Sinjrani Volcanic Group, emplacement of monzonitic stocks of the Cretaceous Chagai intrusions, and the extrusion of flows and tuffs of the Koh-i-Sultan Volcanic Group during the Pleistocene.

The western Chagai Hills remained a stable area only intermittently submergent during the Himalayan orogeny. Marine limestones are interlayered with the Sinjrani Volcanic Group. The Mirjawa-Dalbandin trough formed south of the Chagai Hills and received conglomerates and sandstones of the Cretaceous Humai Formation, and sandstones, shales, and limestones of the Paleocene Rakshani Formation. Doming and faulting are the major structural features in the western Chagai Hills; open folds developed in the sedimentary units to the south in the Mirjawa-Dalbandin trough.

Mineral deposits in the Chagai District include solfataric sulphur deposits on the southern flank of Koh-i-Sultan volcano and scattered travertine marble (locally called onyx marble) deposits; they are related in time to Pleistocene volcanism. Production from the sulphur deposits is about 20 tons per day of ore containing as much as 50 percent sulphur. The ore is shipped by rail to a refinery in Karachi. The travertine marble is quarried in blocks of 16 cubic feet or more. About 20 tons per day are shipped to Karachi for trimming and export.

Hydrothermal and contact metasomatic base metal and iron deposits formed during intrusive activity in the Cretaceous and Eocene. They are widely distributed through the Chagai District, but nearly all are too small to be of economic importance. The Bandagan chalcopyrite-magnetite has been partly prospected by diamond drilling. Ore reserves indicated by drilling are 32,000 tons of 0.5 to 1.0 percent copper ore. Additional prospecting may increase the quantity and quality of reserves.

INTRODUCTION

Location and accessibility

The Chagai District of the Quetta Division is in the northwestern part of Pakistan; it is bordered by Afghanistan to the north and Iran to the west. The general region that includes the Chagai District is still known as Baluchistan, although it no longer is a political division. An all-weather road and a standard gauge railroad traverse the length of the Chagai District (fig. 1) linking the city of Quetta, Pakistan, with Zahidan, Iran.

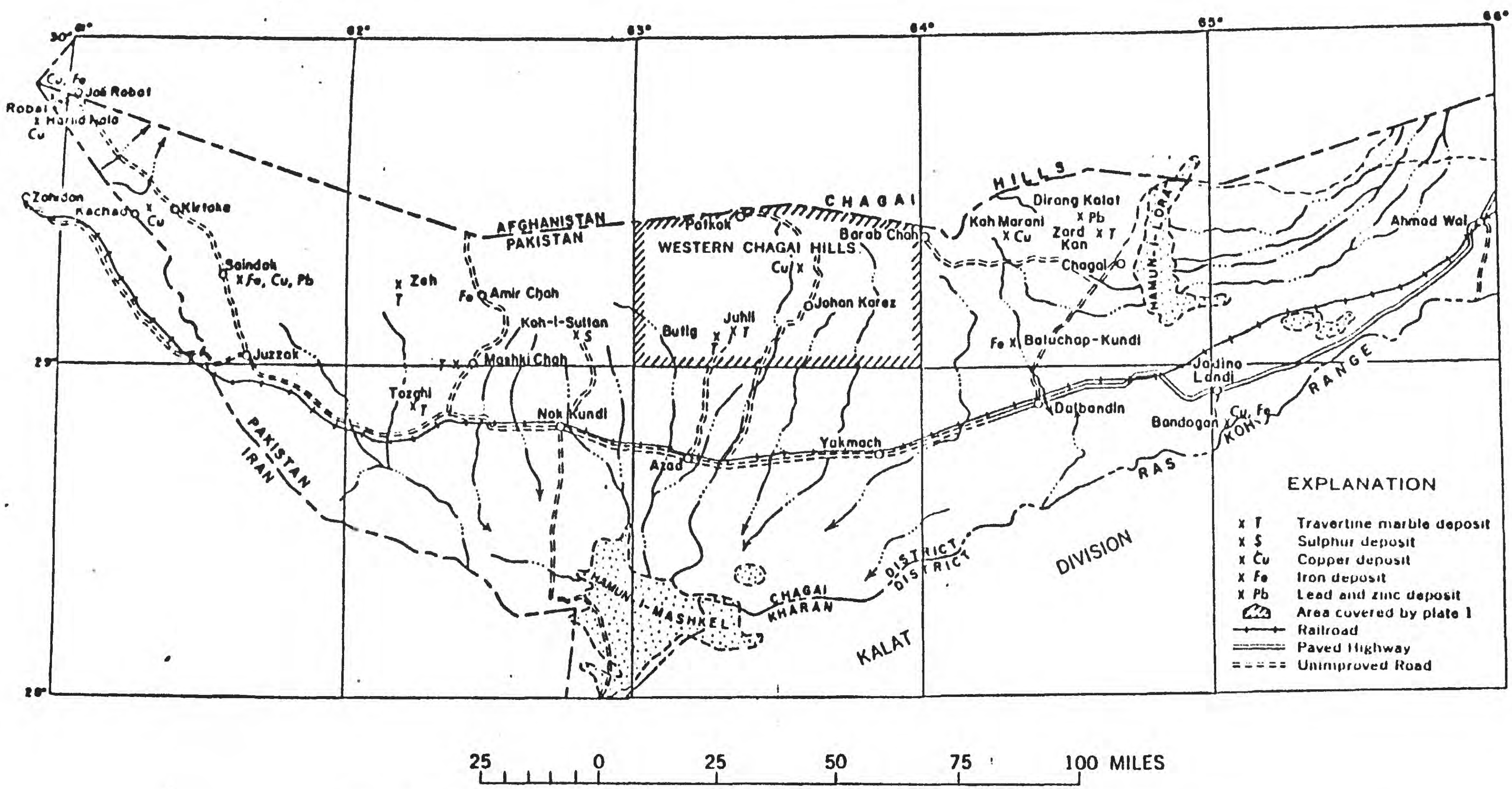

Figure 1.—Index map showing mineral localities in Chagai District, Quetta Division, and the area covered by Plate 1.

The western part of the Chagai Hills (pl. 1) lies in the north-central part of the Chagai District. The area covered by plate 1 is bounded by Afghanistan on the north, parallel 28°N. on the south, and by the meridians 63° and 64°E.

Access to the western Chagai Hills is by road from Quetta to milepost 284.25. From this point on the main road, a tract passable for trucks and four-wheel-drive vehicles winds north across the stony and sandy desert and enters Amuri Nala[1/] at the south edge of the Chagai Hills. The road follows the nala north to Johan Karez, Shah (Sor) Karez, and to the levy post, Patkok, on the Afghanistan border. Because of the rugged terrain, access to areas away from the road is limited to foot and camel trails and boulder-strewn nalas in the hill area. The stony desert south of the hills is traversible in most places by four-wheel-drive vehicles. The sandy desert in the northwestern part of the area shown on plate 1 is not readily accessible to wheeled vehicles.

Climate and vegetation

Rainfall in this arid desert varies from year to year but averages about 4 inches annually. Some years may pass with no measurable rainfall. Summer temperatures exceed 100°F., and in winter, fall below freezing.

1/ The term "Nala" means gully, arroyo, or dry wash. The term "Rud" is also used in this sense and appears on topographic maps of the area.

Scope of the report

Numerous showings of base metals have been reported from the Chagai District, especially in the area covered by this report. The association of these deposits with the largest continuous exposure of igneous rocks in Pakistan was assigned for investigation. The investigation was a joint activity of the Geological Survey of Pakistan and the U.S. Geological Survey, under the auspices of the Government of Pakistan and the U.S. Agency for International Development.

The area included in plate 1 was examined from October 1963 through January 1964. All showings of copper, iron, and travertine marble were studied and mapped. Contacts between the Sinjrani Volcanic Group*[1/] Chagai intrusions,* and Humai* and Rakshani* Formations were mapped on aerial photographs. Aerial photographs were used because suitable maps of sufficiently large scale and accuracy were not available; the Survey of Pakistan is currently compiling a series of 1:50,000-scale, 15-minute quadrangle sheets in the Chagai District; at the time of the investigation only 1:253,440-scale, 1-degree sheets of low accuracy were available.

During March, April, and May of 1964, mineral deposits in other areas of the Chagai District (fig. 1) were examined. Data in the

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1/ Stratigraphic names in this report followed by an asterisk are formal published names reports whose status with respect to the Stratigraphic Code of Pakistan is currently under examination.

files of the Geological Survey of Pakistan on the more important deposits have been augmented by the recent field investigations, as described in the section "Ore mineralization of other parts of the Chagai District" of this report.

Previous work

Pioneer work in the area was by E. W. Vredenburg (1901). The general structural and age relations of the rocks described in his report are valid and represent keen observation at a time when travel in the region was slow and difficult.

The most complete recent work is by the Hunting Survey Corporation, Limited (1960), under a Colombo Plan cooperative project. Regional geologic maps at a scale of 1:253,440 were compiled from aerial photographs and checked by field traverses along major access routes. An orderly system of stratigraphic names was introduced.

More recently, M. I. Ahmed (1951, 1962) reported on sulphur and lead deposits of the Chagai region, and W. Ahmed (1960b, 1964) described iron and onyx marble deposits.

Acknowledgments

I wish to acknowledge the field assistance of Mohammad Ameen Khan, of the Geological Survey of Pakistan, and the whole-hearted cooperation of the officials and people of the Chagai District. Those most directly facilitating the project were Inayatullah Khan, Political Agent; Nasibullah Khan, Assistant Political Agent; Mullah Abdullah, Dafedar of Yakmach; Malik Gul Mohammad, Numerdar of Amuri; and Jumma Khan, guide, cook, and stadia rodman. The hospitality of the Chagai Militia in the western part of the district greatly facilitated fieldwork. Abdul Mannan Mian, Surveyor, Geological Survey of Pakistan, assisted in fieldwork in the Chagai District.

The work was done under the general supervision of Max G. White of the U.S. Geological Survey and Mr. Asrarullah of the Geological Survey of Pakistan.

GEOLOGY

The Cretaceous Sinjrani Volcanic Group,* mostly andesite, is the oldest rock exposed in the Chagai region. In the area included on plate 1, the western Chagai Hills, the horizontally layered volcanic group was intruded by quartz monzonite and granodiorite of the Chagai intrusions* during the Cretaceous. Renewed igneous activity during the Pleistocene is represented by the Koh-i-Sultan Volcanic Group. Only small remnants of these rocks are found in the southwest corner of the mapped area, but these are the dominant rocks exposed to the west, north of Nok Kundi (figs. 1 and 2). Igneous rocks extend from the Pakistan-Iran border east for more than 200 miles and form the largest area of eruptive rocks in Pakistan.

Two sedimentary formations are exposed in the western Chagai Hills, the Cretaceous Humai Formation,* consisting of limestone, shale, sandstone, and conglomerate, and the Paleocene Rakshani Formation,* consisting of calcareous sandstone and shale. Both formations are younger than the Chagai intrusions.* They crop out along the southern border of the igneous rocks in the Mirjawa-Dalbandin trough, most of which lies south of the area included in plate 1.

The structural evolution of the Chagai region accompanied the Himalayan orogeny which culminated in the Pleistocene. The arcuate pattern of major deformational axes is shown of figure 2. Uplifted

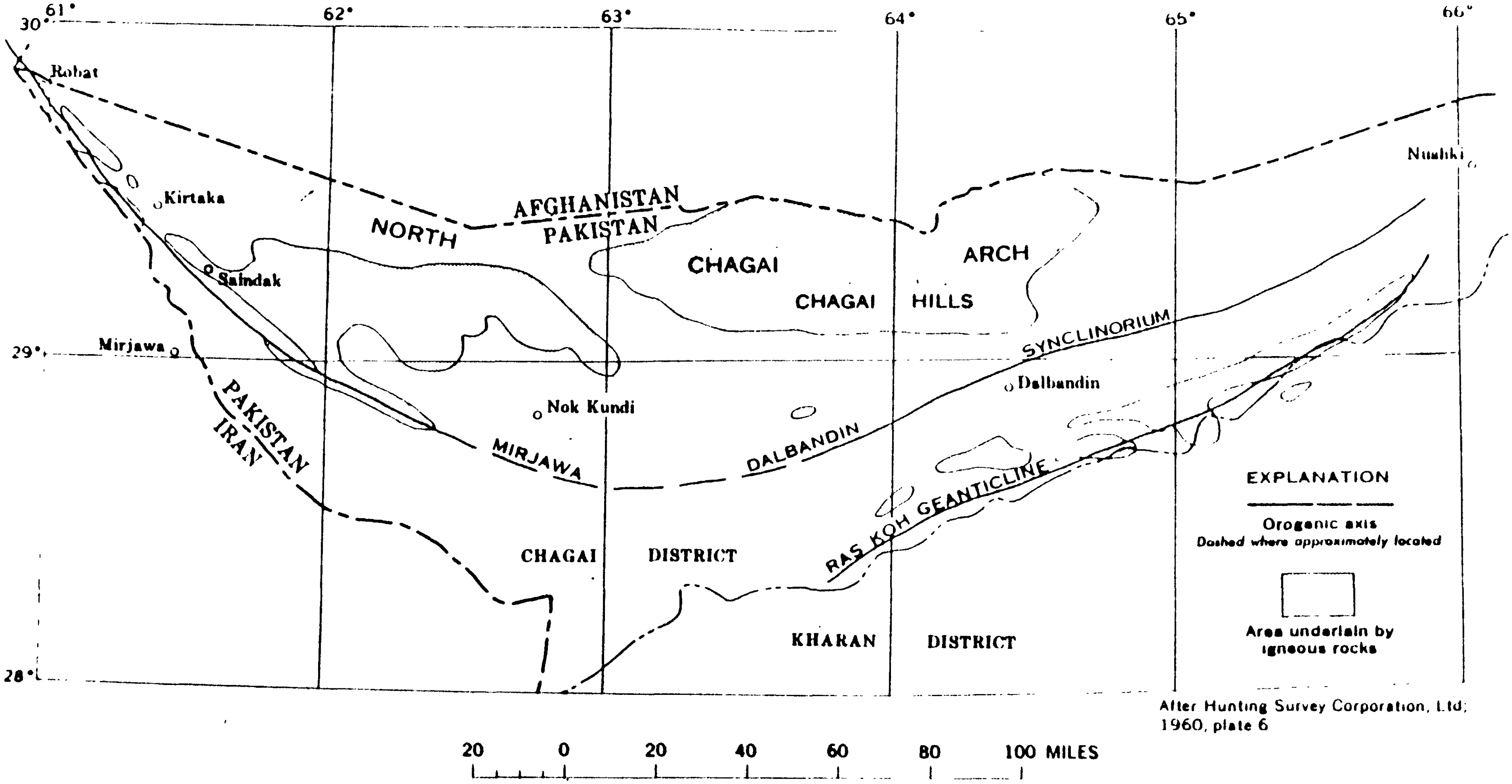

Figure 2.—Sketch map showing distribution of igneous rocks and the trend of major oragenic axes in the Chagai District, Pakistan.

areas of the North Chagai arch and the Ras Koh geanticline (Hunting Survey Corp., 1960) parallel the axis of the Mirjawa-Dalbandin trough.

