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PHOSPHATE ROCK AT WEST THANIYAT SIRHAN - TURAIF (JAWF-SAKAKAH) BASIN KINGDOM OF SAUDI ARABIA

by

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U.S. Geological Survey

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PREFACE

In 1963, in response to a request from the Ministry of Petroleum and Mineral Resources, the Saudi Arabian Government and the U. S. Geological Survey, U. S. Department of the Interior, with the approval of the U. S. Department of State, undertook a joint and cooperative effort to map and evaluate the mineral potential of central and western Saudi Arabia. The results of this program are being released in USGS open files in the United States and are also available in the Library of the Ministry of Petroleum and Mineral Resources. Also on open file in that office is a large amount of material, in the form of unpublished manuscripts, maps, field notes, drill logs, annotated aerial photographs, etc., that has resulted from other previous geologic work by Saudi Arabian government agencies. The Government of Saudi Arabia makes this information available to interested persons, and has set up a liberal mining code which is included in "Mineral Resources of Saudi Arabia, a Guide for Investment and Development," published in 1965 as Bulletin 1 of the Ministry of Petroleum and Mineral Resources, Directorate General of Mineral Resources, Jiddah, Saudi Arabia.

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INTRODUCTION

Phosphate rock was discovered at Thaniyat Turaif in the southwestern end of the Sirhan-Turaif (Jawf-Sakakah) basin, northern Saudi Arabia (Fig. No.1a) by James Mytton (1967) of the U.S. Geological Survey in October 1965. The western limit of his work was the 38° meridian. Since then investigations west of the 38° meridian at West Thaniyat (Fig. No. 1b) have revealed promising deposits of phosphate rock.

GEOLOGIC SETTING

The area herein described is referred to as West Thaniyat (between lat. 29°40'-29°43'N. and long. 37°52'-38°02'E.) where phosphate rock is found at the top of the Cretaceous Aruma Formation in transitional contact with the overlying Paleocene-Eocene Hibr Formation. Mytton describes this same zone equivalent to the east as being at the base of the Hibr Formation, but later work has revealed its strong lithologic affinity to the Aruma Formation. The rock beds are nearly flat-lying with about 1½ degree dip to the northeast. The phosphate bearing zone, called Zone 2, ranges in thickness from 1.75 meters to 5.3 meters or more. Within this zone there are from one to four or more layers of phosphate rock with an average of 28 to 29% P_2O_5. At some localities samples of phosphate rock contain up to 36% P_2O_5. The zone occurs along a 90-meter or more high, south-facing, steep bluff which undulates considerably along its east-west strike. The zone is about 30 meters up from the valley floor at the eastern end of the area of interest and gradually rises higher up the bluff westward as more and more older rock underlying the Aruma Formation has been exposed by erosion. There are sufficient exposures of the phosphate rock along the bluff to suggest that the better grade material extends for an outcrop distance of 43 kilometers, or a strike length of about 16 kilometers.

