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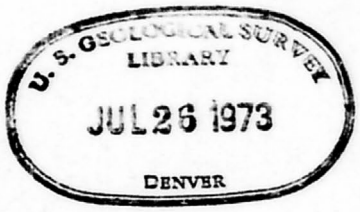

RECONNAISSANCE FOR PHOSPHATE IN PAKISTAN

by

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U. S. Geological Survey

and

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Geological Survey of Pakistan

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ABSTRACT

Low-grade phosphatic nodules have been found in (1) the lower argillaceous sections of the Jakkher group*[1/] in the Pab Range; (2) strata of the Mughal Kot formation*, Drazinda Shale Member**, Domanda Shale Member**, and the lowermost beds of the Ghazij Shale in the Sulaiman Range; (3) the Patala Formation and the basal shale member of the Chhidru Formation** in the Salt Range; and (4) the basal glauconitic beds of the Chichali Formation in the Kohat Range. The phosphatic nodules seem to be original constituents of the containing rocks. X-ray diffraction data show that the phosphate mineral in nodules from the Chichali Formation is apatite. The Habib Rahi limestone member* along the eastern flank of the Sulaiman Range contains beds of slightly phosphatized, dark-colored, cherty limestone that suggests these rocks may have been deposited under upwelling marine conditions. None of the formations in the areas investigated seem to contain sufficient reserves, or high enough in phosphorous to be of economic importance. Encouraging indications, however, of phosphate in the Babib Rahi limestone member,* Ghazij Shale, and Chichali Formation warrant detailed investigations of these formations in adjacent areas.

1/ Stratigraphic names used in this report and not followed by asterisks have been used in published reports and are believed to meet the requirements of the Stratigraphic Code of Pakistan. The status of other stratigraphic names is indicated by asterisks in categories defined as follows:

* Formal name used in published reports; status with respect to the Stratigraphic Code of Pakistan is currently (1965) under examination.

** Name used in manuscript currently (1965) being processed for publication by the Geological Survey of Pakistan and believed to meet the requirements of the Stratigraphic Code of Pakistan.

*** Name does not meet the requirements of the Stratigraphic Code of Pakistan, but has been used in published reports.

INTRODUCTION

A Mineral Exploration and Development Program in Pakistan, included as a part the Geological Exploration and Resources Appraisal Project, was initiated in 1956 under the auspices of the U. S. Agency for International Development (formerly International Cooperation Administration), U. S. Department of State, and the Government of Pakistan. Under this program the U. S. Geological Survey and the Geological Survey of Pakistan cooperated to intensify the exploration and appraisal of Pakistan's mineral, mineral fuel, and water resources, and a preliminary investigation for phosphate was jointly undertaken in 1963.

Purpose and scope of the report

It was evident after a review of the literature that the rocks of several formations in Pakistan contain phosphatic nodules, but that none of these formations were reported to contain sufficient amounts of phosphatic material to exploit. Moreover, very little was known as to whether the nodules are original constituents of the containing formations or are redeposited material derived from older rock sources that might have contained phosphate.

In order to appraise the phosphate possibilities of Pakistan, reconnaissance investigations were made in the areas where phosphatic nodules were reported. These investigations were made to determine the areal extent and stratigraphic distribution of phosphatic nodules in each area; to measure and describe any sections of strata that contain appreciable quantities of phosphatic nodules or beds; to collect representative samples of nodules and country rock for laboratory studies; to determine from field observations the sedimentary relationship and apparent source of phosphatic

material; and to reconnoiter surrounding areas for any additional indications of phosphatized rocks.

A scintillation counter, spot tests with hydrochloric acid, and semi-quantitative chemical tests for phosphate were utilized during field investigations. Many nodules were collected for chemical and radiometric analyses in the laboratory. The analytical data and locations of phosphatic samples collected during field investigations are shown in several tables included in this report. Data presented herein are as of 1964.

