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Cretaceous Phosphorites of the Darwin Region

by

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CRETACEOUS PHOSPHORITES

OF THE DARWIN REGION

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SUMMARY

The discovery in 1965 of phosphatic material in a Recent beach conglomerate at Lee Point near Darwin led to a search for the source of the phosphate in the Cretaceous rocks from which this conglomerate was principally derived. Thin nodular phosphatic beds were subsequently found to outcrop near the base of the Cretaceous succession in the Darwin area and were tested by diamond drilling at Gunn Point and Lee Point. Pelletal and nodular phosphate was also identified in two wells drilled by Oil Development on the south west of Bathurst Island. All the known occurrences of phosphorite are much too thin to be of economic significance, but they are of interest in so far as they establish the presence of phosphatic material in the Cretaceous of this area and the possibility of substantial concentrations being present cannot be ruled out.

INTRODUCTION

In April 1965, Mr. A.J. Turner of Katherine sent to the Bureau of Mineral Resources in Canberra a sample of phosphatic rock from Lee Point (see Plate 5). The sample contained 27% phosphate. Rix (1965) examined and reported on the Lee Point occurrence in May 1965. He considered that the phosphorite occurs as pebbles in a Recent beach conglomerate resting on ferricrete. The deposit has no economic significance.

Pontifex (1965) and C. Gatehouse, carried out preliminary mineralogical and paleontological investigations. Pontifex reported that the original sample was a mixture of crystalline fragments of igneous rock (15 percent) and fragments of phosphatic calcareous siltstone (75 percent). The fragments of phosphorite consist mainly of collophanite which is concentrated within and around Cretaceous radiolaria. Minor detrital quartz, feldspar and mica grains are also present.

Dodson (1965) compiled a further report on the Lee Point occurrence summarising the above data.

L.C. Noakes (correspondence) considered it likely that the pebbles at Lee Point would lead, through investigation, to a phosphorite horizon within the Cretaceous sequence in the Darwin area. Advice regarding the phosphate mineralization was received from L.C. Noakes (B.M.R.) R. Sheldon (U.S.G.S.) D. Zimmerman (I.M.C. Dev.Corp.) B. Parker (Homestake Mining Co.) and A. Temple (Mobil Chemicals) during their visits to Darwin.

REGIONAL GEOLOGY

The geology of the Cretaceous sedimentary rocks in the Darwin region is summarised in Plate 1. In the southern part of this area the Cretaceous succession unconformably overlies Proterozoic rocks and the base of the Cretaceous dips gently northwards from a few hundred feet above sea level in the south, where it forms mesa-like residuals, to well below sea-level on Bathurst and Melville Islands. The sediments consist of claystones, mudstones, and glauconitic sandstones and mudstones, together with rarer bands, beds, nodules and concretions of siderite, limestone and phosphorite. Some manganiferous nodules may be present within the succession at Lee Point (Cretaceous manganiferous beds are present at Green Ant Creek, 100 miles south of Darwin; Owen, 1954).

Although the total maximum section known from drill cores and outcrops probably does not exceed 1,500 feet, refraction surveys (Fife and Tinline, 1962) and aeromagnetic surveys (Howe and Faessler, 1963) suggest thicknesses of 3,000 feet and possibly as much as 4,400 feet in the northern part of Melville Island. The sedimentary rocks are more or less horizontal, but both the irregularities of the regional topography and the geophysical surveys suggest the presence of large faults. Such faults and a gentle regional dip should result in a large portion of the Cretaceous succession occurring at or near the surface within the region.

An extensive Tertiary lateritisation surface (or surfaces) occurs over the whole region under consideration. This lateritisation causes radical changes in the physical and chemical properties of the rocks and generally extends about 70 feet below the surface of the ferruginous zone of the laterite, although in certain localities (McMinns Lagoon area) it reaches a depth of 180 feet. As a result of these changes mapping becomes difficult even though the textures of the original rocks, such as bedding, are preserved.

Although the laterite surface has been gently folded, as a general rule it can be said that in the Darwin area lateritisation extends approximately to sea level, whereas on Bathurst and Melville Islands, interpreting Daily's (1956) report, unlateritised strata occur in places above sea level. On Cobourg Peninsula (Brown 1906, Owen 1949 and G. McLellan, personal communication) there are no records of unlateritised strata in natural exposures.

Lateritisation is significant in the search for commercial deposits of phosphorite because the process transforms the citrate-soluble calcium phosphates to citrate-insoluble iron and aluminium phosphates, which have little commercial value at present. Unlateritised phosphorites are likely to have a thick overburden.

CORRELATION BETWEEN DARWIN, GUNN POINT AND BATHURST ISLAND

At present, knowledge of Cretaceous geology in the Darwin region depends to a large extent on biostratigraphy. Although some paleontological work has been carried out, it has been largely of a preliminary nature and reliable biostratigraphic standards and detailed work are lacking.

Skwarko (1966) notes that although the Darwin cliff exposures have been regarded as Upper Albian or Lower Cenomanian, this dating is not based on paleontological grounds. Skwarko dates the cliff exposures at Gunn Point as Upper Albian on the basis of ammonites and lamellibranchs. This is in contradiction to formainiferal evidence provided by Terpstra (see Appendix 4) who correlates strata slightly below the cliff exposures with Lower Cenomanian sections on Bathurst Island.

The occurrences of Albian strata on Bathurst Island (Daily,1956) and Charles Point (Skwarko, 1966) are equally questionable.

In general, on the basis of micropaleontological work done by Wade and Glaessner for Oil Development N.L., rocks 132 feet above the base of the unconformity at Gunn Point can be considered as Lower Cenomanian. On Bathurst Island the Cretaceous rocks range from Lower Cenomanian to Turonian.

There is no paleontological evidence for the age of the Cobourg Peninsula rocks. They have been dated as Cretaceous on lithological and structural grounds.

DARWIN AREA

Data for this area were obtained from exposures in coastal cliffs, Gunn Point D.D.H. 1 and numerous rotary drill holes for groundwater. In Darwin itself, the unconformity is well exposed but disappears gradually below sea level and from Fannie Bay northwards to Dripstone Caves a total thickness of 70 feet of the basal sediments is exposed. An additional 90 feet of the succession in the cliffs at Lee Point is covered with scree and thick overgrowth. Between low water mark and the top of the cliff at the site of Gunn Point D.D.H. 1 about 100 feet of sediments form the section overlying the Lee Point section. It is possible that at Fright Point or Cape Hotham overlying beds are present.

The Darwin area coastal succession is summarised below.

Unit	Strata	Thickness (feet)
7	Claystone	80
6	Claystone with siderite bands	10
5	Claystone and mudstone	130
4	Phosphatic beds	up to 10
3	Mudstone and claystone	60
2	Glauconitic sandstone	up to 10
1	Basal Conglomerate	up to 3
	Unconformity	

To the south and south-east of Darwin, water bore data indicate a marked change in facies from the pure, sand-free claystones and mudstones to very sandy claystones and often clayey sandstone.

To the west, groundwater bores on Cox Peninsula reveal claystones and sandy claystone, together with unlateritised glauconitic claystones and sands resting on micaceous and lithic sandstones derived from local granite. The thickest section penetrated is about 100 feet.

Phosphorites in the Darwin area

In the Darwin area, the phosphatic beds are confined to a horizon about 7 feet thick and 60 feet above the base of the Cretaceous. They are exposed in coastal cliffs from Fannie Bay to Dripstone Caves and form an undulating platform within 20 feet of the ferruginous zone of the laterite profile. Because of lateritisation, the original lithology of the exposed sections has to be interpreted mainly by textural comparison with unlateritised rock found in the Lee Point beach conglomerate or with core from Gunn Point D.D.H. 1. The following three sections have been accurately measured:

1. Strata immediately underlying the phosphorite beds as measured at Fannie Bay, near the Darwin High School.

Thickness	Lithology
60'0"	MUDSTONE, white and brown, siliceous.
2'6"	SANDSTONE, red, brown and yellow, finely bedded and fissile. Consists of fine to medium, well sorted, rounded grains (probably originally glauconite) which have been leached out leaving hollow pores. The matrix is ferruginous. About 10% quartz grains present.
1'6"	SANDSTONE, red, weathered, massive, hard. Fine - to medium-grained as above. Contains 10% quartz grains. The matrix is hard, hematitic and siliceous.
4'6"	SANDSTONE, fissile, as above.
Up to 3'0"	CONGLOMERATE, coarse, poorly sorted. Contains boulders up to 2 feet in diameter of rounded white, grey and green quartz. The matrix is white, red and brown, clayey and sandy.
-----------	Unconformity -------------

2. Phosphatic beds exposed in cliffs at Nightcliff.

Thickness	Lithology
-	Mottled zone of laterite profile.
6'10¾"	MUDSTONE, yellow and white, fissile, soft.
0' 3¼"	PHOSPHORITE, yellow and brown, nodular. Nodules vary in size and shape, usually spheroidal and up to 5" in size. Many nodules leached out of the matrix. (NODULE BED NO.2).
0' 6"	MUDSTONE, yellow, white to grey, soft, characterised by tube texture, contemporaneously made by a boring organism. Contains abundant belemnite guards. (TUBE BED NO.3)
0'9½"	MUDSTONE, as above, weathers slightly differently-softer. (TUBE BED NO. 2.).
0'4½"	PHOSPHORITE as Nodule Bed No. 2 (NODULE BED NO.1).
0'6¾"	MUDSTONES as for Tube Bed No.2, slightly coarser texture. (TUBE BED NO.1).
-	MUDSTONE, yellow, soft, even texture.

3. Dripstone Caves. Here the rock types and their physical properties are the same as at Nightcliff, but there are differences in thickness and an additional two Tube Beds at the top of the section.

Thickness	Rock Type
-	Ferruginous and mottled zone of laterite.
0'7½"	TUBE BED NO. 4.
3'3½"	MUDSTONE BED NO. 2.
0'11¾"	TUBE BED NO. 3.
0'8¾"	MUDSTONE BED NO. 1.
0'2½"	NODULE BED NO. 2.
1'1¾"	TUBE BED NO. 2.
0'3"	NODULE BED NO. 1.
0'6"	TUBE BED NO. 1.
-	MUDSTONE.

It can be seen from the correlation chart given in Plate 2 that strata intersected in Gunn Point D.D.H. 1 are similar to those known from exposures except that the isolated (?) high grade nodules in clay at the top of the section in Gunn Point D.D.H. 1 are either absent or cannot be readily identified in the lateritised exposures.

Assay results of the Gunn Point phosphorites are given in Appendix 2.

The cliff exposures in Darwin have not been systematically sampled and assayed, partly because it was mistakenly believed, on the basis of reaction with acid ammonium molybdate reagent, that the lateritised phosphorite beds contained little or no phosphate. Subsequently, analysis of a nodule from East Point indicated a content of 14% P_2O_5 (G.Wilraith, East Point Laboratories, Mines Branch, Darwin). Several nodules from Rapid Creek beach were assayed by the Shapiro test (Shapiro, 1952) and proved to contain approximately 15% P_2O_5. In this test the sample has to be dissolved in hot concentrated nitric/sulphuric acids which suggests that the phosphate occurs as wavellite or some other iron and aluminium phosphate minerals.

The lower phosphate content of these nodules compared with those found in the beach rock at Lee Point (which assay from 20% to 32% P_2O_5) may be significant and could be caused either by lateritisation or by a facies change. The lower phosphate content of the Bathurst Island nodules is undoubtedly facies controlled.

The most notable effect of lateritisation and weathering on the phosphatic beds in Darwin is upon the nodules themselves. They can be completely intact as at Rapid Creek beach, reduced to a soft clay-like material, or completely leached out. Although changes in colour and mineralogy may be attributed to lateritisation, disintegration and solution of the nodules is most probably the effect of leaching by acid groundwaters. This theory is borne out by the unleached state of the nodules on Rapid Creek beach which is below high water mark, whereas nodules above high water mark in cliffs at Nightcliff and Dripstone Caves are almost completely leached out.

The correlation chart given in Plate 2 indicates that the phosphatic beds maintain a uniform thickness for about 20 miles. There is a possibility that the beds thicken eastwards from Gunn Point D.D.H. 1. towards Adelaide River. This should be tested by diamond drilling.

