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DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES
GEOLOGY AND GEOPHYSICS.

RECORDS.

1959/47

THE PHOSPHATE DEPOSITS OF BELLONA ISLAND

by

W.C. White & O.N. Warin

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SUMMARY

Bellona Island, British Solomon Islands, was visited by a survey team of the Bureau of Mineral Resources, as part of the search for phosphate deposits. The island is a raised coral atoll and has a phosphate deposit mostly of phosphatic clay, overlying and infilling between limestone pinnacles and in chimneys on the old lagoon floor. It is estimated that 4,500,000 tons of the clay with an average grade of 22.2% P_2O_5 and 700,000 tons of phosphatic sand averaging 30.3% P_2O_5 are recoverable. The bulk of material is rich in iron and alumina and its value as an economic deposit is doubtful.

INTRODUCTION

The investigation of the phosphate deposits of Bellona Island was undertaken by the Bureau of Mineral Resources under a Prospecting Licence issued by the Administration of the British Solomon Islands Protectorate. The investigation was part of the first six months field work of the Bureau's programme of search for phosphate deposits on islands in the Western Pacific.

The Bureau's Phosphate Survey party of two geologists - O. N. Warin and A. R. Jensen - and two field assistants, worked on the island for one month during April and May 1958. W. C. White, Supervising Geologist, was with the party for a week at the beginning of this period.

Bellona Island is situated ninety miles south of Guadalcanal, at a position 159°50'E, 17°15'S. It is one of the smallest islands in the British Solomon Islands Protectorate, being six miles long and two miles wide, elongated in the direction east-south-east. The nearest island is Rennell, twenty miles to the east-south-east.

Bellona is surrounded by a fringing reef which is in few places more than fifty yards wide. The island is steeply shelving and there are no good anchorages but small vessels can hang on at the edge of the reef in One Bay and at Ahenga and Angau (Plate No. 1) in favourable weather conditions. The best time of year to visit the island is during the lull between the end of the north-west season and the beginning of the south-east season. This lull usually occurs during April and May. Landing at other times of the year is possible but may be difficult. Landing is by surf boat on to the beach or the edge of the reef, depending on the state of the tide.

The island is inhabited by about 300 people of Polynesian descent. Their villages are spaced out along a wide central track which runs the length of the island and which gives good access to the low lying central area. Fairly dense forest covers some parts of the island, particularly around the rim, but large areas in the centre have been cleared and cultivated. No rainfall figures are available. The climate appears to be relatively dry and non-seasonal.

Fresh water is very scarce on the island. Several small springs of rather brackish water occur just above sea level at the foot of the outer rim, e.g. Angau., but for the most part the inhabitants collect rainwater. Two auger holes drilled during the survey intersected wet clay and might provide a small supply of relatively good water if deepened into the underlying limestone.

PREVIOUS INVESTIGATIONS

Bellona Island was apparently discovered by Captain Butler of the "Walpole" in 1801. Although the neighbouring island of Rennell was investigated by Stanley in 1927 (Stanley, 1929) and traces of phosphate noted, Bellona does not appear to have been investigated until 1956 when both Rennell and Bellona were visited by Grover (Grover, 1956, 1957, 1958). On Bellona nodular to crustified and mammilary phosphate rock containing up to 73.3% tricalcium phosphate was found in veins and cavities in the limestone cliffs near Ahenga at the north-west end of the island, and a clayey material from a pit near Ngotokanava village was found to contain up to 50% tricalcium phosphate.

A second visit was made by Grover later in the same year when over 30 pits were sunk to depths up to 28 feet. Subsequently a more extensive programme of pitting was carried out (unpublished report) which showed that a large tonnage of phosphatic material existed and that, although the bulk of the material was highly aluminous, high-grade phosphate rock and incoherent phosphate occurred at the base of the deposit, the full extent of which was unknown.

PHYSIOGRAPHY AND GENERAL GEOLOGY

Bellona Island is an elevated coral atoll raised to approximately 250 ft. above sea level. It is elongated in an east-south-east direction and consists of a relatively narrow, flat central depression surrounded by a wide, double rim of limestone. The outer rim is approximately 135 ft. above sea level, the higher inner rim 260 ft. above sea level. The outer rim is almost continuous and is generally extremely steep on the seaward side, with a prominent wave-cut notch at about 100 ft. above sea level marking an early stage of emergence. A more recent emergence is represented by a narrow terrace at 10 ft. above sea level, outside which is narrow, shallow lagoon and a low fringing reef.

From the inner, higher rim, which is deeply notched in several places, notably near Tinggoa and at Angau, the rough, deeply etched limestone drops steeply to the flat soil covered floor of the central depression, which rises gently from about 50 ft. above sea level near Ngotokanava village to over 100 ft. above sea level, towards the north-west and higher still towards the south-east ends of the island.

There are no drainage channels on the island and no run-off was noted during infrequent heavy storms. A few small sink holes were found in the limestone on the inner slopes of the rim but little evidence exists at the surface of any major sink holes in the central depression although drilling in the phosphate deposits, which blanket much of the central area, suggests that the phosphate commonly fills large collapse structures in the limestone.

Although evidence of erosion by solution is present on the inner slopes of the rim it does not appear to be strong enough to suggest that the entire central depression was formed in this way. It seems more likely that the central depression represents a former atoll lagoon, which may have been deepened by solution erosion, after emergence.

The island has a slight but distinct tilt towards the north-west which, as pointed out by Grover (1958) contrasts strongly with the marked south-easterly tilt of nearby Rennell Island. On Bellona the tilting is most noticeable in the central valley and on the inner rim. It is less apparent on the 100 ft. wave cut notch and is absent on the 10 ft. terrace which suggests that it took place at an early stage of the islands emergence. The tilting of Bellona and Rennell in opposite directions, together with the differential emergence of the two islands (Grover, 1958) indicates that emergence was mainly due to tectonic uplift rather than to a general lowering of sea level. The tilting, as will be shown later, may have an important bearing on the distribution of the phosphate deposits on Bellona.

PALAEONTOLOGY

Microfossils from limestone samples collected by Grover indicate an age not older than Pleistocene (Crespin, 1956A, 1956B). The forms identified include *Lithothamnium*, *Halimeda* sp., *Operculinella venosa*, *Orbulina universa*, *Globigerina* sp., and some indeterminate corals and bryozoa.

SAMPLING AND TESTING METHODS

The phosphate deposits were tested by a programme of drilling and sampling designed to cover the entire soil-covered area of the central depression. Hand operated augers were found most suitable for this purpose. Holes were drilled every 300 ft. on lines 600 ft. apart at right angles to the main access track along the island.