Folding is relatively slight in the Chagai Hills as compared with the Ras Koh geanticline. Faulting is the major mode of deformation in the Chagai Hills. Destructive earthquakes in recent years attest to continued release of stress through faulting in this region. The gross structural form of the Chagai Hills is an elongate dome; layering in the outer margins of the Sinjrani Volcanic Group dips at low angles away from the center.

Physiography

The Chagai District is a region of mountains interspersed with sandy and stony deserts. The western Chagai Hills (pl. 1) are bounded by stony desert on the south and sandy desert on the west and north. Base-level elevations increase from 2,900 feet in the stony desert to 5,200 feet in the alluvium-covered area in the northeast. Mountain peaks rise about 1,600 feet above the nalas. Malik Naro and Malik Teznan are the highest peaks, with elevations of 8,061 feet and 7,679 feet, respectively.

The streams drain north, west, and south. Antecedent streams are controlled by faults. Stream capture has taken place south of Malik Tezanan (pl. 1) in the northern part of the map area. There, stream valleys leading northwest have been diverted by headward erosion of south-flowing streams. The northwest-flowing streams are now tributary to the south-flowing Amuri Nala. In areas underlain by the hard resistant rocks of the Sinjrani Volcanic Group* and diorite of the Chagai intrusions*, the drainage pattern is well developed. More easily eroded areas of quartz monzonite exhibit a less well developed stream pattern, with low hills projecting above a sea of their own coarse sandy debris. Cross-sectional profiles of the streams show concave side slopes with flat boulder-strewn streambeds.

South of the Chagai Hills, in the desert-varnished plain sloping gently to the south, stream channels are as much as a mile wide. A degree of immaturity exists where parallel stream channels a few hundred feet apart may differ in elevation as much as 30 feet. The banks of streams form vertical cliffs as much as 50 feet high in the early Recent sands and gravels underlying the plain. North and west of the Chagai Hills, in the sandy desert, the stream channels are ill defined or disappear beneath windswept sand. All stream valleys in the Chagai region lead to closed basins. The Hamun-i-Mashkel and the Hamun-i-Lora (fig. 1) are dry salt lakes receiving interior drainage.

Igneous rocks

Igneous rocks predominate in the Chagai Hills area. The Sinjrani Volcanic Group* of Cretaceous age and the Chagai intrusions* of Cretaceous to Eocene age cover approximately 60 percent of the map area and probably underlie much of the sandy desert to the west. Both rock units are cut by dikes and are overlain to the south by the Cretaceous Humai* and the Paleocene Rakshani* Formations.

Sinjrani Volcanic Group*

General.--The Sinjrani Volcanic Group* and equivalent formations are found from Kachao (fig.1) on the border of Iran, east to Hamun-i-Lora. The name Sinjrani was first proposed by Hunting Survey Corp., (1960 p.292) after the Sinjrani area north of Dalbandin. The unit includes the "flysch" of Vredenburg (1901, map 1). Hunting assigned the group to the Cretaceous.

In the western Chagai Hills, the Sinjrani Volcanic Group* appears as massive, dark-green to black, fine-grained, layered rocks. The layers are horizontal or gently inclined and range in thickness from a few inches to several feet. At the margin of the hills, the layers dip more steeply and form a domal structure.

Lithology.--The dominant rock type is andesite, followed in abundance by dolerite, basalt, felsic quartz andesite, dacite, and rhyolite. Agglomeratic layers containing volcanic fragments and boulders as much as 2 feet in diameter are locally abundant. Small amounts of limestone and tuff are interbedded with these rocks.

Andesite ranges in texture from very fine grained to prophyritic. Andesine is the most abundant mineral and occurs with epidote, hornblende, biotite, chlorite, and magnetite. Biotite is subordinate to hornblende; the latter is replaced commonly by secondary calcite. Potash feldspar is present in some places, and serpentine (after olivine?) was noted in a few of the rocks. Plagioclase microlites form the groundmass of the porphyritic andesites.

Epidote is widespread in mafic rocks of the Sinjrani Volcanic Group* throughout the Chagai District but is rare in the more felsic rocks. In places, masses of nearly pure epidote as much as 20 feet in diameter with rosettes of epidote crystals are found. The greenish tinge of the dark to black volcanic rocks is due to the presence of epidote.

Dolerite and basalt differ only in the fine-grained texture of the basalt and the coarser texture of the dolerite. Feldspar most commonly lies in andesine-labradorite range of composition. Pyroxene (augite) or hornblende is the most abundant mafic mineral, and magnetite, chlorite, and epidote are common accessories. Some biotite was noted in one thin section of dolerite.

Quartz andesite, trachyte, and dacite were identified in thin sections, but were not mapped as separate units in the field. Quartz is present in these rocks; the dominant feldspar is oligoclase, and biotite is more abundant than in the andesite. Epidote, chlorite, and magnetite are present as accessories. Some of the dacite exhibits a glassy matrix containing feldspar microlites. Trachytic textures are rarely seen.

Rhyolite and tuff are not widespread in the mapped area (pl. 1). A small patch of rhyolite lies opposite Dojeekor Nala in the northern part of the area. The rock is pale brown, hard, fine grained and contains visible quartz. Limonite is present on the weathered surfaces. Quartz, oligoclase, and sericitized orthoclase, make up most of the rock; muscovite and a small amount of sphene are present.[1/]

1/ Two pits, about 50 feet in diameter and 10 feet deep are in the rhyolite. They are locally known as the "Missi" mine (mis is copper in Baluchi). No ore minerals are visible in the pits, and no ore elements were detected by spectrographic analysis of the rock. The local inhabitants do not know when or by whom the pits were dug.

Although most of the Sinjrani Volcanic Group* is andesite, composition varies along the strike and across the layering; no systematic vertical variation was noted in the group.

Sinjrani limestone.--Limestone lenses constitute a very minor part of the Sinjrani Volcanic Group* in the northeastern and southeastern part of the area. They range in thickness from 4 feet to about 300 feet. The limestone is assigned to the Sinjrani Volcanic Group* because it is interlayered with these rocks and is not related to the Rakshani Formation,* which it resembles. Algae, shell fragments of pelecypods, and probable tests of Radiolaria are contained in the white massive limestone. None of the fossils yielded definitive age data; all could be Cretaceous. The limestone contains a small amount of tuffaceous clastic material.

Alteration of the volcanic rocks.--The volcanic rocks are only slightly altered near intrusive contacts where dense fine-grained hornfelsic rock has developed in places. Epidote appears more abundantly near contacts and also near small hydrothermal mineral occurrences. Tiny veinlets of quartz and calcite in rock adjacent to mineralized outcrops are visible under the microscope; to the unaided eye, the rock shows no evidence of hydrothermal alteration.

The volcanic sequence contains small patches of skarn consisting of epidote and garnet. Skarn and hematite are clearly alteration products of limestone. This rock may correspond to the host rock of the Baluchap-Kundi iron deposits (see Iron in the section on "Ore mineralization in other parts of the Chagai District"). West of

Dana Nala, a patch of skarn covers an area of 100 square feet. No limestone is found in this area, although it is seen under the microscope that calcite replaced brown, zoned garnet. Associated minerals are epidote, quartz, hematite, pyrite, and a fibrous amphibole.

Chagai intrusions*

General.--The term Chagai intrusions* was applied by Hunting Survey Corp. (1960, p. 93) to the dominant intrusive rock underlying the Chagai Hills. Intrusive masses of equivalent composition and slightly younger age are found to the west near the Iranian border, and to the east in the Ras Koh Range.

The Chagai intrusions* attain batholithic dimensions and occupy an area 85 miles (east-west) by 30 miles (north-south). They intrude rocks of the Sinjrani Volcanic Group;* they do not intrude the Cretaceous Humai Formation* which contains pebbles and boulders of the intrusives in its basal conglomerate.

Lithology.--The Chagai intrusions* range in composition from granite to gabbro. Most are quartz bearing and of intermediate composition. Quartz monzonite and grandiorite are by far the most abundant. Quartz diorite most commonly is found in a narrow zone near contacts with the Sinjrani volcanic rocks. Relatively rare gabbro forms small pluglike masses. Granite is also relatively rare, and it is regarded as a potash-rich variant of the intermediate intrusive rocks.

Granite, quartz monzonite, granodiorite, and quartz diorite have not been mapped separately because those rock types are gradational, and the differences in composition cannot be determined accurately without extensive microsopic study.

Plagioclase in the oligoclase-andesine range is the most common mineral in these rocks. Plagioclase and orthoclase are cloudy brown and partly sericitized. Hornblende, in different stages of replacement by chlorite, is pleochroic in yellow-brown to green. Chlorite is present in most of the rocks. Magnetite is common; apatite and sphene are rare. Brown biotite is more common in the felsic rocks, whereas hornblende is more common in the mafic end of the series. Myrmekite texture is especially abundant in the quartz diorite. Epidote is relatively rare in the intrusive rocks as compared with the Sinjrani volcanic rocks.

Monzonite and diorite were identified only along the southern margin of the Chagai Hills. Monzonite underlies some of the travertine deposits in the Juhli area, and diorite is found farther east. Graphic intergrowth of andesine and orthoclase is well developed in the monzonite. Hornblende is present in the diorite to the exclusion of biotite.

Gabbro forms small pluglike intrusive masses as much as several hundred yards in diameter. It is not common in the Chagai Hills. Hornblende and labradorite are its chief constitutents; olivine, serpentine after olivine, and magnetite are present in small amounts. The relative lack of weathering of the gabbro suggests that it is younger than the more felsic rocks of the Chagai intrusions* and may be related to the basalt dikes that cut both the Sinjrani volcanic and the Chagai intrusive rocks.

Form of the intrusions.--The intrusive masses are batholiths that invaded the overlying volcanic rocks. In places, the volcanic strata are turned up near the contact with the intrusive, but most contact zones are undeformed. Near such contacts, xenoliths of volcanic rock are found, and the mafic mineral content of the intrusive rock increases slightly. This suggests that the mode of intrusion involved magmatic stoping with assimilation of the volcanic wallrock.

As noted by Hunting Survey Corp. (1960, p. 96), the presence of granitic boulders in the basal part of the Humai Formation* shows that the intrusive rocks were subjected to erosion soon after their emplacement, suggesting a shallow depth of emplacement beneath a thin roof of the Sinjrani Volcanic Group*.

Dikes

Fine-grained andesitic and basaltic dikes as much as 30 feet thick cut the intrusive complex, volcanic rocks, and the Rakshani Formation*. In places, a zone of recrystallized rock 2 to 3 inches thick is seen at the contacts, but most of the contacts are unaltered.

Because flow rocks are not associated with the dikes, it seems unlikely that the dikes are related to the Pleistocene outpourings of tuff and lava to the west at Koh-i-Sultan. They are probably related to a second phase of intrusive activity during or following Paleocene time.

Koh-i-Sultan Volcanic Group

Flow rocks, agglomerates, and tuffs from Koh-i-Sultan volcano crop out in the southwestern corner of the map area and represent a small part of the tremendous outpourings to the west. The flow rocks, mostly andesite, are subordinate in quantity to agglomerates and tuffs.

Some rocks shown as belonging to the Sinjrani Volcanic Group* in the western part of the map area are similar in aspect to the Koh-i-Sultan Volcanic Group. Their distribution as shown on plate 1 follows Hunting Survey Corp. (1960, map n° 22), but more detailed study is required to determine whether they are Cretaceous or Pleistocene in age. The upwarped layering in the volcanic rock surrounding the intrusive plug at Manzil (pl. 1) suggests that these rocks are the Sinjrani Volcanic Group.*

Age of igneous rocks

Igneous activity in the Chagai region continued intermittently from the Cretaceous through the Pleistocene. The horizontal andesitic flows of the Sinjrani Volcanic Group* are assigned to the Cretaceous (Hunting Survey Corp., 1960, p. 292) on the evidence of fossils in interlayered marine limestone lenses.