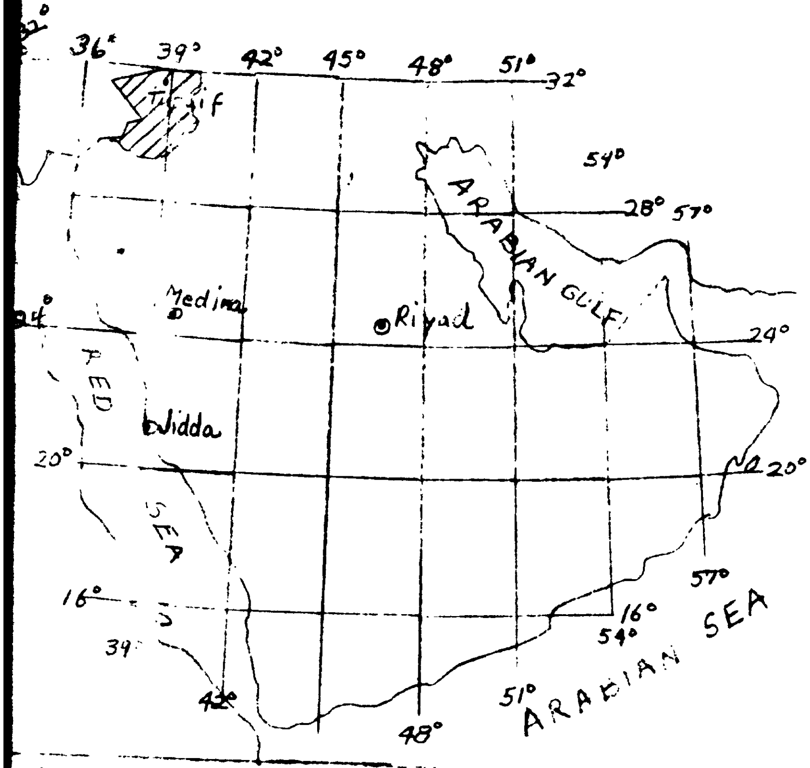


Figure 1a

Index Map of Arabian Peninsula Showing Location of Sirhan-Turaif Basin

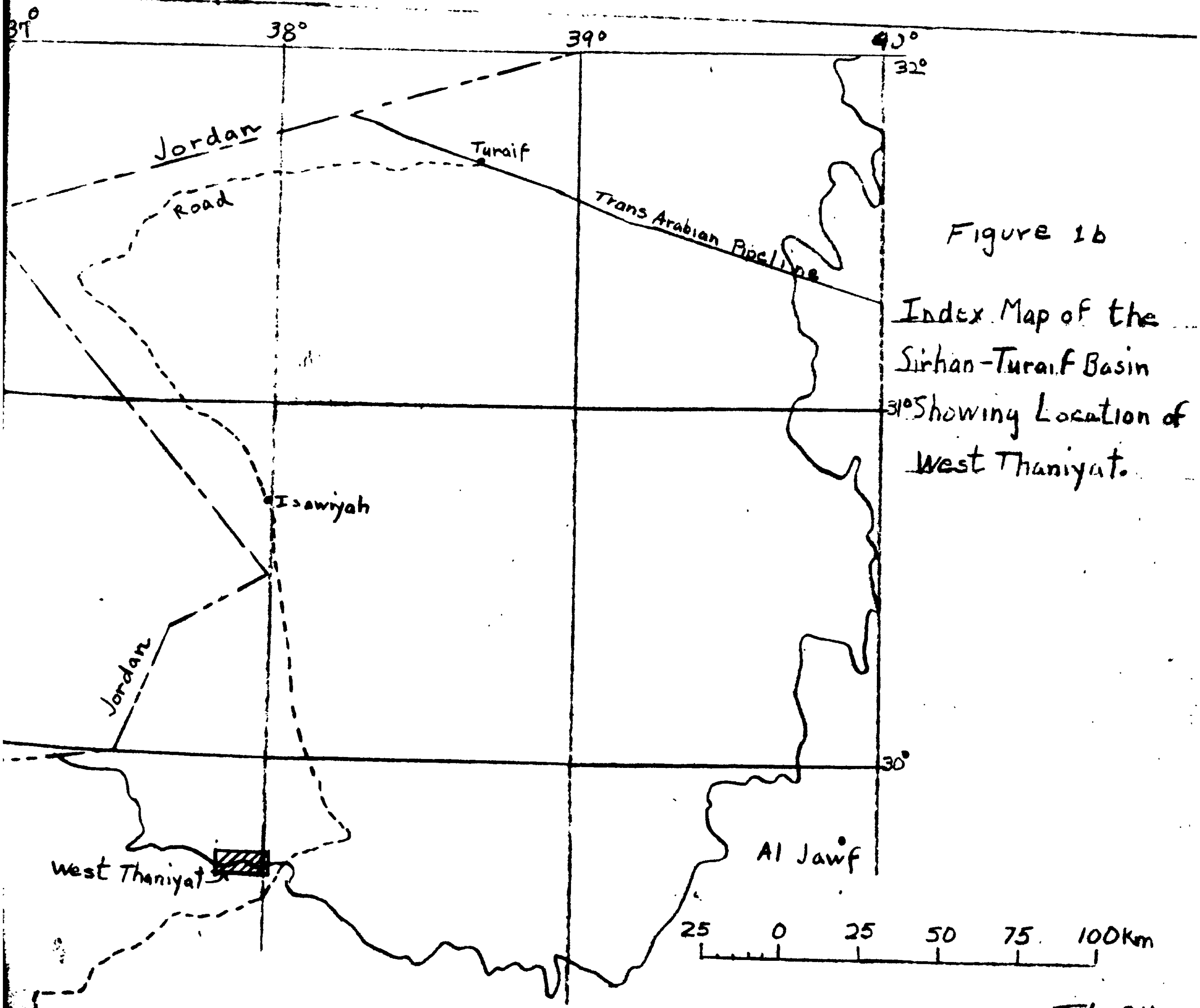


Figure 1b

Index Map of the Sirhan-Turaif Basin Showing Location of West Thaniyat.

STRATIGRAPHY

Disconformably underlying the Aruma Formation at West Thaniyat is the Devonian Tawil Sandstone member of the Tabuk Formation. The Tawil member is a dark weathering, heavily cross-bedded, quartz sandstone which forms low, rounded hills. The top of the Tawil Sandstone is near the valley floor at the eastern end of the area of interest but gradually rises higher westward where a greater thickness of sandstone has been exposed by erosion. This means, of course, that access to the overlying Aruma Formation, and the phosphate at its top, is gradually higher on the face of the bluff westward.

The Aruma Formation lies on the Tawil Sandstone with no visible angularity between the two formations. The thickness of the Aruma is about 30 meters. It is composed of white to yellow, poorly-sorted sandstone with subrounded, and in part frosted quartz grains. The sandstone is friable and weathers into a steep slope of loose sand. The sandstone includes a few beds of yellowish-brown shale 30 to 60 centimeters thick which in some places weathers into paper thin wafers. The Aruma is transitional with the overlying Paleocene-Eocene Hibr Formation. The transition is evident by a gradual change from the sandstone