The total footage drilled was approximately 1900 ft., the deepest hole being 36 ft. Samples were taken at 2 ft. intervals in the holes and all holes were continued until they bottomed in limestone. A representative number of samples were analysed for phosphate in the field by a rapid method involving the precipitation of the ammonium phosphomolybdate and measurement of the volume of precipitate after centrifuging. Though not accurate, the method was found to give a good indication of the grade of material being tested.

THE PHOSPHATE DEPOSITS

The phosphate deposits occupy a large part of the central depression, covering an area of approximately 340 acres. They occur as blanket-like deposits overlying a highly irregular limestone surface and filling chimneys, crevices, and possibly large sink holes in the limestone. The individual deposits, A to F on Plate 2, are separated from each other by wide outcrops of coralline limestone containing steep sided, narrow chimneys and pockets filled with phosphatic material. There is every reason to believe that the deposits were once continuous over the entire central depression but that solution of the underlying limestone and leaching and compaction of the phosphatic material has resulted in lowering of the surface of the deposit to the stage where the phosphate remains only in the deeper parts of the basin.

The floor of the deposit shows considerable relief which makes the estimation of tonnages difficult. Several of the pits sunk by Grover (1956 and unpublished reports) entered deep chimneys in the limestone, some of them 10 or 11 feet deep and only 2 to 3 feet wide, and many of the auger holes drilled in the present survey may have done the same, giving a false impression of the thickness of the deposit. Indeed several auger holes are known to have bottomed in narrow chimneys and all isolated deep holes must therefore to treated with susp[illegible]cion.

The limestone outcropping around the deposits also contains many phosphate filled chimneys and cavities. A few of these were found by drilling and pitting to be up to 8 or 10 feet deep, but the great majority were only one or two feet deep. In addition, the limestone outcrops are fairly flat; it is only on the top of the rim that anything approaching the typical karrenveld pinnacle fields is seen, and it seems reasonable to conclude that the floor of the phosphate deposits is similar. The limestone underlying the deposit is undoubtedly extensively solution etched, but most of the cavities are probably shallow and the irregularities fairly broad although apparently still steep sided. Many of the deeper parts of the deposits may represent infilled (with phosphate) sink holes.

The phosphatic material of the deposits is of three distinct types. Coherent phosphate rock* is found, irregularly, at the base of the deposits and represents replacement of the limestone by phosphate. It occurs as a thin layer, nowhere more than about 2 ft. thick, on top of the fresh limestone, but is not everywhere present; it is most common towards the south-east end of the island.

Incoherent or oolitic phosphate is found in chimneys and crevices in the limestone at the north-west end of the island and as a blanket-like deposit in the vicinity of Matangi village (deposits E and F). It is not found to any great extent in the other deposits.

By far the greatest tonnage of phosphate occurs in the form of a stiff, yellow-brown phosphatic clay, forming a thick blanket over the limestone and the coherent and incoherent phosphate. It is very uniform in appearance throughout the deposits although the top six to twelve inches is usually darker coloured due to humus. In a few places in deposits D and E the clay became slightly gritty and oolitic towards its base and appeared almost to grade into the underlying oolitic phosphate.

Traces of amorphous tricalcium phosphate (nauruite) were found in thin veins and as nodules in the sea cliffs near Ahenga and Angau.

THE PHOSPHATIC MATERIAL

The phosphatic clay which makes up the bulk of the deposits is a damp, tenuous material, yellow-brown in colour and generally even-textured. It averages 22.2% P_2O_5 (360 determinations) and is high in iron and alumina. Average content of Fe_2O_3 is 10 to 12%, and Al_2O_3 is commonly over 30%, reaching 39.6% in one case (A36/2-4 ft.). The ratio of Fe_2O_3 to Al_2O_3 is fairly constant, and this, together with the constantly low CaO/P_2O_5 ratio, low CO_2 and high loss on ignition,

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* Under the term "phosphate rock" is included friable or crumbly, even-textured, buff coloured phosphate as well as the more normal hard phosphate rock.

suggests that much of the phosphate may be present as the hydrated iron and aluminium or iron-alumino phosphate, which would also account for the low fluorine content (see Table 1). Optical and X-ray determinations confirmed the presence of the minerals collophane (tricalcium phosphate) and crandallite (calcium aluminium phosphate) but no iron-bearing minerals were identified.

The coherent phosphate is typically a fairly soft, pale cream to off-white, rather cavernous rock. It commonly contains up to 39% P_2O_5 (average of 23 determinations = 33.8%) with less than 2% of Fe_2O_3+Al_2O_3 (one analysis), is high in fluorine and has a high CaO/P_2O_5 ratio with a very low CO_2 content, indicating that it consists almost entirely of tricalcium phosphate. This is confirmed by optical and X-ray examination in which only collophane and a small amount of calcite were found.

The oolitic phosphate of deposits E and F contains 29.2% P_2O_5 (average of 70 determinations) with some samples containing as much as 39% P_2O_5. Fe_2O_3 is relatively low at 2.9% (average of 5 determinations) but Al_2O_3 is very variable, ranging from 1% to 15.3% with an average of 9.6% (5 determinations). The fluorine content lies between that of the clay and that of the phosphate rock. The CaO/P_2O_5 ratio is relatively high and CO_2 is low, and loss on ignition is fairly high, suggesting that the material may be composed of tricalcium phosphate with some hydrated iron and aluminium phosphates, although only collophane was determined by X-ray work.

Under the microscope the oolities were shown to be fairly small and very uniform in size, with a well-defined oolitic structure marked by concentric iron-rich rings. In no case could any nuclei to the oolites be detected.

No analyses or other determinations have yet been made on the underlying limestones, but a partial analysis was carried out on a water-saturated white clay found below the phosphatic clay and coherent phosphate rock at a depth of 15 ft. in hole A46/1. The analysis is shown in Table 1. The high magnesia (13.1%) and lime (37.9%) and low phosphate (15.8%) suggest that the clay may be composed of a calcium-magnesium phospho-carbonate and probably represents replacement by phosphate of a dolomitic marl.

THE INDIVIDUAL PHOSPHATE DEPOSITS

Deposit "A" near the village of Ngotokanava covers an area of 60 acres. The deepest hole drilled went to 26 feet in phosphatic material and several others were more than 20 feet deep. On the other hand several holes drilled in the centre of the deposit entered limestone at 4 to 6 ft. depth, showing that the bottom of the deposit is very irregular. The true maximum depth of the deposit, allowing for test holes which may have bottomed in chimneys or crevices, is probably about 20 ft.