Figure 1 shows the areas covered by individual base sheets which are included in this report to show the locations of phosphatic rocks in Pakistan. Each base sheet was prepared from part of the base map used in the compilation of the Geological Map of Pakistan (Bakr and Jackson, 1964). The use of base sheets for illustrations in this paper and other reports on mineral information of Pakistan was adopted by the Geological Exploration and Resources Appraisal Project in Pakistan for the purpose of expediting the preparation and publication of technical reports.

Previous investigations

Previous workers have reported that nodules and rock specimens suspected of being phosphatic were found in different parts of Pakistan. The geologic investigations carried out by these investigators, however, were not principally concerned with phosphate deposits, and samples of material collected for phosphate analysis were taken as a matter of secondary interest. The available information about phosphate in Pakistan may be found in the published and unpublished references listed at the end of this report.

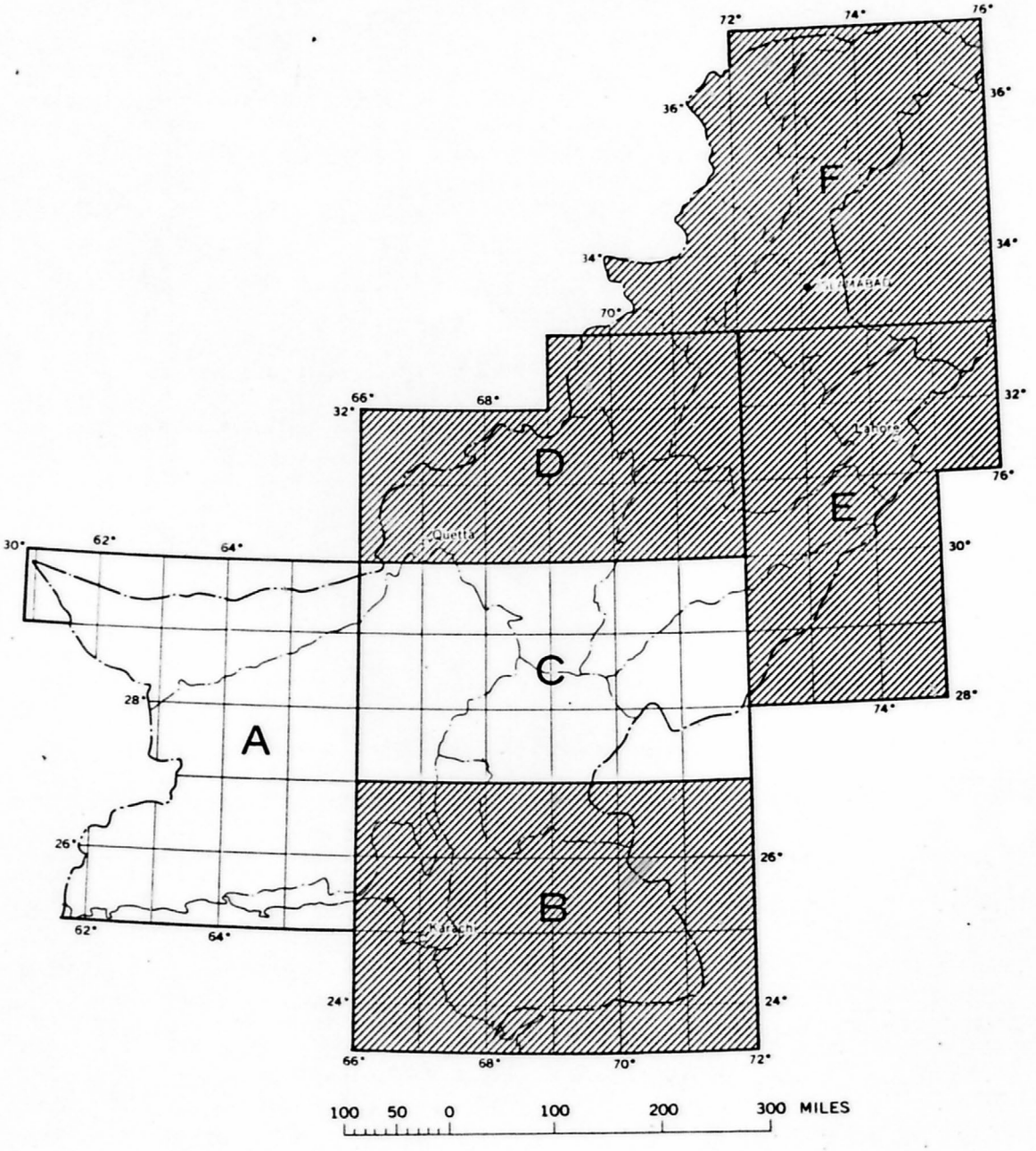

Figure 1. Index map of Pakistan showing the areas covered by individual base sheets.

Kidwai (unpub. data) of the Geological Survey of Pakistan collected phosphatic nodules in the southern part of the Pab Range (fig. 2) from shale beds that were considered to be Upper Cretaceous. These samples contained no more than 3.25 percent P_2O_5.

M. I. Ahmad (oral communication, 1962) of the Geological Survey of Pakistan found nodules in shales of the Nari Formation in an area between Domanda Post and the village of Baska in the Sulaiman Range (fig. 3). These nodules were thought to be phosphatic, but no prospecting was undertaken. Eames (1951, p. 164) reported phosphatic nodules in the Upper Chocolate Clays*** and Lower Chocolate Clays***, represented by the Drazinda Shale Member** and the Domanda Shale Member**, names proposed by Hemphill and Kidwai (unpublished data) for rocks of Eocene age in the Domanda Post and Baska area. In this general area, Hemphill collected a few nodules from the Drazinda Shale Member** that contain between 5 and 10 percent P_2O_5.

Crookshank and Heron (1954, p. 125) reported that geologists of the Burmah Oil Company found phosphatic nodules in shale beds that overlie the Kirthar formation* in the Zinda Pir anticline (fig. 3).

