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THE HYDROLOGY OF THE GIDGEALPA FORMATION OF THE WESTERN AND CENTRAL COOPER BASIN

by

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The following is a list of well-name abbreviations used in the figures.

Arr	Arrabury 1	Or	Orientos 1
Box	Boxwood 1	Pack	Packsaddle 1
Bur	Burley 1	Pan	Pando
Che	Cherri 1	Ros	Roseneath 1
Coong	Coongie 1	Sp	Spencer 1
Coont	Coonatie 1	Strz	Strzelecki 1
C Ck	Cooper's Creek 1	Tall	Tallalia 1
Dar	Daralingie	Tick	Tickalara 1
Dul	Dullingari 1	Til	Tilparee A-1
F L	Fly Lake 1	Tin	Tindilpie 1
Fort	Fortville 3	Tirr	Tirrawarra
Gu	Gurra 1	Tool	Toolachee
Inn	Innamincka	Top	Topwee 1
Kal	Kaladeina 1	T T	Tinga Tingana 1
Kum	Kumbarie 1	Wan	Wancoocha 1
L H	Lake Hope 1	Wee	Weena 1
Mer	Merrimelia	Wir	Wirrarie 1
Moo	Moorari 1	Yan	Yanpurra 1
Mudl	Mudlalee 1		
Mudr	Mudrangie 1		
Mul	Mulga 1		
Murt	Murteree 1		
Nap	Nappacoongee 1		
N P	Pando North 1		

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ABSTRACT

A study of the chemical aspects of Permian and Mesozoic formation waters has enabled the zones of flushing of Permian sediments by artesian waters to be clearly delineated. It has been proved that complete flushing has taken place in the southern areas of the basin where the absence of the Triassic caprock allows hydraulic interconnection between the Permian and artesian aquifers. A limited amount of flushing in the Upper Permian only has occurred in those areas close to the Triassic subcrop limits. There appears to be a possible correlation between the degree of flushing and the type of hydrocarbon production but the present study is insufficient to achieve predictability. The lack of reliable pressure data has prohibited an equally useful potentiometric study from being made to try and explain the water movement patterns, and hence possible hydrocarbon accumulations, within the basin.

INTRODUCTION

The present work is a study of the chemical and physical characteristics of Permian and artesian waters in wells of the Cooper Basin in order to compile isohaline maps of the area, to assess the influence, if any, of artesian and other waters on the Permian waters and to determine whether any correlation exists between water properties and the occurrence of oil and gas.

The absence of the Triassic Nappamerrie Formation (caprock) from the southern Cooper Basin immediately suggests that flushing of the Permian strata by artesian waters from directly overlying Jurassic aquifers is very likely to have occurred. (Fig. 1). Clarification of this question was the main purpose of this study.

The main area under consideration is the Cooper Basin, the South Australian part of which lies in the northeast of the State, and is bounded roughly by the lines of Latitude 26°30'S to 29°30'S and Longitude 139°E to 141°E.

REGIONAL SETTING & STRATIGRAPHY

The Cooper Basin is essentially a Permo-Triassic basin, although its earliest beginning may date into the late Carboniferous. It is an intra-cratonic basin, the development of which was controlled by tectonic movements along major northeast trends. The basin development and its depositional cycle were preceeded by the Kanimblan orogeny and an extensive period of erosion. Thus the basal sediments rest unconformably on a truncated orogene. The rocks on which the basal sediments may rest range in age from late Precambrian to Devonian.

The initial phase of deposition in the Cooper Basin was controlled by widespread glaciation in the late Carboniferous-early Permian, resulting in the deposition of tillites and thick diamictites. These grade upwards into a black shale facies which is considered, in parts, to be of marine origin. So far evidence for the marine character is restricted to the occurrence of one Fenestella sp. Some dirty sandstones and breccias also occur within these sections. This interval has been termed the Merrimelia Formation (Martin, 1967). It is of Lower Permian age, but its base may possibly extend into the uppermost Carboniferous.

The Merrimelia Formation thins out against the structural highs, possibly indicating structural growth during deposition. An unconformity separates the Merrimelia Formation from the overlying sequence of sandstone, siltstone and coal. This sequence which has been termed the Gidgealpa Formation (Kapel, 1966; Wopfner, 1966; Martin, 1967), not only provides the reservoir rocks, but is also regarded as the source of hydrocarbons in the Cooper Basin. The Gidgealpa Formation is informally subdivided into upper, middle and lower members with an additional sand unit being present at its base in the northwestern part of the basin. This latter sand unit contains the oil in Tirrawarra 1 and 2 and Fly Lake 1.

It is generally thought that the ancestral Flinders Ranges supplied most of the detrital material for the Gidgealpa Formation, but the presence of glacial deposits of possibly Permian age (Coats, 1962) would appear to contradict such an assumption. It appears more likely that the source area should be sought in those regions which were affected by early Carboniferous fold movements, which no doubt would have led to the formation of some fold mountains. The most likely area therefore, would be the region of the Bancannia Trough and its immediate surroundings which were folded by the Tabberabberan (Middle Devonian) and Kanimblan (early Carboniferous) orogenies.

The depositional cycle in the Cooper Basin was concluded by the deposition of dolomitic shales, siltstones and red beds of Lower Triassic age. This Lower Triassic unit is referred to as the Nappamerrie Formation (Papalia, 1969); it is of great importance in the hydrocarbon accumulations of the Cooper Basin as it is the caprock. The Nappamerrie Formation is absent from the southern and southwestern parts of the basin and it is in this region that possible hydraulic connection exists between the Permian Gidgealpa Formation and the overlying Jurassic aquifers.

INFORMATION SOURCES & DATE PROCESSING

All data used were obtained from wells drilled in the area and at 15th October, 1971, these totalled approximately 100; they are reasonably evenly-distributed throughout the basin with a higher concentration in the Gidgealpa-Moomba area. Information from wells in Queensland was used to enable a more accurate picture of subcrops to be drawn up.

Initially the company Well Completion Reports were used for the results of water analyses, amount and type of fluid recoveries, pressure data etc. from drill stem tests. Where the information was unavailable or incomplete the "Daily Drilling" and "Technical Reports" were referred to.

The value, in p.p.m., of each ion present in any water was taken from every analysis used and all calculations were done by a computer.

Most waters were taken from drill stem tests during the drilling of the wells and the resulting analyses have only been used when there was a recovery of at least 500 feet of mud-free water.

There was a lack of data from most of the producing wells of the Moomba and Gidgealpa Fields. On the author's request, Delhi International Oil Corporation arranged to collect 15 water samples from some of their producing wells in an effort to make a closer study of the areas possible. Analysis has shown that, with the exception of artesian water from Moomba 3, all samples collected during April, 1971 represent, at least in part, condensed water vapour and not Permian formation water. The samples were all taken at the wellhead meter run.

The Government C.D.C. 3500 computer was used to calculate salinities, convert data from p.p.m. to milliequivalents per litre and plot trilinear and other diagrams.

A computer programme for use in this project was written by G. Pilkington and it saved many hours of calculations and plotting. The programme is given in Appendix II.

The computer originally plotted trilinear and other diagrams using symbols to denote the hydrocarbon production from each horizon; the division between wet and dry gas was taken to 10 bbl condensate per mcf but this was later found to be too approximate and a closer study of salinities and production is reported later in the text.

METHODS AND PRESENTATION OF WATER ANALYSES

Nearly all the water analyses used in this investigation were carried out by AMDEL in Adelaide and a brief summary of the processes involved is given below.

The amount of carbonate present in a water is calculated as HCO_3 while it is still in solution, the water is then evaporated at 100°C and the salts are dried out by heating to over 1 000°C. The radicles are calculated by a number of methods - K, Na by atomic absorption, Cl by titration etc. - and the total salinity is given as a summation of all the radicles.

For the past few years it has been international practice to present the carbonate as HCO_3, and not CO_3, but earlier analyses were generally given in terms of the latter when CO_3 was calculated with the other salts after evaporation. Care should always be taken when inspecting analyses with the carbonate calculated as CO_3 and in this study, when necessary, all values were converted to HCO_3. (HCO_3=2.033 x CO_3, in p.p.m.). The values in milliequivalents/litre of HCO_3 and CO_3 are always identical.

Occasionally the total salts will have been calculated at 180°C and this value will be greater than that at 1 000°C as some H_2O will still be "locked in" at the lower temperature so care must be taken in the few cases where this occurs.

The AMDEL water analysis sheets have columns for "parts per million" and "milliequivalents per litre"; the latter values are calculated directly from the p.p.m. and are useful in the study of water characteristics. The concentration of an ion, in p.p.m., divided by its equivalent weight gives the value of milliequivalents/litre of that ion. The milliequivalents/litre are identical with "reaction values" given by some authors. The totals of anions and cations, when expressed in milliequivalents/litre, should equal each other; if not the analysis may be faulty or the water contaminated.

(1) Water Analysis Patterns

Water analysis patterns were developed by Stiff (1951) and in these diagrams cations and anions are plotted, in milliequivalents/litre, on either side of a zero line; the points are joined to form a "pattern" which is characteristic of the water's relative concentration of ions, and not salinity. It is possible that two waters of roughly identical salinities can have very differing "patterns" and vice versa (See Daralingie 1 and Gidgealpa 5, Upper Member patterns, Enc 2 & 6). These water patterns not only give a quick visual effect of relative ionic concentrations but are helpful in any problem where water analysis is a factor and can be used to determine the extent of contamination by "foreign" water in a sample (Stiff, 1951).

(2) <u>Multiple Trilinear Diagrams</u>

For natural waters, where the cations and anions are in chemical equilibrium, two triangular diagrams (one for cations and the other for anions) can be drawn to show percentages of ions and any water is represented by a single point on each (Piper, 1944). These trilinear diagrams may give good indications of waters that may have evolved from similar sources but there is no way of showing salinities accurately, they therefore need to be used in conjunction with other graphical methods.

(3) <u>Percentage Reaction Value/Salinity Graph</u>

One way of attempting to show salinities and percentages of ions was given by De Sitter (1947) who plotted the percentage of Na (reaction values) against salinities. This method disregards the relative proportions of Ca, Mg and K in the waters but in the present study these ions are nearly always negligable.

(4) <u>Salinity/Ion Ratio Graphs</u>

Trends in water types can sometimes be emphasised by plotting the Ca/Mg ratio, in milliequivalents per litre, against concentration (salinity) in p.p.m. and De Sitter (1947) has been successful in grouping different oilfield brines with this method.

Other ratios, apart from Ca/Mg, could be useful with waters having small amounts of Ca and Mg (Chebotarev, 1955).

(5) Chebotarev's "Metamorphism of Water"

Chebotarev (1955) has suggested that waters undergo a "metamorphism" with age and has classified various kinds of waters into five groups according to their percentage reacting values of bicarbonate, sulphate and chloride. Basically, he demonstrated the relationship of natural waters to the chemical elements in the earth's crust of weathering and the progression from bicarbonate-rich to chloride-rich waters with age.

POTENTIOMETRIC SURFACE

The pressure distribution within an aquifer is best represented by the potentiometric surface of that aquifer. This is the theoretical surface joining all points to which the formation water would rise under its own pressure.

Drill stem test results were used to obtain information on shut-in pressures (formation pressures) which were then converted into potentiometric heights assuming an average salinity of 8 500 p.p.m., a formation temperature of 250°F and a density of 60.58 lbs/ft^3. Obviously, for a detailed study of a potentiometric surface such averages should not be used but it was felt that in this case, where only a limited amount of information was available, it was sufficient to demonstrate broad trends. The heights shown on the maps are in feet above sea level and water will therefore tend to flow from higher to lower areas in an effort to reach hydrodynamic equilibrium.

RESULTS OF THE INVESTIGATIONS

Well Groups

After a preliminary survey of the Permian water patterns for the whole basin, it became clear that they can be grouped into geographical areas demonstrating similar characteristics. In the remainder of this text these groups will be referred to frequently, and are as follows (Fig. 2). The characteristic chemical properties of these groups will be discussed later in this section, part (2).

Southern Area:	Cherri 1, Gurra 1, Mulga 1, Kumbarie 1, Weena 1, Tinga Tingana 1
Eastern " :	Nappacoongee 1, Roseneath 1, Toolachee 2
Central " :	Mudlalee 1, Murteree 1, Strzelecki 1, Toolachee 1 and 3
Western " :	Boxwood 1, Daralingie 1 & 2, Pando 1 & 2, Pando North 1, Topwee 1, Wancoocha 1.
Northern " :	Gidgealpa wells, Moomba wells, Tindilpie 1, Spencer 1, Wirrarie 1, Tirrawarra 1 & 2, Marrimelia wells, Della 1 & 2 and all remaining wells in northern part of the basin.

The artesian waters are roughly uniform throughout the area of the Cooper Basin and do not need dividing into geographical groups.

(1) Isohaline Maps

It was originally planned to plot one map showing average salinities for the whole Gidgealpa Formation but, owing to the marked differences in salinities and other water characteristics between the Upper and Middle-Lower Members, it became necessary to prepare separate maps for the two stratigraphic intervals (i.e.

Upper and Middle-Lower Members).

The Upper Gidgealpa isohaline map (Fig. 3) demonstrates salinities increasing with depth towards the centre of the basin. This increase with depth is known from other basins of all ages in many parts of the world (White, 1965).

A very noticeable feature is the gentle gradient between the 2 000 and 5 000 p.p.m. isohalines and the much steeper one north of approximately 28°30' into the Gidgealpa-Moomba area. Unfortunately the lack of information from the Moomba gas field and the northern wells has not allowed any reliable contours to be drawn over a large part of the basin, but a noticeable "valley" of lower salinities, running through Moomba to Gidgealpa is evident.

In the Gidgealpa Field the three wells south of the faults, 5, 7 and 9, tie in with their southern neighbours while those in the fault-bounded area, 3, 6, and 11, have much lower salinities than any other in that part of the basin.

The one analysis from Tindilpie 1, northwest of the faults, shows greatly increased salinities, and is the highest one recorded from the Upper Gidgealpa Member in the Cooper Basin.

The Middle-Lower Gidgealpa salinity map (Fig. 4) shows a broad "plateau" of salinities between 3 000 and 4 000 p.p.m. covering the whole of the basin south of 28°30'. From the Murteree-Pando area there is a steepening of the gradient with the salinities increasing very rapidly northwards to the Gidgealpa field.

In the eastern part of the basin the Roseneath 1, Nappacoongee 1 and Toolachee 2 wells, which showed slightly higher than expected salinities in the Upper Gidgealpa, clearly belong in an anomalous area of higher salinities for the Middle-Lower Members and there is a "valley" of low salinities through the central and Della wells.

Again the highest salinities are recorded at Tindilpie 1, Gidgealpa 5, 7 and 9, and Merrimelia 4. It is unfortunate that there are no analyses from the remaining Gidgealpa wells to verify, or otherwise, the pattern found for the Upper Member.

The thicknesses of the Gidgealpa Members were initially plotted on the isohaline maps but they showed no trends correlable with salinities.

(2) Water Pattern Diagrams

These diagrams can be grouped according to their salinities and positions in the basin; when used in conjunction with isohaline maps they are helpful in demonstrating trends in the formation waters.

The southern wells (Tinga Tingana 1, Gurra 1, Cherri 1, Kumbarie 1 and Mulga 1, Enc. 1) show only a small increase in salinity between the Upper and the Middle-Lower Gidgealpa and this is due to a slight increase in all ions, shown by the similar patterns for both horizons.

It is interesting to note that the pattern for Mulga's Upper Gidgealpa water is nearly identical with that for the artesian water from Fortville 3, (Wopfner & Cornish, 1967), and that all of these southern waters show many similarities with the artesian waters taken from wells throughout the basin.

To the north of 28°30', the western wells, (Enc. 2), Daralingie 1 and 2, Topwee 1, Pando North 1, and Pando 2, have similar patterns for both the Upper and Middle-Lower Members with the higher Upper salinities due to increased amounts of Na and Cl.

Spencer 1 and Wirrarie 1 water patterns show more similarities to those of the Gidgealpa and northwestern area.

The central wells (Enc. 3) of Mudlalee 1, Murteree 1, Strzelecki 1 and Toolachee 1 and 3 are like the two previously mentioned groups and show little difference between the Upper and Middle-Lower Members; their salinities are higher than those further south and this is due to increased amounts of Na, Cl and HCO_3.

The eastern wells (Enc. 4) (Toolachee 2, Nappacoongee 1 and Roseneath 1) are characterised by their striking differences in pattern between the Upper and Middle-Lower Members. Salinities are much higher than those in surrounding wells and this is due, not only to increased values of Na and Cl, but most noticeably to the presence of Ca, Mg and Fe which are not characteristic of artesian waters.

The two Della analyses are hard to fit into any group; they have been placed in the northern area (Enc. 5) although the Della 1 Lower Gidgealpa water probably represents a mixture of the central and eastern types and the one from Della 2 is unlike any other pattern found in the Cooper Basin.

In the northern area, which includes the Gidgealpa and Moomba gas fields, the Upper Member waters from Gidgealpa 3, 6 and 11, Moomba 4 and Merrimelia 3 (Enc. 5) have patterns quite similar to the artesian and southern ones and are very low in all ions except Na and K. Merrimelia's has a small amount of SO_4, comparable with some artesian waters.

The remaining water patterns (Enc. 5 & 6) bear no resemblance to artesian ones and the high salinities recorded in this region are the result of large amounts of Na, K, Cl, Ca and Fe (especially Gidgealpa 5 and 7). It is interesting to notice that, as elsewhere in the Cooper Basin, the HCO_3 values are high and hardly vary between the Gidgealpa Members.

There is one unusual pattern in the northern area - Wirrarie 1 has very high values for SO_4.

The artesian waters, (Enc. 7), which are taken from a number of Jurassic and Cretaceous horizons, sub-divide into two patterns which are alike in all respects except for the addition of SO_4 in the water from Della 1, Pando 1 and Tirrawarra 2. They all contain large amounts of HCO_3 and clearly belong to the carbonate waters described by Jack (Jack, 1923 and 1930; Ward, 1946).

(3) Trilinear Diagrams

These diagrams have not been as helpful in this study as well hoped initially; this is probably because of the limited stratigraphic and geographic range of the waters being considered but a few simple trends are noticeable despite the crowding of points on each diagram.

The most successful diagram is the $Cl/HCO_3/SO_4$ one (Fig. 5) which demonstrates the low SO_4 content in all waters except Wirrarie 1 and the change from relatively high HCO_3 in the southern to a higher Cl percentage in the northern wells. This diagram points to the anomalous eastern wells (Roseneath 1, Toolachee 2 and Nappacoongee 1) having anion affinities closer to the Gidgealpa 5, 7 and 9 wells than their neighbours.

The two cation trilinear diagrams plotted by the computer are both very crowded towards their Na corners and no clear patterns emerge from either (Fig. 6).

From these diagrams it has not been possible to obtain any correlation between hydrocarbon production and water characteristics.

(4) Other Diagrams

Apart from a chart classifying waters according to Chebotarev's idea (Table 1), all other methods of showing water properties were unsuitable for this study, which is again presumably due to the fact that all the waters are confined to relatively small geographical and time limits.

An attempt has been made to classify the waters according to Chebotarev's (1955) theory of "metamorphism" of subsurface waters (Table 1). There appears to be a definite progression from the artesian and some other waters of Group II through Group III which contains mainly Upper Gidgealpa samples through to Groups IV and V which include the deeper and older waters of the Gidgealpa - Moomba and eastern areas. In any one well there is often an "ageing" from the Upper to Lower Member waters.

IMPLICATIONS OF THE RESULTS

The entire Gidgealpa Formation is a freshwater deposit and this is an important factor to be remembered when considering the chemical compositions of the formation waters. The limited vertical and horizontal extent of certain sand lenses of the Gidgealpa Formation will undoubtedly have restricted water movements and these points should be kept in mind in any attempts to compare results from the Cooper Basin with those from marine basins elsewhere in the world (Chebotarev, 1955; De Sitter, 1947). It is probable that the main sediment source was to the south of the basin and that a river system brought material in via Tinga Tingana and Mulga (Demaison et. al., 1970).

The Upper Member is composed mainly of sands which are known to be hydraulically interconnected in many wells, where they generally produce together. This means that there is a free movement of the formation waters above the intra-Gidgealpa disconformity.

The water movements within the Middle-Lower Members are more restricted, and this is particularly true for the Middle Member where sand layers are generally lenticular in nature.

(a) <u>Salinities in Areas of Flushing</u>

A comparison between the extent of the Triassic and Permian subcrops (Fig. 1) would suggest that in the south, where the Permian strata are in direct contact with the Jurassic aquifers, artesian waters may have forced Permian waters, and hydrocarbons, north-westwards towards the deeper parts of the basin. It can be demonstrated that this has, in fact, happened in the Cooper Basin, but at the moment there is no definite evidence to suggest where the Permian connate waters have gone.

The southern group of wells (Enc. 1) clearly demonstrates extensive flushing by artesian waters - their salinities are as low, or lower, than those of the Mesozoic waters and generally have less HCO_3 than the artesian waters (Enc. 7) but the patterns displayed by these wells are unlike the other Permian ones, especially in their small amounts of Na, K and Cl. This area has obviously been invaded by younger waters.

The western, central and eastern groups (Encs. 2,3,4) all lie near to the limit of the Triassic subcrop and have been affected by artesian flushing to varying extents. Younger, less saline waters have managed to invade the Upper Member further northwards in the Daralingie-Gidgealpa and Murteree-Strzelecki areas. This may be due to better permeability of the strata, which has also produced free vertical movement of the formation waters, and is evidenced by the uniform patterns from Strzelecki 1, Mudlalee 1, Murteree 1, Toolachee 1 and 3. The central group (Enc. 3) while all displaying remarkable similarity between Upper Middle and Lower patterns also show that invasion has occurred from the south (Toolachee 1 has salinities approximately half those at Strzelecki 1, and the Upper Member's salinity in Toolachee 3 is nearly identical with the artesian water at Fortville 3). This group is an excellent example to demonstrate the need to use water patterns, as well as salinity maps and other diagrams, in studying water types.

Two eastern wells (Enc. 4) have been flushed, to a limited extent, in the Upper Gidgealpa only. Toolachee 2 is similar to Strzelecki 1, and Nappacoongee 1, which is further from the area of direct contact with artesian aquifers, has an artesian type of pattern with its higher salinity due to larger amounts of Na, K and Cl. Both waters are classified in Chebotarev's Group III and are clearly different from the remaining analyses in this area which belong to Group V. The anomalous eastern area on the Middle-Lower salinity map is due to the inability of the artesian waters to extend any further than the top of the Gidgealpa Formation at Nappacoongee 1 and Toolachee 1. This fact may be due either to those wells greater distance from the Triassic limit, lower permeabilities of the strata involved or a higher potentiometric surface in this region. Unfortunately there is a lack of information which leaves the question unresolved for the moment.

The western wells (Enc. 2) of Pando 1 and 2 and Pando North 1 have no Upper Member in them so the Middle Member waters are probably artesian, like the southern ones, and it seems likely that the Group III and IV waters at Topwee 1 and Daralingie 1 and 2 have been partly flushed although there is too little evidence apart from the Upper Gidgealpa "valley" to support this.

In the northern area (Enc. 5) it is almost certain that the low salinity values at Gidgealpa 3, 6, 11 and Merrimelia 3 are due to the presence of Mesozoic waters because of the pattern similarities. It seems very likely that artesian waters, from the Hutton Formation, may have entered the Upper Member either from the western side of the major fault, along the fault zone, or from the south where the southern Gidgealpa fault brings the Hutton either into contact with or close to the Permian on the northern side. Fig. 7 shows the relationships between these faulted formations. These water analyses are restricted to the Upper Member so it is impossible to learn the extent of artesian flushing in the fault-bounded area.

The large amounts of Ca and Fe in Gidgealpa 5, 7 and 9 (Enc. 6) precludes anything but the slightest flushing of the Upper Gidgealpa Member extending down to the Middle Member in Gidgealpa 9. It is probable that small quantities of younger waters entered, as above, either from the west, from the flushed fault-bounded Permian to the north, or by direct movement along the faults. The low salinity area extending through the Daralingie gas field in the Upper Gidgealpa may exist because of artesian flushing both from the Gidgealpa fault region and from the south where the Triassic is absent, but the former cause is likely to be the dominant one at Gidgealpa as evidenced by the greater invasion at No. 9.

(b) Salinities in Areas of Non-Flushing

The remaining analyses for this whole northern area (Encs. 5, 6) show large increases of Na, K and Cl and variable amounts of Ca, Mg and Fe. These waters are likely to be as near to the Permian connate ones as any found in the Cooper Basin and their characteristics require explanations other than artesian flushing.

The high salinities of these brines can be explained by compaction and burial of the overlying sediments (de Sitter, 1947), although they are relatively low compared with many oilfield brines (Chebotarev, 1955; White, 1965), and it is the proportions rather than the absolute values of the ions which are important in determine the possible origin of the waters produced.

