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A REVIEW OF THE PETROLEUM PROSPECTS OF THE NORTH-WEST AND FITZROY BASINS OF WESTERN AUSTRALIA AND SUGGESTIONS FOR A FUTURE EXPLORATION PROGRAMME

by

W.F. Schneeberger

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For the evaluation of the petroleum prospects of a sedimentary basin, the following factors are generally considered.

1) Lithology, mode of deposition, thickness of the sediments contained in the basin, source and reservoir rocks.

2) Facies of the sediments, changes in facies and the trends of such facies changes.

3) Relationship of the various formations to each other - conformity, disconformity, unconformity, regressive and transgressive overlap, erosional gaps and their significance structurally and for accumulation.

4) Direct or indirect evidence for the presence of oil - seepages, traces or showings of bitumen, oil and/or gas existing bores, bituminous character of some of the stratigraphic members.

5) Tectonics - folding (single phase, multiple phase), faulting, tectonic history and its bearing on migration and accumulation of oil. Types of tectonic traps, and stratigraphic traps in relation to folding and faulting (sandy facies near basement uplift, reef formation on crests of rising anticlines, sandy facies in connection with ancient fault lines).

Some of these criteria can be applied to the North-West and the Fitzroy Basins, but it is realized that the information available is not complete enough yet to fully discuss all the aspects involved. On the other hand it is felt that, at this stage, a brief review of the results already obtained can greatly assist in an outline of a future programme.

It will be seen that much emphasis is laid on geophysical work i.e. gravity investigations for the regional aspect of the problem - the configuration of the basins - and seismic investigations of structures which are selected for deep testing. In our opinion the results obtained so far in the North-West Basin, by both types of geophysical work, have clearly demonstrated the soundness of this way of approach.

A. The North-West Basin.

Although the sedimentary record of this basin comprises the time interval from Middle Devonian to Tertiary, it is not a continuous or complete record. There are many large gaps in the stratigraphic sequence which were caused by non-deposition and/or erosion.

The Middle and Upper Devonian are represented by 4,800 ft. of sediments, i.e. a basal arkosic sandstone (Nanyarra, 250 ft), a sequence of dense limestone, calcareous sandstone and siltstone (Gneudna, 1,550 ft.), and a sequence of sandstones, subgreywacke, conglomerate and siltstone (Manubia, 3,000 ft.).

None of these formations has the characteristics of a source formation. The mode of their deposition is suggested by mineragraphic analysis of the arenaceous rocks as follows (Edwards, 1952): "The varying character of the sandstones in the sequence suggests that they were deposited in an area in which initial subsidence was followed by a period of increasing stability...". "This stable period was followed by intermittent periods of prounced instability, and relative stability, leading to interdigitation of shales and conglomerates with the sandstones supports the interpretation, and suggests regression and progression of the shore line relative to the area of deposition. The variation in character of the sediments may thus be related chiefly to movements of the shore line relative to different types of source rocks" (source rocks in the mineragraphic sense).

The Lower Carboniferous is represented by only 1,850 ft. of sediments, consisting of crystalline limestone (Moogooree, 900 ft.), cherty kaolinitic subgreywacke, quartzose sandstone, siltstone and some limestone (Williambury, 700 ft.), a higher limestone formation (Yindagindi, 300 ft.) and ferruginous quartzose sandstone (Harris, 250 ft.). None of these formations have the characteristics of a source formation.

The cyclic repetition of four arenaceous formations separated by three calcareous formations in the Devonian - Carboniferous succession is clear evidence for the deposition in an area of moderately deep water with repeated regressive and progressive changes of the shore line.

Fossil evidence indicates that only the Lower Carboniferous (Mississippian) is present and the Upper Carboniferous (Pennsylvanian) is absent, a condition which is known also from other parts of Australia (as for instance Queensland).

The Permian sediments attain a compound thickness of 12,000 feet, approximately a third of which is represented by glacio-marine deposits of the Lyons Group (4,300 ft.).

Highly calcareous sandstones in the upper part of the Lyons Group might indicate the cessation of glaciation and a general amelioration of the climate (Edwards, 1952).

Calcareous rocks with intercalations of arenaceous and pelitic material reach their maxium in the Callytharra Formation (760 ft.), which also contains a rich fauna of crinoids, bryozoa, brachiopods, solitary corals, molluscs and foraminifera. Well aerated water is indicated by these organic forms, excluding the preservation of bituminous substances.

The upper part of the Permian section (x 7,700 ft.) is an alternating sequence of various types of sandstones, shale and siltstone. Some of the shales and siltstones are highly carbonaceous (black colour). The presence of gypsum and possibly also of other evaporites and pyrite might suggest temporary land locked, anaeorobic (euxenix) conditions, similar to the ones described from the upper part of the Permian section in the Irwin Riber Basin (Clarke, Prednergast, Teichert, Fairbridge, 1951).

Based on his mineragraphic analysis of numerous sandstone samples of the young Palaeozoic section, Edwards (1952) comes to the conclusion that "the adsence of greywackes proper is evidence of the absence of strongly orogenic conditions, such as attend the formation of geosynclines" and that "the lithology of the sediments indicates deposition on a mildly unstable shelf, or possibly within an intracratonic basin".

The depositional record of the Mesozoic is even more incomplete that that of the young Palaeozoic. Glauconitic sand- and siltstone of Middle Jurassic age and/or radiolarian bearing siliceous siltstone of Upper Cretaceous age overlap the Permian sediments over large areas.

In the coastal area the Tertiary (Paleocene to Pliocene) is represented mainly in a calcareous facies with the Lower Eocene (Ypresian) missing. Fuanal relationship points to sea connection with Indonesian basins.

Neither the Mesozoic nor the Tertiary sediments have the characteristics of a source formation. Therefore they are not further considered in the discussion of the oil prospects.

