UNITED STATES

DEPARTMENT OF THE INTERIOR
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TECHNICAL LETTER

22

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JIDDAH, SAUDI ARABIA

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Technical Letter
Saudi Arabian Mineral
Exploration - 22
September 3, 1965

Dr. Fadil K. Kabbani
Deputy Minister for Mineral Resources
Directorate General for Mineral Resources
Ministry of Petroleum and Mineral Resources
Jiddah, Saudi Arabia

Dear Dr. Kabbani:

Transmitted herewith are 10 copies of:

TECHNICAL LETTER NUMBER 22
DISCOVERY OF PHOSPHATE ROCK IN
SAUDI ARABIA AND RECOMMENDED
PROGRAM OF FURTHER STUDY

by

Richard P. Sheldon*

Sincerely,

Glen F. Brown

Glen F. Brown, Chief
Saudi Arabian Mineral exploration Project

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DISCOVERY OF PHOSPHATE ROCK IN SAUDI ARABIA AND RECOMMENDED PROGRAM OF FURTHER STUDY

by

Richard P. Sheldon*

Introduction

In the period August 12, to September 3, 1965, I was assigned as a phosphate specialist to the U.S. Geological Survey group in Saudi Arabia to work in co-operation with the Ministry of Petroleum and Mineral Resources of the Saudi Arabian Government. My assignment was to evaluate the phosphate potential of Saudi Arabia, train a Saudi Arabian geologist counterpart in modern techniques of phosphate exploration, and to help set up a program of exploration. These objectives have been largely fulfilled. In addition phosphate rock was discovered.

This phosphate rock could not be evaluated in the short time of study, but it is obviously a deposit of excellent potential. It is an extension of the phosphate deposits of Iraq southward into Saudi Arabia. In Iraq about 1-1/2 billion tons reserve of calcareous phosphate rock have been estimated (Mustafa Al Dugaither, oral communication, 1965). At this stage of knowledge, the Saudi Arabian phosphates may be equally important. In addition the large potential of sulfuric acid production from sour gas in Saudi Arabia would make possible the production of triple super phosphate fertilizer from the phosphate rock. The market for such fertilizer in countries around the Indian Ocean is great. Thus, it seems that excellent reasons exist for the further study of the Saudi Arabian phosphate rock.

* U. S. Geological Survey, Jiddah, Saudi Arabia

Many people have been helpful in this study. Mustafa Al Dugaither, my counterpart geologist, helped me in the study of well logs and cuttings in the Aramco office in Dhahran and his personal knowledge of the Iraqi phosphate deposits proved invaluable. The geologic staff of Aramco in Dhahran, in particular R. W. Powers and S. Bowers, were tremendously helpful in supplying well data. Without the 1:500,000 scale geologic map series made by Aramco geologists of the part of Saudi Arabia underlain by sedimentary rocks, this job would not have been done so rapidly.(Bramkamp and others, 1963).

John Haworth of the Ministry of Petroleum and Mineral Resources was very helpful in supplying information in the Riyadh office. Finally, without the full support of the U. S. Geological Survey and the Ministry of Petroleum and Mineral Resources, the job could not have been done. Glen Brown and William Overstreet of the U. S. G. S. and Dr. Fadil Kabbani and Hisham Nazzah of the Ministry in particular should be singled out. Ismail Husseini of the Ministry ably assisted me in the field.

History and method of discovery

On August 12, 1965, I arrived in Jiddah, where I spent four days in discussion of plans with staff of the U.S.G.S. and the Ministry. On August 17, I left for Riyadh where I spent two days going over geologic information from the Ministry files. I was joined by Dugaither in Riyadh. Dugaither and I went to Dhahran on August 19 where we spent four days discussing the sedimentary geology of Saudi Arabia with Aramco geologists and studying well logs and cuttings. We returned to Jiddah to prepare for a field trip to the area between Turayf and Ar'ar in northern Saudi Arabia near the Iraqi border. Dugaither unfortunately was unable to continue with the project due to previous committments, and I was joined on the field trip by Husseini. We left Jiddah on August 24, spent four days travel and on August 28-29 traversed Upper Cretaceous to Eocene rocks along the pipeline road between Asir and Turayf. Phosphate was located on August 29. On August 31 I flew back to Jiddah from Turayf and upon compilation of reports left Saudi Arabia on September 3.

These deposits were found by application of the knowledge of geology of phosphate rock to Saudi Arabian rocks. A summary of these techniques is given in Mc Kelvey (1963) and Sheldon (1964). Basically, the technique consists of identifying sediments that were deposited in areas of upwelling ocean currents. This environment of deposition is unique and gives a very distinctive suite of rocks. Arabia lies to the east and south of the North African Middle East phosphorite genetic province and obviously should be looked at for phosphate deposits. Geologic maps show that rocks of the same age as those containing phosphate rock in Jordan and Iraq extend into Saudi Arabia. Also, a study of the sub-surface geology of the Persian Gulf shows that phosphate occurs there in the sub-surface. Thus, Saudi Arabia is bounded on the north and east by rocks containing phosphate. A study of well logs and geologic reports made by Aramco geologists disclosed the unique phosphorite-bearing suite of rocks in the Eocene and Paleocene rocks in the Jawf-Sikakah basin in northern Saudi Arabia. A microscopic and chemical study of cuttings of these rocks showed abundant phosphate, and a traverse of these rocks in the field revealed phosphate rock in outcrop.