No study of formation waters is straightforward and many factors, including the less obvious ones like permeability, textures, structure, fractures etc., will all play important roles in developing the waters particularly in the large timespans involved with deep brines.

One noticeable feature of the northern wells, (Encs. 5, 6) in both flushed and unflushed horizons, is the nearly constant amount of HCO_3 at all levels. This suggests that a relatively large amount of HCO_3 was present in the waters during or soon after deposition, which may have been due to carbonaceous material in the fresh-water sediments releasing CO_2 ($CO_2 + OH \rightarrow HCO_3$). HCO_3 is certainly not a predominant ion in most marine "connate" waters.

The very low, or non-existant, amount of SO_4 present in all analyses (except Wirrarie 1) may also be associated with the production of large amounts of CO_2 (and consequently HCO_3). The reduction of SO_4 to sulphides by bacteria or plant material is known to produce CO_3 and this factor could be significant in the Cooper Basin which is nearly sulphur-free (Levorsen, 1967).

Wirrarie 1 is unusual in being the only Chloride-Sulphate water recorded so far in the Cooper Basin and its associated small amount of HCO_3 possibly confirms the relationship between these two ions. With the present limited amount of data it is not possible to speculate on the reason for the unusual pattern obtained from Wirrarie 1, a non-producer.

The high proportions of Na, K and Cl in the brines have been concentrated, and not subsequently flushed, by the normal compaction and burial of overlying sediments (de Sitter, 1947 etc.). Na, once absorbed in formation waters, is not easily precipitated out again and Cl is a 'subdued' element that plays little part in later reduction/oxidation cycles. K, while being more abundant than Na in sediments, is not easily dissolved into and transported by water and is therefore a very minor constituent of any brines.

The relationship between Ca and Mg can sometimes be an important one and in this northern area the amount of Mg is always small (less than 5 meq/l) and Ca generally not much greater, except at Gidgealpa 5 and 7 which could be the result of selective precipitation of dolomite in this part of the basin.

The results of chemical studies of Cooper Basin connate waters indicate that they are in general much less saline than many oilfield brines, and have more HCO_3, probably because of their original freshwater origin, but otherwise are much as expected for waters of similar age and depths of burial and show small variations of minor constituents which would be expected from freshwater sediments with restricted lateral and vertical limits.

Zanier and Pert (1971) have shown that gas accumulations may be expected in more saline areas, i.e. unflushed regions, but, in the Cooper Basin, whereas gas discoveries have been from formations with water salinities over 5 000 p.p.m., these discoveries are not restricted to unflushed horizons. Zanier and Pert demonstrated the influence of water movements in altering the original hydrocarbon distribution, and from their work it would seem probable that future discoveries are more likely to be from higher salinity areas or ones with original high salinities that may have been partially flushed later.

In the Gidgealpa field there appears to be a definite correlation between the amount of condensate produced with the gas and the salinity of the associated Permian formation water. (Table II). From the figures available, it is quite clear that the flushed horizons produce much less condensate (up to 6.3 bbl/mcf) compared with the unflushed levels, which produce about 8 to 10 times as much condensate per mcf. This is due to most of the heavier hydrocarbons having been flushed out and when more statistics become available it seems likely that it will be possible to predict future areas of dry (and wet) gas production. Oil production is almost certain to be restricted to the unflushed areas of the north and northwest Cooper Basin.

TABLE II

The Relationship between Formation Salinities and Hydrocarbon Production in the Gidgealpa Field.

Well Name	Producing Horizon	Condensate bbl/mcf	Salinity p.p.m.	Ratio: p.p.m.: bbl/mcf.
Gidgealpa 3	middle	4.3	?	?
" 4	upper	2.0	c. 6 000 *	c. 3 000
" 5	middle	53.0	14 594	275
" 7	upper	6.3	9 760 *	1 549
" 7	middle	35.0	12 522	358
" 9	upper	3.9	c. 7 500 *	c. 1 923
" 11	upper	3.1	5 391 *	1 739

* denotes a flushed horizon

(c) Hydrodynamics

No study of underground waters should be confined entirely to the chemistry of the waters and their surrounding rocks and for many years several writers have been aware of the great importance of hydrodynamics in studying petroleum movements and accumulations (Chebotarev, 1955; Hubbert, 1953; Levorsen, 1967; Back and Hanshaw, 1965 etc.).

Much work has been done on osmosis through semi-permeable membranes and it is possible that small local variations in salinities and pressure may be due to this effect but on the whole it is unlikely that any major trends can be related to such phenomena after the length of time involved since Permian deposition (White, 1965; Levorsen, 1967; Hem, 1970 etc.). Likewise, the Mills and Wells' (1919) theory of water evaporation coincident with gas escape could only account for local variations in sand lenses entirely enclosed by impermeable strata and is therefore not considered a significant factor in the Cooper Basin.

Increases in temperature are known to decrease the viscosity of water and increase its solvent action on salts (except for NaCl which is altered very little with increasing temperature). In the Cooper Basin it has been possible to demonstrate a northerly increase in bottom hole temperatures (Fig. 8); these are all values taken from logs and drill stem tests and therefore represent the trend and not the stabilised formation temperatures which could be as much as 100°F higher in some areas. It is possible that the increased salinities in the wells of the northern area could be partly due to these higher temperatures and that water movements have been effected by flows away from the warmer areas.

Landes (1967) reported the effects of increased temperatures on hydrocarbon accumulations; he stated that the complete breakdown of oil occurs at 250°F and at temperatures greater than that the gases will become increasingly drier. In the Cooper Basin it seems unlikely that the varying condensate ratios are in any way related to the temperatures, because most bottom hole temperatures are greater than the critical temperatures. However, it is worth realising that substantial oil accumulations will only be found in areas with formation temperatures that have been less than 250°F since the formation of oil, providing other conditions are also suitable.

Pressure studies are more important than temperature ones in understanding the movements of waters, both within and between aquifers, and it is unfortunate that the present study has had to be restricted nearly entirely to the chemical characteristics of the brines. With the very small number of reliable determinations of the potentiometric surface in the Cooper Basin (Figs. 9, 10) it is not at all possible to make any assumptions on the directions of water movements within the Permian and Mesozoic strata. At this stage the Upper Gidgealpa Member's surface appears to be very undulating, possibly due to the considerable invasion of foreign water, while that for the Middle-Lower Member demonstrates a general direction of flow away from the northern wells. This flow direction, which is down-dip in relation to the whole basin, could be encouraging in terms of stratigraphic traps along the northern basin margin. A very unreliable picture has been obtained for the artesian surface, but, from the small amount of data available, it would seem to confirm Jack's theory (1923) of flow from the northeast and potentiometric heights are in general agreement with his of 50 years ago (Nugent, 1969).

All hydrocarbon migrations are closely associated with movements of formation waters towards lower pressure areas; they will occur perpendicularly to the potentiometric contours and towards the lower values. Although formation waters can move in different directions at different times during compaction and structural change, a knowledge of present water movements within the reservoir rocks must undoubtedly assist in the delineation of possible hydrocarbon accumulations. Similarly, in areas where the hydrodynamic gradients are found to be great enough to cause extensive flushing and the possible removal of hydrocarbons, any further exploration efforts could be excluded or at least proceed with the knowledge of the high failure risks involved. It was hoped to show some correlation between salinities, pressure gradients and temperatures throughout the basin, but clearly the lack of reliable data on pressures and temperatures has prevented this and any predictions on further discoveries.

CONCLUSIONS

This survey conclusively demonstrates flushing by artesian waters of the entire Gidgealpa Formation in the southern part of the Cooper Basin and, to a lesser extent, northwards into the centre of the basin. This is the direct result of the absence of the Triassic aquiclude from the southern area. The chemical studies and associated diagrams have proved invaluable in showing this quickly and convincingly, but it is unfortunate that, whereas many drill stem tests have frequently provided good samples of water, the same tests have generally failed to produce reliable pressure data. The present work shows that gas discoveries have been made in both flushed and unflushed horizons thereby demonstrating the role played by moving waters in accumulating some gas fields. It is therefore hoped that this small study of the chemistry and physics of the Cooper Basin formation waters may convince future operators in the area to sample carefully all waters, pressure and temperatures encountered during drilling in order that in years to come they will have some information to guide them relatively easily to the less obvious hydrocarbon accumulations that will undoubtedly have to be sought after the present targets have been exhausted.

ACKNOWLEDGEMENTS

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The following well completion reports are available on "Open File" at the Department of Mines, all other data used are confidential.

Delhi Santos	Daralingie No.	1	DM.	Env.	No.	837
" "	" "	2	DM.	"	"	900
" "	Dullingari No.	1	DM.	"	"	258
" "	Gidgealpa "	1	DM.	"	"	363
" "	" "	2	DM.	"	"	367
" "	" "	3	DM.	"	"	395
" "	Innamincka "	1	DM.	"	"	146
" "	" "	2	DM.	"	"	529
" "	Kalladeina "	1	DM.	"	"	813
" "	Merrimelia "	1	DM.	"	"	471
" "	" "	2	DM.	"	"	496
" "	" "	3	DM.	"	"	508
" "	" "	4	DM.	"	"	513
" "	Naryilco "	1	DM.	"	"	291
" "	Orientos "	1	DM.	"	"	284
" "	Pandieburra"	1	DM.	"	"	312
" "	Putamurdie "	1	DM.	"	"	322
" "	Spencer "	1	DM.	"	"	558
" "	Tinga Tingana "	1	DM.	"	"	889
Flinders	Coongie "	1	DM.	"	"	1388
F.P.C. (A) (Total)	Poonarunna "	1	DM.	"	"	451
" "	Roseneath "	1	DM.	"	"	1298
" "	Tickalara "	1	DM.	"	"	1297
Pexa	Cherri "	1	DM.	"	"	1340
"	Kumbarie "	1	DM.	"	"	1301

APPENDIX I

Since the writing of this report, water analyses from five recent wells have become available and a summary of the results is presented here. The Stiff water patterns for all the additional results are shown in Enclosure No. 8.

At this stage the detailed stratigraphy of the Gidgealpa Formation is not known for the Lake Hope 1 and Toolachee 5 wells but a tentative age has been assigned to the horizons that produced water.

The two artesian waters are similar to those known previously and it is interesting to note that again the water from the Della field has an above average salinity.

The Upper Member analyses from Della 3 have salinities as expected and fit in well with the isohaline contours around the Della gas field (Fig. 3). Like the other Della wells, this one clearly belongs to the northern group of wells and again shows unusual patterns not found elsewhere in the Cooper Basin.

The Upper Gidgealpa at Tilparee A-1 has clearly been entirely flushed and, without seeing an analysis for the Middle-Lower Member, it is impossible to place it in either the southern or central group although it would probably show characteristics similar to those of Toolachee 3 and therefore belong to the latter group.

The analysis from Toolachee 4, Middle Member, fits in with the contours for the Middle-Lower Salinity Map (Fig. 4) and, judging by the unflushed nature of this Middle Member water, it possibly correlates with the eastern group.

Lake Hope 1 was drilled about 20 kilometres from the nearest well (Spencer 1) and is therefore in an unknown hydrological province and to the west of the main Gidgealpa Fault. The Upper Member is entirely flushed, as would be expected with a well near to the Triassic limit (Fig. 3); the other two analyses, presumably from the Middle-Lower Members, show similarities with the Middle and Lower analyses from Gidgealpa 9 and appear to be unflushed.

All of the above water analyses can be given appropriate classifications according to Chebotarev (1955) and these correlate with those already shown in Table I. The additional analyses are as follows:-

Lake Hope No. 1	?Upper Member	Group II
Lake Hope No. 1	?Middle Member	Group IV
Lake Hope No. 1	?Lower Member	Group IV
Della No. 3	Upper Member	Group V
Toolachee No. 4	Middle Member	Group V
Tilparee A-1	Upper Member	Group II
Della No. 3	Artesian	Group III
Toolachee No. 5	Artesian	Group II

APPENDIX II

The Computer Programme used for all calculations in the Study.

```
FORTRAN (3.2)/MASTER                                                                    1

      PROGRAM SALINITY
      DIMENSION NAME(20)
      COMMON STORE(51,203),HCP(100),LL,Z(100,6),LOC(100),COL(100)
      REAL NA,K,MG,NAM,KM,MGM,NO3,HC3M
      CHARACTER     STORE
      INTEGER BL,HCP ,DHD
      DO 8 J=1,203
      DO 8 I=1,51
    8 STORE(I,J)=1H
      DHD=4H....
      DO 9 I=2,154,2
    9 STORE(26,I)=DHD
      DO 10 I=1,25,2
      STORE(I,51)=STORE(I+26,52)=DHD
   10 STORE(I,153)=DHD
      DO 11 J=3,47,4
      I=26-J/2 $STORE(I,J)=STORE(I,J+102)=DHD
   11 STORE(I+24,J+51)=DHD
      LL=1 $BL=4H
      PRINT 100
  100 FORMAT(1H1,40X,24HS.A. DEPARTMENT OF MINES /30X,49HANALYSIS OF PET
     +ROLEUM WATER SAMPLE SALINITY DATA //60X,19HG.PILKINGTON (1971) /)
   20 READ 50,NAME
   50 FORMAT(20A4)
      CALL EOFCK(60,J)
      GO TO(1,2)J
    2 PRINT 71,(NAME(I),I=1,18),LL
   71 FORMAT(1H1,9X18A4,20X12HWELL NUMBER I3,7H OF SET )
      NT1=NAME(19) $NT2=NAME(20)
      READ 50,NAME
      CALL CHECK(NAME(19),NAME(20),NT1,NT2)
      IF(NAME(19).EQ.BL)20,3
    3 PRINT 51,(NAME(I),I=1,18),LL
   51 FORMAT(  10X,18A4,20X12HWELL NUMBER I3,7H OF SET )
      READ 50,NAME
      CALL CHECK(NAME(19),NAME(20),NT1,NT2)
      IF(NAME(19).EQ.BL)20,5
    5 PRINT 51,(NAME(I),I=1,18),LL
      READ 52,HCP(LL),HC,NA,K,CA,MG,FE,CL,HCO3,SO4,CO3,NO3,NAME(19),NAME
     +(20)
   52 FORMAT(A1,A8,X,5F5,5X,5F5,7X,2A4)
      CALL CHECK(NAME(19),NAME(20),NT1,NT2)
      IF(NAME(19).EQ.BL)20,6
    6 PRINT 53,HCP(LL),HC
   53 FORMAT(/20X,33HHYDROCARBON PRODUCTION LISTED AS A1,A8//10X, 7HCATI
     +ONS,10X,6HIN PPM,10X,17HIN MILLI-EQ/LITRE ,20X,6HANIONS,10X,6HIN P
     +PM,10X,17HIN MILLI-EQ/LITRE/10X,7(1H-),10X,6(1H-),10X,17(1H-),20X
     +,6(1H-),10X,6(1H-),10X,17(1H-)/)
      NAM=NA*0.0434 $CLM=CL*0.0282 $KM=K*0.0256 $HCO3M=HCO3*0.0164
      CAM=CA*0.0499 $SO4M=SO4*0.0208 $MGM=MG*0.0821$CO3M=CO3*0.0333
      FEM=FE*0.035  $NO3M=NO3*0.1061
      PRINT 54,NA,NAM,CL,CLM
      PRINT 55,K,KM,HCO3,HCO3M
      PRINT 56,CA,CAM,SO4,SO4M
```

```
      PRINT 57,MG,MGM,CO3,CO3M
      PRINT 58,FE,FEM,NO3,NO3M
   54 FORMAT(/8X,10HSODIUM  NA,10X,F5,12X,F10.4,19X,13HCHLORINE   CL10X,
     +F5,12X,F10.4)
   55 FORMAT(/5X,13HPOTASSIUM    K10X,F5,12X,F10.4,16X,16HBICARBONATE HCO
     +3,10X,F5,12X,F10.4)
   56 FORMAT(/7X,11HCALCIUM  CA10X,F5,12X,F10.4,19X,13HSULPHATE  SO410X,
     +F5,12X,F10.4)
   57 FORMAT(/5X,13HMAGNESIUM  MG10X,F5,12X,F10.4,18X,14HCARBONATE  CO3,
     +10X,F5,12X,F10.4)
   58 FORMAT(/10X,8HIRON  FE,10X,F5,12X,F10.4,20X,12HNITRATE  NO310X,F5
     +,12X,F10.4)
      PPMC=NA+K+CA+MG+FE $PPMCM=NAM+KM+CAM+MGM+FEM
      PPMA=CL+HCO3+SO4+CO3+NO3 $PPMAM=CLM+HCO3M+SO4M+CO3M+NO3M
      PRINT 59,PPMC,PPMCM,PPMA,PPMAM
   59 FORMAT(/5X,120(1H-)/10X,5HTOTAL,12X,F6,12X,F10.4,22X,5HTOTAL,14X,
     +F6,12X,F10.4)
      GTP=PPMC+PPMA $GTM=PPMCM+PPMAM
      PRINT 60,GTP,GTM
   60 FORMAT(/20X,29HPPM GRAND TOTAL = SALINITY = F6/9X,28HMILLI-EQ/LITR
     +E GRAND TOTAL =11X,F10.4)
      AMK=NAM+KM $CAN=CAM+MGM
      PRINT 61,AMK,CAN
   61 FORMAT(//10X, 9H(NA+K) = F10.4,15H MILLI-EQ/LITRE /9X,10H(CA+MG) =
     + F10.4)
      CALL TRI(1,AMK,CAM,MGM,I,J,0)
      PRINT 62,I,J
   62 FORMAT(/10X,33HPOSITION OF (NA+K),CA,MG RATIO = I3,1H,I3)
      CALL TRI(2,CAN,NAM,KM,I,J,0)
      PRINT 63,I,J
   63 FORMAT(/10X,33HPOSITION OF (CA+MG),NA,K RATIO = I3,1H,I3)
      CALL TRI(3,CLM,HCO3M,SO4M,I,J,0)
      PRINT 64,I,J
   64 FORMAT(/10X,33HPOSITION OF CL,HCO3,SO4  RATIO = I3,1H,I3)
      Z(LL,1)=CAM/MGM $Z(LL,2)=CLM/SO4M $Z(LL,3)=HCO3M/SO4M
      Z(LL,4)=CLM/HCO3M $Z(LL,5)=NAM/KM $Z(LL,6)=GTP $LL=LL+1
      IF(MG.EQ.0.) 30,31
   30 Z(LL,1)=100.
   31 IF(SO4.EQ.0.) 32,33
   32 Z(LL,2)=Z(LL,3)=100.
   33 IF(HCO3.EQ.0.) 34,35
   34 Z(LL,4)=100.
   35 IF(K.EQ.0.) 36,37
   36 Z(LL,5)=100.
   37 CONTINUE
      GO TO 20
    1 LL=LL-1
      CALL TRI(1,Y,Y,Y,I,J,1)
      CALL TRI(2,Y,Y,Y,I,J,1)
      CALL TRI(3,Y,Y,Y,I,J,1)
      CALL PLOT
      CALL COMPARE
      STOP
      END
```

FORTRAN DIAGNOSTIC RESULTS FOR SALINITY

RORS

RTRAN (3.2)/MASTER 11/

```
      SUBROUTINE CHECK(N1,N2,NT1,NT2)
      IF(N1.NE.NT1)1,2
    2 IF(N2.NE.NT2)1,3
    3 RETURN
    1 PRINT 10,N1,N2,NT1,NT2
   10 FORMAT(/5X,37HERROR IN DATA,TIES ARE NOT EQUAL VIZ 2A4,5H AND 2A4/
     +2X,12HDATA IGNORED /)
      N1=4H
      RETURN
      END
```

FORTRAN DIAGNOSTIC RESULTS FOR CHECK

S

P 00115 C 00000 D 00000

FORTRAN (3.2)/MASTER

```
      SUBROUTINE TRI(N,A,B,C,I,J,M)
      COMMON STORE(51,203),HCP(100),LL,Z(100,6),LOC(100),COL(100)
      DIMENSION E(4)
      CHARACTER  CP,STORE ,BE,E
      INTEGER D,BL,HCP
      BE=1H      $E(1)=1HN $E(2)=1HZ
      GO TO(1,2) M+1
    1 J=1
      ABC=A+B+C $AA=A/ABC $CA=C/ABC $I=AB=AA*50.+1. $AB=AB-I $I=I+AB+AB
      ENCODE(4,59,IHCP) HCP(LL)
   59 FORMAT(3X,A1)
      J=AB=J+CA*100. $AB=AB-J $J=J+AB+AB  $CP=IHCP
      IF(J.GT.I+I-1) 60,61
   60 J=J-1
   61 GO TO(5,5,4)N
    4 J=102 + J
    5 GO TO (6,7,6)N
    7 I=51-I $ J=103-J
    6 IF(STORE(I,J).EQ. BE ) 9,15
   15 IF(STORE(I,J).EQ.E(1)) 9,8
    8 IF(STORE(I,J).EQ.E(2)) 9,11
   11 IF(CP.EQ.E(1)) 10,12
   12 IF(CP.EQ.E(2)) 10,9
    9 STORE(I,J)=CP
   10 RETURN
    2 PRINT 20
   20 FORMAT(1H1,20X,26HPLOT OF A TRIANGLE DIAGRAM //10X,37HVERTICAL SCA
     +LE = 2 PERCENT PER LINE. / 8X,49HHORIZONTAL SCALE = 1 PERCENT PER
     +PRINT POSITION. /)
      GO TO (21,22,23)N
   21 PRINT 211
  211 FORMAT(62X,6H(NA+K))
      GO TO 24
   22 PRINT 221
  221 FORMAT(62X,7H(CA+MG))
      GO TO 24
   23 PRINT 231
  231 FORMAT(65X,2HCL)
   24 K=51 $D=1H* $BL=1H
      PRINT 25
   25 FORMAT(/65X,1H*)
      GO TO(26,27,28)N
   27 I=1 $JI=102 $JM=102 $GO TO 29
   26 I=51 $JI=1 $JM=1 $GO TO 29
   28 I=51 $JI=103 $JM=103
   29 PRINT 30,(BL,L=1,K),D,(STORE(I,J),J=JI,JM),D
   30 FORMAT(13X,105A1)
      GO TO(31,32,31) N
   31 I=I-1 $GO TO 33
   32 I=I+1 $JI=JI-2 $K=K-1 $GO TO 34
   33 JM=JM+2 $K=K-1
      IF(I.EQ.0)35,29
   34 IF(I.EQ.52)35,29
   35 PRINT 36
```

```
36 FORMAT(13X,105(1H*)/)
   GO TO(37,38,39)N
37 PRINT 371
71 FORMAT(12X,2HCA,102X,2HMG)
   RETURN
38 PRINT 381
31 FORMAT(12X,2H K,103X,2HNA)
   RETURN
39 PRINT 391
91 FORMAT(11X,4HHCO3,101X,3HSO4)
   RETURN
   END
```

FORTRAN DIAGNOSTIC RESULTS FOR TRI

SIMPLE VARIABLES

P

P 00777 C 10136 D 00000

FORTRAN (3.2)/MASTER 1

```
      SUBROUTINE SORT(M)
      COMMON STORE(51,2,3),HCP(100),LL,Z(100,6),LOC(100),COL(100)
      CHARACTER STORE
      INTEGER HCP
      DO 10 I=1,LL
      COL(I)=Z(I,M)
   10 LOC(I)=I
      LIM=LL-1
    1 INT=1
      DO 2 I=1,LIM
      IF(COL(I+1).GE.COL(I)) 2,3
    3 TEMP=COL(I+1) $L=LOC(I+1) $COL(I+1)=COL(I) $LOC(I+1)=LOC(I)
      COL(I)=TEMP $LOC(I)=L $INT=I
    2 CONTINUE
      IF(INT.EQ.1) 4,5
    5 LIM=INT-1 $GO TO 1
    4 RETURN
      END
```

