DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY

OTWAY BASIN - PAPER NO. 20

THE OCCURRENCE OF CARBON - DIOXIDE IN THE GAMBIER EMBAYMENT

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ABSTRACT

Two oil exploration wells drilled in the southern on-shore part of the Gambier Embayment encountered quantities of Carbon dioxide gas. In Kalangadoo No.1, the gas was found in fractured, dolomitic sandstone of assumed Palaeozoic age and just below the unconformity at the base of the Mesozoic Otway Group. It is in an unconformity type trap. In Caroline No.1 the gas is contained in the Middle Cretaceous Waarre Formation and entrapment is facilitated by doming. The latter well which is capable of producing in excess of 2 MMCF of gas per day, consisting of 98% carbon dioxide, has been completed as a commercial carbon dioxide producer.

As this area of the Gambier Embayment features many subrecent volcanoes, some of which were active less than 5,000 years ago, we consider the carbon dioxide to have originated from volcanic and post-volcanic emanations.

INTRODUCTION

One of the features of the Gambier Embayment is the occurrence of large quantities of fairly clean carbon dioxide gas in subsurface reservoirs. Carbon dioxide is quite commonly associated with natural hydrocarbon gases (e.g., the natural gas of the Cooper Basin; Wopfner, 1967; Martin, 1967) and the generation of carbon dioxide in this association has even been ascribed to oxidation of hydrocarbons by mineralised waters (Rogers, 1921). The carbon dioxide encountered in the Gambier Embayment cannot be regarded as such a "common association gas" and its origin needs to be explained in a different context.

Gas Occurrences

A.O.D.A.N.L. Kalangadoo No.1

Major quantities of carbon dioxide gas were discovered in the Alliance Oil Development Australia N.L. well, Kalangadoo No.1, drilled in 1965. The well was located on a closed structure, identified by seismograph surveys. The structure apparently resulted from block faulting within a (?) Palaeozoic high, the Kalangadoo basement ridge. Nearly 7000 feet of Lower Cretaceous (Otway Group) and Tertiary sediments are draped over this (?) Palaeozoic high.

A drill stem test of an interval immediately beneath the Mesozoic strata resulted in flows of up to 2.68 MMCFD of carbon dioxide. Analysis showed the gas to be composed of 96 per cent carbon dioxide with minor amounts of hydrocarbons and other gases (see Table 20-1). The reservoir rocks, from which the carbon dioxide was produced, consisted of sheared and fractured dolomitic sandstone and shale, which are thought to be of Palaeozoic age (possibly Devonian). The reservoir is thus aided by fracture porosity developed near the (?) Palaeozoic - Mesozoic unconformity, whereas the siltstones and greywacke of the Upper Otway Group (Lower Cretaceous) may be regarded as effective cap rock. The carbon dioxide accumulated in an unconformity type trap.

Five additional tests of this gas zone were largely unsuccessful or inconclusive, as extensive caving of the fractured reservoir formation created insurmountable technical difficulties. Consequently an attempt was made to side-track the hole in order to re-drill, core and test the gas zone. This attempt again failed and the hole was finally plugged and abandoned.

The data obtained from the discovery test were however sufficient to indicate that a very small reservoir was discovered and that it was essentially depleted during the test. Evaluation of the results of DST.No.14 indicates that the gas was probably produced from a fractured reservoir and suggests that the actual porosity within the tested interval is considerably less than that indicated by the logs, and that there were no substantial reserves present.

TABLE 20-1 - Gas Analyses for Caroline No.1 and Kalangadoo No.1.

	CAROLINE NO. 1			KALANGADOO NO. 1.
	(a) DST No.4 8256-8433	(a) DST No.5 8610-8730	(a) DST No.8 9154-9182	(b) DST No.7 6890-7005
Helium	0.008	0.0026	0.0071	
Hydrogen	0.04	0.054	0.0023	
Nitrogen	0.42	0.094	0.46	1.33
Methane	1.31	0.74	0.93	2.40
Ethane	0.03	0.039	0.006	
Propane	0.011	0.022	<0.001	
Isobutane	0.001	0.003	<0.001	
N-butane	0.001	0.004	<0.001	
Higher hydro-carbons				<0.02
Carbon dioxide	97.5 (probably 0.7% higher.)	99.1	98.6	96.25

<u>Notes:</u> (a) Carried out by Gas and Fuel Corporation, Victoria.

(b) Gas sample as received contained 2.55% of air by volume. Analysis is calculated on a dry, air free basis. Carried out by H.W. Sears, Australian Mineral Development Laboratories.

