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THE OCCURRENCE OF GROUNDWATER SUITABLE FOR IRRIGATION, WILLOWRA STATION, NORTHERN TERRITORY.

by
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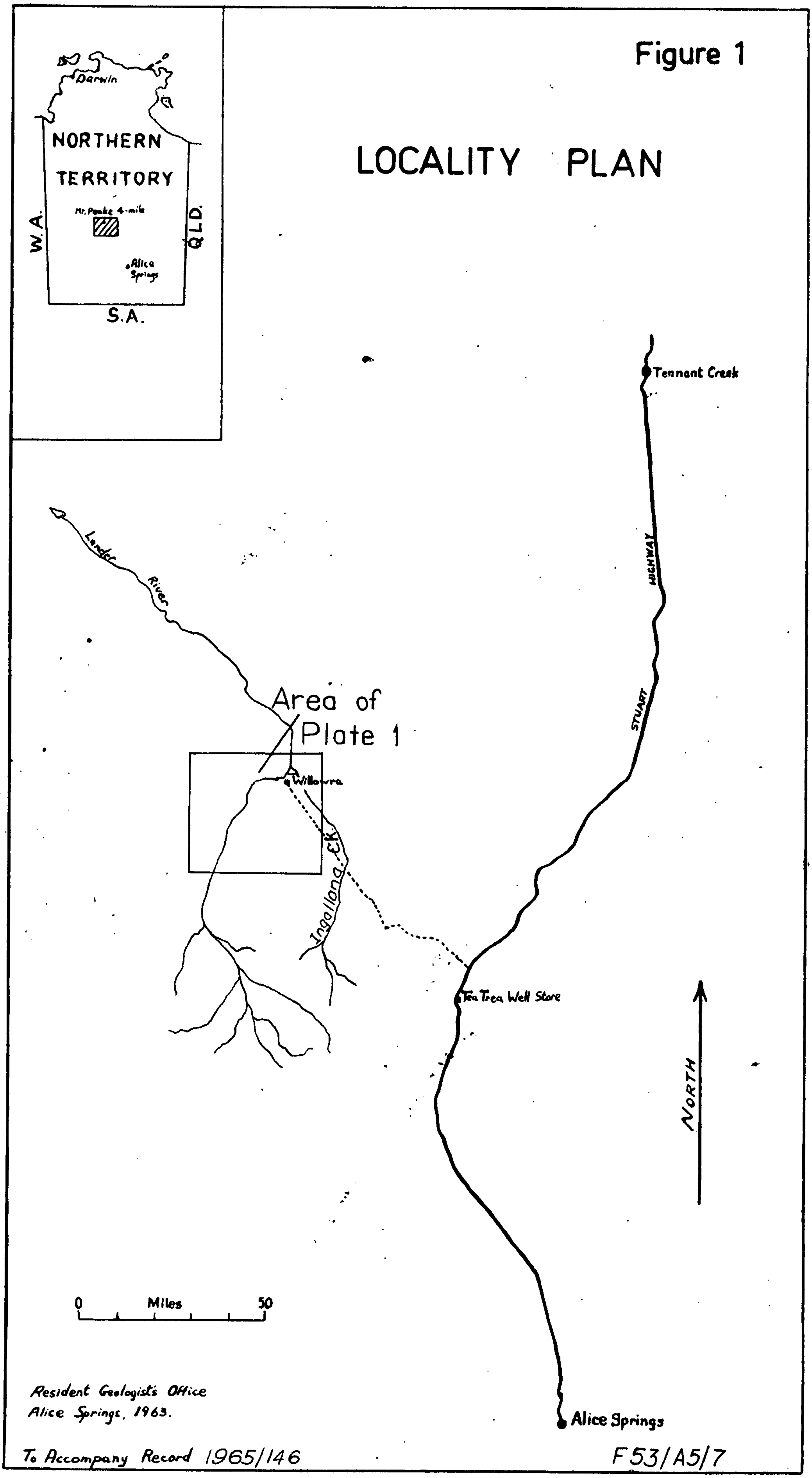
LOCALITY PLAN



Resident Geologist's Office
Alice Springs, 1963.