FORTRAN DIAGNOSTIC RESULTS FOR SORT

RORS

RT P 00162 C 10136 D 00000

```
      SUBROUTINE PLOT
      COMMON STORE(51,203),HCP(100),LL,Z(100,6),LOC(100),COL(100)
      CHARACTER STORE
      DIMENSION X(6),C(120),LOCC(10)   ,A(2)
      INTEGER A,C,HCP
      CALL SORT(6)
      X(6)=COL(LL)
      DO 5 L=1,5
      X(L)=Z(1,L)
      DO 5 I=2,LL
      IF(X(L).LT.Z(I,L))6,5
    6 X(L)=Z(I,L)
    5 CONTINUE
      L=M=1 $IGU=GU=YX=CM=50.   $IG5=250
      DO 33 K=1,115
   33 C(K)=1H
      DO 32 K=1,LL
   29 IF(COL(K).GT.CM)30,31
   30 CM=CM+GU    $M=M+1 $GO TO 29
   31 COL(K)=M
   32 CONTINUE
      KINITAL=IFIX(COL(1))/5-1    $KINIT=5*KINITAL+1
   60 GO TO(7,8,9,10,11)L
    7 A(1)=4H CA/   $A(2)=4HMG      $GO TO 12
    8 A(1)=4H CL/   $A(2)=4HSO4     $GO TO 12
    9 A(1)=4HHCO3   $A(2)=4H/SO4    $GO TO 12
   10 A(1)=4H CL/   $A(2)=4HHCO3    $GO TO 12
   11 A(1)=4H NA/   $A(2)=4HK
   12 PRINT 3,A,YX
    3 FORMAT(1H1,20X,36HPLOT OF SALINITIES AGAINST ION RATIO
     +X,2A4,/29X,10(1H-),9X,9(1H-)
     +   // 7X,29HSALINITY SCALE = ONE LINE TO F5.1,4H PPM /)
      AK=K=1 $MM=KINITAL*IG5
  198 IF(X(L)*AK.GT.11) 1,2
    1 AK=AK*0.5 $K=3
      IF(X(L)*AK.LE.11) 202,199
  199 AK=AK*0.2 $K=1 $GO TO 198
    2 IF(X(L)*AK.LT.5.5) 200,202
  200 AK=AK+AK $K=2
      IF(X(L)*AK.LT.2.2) 201,202
  201 AK=AK*5.  $K=1 $GO TO 2
  202 AK=1./AK
      PRINT 15,AK
   15 FORMAT(10X,43HRATIO SCALE = ONE INCH TO A RATIO CHANGE OF F7.3/38X
     +,5(1H-)/)
      GO TO (203,204,206) K
  203 PRINT 16,MM
   16 FORMAT(19X,1H0,9X,1H1,9X,1H2,9X,1H3,9X,1H4,9X,1H5,9X,1H6,9X,1H7,9X
     +,1H8,9X,1H9,9X,2H10/19X,11(1H.,9X)/13X,I5,1H.,111(1H*))
      GO TO 205
  204 PRINT 17,MM
   17 FORMAT(19X,1H0,19X,1H1,19X,1H2,19X,1H3,19X,1H4,19X,1H5/19X,11(1H.,
     +9X)/13X,I5,1H.,111(1H*))
      GO TO 205
```

```
  206 PRINT 18,(K,K=2,8,2),(K,K=2,8,2),MM
   18 FORMAT(19X,2H0 ,4( 7X,2H0.,I1), 7X,3H1.0,4( 7X,2H1.,I1), 7X,3H2.0/
     +19X,11(1H.,9X)/13X,I5,1H.,111(1H*))
  255 M=1
      DO 60 K=KINIT ,390
      DO 2345 KKK=22,102,20
 2345 C(KKK)=1H.
      JL=0
      GO TO(48,40,41,42,43,44,43,45,46,47,48) K-(K/60)*60-KINIT
   40 C(1)=1HS $GO TO 48
   41 C(1)=1HA $GO TO 48
   42 C(1)=1HL $GO TO 48
   43 C(1)=1HI $GO TO 48
   44 C(1)=1HN $GO TO 48
   45 C(1)=1HT $ GO TO 48
   46 C(1)=1HY $GO TO 48
   47 C(1)=1H
   48 IF((K/5 )*5 .EQ.K)49,50
   49 MM=MM+165 $C(2)=1H. $MMM=MM $GO TO 51
   50 C(2)=1H $MMM=0
   51 IF(COL(M).EQ.K)52,53
   52 I=LOC(M)$J=Z(I,L)*10./AK $JL=JL+1
      IF(J.GT.110)35,36
   35 C(114)=1H* $LOCC(JL)=111 $GO TO 37
   36 LOCC(JL)=J $C(J+3)=HCP(I)
   37 M=M+1
      IF(M.GT.LL)53,51
   53 IF(MMM.EQ.0)70,71
   70 PRINT 72,(C(I),I=1,114)
   72 FORMAT(10X,A1,7X,A1,1H*,112A1)
      GO TO 55
   71 PRINT 54,C(1),MMM,(C(I),I=2,114)
   54 FORMAT(10X,A1,2X,I5,A1,1H*,112A1)
   55 DO 56 I=1,JL
      J=LOCC(I)
   56 C(J+3)=1H
      IF(M.GT.LL)61,60
   60 CONTINUE
   61 PRINT 64
   64 FORMAT(1H1,30X,17HPLOTTED DATA LIST /31X,17(1H-))
      M=M-1 $K1=1
   63 PRINT 62
   62 FORMAT(/10X, 8HWELL NO.,10X, 8HSALINITY,10X,5HRATIO,10X,11HHYDROCA
     +RBON /11X,6HOF SET,13X,4HPPM.,29X,6HSYMBLE /)
      DO 66 K=K1,M
      KLOC=LOC(K)
   66 PRINT 67,KLOC,Z(KLOC,6),Z(KLOC,L),HCP(KLOC)
   67 FORMAT(12X,I3,14X,F5,10X,F8.3,16X,A1)
      IF(M.EQ.LL) 81,68
   68 PRINT 69
   69 FORMAT(///30X,19HUNPLOTTED DATA LIST /30X,19(1H-))
      K1=M+1 $M=LL $GO TO 63
   81 L=L+1
      IF(L.GE.6)90,100
```

```
90 RETURN
   END
```

FORTRAN DIAGNOSTIC RESULTS FOR PLOT

P 02016 C 10136 D 00000

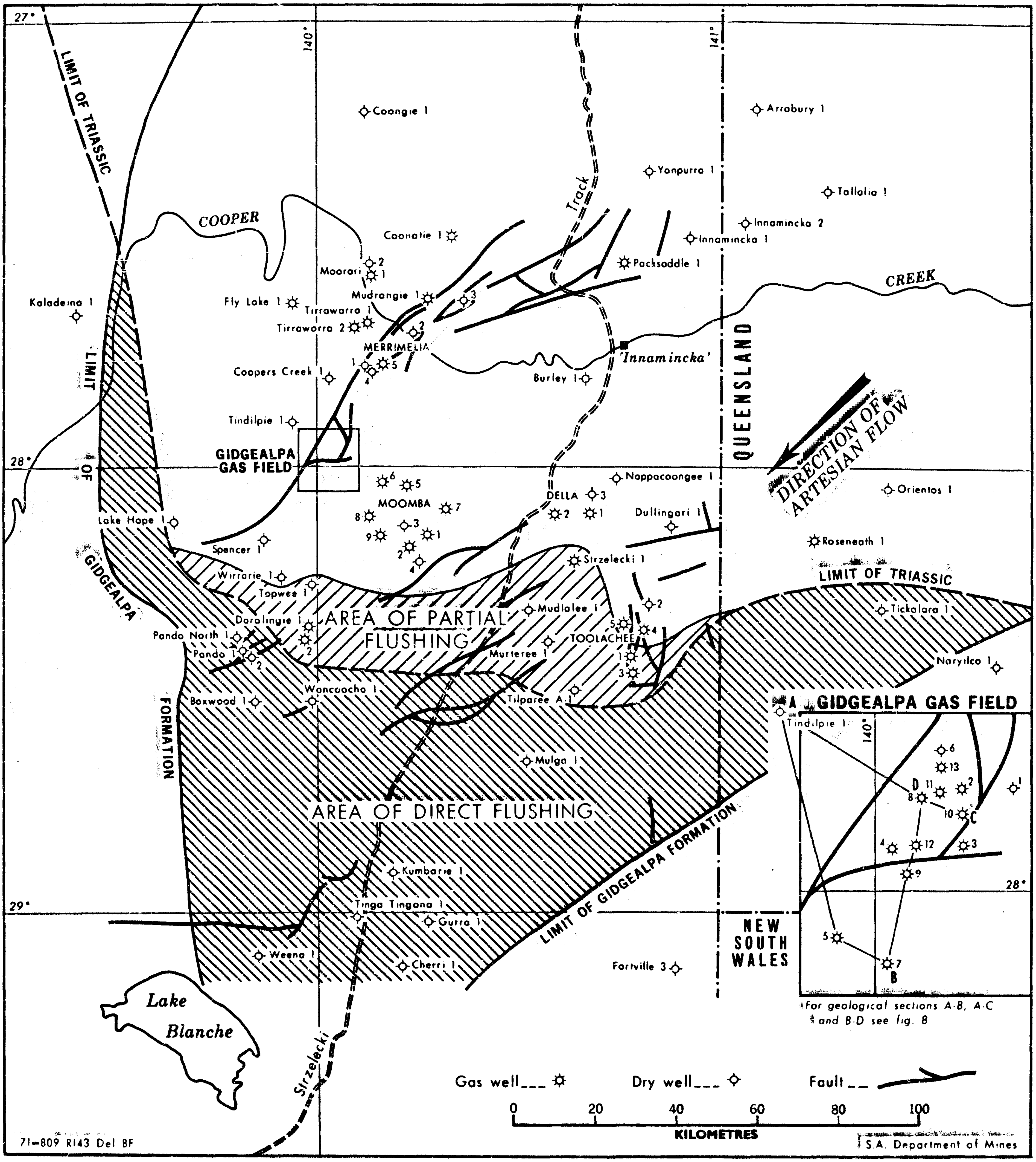
FORTRAN (3.2)/MASTER

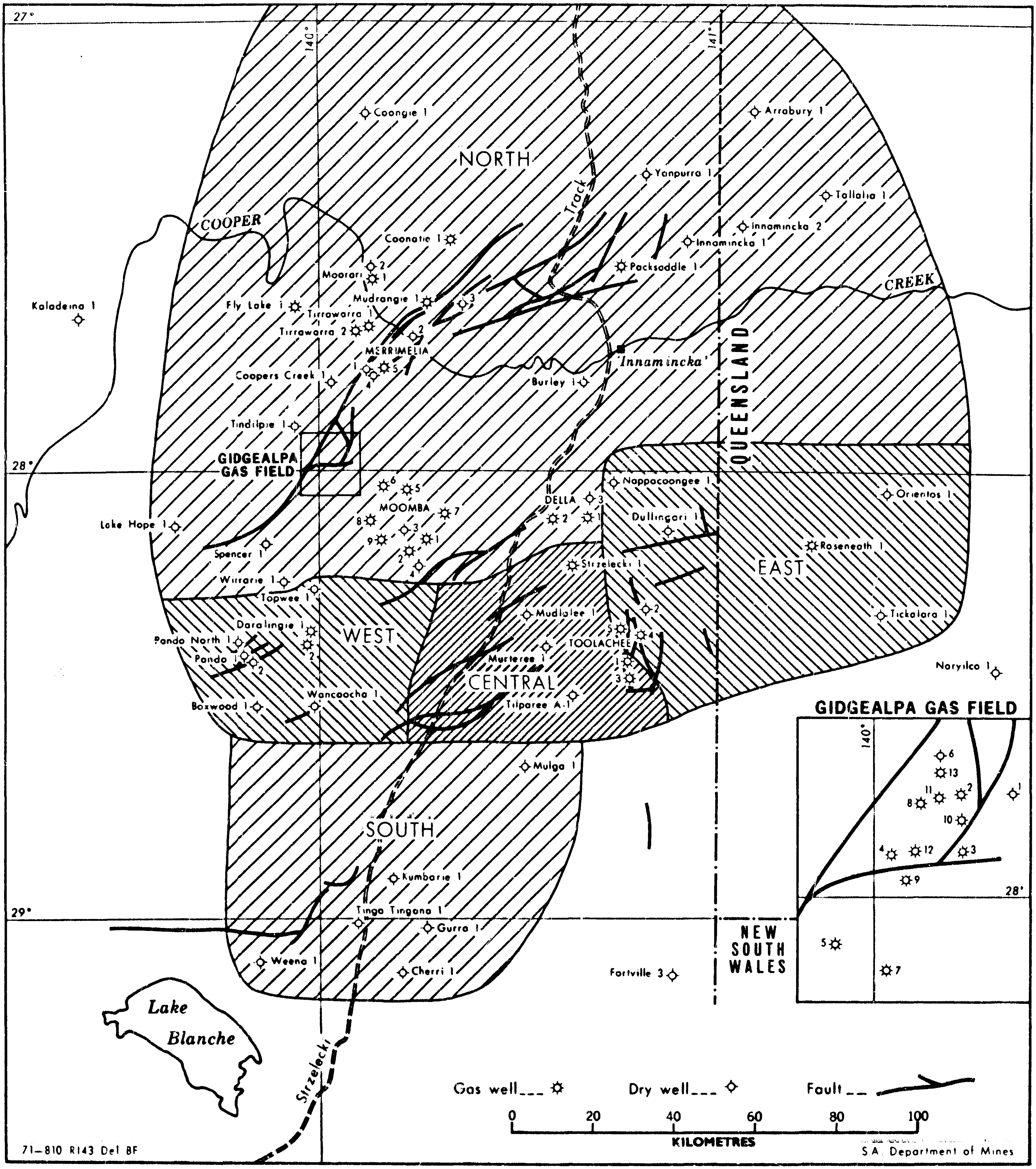
```
      SUBROUTINE COMPARE
      COMMON STORE(51,2,3),HCP(100),LL,Z(100,6)
      CHARACTER STORE
      DIMENSION MEAN(4),SD(4),SUM(4),S(5),SSUM(4),N(5)
      REAL MEAN
      INTEGER HCP
      DO 1 L=1,4
    1 SUM(L)=SSUM(L)=S(L)=0.
      N(1)=1HN $N(2)=1HW $N(3)=1HD $N(4)=1HO  $N(5)=1HZ $S(5)=0.
      DO 20 L=1,LL
      DO 19 K=1,5
      IF(HCP( L).EQ.N(K)) 2,19
   19 CONTINUE
    2 IF(K.EQ.5) 3,9
    9 SUM(K)=SUM(K)+Z( L,6) $S(K)=S(K)+1. $SSUM(K)=SSUM(K)+Z(L,6)*Z(L,6)
      GO TO 20
    3 S(5)=S(5)+1.
   20 CONTINUE
      DO 10 L=1,4
      IF(S(L).EQ.0.)4,5
    4 MEAN(L)=0. $GO TO 7
    5 MEAN(L)=SUM(L)/S(L)
    6 IF(S(L).LT.2)7,8
    7 SD(L)=0. $GO TO 10
    8 SD(L)=SQRT((SSUM(L)+MEAN(L)*(MEAN(L)*S(L)-2.*SUM(L)))/(S(L)-1.))
   10 CONTINUE
      PRINT 30
   30 FORMAT(1H1,20X,36HSALINITY AND HYDROCARBON PRODUCTION /21X,36(1H-)
     +//10X,10HPRODUCTION ,15X,14HMEAN SALINITY ,15X,18HSTANDARD DEVIATI
     +ON ,10X,6HNUMBER/10X,10(1H-),15X,13(1H-),16X,18(1H-),10X,6(1H-)/)
      PRINT 31,(MEAN(I),SD(I),S(I),I=1,4)
   31 FORMAT(/11X,7HNOTHING,19X,F8.1,23X,F8.2,18X,F2//11X,7HWET GAS,19X,
     +F8.1,23X,F8.2,18X,F2//11X,7HDRY GAS,19X,F8.1,23X,F8.2,18X,F2//13X,
     +3HOIL,21X,F8.1,23X,F8.2,18X,F2/)
      PRINT 32,S(5)
   32 FORMAT(11X,7HUNKNOWN,76X,F2)
      RETURN
      END
```

FORTRAN DIAGNOSTIC RESULTS FOR   COMPARE

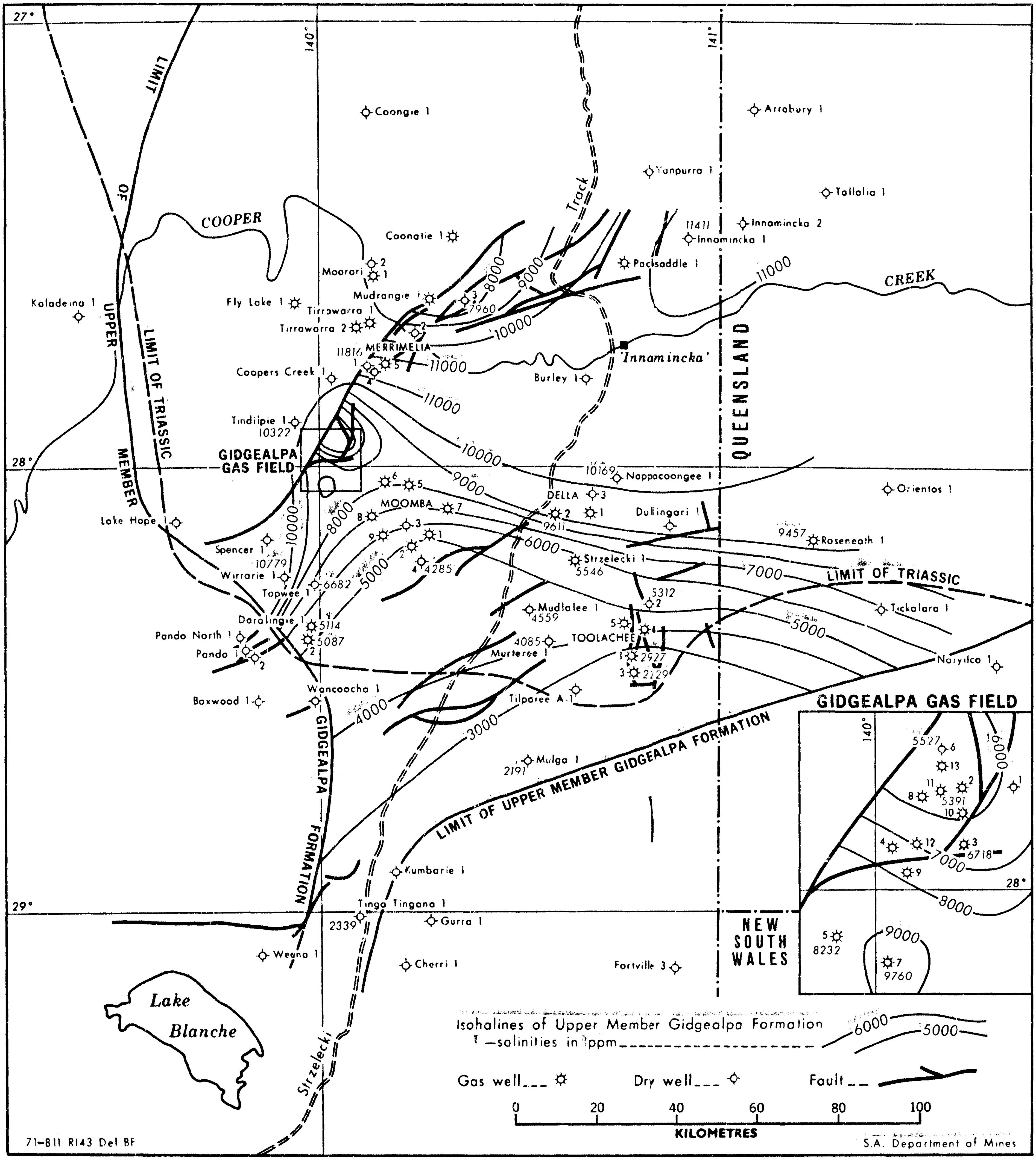
L STATEMENT NUMBERS
 6

OMPARE   P   00564   C   07462   D   00000
0
BOERROR MAY 41   00217

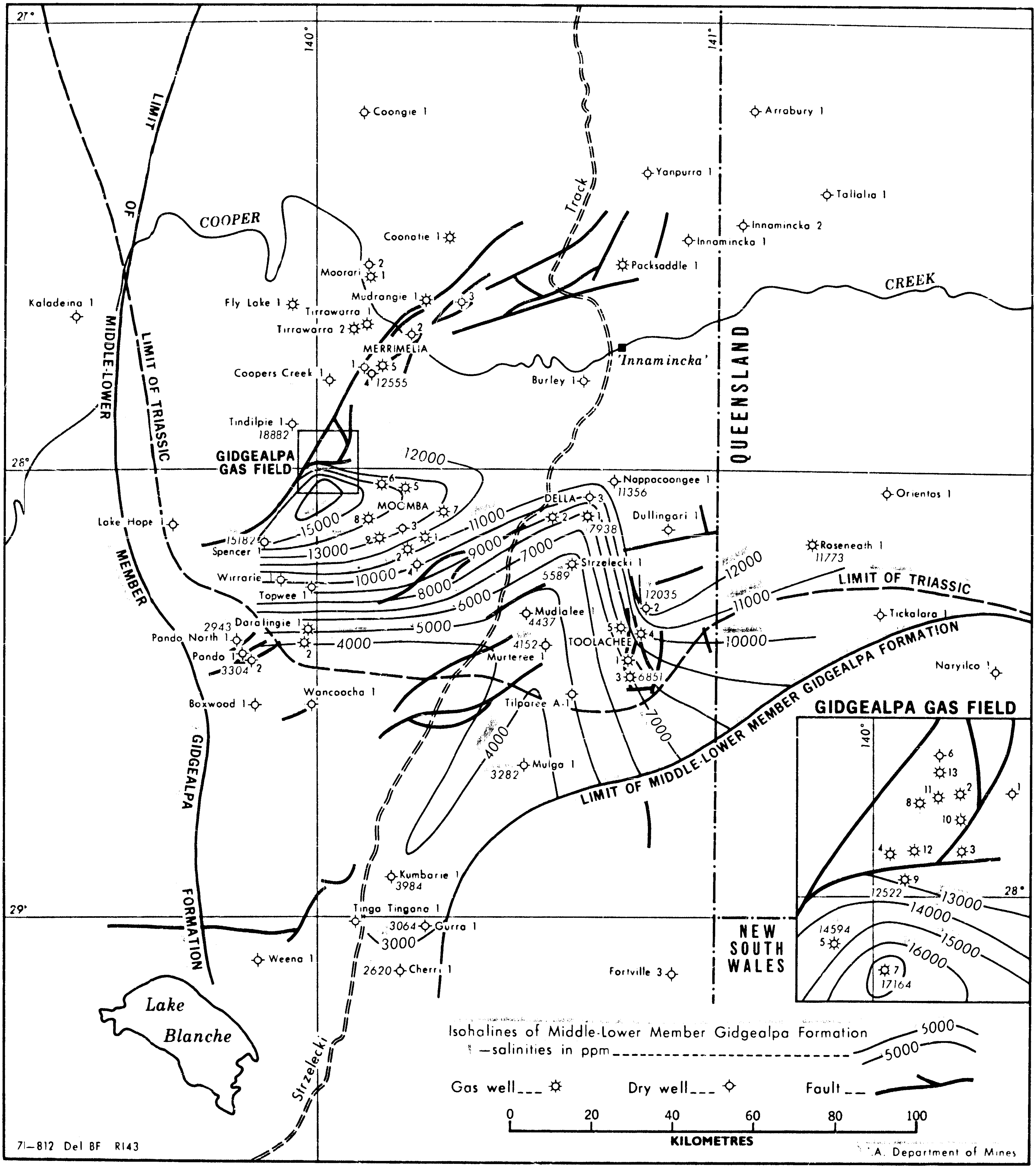

LIMIT OF TRIASSIC
LIMIT OF GIDGEALPA FORMATION
COOPER CREEK
Track
'Innamincka'
QUEENSLAND
NEW SOUTH WALES
DIRECTION OF ARTESIAN FLOW
GIDGEALPA GAS FIELD
MERRIMELIA
MOOMBA
DELLA
TOOLACHEE
AREA OF PARTIAL FLUSHING
AREA OF DIRECT FLUSHING
Lake Blanche
Strzelecki
Coongie 1
Arrabury 1
Yanpurra 1
Tallalia 1
Innamincka 2
Innamincka 1
Coonatie 1
Packsaddle 1
Moorari 2
Moorari 1
Mudrangie 1
Fly Lake 1
Tirrawarra 1
Tirrawarra 2
Kaladeina 1
Coopers Creek 1
Burley 1
Tindilpie 1
Nappacoongee 1
Orientos 1
Dullingari 1
Lake Hope 1
Spencer 1
Roseneath 1
Strzelecki 1
Wirrarie 1
Topwee 1
Mudlalee 1
Tickalara 1
Daralingie 1
Pando North 1
Pando 1
Murteree 1
Narylico 1
Boxwood 1
Wancoocha 1
Tilparee A-1
Mulga 1
Kumbarie 1
Tinga Tingana 1
Gurra 1
Weena 1
Cherri 1
Fortville 3
GIDGEALPA GAS FIELD
For geological sections A-B, A-C and B-D see fig. 8
Gas well
Dry well
Fault
0 20 40 60 80 100
KILOMETRES
27°
28°
29°
140°
141°
71-809 R143 Del BF
S.A. Department of Mines



