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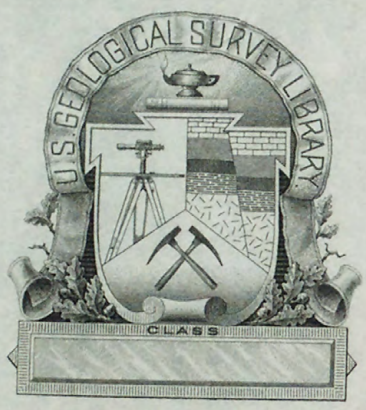
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POTENTIAL FOR POTASH AND OTHER EVAPORITE MINERAL RESOURCES IN WEST PAKISTAN

by

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U. S. Geological Survey

and

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Geological Survey of Pakistan

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1. Preliminary structure map of the Paint Lick quadrangle, east central Kentucky, by Gordon W. Weir. 1 sheet, scale 1:24,000. USGS, 710 West High St., Lexington, Ky. 40508; Kentucky Geological Survey, 307 Mineral Industries Bldg., University of Kentucky, Lexington, Ky. 40506. Material from which copy can be made at private expense is available in the USGS office in Lexington.

2. Potential for potash and other evaporite mineral resources in West Pakistan, by C. L. Jones and Asrarullah. 17 p., 2 figs.

3. A study of suitability of Dacca clays for light-weight aggregate production in East Pakistan, by M. A. Maroof Khan and N. A. Parker. 85 p., 1 fig., 5 tables.

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4. Provisional topographic map, Isla Desecheo, Puerto Rico, by the U. S. Geological Survey, 1 sheet, scale approx. 1:10,000.

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ABSTRACT

Reconnaissance examination of marine evaporites in West Pakistan has revealed a highly favorable resource situation with respect to anhydrite, and a potentially favorable position for potash and sulfur. Further work is needed to evaluate the preliminary interpretations made during the present study. The establishment of a potash resource organization within the Mineral Resource Directorate of the Geological Survey of Pakistan is proposed. The organization would be concerned exclusively with the investigation of potash deposits in the Salt Range and adjacent parts of the Potwar and Indus Plains.

INTRODUCTION

Marine evaporites underlie wide sections of the Salt Range and parts of the Kohat, Potwar, and Indus Plains, West Pakistan, and substantial reserves of salt and gypsum are known to exist at many places. The resource situation with respect to other mineral commodities commonly associated with salt and gypsum is virtually unknown, but indications are favorable that additional evaporite mineral resources may be found by a well-planned exploration program. The known area of evaporite deposits is large and has been only slightly explored, yet the little work that has been done has revealed the existence of potassium salts in salt mines scattered across half the length of the Salt Range.

The present investigation was undertaken to ascertain the potential for potassium salts and other evaporite mineral resources. The investigation included a review of available information on evaporite deposits in West Pakistan and a reconnaissance examination of the evaporites exposed in part of the Salt Range and Kohat district (fig. 1). The examination was carried out jointly by members of the U.S. Geological Survey and the Geological Survey of Pakistan in April 1968. It was done as part of a fertilizer mineral resource appraisal program sponsored jointly by the Government of Pakistan and the Agency for International Development, U.S. Department of State.