Crookshank and Heron (1954) also reported that the shale above the coal beds near Dandot Colliery in the Salt Range (fig. 4) contains phosphatic nodules. Nodules collected near Dandot were reported by Warth (1887, p. 50) to contain 66 percent calcium phosphate (30 percent P_2O_5). Other samples of nodules collected in the same area by N. M. Khan of the Geological Survey of Pakistan contained a much lower percentage of P_2O_5 (Crookshank and Heron, 1954).

A few phosphatic nodules in the basal shale member of the Chhidru Formation** of Late Permian age were found south of Kathwai in the Salt Range

by Curt Teichert (oral communication, 1963) of the U. S. Geological Survey. These nodules contained 23 percent P_2O_5.

A. N. Fatmi of the Geological Survey of Pakistan collected a few phosphatic nodules from Lower Cretaceous beds (Crookshank and Heron, 1954) near Nizampur (fig. 5). The nodules contained as much as 35.2 percent tricalcium phosphate (16 percent P_2O_5), but they are too few to be of economic value.

Samples taken from glauconitic beds in the basal part of the Chichali Formation (Lower Cretaceous) near Fort Lockhart (fig. 5) by Walter Danilchik of the U. S. Geological Survey were found to contain apatite in mineral containing 16 to 20 percent P_2O_5.

Acknowledgments

The authors gratefully acknowledge the assistance of J. J. Matzko of the U. S. Geological Survey, who arranged for rapid determinations of samples submitted to the Geological Survey of Pakistan laboratories. The suggestions and advice given in the initial stages of this work by Vincent E. McKelvey of the U. S. Geological Survey were extremely helpful. The authors appreciate the cooperation and helpful suggestions offered by staff members during the course of preparation of this report.

AREAS INVESTIGATED

Southern Pab Range

Reconnaissance traverses were made across the southern part of the Pab Range between Shah Bilawal and Bahwani (fig. 2). Many nodules were found in the lower argillaceous sections of the Jakkher group* that overlie the Pab Sandstone. These argillaceous rocks are believed to be Paleocene in age, but the lowermost beds may be Late Cretaceous in age in some places. The strata consist of thick sequences of dark-gray to black and greenish-gray to

brownish-gray calcareous shale with thin interbeds of sandstone and layers of nodular limestone.