The Chagai intrusions,* Raz Koh intrusions,* and Shor Koh intrusions* represent suites of similar composition that date from the Cretaceous through the Paleocene. In the western Chagai Hills, pebbles and boulders of the Chagai intrusions* are found in the basal conglomerate of the Cretaceous Humai Formation;* in the eastern Chagai Hills, near Baluchap-Kundi (fig. 1) and to the south at Nuhli Koh, the Chagai intrusions* invaded the Paleocene Rakshani Formation (Hunting Survey Corp., 1960, p. 94).

Andesite and basalt dikes cut the Rakshani Formation* east of the western Chagai Hills. They also intrude the Chagai intrusions* of the western Chagai Hills and may represent intermittent volcanism during the Cenozoic.

A Pleistocene age for the Koh-i-Sultan volcanic activity is suggested by Hunting Survey Corp., (1960, p. 182) on the basis of the relatively undissected volcanic cones, the still-active Koh-i-Taftan volcano, and the unconformable contacts of the Koh-i-Sultan Volcanic Group with the underlying Cretaceous Sinjrani Volcanic Group* Tertiary-Cretaceous Chagai intrusions,* and the Paleocene Juzzak Formation* which crop out in the western part of the Chagai District. The layering in the Koh-i-Sultan volcanic material does not appear to be folded or tilted, and some of the red coloration in lacustrine deposits in the Pleistocene Kamerod Formation* is thought to have been derived from contemporaneous volcanic activity (Hunting Survey Corp., 1960, p. 182).

Sedimentary rocks

Cretaceous and Paleocene sediments are represented by the Humai* and the Rakshani* Formations that crop out along the southern margin of the Chagai Hills. The beds generally dip gently to the south, away from the hills, and are at most gently folded.

Humai Formation*

The Humai Formation* was named by Hunting Survey Corp., (1960, p. 143) after Koh Humai west of the Koh-i-Sultan volcano. The formation includes the "Hippuritic limestone" of Vredenburg (1901), as well as shale, sandstone, conglomerate, and tuff.

A basal red conglomerate sequence 240 feet thick dips 35°S. and overlies the Sinjrani Volcanic Group* at Huki-Luti (Mazenen) Nala. This red-bed sequence is gritty and contains boulders of Sinjrani volcanic rocks, some granitic rock, and pelecypod-bearing limestone boulders which may have come from limestone layers in the Sinjrani. Above the basal conglomerate is a gray to drab-green sequence of sandstone, grit, and conglomerate, consisting of beds as much as 2 feet thick. Near Huki-Luti (Mazenen) Nala, the Humai Formation* exceeds 1,000 feet in thickness and grades upward into the Rakshani Formation.* Lithologic variations within short distances along the strike are reported by Hunting Survey Corp., (1960). North of Butig, a layer of biohermal limestone containing pelecypods and gastropods was mapped by Hunting as the Humai Formation;* this investigation found it to be interlayered with Sinjrani volcanic rocks.

The Humai Formation* is readily eroded and largely covered by early Recent gravels. Some of the best exposures are in nalas where recent erosion has cut through the gravels and exposed the underlying beds.

C. L. Cox (Hunting Survey Corp., 1960, p. 146) has correlated the Hippurite fauna of the Humai Formation* with the Maestrichtian or Upper Cretaceous. The age of the uppermost beds is unknown because they and the lower part of the Rakshani Formation* are unfossiliferous.

Rakshani Formation*

The name Rakshani Formation was proposed by Hunting Survey Corp., (1960, p. 248) to include various rocks mapped by Vredenburg (1901) as Cardita Beaumonti beds, volcanic Flysch, Ranikot, and Siwalik.

The Rakshani Formation* (pl. 1) consists of green to brown gritty calcareous sandstone and sandy shale. Although most beds are less than 2 inches thick, some are as much as 10 feet thick. Near the Chagai Hills, conglomerate layers contain rounded pebbles of the Sinjrani Volcanic Group* and some pebbles of the Chagai intrusions.* Cross-bedding near the Chagai Hills suggests a steep gradient of deposition, and marine fossils indicate that marine conditions prevailed during deposition. Hunting Survey Corp., (1960, p. 250) noted the presence of volcanic material in the formation east of Dalbandin near Ahmad Wal. No rocks of volcanic origin were seen in the Rakshani Formation* in the mapped area.

Hunting Survey Corp., (1960, p. 251) considers most of the formation to be Paleocene in age and the basal strata to be of possible Danian age (Late Cretaceous or Early Paleocene).

Early Recent deposits

Most of the early Recent deposits are in the broad south-sloping plain south of the Chagai Hills. They are outwash deposits from the Chagai Hills and are coarsely stratified and unconsolidated. The material consists of boulders, pebbles, and sand. The surface of the deposits is deeply dissected by nalas. Broad interstream areas are flat, and surface pebbles are covered by black to dark-brown desert varnish composed mostly of iron and manganese oxides. In places, the unconsolidated material is cemented by lime, giving sufficient cohesion to permit vertical cliffs up to 50 feet high to stand above the dry stream valleys.

The outwash deposits are Pleistocene to Recent in age and, in contrast to the Humai* and Rakshani* Formations, are not folded or warped. As noted by Hunting Survey Corp., (1960, p. 299), mapping of early Recent deposits, as distinguished from Recent deposits, serves no useful purpose, except that within small areas it offers a broad basis for comparing alluvial overburden. The early Recent deposits are distinguished from the Recent deposits by being older, more stable, and subject to normal processes of stream erosion.

Recent deposits

Recent deposits consist of loose unconsolidated windblown sands in dune areas in the western part of the map area and sand-to boulder-size alluvium in dry stream valleys. This material is more obviously transported by wind and water action than are the early Recent deposits.

Ths soil cover on the hills rarely exceeds a few inches and in most places consists of a thin veneer of rock shards. Calcium carbonate is a major constituent of the light brown soil; throughout the Chagai region a drop of acid produces effervescence in soil.

Structure

The Chagai Hills are bordered by the Mirjawa-Dalbandin trough to the south and the Hamun-i-Lora, a large flat dry lake, to the east. To the west is the recently active Koh-i-Sultan volcano with its surrounding volcanic effluvia, and to the north, in Afghanistan, is a broad plateau area of low relief. The Cretaceous Sinjrani Volcanic Group* and Chagai intrusions* are sporadically traceable to the west where they are not covered by alluvium and recent volcanic outpourings.

Deformation of the Chagai region took place before and during the Himalayan orogeny. In Permian time, the orogeny began with the development of the Baluchistan geosyncline in the area now occupied by Pakistan. Downwarping continued through the Jurassic, with the accumulation of thousands of feet of sediments. Following the Jurassic, the geosynclinal area was deformed into a series of east-trending ridges and intervening basins.

The North Chagai arch, the western part of which includes the Chagai Hills, borders the north flank of the synclinal Mirjawa-Dalbandin trough (fig. 2). Mountains in the arch exhibit the festoon pattern so well developed to the east in Pakistan, India, and Burma. Volcanic and intrusive activity, beginning in the Cretaceous, represents the beginning of the collapse of the syncline prior to the main pulse of the Himalayan orogeny in the Pleistocene.

Following emplacement of the igneous rocks, the Chagai Hills area remained stable in comparison with highly deformed areas to the south and east. That strong folding did not take place during the Himalayan orogeny is shown by the nearly horizontal attitude of the Sinjrani Volcanic Group.* Orogenic effects are represented by the many faults cutting the intrusive and sedimentary rocks, the broad domal uplift of the Hills, and the gentle warping of the layered rocks.

The relative stability of the North Chagai arch led Hunting Survey Corp., (1960, p.22, 28) to suggest that the area rests on the shelf of the hinterland craton underlying Afghanistan. The conclusion is tentative because the geology on the Afghanistan side of the border is obscure; the relation of the Chagai arch to the hinterland craton and the mobile belt of the geosyncline has not been definitely established.

Structure of the Chagai Hills

Folds are not well developed in the western part of the Chagai Hills. Layering in the volcanic rocks is horizontal, or nearly so, in most places. Around the periphery of the Chagai Hills, the general direction of dip is away from the center. Adjacent to some intrusive bodies the volcanic rocks are arched, but in most places the magma invaded the volcanic rocks with no noticeable upturning of the strata.

Formations of sedimentary rock are monoclinal and dip to the south near the Hills. Farther south, they exhibit open anticlinal and synclinal flexures whose axes trend east-west.

Faulting has played a more active part in the deformation of the Chagai Hills than has folding. The faults form a conjugate pattern: the average strike of one set is N.47°E. and the other is N.42°W. Along the southern margin of the Hills a third set of faults strikes east. All faults dip steeply. Many of the straight stream valleys are controlled by faults.

Beds of the Sinjrani Volcanic Group* are not notably displaced except by rare drag folds and displacements of a few feet on dikes that are transected by faults. Displacements are not readily discernible because of the difficulty in correlating displaced layers in a lithologically similar sequence.

Intrusive contacts are marked by faults in places. The Amuri Nala, opposite Dojeekor Nala in the north-central part of the mapped area (pl. 1), occupies a fault contact between intrusive rocks to the east and volcanic rocks to the west. In most places contacts seem to be controlled by the vagaries of magmatic intrusion.

The basal conglomerate of the Humai Formation* shows an apparent horizontal displacement of 500 feet where it crosses Huki-Luti (Mazenen) Nala. The fault, not visible, is in the nala bed and strikes about N.20°E. A similar fault, half a mile to the west, offsets the conglomerate by 1,000 feet. The apparent horizontal direction of movement is left lateral; i.e., the west side has moved south with respect to the east side along both of the faults. To the east, at Sohtag Nala, the apparent horizontal displacement of the Humai Formation* is 8,000 feet along a right-lateral fault striking N.70°W. This is the greatest displacement noted on any of the faults in the Chagai Hills.

Gentle outward tilting of layered rocks at the margins of the Chagai Hills indicates that doming has taken place. Travertine marble cappings in the southwestern part of the Chagai Hills, believed to have been deposited in a body of water, are related to Pleistocene volcanic activity. They are now found at successively higher elevations toward the interior of the Hills. This would suggest that doming has taken place following the Pleistocene if the travertine marble originally formed in a horizontal sheet, as described later in this report. Local doming in the Sinjrani Volcanic Group* took place near contacts with plugs of the Chagai intrusions.*

The Chagai igneous region is thought to lie on the south edge of the hinterland craton that manifests itself in the stable area of Afghanistan. Because of the nearly horizontal attitude of the Sinjrani Volcanic Group,* the Chagai Hills represent a stable area that was emergent or intermittently emergent throughout the Himalayan orogeny. Regional uplift began toward the end of the Tertiary. Marine fossils disappear and terrestrial red beds predominate in successively younger formations. Sedimentary Pleistocene formations in the Chagai region are of terrestrial origin.

Dikes were mapped by Hunting Survey Corp., (1960) but are not shown on plate 1. On aerial photographs the dikes seem to be more abundant in the intrusive rocks than in the volcanic rocks because they contrast more with the lighter colored intrusive rocks; actually, the dikes are about equally distributed in both rock types. Some of the dikes are parallel to faults and are controlled by preexisting fracture planes. In the center of the mapped area, near Mirenjo (a small cemetery), the dikes curve parallel to the contact between intrusive and volcanic rocks. Although most dikes parallel fault trends, the curved pattern suggests control by primary flow structure in the intruding granitic rock.

The relative horizontal displacement observed along the conjugate faults in the Chagai Hills is in accord with the general interpretation in Pakistan that maximum compressional stress was oriented north-south and horizontal minimum stress east-west. The east-striking faults elsewhere in Pakistan are steeply inclined, mostly to the north; they exhibit a reverse slip movement and are older than the conjugate system of tear faults (Hunting Survey Corp., 1960, p. 333). This probably is true also in the western Chagai Hills, although age relations were not observed in the field. The steep dip of the reverse faults requires an explanation other than horizontal compression which serves to explain the formation of the conjugate tear faults. Hunting Survey Corp., (1960, p. 377-379) proposes that initial folding and development of east-west reverse faults were initiated by movement of the basement which transmitted stress inclined upward to the south.

As the rocks deformed by folding and assumed arcuate shapes, the minimum stress axis rotated to the horizontal, parallel to the fold axes; further deformation took place along the younger tear faults.

In the region of the Chagai Hills, folds and reverse faults did not attain the degree of development noted in sedimentary rocks in other areas of Pakistan. This may be due to the greater competency of the volcanic and igneous complex and to the more stable position of the region in relation to the hinterland craton. Under these circumstances, in the Chagai Hills, the maximum Himalayan orogeny manifested itself mainly in pre-Pleistocene time with the formation of the conjugate strike-slip fault pattern.

ECONOMIC GEOLOGY

Deposits of copper, lead, zinc, iron, sulphur, travertine marble, and chromite represent the minerals found in the Chagai District (fig. 1). Base-metal deposits are widely scattered throughout the District but are small and weakly mineralized; most consist of stains of green copper oxide (malachite, chrysocolla) on fracture surfaces. Some deposits contain small amounts of the sulfide minerals chalcocite, chalcopyrite, galena, and pyrite. The Sinjrani Volcanic Group,* the Chagai intrusions,* and related intrusive rocks are the host rocks for most deposits, contact metasomatic deposits are in skarn and hornfels. One of these contact metasomatic deposits, the Bandagan, is considered worthy of additional prospecting as described below. A small lead deposit near Dirang Kalat is being mined on an exploratory basis; a few tons of hand-cobbed ore have been shipped by rail 800 miles to Karachi. Slag piles at Jali Robat, Saindak, and Bandagan indicate local smelting of copper and lead ores in the distant past. No historical record of this activity is known to the author.

