FERTILIZER MINERAL OCCURRENCES IN THE ASIA-PACIFIC REGION

Edited by Annabelle I.N. Lee
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The East-West Center
East-West Resource Systems Institute
1777 East-West Road
Honolulu, Hawaiian, USA

Published: February 1980
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The major fertilizer minerals are phosphate, potash and natural gas (nitrogen source). Of these minerals, the supply of phosphate is the most critical to the production of fertilizers. Up until twenty years ago it was believed by most people that few major phosphate deposits occurred in the Asia-Pacific region and that the potential for finding economically substantial deposits was very low. The predicted potential seems to have been a self-fulfilling prophesy. Since the discovery of large deposits was unanticipated, there were few exploration projects and consequently, no new deposits were found.

Beginning in about 1960, newly developed geologic knowledge of phosphorite and its geologic habitat was applied to the Asian and Pacific regions, resulted in the discovery of several major deposits including the Duchess deposit of Australia and the Udaipur deposit of India. Despite the discovery of these major accumulations, the idea still persists that the Asia-Pacific region does not have substantial phosphate deposits and that the global distribution of such deposits is very unequal.

A workshop on fertilizer raw material resources was held in Honolulu, Hawaii at the East-West Center during August 20-24, 1979 to review and assess the existing resources and potential for finding more deposits of fertilizer raw materials in the Asia and Pacific regions. As a part of this effort, representative participants were asked to submit papers on the major fertilizer mineral occurrences in their countries for the purpose of compiling a map of identified fertilizer mineral occurrences.

This volume presents these papers as a supplement to the Proceedings of the Fertilizer Raw Materials Resources Workshop. They give an overall view of the distribution of fertilizer mineral occurrences in the region, as well as details on the individual deposits. In addition, this volume contains a compilation of fertilizer mineral occurrences in a series of maps of the Asia and Pacific region. A list of the occurrences accompanies these maps. For each occurrence, available information was listed in the following order:

- Location and name of the deposit
- Type of occurrence
- Age of the producing rock unit, stratigraphic name of the rock unit
- References

Much of the information on the mineral occurrences came from the country papers submitted for the project. The rest was obtained from the United Nations Mineral Development Series publications, the American Association of Petroleum Geologists (AAPG) yearly surveys of foreign petroleum developments, and other publications on the mineral deposits in the Asia-Pacific region.
Because the country papers were prepared for the purpose of compiling a list of mineral occurrences and to show their distribution throughout the Asia-Pacific region, some are simply lists or tables of known occurrences whereas other papers are detailed discussions of the mineral occurrences in their respective countries. In several cases, the accompanying maps and illustrations were too large or detailed for publication in this volume and therefore were excluded. Maps that showed only the location of mineral deposits (information that would be repeated in the overall distribution maps) also were excluded.

The phosphate and natural gas occurrences were plotted, using circle (○) and square (□) symbols to represent their locations. Because natural gas occurrences are found in sedimentary basins, basin boundaries have been indicated on the maps. Potash occurrences (the triangle (△) symbol) are indicated only on the Pakistan, Thailand and Australia maps. In the other countries, areas of high potential for potash accumulations are shown. These areas are sedimentary basins deemed prospective for substantial accumulations (see panel report on potash in the Proceedings of the Fertilizer Raw Materials Resources Workshop).

Most of the work done in compiling and preparing this volume for publication was accomplished while I was on leave from my grant from the East-West Center. During that leave period, I was employed by the U.S. Geological Survey to complete this report.

I wish to express sincere appreciation to Richard P. Sheldon, Research Associate of the East-West Center and Geologist of the U.S. Geological Survey who initiated this project and whose helpful guidance and ideas were invaluable to the successful completion of this compilation. I also wish to thank Asrarullah, Director General of the Pakistan Geological Survey; Peck Chin Aw, Senior Geologist of the Malaysia Geological Survey; Evelyn Nicholas of the Bureau of Mineral Resources, Geology and Geophysics, Australia; and Arthur J. G. Notholt, Principal Geologist of the Institute of Geological Sciences, London for their helpful suggestions and review of the lists of mineral occurrences. The clerical support of the Resource Systems Institute staff and by Mae Jones of the U.S. Geological Survey was greatly appreciated.

Annabelle I. N. Lee
Editor
January 3, 1980
# AUSTRALIAN GAS DISCOVERIES

by Evelyn Nicholas*

<table>
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<tr>
<th>WELL NAME</th>
<th>BASIN</th>
<th>LAT. (deg. S)</th>
<th>LONG. (deg. E)</th>
<th>AGE OF OCCURRENCE</th>
<th>NAME OF FORMATION</th>
<th>DRILLING ACTIVITY</th>
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<tr>
<td>Gilmore no. 1</td>
<td>Adavale</td>
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<tr>
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<td>Amadeus</td>
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</tr>
<tr>
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</tr>
<tr>
<td>Pelican no. 1</td>
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<td>40°20'20&quot;</td>
<td>145°50'37&quot;</td>
<td>early Eocene</td>
<td>Eastern View Coal Measures</td>
<td>gas/condensate discovery</td>
</tr>
<tr>
<td>Petrel no. 1</td>
<td>Bonaparte Gulf</td>
<td>12°49'35&quot;</td>
<td>128°28'27&quot;</td>
<td>Late Permian</td>
<td>Hyland Bay Fm.</td>
<td>gas discovery</td>
</tr>
<tr>
<td>Sunrise no. 1 and</td>
<td>Bonaparte Gulf</td>
<td>9°35'24&quot;</td>
<td>128°09'14&quot;</td>
<td>late Middle Jurassic</td>
<td>Petrel Fm.</td>
<td>gas discoveries</td>
</tr>
<tr>
<td>Troubadour no. 1</td>
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<td>128°07'38&quot;</td>
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<td>Tern no. 1</td>
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</tr>
<tr>
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<td>Permian</td>
<td>'Klanga Fm.'</td>
<td>gas/condensate discovery</td>
</tr>
<tr>
<td>Kincora no. 3</td>
<td>Bowen-Surat</td>
<td>27°02'53&quot;</td>
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<td>Evergreen Fm.</td>
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<tr>
<td>Rolleston no. 1</td>
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Roma area. Twenty-five fields are located within the area delineated by the following four wells:

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<th>WELL NAME</th>
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<th>NAME OF FORMATION</th>
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<td>Tinowon Fm.</td>
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<tr>
<td>Snake Creek no. 1</td>
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</tr>
<tr>
<td>Pringle Downs no. 1</td>
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*Bureau of Mineral Resources, Geology and Geophysics, Australia National University, Canberra, Australia
<table>
<thead>
<tr>
<th>WELL NAME</th>
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<th>DRILLING ACTIVITY</th>
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*Senior Research Fellow in Economics Geology, Research School of Earth Sciences, Australian National University.
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SELECTED PHOSPHATE REFERENCES - AUSTRALIA


COOK, P.J., 1972b. Petrology and geochemistry of the phosphate deposits of Northwest Queensland, Australia. Econ. Geol., 67(8), 1193-213.


The search for petroleum in Bangladesh started in the early years of the present century. The first well was drilled in 1910. Though no oil has been found so far, nine gas fields have been discovered including one in the offshore area. The gas fields are Chhatak, Sylhet (Haripur), Kailas Tila, Rashidpur, and Habiganj in Sylhet district, Titas and Bakhrabad in Comilla district, Semutang in the Chittagong district, and the offshore field of Kutubdia, west of Chittagong. A brief description of each field is given below.

Chhatak.—A northwest-southeast trending faulted anticline about 8 miles long and 3 miles wide forms the small Chhatak field. This is located about 35 miles northwest of Sylhet town. The field has been in production since 1960 for fuel supply to the cement and paper pulp plants at Chhatak and domestic supply in the plant areas. Only one hole was drilled and gas was found in Bokabil and upper Bhuban beds of Miocene age at a depth of 3550 to 3616 feet from the surface. The reserves were estimated at $0.04 \times 10^{12}$ standard cubic feet (SCF) and production till the end of 1977 was $0.013 \times 10^{12}$ SCF.

Further exploration in this field has been started recently.

Sylhet.—A complex, northeast-southwest trending anticline only a few miles northeast of Sylhet town forms the Sylhet field. It is about 6 miles long and 4 miles wide. This field has been in production since 1961 to supply gas to the fertilizer complex at Fenchuganj and for domestic supply to Sylhet town. Six wells have been drilled in this field, and two gas-bearing sand beds of the Bokabil Formation occur at depths of 3771 to 4216 feet and 4296 to 4476 feet. The reserves have been placed at $0.34 \times 10^{12}$ SCF, and production till the end of 1977 was $0.069 \times 10^{12}$ SCF.

Kailas Tila.—Kailas Tila field, located about 12 miles south of Sylhet town, comprises an anticline 14 miles long and 4 miles wide with a north-south trend. One well was drilled in this field. The gas-bearing beds are in Bokabil and upper Bhuban at depths of 9628 to 9729 feet and 11647 to 11675 feet. The reserves have been estimated at $0.60 \times 10^{12}$ SCF. The field, discovered in 1962, has not been put in production.

Rashidpur.—A narrow north-south anticline about 45 miles south-southwest of Sylhet town forms this field. The anticline is 25 miles long

*Director General, Geological Survey of Bangladesh, Dacca, Bangladesh
and 3 miles wide and plunges at both ends. Two wells were drilled on this structure and both encountered gas. The gas-bearing beds are Bokabil and upper Bhuban at depths of 9104 to 9116 feet. The reserves were put at $1.06 \times 10^{12}$ SCF. This field, discovered in 1961, has not been exploited.

**Habiganj.**—The Habiganj field is located about 75 miles northeast of Dacca and consists of an asymmetric anticline 16 miles long and 5 miles wide with a north-south trend. Only one well has been drilled on this structure and has been in production since 1969 for supply to a power plant at Shahazi Bazar and to surrounding tea estates. The gas-producing beds are in Bokabil and upper Bhuban at depths of 4650 to 4865 feet. The reserves were estimated at $1.28 \times 10^{12}$ SCF, and cumulative production up to the end of 1977 was $0.028 \times 10^{12}$ SCF.

**Titas.**—Most of the gas now produced in Bangladesh comes from the Titas field located near Brahmanbaria, a town about 50 miles east-northeast of Dacca. The structure is a north-south trending asymmetrical anticline 15 miles long and 9 miles wide. Bokabil and upper Bhuban sands at depths of 8587 to 8977 feet are the gas-producing horizons. Four wells have been drilled in Titas field, and the reserves have been estimated at $2.25 \times 10^{12}$ SCF. Production till the end of 1977 was $0.115 \times 10^{12}$ SCF. This field supplies gas to a number of power plants, fertilizer plants, industries, and is for domestic use in Dacca city and several other towns.

**Bakhrabad.**—Bakhrabad field, located about 35 miles east of Dacca, consists of an asymmetrical anticline, 38 miles long and 6.3 miles wide, trending north-south. The structure has three culminations. One well was drilled in the southernmost culmination and gas was found. The reserves have been estimated at $1.50 \times 10^{12}$ SCF. The gas-bearing horizons are Bokabil and upper Bhuban at depths of 7111 to 7141 feet and 8040 to 8060 feet. This field has not been exploited yet.

**Semutang.**—An asymmetric anticline with a northwest-southeast trend, located east of Sitakund in Chittagong district, forms the Semutang field. It is 16 miles long and 3 miles wide. Five wells were drilled and two encountered gas. The gas-bearing sands are in the Bokabil Formation at depths of 3212 to 3258 feet and 4196 to 5553 feet. The reserves have been estimated at $0.08 \times 10^{12}$ SCF. This field has not been exploited yet.

**Kutubdia.**—The only offshore gas field in Bangladesh is Kutubdia, discovered by Union Oil Company several years ago. It is located about 60 miles southwest of Chittagong, in the Bay of Bengal. The structure, well-defined at depth but only slightly so in shallower sedimentary sections, is about 12 miles long and 6 miles wide. The upper Bhuban beds, at depths of 8730 to 8760 feet, are the gas-bearing beds. The reserves have been put at $2.0 \times 10^{12}$ SCF. This field also has not been exploited.

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PHOSPHATE, POTASH AND NATURAL GAS
OF FIJI

H. G. Plummer*

Phosphate

The main Fiji occurrences and deposits are in the Lau group of islands. The islands are primarily composed of late Miocene volcanics, andesite, basalt, and some dacite overlain in places by late Miocene detrital limestone. The limestone may have eroded from reefs formed upon volcanics-based atolls or patch reefs.

The phosphate deposits are described as loams, nodules, and oolites, often found in cavities and cracks in between limestone pinnacles of late Miocene age. In the most important deposit, on Tuvutha, they also occur as clays overlying andesite as well as limestone. The limestone at Tuvutha is dolomitic (15 to 20% MgO).

A review of previous investigations on the Lau Islands phosphate deposits was carried out by Colley (1975). This was done to estimate the probable accuracy and reproducibility of the results stated and to indicate which deposits warranted more detailed investigation to verify tonnages and grades available. His conclusions were that tonnage estimates of phosphatic rock had been proved in a sufficient manner only on Ongea Ndriki (77,000 tons, 25 to 30% \( P_2O_5 \)) and Vanua Vatu (80 to 140,000 tons, about 30% \( P_2O_5 \)). It was, however, evident that a large phosphate deposit in excess of 1 million tons probably existed on Tuvutha.

A further detailed study of the Tuvutha phosphate deposits was carried out by Rodda (report in prep.). He proved a minimum amount of "phosphatic clay" of: 430,000 tons averaging 16.7% \( P_2O_5 \), an additional 1,193,000 tons averaging 8.8% \( P_2O_5 \), and a further 213,000 tons averaging 4.5% \( P_2O_5 \).

The deposits are quoted as minimum values because 19 of a total 180 sites augered did not reach bedrock at 11.6 m, the length of the longest auger. Most holes showed little variation of phosphate content with depth, although in the richest area, Nggilo (approximately 160 m x 120 m), there was a definite layering of values. The top layer of 2 to 4 m thickness averaged 22% \( P_2O_5 \), the next layer of 2 to 7 m thickness averaged 16 to 17% \( P_2O_5 \), and the bottom layer of about 5 to 7 m thickness, averaged 12% \( P_2O_5 \). Staargaard (1962) published analyses of the clays

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from Tuvutha which contained $\text{RO} = (31 \text{ to } 42\%, R = P + Al)$, $\text{FeO} = (13 \text{ to } 19\%)$, $\text{SiO}_2 = (5 \text{ to } 10\%)$, $\text{L.O.I.} = (17 \text{ to } 20\%)$, and $\text{TiO}_2 = (1.4 \text{ to } 1.9\%)$. The Tuvutha clays are therefore also bauxitic and have a relatively high iron content. Comments in other early reports about other deposits in the Lau Islands mention the probable deleterious effect of relatively high iron and aluminium content on the phosphate tenor. Staargaard (1962) also suggested that the calcium aluminium phosphate minerals identified in Tuvutha samples were crandallite or pseudowavellite. Other minerals mentioned were geothite, gibbsite, boehmite, unidentified clay minerals, and possibly hematite.

As regards to the mode of formation of the phosphate occurrences, evidence is suggestive of them being guano-derived though no primary guano remains. At Tuvutha, the deposits occupy the center of the island within a depression approximately 60 m lower than encircling cliffs which rise 200 m above sea level. The Miocene and Tertiary are known to be phosphate deposit-generating times testifying that certain oceanic conditions were suitable. Upwelling could have resulted against the line of volcanoes formed along the north-south trending Lau Ridge, thus encouraging bird life. The bauxitic association probably points to later leaching and reconstitution of phosphatic compounds. Tuvutha is of an atoll shape. Rennell Island, an atoll in the Solomon Islands, is also bauxitic. This suggests a link between phosphate/tauxite formation in atoll situations.

Chemical analysis data were scanned to examine the phosphate and magnesium content of limestones, calcareous rocks, and other sedimentary rocks. In the case of limestones, only the Lau (Tuvutha) group was high in MgO (15 to 20%). All the mainland limestones were low, usually less than 1% MgO, except in the case of a rather impure type in the Wainimala Group at Masovatova which has 10% MgO. In all these limestones (Lau and Mainland) the $P_2O_5$ content was less than 1% and often much less than this. In rocks of various groups and formations (Vunda Beds, Suva Marl, Lami Limestone, Thuvu Sedimentary Group, Nandi Sedimentary Group, Mbarotu Sandstone, Waindina Sandstone, Wainimala Group, Singatoka Sedimentary Group), the $P_2O_5$ content was less than 1% and usually much below this, even though the acid soluble content was appreciable.

Potash

There are no known potash reserves in Fiji of the bedded marine evaporites type. Bligh Water, situated between the northern coast of Viti Levu and the Yasawa line of islands, occasionally could have had an area of restricted circulation/dessication since Miocene times. Logs of offshore wells for oil prospecting will no doubt show the presence or absence of evaporites. No reports of glauconite have been made.
Natural Gas

Exploration for natural gas is concurrent with oil exploration. Intensive exploration for oil is currently taking place in the shallower offshore areas of Fiji. There are several aspects of this exploration that are of great geologic interest. From seismic data and geological reasoning it is known that up to 6,000 m of sediments of Miocene to Recent age exist offshore above basement rock. These sediments may contain both cap (sealing) rocks, for example, marls, mudstones, and tuffs; and reservoir rocks, viz. sandstones and reefal (patch, barrier and fringe) material. Considerable thicknesses of Miocene limestones crop out in two areas on land. Offshore limestone reefal thicknesses could be 300 m or more. Seismic interpretation has indicated such structures exist, and the present reef manifestations in Fiji offshore areas may have been repeated at intervals throughout Miocene and Pliocene times.

In Curie Point studies, heat gradient profiles calculated from magnetic data strongly indicate that there had been a sufficient heat regime operating in some offshore areas to generate oil or gas hydrocarbons if primary hydrocarbon substances were present in the host rocks. In fact, the heat gradient is somewhat on the high side in places (85°C per km) so that gas rather than oil might have resulted. Many suspected oil and gas seeps have been reported and photographed by sightings from low-flying aircraft. Some of these have been followed up from sea craft and by diving, and in some cases samples have been confirmed as containing hydrocarbons. Confirmed oil seeps occur in Tonga (Nuku-alofa) approximately five miles from the volcanic line. Other gas deposits nearby are the Maui field in New Zealand and the gas/distillate occurrence in the Gulf of Papua New Guinea.

Four tracts totalling 30,000 sq km are under license in Fiji for oil prospecting, and it is anticipated that drilling may commence in early 1980. Gas, if found relatively close to the mainland, may be cheap to bring ashore for its use in electrical generating facilities and other industries. Consideration is likely to be given for its use as a raw material for a fertilizer industry.


Compiles tonnages and grades given by various authors for the deposits, and assesses their worth (thoroughness of survey and therefore reliability of estimates).


Little more than a table.


Bat guano in cave; once mined.


Brief mention of the bat guano that was once mined from a cave.


Mentions results of observations and qualitative tests on various islands but is very cursory and contains surprising errors of fact.


The main report, Howling's was preliminary and the same reference number was used. Gives results of analyses.

A diary mentioning locations and results of qualitative tests for phosphate on various islands in Lau.


Estimates tonnage and grade based on preliminary survey (augering).


Refined figures, after completion of survey (closer spacing to holes, and completion to bedrocks or limit of auger of some holes not previously completed.

______ (in preparation), The phosphate deposits of Tuvutha, Lau: Fiji Mineral Resources Division Economic Investigation, no. 3.


Mainly on beneficiation and plant trials but gives results of analyses before and after beneficiation (by calcining).


Most of the geological section is taken directly from previous reports, but many new analyses are given. Much of the report deals with field trials.


A NOTE ON THE KNOWN RESOURCES OF PHOSPHATE AND POTASH IN INDIA

V.N. Sant and A. Pant*

The known phosphate and potash occurrences and deposits in India listed in this note are based on available published literature. A selected bibliography is also given.

Phosphate.—The phosphate occurrences and deposits include veins of apatite, beds of phosphorite (sedimentary phosphate), and guano. While the apatite mineralization is confined to the Precambrian hard rocks, the phosphorite occurs in rocks of different geological ages from Precambrian to Eocene. The presence of phosphatic nodules in the Cretaceous rocks of coastal Tamil Nadu and Jurassic rocks of the Mussoorie area in Uttar Pradesh have been known since the last century. Similarly the presence of apatite in Bihar and Andhra Pradesh has been known for many years. However, a large number of promising occurrences and deposits were discovered in the 1960's after the systematic application of the "oceanic upwelling" concept of phosphate formation. Most of the phosphate occurrences are located in Precambrian, Jurassic and Creto-Eocene rocks. Of these, those associated with the Precambrian Aravalli rocks of Rajasthan and Madhya Pradesh are most promising, followed by those in the Jurassic Tal Formation of Uttar Pradesh. The rest of the occurrences and phosphogenic areas are either minor or need further investigation. Minor deposits of guano are known to occur on a few islands of the Lakshadweep group.

Potash.—No commercially exploitable potash deposits have so far been identified. Potassium nitrate is locally collected from the saline efflorescences called 'Reh' from the Indo-Gangetic plains. Potash-rich brines are known from some parts of the Runn of Kutch.

Resources

Phosphate.—The known Indian phosphate resources total nearly 100 million tons, varying in grades from 10 to over 30 percent of $P_2O_5$. Of this, nearly 60 percent are from the stromatolitic phosphorites of the Precambrian Aravalli belt of Rajasthan and Madhya Pradesh, with a contribution of nearly 18 million tons of low grade (5 to 8 percent of $P_2O_5$) have been reported from the Vindhyan rocks of Bihar.

A sizable portion of the known phosphate resources require beneficiation for upgrading the material for utilization in industries. Phosphate from the Mussoorie area of Uttar Pradesh has the advantage of being directly

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* Geological Survey of India, Lucknow, India
usable in the acidic soils and for long duration crops. It is also reported that phosphate from the Bhawanathpur area in Bihar is also suitable for direct application in acidic soils of the Chotta Nagpur area in Bihar.

Potash.--In some solar salt works potassium salts are recovered as by-products.

Known Phosphate Occurrences

Apatite

Precambrian

Kasipatnam (Sitharamapur area), Visakhapatman district, Andhra Pradesh

Geological set up: Apatite magnetite vermiculite veins occur as shear fracture and (or) joint fillings within charnockitic gneisses and associated pyroxene granite, calc-granulites, quartzite and leptinite.

Reserves: 1,680,000 tons, 35 to 42 percent of P$_2$O$_5$


Nandup, Sunrgi, Kulamara and Pathargora areas, Singhbhum district, Bihar

Geological set up: Apatite magnetite veins and aggregates of apatite, quartz, chlorite, etc., localized along the shear zone of the phyllites and schists of the iron ore stage of the Iron Ore Series.

Reserves: 1,094,165 tons, 14 to 19 percent of P$_2$O$_5$

References: Agarwal, 1945; Dunn, 1937, 1941a, 1941b; Geological Survey of India, 1974; Shukla, 1976.

Newania, Udaipur district, Rajasthan

Geological set up: Apatite veins and stringers within carbonatite bodies in the Untala granite.

Reserves: 30,000 tons, 32 to 35 percent of P$_2$O$_5$


Chapoli area, Jhunjhunu district, Rajasthan

Geological set up: Apatite as stringers and disseminations in quartz veins, amphibolites and pegmatites which are associated with garnetiferous biotite schist.

Reserves: 37,000 tons, about 15 percent of P$_2$O$_5$

Apatite - Precambrian (continued)

Sevathur, North Arcot district, Tamil Nadu
Geological set up: Disseminations of apatite crystals within carbonatite bodies
Reserves: 190,000 tons, 10 to 30 percent of P₂O₅
References: Geological Survey of India, 1974; Shukla, 1976.

Hungenekal area, Dharmapuri district, Tamil Nadu
Geological set up: Disseminated crystals of apatite in carbonatites which are associated with pyroxenites and syenites
Reserves: 50,000 tons, 36 percent of P₂O₅
References: Geological Survey of India, 1974; Shukla, 1976.

Beldih, Kutni, Mednitanr, Chirugora and Panrkidih, Purulia district, West Bengal
Geological set up: Quartz apatite and apatite magnetite quartzite veins along shear zones within phyllites, schists, and granitic rock.
Reserves: Beldih, 59,000 tons of 14 to 30 percent of P₂O₅; Chirugora, 40,000 tons of 6.72 percent of P₂O₅ and 20,000 tons of 16.16 percent of P₂O₅; Kutni, 46,000 tons of 10.52 percent of P₂O₅
References: Geological Survey of India, 1974; Shukla, 1976.

Phosphorite

Chelima, Karnool district, Andhra Pradesh
Geological set up: Phosphatic quartzite in the Cumbum Formation of the Cuddapah Super-group
Reserves: n.a.