Many nodules ranging in diameter from less than 1 inch to 1 foot, and a few nodules as much as 3 feet in diameter, are scattered throughout the shale sequences. In many places, the shale sections contain discontinuous layers and lenses of nodular material, and this material apparently erodes out in the form of nodules.

Most of the nodules are black, dark-gray, and dark reddish-brown, and many are coated with a reddish-brown to yellow powdery substance. Many other nodules have a thin veneer of olive-green to dark-green clayey material which seems to derive from the containing rocks.

The individual nodules consist of ferruginous concretions, calcareous clay balls, and limestone nodules. Positive indications of phosphate were obtained only from ferruginous concretions or clay balls, but even with these types of material it is extremely difficult to differentiate between phosphatic and barren nodules on physical appearance alone. In many places, nodules that seemed to be alike physically proved to be dissimilar in phosphate content when they were analyzed. Furthermore, similar-appearing nodules from different areas, when analyzed, yielded both positive and negative results. Field and laboratory analytical data show that the phosphate content of nodules from the southern Pab Range ranges from less than 5 percent to as much as 15 percent P_2O_5 (table 1).

Most or all of the nodules and nodular layers and lenses in the shale of the Jakkher group* in the southern Pab Range seem to have been developed in place. Accumulations of phosphatic, calcareous, and ferruginous colloidal materials apparently were concentrated to form discrete nodules and irregular layers and lenses during deposition.

Table 1.--Partial chemical and radiometric analyses (in percent) of phosphatic nodules collected from shale beds of the Jakkher group* in the southern part of the Pab Range

Sample number	P_2O_5 (percent)	eU_3O_8 (percent)	Locality	Lat. N	Long. E
62-MSH-8P	10	0.001	E of Pabni Chawki	25°16'15"	66°56'45"
63-SAS-5P	< 5	< .001	do	25°16'30"	66°57'00"
63-SAS-6P	15	< .001	do	25°16'30"	66°57'00"
63-SAS-7P	10	< .001	do	25°16'30"	66°57'00"
63-SAS-9P	15	< .001	do	25°16'25"	66°57'00"
63-SAS-11P	15	< .001	do	25°16'25"	66°57'00"
63-SAS-12P	12	< .001	do	25°16'25"	66°57'00"
63-SAS-13P	15	< .001	do	25°16'20"	66°56'55"
63-SAS-14P	15	< .001	do	25°16'20"	66°56'55"
63-SAS-15P	15	< .001	do	25°16'20"	66°56'50"
63-SAS-16P	10	< .001	S of Pabni Chawki	25°14'00"	66°56'45"
63-SAS-20P	5	< .001	do	25°14'05"	66°56'40"
63-SAS-24P	10	< .001	do	25°14'00"	66°56'40"
63-SAS-25P	12	< .001	do	25°14'00"	66°56'40"
62-MSH-12P	10	< .001	S of Naka Levy Post	25°28'18"	67°03'42"
63-SAS-26P	15	< .001	do	25°29'00"	67°01'30"
63-SAS-27P	12	< .001	do	25°29'00"	67°01'30"
63-SAS-28P	10	< .001	do	25°28'50"	67°01'45"
63-SAS-29P	12	< .001	do	25°28'30"	67°02'00"
63-SAS-30P	< 5	< .001	do	25°28'30"	67°02'00"

It would be very difficult to exploit the nodules and nodular material in this area because both the amount of material and the phosphatic content differ from place to place, and the grade of the phosphatic nodules is very low. Mining operations would in all probability require a great amount of hand cobbing. The separation of phosphatic material from barren material would require constant chemical testing in the field, which, in addition to being costly and time consuming, would require trained personnel.

