Report on Mineral Resources of Micronesia

U. S. Commercial Company, Economic Survey
Honolulu, October 1946

by

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I. REPORT ON GUAM MINERALS

A. SOME NOTES ON MANGANESE ON GUAM

The presence of showings of manganese on Guam was reported by Dr. Harold T. Stearns of the U. S. Geological Survey a few years before the outbreak of the war with Japan, but so far as the writer is aware, no one has made an effort to prospect or work the deposits.

Dr. Stearns reported on such an occurrence of manganese at Libugon Farm. This locality is on the east side of the road, a few hundred yards south of the Officers' Club at Commander Marianas Headquarters. The place where the most work was done is on a small knoll, about 20 feet high and 100 yards across, immediately west of the golf course. Earth has been scraped from the top of the knoll for filling a nearby machinery yard, adjacent to the Marine carpenter shop. The northwest side of the knoll is followed by a road and the southeast side has a common boundary with the golf course. A small stream, along which there are a number of pandanus trees, marks the north edge of the knoll.

In the bank to the east of the coral-covered yard, several caved tunnel portals can still be seen. Near these tunnels there are the croppings of several steep-dipping manganese veinlets. The black pyrolusite (manganese oxide) stands out in sharp contrast with the red weathered volcanic tuff in which it is enclosed. Volcanic agglomerate and tuff, which weather to a powdery red material that is soft and light-weight, are exposed at the portals of the caved workings. Banding can still be discerned in the volcanics, showing the formation to have a very steep dip, which is not unusual in this formation.

Here the Japanese are said to have found most of the manganese in the upper 10 feet of soil and weathered material. Originally the knoll was covered by rank grass growing in yellow soil about 7 feet deep, under which was the red soil containing the manganese. The red soil grades gradually downward into the altered tuffs and volcanic agglomerate.

Nodules of the black manganese mineral were weathered from the small veinlets, such as those exposed in the ledge near the coral-covered yard. The black mineral is pyrolusite of good quality and very likely was derived from the weathering of the pink manganese carbonate mineral rhodocrosite,

this being by far the commonest primary manganese mineral.

During their occupation of Guam, the Japanese put the natives to work hand-screening the nodules from the soil and are reported to have shipped out several hundred tons of such concentrates. Good specimens of pyrolusite are still plentiful on the hill and a surprising number of nodules show up on the surface after a heavy rain. Few of the nodules are larger than two inches in diameter, most of them ranging between the size of cherries and hens' eggs. One large lump of high grade ore, weighing about 40 pounds, was found by the writer.

Not enough nodules could be recovered from what remains of the deposit to be worth starting an operation at the place. Moreover, it is so hemmed in by the yard, golf course, roads, and buried telegraph lines that there would be no place to dispose of the waste rock produced. A similar, but smaller, deposit was worked directly across the golf course about 200 yards to the east.

Neither deposit is of any value, but knowledge of the occurrence of manganese on Guam may some day result in the development of a worthwhile deposit somewhere in the volcanic area.

Another deposit was worked at Santa Rosa. Like the one at Libugon, this one is also situated on an isolated knoll, underlain by tuffs and agglomerate. This one is on an isolated knoll 300 feet above sea level at a point 1.3 miles N. 85° E. from Agat village. On it the 109 Naval Construction Battalion built its camp.

At this place the Japanese made excavations in a prominent high knoll, the top of which is a little over 300 feet above sea level. The knoll is now quite bare and deeply scarred by the work which covers an area about 100 yards square. The south side of the area is bounded by a small stream which rises just to the east of the workings and discharges into the sea at Agat village.

Little evidence remains to show that the area was ever worked for manganese. Three small piles of nodules of pyrolusite were found at various places on the workings. Pyrolusite was the principal mineral and the nodules were mostly less than an inch in diameter, over half of the piles being composed of pieces one-half inch or less across. A few lumps of rich egg-size psilomelane were found. Some shiny limonite nodules were also noted.

At places the excavations reached a depth of 10 to 15 feet below the original surface. No underground workings were driven at this place.

The bedrock is mostly folded red volcanic tuff, which is deeply weathered and easily excavated. The excavated material is said to have been hand-screened by Guamanian "slave" labor to save the nodules. The appearance of the remaining material indicates many cubic yards of it would have to be screened to recover a cubic food of nodules, and the operation would not be economic with paid workers.

Where the bedrock can be seen, it is traversed by a reticulate pattern of slips, most of which have flat dips and are well marked by the smeared black manganese minerals which they contain.

To the north of the highway, which now bounds the north side of the workings, volcanic agglomerate crops out. It is comprised of cobblesize weathered stones of red, gray, and black volcanic rocks, ranging in composition from olivine andesite or basalt to light-colored rocks which have the appearance of latites. These boulders evidently were eroded from the underlying volcanic agglomerate with the tuff matrix. The agglomerate contains small veins of chalcedony and agate up to 2 inches thick. Some such veinlets crop out for a length of 30 feet or more.

The manganese may be related to similar veinlets that contained manganese carbonate minerals, which are now weathered to their black oxides.

The writer looked for manganese workings in the upper basin of Fena Valley beyond Santa Rita, where the large naval ammunition depot has been constructed. Either the native could not find the place, or evidence of it has been destroyed by construction.

B. BENTONITE ON GUAM, M. I.

Certain plastic clays believed to be bentonites were discovered by the writer in two localities on Guam. Similar clays very likely exist at other localities on the southern portion of the island wherever volcanic tuffs are exposed, from which formation the clays have been derived.

Such clays were first noted in the area presently occupied by the large Naval Ammunition Depot southeast of Santa Rita in the savanna-like basin south and east of the springs which are the source of the water pumped to the

reservoir on the hill a short distance east of Santa Rita village. This area is south of the old community of Bona, and its center is about 2000 yards east of Mt. Alifan in an area characterized by grass-covered rolling hills now traversed by a network of winding roads along which revetments have been built for storing ammunition.

In this area, which is all underlain by fine-grained volcanic tuffs, an observer may note that after a shower, where the surface is bare of vegetation, thin crusts of the wetted clay will arch upwards separating itself from the underlying dryer clay. This phenomenon is particularly characteristic of bentonite because of its peculiar property of expanding substantially when wetted. Bentonites also have the peculiar property of remaining suspended in water indefinitely, instead of settling to the bottom as do ordinary clays. Anyone who has stepped on wet mud in the borrow-pits along the roads in this area can testify to the instability of such clays.

The second locality known to the writer where clay, believed to be bentonite, was noted is near the southeastern corner of Apra Harbor where Marine Drive passes through a deep highway cut. This is at a point 50 yards south of the intersection of the road going east to the camp of J. H. Pomeroy & Co., Inc., and 300 yards north of the Fleet Laundry. The clay is in the steep bank of the cut on the west side of the road. It is about 18 feet thick and is overlain by about 15 feet of coral. This clay has an olive drab color and the lower portion of it is quite gravelly. In the upper portion of the bank there are numerous calcite geodes, exhibiting a radiating structure, and having about the same size range as potatoes. Another exposure of similar material may be seen in a nearby highway cut.

Clays believed to be bentonite were noted by the writer at the latter localities on the day before his departure from Guam. They were called to the attention of Dr. Bridge and specimens of the material were furnished him. He and Arthur Piper visited the locality on the following day and expressed the opinion that they too believed the material to be bentonite.

Hereto attached is an article taken verbatim from Taggart's Handbook on Mineral Dressing, 1945 Edition.

In addition to the uses for the material mentioned therein, bentonite is used extensively for waterproofing the bottoms of canals and small reservoirs. Use for the material may be found locally for waterproofing such excavations in coral rock.

BENTONITE

Extract from: Handbook of Mineral Dressing Ores and Industrial Minerals
By Arthur F. Taggart, Columbia University, New York, 1945

Properties. Bentonites are fine-grained, plastic clays, composed principally of montmorillonite or beidellite. TYPE 1, of which the Black Hills bentonites are characteristic, swells enormously when wetted; TYPE 2, sometimes called SUB-BENTONITES, swells no more than ordinary clays. High-grade bentonite will absorb 5 times its weight of water and swell 15 times its dry bulk. With 18 to 20 parts of water it forms a thin sol, and in concentrations as low as 1 : 5,000 most bentonites remain dispersed for months.

Uses. Type 2 bentonites are used chiefly in oil-well drilling muds, or for making acid-treated bleaching earth. In 1939 it was found that they were preferable to Type 1 for certain kinds of foundry work. Type 1 is used chiefly in foundry and molding sands, to a lesser extent for oil-well drilling, in still smaller quantities in a variety of industries as a suspending, spreading, thickening, adhesive, or paste-forming agent; and to some extent as a detergent and as a lubricant. See also TP 609 USBM for a list of minor uses; also a description of evaluation tests.

Occurrence. The Black Hills deposits worked at 2 to 4 ft. thick, close to surface; the bentonite contains 25 to 45% moisture. Other bentonite and sub-bentonite deposits are typically thin-bedded; some spread over wide areas, others are lenses of no great extent. Underground mining is handicapped by the sticky and sometimes almost fluid nature of the water-soaked bentonite strata.

Production. In 1925 was 2,500 short tons; in 1937, 194,768 tons, valued at $1,500,758, was produced in the United States, of which slightly over half was Type 1 and came chiefly from South Dakota and Wyoming. Except for a small amount in British Columbia, there is no commercial production of Type 1 outside of the United States. Type 2 is produced principally in Texas, Mississippi, California, Arizona, Oklahoma, and Utah; deposits in Arkansas, Kentucky, Tennessee, and other states have been investigated but not worked extensively. Italy began to exploit deposits of white bentonite in 1938.

Selling. Powdered bentonite, in bags, f.o.b. Black Hills plants, sold at $30 a short ton and upward from 1923 to 1927, later declined to $11 to $13, and the price for air-flated f.o.b. Chicago in 1938 was $25 a ton. Dried, coarsely crushed bentonite was quoted at $7 to $8 a ton, in bulk, or $10 in bags, f.o.b. Wyoming, in the same year. The usual commercial grade is powdered, 90 to 95% 200-m (dry sieve) and is packed in 100-lb. bags. Some uses require 99% 300-m., which costs up to $40 or $50 a ton. Sub-bentonites are mostly sold crude, at prices ranging from $2 to $5 or more f.o.b. mines, according to location.

Treatment. Bentonite is ordinarily dug by hand and hauled by trucks to processing plants, often 10 to 15 mi. distant. It is dried in rotary driers to 8% moisture; temperature is held to about 480° F., as the gel-forming properties are injured by temperatures above 750° F. The dried material is quite friable. It is crushed to about 3/8-in., usually in rolls driven at different speeds to cause tearing; special cutting boxes are also used. Thereafter it is ground, preferably by attrition, using ball mills, slug mills, rod mills, or roller mills. COST of crushing and drying alone is reported as high as $3 per ton.

Japanese Manganese workings in volcanic tuff at 109 CB Camp near Santa Rosa, Guam. Note: Small pit in upper left is the subject of photo #360E this group. June, 1946.

Japanese workings: Left foreground contains small pile of manganese nodules screened from pit shown. Guam, near 109 CB Camp at Santa Rosa.

Japanese Manganese workings at 109 CB camp near Santa Rosa, Guam. June 1946.

Six feet of red lateritic soil overlying partially decomposed volcanic tuff near golf course, Commander Marianas Headquarters.

Pyrolusite (Mn) veinlets in weathered volcanic tuff near W. side of Golf Course and Marine Carpenter shop, Commander Marianas Headquarters, Guam. April, 1946.

Hill worked for manganese ore during Japanese occupation. Hill is near Golf Course and Marine Carpenter shop at Commander Marianas Headquarters, Guam. April 1946.

II. PHOSPHATE AND MANGANESE ORE DEPOSITS ON ROTA, M. I.

A. ABSTRACT

On a plateau 1500 feet above sea level on the island of Rota, the Japanese mined 236,000 tons of guano phosphate ore, during the years from 1937 to 1944, inclusive. This material was transported to a drying plant at tidewater by an aerial tramway. Bombardment during the war has destroyed all existing facilities.

The Japanese had worked out five-sixths of the 300,000 tons of phosphate reserves originally estimated, including all of the higher grade material. Only about 50,000 tons of low-grade ore remain in the ground, which the writer recommends be left there because it is not sufficient to warrant restoration of the plant, and to mine it would ruin fertile farm land.

The dry storage building at tidewater contains 700 short tons of ore. On the plateau, which is connected to tidewater by a 14-mile road, there are several stock piles totaling 16,800 additional tons.

Because of the peculiar nature of this phosphate, it is believed that it can be applied directly to phosphate-deficient soils with beneficial results. Owing to the presence of giant African snails on the island, the material should be sterilized by drying, which will aid pulverization of the material, thus facilitating its better distribution as fertilizer in the soil. It is recommended that this material be used to fertilize phosphate deficient soils on nearby Guam.

There are no developed reserves of manganese ore on the island and it is recommended that no effort be made to produce manganese ore on Rota at this time.

Rota town, the principal settlement on the island, was built on the low portion of the aforementioned peninsula where it joins the mainland. It had a police station, public school, post office, and church. Nearby there was a sugar factory and 2.5 miles to the southeast on Sosanjaya Bay there was a phosphate drying, storage, and ship-loading plant. A narrow gauge railway, used largely for hauling sugar cane, extended along the north coast of the island to its eastern extremity, where it doubled back on the low plateau several miles to and beyond the village of Shinaparu. Another branch extended from Rota to the phosphate plant and a couple of miles beyond, where cane was grown.

The island had been fortified and garrisoned by the Japanese. Owing to its proximity to Guam, Rota was very heavily bombarded at frequent intervals from the air, as well as from the sea, and virtually every building and man-made installation was completely destroyed. The air strip on the eastern plateau has been restored for use, but all other pre-existing structures are in ruins. The natives now live in shacks erected from the debris, but Military Government has plans for building a new village where Rota once stood.

4. Loading Facilities and Navigation

A cut has been made through the reef on the northwest side of the peninsula near the sugar factory in Rota. This cut is only about 40 feet wide and shallow draft vessels, such as a LCT, can reach the beach here at high tide. One such craft lies on the reef near this cut and another was towed to Guam after being badly damaged in trying to run through this channel, the use of which has been discontinued. A similar channel and dock exist on the southeast side of the peninsula at Rota village, but it is no better than the northwest channel.

Phosphate was moved from the dry storage building on Sosanjaya Bay to ships through the use of a steel-belt conveyor which delivered the ore from the storage building to lighters. This conveyor and loading bridge was of all-steel construction. A cantilever truss extended out over the reef far enough so that the discharge from the end of the belt could be dumped down a vertical pipe directly into 100-ton lighters. Usually four 100-ton lighters were used, which were towed by two small steam tugs to the steamer anchored off-shore. Each lighter was manned by 30 men who shoveled the ore into "baskets" which held 1000 pounds.

Four baskets were used on each lighter. The steamers which called for the ore had two cargo hatches and could carry 3000 tons. When using 4 lighters, 2000 tons could be loaded in 24 hours.

The best loading season is from January to June. During the last half of the year the sea is so rough that ships can be loaded on an average of only about one-third of the days of each month. The foregoing loading information was obtained by the writer in Tokyo from the Japanese engineer who used to work at Rota.

5. History

According to Aso[1] phosphate was discovered on Rota in 1935 by the South Seas Development Corporation. In 1936 construction was begun and from 1937 on ore was mined.

6. General Geology

Like the other islands of the Marianas, Rota has a core of volcanic rock. Mt. Manira, a rounded knoll forming the highest point on the island, is composed of andesite agglomerate and doubtless owes its eminence to the greater resistance of this formation to erosion than the surrounding rock, which is coral limestone. This resistant knoll is about 1000 yards long by 700 yards wide, containing more than 100 acres, and rising a little over 100 feet above the level plateau to the south.

Basic volcanic rocks and their associated agglomerates and tuffs underlie an area of almost 400 acres from a point about a mile south of Mt. Manira to a point half-way to the sea. This area is two miles long by almost half a mile wide. Structurally it is a "window," representing an area where erosion has removed the veneer of coral which, with the exception of Mt. Manira, is plastered over the volcanic foundation and core of the island. The plateau between Mt. Manira and the volcanics to the south is undoubtedly underlain by the volcanics. This remarkably flat plateau comprises the phosphate mining area.

Rain falling on the plateau quickly sinks through the porous coral until it strikes the underlying volcanics, whereupon it flows southernly down the gentle slope of the

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[1]Aso, Yawata, book entitled "Phosphorites," published by Maruzen Company, Inc., Tokyo, April 1940.

impervious lavas and their pyroclastic derivatives to rise as a series of springs at the foot of a cliff about 300 feet below the plateau. It is a singular fact that the only running water on the island issues from the above described limestone-volcanics contact; springs on Guam rise under similar circumstances. Pipes convey this water by gravity to both the east and the west ends of the island and a pump installed at the most westerly spring delivered water to the villages on the plateau.

Other than the volcanics above described, coral limestone is the only important geological formation on the island. Some large boulders of basaltic lava are strewn about the site of the phosphate drying plant. These have, no doubt, rolled down from the steep slope above the plant, but the formation in place was not seen by the writer.

Rota has a notably terraced appearance, there being at places four or five successions of flat slopes surmounted by prominent cliffs. Although these have sometimes been described as wave-cut terraces, they appear to the writer to owe their existence to thick formations of massive cliff-making limestone, alternating with less resistant material. As viewed from the airfield, such ledges have a dip of about 5 degrees to the north, indicating that the island has undergone considerable tilting since the coral was formed.

Inasmuch as coral forms only in sea water, and the 1500-foot plateau is covered with coral, it is evident that the island has emerged from the sea. This emergence is believed to have taken place during late-Tertiary time and may still be continuing.

7. Origin and Description of the Deposits

According to Aso, a Japanese authority, the guano phosphates of the Pacific islands are derived from the droppings and skeletons of seafowls which feed on fish. The shells and bones of the fish are not assimilated by the birds' digestive systems, with the result that their droppings are rich in phosphates. Where rainfall is heavy, the nitrate and other organic contents soon disappear, leaving a residue of mineral matter. The phosphates react with the calcium carbonate of the coral limestone forming tricalcium phosphate, the rock phosphate of industry. The chemical reactions that take place in transforming the phosphates in

bird droppings to phosphate rock are complex and poorly understood, but the theory appears to be well supported by the occurrence and physical nature of the deposits.

According to Aso, the seafowl nest at locations safe from the waves where there is an unobstructed view of the sea, at elevations of not more than 50 meters. Rota is perhaps the highest of the guano phosphate islands and it is believed that most of its elevation took place after formation of the phosphate. It is remarkable that this high plateau is so well preserved and that the phosphates, which are shallow surface deposits, have not been eroded from it.

Before mining commenced on Rota, the plateau was covered with a shallow layer of russet-colored soil, averaging less than a foot deep. Beneath this soil, which supported a dense growth of trees and brush, the surface of the underlying coral is deeply pitted with a peculiar type of erosion that is common to many of the phosphate islands, particularly the elevated ones. The general surface of the limestone is level, but from 10 to perhaps 25 per cent of its area is, in places, occupied by steep-sided cylindrical cavities that resemble post holes. They hold their cross-sections very well with depth and they are usually four or five times as deep as they are side. Where such holes are most numerous, several sometimes coalesce into a large cavity, some of which are as much as four feet wide and 12 feet long. However, the great bulk of holes range from 14 to 24 inches in diameter and between 4 to 6 feet deep. At a few places holes more than 10 feet deep were measured.

Before mining was started there was no surface expression of any kind to indicate the pitted nature of the underlying bedrock. The diameter and depth of the holes is quite uniform in any given area; when one hole has a comparatively small diameter and corresponding shallow depth, all holes in the immediate area will be of approximately the same dimensions, and likewise, where the holes are wide and deep, narrow, shallow holes will be absent. All such holes are smooth-sided and steep-walled and maintain their size without respect to the different sizes and types of coral organisms transected.

The phosphate area is quite uniformly pitted wherever the surface is uniformly level, but at places where the surface rises a few feet above or below the gentle undulations

of the plain, the holes are absent. This is particularly noticeable at certain edges of the worked-out area where the elevation drops off slightly.