Khatamba-Kelkua-Amlamal-Piplod, Jhabua district, Madhya Pradesh
Geological set up: Phosphatic stromatolites associated with chert and dolomite of the Aravalli Super-group
Reserves: about 5.7 million tons, 10 to over 30 percent of P₂O₅
Phosphorite - Precambrian (continued)

Pithorgarh, Almora district, Uttar Pradesh

Geological set up: Phosphatic stromatolites associated with the Gangoliihat Formation dolomites

Reserves: n.a.


Lalitpur area, Lalitpur district, Uttar Pradesh

Geological set up: Phosphorite associated with brecciated massive quartzite of the Bijawar Group

Reserves: not available

References: Pant and others, 1979

Jhamarkotra, Maton, Kanpur, Kharbariaka Gurha, Dakan Kotra; Neemach Mata, Badgaon, Sisarma, and other occurrences, Udaipur district; and Sallapat, Ram ka Munna Jher Moti, Banswara district; Rajasthan

Geological set up: Phosphatic stromatolite horizons associated with the dolomitic marble and jaspery brecciated quartzite of the Aravalli Super-group.

Reserves: Jhamarkotra, 49.19 million tons of 13 to over 30 percent of P2O5; Maton, 5.4 million tons of 21 to 29 percent of P2O5; Kanpur, 3.9 million tons of 11.6 percent of P2O5; Kharbariaka Gurha, 1.3 million tons of 10 to 25 percent of P2O5; Dakan Kotra, 2.78 million tons of 10 to 20 percent of P2O5; Neemach Mata, 2.0 million tons of 15 to 25 percent of P2O5; Badgaon, 1.0 million tons of 15 to 25 percent of P2O5; Sisarma, 0.7 million tons of 8 to 10 percent of P2O5


Bhawanathpur area, Palamau district, Bihar

Geological set up: Phosphatic horizon associated with calcareous shale underlying the Kajrahah limestone of the Vindhyan Super-group

Reserves: 87.8 million tons, 5 to 7 percent of P2O5

References: Shukla, 1976
Paleozoic

Birmania, Jaisalmer district, Rajasthan
Geological set up: Phosphatic sandy shale and phosphatic limestone of the Birmania Formation
Reserves: 3.5 million tons, 12.91 percent of $P_2O_5$
References: Deshmukh, 1979; Muktinath, 1967; Sant and Sharma, 1971; Sheldon, 1966; Srikantant and others, 1969.

Jurassic

Godpar-Gadhsisa, Sadanbari and Jhura area, Kutch district, Gujarat
Geological set up: Phosphatic concretionary horizon within ferruginous sandstone of the Bhuj Formation
Reserves: not available
References: Muktinath, 1974

Nigalidhar, Korgai and Solan areas, Sirmur, Simla and Solan districts, Himachal Pradesh
Geological set up: Phosphatic quartzite of the Krol chert and shale member of the Lower Tal Formation
Reserves: not available

Maldeota, Durmala, Partibba-Chamasari, Bhusti-Jamthialgaon-Jalikhal, Bagi-Mathiagaon blocks and other occurrences, Mussoorie area, Dehradun and Tehri districts, Uttar Pradesh
Geological set up: Bedded chert and shale of the chert member of the Lower Tal Formation
Reserves: Maldeota West, 5.13 million tons of 18.6 percent of $P_2O_5$; Maldeota East, 0.235 million tons of 28.2 percent of $P_2O_5$; Durmala, 4.58 million tons of 27.8 percent of $P_2O_5$; Partibba-Chamasari, 2.79 million tons of 18.3 percent of $P_2O_5$; Bhusti-Jamthialgaon-Jalikhal area, 2.0 million tons of 26 to 33 percent of $P_2O_5$. Total of all occurrences and deposits: 18.2 million tons of 10 to 27 percent of $P_2O_5$.
Cretaceous

Nambakhurichi-Varagupadi area, Tiruchirapalli district, Tamil Nadu

Geological set up: Phosphatic nodules associated with calcareous shales and a sandy clay horizon of the Uttatur stage.

Reserves: 2.0 million tons, 21 to 26 percent of $P_2O_5$


Cretaceous-Eocene

Fatehgarh, Jaisalmer district, Rajasthan

Geological set up: Ferruginous phosphatic sandstone of the Fatehgarh Formation

Reserves: not available


Eocene

Khasi-Jaintia-Garo hills, Meghalaya

Geological set up: Phosphatic nodules associated with dark shale of the Kopili Formation

Reserves: not available


Guano

Laccadive-Amindivi Islands

Geological set up: Guano deposits

Reserves: 92,000 tons, 13.11 percent of $P_2O_5$

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FERTILIZER RAW MATERIALS IN INDONESIA

F. HEHUWAT*

ABSTRACT

This paper is a brief summary of the availability or potential availability of fertilizer raw materials in Indonesia. Of the three main types of fertilizer, namely phosphate, potash, and ammonia (urea), only the raw material for ammonia (urea) is available in sufficient quantities. Estimates of natural gas reserves vary widely, but a reasonable assumption is 56,085 billion standard cubic feet (BSCF), comprising 4,909 BSCF of associated gas and 51,085 BSCF of non-associated gas. Indonesian production of natural gas amounted to 312,603 million standard cubic feet (MMSCF) in 1976. Its consumption pattern was as follows: Own (producers) use 32.43%, fertilizer 4.52%, carbon black and liquified petroleum gas (LPG) 1.01%, refinery 2.45%, flared 59.59%. Domestic production of nitrogenous fertilizer exceeded 2,200,000 metric tons in 1978, of which about 500,000 metric tons were exported. Phosphogenic sediments have been indicated to occur at several localities on Java and Irian Jaya, but investigations until now have failed to locate deposits of any size. Although phosphate fertilizer is produced in the country, the raw materials for this are imported. Leucite-bearing volcanic rocks are possible raw materials for producing potash fertilizer.

INTRODUCTION

Indonesia is an agrarian country. Future developments, as expressed in its development plans, indicate that the main emphasis will still be on the development of the agricultural sector. This is in spite of the anticipated gradual increase of the industrial sector’s share in the gross national product (GNP). To cope with its growing population, the increase of production of rice is to be achieved by intensifying production of existing rice growing areas, and by extensifying these areas. In the seventies, the average yield of rice was approximately 2.5 metric tons/hectare. This production figure can be considered low when compared with rice production figures for developed countries. One likely reason for this low yield per hectare is the much lower fertilizer consumption per hectare compared to that of more advanced countries. With more than 8 million hectares under rice cultivation, and, bearing in mind the intensification and intensification programs as described in the development plans, there will be a huge increase in demand for fertilizer in Indonesia in the coming years. In the following discussion, fertilizer production and availability or potential availability of fertilizer raw materials will be reviewed with special emphasis on nitrogenous, phosphate and potash fertilizers.

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Table 1. Natural gas reserves in Indonesia (from Directorate of Oil and Gas, pers. comm., 1977)

<table>
<thead>
<tr>
<th>Location of field</th>
<th>&quot;Wet&quot; Gas (BSCF)</th>
<th>&quot;Dry&quot; Gas (BSCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>North Sumatra</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pertamina Unit 1</td>
<td>375</td>
<td>113</td>
</tr>
<tr>
<td>Mobil Oil</td>
<td>---</td>
<td>10,417</td>
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<tr>
<td>Asamena</td>
<td>113</td>
<td>---</td>
</tr>
<tr>
<td><strong>South Sumatra</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pertamina Unit 2</td>
<td>346</td>
<td>300</td>
</tr>
<tr>
<td>Caltex</td>
<td>52</td>
<td>116</td>
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<tr>
<td>Stanvac</td>
<td>105</td>
<td>359</td>
</tr>
<tr>
<td><strong>West Java</strong></td>
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</tr>
<tr>
<td>Pertamina Unit 3</td>
<td>170</td>
<td>82</td>
</tr>
<tr>
<td>Iiapco</td>
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<tr>
<td>Arco</td>
<td>539</td>
<td>1,069</td>
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<td><strong>East Java</strong></td>
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<td></td>
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<td>Lemigas</td>
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<td>22</td>
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<td>Cities Service</td>
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<td><strong>East Kalimantan</strong></td>
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<td>Union Oil</td>
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<tr>
<td>Total Indonesia</td>
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<td>Huffco</td>
<td>48</td>
<td>6,261</td>
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<tr>
<td>Tesoro</td>
<td>38</td>
<td>---</td>
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<tr>
<td><strong>Irian Jaya</strong></td>
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<td></td>
</tr>
<tr>
<td>Phillips</td>
<td>22</td>
<td>205</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agip (offshore South China Sea)</td>
<td>---</td>
<td>29,000</td>
</tr>
<tr>
<td>Different fields</td>
<td>---</td>
<td>3,000</td>
</tr>
<tr>
<td>Total Indonesia</td>
<td>4,909</td>
<td>51,176</td>
</tr>
<tr>
<td>Total Indonesia, Agip excluded</td>
<td>4,909</td>
<td>22,176</td>
</tr>
</tbody>
</table>

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Fig. 1 Important gas fields of Indonesia
Nitrogenous Fertilizer

Considering the importance of the agricultural sector, it was logical that Indonesia developed its domestic fertilizer industry. Production increases over the past decade of nitrogenous fertilizer have been quite spectacular. While production of urea in 1971 amounted to 104,750 metric tons, production in 1978 exceeded 2,200,000 metric tons, of which approximately 500,000 metric tons were exported.

It is expected that within the next 2 to 4 years, the Association of Southeast Asian Nations (ASEAN) fertilizer plant will start producing an additional 570,000 metric tons annually. As far as the feed stock for the fertilizer industry is concerned, Indonesia can boast substantial reserves of natural gas. Table 1 lists the location and the size of these occurrences. The figures in Table 1 are in some cases on the conservative side. The Mobil Oil deposit in North Sumatra (the Arun field) might have a reserve of 28,000 BSCF while the Huffco deposit in East Kalimantan (the Badak field) might have reserves up to 7,500 BSCF.

Although there seems to be adequate reserves of natural gas, competition for its use has increased. Table 2 shows the consumption pattern of natural gas production in Indonesia.

Table 2. Use of natural gas in Indonesia in 1970 and 1976

<table>
<thead>
<tr>
<th>Use (percent)</th>
<th>1970</th>
<th>1976</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used by producer</td>
<td>32.98</td>
<td>32.43</td>
</tr>
<tr>
<td>Carbon black and LPG</td>
<td>3.45</td>
<td>1.01</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>4.57</td>
<td>4.52</td>
</tr>
<tr>
<td>Other uses</td>
<td>0.03</td>
<td>2.45</td>
</tr>
<tr>
<td>Flared</td>
<td>58.97</td>
<td>59.59</td>
</tr>
<tr>
<td>Production (MMSCF)</td>
<td>108,561</td>
<td>312,603</td>
</tr>
<tr>
<td>Fertilizer production</td>
<td>98.4</td>
<td>365.3</td>
</tr>
</tbody>
</table>

Although this competition does not seem obvious from the available data shown in Table 2, one should bear in mind that since 1976, fertilizer production has increased six fold. This competition is very much dependent on the proximity of consumers. In the West Java region, city gas, the fertilizer industry, electricity generation and heavy industries (iron and steel and cement) are competing for limited resources. Figure 1 indicates the locations of the more important gas provinces. Although, like oil, natural gas is mainly produced in the back-arc basins, exploratory wells have indicated the occurrence of hydrocarbons in the interarc basins of the Sunda Arc System. The Union Oil well Meulaboh, drilled in 1970, which tested 7.0 million standard cubic feet per day (MMSCFPD), is considered encouraging as it indicated the possibility of a new natural gas province.
Phosphate Fertilizer

As has been the case with nitrogenous fertilizer, the demand for phosphate fertilizer in Indonesia has risen dramatically over the past decade. Import of these fertilizers amounted to 37,500 metric tons in 1972, and this figure rose to 320,945 metric tons in 1975. A phosphate fertilizer plant is in the final stages of construction, its design capacity being 330,000 metric tons triple super phosphate (TSP), 80,000 metric tons diammonium phosphate (DAP), and 50,000 metric tons compound fertilizer (NPK) annually. All raw materials for this plant will be imported.

Domestic production of phosphate rock consists solely of cave phosphate, of which 7,600 metric tons were mined in 1976. This phosphate is usually sold in a ground form to plantations.

Phosphate-bearing sediments (marine phosphorites) are known from at least two areas, East Java and Irian Jaya. The East Java deposit contains horizons of nodules and concretions in which the P$_2$O$_5$ content of the sediments is variable. Until now, no deposits of any interest have been located.

Potash Fertilizer

Data on imports of potash fertilizer are scarce. In 1974 imports of NPK amounted to 86,077 metric tons. No potash deposits are known from Indonesia, although some evaporites do occur in the Bird's Head of Irian Jaya, in the basal Tertiary of the Salawati oil basin. Evaporites are also known to occur in the Gulf of Thailand, and some of the formations may extend to the Indonesian continental shelf in the South China Sea. Leucite-bearing volcanic rocks have been mentioned as a possible source for potash. They occur in the back-arc region of the Sunda Arc. The K$_2$O content of the Indonesian volcanic rocks in this suite averages 6 percent, with a maximum value of 9.5 percent. The 6 percent of potash oxide would correspond with a 28 percent of leucite content. Figure 2 indicates the occurrences of leucite-bearing rocks and evaporites as is known from well data.
Fig. 2 Leucite-bearing rock occurrences in Indonesia.
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Phosphate Rock


A BRIEF SUMMARY ON THE ALUNITE DEPOSITS

IN SOUTH KOREA

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Hi Soo Moon*
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Jeonranamdo and Gyeongsangnamdo are known alunite provinces in South Korea. In the past, Kim (1970), Park (1974), and Cho and Moon (1974, 1975) surveyed the alunite deposits as part of an exploration project for fertilizer and alumina raw materials that was sponsored by the government of the Republic of Korea.

The purpose of investigating ways of utilizing alunite as fertilizer raw materials was to examine alumina and potassium sulfate production from alunite by the potassium alum process. The tests were conducted by the Korea Research Institute of Geoscience and Mineral Resources (KIGAM) in 1978. The experimental results pointed out that recovery efficiency was very high. By weight, 90 percent of alumina and 85 to 89 percent of potassium values are recovered from the alunite ore but the economical value is still uncertain. A feasibility study on establishing more practical data for alumina and on determining the economics of potassium sulfate production as a by-product will be conducted.

The geological setting of the alunite province is mainly volcanic and sedimentary rocks of volcanic origin. Tuff, andesite, porphyrite, rhyolite, and other volcanic rocks of Cretaceous age represent different episodes of volcanic activity during the Cretaceous period.

The main area of nonmarine deposition of Cretaceous strata on the South Korean peninsula is known as Gyeongsang Basin. The Gyeongsang System of Cretaceous age in this region unconformably overlies a basement which in parts is the Ryeongnam Massif of Precambrian age. The same Cretaceous rocks were scattered over the Jeonman area, an area not directly connected to the main basin. The Gyeongsang System is divided into two series, the Bulgugsa and Silla Series. The Bulgugsa Series rests unconformably upon the Silla Series.

In the above two series, alunites are scattered within the intermediate and acidic tuff layers. The dominant host rocks are subaerially deposited rhyolitic tuff, andesitic tuff and breccia. These deposits appear as layered deposits that have a limited vertical extent. The dips of the bedding of the tuffaceous rocks are gentle, resulting in good stratigraphic control. Although a lateral mineral assemblage cannot be clearly distinguished in all deposits,

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the general distribution of alteration zones suggests that all these deposits have some type of alteration such as silicification and kaolinitization, as well as alunite and pyrophyllite zones.

Alunite deposits are usually aggregates of small alunite granules, kaolinitic clay, and chalcedonic silica. Some deposits contain dumortierite and jarosite as minor accessory minerals. Pyrite is particularly common in the alteration zones. In surficial parts it is oxidized to jarosite or hematite. All the alunite deposits in Korea are considered to be formed by low-temperature hydrothermal alteration of tuffaceous rocks. By drilling, alunite reserves of four major deposits in Korea (see map) are estimated to be 37,412,000 metric tons containing 18 to 25 percent of Al₂O₃ and 3 to 5 percent K₂O.

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Distribution map of Alunite Deposits in South Korea.
INTRODUCTION

Malaysia, being essentially an agricultural country, needs an ever increasing amount of fertilizers to improve crop yields. Currently, all requirements of potash and nearly all of phosphate are met by imports. Part of the nitrogen fertilizer requirement is locally produced. The only known source of fertilizer is guano which is exploited on a small scale in some of the states.

Neither phosphorite nor potash is known to occur in Malaysia. However, no thorough prospecting has been carried out for either type of mineral ore. With better knowledge of phosphate and potash geology, there is a greater likelihood of finding phosphate and potash occurrences in the country.

Natural gas deposits either associated or not associated with oil occur in the South China Sea (See Figure).

GUANO OCCURRENCES

Guano occurs in most of the limestone caves (See Figure and Table 1). The $\text{P}_2\text{O}_5$ content of the guano ranges from 10 to 30 percent. In Peninsular Malaysia, guano is exploited as a cottage industry in the states of Kedah, Kelantan, Pahang, and Perlis. The guano is obtained from the cave floor by hand labor. It is placed in sacks and sold without drying or beneficiation. The guano is mainly used by farmers in rice nurseries to promote the growth of rice seedlings.

In Sarawak, the guano reserves from Niah Caves are estimated to be 28,200 long tons (Wilford, 1951). The guano deposits originate chiefly from the accumulation of bat and swift droppings and remains of insects which lived in them. The deposits are of two types. The first type is called guano which is a soft, moist, friable, dark brown substance which gives off ammonia. It has the consistency of wet sawdust and contains chitinous insect remains and a black clay-like substance. The second type is called "fossil" guano and rock phosphate which underlies the first type and overlies the limestone bedrock. The surface guano contains about 5 percent of nitrogen and 4.5 percent of $\text{P}_2\text{O}_5$. The "fossil" guano and rock phosphate contain an average of 23 percent of $\text{P}_2\text{O}_5$. The guano from Niah caves has been exploited since 1928.

*Senior Geologist, Industrial Minerals Division, Malaysia Geological Survey, Perak, Malaysia
Figure 1. Location of Guano and natural gas occurrences in Malaysia
Table 1. Locations of guano occurrences in Malaysia

<table>
<thead>
<tr>
<th>AREA</th>
<th>LONGITUDE (in degrees East)</th>
<th>LATITUDE (in degrees North)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Peninsular Malaysia</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chuping</td>
<td>100°13'</td>
<td>6°28'</td>
</tr>
<tr>
<td>Bt. Baling</td>
<td>100°55'</td>
<td>5°40½'</td>
</tr>
<tr>
<td>Dalam Wang</td>
<td>101°53'</td>
<td>6°12'</td>
</tr>
<tr>
<td>Gunong Keriang</td>
<td>100°20½'</td>
<td>6°12'</td>
</tr>
<tr>
<td>Kota Jin</td>
<td>102°29'</td>
<td>3°53'</td>
</tr>
<tr>
<td>Gua Setir</td>
<td>101°55½'</td>
<td>5°40'</td>
</tr>
<tr>
<td>Gua Musang</td>
<td>101°54½'</td>
<td>4°53'</td>
</tr>
<tr>
<td><strong>Sabah</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Batu Sapad</td>
<td>118°10'</td>
<td>4°42½'</td>
</tr>
<tr>
<td>Madai</td>
<td>118°9'</td>
<td>4°43½'</td>
</tr>
<tr>
<td>Baturong</td>
<td>118°00'</td>
<td>4°43'</td>
</tr>
<tr>
<td>Siput</td>
<td>118°20'</td>
<td>4°35'</td>
</tr>
<tr>
<td>Tempadong</td>
<td>118°9'</td>
<td>5°51'</td>
</tr>
<tr>
<td>Gomantong</td>
<td>118°04'</td>
<td>5°31'</td>
</tr>
<tr>
<td>Lian</td>
<td>116°11'</td>
<td>5°29'</td>
</tr>
<tr>
<td>Punan Batu</td>
<td>116°12'</td>
<td>4°48'</td>
</tr>
<tr>
<td><strong>Sarawak</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melinau</td>
<td>114°46½'</td>
<td>4°02'</td>
</tr>
<tr>
<td>Niah</td>
<td>113°49'</td>
<td>3°48'</td>
</tr>
<tr>
<td>Selabor</td>
<td>110°27½'</td>
<td>0°55'</td>
</tr>
<tr>
<td>Sta'at</td>
<td>110°10'</td>
<td>1°25'</td>
</tr>
<tr>
<td>Bidi</td>
<td>110°5'</td>
<td>1°21'</td>
</tr>
</tbody>
</table>
Guano is found in caves elsewhere in Sarawak. The reserves are not known and most of them have not been exploited.

In Sabah, about 20,500 long tons of guano occur in the two caves of Madai (Fitch, 1955) and Gomantong (Haile and Wong, 1965). Guano also occurs in at least six other caves, but their reserves are not known. None of the deposits in Sabah has been developed. Most of the guano deposits are found in caves where edible bird nests are collected. These caves are privately owned and the owners do not allow mining of the guano for fear of upsetting the collection of bird nests.

NATURAL GAS OCCURRENCES

The gas reserves as given by Petronas, the National Petroleum Corporation of Malaysia, are shown in Table 2. Some of the associated gas from Sarawak is being piped to land for domestic and minor industrial use. The associated gas from Sabah and Peninsular Malaysia is not being utilized, though there are plans to use it for industries.

Table 2. Gas reserves of Malaysia (from Mohammad Ayob, written comm.)

<table>
<thead>
<tr>
<th>AREA</th>
<th>NON-ASSOCIATED GAS (trillion cu ft)</th>
<th>ASSOCIATED GAS (trillion cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sabah</td>
<td>0.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Sarawak</td>
<td>14.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Peninsular Malaysia</td>
<td>6.6</td>
<td>2.3</td>
</tr>
</tbody>
</table>

The bulk of the non-associated gas occurs in the Central Luconia gas fields in Sarawak. Most of it will be piped to the liquified natural gas (LNG) plant which is being set up in Bintulu, Sarawak. According to a news report, the Association of Southeast Asian Nations (ASEAN) nations have agreed to set up a urea plant as a joint venture project near the LNG complex in Bintulu. The plant is planned for a daily production of 1,300 tons of urea. The project is scheduled for completion in 1983.

POTENTIAL OCCURRENCE OF PHOSPHORITE

As the country is being progressively mapped, its geology and stratigraphy are becoming better known. Some of the areas which appear favorable for phosphorite deposition warrant detailed studies using modern prospecting techniques based on exploration elsewhere. Areas underlain by the following formations deserve attention.
Machinchang Formation.—The Formation is made up of shallow marine clastics of Late Cambrian age which are overlain conformably by a thick shelf limestone of Ordovician to Silurian age (Jones, 1913). It can be divided into three units, viz., a basal unit of interbedded subgreywacke and argillite (1080 m); a middle unit of thickly current-bedded sandstone, minor conglomerate and mudstone (900 m); and a top unit of "passage beds" consisting of sandstone, shale and limestone (30 m).

Mahang Formation.—Mahang Formation was mapped and interpreted by Burton (1967) as an euxinic facies. The rocks were initially deposited under open platform and shelf conditions and later in an environment of restricted circulation. The age of the rocks range from Late Ordovician to Early Devonian. The rocks consist mainly of carbonaceous shale with minor amounts of sandstone, chert and limestone. The association of black shale and chert may be significant in the search for phosphorite in the area.

Karak Formation.—The Karak Formation with its type area to the east of Kuala Lumpur and the Main Range granite in Peninsular Malaysia is at least of Late Devonian age (Jaafar, 1976). The formation consists mainly of argillite with minor amounts of conglomerate, sandstone, chert, and greywacke. Tuff and limestone occur in the upper part of the unit. This formation also has an associated black shale and chert.

POTENTIAL OCCURRENCE OF POTASH

The Late Triassic orogeny in Peninsular Malaysia produced a few lagoonal or barred basins in the central part of the country. The rocks commonly referred to as the Tembeling Formation (Koopmans, 1968) were deposited in Late Triassic time under marine conditions and in Jurassic to Early Cretaceous time under nonmarine conditions. The rocks consist of red polymictic conglomerate, massive sandstone, and red shale. In places, thin lenses of fresh water limestone occur at the top of the succession (H.P. Khoo, personal comm.).

Although no evidence of evaporite or potash has been found, the rocks are lithologically similar to the Khorat Group (Kulasang, 1975) in Thailand where rock salt and gypsum have been found.