To Accompany Record 1965/146

F53/A5/7

THE OCCURRENCE OF GROUNDWATER SUITABLE FOR IRRIGATION, WILLOWRA STATION, NORTHERN TERRITORY

SUMMARY

Results of drilling show that the strata in the area south of Willowra homestead are late Tertiary and Quaternary sediments which unconformably overlie deeply weathered Precambrian (Archaean) rocks. The name Willowra Basin is used for the basement depression which is filled with this sediment. Tertiary sediments are known to be at least 115 feet thick in places; they include aquifers of unconsolidated fluvial channel sand. Aquifers occur also in the deeply weathered parts of the underlying basement rocks.

Countours of the piezometric surface and of the total dissolved salts in groundwater suggest that the Tertiary aquifers are being recharged with good quality water from Quaternary river sand at the southern boundary, and that a small amount of poor quality water enters from the surrounding Precambrian rocks.

The quality of groundwater is critically examined, and a classification is given which enables the groundwater to be assigned to particular aquifers. It is possible on this basis to distinguish areas of contamination of aquifers.

It is concluded that all groundwater in the Tertiary aquifer south of Willowra Homestead can be used for irrigated agriculture on the soil available.

INTRODUCTION

Willowra Homestead is located at latitude 21° 16', longitude 132°37'. It is 200 miles north-north-west of Alice Springs and 100 miles by road north-west of Tea Tree Well Store (which is on the Stuart Highway), at the junction of the Lander River and Ingallana Creek. The terrain consists of aeolian-sand covered plains, with occasional steep-sided hills of metamorphic rock rising up to 200 feet above the plains. The plains support a vigorous growth of spinifex; the few areas of dense mulga scrub are associated with laterite outcrop or shallow bedrock.

The climate is typical of the arid continental interior. The annual rainfall is twelve inches, falling mainly in the summer period, when mean maximum temperatures exceed 90°F. Loose surface sand on the plains allows a relatively high rate of rainwater infiltration so that runoff is small. Brief flows of the Lander River are caused by the higher percentage of run-off in the catchment area, well south of Willowra, which consists of outcrops of igneous and metamorphic rocks of Precambrian age.

Water supply for Willowra Homestead is obtained from bores close to the Lander River; it is drawn from aquifers in Quaternary and Tertiary river gravel and sand. The bores show a marked rise in water level, and decrease in water salinity after a flood of the Lander River. In October 1960 a bore (EasyBore) was drilled 2½ miles south-east of the homestead to provide additional water for stock. The bore has a total aquifer thickness of 60 feet and was proved by test to have a specific capacity of 1000 gallons per hour per foot drawdown The bore water at the time of the test contained 1039 parts per million (p.p.m.) of total dissolved salts. The lessee was impressed by the results of drilling this bore, and conceived the idea of using groundwater for irrigation.

Quinlan and Woolley, Resident Geologists, Alice Springs, wrote an opinion titled "The Occurrence of Groundwater on Willowra Station, N.T." (October 1962, unpublished) with special reference to the possibility of irrigated agriculture. They concluded that water is available in sufficient quantities from the Tertiary and Quaternary sediments for use in irrigated agriculture, and that "the quality of groundwater from a small area in the immediate vicinity of Willowra Homestead is suitable for agricultural purposes, but the remainder of the basin is marginal or unsuitable". A drilling programme was recommended to estimate the quality of groundwater available in the area and to establish:-

(a) the stratigraphy and areal distribution of the Tertiary and Quaternary sediments including a delineation of the aquifers;

(b) the limits of saturated sediments, in area and depth;

(c) the shape of the piezometric surface;

(d) the distribution and variation in salinity of the groundwater, in particular, whether a salt water interface exists between Sandfords Well and Willowra Homestead.

Water Resources Branch, Northern Territory Administration, Alice Springs, commenced investigation drilling in February 1963, using an Edico rotary rig. By July 1963 a total of 29 holes had been drilled; they provided information for a comprehensive geological interpretation of the area. Water samples were collected from most bores and analysed by the Animal Industry Branch, N.T.A., Alice Springs. In October 1963 Water Resources Branch, Alice Springs, using a Portadrill rotary rig, drilled a further 16 holes aimed at providing bore suitable for pump testing and as observation bores in the test area.