The material in this deposit is almost entirely the phosphatic clay which generally rests directly on the limestone with very little replacement of the limestone by phosphates. A very thin layer of phosphate rock and traces of oolitic phosphate were seen in a few of the deeper test holes (A1/4, A4, A9), but mostly the contact between clay and limestone is sharp, though irregular.

To the north-west of Deposit "A", along the main track to Ahenga many shallow pockets in the limestone are filled with a crumbly, rather clayey, brownish coloured oolitic phosphate containing 30-34% P_2O_5 and about 10% $(FeAl)_2O_3$ (Grover, 1956).

Deposit "B", near Kapata village, consists of two small, shallow basins filled with phosphatic clay, and several small clay filled pockets in the adjoining limestone, with a total area of 33 acres. South of the main track the clay reaches a depth of 26 ft., but again the base of the deposit is highly irregular and it is known, from the earlier pits, that chimneys 9 or 10 feet deep occur under the deposit. The clay is again very uniform and rests directly on the limestone with no sign of phosphatization of the latter.

Fairly large pockets of clay to the north and west of Kapata village appear to be infilling an old sink hole. Between Deposits "A" and "B" and between "B" and "C" many shallow solution hollows and deeper chimneys (up to 10 to 12 ft.) in the limestone are filled with phosphatic clay with no trace of oolitic phosphate or phosphatized limestone.

Deposit "C" is a shallow, irregularly shaped body composed mainly of the phosphatic clay, and approximately 37 acres in extent. Few of the test holes went beyond 6 feet in phosphate except at the north end of the deposit where four adjoining holes were drilled to a depth of more than 20 feet. Two of these were located close to the margin of the deposit and it is believed that this portion of the deposit occurs in a broad steep-sided sink hole or solution hollow more than 20 feet deep.

In the deeper parts of this deposit the clay rests directly on white limestone, but elsewhere there is a thin layer, from a few inches to two feet thick, of phosphate rock between the two. This tends to support the view that the deep portion represents an old sink hole where the phosphate solutions would have been carried away before they could replace the limestone.

Deposit "D", with an area of 106 acres, is the largest single deposit on the island. It is uniformly thicker than any of the other deposits and, except on the extreme edge of the deposit is nowhere less than 8 feet thick, with several deep areas extending down to more than 20 feet. It is steep sided, commonly going down to 20 feet or more within a few feet of the margin, and the drilling results together with the sections exposed in Grover's pits suggest that the bottom, though irregular and uneven, is not deeply pocketed. The test holes therefore indicate the true depth of the deposit in most cases.

The bulk of the phosphate again occurs as the phosphatic clay, but most of this clay deposit is underlain by 2 to 3 feet of coherent phosphate rock. In one or two holes more than 4 feet of phosphate rock was recorded but this may be the result of intersecting this horizon at an acute angle on the undulating floor of the deposit. In general the layer of phosphate rock is thinnest, or is absent, in the deepest parts of the deposit.

The junction between clay and phosphate rock appears generally to be sharp and well defined, but in a few instances the phosphatic clay becomes slightly gritty and oolitic near the base and contained scattered small fragments of phosphate rock.

At one place, near hole A46/1 the phosphate rock is underlain by the water-saturated white clay referred to previously.

Deposits "E" and "F", between Gonggau and Matangi villages, are continuous is outcrop and together cover an area of approximately 100 acres. Deposit "F" consists entirely of incoherent or oolitic phosphate and is in part overlain by the phosphatic clay of Deposit "E".

Deposit "E" occupies two well defined, deep, steep sided basins, both of them over 15 feet deep. The larger western basin was tested to a depth of 34 feet in phosphatic clay. It is roughly conical in shape, but slightly elongated in a north-south direction and the clay rests directly on apparently solid, i.e. uncreviced, limestone. In the eastern portion of this deposit the clay reaches a maximum depth of 16 feet and is underlain by up to 12 feet of buff-coloured coherent phosphate rock and oolitic phosphate, which is here included in Deposit "F".

Deposit "F" occupies an extension to the east of the eastern basin of Deposit "E" by which it is in part overlain. It is up to 18 ft. thick and consists entirely of phosphate rock and oolitic phosphate. The former is predominant where the deposit is overlain by the clay of deposit "E", and the oolitic phosphate is predominant in the eastern, outcropping portion. To the east of this area scattered chimneys and other solution hollows in the limestone are filled with the oolitic phosphate. Where the phosphatic clay overlies the oolitic phosphate the one clearly grades into the other.

ECONOMIC CONSIDERATIONS

The tonnage of phosphatic material available in the Bellona deposits has been calculated from the thickness contours or isopachous lines shown on Plate 3. In constructing these contour lines the probably etched and pitted nature of the underlying limestone surface has been taken into account and isolated deep test holes have been ignored. Where three or more deep holes occur together it is assumed that they have all penetrated the same broad depression rather than that each has bottomed in a separate narrow chimney or crevice. Nevertheless it is probable that the bottom of the deposits may be rather more irregular than is indicated by the drilling and pitting, and that small limestone pinnacles may project up into the lower part of the deposits.

The calculated tonnages must therefore be cut by a substantial factorto approximate the available tonnage. A cut of 50% has been used in the case of the phosphate rock and oolitic phosphate at the base of the deposits, and 25% in the case of the thicker phosphatic clay.

The calculated tonnages and average grades are as follows:

1. Phosphatic clay: on basis of approx. 15 cu. ft. = 1 ton.

Deposit	Surface area in sq. ft.	Calculated volume in cu. feet.	Tonnage
A	2,632,000	20,964,000	1,400,000 tons
B	1,446,000	10,336,000	690,000 "
C	1,637,000	10,710,000	714,000 "
D	4,656,000	30,150,000	2,010,000 "
E	2,819,000	20,138,000	1,342,000 "
TOTAL	13,190,000	92,298,000	6,156,000 tons

Calculated tonnage = 6,156,000 tons
Less 25% cut = 4,600,000 tons

Average grade (of 360) = 22.3% P_2O_5.

2. Phosphate rock and oolitic phosphate: Approx. 20 cu. ft. = 1 ton.

Deposit	Area in sq. ft.	Calculated volume in cu. ft.	Tonnage
D and F	5,500,000	28,740,000	1,400,000 tons

Calculated tonnage = 1,400,000 tons
Less 50% cut = 700,000 tons

Average grade (of 93) = 30.3% P_2O_5

The total of both types of material is equivalent to 5.3 million tons of 23.3% P_2O_5.