SUMMARY

To date, phosphorite and potash have not been found in Malaysia, though there are favorable lithologic associations for their occurrences. Associated and non-associated gas deposits occur in the offshore areas. Only some of the associated gas is currently being used. There is an ASEAN joint venture project for urea which is scheduled for completion by 1983.
ACKNOWLEDGEMENTS

I wish to thank Dr. Mohammad Ayob of Petronas for information on the gas occurrences and my colleague, Mr. Lim Peng Siong, for information on the guano reserves of Sabah.

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OCCURRENCES OF PHOSPHATIC ROCKS IN NEPAL

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J. M. Tater
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ABSTRACT

The geological setting of Nepal Himalaya suggests that the Midland, Kathmandu, and Tethys Groups of rocks have had miogeosynclinal-type sedimentation during early Paleozoic time. The Midland Group is more extensive compared to the latter two and, because of its easier accessibility, has been investigated for phosphorite near the carbonate sequence at its southern margin with the Main Boundary Thrust. Phosphatic rocks were found in a zone of shale-dolomite-cherty limestone, generally underlain and overlain by argillites and (or) quartzites. Chemical analyses of a large number of samples have indicated a low $P_{2}O_{5}$ content, being generally less than 1 percent and occasionally about 5 percent.

INTRODUCTION

Large sections of the Himalayan Mountain Chain, extending for about 2500 km, have been covered by various geological and geophysical studies. The Nepal Himalaya, which lies in the central part of the Chain and spans a length of over 800 km, has primarily been investigated by field mapping. The search for phosphatic rocks in Nepal began in 1966 when Dr. Richard P. Sheldon of the U. S. Geological Survey studied some of the field outcrops in the western and far-western parts of the country and looked at available information in unpublished reports. He suggested that some of the lithological settings could be attributed to miogeosynclinal conditions, and therefore warranted a search for sedimentary phosphatic rocks. On his advice, the Department of Nepal Geological Survey (presently the Department of Mines and Geology) began investigations in selected areas. In 1970, the Department asked Dr. Y. Kazitsin of the U.S.S.R. to investigate the possible presence of phosphorite in eastern Nepal where occurrences of Paleozoic ostracods have been reported on the basis of departmental regional mapping. Kazitsin's findings established the presence of low-grade phosphatic layers between Takure and Barahkshetra in eastern Nepal. In some of the nodules embedded in the shaly rock, the $P_{2}O_{5}$ content was as high as 30 percent, but the phosphatic layers were found to be thin and erratic. The trend of these occurrences was almost WNW-ESE, parallel to the Main Boundary Thrust. In subsequent years, search continued along that extension, but the $P_{2}O_{5}$ content was found to be generally low or nil.

In the meantime, more regional geological mapping work in different parts of the country were completed. Existence of various rock types such as low- and high-grade metamorphic rocks, marine and continental sedimentary

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deposits, mafic to silica-rich igneous rocks, have been established. Some of the rocks included diverse invertebrate fossils as well as some plants and vertebrate fossils. But generally, the lithologic units were poor to barren in fossil content and have undergone complex tectonic movements. A study has been taken up by the Department of Mines and Geology to identify possible horizons of phosphatic rocks on the basis of available field and laboratory information.

Geological Setting

Six lithostratigraphic units span the geological time scale from Precambrian to Recent. The oldest of these, the Himal Group, is considered to be Precambrian in age. The Group is composed of highly metamorphosed rocks such as gneisses and schists, with feldspathization in places. The lower parts of the Kathmandu and Midland Groups are late Precambrian, with their remaining thicknesses made up of lower Paleozoic rocks. The Kathmandu Group has identifiable invertebrate index fossils, but the Midland Group has very poor fossil preservation on account of its tectonic setting. It has been assigned a late Precambrian to Devonian age. The Tethys Group, largely consisting of marine argillaceous and carbonate sediments, ranges in age from middle Paleozoic to the end of the Mesozoic. The Group has good preservation of such fossils as graptolites, brachiopods, and ammonites and has a number of datable marker horizons. The Surkhet Group occupies a narrow zone mostly in the western Nepal region and is considered to be Late Jurassic to middle Paleogene in age. It has an angular unconformity at its base and generally consists of shales and limestones. The Siwalik Group is made up of fluvialite deposits that were carried by high velocity rivers subsequent to the final phase of the main Himalayan orogeny. The Group ranges from middle Paleogene to early Quaternary in age and consists mainly of shales and sandstones. Besides the above groups, granites, paragranites and partly metamorphosed basic igneous rocks are present in various parts. The alluvium of the Terai area, valley deposits, and river terraces were deposited and formed in Recent times.

The Himalayan orogeny involved considerable shortening of the crust in which rocks were deformed and modified in the process. The possible relationships of the rocks to the north and south of the Himalayas have been studied by many investigators. In recent years, considerable information has been made available because of subsurface studies in India. South of the sub-Himalaya, five basins have been recognized, and their demarcation is based on the intervening basement ridges (Fig. 1). These basins are (from west to east): the Indus Basin, the Punjab Basin, the Ganga Basin, the Bengal Basin, and the Brahmaputra Basin. Though the basement in the Indus Basin has a large cover of Mesozoic and Cenozoic sediments, the basement in the Ganga Basin is directly overlain by the Middle Siwalik rocks. In the case of the Punjab Basin, the possibility of an intervening zone of pre-Cenozoic sediments has been considered. To the east, the presence of Mesozoic and Cenozoic sedimentary rocks, including Jurassic Rajmahal Traps and Miocene sediments, have been reported in the Bengal Basin (Sengupta, 1966). Further to the east in the Brahmaputra Basin, Karunakaran and Ranga Rao (1976) suggested the presence of Gondwana rocks beneath the Neogene sediments. As a whole, the subsurface stratigraphy to the south of the Himalayas indicates
Fig. 1 Geological cross-sections through the Indo-Gangetic plains (after Rao, 1973).
that the basement was overlain by rocks ranging in age from Precambrian to Miocene, and that the stratigraphic hiatus met in drill holes could be attributed to the local nondeposition or erosion.

A belt of flysch sediments ranging in age from Triassic to Paleocene and mixed with oceanic crustal material such as volcanics, melanges and ultrabasic slabs, crops out beyond the northern border of Nepal, north of the Tethyan rocks (Gansser, 1978). The belt is highly tectonized and has been referred to as Suture Zone. The Zone extends for almost the entire length of the Alpine-Himalayan mountain chain, spanning a distance of over 2500 km. Considered to be a major structural element, it is not a continuous feature, and there usually occurs parallel to subparallel ophiolite-bearing belts north of the main Suture Zone. The evolution of the Zone reflects the relative motions of large lithospheric plates such as the Indian Plate and complex microplates to the north. A comparison of the behavior of the regions to the south and north of the Suture Zone indicates that the Tibetan area north of the Himalayas behaved in a completely different manner from the Indian Shield mass to the south (Gansser, 1979).

**Stratigraphy**

The six lithostratigraphic units (Tater, et al., 1977) follow the general trend of the Himalayas. Some of them extend over almost the entire length of Nepal. These units have formally been called groups, and they incorporate the corresponding series, formations, nappes, etc., of earlier workers.

**Siwalik Group.**—The Siwalik Group includes all rocks formerly called Siwalik of middle Miocene to early Pleistocene age. The Group extends over the entire length of Nepal and has longitudinal extension to the east as well as to the west where it has been referred to as Siwalik rocks. A three-fold division of the Siwalik rocks has been attempted, and the use of the terms, Lower Siwalik Group, Middle Siwalik Group and Upper Siwalik Group, has been established. In the Surkhet area, the Middle Siwaliks are divided into two subunits (Tater, et al., 1977): Upper Middle Siwalik ($MS_2^U$) and Lower Middle Siwalik ($MS_1^L$). The lithology of the Siwaliks is as follows:

- **Upper Siwalik (US):** Coarse, boulder conglomerates with irregular bands and lenses of sandstone and thin intercalations of yellow, brown, and grey sandy clays. Upper contact fault bounded. Thickness: 1500 m to 3000 m.

- **Upper Middle Siwalik ($MS_2^U$):** Fine- to medium-grained, arkosic pebbly sandstones with lesser amounts of grey to dark-grey clays and occasionally silty sandstones and pebble conglomerates. Thickness: 600 m to 1500 m.

- **Lower Middle Siwalik ($MS_1^L$):** Medium- to coarse-grained, friable arkosic sandstones and fine- to medium-grained, hard, massive grey shales, and thin sands of pseudoconglomerates and claystones. Plant and animal fossils present in clays and shales. Thickness: 2000 m to 3000 m.
Lower Siwalik (LS): Fine-grained, hard grey sandstones interbedded with purple-red, evenly chocolate-colored shales, nodular maroon clays, pseudoconglomerates, and clayey shales. Plant fossils are present in shales. Lower contact fault bounded. Thickness: 1800 m to 3300 m.

Surkhet Group.--The Surkhet Group is identifiable in southwestern Nepal as a narrow strip running parallel to the Main Boundary Thrust. In its eastern continuation it crops out discontinuously for about 70 km. The Group invariably overlies the Precambrian Lakharpata Limestone with an angular unconformity along the Main Boundary Thrust, except at its westernmost extension where it lies directly on the Siwaliks. The top of the Group is faulted along the Ranimata Thrust which brings it in direct contact with the older Midland Group. In the area where the type section was defined, the Surkhet Group was divided into the Suntar Khola Formation and Swat Khola Formation (Tater, et al., 1977):

Suntar Khola Formation (Sn. F.): Fine- to medium-grained, greenish-grey to grey sandstones and purple shales with intercalations of green splintery shales. Thickness: 200 m to 1500 m.

Swat Khola Formation (Sw. F.): Grey to dark grey, carbonaceous, crumpled shales with bands and lenses of fine-grained fossiliferous limestones (Nummulites sp., Assilina sp., etc.); ferrugenous quartzites at the base. Thickness: 120 m to 750 m.

Tethys Group.--This Group consists of limestones, dolomites, shales, sandstones, conglomerates, and minor slates and low-grade crystalline schists. It overlies a rather complex crystalline basement which is bounded further down by the Main Central Thrust. The stratigraphy of the Group is well known, and in Nepal it extends from Cambrian to Cretaceous in age. Well-preserved remains of trilobites, graptolites, brachiopods, corals, crinoids, and ammonites are present and have been studied by many paleontologists, particularly by Waterhouse (1978). The Group consists of platform-type deposits (miogeosynclinal) with a general thickening northwards (eugeosynclinal). In Nepal, the rocks of the Group were confined to the Mustang and Langu Basin which were structurally bounded.

Kathmandu Group.--The Kathmandu Group outcrops in the shape of a large spoon in central Nepal. It has been subdivided into an upper carbonate subgroup and a lower clastic subgroup. The upper subgroup has been assigned an age of middle Paleozoic, more specifically Ordovician to early Devonian age. It consists of a lower calcareous facies (Chandragiri Limestone), a middle arenaceous facies (Chitlang Formation), and an upper calcareous facies (Godavari Limestone). The lower clastic subgroup has been assumed to be of late Precambrian to Cambrian age and consists of fine- to medium-grained grey sandstones and quartzites with intercalations of calcareous phyllites and sandstones, argillaceous limestones, sericitic and black phyllites, and shales. The Group overlies the Suparitar Series or the older tectonically disposed Bhimphedi Series (or their equivalents) of the Midland Group. The contact is assumed to be a thrust fault; however, Arita, et al. (1973) consider it an unconformity. At some places along the southern margin, it overlies the Siwaliks in direct contact with the Main Boundary Thrust. In
the central parts, the Group is overlain by the Pleistocene lake sediments of the Kathmandu Valley.

Other stratigraphic names associated with the name Kathmandu are also in use, such as Kathmandu Nappe and Kathmandu Complex. However, they are considered entirely different from the Group described above. Unlike other Kathmandu groupings, the Kathmandu Group does not include the schists and gneisses of central Nepal.

**Midland Group.**—The Midland Group consists of phyllites and quartzites of different hues, garnetiferous schists and gneisses, stromatolite-bearing dolomitic limestones, slates, and grayish-white to pink limestones and marbles. The Group, though nearly unfossiliferous, has been assigned a Precambrian to middle Paleozoic age, and has the widest outcrop compared to other lithological groups in Nepal. It is tectonically complex; younger formations have often been repeatedly overthrust by older rocks. Major lithological units, the Bhimphedi Series and Suparitar Series, and the Kathmandu Nappe and Nuwakot Nappe, are part of this Group. As a rule, rocks having a higher grade of metamorphism have been assigned a lower stratigraphic position. In eastern Nepal, recovery of broken tests of ostracods with lower Paleozoic affinities from a grey argillaceous dolomite (Tater, 1968) was very suggestive of the continuation of the Midland Group into middle Paleozoic time. However, the occurrence of coaly or carbonaceous matter in some of the layers is indicative of a possible Gondwana age for some of these units (Auden, 1965; Tater, 1968). Recently, Bashyal (1978) recorded the presence of such plant fossils as *Schizoneura gondwanesis* Feistm and *Glossopteris indica* Schimp in a one-meter thick coaly bed in black quartzite. The plant fossils are known as Damuda flora in Indian geology and have been assigned a Permian age. It may therefore be reasonable to assume that the Midland Group has a larger time span in eastern Nepal, or conversely, a separate, overlying stratigraphic unit needs to be identified formally. Many of the phosphorite occurrences described later in this paper belong to the rocks with Gondwana affinities (Barahkestra Formation of Bashyal, 1978).

**Himal Group.**—The Himal Group occupies large areas in the central and northern regions of the country and extends through the entire length of the country. It consists mainly of banded kyanite, garnet-mica and sillimanite-mica gneisses, calc-silicate rocks, quartzites, schists, marbles, and amphibolites. Migmatites and augen structures also occur frequently. Field workers have often subdivided the Group into two units; the lower crystalline unit consisting mainly of gneisses and migmatites with augen structures and the upper crystalline unit consisting mainly of quartzites, schists, phyllites, and amphibolites. This subdivision is not necessarily true for the entire country. The equivalent names to the east in India are Darjeeling Gneisses and Daling Schists in the Darjeeling region and Slang Group and Sela Group in the Arunachal Pradesh region. To the west of Nepal, the equivalents are Vaikrita Group and Martoli Formation in the Garhwal-Kumaon region of India.
The Himal Group is overlain by the Tethys Group to the north, and its base is identified as the Main Central Thrust. In most places the Thrust fault is not conspicuous and in fact appears as a zone whose thickness varies from zero to a few thousand meters. The zone consists mainly of mica phyllitic schists, green schists, green and black phyllites, garnet-mica-chlorite phyllitic schists often bearing rotated garnet porphyroblasts, quartzites and minor amphibolites. Occasional occurrences of graphitic phyllite and mylonitic augen gneiss is a special characteristic of the zone; the augen gneiss is strongly sheared and intensely foliated with flaky biotite and muscovite.

Phosphorite Occurrences

The investigated phosphorite occurrences are primarily localized in eastern Nepal along the southern boundary of the Midland Group close to the Main Boundary Thrust (Fig. 2). They extend over a distance of about 160 km, and lie on either side of Barahkshetra, a village located along the Sun Kosi River. The Main Boundary Thrust passes just north of this village. The phosphorite occurrences to the east of Barahkshetra extend up to Takure, a distance of about 30 km, and those to the west of Barahkshetra extend up to Tangsar, a distance of about 130 km. The occurrences of Barahkshetra-Takure region have been more intensively studied since they were first discovered. The low-grade phosphorites were generally found in or along the subunits b and c of Sanguri Formation (Tater, 1968). A more or less regular belt, 10 to 30 meters thick, of clastic and carbonate rocks such as black shale, limestone, chert, and marl is recognizable. The belt is a part of the margins of the southern position of the Paleozoic basin. It has been observed by systematic chemical analyses that the phosphate-bearing rocks of the belt are not consistent in their \( \frac{P_2O_5}{W} \) content, occasionally reaching 5 percent but seldom more than that. There are marked lithological variations as well, and intraformational conglomeratic bodies have also been seen (Singh, 1970).

**Barahkshetra area.**—Four horizons of phosphorite rocks are present in this area. The lowest horizon (H-1) consists of quartzitic sandstone and sandy shale; the shale has lenticles of siderite and shows a weak phosphatic concentration (\( \frac{P_2O_5}{W} \) is less than 1 percent). The next horizon (H-2) consists of carbonaceous phyllite, cherty dolomite, bituminous shale, and quartzite. The chemical analyses showed a \( \frac{P_2O_5}{W} \) content as high as 3 percent in some of the samples from this horizon. Horizon H-1 is about 45 m and H-2 is about 20 m thick. H-2 is overlain by a 2-m thick conglomerate unit and is then followed by horizon H-3 that consists of pink to chocolate-brown dolomite, chert, shale with sheared bodies of bituminous shale, and quartzite. H-3 has a variably low \( \frac{P_2O_5}{W} \) concentration; its highest percentage value falling about 5 percent. H-3 is also overlain by conglomerate, about 3 m thick, which is then followed by the 45- to 50-m section of the H-4 horizon. H-4 consists of purple to violet clay, marl, chert, black shale with sheared bodies of bituminous shale, and quartzite. In H-4, like H-3, the \( \frac{P_2O_5}{W} \) percentage does not exceed five. Higher in the stratigraphic section, H-4 is overlain by quartzites and argillites.
Figure 2. Locations of phosphorite occurrences in Nepal
Barahkshetra-Tangsar region.—The Barahkshetra region extends over a distance of about 130 km between the villages of Barahkshetra and Tangsar, and lies north of the Main Boundary Thrust. The formation immediately to the north of the Main Boundary Thrust consists of siliceous white to dark-grey dolomite, with layers of greenish quartzitic sandstone, white quartzite, and green to purple-colored shales. It has no formal formation name but is persistent throughout the region (Bashyal, 1973). Generally, the outcrop is thicker (thickness up to 600 m) in the eastern part of the region and thins down to a constant thickness of 100 m in most of the western part. This variation in thickness can be attributed to the Main Boundary Thrust. To the north of this formation, argillites with lesser amounts of dolomite, carbonaceous phyllite, and cherty limestone crop out along the length of the region. The thickness of the argillites attains a maximum of 200 m, but it is generally variable because of folding. The carbonaceous and calcareous rocks are particularly frequent at its base, in contact with the previously described siliceous dolomite. The phosphorite occurrences are located along this basal part. The argillites are overlain by garnetiferous quartz-mica schists throughout the region.

Phosphorite occurrences crop out along the contact between the siliceous dolomite and argillites of the Midland Group. Individual occurrences have been traced over 4 km along the contact. The \( \text{P}_2\text{O}_5 \) content is generally less than 1 percent though occasionally it has been greater than 5 percent. The zone bearing the phosphatic rocks is about 30 m thick and is fairly persistent throughout the region. It contains layers of argillites interbedded with irregular beds and lenses of carbonaceous shale, dolomite, cherty limestone, quartzite, and chloritic phyllite. A slight degree of metamorphism in the phosphate rock-bearing zone can be discerned; the zone commonly has shales and sandstones in the eastern part of the region while chloritic phyllite is more common in the western part. The \( \text{P}_2\text{O}_5 \) content is less than 1 percent for most of the channel samples examined to a depth of 1.5 m. In the western part, the presence of phosphatic nodules with up to 6.38 percent of \( \text{P}_2\text{O}_5 \) has also been recorded.

Other regions.—Investigations for phosphatic rocks elsewhere in Nepal have also been carried out in the formations that crop out close to the Main Boundary Thrust. However, to the west of Tangsar the \( \text{P}_2\text{O}_5 \) content of the rocks has been extremely poor. In isolated cases, \( \text{P}_2\text{O}_5 \) up to 1 percent have been recorded. A few occurrences in the rocks of the Surkhet Group were found north of Dang and in Khulia Khola northwest of Chisapani in western Nepal. These occurrences were in Eocene shales and carbonates and were generally poor in \( \text{P}_2\text{O}_5 \) content, though over 4.5 percent \( \text{P}_2\text{O}_5 \) was reported from Khulia Khola. Kazitsin (1970) recorded the occasional presence of phosphatic concentrations in some of the shales and sandstones of the Siwalik Group in central Nepal. These concentrations never exceeded 1 percent of \( \text{P}_2\text{O}_5 \), and were generally present in rocks that cropped out within a distance of 30 m south of the Main Boundary Thrust.
In more recent work, Bashyal (1978) advanced support for establishing a separate formation by the name of Barahkshetra Formation. He assigned it a Permo-Carboniferous age on the basis of such Gondwana flora as *Schizoneura gondwanensis* Feistm and *Glossopteris indica* Schimp. Though these flora were not identified in the Barahkshetra region but rather in the Takure area which is about 30 km to the east, formational continuity has been observed in the field. The base of the proposed Barahkshetra Formation consists of sandstone that includes debris of pre-existing volcanic rocks. X-ray analyses of this debris show the presence of alpha quartz, microcline, orthoclase, ankerite, ilmenite, and chlorite. The absence of albite suggests that the debris was derived from calc-alkaline trachyte-type volcanic rock (Bashyal, 1978). The Barahkshetra Formation thus includes subunits b and c of the Sanguri Formation and the phosphate-bearing rocks (H-1 to H-4). Chemical analyses of field samples taken from H-1, H-3, and H-4 showing the distribution of major elements and trace elements are given in Table 1.

**Takure region.**—A 10- to 15-m thick phosphate rock-bearing formation crops out over a distance of about 1600 m. The formation consists of shale, calcareous shale, chert, and glauconitic sandstone. The P\textsubscript{2}O\textsubscript{5} percentage generally falls between 1 and 2, and in a few isolated cases, may range up to 20 percent of P\textsubscript{2}O\textsubscript{5} (Kayastha, 1971). The phosphorite horizon is localized between the overlying dolomite and the underlying quartzite. The Main Boundary Thrust nearby occasionally cuts off the dolomite and quartzite causing discontinuity in outcrop pattern of the phosphorite horizon. A lithologic description of the region is given below.

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Thickness (in meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biotite schist, grey to greyish-white, medium-grained; often massive and impregnated with porphyroblastic grains of quartz and feldspar. Lenses and dikes of amphibolites present</td>
<td>300</td>
</tr>
<tr>
<td>Quartzite, white to bluish-white, massive</td>
<td>80</td>
</tr>
<tr>
<td>Phyllite, grey to dark-grey, medium-grained; often crumpled and calcareous; occasional coarse material and pyrite mineralization (less than 0.5 percent of P\textsubscript{2}O\textsubscript{5} recorded in isolated samples)</td>
<td>75</td>
</tr>
<tr>
<td>Dolomite, grey to cream-colored, laminated. Associated with minor shales; often carbonaceous at base (1 to 2 m thickness) and having variable P\textsubscript{2}O\textsubscript{5} content</td>
<td>20</td>
</tr>
<tr>
<td>Quartzite, white</td>
<td>20 - 30</td>
</tr>
</tbody>
</table>

----------Main Boundary Thrust----------

Siwalik Sandstone and shale
Table 1. Chemical analyses results of field samples

<table>
<thead>
<tr>
<th>Major Elements (in percent)</th>
<th>H-1</th>
<th>H-3</th>
<th>H-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>46.0</td>
<td>67.98</td>
<td>43.66</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>11.15</td>
<td>13.84</td>
<td>0.61</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>12.01</td>
<td>5.29</td>
<td>0.10</td>
</tr>
<tr>
<td>MnO</td>
<td>0.11</td>
<td>0.08</td>
<td>trace</td>
</tr>
<tr>
<td>MgO</td>
<td>5.49</td>
<td>1.77</td>
<td>11.44</td>
</tr>
<tr>
<td>CaO</td>
<td>4.58</td>
<td>0.62</td>
<td>16.70</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.78</td>
<td>2.09</td>
<td>trace</td>
</tr>
<tr>
<td>K₂O</td>
<td>5.62</td>
<td>3.56</td>
<td>0.08</td>
</tr>
<tr>
<td>TiO₂</td>
<td>5.81</td>
<td>0.66</td>
<td>0.08</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.86</td>
<td>0.17</td>
<td>trace</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>6.31</td>
<td>3.20</td>
<td>25.0</td>
</tr>
<tr>
<td>Total %</td>
<td>98.72</td>
<td>99.26</td>
<td>97.67</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trace Sample (in ppm)</th>
<th>H-1</th>
<th>H-3</th>
<th>H-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ba</td>
<td>2254</td>
<td>590</td>
<td>46</td>
</tr>
<tr>
<td>Co</td>
<td>49</td>
<td>18</td>
<td>27</td>
</tr>
<tr>
<td>Cr</td>
<td>514</td>
<td>77</td>
<td>26</td>
</tr>
<tr>
<td>Cu</td>
<td>18</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Ni</td>
<td>185</td>
<td>52</td>
<td>41</td>
</tr>
<tr>
<td>Sr</td>
<td>1024</td>
<td>131</td>
<td>50</td>
</tr>
<tr>
<td>V</td>
<td>264</td>
<td>130</td>
<td>42</td>
</tr>
<tr>
<td>Rb</td>
<td>182</td>
<td>167</td>
<td>110</td>
</tr>
</tbody>
</table>

(The analyses were conducted by quantometre in CRPG at Nancy, France.)
CONCLUSION

The search for phosphorite in Nepal has focused on the region of the Midland Group carbonates that crop out close to the Main Boundary Thrust. All results have indicated low phosphatic concentrations. With the help of paleogeographic reconstructions based on the investigations of regional mapping, the Department of Mines and Geology will evaluate the results obtained thus far. It hopefully will be possible to delineate areas of higher phosphatic concentrations.