All investigation holes were sited on a 5000-foot magnetic grid whose origin was taken to be 100,000 feet west and 100,000 feet south of Easy Bore. Reference numbers are given in 1,000's of feet and accompanied by the letter W for area reference. Eastings are given first, followed by the area reference letter and then by the northings, hence Easy Bore has the co-ordinates 100W100. Reference numbers to the bores in this report, including the Plates, is made using the bore reference numbers recorded in the Alice Springs Resident Geological Office. Bores within a 1:250,000 Sheet area are numbered consecutively, generally in order of siting, and the number is preceded by the Sheet reference number. Easy Bore is bore No. F53/5-59. For convenience, only the serial number is used in the report. Table 1 gives the grid reference for all bores drilled in the Willowra area in the course of the present investigation of irrigation water supplies.

GEOLOGY

The regional geology is described by Quinlan and Woolley (1962). The succession of rocks occurring in the Mount Peake area is arbitrarily assigned to the Archaean, Proterozoic, Tertiary and Quaternary periods (Plate 1).

The oldest rocks in the area have been assigned an Archaean age; they consist of tightly folded and faulted schist and gneiss which have been intruded by granite, and quartz veins. One of the few outcrops of these rocks is on the north-western side of Mount Barkly where they are overlain to the south by sedimentary rocks of Proterozoic age. Lithologically, the Proterozoic rocks consist of a sequence of interbedded medium-grained kaolinitic and micaceous quartz sandstone and hard white massive quartzite, and an underlying sequence of black shale with thin interbeds of quartzite and silty sandstone. These sedimentary rocks are strongly jointed and sheared, and have been infolded and faulted into the Archaean rocks.

The texture and chemical composition of the Archaean and Proterozoic rocks have been altered by processes of deep weathering and lateritisation, which could have occurred at any time from Cambrian to Lower Tertiary. Deeply weathered rocks are widespread in Central Australia and observations on the age of the weathering point to at least three possible intervals (Quinlan, personal communication):

(1) the interval of time between the Upper Proterozoic and Lower Cretaceous

(2) the interval from Upper Cretaceous to Lower Tertiary

(3) during the Middle Tertiary, possibly Miocene.

TABLE 1 - CO-ORDINATES OF WILLOWRA BORES

Bore Reference Number Resident Geologists' Office	Bore Grid Reference Water Resources Branch	
F53/5-72	101.25W85	
73	100W95	(1st Attempt)
74	100W105	
75	100W110	
76	100W115	
77	100W120	
78	95W120	
79	105W120	
80	110W120	
81	120W120	
82	100W85	
83	100W90	
84	90W120	
85	85W120	
86	80W120	
87	75W120	
88	100W80	
89	100W75	
90	100W70	
91	100W65	
92	100W55	
93	100W45	
94	100W35	
95	95W35	
98	110W75	
99	105W75	
100	95W75	
101	90W75	
102	85W75	
103	80W75	
105	98.75W82.5	
106	101.25W82.5	
107	98.75W85	
108	95W82.5	(1st Attempt)
109	92.5W82.5	
110	93.75W82.5	
111	95W88.75	
112	100W95	(2nd Attempt)
113	95W82.5	(2nd Attempt)
114	95W90	
115	100W95	(1st Production hole)
116	100W94.5	Observation bore
117	100W95.5	Observation bore
118	100.5W95	Observation bore
119	99.5W95	Observation bore

In areas such as Willowra, where no sediment was deposited from the end of the Proterozoic to Upper Tertiary periods, the processes of deep weathering and lateritisation could have been operative since Upper Proterozoic time.

The deep weathering and laterite profile extends to depths of 200 feet below the present surface. Erosion of the laterite surface gave rise to channels, more than 100 feet deep, which were later filled with fluvial sand and silt. An Upper Tertiary age for the fluvial sediments is suggested by lithological correlation with Tertiary deposits at Alcoota, 50 miles north-east of Alice Springs, which contain fossil bones of Pliocene age. The Tertiary sediments do not occur in outcrop but have been intersected in most of the investigation bores.

