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COMMONWEALTH OF AUSTRALIA

6 JAN 1966
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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

1965/149

REPORT ON MAIN CARBOATE SEQUENCE OF WELL LAKE NASH NO.1.
(AMALGAMATED PETROLEUM N.L.)

by

M. Brown

The information contained in this report has been obtained by the Department of National Development, as part of the policy of the Commonwealth Government, to assist in the exploration and development of mineral resources. It may not be published in any form or used in a company prospectus without the permission in writing of the Director, Bureau of Mineral Resources, Geology and Geophysics.

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REPORT ON MAIN CARBONATE SEQUENCE OF WELL LAKE NASH NO. 1 (AMALGAMATED PETROLEUM N.L.)

SUMMARY

Detailed examination of the Lake Nash No. 1 section above 990' depth has shown that the carbonate rocks can be subdivided into 7 lithological units, some of which are sufficiently distinctive and may be laterally persistent enough to be useful markers. The limestone interval may not persist laterally but the interval with silt and clay-rich carbonates of which it forms approximately the lower half, may be more persistent laterally.

Skeletal remains of organisms are moreabundant than previous work would indicate. This applies especially to the dolomites below the limestone interval.

GENERAL

Lake Nash No. 1 well is situated in the Georgina Basin, an area of largely carbonate sediments of Cambrian to Lower Ordovician age. The well was drilled to test the Lake Nash anticline, an east-west trending structure about 8 miles long. The outcropping rocks form part of an extensive outcrop area of dolomite covering much of the central part of the Georgina Basin.

Details of stratigraphy and structure of this area of dolomite are poorly known from surface mapping, partly due to poor exposure, low relief, and superficial cover, and partly to a lack of identifiable fossils. Underground information from bores is thus especially useful.

The Bureau of Mineral Resources has had several continuously-cored holes drilled down to maximum depths of 750' (Milligan, 1963) and some deeper holes with recovery of cuttings and core samples. Detailed petrological studies are made on this material to try to make correlations based on comparison of detailed logs of components, textures, and sedimentary structures. Results from two holes 80 miles apart in an east-west direction (Grg4 and Grg14), have already been recorded and some tentative correlations made (Fehr and Nichols, 1963, Nichols and Fehr, 1964). Lake Nash No. 1 is situated about 45 miles east-north-east of Grg14.

Material from Lake Nash No. 1 well consists mainly of cuttings, with 4 cores about 10' long and about 300' apart. The log submitted by Wolff (1963) shows carbonates down to 990' with underlying siliceous sandstone (with an interbedded dolomite) down to total depth of 1315'. Wolff recognised 4 lithological units; unit A (from surface to 586'), dolomite; unit B (586' to 790'), limestone; unit C (790' to 990') dolomite; unit D (990' to 1315'), sandstones with interbedded dolomite between 1090' and 1160'.

TECHNIQUES

Washed cuttings from all the 10 foot intervals were examined wet under a binocular microscope at magnifications of between X8 and X40. The lithologies were briefly described and their relative proportions noted. Particular attention was paid to depositional textures or structures, and any organic remains. Plastic "button" mounts were made of cuttings from intervals about 40' apart, and thin sections were prepared of cuttings from intervals selected to provide thin sections of all the major lithological types. In addition, oriented thin sections were prepared of each lithology represented in the cores. One half of each of the buttons and half of each uncovered thin section was stained with Alizarin Red S solution, to differentiate limestone and dolomite.

Calcimetry determinations were carried out on ground samples of mixed cuttings from each interval. The volume of CO_2 evolved with dilute HCl after one minute and after nine minutes was used to calculate the approximate percentages of calcite and of calcite plus dolomite respectively.

One ~~grain~~ gram of the powder was then dissolved in warm HCl, the residues dried and weighed and their proportion calculated. The proportion of insoluble residue calculated from calcimetry shows a good correspondence with the direct determination (except for a few minor anomalies which seem to be due to incomplete solution in calcimetry).