Considering the stratigraphy as far as it can be studied in surface sections, it appears to be evident that we have to deal here with a rather stable area of deposition adjacent to the Westralian Shield. At several times in its geological history this area has undergone subsidence and emergence, the latter accompained by erosion, as it is typical for a shelf or an intercratonic basin. There areno indications in the sedimentary record that geosynclinal conditions have obtained at any time, although the thickness of some of the formations, especially the Permian sediments, is considerable. This indicates that at times the rate of deposition had kept pace with the rate of subsidence. The most important gaps in the sequence are between the Lower Carboniferous and the Permian and between the Permian and the Cretaceous. The absence of strong orogenic movements in the erosional intervals accounts for the near-conformity of the under- and overlying sequences.

The fact that the area of deposition is a moderately stable shelf or even an intercratonic basin, is in itself not to be taken as a detrimental factor for the formation of petroleum in the deeper parts of the basin, where a more favourable facies development can be expected. As mentioned before, the facies of the Young Palaeozoic sediments in the eastern part of the basin, is, with the possible expection of some stratigraphic members of the upper part of the Permian sequence, not a source facies. It is therefore necessary to search for areas within the basin, where more favourable conditions can reasonably be expected. Because of the lack of subsurface information, such areas can only be indicated indirectly by a gravity survey at the present time.

The gravitymeter reconnaissance carried out by the Bureau in the last quarter of 1950 has yielded a preliminary gravity picture which for parts might reflect the configuration of the basement floor. However, it has to be realised that gravity anomalies are caused, apart from the configuration of the actual buried basement surface, by petrographic differentiations within the series composing the basement. Observations covering large outcrop areas of the Pre-Cambrain basement have not been made yet, or the results are not available at the moment. Therefore it is as yet impossible to assess the value of gravity anomalies and the range of their variation within the basement complex. In this connection attention is drawn to the fact that the gravity values obtained on outcropping basement along the eastern margin of the basin, are exceptionally low (0 to -10 milligalls). For this reason, and also because of the lack of systematic information on density differnetials between basement rocks and sediments, any interpretation of the gravity values in geological terms can only be tentative.

Experience elsewhere has shwon that assumed density differentials have led to geophysical predictions on thicknesses of sedimentary sequences which were subsequently proved erroneous by seismic investigations and/or drilling.

However, the main features disclosed by the isostatic anomalies map (plate 4 of Records 1951/69) can be described as follows:

1) A major minimum of -40 milligalls in the eastern part of the northern North-West Basin.

2) A major minimum of -50 milligalls near Carnarvon.

3) an elongated, relative maximum separating features 1 and 2.

4) a local mimimum of -30 milligalls in the vicinity of Cape Cloates.

5) a local minimum of -20 milligalls at Ashburton Bridge.

6) a local maximum of x 5 milligalls to the east of the southern end of Exmouth Gulf, and

7) a pronounced maximum of x 10 milligals at the west coast of North-West Cape Peninsula.

There is a regional rise of the gravity values in a northern direction which might coincide with a regional rise of the basement floor, in the same direction. The minimum near Carnarvon appears to have a tendency to deepen to the south. Therefore the deepest part of the basin might be situated near the coast and to the south of the Gascoyne River.

This assumption is supported by the configuration of the coast line and the trend of the 100-fathoms line (edge of the continental shelf). The trend of the islands enclosing Shark Bay (Bernier, Dorre and Dirk Hartog) as well as that of Peron Peninsula, suggest that Shark Bay itself is a submerged part of the North-West Basin, which reaches its greatest width (approximately 200 miles) between Cape Inscription and the upper reaches of the Wooramel River.

The 100-fathom line which is very close (2 to 4 miles) to the coast line of North-West Cape Peninsula, gradually swings away from the coast farther south and is off Bernier Island at a distance of about 100 miles to the west (Admirality charts). This widening of the shelf platform goes parallel with the widening out of the coast line and is in our opinion an indication of a widening of the basin in this area.

Basement rocks are widely exposed around Geraldton and to the north of it, and it is possible that Houtman's Abrolhos, including the shallow platform which links them to the mainland, are also underlain by basement rocks at shallow depth. It is probable that the Irwin River Basin was linked to the North-West Basin by a narrow channel between the Geraldton basement high and the actual Westralian Shield.

The tectonices of the North-West Basin are in close relationship with its depositional history. In the northern part of the basin, as far as it has been mapped, faulting is the predominant type of tectonic disclocation. A series of antithetic faults has displaced the young Palaeozoic sequence into a number of fault blocks. Local folding is indicated in the Barrabiddy Creek area, but this might be in connection with the faulting there. An area of major faulting is around Wandagee Hill. It coincodes with the gravity maximum mentioned earlier under 3).

The other instance where folding in the outcropping young Palaeozoic sediments was observed, is an area underlain by the upper part of the Permian sequence, partly overlapped by Creta ceous and Tertiary sediments, immediately to the west of the Kennedy Ra nge, where Australian Mining and Smelting Company Pty. Ltd. discovered and ampped in their Reserve No. 1293H a group of five dome-like structures. Of these, however, only one - Central

East Wandinny - is completely exposed. The others are partly overlapped by Cretaceous and Tertiary rocks. Central East Wandinny appears to be a slightly elongated dome with its azis trending north-south, of a known width of approximately one mile. Three fossil horizons in the uppermost part of the Wandagee Formation were used as markers for the mapping of the structure. The dips range from 10 to 15 degrees and closure is estimated to be of the order of 500 feet.

Subsequent gravity and magnetometer surveys indicated that neither local instrusive bodies nor deep seated salt plugs are responsinle for the formation of these structures. The most plausible explanation is that flowage of salt at shallow depth had caused buckling of the younger Permian strata. Water wells with high salinity occur in this area, and in outcrops farther north various shale members of the upper part of the Permian sequence show a high content of gypsum. A connection between the presence of evaporites and the local doming of the uppermost Permian strata is therefore very probable.

Considering their small size and their superficial nature, these domes do not offer very attractive prospects. However, a well drilled in the apex of Central East Wandinny, even if it would not prove the presence of oil, might well prove commercial accumulations of evaporites.