of the Aruma to the limestone and chert of the Hibr. Phosphatic rock and phosphate beds occupy this transitional zone which, as mentioned before, ranges in thickness from 1.75 to 5.3 meters or more. At the base of the transitional zone is non-phosphatic sandstone, and at the top is a 1 to 1½ meter thick (basal Hibr) chert bed.

The Hibr Formation is up to 90 meters thick above the phosphate zone but in most places over the area of interest is only about 50 meters thick. This thickness of the Hibr is that found at the face of the bluff and naturally Hibr overburden increases as the phosphate zone dips northeastward into the hills. The Hibr Formation is composed of thick bedded to massive limestone, marly limestone, and marl with occasional beds of chert up to 1 meter or more thick, nodules of chert, and geodal zones. Within the Hibr Formation, and about 50 meters above the phosphate of Zone 2, is a bench-forming, bed of chert 60-centimeter to 1-meter thick with associated phosphate rock. This phosphate is called Zone 1 and is composed of a 15- to 60-centimeter bed on top of the chert and a bed of similar thickness below the chert. In some places at the top of the bluff, Zone 1 has been eroded off. There are no immediate plans to further evaluate Zone 1 at West Thaniyat, but there is a plan to have it trenched and sampled at its continuation in an area to the east at Thaniyat Turaif. Zone 1 at Thaniyat Turaif contains phosphate with up to 27% P_2O_5.