Gas chromatography analyses on Caroline No.1 and Kalangadoo No.1 carried out by J. Puchel, Bureau of Mineral Resources, have been disregarded due to the great discrepancy with all other analyses.

A.O.D.A.N.L. Caroline No.1

This well is situated some 10 miles SE of Mt. Gambier. The well location was selected on a positive gravity anomaly established by the "Caroline Gravity Survey". A subsequent reflection seismograph survey indicated a closed structure but poor record quality prevented determination of the extent or amount of closure. In order to avoid lost circulation problems, experienced in the near surface Gambier Limestone when drilling Kalangadoo No.1, a large-diameter percussion hole was drilled through this formation using a South Australian Department of Mines percussion rig. Rotary drilling commenced on 15th November, 1966. Eight formation tests were conducted but no hydrocarbons were encountered. However two tests (DSTS. Nos. 4 and 5), carried out in the Middle Cretaceous sequence, equivalent to the Waarre Formation (8256 feet to 8433 feet and 8610 feet to 8730 feet) each resulted in flows of about 2.5 MMCFD of non-combustible gas, which on analysis proved to consist of almost 99 per cent carbon dioxide with traces of hydrocarbons and other gases.

The reservoir formation consists of white to cream, poorly sorted and friable sandstone ranging in grain size from very fine to coarse grained. Interbedded with the sandstones are medium to dark grey shale and siltstone. They are slightly carbonaceous and micaceous, and contain moderate amounts of weathered feldspar and traces of glauconite. The sandstone/shale ratio is about 1.4. The overlying Belfast Mudstone which is over 1000 feet thick, forms the cap rock. The accumulation is in an anticlinal type trap.

Caroline No.1 well has been completed as a commercial carbon dioxide producer. Some details of completion and treatment installations are given in the final part of this paper.

Origin of Carbon Dioxide

As mentioned in the introduction of this paper, carbon dioxide is quite commonly contained within the earth's crust, both in sedimentary and crystalline rocks and the problem of its origin is by no means unique to the Gambier Embayment. A detailed description of carbon dioxide occurrences in the U.S.A. was, for instance, presented by Miller (1938) and the status of our knowledge on the matter was reviewed recently by Farmer (1965).

According to the latter author, the theories of origin of carbon dioxide may be divided into two general groups - (a) organic and (b) inorganic. These may be further divided as follows:

(a) Organic theories:

1. Decay of organic matter
2. Oxidation of hydrocarbons by mineralised waters.

(b) Inorganic theories:

1. Igneous emanations.
2. Metamorphism of carbonates.
3. Solution of limestone by groundwater.

Of these theories, group (a) may be excluded from further consideration in respect to the origin of carbon dioxide in the Gambier Embayment for the reasons that the occurrences are contained in formations of completely different ages to each other and also because of the apparently low content of organic material, at least within the (?) Palaeozoic formations of Kalangadoo No.1.

Of the inorganic theories 1 and 3 could be considered possible for the occurrence in Kalangadoo No.1 but the absence of carbonate rocks both in the section containing the carbon dioxide and below in Caroline No.1 excludes these theories from further consideration for the later accumulation.

The only factor common to both carbon dioxide occurrences is their proximity to centres of late Tertiary to sub-recent volcanic activity (Fig.20-1). Radio-active datings from Mt. Gambier for instance indicate that volcanoes were still active in the area less than 5,000 years ago and well preserved ash-cones (e.g. Mt. Salt), crater lakes (Blue Lake) and calderas are further witnesses to the youth of this volcanic activity. The volcanic activity consisted largely of expulsion of basaltic ash with olivine bombs, actual flows being very subordinate. This volcanism originated along northwest-trending fault zones, movements along which probably represent the final adjustment to the breaking up and removal of a southern landmass. This process, which originated in the Lower Cretaceous was responsible for the shaping of the Otway Basin (Wopfner, 1969).

Large volumes of carbon dioxide are commonly associated with volcanic or post-volcanic activities. Volcanic gases high in carbon dioxide have been reported from Iceland, Italy, Germany, Martinique, Hawaii and Java. In the United States, carbon dioxide seeps occur in the Imperial Valley of California and in Yellowstone National Park (Farmer, 1965), and according to Clarke (1924) carbon dioxide together with steam forms the end product of gases evolved from igneous activity.

As volcanism is a common feature to both areas of carbon dioxide occurrences and large quantities of carbon dioxide appear to be absent outside the areas of influence of young volcanic activity, it would be folly to look for any other mode of origin of carbon dioxide in the Gambier Embayment. We therefore conclude that the carbon dioxide accumulations in Kalangadoo No.1 and Caroline No.1 resulted from emanations of volcanic and post-volcanic nature.