ACKNOWLEDGEMENTS

The result of phosphorite investigations carried out by the Department of Mines and Geology are available in unpublished form at its library. The author wishes to acknowledge his sincere appreciation to Mr. M. N. Rana, director general, for permitting the use of these reports in preparation of this paper.

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PHOSPHATE, POTASH AND NATURAL GAS OCCURRENCES IN PAKISTAN

Asrarullah*

PHOSPHATE

Previous Work

The first published record by Stanin and Hasan (July 1966) presented bleak prospects of finding phosphate in Pakistan. The next serious search was undertaken in 1971 when Mr. Latif of Punjab University found phosphorite in 1970 while working on the geology of Hazara at Kakul for his doctoral thesis. N. A. Bhatti and Mirza Talib Hasan of the Geological Survey of Pakistan (G.S.P.) conducted detailed investigations on phosphate deposits of the Kakul and Mirpur areas (1972). M. T. Hasan and Ishaq Ghaznavi (G.S.P.) conducted investigations in the Sirbun Hill area in 1973. Ghaznavi and Tahir Karim conducted further investigations in the Dalola, Lagarban and Kalu-de-band area of Hazara Division in 1975.

Phosphate occurrences of little economic significance have been reported from many other parts of Pakistan. The occurrences are mostly nodular and bedded forms ranging in age from Cambrian to Eocene. Table 1 lists the mode of occurrences and P₂O₅ percentages of different phosphogenic provinces.

The occurrences are found in the provinces of North West Frontier Province, Punjab, Sind, and Baluchistan. In view of the latest research on a nitrogen phosphate generator, these occurrences can be of economic interest in the near future. The only economic deposits discovered so far are located in the Hazara Division of the North West Frontier Province of Pakistan.

Phosphate Deposits of Hazara

General Description.—The phosphate deposits of Hazara are of sedimentary origin. These phosphorite deposits cover an area of 160 sq km in the northern part of the North West Frontier Province of Pakistan between lat. 34°5' and 34°22' and long. 73°0' and 73°23'.

Collophane, dahlite and minor amounts of francolite are the principal phosphate minerals while glauconite, dolomite, iron oxide, and pyrite are the common impurities in the Hazara phosphorite. These impurities vary throughout the phosphorite deposit.

*Director General, Geological Survey of Pakistan
Table 1. Mode of phosphate occurrence and $P_2O_5$ content of some phosphogenic areas

<table>
<thead>
<tr>
<th>Phosphogenic area</th>
<th>Type of occurrence</th>
<th>Formation and Age</th>
<th>$P_2O_5$ content (in percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baluchistan Province:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lasbela</td>
<td>nodules in shales</td>
<td>Jakkar Group, Palaeocene</td>
<td>5 - 15</td>
</tr>
<tr>
<td>Loralai</td>
<td>nodules</td>
<td>Moghal Kot Formation, Cretaceous</td>
<td>5</td>
</tr>
<tr>
<td>North West Frontier Province:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kohat-Nizampur-Cherat</td>
<td>nodules in shale</td>
<td>Chichali Formation, Upper Jurassic and Lumshiwal</td>
<td>10 - 15</td>
</tr>
<tr>
<td>Hazara Division</td>
<td>bedded in dolomite and silty beds</td>
<td>Abbottabad Formation and Hozira Formation, Cambrian</td>
<td>10 - 30</td>
</tr>
<tr>
<td>Dera Ismail Khan</td>
<td>nodules in shale</td>
<td>Chichali Formation, Upper Jurassic</td>
<td>n.a.</td>
</tr>
<tr>
<td>Parachinar Agency and Tirah</td>
<td>n.a.</td>
<td>Chichali Formation, Upper Jurassic</td>
<td>5 - 10</td>
</tr>
<tr>
<td>Khyber Agency</td>
<td>apatite in carbonatite</td>
<td></td>
<td>5 - 10</td>
</tr>
<tr>
<td>Punjab Province:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dera Ghazi Khan</td>
<td>nodules</td>
<td>Ghazij Shale, n.a.</td>
<td>5 - 20</td>
</tr>
<tr>
<td>Kala Chitta</td>
<td>layers (bedded?)</td>
<td>Chichali Formation</td>
<td>n.a.</td>
</tr>
<tr>
<td>Salt Range</td>
<td>n.a.</td>
<td>Lumshiwal Formation, Lower Cretaceous</td>
<td>n.a.</td>
</tr>
<tr>
<td>Sind Province:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dadu</td>
<td>layers</td>
<td>Gaj Formation, Miocene</td>
<td>10 - 15</td>
</tr>
<tr>
<td>Karachi</td>
<td>nodules in shale</td>
<td>Chichali Formation, Upper Jurassic</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td>n.a.</td>
<td>Lumshiwal Formation, Lower Cretaceous; and Tion Formation, Eocene</td>
<td>n.a.</td>
</tr>
<tr>
<td>Nagarparkar¹</td>
<td>n.a.</td>
<td></td>
<td>n.a.</td>
</tr>
</tbody>
</table>

¹Sub-surface extension of Birmania Formation of Rajasthan, India, Permian age.
The lower-most part of the Hazira/Galdanian Formation\(^1\) of Cambrian age and the upper cherty dolomite part of the Abbottabad Formation are phosphatic in the Hazara area. The deposits are generally pelletal though the lithology may vary greatly in the area. The entire horizon contains at least 10 to 15 percent of $P_2O_5$ and may range as high as 30 percent of $P_2O_5$.

At some places in the Hazira Formation, for example, Dalola, the phosphorite is dense and dark and the pellets are not well developed. The black color is due to organic material. In some places the pellets were deformed and obliterated during diagenesis. The pellets are generally oolitic or nodular and are ovoid in shape. They are completely phosphatized, and thus structures are not well defined. The oolites have concentric structure. There is a large range of pellet sizes between beds and between localities. The cementing materials are dolomitic and in places, microcrystalline silica-phosphate. Grains of quartz, calcite, dolomite, pyrite, glauconite, and some clayey minerals are commonly included among the pellets.

Most of the phosphate pellets appear to have been originally calcium carbonate or aragonite. The aragonite or calcium carbonate has been completely or partially replaced by phosphate minerals. In thin sections spicules are present, particularly in the Sirbun Hill area samples. The spicules are needle-like and curved. They have been identified as Hyolithid fossils of Cambrian age. The spicules have been phosphatized though some are siliceous and calcareous.

Economic deposits exist over a distance of 35 km in the Kakul to Dalola areas along the contact between the upper cherty dolomite part of the Abbottabad Formation and the lower part of the Hazira Formation (see Table 2). The two major lithologies are: (a) cherty phosphorite of the Abbottabad Formation; and (b) calcareous silty phosphorite of the Hazira/Galdanian Formation.

**Mining and Utilization of Hazara Phosphorite.**—In 1975, Sarhad Development Authority engaged British consultants from the Powell & Dufferin National Coal Board to conduct detailed exploration and studies for exploitation of the Hazara phosphorite deposits. In 1978, the consultants applied for a further extension to carry out detailed exploration in the Lagarban and Delola areas. They also prepared a conceptual mining plan for feasibility studies based on an annual production rate of 306,000 tons per annum of beneficiated ore at an average grade of 26 percent of $P_2O_5$. Mine development depends greatly on the grade, size, and ore quality of the material.

Currently the consultants have developed a mine at Kakul that has two levels of mining. The two adits have an elevation difference of 19 meters. The first and second adits are 546 m and 485 m long, respectively. Up until December 31, 1978, 15,300 metric tons of phosphorite have been mined. The most recently reported rate of mining is 166 metric tons per month.

\(^1\) The Hazira and Galdanian Formations are laterally equivalent rock units.
Table 2. Probable and proved reserves of phosphorite in Hazara

<table>
<thead>
<tr>
<th>Location</th>
<th>Dip Depth (m)</th>
<th>Proved Reserves (million tons)</th>
<th>Probable Reserves (million tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kakul-Mirpur</td>
<td>91</td>
<td>0.4</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>high to medium grade 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>low grade 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lagarban (North)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>152</td>
<td>0.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>high to medium grade 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>low grade 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kalude-Bandi</td>
<td>91</td>
<td>1.9</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>eastern phosphorite 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>western phosphorite 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dalola</td>
<td>91</td>
<td>2.3</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>low to medium grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>low grade 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sirbun</td>
<td></td>
<td></td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>low grade 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>1.2</strong></td>
<td><strong>21.78</strong></td>
</tr>
</tbody>
</table>

Total reserves are 22.98 million tons.

1 High to medium grade contains 25 to 34 percent of P₂O₅.
2 Low grade contains less than 25 percent of P₂O₅.

A test mine at Lagarban is also being developed. Detailed beneficiation tests still remain to be carried out. The rock is hard to grind and at places contains impurities. The impurities are detrimental to normal sulphuric acid processing, and have to be reduced by beneficiation which raises the cost of production. Tests done by TVA on Kakul phosphates showed that the phosphorite is inert and thus less reactive and amenable to treatment processes. Upgrading the ore will be expensive and will adversely affect the economics of production.

For mining development purposes, the consultants drilled a total of 31 holes in the area; 2091 m at Kakul, 1415 m at Lagarban, and 401 m at Dalola. In addition, the first and deepest drill hole in Kakul was drilled by the G. S. P. in 1973. About 0.4 million tons of proved phosphate reserves occur in Kakul up to a dip depth of 78 m.
Carbonatites

The Loe-Shilman carbonatite deposit occurs in the topographic sheet 34 N/4 area in the North West Frontier Province of Pakistan. The carbonatite has intruded into slate, phyllite and marble of the Landikotal Formation of Paleozoic age. Four mineralogical types of carbonatites have been recognized: sovite which is a calcitic carbonatite, a phosphate-bearing mica carbonatite, a phosphate-bearing amphibolitic (mainly glaucophane) carbonatite, and a strontium carbonatite.

In the eastern part of the outcrops, the phosphate-bearing carbonatites are estimated at 45 million tons of which 1.8 million tons (4.0 percent) are phosphate. In the western part, ore reserves have been estimated at 14 million tons of which 0.8 million tons (5.5 percent) are phosphate.

POTASH ROCKS

Introduction

The Salt Range Formation of Cambrian age in the Salt Range and the Dhariala brine in the Punjab have the best potential for potash mineral occurrences. The Salt Range has long been an area of geologic interest. Warth (1891), Wynne (1878), Stuart (1919), Cee (1934, 1945 and 1950), and Christie (1941) are some of the significant early workers. Further investigations have been done by Schindewolf and Seilacher (1955), Asrarullah (1963), and Alam and Asrarullah (1972). The Saline Series or the Salt Range Formation has long been known for its halite deposits. Potash was first discovered by Warth (1891). Later work described the potassium salts in the Khewra mine and Nurpur area (Christie, 1941) and the presence of potassium salts in the Warcha and Kalabagh salt mines (Stuart, 1919).

Khewra Deposits

The Salt Range is about the only place in Pakistan where low-grade potash ore has been found in association with halite deposits. The Salt Range Formation, formerly known as the Saline Series, is the oldest rock unit in the area. The formation has been subdivided into the following members (Alam and Asrarullah, 1972, p. 2):

Sahwal Marl Member: (a) Bright red marl beds (3.0 to 91 m [10 to 300 ft])
(b) Dull red marl beds (more than 37 m [120 ft])

Bhandar Kas Gypsum Member: More than 76 m (250 ft)

Billianwala Salt Marl Member: Base not exposed (over 610 m [2000 ft])

In the Khewra area, the potash deposits occur in the salt marl beds that separate the various salt seams. Alam and Asrarullah (1972, p. 3)
recognized seven potash-bearing horizons which are, from top to bottom, 1.5 m (5 ft), .53 m (1.75 ft), .18 m (6 ft), 10 m (34 ft), 2.1 m (7 ft), and .91 m (3 ft) thick, respectively.

**Dhariala Brine Deposit.**

The Attock Oil Company in 1952 drilled Dhariala Well No. 1 in the Punjab. An unusually thick section of Precambrian salt was found from 480 to 2596 m (1575 to 8518 ft). At 1201 m (3939 ft), brine flowed to the surface at a rate of 1,500 barrels per hour. On an average, the brine was found to contain, by weight, 6.7 percent of potassium chloride, 16.5 percent of magnesium chloride, 4.6 percent of calcium chloride, 5.7 percent of sodium chloride, and small quantities of sulphate derivatives.

The surface of the Dhariala-Khajura fold is characterized by narrow, linear or arcuate alignments of subparallel folds and thrust faults. The exposed rocks belong to the Ranikot, Laki, Bhadrar and Kamial Formations of Tertiary age. The subsurface interpretation indicates a thrust fault zone with a contorted section overlying a section with no discernable dip. The surface and subsurface geological interpretation is that the Dhariala Well was drilled on a thrust fault-controlled surface fold.

The potassium content of the Dhariala brine is considerably higher than those of Salt Lake (Utah, USA), Salt Flats (Utah, USA), Searles Lake (California, USA), the Dead Sea, and sea water. The salts are chloride salts which are simpler and less costly for the recovery and purification of potassium.

The potash minerals occur as specks, streaks, thin seams, and lenticles of limited extent in the salt and salt marl beds. Some of the potash and salt marl beds are brecciated; small pieces of potash and salt marl are set in a marly matrix.

The salt marl varies from 1.40 to 5.0 percent of K₂O, and rocks without the salt marl vary from 1.40 to 18.80 percent of K₂O. The potassium minerals in the ores are sylvite, kyanite, langbeinite, kieserite, polyhalite, and mirabilite. The associated common minerals and materials include halite, silica, and clays. Most of the potash-bearing lenticles contain sulphate minerals. Sylvite is present in one potash-bearing salt marl bed.

**Reserves and Grade.**—Although seven potash-bearing zones were identified (Alam and Asrarullah, 1972, p. 4), reserves and grades have been estimated for only two, namely, PK-1 and PK-4, which have the best economic potential (see Table 3). Some potash and salt have already been mined, and most of the remaining reserves are in pillars which may not be easily recoverable.

The Dhariala brine deposit is still in the early stages of exploration. The Williams Brothers Engineering Company of Tulsa, Oklahoma (1978), evaluated the existing surface and subsurface data from wells...
Table 3. Reserves and grades of potash ores in the PK-1 and PK-4 beds. (Alam and Asrarullah, 1972, Tables 2 and 3)

<table>
<thead>
<tr>
<th>Beds</th>
<th>Seams</th>
<th>Length (ft)</th>
<th>Average thickness (ft)</th>
<th>Exposed height (ft)</th>
<th>Reserves (tons)</th>
<th>Average grade (X K₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PK-1</td>
<td>A</td>
<td>1,300</td>
<td>6.5</td>
<td>70</td>
<td>29,575</td>
<td>2.80</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>1,300</td>
<td>13.0</td>
<td>70</td>
<td>59,150</td>
<td>9.35</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1,300</td>
<td>14.0</td>
<td>70</td>
<td>63,700</td>
<td>8.40</td>
</tr>
<tr>
<td>PK-4</td>
<td>A</td>
<td>800</td>
<td>4.0</td>
<td>10</td>
<td>1,600</td>
<td>2.30</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>800</td>
<td>5.0</td>
<td>10</td>
<td>2,000</td>
<td>10.50</td>
</tr>
</tbody>
</table>

1. The length, thickness and height for the purpose of the above mentioned reserves are exposed dimensions measured in underground mines.

2. The tonnage factor was 2.0 based on an average specific gravity of 2.3.

and recommended a number of studies to assess the potential of the deposit with regard to potassium and other byproducts production.

NATURAL GAS

Although some of the natural gas fields of Pakistan were known since 1925, most of them were developed between 1951 and 1975. The known and developed fields are located in the Potwar and Sulaiman sedimentary basins in the Punjab, Sind and Baluchistan provinces. The known gas fields of Pakistan are located at Mari, Jacobabad, Khandkhot, Sari, Pirkoh, Khairpur, Uch, Mazarani, Kothar, Dhodak, Zin, Sui, Hund, and Rodho. In addition, small amounts of gas are produced from some oil fields in the Potwar region.

The natural gas in the known fields mentioned above occurs in formations of Cretaceous, Paleocene and Eocene ages (see Table 5). The Pab Sandstone is the gas-bearing horizon of Cretaceous age, while the Ranikot, Dunghan and Laki Limestone Formations of Paleocene and Eocene ages also have natural gas.

The total reserves of natural gas in the 14 fields listed in Table 4 is about 20.5 to 21.5 trillion cu ft. The Sui field is largest with about 9 trillion cu ft of gas. In some of the fields, the gas is rich to very rich in carbon dioxide and in others, low to very low in methane. (See Table 5.)

The present total production of gas, estimated at about 170,000 million cu ft per year, comes mainly from the Sui, Mari, and Dhulian fields with only a very small amount coming from oil fields.
<table>
<thead>
<tr>
<th>Name</th>
<th>Spud in Date</th>
<th>Operated by</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mari</td>
<td>29.12.1956</td>
<td>ESSO</td>
<td>27°56'35&quot;.4 N, 69°45'10.4&quot; E.</td>
</tr>
<tr>
<td>Khairpur</td>
<td>n.a.</td>
<td>Pakistan Petroleum Limited (PPL)</td>
<td>27°30' N, 68°47' E.</td>
</tr>
<tr>
<td>Zin</td>
<td>23.1.1953</td>
<td>PPL</td>
<td>28°56'10&quot; N, 69°45'13&quot; E.</td>
</tr>
<tr>
<td>Jacobabad</td>
<td>8.5.1958</td>
<td>PPL</td>
<td>28°20'52&quot; N, 69°38'15&quot; E.</td>
</tr>
<tr>
<td>Uch</td>
<td>15.2.1955</td>
<td>PPL</td>
<td>28°38'30&quot; N, 69°37'15&quot; E.</td>
</tr>
<tr>
<td>Sui</td>
<td>10.10.1951</td>
<td>PPL</td>
<td>28°38'30&quot; N, 69°12'21&quot; E.</td>
</tr>
<tr>
<td>Kandkhot</td>
<td>7.3.1959</td>
<td>PPL</td>
<td>28°17'50&quot; N, 69°20'40&quot; E.</td>
</tr>
<tr>
<td>Mazarani</td>
<td>21.8.1958</td>
<td>PPL/Hunt</td>
<td>27°40'31&quot; N, 67°30'27&quot; E.</td>
</tr>
<tr>
<td>Hundi</td>
<td>21.9.1969</td>
<td>Oil and Gas Development Corporation (O.G.D.C.)</td>
<td>25°12' N, 67°42' E.</td>
</tr>
<tr>
<td>Sari</td>
<td>1.8.1965</td>
<td>O.G.D.C.</td>
<td>25°14'50&quot; N, 67°32'16&quot; E.</td>
</tr>
<tr>
<td>Rodho</td>
<td>10.1.74/73</td>
<td>O.G.D.C.</td>
<td>30°44'26&quot; N, 70°26'31&quot; E.</td>
</tr>
<tr>
<td>Pirkoh</td>
<td>25.10.1975</td>
<td>O.G.D.C.</td>
<td>29°08'32&quot; N, 69°05'37&quot; E.</td>
</tr>
<tr>
<td>Location</td>
<td>Depth (m)</td>
<td>Methane (%)</td>
<td>Ethane (%)</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
<td>-------------</td>
<td>------------</td>
</tr>
<tr>
<td>MARI</td>
<td>700</td>
<td>71.2</td>
<td>0.2</td>
</tr>
<tr>
<td>KHAIRPUR</td>
<td>640</td>
<td>12.2</td>
<td>0.2</td>
</tr>
<tr>
<td>ZIN</td>
<td>975</td>
<td>14.1</td>
<td>0.4</td>
</tr>
<tr>
<td>JACOB-ABAD</td>
<td>1035</td>
<td>25.0</td>
<td>0.5</td>
</tr>
<tr>
<td>UCH</td>
<td>1260</td>
<td>27.3</td>
<td>0.7</td>
</tr>
<tr>
<td>SUI</td>
<td>1340</td>
<td>88.52</td>
<td>0.89</td>
</tr>
<tr>
<td>KANDH. KOT.</td>
<td>1370</td>
<td>79.2</td>
<td>1.1</td>
</tr>
<tr>
<td>MAZARANI</td>
<td>1920</td>
<td>87.0</td>
<td>2.5</td>
</tr>
<tr>
<td>RODHO</td>
<td>1150</td>
<td>82.0</td>
<td>7.57</td>
</tr>
<tr>
<td>HUNDI</td>
<td>1180</td>
<td>79.40</td>
<td>1.62</td>
</tr>
<tr>
<td>SARI</td>
<td>1243</td>
<td>80.01</td>
<td>1.88</td>
</tr>
<tr>
<td>KOTHAR</td>
<td>1517</td>
<td>80.75</td>
<td>3.81</td>
</tr>
<tr>
<td>RODHO</td>
<td>1441</td>
<td>82.78</td>
<td>6.20</td>
</tr>
</tbody>
</table>

Compiled by: M.A.R. Chori

20.51
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THE OCCURRENCE OF ROCK PHOSPHATE DEPOSITS IN SRI LANKA
IN RELATION TO THE PRECAMBRIAN BASEMENT

D. E. de S. Jayawardena*

ABSTRACT

Two significant discoveries of rock phosphate in Sri Lanka have been made during recent years by the Geological Survey Department. The Eppawela rock phosphate deposit located in the northwest of the island and the Seruwila copper-magnetite prospect on the northeast which has fluorapatite have stimulated much interest in the relationship between the two major lithological zones of the Precambrian basement in Sri Lanka. These facies are the high-grade granulite facies, charnockites and metasediments, and the amphibolite facies, gneisses and metamorphosed granites. It is believed that a structural discontinuity exists between these two lithological zones in the east and a major dislocation is suspected in the northwest of the island. The geology of Sri Lanka is summarized in light of recent findings of the emplacement of the two phosphate deposits at the margins of these two lithological zones.

INTRODUCTION

Sri Lanka is located 30 km east of the southern tip of India at long. 81°E and lat. 8°S (Fig. 1). The island has an area of 66,000 sq km and is 435 km long and 225 km wide. The main physiographic divisions of the island are as follows:

1. The low-lying coastal plain has low relief and is transversed by rivers which have reached their base level of erosion in the coastal plain. The general relief of the coastal plain ranges from 152 m with erosional remnants up to 305 m above mean sea level.

2. The central highlands show increased drainage patterns and marked relief abounding in numerous strike ridges, hills and mountains. The highlands rise steeply from the coastal plain and the northeast mountain range (Pidurutalagala) is at an elevation of 2524 m above mean sea level.

Sri Lanka is located in the monsoon region of Southeast Asia and has a humid tropical climate. Three major climatic divisions, a wet zone, a dry zone, and an intermediate zone have been delineated by the rainfall

*Deputy Director, Geological Survey Department, Sri Lanka
Figure 1. Location of Sri Lanka relative to India patterns. The average rainfall varies from 127 cm in the northwestern and southeastern parts, to over 508 cm on the southwest slopes of the hill country. The average temperature varies between 21 to 27° C.

Over 90 percent of the surface area of the island is underlain by high-grade metamorphic rocks of Precambrian age. Granites and granitoid rocks of igneous origin are occasionally associated with the high-grade metamorphic rocks. Sedimentary rocks of Miocene age occur in the northwest and northern coastal stretch of the island. The main lithological unit in the Miocene is massive limestone of marine origin which is overlain by Pleistocene deposits such as red earth and gravels. Two insignificant pockets of Jurassic rocks are located in the northwestern coastal stretch and are composed of sandstones, grits, brown shales, and black carbonaceous shales. These sediments appear to have been deposited in deep-faulted blocks, and drilling has revealed that the sediments are over 366 m thick with features showing cyclic sedimentation.