The low grade of the deposits compared to Ocean Island and Nauru deposits, together with the high iron and alumina of much of the material probably rule it out as a source of phosphate for manufacturing superphosphate. It is possible, however, that under suitable conditions the material could be used for direct applicationtto the ground. Similar phosphate from former Japanese mandated islands has been used in the past (Yoneyama, 1923, non vide).

Exploitation of the material should not be difficult. Access to the deposits from the anchorage at Ahenga is relatively easy and, although the anchorage is poor, it is reasonably sheltered during the season of south-easterly winds. Timber is plentiful on the island and the shortage of water could be overcome by construction of storage tanks. Underground water is probably not very plentiful and is likely to be of poor quality.

THE FORMATION OF THE PHOSPHATE DEPOSITS

The phosphate deposits on Bellona are undoubtedly derived from guano deposited by breeding sea birds possibly in late Pleistocene or early Recent times. The phosphate rock at the base of the deposit has been formed by replacement of the limestone by solutions leached out from the guano to form tricalcium phosphate. The origin of the oolitic phosphate and phosphatic clay is however, more problematical and no clear explanation of this type of deposit seems to have been forward.

In describing the very similar deposits on Angaur in the Caroline Islands, Rogers (1948) suggested that the oolites were concretionary and formed in the clay, while Irvine (1953) held the view that the oolites, formed by replacement of limestone oolites, were washed into the lagoon and decomposed to form the phosphatic clay. Neither author seems to have put forward a great deal of evidence in support of his ideas.

From observations made on Bellona and from subsequent laboratory work, as yet incom,lete, the following geological history is suggested for these deposits.

The island was formerly, probably in the late Pleistocene, a low lying coral atoll elongated in the direction of the prevailing wind, i.e. east-south-east. Elevation and slight tilting to the north-west cut off thelagoon from the sea and confined it to the north-western end of the island. Drainage was along the axis of the island, from the higher south-east end into the rapidly dwindling lagoon. With the final disappearance of the lagoon due to evaporation and underground seepage, the drainage went underground and subsequently the main drainage axis was marked by a line of great solution hollows, sink holes and other collapse structures in the limestone.

At about this stage, or perhaps even earlier, the uplifted atoll was colonised by hordes of breeding sea-birds and a thick deposit of guano accumulated, mainly on the inner slopes of the rim of the island. Solutions leached from the guano attacked the limestone to form a mantle of tricalcium phosphate with a distinct concretionary or oolitic structure. (Specimens of coherent phosphate rock from Bellona and from Christmas Island all showed a distinct oolitic texture under the microscope). With subsequent weathering and erosion the oolitic rock was broken down and the oolites, together with "terra rossa" soils derived from the solution erosion of unaltered limestone, were gradually transported into the sink holes along the axis of the island and a thick blanket deposit of loose oolitic phosphate was formed on the old lagoon floor.

With the choking up of the sink holes by this relatively insoluble phosphate, conditions within the central depression became swampy and, due to the presence of humic acids, fairly acid. Decomposition of the oolites began with breakdown of the oolitic structure and leaching out of the tricalcium phosphate. Some of the phosphate was lost, through underground drainage, to the sea, some was reprecipitated in small fissures and cavities in the limestone (e.g. Angau and Ahenga) and much of it recombined with the iron and alumina of the "terra rossa" to form the more insoluble iron-alumino phosphates forming the phosphatic clay.

This process of decomposition of the oolitic phosphate, which is probably continuing even now, began at the surface where the humic acids were more abundant and proceeded downwards to the base of the deposit. Decomposition was more complete towards the lower north-west end of the island and, to a lesser extent over the deep sink holes where percolation of the acid waters was more rapid. Further away from the sink holes and particularly near the higher south-east portion of the island the oolitic phosphate remains.

ACKNOWLEDGMENTS

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TABLE I.

PARTIAL ANALYSIS OF PHOSPHATE SAMPLES FROM BELLONA ISLAND

Sample No.	Type of Material	P_2O_5	CaO	CO_2	Loss on Ignition	F	Fe_2O_3	Al_2O_3	TiO_2	CaO/P_2O_5	Remarks
A42-20'	Phosphate rock	39.1	52.7	0.40	1.82	4.67	0.55	1.1	n.d.	1.34	
A64/4-10'	Oolitic phosphate	31.4	32.5	0.66	11.1	2.04	4.57	14.5	0.24	1.03	
A64/4-14'	Oolitic phosphate	29.8	32.4	1.02	10.9	2.04	4.26	15.3	0.2	1.08	
A60/3-4'	Oolitic phosphate	35.9	45.6	0.84	6.67	3.46	1.52	3.2	n.d.	1.28	
A68-8'	Oolitic phosphate	31.3	34.3	0.77	11.9	1.83	3.85	13.9	0.1	1.09	
A57-20'	Phosphate rock	38.6	52.8	0.24	1.82	3.70	0.65	1.0	n.d.	1.36	
A16/2-6'	Phosphatic clay	25.1	10.4	0.13	17.1	0.31	10.5	31.8	0.60	0.41	
A16/2-22'	Phosphatic clay	24.6	10.3	0.13	18.1	0.10	10.1	33.1	0.45	0.42	
A24/5-8'	Phosphatic clay	26.4	10.9	0.12	16.7	0.41	9.41	30.3	0.55	0.41	
A36/1-5'	Phosphatic clay	30.4	39.8	1.91	7.82	2.42	2.96	7.8	0.10	1.30	Sample heated during field assay.
A36/2-4'	Phosphatic clay	19.8	7.86	0.07	17.4	0.21	11.2	39.6	0.50	0.39	
A44/3-8'	Phosphatic clay	24.6	10.6	0.10	17.2	0.36	10.4	34.8	0.5	0.43	
A6/3-6'	Phosphatic clay	24.2	10.3	0.06	17.1	0.31	8.91	33.5	0.45	0.42	
A46/1-15'	Saturated white clay.	15.8	37.9	14.75	12.2	1.91	0.6	1.8	n.d.	2.4	MgO = 13.1%

Loss on ignition (950°C) does not include CO_2.

All results refer to samples dried at 105°C.

Analyst: S. Baker.

TABLE 2.

PHOSPHATE DETERMINATIONS OF SAMPLES FROM BELLONA

1st column (a) - Depth of sample
2nd column (b) - Lithology of sample
- c - clay
- op - oolitic phosphate
- p - phosphate rock
- l - limestone

3rd column (c) - % P_2O_5 in oven dried sample.