Description of the phosphatic beds.

Darwin

The Darwin outcrops are lateritised.

Nodule bed: A yellowish-white, massive, hard rock consisting of regular and irregular rounded and angular nodules up to about 5 inches in diameter. They are poorly sorted and are set in a similarly coloured matrix and, in places, similar material, to the nodules. Many nodules have an oolitic and some a pelletal texture. Fossil wood fragments are common.

Tube bed: A greyish yellow rock characterised by abundant and evenly distributed tunnels made by some boring organism (similar borings have been described by Matheson 1948). Contains scattered belemnite guards.

Gunn Point D.D.H.1.

The phosphatic beds from Gunn Point D.D.H.1 are identical in texture to those exposed in Darwin, but are not lateritised.

Nodule bed: A soft, dark grey, glauconitic clay containing abundant, hard, grey, round, phosphorite nodules.

Tube bed: A soft, dark grey, phosphatic, glauconitic clay. The tubes or tunnels are light grey in contrast to the dark grey matrix.

In addition to tube and nodule beds, there are a number of very hard, high grade phosphorite nodules within the ordinary clays. These nodules are brownish on the outside but grade into a grey centre.

BATHURST & MELVILLE ISLANDS

The geology of Bathurst and Melville Islands is comparatively well known from the observations of Brown (1906), the traverses of Daily (1956) and diamond drilling and auger sampling by Oil Development N.L. A refraction survey has been made of Bathurst Island and aeromagnetic surveys of both islands. Several companies have mining or prospecting leases for beach sands, and one company has examined the area for bauxite.

Bathurst Island is covered by a variable thickness, sometimes in excess of 120 feet, of Tertiary sands (see Appendix 7) deposited on a pre-existing land surface. Underlying the Tertiary sands are several thousand feet of sediments of Upper Cretaceous age which outcrop along coastal cliffs.

The western half of Melville Island is similar geologically to Bathurst Island, but little is known about the eastern half.

Description of the Phosphorites

Phosphorites from Bathurst Island wells are:

a. Pelletal, e.g. the 220'0" - 220'5" interval of Bathurst Island No. 1 well. Here the phosphate is concentrated in abundant, hard, black, relatively high grade pellets in limestone.

b. Concretionary. The concretionary phosphate exhibits a colour and hardness gradation from a hard centre to the enclosing soft mudstone.

c. Nodules. These are hard, usually spherical in shape, and commonly have a translucent, brown, surface coating.

d. Phosphatic limestone. The phosphate minerals do not appear to be concentrated in pellets or nodules.

Assay results for the Bathurst Island phosphorites are given in Appendix 6. Although the phosphatic material is physically similar to that at Gunn Point, the P_2O_5 content is much lower.

COBOURG PENINSULA

Little is known of the geology within the Cobourg Peninsula 1:250,000 sheet. The southern part of the area consists of granite and Upper Proterozoic sandstones, but Cretaceous sedimentary rocks underlie the whole peninsula to the north and north-west of Murgenella Creek. It can be inferred that the succession dips northwards and that a thickness comparable to that at Melville Island, some thousands of feet of sediments, is present in the northern parts. The relatively high relief of Mount Roe (523 feet above sea level) suggests significant Tertiary or post-Tertiary movements with the possibility that a large section of the Cretaceous is exposed at the surface.

The only published geological information about Cobourg Peninsula is that of Brown (1908) who noted horizontally bedded, ferruginised sandstones, argillaceous sandstones and claystones on both sides of Bowen Straits; ferruginous sandstones and conglomerates on Grant Island; and argillaceous sandstones and claystones at Port Essington.

A number of companies have examined the area for bauxite but record little other geological information.

G. McLellan (B.H.P.Ltd., 1963, Arnhem Land prospecting report) confirmed that the coastal cliff exposures are lateritised.

Owen (1949) examined Port Essington for beach sands and noted that the Cretaceous succession consists of alternating beds of sandstone and shale, the former dark brown to black and ferruginous, the latter arenaceous in part.

FURTHER EXPLORATION

The phosphorites so far discovered in the Darwin region are too thin and too low in grade to be economically exploited at the present time. They are significant nevertheless for indicating the presence of phosphatic sedimentary rocks in the Cretaceous sequence which occurs over about 5,000 square miles of the Darwin area, Bathurst and Melville Islands and Cobourg Peninsula, as well as potentially over an area of similar size of the sea floor in water depths of less than 120 feet.

Land Deposits

Two types of deposits may occur: (a) as part of the Cretaceous sedimentary sequence (b) as a residual concentration of nodules, or as a massive residual concentration of phosphate. Systematic exploration for these deposits should consist of:

1. Geological mapping of Bathurst and Melville Islands and Cobourg Peninsula followed by detailed paleontological study.

2. Diamond, rotary and auger-drilling on the basis of the results of geological mapping.

3. In the search for residual nodule concentration, particular emphasis should be given to the possible occurrence of such a deposit at the base of the Tertiary sands on Bathurst and Melville Islands and on the use of rotary drills and refraction surveys for finding pre-Tertiary valleys.

Submarine Deposits

There is an extensive offshore area in the Darwin region which is inferred to be underlain by Cretaceous sedimentary rocks, but which is covered by shallow seas not exceeding 120 feet in depth (Plate 1). The sea floor may contain either a residual concentration of phosphorite nodules or outcrops of the nodule beds themselves, perhaps under a thin cover of Recent muds. Dredging of a residual nodule deposit is economically feasable and the mining of the submarine outcrops themselves is not outside the scope of present day technology.

Possible submarine occurrences are of particular interest because there is evidence to suggest that lateritisation, if present, is not very extensive. Opposite the cliffs at the site of Gunn Point D.D.H. 1, for example, a platform of fresh Cretaceous mudstones extends at least half a mile out to sea under a cover of about 2 feet of Recent sand and silt. Daily (1956) describes a substantial thickness of fresh Cretaceous strata exposed in the wide intertidal zone on Bathurst Island.

The known gravel deposits in Clarence Strait and Van Diemen Gulf on Melville Island 1:250,000 topographic sheet, Edition 1, is considered worthy of investigation. Prospecting should be carried out by means of dredge sampling and employment of divers.

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APPENDIX 1

GUNN POINT DIAMOND DRILL HOLE NO. 1

COMPLETION REPORT

SUMMARY

Gunn Point D.D.H.1 is a continuously cored diamond drill hole situated 20 miles north-east of Darwin. It was drilled during September and October 1965 and yielded information about clay and phosphorite. A lithologic and radiometric log of the hole is given.

INTRODUCTION

On the recommendation of Rix (1964), a series of shallow diamond drill holes was planned to test the clay deposit at Gunn Point. Gunn Point D.D.H.1 is the first of the planned drill holes and because it was suspected that phosphorite may occur within the Cretaceous sequence, the hole was drilled to the underlying basement (Upper Proterozoic? sedimentary rocks).

GUNN POINT D.D.H. 1.

Location: 20 miles north-east of Darwin. Military grid zone 4, 1:250,000 sheet D524, East 403000, north 343500.

Altitude: 81 feet above approximate mean high water.

Attitude: Vertical hole.

Total depth: 315 feet 4 inches.

Logged by: K.J. Kemezys.

Radiometric log by: J. Gardner.

Commenced drilling: 1.9.65.

Completed drilling: 29.10.65.

Driller: L. Brewster, Mines Branch, Darwin.

Drill type: Edeco Mark 6 with HD Listor motor, skid mounted diamond drill with B.M.S. split inner tube. Working pressure 100 psi, water pressure 120 psi.

Driller's comments: Tentative caving all the way which became too great at final depth for B size drilling. Any deeper drilling should be carried out in A size.

Status of hole: Abandoned after reaching target. Core is stored in Mines Branch core library, Darwin.

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Description of Core

Interval	% Recovery	Strata
0' - 14'	0	Soil and ferruginous zone of laterite.
14' - 15'	33	CLAYSTONE, white, soft like chalk, ironstained in joints.
15' - 20'	40	CLAYSTONE, white soft like chalk, ironstained in joints, core badly fragmented.
20' - 22'	75	CLAYSTONE, white, soft like chalk, ironstained in joints.
22' - 24'	37	CLAY, light brown, soft. Core consists of sludge.
24' - 24' 6"	100	CLAY, light brown, soft, core badly fragmented.
24' 6" - 32'	50	CLAYSTONE, white, soft like chalk, ironstained in places.
32' - 36'6"	76	CLAYSTONE, white and brown, badly fragmented, badly ironstained.
36' 6"- 37'	67	CLAYSTONE, purple, ironstained.
37' - 43'	67	CLAYSTONE, white and brown, badly ironstained, fragmented.
43' - 43'10"	100	CLAYSTONE, cream to white, waxy.
43'10" - 45'10"	75	CLAYSTONE, brown and white, very badly ironstained, badly fragmented.
45'10" - 48' 2"	98	CLAYSTONE, white, waxy, slightly ironstained.
48' 2" - 48' 9"	100	CLAYSTONE, reddish brown.
48' 9" - 51'	100	CLAYSTONE, cream and white, waxy.
51' - 52' 1"	100	CLAYSTONE, white, waxy.
52' 1" - 53'	100	CLAYSTONE, cream, waxy.
53' - 62'	89	CLAYSTONE, greyish, white, waxy.
62' - 63'	100	CLAYSTONE, greyish white, waxy, dark ironstaining in joints.
63' - 63' 6"	84	CLAYSTONE, greyish white, waxy.
63' 6" - 63' 9"	100	CLAYSTONE, greyish white, waxy. Contains ironstained joints.
63' 9" - 68'	77	CLAYSTONE, greyish white, waxy.
68' - 73'	100	CLAYSTONE, grey, waxy.
73' - 73' 1"	100	SIDERITE, grey, medium-grained, even texture, hard.

73' 1" - 84'11"	100	CLAYSTONE, grey, waxy.
84'11" - 85'	100	SIDERITE, grey, medium-grained, even texture, hard.
85' - 85' 6"	100	CLAYSTONE, grey, waxy.
85' 6" - 85'8½"	100	SIDERITE, grey, medium-grained, even texture, hard.
85'8½" - 87' 3"	100	CLAYSTONE, grey, waxy.
87' 3" - 87' 5"	100	SANDSTONE, grey, medium-grained, even texture, hard, iron rich.
87' 5" - 89' 5"	100	CLAYSTONE, grey, waxy.
89' 5" - 89' 6"	100	SIDERITE, grey, medium-grained, even texture, hard.
89' 6" - 89' 8"	100	CLAYSTONE, grey, waxy.
89' 8" - 89'11"	100	SIDERITE, grey, medium-grained, even texture, hard.
89'11" - 90'	100	CLAYSTONE, grey, waxy.
90' - 93'	100	CLAYSTONE, grey, waxy, badly fragmented.
93' - 97' 4"	100	CLAYSTONE, grey, waxy, tough.
97' 4" - 97' 6"	100	CLAYSTONE, grey, silty, soft and crumbly.
97' 6" - 101'	100	CLAYSTONE, grey, waxy, tough. Contains small pyrite concretions and rare pyritised ammonites.
101' - 111' 4"	100	MUDSTONE, grey, silty, medium hard, with vertical jointing planes. Slightly calcareous, fossiliferous with radiolaria, foraminifera and possible plant fragments.
111' 4" - 119' 9"	100	SHALE, grey, very soft and friable, very finely bedded. Contains small specks of white calcareous material throughout.
119 '9" - 139'	100	MUDSTONE, grey, silty, fairly hard, slightly calcareous, contains pyrite concretions, pyritised ammonites as well as foraminifera and radiolaria.
139'- 141' 6"	100	SHALE, grey, very soft and friable, very finely bedded. Contains small specks of white calcareous material throughout.
141' 6" - 143'	100	MUDSTONE, grey, silty, medium hard, slightly calcareous. Contains pyrite concretions, pyritised ammonites as well as foraminifera and radiolaria.
143' - 146'	100	SHALE, grey, very soft and friable, very finely bedded. Contains small specks of white calcareous material throughout.