Iron-mineral deposits are widespread in the Chagai District. Small veins consisting mostly of limonite and hematite are in igneous rocks. A small amount of copper mineral and iron-bearing carbonate mineral is present. The Baluchap-Kundi deposit is of contact metasomatic origin in limestone and contains more than a thousand tons of ore assaying more than 50 percent iron.

Sulphur is mined from small irregular solfataric deposits in tuff on the south flank of Koh-i-Sultan volcano. About 22 tons of ore containing 50 percent sulphur is produced per day. The ore is trucked 25 miles to Nok Kundi where it is shipped by rail about 850 miles to the refinery in Karachi. This mine is the only source of native sulphur in Pakistan.

Travertine marble is quarried at Zeh, Tozghi, Mashki Chah, Juhli, and Zard Kan (fig. 1). The horizontally layered deposits form cappings as much as 25 feet thick on low hills of the Sinjrani Volcanic Group* and the Chagai intrusions.* Because of the pleasing aspect of polished surfaces, the travertine marble is used for building construction, table tops, lamps, ashtrays, etc. Small chips make an attractive terrazzo flooring. The blocks are trucked from the quarries to rail sidings near Nok Kundi, Azad, and Dalbandin (fig. 1). Rail shipments to Karachi averaged 2,500 tons per year from 1958 to 1962. After trimming at plants in Karachi, some travertine marble is exported.

The possibility of finding evaporite deposits in the playa lakes, Hamun-i-Lora and Hamun-i-Mashkel is being considered by the Geological Survey of Pakistan. Some sampling and drilling have been done in an effort to locate favorable areas for prospecting.

Small, low-grade, low-chrome-iron-ratio chromite deposits are in serpentine in the Ras Koh range.

Some major problems of carrying on mining activities in the Chagai region include the absence of water in most places and the high salinity of available water. Rail stations in the District are supplied by tank cars hauling water from Zahidan in Iran and from Nushki east of Ahmad Wal (fig. 1). In this region of exceedingly dry climate, prospects of finding adequate water for large-scale operations have not been investigated.

Because of the dry climate, dust storms of 2 or 3 days duration are frequent and work is halted by low visibility, discomfort of the workers, and the deleterious effects on machinery.

Individual mineral deposits are described in two parts, ore mineralization in the western Chagai Hills, the area covered by plate 1, and ore mineralization in other parts of the Chagai District, the deposit localities of which are shown in figure 1.

Mineral deposits, western Chagai Hills

Copper

More than 23 copper-mineral deposits are in the western part of the Chagai Hills. Most are in fractures in the Sinjrani Volcanic Group* and all are small and weakly mineralized.

Small amounts of the green copper minerals malachite and chrysocolla stain fault and joint planes. Chalcocite, bornite, chalcopyrite, and pyrite are present in some deposits. Limonite, hematite, and manganese oxide are commonly present. Gangue minerals are rare; calcite, quartz, and iron-bearing carbonate are found in some deposits. Alteration of the wallrock adjacent to the showings is negligible, although epidote is more abundant near some deposits in the Sinjrani Volcanic Group.* Two deposits are in garnet-epidote skarn associated with hematite.

The copper minerals virtually disappear at a depth of about 2 feet, indicating that supergene enrichment has taken place near the surface. Because of their small size, none of these deposits is recommended for further prospecting.

A group of 10 deposits, in the north-central part of the western Chagai Hills west of Amuri Nala and south of Dojeekor Nala (pl. 1), represent the most concentrated group of ore-mineral showings in the western Chagai Hills. Access to the area is north by road along Amuri Nala to Kannar Nala north of Mirenjo. A road 6 miles long follows Kannar Nala to the northwest. A trail 3 miles long leads from the end of the road to the Shambi Dik copper deposit (no. 1, pl. 1). Showings 2 through 5 and 7 are most readily accessible from the Shambi Dik and are in Kapisha ridge (not shown on pl. 1) south of Dojeekor Nala. Showings 6 and 8 through 10 are most readily accessible from Amuri Nala. The precise locations of all showings appear on aerial photographs of the area in the files of the Geological Survey of Pakistan. Even with the photographs, the services of local guides familiar with the area would be most helpful to anyone attempting to visit the showings. All the following deposits are in the Sinjrani Volcanic Group.

1. Shambi Dik or Kapisha - Eighteen small pits about 3 feet deep were excavated on copper showings in an area measuring 800 by 600 feet (fig. 3). Shiny black specks of chalcocite and green patches of malachite and chrysacolla are disseminated in small randomly oriented fractures in andesitic Sinjrani volcanic rock. Very little

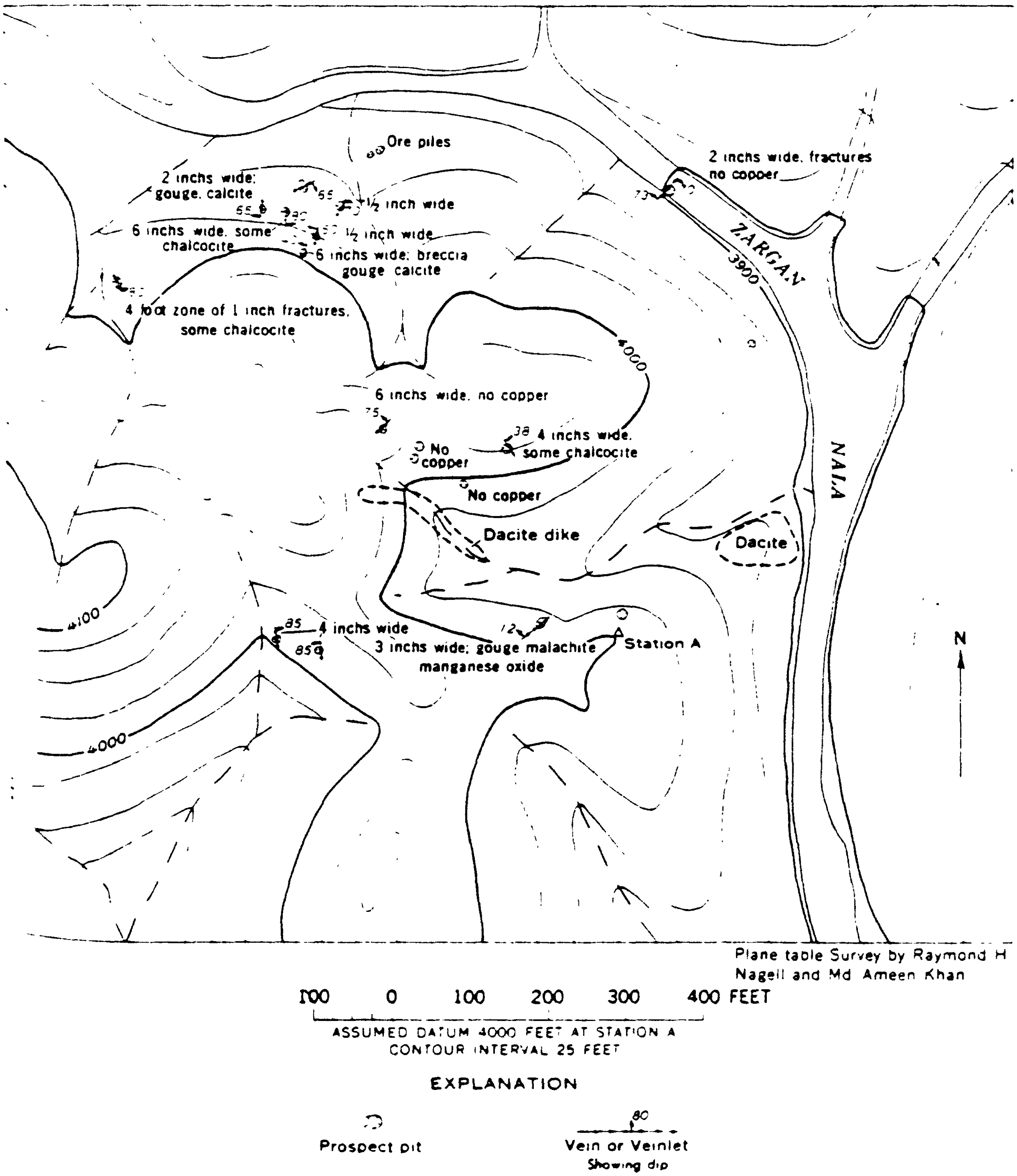

Figure 3 —Sketch map of the Shambi Dik copper deposits Country rock is Sinjrani volcanic group; andesite unless otherwise indicated, near Zargan Nala, Pakistan.

copper mineral remains in the pits; nearly all signs of copper disappear at a depth of 3 feet. Gangue minerals in the fractures include calcite, manganese oxide, and clay. The andesite adjacent to the fractures is unaltered. Epidote is abundant in the andesite at Shambi Dik but is not geologically significant because epidote is found through the Sinjrani Volcanic Group.

Specimens selected for obvious copper content from a pile of material excavated from the pits assayed 3.1 percent copper. Because of the lack of copper at depth in the pits and the small size of the fractures, ore reserves are considered negligible.

2. The Baralop deposit north of Shambi Dik was also test pitted, but no ore is visible in the pit. Four patches of green copper stain are scattered within 50 feet of the prospect.

3. The Pich deposit lies in a shear zone exposed at the head of Dojeekor Nala. This copper showing is in a shear zone 20 feet wide that strikes N.80°E. and controls the position of Dojeekor Nala. Minute quantities of chalcocite and green copper oxide minerals occur in the shear zone over an outcrop length of 200 feet.

4. Gadahar is the local name applied to the copper showings on the south side of the Dojeekor Nala, tributary to Amuri Nala. Small amounts of chalcocite, green copper oxide stains, hematite, manganese oxide, and a brown carbonate mineral are exposed in a vertical fracture zone that strikes N.83°W. Adjacent volcanic rocks contain abundant epidote.

5. The Tamba (copper in Urdu), Gattori, and Neilgar deposits

are within half a mile of one another. Short veinlets 1/2-inch wide contain quartz, chalcocite, and green copper oxide; they strike northwest and dip 50°SW.

6. The Churra and two unnamed showings are represented at deposit number 6. One consists of copper minerals in a small patch of shattered rock, and the other fills a vertical north-striking fissure. The Churra occurrence is in a horizontal 1/2-inch crack.

7. An unnamed deposit contains hematite and green copper oxides filling a vertical fracture zone 1.5 feet wide that strikes N.45°E. A small pit was cut along the fracture. Enclosing volcanic rocks are unaltered.

8. An unnamed deposit is on the north side of a small nala known as Kapisha. Patches of copper minerals can be traced for 400 feet along a fracture zone 6 feet wide that strikes northwest and dips 75°SW.

9. Salaam Khan Nala. The deposit is high on the side of a tributary to the Amuri Nala and lies east of the head of the valley. The copper showings are in a vertical northeast-striking fracture zone 4 feet in width.

10. Siahjik. The southeastermost of this group of deposits consists of several veins less than 4 inches wide containing small amounts of chalcopyrite, magnetite, limonite, and siderite. The siderite appears to be the source of the magnetite and limonite.

11. Patkan (fig. 4). Patkan is east of Amuri Nala 4.5 miles north of Mirenjo. Green copper minerals are found sporadically

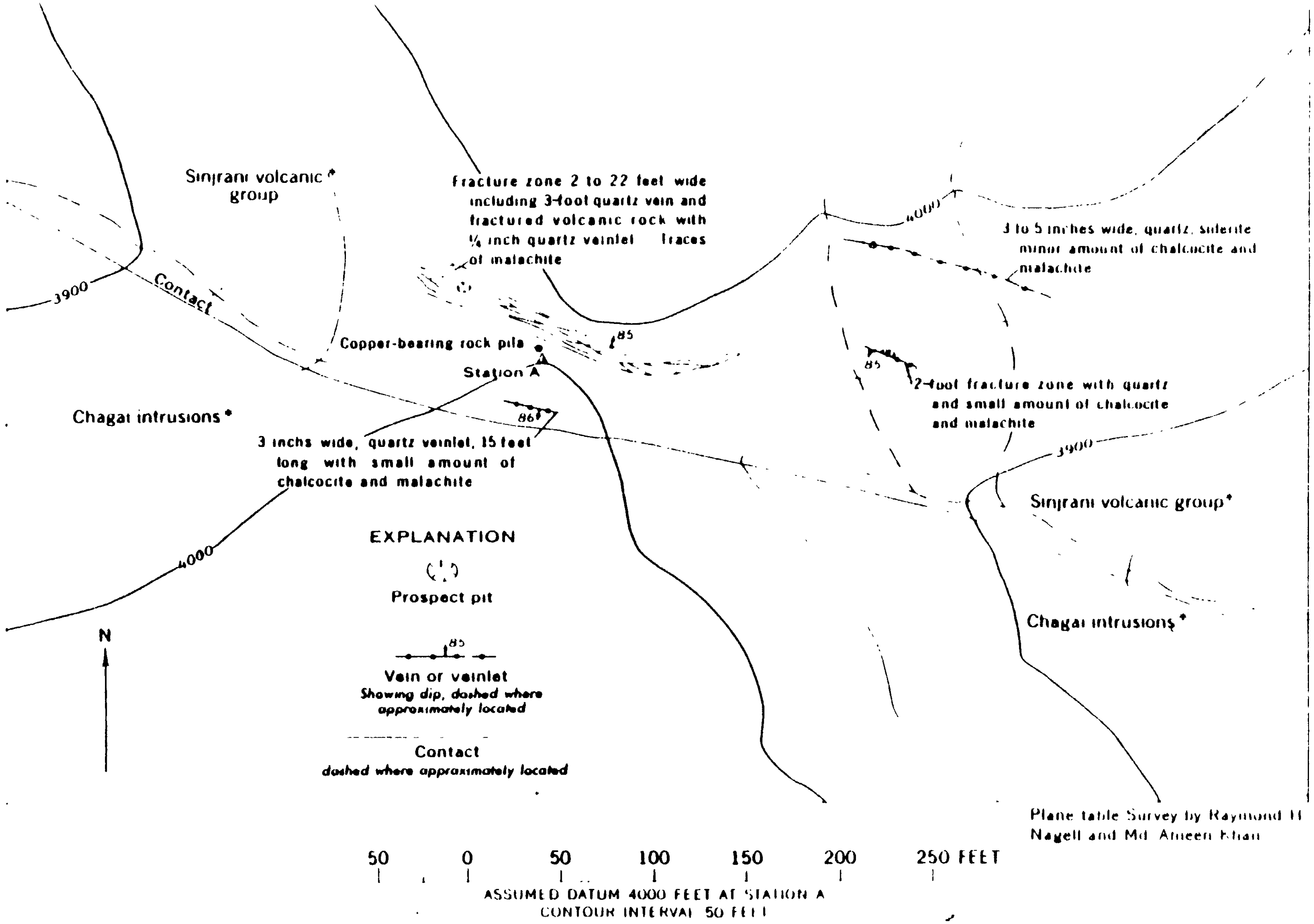

Figure 4.—Sketch map of the Patkan copper deposit near Amuri Nala, Pakistan.

over a distance of 300 feet along a northwest-striking vein in the Sinjrani volcanics, 50 feet north of the contact with monzonite of the Chagai intrusions;* no sign of ore was seen along the contact or in the intrusive rocks. Ore minerals disappear 2 feet below the surface in two small pits excavated in 1962. An assay of selected chalcocite-bearing rock in an ore pile close to one of the pits showed 11.0 percent copper (Chauhan, analyst, Geological Survey Pakistan).