Diagenesis of part of the Tertiary sediments, probably during the Pleistocene epoch, resulted in the formation of calcrete, ferricrete and kunkar, which are formed partly, or completely, by the action of circulating groundwater. Tertiary and Pleistocene deposits were eroded during Recent time and channels formed have been filled by Recent river sand and gravel. The name Willowra Basin is used for the basement depression, to the south of Willowra Homestead, which is filled with sediment of Tertiary to Quaternary age.

Investigations on groundwater occurrence have been confined to the deeply weathered part of the basement rocks and to the Tertiary, Pleistocene and Recent deposits. Text figure 2 shows the stratigraphic relationships of the weathered and unconsolidated strata.

Deeply Weathered Basement Rock

An examination of samples from bores that have been drilled through the weathered rocks shows three zones. They are, in descending order, a ferruginous zone, a mottled zone, and a pallid zone.

The ferruginous zone consists of a red, earthy decomposed rock rich in iron oxide (usually present as haematite). It has a massive texture but in places is pisolitic near the surface. Its thickness varies from 10 to 70 feet.

The mottled zone consists of a mottled red and white earthy decomposed rock formed by the contemporaneous deposition and leaching of chemical tons. It is from 10 to 40 feet thick.

The pallid zone commonly shows traces of the structure and texture of the parent rock and therefore its composition varies with that of the parent rock. It may be a white earthy decomposed rock a white kaolin clay with some free quartz. Below are free quartz, feldspar, mica, and rock fragments showing the original texture of the parent rock. The mica content of the zone increases with depth to the top of the parent rock. The thickness of the pallid zone ranges from 20 to 85 feet but the true base is commonly indiscernable because of the transitional character of the boundary with the parent rock.

The deep weathering profile developed at Willowra closely resembles the laterite profile typically developed in Northern Australia, as described by Fisher (1958). The concentration of alumina in the Willowra profile has not been determined.

Beds of Precambrian quartzite crop out adjacent to areas where weathering has reached depths of 200 feet. They must therefore be very resistant to weathering. Rare occurrences of silcrete, in the form of chalcedony and chalcedonic quartzite, are associated with them (e.g. 0.4 miles due north-west of investigation bore 106). This suggests that the development of laterite or chalcedony is dependent, in part, on the composition of the bedrock.

Tertiary Sediments

The sediments consist of brown clay and silt, and brown, cream and white sand and gravel. They were deposited in a north-south trending channel that extends southward from Willowra homestead. Fifteen miles to the south of the homestead the deposit is 60 feet deep and about 2 miles wide. The depth and width of the channel