Such holes are always filled with soft phosphatic soil the color of new saddle leather. This soil is quite pure, containing only a few small fragments of coral rock. At the edges of worked areas, the continuation of the pits can easily be demonstrated by probing the surface with a long iron rod. Whenever a soil-filled hole is struck the bar can be pushed down 4 or 5 feet almost without effort. A half-inch iron rod 5 or 6 feet long makes a convenient tool for prospecting for sub-surface pitted areas.

In his book heretofore referred to, Aso states that the phosphate deposits on Rota cover an area equal to 245 acres, but that the area in which the deposits are relatively concentrated is 82 acres, while the remaining 163 acres is very low in grade because "the phosphatic soil is run through with mud." He states that the quantity of "low bauxite content ore is only about 50,000 tons," and questions the value of the low-grade material. The foregoing figures pertain to the deposits before mining was started.

The writer's compass and pace mapping, which is only approximate, indicates that between 140 and 150 acres have been mined, which would include all of the 82 acres of the better grade material and some 95 to 105 acres of the low-grade, indicating the possible presence of some 58 to 68 acres of such material remaining to be mined.

Rota ore has the reddish-yellow russet color of saddle leather. It is a soil having the size range of fine silt and loam particles which tend to granulate together. This fine material contains a small percentage of nodules or oolites about the size of bird shot. After wetting, the granules break down to a greasy-feeling, gritless mass when squeezed between the fingers.

8. Ore Reserves, Grade, and Production

In his book referred to heretofore, Aso estimated that in 1938, the reserves on Rota amounted to 300,000 tons, about five-sixths of which has since been mined. He gives analysis of Rota phosphate running as high as 37 per cent

phosphorus pentoxide, but most of the ore shipped appears to have been of substantially lower grade.

The following figures have been extracted from a report entitled "Sources of Phosphate for Japan," Report No. 12, Natural Resources Section, G. H. Q., SCAP, dated December 31, 1945.

Tons of Phosphate Rock Exported from Rota, M.I. to Japan from 1937 to 1944

Year	Tons
1937	9,824
1938	49,714
1939	43,539
1940	52,000
1941	19,000
1942	40,000
1943	18,000
1944	4,000
Total	236,077

NOTE:-Figures given in even thousands of tons are from the Japanese ministry of Agriculture and Forestry and refer to imports to Japan proper only. The figures are for the fiscal year beginning on April 1 of the year stated.

The foregoing figures indicate that roughly 236,000 tons of phosphate have been shipped from Rota. The writer's measurements indicate the quantity now at the plant and stocked in windrows up on the plateau amounts to 17,500 tons, which brings the total tonnage mined to roughly 253,000 tons.

If the deposits originally contained 300,000 tons as above stated, there should remain roughly 50,000 tons of low-grade reserves in the ground. The latter figure checks well with the writer's observations based upon the amount of level land adjacent to the ore faces where mining was not completed and with estimates of the Japanese officials which were given to U. S. Naval officers before the Japanese had been repatriated.

Aso gives the analysis of Rota shipments for the year of 1938 only, which are shown below:

$Ca_3(PO_4)2\%$		Fe_2O_3 and $Al_2O_3\%$	
From -	To	From	To
77.60	81.59	0.12	03.79

The above determinations, when converted from tricalcium phosphate to phosphorus pentoxide, are 35.5 and 37.4, which are believed to be about 10 per cent higher than most of the phosphate shipped from Rota during the latter years of its production.

The writer carefully sampled the 700 short dry tons now in the plant building and his samples averaged 20.5 per cent P_2O_5 which is equivalent to 44.76% tricalcium phosphate. Ore with such an analysis is very low grade and would have no market value in the United States. Because of its proximity to Guam, it might be worth while to move some of this material there for direct application to the soil, as explained in a short paper appended to this report.

Seven samples taken by the writer from the stock piles on the plateau shown on the map accompanying this report averaged 19.1 per cent phosphorus pentoxide (P_2O_5). The analysis of these samples ranged between 18.4 and 20.0 per cent and it appears very unlikely that any ore assaying better than 20 per cent P_2O_5 remains. On the other hand, it is likely that the peripheral areas not yet mined will be of lower grade than indicated by the above figures. The writer's sample No. 12, taken on the east side of the road at a point 1475 yards south of the main road intersection at Sabana, assayed 16.1% P_2O_5. This sample was taken from a pot hole dug out by the writer on farm land 150 yards south of the small isolated mined area to the north. At a point 300 yards west of the location of sample No. 12 the writer took sample No. 13, which assayed only 12.4% P_2O_5.

Because of the low grade of the remaining material, the writer is of the opinion that the phosphate is worth more left in the ground, which was being used as farm land, than it would be worth if mined. This land is level and, being rich in phosphate, produces excellent crops of red sweet potatoes, corn, etc. Once the phosphate is mined, the deep empty holes are dangerous to both man and beast and the land is forever worthless.

9. The Stock Piles

On the attached map are shown the location of several stock piles which were sampled by the writer. The estimated tonnage and the analysis of the material are snown below. These piles are long, narrow windrows of ore which has been stored along the old railroad grades awaiting tramming down the hill to the drying plant.

Tonnage and Grade of Phosphate Stock Piles on Rota

On Plateau Pile No.	Short Dry Tons	% P_2O_5	% $Ca_3P_2O_8$
1	600	20.0	43.67
2	900	18.4	40.17
3	1100	18.7	40.83
4 & 4A	6200	19.7	43.01
5 & 5A	5600	18.9	41.27
6	1300	Not sampled	
Others	1100	Estimated but not sampled	
	16,800	(Total estimated on Sabana Plateau)	
In plant bldg.	700		
Total	17,500		

Tests conducted by the writer indicate the phosphate in the stock piles to have an average weight of 80 pounds per cubic foot. The analysis of a moisture sample taken from the ore in the storage building at Sosanjaya Bay indicated that the material at that time contained 24.5% with the weather. The foregoing estimate is based on the ore containing 25% moisture, weighing 80 pounds per cubic foot wet and 60 pounds per cubic foot when dried, which requires 33.33 cubic feet to be equal to a short ton of 2000 pounds.

10. Present Condition of Plant

On a terrace about 25 feet above high tide, the Japanese had erected a drying plant, dry storage building, and loading bridge on Sosanjaya Bay. An aerial tramway, shown in accompanying photographs, which was 1.2 miles long, lowered the ore a vertical distance of 1500 feet from the upper terminal on the plateau to the drying plant near the beach.

The ore discharged from the tramway buckets into a wooden storage hopper, which has been completely burned as well as the power house. From the storage bin the ore was fed into two 6-foot by 50-foot rotary coal or wood-fired drying kilns, which the Japanese engineer at Tokyo said had

a capacity of 6 tons per hour, or about 150 tons per day, which would amount to some 45,000 tons a year. From the dryers the ore was elevated to the top of the dry storage building by a bucket elevator and trammed in small cars on rails for distribution along the length of the structure. This building was 57 feet by 172 feet, outside measurements, by 30 feet to the caves and was well constructed with a steel frame, wood plank lining, and steel-trussed, galvanized iron roof. Each side of the bin contained 20 chute gates for loading a 27.5 inch steel belt conveyor supported on non-troughing idlers which discharged onto a transverse conveyor of the same construction. The transverse conveyor moved the ore across an automatic scale onto a cantilever loading bridge which delivered it to an "elephant trunk" through which it poured into a lighter, as mentioned in a foregoing section of this report. In spite of the terrific bombardment which the dry ore storage building has undergone, its steel frame is still in line and the building could be restored.

The tramway towers are still standing, but the buckets have all been removed, evidently for water storage in the jungle when the island was being bombarded.

Inasmuch as the writer is of the opinion that restoration of the plant is not warranted, no further description of it is being attempted.

11. Past Mining Operations

Mining on the plateau was conducted by first clearing the trees and brush from the immediate area to be mined. The surface soil was then loaded by hand into side dump mine cars, having a capacity of about three-quarters of a ton, which were trammed on tracks having 16 to 20 pound rails. The cars were trammed to a bin at the upper terminal of the aerial tramway, but whether they were pushed by hand or drawn by a small locomotive is not known.

After scooping off the surface soil it was necessary to gouge the phosphate from the deep, narrow pot holes. For this purpose a three-pronged tool similar to a post hole digger was used. Okinawan miners did this work and were paid by the ton for the ore mined. A man could produce about 3 tons of ore per day, for which he was paid about 3 yen per ton.

As mined, the ore contained between 25 and 30 per cent of moisture. Drying before shipping was the only treatment the ore received.

As stated in a foregoing section of this report, a total of 236,000 tons of phosphate ore was shipped from Rota during the period from 1937 to 1944. When production was finally stopped by bombardment of the plant and facilities, there appears to have been only about 50,000 tons of low-grade ore left in the ground and a total of 17,500 tons in the storage building and above ground on the plateau.

12. Conclusion

The phosphate ore remaining on Rota is too low grade and the reserves are far too small to warrant restoration of the plant facilities. Moreover, if the remaining ore is mined, some of the best farm land on the island would be destroyed forever. Whereas there is now no population pressure in the Marianas, the day may come at some distant time when all available farm land will be needed.

Unfortunately, because of the presence of the giant African snail on Rota the phosphate stock piles may not be removed without sterilization. A description of how this might be done by drying the ore is appended. In so drying the ore its condition would be improved for pulverizing it to break up the particles coalesced into small clods and granules. If first run through a pulverizer, the phosphate would be easier to spread or sew into the soil to obtain a more uniform and effective distribution.

Because of its inert nature, which has preserved it for centuries, the material will not deteriorate where it now lies so long as it is not scattered. The 700 tons in the plant building can be left there without loss for many years. Upon the plateau the windrows are overgrown with wild morning glory vines which help to hold together and preserve the piles.

If experimental work proves the material to be sufficiently beneficial to warrant using it at Guam or elsewhere on phosphate-deficient soils, only a small amount of road improvement needs to be done to make it possible to move the phosphate the some 14 miles from its site on the plateau to tidewater where it could be loaded on ships. Because of its unusual nature, as pointed out in the appened report, the writer is definitely of the opinion that the material can be put to beneficial use as a plant fertilizer without first converting it to superphosphate with sulphuric acid, as is usually done with American phosphate rock.

C. (COPY OF LETTER)

U. S. COMMERCIAL COMPANY
UNITED STATES PACIFIC FLEET
COMMANDER MARIANAS
BOX 22, % F. P. O
San Francisco, Calif.

12 June 1946

From: Wm. D. Mark, Mining Engineer

To: Douglas L. Oliver, Special Representative

Subject: The suitability of Rota phosphate for direct application to the soils in the Marianas without acidulation to form superphosphates

1. You will recall that while in Honolulu I discussed with you the possibility of fine grinding Rota phosphate for direct application to phosphate-deficient soils in the Marianas. I was aware that an increasingly substantial quantity of rock was being ground for direct application in the United States and that Pacific Chemical and Fertilizer Company at Honolulu was also fine-grinding Florida phosphate rock for direct use in the Hawaiian Islands. I went out to the Associated Sugar Companies* research laboratories in Honolulu and discussed the matter there with Mr. Ayers, their soils expert. He advised me that finely-ground rock was very beneficial to acid soils deficient in phosphate and that he was of the opinion that definitely worth while results could also be obtained through application of finely ground phosphate rock to alkaline soils, but that in such case the phosphate would become plant-available more slowly and heavier applications at less frequent intervals would be required.

2. At that time I did not realize that the phosphate at Rota has a soil-like texture which would require no fine grinding. When wetted and pinched between the fingers, Rota phosphate is so fine-grained that no grit can be felt.

(*Experiment Station of the Hawaiian Sugar Planters' Association) Ed.

At least 90 per cent of the mineral particles composing it are fine enough to pass through a 100-mesh screen. However, the material tends to agglomerate into tiny clods and running it through a pulverizer would make it easier to distribute in the soil.

3. It is advisable to digress here for a moment to discuss the difference between phosphate rock imported from the United States as compared with the Pacific islands phosphates.

a. Nodule Phosphate:
Nodule phosphate derives its name from its commonly nodular or oolitic (fish egg) structure. Although occurring as continuous hard-rock strata similar to limestone, it nearly always is composed of a dense mass of cemented rounded grains similar in size to bird shot. The world's largest known deposits, which occur principally in Idaho, are of this nature. Such rock is mined by underground methods and is produced as lumps, like coal or limestone, and hence must be crushed and ground before it can be treated with acid to produce superphosphate. It is generally recognized that such phosphates are of marine origin, having been deposited by organisms in deep clear sea water. In many respects their formation is similar to the formation of ordinary marine limestone, and places are known where such phosphatic oolites are being deposited in the ocean at the present time. When the raw ground rock of this character is treated with 2 per cent citric acid, usually only about 5 per cent and seldom over 8 per cent is found to be soluble. This is regarded as a measure of its plant availability in its unacidulated state. This will again be referred to following discussion of the kind of phosphates which occur in the Pacific Islands. The phosphate rock from Florida and Tennessee, where the great bulk of American phosphates are produced, are of the aforementioned marine type. However, instead of being in continuous hard rock strata the way it occurs in the West, the Florida rock occurs as pebbles and fine grains which are the result of erosion of what were at one time continuous strata. Such pebbles and fine grains occur in a matrix of sand and clay from which they must be separated by washing,

screening, hydraulic classification, and selective flotation or agglomeration. Ten to twenty tons of material are commonly handled in Florida to obtain one ton of phosphate rock, the marketable product.

b. Guano Phosphates:
The phosphates known to occur on the Pacific islands are of the guano type. Unlike the nodule phosphates, which are of marine origin, the guano phosphates are of terrestrial origin. Although the known reserves of guano phosphates amount to only 160 million tons as compared with about 12 billion tons of nodule phosphates, of which 7 billion tons occur in the United States, they are generally of substantially higher grade and more plant soluble than the nodule phosphates. The guano phosphates are derived from the accumulations of bird droppings and their bony skeletons. During the mating season marine birds congregate in great numbers on rocky coral islands at places overlooking the sea, where they mate and rear their young. Such birds feed on fish, but are unable to assimilate the skeletons which are rich in phosphate. The droppings are also rich in nitrate, but this element forms soluble compounds which are leached back into the sea by the rain water, except where the climate is arid, as on certain islands off of the Peruvian coast where great quantities of nitrate-rich guano once accumulated and have since been mined. On the other hand, the phosphoric portion of the guano reacts chemically with the underlying coral limestone to form tricalcium phosphate, a compound which is relatively insoluble in water. Whereas typical nodule phosphates are stone-like, the guano phosphates occur as porous masses, as a powdery or granular form, and sparingly as coagulated lumps. The Rota phosphate occurs as a reddish-brown soil in which small oolites like bird shot can sometimes be seen. A surprising quality of guano phosphates is that from 50% to 90% of the phosphoric contents can be dissolved with a 2% solution of citric acid, as compared with a solubility of only 5% to 8% of the usual nodule phosphates of marine origin,

as are all of the American deposits. Inasmuch as the foregoing test is regarded as a measure of plant-available phosphate, it is thus seen that without acid treatment the Pacific island phosphates, such as those on Rota, Fais, and Angaur, are far better suited to direct application to the soil than would be the fine-ground rock from the United States which nevertheless is now used in quantity without conversion to super-phosphate with sulphuric acid.

4. In the writer's mind there is no doubt that Rota phosphate can be put to definitely beneficial use as a phosphate fertilizer on Guam and other islands of the Marianas. However, for those not well versed in agriculture I wish to point out that phosphate is only one of the most important of the three major fertilizer elements. The three are nitrogen, phosphorus, and potassium, and all three of these major elements, as well as possibly a dozen minor elements such as calcium, magnesium, copper, iron, manganese, boron, etc., must be present in available form to obtain good healthy balanced plant growth. In passing, it is well to mention that in balanced commercial fertilizers, the percentage of phosphate present is usually equal to or greater than the sum of the potash and nitrate; hence, the phosphate amounts to at least half of the fertilizer that would otherwise have to be imported and the other fertilizer elements can be purchased separately without purchasing the phosphate.

5. The phosphate plant building at Rota contains 650 dry tons of phosphate which contains between 20% and 30% P_2O_5. (The Rota stock piles have been sampled by the writer, but he has not yet received their analysis.) In six long windrows on Sabana Plateau, about 12 miles from Rota Harbor, there is a total of 17,000 tons of phosphate which could be cheaply loaded and truked to tidewater. In addition to this, there is roughly 50,000 tons of unmined low-grade material still in reserve.

6. Unfortunately Rota is infested with the giant African snail and therefore proper precautions must be taken to sterilize all phosphate removed from Rota, and this is especially true when the material is to be moved to islands not already infested with this pest. I am informed by Mr. Fred Hadden, U.S.C.C. entomologist, that this can be done by heating the material on a plate dryer up to 150°, which will kill any snail eggs present. (The eggs are white or yellow,

depending on age, and about the size of buck shot.) A plate drier is simply constructed by supporting a ship's plate or piece of sheet iron, about four feet by eight feet, on stones or bricks, about a foot above the ground and building a fire beneath it. The material should be spread not more than a few inches deep on the plate in order that all of it be uniformly heated throughout up to a temperature high enough to kill all eggs present. From the drier the material can be shoveled to a raised snail-proof platform to cool before it is sacked for shipment.

7. All plants, and sweet potatoes particularly, grow luxuriantly in stock piles of Rota phosphate. Therefore, there is no danger of burning a crop by an excessive application of it, as is the case with chemical fertilizers. Inasmuch as this material contains only twenty some per cent of P_2O_5, it is suggested that not less than one ton be applied per acre, and preferably two tons. Because it has not been chemically treated, the material is less soluble than the commercial product and therefore is more slowly released as plant food. When possible, it should be first spread and then disked into the soil to root depth. Phosphates are little affected by rain water and are not subject to being leached to depth out of reach of the roots as are nitrate and potash. Beneficial results could, no doubt, also be obtained by using the material as a top dressing on existing lawns, golf courses, and flower beds, as well as on established pastures.

8. It is strongly recommended that a substantial amount of the Rota phosphate, particularly that now at the plant, be conserved for use at Guam and that steps be taken in the near future to utilize this mineral resource.

Wm. D. Mark
Mining Engineer

D. MANGANESE ORE ON ROTA, M. I.

1. Location

At a point 0.8 miles S. 45° E. by air line from the old phosphate drying plant, and about the same distance N. 45° E. from Poniya Point, the southern extremity of the island, there is a community not shown on existing maps which is known to the natives as Mangan. A dozen or more small houses, that evidently were built after bombardment of the island ceased, are situated on the fertile terrace below the prominent cliffs that makes a U-shaped bend around the ridge rising above Poniya Point, at an elevation of about 500 feet. This village is only a few hundred feet west of the road leading up to a point near the permanent spring which feeds the pipe line.

At the point where the crossed picks are shown on the map accompanying this report, manganese workings will be found which are about 100 yards west of the road and are near a grove of large breadfruit trees. These workings are in the east face of a prominent cliff about 30 to 40 feet high which contains several natural caves that were used as air raid shelters during the bombardment.

2. Mineralization and Development

The cliff at the foregoing location has been prospected for manganese for a distance of 400 feet or more. Black patches of manganese oxides can be seen on the cliff at several places. Such manganese oxides are the product of weathering of pink manganese carbonate minerals which can be found as irregular blotches and anastomosing veinlets in the face of the cliff. This mineralization is very likely related to the vulcanism which produced the volcanic rocks which crop out on both sides of the ridge and underlie the limestone at shallow depth. A considerable period of time must have elapsed between the effusion of the nearby volcanics and the mineralization of the limestone, because the coral limestone was not deposited until long after the lavas and their accompanying pyroclastic rocks were laid down. Inasmuch as the primary manganese veins are enclosed in the limestone, the limestone must have existed before they were deposited. The thermal solutions which deposited the primary manganese mineral very likely came from the same deep source in the bowels of

the earth as did the lavas which were poured forth from great depth at an earlier time. Such a history of repeated volcanic activity followed by later vein formation, both within the lavas and overlying younger formations, is not at all unusual.