THE PRECAMBRIAN IN SRI LANKA

The Precambrian basement complex in Sri Lanka has been subdivided into two broad lithological zones based mainly on the grade of metamorphism (Fig. 2):

1. The charnockite-metasedimentary series which is mainly confined to the central hill massif is composed of charnockites (hyperssthene-bearing rocks), quartzites, marbles, and metasedimentary rocks rich in aluminous minerals such as garnet and sillimanite. Cordierite gneisses and wollastonite-scapolite-bearing rocks are also seen occasionally. These rocks are in the granulite facies of metamorphism.
GEOLOGICAL MAP OF SRI LANKA

RECENT
PLEISTOCENE
(More dates indicate Pleistocene
overlying Miocene & Precambrian rocks)

MIocene
JURASSIC

META SEDIMENTS
LIMESTONES & DOLOMITES
QUARTZITES

CORDIERITE GNEISSES
WOLLASTONITE-SCAPOLITE ROCKS
BIOTITE & HORNBLENDE
BIOTITE-GNEISSES
GRA N ITES
ZIRCON GRANITES
DOLERITE DYKE (Age uncertain)

SCALE: 1:2,000,000
10 5 0 10 20 30 MILES

BATTICALOA
KURUNEGALA
ANURADHAPURA
BADULLA

NEGOMBO
COLOMBO

GALLE
AMBALANGODA

PATTOM
TONGALA
ANDIGAMA

SCALE: 1:2,000,000
10 5 0 10 20 30 MILES

P.N.
2. The Vijayan Series identified in the eastern half of the island is mainly composed of biotite and hornblende biotite gneisses, metamorphosed granites and granitic gneisses. These rocks are mainly of the almandine-amphibolite facies.

3. Granites and zircon granites of probable igneous origin are interspersed in the crystalline basement and their ages are about 600 to 800 m.y. Dolerite dikes of uncertain age are seen cutting both the charnockite-metasedimentary series and the Vijayan Series.

The relationship between the charnockite-metasedimentary series and the Vijayan Series is subject to debate. The two main schools of thought advocate a retrogressive metamorphic episode giving rise to a transition zone (Cooray, 1961) or a structural discontinuity (Katz, 1978). In outlining the theory of structural discontinuity, Katz (1978) believed that the granulite facies rocks of the charnockite-metasedimentary series of Sri Lanka were emplaced within a tensional aulacogen formed by the splitting of a craton composed of Vijayan gneisses. Subsequent volcanism and high-grade metamorphism associated with mantle swelling converted these sediments into granulite facies rocks. During the next episode of transform tectonics, granulite facies rocks moved against the Vijayan series rocks along a steeply dipping tectonic linear fault zone which forms the boundary between the two major series.

EMPLACEMENT OF PHOSPHATE DEPOSITS ('CARBONATITES')

The emplacement of the Eppawela rock phosphate deposit and the Seruwila copper-magnetite prospect which has fluorapatite is confined to the northwestern and southeastern boundaries of the charnockite-metasedimentary and Vijayan Series. It appears that two major faults exist along the boundaries of the major lithological zones. Short descriptions of the two phosphate occurrences appear below in order to elucidate the tectonics of the Precambrian basement complex.

THE EPPAWELA ROCK PHOSPHATE DEPOSIT

The Eppawela rock phosphate deposit is located in the northwestern quadrant of Sri Lanka and lies within the administrative district of Anradhapura. The distance from Colombo to Eppawela via Kurunegala along an all-weather hard surfaced road is 115 km. The deposit forms six elevated hillocks rising to a maximum altitude of 174 m above mean sea level. The apatite in a brecciated zone that forms a capping material on these hillocks is of economic significance. Detailed exploration by the Geological Survey Department has proved a reserve of 25 million tons of rock phosphate with an average grade of 33 percent of \( P_2O_5 \). Mineralogical studies have shown that the apatite is a chlorine-rich fluorapatite that occurs as large green crystals with maximum lengths of .91 m. The brecciated zone is mainly composed of green apatite bound together by martite and geothite. Secondary carbonate apatite (francolite) and a metallic mineral, probably magnetite, are also present. The mineral
Table 1. Chemical analysis of the martite sample.

<table>
<thead>
<tr>
<th>Percent of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiO$_2$</td>
</tr>
<tr>
<td>MgO</td>
</tr>
<tr>
<td>CaO</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
</tr>
<tr>
<td>V$_2$O$_5$</td>
</tr>
<tr>
<td>Nb$_2$O$_5$</td>
</tr>
<tr>
<td>ZrO$_2$</td>
</tr>
</tbody>
</table>

Martite was identified by x-ray emission spectrography at the Institute of Geological Sciences, London, and was found to contain 0.14 percent of Nb$_2$O$_5$ (Table 1).

The chemical analyses of the brecciated apatite-bearing rock are given in Table 2. The variation in the P$_2$O$_5$ content is due to the variable modal composition of apatite. A zone of hard lamprophyric breccia and a softer zone, rich in martite and goethite, have been identified. Fresh carbonatite is seen exposed to the south of the deposit, and chemical analyses of a representative sample are given in Table 3. Figure 3 shows the limits of the brecciated zone in relation to the surrounding lithology. The brecciated zone was earlier identified as a leached zone, but this determination was changed upon further investigation.

Utilization of the Rock Phosphate of Eppawela

The phosphate is presently being exploited on a small scale for tea crops in place of imported rock. The solubility of the Eppawela rock is given in Table 4. The acidic soil in the highland tea plantations helps to liberate the P$_2$O$_5$ in sufficient quantities for the material to be used as a direct applicant. Tests are currently being conducted at the International Fertilizer Development Center (IFDC) in Alabama, U.S.A., on the manufacture of thermal and water soluble acid and super phosphates. The fusion of the Eppawela rock with serpentinite to produce fused magnesium phosphate (FMP) fertilizer is also being investigated in Alabama.

Emplacement of the Eppawela Deposit

It is not clear whether the Eppawela rock phosphate deposit is a carbonatite or was formed due to remobilization of a metamorphosed limestone under conditions of orogenic stress and elevated temperatures. The abrupt termination of the elevated hillocks containing the phosphate rock
Table 2. Chemical analyses of the Eppawela leached apatite-bearing rocks

<table>
<thead>
<tr>
<th>Rock Sample</th>
<th>EP/1/P</th>
<th>EP/2/P</th>
<th>EP/3/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>0.50</td>
<td>0.30</td>
<td>0.60</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>0.95</td>
<td>2.23</td>
<td>7.05</td>
</tr>
<tr>
<td>FeO</td>
<td>0.70</td>
<td>0.70</td>
<td>0.54</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>3.72</td>
<td>2.30</td>
<td>7.70</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.78</td>
<td>0.78</td>
<td>0.60</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>36.60</td>
<td>36.04</td>
<td>33.00</td>
</tr>
<tr>
<td>CaO</td>
<td>52.30</td>
<td>51.60</td>
<td>43.63</td>
</tr>
<tr>
<td>MgO</td>
<td>0.20</td>
<td>0.23</td>
<td>0.29</td>
</tr>
<tr>
<td>SrO</td>
<td>0.66</td>
<td>0.65</td>
<td>0.60</td>
</tr>
<tr>
<td>BaO</td>
<td>0.13</td>
<td>0.26</td>
<td>0.62</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.09</td>
<td>0.08</td>
<td>0.19</td>
</tr>
<tr>
<td>K₂O</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>CO₂</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>F</td>
<td>2.40</td>
<td>2.43</td>
<td>1.74</td>
</tr>
<tr>
<td>Cl</td>
<td>0.88</td>
<td>1.04</td>
<td>0.98</td>
</tr>
<tr>
<td>U₃O₈</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>ThO₂</td>
<td>0.02</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>H₂O</td>
<td>1.46</td>
<td>2.65</td>
<td>3.60</td>
</tr>
</tbody>
</table>

Total          101.39  101.32  101.15
Loss of O for F 1.01   1.10   0.86
Loss of O for Cl 0.21   0.24   0.22

Total          100.17  99.98  100.07
EPPAWALA CARBONATITE COMPLEX

LIMITS OF THE LEACHED PHOSPHATE ROCK

SCALE: 2 INCHES = 1 MILE

Observed "Leached Zone"Rock Boundary (in situ)
Observed Leached Zone Rock"Floor" Boundary
Charnockite
Fresh Carbonatite
Granite Gneiss
Quartzite

Fig. 3
Table 3. Variation limits of chemical analyses of Eppawela carbonatite samples.

<table>
<thead>
<tr>
<th>Percent of Sample</th>
<th>SiO₂</th>
<th>TiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>FeO</th>
<th>MgO</th>
<th>CaO</th>
<th>Na₂O</th>
<th>K₂O</th>
<th>P₂O₅</th>
<th>L. O. I.</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0.58 - 1.67</td>
<td>trace</td>
<td>0.01 - 0.04</td>
<td>0.53 - 1.71</td>
<td>nil</td>
<td>3.93 - 8.29</td>
<td>44.36 - 49.46</td>
<td>nil</td>
<td>nil</td>
<td>trace - 5.97</td>
<td>33.85 - 43.49</td>
</tr>
</tbody>
</table>

CO₂, H₂O⁺, S, F, and Cl indicates swelling of the upper mantle which appears to be due to carbonate magma that originated from the upper mantle. This magma probably moved to the upper levels of the earth's crust along deep-seated fractures or faults. The Eppawela phosphate rock appears to be emplaced along such a deep-seated fracture. The above observations bear indirectly on the hypothesis of the presence of a structural discontinuity between the two major lithological zones.

THE SERUWILA COPPER-MAGNETITE PROSPECT IN NORTHEAST SRI LANKA

The occurrence of copper-magnetite ore along the east in the boundary between the charnockite-metasedimentary and Vijayan Series was discovered in 1971 by the Geological Survey Department. The mineralogical studies carried out have helped in identifying the minerals in the ore zones. The order of mineralization presently recognized is:

- Oxide Group - Magnetite
- Phosphate Group - Apatite
- Silicate Group - Amphibole
  - Pyroxene
  - Scapolite

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Table 4. Results of solubility tests† on the Eppawela apatite-bearing rock

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tr>
<td>1st Week</td>
<td>4.20</td>
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<td>2nd Week</td>
<td>4.37</td>
<td>13.24</td>
<td>0.11</td>
</tr>
<tr>
<td>3rd Week</td>
<td>4.37</td>
<td>13.24</td>
<td>0.10</td>
</tr>
<tr>
<td>4th Week</td>
<td>4.75</td>
<td>14.40</td>
<td>0.10</td>
</tr>
<tr>
<td>5th Week</td>
<td>4.75</td>
<td>14.40</td>
<td>0.10</td>
</tr>
<tr>
<td>After stirring for four hours continuously</td>
<td>4.30</td>
<td>13.03</td>
<td>0.15</td>
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</table>

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>$P_2O_5$ (pct.)</th>
<th>3</th>
<th>2</th>
<th>1</th>
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<td>0.13</td>
<td>9.59</td>
<td>3.38</td>
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<td>EP/2/P</td>
<td>36.04</td>
<td>0.21</td>
<td>9.18</td>
<td>3.34</td>
</tr>
<tr>
<td>EP/3/P</td>
<td>33.0</td>
<td>0.43</td>
<td>10.70</td>
<td>3.55</td>
</tr>
</tbody>
</table>

1 Whole rock sample in 2% citric acid solution, $P_2O_5$ in percent
2 Whole rock sample in 2% citric acid solution, percent of soluble $P_2O_5$ of the total $P_2O_5$ content
3 Whole rock sample in rain water, $P_2O_5$ content in percent

†Solubility in ammonium citrate according to Association of Official Agricultural Chemists (U.S.A.)
Sulphide Group - Pyrite

Chalcopyrite

The apatite was found to be about 25 percent of the nonmagnetic fraction and may be economically significant. Detailed exploration in this area is being done by the Geological Survey Department in collaboration with the Bureau de Recherches Geologiques et Minieres (BRGM) in France. The mineralization is confined to an area of about 39 sq km. Apatites separated from the ores were analyzed and found to be fluorapatite with a trace of chlorine.

CONCLUSIONS

The discovery of rock phosphate in Sri Lanka in significant amounts has stimulated detailed studies of these deposits in order to unravel the mode of emplacement and geological significance of such rocks. The carbonatite occurrence at Eppawela contains a brecciated zone rich in apatite. Total resources are estimated at 50 million tons with proved reserves at about 25 million tons that have an average grade of 33 percent of P₂O₅. The unusual chemical composition and low solubility are major drawbacks in the utilization of this rich phosphate rock as base for the manufacture of water soluble acid and superphosphate. Feasibility studies presently being conducted at the IFDC will identify the type of phosphate fertilizer that can be manufactured. The Seruwila copper-magnetite-fluorapatite ore will be a valuable source material for pure fluorapatite after apatite is separated from the ore. Present exploration has indicated that the fluorapatite constitutes about 25 percent of the nonmagnetic fraction of the ore.

The geological significance of the emplacement of the two rock phosphate occurrences in the Precambrian crystalline complex of Sri Lanka has a direct bearing on the present controversy of the relationship of the two major lithological zones. This geological phenomena may be a good exploration tool for locating carbonatite deposits in a Precambrian terrain.

ACKNOWLEDGEMENTS

This paper is presented with the kind permission of the Acting Director, Geological Survey Department, Sri Lanka. The author wishes to express a deep sense of gratitude to the Resource Systems Institute, East-West Center, Hawaii, for sponsoring his participation at the Fertilizer Raw Materials Resources Workshop, Fertilizer Flows Preparatory Conference, and the Field Workshops in the U. S. A. in connection with the IGCP Project 156 on phosphorites during the period August 6-31, 1979.
REFERENCES


PHOSPHATES AND NATURAL GAS
OF THAILAND

Thawat Japakasetr

Phosphate Deposits

Most of the phosphate deposits found in Thailand are small guano deposits, a few of which are being mined. Recent investigations of a phosphate deposit in the Roi Et Province in northeast Thailand have led to current prospecting of that deposit.

Eight occurrences of phosphate have been found in Thailand, but only four of them are of fair quantity. These four deposits are briefly described below.

Ban Sob Moei, Mae Tha District, Lamphun Province.--Outcrops of phosphate rock were found on the flat plains near Mae Moei River, covering about 0.25 sq km. The reserves are about 50,000 tons of $P_2O_5$. This is the biggest phosphate deposit that has yet been found in Thailand. The production per year varies from 2,000 to 7,500 tons.

Khao Phak Mah, Ratburi Province.--Phosphate rock occurs in caves and in pockets in limestone. The reserves are very small, about 5,000 tons. The production from 1974 to 1975 was about 4,900 tons. The mine is currently not in production.

Khao Cha-Ngoke, Chon Daen District, Phetchabun Province.--The reserves of this deposit were estimated at about 10,000 tons, with $P_2O_5$ contents of 10 to 30 percent. Only 3,200 tons were produced in 1977.

Ban Lao Kham, Roi Et Province.--Phosphate was found as cementing material in sandstone in an area of about 40,000 sq m. The phosphatic unit had a thickness of about 1 m, and occurred about 2 to 3 m below the surface. Reserves are estimated at about 80,000 tons of approximately 20 percent of $P_2O_5$.

Natural Gas

Exploratory drilling for oil and natural gas in the Gulf of Thailand was started in June, 1971. Up to April, 1979, 49 exploratory wells were

*Geologist, Economic Geology Division, Department of Mineral Resources, Rama VI Road, Bangkok 4, Thailand
drilled in 19 blocks covering the gulf area (see table). Only two structural areas within four of these blocks contained natural gas and condensate.

Union Oil Company of Thailand discovered natural gas in 11 wells, of which 8 wells were in one structure that covered an area of about 110 sq km. The natural gas reserves were estimated as 1 to 2.2 trillion cu ft. They can produce at rates of 150 to 250 cu ft per day, and will last 20 years.

Texas Pacific Thailand, Inc. also discovered natural gas in 8 wells drilled in another structure which covered an area of about 180 sq km. The reserves were estimated as 2 to 3.4 trillion cu ft.

In 1976, two companies, Esso and Union Oil Company of Thailand, put down the holes of 5 and 6 wells in the Andaman Sea, respectively. None have been reported as containing sufficient amounts of natural gas or oil.

Three oil wells were found in the Gulf of Thailand in 1973 and 1974, but the quantity is not sufficient for production.

REFERENCES


SUCCESSFUL WELLS DRILLED IN THE GULF OF THAILAND

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>CONCESSION BLOCK</th>
<th>WELL NUMBER</th>
<th>WELL NAME</th>
<th>LATITUDE (deg. N)</th>
<th>LONGITUDE (deg. E)</th>
<th>DATE COMPLETED</th>
<th>FINDINGS</th>
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<tr>
<td>Union</td>
<td>B - 12</td>
<td>4</td>
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<td>9°07’30&quot;</td>
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<td>gas &amp; condensate</td>
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<td>Tenneco</td>
<td>B - 15</td>
<td>7</td>
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<td>10</td>
<td>16-B-1</td>
<td>7°53’26&quot;</td>
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<td>Mar. 4, 1974</td>
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<td>8°53’29&quot;</td>
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<td>Amoco</td>
<td>B - 6</td>
<td>16</td>
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<td>Aug. 29, 1974</td>
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<td>Oct. 6, 1974</td>
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<td>B - 12</td>
<td>24</td>
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<td>B - 10</td>
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<td>Platong-1</td>
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<td>8°57’13&quot;</td>
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<td>(Tenneco)</td>
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<td>35</td>
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<td>9°03’50&quot;</td>
<td>101°20’02&quot;</td>
<td>Apr. 24, 1979</td>
<td>gas</td>
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</tbody>
</table>

MAPS OF THE ASIA-PACIFIC REGION

LEGEND

- △ small occurrences (less than 1,000,000 tons) or size unknown
- □ medium occurrences (1,000,000 to 10,000,000 tons)
- ○ large occurrences (greater than 10 million tons)

- ○ phosphate
- □ natural gas
- △ potash

- Sedimentary basin boundaries
- Political boundaries
- Prospective basin for potash occurrences
- Submarine rise boundary
Map 3  India, Sri Lanka, and Nepal Regions
Map 4  Bangladesh and Burma Regions
Map 6  Malaysia and Brunei Regions
Map 8  Philippines Region
Map 9  Papua New Guinea Region
Map 13  Western China Region
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Map 14  Eastern China Region

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NATURAL GAS OCCURRENCES IN
THE ASIA-PACIFIC REGION

1. Masupora gas field, Hokkaido, Japan
   Fletcher, 1979

2. Toyatomi gas field, Hokkaido, Japan
   Fletcher, 1979

3. Ukawa gas field, Honshu, Japan
   Ikebe and others, 1967

4. Honjo-oki IAI exploration well, west
   of Honshu, Japan (offshore)
   gas discovery
   Caldwell, 1975

5. Akita gas fields, Akita sub-basin,
   Japan
   post middle Miocene
   Ikebe and others, 1967; Fletcher, 1979

6. Oishi gas field, Honshu, Japan
   Ikebe and others, 1967

7. Yamagata gas field, Honshu, Japan
   Ikebe and others, 1967

8. Aga Oki SI-1 exploration well, west of
   Honshu, Japan (offshore)
   gas show
   middle Miocene, Shiiya Formation
   Tanner and Kennett, 1972

Niigata sub-basin, Japan (9-20)

9. Nakajo-Shiunji gas field
   late Miocene to early Pliocene, Shiiya
   to Nishiyama Formation
   Katahira and Ukai, 1976

10. Higashi-Niigata gas fields
    early Pliocene, Nishiyama Formation
    Katahira and Ukai, 1976

11. Niigata gas field
    Ikebe and others, 1967

12. Aga Oki gas field (offshore)
    Grunau and Gruner, 1978

13. Okozu gas field
    Ikebe and others, 1967

14. Higashi-Sanjo gas fields
    late Miocene, Nanatani Formation
    Ikebe and others, 1967

15. Fujikawa gas field
    gas, condensate reservoir
    late Miocene, Shiiya Formation
    Ikebe and others, 1967;
    Katahira and Ukai, 1976

16. Kumoide gas field
    early Pliocene, Nishiyama Formation
    Kujiraoka, 1967

17. Sekihara gas field
    Pliocene, Haizume and Nishiyama
    Formations
    Kujiraoka, 1967

18. Katagai, Myohoji, Higashi-
    Kashiwazaki and Yoshii gas fields
    middle Miocene and early Pliocene,
    Nanatani and Nishiyama Formations
    Katahira and Ukai, 1976

19. Kubiki field
    gas and oil field
    late Miocene, Nanatani to
    Teradomari Formation
    Ikebe and others, 1967

20. Meiji gas field
    Ikebe and others, 1967

21. Iwaki 3-6 exploration well, eastern
    Honshu, Japan (offshore)
    gas show
    Caldwell, 1975

22. Iwaki gas field, eastern Honshu,
    Japan (offshore)
    Grunau and Gruner, 1978

23. Kami Tajima I exploration well,
    Niigata prefecture, Japan
    gas show
    middle Miocene
    Scheidecker, 1977

24. Asakawa gas field, Niigata pre-
    fecture, Japan
    Grunau and Gruner, 1978

25. Odagiri gas field
    Ikebe and others, 1967

26. Imizu gas field
    Fletcher, 1979
Kazusa basin, Japan (27-38)
Kawai, 1967

Otaki gas field
Pliocene, Otadai and Kiwada Formations

28. Mobara gas field
Plio-Pleistocene, Otadai, Kiwada and Umegase Formations

29. Togane gas field
Plio-Pleistocene, Otadai and Umegase Formations

30. Naruto gas field

31. Yokoshiba gas field
Pliocene, Kiwada Formation

32. Yawata gas field

33. Chiba gas field
Plio-Pleistocene, Kakinokidai to Umegase Formation

34. Yotsukaido gas field
Pliocene, Kiwada and Otadai Formations

35. Narita gas field

36. Narashino gas field
Plio-Pleistocene, middle Kazusa Group

37. Funabashi gas field
Miocene to Pleistocene, Kazusa Group

38. Koto gas field
Plio-Pleistocene, middle Kazusa Group

39. Shimizu gas field
Fletcher, 1979

40. Sagara gas field
Fletcher, 1979

41. Yaizu gas field
Fletcher, 1979

42. Hamada-1 exploration well, west of Honshu, Japan (offshore)
gas show
Tanner and Kennett, 1972

43. Agi-A-1 exploration well, west of Honshu, Japan (offshore)
gas discovery
Tanner and Kennett, 1972

44. and 45. Miyazaki gas fields
Grunau and Gruner, 1978

46. Shanghai field, Yellow Sea Basin, China
shallow gas field
Miocene, Pliocene, and Pleistocene
Meyerhoff and Willums, 1976

47. Chekiang province, Yellow Sea Basin, China
over 2,000 shallow gas wells
Miocene, Pliocene, and Pleistocene
Meyerhoff and Willums, 1976

Szechwan Basin, China (48-57)
Meyerhoff and Willums, 1976

48. Shih-you-kou - Tung-ch'i field
gas and oil production
Middle Triassic, Chia-ling-chiang Suite; Early Permian(?)

49. Ch'an-yuan-pi field
gas field with some condensate present
Middle Triassic, Chia-ling-chiang Suite; Early Permian, Mao-kou Suite

50. Kao-mu-tin Field
gas field
Middle Triassic, Chia-ling-chiang Suite; Early Permian, Mao-kou Suite

51. Na-hsi field
gas production
Middle Triassic, Chia-ling-chiang Suite; Early Permian, Mao-kou Suite

52. Na-hsi field
gas production
Early Permian

53. Huang-kuan-shan field
gas production
Middle Triassic, Chia-ling-chiang Suite

54. Teng-ching-kuan field
Middle Triassic, Chia-ling-chiang Suite
gas production
55. Sheng-teng-shan field  
gas production  
Middle Triassic, Chia-ling-chiang Suite; Early Permian, Mao-kou Suite

56. Huan-chia-ch'an field  
gas production  
Middle Triassic, Chia-ling-chiang Suite

57. Chi-luu-ching field  
gas production  
Middle Triassic, Chia-ling-chiang Suite

58. Yu-k'a field, Tsaidam Basin, China  
shut-in gas field  
Miocene, Hung-hsiao-kao Suite  
Meyerhoff and Willums, 1976

59. Ma-hai field, Tsaidam Basin, China  
shut-in gas field  
Miocene, Chun-siao Suite  
Meyerhoff and Willums, 1976

60. Yen-hu field, Tsaidam Basin, China  
shut-in gas field  
Pliocene, Kuang-kou Suite  
Meyerhoff and Willums, 1976

61. Yan-chi-hai field, Dzungaria Basin, China  
shut-in gas field  
Miocene, Tu-shan-tze Series  
Meyerhoff and Willums, 1976

62. Kumger Field, Tarim Basin, China  
shut-in gas field  
Miocene and Jurassic  
Meyerhoff and Willums, 1976

63. Kosaptok field, Tarim Basin, China  
shut-in gas field  
Miocene and Jurassic  
Meyerhoff and Willums, 1976

64. Hsiao-lien-shan field, Tsaidam Basin, China  
gas production  
early Pliocene, Kuang-kou Suite  
Meyerhoff and Willums, 1976