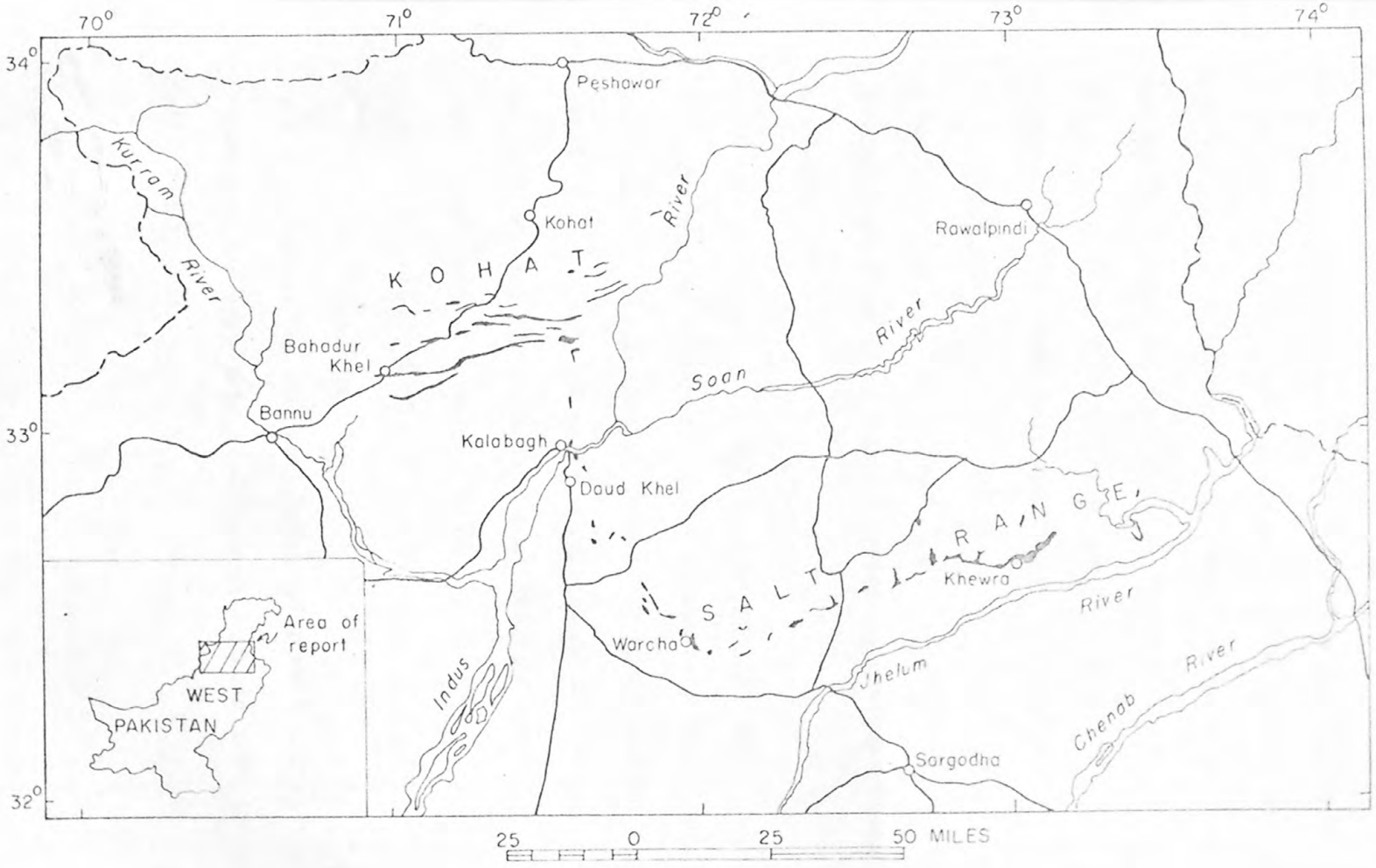

Figure 1. Sketch map of part of West Pakistan, showing areas of outcrop of marine evaporites (areas in black) in the Kohat district and Salt Range (adapted in part from map by Gee, 1945, and by Master, 1963).

The examinations were aided greatly by the cooperation of local officials and employees of the Salt Mines and Quarry Division, West Pakistan Industrial Development Corp. The writers are grateful for the assistance and courtesies extended by Mr. Asif Ullah, Manager, Khewra Salt Mine; Mr. Rana Sultan, former manager, Warcha Salt Mine; Mr. S. A. Naquir, Manager, Kalabagh Salt Mine; Mr. Mirza Hashim, Manager, Bahadur Khel Salt Quarry; and Mr. Javid Iqbal, Manager, Daud Khel Gypsum Quarries. We are especially indebted to Mr. H. S. Qurieshy, Assistant Manager, Khewra Salt Mine, for his assistance in locating and tracing anhydrite and potash deposits in the salt mines at Kalabagh, Khewra, and Warcha.