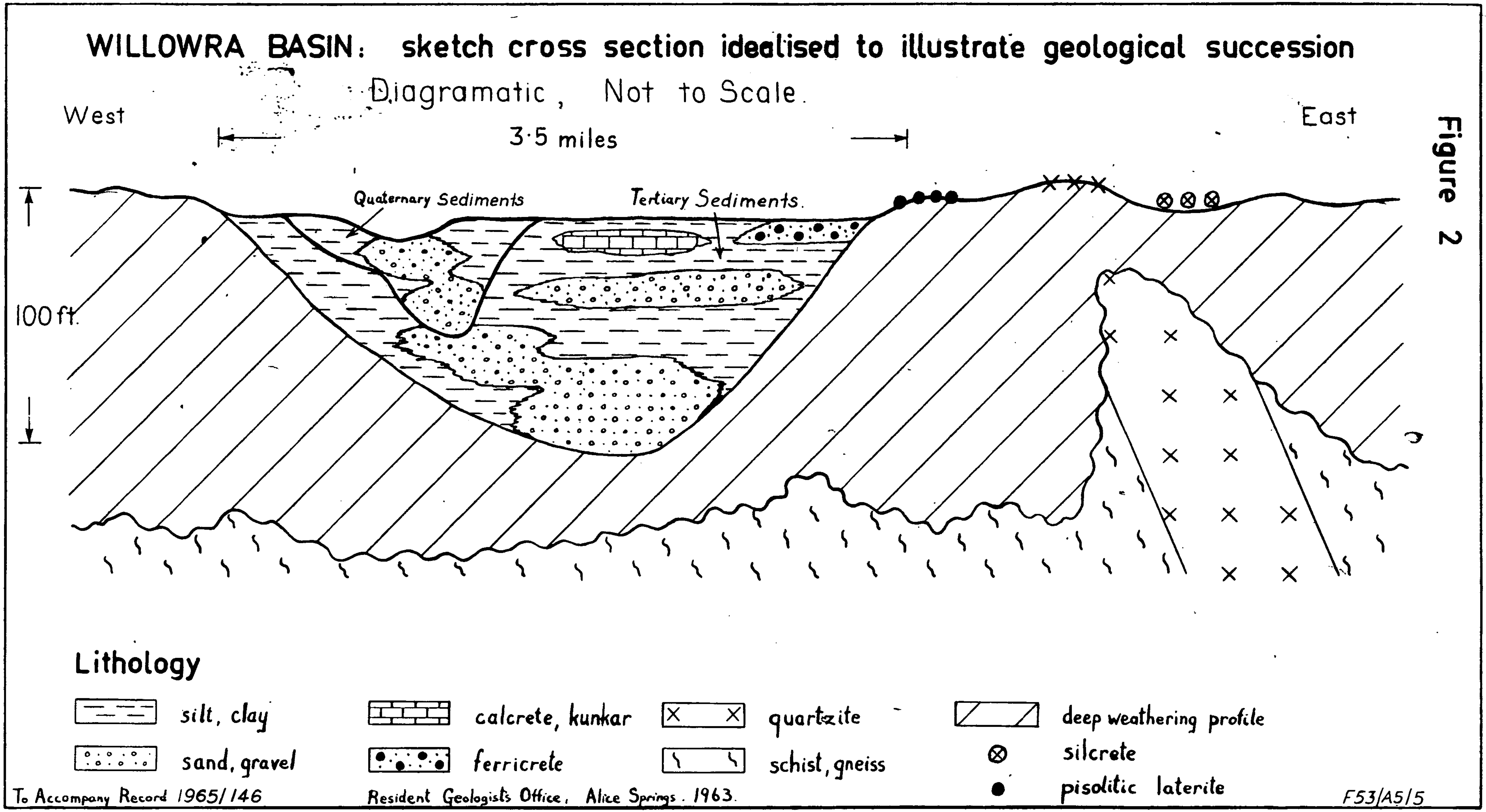


Figure 2

To Accompany Record 1965/146 Resident Geologists Office, Alice Springs. 1963. F53/A5/5 gradually increase northwards, with a maximum known depth of 115 feet just north of Willowra homestead. Sediment, particularly sand and gravel, exists as horizontal lens deposits, elongated parallel to the channel. A fluvial environment of deposition for the sediments is suggested by their occurrence in a channel, by the lenticular shape of the deposit and by the absence of fossils. The coarse sand and gravel represent channel deposits and the clay and silty clay represent floodplain deposits.

The Tertiary sediments were derived largely from deeply weathered basement rocks. Quartz from the lower part of the pallid zone apparently constitutes much of the sand in the channel sands.

There were two major periods of channel sand deposition, separated by a quiescent period represented by clay and silt sediments. The base of the upper channel sand occurs at a depth of about 30 feet, and the top of the lower channel sand is at a depth of about 55 feet below ground surface.

Pleistocene Deposits

Calcium carbonate has accumulated as large concretionary masses in the Tertiary sediments, to form kunkar, and as a calcareous cement to Tertiary sand, to form calcrete. Kunkar appearently grades downwards into calcrete. The carbonate is thought to have been deposited from circulating groundwater or soil moisture during the Pleistocene period.

Ferricrete is commonly well developed near the top of the Tertiary sediments, and generally at the margins of channel deposition. Apparently deposits of sand and gravel were formed from pizolitic and ferruginous laterite and underlying weathered material. The iron oxide was redistributed, presumably by groundwater or soil moisture, to form a ferruginous cement to the sand. In places calcrete occurs below the ferricrete, separated by a thin zone of partly consolidated sand or silt.