The blotchy mineralized zone conforms roughly with the bedding and can easily be traced for some 300 to 400 feet and probably extends considerably farther to the west of the mine workings examined.

The richest place seen by the writer is a cave-like stope, the mouth of which is difficult to enter, it being in the face of a sheer cliff about 15 feet above the terrace below. A photograph of this cave accompanies this report. The cave, which has been greatly enlarged by mining operations, is now about 30 feet long, 18 feet wide, and 10 feet high. Several hundred tons of pyrolusite ore (MnO_2) of good quality must have been mined from this place, the walls of which at places still contain a thin veneer of ore. Picking into the bottom of the cave indicates some ore still remains, but the bulk of this particular deposit has evidently been mined. A sample of fine ore scooped up from a few hundred pounds spilled below the mouth of this cave assayed 33.04% Mn.

About 50 feet east of the above described workings considerable ore has been removed from a zone of loosely cemented black "boulders," about 8 to 10 feet wide, in the same cliff. These "boulders" of ore are subangular and appear to be the result of ground water dissolving away the finer brecciated material from a shear zone. Most of the boulders consist of low-grade pyrolusite ore, but some of them contain thick coatings of rich ore that could be cobbed off and saved. These "boulders," most of which range between one and three feet in diameter, are so loosely cemented that they can easily be loosened and removed with a pick.

The most extensive development working is a nearby tunnel 115 feet long driven into the limestone from the face of the cliff. From a point about 20 feet from the portal, a branch is driven to the right which forms a pillar by connecting with a heading some 20 feet farther on, which is now caved and inaccessible. This tunnel is about 50 feet west of the opening to the cave, the opening to which is about 15 feet above ground, and evidently was driven in search for a downward continuation of the mineralization in the above place, but it did not disclose any ore.

On the flat about 100 feet west of the road near some large breadfruit trees there are two piles of sorted ore. One pile of fine material, which evidently had been washed and screened, contains about 30 tons, all of which would pass through a 10-mesh screen. This material looked high grade, but assayed only 50.56% MnO, which is equivalent to 39.15% Mn.

At the same place another pile containing about 40 tons of ore, the pieces of which ranged in size from about 4-inch down to one-half inch pieces, was sampled and it assayed 50.66% MnO, which is equivalent to 39.23% Mn.

3. Value of the Ore

During the war, Metals Reserve Company would have contracted for the purchase of domestic ore of the above grade for about $34 per long ton, delivered at its stock piles.

Standard grade "ferro" manganese ore must assay 48% Mn. in normal times; if the ore is of lower grade, penalties are applied which seriously discount the price and such ore is difficult to market. The writer was told at Tokyo that the ore from Rota was shipped to Saipan, from where it went to Japan with manganese ore mined on the latter island. All this was done by the Japanese during a "war" economy, which renders most difficult judging the commercial aspects of the situation. However, considering the Japanese standard of living and wages on Rota, it appears likely that the miners who produced this ore may have regarded the operation as profitable.

4. Reserves and Future Outlook

It is likely that intelligent prospecting might reveal more small pockets of manganese ore in the area under discussion, but at present there are no reserves, either proved or probable. The prospects for establishing a small manganese mining industry on Rota are not sufficiently bright to warrant the purchase of the equipment required or the training of natives to do such work.

5. Conclusion

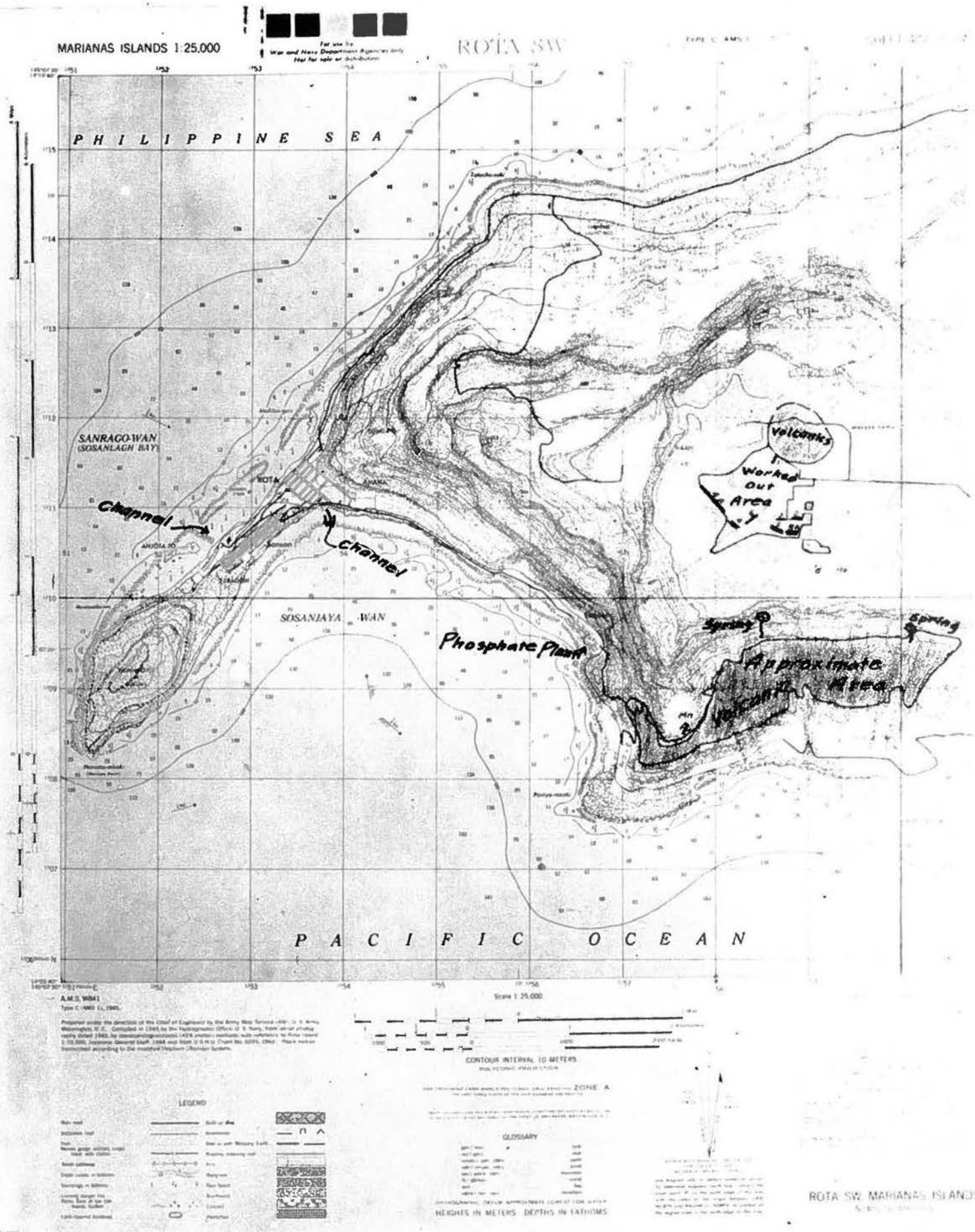
The small "pockety" nature of the deposits and amount of "dead" work that would have to be done, with no assurance that enough ore of shipping grade to justify a "shipment"

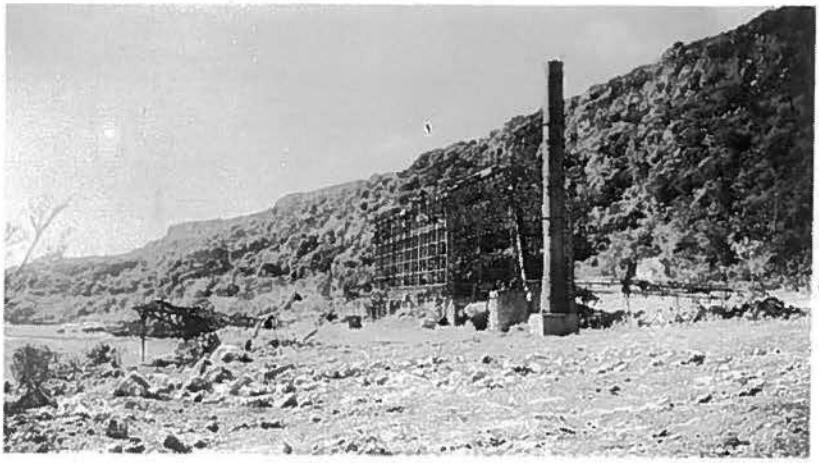
would be found, as well as the long distance and consequently high freight rate to the nearest prospective market, together with the lack of experience of the natives in conducting a business of this kind, are factors which lead this engineer to recommend that no effort be made to mine manganese on Rota at this time.

Some examples of "pot holes" in coral from which the phosphate has been mined on Sabana Plateau, on Rota.

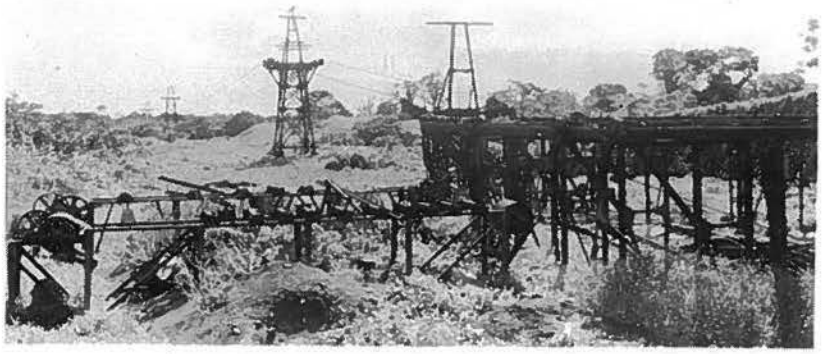
Large worked out pot holes in phosphate mine - Rota.

Worked out pot holes in phosphate field.


MARIANAS ISLANDS 1:25,000
ROTA SW
PHILIPPINE SEA
SANRAGO-WAN
(SOSANLAGH BAY)
ROTA
ANYOTA PO
Channel
Channel
SOSANIAYA WAN
Phosphate Plant
Volcanics
Worked Out Area
Spring
Spring
Approximate Area
PACIFIC OCEAN
A.M.S. W841
Scale 1:25,000
CONTOUR INTERVAL 10 METERS
ZONE A
LEGEND
GLOSSARY
HEIGHTS IN METERS DEPTHS IN FATHOMS
ROTA SW, MARIANAS ISLANDS



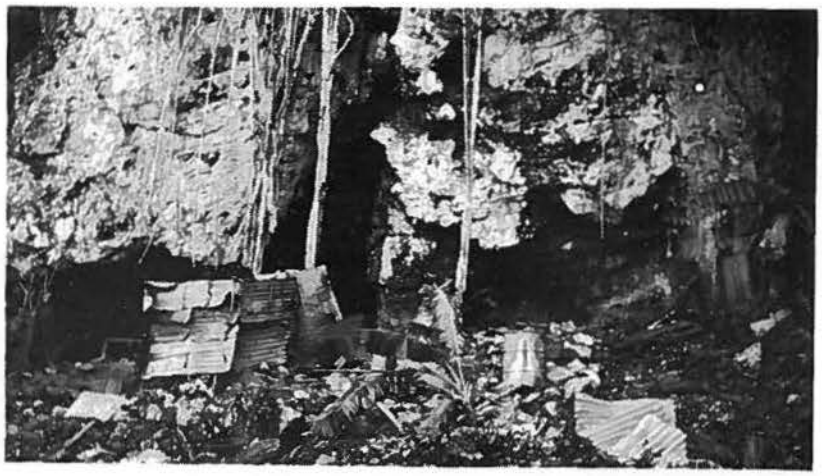
Bombed out Rota phosphate plant and loading bridge.



Burned out upper terminal of Aerial tromway at Rota - part of phosphate works on plateau used to move ore to drying plant on coast.

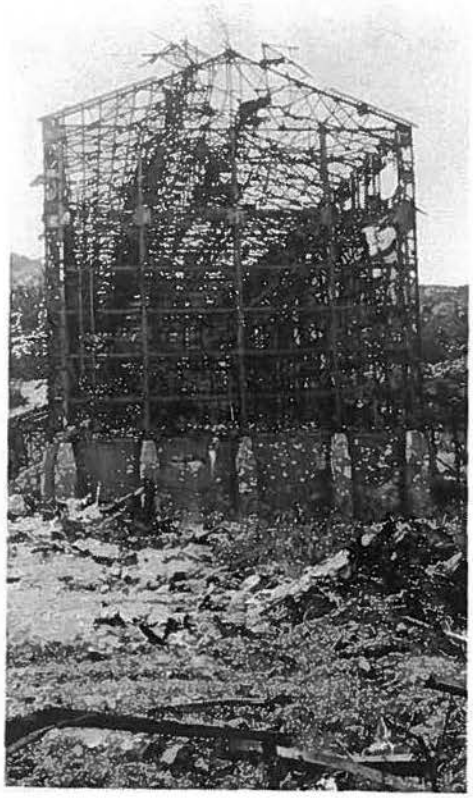
Typical of the larger worked out phosphate pot-holes in coral on Rota.

Note cave in cliff at left from which manganese ore was mined.

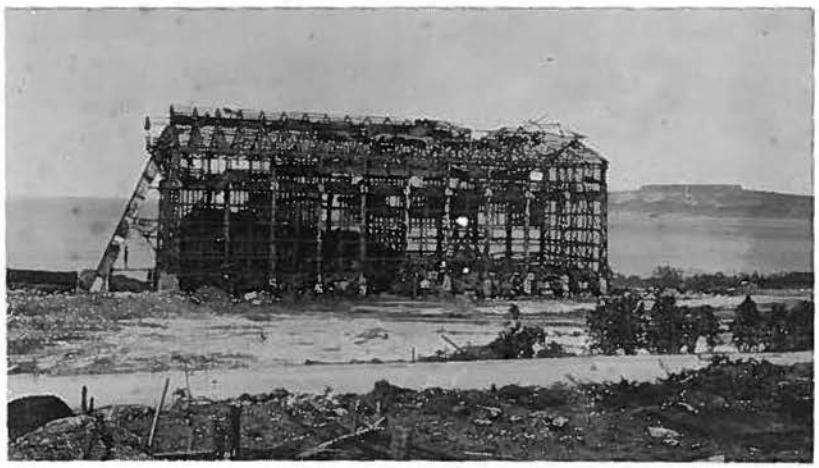


Close-up view of caves in lower part of upper photo. The Japanese mined manganese from these caves which were also used as air raid shelters.

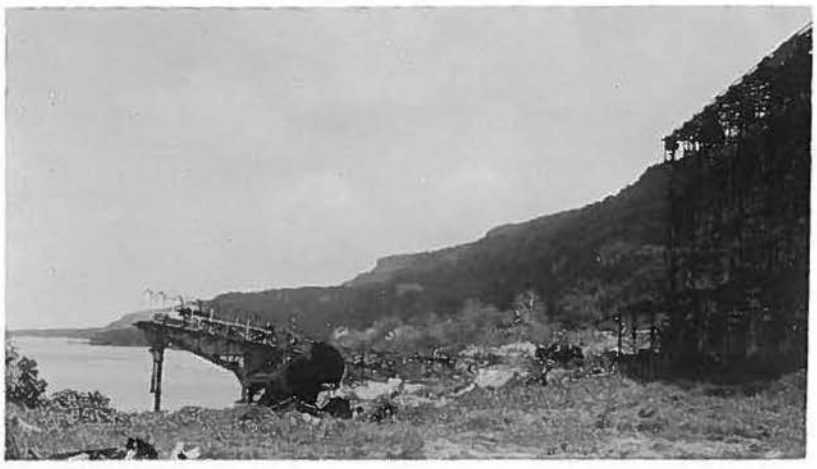
Worked out phosphate pot-holes on plateau at Rota.



N.W. end of dry storage building. Note .50 cailber buttel pits in foundation and shell hole in roof.



Phosphate dry storage building showing the 700 tons on hand. Mt. Taipingot, on the peninsula 3 miles away across Sosanjaya shows in the background.



View showing ruins of the loading bridge and the blasted shell off one of the 6' x 50' rotary dryers.

III. COPPER DEPOSITS ON GAGIL-TOMIL, YAP ISLANDS

While our ship's engines were being repaired at Yap, the writer accompanied Dr. Josiah Bridge and Mr. Arthur Piper on some of their geological traverses of the islands.

As the mining engineer for the Economic Survey, the writer wished to go on record as recommending that additional studies be made in the future of the copper showings on Gagil-Tomil. The Japanese had mined and shipped copper ore from these islands and roughly 200 tons of such ore is still piled on the dock that is 900 feet north of Gatschapar, on the east coast.

Most of this ore is supposed to have come from a cut about 150 feet long, 10 to 20 feet wide, and ranging in depth from a few feet at the east end to about 15 feet on the west end. This cut is in altered gray-green amphibolite schist that strikes east-west and dips 30° S. The walls of the cut are no longer well exposed and only traces of copper minerals can now be seen in them, but at several places small lenses of quartz can be found. Were it not for the abundant copper minerals on the nearby dump from the cut, one might not suspect that any quantity of ore had come from it. The appearance of the wall rock of the cut shows that it had been mineralized with quartz and iron-bearing sulfides and was hydrothermally altered before weathering processes had attacked the rock.

The place above described is on the west side of a ravine and can be found by proceeding southwesterly down the road 1500 feet from the small inlet 200 yards north of the landing at Gatschapar, from which point a trail turns off to the right. The cut is 900 feet N. 15° W. air line distance, from the intersection of the road with the narrow trail, which crosses the center of the mine cut.

Another showing, of more interest to the writer than the one above described, is almost on a direct line drawn between Onean on the east coast and Umung on the west coast. This place is on the northeast side of the 200-foot ridge, near its crest, and is about 500 feet northwest of the crossed picks on the map that represent the location of an old iron mine. Just below the trail at this point there is a trench about 30 feet long and 6 feet deep. In the center of this trench a shaft four feet square has been sunk that was nearly

full of rain water. The shaft is probably less than 10 deep. The upper end of this trench contains a good showing of oxidized green and blue copper minerals. At places where the bedrock is exposed there are a number of places where the schist has been bleached and altered by hydrothermal alteration, indicating that mineralizing waters have been active over a considerable area.

The copper showings seen do not in themselves indicate the "makings" of a mine, but the fact that there are good showings of copper minerals "at the grass roots" in a hot region of heavy rainfall is significant. One would normally expect practically all of the copper to be leached from near the surface to be re-deposited near the ground water level.

It is therefore recommended that when labor is available the old trenches be cleaned out for examination and additional trenches be excavated to explore any indicated extensions of the existing showing or nearby showings that are found. By carefully mapping the entire ridge, or the entire end of the island and studying the copper showings and the patches of altered rock, further exploration may be suggested which might well include trenching, core drilling to depths below water level and a simple geophysical survey using the spontaneous polorization method or a Meggar Ground-Tester.

The original showings on some important copper mines were no more exciting than the small showings above described. Exploratory work such as that suggested above may prove the showings to be of no real significance, but on the other hand if no further work is done a worthwhile copper deposit may be overlooked.

IV. PHOSPHATE DEPOSITS ON FAIS (TROMELIN) ISLAND

A. ABSTRACT

Fais, one of the Western Caroline Islands, 380 statute miles southwest of Guam, is a raised coral island about 60 feet high, inhabited by 236 nearly self-sufficient natives.

When first examined by the Germans in 1911, they found that about half of the surface of the island was covered with guano phosphate, which they estimated to amount to 700,000 tons. Of this amount, 283,000 tons have been mined and shipped to Japan during the period 1938 to 1944. There is good reason to believe that at least 180,000 tons of phosphate rock remain in unmined reserves that can be worked economically by the Japanese if they be permitted to return temporarily to the island to restore the damaged plant facilities and conduct operations. In addition to the unmined ore, there are 55,000 tons stored in a building and in stock piles, bringing the total quantity available to about 235,000 tons.