Previous investigations

The marine evaporites found in the Salt Range and the Kohat district have attracted attention of geologists since the early work of Fleming (1848) on the coal and other resources of the region. Subsequent work by Wynne (1875, 1878), Middlemiss (1891), Stuart (1919a), Davies (1926, 1944, 1945, 1947), Anderson (1928, 1947), Wadia and Davies (1929), Gee (1934, 1935, 1945, 1947, 1950), and a host of other investigators kindled and fed a long-enduring controversy on the age and origin of the evaporites, but the work supplied little information about the potential for evaporite resources other than that for the ubiquitious salt and gypsum.

Occurrences of potassium and magnesium salts in salt beds of the area were described in mineralogical notes by Tschermak (1874), Mallett (1899), and Fox (1912). They were later described in detail by Christie (1914) and Stuart (1919b). Much later, the potential value of the complex magnesium-potassium-calcium chloride brine from the Attock Oil Co., Dhariala No. 1 well, as a source of potash was noted by Richards (1963) in his review of evaporite resources of West Pakistan. Master (1963) summarized available information on gypsum occurrences in Pakistan, and Asrarullah (1963) presented a review of rock salt deposits. Subsequently, Rashid and others (1965) reported on the gypsum and rock salt deposits in the Kohat district and noted the occurrence of sulfur with gypsum. Petroleum-impregnated salt and gypsum from the same district was studied by Stuart (1919c), Lahiri (1945), and Rashid and others (1965).

Locally, surface and mine studies by Asrarullah (1964, unpublished resource report) made sizable increases in the amount of salt reserves known to be present in the vicinity of the Khewra mine, and the work provides a rather clear demonstration of the considerable utility of systematic geological examination in the solution of resource problems involving questions of the structure, origin, and history of an evaporite deposit.

EVAPORITE RESOURCES

The mineral resources associated with marine evaporites in West Pakistan include not only salt and gypsum but also potassium salts, anhydrite, and sulfur. Both salt and gypsum are known to be abundant and widespread in large surficial to near-surface deposits, and they therefore require no further consideration in the present report. The same cannot be said with respect to potassium salts, anhydrite, and sulfur, each of which is essential to the development of a domestic fertilizer industry.

Potassium salts

Associated with salt and marl of the Salt Range Formation of Cambrian age in the salt mines at Warcha and Khewra are a number of sulfate-rich potash deposits, resembling in general form and composition the langbeinitic deposits described by Dunlap (1951) in studies of a New Mexico potash mine. The deposits are typically tabular to lenticular pods and seamlike masses which extend irregularly from rock salt into marl and clayey salt. Langbeinite ($K_2SO_4.2MgSO_4$), kainite ($KCl.MgSO_43H_2O$), and sylvite (KCl) are the only potassium minerals recognized, but kieserite ($MgSO.H_2O$), halite (NaCl), and clay are present throughout the deposits. The deposits at Warcha are few in number, decidedly discontinuous, and typically only a few inches to about 18 inches thick; whereas those at Khewra are generally thicker, more numerous, and laterally persistent. Most of the Khewra deposits are 4 to 6 feet thick over large areas and reach a maximum thickness of about 12 feet in places.

The ore in the Khewra deposits is estimated to grade about 6 to 10 percent K_2O, and it is sufficiently rich in potash (K_2O) to be of immediate interest in the possible establishment of a potash industry in West Pakistan.

The potash deposits at Khewra and elsewhere in the Salt Range are part of an extensive area of potassium-bearing evaporites that is at least 60 miles across, and they may represent a near-shore sulfate-rich facies in that potash basin. If so, the possibility of finding high-grade, more economically important sylvite-rich extensions of the known deposits may be good. Geological studies are required to explore this possibility and to determine what local and regional variations exist in thickness, grade, and mineral composition.