146' -147' 3"	100	MUDSTONE, grey, silty, medium hard, slightly calcareous. Contains pyritic concretions and fossils.
147' 3" - 148'	100	SHALE, grey, very soft and friable, very finely bedded. Contains small specks of white calcareous material throughout.
148' - 150'	100	CLAY, grey, very soft, consists of small pellets loosely held together.
150' - 173'	100	MUDSTONE, grey, silty, medium hard, slightly calcareous, slightly micaceous.
173' - 174' 6"	100	SHALE, grey, very soft and friable, very finely bedded. Contains small specks of white calcareous material throughout.
174' 6" - 198' 9"	100	MUDSTONE, grey, silty, medium hard, slightly calcareous. Contains pyritic concretions, slightly micaceous.
198' 9" - 209'	100	SHALE, grey, very soft and friable, very finely bedded. Contains small specks of white calcareous material throughout.
209' - 210'	100	MUDSTONE, grey, silty, medium hard, slightly calcareous.
210' - 211'	100	CLAY, black, soft.
211' - 211' 1"	100	PHOSPHORITE, pebble, dark brown, grey, very hard, even texture.
211' 1" - 213'10½"	100	CLAY, dark grey, soft. PHOSPHORITE pebble at 212'.
213'10½"- 214' 2"	100	MUDSTONE, grey, silty, medium hard, slightly calcareous.
214' 2" - 214'10½"	100	CLAY, dark grey, soft.
214'10½"- 214'11½"	100	PHOSPHORITE nodule, light grey, medium hard.
214'11½"- 216'	100	CLAY, black, soft.
216' - 216'0¾"	100	PHOSPHORITE nodule, light grey, medium hard.
216'0¾" - 216'2½"	100	CLAY, grey, soft.
216'2½" - 216' 9"	100	MUDSTONE, grey, medium hard.
216' 9" - 217' 1"	100	CLAY, dark grey, soft. Contains dark brown, grey, hard PHOSPHORITE pebbles.
217' 1" - 217' 8"	100	MUDSTONE, light grey, medium hard.
217' 8" - 217'11"	100	CLAY, black, soft, silty. Contains a maze of tubes infilled with light grey-green glauconitic material. (Tube rock).

217'11" - 218' 2"	100	PHOSPHORITE, pebble, bed, dark grey, hard rounded, elongate, poorly sorted pebbles to 2 cm diameter. The pebbles are set in a clay matrix.
218' 2" - 219'4½"	100	CLAY, black, soft, silty. Contains a maze of tubes infilled with light grey-green glauconitic material. (Tube rock).
219'4½" - 219'10½"	100	CLAY, dark grey, soft.
219'10½"- 220'10½"	100	MUDSTONE, grey, medium soft, phosphatic.
220'10½"- 220'22½"	100	MUDSTONE, grey, silty, medium hard.
220'11½"- 221' 2"	100	CLAY, black, soft, phosphatic.
221' 2" - 266' 6"	100	MUDSTONE, light grey, silty, medium hard, calcareous.
266' 6" - 270'	100	MUDSTONE, grey-green, silty, hard and tough when dry crumbly when wet. Contains bands of glauconitic sand.
270' - 273'	100	SHALE, dark grey, very soft, well bedded, micaceous.
273' - 275'	100	SAND, glauconitic, clayey, unconsolidated.
	UNCONFORMITY	
275' - 281'	100	MUDSTONE, light grey silty, even texture, hard, contains a few banded phases with pyrite grains along bedding planes. Bedding dips about 45° to core axis.
281' - 282'	poor	MUDSTONE, light grey, soft, crumbly, silty, badly fragmented, contains carbonaceous phases. Core recovery very poor.
282' - 286' 9"	40	MUDSTONE, as for 275' - 281'.
286' 9" - 290'	poor	MUDSTONE, as for 281' - 282'.
290' - 290' 3"	100	SILTSTONE, light with dark grey, finely banded with sandy bands, medium hard.
290' 3" - 310'	15	MUDSTONE, as for 281' - 282'.
310' - 315' 4"	80	SHALE, light blue-grey, with yellow and dark grey bands, hard. Bedding approximately 45° to core axis.
	END OF HOLE	

SIGNIFICANCE OF DATA

1. Phosphorite

The drill hole at Gunn Point has established the presence of unlateritised phosphorite beds within the Cretaceous sequence of the Darwin area. The similar stratigraphic position and presence of the 'tube' beds gives good reason for correlating these beds with those found in the lateritised cliff sections in the Darwin area. From the drilling data it is inferred that the phosphorite beds form a continuous layer for about 18 miles from Fannie Bay to Gunn Point.

The phosphorite beds recovered by the diamond drill hole have been assayed and the results are included in Appendix 2.

2. Clay

Information gained from the diamond drill hole has clarified the relationship between the dark grey and white clays which were described by Rix (1964). One of Rix's alternative explanations for the origin of the clay has proved correct (Rix 1964) "...the white or light grey claystone, which occurs above the dark grey claystone, but beneath the laterite, is a result of the kaolinization of the montmorillomite clays during the process of lateritisation".

The diamond drill hole also indicated the existence of very large tonnage of the light grey clay. It occurs in the interval approximately 48 feet-68 feet and appears to be free from significant ironstaining.

APPENDIX 2.

GUNN POINT D.D.H. 1.

PHOSPHATE ANAYLSES

Interval	%P_2O_5	Lithology	Sample	Remarks
209' 0" - 210' 0"	0.49	Mudstone,grey,speckled limy,hard.	Channel	
210' 0" - 210' 5"	0.34	Clay,black, soft.	Channel	
210' 5" - 210' 8"	0.45	Clay, black, soft.	Channel	
210' 8" - 211' 0"	0.47	Clay, black, soft.	Channel	
211' 0" - 211' 1"	27.20	Phosphorite nodule,hard	Chip	)Nodule bed
211' 0" - 211' 1"	2.90	Clay enclosing above pebble	Channel	
211' 1" - 211'4½"	0.38	Clay, dark grey,soft	Channel	
211'4½" - 212' 0"	0.17	Clay, dark grey,soft	Channel	
At 212' 0"	10.30	Phosphorite nodule, medium hard.	Chip	)Nodule bed
212' 0" - 212'11½"	0.21	Clay, dark grey, soft	Channel	
212'11½"- 213' 2"	0.28	Clay, dark grey, soft	Channel	
213' 2" - 213' 5"	0.24	Clay, dark grey, soft	Channel	
213' 5" - 213'10½"	0.18	Clay,black, soft	Channel	
213'10½"- 214' 2"	0.15	Mudstone,grey,speckled, limy, hard.	Channel	
214' 2" - 214'10½"	0.20	Clay, dark grey, soft	Channel	
214'10½"- 214'11½"	23.00	Phosphorite nodule, medium hard.	Chip	)Nodule bed
214'11½"- 215' 1"	0.23	Clay, black, soft	Channel	
215' 1" - 215'2½"	0.23	Clay, black, soft	Channel	
215'2½" - 215'5½"	0.21	Clay, black, soft	Channel	
215'5½" - 215' 8"	0.24	Clay, black, soft	Channel	
215' 8" - 215'11"	11.40	Clay, black, soft	Channel	)Phosphatic clay?
215'11" - 216' 0"	0.26	Clay, black, soft	Channel	
216' 0" - 216'0¾"	2.80	Phosphorite nodule, medium hard	Chip	)Nodule bed
216'0¾" - 216'2½"	0.16	Clay, grey, soft	Channel	
216'2½" - 216' 9"	0.24	Mudstone, grey, medium hard.	Representative	
216'2½" - 216' 9"	0.32	¼" black clay bands interbedded with above	Representative	

Interval	$\% P_2O_5$	Lithology	Sample	Remarks
216' 9" - 217' 1"	4.10	Clay, dark grey, soft with phosphorite nodules	Channel	)Nodule bed
217' 1" - 217' 8"	0.32	Mudstone, light grey, medium hard	Channel	
217' 8" - 217'11"	0.78	Tube rock, soft	Channel	)Tube bed
217'11" - 218' 2"	23.60	Phosphorite nodule bed	Chips of 3pebbles	)Nodule bed
218' 2" - 219' 1"	0.75	Tube rock, soft	Channel	)
219' 1" - 219' 3"	2.10	Tube rock, soft	Channel	)Tube bed
219' 3" - 219'4½"	0.95	Tube rock, soft	Channel	)
219'4½" - 219'7½"	0.64	Clay, dark grey,soft	Channel	
219'7½" - 219'10½"	0.87	Clay, dark grey, soft	Channel	
219'10½"- 220'10½"	1.90	Mudstone, grey, medium soft.	Representative.	
219'10½"- 220'10½"	0.54	½" black clay bands interbedded with above	Representative..	
220'10½"- 220'11½"	0.44	Mudstone, grey,silty, medium hard	Channel.	
220'11½"- 221' 2"	3.30	Clay, black, soft	Channel	)Phosphatic clay
221' 2" - 221' 4"	0.08	Mudstone, light grey, medium hard	Channel	
221' 4" - 221'6½"	0.24	Mudstone,light grey, silty, medium hard	Channel	
221'6½" - 221'7½"	0.35	Mudstone,light grey, silty, medium hard	Channel	
221'7½" - 221'10"	0.26	Mudstone,light grey, silty, medium hard	Channel	
221'10" - 222' 2"	0.20	Mudstone,light grey, silty, hard	Channel	
222' 2" - 222' 8"	0.30	Mudstone, light grey, silty, hard	Channel	

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<u>Notes:</u>

1. Hardness values given in this log are complicated by the fact that clays which are very soft when fresh from the core barrel, harden considerably through loss of moisture on exposure to the air. It was not always possible to examine and log the fresh core. The term clay is used either for soft core or for core which shows strong flow characteristics. Mudstone is used for core which shows jointing and flat bedding planes.

2. Channel samples were taken along the core with a $\frac{1}{4}$" x $\frac{1}{4}$" cross section.

3. Core recovery for the interval 209' - 222'8" was 100%.

4. Assays were carried out spectrophotometrically by G. Wilraith, East Point Laboratories, Mines Branch, Darwin.

APPENDIX 3.

SIDERITE BEDS, CRETACEOUS, GUNN POINT

The following report refers to thin siderite bands which outcrop at the base of the cliff of Gunn Point D.D.H. a site. Five of these bands were intersected in Gunn Point D.D.H. 1 in the interval 73 feet to 89 feet 11 inches.

A MINERALOGICAL AND X-RAY ANALYSIS OF A SUSPECTED PHOSPHATE-RICH ROCK FROM NEAR DARWIN N.T.

by

I.R. Pontifex & J.M. Rhodes.

The sample was submitted by L.C. Noakes.

Locality: Gunn Point, approximately 20 miles E.N.W. of Darwin.

Description of thin section:

About 90% of this rock consists of an aggregate of pale brown grains which have an average size of 0.075 mm. Interstices within this aggregate are partly filled with clay and silt-size quartz.

Some of the brown grains have a spherulitic structure; some are concentrically zoned; others have a sub-radiating form. They have an extreme bire-fringence and a uniaxial negative interference figure with numerous rings. Their R.I. is greater than 1.7.

The grains effervesce vigorously in warm 1:1HCI.

These properties suggest that the mineral is siderite. Some of these properties are also characteristic of other carbonate minerals and dahllite; however, the high R.I. is exclusive to siderite.

X-Ray diffraction powder photograph

The X-ray diffraction pattern of a crushed sample of this rock indicates that it consists almost entirely of a carbonate mineral - most likely siderite.

There is no suggestion that the rock contains dahllite and although dahllite is a carbonate-apatite it is the opinion of several authors cited in Deer, Howie and Zussman (1964) that 'the X-ray pattern of carbonate apatites show no evidence of the presence of crystalline carbonates.'

Spectrographic anaylsis

The sample was analysed on the automatic X-ray fluorescent spectrograph and the following results and comments were produced by Rhodes.

	%
Si02	13.46
Ti02	0.18
A1203	3.49
Fe_2O_3	50.63
CaO	1.35
K20	0.38
P_2O_5	0.05
loss (1000°C)	29.01
Total	98.55

From the analysis it appears that most of the sample was the iron carbonate siderite. If this is the case, the Fe would be present in the ferrous state, and would therefore be less than given above. To compensate for this, loss which would be due to CO_2 should be larger, since oxidation of iron during heating will cause the sample to gain weight.