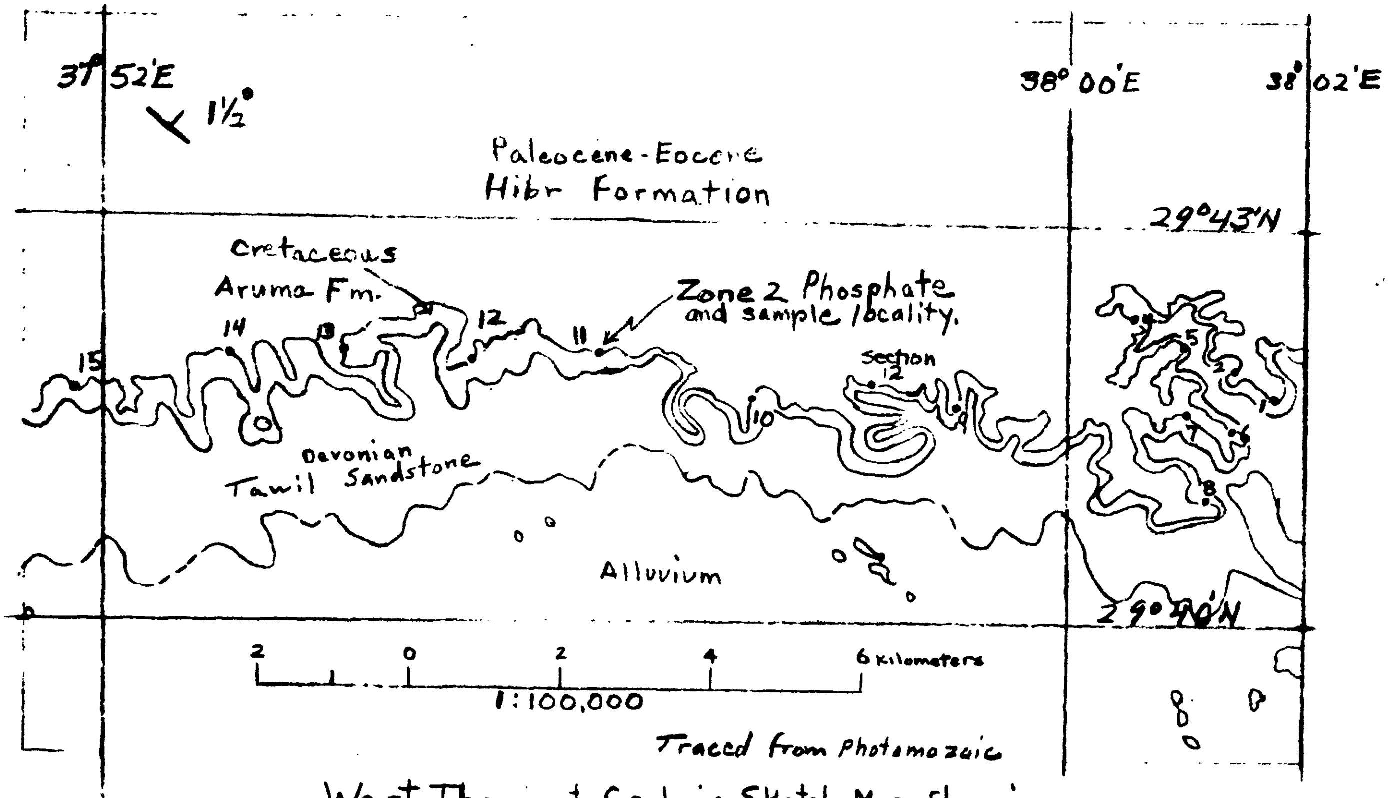
STRUCTURE

There is a definite N.25°W. lineation visible on aerial photographs in the Tawil Sandstone which is exposed south of the West Thaniyat bluff. In most places this lineation is the alignment of fractures in the sandstone with practically no vertical displacement, but in some places faulting or gradens are in evidence. However, a continuation of the lineation is not apparent in the overlying Aruma and Hibr Formation, at least for a distance of several kilometers back from the bluff. It may be that the fractures of the Tawil Sandstone were formed prior to the deposition of the Aruma and Hibr, and in the area of interest there has been little or no movement since. The phosphate zone at the top of the Aruma displays no offsetting other than that caused by slump. At some places across the West Thaniyat area, there is considerable pinching and swelling of the phosphate zone probably caused by the weight of the overlying massive Hibr limestone on the relatively soft, phosphatic interval.