Auger Hole B.22

(a)	(b)	(c)
2'	c	4
4'	c	8
6'	c	8
10'	c	21
12'	c	19
14'	c	7
16'	c	18

Auger Hole B.23

(a)	(b)	(c)
2'	c	7
4'	c	27
6'	c	25
10'	c	23
12'	c	27
16'	c	25
18'	c	21

Auger Hole A1/0

(a)	(b)	(c)
4'	c	17
8'	c	23
12'	c	24

Auger Hole A2/0

(a)	(b)	(c)
2'	c	25
4'	c	23
6'	c	13
8'	c	21
10'	p	33

Auger Hole A2/1

(a)	(b)	(c)
2'	c	18
4'	c	20
6'	c	15
10'	c	15
12'	c	6
14'	c+l	19
18'	c+l	23

Auger Hole A2/4

(a)	(b)	(c)
4'	c	10
8'	c	18
10'	c	26
18'	c	27
20'	c+op	21
2'	c	17

Auger Hole A3/0

(a)	(b)	(c)
4'	c	21
12'	c+p	19

Auger Hole A4/0

(a)	(b)	(c)
2'	c	20
4'	c	9

Auger Hole A4/2

(a)	(b)	(c)
2'	c	7
4'	c	20
6'	c	19
8'	c	24
10'	c	22
14'	c	37
16'	c	37
18'	c	8
20'	c	15
22'	c	28
26'	c+l	27

Auger Hole A5/0

(a)	(b)	(c)
2'	c	24
4'	c	20
6'	c	17
8'	c	17
12'	c	19
14'	c	22
16'	c	24
20'	l+p	27

Auger Hole A6/3

(a)	(b)	(c)
2'	c	21
4'	c	27
8'	c	25
12'	c	22
14'	c	22
6'	c	24

Auger Hole A8/0

(a)	(b)	(c)
2'	c	17
4'	c	23
6'	c	21
14'	l	6
15½'	l	0

Auger Hole A8/3

(a)	(b)	(c)
2'	c	20
4'	c	21
6'	c	29
12'	c	29
14'	op	27
18'	op+l	28

Auger Hole A8/4

(a)	(b)	(c)
2'	c	23
4'	c	21
6'	c	21
8'	c+l	25
12'	c	20
14'	c	17
20'	c+l	17

Auger Hole A9/0

(a)	(b)	(c)
2'	c	23
4'	c	22
6'	c	23
8'	c	20
10'	c	25
12'	c	24
14'	c+p	21
16'	c+p	23

Auger Hole A10/3

(a)	(b)	(c)
2'	c	28

Auger Hole A10/4

(a)	(b)	(c)
2'	c	22
4'	c	23
6'	c	14
10'	c	15
12'	c	12
14'	c	22
18'	c+l	21

Auger Hole A12/1

(a)	(b)	(c)
2'	c	22

Auger Hole A12/2

(a)	(b)	(c)
2'	c	8

Auger Hole A12/4

(a)	(b)	(c)
2'	c	24
4'	c	16
8'	c	22
10'	c	13
14'	c	24
16'	c+l	15

Auger Hole A12/5

(a)	(b)	(c)
2'	c	21
4'	c	22
6'	c	21
10'	c	18
12'	c	28
14'	c	20
18'	c	23
20'	c+l	5

Auger Hole A14/1

(a)	(b)	(c)
4'	c	23
8'	c+l	15

Auger Hole A14/2

(a)	(b)	(c)
4'	c	17

Auger Hole A16/1

(a)	(b)	(c)
2'	c	21
4'	c+l	23

Auger Hole A16/2

(a)	(b)	(c)
2'	c	15
4'	c+l	13
8'	c	12
10'	c	17
14'	c	26
16'	c	27
20'	c	26
26'	c+l	31
22'	c	22
6'	c	25

Auger Hole A16/8

(a)	(b)	(c)
2'	c	9
4'	c	10
6'	c	10
10'	c	10
12'	c	9
14'	c	10
18'	c	11
20'	c	10
22'	c	10
24'	c+l	11

Auger Hole A18/1

(a)	(b)	(c)
2'	c	12
8'	c	8
12'	c	33

Auger Hole A18/2

(a)	(b)	(c)
2'	c	20
4'	c	19
6'	c	20
8'	c	19
10'	c	18
15'	c+l	10
17'	c+l	17
18'	c	18
20'	c	19
22'	c	19
26'	c	15

Auger Hole A18/5

(a)	(b)	(c)
2'	c	34
4'	c	29
8'	c	29

Auger Hole A18/6

(a)	(b)	(c)
2'	c	26
4'	c	30
6'	c	22
10'	c	29
12'	c	30
14'	c	25
20'	c	25
21'	c+p	25
22'	c	23
24'	c	24
26'	c	21

Auger Hole A18/7

(a)	(b)	(c)
2'	c	26
4'	c	22
8'	c	23
10'	c+p	26

Auger Hole A18/8

(a)	(b)	(c)
2'	c	18
4'	c	16
8'	c	16
10'	c	24
14'	c	17

TABLE 2 (Cont'd.)

Auger Hole A20/0

(a)	(b)	(c)
2'	l+c	Nil
3½'	l	Nil

Auger Hole A22/3

(a)	(b)	(c)
2'	c	20
6'	c	16
10'	c	15

Auger Hole A22/5

(a)	(b)	(c)
2'	c+p	31
4'	p	29

Auger Hole A22/6

(a)	(b)	(c)
2'	c	26
4'	c	20
6'	c	16

Auger Hole A22/7

(a)	(b)	(c)
2'	c	22
4'	c	22
6'	c	22
10'	c	24
12'	c+l	18
14'	c	19
16'	c	13
20'	c	17

Auger Hole A24/0

(a)	(b)	(c)
2'	c	29
4'	c	22
6'	c+p	32

Auger Hole A24/1

(a)	(b)	(c)
2'	c	23
4'	c	23
6'	c	21
8'	c	16
10'	l+c	21

Auger Hole A24/4

(a)	(b)	(c)
2'	c	22
4'	c	20
6'	c	22
8'	c	17
10'	c	22
12'	c	21
14'	c	19
16'	c	21

Auger Hole A24/5

(a)	(b)	(c)
2'	c	28
4'	c	27
6'	c	-
10'	c	19
11'	c+p	27
8'	c	26

Auger Hole A24/6

(a)	(b)	(c)
2'	c	21
4'	c	19
6'	c	24
8'	c	22
10'	c	28
12'	c	27
14'	c	19
18'	c+p	27
20'	c	25
22'	c	22
24'	c+l	26
26'	c+p	30