Sulaiman Range

Tertiary, Cretaceous, and Jurassic rocks were examined in the Sulaiman Range on traverses between Fort Sandeman and Drazinda, between Drazinda and Zam Tower, between Zam Tower and Sakhi Sarwar, between Sakhi Sarwar and Rakhni, and on a reconnaissance across the eastern flank of the Zinda Pir structure (fig. 3). These investigations checked the formations that were reported to have phosphatic material in the localities.

Some phosphatic nodules containing less than 5 percent P_2O_5 were found in the Mughal Kot formation* of Late Cretaceous age in Karim Kach Khwar east of Kurgali and in the Drazinda Shale Member** and Domanda Shale Member** of Eocene age between Domanda Post and Baska (table 2).

A shale section containing many nodules was found in the Rakhi Nala near Rakhi Gaj (fig. 3). This section is primarily black, dark-gray, and medium-gray, chunky, conchoidal, silty shale with black nodules distributed at random over a stratigraphic interval of 60 feet. The nodule-bearing shale sequence may be a part of the Dunghan Formation, or it may be within the lower part of the Ghazij Shale of Early Eocene age. The upper limestone unit of the Dunghan Formation seems to be poorly developed in the Rakhi Nala area; hence, the boundary between the Dunghan Formation and the Ghazij Shale is difficult to establish. For the purpose of this report,

Table 2.--Partial chemical and radiometric analyses (in percent) of phosphatic samples collected in the Sulaiman Range

Sample number	Formation and lithology	P_2O_5 (percent)	eU_3O_8 (percent)	Locality	Lat. N	Long. E
63-MSH-14P	Sembar Formation; black shale	< 5	0.001	W of Mughal Kot	31°26'30"	70°02'30"
63-MSH-15P	Mughal Kot formation*; nodules and shale	< 5	.001	Karim Kach Khwar	31°33'15"	69°53'00"
63-MSH-16P	Mughal Kot formation*; nodules and shale	< 5	.002	do	31°33'15"	69°53'15"
63-MSH-17P	Mughal Kot formation*; nodules and shale	< 5	.001	do	31°33'15"	69°53'30"
63-MSH-19P	Domanda Shale Member**; marl with oyster shells	< 5	.001	S of Domanda Post	31°33'15"	70°11'30"
63-MSH-20P	Drazinda Shale Member**; nodules and shale	< 5	.001	do	31°31'15"	70°10'30"
63-MSH-18P	Habib Rahi limestone member*; limestone and chert	< 5	.001	do	31°35'00"	70°12'00"
63-MSH-21P	Habib Rahi limestone member*; limestone and chert	< 5	.001	N of Baska	31°29'30"	70°08'30"
63-MSH-22P	Habib Rahi limestone member*; limestone	< 5	.001	Zam Tower	31°44'30"	70°12'00"
63-MSH-23P	Habib Rahi limestone member*; limestone and chert	< 5	.001	do	31°44'30"	70°12'00"
63-MSH-24P	Habib Rahi limestone member*; limestone	< 5	.001	do	31°44'30"	70°12'00"
63-MSH-25P	Habib Rahi limestone member*; limestone	< 5	.001	do	31°44'30"	70°12'00"
63-MSH-26P	Habib Rahi limestone member*; limestone	< 5	.001	do	31°44'30"	70°12'00"
63-MSH-27P	Dunghan Formation; glauconitic sandstone and limestone	< 5	.001	Zinda Pir	30°24'15"	70°28'15"

the nodule-bearing beds are regarded as part of the Ghazij Shale. Field geochemical analyses determined that many nodules in the lower half of the nodule-bearing sequence contain from 5 to 20 percent P_2O_5 (table 3); however, no phosphate was found in nodules from the upper half of the section. Perhaps highly concentrated zones of phosphatic nodules or possibly bedded phosphatic deposits may be found along strike when detailed investigations are undertaken in this general area.