Insoluble residues from 38 intervals (selected from maxima and minima and important inflexions of the insoluble residue curve) were examined for mineralogy and grain size, in order to see if there were sufficient variations in mineralogy to warrant an examination of residues from all intervals.

EXPLANATION OF THE LOGS

Results of the study are represented on the enclosed log (plate 1). Where possible the properties of the rocks are represented graphically in several columns. A descriptive log is added for completeness. The quantitative and semi-quantitative logs are smoother than those for wells Grg4 and 14. This is due to the different sampling procedure. For the core holes the plotted points represent spot samples taken as representative of small intervals of uniform lithology. The cuttings samples of this well represent average samples over arbitrary 10' intervals, which can overlap lithological boundaries and may also each enclose several lithologies.

CALCILOG

This gives a semi-quantitative picture of the relative proportions of calcite, dolomite, and insolubles. It brings out the sequence of upper dolomite, limestone, and lower dolomite recorded by Wolff.

Staining of spot samples with Alizarin Red and petrographic study of thin sections indicates that the calcite content of the dolomite units may have been overestimated(possibly due to heat-wave conditions when determinations were made).

INSOLUBLE RESIDUES

Apart from the uppermost 50 ft. of weathered dolomite, chert, and (probably partly residual) silty and sandy mudstones, the insolubles are less than 50% of the rock for any 10' interval.

The total insoluble residue includes both detrital and non-detrital minerals, which have very different significances. For this reason a curve of percentage of detrital components was plotted, using visual estimates of the proportion of detritals to non-detritals (and contaminants, the main contaminants being silica gel from broken fragments of cement plugs, and wood).

The dominant detritals are quartz and clay minerals. The remainder of the mineral suite comprises muscovite, microcline, tourmaline and detrital chert, with few grains of zircon, green biotite, chlorite and ?rutile. Apart from the few small flakes of biotite and chlorite this is a very stable mineral assemblage which could have been derived from earlier sediments (possibly also from very acid igneous rocks). It is worth noting that the sandstones below 990' have a similar mineralogy.

The preliminary examination of the residues showed no obvious changes in the mineral varieties throughout the section apart from variations in clay content (discussed below). A more detailed and quantitative study could perhaps reveal some significant differences useful in defining rock units and, hence for correlation.

Some features of the detrital minerals are worth mentioning at this stage. Microcline almost invariably shows a euhedral and probably authigenic clear overgrowth rim around the original generally cloudy detrital fragments. The rim is nearly always untwinned and in places shows small differences in refractive index and frequently notable differences in extinction angle from the detrital core.

Tourmaline occurs as grains with a wide range of sizes from about .04mm down to tiny prisms .005 x .010 mm. The smaller grains are euhedral prisms, but grains larger than .03mm. show some signs of rounding and abrasion. Fehr and Nichols (1963) regarded tiny euhedra from Grg4 and 14 as probably authigenic because of their lack of abrasion. In the residues from Lake Nash I there seems to be a complete gradation in grain size from smallest to largest and the smaller grains have similar colours to the larger. Hence I consider the smaller euhedra to be probably detrital, the lack of abrasion being a consequence of their small size.

Muscovite occurs as flakes which, in plan, often have well rounded edges. Because of their flaky habit and reduced settling velocity they tend to be larger in diameter than quartz grains from the same residues. The flakes usually rest flat on the cleavage plane in microscope slides and with the low interference colours in this position are easily mistaken for quartz. Closer examination shows a distinctive rim of higher colours around the margin due to the crumpling of the cleavage laminae ~~of~~ at the edges.

GRAIN SIZE OF DETRITALS

In each of the 10' intervals examined, the detritals, apart from some clay and some fine to medium grained sand, show good size sorting in a dominant silt mode with a maximum grain size in some intervals reaching into the very fine sand grade. A log has been plotted of the dominant grain size of the detritals based on visual estimates using an eyepiece scale, from direct observation of the residues and with some comparative observations on thin sections. Estimates from thin sections give consistently lower sizes than from the residues, due to the carbonate minerals, in the thickness of the section, partially covering and masking the edges of the grains.