Recent Sediments

Deposits of fluvial sand, gravel and silt occur along the present course of the Lander River and Ingallana Creek, and fill fluvial erosion channels cut into the Tertiary sediments. Investigation bores drilled close to present river courses have intersected up to 20 feet of Recent sediments. It is expected that up to 50 feet of Recent sediment may underlie the river course.

Red earth sand, up to 5 feet thick, covers the whole area apart from the Recent drainage channels. It is a fine to ccarse grained silty sand and was probably derived from ancient sand dunes.

DRILLING RESULTS

An Edico rotary rig drilled twenty-nine (29) investigation holes, with a total footage of 2290 feet. Eleven of the holes penetrated the base of the Tertiary and three were collared in the deeply weathered basement. The remaining fifteen holes ended at shallow depth in Tertiary sediment because of drilling difficulties, mainly due to continual collapse of unconsolidated sand. Correlation and graphical representation of the lithologies of the holes is shown in Plates 2 and 3.

The sixteen (16) holes drilled by the Portadrill rotary rig, of total footage 2382 feet, all reached the base of the Tertiary sediments and four reached fresh schist and gneiss below the weathered zone. The geological data are presented in Plate 4 in three sections showing the logs of 10 drillholes. Some of the holes included were drilled by the Edico rig.

Rigorous tests have not been made on any bore to determine the available water supply. Most of the bores drilled by the Portadrill were pumped by airlifting to clean out the hole and this process indicated that large supplies of water are present in the Tertiary channel sand and deep weathering profile. No estimate of the specific capacity could be made.

HYDROLOGY

Availability of Groundwater

Investigations on the occurrence of groundwater have been confined to three units; the deeply weathered basement, the Tertiary and the Quaternary fluvial sediments. Aquifers are present in each of these units and they may all be interconnected by way of the unconformities at the base of the fluvial sediments.

(a) Deeply Weathered Basement Rocks

The deeply weathered rocks contain groundwater in any of the three zones (see p. 3) where they occur below the piezometric surface. In the ferruginous and mottled zones the material is fairly hard and compact, with ferruginous and porcellanised-clay cement respectively; the zones would not be expected to yield a large amount of water. The fact that small amounts of water are obtained from these zones (e.g. bores 82 and 115), suggests that they have either an original vuggy porosity or that the cementing material has been removed by leaching of groundwater or soil moisture. The pallid zone and weathered basement are normally very permeable owing to the absence of cement and readily yield good quantities of groundwater. However the weathered bedrock and parallel zone in places consist of kaolinitic clay, associated with a parent rock of mica schist; in these places very little, or no, water can be extracted (e.g. bore 72). On the other hand the pallid zone may consist almost entirely of free quartz and weathered gneiss, associated with a parent rock of quartz gneiss; this type of material has a high porosity, and large quantities of water may be available (e.g. bores 88 and 99). Commonly the profile consists of a kaolin subzone passing down into a free-quartz "sand" and "gravel". The lower part of the pallid zone is therefore a very good potential aquifer but the quantity and quality of water available varies greatly according to the source of recharge.

(b) Tertiary Sediments

The main aquifer of the Tertiary sediments is the lower of the two channel sands (see p. 4). An aquiclude of clay and silt separates the main aquifer from the upper channel sand, which is frequently above the piezometric surface. At Easy Bore the aquifer consists of a clean, medium to very coarse, sand and gravel. Bores that penetrate the main aquifer in upstream of Easy Bore (e.g. bore 113) show a large amount of clay in the sand and gravel, and a consequently reduced permeability. The aquifer thickness is 56 feet at Easy Bore and 20 feet at bore 113. This thickening of the aquifer occurs in a "downstream" direction. In a section normal to its long axis, the aquifer is lenticular and has a maximum width of about one mile.

The investigation bores drilled along an east-west line through bore 77 show the presence of two major zones of channel sand at the same stratigraphic level but separated by silt and clay (present in bore 84). One channel is under the present Lander River and the other is three miles to the west, in bore 86. Investigation bores along an east-west line through 89 show only one zone of channel sand, which must therefore bifurcate northwards. The areal extent of the lowermost Tertiary channel sand is indicated by the zone of high permeability marked on Plate 5. The volume of the Tertiary aquifers between Willowra Homestead and the southern limit of investigation bores is in the order of 400,000 acre feet.