Re-calculation of the analysis to allow for the ferrous nature of the iron gives the following results:-

	%
Si02	13.46
Ti02	0.18
A1203	3.49
Fe_2O_3	-
FeO	45.57
CaO	1.35
K_2O	0.38
P_2O_5	0.05
loss (1000°C) ($=CO_2$)	34.12
Total	98.60

Conclusion

The evidence indicates that this rock consists almost entirely of siderite and that it is derived from a sedimentary siderite deposit.

APPENDIX 4.

FORAMINIFERA FROM GUNN POINT D.D.H. 1

by

G.R.J. Terpstra

The two core samples of Gunn Point No. 1 from 101' - 114'4" and 141'6" - 143'6" have been examined for micro-fossils.

Both samples contain an assemblage of foraminifera indicating a Lower Cenomanian age.

As requested, a comparison has been made with Bathurst Island Wells No. 1 and/or 2.

The faunas encountered in Bathurst Well No. 1 between 186 and 817 feet are also of Lower Cenomanian age. Unfortunately, only a few samples of these wells have been received by the Bureau. These are not sufficient to make a close correlation possible.

For comparison there are two separate reports by Dr. Mary Wade on the wells including a distribution chart of Well No. 1. The determinations shown on this chart were mainly given in code form (Haplophragmoides sp. No. 1 and so on).

A typical species '*Globotruncana stephani*' (observed in the samples from Gunn Point No. 1) first appears in Bathurst No. 1 at + 300 feet, whilst at + 600 feet and below in Bathurst No. 1 certain species occur not present in the Gunn Point samples.

These facts may suggest that the strata of Gunn Point No. 1 between 101 and 143 feet have their equivalent in Bathurst No. 1 between 300 and 600 feet. This conclusion, however, should rather be treated with circumspection.

A close correlation between Gunn Point No. 1 and one of the Bathurst wells will only be possible when a continuous sequence from the Bathurst wells is available for comparison.

APPENDIX 5.

LEE POINT QUATERNARY BEACH CONGLOMERATE

by

R. Rix, R.G. Dodson, & K.J. Kemezys

The phosphorite at Lee Point (Plates 5 and 6) occurs as pebbles up to about 4 inches in size, together with pebbles of ironstone (laterite), manganese ore and ferruginous quartzite in a poorly sorted conglomerate cemented by shelly beach sand. The conglomerate occurs as a discontinuous, thin (up to 1 foot) crust resting on the ferruginous zone of laterite. In places it fills hollows in the laterite. The laterite, assumed to be of Tertiary age, is slightly folded, so that the overlying beach conglomerate can be assumed to be of Quaternary age.

Besides the fact that Gatehouse (correspondence) identified Cretaceous radiolaria within the phosphorite pebbles, additional evidence for the origin of the conglomerate as a whole and of the phosphorite pebbles in particular, is the rare presence within the conglomerate of boulders of grey, calcareous mudstone, some dark grey 'tube bed' rock and at least one ferruginous ammonite internal mold. This lithology is characteristic of the Darwin area Cretaceous. Most of the material is unlateritised. Taking into account the fact that at Dripstone Caves, some 3 miles south-west of Lee Point, the lateritised Cretaceous phosphorites dip gently northwards below sea level, and that at Gunn Point the laterite profile extends to approximately high water mark, it seems evident that northwards from Dripstone Caves the phosphorite beds are unlateritised and that the phosphorite pebbles in the beach conglomerate were derived from these beds by cliff or submarine erosion. In this respect it is very likely that the manganiferous pebbles are also derived from within the Cretaceous succession.

Pontifex (1965) described Lee Point phosphorite pebbles submitted by Turner. It should be noted, however, that 15% of the sample examined by Pontifex consisted of fragments of igneous rock none of which have been found at Lee Point or in its vicinity. It can only be assumed that the sample submitted was contaminated with material other than from Lee Point.

Three pebbles from Lee Point were spectrophotometrically analysed by G. Wilraith, Mines Branch, Darwin. They contained 32.0%, 23.0% and 20.0% P_2O_5 respectively. Many pebbles assayed by the Shapiro test were found to contain about 27% P_2O_5.

APPENDIX 6.

PHOSPHORITES ON BATHURST ISLAND

by

K.J. Kemezys & A. Taube.

In 1960 and 1961, Oil Development, N.L. drilled two continuously cored diamond drill holes on the south coast of Bathurst Island (see Plate 1) within C.P.8, N.T. The core is stored at the Mines Branch core library in Darwin. After the discovery of phosphorites within the Cretaceous succession in Darwin, the core from the two Bathurst Island diamond drill holes was re-examined with particular attention to the occurrence of phosphorite.

Bathurst Island No. 1 Well is 828 feet deep, No. 2 Well is 1,024 feet deep. Both wells terminated within Cretaceous (Cenomanian) sedimentary rocks. The rocks consist predominantly of mudstones and siltstones.

Cores from the two wells were examined for phosphorite with the aid of acid ammonium molybdate reagent. Any rock type other than mudstone or siltstone was carefully examined and all of it (except one non-phosphatic sandstone band) assayed for phosphate. It was found that:

1. All the phosphatic material is hard relative to the very soft mudstones and siltstones.

2. The phosphatic material varies greatly in its properties and neither colour, hardness, reaction with acid or with ammonium molybdate reagent is a reliable guide for estimating the phosphate content.

3. All the phosphatic material is nodular (this would include the limestone core; Daly, 1956, records from cliff sections on Bathurst Island larger limestone nodules than those intersected by the drill). The nodules are sparsely distributed in mudstones and siltstones.

4. Without having carried out detailed confirmatory studies it appears that apart from the limestones, the hardness of the other phosphatic material, which has a similar texture and colour to the enclosing mudstones, is due mainly to cementation of the mudstone with a calcium phosphate mineral.

5. The two wells, though relatively close to each other, differ considerably with regard to the amount and stratigraphic distribution of phosphorites. Micro-paleontological evidence given by Oil Development N.L. in their reports suggests that the two wells penetrated a similar biostratigraphic section and therefore the lithologic differences have to be accounted for by change in facies, differences in core recovery or by some other cuase.

Analysis was carried out spectrophotometrically by G. Wilraith, East Point Laboratory, Mines Branch, Darwin.

O.D.N.L. Bathurst Island Well No. 1

Interval	% P_2O_5	Lithology
220' 0" - 220' 3"	5.0	LIMESTONE, grey, fine-grained, hard. Contains elongate black pellets up to 1 cm long scattered throughout. These pellets assay approximately 16% P_2O_5. (Split).
623' 0" - 623' 0½"	2.7	CONCRETION, grey-brown, fine-grained, hard, even texture, calcareous. (Split).
630' 0" - 658' 0"	2.2	CLAYSTONE, containing two ½" pebbles. Pebbles are grey-brown, fine-grained, even texture, hard, calcareous. (Splits of two pebbles).
631' 10½" - 632' 0"	2.1	CONCRETION, brown-grey, silty, moderately hard. Phosphatic. Not calcareous. Gradational contact to a very hard grey centre. (Split).
634' 11¾" - 635' 0"	2.2	CONCRETION, grey-brown, fine-grained, hard, even texture, calcareous. (Split).
642' 2" - 644' 0"	0.34	LIMESTONE, dark grey, shaly, moderately soft. Cone-in-cone structure. Slickensiding. (Representative).
644' 0" - 644' 5"	3.2	LIMESTONE, grey to grey brown, hard, fine-grained, silty, even texture. (Split).

O.D.N.L. Bathurst Island Well No. 2

Interval	% P_2O_5	Lithology
140' 7" - 140' 9"	1.3	NODULE, phosphatic, light grey-brown, silty, even texture, moderately hard. (Split)
210' 0" - 219' 0¾"	1.2	NODULE, phosphatic, light brown-grey, silty, even texture, moderately hard. (Split).
244' 4" - 244' 6"	4.0	MUDSTONE, limy, phosphatic, grey, hard in centre. Contains small <u>Baculites</u>. (Split).
At - 244' 7"	12.0	PHOSPHORITE nodule, ½" diameter, light brown-grey, embedded in dark mudstone. (Split).
260' 6" - 260' 10"	2.0	LIMESTONE, grey, finely bedded, hard, fine-grained, few fossil fragments. (Split).
269' 4" - 270' 0"	1.7	LIMESTONE, grey, fine grained, finely bedded very hard. Contains calcite vein and shell fragments. (Split).
At - 271' 8"	8.9	NODULE, phosphatic, black, hard, even texture. Arcuate fragment ½" long with striations. Occurs at base of sequence of highly plastic shales. (Whole fragment)

At - 355' 3"	9.2	LIMESTONE, concretion, $\frac{3}{4}$" diameter. Consists of dark grey, very fine-grained, hard limestone. Contains 1 mm round and elongate phosphorite pellets. (Split).
368' 8" - 369' 8"	8.3	MUDSTONE, light grey, soft. Contains three $\frac{1}{2}$" phosphorite nodules. The nodules are light brown to light grey, fine-grained, very hard. (Split of 3 nodules.).
At - 371' 3"	4.0	NODULE, phosphatic, elliptical, $\frac{3}{4}$" long, light grey, hard, pelletal texture. (Split).
At - 375'10"	5.5	NODULE, phosphatic, irregular $\frac{1}{4}$" diameter brown-black, fine-grained, hard, calcareous. (Split).
395' 6" - 412' 0"	5.5	MUDSTONE, grey, soft. Core recovery very poor. Contains thirty one (31) phosphorite pebbles from $\frac{1}{4}$" to 1" diameter. Irregular shapes, subrounded calcareous, brownish on outside, grey on inside, fine grained, very hard. Some pebbles have translucent brown botryoidal coating. Some pebbles contain bands of glauconitic sand. (Splits of 31 pebbles).
At - 447' 0"	7.6	NODULES, phosphatic, two $\frac{3}{4}$" nodules in mudstone. The nodules look as for interval 395' 6" - 412' 0". (Splits of 2 nodules).
448' 0" - 450' 0"	0.70	LIMESTONE, dark grey, massive, very fine grained, even texture, very hard. Contains some shell fragments and calcite veins. Incipient cone-in-cone structure at either end of core.(Split).
450' 0" - 450' 3"	1.55	NODULE, phosphatic, dark grey, very fine-grained, even texture, very hard. Probably a pebble or nodule. Contains bands of glauconitic sand. (Split).
At - 487' 0"	0.80	NODULE, phosphatic $\frac{3}{4}$" thick, light brown, silty, hard, slightly calcareous. Contains fossils. (Split).
At - 510' 6"	5.1	NODULE, phosphatic, $\frac{3}{4}$" diameter, dark grey inside, with dark brown coating, fine-grained, even texture, hard, fossiliferous. (Split).
At - 517' 2"	1.7	As above (at 510'6") $\frac{1}{2}$" diameter. (Split).
523'11" - 524' 2"	5.7	CONCRETION, phosphatic, grey-brown to grey at centre, fine grained, even texture, very hard. Gradational contacts to mudstone. Very slightly calcareous. Contains some glauconite grains. (Split).
526'10" - 527' 0"	6.1	NODULES, phosphatic, in mudstone. Four nodules irregularly shaped $\frac{1}{4}$" - 1" diameter, fine-grained, dark grey, even texture, very hard. Brownish translucent coating. Contains shell fragments. (Splits of 4 nodules).