65. Shantzechiao-3 well, Taiwan, China  
gas production  
Fletcher, 1979

66. Chutung field, Taiwan, China  
gas production  
upper Miocene; Kueichulin and Hopai Formations  
Ho and Lee, 1963

67. Fankopeng-3 exploration well, Taiwan, China  
gas show  
Ho and Lee, 1963

68. Chingtsohu gas field, Taiwan, China  
Fletcher, 1979

69. Chiting - Yunghoshan area, Taiwan, China  
gas discovery  
Bowman, 1974; Tanner and Kennett, 1972

70. Chinshui field, Taiwan, China  
gas and condensate production  
middle to upper Miocene;  
Kuechulin, Chuhuangkeng, Shihti, Taliao, and Mushan Formations  
Ho and Lee, 1963; ESCAP, 1975

71. Chuhuangkeng field, Taiwan, China  
gas and oil production  
Miocene; Chuhuangkeng, Taliao and Mushan Formations  
Ho and Lee, 1963; ESCAP, 1975

72. Paishantun, Taiwan, China  
gas discovery  
Tanner and Kennett, 1972

73. Tiehchenshan, Taiwan, China  
gas field  
Miocene; Chuhuangkeng Formation, Piling and Talu Shales  
Ho and Lee, 1963; Grunau and Gruner, 1978

74. Taishi-1 exploration well, Taiwan, China  
oil and gas discovery  
Fletcher, 1979

75. Yichu field, Taiwan, China  
gas show  
Pliocene, Liuchungchi Formation  
Ho and Lee, 1963

76. Tungtzechiao field, Taiwan, China  
gas seeps  
Miocene (?); Ailiaochao and Chutouchi Formations  
Ho and Lee, 1963

77. Liuchungchi field, Taiwan, China  
gas production  
late Miocene to early Pliocene; Niaotsui Formation  
Ho and Lee, 1963
78. Niushan field, Taiwan, China
gas production
late Miocene to early Pliocene,
Liuchungchi Formation
Ho and Lee, 1963

79. Wanchiu WA-1 well, Taiwan, Chingas
gas production
Fletcher, 1979

80. Chutouchi Field, Taiwan, China
gas show
Tanner and Kennett, 1972

82. Napalin-1 exploration well, Taiwan, China
gas production
Ho and Lee, 1963

83. Chienchiuliao-1 well, Taiwan, China
gas production
Fletcher, 1979

84. Kunshuping-1 well, Taiwan, China
gas production
Fletcher, 1979

85. F-1 exploration well, Taiwan, China (offshore)
gas discovery
Caldwell, 1975

86. Tabuk and Apayao, Philippines
gas and oil show
lower Miocene
Philippines Bureau of Mines, 1976

87. Parasilis, Mt. Province, Philippines
gas show
Lubugan Formation
Philippines Bureau of Mines, 1976

88. Aurora Bondoc Peninsula, Philippines
strong gas shows
Miocene, Vigo Formation
Philippines Bureau of Mines, 1976

89. Filipino-1 exploration well, Visayan Sea, Philippines (offshore)
oil and gas shows
Scheidecker, 1977

90. Fe Banlayan and Daanbantayan, Cebu, Philippines
oil and gas shows, gas wells
Oligocene to lower Miocene, Malubog Formation
Philippines Bureau of Mines, 1976

91. Mandurriao, Iloilo and New Lucena, Philippines
gas show
Philippines Bureau of Mines, 1976

92. Malabuyoc and Alegria, Cebu, Philippines
gas and oil show
Miocene
Philippines Bureau of Mines, 1976

93. 102A-20 and 102A-21 exploration wells, Philippines (offshore)
oil and gas shows
Tanner and Kennett, 1972

94. Cotabato, Philippines
gas show
middle Miocene, Pliocene
Philippines Bureau of Mines, 1976

95. South Cotabato, Philippines
gas show
Oligocene
Philippines Bureau of Mines, 1976

96. Sulu Sea (offshore)
gas and oil show
Miocene
Philippines Bureau of Mines, 1976

97. Sulu Sea (offshore)
gas and oil show
Philippines Bureau of Mines, 1976

98. Sulu Sea (offshore)
gas show
Oligocene to Miocene
Philippines Bureau of Mines, 1976

99. Cayagan de Sulu (offshore)
gas show
Oligocene to Miocene
Philippines Bureau of Mines, 1976

100. Cayagan de Sulu (offshore)
gas show
Oligocene to Miocene
Philippines Bureau of Mines, 1976

101. Southwest Palawan (offshore)
gas and oil show
Philippines Bureau of Mines, 1976

102. Sampaguita exploration well, Reed Bank, South China Sea
gas and condensate show
Scheidecker, 1977
103. Iehi field, Papua New Guinea
    gas discovery
    Lower Cretaceous clastics
    Gillespie, 1967

104. Barikewa gas field, Papua New Guinea
    gas discovery
    Lower Cretaceous clastics
    Gillespie, 1967

105. Kuru field, Papua New Guinea
    gas discovery
    lower to middle Miocene limestones
    Gillespie, 1967

106. Bwata field, Papua New Guinea
    gas discovery
    lower to middle Miocene limestones
    Gillespie, 1967

107. Puri gas discovery, Papua New Guinea
    Grunau and Gruner, 1978

108. Uramu gas discovery, Papua New Guinea
    Grunau and Gruner, 1978

109. Pasca gas field, Papua New Guinea
    Grunau and Gruner, 1978

110. Kapuni gas field, New Zealand
    gas and condensate production
    McBeath, 1976

111. Maui gas field, New Zealand (offshore)
    gas and condensate production
    McBeath, 1976

112. New Plymouth, New Zealand
    gas seeps
    DuBois, 1979

113. Pelican no. 1 exploration well, Bass basin, Australia
    gas and condensate discovery
    early Eocene, Eastern View Coal Measures
    Nicholas, 1979

Gippsland Basin, Australia
Nicholas, 1979

114. Barracouta A-Platform (offshore)
    oil and gas producing field
    Eocene, Latrobe Group

115. Golden Beach no. 1A exploration well (offshore)
    gas discovery
    Eocene, Latrobe Group

116. Marlin A-Platform (offshore)
    gas producing field
    Eocene, Latrobe Group

117. Snapper no. 1 exploration well (offshore)
    gas discovery
    Eocene, Latrobe Group

118. Tuna no. 2 exploration well (offshore)
    gas and oil discovery
    Eocene, Latrobe Group

119. Turrum no. 2 exploration well (offshore)
    gas discovery
    Paleocene, Latrobe Group

120. Cabawin no. 1 exploration well
    gas and condensate discovery
    Permian "Kianga Formation"

121. Silver Springs no. 1 exploration well
    gas discovery, field currently in production
    Triassic, Showgrounds Sandstone

122. Boxleigh no. 1 exploration well
    gas discovery, field currently in production
    Triassic, Showgrounds Sandstone

123. Kincora no. 3 exploration well
    gas discovery, field currently in production
    Early Jurassic, Evergreen Formation

Roma area: Twenty-five gas discoveries
(Cook and Nicholas, 1979) within the area delineated by the following wells (124-127):

124. Pleasant Hills no. 2 exploration well
    gas discovery
    Triassic Showgrounds Sandstone

125. Wallumbilla South no. 1 exploration well
    gas discovery
    Permian, Tinowon Formation

126. Snake Creek no. 1 exploration well
    oil and gas discovery
    Early Jurassic, Evergreen Formation
127. Pringle Downs no. 1 exploration well  
oil and gas discovery  
Early Jurassic, Evergreen Formation

128. Rolleston no. 1 exploration well  
gas discovery  
Early Permian, Freitag Formation;  
Late Permian, Peawaddy Formation

129. Gilmore no. 1 exploration well,  
Adavale Basin, Australia  
gas discovery  
Devonian, Log Creek Formation  
Nicholas, 1979

Cooper Basin, Australia  
Nicholas, 1979 (130-153)

130. Big Lake no. 1 exploration well  
gas discovery, field currently in  
production  
Permian, Gidgealpa Group

131. Brogla no. 1 exploration well  
gas and condensate discovery  
Permian, Gidgealpa Group

132. Brumby no. 1 exploration well  
gas discovery  
Permian, Gidgealpa Group

133. Burke no. 1 exploration well  
gas discovery  
Permian Gidgealpa Group

134. Coonatie no. 1 exploration well  
gas and condensate discovery  
Permian, Gidgealpa Group

135. Daralingie no. 1 exploration well  
gas discovery  
Permian, Gidgealpa Group

136. Della no. 1 exploration well  
gas discovery  
Permian Gidgealpa Group

137. Dullingari no. 2 exploration well  
gas discovery  
Permian, Gidgealpa Group

138. Epsilon no. 1 exploration well  
gas discovery  
Permian, Gidgealpa Group

139. Fly Lake no. 1 exploration well  
gas and condensate discovery  
Permian, Gidgealpa Group

140. Gidgealpa no. 2 exploration well  
gas discovery, field currently in  
production  
Permian, Gidgealpa Group

141. Kanowana no. 1 exploration well  
gas and condensate discovery  
Permian, Gidgealpa Group

142. Kidman no. 1 exploration well  
gas discovery  
Permian, Gidgealpa Group

143. Merrimelia no. 5 exploration well  
gas discovery  
Permian, Gidgealpa Group

144. Moomba no. 1 exploration well  
gas discovery, field currently in  
production  
Permian, Gidgealpa Group

145. Moorari no. 1 exploration well  
gas and condensate discovery  
Permian, Gidgealpa Group

146. Mudrangie no. 1 exploration well  
gas discovery  
Permian, Gidgealpa Group

147. Namur no. 1 exploration well  
gas discovery  
Jurassic, Mooga Formation

148. Munkarie no. 1 exploration well  
gas discovery  
Permian, Gidgealpa Group

149. Roseneath no. 1 exploration well  
gas discovery  
Permian Gidgealpa Group

150. Strzelecki no. 1 exploration well  
gas discovery  
Permian, Gidgealpa Group

151. Tirrawarra no. 1 exploration well  
oil and gas discovery  
Permian, Gidgealpa Group

152. Toolachie no. 1 exploration well  
gas discovery  
Permian, Gidgealpa Group

153. Wolgolla no. 1 exploration well  
gas discovery  
Permian, Gidgealpa Group
Amadeus Basin, Australia
Nicholas, 1979 (154-155)

154. Palm Valley no. 1 exploration well
gas discovery
Ordovician, Stairway Sandstone, Horn
Valley Siltstone, Pacoota
Sandstone (main reservoir)

155. Mereenie no. 1 exploration well
gas discovery
Ordovician, Pacoota Sandstone

Perth Basin, Australia
Nicholas, 1979 (156-159)

156. Gingin no. 1 exploration well
gas discovery
Early Jurassic, Cockleshell
Gully Formation

157. Dongara no. 1 exploration well
gas discovery
Basal Triassic sandstone

158. Yardarino no. 1 exploration well
gas and oil discovery
Basal Triassic sandstone

159. Mondarra no. 1 exploration well
gas discovery
Basal Triassic sandstone

Carnarvon Basin, Australia
Nicholas, 1979 (160-168)

160. Angel no. 1 exploration well
(offshore)
gas and condensate discovery
Late Jurassic, Barrow Formation

161. Barrow no. 26 exploration well
gas discovery, field currently
in production
Late Jurassic to Early Cretaceous,
Barrow Formation

162. Dockrell no. 1 exploration well
gas, condensate and oil discovery
Mesozoic

163. Goodwyn no. 1 exploration well
gas and condensate discovery
Triassic, Mungaroo Formation

164. North Rankin no. 1 exploration well
gas and condensate discovery
Triassic, Mungaroo Formation

165. Rankin no. 1 exploration well
gas, condensate and oil discovery
Triassic, Mungaroo Formation

166. Spar no. 1 exploration well
gas discovery
Mesozoic

167. Tidepole no. 1 exploration well
gas, condensate and oil discovery
Mesozoic

168. West Tryal Rocks no. 1 exploration
well
gas discovery
Triassic, Mungaroo Formation

169. Scott Reef no. 1 exploration well,
Browse Basin, Australia (off-
shore)
gas and condensate discovery
Jurassic and Triassic
Nicholas, 1979

Bonaparte Gulf Basin, Australia
Nicholas, 1979 (170-172)

170. Tern no. 1 exploration well (off-
shore)
gas discovery
Late Permian, Hyland Bay Formation

171. Petrel no. 1 exploration well
(offshore)
gas discovery
Late Permian, Hyland Bay Formation

172. Sunrise no. 1 and Troubadour no. 1
exploration wells (offshore)
gas discoveries
Late to Middle Jurassic, Petrel
Formation

173. Mamberamo no. 1 well, Irian Jaya,
Indonesia
Hehuwat, 1979

174. Gesa wells, Irian Jaya, Indonesia
Hehuwat, 1979

175. E-1 exploration well, Irian Jaya,
Indonesia (offshore)
non-commercial gas well
post middle Miocene
Bowman, 1974

176a. Salawati N-IX exploration well,
Irian Jaya, Indonesia
gas discovery
post Eocene
Scheldecker, 1977
176b. 59-133 exploration well, Irian Jaya, Indonesia suspended gas well post Eocene. Fletcher, 1978


178. Muna wells, Sulawesi, Indonesia (offshore) Hehuwat, 1979

179. Bonge-1 exploration well, Sulawesi, Indonesia gas discovery Miocene Scheidecker, 1977


181. Bunyu district, East Kalimantan, Indonesia (offshore) gas field Hehuwat, 1979

182. Tarakan area, East Kalimantan, Indonesia gas discovery Bowman, 1974

183. Sepinggan-1 exploration well, East Kalimantan, Indonesia (offshore) gas discovery Bowman, 1974

184. Panyalitan field, Badak district, East Kalimantan, Indonesia gas field Hehuwat, 1979

185. Serang-1 exploration well, East Kalimantan, Indonesia (offshore) gas discovery Bowman, 1974

186. Mahakan area, East Kalimantan, Indonesia (offshore) gas field Hehuwat, 1979


188. Pamaguan no. 1 and Tunu-1 exploration wells, Mahakan offshore, Indonesia gas discovery middle Miocene Caldwell, 1975; Fletcher, 1978

189. Klandasan-1 exploration well, East Kalimantan, Indonesia gas show Miocene Scheidecker, 1977

190. Lamaru-1 exploration well, East Kalimantan, Indonesia gas well Bowman, 1974

191. Bunyu Tapa-3 and Tutupan Timur-5 exploration wells, Kalimantan, Indonesia gas and condensate show Miocene Fletcher, 1978

192. Jatibarang area, Java, Indonesia gas field Hehuwat, 1979

193. Cemara Selatan-1 exploration well, Java, Indonesia gas show Fletcher, 1978

194. Arjuna field, Java, Indonesia (offshore) gas field Hehuwat, 1979

195. Gantar-1 exploration well, Java, Indonesia gas show Bowman, 1974

196. JJ-1 exploration well, Java, Indonesia (offshore) gas show pre-Tertiary Caldwell, 1975

197. Rama field, Java, Indonesia (offshore) International Petroleum Encyclopedia, 1979

198. Limau field, Sumatra, Indonesia gas field Hehuwat, 1979
199. Dewas field, Sumatra, Indonesia
   oil and gas field
   Eocene and Oligocene
   Tanner and Kennett, 1972; Fletcher, 1978

200. Teras-1A exploration well, Sumatra, Indonesia
   gas show
   Tanner and Kennett, 1972

201. Jambi area, Sumatra, Indonesia
   gas field
   Hehuwat, 1979

202. Sengeti exploration wells, Sumatra, Indonesia
   gas wells
   Caldwell, 1975

203. Minas fields, Sumatra, Indonesia
   gas and oil fields
   Hehuwat, 1979

204. Pelita-1 exploration well, Sumatra, Indonesia
   gas discovery
   pre-Tertiary
   Fletcher, 1978

205. Bagandelada South no. 1 exploration well, Sumatra, Indonesia
   gas well
   Tanner and Kennett, 1972

206. Wampu exploration wells, Sumatra, Indonesia
   gas show
   Bowman, 1974

207. Rantau fields, Sumatra, Indonesia
   gas field
   Hehuwat, 1979

208. Meulaboh no. 1 exploration well 2, Sumatra, Indonesia
   gas show
   Miocene
   Fletcher, 1978

209. Sus Timor and Beritang exploration wells, Sumatra, Indonesia
   gas show
   Miocene
   Fletcher, 1978

210. Kuala Simpang-3 exploration well, Sumatra, Indonesia
   gas well
   Bowman, 1974

211. NSB-C1 exploration well, Sumatra, Indonesia (offshore)
   gas well
   Caldwell, 1975

212. Arun Field, Sumatra, Indonesia
   gas field
   Hehuwat, 1979

213. Terubuk field, South China Sea, Indonesia (offshore)
   gas and oil field
   Caldwell, 1975; International Petroleum Encyclopedia, 1979

214-221. natural gas occurrences, Sabah, Malaysia (offshore)
   associated and non-associated gas
   Aw, 1979

222. Samarang field, Sabah, Malaysia (offshore)
   associated gas
   Aw, 1979

223. Petrel, Brunei (offshore)
   gas discovery
   Scheidecker, 1977

224. Osprey-2X exploratory well, Brunei (offshore)
   gas discovery
   Fletcher, 1978

225. Danau-3X exploratory well, Brunei (offshore)
   gas discovery
   Fletcher, 1979

226. Scout Rock-4 exploratory well
    Brunei (offshore)
    gas discovery
    Scheidecker, 1977

227. Southwest Ampa field, Brunei (offshore)
   gas production
   Fletcher, 1979; Grunau and Gruner, 1978

228. Egret East-IX exploratory well, Brunei (offshore)
   oil and gas discovery
   Fletcher, 1979

229. Fulmar 1-X exploratory well, Brunei (offshore)
   gas and condensate discovery
   Fletcher, 1978

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230–249. natural gas occurrences, Sarawak, Malaysia (offshore) associated and non-associated gas Aw, 1979

250–262. natural gas occurrences, Peninsular Malaysia, Malaysia (offshore) associated and non-associated gas Aw, 1979

263–267. natural gas occurrences, Peninsular Malaysia, Malaysia (offshore) non-associated gas Aw, 1979

268. Block 12, Gulf of Thailand, Thailand (offshore) gas wells post Oligocene Fletcher, 1979; Japakasetr, 1979a

269. Block 17, Gulf of Thailand, Thailand (offshore) subcommercial gas well Scheidecker, 1977

270. Block 16, Gulf of Thailand, Thailand (offshore) gas condensate discovery Fletcher, 1978; Japakasetr, 1979a

271. Block 15, Gulf of Thailand, Thailand (offshore) gas condensate discovery Fletcher, 1978; Japakasetr, 1979a

272. Block 10, Gulf of Thailand, Thailand (offshore) gas wells Fletcher, 1977; Scheidecker, 1977

273. Block 5, Gulf of Thailand, Thailand (offshore) oil and gas shows Fletcher, 1979; Japakasetr, 1979a

274. Wells 3 and 4, Burma (offshore) gas discovery Grunau and Gruner, 1978

275. Syriam, Burma gas discovery Grunau and Gruner, 1978


277. Pyaye, Burma gas discovery Fletcher, 1979

278. Pyaye gas field, Burma gas field Miocene, Pyawbwe clay and Kyaukkok sandstone Brown and Dey, 1975; Government of Burma, 1963

279. Pakaukpin field, Burma gas show Okhmintaung Stage of the upper Oligocene Brown and Dey, 1975

280. Yenanma field, Burma gas show Brown and Dey, 1975

281. Ondwe field, Burma gas show Oligocene Brown and Dey, 1975

282. Palanyon field, Burma oil and gas field Pyawbwe clays, lower Miocene Brown and Dey, 1975

283. Minbu field, Burma mud volcanoes Brown and Dey, 1975

284. Yenangyaung field, Burma oil and gas field Miocene to Oligocene Brown and Dey, 1975

285. Chauk field, Burma oil and gas field middle Oligocene Brown and Dey, 1975

286. Yenangyat field, Burma oil and gas field Padaung Stage, middle Oligocene Brown and Dey, 1975

287. Lanywa gas field, Burma middle Oligocene Brown and Dey, 1975

288. Indau field, Burma oil and gas field lower Miocene Brown and Dey, 1975
289. Chhatak field, Bangladesh
Miocene Bokabil and upper Bhuban beds
Ahmed, 1979  

290. Sylhet field, Bangladesh
Miocene Bokabil Formation
Ahmed, 1979  

291. Kailas Tila field, Bangladesh
gas discovery
Miocene Bokabil and upper Bhuban Formation
Ahmed, 1979  

293. Habiganj field, Bangladesh
gas field
Bokabil and upper Bhuban Formations
Ahmed, 1979  

294. Titas field, Bangladesh
gas field
Miocene Bokabil and upper Bhuban Formations
Ahmed, 1979  

295. Bakhrabad field, Bangladesh
gas discovery
Miocene
Ahmed, 1979  

296. Hijla muladi-1, Bangladesh
gas discovery
lower Miocene
Grunau and Gruner, 1978  

297. Noakhali, Bangladesh
gas discovery
lower Miocene
Grunau and Gruner, 1978  

299. Jaldi gas field, Bangladesh
lower Miocene
Grunau and Gruner, 1978  

300. Kutubdia field, Bangladesh (offshore)
gas discovery
Miocene upper Bhuban beds
Ahmed, 1979  

301. Kathmandu Basin, Nepal
gas show
Pleistocene
Tater (personal communication)  

302. Muktinath Basin, Nepal
gas show
Mesozoic
Tater (personal communication)  

303. Nepalganj Basin, Nepal
gas show
Tertiary
Tater (personal communication)  

304. Mannar Island, Sri Lanka
gas show
Miocene Limestone
Jayawardena (personal communication)  

305. South Bassein, India (offshore)
gas field
Eocene-Oligocene
Chaube, 1979  

306. North Bassein, India (offshore)
oil and gas field
Eocene-Oligocene
Chaube, 1979  

307. Bombay High, India (offshore)
Eocene-Miocene
Chaube, 1979  

308. East Bombay High exploration test, India (offshore)
gas discovery
Fletcher, 1979  

309. South Tapti gas fields, India (offshore)
gas discovery
Oligocene, Miocene
Fletcher, 1978  

310. Hazira gas field, India
gas field
Oligocene
Chaube, 1979  

311. Olpad gas field, India
gas field
Miocene
Chaube, 1979  

312. Matwan-Sisodra, India
oil and gas field
Eocene
Chaube, 1979  

313. Anklesvar field, India
oil field
Eocene-Miocene
Chaube, 1979  

314. Dabka-Gajera field, India
oil and gas field
Eocene
Chaube, 1979  

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315. Cambay field, India
   gas field
   Eocene-Miocene
   Chaube, 1979

316. Nawagam field, India
   oil field
   Paleocene and Eocene
   Chaube, 1979

317. Sanand field, India
   oil and gas field
   Eocene
   Chaube, 1979

318. Kalol field, India
   oil and gas field
   Eocene
   Chaube, 1979

319. Sobhasan gas field, India
   oil and gas field
   Eocene
   Chaube, 1979

320. Manhera gas field, India
   gas field
   Paleocene
   Chaube, 1979

321. Sari field, Pakistan
   gas field
   Paleocene Ranikot Formation
   Asrarullah, 1979

322. Hundii field, Pakistan
   gas field
   Paleocene Ranikot Formation
   Asrarullah, 1979

323. Kothar field, Pakistan
   gas field
   Paleocene Ranikot Formation
   Asrarullah, 1979

324. Mazarani Field, Pakistan
   gas field
   Eocene Laki Formation
   Asrarullah, 1979

325. Khairpur field, Pakistan
   gas field
   Eocene Kipthar Formation
   Asrarullah, 1979

326. Mari field, Pakistan
   gas field
   Eocene Kipthar Formation
   Asrarullah, 1979

327. Khandhkov field, Pakistan
   gas field
   Eocene Laki Formation
   Asrarullah, 1979

328. Jacobabad field, Pakistan
   gas field
   Eocene Laki Formation
   Asrarullah, 1979

329. Uch field, Pakistan
   gas field
   Eocene Laki Formation
   Asrarullah, 1979

330. Sui field, Pakistan
   gas field
   Eocene Laki Formation
   Asrarullah, 1979

331. Zin field, Pakistan
   gas field
   Eocene Laki Formation
   Asrarullah, 197-

332. Pirkooh, Pakistan
   gas field
   Cretaceous Pab Formation
   Asrarullah, 1979

333. Rodho field, Pakistan
   gas field
   Paleocene Dunghan Limestone
   Asrarullah, 1979

334. Dhodak, Pakistan
   gas field
   Cretaceous Pab Formation
   Asrarullah, 1979

335. Kwaya Kogerdaph field, Tadzik
   Basin, Afghanistan
   gas field
   Lower Cretaceous, Hauterivian
   Sandstone
   Scheidecker, 1977