12. Jaffar Wad. Two veins containing green copper, limonite, and manganese oxide lie at the drainage divide Jaffar Wad, between Daldan and Amuri Nalas 3 miles southeast of Mirenjo. One occupies a fracture zone 12 inches wide that strikes N.20°W. and dips 70°E. A few specks of bornite are in the vein which is composed mostly of epidotized volcanic country rock of the Sinjrani Volcanic Group.* The second vein strikes N.45°E. and dips 75°SE.; it lies 50 feet south of the 12-inch vein. It consists of a fracture zone 3.5 feet wide containing small amounts of green copper mineral on some fracture surfaces. The amount of copper exposed is small and unimpressive.

An area containing several showings of iron and copper minerals lies 6 miles northwest of Koh-i-Serbwt in the eastern part of the mapped area. Locally, this general area is known as Huki-Luti. The area is accessible to wheeled vehicles north along the Mazenen, Luti, or Sohtag Nalas to the south edge of the Chagai Hills, and thence by walking along the nalas and over low drainage divides. An alternate route is by walking from Johan Karez along Daldan Nala.

13. Luti Nala. Hematite, associated with epidote and garnet, is the predominant metallic mineral in small skarn and carbonate vein deposits. The skarn represents partial alteration of an unfossiliferous lens of limestone 4 feet thick interbedded with the Sinjrani Volcanic Group.* About 1,000 feet north of the skarn deposits, near the crest of a hill, two veins, each 2 to 13 inches thick, contain hematite, a small amount of magnetite, and green copper oxide stain. The hematite appears to have formed from the oxidation of iron carbonate in the veins. Several similar veins in the area, known to local inhabitants, were not examined.

14. The Spitk copper deposits consist of four small concentrations of chalcopyrite, bornite, and malachite in fractured monzonite. The fracture can be traced for nearly a mile. Other patches of green copper stains are in the area and are indicated, without number, near the Spitk deposits. The deposit at the southeast end of the fracture was prospected with a small pit in which a few chisel-shaped pieces of volcanic rock were found and identified by local inhabitants as digging tools. A few pieces of slag were seen near the pit, indicating that ore was locally smelted at some unknown date. The site of the old smelter has not been found.

15. Number 15 marks the location of some very small showings of iron and copper minerals northeast of the Spitk deposits.

Deposits numbered 16 through 19 trend from west to east, beginning 9 miles northeast of Juhli near the southwest margin of the Chagai Hills. They are similar to those described above.

Number 19, near the head of Huki-Luti (Mazenen) Nala, is unusual because of disseminated pyritic alteration in the Sinjrani volcanic rocks.

Access to these showings in the southern part of the Chagai Hills is by motor vehicle across the desert-varnished plain of early Recent gravels to the nearest nala leading into the hills. Foot trails lead into the hills toward the deposits.

16. Tamba is a small patch of skarn containing garnet-epidote-hematite west of Sailok Nala, a tributary of Dana Nala. Striated cubic crystals of hematite after pyrite and traces of green copper oxide stains are present. A small pit had been dug on the showing.

17. The Tratki Nala-Arghati Nala deposit is just east of the Pudkash Nala, a tributary of the Amuri Nala in the south-central part of the mapped area. Hematite, chalcopyrite, iron carbonate, and green copper oxide stains occupy several veins that range from 0.5 to 3 inches in width. All veins lie within an area 75 feet in diameter; none exceeds 25 feet in length.

18. The Gurandi deposit is east of Nissi Nala. A very small amount of copper stain is in an ill-defined vertical northwest-trending fissure. East of that fracture is a 4-inch-wide vein of hematite and epidote. The showing is in quartz monzonite of the Chagai intrusions.*

19. At Pincashi Nala, a tributary of Mazenen Nala, volcanic rocks contain disseminated pyrite. The alteration zone measure 300 feet in diameter. The volcanic rocks are bleached white, suggesting

that they are hydrothermally altered. Yellow-green sulphurous-smelling alteration of the volcanic rocks is associated with small springs emanating near the floor of the nala. Pyrite and some specular hematite are visible in the bank near the floor of the nala, but only one trace of green copper stain was noted.

Iron

Veinlets and small masses of hematite, magnetite, and iron carbonate are scattered in the western Chagai Hills, two zones of which are shown on plate 1 (locations 13 and 16). Both are skarn deposits. The copper and iron in these deposits is very small.

Iron-bearing veins in the Sinjrani Volcanic Group* reach a maximum of 20 feet in length and average 4 inches in width. Iron carbonate in some veins suggests that hematite may have formed from oxidation of carbonate. A very small amount of green copper oxide stain is found in some of these veins, indicating that iron and copper are related forms of metallization in the region.

Travertine marble

Travertine marble (ornamental travertine) is the only mineral product of economic importance found in the western part of the Chagai Hills. The deposits near Juhli crop out along a north-south zone 6 miles long. The Butig deposits lie 5 miles west of Juhli amidst the barchans of the sandy desert.

Two companies, the Pakistan Industrial and Mining Syndicate Limited at Juhli and the Malik Mir Hassan and Company 3 miles north of Juhli, are producing as much as 30 and 15 tons per day respectively from their leases. The quarried blocks are trucked 30 miles by road to the rail siding at Azad (fig. 1). Rail shipment is 850 miles to the trimming plants at Karachi where the blocks are prepared for local use and export.

Reserves in the Juhli area are estimated at 645,000 tons of recoverable commercial grade marble (W. Ahmed, 1964). This figure includes an estimated 18,000 tons in the Butig deposits.

The travertine marble deposits at Juhli form gently southwest-dipping layered cappings 10 to 15 feet thick on rounded knobs of the Chagai intrusions* and the Sinjrani Volcanic Group.* The deposits decrease in elevation from 3,800 feet at the northernmost to 3,200 feet at the south Butig deposit. Individual cappings are as much as 2,000 feet long. Much of the rock is not of commercial grade because vugs, turraceous impurities, and the inability to take a polish diminish its desirability as a decorative stone.

The Juhli marble exhibits a variety of colors: white, green red, and brown. White and green varieties are translucent and the red and brown varieties are opaque because of contained hematite and traces of manganese. Carbonaceous matter in trace amounts is associated with the hematite (J. J. Matzko, U.S. Geol. Survey, analyst). Aragonite is a minor constituent of the white marble. Most of the Juhli deposits are a variegated mixture of green, red, and brown; deposits of pure white marble are at Butig.

The lower contact of the marble is a calcite-cemented surface rubble of intrusive rock fragments (fig. 5) similar to the present

Figure 5.—Lower contact of the Juhli travertine marble deposit.

surface through the Chagai region. Sill-like sheets of travertine as much as 3 feet thick cut the intrusive rock and join the overlying capping (fig. 6). The sills are mostly white aragonite and are enclosed by sericitized myrmekitic quartz monzonite. These sills probably represent feeders through which the calcium carbonate waters reached the surface.

Most layering within the deposits is even and regular. Individual small layers are less than 1 inch thick and are demarcated by color changes in thin partings. Calcite crystals are elongate normal to layers, and the tips of crystals mark the parting between successive layers. Thin films of hematite coat the tips of the calcite crystals and appear as jagged lines under the microscope. Some hematite layers cut across the calcite crystals and resemble liesegang rings formed in colloidal substances. Massive hematitic calcite replacement of the green travertine marble proceeds outward from fractures (fig. 7). In incipient stages, the replacement is selective in certain layers, but volumes of several thousand cubic feet are completely converted to opaque red hematitic calcite in more advanced stages.

Fractures and microfaults, rarely showing more than 2 inches of displacement, are perpendicular to the layering.

Exceptions to the even layering appear where lower layers were inclined and truncated, prior to the deposition of successive layers. These small unconformities are traceable for distances of less than 20 feet and may have resulted from slumping or tilting during deposition. Vugs are found in hematite-rich layers (fig. 8). The

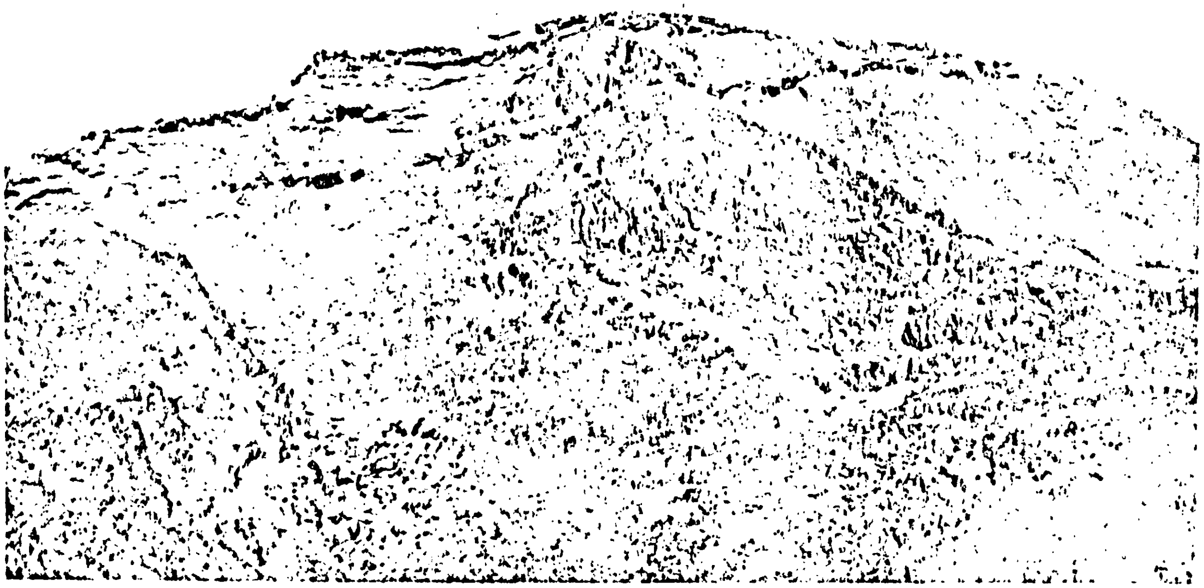

Figure 6.—Sill-like sheet of travertine marble cutting monzonite.

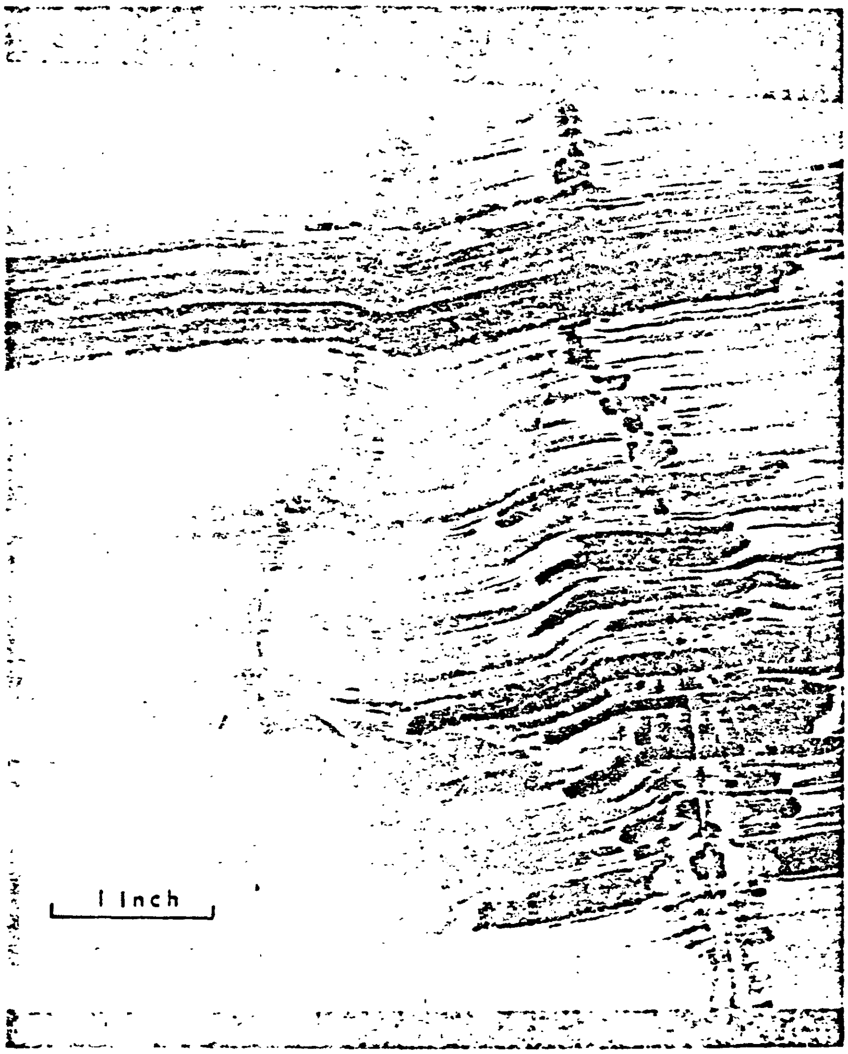

Figure 7.—Hematite and calcite replacing green translucent travertine marble.