If an agreement not inconsistent with policy can be worked out with the Japanese, between $2 and $4 per ton could be realized for the ore in a period of less than five years, which funds could be used for the benefit and welfare of the Caroline islanders.

B. REPORT

1. Location

Fais is at Lat. 9° 45' N. and Long. 140° 33' E., according to Aso, Yawata, but on Hydrographic Chart 5426 the coordinates are given as 9° 46' N. and 140° 31' E. Its nearest neighbor is Ulithi Atoll, about 40 miles to the west-northwest. Guam, the nearest trading center of consequence, is 380 miles to the northeast, and Yap is 145 miles westerly.

2. Hydrography

There is no safe anchorage nearer to Fais than Ulithi. Vessels visiting the island must send passengers and freight ashore by small boat. Upon sighting a vessel approaching the island, the natives will paddle to it in their outrigger canoes and, if given the opportunity, board it and take visitors ashore. The two large mooring buoys set by the Japanese offshore from the phosphate loading pier, as shown by the accompanying map, are no longer in place. One large buoy has drifted ashore and a small one is still afloat, but would not provide safe anchorage for any vessel larger than a motor boat. Situated centrally on the northeast coast of the island, the Japanese have constructed a phosphate loading pier on a high, narrow promontory that rises precipitously from the sea. At a point 800 feet southwest from the loading pier there is a small dock, built where a cut about forty feet wide has been made through the reef. Small boats can land safely at this point. Near the pier there is also a marine railway, but it no longer is in a serviceable condition. With the exception of its northeast and southwest ends, where sheer cliffs meet the sea, the island is surrounded by a fringing reef.

3. Topography

Fais is an oval-shaped, raised table reef 1.7 miles long by .6 of a mile wide, having an area of approximately 600 acres. Its plateau-like surface is unusually flat, the elevation of which ranges between 50 and 60 feet. Narrow sandy beaches paralleling the reefs mark its northeast and southwest shores.

4. General Geology

Although the only formation exposed on Fais is coral limestone of late-Tertiary (?) age, the island, like its

distant neighbors, very likely stands on the volcanic pedestal which has risen from the bottom of the sea.

The surface of the island represents an extreme example of youthful topography. Its flat coral surface has been uplifted from the sea, as has been all terrestrial coral. Approximately 85 per cent of the surface of the island is represented by this flat plateau, the remainder being comprised of more or less shelving areas which descend without prominent bluffs to the narrow sandy beaches bordering the fringing reefs. Such a shelving area extends from the prominent phosphate point a distance of approximately 1500 feet to the southwest, where it meets the sheer cliff near the southwest end of the island. There is a similar shelving area at the native village site on the east side of the southeast end of the island.

The accompanying map shows the location of a fresh water well, which was not visited by the writer. The source of the fresh water used by the Japanese is not known. There are no springs or streams on Fais.

5. Population and Culture

"Sailing Directions for the Pacific Islands" gives the population as 368 in 1930, but the writer was advised by the chief that at the time of our visit there were 300 natives. No white men live on the island and there are no stores or commercial establishments thereon.

The natives fly the American flag on the beach in front of their village when vessels approach and are otherwise friendly to Americans. They have a self-sufficient economy, producing on the island practically everything required. Clothing is limited to G-strings for men and boys, and the women wear only a grass skirt. Formerly, when under the Japanese occupation, some of the natives were employed at the phosphate works. They doubtless would be willing to go back to work in order to earn money for the purchase of hardware and other conveniences of civilization, such as matches, if there were any employment opportunities. Flint and steel now are in general use for lighting cigarettes and starting fires. Outrigger canoes without sails are used by the natives for fishing.

6. Vegetation and Agriculture

In addition to the usual complement of hardwoods found in the region, papaya, breadfruit, and coconut trees are

plentiful around the periphery of the island where the soil has not been disturbed by mining operations. Taro, tobacco, yams, and squash were seen growing in gardens planted on phosphate stock piles. There is also a garden area a short distance east of the phosphate plant, but it was not visited. No chickens were seen at the native village, but the chief advised the writer that the natives have ten pigs. Unlike many of the other islands, bananas were not seen on Fais.

7. Phosphate Deposits

Phosphate was discovered on the island by the Germans in 1910, but it was not until November 1938 that production began, when operations were started by the South Seas Colonization Corporation, which had assumed control of the deposits in January 1937.

The guano phosphate deposits on the island were derived from the accumulation of bird droppings and their bony skeletons. During the mating season marine birds congregate in great numbers on rocky coral islands at places overlooking the sea, where they mate and rear their young. Such birds feed on fish, but are unable to assimilate the skeletons, which are rich in phosphate. The droppings are also rich in nitrate, but this element forms soluble compounds which are leached back into the sea in tropical areas of heavy rainfall such as Fais. The phosphatic portions of the guano react chemically with the underlying coral limestone to form tricalcium phosphate, a compound relatively insoluble in water. On Fais the phosphatic accumulations are now in the form of small nodules ranging in size from fine birdshot to the size of BBs. These nodules are gray in color and are mixed with phosphatic soil, but in quantity the nodular material predominates. The phosphate deposits cover roughly half the area of the island. The grade of the phosphate is reported by Aso to contain an average of 37.4 per cent of P_2O_5, (81.7 $Ca_3P_2O_8$) and 2.1 per cent of combined Fe_2O_3 and Al_2O_3. The first year's production, amounting to 14,222 long tons shipped in 1938, analyzed between 65.52 and 79.72 per cent $Ca_3P_2O_8$ and 0.03 per cent of Fe_2O_3 and Al_2O_3 combined, according to data given by Aso, Yawata. As reported by the Japanese Bureau of Agriculture and Forestry, the phosphates imported from Fais in 1940 contained 36.89 per cent P_2O_5, which is equivalent to 80.56 per cent $Ca_3P_2O_8$ and 1.88 per cent combined Fe_2O_3 and Al_2O_3.

The phosphate occurs as a blanket of soil overlying and filling closely spaced pot holes commonly one to two feet across and four to six feet deep, similar to those on Rota.

8. Production

Below is shown the production from Fais, by years:

	1938	1939	1940	1941	1942	1943	1944
Dry long tons	14,222	43,821	27,000	68,000	87,000	40,000	3,000

Total - 1938 to 1944, inclusive, 283,043 long dry tons.

9. Stocks of Mined Ore

Shown on the map accompanying this report are the location of stock piles of mined ore. These are tabulated below:

Fais Ore Stock Piles

	Dry Long Tons
High, overgrown pile 400 ft. E. of dry storage building	29,300
Large, flat pile between above pile and dry ore storage building, now used as gardens	6,400
Dry ore storage building (63% full)	6,100
500 ft. windrow on E. side of dry ore storage building	2,530
Windrow 1775 feet long on S. W. part of island	4,000
Windrow 1285 feet long near above pile	3,200
"Cross" windrow 1000 feet long	1,000
Windrow not measured	1,000
Total phosphate ore above ground,	53,530

While in Tokyo on May 27, 1946, the writer conferred with H. Kubo, engineer at Fais for the South Seas Colonization Corporation from 1938, when mining operations started, until the plant was closed down late in 1943. He advised me that the piles of ore near the plant contained 48,150 wet tons of ore, averaging 18 per cent moisture, which would equal 39,480 dry tons. In addition to this, he stated there were 9,120 dry tons of ore in the dry storage building and a total of about 10,000 wet tons of ore in various piles in the mining

area on the southwest end of the island. These stocks are tabulated below for comparison with the foregoing table.

Ore Stock Pile Data Obtained in Tokyo

(Equivalent wet or dry tons based on 18% moisture)	Wet Tons	Dry Tons
Ore in wet storage near plant	48,150	39,480
Ore in dry storage building	11,100	9,120
Various windrows in the S.W. mining area	10,000	8,200
Totals, wet and dry equivalents	69,250	56,800
This engineer's independent estimate		53,530

The figures received from the Japanese engineer in Tokyo are equal to 106% of the writer's independent estimate, which is regarded as a reasonably good check. As a round figure, it may be said with some assurance that there are 55,000 long dry tons of ore above ground at Fais.

10. Ore Reserves and Grade

According to Aso[1], the Germans originally estimated the island to contain 700,000 tons of phosphate ore. The Japanese engineer Kubo advised me in Tokyo that all ore on the northeast end of the island has been mined out, but that the southwest end still contains an estimated 220,000 wet tons in the ground. According to figures compiled by the Japanese Ministry of Agriculture and Forestry, 345,000 tons of ore have been imported into Japan from Fais during the period 1938 to 1944.

Tabulated below are data indicating that it is reasonable to assume there may be 220,000 wet tons of unmined reserves.

Equivalent phosphate based on 18% moisture in the wet ore.	Wet Tons	Dry Tons
Exported to Japan 1938-44	345,000	283,000
Present stocks	69,250	56,800
Reserve in ground	220,000	180,000

[1]Aso, Yawata, "Phosphorites," Maruzen Co., Inc., Tokyo, 1940

	Wet Tons	Dry Tons
Tonnage accounted for	634,250	519,800
Plus Tonnage unaccounted for	65,750	54,200
Reserves originally estimated	700,000	574,000

It is to be noted that the sum of the ore shipped, now in stock piles, and still estimated to be in the ground is 54,200 dry long tons less than what should remain unmined, based on the Germans' original estimate. Hence, it appears likely that the island could produce at least 180,000 dry long tons of phosphate ore which should average about 37 per cent P_2O_5, which is equivalent to about 81 per cent $Ca_3P_2O_8$, the tricalcium phosphate or B.P.L (bone phosphate of lime) of the trade. Although this is not as rich as the ore at Angaur Island, it is phosphate rock of very good grade, especially when it is remembered that the material contains less than 2.0 per cent of combined Al_2O_3 and Fe_2O_3.

11. Mining Methods

Mining at Fais is done entirely by hand and is a very simple process. The Japanese have arbitrarily divided the ore body into two parts, known as the shallow seam and the deep seam. The shallow seam is the surface soil, which is phosphatic, and can be simply shoveled from the surface above the solution-pitted coral. This ore probably does not average much over one foot in thickness.

The deep seam ore is the material which must be gouged from the narrow, closely spaced pot holes in the coral. This is done with a three-pronged tool similar to a post hole digger and requires more man hours per ton than does mining the shallow seam ore.

On the accompanying map the extent of the two seams is delineated. The outer border contains shallow seam ore, but the area within the inner line contains both the deep seam and the shallow seam.

A main line of tracks, having a 24-inch gauge, was laid southeasterly from the drying plant, dividing the island into two almost equal parts. From this central track switches were laid so that tracks can be turned off at right angles into either mining area. The tracks are moved from place to place as mining progresses. Side dump cars of the

Koppel type, having a capacity of about three-quarters of a ton, were used. Between one and two dozen such cars were seen. It is understood that trains of these cars were pulled by an internal-combustion powered locomotive, but none was seen.

12. Drying Plant and Storage

As mined, the moisture content of the ore ranges between 15% and 20%, averaging about 18%. Because of its nodular nature, the ore will lose some of its moisture by storage under roofed structures without walls. Such a structure existed a few rods east of the main dry storage building, but it has been destroyed. The 6400-ton ore pile mentioned hereinabove and shown on the map marks the site of this building. It is the large building marked "phosphate refinery" on the accompanying aerial photograph.

From the open-air storage the material was run through coal-fired drying kilns. These are rotary kilns six feet in diameter by 50 feet long and there are three of them, which should make possible the drying of at least 18 tons of ore per hour. A bucket elevator raised the dried phosphate from the kilns to the top of the dry storage building, which, unlike those at Rota and Angaur, is of timber frame construction. The inside measurements of this building are 23 feet wide by 25 feet high to the eaves, by 472 feet long. Having been left about 63% full of ore, this building is still in fair shape; otherwise it would have been demolished as are most of the other plant buildings. The discharge from the bucket elevator is distributed over the length of the building by hand-trammed cars operating on a track at the same elevation as the eaves of the structure.

13. Present Condition of Plant

Fais has undergone no such bombardment as has Rota and Angaur. However, other than the dry ore storage building, the most important and expensive installation on the island, practically all of the smaller structures shown on the attached map and aerial photograph have been destroyed. Part of the roof is gone from the dry ore storage building, but it is otherwise in good shape. Likewise, the dryers are in fair shape and could be repaired for operation, as can also the loading pier and its equipment.

Most of the rails have been removed, but they may still be found on the island. The writer once saw a dispatch

or report at Guam stating that the commander of the forces that had occupied Fais after the Japanese surrender had had all tools, motors, etc., stored in a safe place before leaving the island, but the writer did not have sufficient time to check this detail.

14. Shipping

The dry phosphate is drawn from the building through chute gates near the floor, spaced at an interval of about 8 feet, on both sides of the structure. It is hand-trammed in ore cars down a double track to the pier where there is a turn having a 10 meter radius. At this turn the cars are dumped into a hopper and the empties are trammed back down the other line, thus avoiding the loss of time for switching had only a single track been used. A short belt conveyor transports the ore from the hopper about 25 feet to the end of the loading bridge where it falls into a metal tubelike chute that discharges into a lighter anchored below it.

While in Japan this engineer was told that with 16 lighters and 141 men, 1300 tons of ore was loaded aboard ship in 12 hours. Twenty-five three-quarter-ton cars, with 2 men to the car, were used. Six men were used at the end of the track to dump cars. Four or five men worked each lighter, depending on its size, both 5-ton and 8-ton boats being used. The 5-ton boats were the favorites and were 25 feet long with a 7.5 foot beam. From the lighters the ore was removed in 1.5 ton baskets hoisted aboard with regular ships' tackle. Three baskets were used on the 5-ton lighters. The lighters were towed from shore to ship in threes by a tug.

From February to July the weather is good, but from August to the end of the year only about 10 days out of each month can be counted on during which ships can be loaded.

15. Economic Possibilities

The writer visited Fais in the company of Mr. Chester Fulton, a mining engineer employed at Washington, D. C. in April 1946, by the U. S. Navy's Bureau of Yards and Docks. The writer was designated CINCPAC'S Representative on this junket, which took us to the principal phosphate mines in the ex-mandated Japanese islands.

It is the writer's understanding that Mr. Fulton was assigned the task of seeking ways and means to get to Japan

200,000 tons of phosphate ore by January 1, 1947. It was expected that most of this ore would be shipped from the some 66,000 long dry tons of ore in the stock piles at Angaur, plus enough newly mined ore to make up the balance required.

Because of the poor loading facilities at Angaur and the bad weather prevailing there during the last half of the year, it is extremely unlikely that more than 50,000 of the 200,000 tons desired can be obtained from this source before January 1, 1947. For the above reason, the writer understands that Mr. Fulton is recommending that the Japanese be permitted to remove stock piles of ore from Fais, Sonsorol, and Tobi, in order to more nearly accomplish the task of supplying the Japanese with the required tonnage of ore by the deadline, as above stated. Whether or not Mr. Fulton's recommendation has been approved to permit the Japanese to remove the ore stocked at Fais is not at this time known to the writer, who desires here to point out that the phosphate remaining on Fais is an asset having a substantial cash value which should be sold in order that the natives of Fais and the other Caroline islanders might benefit therefrom, through public improvements such as educational and medical facilities purchased with the proceeds received from such a transaction.

Below is shown an estimate, the purpose of which is to demonstrate the value of the phosphate on Fais, including both mined stocks and ore in the ground.

Approximate Valuation of Phosphate Ore Remaining on Fais

Present stocks above ground	55,000	tons
Reserves in the ground	180,000	"
Tonnage available	235,000	"

Value of 235,000 tons delivered in Japan @ $14 per ton	$2,820,000
Cost of transporting, drying, and loading ore above ground, 55,000 tons @ $2.25	$123,750
Cost of mining, transporting, drying and loading 180,000 tons reserves @ $5	$900,000
Cost of restoring plant, organizing and starting regular operations	$100,000

Freight to Japan on 235,000 tons @ $2.50 per ton $587,500

Total Expense, 1,711,250

Overplus of sales value above expense, $1,108,750

In the foregoing estimate, costs other than freight to Japan and cost of restoring plant and operations, are based on actual costs at Angaur for the year 1942, with yen being exchanged to dollars at the rate of four to one.

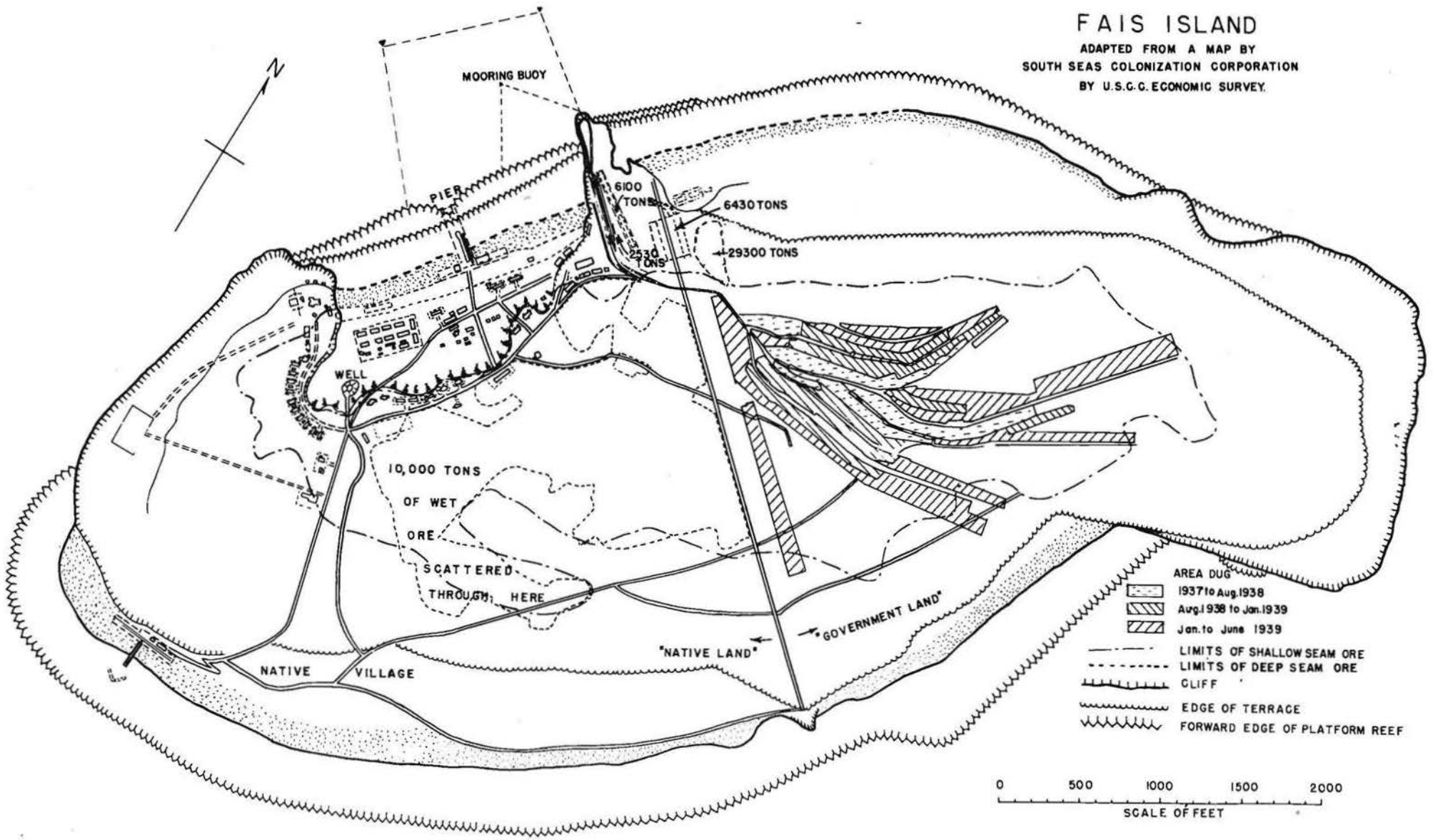
Before going further, the writer wishes to point out here that he is not proposing that the U. S. Government start a mining operation on Fais. If this ore were to be mined and shipped to the United States by an agency of the U. S. Government or by an American contractor, no profit would result. Moreover, a buyer's market generally prevails for phosphate rock in the United States, which is one of the largest phosphate exporting countries in the world.