554' 6" - 556' 6"	0.87	NODULES, phosphatic in mudstone. These nodules ½" - 1" diameter, light brown grey fine-grained, even texture, hard, non-calcareous. (Splits of 3 nodules).
586' 7" - 586' 8"	1.56	MUDSTONE, phosphatic, light grey-brown, moderately hard, silty, even texture, very slightly calcareous, gradational contact to non-phosphatic mudstone. Contains shell fragments. (Split).
590' 4" - 590' 6"	4.5	MUDSTONE, phosphatic, light grey-brown, grading to grey in centre, medium hard, silty, glauconitic, non-calcareous. Gradational contacts with non-phosphatic mudstone. (Split).
670'10" - 671' 0"	2.3	MUDSTONE, phosphatic, brown-grey, fine-grained, even texture, hard. Contains one elongate ¼" black pellet, probably more phosphatic. (Split).
At - 759' 6"	2.5	NODULE, phosphatic, light brown grey, fine-grained, even texture, hard. (Split).
801' 0" - 801' 1"	2.7	MUDSTONE, phosphatic, brown-grey, finely banded, hard. (Split).
830' 6" - 831' 0"	-	SANDSTONE, brown-grey, fine-grained, even texture, no sedimentary structure apparent. Non-phosphatic.
902 ' 0"- 902'3"	2.9	NODULES, phosphatic, three nodules in mudstone, 1" - ½" diameter. Grey, fine-grained, even texture, some with brown botryoidal coating. (Splits of 3 nodules).
At - 920' 0"	2.6	LIMESTONE, nodule in mudstone, 1½" diameter, grey, even texture, some with brown botryoidal coating. (Splits of 3 nodules).
At - 922' 0"	2.6	NODULE, phosphatic, in mudstone, 1" diameter grey, fine-grained, even texture, very hard. (Split).
922' 0" - 933' 0"	3.3	NODULES, phosphatic, in mudstone, three ½" nodules, dark grey, fine-grained, calcareous even texture, very hard. (Splits of 3 nodules). Very poor core recovery.
982' 6" - 983' 0"	5.0	LIMESTONE, dark grey, fine-grained, even texture, hard. Contains ammonites, belemnites and other fossils. (Split).
990' 0" - 991' 7"	3.4	LIMESTONE, dark grey, fine-grained, even texture, moderately hard, silty. (Split).
1004'0" -1004' 6"	2.9	LIMESTONE, dark grey, fine-grained, even texture, hard. Contains one portion of a much larger keeled ammonite. (Split).
1013'8" -1014'4"	3.1	LIMESTONE, dark grey, fine-grained, even texture, hard. (Split).

APPENDIX 7.

BATHURST ISLAND AUGER SAMPLING PROJECT

by

K.J. Kemezys.& A.Taube.

In the dry season of 1961, Oil Development, N.L. carried out an auger drilling programme to sample unweathered Cretaceous rocks below a layer of Tertiary sands on Bathurst Island for the purpose of obtaining calcareous foraminifera. One sample from each of the 79 holes drilled is stored in the Mines Branch core library, Darwin. The samples are assumed to be from the bottom of each hole.

Because of the current interest in Cretaceous phosphorite, the auger hole samples were logged and tested for phosphate content. None of the samples were found to be phosphatic.

Only nine of the 79 holes drilled passed through the Tertiary sands into Cretaceous sediments. The Cretaceous samples are mainly clay, grey to grey-green when unweathered, silty, micaceous, some glauconitic, some sandy.

The Tertiary sands consist generally of light to red-brown, fine- to medium-grained, subangular quartz, generally poorly sorted. Some of the grains have a brown ferruginous coating, the quartz itself being clear to cloudy. Some clayey matrix, usually beige in colour, is present. Heavy minerals noted were chiefly tourmaline, some zircon, and rare garents and rutile. Ferruginous grains are common in the heavy fractions.

A1 SANDSTONE, yellow with red ironstained phases, very fine to silt size, poorly sorted quartz; soft, friable.

A2 SANDSTONE, cream, fine-to medium-grained, moderately well sorted, subangular quartz; soft and friable.

A3 SAND, creamy-yellow, fine-to-medium-grained, well sorted, subangular quartz with some yellow clay matrix.

A4 SILT, greenish-grey, sandy. Contains very fine quartz sand, some glauconite, traces of mica and some fine, thread-like, transparent spicules.

A5 SAND, greenish grey, very fine to fine-grained, poorly sorted, subangular. Quartz clear and cloudy, some ironstained, silty and clayey.

A6 SAND, creamy brown, fine-grained, moderately well sorted, subangular quartz. Some clay matrix.

A7 SAND, reddish brown, fine-to medium-grained, moderately well sorted, subangular quartz. Contains some creamy brown clay matrix adhering to sand grains. Rare glauconite grains.

A8 SAND, red-brown, fine-to medium-grained, moderately well sorted, subangular, clear and cloudy quartz with slight ferruginous coating. Some clay matrix.

A9 SAND, buff, fine-to medium-grained, mostly angular, some subangular grains, moderately well sorted, about 40% of grains have dark reddish brown spotted coating adhering to quartz grains. The quartz is clear and cloudy. Some lithic ferruginous grains and some clay matrix are present.

A10 CLAY, pale pink, silty. Contains some subangular sand quartz grains.

A11 CLAY, pale pink, very sandy. Contains quartz, some mica and ferruginous grains.

A12 SAND, beige, clayey, very fine-grained, well sorted, subangular quartz. Clay matrix white and beige.

A13 CLAY, pale pink, sandy. Sand is poorly sorted, fine to medium grained, subangular quartz. Few ferruginous lithic grains.

A14 CLAY, greenish grey, glauconitic. Contains quartz sand and silt grains.

A15 SAND, red-brown, medium-grained, moderately well sorted, subangular to subrounded, clear and cloudy quartz, some with ferruginous and clayey coating. Few pea size ironstone pebbles.

A16 SAND, red-brown, fine-grained quartz, subangular, clear and cloudy. Generally has ferruginous clayey matrix.

A17 SAND, red-brown, fine-to medium-grained, subangular quartz, moderately well sorted. Grains have ferruginous coating. Contains some clay matrix and some ironstone pebbles.

A18 SAND, light red-brown, fine-to medium-grained, moderately well sorted, clear and cloudy quartz, rarely ironstained. White and brown clay matrix. Contains some ferruginous pebbles.

A19 SAND, as above (A18). Contains rare grains of tourmaline.

32

A20 SAND, banded with white clay. The sand is very fine to fine grained, poorly sorted, subangular quartz. Contains some medium to coarse lateritic grains.

A21 SAND, red-brown, fine-grained, angular to subangular, moderately well sorted. Contains some light brown clay matrix and some ferruginous pebbles.

A22 Sample missing.

A23 SAND, red-brown, fine-grained, subangular quartz, well sorted, ironstained. Reddish clay matrix. Contains some white claystone and ferruginous pebbles. Heavy minerals include zircon, tourmaline and garnet.

A24 SAND, light red-brown, fine-to medium-grained, moderately well sorted, subangular quartz with clay matrix. Contains a few grains of black and red translucent heavy minerals (rutile?).

A25 SAND, light red-brown, clean, fine grained, well sorted, subangular quartz. Contains rare grains of ferruginous material. Heavy minerals include black and brown grains.

A26 SAND, light brown, fine-to medium-grained, moderately well sorted, subangular quartz, some with ferruginous coating. Heavy minerals include tourmaline and garnet.

A27 SAND, light brown, fine grained, well sorted, subangular quartz, usually with brownish coating. Rare heavy minerals include garnet and tourmaline.

A28 SILT, sandy, beige. The sand is fine, subrounded quartz. Contains a few mica grains.

A29 CLAY, grey, slightly micaceous, highly plastic, slightly sandy.

A30 CLAY, grey-brown, silty. Contains mica and some glauconitic grains.

A31 CLAY, dark grey, plastic, silty and sandy.

A32 SAND, red-brown, clayey, fine-grained, poorly sorted, subangular quartz. Grains are coated with clay. Rare heavy minerals include bright orange garnet.

A33 SAND, red-brown, clayey, fine-to medium-grained, poorly sorted, subangular quartz. Contains abundant white and brown clay matrix. Rare heavy minerals include zircon.

A34 SAND, red, fine-to medium-grained, poorly sorted, subangular quartz. Grains are coated with red clay. Contains abundant brown clay matrix. Rare heavy minerals include tourmaline and zircon.

A35 SAND, red-brown, interbedded with pink, sandy clay. The sand is fine to coarse grained, poorly sorted, subangular quartz. Some with adhering clay matrix. Contains coarse grains of ferruginous sandstone and ironstone.

A36 SAND, pink-brown, clayey, fine to medium grained, subangular quartz, poorly sorted. Contains a few ironstone pebbles and grains and a pebble or two of ferruginous sandstone. Rare grains of zircon.

A37 SAND, dark red, fine-to medium-grained, poorly sorted, subangular quartz. Brown clay adhering to grains. Trace of zircon and ferruginous grains.

A38 SAND, brown, fine-to coarse-grained, poorly sorted, subangular quartz. Clay adhering to grains. Heavy minerals are mostly ferruginous.

A39 SAND, red-brown, fine-to coarse-grained, very poorly sorted, subangular quartz. Clay adhering to grains. Contains a few laterite pebbles. Heavy minerals include traces of tourmaline.

A40 SAND, red-brown, clayey, fine-grained, moderately well sorted, subangular quartz. Heavy minerals include rare grains of zircon.

A41 SAND, light brown, ferruginous, fine-grained, moderately well sorted, subangular quartz. Heavy minerals include zircon.

A42 SAND, light brown, fine-to coarse-grained, poorly sorted, subangular quartz, some with clayey coating. Heavy minerals include tourmaline.

A43 SAND, yellow, clayey, fine-to medium-grained, poorly sorted, subangular quartz. Heavy minerals include zircon, tourmaline and garnet.

A44 SAND, pink-violet, fine-to medium-grained, some coarse, poorly sorted, subangular quartz with adhering clay matrix. Heavy minerals include ferruginous grains garnet and zircon.

A45 SAND, pink, very clayey, fine-grained, well sorted, subangular quartz. Heavy minerals include ferruginous tourmaline and zircon grains.

B1 SAND, red-brown, very clayey, fine-to coarse-grained, subangular, poorly sorted quartz. Contains pebbles of ferruginous grains and tourmaline.

B2 SAND, pink-brown, very clayey, fine-to medium-grained, poorly sorted, subangular quartz, clayey coating on grains. Heavy minerals are mainly ferruginous.

B3 SAND, pink, fine-grained. Clear, moderately well sorted, subangular quartz. Heavy minerals include ferruginous and zircon grains.

B4 CLAY, yellow, silty and sandy. Contains some coarse quartz grains and ferruginous pebbles. Heavies include tourmaline and zircon.

B5 SAND, pink-brown, silty, fine-to medium-grained, poorly sorted, subangular quartz coated with yellow clay. Heavy minerals include ferruginous grains, tourmaline and zircon.

B6 SAND, pink, very clayey, fine-grained, well sorted, subangular quartz. Heavies include ferruginous grains, colourless zircon, pale green and black tourmaline and red garnet.

B7 SAND, pinkish brown, clayey, fine-to coarse-grained, poorly sorted, subangular to subrounded quartz. Heavy minerals as above (B6).

B8 SAND, violet-red, fine-grained, clayey, poorly sorted, subangular quartz with clayey coating. Heavy minerals as for B6.

B9 SAND, reddish brown, clayey, fine-to medium-grained, poorly sorted, subangular quartz grains with ferruginous coating. Contains white clay matrix, traces of carbonaceous plant remains. Heavy minerals, mainly ferruginous.

B10	CLAY, red-brown, silty and sandy,with fine-grained subangular quartz.
B11	CLAY, yellow, sandy with fine-to medium-grained subangular quartz.
B12	CLAY, yellow and white, sandy with medium-grained subangular quartz.
B13	CLAY, cream and brown. Contains poorly sorted subangular quartz.
C1	CLAY, grey, sandy, micaceous. Contains poorly sorted subangular quartz, traces of glauconite. Heavy minerals include zircon and tourmaline.
C2	CLAY, pink, sandy. Contains fine-grained subangular quartz.
C3	SAND, red, medium-grained, moderately well sorted, subangular quartz. Clay coating. Contains some cloudy quartz. Heavy minerals include ferruginous grains, tourmaline, garnet and zircon.
C4	SAND, brown, fine- to medium-grained, moderately well sorted, subangular quartz. Heavy minerals as above (C3).
C5	CLAY, sandy, yellow, contains fine-to medium-grained subangular quartz.
C6	SILT, grey, clayey, contains fine subangular quartz.
C7	SILT, grey, clayey and sandy. Contains fine-grained subangular quartz.
C8	CLAY, grey, silty and sandy. Contains fine-to medium-grained subangular quartz.
D1	CLAY, dark grey, highly plastic, contains some quartz sand and silt.
D2	CLAY, dark grey, highly plastic, silty.
D3	CLAY, dark grey, highly plastic, silty.
D4	CLAY, dark grey, highly plastic, silty.
D5	CLAY, dark grey, highly plastic, sandy, contains fine- to medium-grained subangular quartz.
D6	SAND, clayey, brown, shelly. Contains fine, poorly sorted, subangular quartz and shelly micro plankton.
D7	SAND, as above (D6).
D8	CLAY, dark grey, highly plastic, silty.
D9	CLAY, as above (D8).
D10	CLAY, grey and red-brown, sandy. Contains medium grained, subangular quartz.
D11	CLAY, grey and brown, sandy.
D12	CLAY, red brown, sandy. Contains fine-to medium-grained subangular quartz.
D13	CLAY, dark grey, highly plastic, silty.
E1	CLAY, dark grey, highly plastic, sandy. Contains glauconite and rare tourmaline.
E2	CLAY, as above (E1).
E3	CLAY, brown, sandy. Contains abundant fine-to medium-grained, subangular quartz grains, some very fine glauconite grains.