It remains to discuss the signifiance of the major folds of the coastal area in the northern half of the basin, i.e. Giralia and Cape Range anticlines. These are structure of first magnitude, closed in Cretaceous and Tertiary strata respectively. They were considered as first objectives for deep testing, but seismic investigation in the northern part of Giralia, subsequent to field mapping, revealed a suspected pronounced discrepancy between surface structure and structure in depth. It was found that the surface anticilinal azis in Cretaceous strata is underlain by a syncline in the young Palaeozoic sequence. Latest information shows a steady regional rise of the Palaeozoic strata to the west, whereby the east dipping, presumably uppermost Permian beds are being slightly trunkated by the west dipping Cretaceous-Tertiary sequence in the west flank of the northern part of the Giralia structure. Whether similar conditions obtain also in the culmination area farther south, cannot be decided without seismic work in that area. But there is of course a strong possibility that conditions there may not be principally different.

The situation as we have to face it here is an excellent illustration of a problem which at many times and in many areas has either been overlooked or has not been paid the attention it deserves, namely <u>the tectonic significance of erosional gaps in the sedimentary record of an area</u>.

As far as the information available shows, in the northern part of the North-West Basin, there was a period of erosion which ranged in time from the Upper Permian to the Upper Cretaceous, although deposition of Jurassic rocks in the coastal area is not excluded. In this long time interval the surface of the slightly tilted and faulted Permian sediments was subjected to erosion which in its ultimate stage had reached maturity. In the area of the northern Giralia structure, and possibly for the whole of the structure, it came to a reversal of the relief, that is, a tectonic syncline in the young Palaeozoic strata was preserved by the erosion as a morphologically positive area, a long monadnock or range, possibly similar to the present day Kennedy Range across which the Cretaceous and Tertiary seas transgressed. Differential compaction of the younger sediments around this ridge caused an embryonic stage of an anticline which through consequent lateral compression became slightly more pronounced and steepened. The shallowness of the surface structure is in our opinion well indicated by the shallowness of the syncline in the Tertiary rocks to the east of the Giralia surface axis.

The Permian sediments and the configuration of their eroded surface therefore has played a similar role in relation to the Cretaceous-Tertiary cover as does a true basement series and its erosional features to any overlying sedimentary sequence. The Permian synclinal monadnock at the northern end of the Giralia Cretaceous-Tertiary anticline therefore behaved like a buried basement ridge. Consequently the tectonics of the Permian strata have no relation to the structure within the overlapping Cretaceous-Tertiary sequence.

For the Cape Range structure no complete seismic data are available because the s ection which was shot in the northern part of its east flank did not yield conclusive evidence. For the assessment of the tectonic significance of this structure we have therefore to rely entirely on gravimetric information. Judging by the strong regional rise of the gravity values across the peninsula to x 10 milligals, we are inclined to assume that conditions similar to Giralia are also obtaining in the Cape Range structure, with this difference, however, that the basement might be much shallower here than in is at Giralia, where the latest information indicates quite an appreciable thickness of the sediments, up to and possibly even more than 20,ooo feet.

As a consequence to the s tructural situation as outlined above, the following exploration programme is suggested:

1) In order to size up quickly the stratigraphical and structural conditions in the sourthern part of the basin (south of the Gascoyne River) a rapid field geological reconnaissance of one field season should be made. It should comprise the area between the Gascoyne and the basement outcrops around Geraldton. It appears to be essential to obtain information on the regional extent of the Devonian-Carboniferous formations, whether they are present or absent in the southern part of the basin, This is quite apart from information to be obtained as to the type of tectonics in this area. If aerial photographs are available they can be used to advantage, otherwise spotting of observations can be done with conventional methods, speedometer/compass traverses and tie-ins with existing survey fixes (bench marks, section corners, trig-stations etc). This reconnaissance could best be carried out by the Bureau's North-West Basin party, who are now familiar with the stratigraphy and the tectonics of this part of Western Australia.

2) Simultaneously a gravity reconnaissance should be made, of the same type as that already done in the northern part of the basin, but possibly along a denser net of traverses. In view of the fact that the Geophysical Section of the Bureau is already engaged on work of this type elsewhere, this task could best be undertaken by a gravity party of the Companies interested in the area. One field season in 1953 should be sufficient to obtain the information required.

3) The seismic work on Giralia should be concluded by extending Section B to the coast and shooting Section C across the apex area. It is not excluded that a reversal of the regional east dip in this section can be proved, coinciding with the gravity maximum in this area. Section C, across the apex area should prove or disprove the existence of a similar discrepancy between surface structure and structure in depth as was found in the northern part of Giralia.

If such a discrepancy is proved for the apex of Giralia, then further exploration work of the North-West Basin would be entirely a geophysical proposition which should be carried out in three stages, i.e.

a) regional gravity reconnaissance of the southern part of the basin, followed by

b) detailed gravity work on selected areas, and

c) seismic work on the most promising gravity indications.

Should these investigations prove absence of deep seated folding, then possibilities of fault traps as well as overlap possibilities between truncated Palaeozoic rocks and overlapping Cretaceous should be investigated.

B. THE FITZROY BASIN.

The name Fitzroy Basin is given preference to the former name of Desert Basin, because the Desert Basin proper, i.e. the area represented in the Geological Map of the Commonwealth of Australia as a basin might not be part of a sedimentary basin as such.

The geological history and consequently the stratigraphical record of the Fitzroy Basin are in striking contrast to those of the North-West Basin. Its main characteristics are the presence of rocks of Ordovician age, the prolific development of reefs in Devonian time, the absence of sediments of Carboniferous age and the mainly terrestrial origin of part of the Permian sequence.

The discovery of Ordovician sediments by the Bureau's geological party, in the Prices Creek area, is of considerable importance for the oil prospects of the Fitzroy Basin. The lower division of the Ordovician sequence (Emanuel Limestone, 1,670 feet exposed) with its alternation of fossiliferous limestone, shale and marl, has the characteristics of a source formation, whereas the dolomite of the upper division (Gap Creek Dolomite, 780 feet) shows sufficient porosity as to act as reservoir rock. The known thickness of the Ordovician rocks of 2,450 feet is not the total thickness, as the base of the Emanuel Limestone is not exposed.