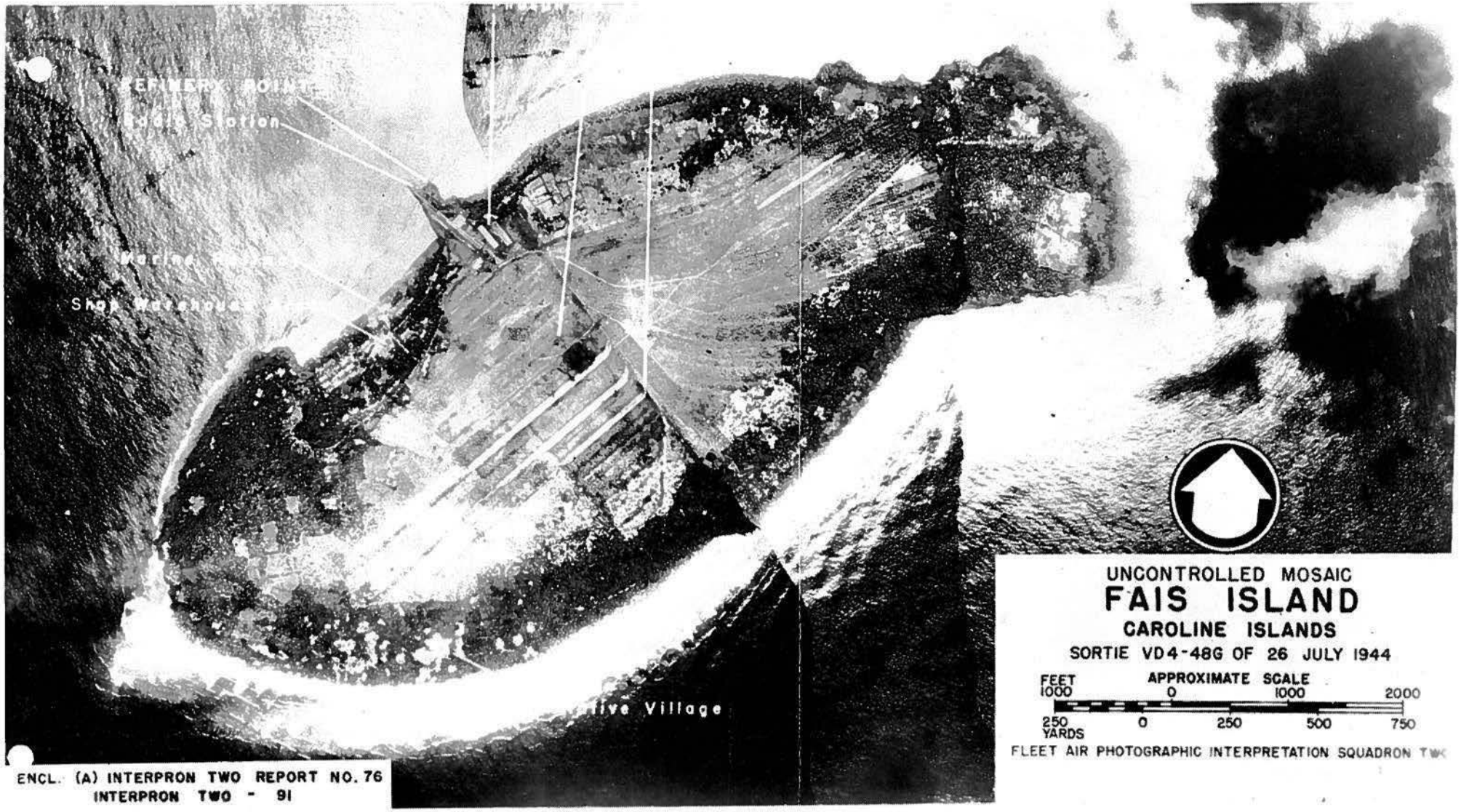
Phosphate production in the Western Caroline Islands meshes well with the Japanese economy. Normally the Japanese use roughly a million tons of phosphate a year, about one-third of which was mined in the Empire, one-third imported from the United States, and remaining third purchased from French and British producers in Africa and Pacific islands, respectively. Since it is well known that the Japanese have received very little phosphate for several years and must produce very high yields from their homeland's small arable acreage to keep from starving, no further comment need be made here as to whether or not they would be interested in operating the mine at Fais. It should also be noted that in recent years the Russians have developed a tremendous phosphate deposit and are looking for customers in competition with American producers.

The writer therefore proposes that, if it is not too inconsistent with our policy with the Japanese, they be given the opportunity to operate the mine on Fais on a royalty basis, all ore produced to be used in Japan, said royalty to be highest on the tonnage above ground and to range between $2 and $4 per ton of ore shipped. In this manner the dual purpose of supplying the Japanese with needed food and the restoration of some industry and income for the ex-

Mandated Islands can be attained. If such negotiations result in a contract, it should contain clauses providing for an American Marine detachment to police the island and the evacuation of all Japanese within a specified period of time.

To the writer, the foregoing plan is more feasible than merely permitting the Japanese to ship out the 55,000 tons in stock piles, because it will make available to them 180,000 tons of additional phosphate rock for which they would no doubt, be willing to pay a reasonable price.


FAIS ISLAND
ADAPTED FROM A MAP BY
SOUTH SEAS COLONIZATION CORPORATION
BY U.S.C.G. ECONOMIC SURVEY.
N
MOORING BUOY
PIER
6100 TONS
6430 TONS
2530 TONS
29300 TONS
WELL
10,000 TONS OF WET ORE SCATTERED THROUGH HERE
"NATIVE LAND"
"GOVERNMENT LAND"
NATIVE VILLAGE
AREA DUG
1937 to Aug. 1938
Aug. 1938 to Jan. 1939
Jan. to June 1939
LIMITS OF SHALLOW SEAM ORE
LIMITS OF DEEP SEAM ORE
CLIFF
EDGE OF TERRACE
FORWARD EDGE OF PLATFORM REEF
0 500 1000 1500 2000
SCALE OF FEET



UNCONTROLLED MOSAIC

FAIS ISLAND

CAROLINE ISLANDS

SORTIE VD4-48G OF 26 JULY 1944

APPROXIMATE SCALE

FEET 1000 0 1000 2000

250 YARDS 0 250 500 750

FLEET AIR PHOTOGRAPHIC INTERPRETATION SQUADRON TWO

ENCL. (A) INTERPRON TWO REPORT NO. 76
INTERPRON TWO - 91

V. PHOSPHATE DEPOSITS ON ANGAUR ISLAND

1. ABSTRACT

Angaur, the southernmost island of the Palau group is at Lat. 6° 54' N. and Long. 134° 9' E. The writer first visited it on May 14 and 15, 1946, as representative of CINCPAC with Chester Fulton, mining engineer, engaged by BUDOCKS at Washington, who was assigned the task of ascertaining how the Navy could get 200,000 tons of phosphate to Japan from the ex-Mandated Islands by January 1, 1947.

A total of 66,000 long dry tons of phosphate rock containing 36.95% P_2O_5 (80.5% $Ca_3P_2O_8$) and about 28% of moisture was found in stock piles near a small boat basin where it could be trucked and loaded into lighters. Arrangements were made by the Navy with a contractor to truck this ore to dock side and load it on Japanese lighters, and to mine additional ore. The contractor's responsibility was to end with loading the lighters, the Japanese being responsible for loading their ships and getting the cargo to Japan.

Of the 3,000,000 tons of this rich ore originally discovered and worked by the Germans, about 2,500,000 tons have thus far been produced, leaving roughly 500,000 tons yet to be won from the deposits. Practically all of the ore above water level has been depleted. The remaining phosphate lies on an unusually rough coral bottom characterized by a maze of deep pot holes and tall pinnacles which makes clean mining of the remainder of the deposit impracticable, if not indeed, impossible.

Based on two short visits to the property, the last being on July 10, and on maps and other data obtained in Tokio and elsewhere, the writer is of the opinion that between 200,000 and 500,000 tons of phosphate may be recovered from the deposits, depending largely on the mining methods and equipment used and the perseverence and skill of the operators.

Because of the difficult operating problems involved and the remoteness from the United States, operation of the property is bound to be unduly expensive and otherwise unsatisfactory.

The writer recommends that the entire operation be turned over to the Japanese as soon as possible, under a contract

providing for reimbursement of all American expenditures thereon, plus a royalty on all ore shipped from Angaur to Japan.

B. REPORT

1. Introduction

By dispatch 050221 from CINCPAC to COMMARIANAS (Schwartz USCC) the writer was commissioned to represent the Commander in Chief, U. S. Pacific Fleet on a phosphate mission of which Mr. Chester H. Fulton, consulting mining engineer, was in charge. Mr. Fulton was engaged in April 1946 by the U. S. Navy's Bureau of Yards and Docks at Washington, D. C. to make a survey of the phosphate resources of the ex-Mandated Japanese Islands.

He was instructed to find ways and means of getting 200,000 tons of phosphate ore to Japan by January 1, 1947, the objective being to supply the Japanese with this ore for the manufacture of fertilizer, as an aid to increasing production and alleviating the acute food shortage in that country.

About two hours were spent by our party on Angaur on May 14. On May 15 the day was spent in cross-sectioning the ore stock piles and examining the phosphate deposits and damaged plant installations on the island. We flew to Guam the following day.

Our inspection of the plant indicated that the drying kilns at Angaur could not possibly be restored for use this year. It was therefore necessary to ascertain whether or not facilities for drying such a large tonnage of ore were available in Japan. Accordingly, our party flew to Japan arriving there on May 22 and getting back to Guam on the 29th. While there every assistance was accorded us by SCAP. Japanese engineers who had first hand knowledge of Angaur and other phosphate islands were called in and questioned. They brought in their data and maps and their cooperation was very good. Much extremely valuable information was obtained, including maps showing the location of the ore reserves at Angaur and Fais, together with much valuable data on stock piles, loading, lightering and weather conditions.

J. H. Pomeroy and Company, Inc., of San Francisco, builders of the breakwater on Guam, were employed by the

Bureau of Yards and Docks to prepare immediately to move phosphate ore from the stockpiles to the dock and to load Japanese lighters which, with Japanese crews, would load ships from Japan. The contractor's responsibility was to end with getting the phosphate on board the lighters, the Japanese being charged with the responsibility of getting the material aboard and shipping it to Japan.

The contractor, having moved equipment from Peleliu to Angaur, established camp and started work which I last visited the operation with Mr. Fulton on July 10, 1946. On July 19, the day before I left Guam for Honolulu, I was advised that the Japanese were sending a steamer and 6 self-propelled barges from Japan on July 21 to get a cargo of phosphate from Angaur.

2. Location

Angaur, the southernmost island of the Palau Group proper, is at Lat. 6° 54' N. and Long. 134° 9' E. Peleliu, the first island of the group to the north, is separated from Angaur by a channel 5.5 miles wide. Guam, the nearest point where supplies can be obtained is 825 statute miles to the northeast and Mindanao, in the Philippines, is 525 miles to the east.

3. Hydrography

Angaur Island is shown on Hydrographic Office Charts Nos. 5423 and 6072. A channel about 5½ miles wide separates Angaur from the other islands of this group. A bank with a least charted depth of 9 fathoms lies in midchannel, on which vessels have anchored temporarily.

The currents around Angaur are extremely irregular. In the above channel they have been reported to run to the westward at the rate of 3 to 4 knots at spring tides.

The lighthouse on the west central side of the island has been blasted from its base and now lies on its side; no lights to aid navigation are now in use.

What is sometimes designated as Angaur Harbor is the open roadstead on the west side of the island. It is not sheltered from northernly or westernly winds which are particularly dangerous during the latter half of the year.

Since the bank of soundings are too steep to be suitable for anchorage, the 100-fathom line being only about 120 meters from the fringing reef at places, buoys have been placed in the harbor to facilitate mooring. Vessels must be prepared to leave on short notice, as swells set in, especially during the latter half of the year, the period of westerly winds.

During the latter half of the year the sea is smooth enough for loading an average of only about 10 days of each month, the worst period being in August and September. Freighters loading phosphate druing these two months have lain at anchor in Palau for more than a month waiting for rough seas to abate.

4. Topography

Angaur is an irregularly shaped island with no long points or deep indentations. Measured in a northeasternly end of the island is widest and measures about 2.25 miles at right angles to the above axis. It has an area of about 5.2 square miles. The shore of the southern half of the island is fringed by a reef which is much the widest on the west side. The northern portion of the west side is also fringed by a reef, as is also a small portion of the north end.

Cliffs and ledges mark the island's north coast at most places, but the southern portion is characterized by shelving sandy beaches.

A row of serrate coral pinnacles, some of which are 160 feet high, mark the northwestern corner of the island. Otherwise the island is quite flat with a gentle southeasternly slope. Mining operations are the cause of two small lakes and a marsh where phosphate has been removed.

5. Vegetation and Agriculture

The usual complement of hardwood trees are found on Angaur where mining operations have not interfered with the natural vegetation. Coconut palms on the island are not very numerous. They covere about 20 acres near the southern tip, and there is a small grove of them on the northeasterly side of the island.

Yams, taro, melons and tobacco are grown by the natives who till the phosphate ore piles in addition to their regular garden patches.

6. Population and Culture

Four hundred forty-nine Carolinians and 33 Chamorros comprised the population of Angaur in 1935. Since then some of the natives have been moved to Peleliu where they are employed by Military Government, and there is now considerable traffic between the two islands.

A discharged American sailor married a native girl and now resides at Angaur. Some 80 white men from the United States are there temporarily, in the employ of the contractor.

At the time of the writer's last visit to the island, 30 odd natives had been employed by the contractor who reported them to be good workers.

Phosphate mining operations have been conducted on the island since 1909, first by the Germans and following 1916 by the Japanese. For this reason, the natives have become used to the clothing and other articles of "civilized" peoples.

Unlike the natives on Fais and Yap, the men and women of Angaur and nearby Peleliu have discarded the G-string and the grass skirt for imported clothing.

A commissary operated by the contractor supplies the food, clothing and other merchandise needed by the native employees.

Numerous Quonset huts, erected by the Marines following invasion of the island, provide plenty of shelter for all employees. Native thatch houses on the island are few in number.

A "loran" station on the island, in caretaker status, is watched by four or five Coast Guardsmen.

The contractor's equipment, supplies and mail come to Angaur via Peleliu. A plane at the command of the contractor shuttles between the two islands, both being equipped with air fields.

7. Brief History of the Phosphate Operations

In 1903 German engineers reported the discovery of Guano phosphate on Angaur. A German company acquired the right

to work the deposits in 1908 and commenced working the deposits the following year. The Japanese Navy captured the island in October 1914 and a certain amount of ore was extracted by the South Seas Management Association, but the following year it came under Japanese Navy management. Control was transferred from the Navy to the South Sea Administration in April 1922. For 16 years thereafter it was managed by this agency and was one of its sources of revenue. Control was transferred to the South Sea Colonization Corporation on January 1, 1937, where it remained until occupation of the island by U. S. Marines.

8. Production (Metric tons)

The following figures reporting production of phosphate on Angaur from 1909 to 1937 are taken from the U. S. Navy's translation No. 399, 22 April 1940, this being a partial translation of Aso's book entitled, "Phosphorites" which was published at Tokyo by Maruzen Company, Inc. 1 April 1940.

1. Period of German Management

Year	No. of Tons of Refined Ore Shipped Out
1909	9,000
1910	40,000
1911	45,000
1912	60,000
1913	90,000
1914 (From Jan. through Oct.)	40,964
Total	284,964

2. Period of Management by South Sea Management Association

Year	No. Tons Refined Ore Shipped
Nov. 1914 through March 1915	11,095
April 1915 through August 1915	26,362
Total	37,457

3. Period of Navy Management

Year	No. Tons Refined Ore Shipped
1915 (Sept. through Dec.)	1,032
1916	26,916

1917		45,097
1918		53,361
1919		69,421
1920		55,298
1921		58,896
1922	(Jan. through March)	18,253
	Total	328,274

4. After Transfer to South Seas Administration

Year		No. Tons Refined Ore Shipped
1922	(April through Dec.)	32,505
1923		60,921
1924		66,698
1925		60,338
1926		62,649
1927		64,873
1928		68,213
1929		70,158
1930		56,383
1931		44,532
1932		57,754
1933		74,720
1934		59,952
1935		83,983
1936		87,821
1937		91,259
	Total	1,042,759

Total from 1909 thru 1937---------- 1,693,454

The following quantities were shipped after compilation of the foregoing table. Figures from 1940 to 1944 are approximations compiled by the Japanese Bureau of Agriculture and Forestry.

Year	No. Tons Refined Ore Shipped
1938	104,186
1939	143,420
1940	122,000
1941	134,000
1942	127,000
1943	98,000
1944	26,000

Total 1938 to 1944	754,606
Total 1909 to 1937	1,693,454
Grand Total 1909 to 1944	2,448,060

9. Geology

Angaur, like its neighbors, is a volcanic pedestal which has been eroded down and covered with coralline limestone.

Like the other phosphate islands in the Pacific, the deposits on Angaur are derived from the droppings and skeletons of seafowl which inhabited the islands in great numbers thousands of years ago. Such accumulations originally contain considerable nitrate as well as phosphate, but the nitrates, being soluble in water, were gradually leached away. The phosphate, reacted chemically with the underlying coral to form tricalcium phosphate, a relatively insoluble compound, which accounts for its preservation.

Two distinctly different types of phosphate are found on the island. The first is a grey to dark brown oolitic type that occurs above water level. The individual pellets are about the size of bird shot and are so loosely consolidated that when disturbed they run like dry sand. They are quite hard and must be ground before the material is treated with acid to make superphosphate. Average analysis of the brown oolites range between 37% and 41% P_2O_5 and between 0.8% and 2.3% combined Fe_2O_3 and Al_2O_3. As mined by the Japanese the material averaged 39% P_2O_5 and 1.5% combined iron and alumina. Ore of this character originally filled pot holes in coral similar to but larger than those found on Rota and Fais. Such ore, occurring as it does above water level, was easily mined.

Two long piles of such material containing an estimated 12,000 tons are stored where dumped under the railroad highline along the road a short distance east of the large dry-ore storage building. The ore of this character remaining on the island is amenable only to hand-mining methods because of the small individual size of the cavities in the coral in which it occurs. At the end of 1942, the Japanese estimated that there still remained 53,241 tons of such material which, when mined and dried would amount to 37,885 metric tons of saleable product.

The other and by far the most important, type of ore remaining on Angaur is a white clayey material of extremely fine individual particle size. When the damp material is pinched between the fingers it has the same feeling as clay, there being no sand or grit of any kind in it. The freshly mined white ore contains 26% to 27% of moisture and has about the same consistency as glazier's putty. It can easily be molded in the palm into a firm ball. The fresh ore sticks to metal tools. German analysis of two samples of typical material of this character showed 39.25% P_2O_5 and 1.61 combined Fe_2O_3 and Al_2O_3, and 41,82% P_2O_5 and 1.15% Fe_2O_3 and Al_2O_3. Rich phosphate ore of this character extends from water level without change or interruption to the coral limestone bedrock, extending at places below sea level.

Because of its tendency to stick to the rotary kilns when dried alone, the Japanese mixed the above type ore with the slightly lower grade but dryer brown oolites, the product marketed being a blend of the two. Some typical assays of the two types and the blend follow:

Type of Ore	% P_2O_5	% $Ca_3P_2O_8$	Fe_3O_4 plus Al_2O_3
Brown oolite	38.00	82.99	1.80
White Clayey	41.00	89.54	0.80
Refined Export Ore	39.80	86.92	1.20

A most important characteristic of the white clayey ore, concerning its minability, is the unusually irregular bottom of the ore body. The coral bedrock underlying it is one great mass of pinnacles and pot holes which will certainly prove to be a tremendous obstacle to the engineers in mining this ore with such mechanical means as draglines and clam shell excavators. As may be noted on the accompanying map showing the results of drilling Area No. 2, there are many holes that go down more than 20 meters in ore, with one 67.6 meters (221.7 feet) deep. These deep holes are the ore to be only a few meters deep. This situation will be discussed farther in following sections of this report.