F1	CLAY, dark grey, highly plastic, silty.
F2	CLAY, as above (F1).
F3	CLAY, dark grey, highly plastic, silty.
F4	CLAY, yellow-brown, sandy. Contains abundant, fine-to medium-grained subangular quartz.
F5	CLAY, grey, silty. Contains some quartz sand and glauconite.
F6	CLAY, grey, highly plastic, silty. Some quartz sand and rare glauconite grains.
F7	CLAY, greenish grey, silty. Contains abundant quartz and some glauconite grains.
F8	CLAY, as above (F7).
F9	CLAY, as above (F7).
Mission Sawmill	CLAY, grey, highly plastic, silty.

APPENDIX 8.

Ore Mineralogy Report No. 7

AN EXAMINATION OF NODULAR PHOSPHATE LATERITE FROM RAPID CREEK BEACH (NEAR DARWIN) - NORTHERN TERRITORY

by

I.R. Pontifex.

Sample submitted by K.J. Kemezys.

Location: 6.5 miles north of Darwin Post Office, Rapid Creek Beach.
Co-ords E. 382800 N. 341900.

Registered No: 66230005

Description of sample:

This is a white indurated nodular rock derived from the laterite profile overlying the Mullaman Beds which are of Cretaceous age.

The nodules form about 25% of the rock; they are structureless, white in colour, and have the appearance of rather indurated chalk; their size ranges between 5 mm and 3 cm. The matrix consists of grey and light brown, fine-grained material which cannot be scratched with a knife. It appears to be silicified.

In thin-section the matrix and the nodules were seen to form extremely fine-grained structureless masses, exhibiting no optical properties of the constituent minerals which allows identification. Angular silt-size grains of quartz and lesser amounts of kaolinite (?) form about 10% of the matrix.

X-ray diffractometer analysis

A sample of (i) total rock and (ii) the nodules were analysed on the X-ray diffractometer in an effort to identify the minerals present.

The trace given by the total rock sample is complex but it does indicate the presence of quartz, crandallite and lesser amounts of probable millisite.

The trace given by the nodule material indicates the presence of millisite and crandallite. The relative proportion of these minerals could not be estimated with certainty, but it is likely that crandallite is more abundant than millisite.

There is no indication of the presence of any of the apatite series of minerals in this rock.

APPENDIX 9.

LEE POINT DIAMOND DRILL HOLES

Towards the end of the 1965 - 1966 wet season, two diamond drill holes were put down in the general vicinity of Lee Point to provide additional information on the Darwin phosphorite bed.

In Lee Point D.D.H. 1 the phosphorite bed occurs at approximately the same level as the beach at Lee Point itself and supports the contention given in appendix 5 that the phosphorite pebbles in the beach conglomerate were derived very locally by cliff erosion of the unlateritised Cretaceous succession.

In Lee Point D.D.H.2, the phosphorite bed occurs well within the laterite profile with consequent radical changes in its physical properties and mineralogy. It is important to note that the bed shows up very well in the gamma-ray log (plate 7) indicating that the relatively high uranium content of the phosphorite bed has been unaffected by lateritisation. Dodson (pers. comm.) during geochemical investigation of Proterozoic rocks in the Rum Jungle area noted that uranium is fixed in the laterite zone. Considering that the majority of surface outcrops of Cretaceous rocks in the Darwin region are lateritised, this retention of radioactivity is an important asset to exploration for phosphorite.

LEE POINT D.D.H. 1.

Location: 1:250,000 SD52-4, Darwin; 3,422, 500 yards north 387,000 yards east. Approximate elevation of 90 feet above beach level at Lee Point.

Drilled: Mines Branch, April, 1966.

Interval	% Recovery	Lithology
0' 0" - 20' 0"	40	SAND, pink, white and brown, medium grained, well sorted, very clayey.
20' 0" - 32' 0"	90	CLAYSTONE, white, brown and yellow, soft badly ironstained.
32' 0" - 72' 0"	90	CLAYSTONE, yellowish, brown, some grey, soft.
72' 0" - 89' 7"	100	CLAYSTONE, grey, moderately hard, with vertical jointing.
89' 7" - 90' 3"	?	PHOSPHORITE about 20 nodules from ½" to 1" in size. The nodules are grey, very hard, irregular in shape. (Nodule bed).
90' 3" - 90' 8"	100	MUDSTONE, grey, hard, phosphatic, glauconitic with 'tube rock' texture. (Tube bed).
90' 8" - 91' 1"	100	MUDSTONE, grey, hard, phosphatic, glauconitic, with 'tube rock' texture. Contains sparse PHOSPHORITE nodules. (Nodule bed).
91' 1" - 91' 8"	100	MUDSTONE, grey, hard, phosphatic, glauconitic, with 'tube rock' texture. (Tube bed).
91' 8" - 131' 4"	100	MUDSTONE, grey, moderately hard, with fine white, calcareous speckles.
131' 4" - 133' 6"	100	GLAUCONITIC SANDSTONE, very clayey, grey to greenish grey, hard. Contains numerous pebbles of quartz quartzite and phyllite towards base.
	UNCONFORMITY	
133' 6" - 157' 8"	100	PHYLLITE, grey to light greenish grey, hard; bedding slightly contorted, approximately 60° to core axis.
	END OF HOLE	

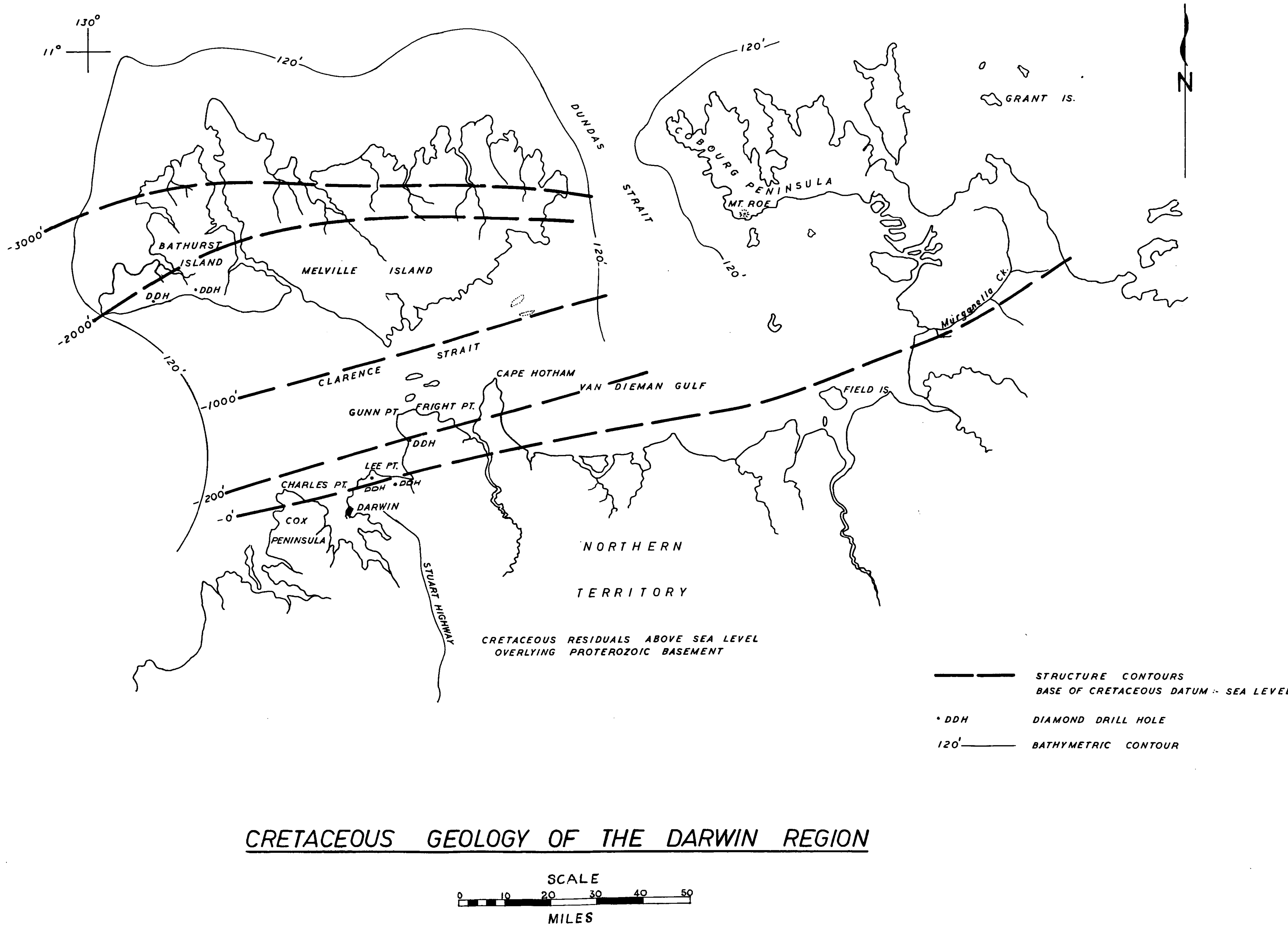
LEE POINT D.D.H. 2

Location: 1:250,000, DS52-4, Darwin; 3,421,500 yards north, 395,000 yards east.

Drilled: Mines Branch, April, 1966.

Interval	% Recovery	Lithology
0' 0" - 22' 0"	40	CLAY, brown, soft with white, yellow and red phases. Unevenly weathered and ironstained. Core badly fragmented.
22' 0" - 22' 6"	50	PHOSPHORITE, 3 or 4 irregular 1" nodules. Dark brown, silicified and ironstained, very hard.
22' 6" - 30' 0"	60	CLAY, brown and white, soft, unevenly weathered and ironstained. Core badly fragmented.
30' 0" - 31' 4"	100	CLAYSTONE, white, silty and sandy, very hard (silicified).
31' 4" - 46' 0"	45	CLAYSTONE, white kaolinitic, soft, free from impurities.
46' 0" - 53' 0"	50	CLAYSTONE, white to greyish white, kaolinitic, free from impurities.
53' 0" - 82' 6"	73	CLAYSTONE, grey to dark grey, soft with thin shaly and glauconitic phases towards base.
82' 6" - 84' 6"	100	GLAUCONITIC SANDSTONE, dark greenish grey, soft, pyritic, clayey. Contains small rounded pebbles of quartz, quartzite and black shale towards base.
	UNCONFORMITY	
84' 6" - 102' 0"	95	MUDSTONE OR WEATHERED SLATE, dark grey, carbonaceous, moderately hard, even texture.
102' 0" - 120' 0"	85	SLATE, black, hard, massive, poorly bedded, slightly calcareous or dolomitic. Well developed cleavage parallel to core, bedding at approximately 70^{o} to core.

