This final report summarises the work done in connection with E.L. 2067 over almost four years. The detail of work done and results obtained is given in each of the annual reports which are attached.

The aim of the exploration was to find limestone suitable for the manufacture of lime or cement;

(a) for quicklime manufacture a high grade stone with a magnesia content less than 4% MgO is required. Plans to install a lime calcining plant to produce lime for use in the uranium mining industry have been shelved due to the uncertain future of the industry and the possible use of limestone instead of lime for neutralising wastes. This last factor led to the surrender of the E.L. as the search was directed to shell occurring closer to Nambalek.
(b) for cement manufacture - this was, and still is, a future need.

The grade of limestone can be as low as 78% calcium carbonate, but
the magnesia must be under 2.5% and preferably under 2%.

The difficulty of finding suitable limestone in this part of the Daly
River Basin was not, at first, realised. Surface outcrops of limestone
are quite extensive, but samples taken from these, relate poorly with
the material below ground. Deposits are highly altered due to weather-
ing, resulting in dolomitisation and silicification.

The first work was done in the northern section of the tenement.
Fifteen holes were drilled, little limestone was found except adjacent
to outcrops, the western part of the tenement is mantled with a sequence
of shales. In the eastern section much of the limestone was found to be
highly dolomitic. Later work was concentrated in the eastern section,
with much of the western area being dropped off at the time of Licence
renewals.

A second program of sampling and drilling in the eastern area showed
promising surface samples but subsurface samples showed low grade or
high magnesia contents. A sample of the surface material was sent to
the United States for testing in a calcining plant. The limestone was
suitable for burning provided low grade material could be eliminated.
At this stage at the end of the first year, the position did not look very promising and a thorough review at alternative sources and processes was made. Sources included coral debris from N.W. Vernon Islands and several overseas limestones; the latter were studied because of the very high cost penalty in processing and transporting the rather low grade material from E.L. 2067.

Further surface samples were taken to assist indentation of targets for more intensive exploration. Three bulk surface samples were prepared and sent to a laboratory in Victoria and to equipment manufacturers in Germany and Switzerland to see if the stone was suitable for burning in highly sophisticated fuel efficient kilns to see if the overall economics could be improved.

In the first two years the work was essentially of a prospecting nature. No geological mapping was undertaken, although photogeological maps were prepared and used for outlining occurrences of limestone. The work in the third year was directed to a geologically biased programme of mapping, sampling and interpretation of the sedimentary environments in the basin as a whole and the mining tenement in particular. Of special interest was the identification and correlation of limestone units over considerable distances with a view to further exploration elsewhere in the basin.
The services of Dr. B. Daily were used to correlate limestone from various parts of the basin and to interpret the sedimentary environments in which the limestone occurred. Palaeontological examination of the fossil content of the limestone was commenced.

The above work resulted in the identification of mappable, litho and biostratigraphic units. The results are detailed in the report to 10/6/82.

Results of the burning properties of the three bulk samples showed that all three were suitable for use in a vertical kiln.

Work in the fourth year by Dr. B. Daily showed some correlation of the limestone from E.L. 2067 with limestone from other areas of the Daly Basin. This suggests that on economic grounds, future work be concentrated in areas nearest to Darwin.

In conclusion, the work carried out enabled recognition of a stratigraphic sequence of carbonates, identifiable across the licence area. Unfortunately, the suitable limestone occurs in strata only 2 - 5 metres thick. The limestone is only marginally suitable for lime manufacture, and because of the long distance from Darwin and Narbalek, the area has been abandoned. Limestone suitable for cement making occurs in slightly thicker strata, but grade control would be very complex due to dolomitisation and silicification.
Total expenditure on the area covered by this Exploration was $82,146.

Yours faithfully,

[Signature]

M.I. MOORE,

Group Technical Superintendent

Attachments: Report for Year Ended 11/6/80
11/6/81
10/6/82
10/5/83

8th August, 1983
Results to the end of the third year (11/6/82) had shown rather small quantities of limestone suitable for cement manufacture and even smaller quantities suitable for quicklime manufacture.