Geology of Upper Cretaceous - Eocene phosphate deposits

The detailed geology of the phosphate deposits is not known at present, so the following description is of necessity quite general. The stratigraphy, tectonic setting, depositional environment, structure, and nature of outcrops are discussed below.

Stratigraphy

A large part of the Arabian craton was transgressed by the sea to the north and west in late Cretaceous time with the deposition of a sedimentary cycle of rock, several thousand feet thick ranging in age from late Cretaceous to Eocene. This transgressive sequence includes the Upper Cretaceous Aruma Formation at the base and at the top a Paleocene-Eocene unit informally called the Hibr Formation by Aramco, and mapped as Tlc on the 1:500,000 geologic map.

The Aruma Formation is composed of shallow-water limestone and sandstone, with a few thin beds of chert. The lower part of the Formation makes up a series of low hills and the upper part is less resistant and forms a low flat nearly featureless plain. No phosphate rock has been found in the Aruma, but it may possibly contain some.

The Hibr Formation consists of interbedded sandy shelly limestone and aphantitic limestone, chert, marl, and phosphate rock. A crude cyclical sequence was observed in the Turayf water well #2 and in well S-460 south of Turayf. The cycle consists, in vertical sequence, of sandy limestone, chert, phosphate rock, marl, phosphate rock, chert, and sandy limestone. This cycle was repeated several times. The fauna of the marl-phosphate rock beds is largely pelagic foram, in part phosphatized.

The phosphate rock identified in the cuttings largely consists of individual oolites, but the phosphate rock identified in outcrop is a calcite and siliceous cemented apatite oolite that contains 20-30 percent P_2O_5. All of this phosphate was positively identified by chemical tests. Thickness of phosphate beds was impossible to determine because the drill cuttings were of 5 foot intervals, and the outcrop was very poor and actually consisted of lag blocks in residual desert gravel formed by eolian deflation. However, the abundance of apatite in the rocks indicated that considerable bedded phosphate rock is present.

The location of the outcrop of phosphate rock is 300 meters west of the 746 kilometer mark on the pipeline and 3.5 kilometers due north. The outcrop is marked by three stone monuments 50 or so meters apart. The point of departure from the pipeline is marked by a stone monument on top of a half of a 55-gallon drum which sits on top of a gravel pit dump on the north side of the road and is easily visible from the road.

Tectonic setting

The Hibr Formation was deposited on the west side of the Ha'il arch in the Jawf-Sikakah basin. These tectonic units are reflected by the present structure but also were active in Cretaceous and early Tertiary Time. The west side of the Jawf-Sikakah basin is now bounded by the Dead Sea rift which brings Cretaceous rocks to the surface, but in Cretaceous and early Tertiary Time probably no uplift was present in the Dead Sea area and the basin probably represented the east boundary of the marginal trough or miogeosyncline bounding the northern side of the Afro-Arabian craton.

Depositional Environment

The depositional environment of the Hibr Formation was broadly controlled by the tectonism. The Hibr Formation was deposited on the eastern edge of the Tethys Sea where it swung from its easterly trend across North Africa to a northerly direction on the west side of the Arabian Craton. The deeper water facies of the marl chert and phosphate deposited in this part of Tethys Sea coincide with the pelagic fauna of the marls which is distinctly different from the faunas of the same age in the rest of Saudi Arabia (Mr. Nine, Aramco paleontologist, oral communication, 1965). Upwelling occurred in this area of open ocean causing the distinctive suite of sediments. The ocean shallowed to the east over the Ha'il arch and the shelf to the east of the Ha'il arch was intermittently an evaporite basin in the Eocene Time. However, cherty massive rocks occur in the upper part of the Eocene in this area to east of the Ha'il and apparently were deposited at the time of maximum transgression. So far phosphate is known to occur only in the Hibr Formation of the Jawf-Sikakah basin, but the possibility exists that the upper Eocene rocks cropping out between the Ha'il arch and the Persian Gulf are phosphatic.

The Hibr Formation is similar in all essential characteristics to phosphatic formations of the rest of the Afro-Arabian phosphate province and in fact phosphate-bearing formations of other parts of the world. Thus, the general depositional environments are the same and the reader is referred to the large published literature on the subject (See bibliographies in Mc Kelvey, 1963 and Sheldon, 1964)

Structure

The beds of the Hibr Formation on the west flank of the Ha'il arch dip very gently westward, so gently that the dip is not discernable to the eye. It is in this area that the phosphatic beds come to the surface. Thus the mining condition insofar as structure is concerned should be excellent and open pit mining will probably be possible.

Nature of outcrops

The most difficult feature of exploration for phosphate in the Jawf-Sikakah basin is the lack of clear-cut outcrops. The area is a plain of very low relief covered by veneer of desert pavement, that is, residual gravels produced by eolian deflation. True outcrops are almost non-existant and the few that were found were of thick-bedded resistant limestone.