336. Yatim Dagh field, Tadzik Basin,
   Afghanistan
   gas field
   Lower Cretaceous, Hauterivian
   Sandstone
   Scheidecker, 1977

337. Hodja-Gugerdag
   gas field
   Lower Cretaceous, Hauterivian
   Sandstone
   Scheidecker, 1977
338. Kwaja Borham field, Tadzik Basin, Afghanistan
gas field
Lower Cretaceous, Hauterivian Sandstone
Scheidecker, 1977

339. Ak-Darza, Afghan-Tadzhik Basin
gas field
Lower Cretaceous, Hauterivian Sandstone
Scheidecker, 1977

340-341. Gas fields in Karakum Basin
Afghanistan
Fletcher, 1979

342. Sarakhs field, Iran
gas production
International Petroleum Encyclopedia, 1979

343. Gorgan field, Iran
gas production
International Petroleum Encyclopedia, 1979

344. Sarajeh field, Iran
gas production
International Petroleum Encyclopedia, 1979

345. Halush gas field, Iran
Hasson and others, 1978

346. Samand SM-2 gas well, Iran
gas discovery
Permian
Hasson and others, 1978

347. Tang-e-Bijar (Kangiran?), Iran
producing gas wells
Hasson and others, 1977

348. Naft Safid field, Iran
producing gas wells
Hasson and others, 1977

349. Mamatain MA-10 exploration well, Iran
suspended gas well
Middle and Lower Cretaceous
Hemer and others, 1979

350. Ahwaz AZ 101 exploration well, Iran
gas discovery
Lower Cretaceous
Hemer and others, 1979

351. Marun MN123 exploratory well, Iran
gas well
Lower Cretaceous
Hemer and others, 1979

352. Pazanan field, Iran
producing gas wells
Hasson and others, 1977, 1978

353. Ardeshir field, Iran (offshore)
producing gas wells
Hasson and others, 1978

354. Milatun MT-1 exploration well, Iran
Khami gas discovery
Hasson and others, 1978

355. Aghar field, Iran
gas discovery
Hasson and others, 1978

356. Dalan DL-1 exploratory well, Iran
gas discovery
Permian
Hasson and others, 1977, 1978

357. Kuh-e-Mand MD-3 exploratory well, Iran
gas discovery
Hasson and others, 1977

358. Pars field, Iran (offshore)
producing gas well
Hasson and others, 1977

359. Kangan field, Iran
producing gas well
Hasson and others, 1977

360. Nar field, Iran
producing gas wells
Hasson and others, 1977

361. Varavi (Zalemi) gas field, Iran
Hasson and others, 1978

362. Bavush, Iran
gas show
Aptian, Dariyan Formation
Hasson and others, 1978

363. Sarkhun field, Iran
producing gas well
Hasson and others, 1978

364. Gavarzin field, Iran
gas production
International Petroleum Encyclopedia, 1979

365. Salakm field, Iran
gas production
International Petroleum Encyclopedia, 1979

366. Agha Jari AJ140 exploration well, Iran
Suspended gas discovery
Lower Cretaceous
Hemer and others, 1979
ONLAND PHOSPHATE OCCURRENCES IN THE ASIA-AUSTRALIA REGION

1. From south of Kazerun northwestwards for about 300 miles to near Masjed Soleyman, Iran pelletal phosphorite upper Eocene, Pabdeh Formation Namin and others, 1965; Notholt, 1968

2. Dogombadan, Iran pelletal phosphorite upper Eocene, Pabdeh Formation Namin and others, 1965

3. Dehloran, Iran phosphatic pebbles in a glauconitic marly bed Upper Cretaceous, Gurpi Formation Namin and others, 1965

4. Gilan-e-Gharb area, Iran phosphatic glauconitic limestone lower Eocene Namin and others, 1965

5. A 120-mile belt in the Elburz Mountains, Iran pelletal phosphorite Upper Devonian, Geirud Formation Namin and others, 1965; Notholt, 1968

6. Azerbaijan to Kuh-e-Forghum, Iran pelletal phosphorite Upper Devonian, Geirud Formation Notholt, 1958

7. Yazd, Iran pelletal phosphorite Upper Devonian, Geirud Formation Notholt, 1968

8. Farrashband, Fars province, Iran phosphatic pebble bed Upper Cretaceous and Paleocene, lower Pabdeh Formation Namin and others, 1965; Notholt, 1968


10. Gerishk, Afghanistan cave guano ECAFE, 1967


12. Dera Ismail Khan division, Pakistan phosphatic nodules Upper Jurassic, Chichali Formation Asrarullah, 1979


14. Karim Kach Khwar, Quetta division, Pakistan phosphatic nodules Late Cretaceous, Moghal Kot Formation British Sulphur Corporation, 1971

15. Abbottabad area, Hazara division, Pakistan. Important occurrences in this area are a) Sirbun, b) Kakul-Mirpur, c) Lagarban, and d) Dalola. Cherty phosphorite and silty calcareous phosphorite Cambrian, Abbottabad and Hazira/Galdanian Formations Asrarullah, 1979


17. Loe-Shilman deposit, north of Bannu district, Pakistan phosphate-bearing carbonatite Precambrian (?) Asrarullah, 1979

18. Loralai district, Baluchistan province, Pakistan phosphatic nodules Cretaceous, Moghal Kot Formation Asrarullah, 1979

19. Dera Ghazi Khan division, Pakistan phosphatic nodules Eocene, Ghazij shale Asrarullah, 1979
20. Srikakulam district, Andhra Pradesh, India
igneous apatite
Krishnaswamy, 1972

21. Sitharamapur area, Kasitpatnam, Visakhapatnam district, Andhra Pradesh, India
apatite-magnetic-vermiculite veins
Precambrian
Mahendra, 1975

22. Valdavur, Tamil Nadu, India
phosphatic concretions and nodules
Upper Cretaceous (Senonian and Maestrichtian), Ariyalur stage
Notholt, 1968

23. Cuddalore, Tamil Nadu, India
phosphatic nodules
Krishnaswamy, 1972; Narasimhan, 1960-1961

24. Kottagudie area, Tamil Nadu, India
apatite-pegmatite
Krishnaswamy, 1972

25. near Quillon, India (offshore)
phosphatic nodules
British Sulphur Corporation, 1971; Pant, 1979

26. Sevathur, North Arcot district, Tamil Nadu, India
carbonatite-mica-pyroxenite soil and apatite crystals in carbonatite bodies
Krishnaswamy, 1972; Narasimhan, 1960-1961

27. Channapatna, Mysore, India
apatite in pockets
Krishnaswamy, 1972

28. Arsikere, Mysore, India
apatite in pockets
Krishnaswamy, 1972

29. Hole Narsipur, Mysore, India
apatite in pockets
Krishnaswamy, 1972

30. Amba Dongar in Berbada Valley, Gujarat, India
apatite in carbonatite body
British Sulphur Corporation, 1971

31. Jhabua district, Madhya Pradesh, India
phosphatic stromatolites
Precambrian Aravalli Supergroup
Basu, 1976; Basu and Banerjee, 1975; Khan, 1979

32. Dungarpur, Rajasthan, India
apatite-bearing schist
Krishnaswamy, 1972

33. Udaipur district, Rajasthan, India.
Important occurrences in this area include Jhamarkotra, Dakan Kotra, Maton, Kanpur, Kharbariaka Gurha, Neemach mata, Badgaon, Sisarma, Berawas, Bhiola, and Jhameshwar.
phosphatic stromatolites
Precambrian, Aravalli Supergroup,
Matoon Formation
Banerjee, 1971b, 1971c; Muktinath, 1967; Muktinath and Sant, 1967; Muktinath and others, 1969; Pandya and Chauhan, 1976

34. Birmania, Jaisalmer district, Rajasthan, India
phosphatic sandy shale and phosphatic limestone
Paleozoic, Birmania Formation
Deshmukh, 1979; Muktinath, 1967; Sant and Sharma, 1971; Srikantan and others, 1969

35. Poonch (Punch), Kashmir, India
phosphatic nodules

36. Riasi, Kashmir, India
phosphatic nodules
Krishnaswamy, 1972; Singh and Sharma, 1964-1965

37. Udampur, Kashmir, India
phosphatic nodules
Krishnaswamy, 1972; Singh and others, 1970-1971

38. Nigalidhar, Korgai and Solan areas, Solan, Sirmur, and Simla districts, Himachal Pradesh, India
phosphatic quartzite
Jurassic, lower Tal Formation, Krol Member
Agarwal, 1970; Dass, 1963; Joshi, 1970

39. Jagadhri (Tehri Garhwal), Uttar Pradesh, India
phosphatic nodules
Jurassic, Tal Formation
Krishnaswamy, 1972; Ghosh, 1968
40. Mussoorie area, Dharadun and Tehri districts, Uttar Pradesh, India. Important occurrences in this area include Maldeota, Durmala, Partibba-Chamsari, Bhusti-Jamthialgaon-Jalikhal areas, Masran, and Bagi-Mathiagaon areas.


42. Hirapur, Madhya Pradesh, India. Phosphorite Precambrian, Bijawar Group, Gangau Formation Pant, 1979

43. Singhbhum district, Bihar, India. Important occurrences in this area include Nandup, Sunrgi, Kulamara, and Pathargora areas. Apatite-magnetite veins Precambrian, Dharwar System Agarwal, 1945; Dunn, 1937; Notholt, 1968

44. Purulia district, West Bengal, India. Important occurrences in this area include Beldih, Kutni, Mednitanr, Chirugora, and Panrrkidih. Quartz-apatite and apatite-magnetite-quartzite veins India Geological Survey, 1974


47. Giridih, Bihar, India. Apatite in mica-peridotite dikes Notholt, 1968

48. Hunuganakal area, Dharmapuri district, Tamil Nadu, India. Apatite in carbonatite body Precambrian India Geological Survey, 1974; Shukla, 1976


50. Sallapat and Ram ka Munna Jher Moti, Banswara district, Rajasthan, India. Phosphatic stromatolites Precambrian, Aravalli Supergroup Banerjee, 1971a; Sant and Sharma, 1971; Shukla, 1976

51. Lalitpur district, Uttar Pradesh, India. Phosphorite Precambrian, Bijawar Group Pant and others, 1979

52. Kutch district, Gujarat, India. Important occurrences in this area include Godpar-Gadhhsisa, Sadanbari, and Jhura area. Phosphatic concretions Jurassic, Bhuj Formation Muktinath, 1974


54. Fatehgarh, Jaisalmer district, Rajasthan, India. Ferruginous phosphatic sandstone Cretaceous-Eocene, Fatehgarh Formation Deshmukh, 1979; Muktinath, 1967; Sant and Sharma, 1971


57. Chapoli area, Jhunjhunu district, Rajasthan, India. Apatite associated with garnetiferous schist Precambrian Sethi, 1969; Shukla, 1976
58. Bhawanathpur area, Palamau district, Bihar, India
phosphatic horizon associated with calcareous shale
Precambrian
Shukla, 1976

59. Laccadive-Amindivi Islands, India
guano
Mukherjee and Rao, 1970

60. Eppawela deposit, Sri Lanka
apatite crystals in a brecciated zone
Precambrian
Jayawardena, 1976, 1979

61. Seruwila deposit, Sri Lanka
fluorapatite in copper-magnetite ore
Precambrian, Vijayan Series
Jayawardena, 1979

62. Thuligad, Nepal
phosphatic rocks
Eocene to Oligocene, Surkhet Group
Tater, 1979

63. Khulia Khola, Nepal
phosphatic shales and carbonates
Surkhet Group, Eocene
Tater, 1979

64. near Khulia Khola, Nepal
phosphatic rocks
Eocene, Surkhet Group
Tater, 1979

65. near Gwar Khola, Nepal
phosphatic rocks
Eocene to Oligocene, Surkhet Group
Tater, 1979

66. Gwar Khola, Nepal
phosphatic shales
Late Precambrian to Paleozoic, Midland Group
Tater, 1979

67. Northeast of Bhairawa, Nepal
phosphatic shales and sandstones
Siwalik Group
Tater, 1979

68. Tawa Khola, Nepal
phosphatic shales
Eocene to Oligocene, Surkhet Group
Tater, 1979

69. near Tawa Khola, Nepal
phosphatic shales
Eocene to Oligocene, Surkhet Group
Tater, 1979

70. Barahkshetra area, Nepal
phosphatic nodules
Barahkshetra Formation, Perm-Carboniferous
Tater, 1979

71. Pakokku district, Burma
phosphatized coprolitic nodules and crustacean fragments
upper Eocene, Yaw Stage
Notholt, 1968

72. Amberst district, Burma
cave guano
ECAFE, 1967

73. North Andaman, Andaman Islands, India
(offshore)
phosphatic and slightly ferruginous nodules
Notholt, 1968

74. Surat Thani province, Thailand
phosphatic shales
Devonian and Carboniferous
ECAFE, 1967

75. Khao Khlong Wan, Thailand
phosphate pockets in the Rat Buri limestone of Permian age
Pleistocene (?)
Notholt, 1968

76. Khao Phak Mah, Ratburi province, Thailand
phosphate in limestone and caves
Japakasetr, 1979

77. Khao Cha-Ngoke, Chon Daen district, Phetchabun province, Thailand
phosphate rock
Japakasetr, 1979

78. Ban Sob Moei, Mae Tha district, Lamphun province, Thailand
phosphate rock
Japakasetr, 1979
79. Ban Lao Kham, Roi Et province, Thailand
   phosphate cement
   Japakasetr, 1979

80. along the Song Ma River,
   Than Hoa area, Vietnam
   concretionary or compact
   phosphate rock, phosphatic
   pisolites
   upper Paleozoic
   Notholt, 1968

81. Ham Rong, Nam Phat, Thuong
   Hoa and Yen Son, south of
   Hanoi, Vietnam
   nodular and vein-like masses
   of phosphate
   upper Paleozoic
   Notholt, 1968

82. Lao Gai, northern Tonkin,
    Vietnam
    granular apatite, apatite dis-
    seminated in quartzite, and
    apatite-bearing calc-schists
    Cambro-Ordovician, Coc-Xan series
    Notholt, 1968

83. Vinh Thinh, Tonkin, Vietnam
    earthy phosphate and phos-
    phatized limestone
    upper Paleozoic
    Notholt, 1968

84. Sisophon, Kampuchea
    Notholt, 1968

85. Phnom Sampou, Battambang
    province, Kampuchea
    concretionary phosphate
    Notholt, 1968

86. Tuk Meas, Kampot province,
    Kampuchea
    phosphate filling fissures and
    cavities in limestone of Carbo-
    Permian age
    Notholt, 1968

87. Chupling, Peninsular Malaysia,
    Malaysia
    guano
    Aw, 1979

88. Gunong Keriang, Peninsular
    Malaysia, Malaysia
    guano
    Aw, 1979

89. Bt. Baling, Peninsular Malaysia,
    Malaysia
    guano
    Aw, 1979

90. Dalam Wang, Peninsular Malaysia,
    Malaysia
    guano
    Aw, 1979

91. Guo Setir, Peninsular Malaysia,
    Malaysia
    guano
    Aw, 1979

92. Guo Musang, Peninsular Malaysia,
    Malaysia
    guano
    Aw, 1979

93. Kota Jin, Peninsular Malaysia,
    Malaysia
    guano
    Aw, 1979

94. Gunong Staat, Sarawak, Malaysia
    guano and phosphate rock
    Aw, 1979; Notholt, 1968

95. Bidi, Sarawak, Malaysia
    guano
    Aw, 1979

96. Lobang Batu caves, Gunong Selabor,
    Sarawak, Malaysia
    guano and phosphate rock
    Aw, 1979; Notholt, 1968

97. Niah caves, Sarawak, Malaysia
    bat and swift guano and phosphate
    rock
    Aw, 1979; Notholt, 1968

98. Melinau, Sarawak, Malaysia
    guano
    Aw, 1979

99. Funan Batu, Sabah, Malaysia
    guano
    Aw, 1979

100. Lian, Sabah, Malaysia
    guano
    Aw, 1979

101. Batu Sapad, Sabah, Malaysia
    guano
    Aw, 1979
102. Madai, Baturong and Pidtong caves, Tawau residency, Sabah, Malaysia
cave guano and phosphate rock
Aw, 1979; Notholt, 1968

103. Baturong, Sabah, Malaysia guano
Aw, 1979

104. Siput, Sabah, Malaysia guano
Aw, 1979

105. Tempadong, Sabah, Malaysia guano
Aw, 1979

106. Gomanton caves, Sandakan residency, Sabah, Malaysia
cave guano and phosphate rock
Aw, 1979

107. Goemai Mountains, Balembang province, Indonesia apatite in limestone
Cretaceous ECAFE, 1967

108. Tangkuban Parahu volcano, near Tjilater, Java, Indonesia phosphatic sinter
Notholt, 1968

109. Adjibarang area, near Tjilatjap, Java, Indonesia limestone breccia cemented and partly replaced by phosphate
Notholt, 1968

110. Kromong Mountains near Tjirebon, Indonesia
cave phosphate (?) ECAFE, 1967

111. More than 100 caves in western and northern Rembang Hills, Java, Indonesia
cave guano Notholt, 1968

112. Eastern Java, Indonesia marine phosphorite (nodules and concretions)
Miocene Hehuwat, 1975

113. Parigi, Seluwasi, Indonesia ECAFE, 1967

114. Irian Jaya, Indonesia phosphorites Hehuwat, 1979

115. Arafura Sea, near the Tanimbar Islands, Indonesia (offshore) phosphatic sediments Jongsma, 1974; Hehuwat, 1975


117. Southern Hainan Island, China sedimentary phosphorite Cambrian Chang and Chao, 1978

118. Mengci area, Yunnan province, China apatite Lower Cambrian, Koksan suite Bushinskii, 1969

119. near Guangnan, Yunnan province, China sedimentary phosphorite Devonian Chang and Chao, 1978

120. Debao area, Kwangsi province, China sedimentary phosphorite Devonian Chang and Chao, 1978

121. Yu Jiang area, near Heng Xian, Kwangsi province, China sedimentary phosphorite Devonian Chang and Chao, 1978

122. west of Chiang men, Kwangtung province, China nodular phosphorite pre-Devonian or Cambro-Sinian, Lungshan complex Bushinskii, 1969

123. Kueilin area, Kwangsi Chuang province, China nodular phosphorite Sinian, Towshanto suite; Lower Cambrian, Shuikow suite Bushinskii, 1969

124. north of Lochang, Kwangtung province, China nodular or shaly phosphorite Lower Cambrian Bushinskii, 1969
125. southwest of Wenchengzhen, Yunnan province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

126. near Huize, Yunnan province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

127. near Dongchuan, Yunnan province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

128. north of Anshun, Kweichow province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

129. northwest of Guiyang, Kweichow province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

130. east - northeast of Guiyan, Kweichow province, China
sedimentary phosphorite
Cambrian, Precambrian (Sinian)
Chang and Chao, 1978

131. north of Leigong Shan, near Taigong, Kweichow province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

132. Chaping (San chiang), Kweichow province, China phosphorite lenses in argillaceous shales
Lower Cambrian
Bushinskii, 1969

133. south of Fanjing Shan, Kweichow province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

134. near Wanshan, Hunan and Kweichow provinces, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

135. near Zhijiang, Hunan province, China
sedimentary phosphorite
Cambrian (Sinian)
Chang and Chao, 1978

136. north of Huahua Xian, Hunan province, China
sedimentary phosphorite
Cambrian (Sinian)
Chang and Chao, 1978

137. near Anjiang, Hunan province, China
sedimentary phosphorite
Cambrian (Sinian)
Chang and Chao, 1978

138. Southern Suehpfeng Shan area, Hunan province, China
nodular phosphorite, granular and aphanitic phosphorite
Lower Cambrian, Precambrian (Sinian)
Bushinskii, 1969; Notholt, 1979

139. Northern Suehpfeng Shan area, Hunan province, China
phosphatic nodules and granules
Lower Cambrian; Precambrian (Sinian), Towshanto suite
Bushinskii, 1969; Notholt, 1979

140. Chayuanpu deposit, Chiling, Hunan province, China
granular and aphanitic phosphorite
Precambrian (Sinian)
Bushinskii, 1969

141. Northeast of Changsha, Hunan province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

142. Huah wai area, south of Yihuang, Kiangsi province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

143. northeast of Fuzhou, Fukien province, China
metamorphosed phosphate
Chang and Chao, 1978
144. Southwest of Guiqi, Kiangsi province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

145. south of Hekou, Kiangsi province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

146. north of Yushan, Kiangsi province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

147. near Wusheng, Chekiang province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

148. Northern Chiuling Shan area, Kiangsi province, China
phosphate nodules in argillaceous shales
Lower Cambrian (?), Kuanyingtang suite
Bushinskii, 1969; Notholt, 1979

149. Northern Qianyang region, Hunan province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

150. Near Guzhang in the Wuling Mountains, Hunan province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

151. Northwest of Sang chih, Hunan province, China
bedded phosphorite
Lower Cambrian
Bushinskii, 1969

152. Huangling anticline, near Yicheng, Hupeh province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

153. near Xunjiaya, Hupeh province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

154. north of Badong, Hupeh province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

155. north of Jiaochangba, Hupeh province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

156. near Shangkan, Hupeh province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

157. Han River area, south of Xiangfan, Hupeh province, China
bedded phosphorite
Lower Cambrian; Precambrian (Sinian), Towashanto suite
Bushinskii, 1969; Notholt, 1979

158. Dahong Shan area, Hupeh province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

159. east of Erlangtian, Hupeh province, China
metamorphosed phosphate
Chang and Chao, 1978

160. near Hongan, Hupeh province, China
metamorphosed sedimentary phosphorites pre-Sinian
Bushinskii, 1969

161. Northeast of Taihu, Anhwei province, China
metamorphosed phosphate
Chang and Chao, 1978

162. near Wangjiang, Anhwei province, China
metamorphosed phosphate
Chang and Chao, 1978

163. Chaoxian area, Anhwei province, China
metamorphosed phosphate
Chang and Chao, 1978

164. near Zhujiang, Kiangsu province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978
165. West of Chengxi Hu, Anhwei province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

166. Southeast of Fengtai, Anhwei province, China
Oolitic and conglomeratic phosphorite
Lower Cambrian, Mantow suite
Bushinsky, 1969; Notholt, 1979

167. Near Wanyuan, Szechwan province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

168. North of Zhongba, Szechwan province, China
sedimentary phosphorite
Devonian
Chang and Chao, 1978

169. Jiuding Shan area, near Hanwang, Szechwan province, China
sedimentary phosphorite
Devonian
Chang and Chao, 1978

170. West of Omei Shan, Szechwan province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

171. East of Ebian, Szechwan province, China
bedded granular phosphorite
Lower Cambrian, Leipo suite
Chang and Chao, 1978

172. Yangtze River area, near Leibo, Szechwan province, China
bedded granular phosphorite
Lower Cambrian, Leipo suite
Bushinsky, 1969

173. Near Zhongshu, Kweichow province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

174. Zunyi area, Kweichow province, China
bedded phosphorite
Lower Cambrian; Precambrian (Sinian), Sung Ling suite
Bushinsky, 1969

175. Near Tongzi, Kweichow province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

176. West of Tongzi in the Dalou Mountains, Kweichow province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

177. Near Chengxian, Kansu province, China
sedimentary phosphorite
Devonian
Chang and Chao, 1978

178. North of Liuba, Shensi province, China
sedimentary phosphorite
Devonian
Chang and Chao, 1978

179. Near Mianxian, Shensi province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

180. Northern Micang Shan, near Zhoujiaping, Shensi province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

181. Near Diangasi, Kansu province, China
sedimentary phosphorite
Devonian
Chang and Chao, 1978

182. Near Longxian, Shensi province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

183. North of Baoji, Shensi province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

184. Near Qianxian, Shensi province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

185. Northern Qinling Shanmo (mts.), Shensi province, China
quartzitic conglomeratic phosphorite and bedded phosphorite
Lower Cambrian
Bushinsky, 1969; Notholt, 1979
186. Southwest of Guoluezhen, Honán province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

187. Eastern Zhongtiao Shan, near Pinglu Xiao, Shansi province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

188. near Unxi, Hupeh province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

189. west of Nanhuatang, Hupeh province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

190. near Baisang, Hupeh province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

191. near Paofeng, Honan province, China
bedded quartzitic phosphorite
Lower Cambrian
Bushinskii, 1969

192. near Pingding Shan, Honan province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

193. Song Shan area, near Dengfeng, Honan province, China
metamorphosed phosphate
Chang and Chao, 1978

194. Hsin an, Kiangsu province, China
metamorphosed sedimentary phosphorites
Upper Proterozoic, Yungtai suite
Bushinskii, 1969

195. near Cilai Shan, Shantung province, China
igneous apatite
Chang and Chao, 1978