Palaentological studies were to be undertaken to determine whether samples taken from E.L. 2067 could be correlated with samples taken from other parts of the Daly Basin closer to Darwin.

These studies reported by Dr. Brian Daily of the Adelaide University in the attached report of 2/11/82 confirm the possibility of such correlation.

In view of the relatively poor occurrences of suitable limestone, the distance from Darwin and the likelihood that the quicklime market might disappear, it was decided to suspend work and surrender the Exploration Licence.
Expenditure in the period was -

Dr. B. Daily
Mr. L.G. Nixon
Management

$892
$1,098
$2,050
$4,040

Total

This makes the total expenditure in the Licence area $81,396.

Yours faithfully,

M.I. MOORE,

Group Technical Superintendent.

8th August, 1983
ADLAIIDE BRIGHTON CEMENT LTD.

REPORT

ON

CAMBRIAN LIMESTONES

DALY RIVER BASIN, NORTHERN TERRITORY

BY

DR. BRIAN DAILY

GEOLOGY DEPARTMENT

UNIVERSITY OF ADELAIDE

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CAMBRIAN LIMESTONES, DALY RIVER BASIN, NORTHERN TERRITORY

by

DR. BRIAN DAILY, GEOLOGY DEPARTMENT, UNIVERSITY OF ADELAIDE.

INTRODUCTION

This report summarised the results of a helicopter survey carried out jointly with L.G.B. Nixon (9th to 14th February, 1982) to examine the Cambrian and Ordovician limestones of the Daly River Basin, Northern Territory. It also incorporates later palaeontological studies undertaken on samples collected during that trip and their correlation with surface samples collected by L.G.B. Nixon from EL 2067 (see reports by Daily - 24/6/81 and 6/1/82) and drill core samples from EL 1373 (Daily 4/10/82).

DEPOSITS INSPECTED AND/OR SAMPLED

Possible Ordovician carbonates were inspected but were found to be siliceous and dolomitised and are not discussed further.

1. MOTTLED LIMESTONES ADJACENT TO THE DALY RIVER ROAD (EL 1373)

Macroscopically these carbonates contain abundant eocystids and algal balls of Girvanella. They are partially dolomitised, heavily stylolitised, and contain variable amounts of silt. A detailed sampling program would be necessary to evaluate the Ca/Mg ratio of such carbonates as dolomitisation is laterally and vertically variable. This recommendation is supported by the variability of this ratio in the analyses of the purer carbonates in N/C No. 7, DDH No.1 from EL 1373.

2. MOTTLED LIMESTONES, NORTH WEST PORTION OF EL 1426

Mottled dolomitic and silty limestones containing fragments of trilobites and eocystids occur in a trench and sinkhole in the
northwest part of EL 1426. A green calc-shale with trilobite fragments is stratigraphically below the mottled, biscuity and extensively dolomitised limestones. The deposits are too impure to consider further as a source of suitable limestone. No correlation can be made with limestones examined in other parts of the basin.

3. **MOTTLED LIMESTONES, CENTRAL WESTERN PORTION OF EL 1747**

A traverse was made across strike in variably dolomitised mottled limestones forming high karst towers in EL 1747 (Fenton NW). Associated limestone breccias were interpreted as Cambrian karst fills.

To the south, another deposit of dolomitised mottled limestone with interbeds of laminated to wavy bedded dolomite limestone was examined (Fenton, south of NW).

Both deposits were regarded as too impure to warrant further work.

4. **CAMBRIAN LIMESTONES IN EL 1748**

Three separate deposits of limestone were inspected in EL 1748.

(a) Low outcrops of limestone breccia containing worm burrows and eocystids were examined adjacent to the road in the central-northern portion of EL 1748. To the south high karst towers of mottled, dolomitic and silty limestone outcropped.

Several large blocks of limestone with bedding orientation 60° to normal bedding were associated with limestone breccias and possible vadose silt suggesting a paleo-karst fill of Cambrian age.