PHOSPHATE ROCK (ZONE 2)

At West Thaniyat better grade phosphate rock in a zone at the top of the Cretaceous Aruma Formation, referred to as Zone 2, has been traced intermittently east-west along the outcrop for a distance of about 43 kilometers. This outcrop distance follows the numerous undulations of the outcrop up and down wadis over a straight line distance of about 16 kilometers. Much of the zone is partially or completely covered by talus limestone that has been broken off from the overlying Hibr Formation, but fifteen localities of good or relatively good exposures were measured and channel sampled (fig. 2). These measured sections have been plotted to illustrate the grade and thickness of the phosphate layers at each locality (fig. 3 and fig. 4). From locality No. 1 on the east to locality No. 15 on the west there is a layer of phosphate rock at the top of the zone in contact with the basal Hibr chert bed. This layer, designated Bed No. 1, ranges in thickness from 25 to 90 centimeters, or an average of 55.5 centimeters over the 15 localities (43-kilometer outcrop distance). Grade ranges from 20.6% to 36.6%. The phosphate rock of Bed No. 1 at localities No. 1 through No. 11, including Section 12 measured during earlier work, is sandy and calcareous; usually it is tough and hard so that it is difficult to break with a hammer, but in part it is friable and is easily crumbled into loose grains. The phosphate rock of this bed at localities No. 12 through 15 contains less sand, is marly, and in part friable. At Section 12 westward through locality No. 15 the grade is 32% P_2O_5 except for locality No. 13 (Note in Fig. 2 that Section 12 and locality No. 12 are two separate points). Binocular microscopic examination of all of the channel samples collected from Bed No. 1 revealed that the samples were composed on the average of 80% phosphate grains and 20% matrix consisting of quartz sand, marl, and calcareous material. The value of Bed No. 1 deteriorates east of locality No. 1 and west of locality No. 15.

Figure 2



West Thaniyat Geologic Sketch Map Showing
Zone 2 Phosphate Interval at top of Aruma formation