END OF HOLE



CRETACEOUS GEOLOGY OF THE DARWIN REGION

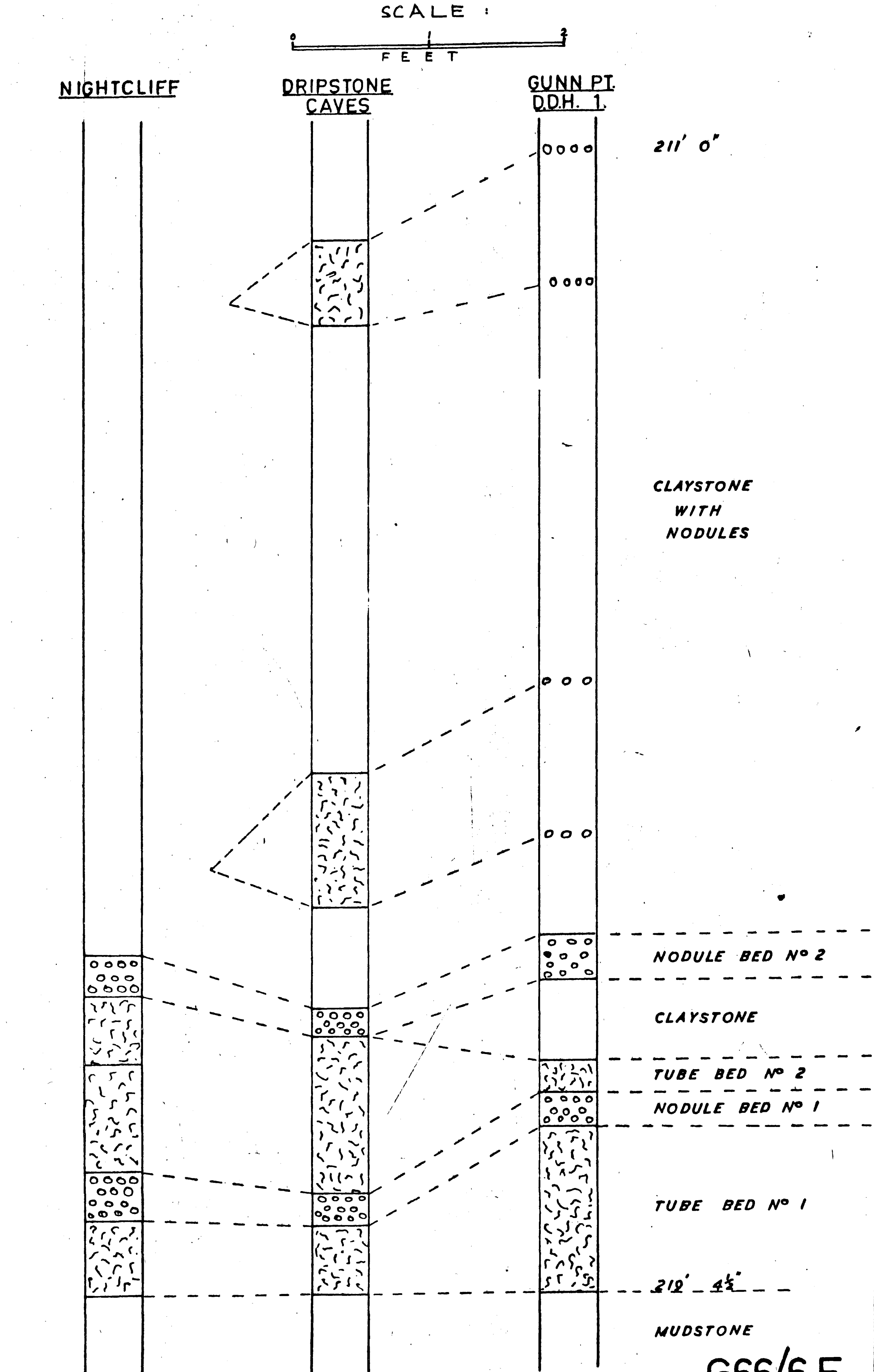
COMPILED BY RESIDENT GEOLOGICAL SECTION. DRAWN BY MINES BRANCH DRAUGHTING OFFICE, DARWIN N.T. APRIL 1966.

To accompany record 1968/52

G66/7D

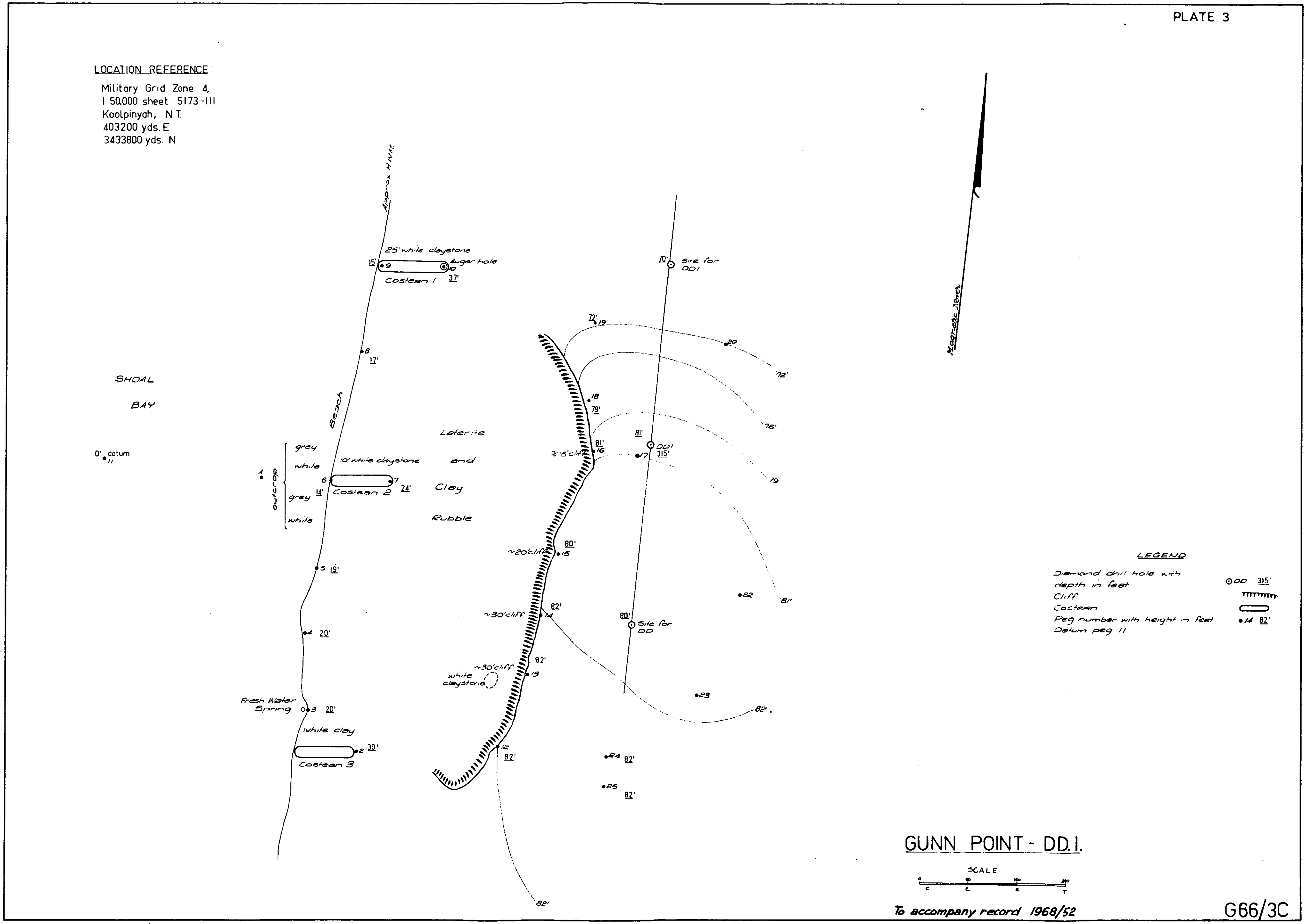
PLATE 2

CORRELATION OF DARWIN AREA PHOSPHORITES



Compiled by Resident Geological Section
Drawn by Mines Branch Drawing Office. March 1966. Darwin, N.T. To accompany record 1968/52

G66/6 E



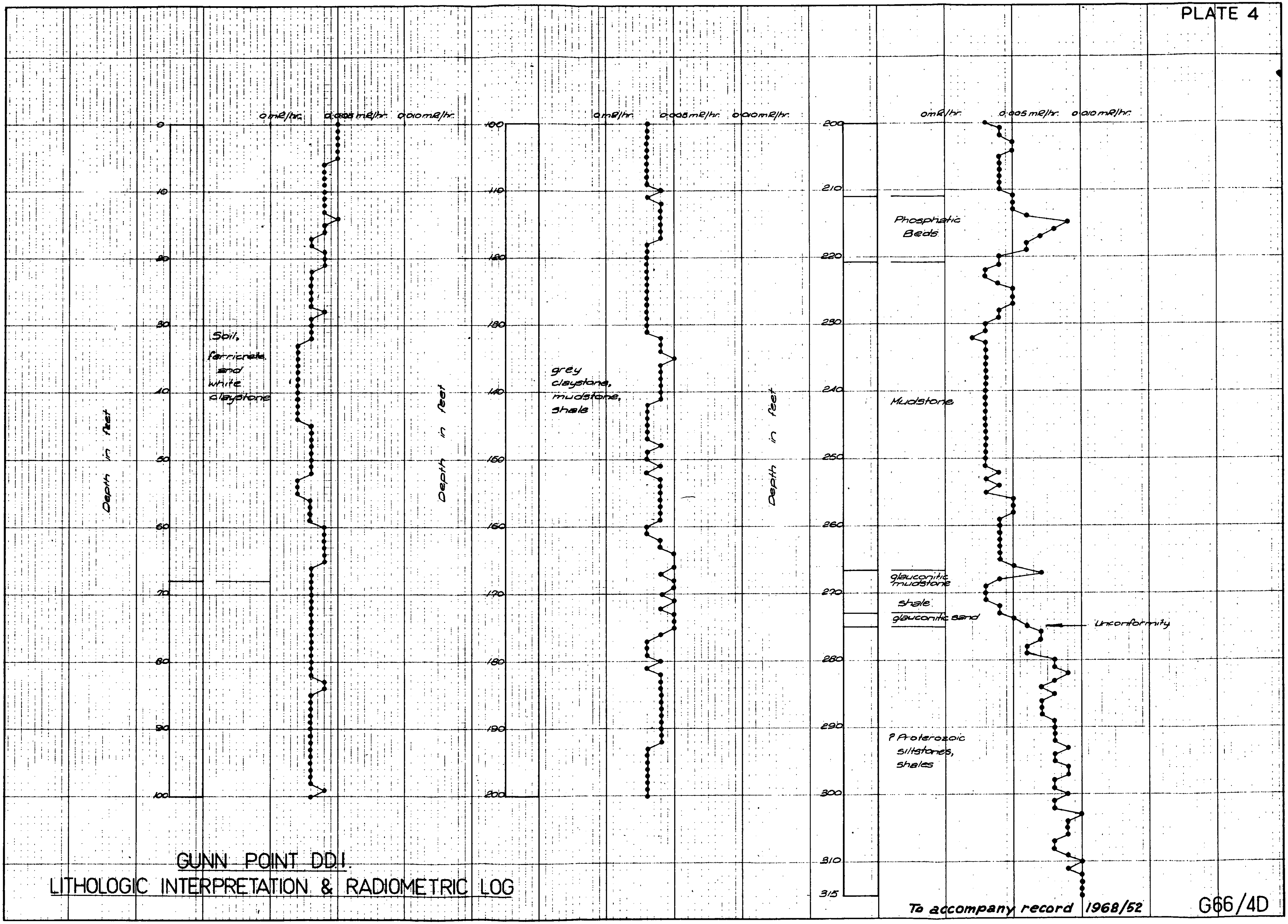
GUNN POINT - DD.I.