(b) About 1.5 Km to the north west low outcrops of coarsely crystalline limestone (sample EL 1748 (2) ) contained conspicuous phosphatic shelled brachiopods and dolomitised
calcereous shell fragments.

An acetic acid residue was rich in the phosphatic brachiopods Lingulella and acrotretids, dolomitised remains of the calcereous sponge Chancelloria and ossicles of eocystids. Traces of the mineral glauconite suggest deposition under reducing conditions.

Laterally a short distance away two samples of reddish limestone were collected and processed in acetic acid. Sample EL 1748 (2a) contained abundant fragments of phosphatic shelled brachiopods including Acrothele and acrotretids, together with glauconite infilled moulds of Chancelloria and hyolithids. Sample EL 1748 (2b) contained mainly fragments of a species of the phosphatic brachiopod Westonia. This species is identical to that found in red limestones collected by L.G.B. Nixon (Samples E/4 and E/4a) from EL 2067 and together with other fossils allows direct correlation of the two deposits, i.e. the red limestones outcropping in or near the sinkholes in EL 1748 and EL 2067 are of the same age and facies. These two deposits are 80 Km apart, and thus the nearer of the two to Darwin, namely the EL 1748 deposits, are worthy of further investigation. Step out drilling, updip from the outcropping deposits, is warranted to test the quality of the carbonate succession with a view to exploitation of appropriate intervals.

(c) Silicified specimens of Archaeocyatha occur in mottled, dolomitic and siliceous limestones, approximately 6 Km south-south-west of the previously discussed deposit (b). The remoteness and poor quality of the carbonates make them unsuitable for the company's needs.
5. CAMBRIAN LIMESTONES IN EL 2067 AND EAST THEREOF

Several limestone outcrops in EL 2067 and east thereof were inspected and sampled with the view of correlating them with similar limestones in company leases nearer to Darwin. The geological map (Fig 7/4) produced by L.G.B. Nixon provided a sound base for the investigations.

The crystalline basement on which the Daly River Group was deposited outcrops on or to the east of the track cutting the lease. Just west of the track the basal Daly River Group is comprised of grey mottled, variably dolomitised and siliceous, silty limestone with at least three bands containing the calcareous alga Girvanella. No diagnostic fossils were seen in outcrop but the colour of the rock, its foetid smell when struck, and the presence of disseminated pyrite, indicate deposition in a reducing environment. As pointed out previously (Daily, 4/10/82) these bands may correlate with the Girvanella - bearing mottled limestones outcropping in EL 1373 and those intersected in N/C No. 7, DDH No. 1, EL 1373, which presumably lie close to the base of the Daly River Group in that area.

All other outcrops examined in the area are stratigraphically above the near-basal Girvanella - bearing mottled limestones except for a prominent mass of ferruginised limestone. This was inspected in the vicinity of a stockyard some 2.5 Km north-west of the Girvanella limestone locality. It probably represented the same horizon as the latter.

Five sections were made across the strike of the limestone beds in areas covered by the inset figures 2, 3 and 4 of Fig. 7/4 of Nixon (10/1/81), an area 2 Km east-south-east of Fig. 4 (Daily 24/6/81) and a section approximately 4.5 Km south east of the latter. It is clear that the stratigraphic succession is the same
in all areas and this is substantiated by the available fossils seen in outcrop. Of significance is the fact that the red coloured silty limestones which are interbedded in blue-grey limestones correlate with similar reddish limestones found outcropping in EL 1748, 80 km to the north-west. Consequently, it seems desirable that additional work be carried out in the latter area because of economic considerations.

6. CAMBRIAN LIMESTONES, DOUGLAS RIVER, SOUTH-WEST OF EL 2052.
Mottled limestones with Archaeocyatha, wavy to flat algal laminated limestones associated with intraformational limestone conglomerates and diagenetic chert nodules and layers occur along the banks of the Douglas River near the south-west portion of EL 2052. Associated with the blue-grey limestones are red coloured limestones and silts and also breccia. It is possible that they represent a karst fill produced by renewed transgression. Hyolithids occur in some of the limestones. The oldest beds seen in the section examined are red calcareous siltstones. The section was seen to be tectonically warped and faulting may be present.