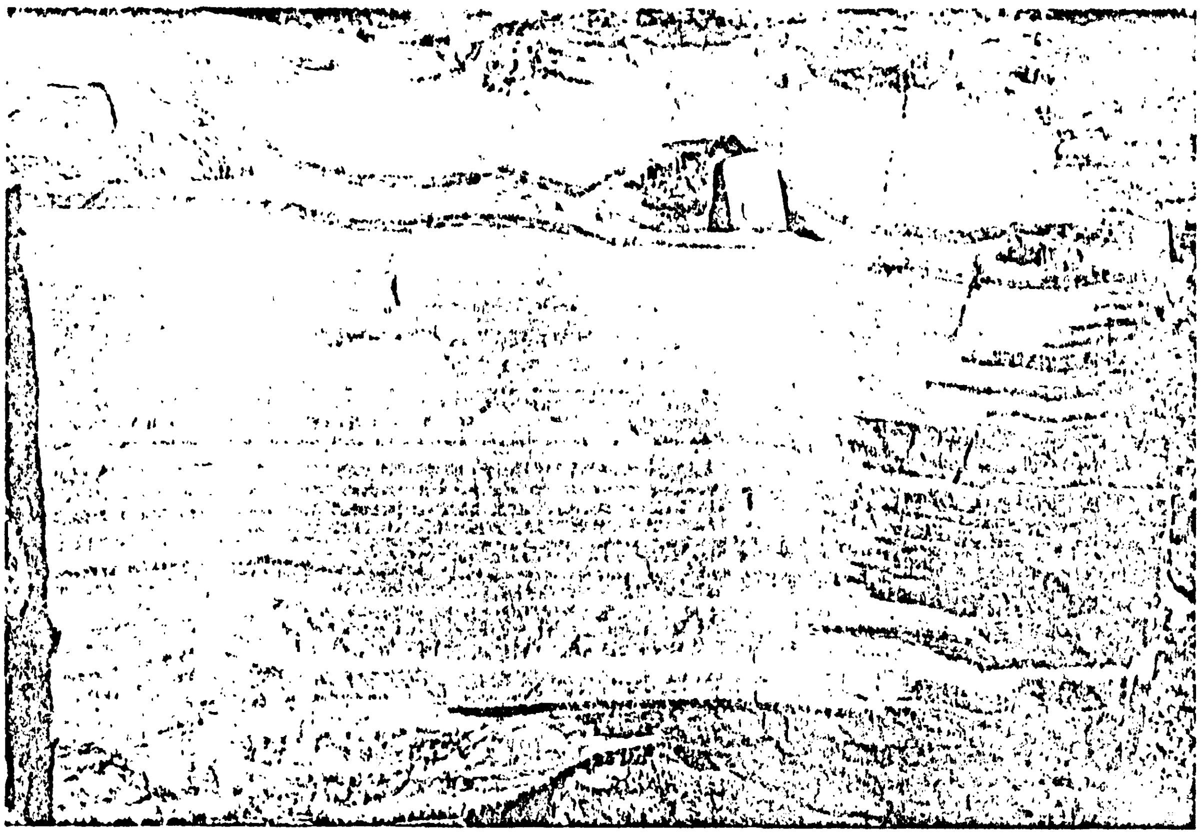

Figure 8.—Vuggy layer in travertine marble.

vugs are about 1 foot in height, circular in cross section, flat-bottomed, and rest on undisturbed travertine marble layers. The tops of the vugs are arched, and successive travertine marble layers are also arched through a thickness of about 1 foot. The vug-bearing layers bend sharply upward adjacent to the vugs. Their origin is not clear. Because the vugs are confined to certain layers and are nearly equidimensional, slumping or sliding of unconsolidated travertine along a layering plane does not offer a satisfactory explanation of origin. Carbonaceous matter is contained in the hematitic vug-forming layers. Gases may have formed during the decomposition of organic matter contained in the layers and may have moved upward through semi-consolidated travertine marble layers.

Valleys have been eroded in what apparently was a large continuous area of travertine marble, leaving the isolated cappings on knobs of bedrock. Some higher knobs are devoid of travertine marble and may have been islands above the marble, if they were capped originally, they have been eroded. Evidence that the travertine precipitated in a body of water is seen where nearly horizontal layers of travertine marble abut a sloping bedrock surface (fig. 9). The presence of organic matter in the travertine marble may represent algae that lived in such a body of water. The increasing elevation of deposits from Butig northwest through Juhli suggests that doming of the Chagai Hills followed the deposition of the travertine, if the travertine were deposited

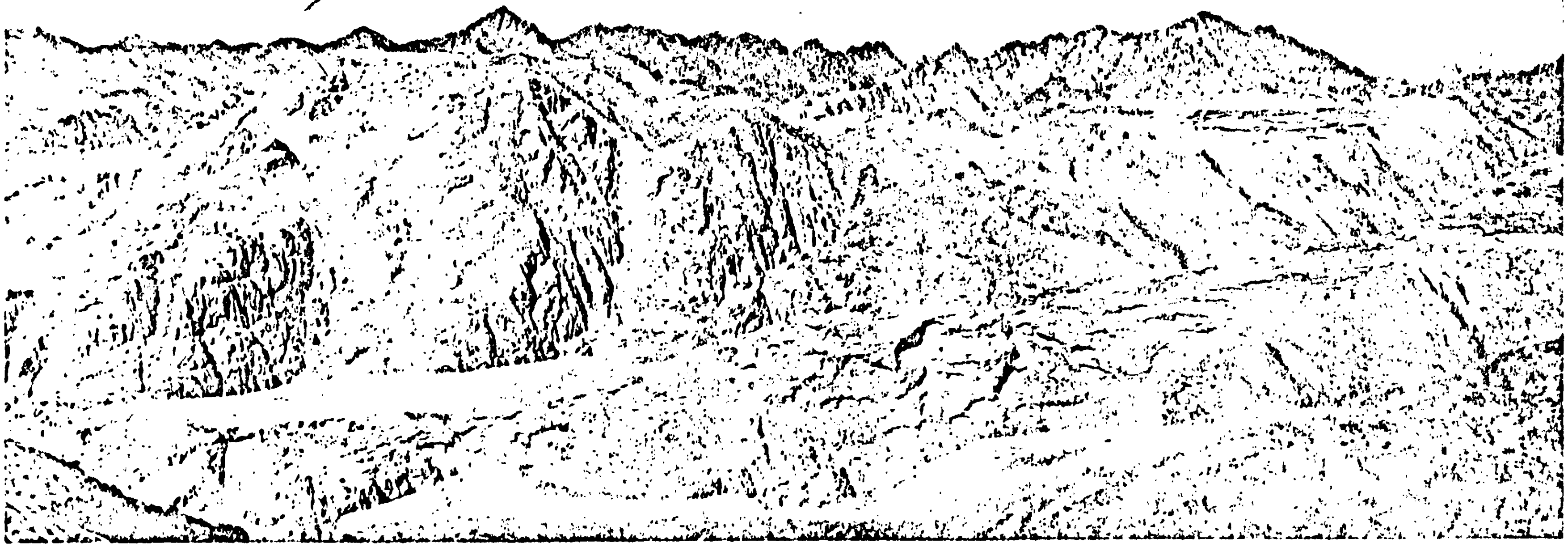

Figure 9.—Horizontal layers of travertine marble in contact with a sloping bedrock surface.

in a single large body of water. If travertine had been precipitated from water cascading down hill slopes, there would be greater irregularity in the layering, and the layers would be approximately parallel to the slope of the bedrock surface.

Commercial-sized shippable blocks measure a minimum of 4 feet on a side and 1 foot thick. Contractors are paid Rs. 4 (about $0.80) per cubic foot of shippable rock. Company production records refer to tons shipped and are calculated from the volume measurements by a factor of 2 maunds 6 seers (about 176 pounds) per cubic foot. No records of total rock broken or ore/waste ratios are kept. Waste (undersized fragments) from the mining process is estimated by this writer to be 25 to 50 percent.

Because the opaque travertine marble is not as desirable as the translucent and variegated varieties, it is not shipped and under present operating conditions must be regarded as waste. The amount of this rock varies from place to place in individual deposits and from one deposit to another. In the active quarry area at Juhli (figs. 10 and 11) the amount of opaque waste is estimated at 25 percent; in other deposits this figure ranged from 5 to 100 percent.

Ore reserves in the active quarry areas at Juhli (fig. 11) total about 50,000 tons of producible travertine marble under present operating conditions (table 1). This figure could be increased by improved mining methods to reduce undersized waste and by greater acceptance of the opaque travertine marble. Measurements made in 1959 by W. Ahmed (1964) show a total of 16,600,000 cubic feet which

Figure 10.—Juhli travertine marble deposit showing active quarry bench.

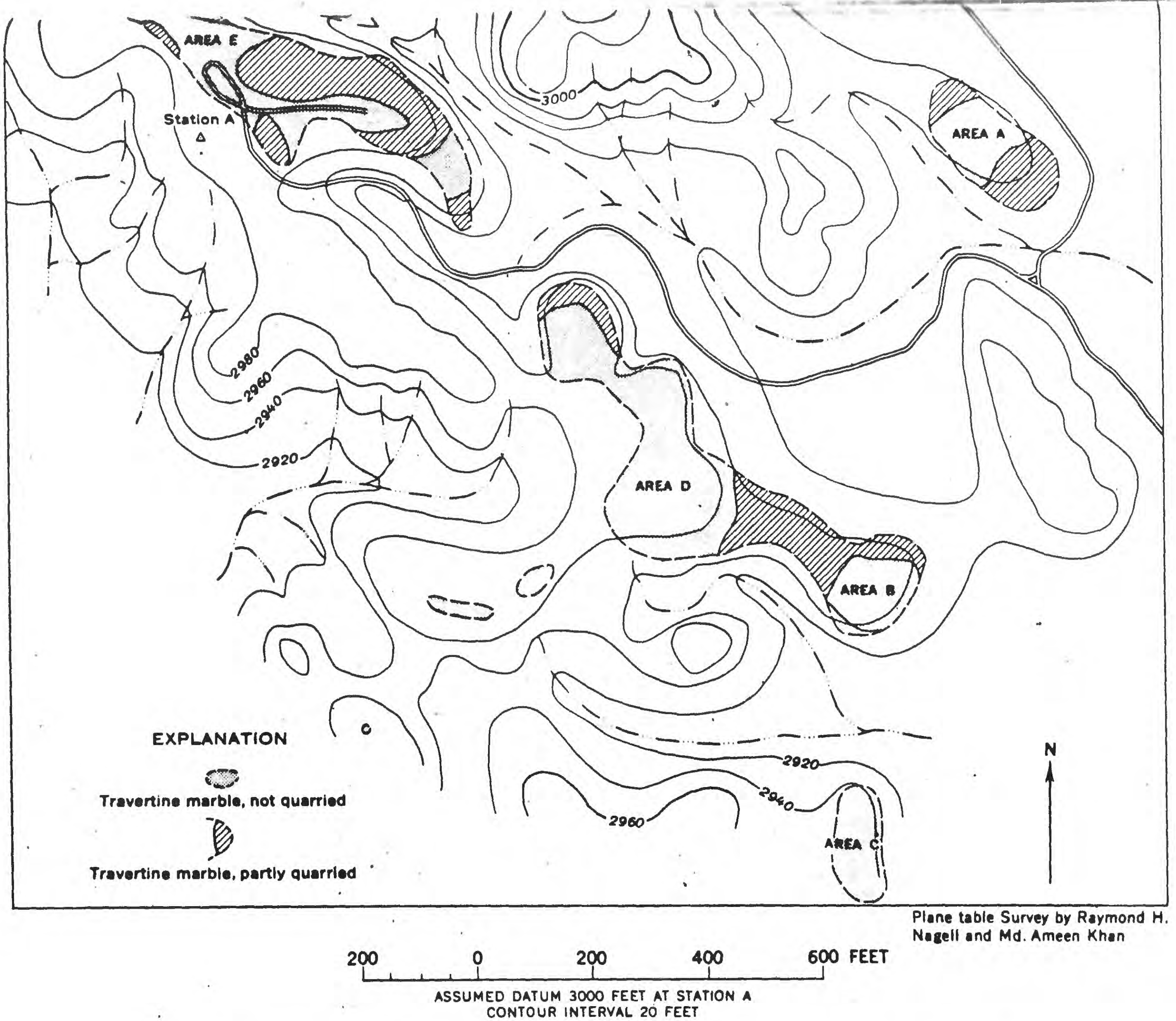

Figure 11.—Sketch map showing the quarry area of the Juhli travertine marble deposits.