SCALE

To accompany record 1968/52

G66/3C

PLATE 4

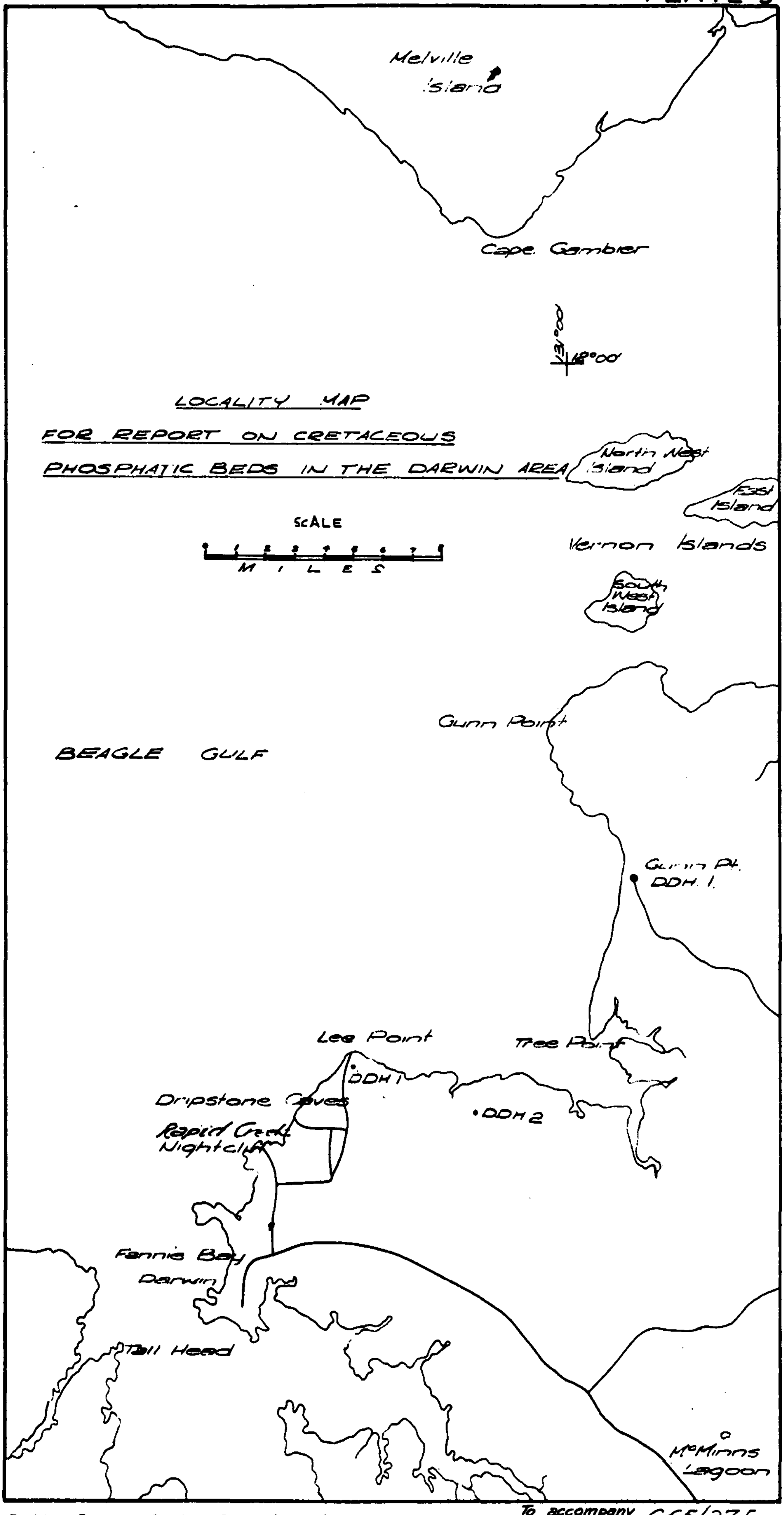


GUNN POINT DD1

LITHOLOGIC INTERPRETATION & RADIOMETRIC LOG

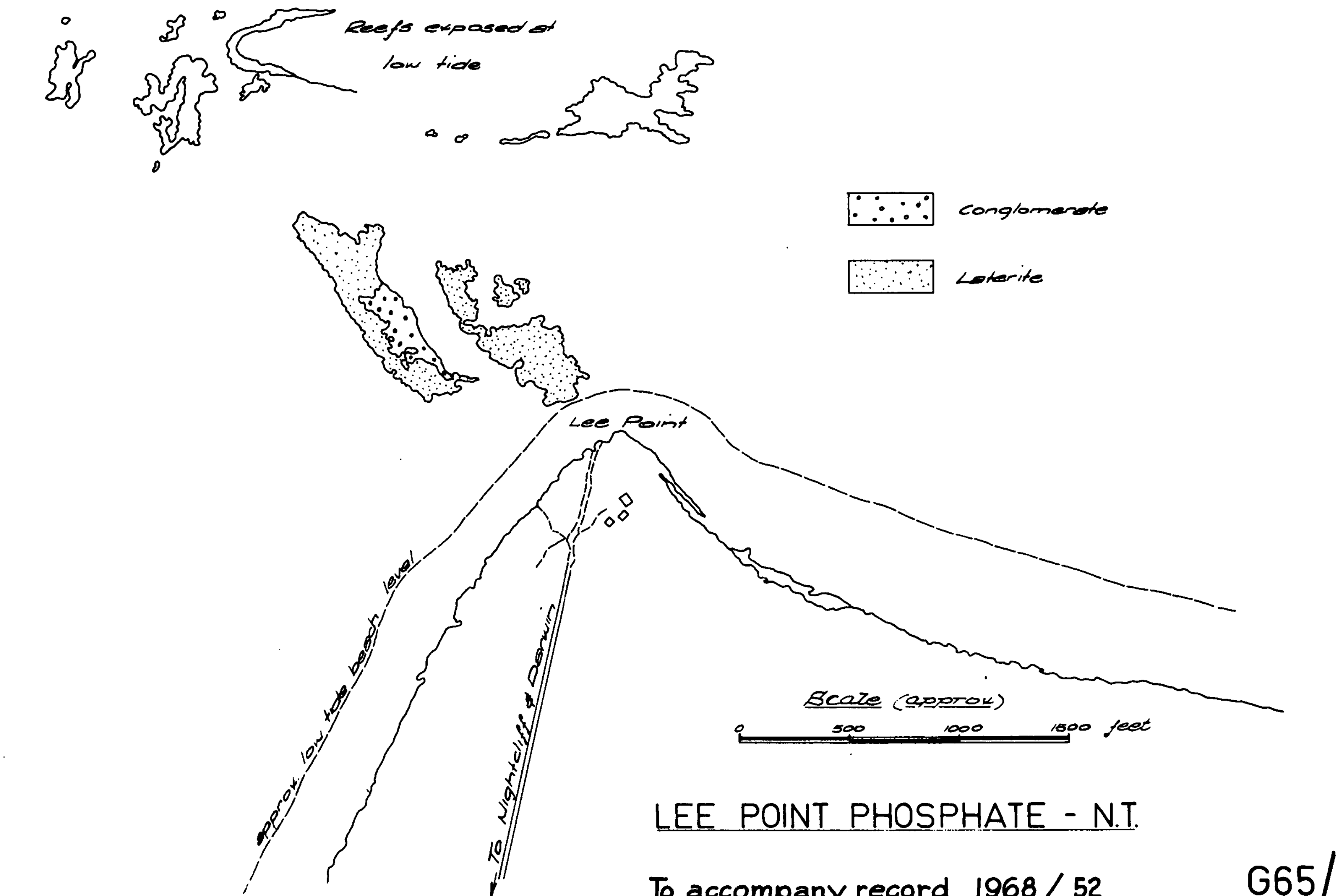
To accompany record 1968/52

G66/4D



Resident Geological Section – Draughting Office : Mines Branch, N.T.A. To accompany record 1968/56 G65/27E.

PLATE 6



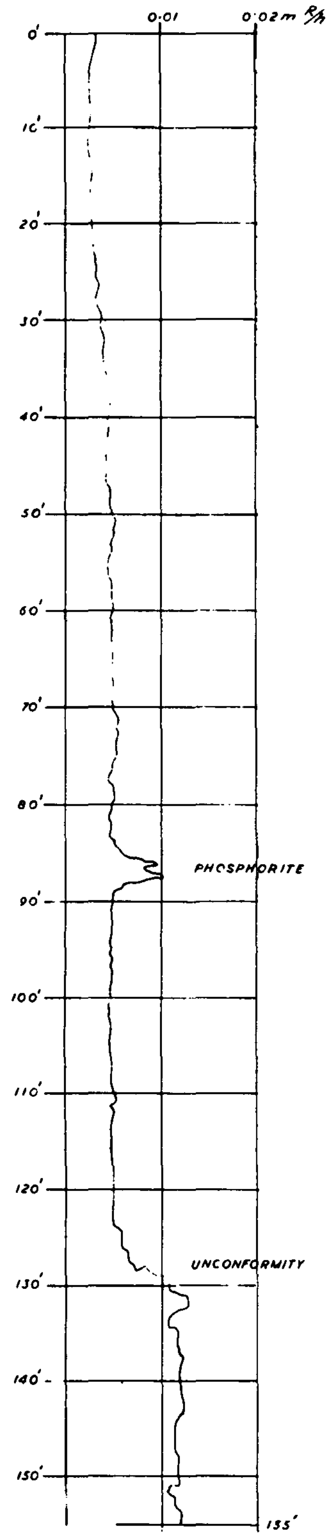
LEE POINT PHOSPHATE - N.T.

To accompany record 1968 / 52

G65/10E

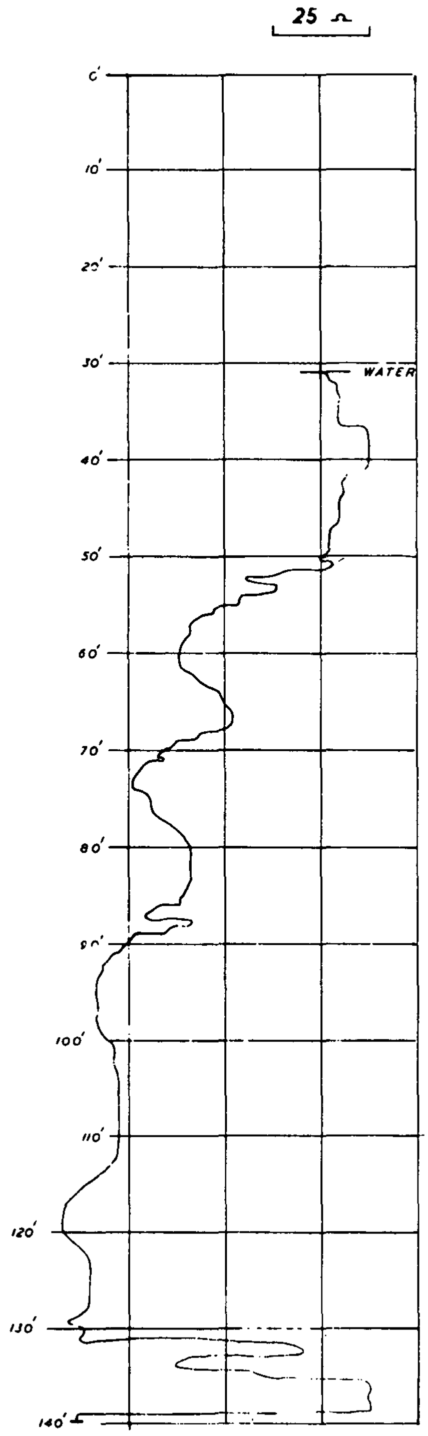
LEE POINT D.D.H. I.

GAMMA-RAY



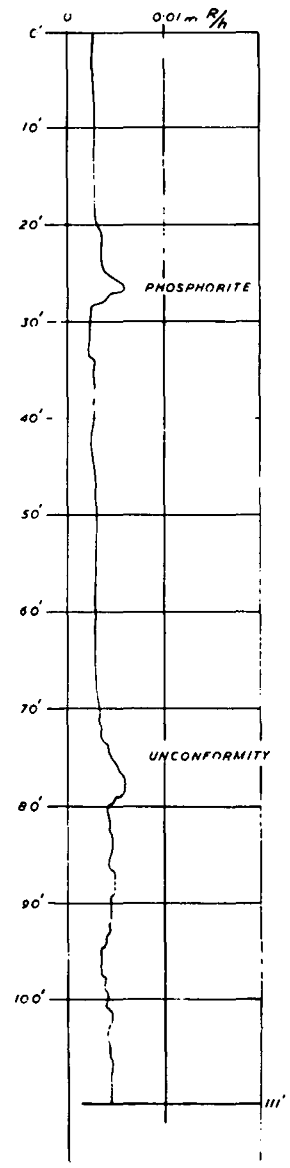
LEE POINT D.D.H. I.

RESISTIVITY



LEE POINT D.D.H. 2.

GAMMA-RAY



GEOPHYSICAL LOGS OF DRILL HOLES

LEE POINT, N.T.

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