Auger Hole A24/7

(a)	(b)	(c)
2'	c	22
4'	c	14
6'	c	18
10'	c	23
12'	c	24
18'	c	20

Auger Hole A24/8

(a)	(b)	(c)
2'	c	19
4'	c	20
6'	c	18
10'	c	20
12'	c	20
14'	c	21
18'	c	19
20'	c	19
22'	c	21

Auger Hole A26/1

(a)	(b)	(c)
2'	c	25
6'	p	35

Auger Hole A26/3

(a)	(b)	(c)
2'	c	28
4'	c	28
6'	c	14
7'	p	26
11'	c	21
13'	p	30

Auger Hole A28/1

(a)	(b)	(c)
6'	c	18

Auger Hole A28/2

(a)	(b)	(c)
2'	c	19
4'	c	18
6'	p	35

Auger Hole A28/3

(a)	(b)	(c)
2'	c	25
4'	p	23
6'	l	Nil

Auger Hole A28/4

(a)	(b)	(c)
1'	l	Nil

Auger Hole A30/7

(a)	(b)	(c)
2'	c	22
4'	p	32
6'	p	26
8'	p	38
10'	l+p	11

Auger Hole A30/8

(a)	(b)	(c)
2'	c	25
4'	c	27
6'	c	24
8'	c	26
10'	c	30
12'	c	26
14'	c	26
16'	c	34
18'	c	22
20'	c	22
22'	c	23
24'	p	37
26'	p	32
28'	p	35

Auger Hole A33/0

(a)	(b)	(c)
2'	c	23
4'	c	24
6'	c	25
8'	c+p	37
9'(end)	l	7

Auger Hole A32/1

(a)	(b)	(c)
1'	c	28
3'	c	14
5'	p	30

Auger Hole A32/2

(a)	(b)	(c)
2'	c	28
4'	c	29
6'	p	31
8'	p	27

Auger Hole A32/3

(a)	(b)	(c)
2'	c	18
4'	c	18
6'	c	24
8'	c	21

Auger Hole A32/0

(a)	(b)	(c)
2'	c	16
4'	c	17
6'	l	8
8'	l+p	26

Auger Hole A34/0

(a)	(b)	(c)
2'	c	22
4'	c	23
6'	c	27
8'	c	22
12'	p	37

Auger Hole A34/1

(a)	(b)	(c)
2'	c	23
4'	c	25
6'	c	26
8'	c	18
10'	cl	19
12'	c	22
14'	c	22
15'	p	39
17'	p	39
19'	p+l	15

Auger Hole A34/2

(a)	(b)	(c)
2'	c	22
4'	c	17
6'	c	27
8'	c	16
9¼'	p	24

Auger Hole A35/0

(a)	(b)	(c)
2'	c	25
4'	c	30
6'	p	39
10'	p	31

Auger Hole A36/0

(a)	(b)	(c)
4'	c	25
6'	p	34
7'	l	7

Auger Hole A36/1

(a)	(b)	(c)
2'	c	31
5'	c	30
7'	c	35

Auger Hole A36/2

(a)	(b)	(c)
2'	c	18
4'	c	20
6'	c	15

Auger Hole A36/3

(a)	(b)	(c)
2'	c	6

Auger Hole A37/0

(a)	(b)	(c)
2'	c	24
4'	c	30
6'	l	15
8'	l	Nil

Auger Hole A38/0

(a)	(b)	(c)
2'	c	28
4'	c+l	23
6'	p	36
8'	p	32

Auger Hole A38/2

(a)	(b)	(c)
4'	c	23
8'	l	6
10'	l	Nil

Auger Hole A38/5

(a)	(b)	(c)
4'	c	26
6'	c	28
8½'	p	40
(coherent rock)		
8¾'	p	37

Auger Hole A38/1

(a)	(b)	(c)
2'	c	27
4'	c+p	31
6'	c+l	20

Auger Hole A39/0

(a)	(b)	(c)
2'	c	26
4'	p	33
6'	l	12
8'	p	36
9' end	l	7

Auger Hole A40/0

(a)	(b)	(c)
2'	c	26
4'	c	24
6'	c+p	32
8'	p	30
9'	p	32

Auger Hole A40/1

(a)	(b)	(c)
2'	c	25
6'	c	25
9'	p	30

Auger Hole A40/5

(a)	(b)	(c)
2'	c	23
7'	p	33

Auger Hole A41/0

(a)	(b)	(c)
2'	c	26
4'	c+p	20
6'	p	27
8'	l	Nil

Auger Hole A42/0

(a)	(b)	(c)
2'	c	12
4'	c	28
6'	c	20
8'	c	28
10'	c	18
12'	c	16
14'	c+l	26
16'	c	23
18'	p	37
20'	p	39

Auger Hole A42/1

(a)	(b)	(c)
2'	c	17
4'	c	15
6'	c	14
8'	c+l	11
10'	c+l	11

Auger Hole A42/3

(a)	(b)	(c)
2'	c	16
4'	c	14
6'	c	28
10'	c	25
12'	c	30
14'	c	27
16'	c	21
18'	c	20
21'	p	33

Auger Hole A43/0

(a)	(b)	(c)
2'	c	22
4'	p	27
6'	l	1

Auger Hole A44/0

(a)	(b)	(c)
2'	c	29
4'	c	30
6'	c+l	19
8'	c	19

Auger Hole A44/2

(a)	(b)	(c)
2'	c	25
4'	c	27
6'	c	22
8'	p	36
11'	l	8

Auger Hole A44/3

(a)	(b)	(c)
2'	c	17
4'	c	15
6'	c	18
8'	c	25
10'	c	21
14'	l	2

Auger Hole A44/4

(a)	(b)	(c)
Surface	l	1

Auger Hole 44/5

(a)	(b)	(c)
Surface	c	3

Auger Hole A45/0

(a)	(b)	(c)
2'	c	22
4'	c	23
6'	c	21
10'	c	17
12'	c	33

Auger Hole A46/0

(a)	(b)	(c)
2'	c	15
4'	c	27
6'	c	19
8'	c	25
10'	c	24
12'	c	23
14'	c	20
17'	c	29
19'	c	24
21'	c	28
23'	c	26
25'	c	20
27'	c	21
30'	c	20

Auger Hole A46/1

(a)	(b)	(c)
2'	c	1
4'	c	17
10'	c	24
14'	p	34
15'	saturated clay	24
16'	saturated p	16