27°
140°
141°
28°
29°
NORTH
WEST
CENTRAL
EAST
SOUTH
COOPER
CREEK
QUEENSLAND
NEW SOUTH WALES
Track
Strzelecki
Innamincka
Lake Blanche
GIDGEALPA GAS FIELD
MOOMBA
DELLA
TOOLACHEE
MERRIMELIA
Coongie 1
Arrabury 1
Yanpurra 1
Tallalia 1
Innamincka 2
Innamincka 1
Coonatie 1
Packsaddle 1
Moorari
Mudrangie 1
Fly Lake 1
Tirrawarra 1
Tirrawarra 2
Kaladeina 1
Coopers Creek 1
Burley 1
Tindilpie 1
Nappacoongee 1
Orientos 1
Dullingari 1
Lake Hope 1
Spencer 1
Roseneath 1
Strzelecki 1
Wirrarie 1
Topwee 1
Daralingie 1
Mudlalee 1
Tickalara 1
Pando North 1
Pando 1
Murteree 1
Noryilco 1
Boxwood 1
Wancoocha 1
Tirparee A-1
Mulga 1
Kumbarie 1
Tinga Tingana 1
Gurra 1
Weena 1
Cherri 1
Fortville 3
Gas well
Dry well
Fault
0 20 40 60 80 100
KILOMETRES
71-810 R143 Del BF
S.A. Department of Mines



27°
140°
141°
28°
29°
LIMIT OF UPPER MEMBER
LIMIT OF TRIASSIC
COOPER
CREEK
Track
Strzelecki
QUEENSLAND
NEW SOUTH WALES
'Innamincka'
GIDGEALPA GAS FIELD
MERRIMELIA
MOOMBA
DELLA
TOOLACHEE
GIDGEALPA FORMATION
LIMIT OF UPPER MEMBER GIDGEALPA FORMATION
Lake Blanche
Coongie 1
Arrabury 1
Yanpurra 1
Tallalia 1
Innamincka 2
Innamincka 1
Coonatie 1
Packsaddle 1
Moorari
Fly Lake 1
Mudrangie 1
Kaladeina 1
Tirrawarra 1
Tirrawarra 2
Coopers Creek 1
Burley 1
Tindilpie 1
Nappacoongee 1
Orientos 1
Dullingari 1
Lake Hope 1
Spencer 1
Wirrarie 1
Topwee 1
Roseneath 1
Strzelecki 1
Mudlalee 1
Tickalara 1
Daralingie 1
Pando North 1
Pando 1
Murteree 1
Naryilco 1
Boxwood 1
Wancoocha 1
Tilparee A-1
Mulga 1
Kumbarie 1
Tinga Tingana 1
Gurra 1
Weena 1
Cherri 1
Fortville 3
Isohalines of Upper Member Gidgealpa Formation — salinities in ppm
Gas well
Dry well
Fault
0 20 40 60 80 100
KILOMETRES
71-811 R143 Del BF
S.A. Department of Mines



27°
28°
29°
140°
141°
LIMIT OF MIDDLE-LOWER MEMBER GIDGEALPA FORMATION
LIMIT OF TRIASSIC
COOPER CREEK
Track
Strzelecki Track
QUEENSLAND
NEW SOUTH WALES
Lake Blanche
'Innamincka'
GIDGEALPA GAS FIELD
MERRIMELIA
MOOMBA
DELLA
TOOLACHEE
Coongie 1
Arrabury 1
Yanpurra 1
Tallalia 1
Innamincka 2
Innamincka 1
Coonatie 1
Packsaddle 1
Moorari 2
Moorari 1
Mudrangie 1
Fly Lake 1
Kaladeina 1
Tirrawarra 1
Tirrawarra 2
Coopers Creek 1
Burley 1
Tindilpie 1
18882
12555
Nappacoongee 1
11356
Orientos 1
Dullingari 1
Roseneath 1
11773
Lake Hope 1
Spencer 1
15182
Wirrarie 1
Topwee 1
Strzelecki 1
5589
7938
12035
Mudlalee 1
4437
Tickalara 1
Daralingie 1
2943
Pando North 1
Pando 1
3304
4152
Murteree 1
Naryilco 1
Boxwood 1
Wancoocha 1
Tilparee A-1
6851
Mulga 1
3282
Kumbarie 1
3984
Tinga Tingana 1
3064
Gurra 1
2620
Cherri 1
Weena 1
Fortville 3
12000
15000
13000
11000
10000
9000
8000
7000
6000
5000
4000
3000
12522
14594
14000
16000
17164
Isohalines of Middle-Lower Member Gidgealpa Formation — salinities in ppm
5000
Gas well
Dry well
Fault
0 20 40 60 80 100
KILOMETRES
71-812 Del BF R143
S.A. Department of Mines

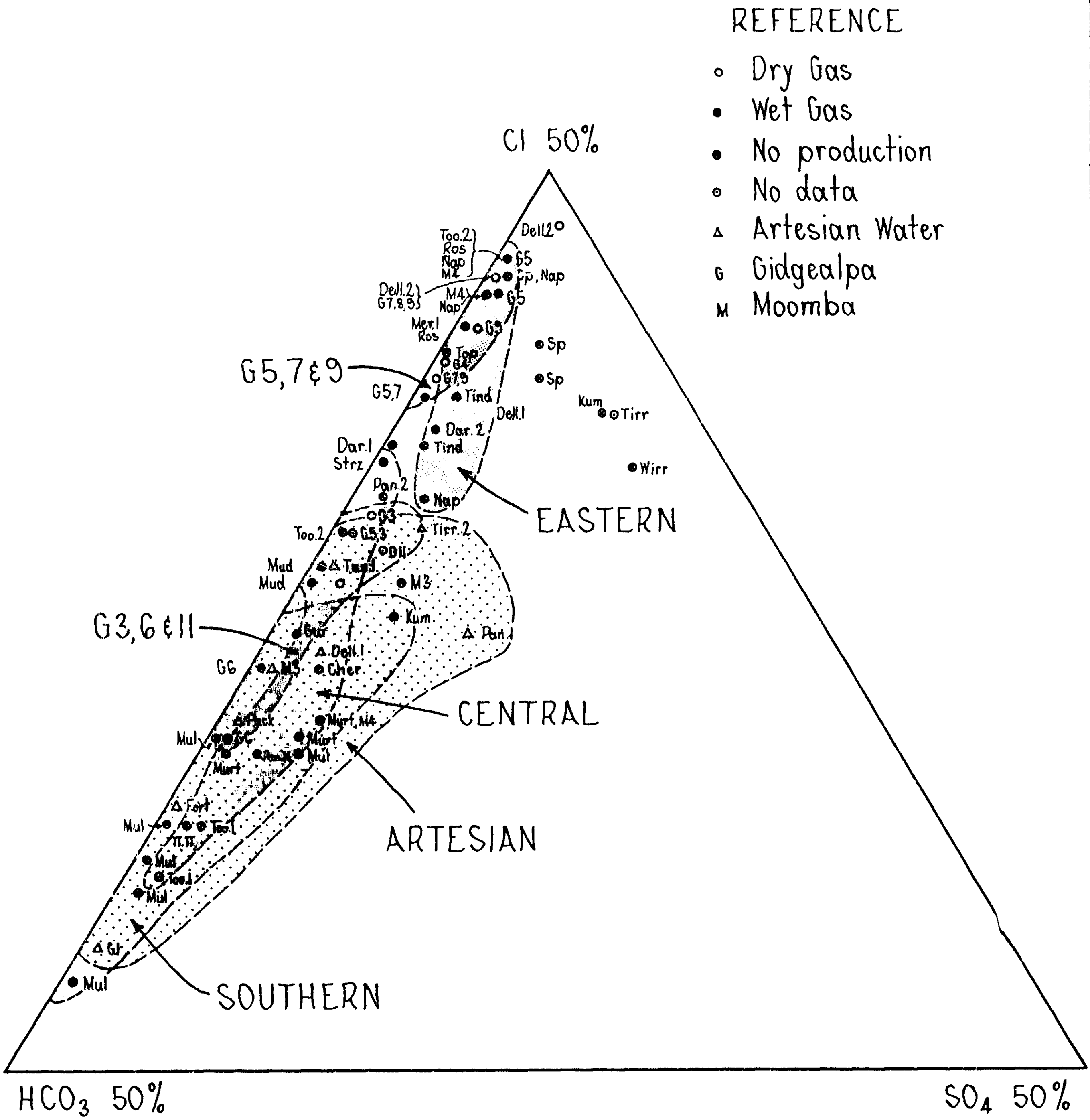


FIG. 5

PETROLEUM GEOLOGY SECTION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale: Diagrammatic
Compiled: B. Youngs	COOPER BASIN – S.A. & QLD.	Date: 15 Nov. 1971
Drn. R.H. Ckd.	ANION TRILINEAR DIAGRAM	Drg. No. S9558 994-2/3

1M–2.70 A1810

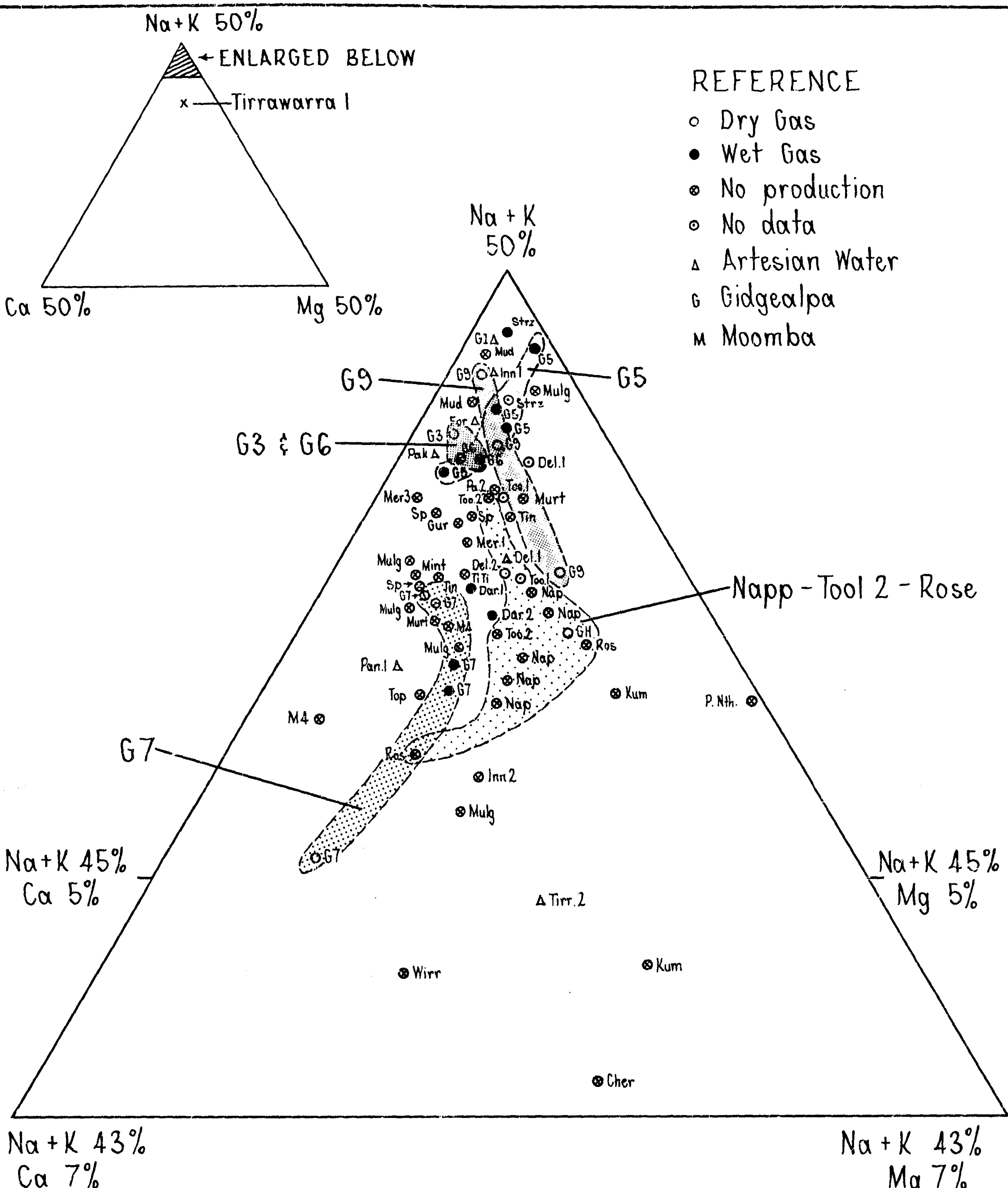
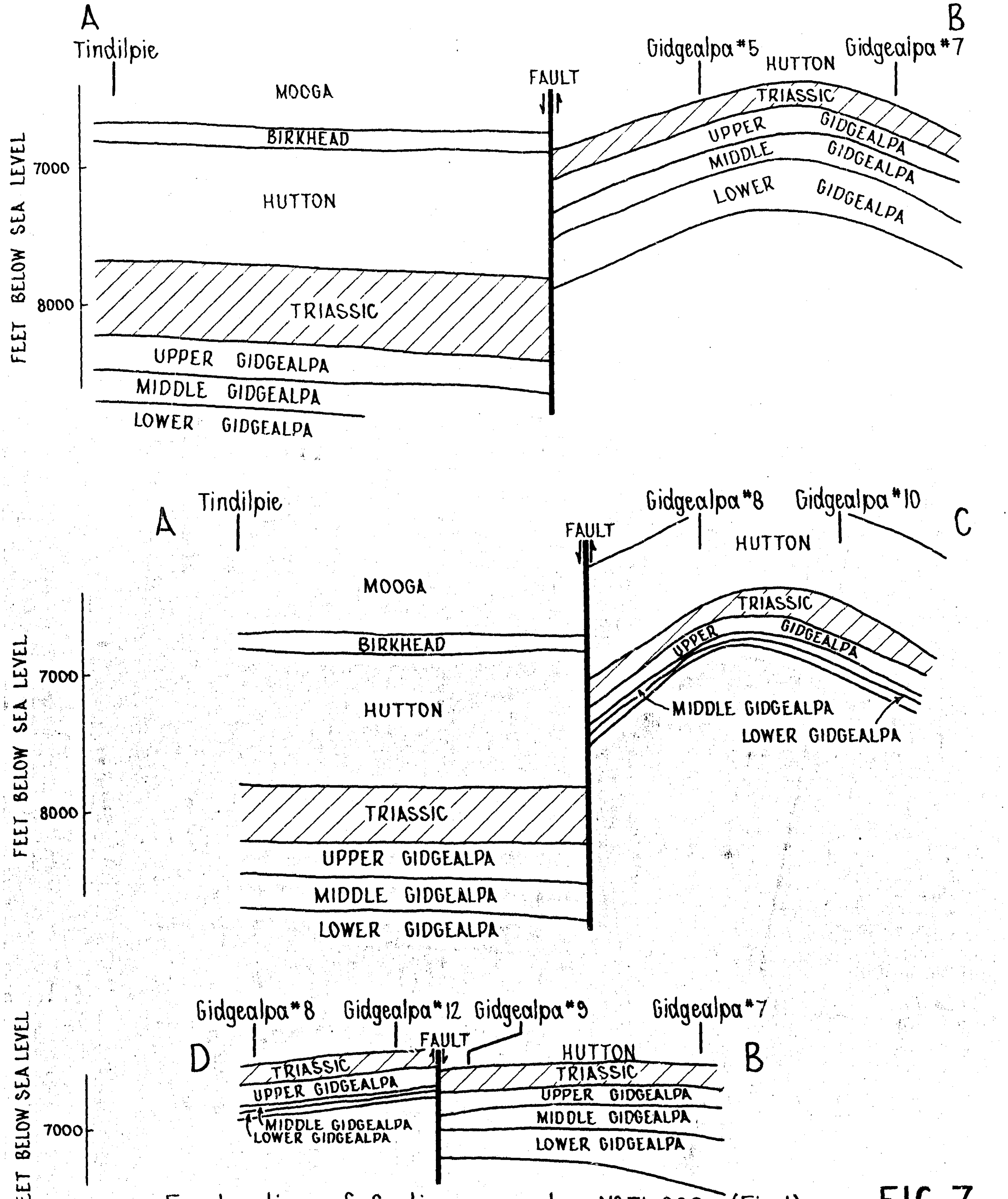


FIG. 6

PETROLEUM GEOLOGY SECTION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale: Diagrammatic
Compiled: B. Youngs	COOPER BASIN – S.A. & QLD.	Date: 12 Nov. 1971
Drn. R.H. Ckd.	CATION TRILINEAR DIAGRAM	Drg. No. S9559 994·2/3

1M–2.70 A1810

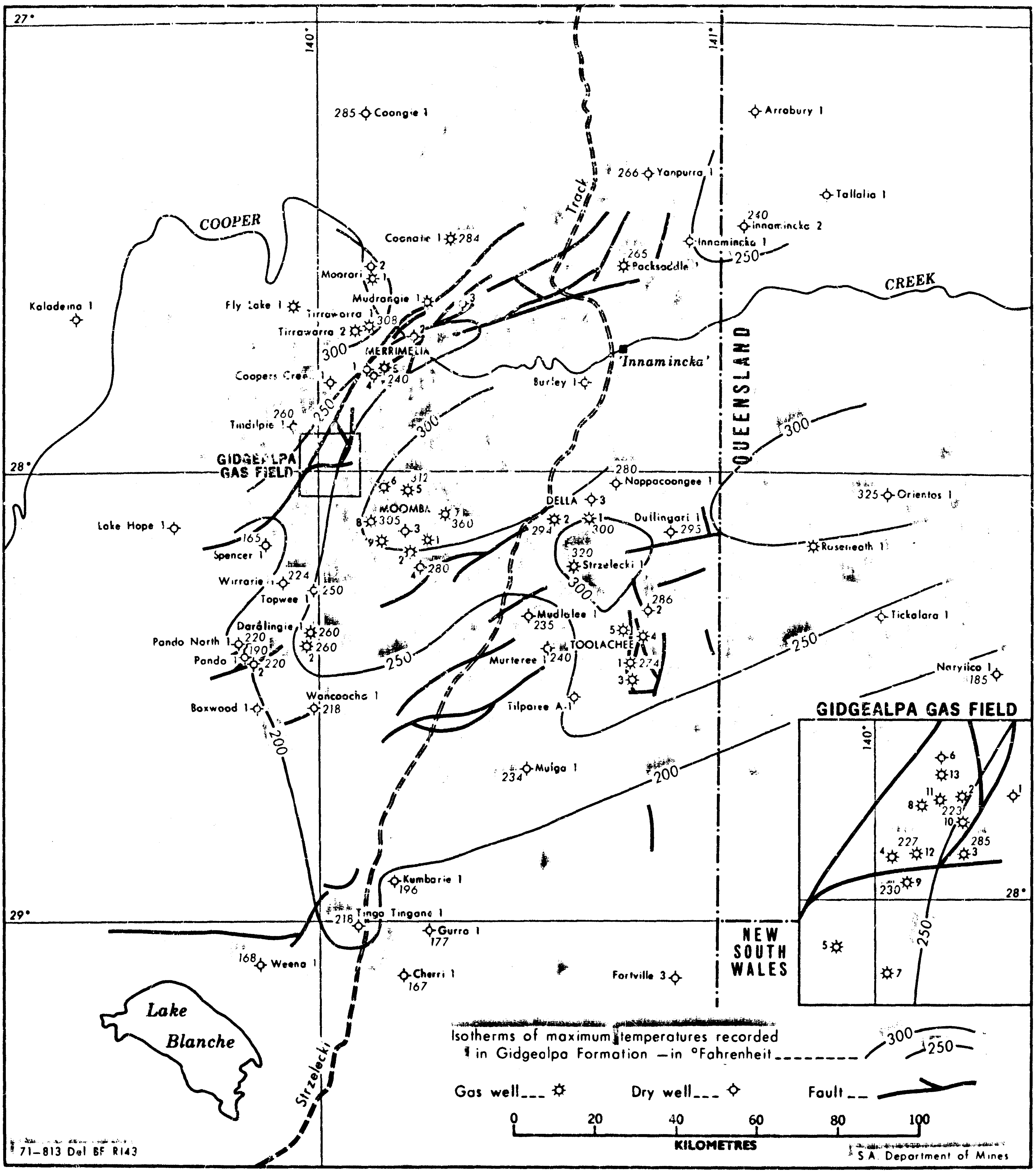


For location of Sections see plan Nº 71-809 (Fig.1)

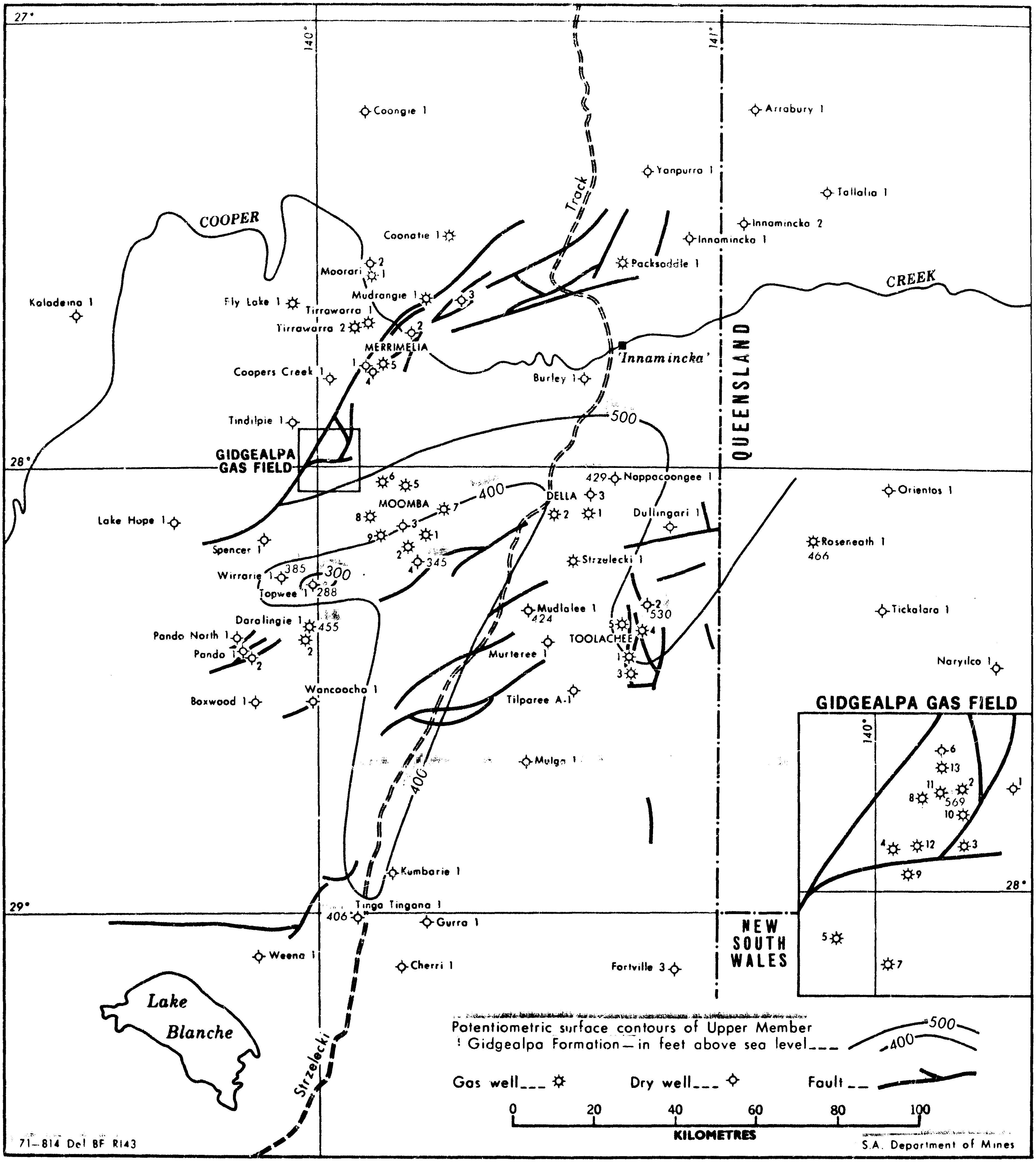
FIG. 7

PETROLEUM GEOLOGY SECTION	**DEPARTMENT OF MINES – SOUTH AUSTRALIA**	Scale: Not to scale
Compiled: B. Youngs	COOPER BASIN – S.A. & QLD. GENERALISED GEOLOGICAL SECTIONS THROUGH GIDGEALPA FIELD	Date: 12 Nov 1971
Drn. R.H. Ckd.		Drg. No. S9560 994·2/3