Anhydrite

Anhydrite is the least critical of the three evaporite mineral resources; a supply is assured at Kalabagh, Khewra, and elsewhere in the Salt Range. All the gypsum deposits, which are presently being studied and sampled by a mineral resource team from the Geological Survey of Pakistan, are the leached and hydrated remnants of anhydrite beds that are part of the Salt Range Formation, and they will grade laterally into anhydrite within fairly short distances of the outcrop. At the anhydrite mine near Daud Khel, for example, the change from gypsum to anhydrite takes place in a distance of 60 feet. The distance may be even shorter at Kalabagh, where an anhydrite bed, 7 to 8 feet thick, can be traced from the mine workings to a surface exposure of

gypsum lying only a few feet above the mine entrance. This bed of anhydrite has immediate resource value in the production of ammonian sulfate, and it represents an important addition to known anhydrite resources of West Pakistan.

Sulfur

No sulfur was found during the present reconnaissance examination of marine evaporites, but it has been previously reported by Wynne (1875) and Rashid and others (1965) to occur with massive gypsum in the eastern Kohat district. The gypsum and associated rock salt of this area and parts of the Potwar occur in the centers of narrow elongate flexures that resemble salt anticlines, such as those found in some parts of the world to be productive of petroleum and caprock sulfur. The rock salt forms a complexly folded ridge or welt-like mass in the core of the elongate flexures. In structure and texture the salt is strikingly similar to that forming the intrusive cores or plugs at the centers of salt anticlines in the Paradox basin of southeastern Utah and southwestern Colorado. Furthermore, like some of the intrusive salt of the Paradox basin, the salt and gypsum in part of the Kohat district are impregnated with petroleum. The occurrence of petroleum in association with gypsum and rock salt in narrow flexures resembling salt anticlines constitutes a combination of geological conditions which are highly favorable for the formation of caprock-type sulfur deposits. A careful investigation of the area is needed to determine whether the resemblance to salt anticlines is only superficial; the potential rewards are great.

COMMODITY INVESTIGATIONS

Recommended program

Potash is by far the most critical of the three commodities known to be associated with marine evaporites in West Pakistan, and, therefore, it should be assigned the highest priority in the development and operations of a fertilizer mineral resource appraisal program. Accordingly, a recommendation is made herewith for the establishment of an organization within the Mineral Resource Directorate of the Geological Survey of Pakistan to investigate potash resources with such technical guidance from the U.S. Geological Survey as might be required. The organization and its personnel should be concerned exclusively with the investigation of potash occurrences in the evaporites of the Salt Range Formation; its only functions would be (1) to explore for possible extensions of the potash deposits found at Khewra, (2) to determine local and regional variations in the grade, thickness, and composition of the known deposits, and (3) to prepare reserve estimates and recommendations as may be required by the results of resource investigations.

In order that potash occurrences may be properly evaluated, the potash-resource organization must be staffed and supplied with adequate technical and support personnel and equipment to undertake (1) detailed geological and geophysical mapping and analysis of surface and subsurface structure in selected target areas; (2) exploratory core-drilling operations to test for potassium salts to depths of at least 5,000 feet; (3) systematic mapping and related geologic studies in the Khewra Salt Mine to determine criteria for use in the analysis and interpretation of drilling results; and (4) chemical and mineralogical analysis of potash ores and mineralized rock.

Target areas

For systematic study and investigation by the potash-resource organization, the parts of the Salt Range, Potwar, and Indus Plains judged to have the greatest potential for potassium salts are divided into three target areas (fig. 2): Area 1, Area 2, and Area 3, in diminishing order of importance. A brief description of each area is given below:

1. Area 1.--This target area is a rectangular section of the Salt Range and Potwar which is centered near the village of Choa Saidan Shah. It is about 30 miles long and 10 miles wide, and extends from Gharibwal to Kallar Kahar, and from the south edge of the Salt Range northward into the belt of outcrop of upper Tertiary rocks north of Dhariala. The area offers the best possibility for finding sylvite-rich extensions of the known deposits of potassium salts, and its principal geological features are fairly well known from mapping by Gee (1945, 1947) and exploratory drilling for petroleum. The potash deposits at Khewra and the magnesium-rich brine well drilled by the Attock Oil Co. near Dhariala lie within the area, and they constitute sources of information that will have considerable value and much utility in the analysis and interpretation of any results obtained in an exploratory drilling program for potassium salts.