196. Northeast of Duancun, Shansi province, China
metamorphosed phosphate
Chang and Chao, 1978

197. east of Heichengzhen, Ningsiahui, province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

198. west of Bayan, Tsinghai province, China
igneous apatite
Chang and Chao, 1978

199. south of Zhongning, Ningsiahui province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

200. Southern Holan Shan, Ningsia Hui autonomous region, China
phosphatic conglomerate
Lower Cambrian
Bushinskii, 1969; Notholt, 1979

201. Wutai Shan area, Shansi province, China
bedded and nodular phosphorite
Precambrian (Sinian)
Bushinskii, 1969, Notholt, 1979

202. Northeast of Yuxian, Shansi province, China
metamorphosed phosphate
Chang and Chao, 1978

203. Northwest of Baoding, Hopeh province, China
metamorphosed phosphate
Chang and Chao, 1978

204. Southwest of Beijing, Hopeh province, China
igneous apatite
Chang and Chao, 1978

205. Northern Holan Shan, Ningsia Hui autonomous region, China
conglomeratic phosphorite
Lower Cambrian
Bushinskii, 1969; Notholt, 1979

206. near Baiyunebo, Inner Mongolia (Neimunggu province), China
metamorphosed phosphate
Upper Proterozoic, Payunopo System
Bushinskii, 1969

207. near Zhuozi, Neimunggu (Inner Mongolia) province, China
igneous apatite
Chang and Chao, 1978
208. Southwest of Jining, Neimunggu (Inner Mongolia) province, China
ingeous apatite
Chang and Chao, 1978

209. near Datong, Shansi province, China
igneous apatite
Chang and Chao, 1978

210. east of Jining, Neimunggu (Inner Mongolia) province, China
Metamorphosed phosphate
Chang and Chao, 1978

211. Near Xinghe, Neimunggu (Inner Mongolia) province, China
igneous apatite
Chang and Chao, 1978

212. south of Zhangjiakou, Hopeh province, China
igneous apatite
Chang and Chao, 1978

213. Northeast of Zhangbei, Hopeh province, China
igneous apatite
Chang and Chao, 1978

214. near Dagezhen, Hopeh province, China
metamorphosed phosphate
Chang and Chao, 1978

215. north of Miyun, Hopeh province, China
igneous apatite
Chang and Chao, 1978

216. south of Chengde, Hopeh province, China
igneous apatite
Chang and Chao, 1978

217. near Miyun, Hopeh province, China
sedimentary phosphorite Precambrian (Sinian)
Chang and Chao, 1978

218. Liaoning province, China
fluorapatite ore bodies in a tillite sedimentary unit Precambrian (Sinian), Tiao yu tai suite
Bushinskii, 1969

219. Kacha-do deposit, Korea Bay, North Korea
apatite-bearing diopside rock
Notholt, 1968

220. Yongyu in South Pyongyang, North Korea
residual soil phosphate and apatite veins in mica-schists and limestones of the Yonchon System
Notholt, 1968

221. near Dandong, Liaoning province, China
metamorphosed phosphate
Chang and Chao, 1978

222. near Kuandian, Liaoning province, China
metamorphosed phosphate
Chang and Chao, 1978

223. near Liuhe, Kirin province, China
metamorphosed phosphate
Chang and Chao, 1978

224. east of Huinan Xian, Kirin province, China
metamorphosed phosphate
Chang and Chao, 1978

225. Southwest of Kulunzhien, Kirin province, China
metamorphosed phosphate
Chang and Chao, 1978

226. Nuluerhu Shan, west of Chaoyang, Liaoning province, China
metamorphosed phosphate
Chang and Chao, 1978

227. west of Ningan, Heilungkiang province, China
metamorphosed phosphate
Chang and Chao, 1978

228. near Linkou, Heilungkiang province, China
metamorphosed phosphate
Chang and Chao, 1978

229. Pei Shan area, Chekiang province, China
bedded and nodular phosphorites Lower Cambrian
Bushinskii, 1969

230. north of Qingguandu, Hunan and Hupeh provinces, China
sedimentary phosphorite Precambrian (Sinian)
Chang and Chao, 1978
231. Funlu Shan area, west of Wuyang, Honan province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

232. near Huailai, Hopeh province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

233. near Shimian, Szechwan province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

234. Huidong area, Szechwan province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

235. near Wuding, Yunnan province, China
sedimentary phosphorite
Precambrian (Sinian)
Chang and Chao, 1978

236. Kunming – Chinning (Kunyang) area, Yunnan province, China
bedded phosphorite, phosphate nodules
Lower Cambrian, Leipo suite
Wang, 1942; Ho, 1942; Bushinskii, 1969

237. east of Pei Shan, Kansu province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

238. west of Pei Shan, Kansu province, China
sedimentary phosphorite
Cambrian
Chang and Chao, 1978

239. Western Kuluko Shanmo (mts.), Sinkiang province, China
bedded aphanitic phosphorites
Lower Cambrian
Bushinskii, 1969

240. near Koping (Kelpin), Sinkiang province, China
bedded or nodular phosphorite
Lower Cambrian
Bushinskii, 1969

241. near Bachu, Sinkiang province, China
sedimentary phosphorite
lower Cambrian
Chang and Chao, 1978

242. Mao Island, Penghu Islands, Taiwan, China
phosphatic clay and phosphatized rock
Ho and Lee, 1963; Notholt, 1968

243. Mienhua Island, Taiwan, China
phosphatic clay and phosphatized rock
Ho and Lee, 1963; Notholt, 1968

244. Agno and Mabini, Pangasinan province, Luzon, Philippines
cave guano and phosphatized limestone
Notholt, 1968

245. near Libmanan, Camarines Sur province, Philippines
cave guano and phosphatized limestone
Notholt, 1968

246. Marilima cave deposit, near Virac, Catanduanes, Philippines
guano and phosphatized rock
Notholt, 1968

247. near Escalante, Negros Occidental, Philippines
earthy masses of phosphatized limestone
Notholt, 1968

248. Four caves near Toboso, Negros Occidental, Philippines
phosphatized soil mixed with guano
Notholt, 1968

249. near San Carlos, Negros Occidental, Philippines
oolitic phosphate and phosphatic concretions
Miocene and Pliocene (?)
Notholt, 1968

250. Cave deposits, Iloilo province, Panay, Philippines
cave guano and phosphate rock
Notholt, 1968

251. Pupug caves, near Mabini, Bohol, Philippines
cave guano
Notholt, 1968
252. Ashmore Reef, Western Australia, Australia guano, Recent Hutchinson, 1950

253. Browse Island, Australia guano and phosphate rock Hutchinson, 1950

254. Adele Island, Australia guano Hutchinson, 1950

255. Lacepede Islands, Australia guano Hutchinson, 1950

256. Murchinson River, Western Australia, Australia phosphorite, Cretaceous Low, 1959

257. Geralton, Western Australia, Australia phosphate rock, Jurassic Colalura Sandstone British Sulphur Corporation, 1971

258. Houtman's Abrolhos, Western Australia, Australia guano and phosphate rock, Recent Barrie, 1965a; Woodward, 1917

259. Dandaragan, Western Australia, Australia phosphate nodules and phosphatized wood, Cretaceous Matheson, 1948

260. Lake Weelhamby, Western Australia, Australia biogenic phosphatization of igneous rock Hutchinson, 1950

261. Perth area, Western Australia, Australia cave guano, Recent Cook, 1979

262. Recherche Archipelago, Australia guano Hutchinson, 1950

263. Islands in the Great Bight, Australia guano Hutchinson, 1950

264. Brothers Islands, Australia guano Hutchinson, 1950

265. Marum Island, Sir Joseph Banks Group, Australia guano, Recent Barrie, 1965a

266. Bickers Islets, South Australia, Australia guano, Recent ECAFE, 1967

267. McDonnell Range, Northern Territory, Australia phosphatic nodules, sandstones and siltstones, Ordovician Stairway Sandstone Cook, 1963

268. George Gill Range, Northern Territory, Australia phosphatic nodules, sandstones and siltstones, Ordovician Stairway Sandstone Cook, 1963

269. Ringwood, Northern Territory, Australia phosphorite, Upper Proterozoic Cook, 1963

270. Mud Tank, Northern Territory, Australia igneous apatite, Precambrian Crohn and Gellatly, 1969

271. Barrow Island, Australia guano Hutchinson, 1950

272. Amaroo, Northern Territory, Australia phosphorite, Ordovician (?) Cook, 1979

273. Sleisbeck and Coronation Hill, South Alligator River Valley, Australia phosphorite, Precambrian Barrie, 1965

274. Rum Jungle, Northern Territory, Australia phosphorite, Precambrian Castlemaine Hill Beds Pritchard and Cook, 1965
275. Fannie Bay and Lee Point, Northern Territory, Australia phosphorite, Cretaceous Kemezys, 1968

276. Bathurst Island, Northern Territory, Australia pelletal and concretionary phosphates, phosphatic nodules, phosphatized limestone, Cretaceous Kemezys, 1968

277. Islands in Shark Bay, Australia guano Hutchinson, 1950

278. Bramble Bay, Australia guano, Recent (?) Hutchinson, 1950

279. Raine Island, Queensland, Australia guano Hutchinson, 1950

280. Alroy, Queensland, Australia phosphorite, Cambrian Cook, 1979

281. Alexandria - Wonarah, Queensland, Australia phosphorite, Middle Cambrian Wonarah and Burton Beds Howard, 1972; Howard and Perrino, 1976


295. St. Ann's, Queensland, Australia Phosphorite, Devonian-Carboniferous Cook, 1979

296. Wooltana Caves, South Australia, Australia cave guano, Recent ECAFE, 1967

297. Oroparina, South Australia, Australia guano, Recent Cook, 1979

298. Clinton, South Australia, Australia phosphate rock as fillings in solution cavities and fissures in limestone, Recent Cook, 1979

299. Myongpa-Kapunda-Carrieton, South Australia, Australia phosphorite, Lower Cambrian Blissett and Callen, 1967; Callen, 1970a, 1970b

300. Lower Hermitage, South Australia, Australia guano, Recent Cook, 1979

301. Orroroo, South Australia, Australia phosphorite, Recent Dickinson, 1943

302. Olary region near Flinders Range igneous apatite Campana and King, 1958

303. Mootwingee, New South Wales, Australia phosphorite, Cambro-Ordovician Cook, 1979

304. Bulumwaal, Victoria, Australia phosphorite, Ordovician Cook, 1979

305. Mansfield district, Victoria Australia. Deposits occur at Phosphate Hill, Howe's Creek and Whitfield. phosphorite, Ordovician and Upper Cambrian Howitt, 1923
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385. Kagoshima prefecture, Japan
phosphate
ECAFE, 1967

386. Miyazaki prefecture, Japan
phosphatic nodules
Tertiary
Notholt, 1968

387. Sinpung deposits, near
Tanchon, South Hamgyong
province, North Korea
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with minor amounts of magnetite, pyrrhotite and biotite
Precambrian, Mach'onnyong Series
Notholt, 1968, 1978

388. Songjin, North Korea
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Precambrian, Mach'onnyong Series
Notholt, 1968

389. Sangpochi-dong, near Kilchu,
North Korea
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metamorphism
Notholt, 1968

390. Toba, Mie prefecture, Japan
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manganese ore
Paleozoic
ECAFE, 1967; Notholt, 1968

391. near Suwa, Nagano prefecture,
Japan
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bog iron deposits
Notholt, 1968

392. Yamanashi prefecture, Japan
phosphatic nodules
Tertiary
Notholt, 1968

393. east of Noto Peninsula, Ishikawa
prefecture, Japan. Important
occurrences in this area include Hiuchidani, Oyaemondani,
Noto Shima, Sichimi, Usetsu,
Takai, and Hamada
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Miocene, Nanao Group
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394. Ibaraki prefecture, Japan
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395. Yamagata prefecture, Japan
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396. Niigata prefecture, Japan
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397. Akita prefecture, Japan
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332. Bird Islet (Wreck Reef) guano Hutchinson, 1950
333. Iles Chesterfields guano Hutchinson, 1950
334. Iles Huon guano Hutchinson, 1950
335. Mare guano Plummer, 1979
336. Walpole Island guano Hutchinson, 1950
337. White Island guano Hutchinson, 1950
338. Cape Kidnapper guano Hutchinson, 1950
339. New Plymouth phosphate in fissures Hutchinson, 1950
341. The Snares guano Hutchinson, 1950
342. Antipodes Islands guano Hutchinson, 1950
343. Bounty Islands Hutchinson, 1950
344. Tioriori deposit, Chatham Islands, New Zealand phosphorite nodules Paleocene, Tioriori Group Watters, 1968
345. Santa Catalina Phosphatic clay White and Warin, 1964
346. Rennell Phosphate Grover, 1958
347. Bellona Oolitic and incoherent phosphate White and Warin, 1964
348. Laughlan guano Plummer, 1979
349. Purdy Islands (Bat, Mole, and Mouse) Phosphatic Crust White and Warin, 1964
350. Wuvulu Phosphatic clay Hutchinson, 1950 White and Warin, 1964
351. Aua Phosphatic crust Hutchinson, 1950 White and Warin, 1964
352. Manu Phosphatic guano, phosphatic mud Hutchinson, 1950 White and Warin, 1964
353. Sae Phosphatized sand White and Warin, 1964
354. Greenwich Atoll (includes 14 phosphatic islands) Hutchinson, 1950
355. Ngatik rock phosphate, phosphatic nodules Hutchinson, 1950
358. Udot Phosphate Hutchinson, 1950
359. Gaferut Phosphate Hutchinson, 1950
360. Saipan, Tinian and Aguijan Islands earthy and rock phosphate, phosphatic clay Hutchinson, 1950, Rodgers, 1948
361. Rota granular and nodular phosphate, phosphatic soil Hutchinson, 1950
362. Palau Islands: including Angaur, Peleliu, Eil Malk, Urukthapel earthy phosphate, phosphatic nodules Hutchinson, 1950
363. Fais earthy phosphate, phosphatic nodules Hutchinson, 1950
364. Sonsorol Islands earthy, sandy and tuffaceous phosphates Hutchinson, 1950
365. Tobi earthy phosphate, phosphatized sand, phosphatic nodules Hutchinson, 1950
366. Ajawi phosphorite?, nauruite-like phosphate Hutchinson, 1950
367. Baar's guano Hutchinson, 1950
368. Batu Kapal guano Hutchinson, 1950
369. Amboina Bay guano and phosphate Hutchinson, 1950

370. The Shinan Islands, including North Danger-REEF, West York, Thi-tu, Flat, Loafta, Itu Aba, Nam Yit, Sin Cowe, Spaatly Islands guano Hutchinson, 1950
371. Paracel Islands, including Tree, Rocky, Woody, Lincoln, North Reef, Pattle, Robert, Money, Drummond, and Duncan Islands guano and phosphate Hutchinson, 1950
372. Tung-sha-tao Sandy or earthy phosphate Hutchinson, 1950
373. Okino Daito Jima calcium and aluminum phosphate Hutchinson, 1950
Rodgers, 1948
374. Kita Daito Jima Aluminum phosphate Hutchinson, 1950
Rodgers, 1948
375. Kuchino Shima granular phosphate Hutchinson, 1950
376. Kaminone Sho guano Hutchinson, 1950
377. Kikaigashima Phosphate Hutchinson, 1950
378. Yoron Jima Phosphate Hutchinson, 1950
379. Tori Shima Guano, phosphate rock Hutchinson, 1950
380. Ajuni Jima Phosphate Hutchinson, 1950
381. Okinawa cave guano Hutchinson, 1950
382. Miyako Jima phosphate in limestone fissures, cave guano middle Pleistocene(?) Hutchinson, 1950
383. Tarama Jima
   earthy and rock phosphate
   Hutchinson, 1950

384. Hateruma Shima
   Phosphate in limestone fissures,
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   Hutchinson, 1950

404. Marcus (Minami Tori Shima)
   guano, phosphatic soil, granular
   phosphate
   Hutchinson, 1950

425. Johnston Island
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439-440)
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429. Midway
   guano

431. Lisiansky
   guano

432. Laysan
   phosphatized coral sand

433. Gardner
   Phosphate as fracture fillings

434. French Frigate Shoals
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435. Necker
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439. Nihoa
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440. Kaula
   guano

441. Palmyra
   phosphatized coral

442. Fanning Island
   phosphatized sand
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443. Washington
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   Hutchinson, 1950

444. Christmas Island
   phosphatic soil
   Hutchinson, 1950

445. Jarvis Island
   guano
   Hutchinson, 1950

446. Malden Island
   guano
   Hutchinson, 1950

447. Starbuck Island
   guano
   Hutchinson, 1950

448. Coral Island
   Hutchinson, 1950

449. Herghest Rocks
   guano
   Hutchinson, 1950

455. Caroline Island
   guano
   Hutchinson, 1950

481. Bikar atoll
   earthy phosphate
   Hutchinson, 1950

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SUBMARINE PHOSPHORITES

344. Chatham Rise, New Zealand
   (submarine)
   phosphatic nodules
   Miocene
   Cullen and Singleton, 1977;
   Norris, 1964; Reed and
   Hornibrook, 1952

399. Pike Seamount
   phosphatized limestone
   Cenomanian - late Cretaceous
   Baturin, 1978

400. Winterer Guyot
   phosphatized limestone
   Cretaceous
   Baturin, 1978

401. Thomas Washington Seamount
   phosphatized limestone
   Cenomanian-Turonian -
   middle Eocene
   Baturin, 1978
402. Isakov Seamount
Phosphatized rudist limestones
Early Cretaceous
Baturin, 1978

403. Makarov Seamount
phosphatized rock
Cenomanian-Turonian -
Middle Eocene
Baturin, 1978

405. Scripps Guyot
phosphatized lutite
Middle Eocene
Baturin, 1978

406. Lamont Guyot
partially phosphatized
limestone
Eocene
Baturin, 1978

407. Miami Guyot
phosphate cement, phosphatized limestone
Eocene
Baturin, 1978

408. Wilde Guyot
partially phosphatized
limestone
Middle Eocene
Baturin, 1978

409-412. Mid-Pacific Seamounts
Garrand, 1977

413. 20°42'N, 170°E Seamount
Bezrukov and Andruschenko, 1969

414. Menard Guyot
phosphatized limestone
Cenomanian-Turonian
Baturin, 1978

415-416. Mid-Pacific Seamounts
Garrand, 1977

419. Jacqueline Guyot
Lutitic phosphorite, phosphatized coquina
Cenomanian-Turonian
Baturin, 1978

420. Shepard Guyot
phosphatized limestone
Cenomanian-Turonian
Baturin, 1978

421. Station 6352
Late Cretaceous
Baturin, Shumenko and Dubinchuk, 1977

422. Cape Johnson Guyot
phosphatized foraminiferal limestone
Middle Eocene
Baturin, 1978

423. A Guyot
phosphatized chalk
Early Eocene
Baturin, 1978

424. Station 6349
Late Cretaceous
Baturin, Shumenko and Dubinchuk, 1977

426. Station 6343
Late Cretaceous
Baturin, Shumenko and Dubinchuk, 1977

427. Kimmey Seamount
Washington, 1971

428. A Seamount
Washington, 1971

430. Milwaukee Bank
Pleistocene
Baturin, Shumenko and Dubinchuk, 1977

436. Mussorgski Seamount
Washington, 1971

437. Rachmaninoff Seamount
Washington, 1971
POTASH OCCURRENCES IN THE ASIA–PACIFIC REGION

Khorat Plateau (1–9)

1. Vientiane, Laos
   sylvite
   Japakasetr, 1979b

2. Sri Chiengmai district, Thailand
   sylvite
   Japakasetr, 1979b

3. Udon Thani, Thailand
   sylvite
   Japakasetr (personal communication)

4. Wanorn Niwat district, Thailand
   sylvite
   Japakasetr, 1979b

5. Khon Kaen, Thailand
   sylvite
   Japakasetr, 1979b

6. Chaturapak–Piman district, Thailand
   sylvite
   Japakasetr, 1979b

7. Yasothon, Thailand
   sylvite
   Japakasetr, 1979b

8. Bamnet Narong district, Thailand
   sylvite
   Japakasetr, 1979b

9. Khorat, Thailand
   sylvite
   Japakasetr, 1979b

10. Dhariala brine deposit, Pakistan
    salt brine containing potassium chloride
    Precambrian
    Asrarullah, 1979

11. Khewra mine, Pakistan
    salt marl containing sylvite, kainite, and other potash minerals
    Cambrian, Salt Range Formation, Billianwala Salt Marl Member
    Asrarullah, 1979

12. Warcha salt mine, Pakistan
    potassium salts
    Asrarullah, 1979

13. Kalabagh salt mine, Pakistan
    potassium salts
    Asrarullah, 1979

14. Northampton, Western Australia, Australia
    jarosite lode with up to 46% alunite
    Simpson, 1919

15. Gingin, Western Australia, Australia
    greensand beds with up to 40% glauconite
    Barrie, 1965b

16. Lake Campion, Western Australia, Australia
    lake sediments containing up to 60% alunite
    Barrie, 1965b

17. Mt. Palmer and Yellowdine, Western Australia, Australia
    lake sediments with up to 59% alunite
    Hobson, 1944

18. Kanowna, Western Australia, Australia
    alunite as nodules and veins in kaolinitized sedimentary rocks
    Barrie, 1965b

19. Ravensthorpe and Caglan River areas, Western Australia, Australia
    jarosite
    Barrie, 1965b

20. Sheoak Flat Wells and Stansbury, South Australia, Australia
    nodular masses and irregular layers of alunite
    Tertiary
    Jack, 1918

21. Carrickalinga Head and Rapid Bay, South Australia, Australia
    alunite as nodules disseminated in shaly or slaty rocks
    Upper Proterozoic, Cambrian
    Jack, 1917

22. Rocky Point and Point Addis near Anglesea, New South Wales, Australia
    jarosite
    Eocene–Oligocene, Demons Bluff Formation
    Ulrich, 1866, Barrie, 1965b
23. Bulahdelah, New South Wales, Australia
   alunite, leticular to pipe-like masses
   Booker, 1950

Sedimentary Basins with High Potential for Potash Occurrences

1. Khorat-Sakhon-Nakhon basins, Thailand and Laos

2. Muktinath basin, Nepal Mesozoic

3. Nagaur basin, India

4. Potwar basin, Pakistan
   Late Precambrian to Cambrian

5. Kohat-Bonnu basin, Pakistan Tertiary

6. Yunnan basin, China
   Triassic to Cretaceous

7. Szechwan basin, China
   Triassic to Cretaceous

8. Chinghai area, China
   salt lakes

9. Shensi basin, China
   Triassic to Jurassic

10. Peninsular Malaysia, Malaysia
    Late Triassic, Tembeling Formation

11. Selawati basin, Irian Jaya, Indonesia
    halite beds at 1,000 feet depth
    lower Paleocene (?)

12. Bonaparte Gulf basin, Australia
    Devonian
    Barrie, 1965b

13. Canning basin, Australia
    Silurian to Devonian
    Barrie, 1965b

14. Carnarvon basin, Australia
    Silurian
    Barrie, 1965b

15. Officer and Arckaringa basins, Australia
    Cambrian
    Barrie, 1965b

16. Amadeus basin, Australia
    Cambrian
    Barrie, 1965b

17. Adavale basin, Australia
    Devonian
    Barrie, 1965b

18. Gyeongsang basin, South Korea
    known alunite province
    Cretaceous
    Moon, 1979
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THE EAST-WEST RESOURCE SYSTEMS INSTITUTE is directed to the overall goal of understanding how nations can maintain adequate, equitable, and reliable access to resources. The Institute consists of a broad study of three interrelated programs: Food Systems, Energy Systems, and Raw Materials Systems.

International research groups are collaborating with RSI staff to analyze and conduct research on these systems. A series of data bases and information exchange facilities is now being developed to support their studies. On an interdisciplinary basis, the various teams will explore these problems stressing their interrelationships in both local and international terms in the Asian and Pacific region.

**Food Systems** conducts research on the institutional and policy aspects of improving food security in the Asia-Pacific region; examines the complex interactions of administrative, technological, and social issues involved in developing food systems in marginal areas; and explores alternate food systems with special emphasis on food and the city, food systems based on water environments, and institutional and policy aspects of biological nitrogen fixation.

**Energy Systems** provides analyses of the vulnerabilities of nations to disruptions in the flow of fuels; collects and analyzes data on energy supply, demand, and flows, especially those in rural areas; evaluates alternative development policies on a variety of energy systems and develops energy indexing methodologies and information exchange both within and among nations.

**Raw Materials Systems** is concerned with the identification and evaluation of policy and strategy options that will benefit nations from the exploration and development of their mineral resource potential. The main research areas are: mineral assessment for national planning, innovative government-transnational company arrangements, uncertainties in future commodity trade, and case histories of mineral projects.