Auger Hole A46/2

(a)	(b)	(c)
2'	c	22
4'	c	27
6'	c	22
8'	c	20

Auger Hole A48/2

(a)	(b)	(c)
2'	c	18
4'	c+l	23

Auger Hole A48/3

(a)	(b)	(c)
4'	c+l	5

Auger Hole A50/0

(a)	(b)	(c)
1½'	c	23
2'	c+l	14
4'	c+l	16

Auger Hole A52/2

(a)	(b)	(c)
2'	c	24
4'	c	17
6'	c+p	25
8'	c+p	19
10'	c	27
12'	c	32
14'	c	28
16'	c	32
18'	c	30
20'	c	32
22'	c	33
24'	c	35
26'	c	34
28'	c	32

Auger Hole A52/3

(a)	(b)	(c)
2'	c	26
4'	c	26
6'	c	25
8'	c	25
10'	c	26
12'	c	23
14'	c	21
16'	c	21
18'	c	28
20'	c	19
22'	c	24
24'	c	24
28'	c	26
30'	c	12
32'	c	28

Auger Hole A52/4

(a)	(b)	(c)
2'	c	17
4'	c	27
8'	c	16
10'	c	16
12'	c+l	22

Auger Hole A54/1

(a)	(b)	(c)
2'	c	24
4'	c	35
6'	c	23
7'	p	25
8'	c	25

Auger Hole A54/3

(a)	(b)	(c)
2'	c	19
4'	c	11
6'	c	18
8'	c	15

Auger Hole A55/0

(a)	(b)	(c)
2'	c	22
4'	c	18
6'	c	24
7'	c+l	21
8'	c	19

Auger Hole A56/0

(a)	(b)	(c)
2'	c	19
4'	c	25
6'	c+l	23
8'	l	7
10'	p	37

Auger Hole A56/1

(a)	(b)	(c)
2'	c	25
4'	c	19
6'	c	27
8'	l	2
9'10"	p	37

Auger Hole A56/2

(a)	(b)	(c)
3'	c	21
6'	c	15
8'	c	24
10'	c	15
12'	c	15
14'	p	32

Auger Hole A57/0

(a)	(b)	(c)
2'	c	15
4'	c	23
6'	c	24
8'	c	20
10'	c	30
12'	c	24
16'	c	29
19'	p	29
20'	p	39

Auger Hole A58/0

(a)	(b)	(c)
2'	c	23
4'	c	18
6'	c	22
8'	c	17
10'	c	27
12'	c	27
14'	p	29
16'	c	34
18'	p	36
20'	p	37
22'	p	31
24'	p	34
26'	p	32

Auger Hole A58/1

(a)	(b)	(c)
2'	c	19
4'	c	17
6'	c	17
8'	c	15
10'	c	23
12'	c	20
14'	c	26
16'	c	24
18'	c	19
19½'	p	32
20½'	p	33

Auger Hole A58/5

(a)	(b)	(c)
2'	op	25
4'	op	18
8'	c	26
9'	l	7

Auger Hole A59/0

(a)	(b)	(c)
2'	c	26
4'	c	20
6'	c	24
8'	c	26
10'	c	25
12'	c	23
14'	c	23
16'	c	21
18'	p	34
22'	p	37
24'	p	29
26'	p	24
28'	p	35
30'	p+l	7
34'	p+l	6
37'	p+l	11

Auger Hole A60/0

(a)	(b)	(c)
2'	c	25
4'	c	24
6'	c	22
8'	c	20
10'	c	8
12'	c+p	21
14'	c+p	32
16'	op	31
17'	Pebble	32
18'	op	28
20'	c+op	35

Auger Hole A60/3

(a)	(b)	(c)
2'	op	23
4'	op	36

Auger Hole A60/1

(a)	(b)	(c)
2'	c	21
4'	c	20
6'	c	26
8'	c	14
10'	c	26
12'	c	26
14'	c+p	26
16'	c	31
18'	c	35
22'	c+op	35

Auger Hole A 60/5

(a)	(b)	(c)
6'	c	15

Auger Hole A61/0

(a)	(b)	(c)
2'	c	21
4'	c	24
6'	c+op	29
8'	op	25
10'	p	32
12'	p	32
14'	p	35

Auger Hole A62/0

(a)	(b)	(c)
2'	c	17
4'	c	12
6'	c	20
8'	c	20
10'	c+op	23

Auger Hole A62/1

(a)	(b)	(c)
2'	op	26
4'	op	31
6'	op	24
8'	op	25

Auger Hole A62/2

(a)	(b)	(c)
2'	l,c+op	19
6'	op	29
8'	op	26
12'	op	34

Auger Hole A63/0

(a)	(b)	(c)
2'	c+op	26
4'	l+op	29

Auger Hole A64/0

(a)	(b)	(c)
2'	c	32
6'	op	29
8'	op	33
10'	op	33
12'	op	26
14'	op	34
16'	op	30

Auger Hole A64/1

(a)	(b)	(c)
2'	op	35
4'	op	25
6'	op	35
8'	op	35
10'	op	36
12'	op	34
14'	op	35
16'	op	32

Auger Hole A64/4

(a)	(b)	(c)
4'	op	30
6'	op	33
8'	op	27
10'	op	31
12'	op	33
14'	op+l	30

Auger Hole A64/5

(a)	(b)	(c)
2'	op	30
4'	op	21
6'	op	28
8'	op	25

Auger Hole A65/0

(a)	(b)	(c)
2'	op	33
6'	op	26
8'	op	35
10'	op	27
12'	op	26
14'	op	28
18'	op	34

Auger Hole A66/0

(a)	(b)	(c)
4'	op	25
6'	op	27
8'	op	18
10'	op	30
16'	op	23
17'	op	30
12'	op	30
14'	op	29

Auger Hole A66/1

(a)	(b)	(c)
2'	c	28
4'	c	21
8'	c+l	24

Deepening of Pit near A60

(a)	(b)	(c)
20'	c	27
22'	c	28
24'	c+op	34
24½'	c+op	30
26'	op	31

Auger Hole A66/2

(a)	(b)	(c)
2'	op	28
4'	op	28
6'	op	30
8'	op	21
10'	op	28

Auger Hole A66/3

(a)	(b)	(c)
2'	c	24
4'	c	23
6'	c	20
8'	c	32
10'	op	27
12'	op	25
13'	op	28
14'	op	32
16'	op	29
18'	op	27
20'	op	22
21'	op	28