Table 1.--Travertine marble reserves in part of the Juhli quarries

Deposit	Area (sq. ft.)	Average thickness (ft.)	Volume (cu. ft.)	Tonnage[1/] (long tons)
		Unmined area		
A	12,800	5	64,000	5,000
B	13,000	5	65,000	5,000
C	12,800	6	76,800	6,000
D	53,800	8	430,400	33,000
E	45,000	7	315,000	24,000
Total				73,000
		Partly Mined Area		
A	-	0	-	-
B	21,100	4	84,400	6,000
C	-	0	-	-
D	5,100	4	20,400	21,000
E	23,000	4	92,000	7,000
Total				34,000

1/ The tonnages given are gross tonnage figures and should be reduced by approximately 50 percent to arrive at the producible tonnage under present operating conditions.

converts to about 1,100,000 tons of total reserves or 645,000 tons of producible reserves in the Juhli and Butig area. Examination of travertine marble deposits outside the active quarry area indicates high-quality shipments of travertine marble.

Patkok deposits.--Small, impure gray-brown deposits of travertine marble are near Patkok (pl. 1) in the northwestern part of the Chagai Hills. Because of their apparent low quality and the long haulage over poor roads, the Patkok deposits are considered uneconomical.

Other deposits.--A few small impure deposits, measuring a few tens of square feet, are scattered through the Chagai Hills. One of these is shown in the southwestern corner of the northeast 15-minute quadrangle on plate 1. The deposits resemble those near Patkok in color, high porosity, and an apparent initial dip parallel to the bedrock surface. They probably formed by precipitation of calcium carbonate at the air-rock interface rather than in a body of water.

Summary

The sparsely distributed and weak showings of iron and copper are associated with the waning phase of the emplacement of the Chagai intrusions*. Weak, tenuous iron and copper-bearing solutions migrated from the intrusive centers into the Sinjrani Volcanic Group* of host rocks. Metallic minerals precipitated from the ore fluid in tiny cracks bearing no apparent relation to regional structures, and also in well-defined shear zones and faults. In all places, the amount of metal deposited is very small.

The emplacement of travertine marble with its tuffaceous interlayers indicates that the deposits are related to Pleistocene volcanic activity, represented by the tremendous outpouring of tuff and lavas at the Koh-i-Sultan volcano to the west. The position of the deposits on the present erosional surface attests to the relatively recent age of these deposits. No apparent spatial or genetic relationship exists between the metalliferous deposits and the travertine marble deposits.

The origin of travertine marble cannot be stated with certainty. The possibility is considered that calcareous rocks beneath the Sinjrani Volcanic Group* may have been taken into solution by heated meteoric or magmatic waters during the Pleistocene and Recent volcanic activity and poured out on the surface. Except for limestone lenses in the volcanic rocks, the existence of such rocks is unknown.

Mineral deposits, other parts of the Chagai District

Deposits of copper, lead, zinc, iron, sulphur and travertine marble were examined in other parts of the Chagai District; the following descriptions augment data in file reports and publications of the Geological Survey of Pakistan.

Sulphur is mined from small solfataric deposits high on the southern slope of the Koh-i-Sultan volcano. A company was formed by Messrs. A. Hamid, R. Ahmed, and associates to produce sulphur from ore stockpiled at Nok Kundi by Sulphur Operations, a wartime emergency mining activity of the Geological Survey of India. The company has supplied sulphur to the munitions, match, sugar refining, and rubber industries while experimenting with sulphur-refining methods and developing the ore deposits. The high cost of domestically produced sulphur (about Rs.300 per ton or $60) is protected by a warehouse tax on imported sulphur. Leases on the mineral deposits were acquired in 1961 and mining began in 1963. Systematic mapping and prospecting are recommended to assure sustained production from the Koh-i-Sultan sulphur deposits.

Travertine marble is produced in small quantities from deposits at Zah, Tozghi, Mashki Chah, and Zard Kan; quarrying methods are primitive. Much of the rock is freed by driving wedges and iron bars along partings; some is freed by blasting. Blastholes are drilled by tamping with a heavy iron bar. The total annual production in the District was as much as 4,900 tons in 1961. Additional deposits are not likely to be found.

Small deposits of hematite and magnetite are distributed throughout the Chagai District. Of these, the Baluchap-Kundi contact metasomatic deposit north of Dalbandin is the largest. A few thousand tons of ore assaying more than 50 percent iron is present, but available geological information and the prospecting done to date furnish little hope for developing a substantial ore reserve at Baluchap-Kundi.

Small low-grade copper mineral deposits are widespread throughout the Chagai District. Most formed from weak hydrothermal activity associated with igneous intrusions of Cretaceous and Eocene age; others are contact metasomatic deposits. Conditions favorable for supergene enrichment were not present in the Chagai District; some deposits are enriched to a depth of 2 feet.

The Bandagan copper deposit contains an estimated reserve of 32,000 tons of ore assaying between 0.5 and 1.0 percent copper, as established by mapping, geophysical testing, and diamond drilling. Although it is located in an area of difficult access, more prospecting is recommended to augment reserves.

Lead and zinc minerals are associated with some copper mineral deposits in the Chagai District. The deposit of Dirang Kalat, north of Dalbandin, yielded a few tons of high-grade galena ore and is worked on an exploratory basis by Pakistan Industries, Limited.

Small chromite deposits are in serpentine derived from ultrabasic intrusive plugs in the Ras Koh range. They were not visited and are not described in this report. Chromite localities are shown on Hunting Survey Corporation maps (1960).

A vermiculite deposit in the western part of Ras Koh range has been described by Abu Bakr (1962) but its usability as a source of vermiculite remains doubtful.

Sulphur

The sulphur deposits at Koh-i-Sultan (fig. 1) produced 51,700 tons of ore containing 50 percent sulphur and 14,000 tons of ore containing 25 to 50 percent sulphur from 1941 to 1944 (M.I. Ahmed, 1951). In 1961, mine development was resumed, and in 1964, production reached as much as 22 tons per day. The crude ore, containing about 50 percent sulphur, is shipped by rail from Nok Kundi to the company refinery in Karachi. The rail distance to Karachi is 870 miles.

The deposits are 25 miles north of Nok Kundi near the crest of the extinct volcano Koh-i-Sultan. Three main deposits, Batal, Miri, and Nawar, are distributed around the southern half of the volcano's crater. Other deposits are known, but because of their difficult accessibility have not been explored.

The sulphur is in irregular lenses impregnating volcanic tuff and ash. The larger sulphur bearing masses are about 100 feet long and 20 to 30 feet thick.

Hydrogen sulfide gas emanating from some of the deposits renders them impossible to work and is lethal to small birds and insects. The gas confirms the solfataric origin of the deposits.

Ore reserves were classified as ore containing more than 50 percent sulphur (high grade) and ore containing 35 to 50 percent sulphur (low grade). Of the three major deposits at Koh-i-Sultan, the Batal deposit was depleted of high-grade ore in 1944. The Miri deposit, according to Gee (1946), contains 40,000 tons of high-grade and 17,000 tons of low-grade ore; according to M. I. Ahmed (1951) the Miri deposit contains 50,000 tons of high-grade and 38,000 tons of low-grade ore. Gee (1946) estimated 7,000 tons of high-grade and 5,950 tons of low-grade ore in the Nawar deposit. These estimates indicate a total reserve of about 85,000 tons of ore containing less than 50 percent sulphur.

Because the Koh-i-Sultan deposits constitute the only known large source of native sulphur in Pakistan, an effort should be made to increase the reserves through detailed exploration and geologic mapping. Buried ore lenses might be prospected by long-hole percussion drilling from the surface.

Travertine marble

Onyx marble is quarried at Zard Kan, 46 miles by road north of Dalbandin; at Mashki Chah, 35 miles by road northwest of Nok Kundi; and at Zeh, 56 miles by road northwest of Nok Kundi (fig. 1). The following descriptions and reserve estimates are abstracted from a report by W. Ahmed (1964). Travertine marble at Zard Kan forms a triangular east-dipping capping overlying syenodiorite and volcanic tuff. The rock is yellow, pale green, grayish white, and white, and makes attractive decorative stone when polished. Red ferruginous layers in the upper part of the deposit suggest that the material added during its later stages of formation was richer in iron. Blocks as much as 3 feet thick can be quarried.

Reserves calculated by Ahmed (1964) total 240,000 tons (tonnage factor 15 cubic feet per ton), of which an estimated 180,000 tons is of shipping quality. Quarrying was started in 1959 by the Malik Mir Hasan and Company.

Mashki Chah.--Seven deposits in the Mashki Chah area consist of brown and white travertine marble. The deposits form cappings on low rolling hills underlain by volcanic tuffs and flows and Chagai intrusive rock.

Reserves calculated by Ahmed (1964) indicate 1.2 million tons of usable material (table 2).

The Pakistan Industrial and Mining Syndicate holds leases on the Mashki Chah deposits.

Table 2.--Travertine marble resources at Mashki Chah

Deposit	Total tons	Producible tons
Mashki Chah N° 1	127,600	Not estimated
Mashki Chah N° 2	60,000	Not estimated
Mashki Chah N° 3 1/		
Mashki Chah N° 4	1,350,000	500,000
Mashki Chah N° 5	1,294,600	670,000
Mashki Chah N° 6	8,000	4,000
Mashki Chah N° 7	1,750,000	70,000
Total	4,590,200	1,244,000

1/ Marble not suited for decorative use.

Zeh--.Several leases are held in the Zeh area, including those of Sheik Mohammad Din and Sons, Pakistan Industrial and Mining Syndicate, and others. In 1964, the Sheik Mohammad Din and Sons quarry was producing at the rate of 6 to 7 tons per day. The deposits form cappings on low rolling hills surrounded by flat stony desert.

Most of the travertine marble is pure white containing some green layers. The deposits are about 10 feet thick and are mined in blocks exceeding 2 feet in thickness.

Reserves are visually estimated to exceed 50,000 tons, but the deposits have not been mapped, and more precise estimates are not available.

Total travertine marble reserves in the Chagai District (given in Table 3) were calculated by W. Ahmed (1964) to be on the order of 7 million tons. The tonnages listed are estimated producible tonnage. They were calculated with a tonnage factor of 15 cubic feet per short ton, reduced by a factor ranging from 25 to 70 percent to allow for mining losses. As stated above, about 50 percent of the rock is wasted. Marsh (1963, p. 171), states that only 25 percent of the production of most marble quarries is suitable for export in sound blocks. This figure agrees with the author's qualitative assessment of producible rock in many of the inactive travertine marble deposits in the Chagai District.

Production.--Daily production at the quarries fluctuates widely, depending upon the availability of labor and trucks to haul the rock to rail sidings. Occasional days of freezing cold weather or blinding

Table 3.--Summary of travertine marble reserves in Chagai District (after W. Ahmed, 1964)

Deposit	Volume (cu. ft.)	Gross tons	Producible tons
Zard Kan	3,600,000	240,000	180,000
Pat Kok	321,000	21,400	16,000
Juhli	16,212,000	1,080,800	626,900
Butig	390,000	26,000	18,000
Mashki Chah	69,604,800	4,840,200	1,244,000
Tozghi	2,880,000	190,000	142,500
Zeh 1/	15,000,000	1,000,000	-
Total	108,007,800	7,398,400	2,227,400

1/ Possible reserve

sandstorms also halt production. In 1964, the maximum productive capacity of the Chagai District is estimated at 70 tons per day, with an actual rate of about 20 tons per day average for the year. The yearly production of travertine marble is as follows (Industry and Natural Resources, 1963):

Year	Production (in long tons)
1958	553
1959	2,796
1960	2,245
1961	4,921
1962	2,113

Iron

Several high-grade iron deposits are scattered through the Chagai District. The Baluchap-Kundi deposits north of Dalbandin are the largest, the others much smaller.

Baluchap-Kundi deposits.--The Baluchap-Kundi deposits are 22 miles by road north of Dalbandin (fig. 1) and are known variously as the Dalbandin deposits, Baluchap-Kundi deposits (W. Ahmed, 1960b), and the Gorband deposits (Hunting Survey Corp., 1960). The Baluchap deposits and the Kundi deposits are 4 miles apart and are separated by the broad alluvial swath of Bulo Nala.

The iron deposits are in a jasperoid alteration zone at the contact between limestone in the Sinjrani Volcanic Group* and intrusive rocks. The limestone near the contact has altered to an epidote-grossularite-pyroxene-jasperoid assemblege. Hematite is the chief ore mineral and is associated with some magnetite, garnet, epidote, dioptase, and a tourmaline-bearing jasperoid gangue. Some hematite, associated with arsenopyrite and covellite, follows joint and fault planes. Unaltered limestone is coarsely crystalline, white to light gray, and consists mostly of calcite. In both deposits, Baluchap and Kundi, the limestone appears to form a capping over the alteration zone and the iron deposits. The limestone may correspond to Cretaceous limestones interlayered with the Sinjrani Volcanic Group.*

Partial analyses of 12 samples taken from the Baluchap and Kundi prospect pits range from 43.5 to 64.7 percent iron, 0.1 to 11.0 percent manganese, and 0.01 to 0.08 percent arsenic (W. Ahmed, 1960b).