Commercial Utilization of Carbon Dioxide

Caroline No.1 well was completed as a commercial carbon dioxide producer on 21st February 1967. Production is obtained through casing perforations in the intervals 8204-8230, 9152-9172 and 9303-9321 (see Fig.20-2). A normal completion procedure was employed, using a standard tubing string and a conventional oil-field type packer.

Carba Australia Ltd. set up a pilot plant and began tests in August 1967, to determine the feasibility of purification of the gas to commercial standards and by the end of that year this was indicated. A contract for the sale of gas was negotiated early in 1968 and design and construction of the full scale treatment plant was begun.

The plant, located adjacent to the well site, began pilot operation late in 1968 and, since early 1969, has supplied the greater part of the markets in Victoria and South Australia for liquid carbon dioxide and, in addition, some dry ice is being produced for local use.

Purified gas is transported in liquid form to Adelaide and Melbourne in road tankers of twelve tons capacity, this method being used largely because of its flexibility.

The amount of helium in the gas is too small to be of economic interest.

ACKNOWLEDGEMENT

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assistance with completion and production data ~~presented in~~ of Caroline No. 1

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APPENDIX 20 - I

SUMMARY OF RESULTS OF DRILL STEM TESTS

Caroline No.1

DST.No.4	8256-8433 Waarre Formation Unit 1	Non-combustible gas to surface in 7 mins. at RTSTM; flow increased to rate in excess of 800,000 CFD after 12 mins, after 20 mins. gas was accompanied by slugs of mud and muddy salt water; after 40 mins. gas was accompanied by slugs of clean salt water. Flow rate estimated: 2-3 MMCFD. Rec. 4333' salt water separated by pockets of NCG. Resistivity salt water 0.266 ohms at 68°F
DST No.5	8610-8730 Waarre Formation Unit 2	Non-combustible gas to surface in 20 mins at RTSTM; flow rate steady throughout first flow period. During 2nd flow period solution gas to surface immediatel at 340,000 CFD, decreasing to 140,000 CFD after 5 mins. and TSTM after 7 mins. Recovered 279' gascut, watery mud and 6603' gascut salt water (0.341 ohms at 58°F).
DST No.8	9154-9182 Waarre Formation Unit 4	Non-combustible gas to surface in 2 mins. at RTSTM. Flow rate increased to 1.54 MMCFD after 17 mins. and to 2.29 MMCFD at end of first flow period. During 2nd flow period gas stabilised at 2.73 MMCFD. Flow rates were then restricted to ¼, ½ and ¾ of stabilised flow rate for periods of one hour. The well was then flowed without restriction for the duration of the test. During this perio the flow rate stabilised at 2.495 MMCFD.

Kalangadoo No.1

DST No.7	6890'-7005' Unnamed unit; age unknown (underlying U. Otway).	Non-combustible gas to surface in 6 mins. at max. rate of 1.55 MMCFD. Packer began to fail after 10 mins. and flow rate decreased after 20 mins. Misrun. Test was of insufficient duration to permit collection of uncontaminated samples or to provide enough data for the determination of reservoir parameters.
DST No.14	6730'-7010'	Non-combustible gas to surface 43 mins. after initial opening at max. rate of 686,000 CFD. Testing head partly plugged. Obstruction was cleared and gas flow reached max. of 2.68 MMCFD (with mud slugs) during 2nd flow period.

Fig. 20-1 Locations of Kalangadoo No.1 and Caroline No.1 in relation to centres of sub-recent volcanic activity.

Fig. 20-2 Composite log of carbon dioxide producing section (Waarre Formation) in Caroline No.1.

Fig. 20-3 View wethead and carbon dioxide treatment plant at Caroline No.1 operated by Carba Australia Ltd. (photo M. Henningsen).