2. Area 2.--This target area, centered near the village of Nurpur, is square in shape, about 12 miles long on a side; it extends from the southern flanks of the Salt Range northwestward across part of the

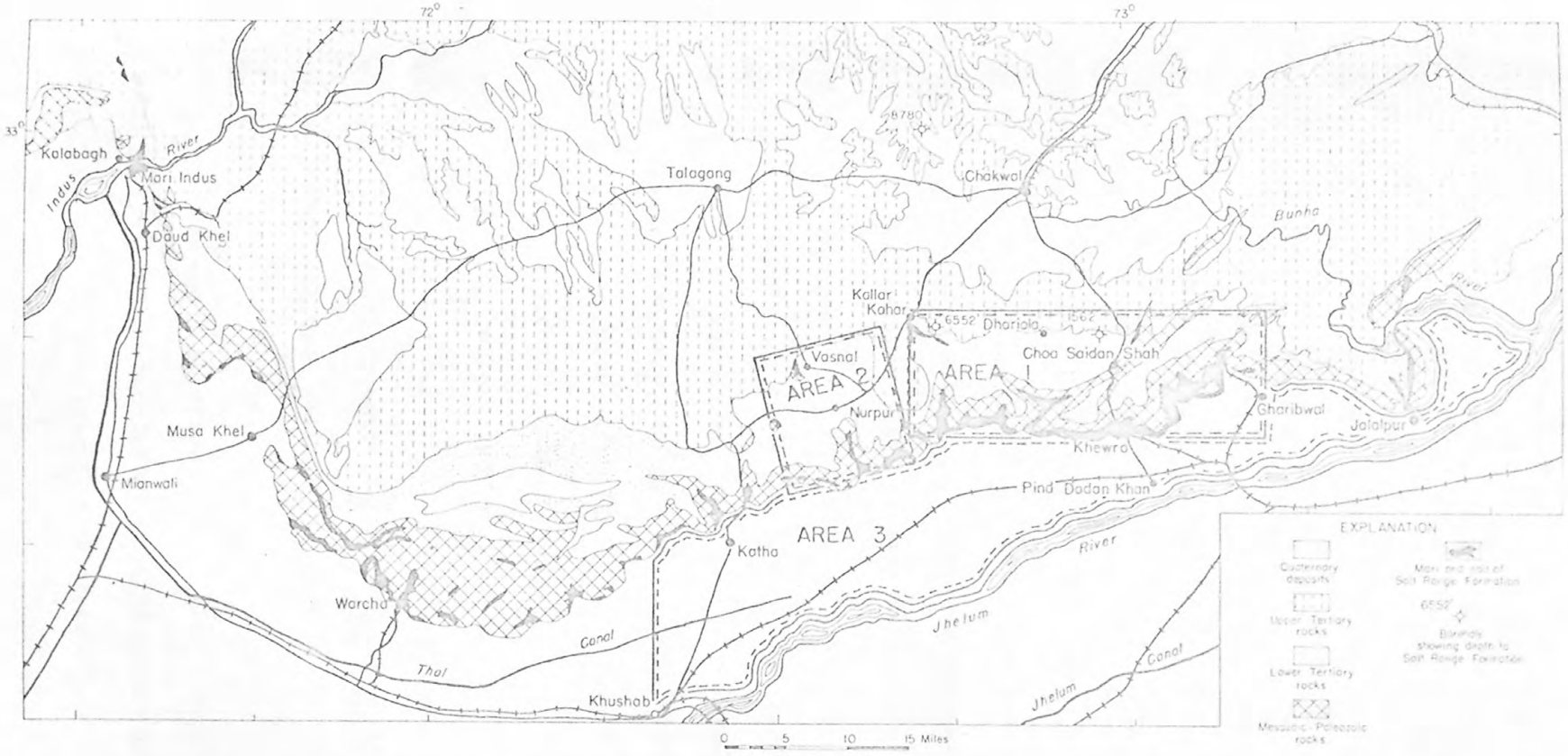

Figure 2. Generalized geological map of the Salt Range, showing target areas for exploratory work on potash deposits (modified from Gee, 1945, pl. 1).