There appears to be some significant variation in the grain size of the silt mode. The lowest dominant grain sizes occur in the limestone (which also is rich in clay).

In addition to the ubiquitous silt, clay is usually present and some fine to medium-grained sand occurs. Both of these are noted on the log where they have been found (underlined if 50% of residue or more). Fine to medium sand is notable in the section down to 180', in the main interval containing oolith-intraclast dolomites, and near the base of the section. Some of the other minor occurrences may be due to contamination of cuttings with material from higher in the section.

Clay is absent or present only in traces in samples from the main oolith and intraclast dolomite interval. It is consistently abundant (both in proportion to the other residues and as a constituent of the whole rock) in the limestone.

NON-DETRITAL MINERALS

The non-detrital minerals recorded on the log include some normally regarded as diagenetic, and glauconite which is normally regarded as of syn-depositional origin.

Chert is present in the section down to 190' and again at 880' to 890' and 900' to 910'. Otherwise it appears to be absent. The chert from surface down to 190' is probably within the zone of surface alteration and could feasibly be the result of near-surface silicification and not related to the original composition or to diagenetic processes in the carbonate sediments. The chert at 880' to 890' and 900' to 910' occurs in a distinctive lithology and appears to have formed by local accumulation of silica at least in part derived from sponge spicules in the original sediment (see below).

Glauconite is found as small pellet-like aggregates in most intervals between 770' and 930'. It is usually regarded as a reliable indicator of a normal marine environment and is usually (as here) associated with marine fossils.

The occurrence of pyrite appears to be controlled by lithology. It is present usually in grey and dark grey-brown lithologies, probably with a relatively high content of carbonaceous organic material. In cores from the limestone (core 2) it occurs as concentrations along burrows and in places around fossil shells.

Collophane is notably abundant in cuttings from the intervals 830' to 860' and 870' to 920'. In these intervals it occurs as replacements of skeletal fragments, many of which have the shapes of sponge spicules, in places with an axial canal preserved and in places branching. Mr. P. Jones (B.M.R., pers.comm.) has examined some of these in thin section of cuttings from 830' to 860' and suggests that some shapes could correspond to phosphatised spicules of Chancelloria sp. If the collophane has replaced siliceous spicules then the chert recorded from 880' to 890' and 900' to 910' could have been derived at least in part from the replaced spicules. Some shells (probably inarticulate brachiopods) are also preserved in collophane, in the limestone and in some of the underlying dolomites (as in those of core 3). Collophane does not occur in the insoluble residues as these were obtained by solution in warm HCl. It is identified in thin section by its brown colour, very low to zero birefringence, and refractive index > balsam (hence not opal).

GRAIN SIZE OF ORIGINAL CARBONATE SEDIMENTS (WITH NOTE ON NATURE OF ORIGINAL SEDIMENT PARTICLES).

This log is an interpretation of the original sediment grain sizes based on examination of the textures of the rocks which especially in the dolomites, have undergone diagenetic changes. Fortunately, despite the dolomitisation, many textures interpreted as "ghosts" of original sediment particles have been found, including skeletal fragments, ooliths, intraclasts, and pellets.*

*Footnote. Pellet is used here as a general term for near-spherical (usually fine or very fine) sand sized grains of microcrystalline carbonate, and of uncertain origin. "Intraclast" is used here for sand sized particles formed by breaking-up of earlier carbonate sediments. Many of the carbonate sand grains in the arenites have rather low sphericity and incomplete rounding and appear to be intraclasts as defined here. The ooliths in these dolomites have their concentric structure very well preserved. Often there are partial or complete annular cavities, which are thought to be due to preferential leaching of less dolomitic layers. Staining with Alizarin Red shows that some layers have a stronger stain than others.