Along the eastern flank of the Sulaiman Range, the Habib Rahi limestone member* of Eocene age contains many thin beds of black to dark-gray argillaceous limestone and very thin beds and lenses of black to dark-brown chert. Many phosphoritic deposits in other parts of the world are associated with chert and cherty limestone, and this fact stimulated interest in the Habib Rahi limestone member* during reconnaissance work in the Sulaiman Range. Analytical results on samples disclosed a maximum phosphate content of nearly 5 percent P_2O_5 (table 2). The samples showing positive results were taken from outcrops near Domanda Post, Baska, and Zam Tower (fig. 3). Negative results were obtained from samples collected along the Zinda Pir structure and from outcrops farther south in the Rakhi Nala area. The Habib Rahi limestone member* may contain high-grade phosphorite beds north of Drazinda and Zam Tower, and this area will require more detailed investigation.

Salt Range

Reconnaissance traverses were made in the Salt Range between Khewra and Khairabad (figs. 3 and 4) to examine the Patala Formation of Paleocene age. The Patala Formation contains minable coal beds which are overlain by a sequence of dark-gray, greenish-gray, olive-green and some light-lavender,

Table 3.--Partial chemical and radiometric analyses (in percent) of phosphatic nodules collected from the Ghazij Shale in Rakhi Nala (lat. 29°57'45" N.; long. 70°05'30" E.) in the southern part of the Sulaiman Range

Sample number	P_2O_5 (percent)	eU_3O_8 (percent)
63-MSH-33P	20	0.002
63-MSH-113P	20	.003
63-MSH-114P	15	.001
63-MSH-115P	5	< .001
63-MSH-116P	8	.001
63-MSH-117P	15	.001
63-MSH-133P	15	.002
63-MSH-134P	10	.002
63-MSH-136P	10	< .001
63-MSH-137P	5	.002

calcareous, gypsiferous, and carbonaceous shale. This shale contains small amounts of scattered ferruginous and calcareous nodules and gypsiferous clay galls. Several black phosphatic nodules were collected from these beds. One nodule which was collected directly west of the Dandot Colliery yielded 25 percent P_2O_5, but none of the other phosphatic samples found in the Salt Range contain more than 10 percent P_2O_5 (table 4).

Below the coal beds, the Patala Formation is composed of maroon, reddish-brown, and brown shale, siltstone, and interbeds of ferruginous sandstone. A few nonphosphatic ferruginous nodules were found at places within this sequence.

The Sakesar Limestone of Eocene age and limestone sections in the Wargal Limestone** of Permian age contain thin lenses of chert and chert nodules. These rocks were tested for phosphate at a number of places, but only negative results were obtained.

Kohat Range

The Chichali Formation was investigated at a number of places between Thal and Nizampur (fig. 5) along the southern flank of the Kohat Range.

Highly glauconitic basal beds of the Chichali Formation crop out in a well-exposed section, 17-feet thick, at milepost 10.7 on the road from Hangu to Fort Lockhart. The rocks in the lower 7 feet of this section are extremely glauconitic and contain zones rich in Belemnites. Many black nodules are disseminated throughout this interval. The upper part of the outcrop contains interbedded glauconitic sandstone, siltstone, and very sandy shale and thin zones of scattered nodules.

The analyses of channel samples taken from this outcrop showed a range of 0 to 5 percent P_2O_5; maximum radioactivity was 4 microroentgens per hour.

Table 4. Partial chemical and radiometric analyses (in percent) of phosphatic nodules collected from the Patala Formation in the Salt Range

Sample number	P_2O_5 (percent)	eU_3O_8 (percent)	Locality	Lat. N	Long. E
63-MSH-38P	25	0.006	W of Dandot	32°39'15"	72°56'20"
63-MSH-41P	10	.002	S of Dandot	32°39'10"	72°57'35"
63-MSH-44P	> 5 < 10	.001	Arara	32°32'30"	72°22'30"
63-MSH-45P	< 5	< .001	do	32°32'30"	72°22'30"
63-MSH-48P	< 5	.001	do	32°32'30"	72°22'30"
63-MSH-49P	> 5 < 10	< .001	Khattha Colliery	32°35'15"	72°28'45"
63-MSH-50P	< 5	< .001	do	32°35'20"	72°28'50"
63-MSH-58P	< 5	.001	Nammal Gorge	32°39'50"	71°48'00"

Selected nodules gave analytical results as high as 10 percent P_2O_5 (table 5).