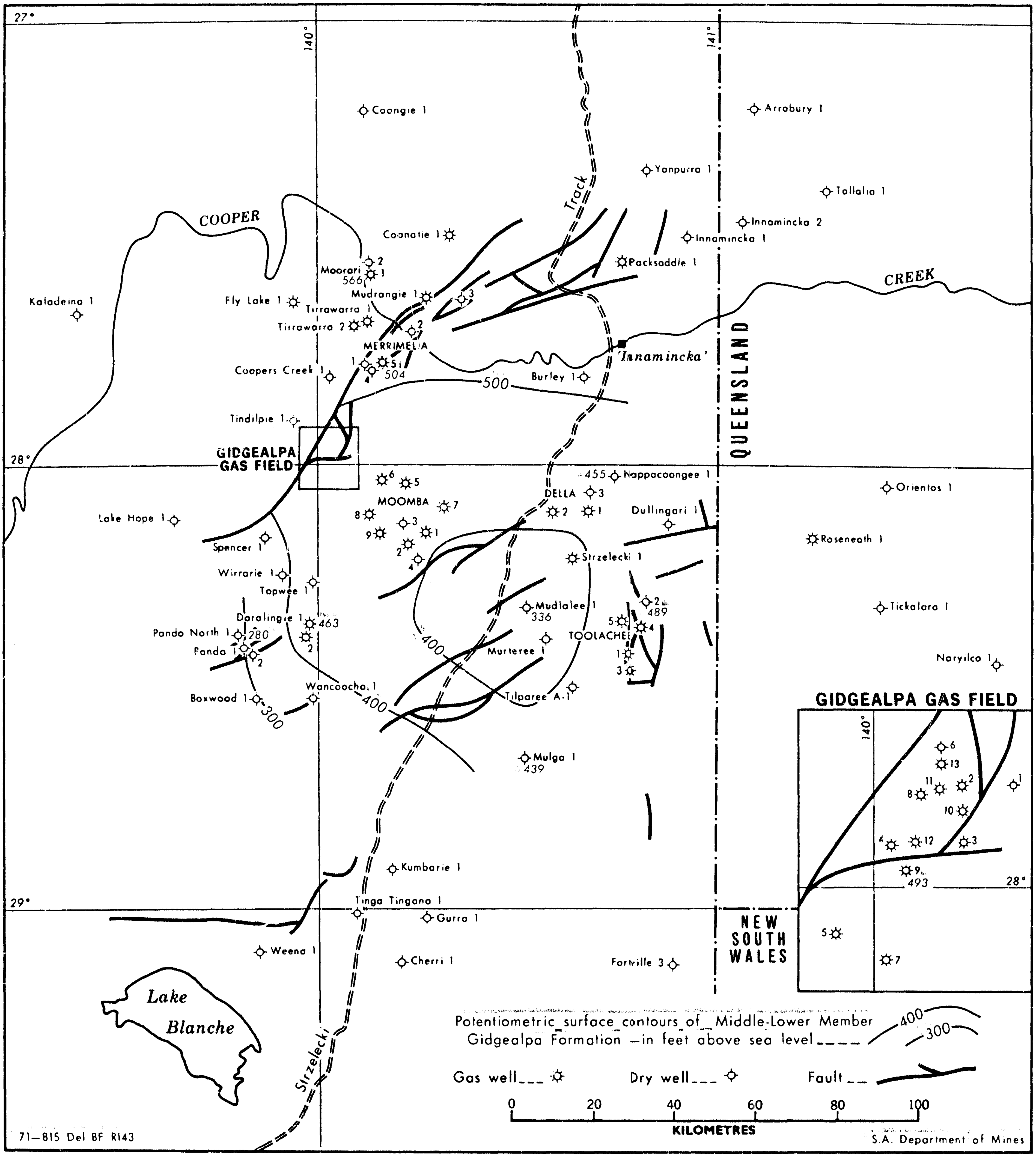
1M–2.70 A1810



COOPER
CREEK
Track
Strzelecki
'Innamincka'
QUEENSLAND
NEW SOUTH WALES
Lake Blanche
GIDGEALPA GAS FIELD
MERRIMELIA
MOOMBA
DELLA
TOOLACHEE
285 Coongie 1
Arrabury 1
266 Yanpurra 1
Tallalia 1
240 Innamincka 2
Innamincka 1
265 Packsaddle 1
Coonatie 1 284
Moorari
Mudrangie 1
Fly Lake 1
Tirrawarra 1 308
Tirrawarra 2
Kaladeina 1
Coopers Creek 1
Burley 1
260 Tindilpie 1
280 Nappacoongee 1
325 Orientos 1
Lake Hope 1
Dullingari 1 295
Roseneath 1
165 Spencer 1
Strzelecki 1
Wirrarie 1 224
Topwee 1 250
Mudlalee 1 235
Tickalara 1
Daralingie 1
Pando North 1 220
Pando 1
Murteree 1 240
Naryilco 1 185
Boxwood 1
Woncoocha 1 218
Tilparee A.1
Mulga 1 234
Kumbarie 1 196
Tinga Tingana 1 218
Gurra 1 177
168 Weena 1
Cherri 1 167
Fortville 3
300
250
200
Isotherms of maximum temperatures recorded in Gidgealpa Formation — in °Fahrenheit
Gas well
Dry well
Fault
0 20 40 60 80 100
KILOMETRES
71-813 Del BF R143
S.A. Department of Mines
27°
28°
29°
140°
141°



27°
140°
141°
28°
29°
Coongie 1
Arrabury 1
Yanpurra 1
Tallalia 1
Innamincka 2
Innamincka 1
Track
COOPER
CREEK
Coonatie 1
Moorari 2
1
Packsaddle 1
Kaladeina 1
Fly Lake 1
Mudrangie 1
3
Tirrawarra 1
Tirrawarra 2
2
MERRIMELIA
'Innamincka'
QUEENSLAND
Coopers Creek 1
Burley 1
Tindilpie 1
500
GIDGEALPA GAS FIELD
429
Nappacoongee 1
Orientos 1
MOOMBA
400
DELLA
Lake Hope 1
Dullingari 1
Roseneath 1
466
Spencer 1
Strzelecki 1
Wirrarie 1
385
300
345
Topwee 1
288
Mudlalee 1
424
530
Tickalara 1
Daralingie 1
455
TOOLACHEE
Pando North 1
Pando 1
Murteree 1
Naryilco 1
Boxwood 1
Wancoocha 1
Tilparee A.1
GIDGEALPA GAS FIELD
569
Mulga 1
400
Kumbarie 1
Tinga Tingana 1
406
Gurra 1
NEW SOUTH WALES
Weena 1
Cherri 1
Fortville 3
Lake Blanche
Strzelecki
Potentiometric surface contours of Upper Member Gidgealpa Formation — in feet above sea level
500
400
Gas well
Dry well
Fault
0
20
40
60
80
100
KILOMETRES
71-814 Del BF R143
S.A. Department of Mines



Reduce to 6⅓"

Fig II. Potentiometric surface contours of Middle-Lower Member Gidgealpa Formation

71·815/4
994·2/3
31·5·74

→ DIRECTION OF INCREASING "METAMORPHISM" OF WATERS →

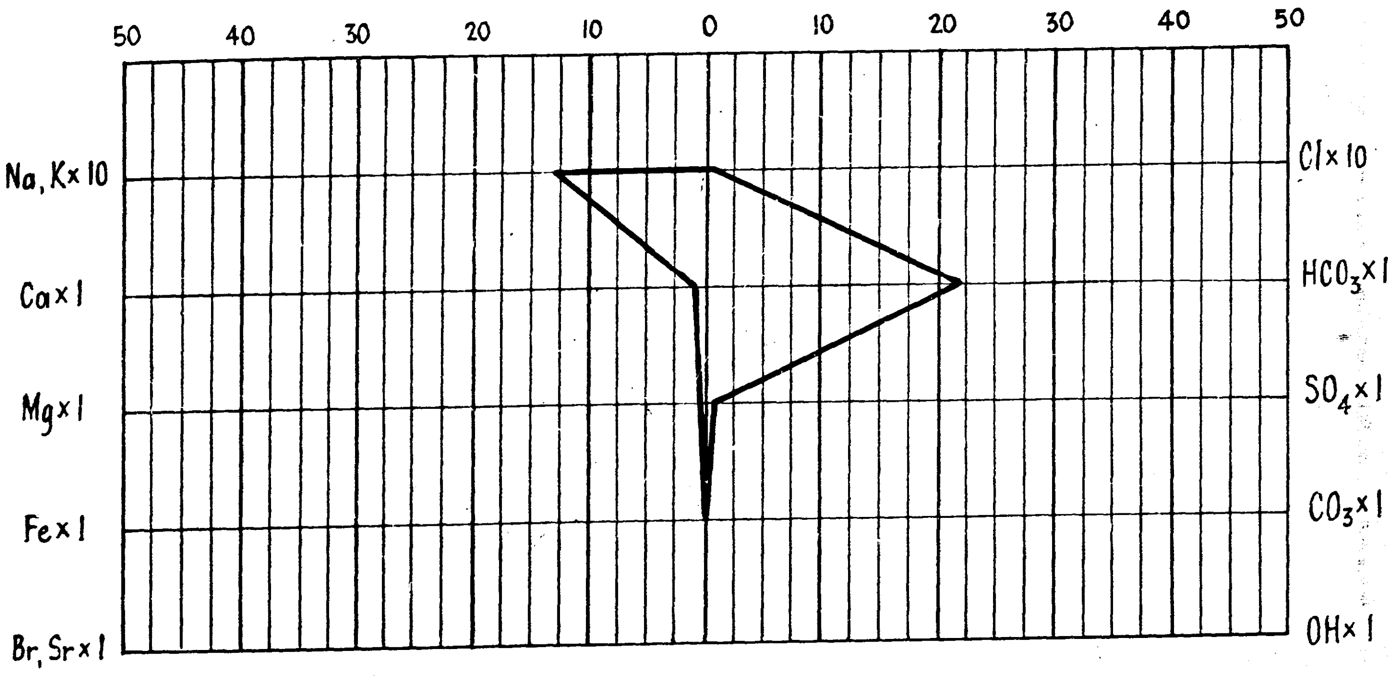
AREA	GIDGEALPA MEMBER	GROUP I BICARBONATE	GROUP II BICARBONATE-CHLORIDE	GROUP III CHLORIDE-BICARBONATE	GROUP III CHLORIDE-BICARBONATE	GROUP IV CHLORIDE-SULPHATE	GROUP V CHLORIDE
NORTHERN AREA	UPPER		GIDGEALPA 6		GIDGEALPA 3 & 11 MERRIMELIA 3	GIDGEALPA 5 & 7 MERRIMELIA 1 TINDILPIE	DELLA 2 MOOMBA 4 INNAMINCKA 2
	MIDDLE					GIDGEALPA 9 SPENCER	GIDGEALPA 7
	LOWER					DELLA 1 TINDILPIE MERRIMELIA 4	GIDGEALPA 5,7 & 9
WESTERN AREA	UPPER			DARALINGIE 1		TOPWEE DARALINGIE 2	
	MIDDLE		PANDO NORTH	PANDO 2			
	LOWER						
EASTERN AREA	UPPER			NAPPACOONGEE	TOOLACHEE 2		ROSENEATH
	MIDDLE						
	LOWER						NAPPACOONGEE TOOLACHEE 2 ROSENEATH
CENTRAL AREA	UPPER		MURTEREE TOOLACHEE 1 & 3		STRZELECKI MUDLALEE		
	MIDDLE				STRZELECKI		
	LOWER				MUDLALEE	TOOLACHEE 3	
SOUTHERN AREA	UPPER		TINGA TINGANA	MULGA			
	MIDDLE	MULGA		CHERRI GURRA			
	LOWER			KUMBARIE	MULGA		
ARTESIAN		GIDGEALPA 1	PACKSADDLE FORTVILLE 3 MOOMBA 3	TIRRAWARRA 2 DELLA 1 PANDO 1 INNAMINCKA 1			

Classification according to Chebotarev (1955)

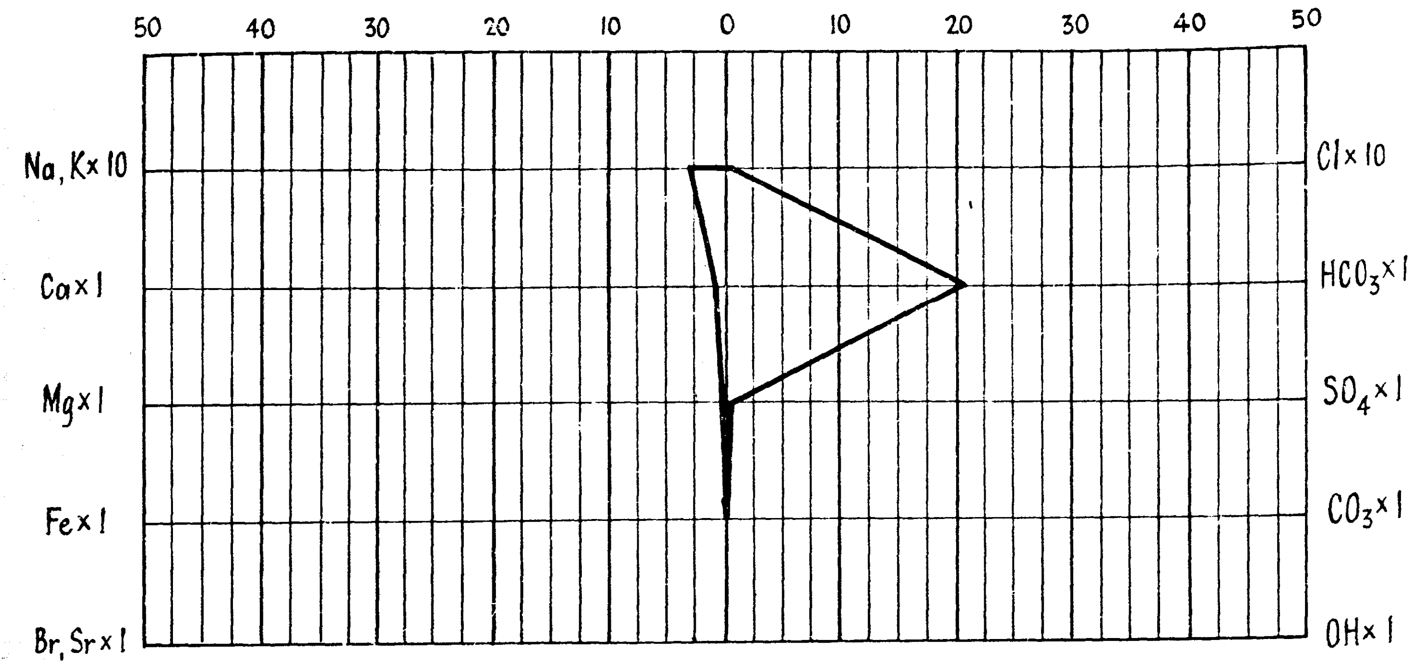
TABLE I

PETROLEUM GEOLOGY SECTION	**DEPARTMENT OF MINES – SOUTH AUSTRALIA**	Scale:
Compiled: B. Youngs	COOPER BASIN – S.A. & QLD.	Date: 1 Dec 1971
Drn. R. H. Ckd.	CLASSIFICATION OF WATERS	Drg. No. S9573 994·2/3

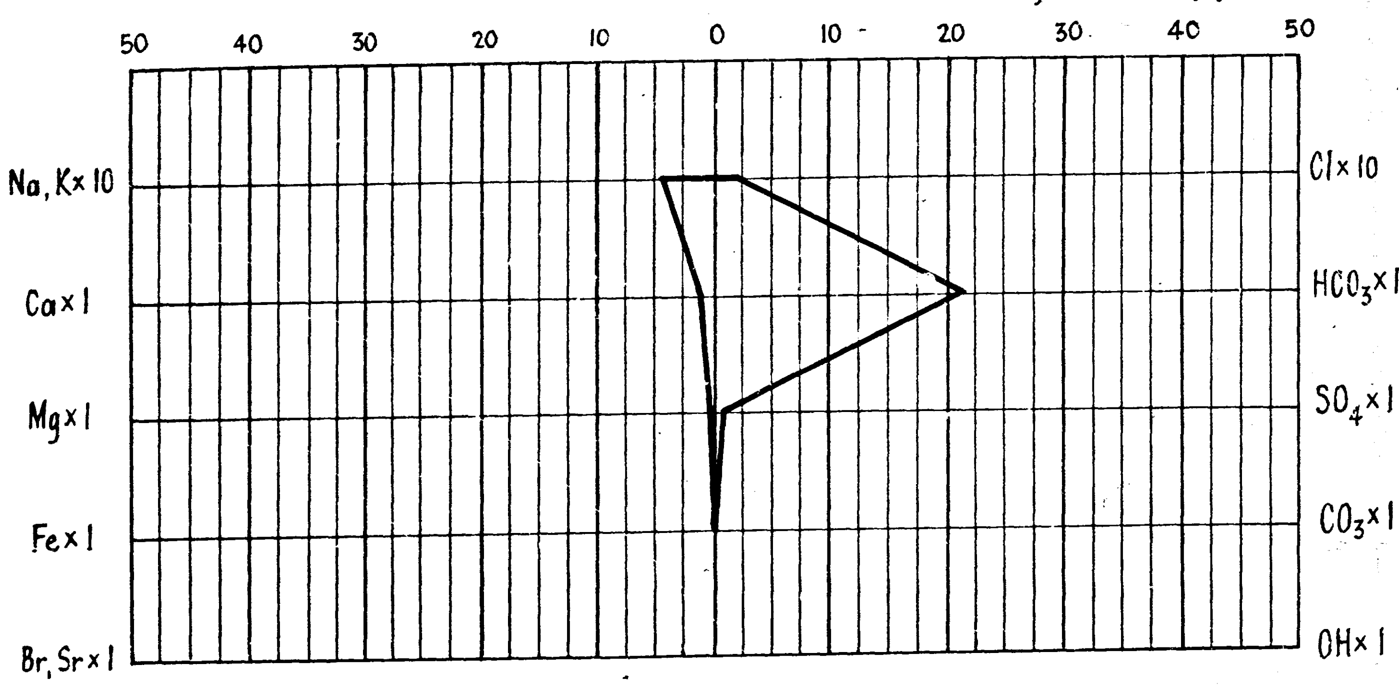
Well Name & Nº TINGA TINGANA 1 Upper Member Salinity 2339 ppm



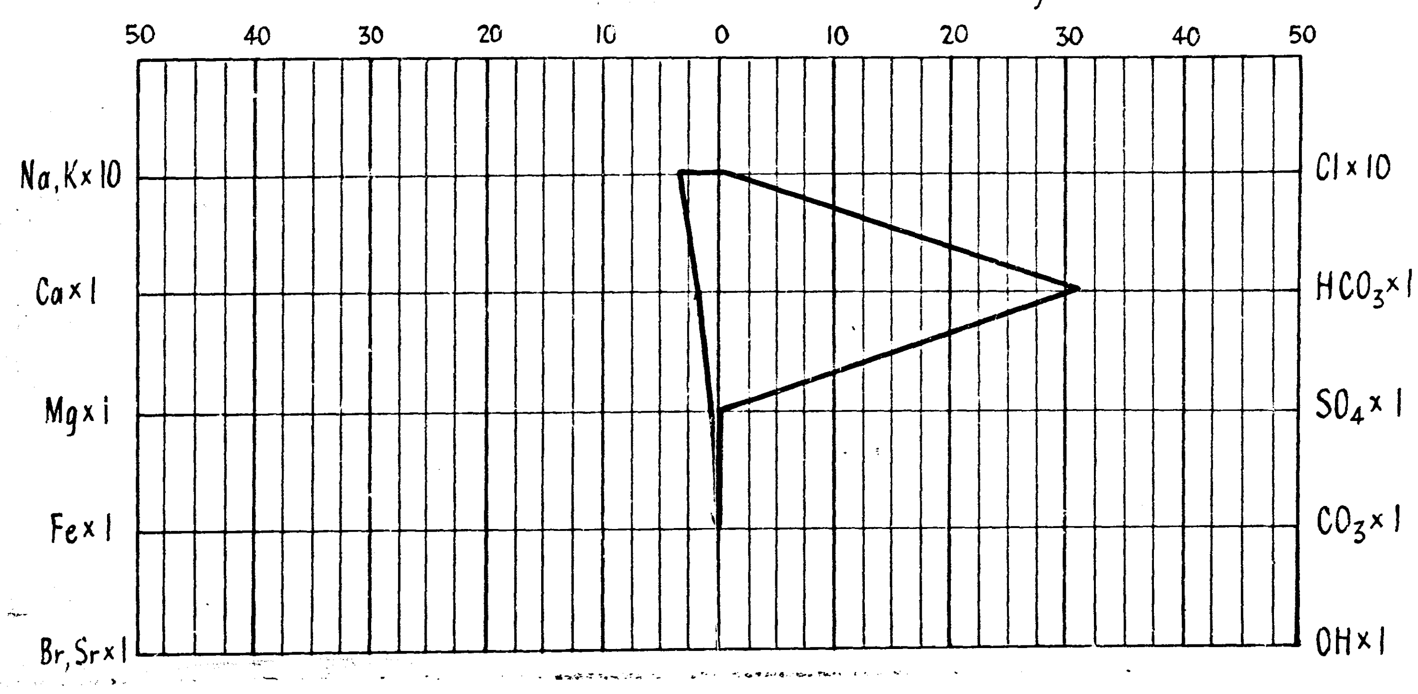
Well Name & Nº MULGA 1 Upper Member Salinity 2191 ppm



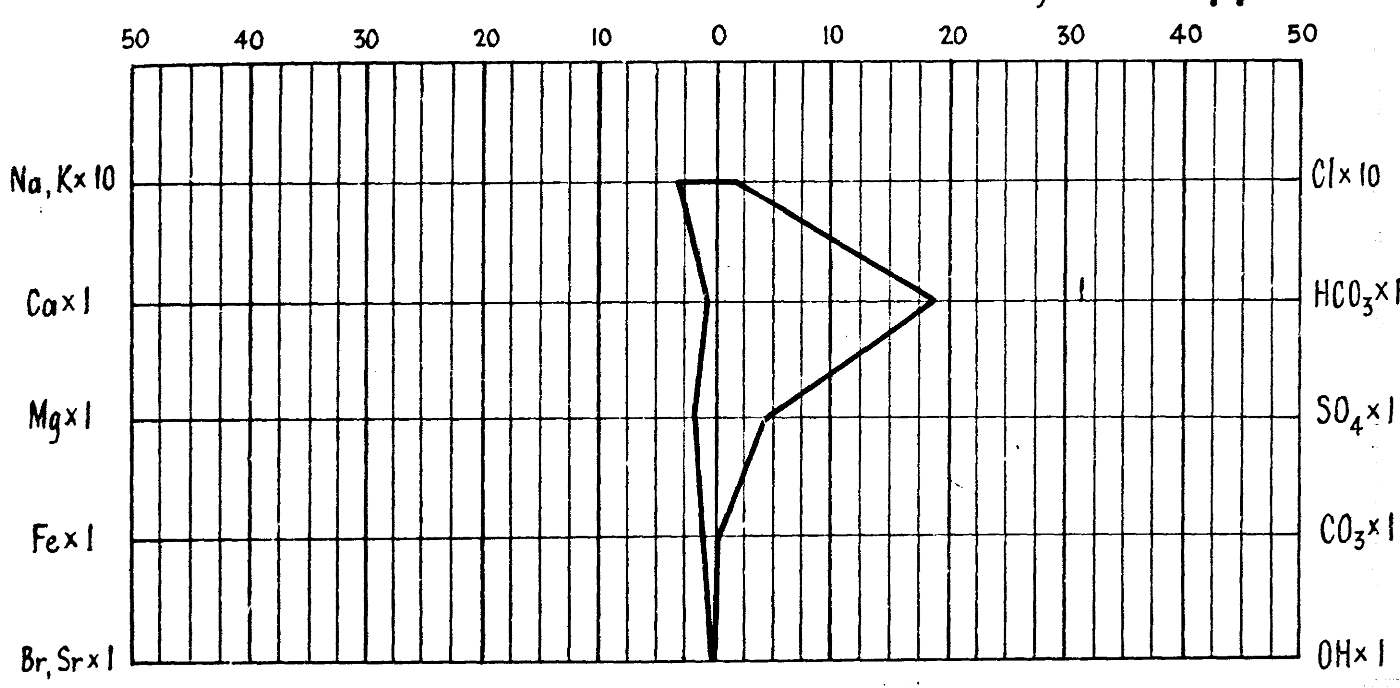
Well Name & Nº GURRA 1 Middle Member Salinity 3064 ppm