The outcrop area of the Ordovician sediments in Prices Creek and vicinity is approximately 12 square miles. They have not been found at the surface elsewhere. It therefore cannot be decided whether this important stratigraphical unit attains regional significance within the basin or whether it might only be preserved as erosional remnants in local depressions of the Pre-Cambrian basement floor.

Three shallow bores were drilled in Ordovician rocks in the Prices Creek area by Freney Kimberley Oil Company in 1922/23. From all of these bores traces of oil have been reported by L.M. Waterford, Superintendent of the company. Rock samples from No. 1 Bore were submitted to E.S. Simpson, Government Mineralogist and Analyst in Perth, who reported on his findings as follows: "These samples all consisted of coarsely crushed grey coloured shale containing a considerable amount of calcium carbonate and organic matter. The oil yielded in each case was of a pale yellow colour, with petroliferous odour and evidently of mineral origin".

The Ordovician rocks in Prices Creek area are unconformably overlain by Middle Devonian limestone, which forms part of a wide belt of fringing and capping reefs along the north-eastern margin of the basin near the Middle Dovonian shore line. The greatest development of these reefs is to be found in the Margaret River area, i.e. in the south-eastern part of the basin. There the Middle Devonian Pillara limestone attains a thickness of 2,000 feet. An interesting fact is, that the Pre-Cambrain surface was by no means a level plain, but had a quite rugged topography. The depressions are occupied by a basal sequence of rhythmically deposited nodular marl and limestone with a basal arkosic grit, which is entirely missing on Pre-Cambrain highs which are capped by the lowest measive stromatoporoid limestone of the Pillara.

There is a marked change in thickness, and to a certain extent also a facies, in a north-western directions. On the north-east side of the Oscar Range the Pillara Limestone decreases in thickness from 2,000 feet at Geikie Gorge (Fitzroy River) to a few erosional remnants in the Napier Range and on the south-western flank of the Oscar Range. This decrease is partly due to overlap of the Upper Devonian sediments, but also to wide spread erosion in epi-Middle Devonian time.

In the Margaret River area, reef growth continued well up into Upper Devonian time (Stages 1-111, Mount Pierre Group) and reached a second peak in Bugle Gap time (Upper Devonian Stage 1V). The red limestone-siltstone sequence with Goniatites of the Mount Pierre Group represents clearly the inter-reef facies of contemporaneous reefs and is seen interfingering with the actual reef facies. The Upper Devonian sediments in this area attain a thickness of 3,000 feet.

In the lower portion of the Bugle Gap limestone intra-formational breccias occur. In these zones the limestone is broken up into subangular to rounded fragments, up to head-size, which are embedded in a marly matrix and are mixed with smaller and more angular fragments. They are the result of the action of waves and currents on shoals in the Upper Devonian sea. Such intra-formational breccias have yielded excellent production in many parts of the world.

A very peculiar feature is the J8 Conflomerate. It was previously considered as being a Permian age and glacial origin, There is, however, convincing proof of interfingering of the conglomerate with Upper Devonian limestone even up to Bugle Gal time. In our opinion the J8 Conglomerate is a piedmont deposit which owes its existence to active fault scraps in the vicinity of the shore line. The mode of its distribution as isolated accumulations of clastics suggests local origin near to the actual source.

To the north-west of the Margaret River area, i.e. on the Oscar Plateau and in the Napier Range, the Upper Devonian is also developed in two distinct formations, although of a different facies from that of the Mount Pierre Group and the Bugle Gap Limestone.

The Napier Formation (2,800 feet on the Oscar Plateau, 950 feet at Barker River) in its lower portion is essentially a clastic and arenoceous sediment. It contains abundant fragments of Pillara Limestone mixed with fragments derived from the Pre-Cambrian sequence. The clastics and their derivation from Middle Devonian limestone and Pre-Cambrian are evidence for strong erosional processes, possibly in connection with uplift in this part of the margin of the basin. In places only could reef forming organisms establish themselves for a short time, as can be seen in the scattered small bioherms throughout this part of the section. More stable conditions were apparently re-established in Upper Napier time, when large reef masses were formed in places (Windjana Gorge, Barker River).

Along the south-western flank of the Oscar Range, the Upper Devonian limestones attain a thickness of 1,500 to 2,000 feet. But here, the arenaceous and clastic sediments of the lower part of the Napier are absent.

The Fairfield Formation mainly consists of silty and sandy limestones, with possible intercalations of marl. It represents, similar to the Bugle Gap Limestone of which it might be the stratigraphical equivalent, a time of undisturbed sedimentation.

Similar to the J8 Conglomerate of the Margaret River area, are the local accumulations of coarse clastics (Mt. Behn and Mt. Patterson Conglomerate) in the Napier Range of its north-western extension.

Summarizing the Devonian stratigraphy we can say, that two areas can be distinguished, the comparatively stable Margaret River area with the maximal development of reef growth and the absence of a pronounced hiatus between Middle and Upper Devonian, and the unstable area of the north-western part of the basinal margin (Napier Range) and of the south-western flank of the Oscar Range), where erosion in epi-Middle Devonian and early Upper Devonian time has removed part of the Middle Devonian sediments, which as clastics, were redeposited in the lower part of the Napier Limestone. Here the hiatus between Middle and Upper Devonian is greatest and the overlap of the Upper Devonian sediments onto the remnants of the Middle Devonian limestone strongest.

This fact has to be given due weight in the evaluation of the petroleum prospects of the whole basin.

Where the Devonian limestones are exposed over wide areas, they display a well defined bevelled surface, on which, in places, outliers of Permian glacial sediments are still preserved. We consider this bevelled plain as a stripped pre-Permian land surface and the larst phenomena on it as largely the result of weathering in Pre-Permain time. The distribution of the Permian glacial sediments in deep valleys cut in the land surfaced, as for instance in the Bugle Gap Gorge, is evidence for the erosional processes which have affected the limestones in pre-Permian time.