CONCLUSIONS
It is clear that all the Cambrian carbonates examined were deposited under shallow water conditions. There is also evidence to suggest breaks in deposition represented by periods of karst development followed by renewed transgression. The available palaeontology allows correlation of some of the carbonates over the limits of the basin studied. Notable is the correlation of sections in EL 1748 with those previously reported upon by Nixon (10/1/82) and Daily (6/1/82) from EL 2067. This is of practical significance as it shifts the site of interest
closer to Darwin. However, the major problem that must be faced is maintenance of a suitable grade of limestone, both laterally and vertically. The vagaries of dolomitisation, silicification and ferruginisation are particularly evident in all areas studied and only tight sampling of prospective areas will ameliorate the situation. Added to this organic phosphate, present in many of the limestones as phosphatic shell fragments, could prove a problem if the present of $P_2O_5$ is deleterious to the final product produced by the company.
The 25.5 m hole was drilled through early Middle Cambrian limestone and siltstone. From the surface downwards the drill penetrated pale grey-brown mottled silty limestone containing abundant stylolites and horizons with chert nodules, glauconite and shelly fossils. The mottled limestone passes downwards into bedded grey limestone and siltstone below 20.11 m and at 25.35 m depth passes into purple siltstone carrying pyrite.

Five samples were selected for palaeontological examination. They were leached with acetic acid and residues examined under a binocular microscope.

Sample 1 - depth 7.65 m - partially silicified limestone containing balls of the alga Girvanella, spicules of the calcareous sponge Chancelloria, the phosphatic brachiopod Lingulella and indeterminate fossil fragments.

Sample 2 - depth 10.44 m - partially dolomitised pale grey-yellow limestone with poorly silicified fragments of the gastropod Latouchella.

Sample 3 - depth 19.20 m - a glauconitic and pyritic fossiliferous mottled limestone, pale grey in colour but with yellow patches of dolomitised limestone. The rock contains sections of trilobites and conical tubes of the hyolithid Biconulites and other indeterminate fragments.

Sample 4 - depth 19.50 m - a stylolitised pale grey mottled limestone with carbonate intraclasts in a fossiliferous trash bed. Fossils include cross-sections of trilobites, eocystid ossicles and Biconulites. Glauconite grains are abundant and pyrite is visible in the fresh rock.

Sample 5 - depth 19.96 to 20.11 m - a conspicuously fossiliferous mottled pale grey limestone containing eocystids, hyolithids, brachiopods and other indeterminate fragments.

The sequence is interpreted as a transgressive limestone above a regressive purple siltstone, the latter laid down under oxidising conditions. With the transgression, the build up of benthic communities produced sufficient organic material to allow a reducing environment to prevail below the sediment/water interface. This gave rise to the authigenic minerals glauconite and pyrite within the shallow marine deposits. A possible shallowing of the sea is indicated by the large algal balls of Girvanella found in the upper levels of the hole. The age of the limestone is early Middle Cambrian as indicated by the presence of Latouchella sp. There are no fossils present which allow correlation of this predominantly mottled limestone with the two lots of samples reported upon previously from EL 2067. However, it is conceivable that the drill hole sequence may correlate with the mottled limestones containing Girvanella found in the southeastern part of EL 2067. It should be noted that the latter limestones are close to the base of the Cambrian sequence as basement occurs just to the east. Ópik (1956, p. 37) has stated that "the basal bed is a Girvanella limestone" for the Daly River Basin. However, beds containing Girvanella may have little stratigraphic significance and may merely reflect a marginal facies. Nevertheless, the facies is widespread and was seen in outcrop in EL1373 (run 13, photo 2485) and elsewhere associated with mottled limestones.