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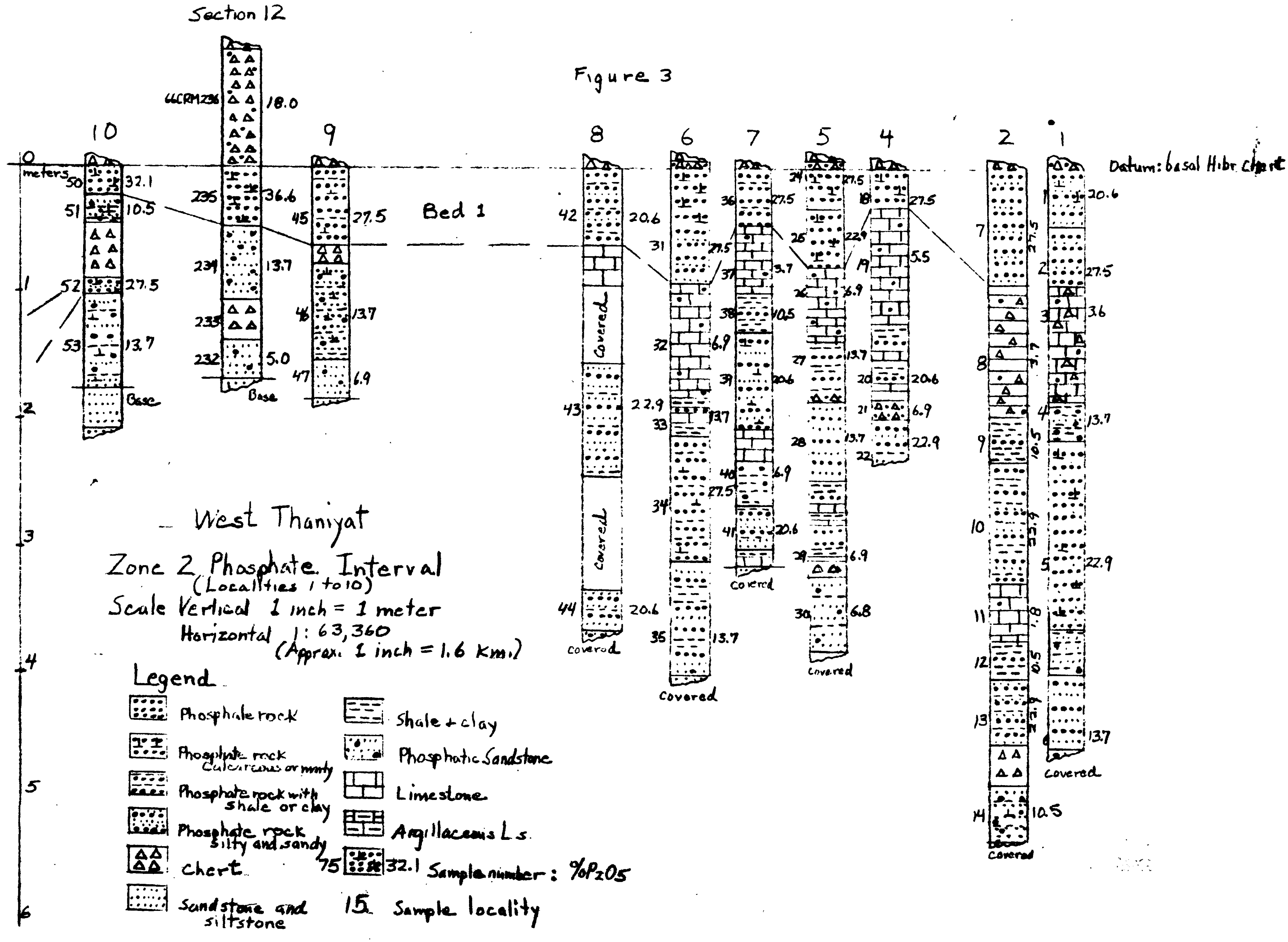
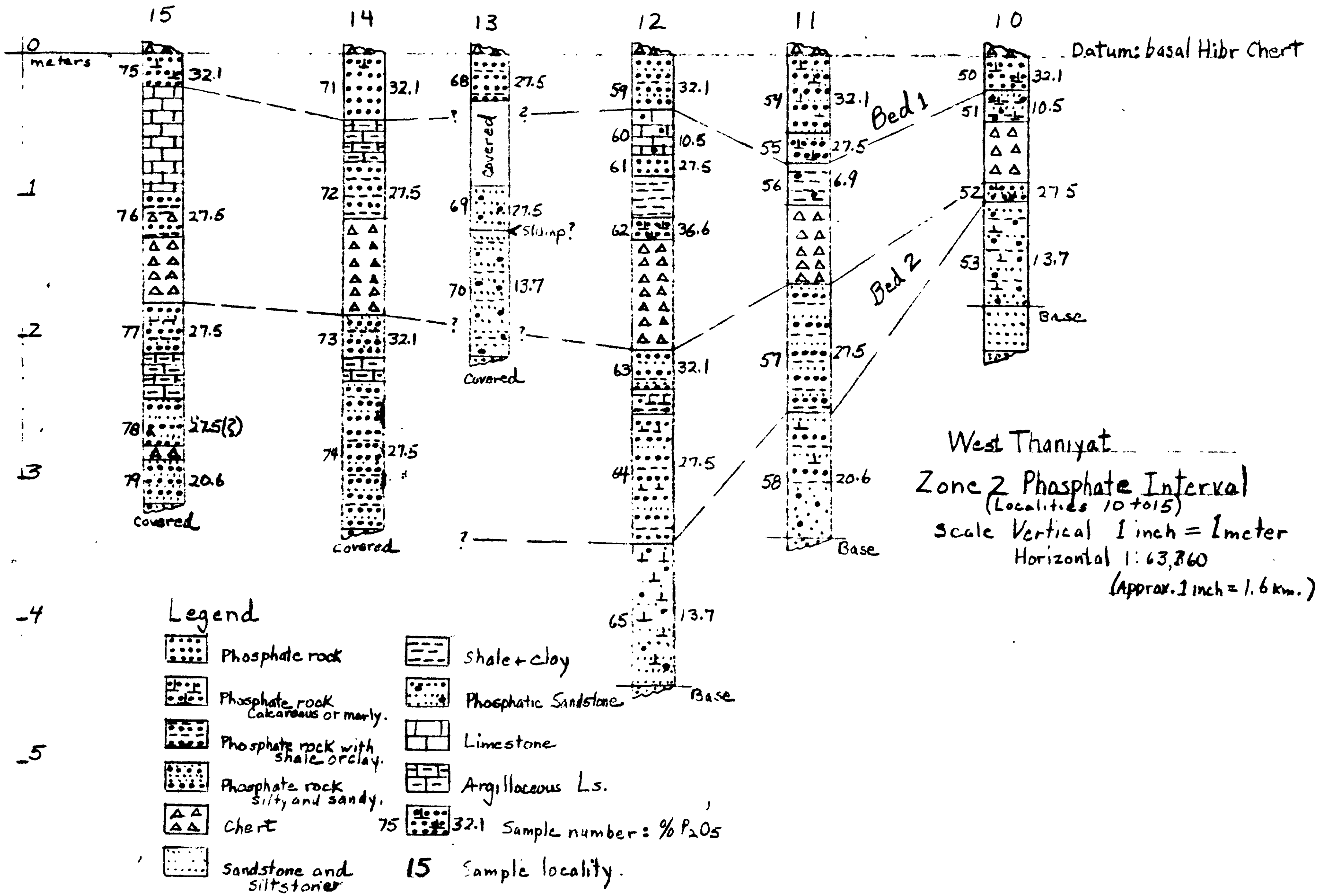
Figure 3