Basinward, the Devonian limestones are overlapped and completely concealed by Permian sediments. It is therefore impossible to arrive at a conclusion regarding their distribution over the deeper parts of the basin. By virtue of their nature of a fringing reef on a subsiding shelf, it is to be assumed that they are restricted in lateral extent to the immediate vicinity of the ancient shore line. Basinward they might merge into a deeper water facies, provided of course, that these sediments were not removed by erosion in pre-Permian time. It was mentioned before that there is evidence that the Pre-Cambrain basement floor was not a perfect peneplain, but that it had a rather rugged topography. We can visualize the possibility that, in the deeper parts of the basin, around and over such basement highs, forming islands and shoals in the Devonian sea, reef growing organisms could have established themselves and that fringing and capping reefs were formed. Such basement highs can, as shall be discussed later, be expected to coincide with major structures.

The Permain sequence calls for little comments. Its total maximal thickness is of the order of 7,000 feet, whereof about half (3,500 feet) is occupied by the terrestrial, fluvio-galcial and glacial Grant Formation. It is the equivalent of the mainly marine Lyons Group of the North-West Basin. It shows all the characteristics of a glacial deposit such as tillites, varve-shales, fluvio-glacial gravels, polished walls etc.

In places there is a marked unconformity between the Grant Formation and the overlying Poole Sandstone, but it is doubtful whether it attains regional significance. The Poole Sandstone is mainly a neritic sequence of sandstones and conglomerates, and in places, has at its base a fossiliferous sandy limestone (Nura-Nura). It increases in thickness in a westerly direction from 200 feet in the Poole Range to 1,200 feet in the Nerrima Dome (Nerrima No. 1 Bore).

The Noonkanbah Formation (1,200 feet) is a sequence of sandstone, fossiliferous limestone, siltstone and conglomerate, of marine shallow water origin, overlain by the estuarine sandstones and siltstone of the Liveringa Formation (1,200 feet).

Throughout the deposition of the Permian sediments, with the exception of the terrestrial Grant Formation, shallow water and near-shore conditions obtained, which are typical for a slightly unstable area of deposition, possibly of limited extent. There is little evidence for changes of facies, excepting one instance, which because of its tectonic significance is mentioned here. In the vicinity of the Pinnacle Fault, the Noonkanbah Formation shows a transition into an arenaceous facies, which indicates positive movements along this fault line in Noonkanbah time.

Structurally the Fitzroy Basin differs entirely from the North-West Basin. Whereas in the latter, faulting is the main tectonic feature and folding nearly absent, in the Fitzroy Basin folding is predominant and the faulting, although quite conspicuous is an auxiliary to the folding.

Two longitudinal faults, presumably of regional significance, are exceptions to this rule, namely the Mt. Fenton Fault near the south-western margin of the Fitzroy Basin and the Pinnacle Fault in front of the Devonian reef zone.

The Mt. Fenton fault line trends approximately north-west to south-east, from Geegully Creek through Moulamen Hill, Mt. Arthur, Mt. James and Mt. Fenton. Its continuation to the north-east is unknown, but it might extend along the east coast of Dampier Land, and to the South-east as far as Wolf Creek.

Recent field work has yielded evidence for a down-throw on the outer, south-western side, of this arcuate fault zone with a steep hade of the fault to the north-east, in other words an upthrust from the north-east. Richly fossiliferous marine sediments of Jurassic age, folded into several anticlines and synclines, have recently been found on the outer side of the fault zone. Only in places do these younger sediments cross the fault line and are preserved on its inner side.

As has been mentioned previously (Records 1950/35), the Mt. Fenton Fault line separates two areas of entirely different surface appearances. On its north-east and north side the major folds show up clearly in the morphological pattern, whereas the areas to the west and south of it (Dampier Land and Desert Basin proper) are, excepting some low ridges of Upper Permian and Jurassic rocks, a perfect peneplain.

The correct interpretation of this fault line is essential for the proper understanding of the regional relationship between the Fitzroy Basin, Dampier Land and the Desert Basin proper. Two alternatives were then postulated and will be repeated here:

a. The Mt. Fenton Fault zone is situated near or on the Devonian-Permian shelf edge and would consequently separate the shelf area to the north and east from a deep sea region to the south and west. It would represent a tectonic step caused by deep seated fault movements in the basement complex. Within the area to the south and west a pelagic facies, correlative to the neritic facies of the shelf zone, could be expected. The weakness, or even absence of surface evidence of folding could be explained by a regional decrease of tectonic movement with increasing distance from the basin margin, and by an unconformable superposition of the Permian and younger sediments on the older Palaeozoics. Preservation of Ordovician rocks and the occurrence of Carboniferous strata could be expected in this deeper part of the basin.

b. The fault zone indicates the eastern and northern edge of a rigid segment of the basement, bordering on a shallow fault-bounded basin, of which King Sound as its deepest part, is still occupied by the sea. From there it gradually rises to the south-east and east. The sea has in the past, repeatedly transgressed on and regressed from this embayment, overlapping possibly for short periods on to the margin of the southern mainland, which because of its stability, had gradually been worn down to a peneplain. The rigidity of the basement complex in this area, and the reduced thickness of the sedimentary cover would account for the weakness or even absence of folding.

In case a. The Fitzroy Basin would represent the shelf area of a wide basin, the Desert Basin proper. In case b. it would be a graben or trough, bounded on three sides by basement, forming the ancient upland and open to the sea to the north-west.

Although case b. appears to be more likely, only geophysical evidence can give the final solution to this problem.

The Pinnacle Fault is recognizable at the surface to the south of the Rough Range, in the Prices Creek area, but it may extent for a considerable distance to the north-west. In the Prices Creek area, the lower beds of the Ordovician sequence are brought into contact with the Noonkanbah Formation. This indicates a down throw on the south-west side of several thousand feet. As mentioned before, the arenaceous facies of the Noonkanbah in the immediate vicinity of the fault line, is evidence for the fact, that the fault had been active in Permian time, and that during the deposition of the Noonkanbah Formation, the coast line was close to, or even coinciding with the fault. It is difficult to assess the regional significance of the Pinnacle fault zone without having geophysical information available. However, it is not excluded that it is a step fault at or near the edge of the Devonian reef platform. It should be taken into consideration in future work as a fault trap possibility.