Similar analytical results were obtained for channel samples collected from a 23-foot thick section of the lowermost part of the Chichali Formation about 1 mile north of the village of Darsamand (fig. 5). Maximum values of 15 percent P_2O_5 and 4 microroentgens per hour radioactivity were obtained from selected nodule specimens (table 5).

The highest analytical results were obtained for nodules collected from Lower Cretaceous beds in the Wuch Khwar stream valley, a small tributary of the Indus River southeast of Nizampur (fig. 5). The Cretaceous strata in this area consist of interbeds of dark-green, reddish-brown, black, glauconitic, ferruginous, and carbonaceous sandy shale containing many Belemnites, numerous other molluscs, and dispersed black to dark-brown nodules. Many nodules are ferruginous, pyritic, and limonitic. Dark-green to greenish-brown, very glauconitic, argillaceous sandstone containing zones of Belemnites, and dark-gray, gray to brown, crystalline, and sandy limestone containing ammonites interstratify the shale sequence.

Channel samples collected from several shale intervals in Wuch Khwar were found barren of phosphate; selected nodule samples gave encouraging results of 15 to 25 percent P_2O_5. X-ray diffraction data on several samples indicate that hydroxylapatite or fluorapatite is the possible source of phosphate in these samples.

The Cretaceous section in the Nizampur area is sufficiently thick and well exposed to the east to warrant additional investigations.

Table 5.--Partial chemical and radiometric analyses (in percent) of phosphatic samples collected from the Chichali Formation along the southern flank of the Kohat Range (including part of the Kala Chitta Range)

Sample number	Type of sample	P_2O_5 (percent)	eU_3O_8 (percent)	Locality	Lat. N.	Long. E
63-MSH-73P	Glauconitic sandstone, shale, and nodules	5	0.003	N of Kohat	33°37'50"	71°27'40"
63-MSH-80P	Glauconitic shale	< 5	.001	do	33°37'50"	71°27'45"
63-MSH-81P	Glauconitic shale	< 5	.003	do	33°37'50"	71°27'50"
63-MSH-87P	Nodules	15	.002	Wuch Khwar	33°46'00"	72°02'45"
63-MSH-88P	Nodules	25	.001	do	33°46'00"	72°02'45"
63-MSH-95P	Glauconitic sandstone, siltstone, shale	< 5	.001	S of Ft. Lockhart	33°32'10"	70°56'45"
63-MSH-98P	Glauconitic sandstone, siltstone, shale	< 5	.002	do	33°32'10"	70°56'45"
63-MSH-99P	Glauconitic sandstone, siltstone, shale, and nodules	< 5	.003	do	33°32'10"	70°56'45"
63-MSH-100P	Glauconitic sandstone and nodules	5	.004	do	33°32'10"	70°56'45"
63-MSH-101P	Glauconitic sandstone and nodules	< 5	.004	do	33°32'10"	70°56'45"
63-MSH-102P	Glauconitic sandstone and nodules	< 5	.002	do	33°32'10"	70°56'45"
63-MSH-103P	Glauconitic sandstone and nodules	< 5	.002	do	33°32'10"	70°56'45"
63-MSH-103Pa	Nodules	10	.004	do	33°32'10"	70°56'45"
63-MSH-107P	Glauconitic sandstone, siltstone, and nodules	< 5	.001	N of Darsamand	33°26'45"	70°39'30"
63-MSH-108P	Glauconitic sandstone, siltstone, and nodules	< 5	.001	do	33°26'45"	70°39'30"
63-MSH-111P	Nodules	15	.004	do	33°26'45"	70°39'30"

ECONOMIC ASPECTS

None of the formations in the four principal areas investigated and described in this report contain sufficient deposits of phosphatic nodules to warrant mining.