Section 12
Datum: basal Hibr chert
Bed 1
West Thaniyat
Zone 2 Phosphate Interval
(Localities 1 to 10)
Scale Vertical 1 inch = 1 meter
Horizontal 1: 63,360
(Approx. 1 inch = 1.6 Km.)
Legend
Phosphate rock
Phosphate rock Calcareous or marly
Phosphate rock with shale or clay
Phosphate rock silty and sandy
Chert
Sandstone and siltstone
Shale + clay
Phosphatic Sandstone
Limestone
Argillaceous Ls.
75 32.1 Sample number : %P2O5
15 Sample locality
meters
Base
Covered

Figure 4



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Directly underlying the above described Bed. No. 1 (top layer) of phosphate rock in Zone 2 is a limestone bed changing laterally into chert which ranges in thickness from about 15 centimeters to 1 meter. The limestone is slightly phosphatic, 3% to 7% P_2O_5, and the chert is non-phosphatic. Underlying this bed is an irregular sequence of phosphate rock interbedded with partially phosphatic sandstone, shale, limestone, and chert down to the top of non-phosphatic Aruma sandstone. From locality No. 1 through Section 12 the phosphate rock contains less than 30% P_2O_5 with a maximum of 27.5% P_2O_5 and a minimum of 20.6% P_2O_5. Interbedded rock containing phosphate with less than 20% P_2O_5 is not included as phosphate rock but is called "phosphatic". Exposed thickness of this irregular sequence ranges from about 1.1 meters to 4.5 meters. Although parts of the sequence appear to contain phosphate rock of sufficient grade and composition which could be upgraded to a commercial product of 30% P_2O_5 or more, there is no immediate plan to further evaluate this material between localities No. 1 and Section 12. However, this same sequence contains consistently better grade phosphate westward at localities No. 10 through 15, an outcrop distance of about 18 kilometers where there are layers with up to 36.6% P_2O_5. One layer of interest is found under a chert bed in the lower part of Zone 2 and is referred to as Bed. No. 2. The eastern end of Bed No. 2 at locality No. 10 is only 15 centimeters thick with a P_2O_5 of 27.5%, but it thickens westward and splits into two layers. At locality No. 11 it is 90 centimeters thick containing 27.5% P_2O_5. At locality No. 12 Bed No. 2 contains a thin shale split with an upper layer, 30 centimeters thick containing 32% P_2O_5, and a lower layer about 92 centimeters thick containing 27.5% P_2O_5. Bed No. 2 is covered at locality No. 13 but is found at locality No. 14 where the upper layer is 40 centimeters thick with 27.5% P_2O_5, and the lower layer is 75+ centimeters thick (base is covered) with possibly only 20.6% P_2O_5. Bed No. 2 contains variable amount of marl, clay, silt, and sand and is very coarse grained to conglomeratic in most places; it contains shell fragments and is friable. Binocular microscopic examination of semicrushed channel samples revealed a composition on the average of only 30% phosphate grains with the remainder of the material consisting of sand, silt, marl, and clay. The friability of the material may allow for screening and flotation to separate out the high grade phosphate.