The major structures of the Fitzroy Basin are arranged along two paralled trends which cross the basin at an oblique angle. They are separated by a regional syncline in the deepest part of which the Tertiary Leucitite plugs are situated.

The southern trend comprises the Poole Range, St. George Range and Nerrima Domes, whereas the northern trend is formed by the Mt. Wynne and Grant Range Domes. All of these structures show very intensive faulting, expecially in their flanks. Many of the faults, however, cross the structural axes in a dense pattern. Only in the Mt. Wynne and the Grant Range Domes are the major faults arranged more or less paralled to the axis in a longitudinal pattern. Some of the cross faults are hinged or even double hinged. The amount of throw is difficult to assess where Grant Sandstone occurson either side of a fault, but a careful analysis of the fault pattern in the geological maps now in course of preparation, will allow a determination of the amount of throw in many of these faults. Special attention should thereby be paid to the influence the faults might have on closure. In our opinion the faults in the major structures are an expression of the high degree of competency of the sediments involved. They might have their origin in a basement fault pattern. As a working hypothesis, basement buried ridges with fringing or capping Devonian reefs can therefore be assumed to form the core of these structures.

The seismic survey now in progress on Nerrima Dome has already yielded some interesting results which might throw some light on the problem of the thickness of formations closed in a major structure. A high velocity refractor, presumably basement rocks, is reported to occur at approximately 10,000 feet depth. Nerrima No. 1 Bore had reached a final depth of 4,271 feet and was abandoned in Grant Formation, of which it had penetrated about 2,000 feet. The greatest, but not total thickness of this formation obtained in the Poole Range (outcrop and well section), was 3,500 feet. The greatest, but not total thickness of this formation obtained in the Poole Range (outcrop and well section), was 3,500 feet. Therefore about 1,500 feet of Great Formation can still be expected below the final depth of the bore, i.e. to a depth of approximately 5,700 feet. This would still leave a thickness of at least 4,000 feet for formations older than Permian, presumably Devonian, between the assumed base of the Permian section and the high velocity refractor at 10,000 feet.

In order to solve the problems for which surface mapping cannot supply a satisfactory solution, the following geophysical programme is suggested:

a. A regional gravity reconnaissance covering the whole basin, as was previously suggested (our memo to Chief Geologist of 29/10/51 and fig. 1). Although the density of the net of observations depends on existing roads and tracks, in view of the special problems of the Fitzroy Basin, it is strongly recommended to cover each major structure, as far as accessability allows, by as many gravity stations as possible within the time limit of the overall programme. Pronounced gravity maxima, coinciding with major structures would, in our opinion, be a preliminary evidence for buried basement ridges. In order to collect sufficient information on gravity variation within the basement complex it is recommended to extend at least one, but still better two or three of the traverses well into the basement area. Moreover, gravity observations, within the regional programme, should be concentrated on the Pinnacle and Mt. Fenton Faults and their possible extensions. Steep gravity gradients across those fault zones and the direction of the gradient slope should give invaluable information on the nature of the faults.

b. It was suggested in the above mentioned memo that a semi-detailed gravity survey be made of the Nerrima Dome and its immediate surroundings. Quite apart from the information on basement configuration in this particular area, a combination of the gravity results with the seismic data, in conjunction with the S.G. determinations on cores (see bore log Nerrima No. 1 Bore, enclosed in our memo to Chief Geologist of 28/3/51) would greatly assist in the interpretation of the gravity pattern of other major structures of the Fitzroy Basin.

c. The seismic survey in progress on Nerrima should be concluded.

d. For reasons to be discussed presently, we would strongly recommend a seismic survey - reflection and/or refraction of the Poole Range Dome.

Regarding the outline of a drilling programme for the Fitzroy Basin, it has to be stated that we are in a much better position here than we are in the North-West Basin where no target for a deep test is available yet.

In the Fitzroy Basin at least five major structures have been outlined by field mapping. Any one of these, after the necessary gravity and seismic surveys, would be ready for a deep tests.

In this review we cannot enter into details, but all the relevant structural problems, such as closure, control of structural closure by faults, acreage of collection areas etc. will be dealt with in the report on the Fitzroy Basin by the Senior Geologist in charge of field work there.

For several reasons we are inclined to assign the following order of priority to the five major structures already mapped:

1.	Poole Range	)
2.	St. George Range	)
3.	Grant Range	) Dome
4.	Nerrima	)
5.	Mt. Wynne	)

The Poole Range Dome is situated at the south-eastern end of the Nerrima - St. George - Poole Range Trend. It is a faulted dome with a definite closure to the east, and has Grant Formation exposed on its apex. To the west there is a secondary structure - Mt. Hutton. For the determination of closure to the west, Mt. Hutton has to be included in the Poole Range Dome.

Closure toward St. George Range Dome is indicated and might be enhanced by a major cross fault. There are two reasons which have induced us to assign the Poole Range Dome first priority.

Out of five structures mapped, it is situated closest to the outcropping Ordovician section, which as mentioned before, has yielded traces of oil in three of the Prices Creek bores. It is also closest to the outcrop of the prospective Devonian reef limestone, in an area of greatest stability and greatest development of reefs. The distance from its apex to these outcrops is 14 to 16 miles. The Pinnacle fault and the Talbot syncline are the only tectonic features intervening. Because of its promimity to known outcrops, the chances that either one or both of the Ordovician and Devonian sequences occur in this structure, are good.

It is superfluous to specifically mention the importance of reef formations as producers, but their limited extent by virtue of their organix origin, controlled by biological factors, should be realized. Therefore, structures close to known reefs, and separated therefrom by a syncline or a fault or both, as is the case here, should receive first consideration.