The lower shale sequences of the Jakkher group* in the southern Pab Range contain many more nodules and zones of nodular material than were observed in stratigraphic sections of other areas; however, many nodules in the Jakkher group* are not phosphatic. The phosphatic nodules are low grade and, therefore, the rocks of this group and those of the southern Pab Range area have little economic potential.

The nodule-bearing section of the Ghazij Shale at Rakhi Gaj, the dark-colored cherty limestone zones of the Habib Rahi limestone member* near Drazinda and Zam Tower, and the Chichali Formation in Wuch Khwar may have lateral facies of phosphoritic beds which might be economically significant.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions and inferences based on the results of reconnaissance investigations for phosphatic rocks in Pakistan are as follows:

1. Rocks representing several geological periods of deposition contain nodules in variable quantities and of different phosphatic content. Scattered phosphatic nodules are found in the following formations and localities:
   a. The lower shale beds of Paleocene and possibly Late Cretaceous age in the Jakkher group* in the southern part of the Pab Range.

b. The Mughal Kot formation* of Late Cretaceous age; the Ghazij Shale of early Eocene age; and the Domanda Shale Member** and Drazinda Shale Member** of Eocene age in the Sulaiman Range.

c. The Patala Formation of Paleocene age and the basal shale member of the Chhidru Formation** of Permian age in the Salt Range.

d. The basal beds of the Chichali Formation of Early Cretaceous age in the Kohat Range.

2. On the basis of field observations, it seems that the phosphatic nodules and other types of nodules found in these formations were formed in place during deposition.

3. None of the formations contain phosphatic nodules in sufficient quantity or quality to warrant mining consideration.

4. The Habib Rahi limestone member* along the eastern flank of the Sulaiman Range displays several characteristics commonly found in upwelling marine lithofacies (dark-colored rocks, associated chert and organic matter, and phosphatic content). Rich phosphatized rocks may have been deposited north of Drazinda and Zam Tower.

5. The basal glauconitic beds of the Chichali Formation in the Kohat Range contain phosphatic nodules having as much as 25 percent P_2O_5. The phosphate seems to be derived from hydroxylapatite or fluorapatite. The possibility of finding less glauconitic and richer apatitic sequences east of Wuch Khwar should be investigated.

Recommendations for future exploration are:

1. Detailed stratigraphic and geochemical investigations (utilizing scintillation counters, trenching, sampling, measuring thickness of sections, and describing the mineralogy and petrology of the rocks) should be made in the following areas:
   a. From Drazinda and Zam Tower, outcrops of the cherty Habib Rahi limestone member* should be examined northward along the eastern flank of the Sulaiman Range for possible lateral lithofacies of high-grade phosphoritic limestone and phosphorite.
   b. The nodule-bearing section of the Ghazij Shale in the southern part of the Sulaiman Range should be followed southward from Rakhi Nala in search of much higher concentrations of phosphatic nodules, or possibly bedded phosphate deposits.
   c. The Chichali Formation of the Kohat Range and Kala Chitta Range should be examined in detail in Wuch Khwar. Traverses to search for richer apatitic and phosphatic outcrops should be made across the strike of the formation at a number of places east of Wuch Khwar.
2. Rocks having positive indications of phosphate should be sampled so that detailed petrographic, mineralogic, chemical, paleontologic, and physical properties studies can be made. The information derived from these studies is important for the evaluation of deposits, calculation of reserves, determination of necessary beneficiation, and might lead to the discovery of valuable byproducts.

3. When correlations and the stratigraphic relationships of the formations in Pakistan are resolved so that the genesis, environment of deposition, and facies relations are understood, a systematic geologic program for phosphate investigation should be planned. Coordinated stratigraphic, geochemical, mineralogical, and chemical studies should be programmed to prospect and appraise favorable areas in Pakistan where tectonic, oceanographic, and stratigraphic conditions conducive to the deposition of phosphorite and companion members of the phosphoritic suite may have existed in the geologic past.

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