Auger Hole A66/4

(a)	(b)	(c)
2'	op	28

Auger Hole A67/0

(a)	(b)	(c)
2'	op	33
6'	op	27
8'	op	32

Auger Hole A68/0

(a)	(b)	(c)
2'	op	29
6'	op	28
10'	op	31
12'	op	31
8'	op	31

Auger Hole A68/1

(a)	(b)	(c)
2'	c	17
4'	op+l	21

Auger Hole A68/4

(a)	(b)	(c)
2'	op	25
5'	op	31
6'	op	20
8'	op	27
10'	op	26
12'	op	31

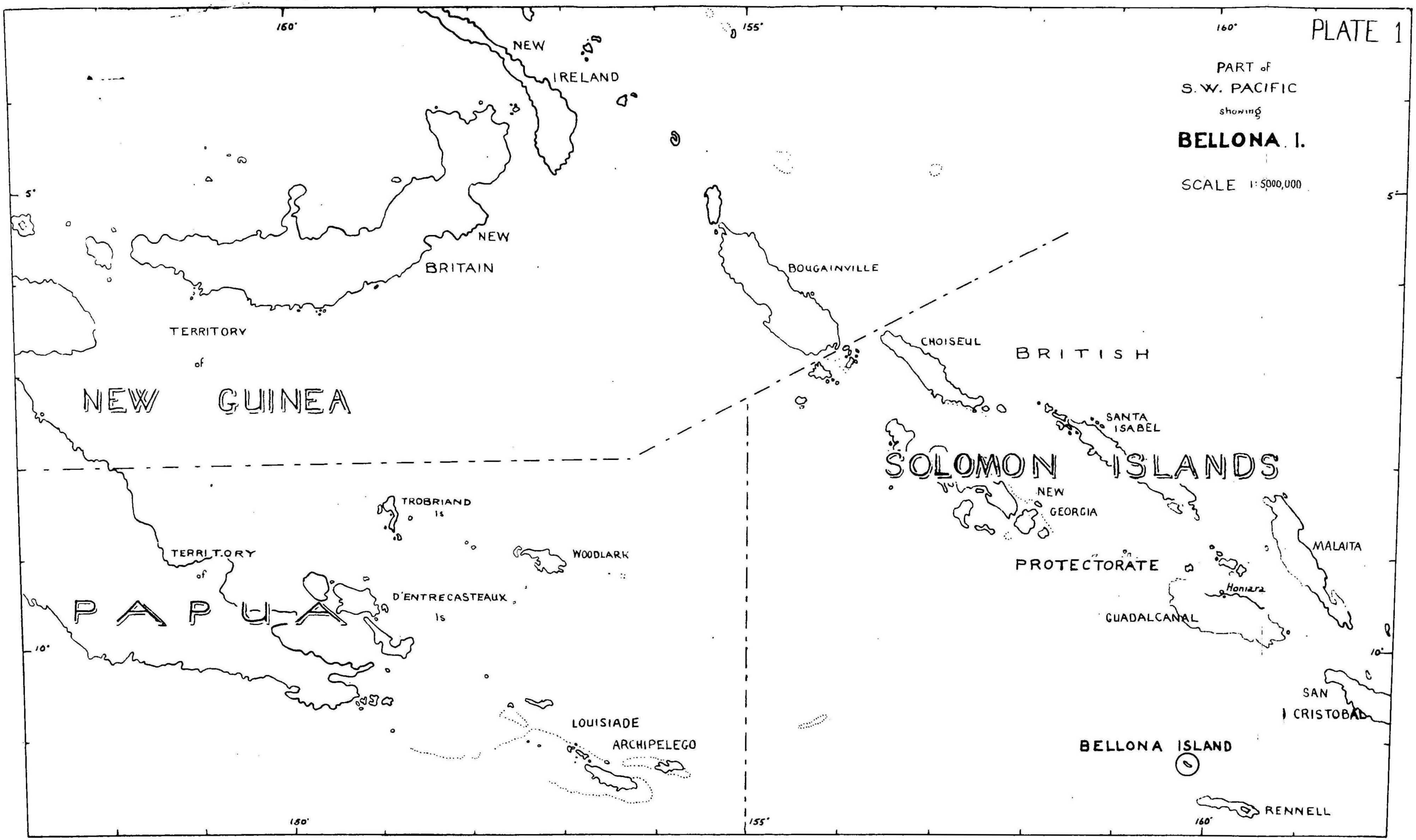
PLATE 1
PART of
S.W. PACIFIC
showing
BELLONA. I.
SCALE 1:5,000,000
NEW
IRELAND
NEW
BRITAIN
BOUGAINVILLE
TERRITORY
of
NEW GUINEA
CHOISEUL
BRITISH
SANTA
ISABEL
SOLOMON ISLANDS
NEW
GEORGIA
TROBRIAND
Is
TERRITORY
of
PAPUA
WOODLARK
D'ENTRECASTEAUX
Is
PROTECTORATE
MALAITA
Honiara
GUADALCANAL
SAN
CRISTOBAL
LOUISIADE
ARCHIPELEGO
BELLONA ISLAND
RENNELL
160°
155°
160°
5°
5°
10°
10°
150°
155°
160°

PLATE 2

BELLONA ISLAND

(159° 50' E, 17° 15' S)

BRITISH SOLOMON ISLANDS PROTECTORATE

Scale 6 inches to 1 mile

0 ¼ ½ ¾ 1 mile.

0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 yards.

PLATE 3

BELLONA ISLAND

[159° 50'E, 17°15'S]

BRITISH SOLOMON ISLANDS PROTECTORATE

SCALE: 6 inches to 1 mile

0 ¼ ½ ¾ 1 mile

0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 yds

REFERENCE

Boundary of phosphate deposits.

Isopach in phosphatic clay deposit
[Isopach interval : 5ft]

Isopach in oolitic phosphate and phosphate rock
[Isopach interval : 5ft]

Inland cliff

AREA	Material	Volume (cu. ft)	Tonnage	Grade
A	clay	20,964,000		
B	clay	10,366,000		
C	clay	10,710,000	4,600,000 tons	
D	clay	30,150,000		
E	clay	20,138,000		
•D and F	oolitic phosphatic and phosphate rock	28,740,000	700,000 tons	

PLATE 4

BELLONA ISLAND

(153°50'E 11°15'S) BRITISH SOLOMON ISLAND PROTECTORATE

Horizontal Scale 6 inches to 1 mile
Vertical Scale 1 inch to 80 feet
Vertical Exaggeration 11

Brown phosphatic clay

Phosphate rock

Oolitic phosphate

Coral limstone