The other reason for the preference given to this structure is the fact that oil shows were obtained in Poole Range No. 3 Bore in the Grant Formation. It was determined by the analyst as a crude of mixed base (asfaltic and waxy), a fact which appears to exclude any doping of the well.

The <u>St. George Range Dome</u>, second on our list of priorty, and accupying the central part of the southern trend, is a larger structure than the Poole Range, but similarily transsected by faults. It indoubtedly has a much wider collecting area, but is far more difficult to access than the Poole Range Structure. In either case, whether production would be proved or not in the Poole Range Dome, it would come next for a deep test.

The <u>Grant Range Dome</u> or better Anticline is the western structure on the northern trend. It is at least 25 miles long and 10 miles wide between the Noonkanbah/Liveringa contact in each flank, but much wider from syncline to syncline. It has Grant Formation exposed in its core and is complicated by a series of longitudinal faults, one of which is of considerable throw. It is situated in a part of the basin about 60 miles to the southwest of the Devonian reef limestone outcrops of the Oscar Range. Therefore no prediction can be made whether Devonian reef limestone is present in depth.

<u>Nerrima Dome</u> is an elongated dome about 16 miles long and 8 miles wide, closed in Noonkanbah Formatiom. It shows a similar pattern of cross faulting as do the larger structures. It was mapped by a field party of the Bureau and is being investigated by gravity and seismic methods.

Nerrima No. 1 Bore was abandoned at a depth of 4,271 feet in Grant Formation. It had not reached its target and therefore it is inconclusive. There are plans to drill a second well as a joint venture of the Commonwealth, the Western Australian Government and the Freney Kimberley Oil Company. We have some hesitation to recommend this structure for a first test (10,000 feet) in the Fitzroy Basin, mainly because of its proximity to the Mt. Fenton Fault which might have adversely affected its western closure. Structural conditions there are rather obscure and complicated. Moreover the occurrence of many warm water springs along the fault line might indicate flushing in depth. Failure of a test on this structure might prejudice the opinion regarding the prospects of the Fitzroy Basin and consequently after disappointing results at Nerrima other, and in our opinion more promising, structures might be left untested.

<u>Mt. Wynne Dome</u> is a comparatively small (about 10 miles long and wide) structure showing extreme complication by faulting. Asfaltic matter in fissures and cracks was reported from Mt. Wynne

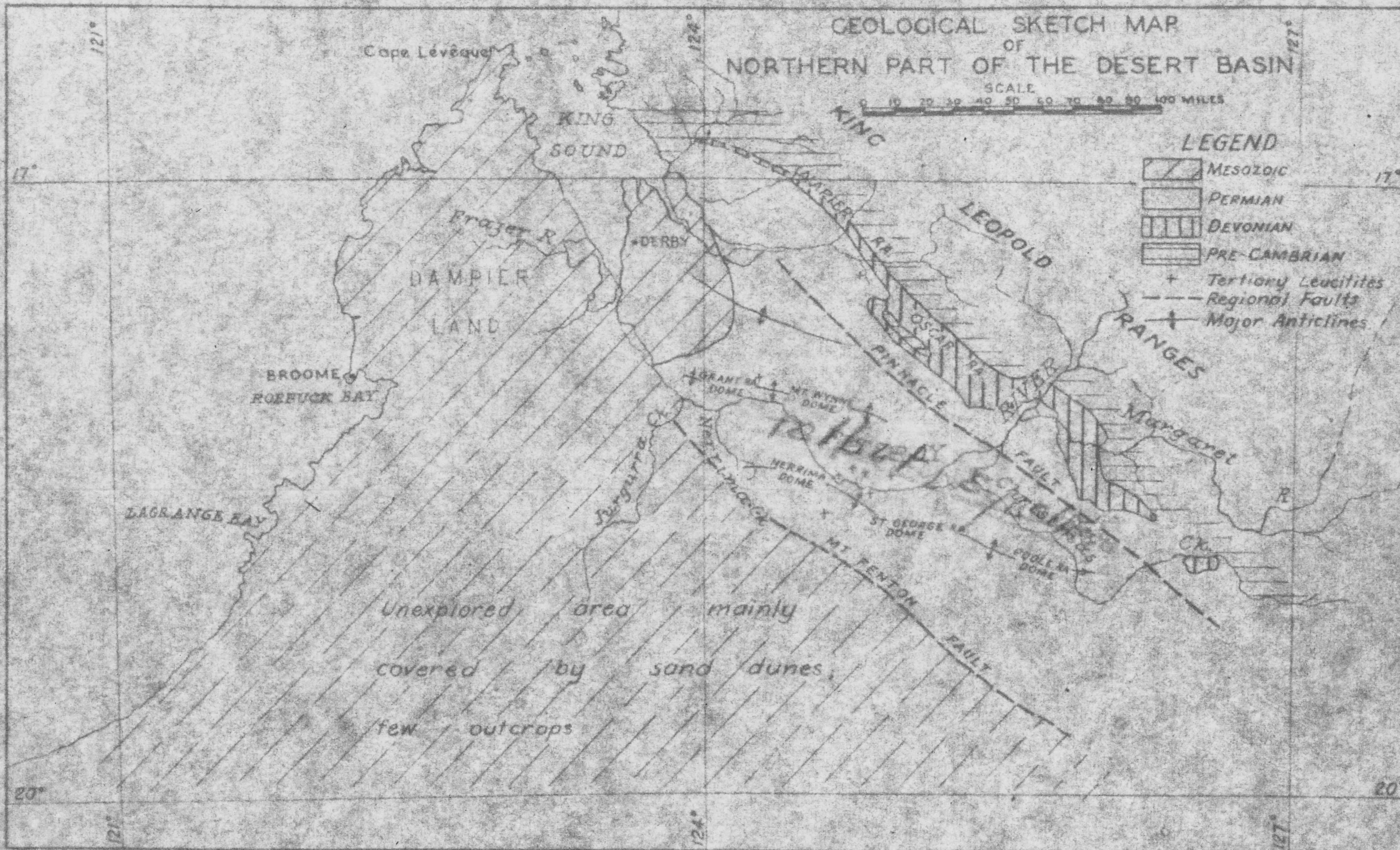
Bore. Because of its complex tectonics we can not recommend this anticline for a deep test, unless production has been proved in other, less complicated structures.