CONCLUSIONS

We plan to take assay samples from phosphate Beds No. 1 and 2 of zone 2 at West Thaniyat. Samples from Bed No. 1 will be taken at the 15 localities investigated (Nos. 1-15), and samples from Bed No. 2 will be taken at the 6 localities investigated (Nos. 10-15). It is recommended that two samples, each weighing 50 kilograms, be taken for each interval in order to send one set for assay to France and another to the United States; two separate assays assured good comparative results. The samples must be fresh, unweathered phosphate rock to give correct results. This will require tunnelling and sampling. Results of these assays will be used to plan closer-spaced assay sampling preliminary to considering a mining feasibility plan.

Samples of the equivalent phosphatic Zone 2 interval collected by James Mytton in October 1965 at Thaniyat Turaif were examined by James Cathcart (Cathcart, 1970). Mr. Cathcart concluded that the phosphate containing over 30% P_2O_5 could be mined and shipped without beneficiation or could be converted to super or triple superphosphate. The phosphate containing from 15% to 30% P_2O_5 could be easily upgraded by disaggregation followed by screening and flotation. These encouraging results were obtained from phosphatic material considered to be inferior to that recognized at West Thaniyat.

The third dimension of the phosphate beds, or how far they extend into the subsurface back from the face of the bluff, is not known. This information can only be obtained by drilling, but the justification of drilling is partly hinged upon positive results of the phosphate rock assays. It is not possible to make accurate tonnage estimates at this time, but tonnages are expected to be high. For example the straight line east-west length of Bed No. 1 (top layer of Zone 2) at West Thaniyat is 16 kilometers or 10 miles. Undulations show that the bed continues into the subsurface northward for at least 2 miles which gives an area of 20 square miles or 12,800 acres. Assuming average thickness of the Bed No. 1 into the subsurface remains at 55.5 centimeters or 1,8 feet and average P_2O_5 remains at 29%, the following formula can be used (Cathcart 1970): 2000 x percent P_2O_5 x thickness in feet = tons of P_2O_5 per acre. Therefore: 2000 x .29 x 1.8 = 1044 tons of P_2O_5 per acre. Therefore: 12,800 acres x 1044 = 13,360,000 (rounded) short tons of P_2O_5 in the assumed 20 square miles for one bed. Naturally, tonnage estimates increase for calculations of Bed No. 2 and others at West Thaniyat and for any increase in area.

If outcrop assay sampling for the purposes of ore dressing and beneficiation research gives encouraging results, then a drilling program may be justified. This program would be designed to determine the thickness, grade, and areal extent of phosphate rock in the subsurface at West Thaniyat in order to make accurate tonnage estimates. Current information strongly suggests that estimated tonnage of recoverable phosphate rock at West Thaniyat will be well over the 20,000,000 ton minimum required to consider a mining program.

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Cathcart, J.B., 1970, Phosphate deposits in the Jawf-Sakakah Basin, Kingdom of Saudi Arabia. Part III Preliminary observations on the textures and composition: U.S. Geol. Survey open file report (IR) SA-83, 22 pp.

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