Where the quantity of sand size material recognised is sufficient to have formed a close packed arenite sediment without mud support, and especially where the grains are set in clear and coarser dolomite, an original mud-free arenite sediment is inferred. Rocks of this type are the abundant intraclast, oolith, and pellet bearing dolomites occurring between 270' and 380'; many of the collophane-rich dolomites between 890' and 920' in which the phosphatised skeletal fragments are abundant enough to have formed a mud-free arenite sediment; and sandy and intraclast-rich dolomites near the base of the section below 950'. Several intervals of the dolomites above 270' show some cuttings with intraclasts or pellets. These are generally not well defined and are set in a cloudy microcrystalline matrix which could be an original mud.

Most of the rocks in the section appear to have been originally carbonate muds. This is most obvious for the paler and more silt-free variety of limestone which in thin section is a near-uniform cryptocrystalline to microcrystalline rock ("micrite" of Folk, 1959) containing shell fragments which show little sign of abrasion. The paler and near-pure varieties of dolomite usually show uniform microcrystalline to very fine crystalline textures with several patches of coarser clear dolomite which often can be seen partially filling vugs. Absence of traces of original carbonate sand grains in rocks of this type is taken as indicating an absence of such grains in the original sediment (i.e. an original mud). Relatively few of the pale dolomites have uniform crystal sizes up to 0.15 mm., with each crystal having a cloudy centre and a clear margin. This simulates an original pelleted texture under the binocular microscope (noted from 480' to 490' interval). An original carbonate mud is indicated for dolomites of core 3 in which thin sections show ghosts of shells which, like those in the paler limestones, show few or no signs of abrasion.

The carbonate, in the silt-rich varieties of the dolomites and limestones, in places shows fairly clear signs of having been composed of small silt-size clots or very fine pellets of clay size carbonate, each of which behaved as an individual sediment particle. Some lamination seen in these rocks is an expression of interlayering of "clotted" and more homogeneous clay size carbonate sediment.

LITHOLOGY

This log is presented as a "percentage of cuttings" log, and designed to stress the original sediment components and textures. Silty carbonates are shown by adding silt symbols to those for the carbonates. Sorted dolarenites are distinguished by double spacing of the standard dolomite symbol. The percentage of cuttings is based on visual estimates only, which may have led to overestimation of traces of distinctive lithologies.

Production of an interpreted lithological log, using the available information from cuttings and the geophysical logs is not very feasible due to the dependence of many of the logs (especially the electric logs) on factors such as permeability and porosity which correlate poorly with lithology. An exception is the gamma-ray log which correlates well with the insoluble residue content but, however, is not of use in locating the positions of distinct lithologies among the "cleaner" carbonates.

"Caving" does not appear to be quantitatively important but seems to have given rise to noticeable traces of distinctive lithologies appearing in cuttings from much lower in the section than where they actually occur. For example, dolomitised oolites and intraclast dolomites resembling those from between 270' and 380' occur in traces in cuttings down to the bottom of the section. Similarly fragments of limestone similar to the main limestone interval occur in cuttings down to the base of the section, and these if due to caving would have produced significant errors in the insoluble residue curve for the "clean" dolomites.

COLOUR

This is represented using one column to show hue and another to show darkness. In general the darker lithologies have high silt and clay contents and give high gamma-ray counts. Dolomites tend to be paler than limestones with similar insoluble residue contents and gamma ray counts. The buff or red-brown hues which prevail down to about 320' are attributed to the presence of small amounts of hydrated ferric oxides. The hues and darknesses on the log are those of the dominant lithologies. Minor amounts of cuttings with other colours are noted in the descriptive log.

DESCRIPTIVE LOG

This is a summary of the main features of the cuttings and cores as seen under the binocular microscope, and in thin sections where these have been made.