Potwar to the outcrop of upper Tertiary rocks near Vasnal. The area includes the long-abandoned Nurpur Salt Mine where Christie (1914) and Stuart (1919b) found tabular bodies of potassium and magnesium salts containing as much as 14 percent K_2O.

3. Area 3.--This target area is an elongate section of piedmont and plains area lying between the Jhelum River and the foot of the escarpment at the southern edge of the Salt Range. The area is about 70 miles long and from 1 to 12 miles wide, and it extends from the longitude of Khushab northeastward to the confluence of the Bunha and Jhelum Rivers. It is completely untested; no information is available as to whether potassium salts, or even rock salt, are present at reasonable drilling depths below the surface.

For each of the three target areas, the investigations of the potash-resource organization should follow a regular pattern:

1. As a first step, detailed geological mapping and geophysical study (gravity, seismic, and possibly resistivity investigations) should be undertaken to determine the surface and subsurface structure, and to outline the structure and depth to the top of salt. This work should yield detailed geological and geophysical maps and cross sections, and it should involve the preparation of structure contour maps of one or more geologic horizons, such as the base of the Tertiary rocks or the top of salt.

2. Following completion of step (1), the geological and geophysical data must be analyzed and interpreted to determine the most structurally favorable areas for the location of exploratory core drill holes to test

for potassium salts. As a general rule, the exploratory drilling should be restricted to areas of minimum depth to the top of salt and maximum thickness of salt above a depth of 5,000 feet.

3. After completion of the site selection work in steps (1) and (2), exploratory core drilling can be undertaken. This step includes not only the actual drilling operations but also the examination, study, sampling, and chemical analysis of the drill cores. All sections of the cores should be described in detail--the lithology, texture, structure, and mineralogy of the materials present should be recorded.

4. Between the completion of one drill hole and the start of the next, all the geological and geophysical data must be reexamined and reinterpreted to provide the best available information for guidance in determining the location of additional drill holes.

Mine studies

Systematic mapping and study of the potash deposits in the Khewra mine are an essential function of the potash-resource organization. In general the work is a specialized continuation of the type of mine studies carried out by Asrarullah in determining the reserves of salt available at Khewra, and it is required to establish definite criteria for use in the analysis and interpretation of drill-hole data obtained by the organization. A further objective of the work is to determine the salient features of the deposits and what local variations in thickness, grade, and mineral composition may exist. To accomplish these objectives, the mine studies at Khewra must be sufficiently broad in scope to include the following:

(1) Preparation of geologic sections along major haulage tunnels, such as the New Low Level Tunnel on the Pharwala development level.

(2) Preparation of detailed stratigraphic sections of the rock sequence in the Khewra mine.

(3) Preparation of detailed geologic maps showing the distribution of the potash deposits and their structural relations to the salt and marl beds.

(4) Preparation of isopach and isopleth maps of the principal deposits, and of a structure contour map of the mine area.

(5) Systematic collection of channel samples for chemical analysis and mineralogical study.

(6) Exploratory core drilling of the extensions of the major deposits which underlie mine workings in the central part of Khewra mine.

(7) Preparation of an estimate of the amount, grade, and thickness of potash ore available at Khewra.

SUMMARY

The recognition of a potentially favorable resource situation with respect to potash has resulted in specific recommendations for a multi-phase program of exploratory geological and geophysical investigations in part of the Salt Range, Potwar, and Indus Plains of West Pakistan. The program involves the establishment of a potash-resource organization within the Mineral Resource Directorate of the Geological Survey of Pakistan, and its objectives are to obtain precise information on all aspects of the geology, structure, composition, grade, and thickness of the Salt Range potash deposits necessary to demonstrate their potential value as a mineral resource.

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