Tonnage reserves in five deposits at Baluchap total 1,082 tons of measured ore per foot of depth and 233 tons of inferred ore per foot of depth. The greatest length of exposed ore is 130 feet (W. Ahmed, 1960b, table 3).

Beginning in 1957, several shallow pits were dug in croppings of ore, and geologic and topographic mapping was carried on by officers of the Geological Survey of Pakistan. Two diamond drill holes drilled in 1959 failed to encounter ore in areas with high magnetic anomalies. The results of these investigations are inconclusive in that the drilling done on the basis of the magnetic anomaly did not eliminate the possibility of ore at depth.

After 3 years of exploratory work, the relatively small tonnage developed suggests that the chances of finding sizeable reserves in the Baluchap-Kundi area are remote.

Robat.--Two miles north of Robat (fig. 1) small scattered showings of hematite and copper minerals are associated with a contact metasomatic zone(s) in the Robat limestone* near the Shor Koh intrusions*.1/ Patches of epidote and garnet are in the limestone near the iron showings. All the deposits are too small to be of economic value.

Saindak, Mashki Chah, and Amir Chah.--Small deposits of hematite in jasperoid, disseminated in limestones and volcanic rocks, and in skarn rock formed from thermal alteration of limestone, are described by Hunting Survey Corp., (1960, p. 448-449) near Saindak, Mashki Chah and Amir Chah (fig. 1). All measure less than 100 feet in longest dimension. Veins of high-grade hematite up to 1 foot wide can be traced for distances of as much as 30 feet. Siderite in some veins suggests that the hematite is a weathering product.

Bandagan.--The Bandagan deposits are in the Ras Koh Range near the border of Kalat Division. Associated chalcopyrite is of greater importance than the magnetite, as described below. These are in hornfelsic rock, which originally may have been calcereous or tuffaceous.

1/ The Shor Koh intrusions are similar in composition to the Chagai intrusions* although they appear to be younger because they cut the Eocene Robat limestone* (Hunting Survey Corp., 1960).

Copper

Showings of copper minerals are widespread throughout the Chagai District. Most of them are isolated green copper oxide mineral stains on fracture surfaces; some contain chalcopyrite, bornite, and chalcocite. Supergene enrichment has taken place within 2 or 3 feet of the surface. The most promising copper deposit in the district is in Bandagan Nala in the Ras Koh Range.

Bandagan.--The Bandagan copper-magnetite deposit (figs. 1, 12) is in the Ras Koh Range west of Shehin Peak. Access to the area is from Jadino Landi, a rest hut on the Quetta-Zahidan road 43 miles east of Dalbandin. From Jadino Landi a road leads 6 miles south to an old base camp. From the old base camp, a 3-mile footpath leads over a steep divide and down into Bandagan Nala. W. Ahmed (1960a) prepared a geologic map of the area. This work was followed by magnetic and electromagnetic surveys by I. R. Mufti and Mohammad Ali in 1961. On the basis of the geophysical results, nine holes were drilled in 1962 for a total depth of 1,563.5 feet. Five adits, the longest of which is 87 feet, were driven under the supervision of R. G. Bogue.

Black slag below a talus slope at the southeastern end of the mineralized zone indicates that the ore was smelted at one time.

The rocks in the vicinity of the deposits consist mostly of hornfels intruded by dioritic rocks of the Ras Koh intrusions.* The age and original composition of the host rock is not definitely known; the Paleocene Rakshani Formation* is in this area as shown on Hunting Survey Corporation map number 19 (1960).

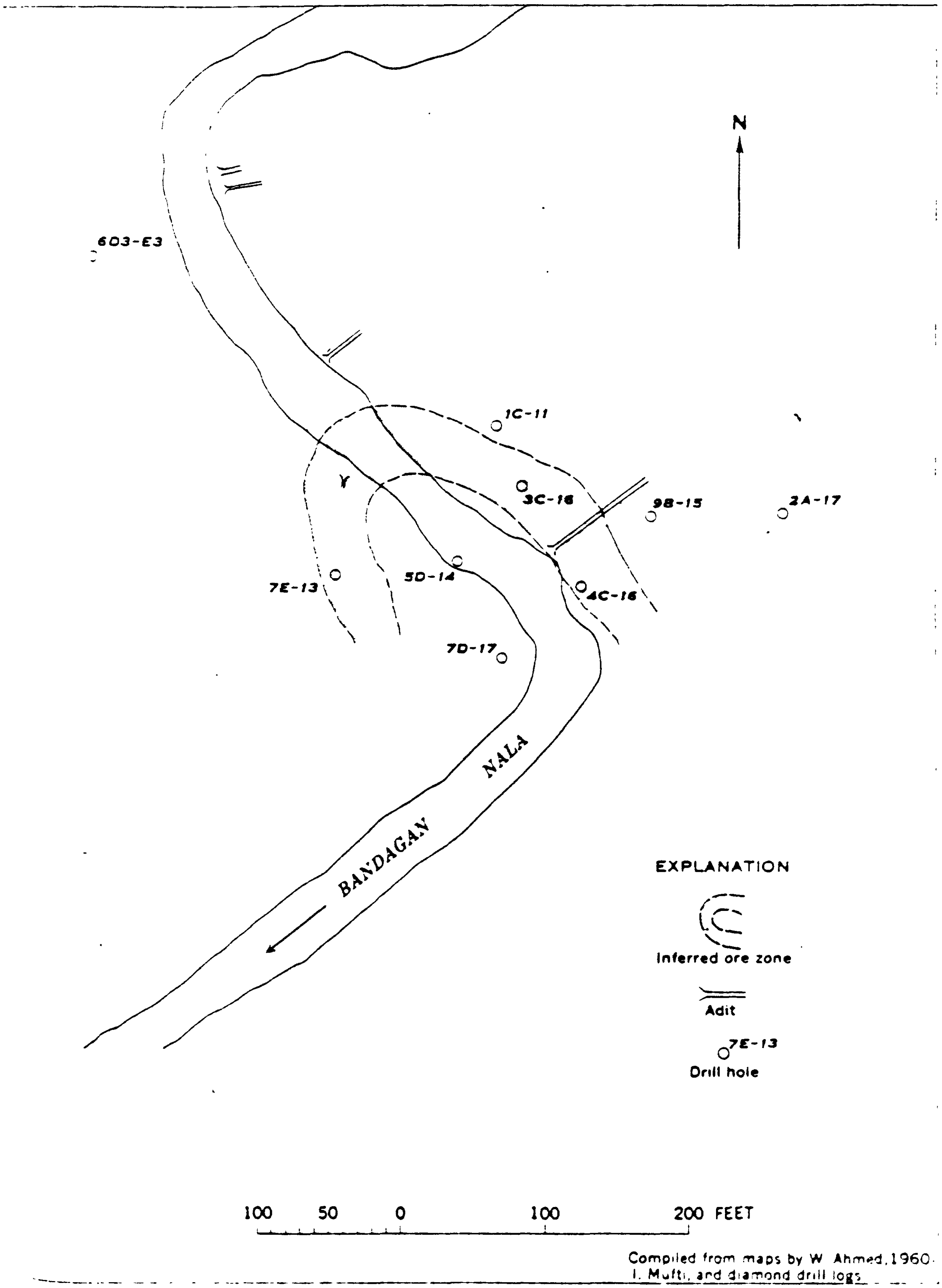

Figure 12 —Sketch map showing inferred copper-bearing zone in the Bandagan copper-magnetite deposit, Pakistan.

The chalcopyrite-magnetite zone is 40 feet thick and includes barren zones of tuff(?) and diorite (Diamond drill logs, 1962, on file in the Geological Survey of Pakistan). The zone forms a U-shaped body (fig. 12), its open end to the south. The lowest point of the ore zone lies just east of Bandagan Nala. In holes 9 (B-15) and 2 (A-17) chalcopyrite and magnetite are logged as being small in quantity. Hole 1 (C-11) contains ore estimated at 1 percent copper in the interval from 141 to 172 feet. This zone is 50 feet below that in hole 3 (C-16) and may indicate a northern extension of the ore zone.

Inferred reserves, estimated from available data, are 32,000 short tons, probably assaying between 0.5 and 1.0 percent copper and from 40 to 50 percent iron.1/ The diamond drilling done does not define the limits of the ore body or the amount of copper and iron in the ore. The deposit is considered worthy of additional prospecting following the preparation of topographic maps and sections.

In addition to more quantitative data on copper and iron, gold and silver should be assayed. In a set of three analyses of samples by a "Japanese Research Team," May 21, 1959, one of the samples

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1/ Grade estimates are derived from descriptive phrases and visual estimates in the diamond drill logs. The drill core was not assayed and is available for inspection near the collars of the drill holes.

contained 7 grams of gold and 5 grams of silver per ton. The other two samples contained traces of these elements.

Robat.--Jali Robat (fig. 1) in Afghanistan, 3 miles east of the Chagai Militia Post at Robat, was the scene of extensive copper smelting in the distant past. The slag pile measures 450 feet wide by 1,200 feet long. Vredenburg (1901), mentioning the slag pile, said that the source of the ore was unknown. The old mines are in Harlid Nala (fig. 1) near Lar Koh in Iran, about 6 miles south of Robat.

Local inhabitants say that the mines were worked prior to British occupation of the region.

Old pits and tunnels are along the contact between monzonitic Shor Koh intrusions* and hornfels and skarn that formed in the adjacent Robat limestone.** The ore is chalcopyrite and chalcocite in a gangue of epidote, garnet, calcite, and hematite.

Several small copper showings with a similar mineralogy are in Pakistan near Robat. None of these have been worked in the past, nor do they merit attention at this time.

Kirtaka--M.G. White (written communication, 1963) reports small copper carbonate and copper sulphide minerals in massive Cretaceous conglomerates; the deposit is at lat. 29°29'18"N., long. 61°17'24"E., near Kirtake (fig. 1).

Saindak.--Several small showings of weak copper mineralization are near Tarani Nala 3 miles east of Saindak (fig. 1; W. Ahmad, S. N. Khan and R. G. Schmidt, in press; M.G. White, written communication, 1963). The deposits consist of a few small showings of green copper oxide minerals associated with chalcopyrite in a north-trending zone of dioritic intrusive rocks. Assays of seven samples collected by R. G. Schmidt from this area are as follows:

1. Four bulk samples of diorite assayed from 100 to 350 ppm (parts per million) copper.
2. One sample of sulphide-rich metamorphic rock assayed 350 ppm copper.
3. One sample of tuff or diorite with visible copper mineral assayed 0.8 percent copper.

Two samples from this area selected by the author assayed 0.26 and 1.49 percent copper, a trace of silver, and 2.44 and 1.98 percent lead (Chauhan, analyst, Geol. Survey Pakistan). The samples are from pits that were readily excavated to a depth of about a foot. Below this depth, the rock is hard and the copper disappears.

Copper in this dry alkaline desert environment is stable at the ground surface and represents supergene enrichment. The low copper content and the small amount of copper showing at Tarani Nala indicate that this area has little potential as an ore reserve. The presence of lead indicates that this area is similar to other weakly mineralized lead deposits in the Saindak area, as described below.

Koh Marani.--Small veins containing copper and gold are described in the Koh Marani area (fig. 1) of the eastern Chagai Hills by M. I. Ahmed (1962) at Mukani Wad, Anjiri Lop, and Mahian Rud. Four samples from the Mahian Rud deposit assay as much as 2.86 percent copper. Gold reported in a small vein on the west side of Anjiri Lor (M. I. Ahmed, 1962) has not been confirmed by analysis.

Other deposits.--Locations and brief descriptions of other copper showings in the Chagai District are given by White (1975).

Lead and zinc

Saindak and Dirang Kalat (fig. 1) are two areas containing lead with small amounts of zinc. At Saindak, small slag piles indicate mining activity in the past. A few carloads of hand-cobbed lead ore were shipped in recent years from the Dirang Kalat area, east of Koh Marani, by Pakistan Industries, Limited.

Saindak.--Several galena-bearing veins have been described in the Saindak area (Vrendenburg, 1901; M. I. Ahmed, 1943; W. Ahmed, S. N. Khan, and R. G. Schmidt, in press). Malachite, cuprite, and azurite are present in addition to cerussite, galena, calcite, quartz, limonite, hematite, and manganese oxide. All veins are short and narrow, and ore minerals in small clots are sporadically distributed through the gangue. Some of the veins have been prospected by pits. Because of the low grade and spotty distribution of ore minerals in these deposits, further prospecting is not warranted.

Dirang Kalat.--M. I. Ahmed (1962) describes the Dirang Kalat vein as consisting of three galena-bearing zones in faulted andesite. He visited the area several times between January 1949 and April 1962. During this period, as exploratory mining progressed, the mineralized area decreased from 60 square feet near the surface to 40 square feet at a depth of 47 feet.

Assays of two channel samples of the vein averaged 0.01 oz. Au/ton, 1.19 oz. Ag/ton, 46.8 percent Pb, and 3.1 percent Zn. Later, samples taken by R. C. Bogue of unsorted dump ore, ore channeled in place, and hand-sorted dump ore (four samples total) ranged from 23.8 to 34.9 percent Pb, 0.96 to 3.1 percent Zn, and 0.3 to 2.4 percent Fe. Traces of copper and silver were present in these samples.

Ahmed (1962, p. 13) states that, "The mineralization is not expected to continue at depth at the present dimensions as the vein is lenticular. The possibility of its widening at a deeper level, however, cannot be ruled out." Several other veins containing a few crystals of galena are in the Dirang Kalat area.

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