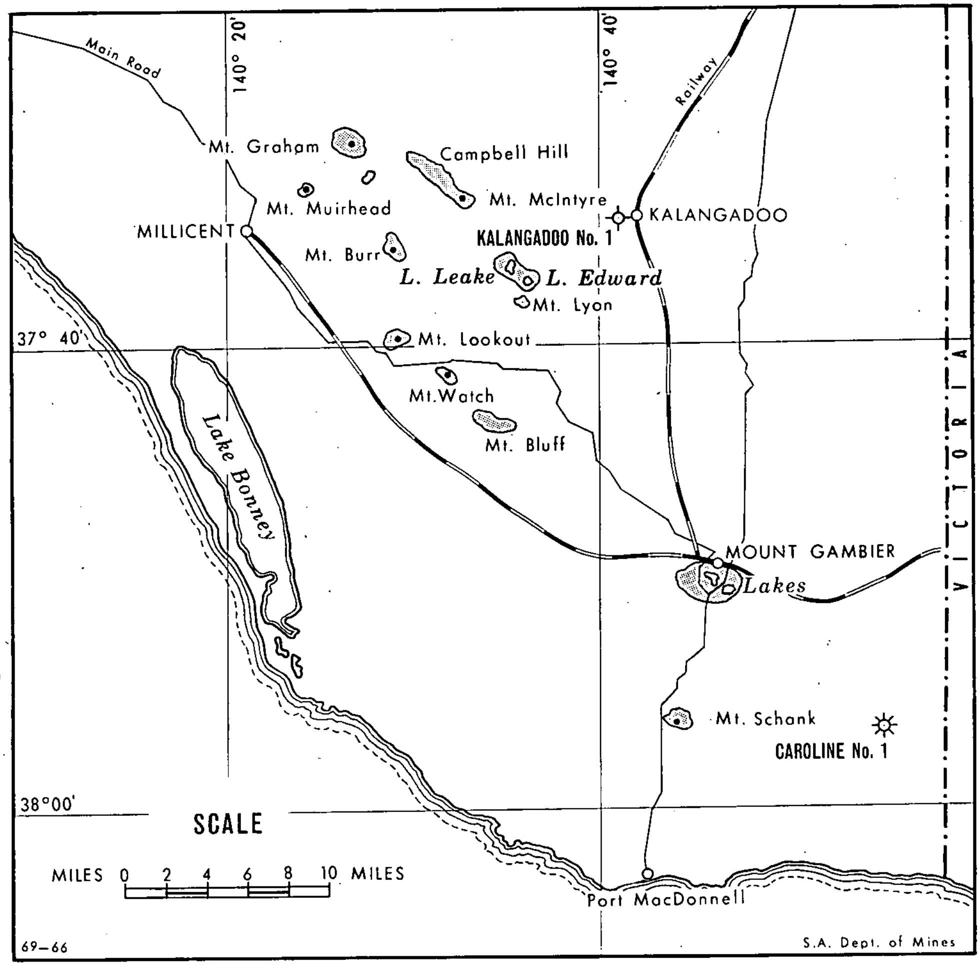
140° 20'
140° 40'
Main Road
Railway
Mt. Graham
Campbell Hill
Mt. Muirhead
Mt. McIntyre
KALANGADOO
MILLICENT
KALANGADOO No. 1
Mt. Burr
L. Leake
L. Edward
Mt. Lyon
37° 40'
Mt. Lookout
Mt. Watch
Lake Bonney
Mt. Bluff
VICTORIA
MOUNT GAMBIER
Lakes
Mt. Schank
CAROLINE No. 1
38°00'
SCALE
MILES 0 2 4 6 8 10 MILES
Port MacDonnell
69–66
S.A. Dept. of Mines