10. Stock Piles of Mined Ore

Near the southeast end of the large dry ore storage building there is a stock pile of ore that is 1025 feet long, up to 230 feet wide and 24 feet thick, containing 1,471,320 cubic feet. Using a tonnage factor of 28 cubic feet per dry long ton of 2240 pounds indicates this pile to contain 52,547 tons of ore.

Two long windrows of ore piled beneath the elevated track at the east end of the dry ore storage building, just to the north of the pile described, contain 12,000 long tons, and it is estimated that there are 1,500 tons in the dry storage building, which totals as follows:

Place	Long Dry Tons
Big Stock Pile	52,547
Piled under elevated tracks	12,000
In Dry Storage Bldg.	1,500
Total	66,047

Five carefully taken samples of ore from the stock piles averaged 36.95% P_2O_5 which is equivalent to 80.5% $Ca_3P_2O_8$.

The near end of the large stock piles is one-quarter mile from the small boat basin to which it was being trucked for loading on lighters by the contractor. To haul the ore piled under the tracks to the above place is about 200 yards farther.

At the time of the writer's last visit to Angaur on July 10, the contractor had piled about 3900 tons of ore at dockside where it could be loaded conveniently into lighters with a power shovel.

The large stock pile, from which the ore at dockside had been hauled, is still surprisingly wet. Although this ore has stood for a period of nearly three years, the inside of the pile still contains almost as much moisture as it did when mined as shown by the following moisture analysis which were supplied by Mr. A. C. Smiley, project manager for the contractor.

Sample No.	% Moisture	Location of Sample
1	31	Bottom of big pile
2	23	Top of Big Pile
3	27.7	Middle of big pile (dark)
4	27.7	Middle of big pile (light)
5	27.2	Bottom of 16' hole at small lake
6	26.4	Bottom of 24' hole at small lake
7	26.3	Ore from surface near the above.

The top and side slopes of the pile have dried out and hardened to such an extent that the material is difficult to penetrate with a sharp pick. Otherwise the ore appears to have lost none of its original moisture. Evidently this is due to the very fine size of the individual phosphate grains. They are so small that the voids between them are of capillary size and drainage by the influence of gravity alone is ineffectual.

11. Ore Reserves and Mining Methods

The subject of ore reserves at Angaur must be approached with considerable caution for the following reasons:

a. Most of the Japanese figures that one can find represent the wet weight of phosphatic material on the island and otherwise have but little bearing on the dry tonnage of phosphate that can actually be recovered as a marketable product.

b. The remaining ore-bearing areas are irregularly shaped in plan and their depth ranges over extreme variations due to the pot hole and pinnacle character of the underlying bedrock.

c. For all practical purposes, the ore remaining to be mined is under water, some of it going to substantial depths below sea level.

d. The amount of ore that will finally be won from the deposits will be dependent, to an unusually large degree, on the mining method or methods used, equipment available, perseverance and skill of the operators, and importance arbitrarily placed upon recovering as much ore as is practicable; that is, whether or not the operation must "pay" or whether it may be advisable to produce the greatest quantity of phosphate possible for strategic or other reasons, it being well known that many countries that normally export phosphate will be reserving all of their production for the next several years for application to their own soils.

The following table (Table I), was obtained at Tokyo through S. Minami of the Phosphate Import Association, c/o San-Ko-Kan, 2 Nichome, Shinbashi, Shiba-KU, Tokyo. Although the mine was operated for three years after this estimate was made, study of it is still worthwhile to learn something of the distribution, area, thickness and quantity of ore that

may remain in to be worked. The areas enumerated on the estimate correspond with the numbers shown on the accompanying map, which was obtained through the above source. Practically all of the phosphate above water level has already been mined from the areas mentioned, i.e., Areas 1 to 6, inclusive. The figures showing reserves are of no present value in ascertaining the remaining quantity of ore.

Another table (Table II), from the aforementioned source, which is supposed to indicate the amount of saleable mineral remaining at the end of 1942 follows Table I.

The 37,885 tons of ore shown on the second line under "Highland Mine" is believed by the writer to be, for all practical purposes, completely exhausted. This was ore of the pot hole type that occurred above water level in high coral areas and was worked by hand, the miner's being paid on a unit basis for the ore produced. Normally the annual production from Angaur, in late years consisted of about 33% of such ore. Inasmuch as the total production for 1943 was 98,000 tons which was followed by 26,000 tons in 1944, a third of this total of 124,000 tons would be 41,000 tons, which is greater than the reserves of such ore carried at the end of 1942; hence if any such ore remains the amount is very small.

By using the above production figures for the years 1943 and 1944, and deducting one-third from their total, this representing the above Highland ore, the result is 83,000 tons, which should be the approximate amount of ore mined from the Low Land Mine in said period.

Now going back to the Japanese note quoted immediately following the table, it is noted that they estimated 1,147,000 tons of ore to be minable from the 1,491,190 tons "Minable Reserve" at the end of 1942. If the percentage factors which are shown in the table are applied to the 1,147,000 tons, the result is 654,250 tons of "sellable" ore. But from this the 83,000 tons produced in 1943 and 1944 must be deducted which indicates the present reserves to be 571,000 tons, provided the land can be drained. If it cannot be drained, and must be mined by the Japanese "Dredger" system, they estimate only 344,000 tons out of 1,147,000 could be mined at the end of 1942, which is equal to 30 per cent. Now applying this factor of 30 per cent to the present reserves, as compiled above, the amount being 571,000 tons, and the answer is 171,300 tons, this being the amount of "saleable ore" which could be recovered from the present reserves, based upon Japanese estimates, if the land is not drained but is mined by their "dredger" system.

TABLE I

ANGAUR NANYO DEVELOPMENT CO.
(Phone (23) 2.3.2-19)

STOCK PILE AND RESERVE AT THE END OF 1941

Investigation Material by Mr. Ikeda, Engineer

Area No.	Production Place	Production Distinction	Area Square Meters	Plane Mineral Thickness Meters	Volume Cubic Meters	Unit ton	Ore ton (wet tons)
1	No. 1 Area at large basin		49,111	3.79	186,130	1.7	316,421
2	From Gabian wet lowland to the ponds North of the Mice Office	Less than 2 meter area	52,800	1.26	66,528	1.3	99,792
		Above to meter area	16,500	13.20	217,800	1.7	370,260
		Right Center Region	87,060	5.06	440,524	1.7	748,890
3	Forest wetland No. 1 Prospect		55,488	3.36	186,440	1.7	316,948
4	Area Vicinity		56,000	1.50	84,000	1.7	142,800
5	Other low Wet land		50,000	0.50	25,000	1.7	42,500
6			30,000	1.00	30,000	1.7	51,000
			396,959		1,236,422		553,248

TOTAL 2,088,611

TABLE II

AT THE END OF 1942, ANGAUR RESERVES

Location	Remaining Reserve	Loss Ratio	Minable Reserve	Useful Mineral	Concentrates	Loss Ratio	Sellable Mineral
Low Land Mine	1,887,582	21%	1,491,190	62%	924,538	8%	850,575
Highland Mine	53,237	9%	48,446	85%	41,179	8%	37,885
TOTAL	1,940,819		1,539,636		965,717		888,460

"Of 1,491,000 tons of low land reserve about 1,147,000 tons are considered to be minable upon drying the land after pumping out the water from the low land wet district. However, in case the drying the land by pumping out the water is impossible, dredger system may be used; then the minable smounts are conjectured to be about 344,000 tons."

The Japanese had two small barges on which were mounted short booms with sheave wheels at the end over which a cable was reaved from excavating with a small clam shell bucket. Power for hoisting the clam shell buckets was supplied by donkey engines mounted on the barges. The material brought up by the excavators was loaded onto a second barge which transported it to the shore of the small lakes or ponds in which the excavators were working. The greatest depth in the larger of these ponds is 31 feet, the other being 20 feet deep at its deepest place. Equipment used as described above is what the Japanese refer to as the "dredger system."

One of the ore reserve maps accompanying this report shows the depth of the ore to bedrock in meters. It may be noted that the deepest place is shown as 67.6 meters, which equals 222 feet. There are 7 additional bore holes where the ore is more than 17 meters (56 feet) deep in this area. Shown on the map as No. 2, this area is assigned an average thickness of 13.2 meters (43.3 feet) in the first table. By again referring to the map showing the thickness of the ore, it may be noted that these deep borings are adjacent to other holes where the ore is only a few meters thick.

The reason the Japanese estimated they would be able to mine only 30% of the under-water ore in such places is evident from the foregoing discussion, and, in the writer's opinion, the contractor now working the deposits with dragline and clam shell excavators is not likely to recover any more ore than the Japanese had estimated.

Although the other ore areas are not as deep as No. 2, their bottoms are likely to be equally irregular and in the absence of our own experience with the deposits, it appears wise to be guided by the Japanese estimates, at least until first-hand experience is gained in knowing what can be done.

With reference to the grade of the ore, its remarkable uniformity has been well established by the production record over a long period of years. As reported by the Japanese Department of Agriculture and Forestry, Angaur phosphate imported in 1940 and 1943 averaged as shown below:

Angaur Phosphate - Dry Basis

Year	% P_2O_5	% $Ca_3P_2O_8$	Fe_2O_3 & Al_2O_3
1940	36.27	79,21	5.82
1943	35.98	78.56	2.84

Five samples taken from the stock piles by the writer averaged 36.95% P_2O_5 which is equal to 80.5% $Ca_3P_2O_8$. Unless the ore is diluted with too much coral rock, future production should average between 36% and 37% P_2O_5.

Further field work cannot reveal much to change the above picture as to tonnage of reserves and grade. The phosphate area covers roughly 240 acres and even though this were all re-drilled and sampled, it is not likely that the foregoing picture would be greatly changed. As said at the beginning of this section, in the writer's opinion, the amount of ore to be won depends largely on how the mining operations are conducted.

Originally the island contained much ore above water level which was simply shoveled by hand into mine cars and hauled away by a small locomotive. At higher places in the coral, pot holes up to 25 feet deep were cleaned out by hand methods. Later, when dry ore was no longer plentiful, large trenches were pumped out at night so that workmen could enter during the period of low tide and shovel out ore.

Below is shown data taken from a captured document reporting on the tonnage mined, by methods, during the first three months of 1944.

"Angaur Phosphorous"
For the Period of 1944 (27 May '44)
Phosphorous Production = 27,389 tons
Underwater = 13,070 tons
Surface = 14,319 tons

Assignment	January	February	March	Total	Working Days	Av. Daily Produc'n
AA Dredger	1503 tons	1382 tons	410 tons	3295	59	55.8 tons
DD Dredger	2081	4332	1990	8403	59	142.4
Low-Tide Diggings	880	492	-	1372	14	98.0
#1 Min Distr	2803 tons	1820 tons	185 tons	4808	-	-
#2 Min Distr	2586	2360	1130	6076	71	184.1
#3 Min Distr	2235	1200	-	3435	-	-
Totals	11288 tons	11586 tons	3715 tons	27389 tons	203	480.3

From this tabulation it will be noted that the 27,389 tons produced was divided almost equally between "underwater" mining (dredging) and surface mining (low-tide diggings). Likewise the table (Table III) on the following page entitled, "Methods of Phosphorous Mining ..." was copied from a captured document.

This table shows the gross reserves to be 1,320,663 tons of which it was estimated 924,463 tons was minable and 396,200 tons could not be mined by the equipment in use. The 924,463 tons is further divided into 501,135 tons that can be mined by the low-tide pump mining method above mentioned, and the balance of 423,328 is to be worked by the dredges. Of the total to be worked, 54.2% is to be "pump-mining." Converting the 124,463 "English" (short" tons to long tons, the result is about 824,000 long tons. To find the exact amount of "sellable ore" the Japanese deduct for "white ore," 18% as an unminable loss, and 1% each as stock pile, transportation and warehouse losses, which totals 21%. After deducting this 21% loss, the result is 651,000 tons. From this must be subtracted the 124,000 tons produced in the years 1943 and 1944, which indicates the ore remaining to be mined to be 527,000 tons. The latter figure is roughly comparable with the 571,000 tons figure arrived at by different means in a foregoing paragraph. Too much reliance should not be placed on these figures because no explanation or interpretation was found with the tables.

There is not sufficient labor available to do the low-tide pump mining such as was practices by the Japanese. Under American management, using imported high-cost American labor, no manual mining can be done, it being necessary to mechanize the operation with dragline and clam shell excavators. This upsets all of the foregoing calculations to a large degree. The adaptability and efficiency of this equipment to the deposits is not yet demonstrated to the point where any comparisons of the amounts of ore that can be recovered with it, as compared with the methods on which the Japanese estimates are based, are at this time justified.

From the above discussion it should be evident that this engineer can give no simple figure or concise statement as to the amount of ore that will eventually be won from Angaur. The best that can be said is that between 200,000 and 500,000 tons may be recovered, the first figure being based on simple dragline and clam shell excavation, the second figure being based on the use of pumps in conjunction with the above equipment, if the experience yet to be gained justifies the installation of such equipment.

12. Drying Plant and Storage and Loading Bridge

The Japanese transported the ore from the mine to stock piles in 1-ton side-dump cars hauled in short trains by an internal combustion powered locomotive on 24-inch gauge tracks.

TABLE III

METHODS OF PHOSPHOROUS MINING AND THE ESTIMATED
RESERVE OF SURFACE AND UNDER-WATER PHOSPHOROUS MINE OF ANGAUR ISLAND

Estimates of Ore
For the First Half Period of 1943: (South Sea Bureau's figure -- 1 cubic meter equals 1.76 English ton)

A Chart showing the 1,320,663 English tons of untouched under-water ore:

Zone	District	Untouched ore Estimates	To be mined tonnage	Unable-to-mine tonnage	Pump-Mining Tonnage (A)	Dredge-mining Tonnage	Note
I Zone	#1 Mining District	318,934 tons	223,253 tons	95,681 tons	63,153 tons	160,100 tons	28%
I I Zone	#2 Mining District	1,001,729 tons	701,210 tons	300,519 tons	437,982 tons	263,228 "	62.4%
	TOTALS:	1,320,663 tons	924,463 tons	396,200 tons	501,135 tons	423,328 tons	54.2%

A) The estimated pump-mined tonnage is figured as at an average of 3 metres.
B) The annual mining of 18,000 tons by the "PRIESTMAN" model "A" machine of I Zone was mined from an area of 49,111 sq. metres; and half of that area was dug to a depth of only 10 feet or so off the surface. The main pump digging at #2 Mining District was used to its fullest extent; but #1 Mining District has about 100,000 sq. metres with the use of the pump.
C) The unable-to-mine tonnage is estimated at 30% of the lower part (pocket) of the whole mining area. Rather difficult to mine.
D) Dredging-&-Pump-mining combined use helped to uncover a small portion of the unable-to-mine tonnage.

From storage it was dried in 6-foot by 50-foot rotary coal-fired kilns, and raised by a bucket elevator to the top of a steel-frame plank-lined building 32.5 feet wide by 460 feet long by 40 feet high to the eaves. Chute gates at the sides of this building delivered the ore to a conveyor belt which elevated it to the top of an extendable-type cantilever loading bridge. This bridge was high enough so that steamers could get directly beneath it so that the ore dumped down flexible pipes from the end of the bridge could be discharged directly into the hatches. This loading plant had a capacity of about 3500 tons in 24 hours.

The above described works has been bombed and burned to complete ruins, as well as has all installations accessory to it with the exception of a small concrete dry ore storage warehouse having a capacity of only a few thousand tons.

13. Production Costs and Profits

Below (Table IV) is shown a statement of the Japanese cost of mining at Angaur in metric tons (2204 lbs.) and yen for the year 1942.

TABLE IV

COST OF MINING AT ANGAUR
UNDER JAPANESE MANAGEMENT FOR 1942
In Metric Tons & Yen

Expense at Mine	Yen	Tons	Cost per Ton
Mining	696,616.75	159,663	3.74
Transportation	184,138.16	159,663	1.15
Drying	514,741.16	147,310	3.49
Loading	104,591.23	150,644	.69
Office Expense	454,750.84	147,310	3.09
Taxes (Gov.)	60,106,30	147,310	.41
	1,914,954.44		12.57
Redemption			
Mining rights	1,048,535.36	157,413	6.66
Depreciation	308,423,43	150,644	2.04
	1,356,956.79		8.70

Business Expense			
Sales	48,893.59	147,310	.33
All other expense	1,011,502.08	147,310	6.87
Income Tax	193,367.26	147,310	1.31
	1,253,762.93		8.51
Interest	340,497.74	147,310	2.31
	¥4,866,171.90		¥32.09

From this statement it is seen that the direct costs for mining, transportation, drying, loading and mine office expense amounted to 12 yen 57 sen, which, with exchange at 4 to 1 would equal $3.14. Total costs, including redemption, sales expense, taxes and all other expenses amounted to 32 yen 9 sen, which with exchange as above stated would amount to $8.02.

Ore of the grade produced at Angaur should have sold in Japan before the war for between 48 and 52 yen. With total costs at 32 yen this would indicate between 16 and 20 yen, or between $4.00 and $5.00 per ton to cover the cost of sea freight and profits. The freight at $3 or 12 yen per ton would leave an indicated profit of between $1.00 and $2.00 per ton.

Under the present arrangement, the contractor delivers the wet ore, containing some 26% to 27% moisture to the Japanese lighters which load the ships. This practice adds to the freight rate of the phosphate by the percentage of additional water, plus the additional cost of loading and unloading the wet material. The phosphate must still be dried before it is acidulated to convert it to superphosphate fertilizer. The product now shipped is therefore inferior to the dried ore which could be cheaply loaded and unloaded, but what this differential might amount to is not known to the writer. The present market price of phosphate in Japan likewise is not known.

It is the writer's understanding that the drying plant and dry storage building are not being restored, but that a new loading bridge is to be constructed, which should greatly speed up the slow and awkward loading arrangement now in use.

14. Conclusion and Recommendation

Because of its remoteness from the United States with respect to both supplies and labor, working costs under the present arrangement are bound to be very high and there is no

way of reducing them substantially enough to make the operation economical so long as it is operated with American labor. Many knotty operating problems have already been recognized and more difficulties will very likely appear in the future.

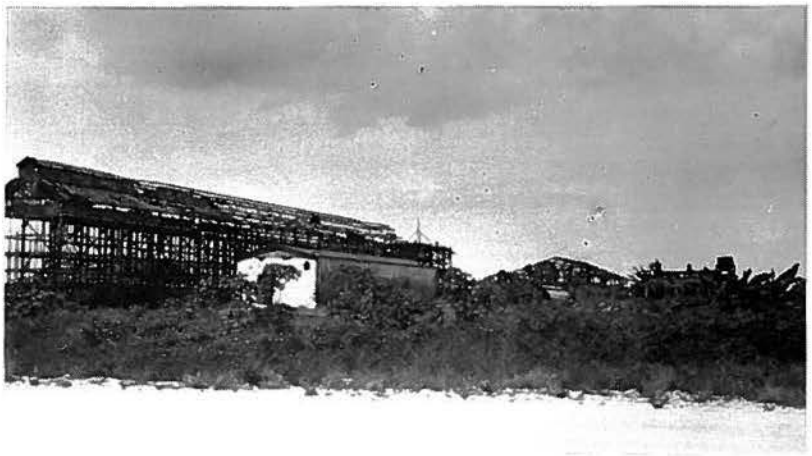
Operation of the property by this government to get phosphate to Japan in the near future was, no doubt, justified by the existing circumstances, but the phosphate delivered to Japan by this expedient is bound to be excessively costly as long as we operate the property.

If it is at all possible to do so, the writer recommends that the operation be turned over to the Japanese as soon as possible, under a contract providing for eventual reimbursement of all American expenditures thereon plus a royalty on all ore shipped from Angaur to Japan. Such an agreement should contain clauses providing for an American Marine police force and complete evacuation of the island by the Japanese by a stipulated date.