The desert pavement is largely residual so that the character of the underlying rock can be crudely determined by examining the pebbles. Most of the pebbles are chert fragments that more or less show the effect of wind abrasion and are colored black to dark brown by desert varnish. Limestone pebbles, on the other hand, occur as cappings of some of the very low hills and are white, solution pitted and fluted, and have no desert varnish. Pebbles of phosphate rock resemble in all respects, except the solution pitting and fluting, the limestone pebbles, and can be distinguished from the limestone only by careful hand lens examination or chemical testing.

Detailed bedrock geologic mapping of the area would be impossible due to the desert pavement, and reconnaissance bedrock mapping would have to be based on distribution of residuum, a difficult job at best.

Program of further study of the Jawf-Sikakah basin

The initial discovery of the phosphate is only the start of a long and tedious job. The critical task of proving up the deposits lies ahead. As explained at the outset, the potential of the deposits warrants such a study.

The planning of the study must allow a high degree of fluidity, as each step depends on the preceding one. The general approach I would follow is outlined below and is based on the concept of doing the easiest and cheapest thing first.

1. A series of radiometric traverses of the area should be made to determine if a scintillation counter is helpful in locating the slightly radioactive phosphate rock under the desert gravel. If successful, a bulldozer should be used to expose the phosphatic beds. This technique may not find all beds of phosphate rock as some are possibly not sufficiently radioactive and others may be too deeply buried by desert gravel and alluvium to be detected.

2. A photogeologic map backed by field work should be made aimed at both surficial and bedrock geology. I observed the terrain from the air on the Saudair flight from Turaif to Badana and a photogeologic map is definitely feasible.

3. Cuttings of all wells in the area should be logged in detail and the initial physical stratigraphy set up.

4. If all the above warrants it, a program of coring the section should be undertaken with several aims:

a) to establish the sequence of strata and the number of phosphatic horizons.
b) to establish grade of phosphate rock. Splits of the core should be analyzed chemically.
c) to establish thickness of phosphate beds. The cores themselves are not particularly helpful in this regard but the holes should be gamma ray logged. This would give relatively accurate thickness.
d) to construct cross-sections to predict outcrop of phosphatic beds.
e) to construct structure contour maps on phosphate beds and in making a bedrock geologic map.
f) to construct isopach maps of desert gravel and alluvium to aid in estimating overburden on phosphate beds.

5. Topographic profiles and maps should be made of the area to help in achieving steps d, e, and f above.

6. Once the subcrop beneath the alluvium and desert gravel of the phosphate beds is established, a bulldozer trenching program to expose phosphate beds should be started, and sampling, measurement and description of the beds begun.

7. Finally, a detailed stratigraphic study of the Upper Cretaceous - Eocene rocks should be made to determine the control of the ore. This is a most important study, bacause in order eventually to find the area of highest grade and thickest phosphate rock, the local sedimentologic controls of the deposition of phosphate must be understood. This is approached through a thorough study of the stratigraphy both physical and biologic. A trained sedimentologist-petrographer, with the assistance of a paleontologist, should undertake such a study.

Program of study of other basins

Several other areas in Saudi Arabia need investigation in regards to phosphate. It was impossible in the limited time I had, to check out every possibility. The general approach in checking the Jauf-Sikakah basin should be used in the other areas. In particular, the Upper Cretaceous to Eocene rocks east of the Ha'il arch should be checked. The Aruma Formation in the Fanliya field shows anomalous radioactivity in gamma ray logs, and if it is caused by phosphate, the phosphate may extend to outcrop. Also, the upper part of the Eocene is cherty, and chert is a rock commonly associated with phosphate rock.

The Jurassic marine transgressive sequence offers another possibility in the outcrops near Riyadh. These rocks wree formed in quite shallow water according to Powers of Aramco, and if this is true for all these Jurassic rocks, there seems to be little probability of phosphate. However, the possibility that the Jurassic rocks are phosphatic should be checked.

The rest of the sedimentary section of Saudi Arabia consists of non-marine rocks of very shallow water deposition for which little hope can be held for signigicant phosphate deposits.

Bibliography

Bramkamp, R. A., Brown, G. F., Hom, D.A., and Layne, N.M., Jr., 1963, Geology of the Wadi As Sirhan quadrangle, Kingdom of Saudi Arabia: U. S. Geol. Survey Misc. Geol. Inv. Map I-200A.

Bramkamp, R.A., Ramirez, L.F., Steineke, Max, and Reiss, W. H., 1963, Geology of the Jawf-Sakakah quadrangle, Kingdom of Saudi Arabia: U.S. Geol. Survey Misc. Geol. Inv. Map I-201A.

McKelvey, V.E., 1963, Successful new techniques in prospecting for phosphate deposits: Science, Technology, and Development, United States papers prepared for the United Nations Conference on the application of science and technology for the benefit of less developed areas, v.2, p.163-172.

Sheldon, R.P., 1964, Exploration for phosphorite in Turkey - a case history: Econ. Geology, v.59, p.1159-1175.