Final Remarks.

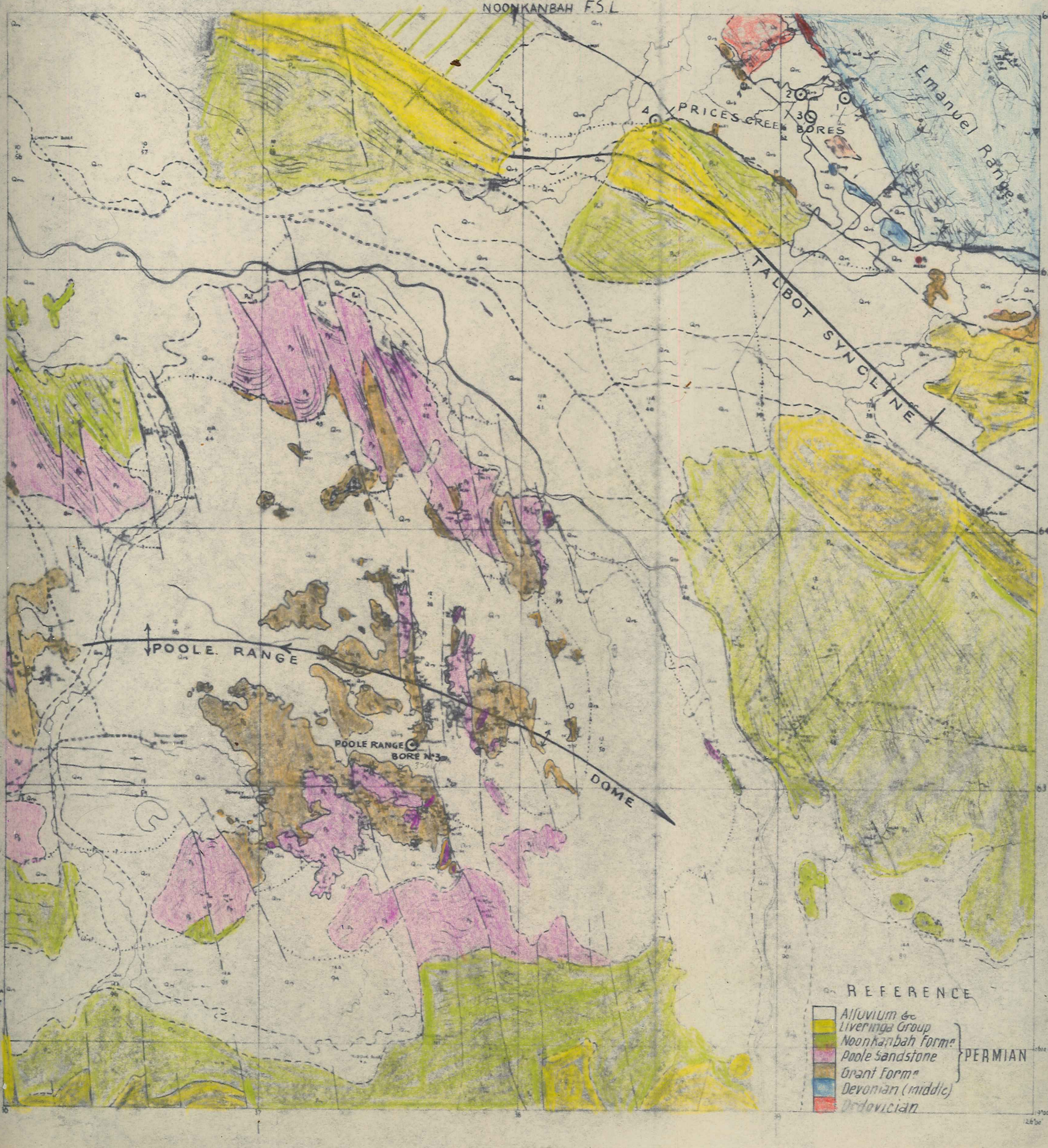
This brief review reflects the personal views of the author. It gives only a very broad outline of the working hypotheses applicable to further search for oil in the North-West and the Fitzroy Basins. The regional aspect of the problem has been given first consideration and details are relegated to the reports on these areas.

For maps, tectonic sections, stratigraphic columns and other graphic representations of the facts discussed in this review reference is made to the respective gepphysical and geological reports, either published, or in the course of preparation.

Canberra, 24th July, 1952. (W.F. Schneeberger).



GEOLOGICAL SKETCH MAP
OF
NORTHERN PART OF THE DESERT BASIN
SCALE
0 10 20 30 40 50 60 70 80 90 100 MILES
LEGEND
MESOZOIC
PERMIAN
DEVONIAN
PRE-CAMBRIAN
Tertiary Leucitites
Regional Faults
Major Anticlines
121°
124°
127°
17°
20°
Cape Lévêque
KING SOUND
Fraser R.
DAMPIER LAND
DERBY
BROOME
ROEBUCK BAY
LAGRANGE BAY
KING LEOPOLD RANGES
DAMPIER RA
OSCAR RA
RIVER
PINNACLE FAULT
Margaret R
GRANT RA DOME
MT WYNNE DOME
NERRIMA DOME
ST GEORGE RA DOME
POOLE RA DOME
MT FENTON FAULT
Ck
Unexplored area mainly covered by sand dunes, few outcrops


NOONKANBAH F.S.L.
PRICES CREEK BORES
Emanuel Range
TALBOT SYNCLINE
POOLE RANGE DOME
POOLE RANGE BORE No 3
REFERENCE
Alluvium &c
Liveringa Group
Noonkanbah Formn
Poole Sandstone
Grant Formn
PERMIAN
Devonian (middle)
Ordovician