Complete photo of loading bridge at Angaur.

Large structure is dry storage building. Concrete structure is small dry storage building and to right is part of the dry kilns and dust collection at Angaur. May, 1946.

Dust collector to catch dust swept by draft thru dryers at Angaur. Ruins of dry storage building in background. May, 1946.



Top -
Ruins of phosphate plant at Angaur.

Left -
Deck of loading bridge, Angaur.
May, 1946.

Ruins of dry storage
building, looking south.
Angaur, May, 1946.

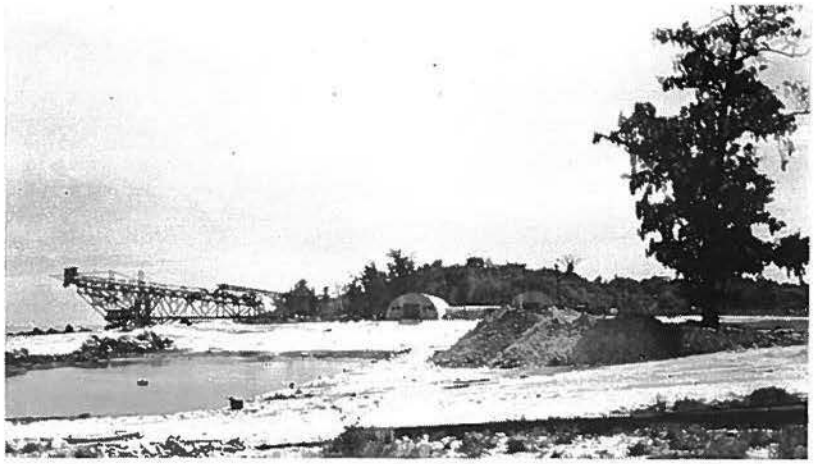
Wrecked landward end
of loading bridge.
Angaur, May, 1946.

Large Phosphate stockpile on Angaur. May, 1946.

Stockpile at Angaur from which 3900 tons had been removed. July, 1946.

Ruins of barge for missing phosphate at last "lake" on Angaur. May, 1946.

Small boat basin,
Angaur, May, 1946.



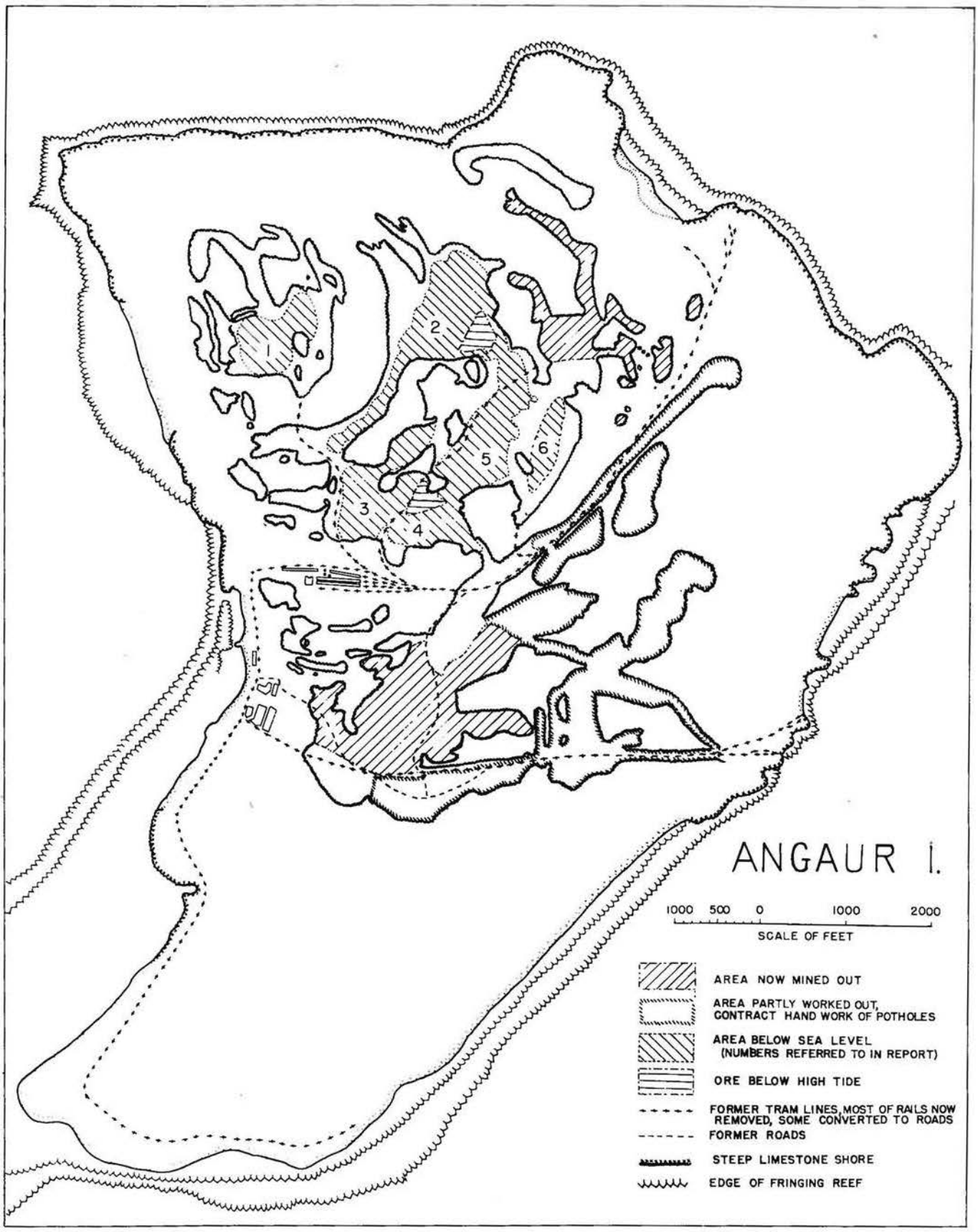
Loading bridge from
small boat basin.

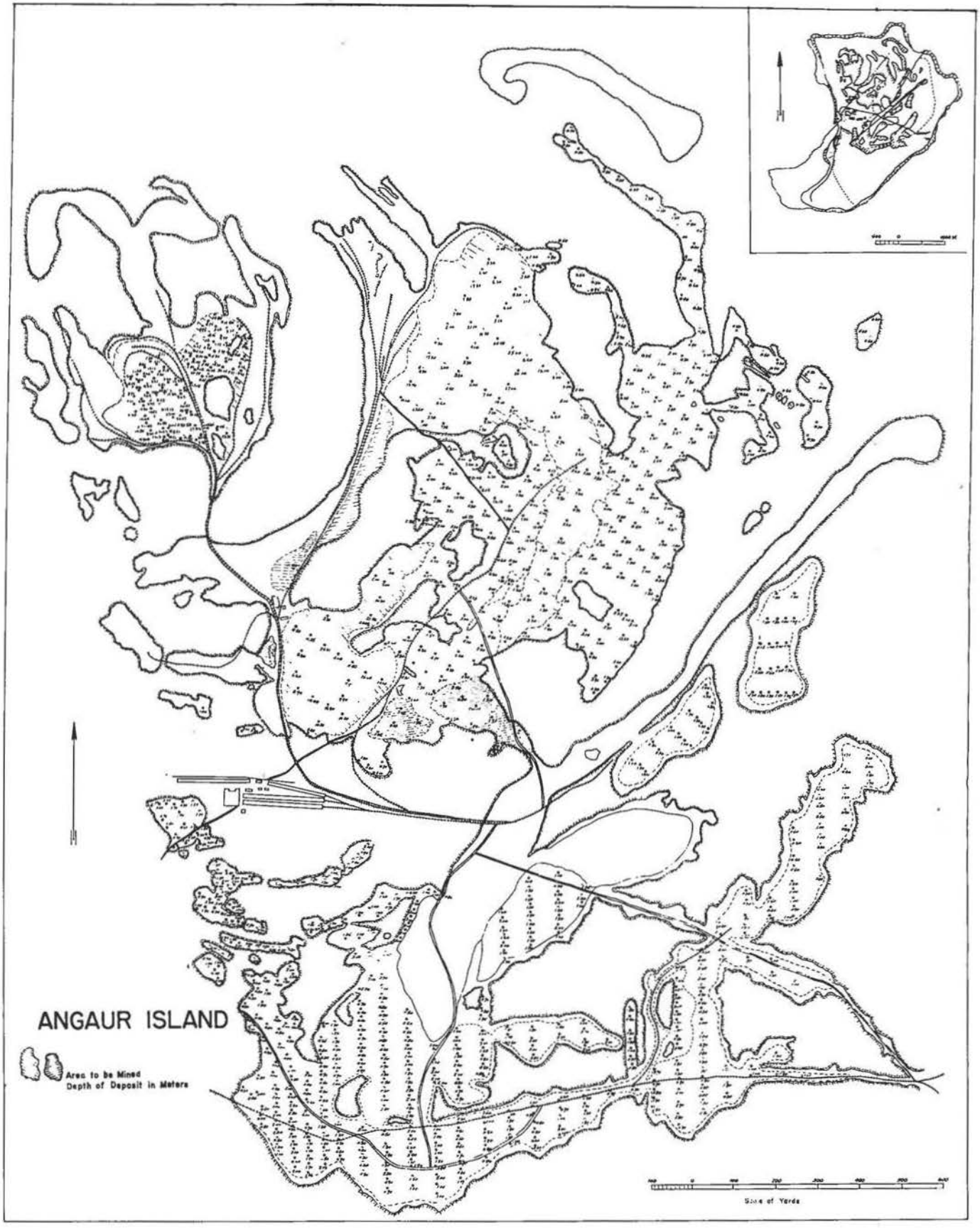
Drag-line excavator
at West Lake.
July, 1946.

3900 tons phosphate piled at boat basin dock on July 10, 1946 ready for lighters.

Looking seaward through entrance to small boat basin.

Small boat basin with 3900 tons of phosphate on dock.


1
2
3
4
5
6
ANGAUR I.
1000 500 0 1000 2000
SCALE OF FEET
AREA NOW MINED OUT
AREA PARTLY WORKED OUT, CONTRACT HAND WORK OF POTHOLES
AREA BELOW SEA LEVEL (NUMBERS REFERRED TO IN REPORT)
ORE BELOW HIGH TIDE
FORMER TRAM LINES, MOST OF RAILS NOW REMOVED, SOME CONVERTED TO ROADS
FORMER ROADS
STEEP LIMESTONE SHORE
EDGE OF FRINGING REEF


ANGAUR ISLAND
Area to be Mined
Depth of Deposit in Meters
Scale of Yards

VI. PHOSPHATE DEPOSITS ON SONSOROL (ST. ANDREW) ISLANDS

A. REPORT

1. Geography

This group consists of two small islands at Lat. 5° 20' N. and Long. 132° 13' E., as shown on Hydrographic Chart No. 5026. The larger island is a mile long and half a mile wide. Fana (Panna) Island is only half a mile north of Sonsorol, but was not visited. It is nearly circular and is only a half mile across. Both islands are fringed with coral reefs which are above sea level at low tide. There is a deep channel 1200 yards wide between the islands that is safe to navigate.

A luxuriant growth of tall trees, including many coconuts, covers the islands. None of the 146 natives on the island speaks English, but they are Christians and have forsaken the G-string and grass skirt for the attire of "civilized" people. Sailing outriggers are used by the natives for catching tuna and other fish. The natives are nearly self-sufficient, but would doubtless welcome an opportunity to work in the phosphate mines in order to earn money for the purchase of clothing, hardware, and other necessities. At the present time there is no trade or industry of any kind on the islands.

2. Phosphate Stock Piles

Opposite the remains of the old loading pier near the south end of the village on the west side of the island there are two stock piles of phosphate ore, containing a total of 35,000 tons.

The near ends of these piles are about 500 feet from shore. A trench some 6 to 8 feet deep, about 500 feet long, which contains what remains of an old mine track, extends from the end of the ruins of the pier to the stock piles. The stock piles are parallel and near together, their long dimension having the same direction as the rail tramway extending to the shore. Having been built up from the landward side, the piles are thickest and widest at their seaward ends. Both piles are of about the same length, but the south one is the wider and thicker one, it being 120 feet wide and 27 feet thick on the seaward end. The north pile is almost as wide as the south pile, but it is only about half as thick. Careful cross-sectioning of the

two piles indicates the north pile to contain about 13,500 tons and the south pile to contain about 21,500 tons, totaling 35,000 long dry tons.

Shown below are some analyses of production as reported by the Japanese Bureau of Agriculture and Forestry.

Year	% H_2O	% P_2O_5*	% $Ca_3P_2O_8$*	% Fe_2O_3 and Al_2O_3*
1940	19.86	30.73	67.11	0.41
1943	29.07	33.85	73.93	0.25

* Dry basis

This ore was shipped undried, no drying plant having been built on Sonsorol.

The ore in the piles is dark brown earthy and sandy material, containing some small lumps which evidently are also phosphatic.

3. Loading Conditions

The pier, which extended from shore about 450 feet to the edge of the reef, where a cut large enough to permit a lighter to come alongside was made, has been completely destroyed, there being only a few posts left standing, as shown in the accompanying photographs.

The Japanese once had a mooring buoy anchored a few hundred yards offshore. On June 28, 1946, when the writer visited the island, several tons of anchor chain were piled on shore near the old dock. Several old 5-ton lighters, about 22 feet long by 7 foot beam, were beached on shore.

Before any loading can be done, it will be necessary to rebuild the dock and lay track on it. The track will also have to be laid through the trench to the stock piles. An anchor buoy for mooring ships will have to be set off shore because the water is 100 fathoms or more deep a short distance from the reef. No ore cars were seen.

4. Ore Reserves

The writer followed the old railway grade from the stock piles almost across the island. This area, where phosphate had been mined, is now thickly overgrown with brush and is marshy in places.

Any remaining ore is believed to be too small in quantity to warrant further mining.

The deposits were supposed to extend over only about 64 acres and to be very shallow, ranging from 6 to 14 inches deep. In 1939 reserves were supposed to amount to about 30,000 tons. The writer's record of production very likely is incomplete, showing shipments of 2,000 tons in 1940 and 16,000 tons in 1941, with no shipments thereafter. Even so, the foregoing 18,000 tons, plus 35,000 still in stock, probably accounts for the bulk of all of the ore originally in the deposits, in asmuch as the first shipments are reported to have been made in 1937 and only 30,000 tons were reported to exist as reserves in 1939.

5. Conclusion and Recommendation

Although the reserves are believed to be exhausted, enough ore remains in the stock piles to warrant reconstruction of the pier and loading facilities. This ore could be used to augment that being shipped from Angaur to Japan. It is therefore recommended that an agreement be negotiated with the Japanese which should provide for the payment of a small price for the ore. Owing to the long distance from Japan, bad loading conditions, and necessity for restoring all loading facilities, and the small quantity of available ore, the value of the stock piles is small.

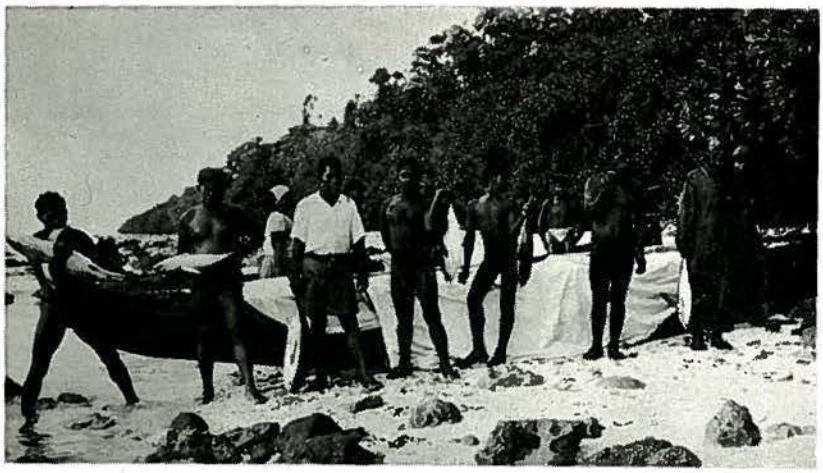
Men standing on 35,000 ton stock pile of phosphate ore on Sonsoral. 28 June 1946.

Ruins of loading pier on West Central side of Sonsoral. Old lighters formerly used for loading phosphate are worthless.

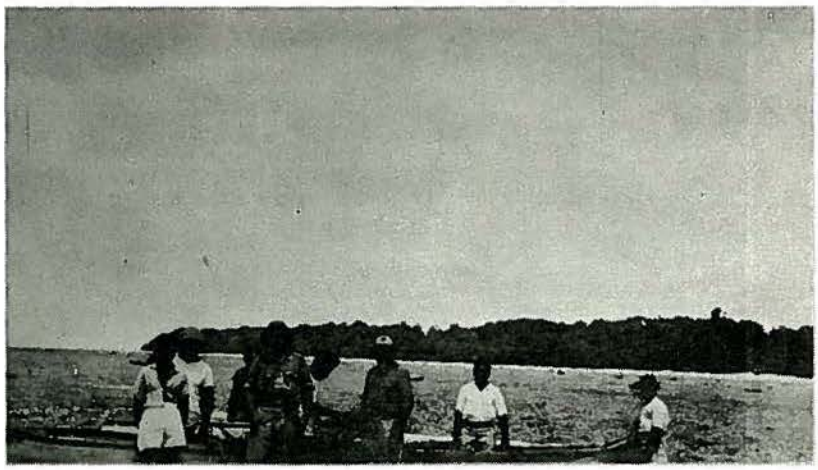
Village on the SW side of Sonsoral.


21
28PR 4MB47-1 21OCT44-1250GCT 24"-5000' SONSOROL REST. JICPOA 8385-2

28PR 4MB47-1 210CT44-1250GCT 24"-5000' SONSOROL REST. JICPOA 8385-2



Men on northeast coast of Sonsorol displaying early morning catch of tuna taken by trolling with plugs from sailing outrigger. 6/28/46
Note varied dress of men.



On dry reef at Sonsorol.
Natives preparing to carry outrigger out to edge of reef to make trip to ship. 6/26/46

VII. PHOSPHATE DEPOSITS ON TOBI (TOKOBEI OR LORD NORTH) ISLAND

A. REPORT

1. Geography

This island is only seven-eights of a mile long by five-eighths of a mile wide. It is at Lat. 3° 00' N. and Long. 131° 11' E. on Hydrographic Chart No. 5426. The Japanese give its position as 3° 2' N. Lat. and 131° 07' E. Long. The island is surrounded by a fringing coral reef which is widest at the northeastern end and is above sea level at low tide. There is no safe anchorage near the island.

Most of the natives live on its western and northwestern shores. Luxuriant vegetation covers the island. The elevation is perhaps at no place greater than 25 feet. Numerous shallow ponds, some of which are an acre or more in area, cover a considerable portion of its basin-like interior. Dike-like piles of earth, said to have been excavated by the natives, are a conspicuous part of the landscape near the ponds. Some of these dikes are as much as 10 feet high and are said to have been made by the natives in connection with the construction of irrigated paddy fields. Nothing other than small patches of lowland taro was observed growing in such places.

In 1945 there were 130 inhabitants, most of whom have forsaken the G-string and grass skirt for the garb of the "civilized" man. Gardening, fishing, and the raising of chickens make the natives nearly self-sufficient. Catholic missionaries have in the past Christianized the people, who speak no English, but are very friendly.

2. Phosphate Stock Piles

Near the shore on the west-central side of the island, about 100 yards from a pier, are several stock piles of phosphate ore. The largest of these piles is about 40 feet wide by 100 feet long by 10 feet thick. The piles seen contain roughly 7,000 tons, but it is possible that additional piles may exist in the wooded area some distance inland.