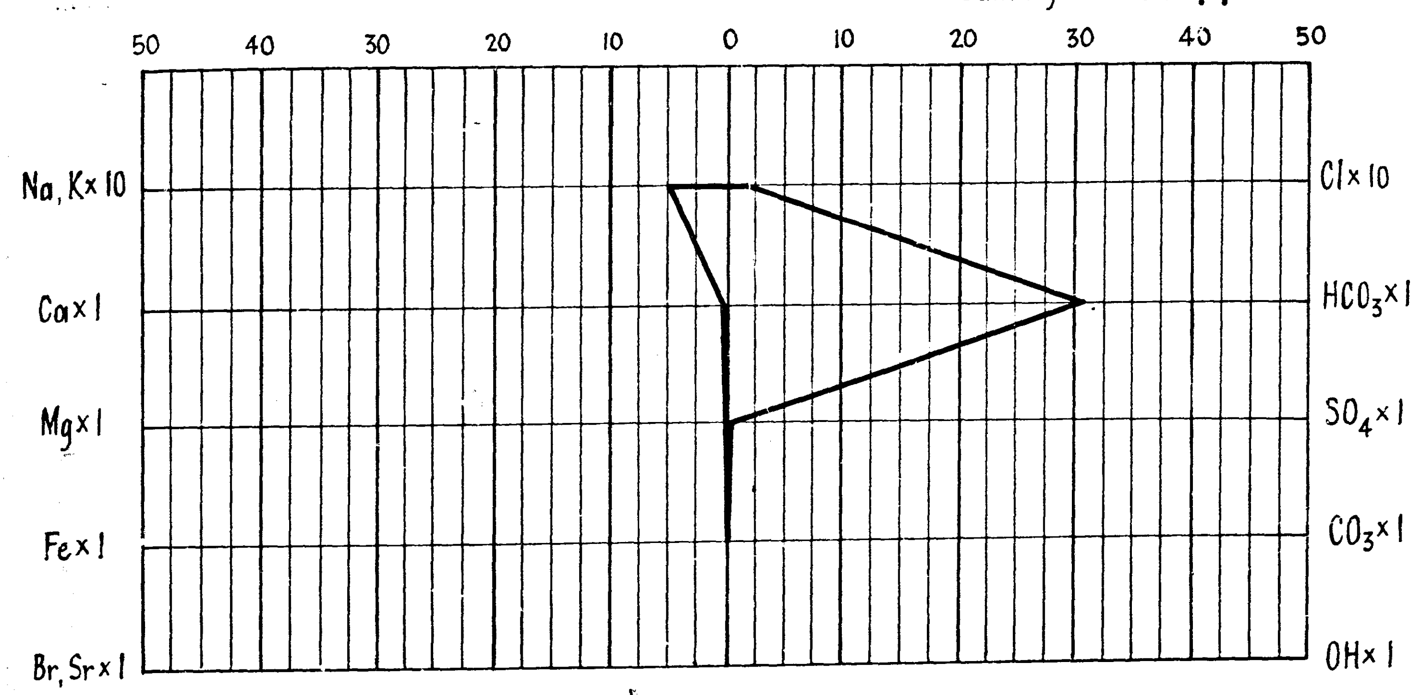
Well Name & Nº MULGA 1 Middle Member Salinity 2815 ppm



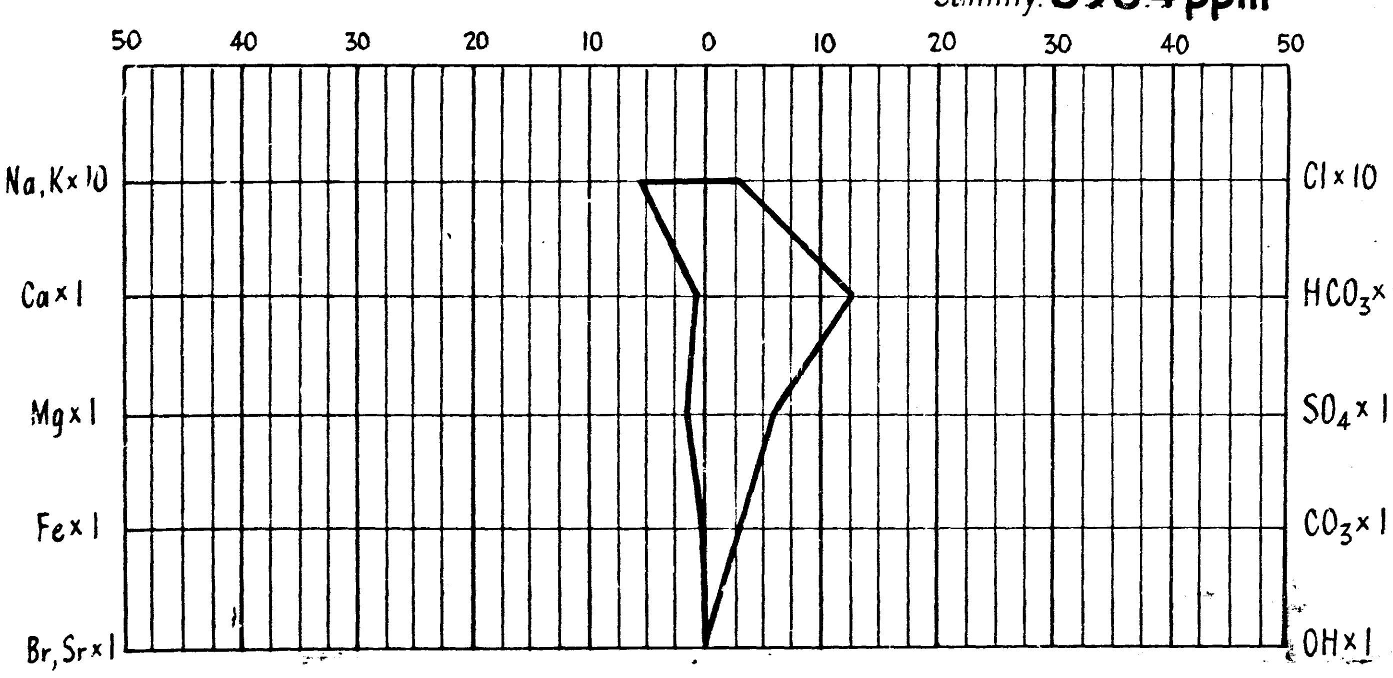
Well Name & Nº CHERRI 1 Middle Member Salinity 2620 ppm



Well Name & Nº MULGA 1 Lower Member Salinity 3667 ppm



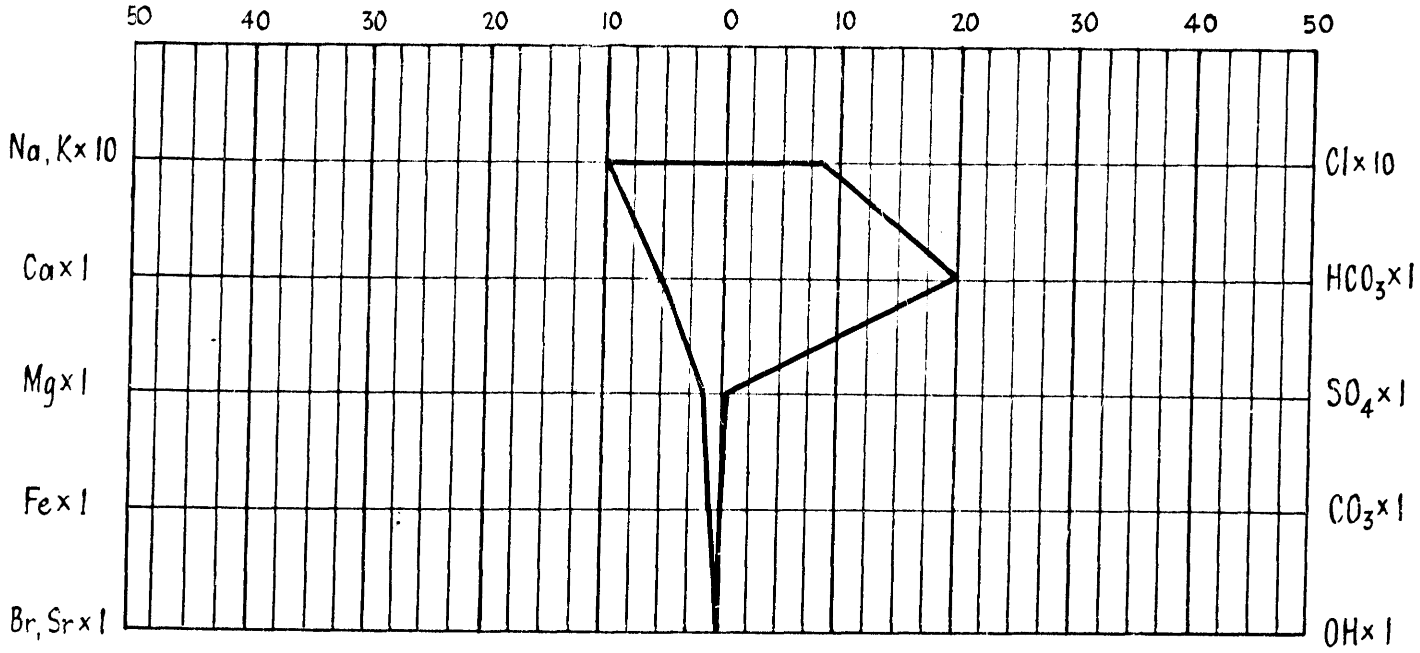
Well Name & Nº KUMBARIE 1 Lower Member Salinity 3984 ppm



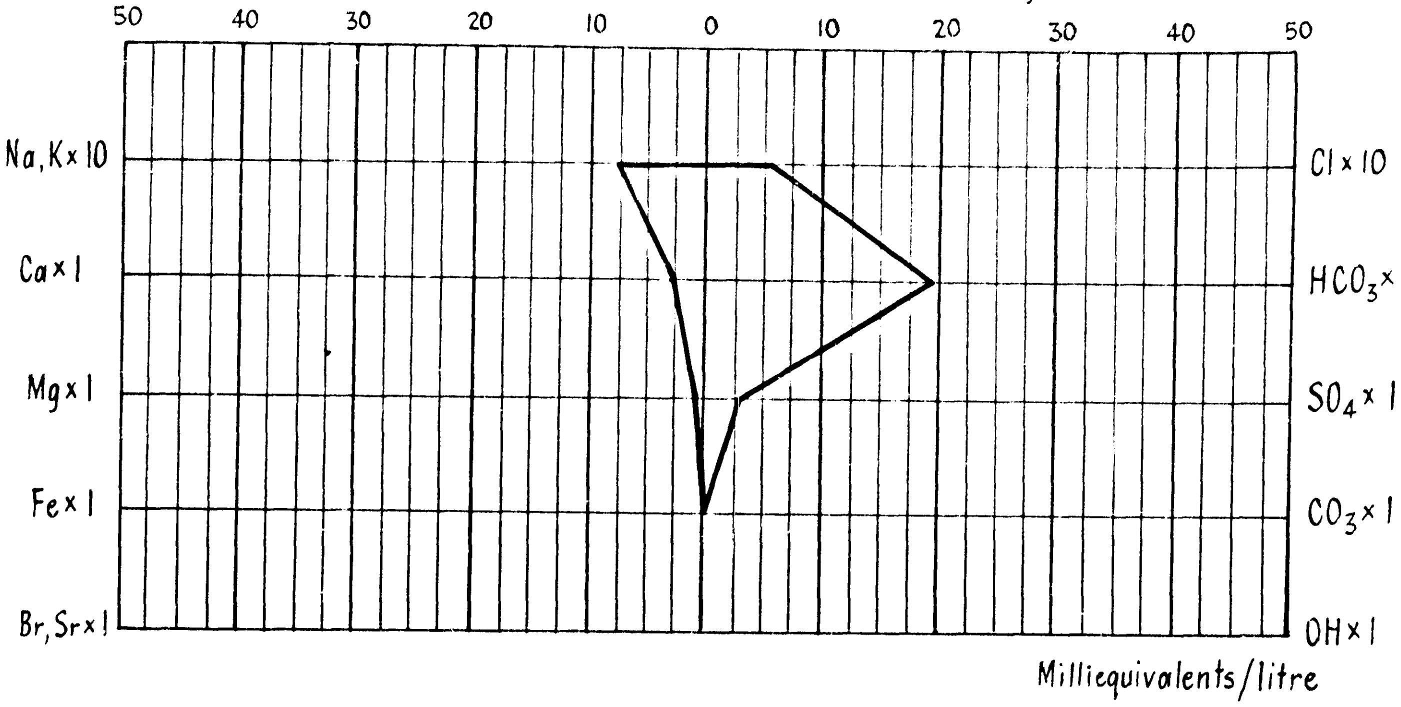
ENCLOSURE 1

PETROLEUM GEOLOGY SECTION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale: As shown
Compiled: B. Youngs	COOPER BASIN – S.A. & QLD.	Date: 11 Nov 1971
Drn. R.H. | Ckd.	STIFF WATER PATTERNS SOUTHERN AREA	Drg. No. 71-801 334-2/3

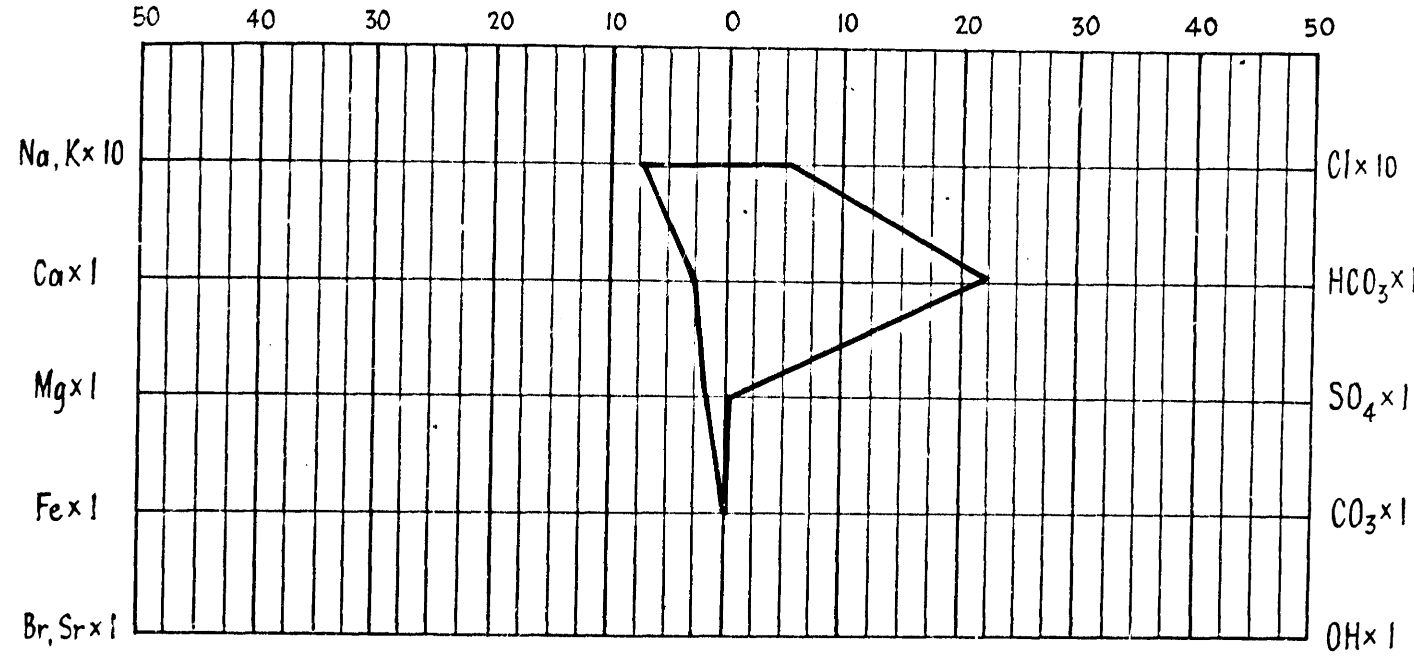
Well Name & Nº TOPWEE 1 Upper Member
Salinity 6682 ppm



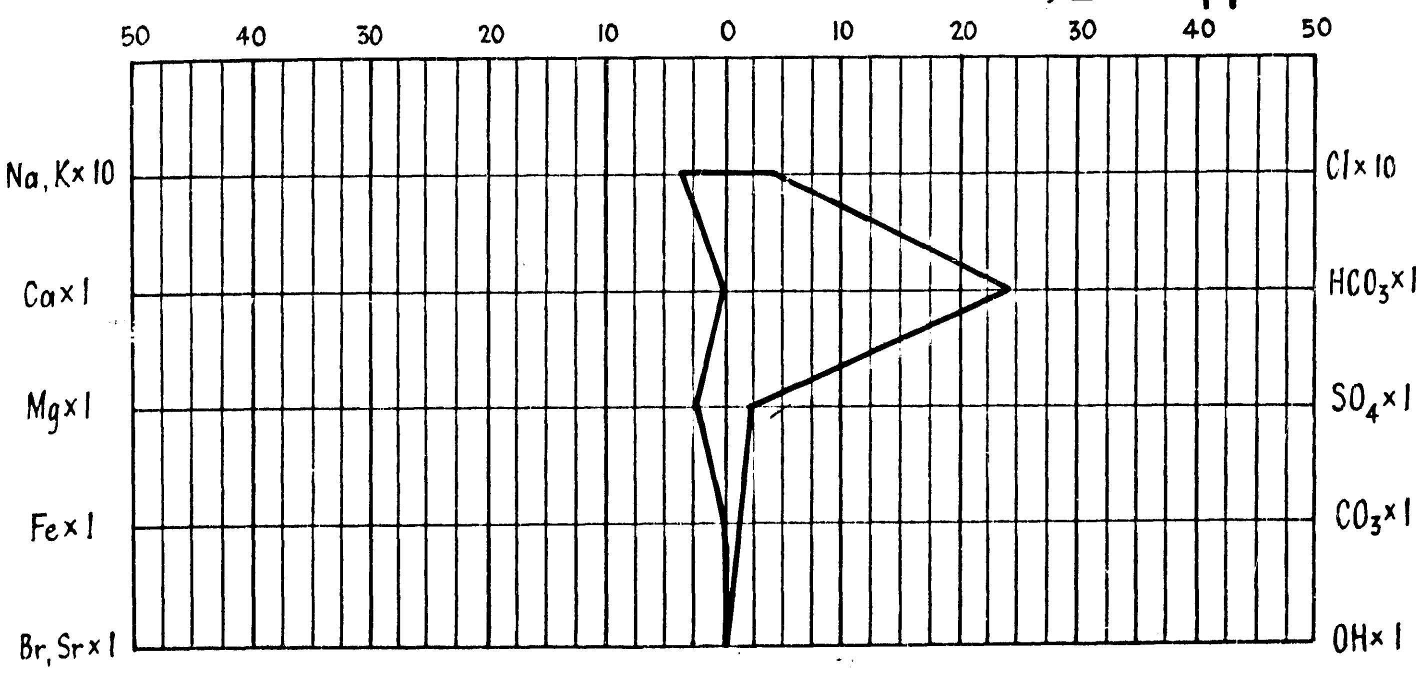
Well Name & Nº DARALINGIE 2 Upper Member
Salinity 5087 ppm



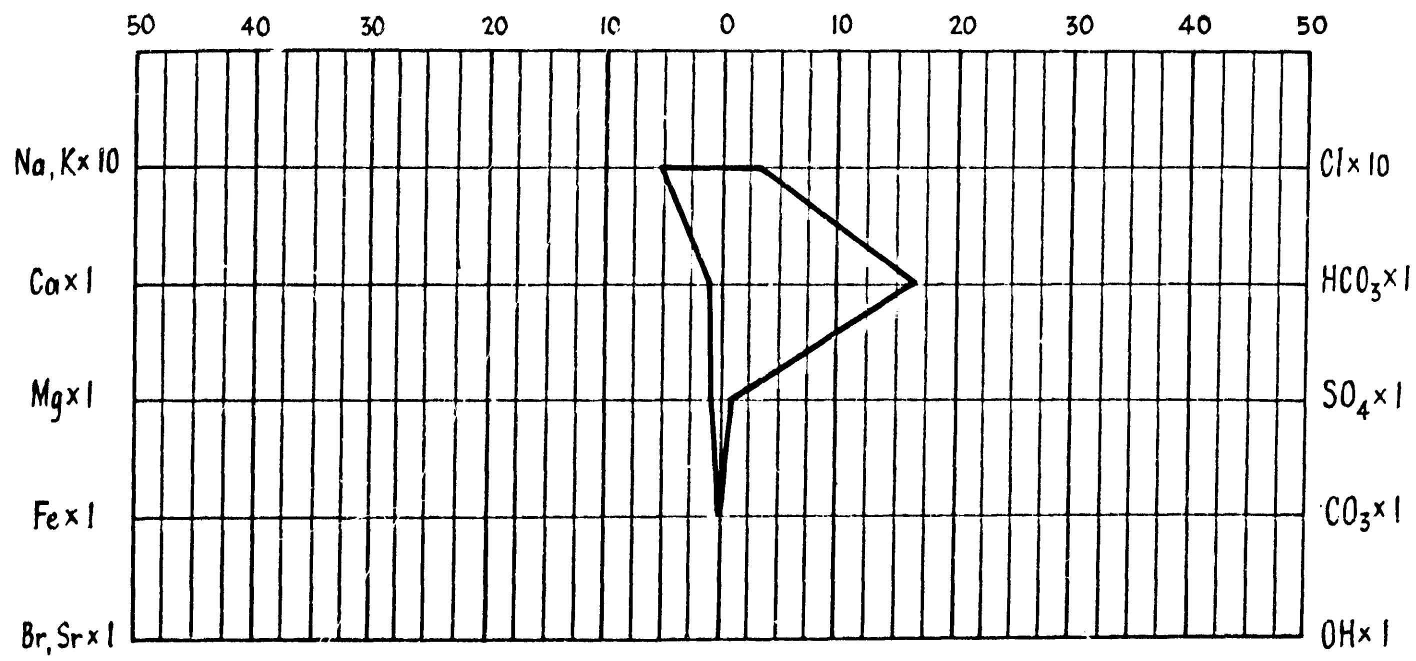
Well Name & Nº DARALINGIE 1 Upper Member
Salinity 5114 ppm



Well Name & Nº PANDO NORTH 1 Middle Member
Salinity 2943 ppm

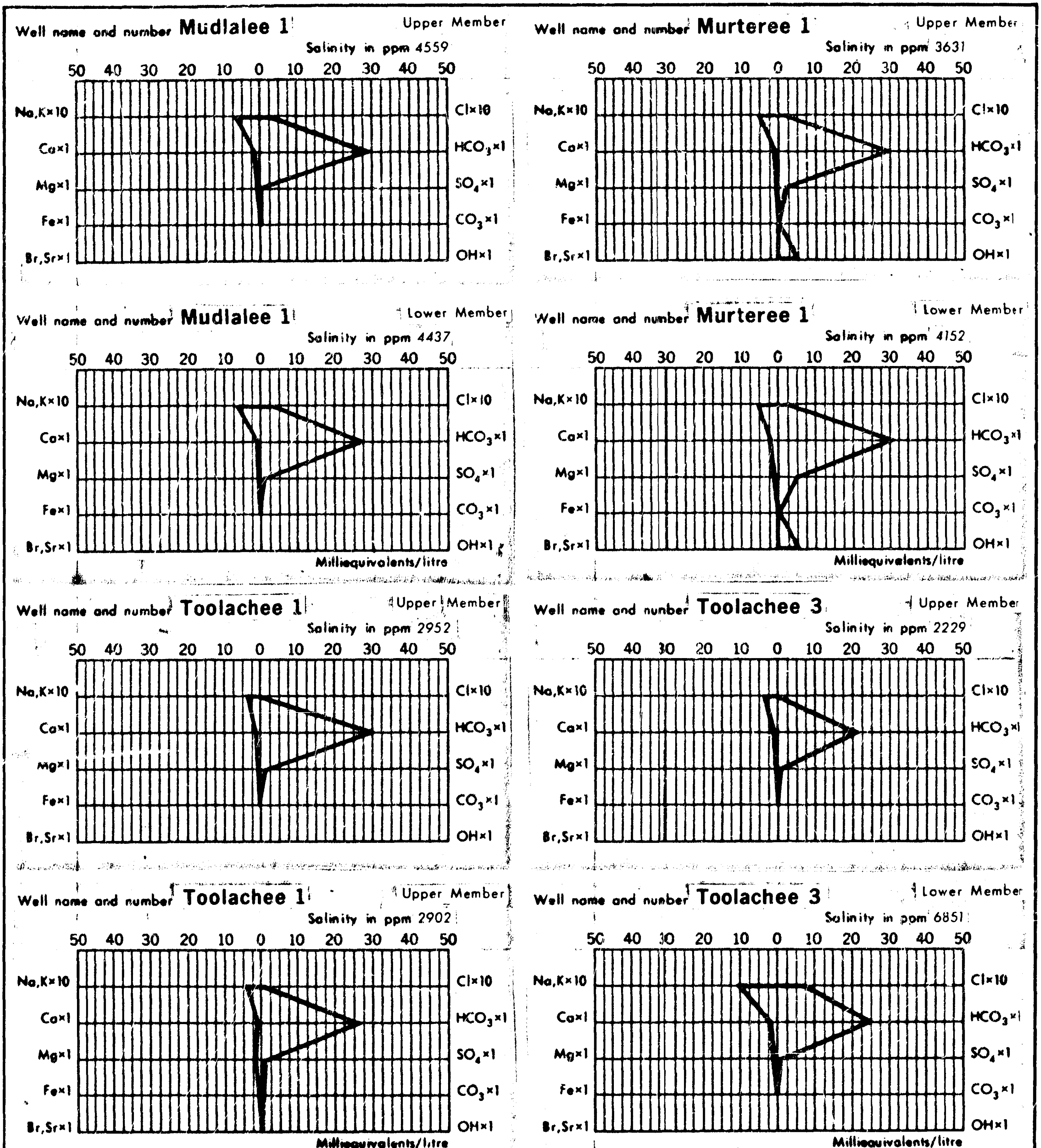


Well Name & Nº PANDO 2 Middle Member
Salinity 3304 ppm



ENCLOSURE 2

PETROLEUM GEOLOGY SECTION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale: As shown
Compiled: B. Youngs	COOPER BASIN – S.A. & QLD.	Date: 11 Nov 1971
Drn. R. H. Ckd.	STIFF WATER PATTERNS WESTERN AREA	Drg. No. 71-802 ~~994-2/3~~