(c) Quaternary Sediments

Quaternary fluvial sediments occur in association with the present day river courses and, as in the Tertiary sediments, the channel sands constitute the main aquifers. There is probably no aquiclude between the Quaternary and underlying Tertiary aquifers. The former is recharged after a river flow but this recharge water permeates downwards into the Tertiary aquifer; during periods of drought the Quaternary aquifer may be almost completely drained. This is demonstrated by measurements of the water levels in the Willowra Homestead bore (which intersects both of the aquifers), before and after river flow, show fluctuations of up to 40 feet. The maximum depth of Quaternary sediments is about 50 feet and the average depth to the piezometric surface during dry periods, between stream flow, is about 40 feet. Hence, the Quaternary aquifers alone are an unreliable source of underground water.

Piezometric Surface

On 23rd July, 1963, on completion of the investigation drilling with the Edico rig, water level measurements were made in most of the investigation bores. Surface levelling was completed by the Water Resources Branch, Alice Springs, using the surface level of Easy Bore as a datum of 100 feet.

The information obtained was used to construct contours of the piezometric surface (Plate 5). It was necessary to construct three sets of contours to define the following:-

(1) Groundwater flow down Ingallana Creek

(2) Groundwater flow through the main Tertiary aquifer

(3) A body of perched water in Quaternary sediments of the Lander River.

Zones of high permeability have been defined using information from the drilling shown on Plates 2, 3 and 4. The contours on the piezometric surfaces shown on Plate 5 have been constructed using the principles established in the vicinity of bore 105, which lies on a permeability boundary.

The flow of groundwater in the main Tertiary aquifer is northward, through Easy Bore and below the Lander River. Contour spacing indicates an area of lower permeability between bores 83 and 88. Groundwater flows at shallow depth down Ingallana Creek. Groundwater movement from the Sandfords Well area to Easy Bore is most unlikely as this entails a flow upgradient against a strong movement of groundwater from the south into Easy Bore. The movement of saline groundwater from Ingallana Creek to the Homestead area might be possible if no impermeable boundary exists between the two areas, particularly after long periods without recharge of the Quaternary deposits, when the present hydraulic gradient might be reversed.

The perched mound of groundwater in the Quaternary sediments of the Lander River is subject to large fluctuations in height according to river flow, and provides local recharge into the Tertiary aquifers.

Recharge of Groundwater

Recharge to the main Tertiary aquifer comes from the southern area of the basin, whose southern limits are unknown. It is suggested that the recharge occurs from river flow west of Mount Barkly where Quaternary sands of the Lander River are believed to be in contact with the Tertiary aquifer (i.e. Barkly Bore). Local recharge occurs in this way in the Willowra Homestead area.

An important amount of recharge of poor quality water comes from weathered and unweathered metamorphic rocks on the eastern side of the basin; also from south and east of bore 94, and south-east of bore 115 (shown by the trend of the contours on Plates 5 and 6). The water may flow at depth under the Tertiary aquifer and permeable zones of the deep weathering profile.

Recharge of the weathered and unweathered metamorphic rocks occurs through surface infiltration from local accumulations of run-off water. This process would be less effective over Tertiary aquifers, where flat topography does not allow accumulations of surface water.

Along a line joining bores 99 and 105 recharge to the pallid zone of the deep weathering profile comes from the Tertiary aquifer sands, which are in contact with the weathered rock to the south-west. The pallid zone here is very porous and consists of free quartz and quartz gneiss fragments. To the north it passes into an impervious micaceous kaolin, indicating a change in bedrock from quartz gneiss to quartz schist. Hence, recharge is not effective for any great distance into the pallid zone but is confined to a thin belt parallel to the junction with the Tertiary aquifer.

The Tertiary aquifers under Ingallana Creek are recharged through the Quaternary fluvial sediments and by percolation through the surrounding metamorphic rocks. The Tertiary deposits are shallow, consequently the movement of underground water would occur mostly at the base of the Tertiary and in the top of the metamorphic rocks.

Quality of Groundwater

Water samples have been analysed by the Animal Industry Branch, Northern Territory Administration, Alice Springs.