3. Loading Conditions

For the purpose of loading phosphate, the Japanese have built a pier, about 8 feet high at low tide, and 170 yards long,

on the southwest side of the island. A channel has been cut through the reef near the end of the pier so that lighters can come alongside. This pier is equipped with a double set of mine railway tracks for carrying ore in 1-ton cars from the stock piles to the lighters. Offshore about 200 yards just to the south of the pier are two concrete posts, on the top of which are mounted iron bollards which evidently were used for handling lighters. On the south side of the pier is a two-track marine railway which was used for launching lighters. A 60 foot schooner, her white paint still showing, lies on her side on the nearby reef. The plank deck and the rails on the pier need some repairs, but were still in fair shape when the writer visited the island on June 26, 1946.

The leading capacity in normal weather is said to be 400 to 500 tons a day. Any loading operations contemplated should be planned for the first half of the year when good weather usually prevails.

4. Past Production and Ore Reserves

Although phosphate was discovered on Tobi in 1918, construction on the island did not start until 1936 and the first ore was shipped in 1937.

The ore body was originally estimated to contain roughly 100,000 tons. It covered about 65 acres and its thickness was reported to be a scant meter. The tonnage remaining in the ground could not be ascertained by the writer.

The annual production of the islands is shown below and totals 25,643 tons.

1937	1938	1939	1940	1941	1942	1943	1944
1,407	2,810	4,426	3,000	11,000	3,000	-	-

A drying plant does not exist on the island, the ore having had its moisture reduced by storing it on raised platforms.

The ore is a dark brown earthy and sandy material, said to range between 15% and 37% P_2O_5, with combined Fe_2O_3 and Al_2O_3 amounting to about 0.85%.

Because of the remote situation of this island and the poor drying and loading situation, it appears inadvisable for anyone to consider the mining of any remaining ore reserves.

5. Conclusion and Recommendation

It is recommended that the Japanese be permitted to remove the existing stock piles on this island to augment their short supplies. This operation could well be combined with removal of the stock piles on Sonsorol. The Japanese engineers who worked on the island were reported to be in Indo-China at the time the writer was in Tokyo, but it may be possible to find someone there who has additional information on the grade and tonnage of the phosphate stock piles, which have been reported to contain as much as 50,000 tons. The writer could not confirm this estimate and surmises that the dikes of earth piled up by the natives may have confused the estimator.

VIII. NOTES ON SOME WESTERN CAROLINE ISLANDS (FAIS, SONSOROL AND TOBI)

A. GENERAL STATEMENT

The following notes and observations represent by-product information collected by the writer in June 1946 incidental to visiting the islands for the purpose of measuring the stockpiles of phosphate thereon. The voyage was made in the U.S.P.C. 1145 with Lieut. (j.g.) Alva Hall, Captain of the ship, Chester, *phosphate mining engineer, and J. Bridge and A. Piper, federal geologists employed on the Economic Survey. Messrs. Bridge and Piper visited only Fais.

B. FAIS (TROMELIN) ISLAND

1. Geography

This island is at Lat. 9° 46' N. and Long. 140° 31' E. and is shown on Hydrographic Office Chart 5426. It is a raised coral island one and one-half miles long by three-fifths of a mile wide and is thickly covered by coconut palms over its outer part, but most of the trees in the interior have been destroyed by phosphate mining operations. The northeastern and southwestern parts of its coast are steep, and the greater part of the island is fringed by coral reefs. The surface of the island is a level plateau ranging in height between 40 and 60 feet. There is no safe anchorage near the island. Small boats can be landed at a point 800 feet west of the prominent phosphate loading pier, situated centrally on the northwest coast, where there is a concrete dock on the west side of a cut through the reef containing a marine dock on the west side of a cut through the reef containing a marine railway. Usually the natives sight approaching vessels and paddle out to them in their outrigger canoes if given the opportunity. Their village is on the south side of the island about half a mile east of its most westerly point. Although the sea generally breaks on the outer edges of the reefs, small boats can reach either the north or south shores at high tide. It is generally safer and more convenient to go ashore with the natives in their outrigger canoes than to make a landing with the usual type of boat and crew available on small vessels.

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* Consulting Engineer employed by Bureau of Yards and Docks.

2. The Native Population

Galmar, the native chief, will be found in one of the first canoes approaching a visiting ship. He is the only native who speaks much English. His name is tatooed on his forearm and his curly black hair is turning grey. Galmar has fine features and a dignified and pleasant bearing, although he will be clad in only a g-string, as all men of Fais. The women wear only a grass skirt and go bare from the waist up. A wooden comb having a double prong pointing forward, which is similar to the ornaments on the bows on their canoes, adorns the heads of the men. Some also wear a few feathers attached to the comb, which juts forward from their bushy hair. Both the men and the women are tatooed extensively over a large part of the body.

Galmar is the chief and he is suject to the king, whose name I did not learn. The king is a stout individual having features so similar to Galmar's that he looks as though they may be of near kin. Both of them appear to be about 45-50 years old, but unlike Galmar, the king has no grey hair.

When Galmar took me to the king's house and introduced me to him, the king shook my hand and then, still holding it, bowed low and touched his nose to it. He is a pleasant individual of quiet demeanor and smokes an American made pipe filled with Fais-grown tobacco. In reply to his question concerning the war, he seemed pleased and relieved to hear there would be "no more shoot." I had sent rice, cloth and cigarettes to him from the ship. He offered to pay for the merchandise and asked the price. When told that it was a present for which there was no charge, he thanked me kindly. Much of this conversation was conduted through Galmar as interpreter, who speaks more English.

I asked Galmar about handicraft and he said that on Mr. Snyder's last visit to the island, he told them to make no more. Upon our departure from the Chief's house, he presented Mr. Fulton and me each with a grass skirt neatly folded into a small bundle.

3. General Condition of the Natives

So far as the writer was able to observe, the natives appear to be getting along fairly well. Galmar stated the total population is about 300. I asked him how many were sick and he stated 10 were. I asked him if they were old people and

he siad no, they were all young. Through Galmar, the king, upon learning we were from Guam and were going to Yap, asked if we could take a sick man with us. He had previously indicated his disappointment upon learning we had no doctor with us. I asked if the man could walk. The king replied in the affirmative and sent for him. The sick man appeared to be about 35 years old and had numerous boils and a marked swelling below the jowls over the lymphatic glands. I told the king to send him out in a canoe and that if it was all right with the ship's captain, we would take him to the hospital at Yap, which we did.

One native was observed to have a protruding boil on the buttocks and several had skin diseases.

4. Gardening and Food

The extensive phosphate stock piles had been planted to tobacco, sweet potatoes and squash. Other areas are also being cultivated. The large stock piles had been divided into small rectangles by making continuous fences with sheets of corrugated iron, which had been bombed from the dry-ore storage building. The natives raise no corn. There are no bananas on the island. The native diet evidently consists chiefly of taro, sweet potatoes, papaya, breadfruit, squash, coconut and fish. I do not remember seeing any chickens, but upon drawing a picture of a pig, Galmar said they had 10 of them.

Corn, if introduced, could perhaps be grown successfully on the island, as could bananas, orangeds and limes. The natives should also be supplied with a few chickens. If the natives were taught to raise some corn to maturity, and to make bread from it, it would at least add to the variety of their diet. If a legume such as lima beans or black-eyed peas could be grown, a better balanced diet would result, but this is not important provided they can catch all the fish they want, which presently appears doubtful. No sailing canoes were seen at Fais. The natives on other islands who use sails and troll for fish appear to be much more successful in catching all the fish needed than are the natives who use only paddles. The coconut trees appear to be free of disease and thriving, and some copra could be gathered for export.

5. Native Requirements

I asked Galmar what his people needed most and a list of the things he asked for follows:

(1) Flints, preferably black, for striking fire with steel

(2) Matches, for lighting the few lamps they have.

(3) Axes.

(4) Fishing line, large and small.

(5) Red and black cloth, for g-strings for the men.

(6) Rice, sugar and meat.

(7) Medicine.

6. Recommended Supplies to be Furnished to the Natives

The natives can get along very well without being furnished rice, sugar or meat. Provided they can catch all the fish they want, none of the foregoing foods adds anything essential to their diet. Matches and small kerosene lamps and kerosene should be provided. A few medium-size long-handled axes, and adze and a few small hand axes would be a great help to the natives for building canoes and houses. Both large and small fishing line and hooks are essential to obtain the fish that play a most important part in the native diet. Red and Black cloth should be provided for g-strings for the men and boys. A few medical supplies should also be provided, such as the now commonly used and individually packed, small sterile adhesive bandages for covering small wounds. Sterile roller bandage in a variety of sizes, and a safe lotion or ointment for treating skin diseases, should also be provided.

Cheap, large-size knives, for gathering and cutting open coconuts are also needed by the natives. An old fashioned hand-cranked circular grinding stone for sharpening axes, knives, etc., would make a great present to the community.

It is to be remembered that most of the foregoing articles were previously provided by the Japanese, who maintained a mining establishment on the island and employed the natives. The actual cost of providing such materials is negligible when compared with the value of the good will of the natives and the cost of sailing a ship on an inspection trip to the island.

C. SONSOROL (ST. ANDREW) ISLANDS

1. Geography and Vegetation

This group consists of two small islands at Lat. 5° 20' N. and Long. 132° 13' E., as shown on Hydrographic Chart No. 5426. The larger island is one mile long and half a mile wide. Fana (Panna) Island is only a mile north of Sonsorol, but was not visited. It is nearly circular and is only a half a mile across. Both islands are fringed with coral reefs but there is a deep channel 1200 yards wide between them that is safe to navigate. The highest point on the island is perhaps less than 25 feet above high tide. A pier was built by the Japanese from shore to the outer edge of the reef, a distance of about 400 feet, on the west central side of the island, but it has been completely destroyed. Only a few scattered concrete piles are still standing. The concrete piles once supported a deck on which tracks had been laid for pushing ore cars to lighters. These carried phosphate ore to ships anchored to a buoy offshore. Likewise the anchor buoy is gone, but several tons of anchor chain are piled on shore. Stock piles opposite the location of the old pier contain 35,000 tons of phosphate ore.

Tall trees cover the entire island with the exception of a few small ponds in the interior where the Japanese excavated phosphate from below water level. Quite a variety of trees grow on the island. Perhaps due to the richness of the soil, all trees and other plants appeared to be very large for their species. The island contains a great many coconut palm trees, all of which contain markings in black paint. The Japanese are said to have employed the natives for gathering copra and drying fish, as well as for mining phosphate. No diseased coconut trees were noted.

In addition to coconut palms, many wild papaya, breadfruit, and pandanus were noted. Huge taro plants are growing in the ponds and depressions where phosphate has been mined. Neither corn nor bananas were seen growing on the island.

2. The Native Population

No one on the island speaks more than a few words of English. Only Sonsorol was visited, but Fana is also inhabited and the natives make frequent trips across the channel in their outrigger sailing canoes. The two islands have a total population of 160.

The natives all profess to be Catholics and many of them wear medals and crucifixes. Mother Hubbard dresses and woolen sweaters are worn by the women. Most of the men and boys were wearing pants, shorts, shirts, caps, etc., many of which were from the U. S. Marines and the Japanese army. The natives seen were all pleasant people having straight black hair, nice features and a clear brown skin.

3. Native Foods

All appeared to be very well nourished and energetic. Many of the women were pregnant and healthy looking children were numerous. Four sailing canoes were seen at 8 a.m. and each contained at least six tuna, some of which weighed between 20 and 30 pounds. These fish were taken by trolling with lines and artificial lures. The ability of the natives to catch all the fish they want may account for their healthy appearance. Quite a number of chickens, but no hogs, were seen. On shore I saw a woman with a sea turtle about 18 inches long.

Although the natives were avid for tobacco, I saw none growing. Although squash was seen growing, no sweet potatoes were noted, but they very likely are being raised on the island. There are no banana trees on the island, but they would no doubt do very well there.

4. Native Needs

The natives stated they would like to have clothing for both men and women, including shoes. They also want fish hooks and line, cigarettes, and the old fashioned stick tobacco carried by traders, axes, knives, matches and medicine.

5. Recommended Trade Goods

What was recommended for Fais applies in large part here also. Instead of sending ready-made women's dresses, it would be better to send bright colored cloth, thread, buttons, shears, etc., so that they can make their own garments. A few cheap cotton slip-on sweaters might be included. Almost any type of inexpensive cotton clothing would be suitable for the men.

The natives could pay for such articles with copra, sea shells and handicraft made from shells. A half-dozen sponges, which appeared to be of good quality, were offered to me for a package of cigarettes, but I have no idea whether or not they are numerous enough in the area to form the basis

of a small industry. Likewise, there are sea turtles present, the shells from which may have possibilities for making combs and other handicraft.

D. TOBI (TOKOBEI OR LORD NORTH) ISLAND

1. Geography and Vegetation

This island is only seven-eighths of a mile long by five-eighths of a mile wide. It is at Lat. 3° 00' N. and Long. 131° 11' E. On Hydrographic Chart No. 5426. The Japanese give its position as 3° 2' N. Lat. and 131° 07' E. Long. The island is sourrounded by a fringing coral reef which is widest at the northeastern end. There is no safe anchorage near the island.

Most of the natives live on the western and northwestern shores of the island. Like Sonsorol, most of the island is covered with tall trees and luxuriant vegetation. There are many coconut palms some of which are the tallest seen anywhere by the writer. The vegetation is very similar to that found on Sonsorol, and as there, no bananas or corn were seen on Tobi. Although there are enough coconut palms on the island to serve native needs, they are not numerous enough, at present, to form the basis of a worthwhile copra industry. There are no wells on the island and large numbers of nuts are no doubt harvested before maturity for the drinking water they contain.

The Japanese have mined phosphate in the central portion of the island. Considerable mining apparently was done below water level and there are now numerous shallow ponds, some of which are an acre or more in area. In some of the low areas taro grows luxuriantly. Like Sonsorol, the highest point on the island is not over 25 feet above high tide.

For the purpose of loading ships with phosphate, the Japanese built a pier, about eight feet high at low tide, and about 150 feet long, near the southwest end of the island, in the only channel through the fringing reef. This pier is equipped with a double set of mine railway tracks for carrying ore from the stockpiles to lighters. Offshore about 175 yards just to the south of the pier, there are two concrete posts on the top of which are mounted iron bollards which evidently were used for handling lighters. On the south side of the pier is a two-track marine railway which evidently was used for hauling lighters ashore when not in use. A 60-foot schooner lies on her side on the nearby reef.

On shore about 100 yards from the pier are several stock piles of phosphate ore. The larger of the piles is about 40 feet by 100 feet by 10 feet thick and together they contain between 5,000 and 10,000 tons of ore in the aggregate. Sweet potatoes have been planted by the natives in the piles of ore.

2. The Native Population

None of the natives speaks more than a few words of English and they are unable to understand or answer any questions in our language. Two men who stated they had come from Peleliu knew only a few English words.

When presented to them the natives will accept cigarettes, but only a few of the men smoked. Like the people on Sonsorol, most of the natives have been Christianized by Catholic missionaries and many still wear medals and crucifixes. The women wear Mother Hubbard dresses and most of the men and boys some cloth garments other than g-strings.

When asked how many people there were on the island, one of the more intelligent natives stated there were 60, but he probably thought the number of men was wanted. About 40 men and boys formed the cavalcade which followed our party about the island, so it seems reasonable to assume that there must be about 160 inhabitants.* The people were very friendly and appear to be well nourished. Many chickens, but no hogs, were seen.

A few of the natives have "fuzzy hair" indicating they may be of Melanesian stock. Several of the natives have gold teeth which probably date from the time when the Japanese worked phosphate on the island.

3. Needs of the Natives

Because of language difficulties it was impossible to converse with the natives, as previously explained. However, the needs of the natives on Tobi would appear to be similar to those mentioned for Sonsorol, with the exception that the natives of Tobi are not avid for tobacco. Like the people of Sonsorol, the natives of Tobi fish offshore in sailing canoes and they would no doubt appreciate any fishing tackle furnished them. They have the same need for clothing

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(*Population, Nov. 1945, 130.--Ed.)

and hardware as the natives of Sonsorol. These people should be taught to make desirable types of handicraft which they can exchange for the articles they are used to receiving and therefore need.

It is to be remembered that the prime purpose of the visits to the foregoing islands was for the purpose of measuring the stock piles of phosphate ore thereon. Less than a day was spent on each of the islands and the foregoing notes therefore represent only cursory observations made over a very short period of time.

Ponds in central part of Tobi Island, said to be made by natives for paddy rice fields.

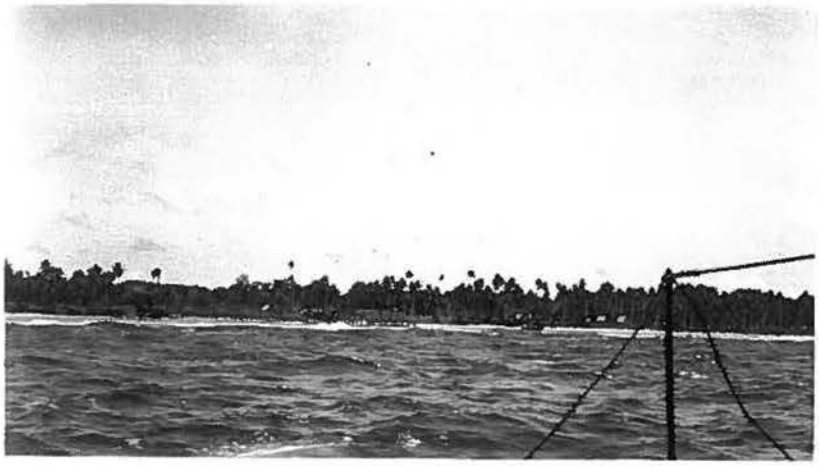
Natives of Tobi in shade on SE coast of Island. Note log and luxurient Pandanus trees.

Village near beach on the SW side of Tobi.

Natives in village on W. central side of Tobi. With Mr.C. Fulton phosphate engr. near right side of picture. 26 June 1946.

Top -
Ponds on central part of
Tobi Island.

Left -
Hummocky topography on Tobi.
Note varied dress of the natives
cavalcade following the party.
26 June 1946.



Phosphate loading pier
and bollards at edge of
reef on Tobi.

The mounds in center
are stock piles of phos-
phate overgrown by yams
vines.
26 June 1946.

Phosphate stock piles on W. Central coast of Tobi. The piles have been planted to yams. The parallel lines on the ground are the sills for drying racks. There was no drying furnace on Tobi.

Double tracked phosphate loading pier at Tobi. Note bollards set near edge of reef and marine railway and lighters to left of pier, on W. central side of island.

Phosphate loading pier at Tobi, PI. The dark spot in the center is a wrecked schooner. 26 June 1946.

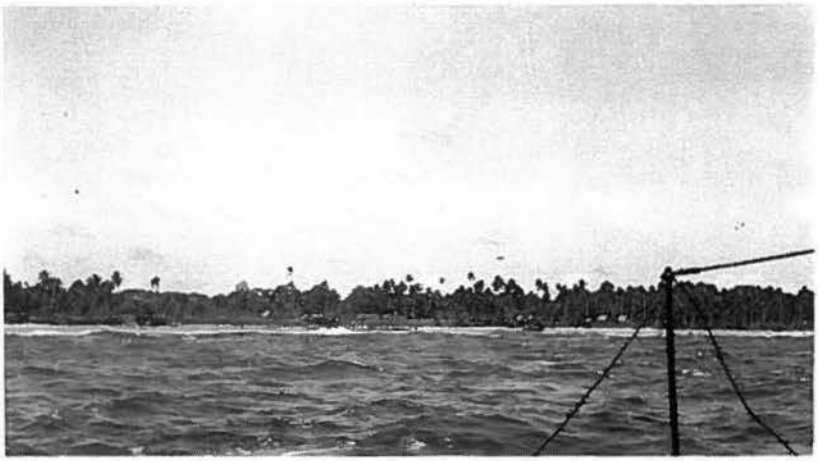
Ponds in central part of Tobi Island, said to be made by natives for paddy fields.

Hummocky topography on Tobi.

Note varied dress of the native cavalcade following the party.

Ponds on central part of Tobi Island.

Tobi. The mounds in center are stock piles of phosphate overgrown by yam vines.



Phosphate loading pier and bollards at edge of reef on Tobi.