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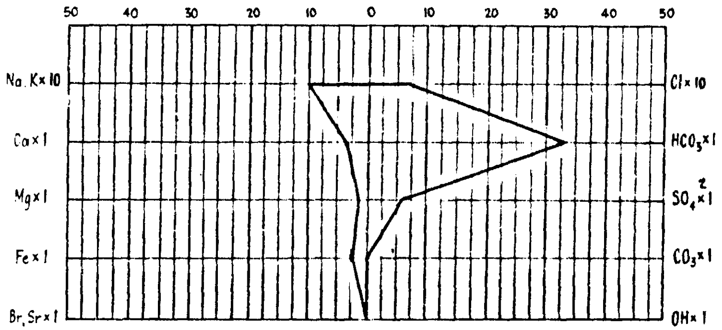
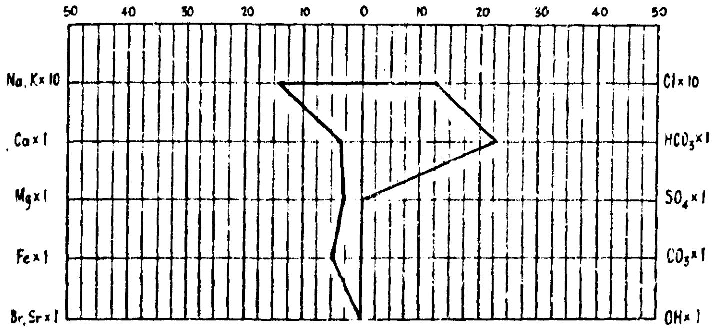
S.A. Department of Mines

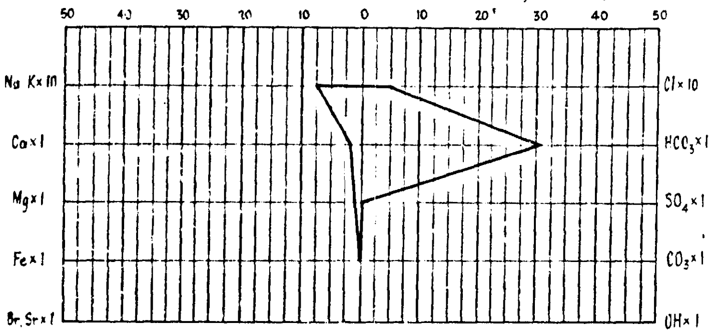
Well Name & No NAPPACOONGEE 1 Upper Member Salinity 7326 ppm



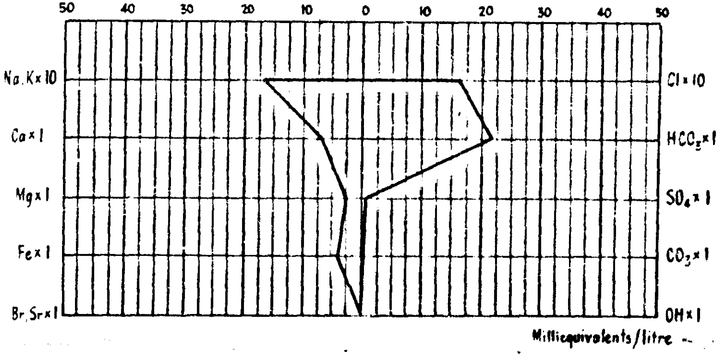
Well Name & No ROSENEATH 1 Upper Member Salinity 9457 ppm



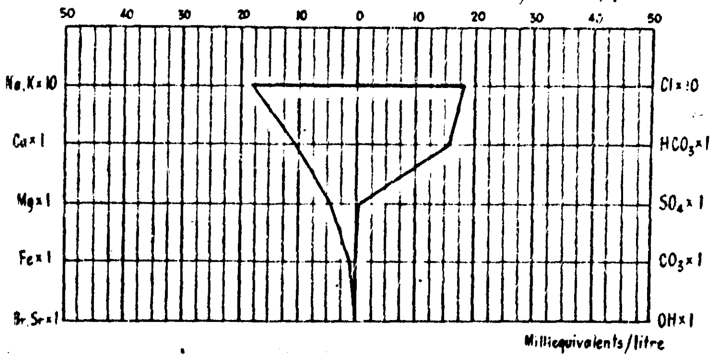
Well Name & No TOOLACHEE 2 Upper Member Salinity 5312 ppm



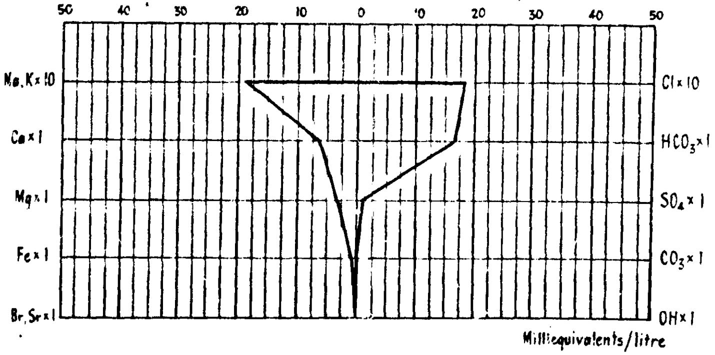
Well Name & No NAPPACOONGEE 1 Lower Member Salinity 11356 ppm



Well Name & No ROSENEATH 1 Lower Member Salinity 11773 ppm

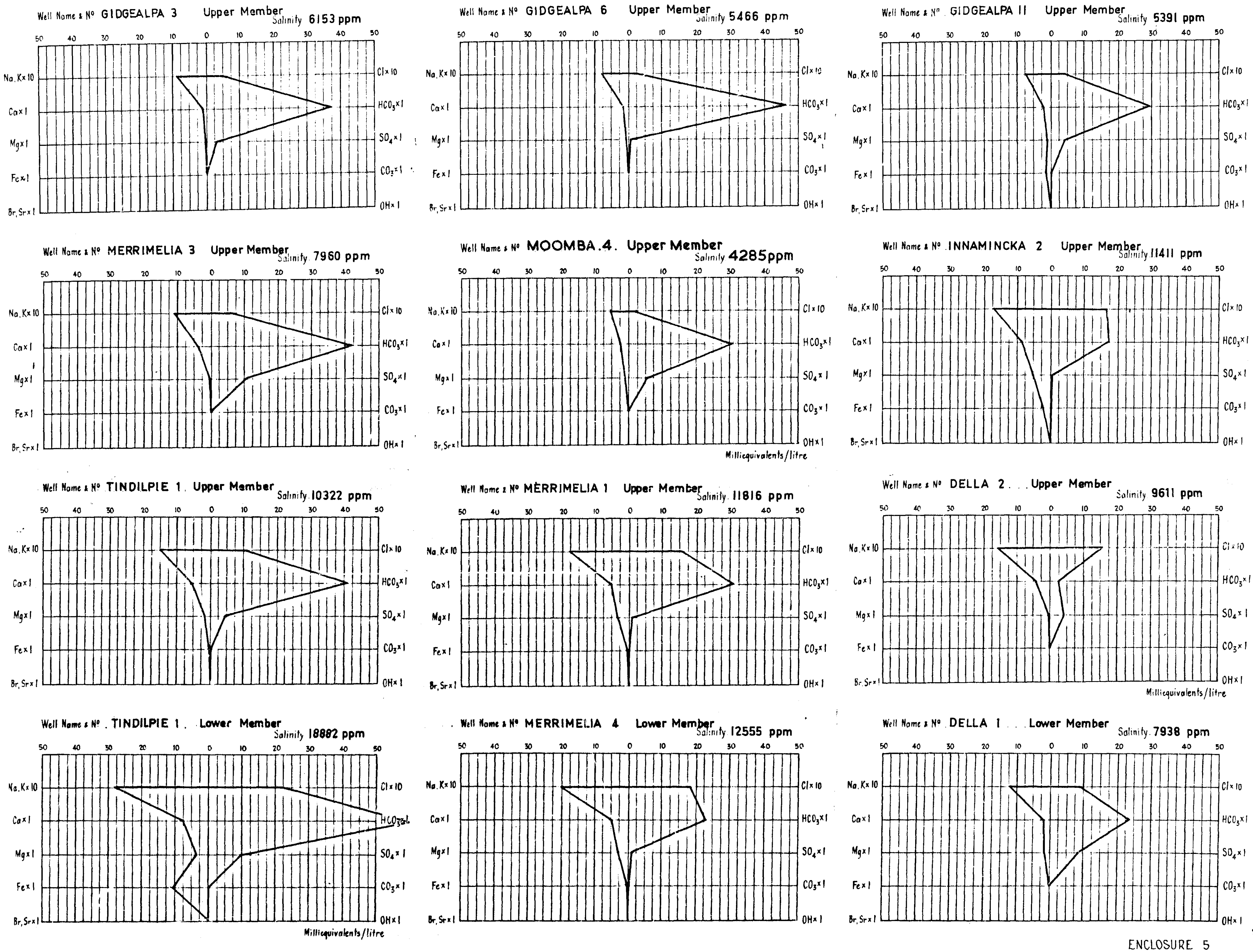


Well Name & No TOOLACHEE 2 Lower Member Salinity 12035 ppm



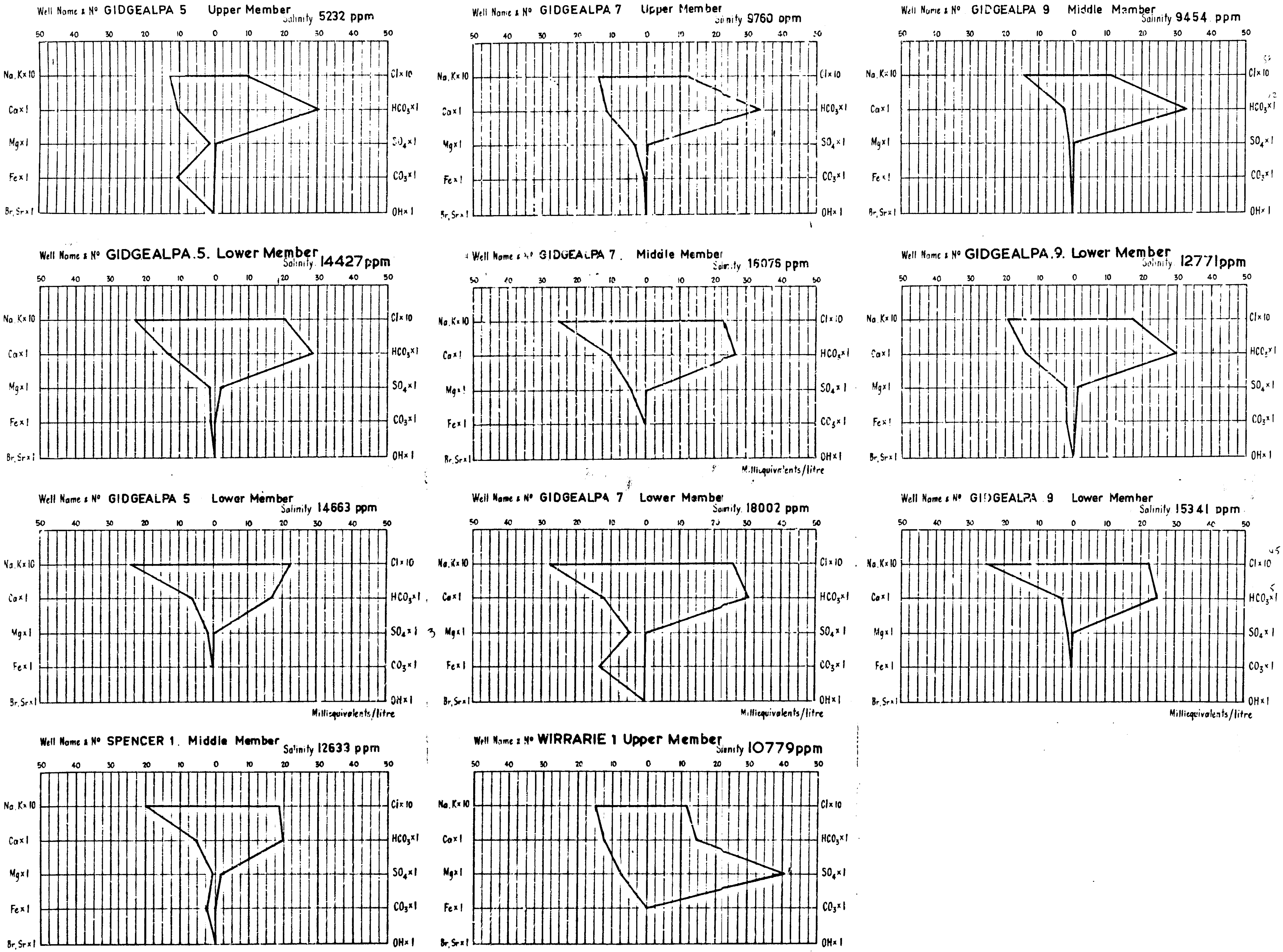
ENCLOSURE 4

PETROLEUM GEOLOGY SECTION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale: As shown
Compiled: B. Youngs	COOPER BASIN – S.A. & QLD.	Date: 11 Nov 1971
Drn R. H. Ckd.	STIFF WATER PATTERNS EASTERN AREA	Drg. No. 71-804



ENCLOSURE 5

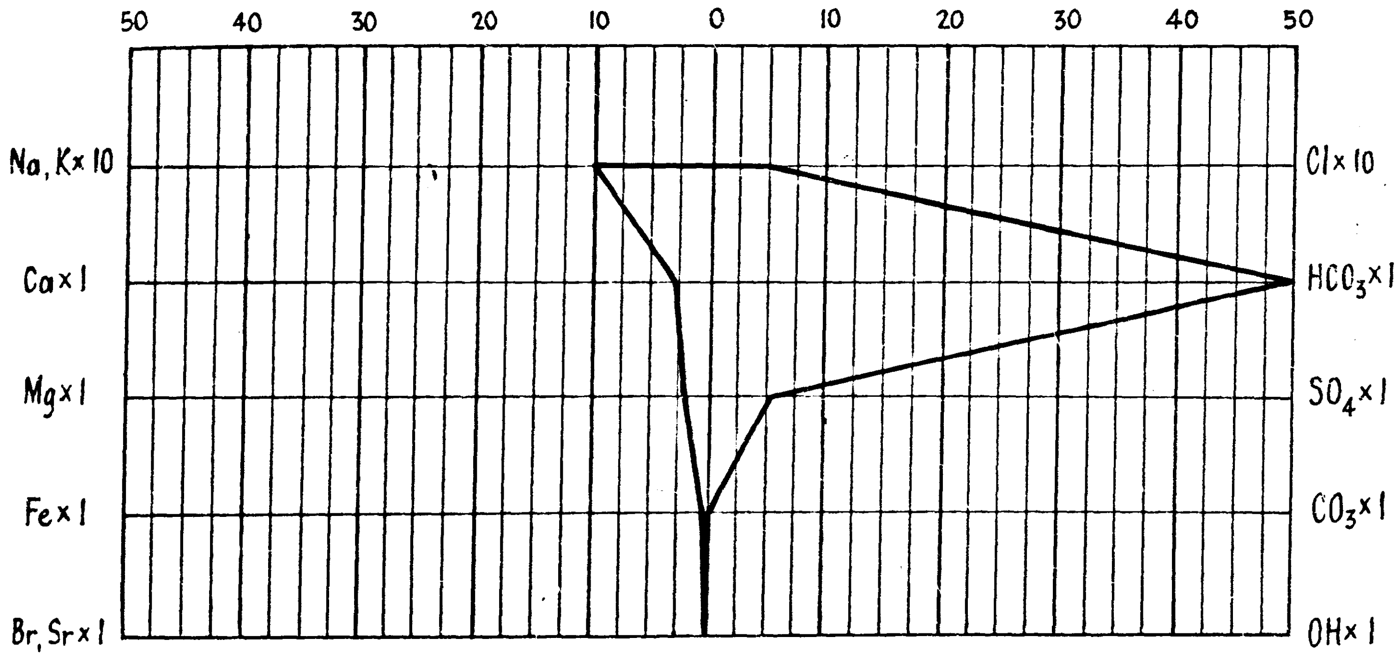
PETROLEUM GEOLOGY SECTION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale: As shown
Compiled: B. Youngs	COOPER BASIN – S.A. & QLD.	Date: 11 Nov 1971
Drn R.H. / Ckd.	STIFF WATER PATTERNS NORTHERN AREA	Drg. No. 71-805 S94/2/3



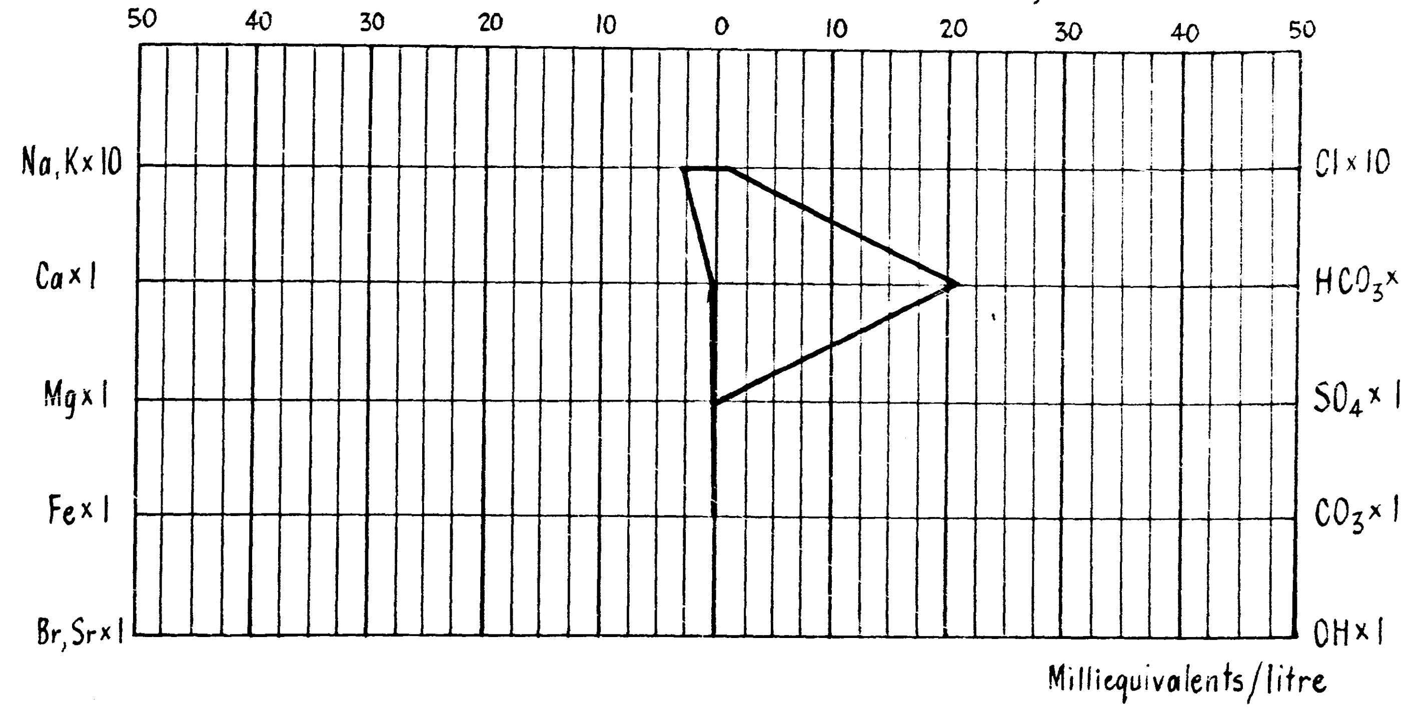
ENCLOSURE 6

PETROLEUM GEOLOGY SECTION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale As shown
Compiled B. Youngs	COOPER BASIN – S.A & QLD.	Date 11 Nov 1971
Drn R.H. Ckd	STIFF WATER PATTERNS NORTHERN AREA	Drg. No. 71-806 394-2/3

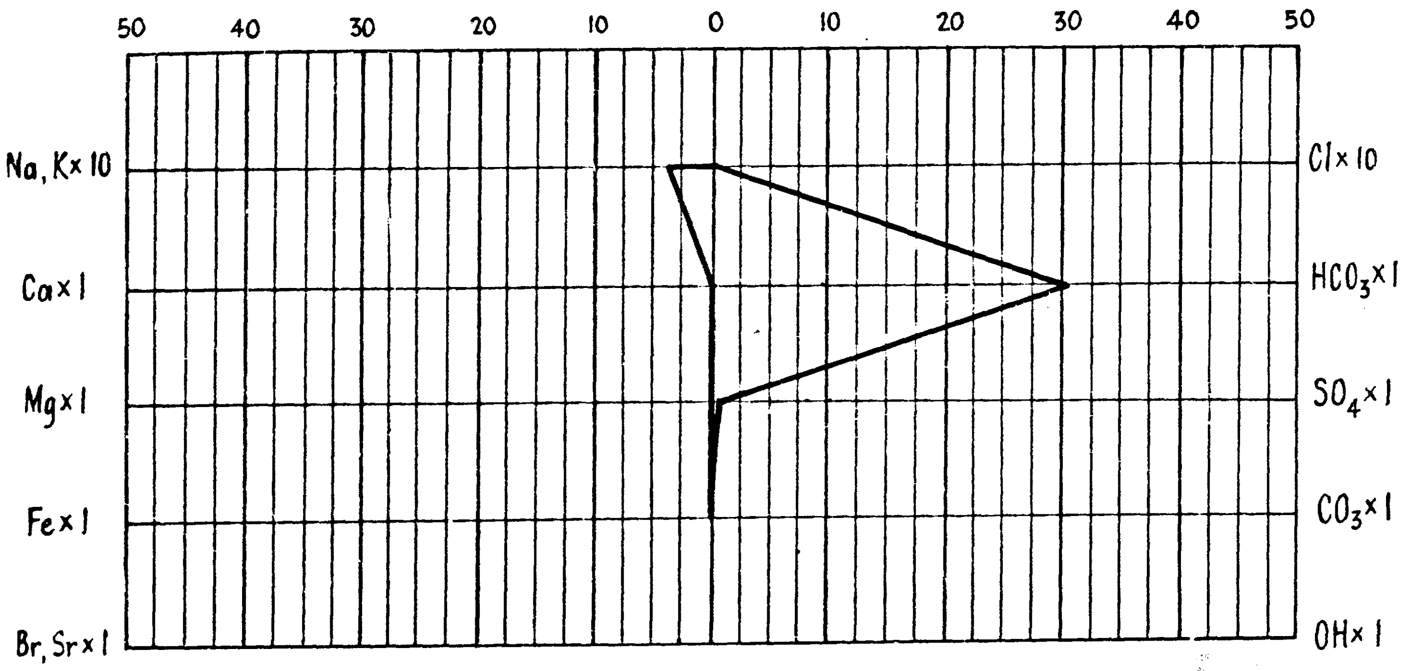
Well Name & Nº DELLA 1 Artesian - Hutton
Salinity 7319 ppm