GAMMA RAY LOG

Of the geophysical logs available, the gamma ray log is the most readily correlated with depositional characteristics of the sediments. A close correlation with the detrital insoluble residue log is immediately apparent, and the high residue limestones and dolomites between 400' and 780' are readily located by the gamma ray counts. The gamma ray count does not appear to have been noticeably affected by dolomitisation, since limestones and dolomites with similar insoluble residue contents give similar counting rates.

A notable high in the gamma ray count which does not correspond to a high content of detrital insolubles is that between 875' and 895'. The lithology of cuttings over this interval is a clean dololutite with a high content of collophane. The neutron log has no corresponding low which could indicate unrecovered clay or shale, so that presumably the radio ctive elements are associated with the collophane.

LITHOLOGICAL UNITS

The main carbonate sequence below the upper 50' with weathered dolomite and chert has been subdivided into 7 lithological units numbered 2 to 8 from the base up. The main difference from Wolff's subdivision of the section is the subdivision of the dolomites into units based on their depositional characteristics, which are mainly revealed by microscopic examination, especially of thin sections. The limestone has not been further subdivided.

The contact of unit 2 with silica-cemented sandstones of unit I is sharp and probably a disconformity. This is indicated by the presence in the unit 2 dolomite of fragments of the sandstone which had been cemented by silica before incorporation into the carbonate sediment. Another possible (but much less definite) break is at the base of the dolarenites of unit 7 which contain clasts of silty dolomite similar to silty dolomites of the underlying unit 6.

Apart from the above, the units appear to be essentially conformable, and there appears to be transition zones with alternations of lithologies characteristic of the underlying and overlying units.

Neglecting the difference in carbonate mineralogy there are no obvious differences in lithology between the limestone and the lower parts of unit 6. If the dolomite is late diagenetic and not directly related to conditions of deposition then units 5 and 6 could be more usefully regarded, for correlation purposes, as a single unit of dark clayey and silty carbonate lutites with interbedded paler and cleaner carbonate lutites becoming more important higher in the unit. The limestone, as such, may not be laterally persistent.

The possible lateral persistence of units in the dolomites needs some discussion. The well-sorted arenite lithologies suggest high energy conditions and hence (especially for the oolites) a shallow water environment. In such an environment rapid lateral changes would be expected, especially if there is any bottom topography. The arenites could represent rather local high energy shoals and be laterally equivalent to carbonate muds in more sheltered positions or deeper water. If the basal contact is an unconformity then the unit 2 dolarenites would for the above reasons be an unreliable marker (i.e. the unit probably represents a local high energy deposit formed around topographic highs in the pre-existing surface). Other units may persist laterally for some tens of miles, and some are sufficiently distinctive to be useful markers.

The most useful markers for use in comparing the Lake Nash I section with any future wells in the vicinity would be (a) the fossiliferous clean dololutites of unit 4 (in which especially the collophane-rich intervals are easily recognisable), (b) the silty and clayey carbonate lutites of units 5 and 6 (immediately recognisable from the gamma ray log), and (c) the dolarenites with ooliths of unit 7 (in which the ooliths are easily seen with a hand lens).

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Lat: 20° 54' 18" S.
Long: 137° 53' 20" E.

LAKE NASH No.1

(AMALGAMATED PETROLEUM N.L.)

Scale: 1" = 20ft.

LITHOLOGIES

- Dolomites, microcrystalline to very fine crystalline (probably original carbonate muds)
- Calcilutites
- Dolomitic calcilutites
- Dolomite with sorted and close-packed arenite textures
- Chert
- Silty and very fine sandy mudstones

SEDIMENTARY PARTICLES

- Pellets, intraclasts
- Ooliths
- Shells and unidentifiable fragments
- Echinoderm ossicles
- Spicules
- Algal filament
- Terrigenous sand, silt (mainly quartz with microcline, muscovite, tourmaline)

NON-DETRITAL MINERALS

- Chert
- Pyrite
- G Glauconite
- Cp Collophane

To accompany Record 1965/149

F53/A4/8