Fig 20-1

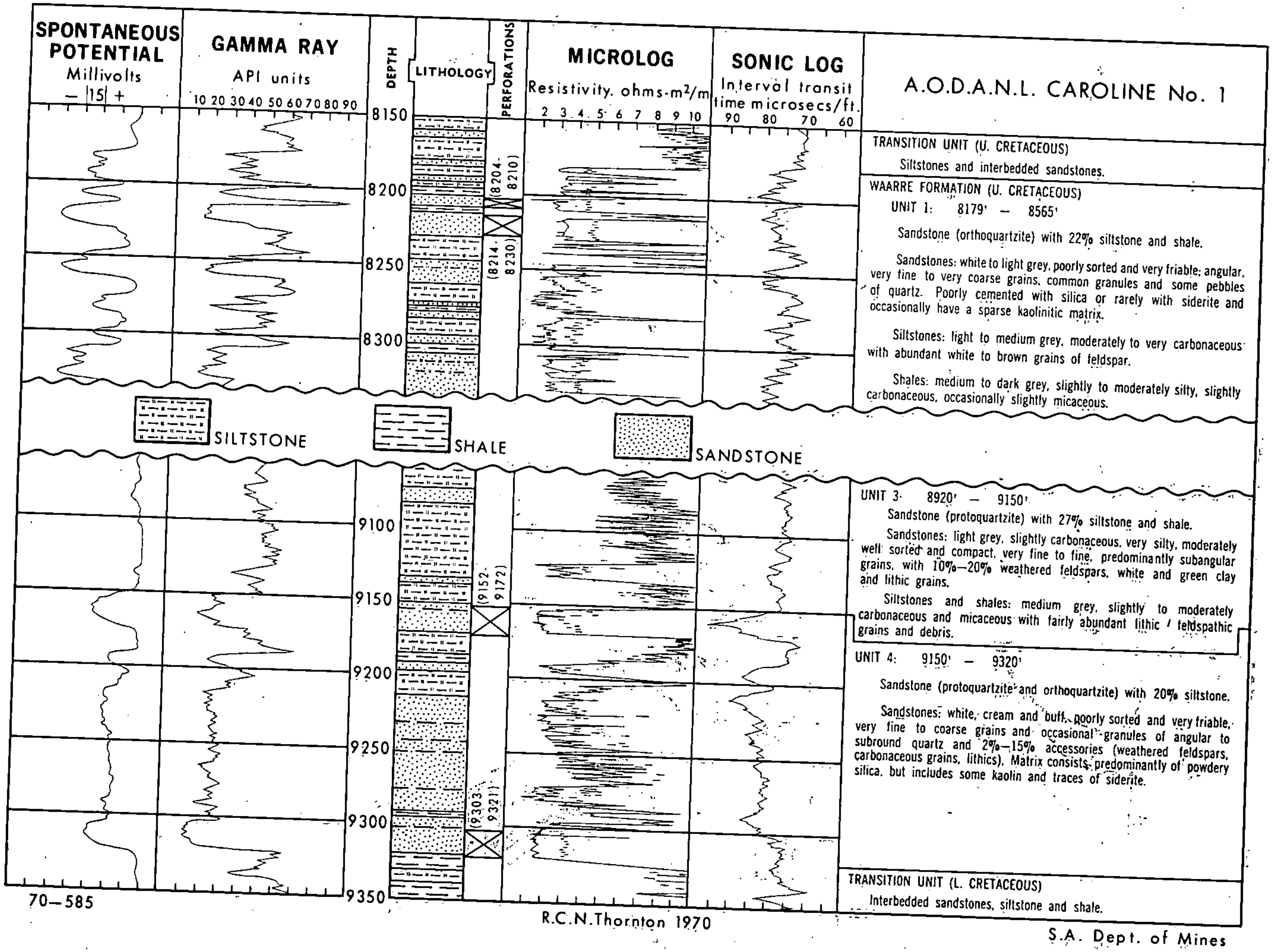
SPONTANEOUS POTENTIAL
Millivolts
— |15| +
GAMMA RAY
API units
10 20 30 40 50 60 70 80 90
DEPTH
LITHOLOGY
PERFORATIONS
MICROLOG
Resistivity. ohms-m²/m
2 3 4 5 6 7 8 9 10
SONIC LOG
Interval transit time microsecs/ft.
90 80 70 60
A.O.D.A.N.L. CAROLINE No. 1
8150
8200
8250
8300
(8204-8210)
(8214-8230)
SILTSTONE
SHALE
SANDSTONE
9100
9150
9200
9250
9300
9350
(9152-9172)
(9303-9321)
TRANSITION UNIT (U. CRETACEOUS)
Siltstones and interbedded sandstones.
WAARRE FORMATION (U. CRETACEOUS)
UNIT 1: 8179' – 8565'
Sandstone (orthoquartzite) with 22% siltstone and shale.
Sandstones: white to light grey, poorly sorted and very friable; angular, very fine to very coarse grains, common granules and some pebbles of quartz. Poorly cemented with silica or rarely with siderite and occasionally have a sparse kaolinitic matrix.
Siltstones: light to medium grey, moderately to very carbonaceous with abundant white to brown grains of feldspar.
Shales: medium to dark grey, slightly to moderately silty, slightly carbonaceous, occasionally slightly micaceous.
UNIT 3: 8920' – 9150'
Sandstone (protoquartzite) with 27% siltstone and shale.
Sandstones: light grey, slightly carbonaceous, very silty, moderately well sorted and compact, very fine to fine, predominantly subangular grains, with 10%–20% weathered feldspars, white and green clay and lithic grains.
Siltstones and shales: medium grey, slightly to moderately carbonaceous and micaceous with fairly abundant lithic / feldspathic grains and debris.
UNIT 4: 9150' – 9320'
Sandstone (protoquartzite and orthoquartzite) with 20% siltstone.
Sandstones: white, cream and buff, poorly sorted and very friable, very fine to coarse grains and occasional granules of angular to subround quartz and 2%–15% accessories (weathered feldspars, carbonaceous grains, lithics). Matrix consists predominantly of powdery silica, but includes some kaolin and traces of siderite.
TRANSITION UNIT (L. CRETACEOUS)
Interbedded sandstones, siltstone and shale.
70—585
R.C.N.Thornton 1970
S.A. Dept. of Mines

Fig. 20-2