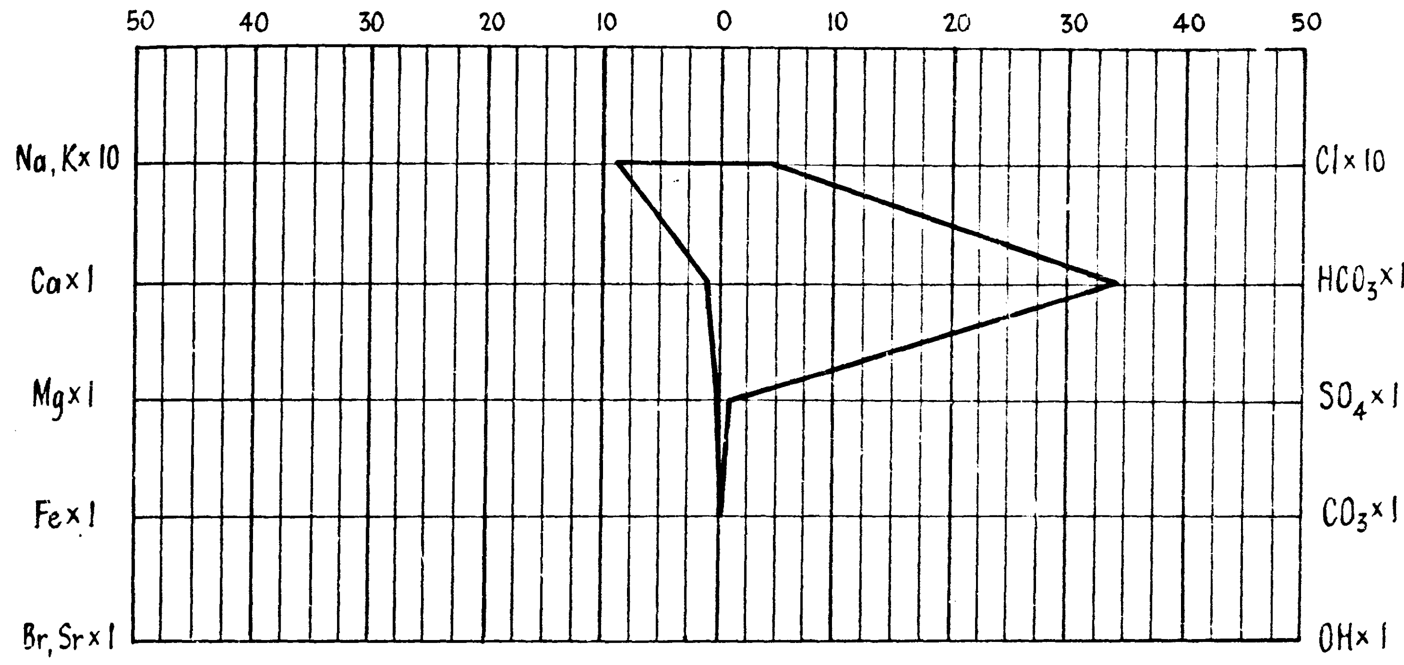
Well Name & Nº FORTVILLE 3 Artesian - Cret.
Salinity 2256 ppm



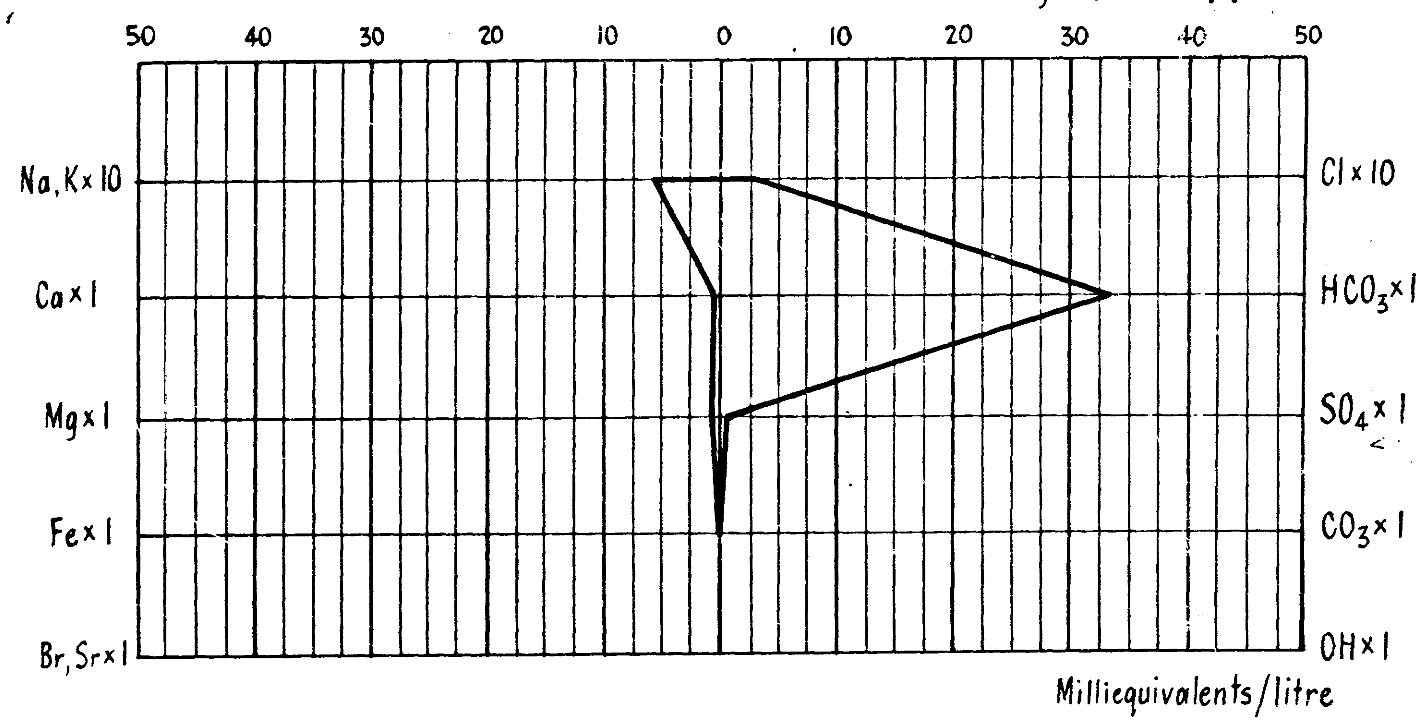
Well Name & Nº GIDGEALPA 1 Artesian - Mooga
Salinity 2816 ppm



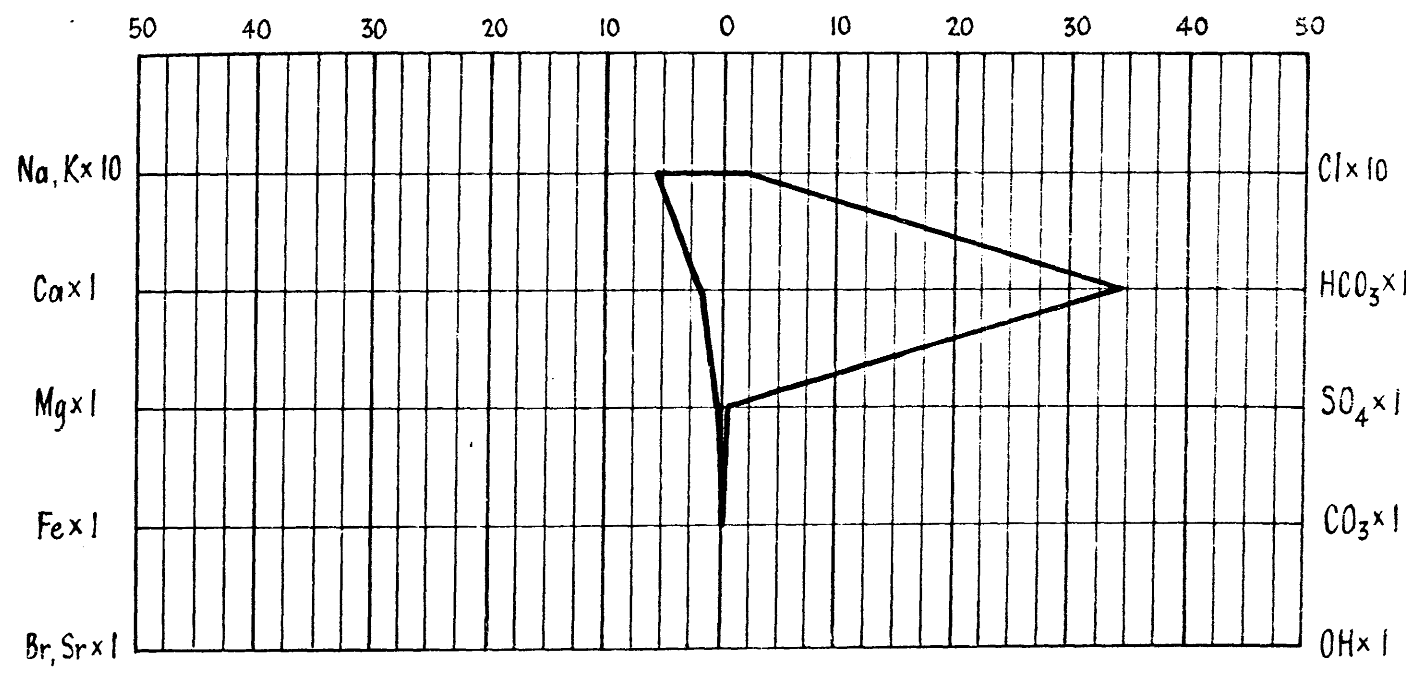
Well Name & Nº INNAMINCKA 1 Artesian-L.Cret.
Salinity 5748 ppm



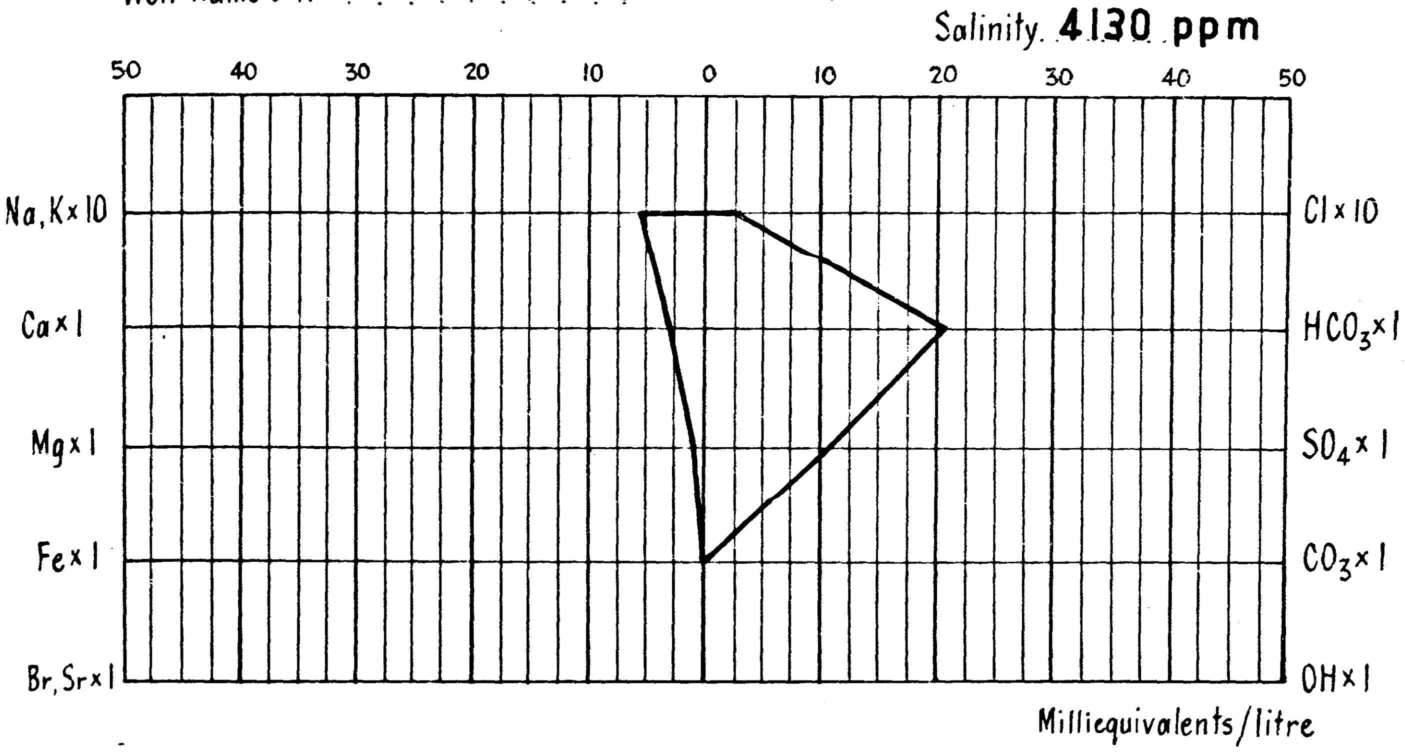
Well Name & Nº MOOMBA 3 Artesian - Hutton
Salinity 4338 ppm



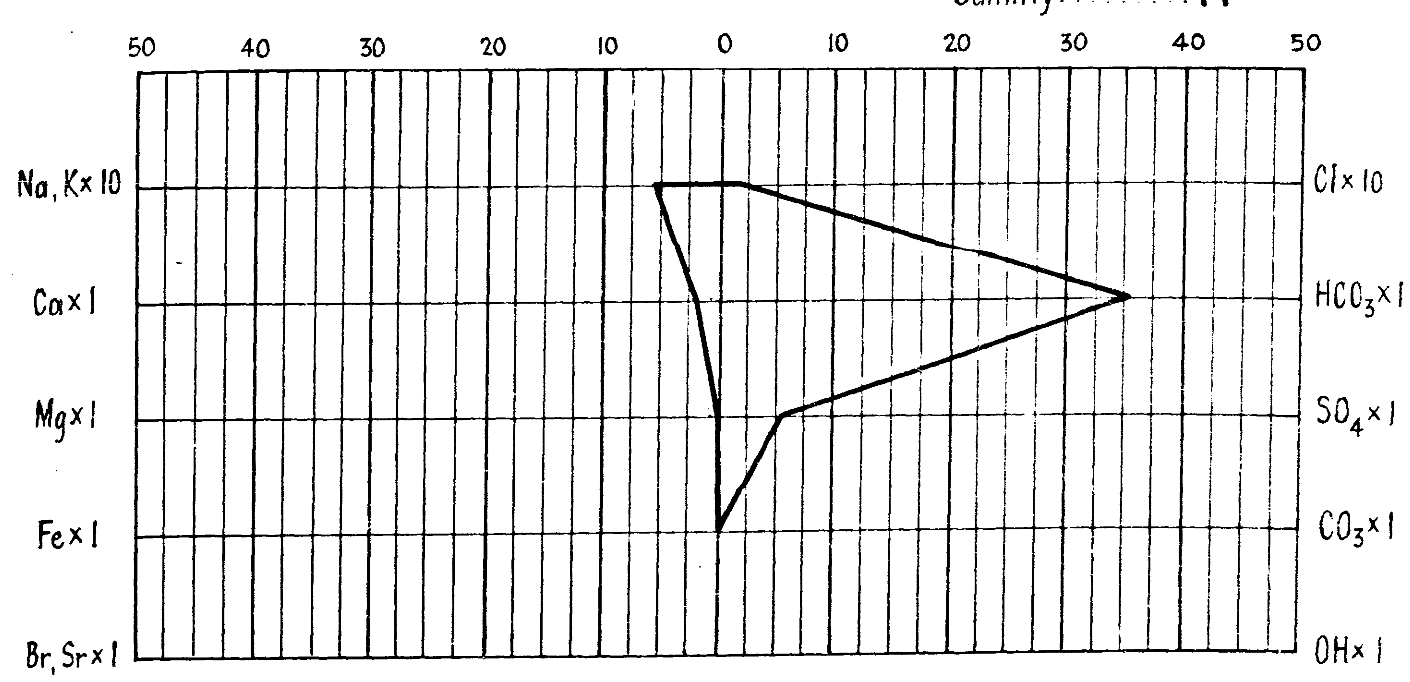
Well Name & Nº PACKSADDLE 1 Artesian - Birkhead
Salinity 4105 ppm



Well Name & Nº PANDO 1 Artesian- Hutton
Salinity 4130 ppm

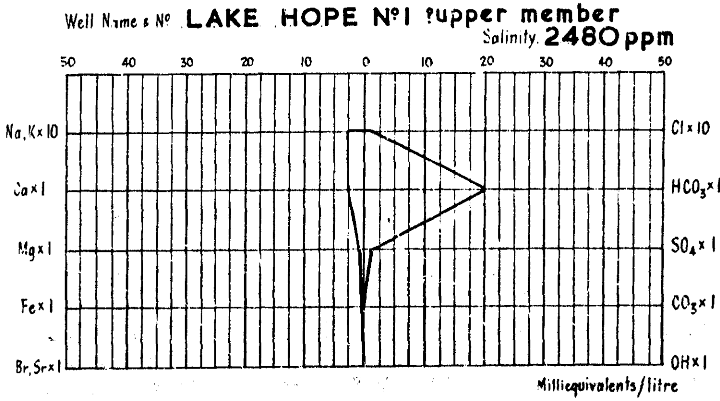


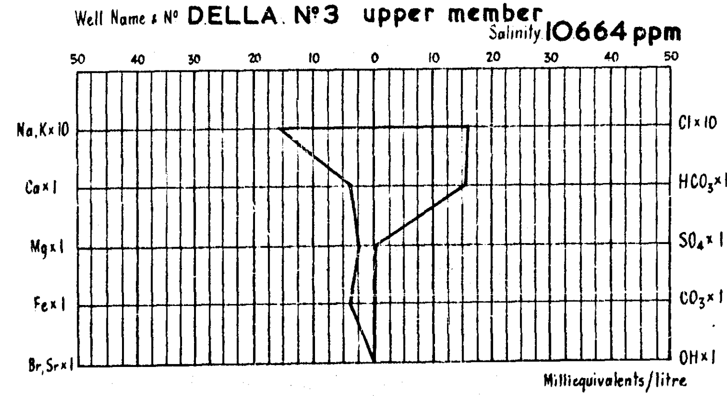
Well Name & Nº TIRRAWARRA 2 Artesian - Hutton
Salinity 3265 ppm

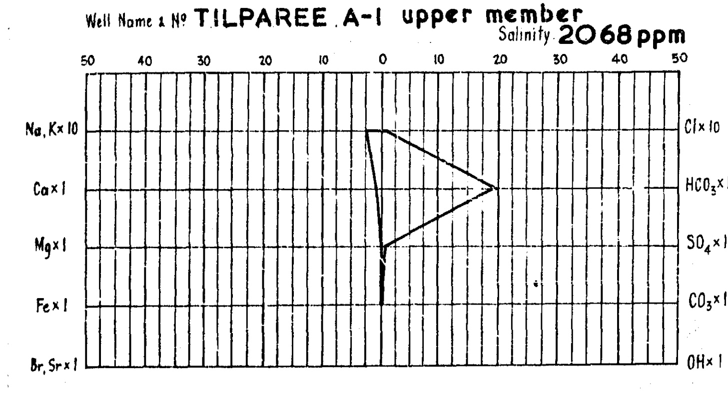


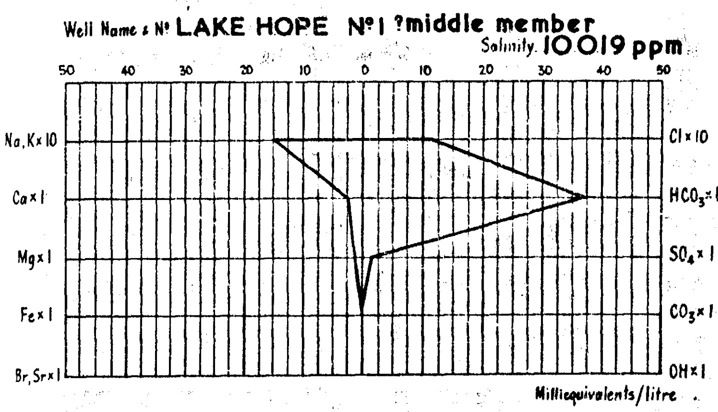
ENCLOSURE 7

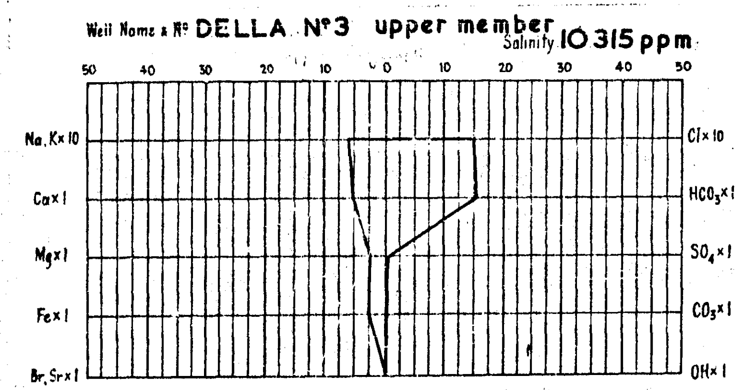
PETROLEUM GEOLOGY SECTION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale As shown
Compiled B. Youngs	COOPER BASIN — S.A. & QLD.	Date 11 Nov 1971
Drn. R.H. | Ckd.	STIFF WATER PATTERNS ARTESIAN WATERS	Drg. No. 71-807 994-2/3

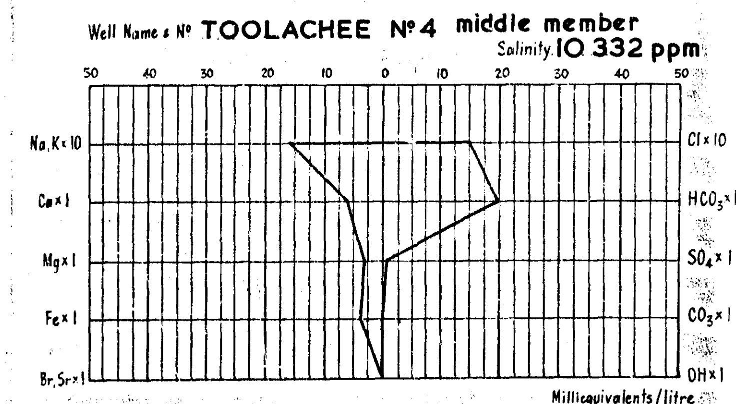


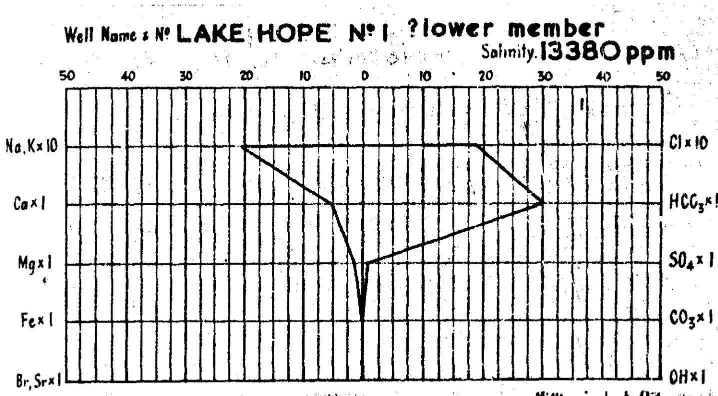


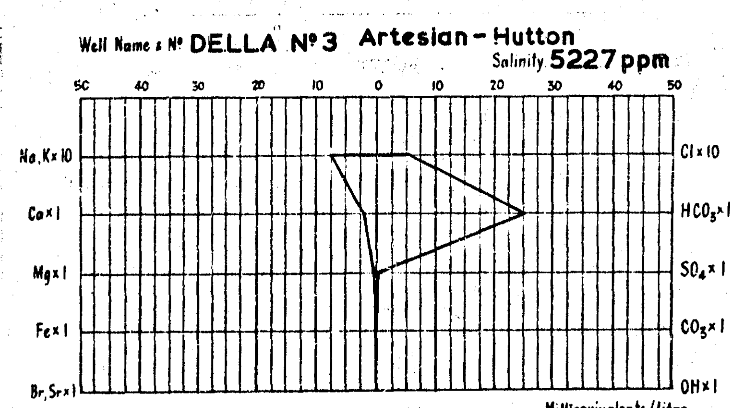


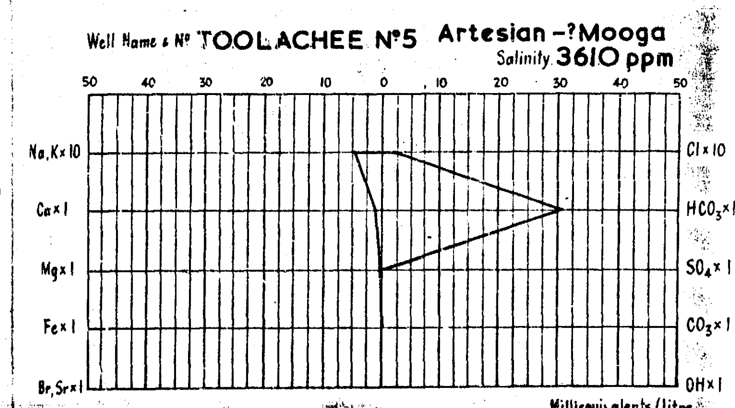












ENCLOSURE 8

PETROLEUM GEOLOGY SECTION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale: As shown
Compiled: B. Youngs	COOPER BASIN – S.A. & QLD.	Date: 30 Nov 1971
Drn. R. H. | Ckd.	STIFF WATER PATTERNS ADDITIONAL DATA	Drg. No. 71-853 994-2/3