The total dissolved salts content of groundwater ranges up to 3600 p.p.m. in the sediments and 17000 p.p.m. in the deeply weathered rocks (Plate 6). No indication of the general characteristics of the waters can be obtained from these variations. Waters have therefore been classified under the system proposed by Piper (1953) in which the quality of water is represented by a binomial symbol. The two terms of the binomial symbol, written in the form of a decimal fraction, are:-

(a) The percentage of Ca + Mg among the cations,

(b) The percentage of HCO_3 + CO_3 among the anions

For example, the binomial symbol of 40:60 would indicate a water in which the constituents (Ca + Mg) make up 40% of all the cations and the constituents (Hco_3 + CO_3) amount to 60% of the total anions, both measured in terms of reacting values. This form of classification indicates the general character of a water regardless of the concentration of salts.

The available water analyses from bores throughout the area shown on Plate 1 (i.e. investigation bores and pastoral bores), when represented under the binomial system, fall into three major classes.-

Class 1 has a binomial symbol in which the first term is greater than the second and both are less than 50. Water in this class has a high content of total dissolved salts, ranging between 750 and 9900 p.p.m. Groundwater obtained from aquifers in the metamorphic rocks, the deeply weathered zone and the kunkar-calcrete, has the characteristics of Class 1.

In the binomial symbol for Class 2 the second term is greater than the first, and is greater than 49. The first term extends over a wide range and tends to be low in areas close to, and possibly influenced by, Class 1 water. The total dissolved salts content of Class 2 water is relatively low: less than 1124 p.p.m. These characteristics apply to water from aquifers in the Quaternary and Tertiary sediments.

In Class 3 both terms of the binomial symbol are less than 50, and the second term is greater than the first. The total dissolved salts content ranges between 750 and 1500 p.p.m. Groundwater of this class shows a combination of the characters of Classes 1 and 2 and is stored in aquifers within those Tertiary sediments which are influenced by local recharge of groundwater from the deeply weathered rocks.

The binomial symbol for each water sample analysed from bores in the area investigated is given below in Table 2.

TABLE 2 - CHEMICAL CHARACTER OF WATER FROM WILLOWRA BORES, PRESENTED BINOMIALLY

Bore Reference No. F53/5	Bore Name or Reference Co-ordinates	Binomial Symbol
	CLASS 1	
48	Willowra Soak	8:8
38	Crows Nest Well	14:4
36	Brown Yard Well	29:9
81	120W120 (top water)	22:11
81	120W120 (bottom water)	22:11
80	110W120 (top water)	16:8
80	110W120 (bottom water)	18:13
52	Sandfords Well	39:15
42	Ajax	34:23

Bore Reference No. F53/5	Bore Name or Reference Co-ordinates	Binomial Symbol
24	Dud	30:10
22	Dud	34:25
20	Syphon	26:20
55	Midway	31:28
57	Pilooman	41:12
91	100W65 (top water)	45:32
91	100W65 (bottom water)	42:30
93	100W45 (top water)	46:24
93	100W45 (bottom water)	43:27
1	Homestead (1.12.58)	44:41
75	100W110 (top water)	40:38
	CLASS 2	
19	Barkly Bore	61:89
100	95W75	27:52
89	100W75 (top water)	71:71
89	100W75 (bottom water)	62:70
99	105W75 (top water)	39:86
99	105W75 (bottom water)	35:82
88	100W80 (top water)	52:79
88	100W80 (bottom water)	36:85
82	100W85 (top water)	40:88
82	100W85 (bottom water)	44:84
83	100W90 (top water)	32:81
83	100W90 (bottom water)	27:72
73	100W95 (top water)	24:69
90	100W70 (top water)	48:56
74	100W105 (top water)	30:71
74	100W105 (bottom water)	26:67
16	100W115	41:88
106	101.25W82.5	22:77
105	98.75W82.5	12:69
1	Homestead (1.3.60)	42:56
107	98.75W85	18:49
	CLASS 3	
92	100W55 (top water)	38:39
92	100W55 (bottom water)	39:40
90	100W70 (bottom water)	46:49
59	Easy Bore	28:39
115	100W95 (bottom water)	28:29
75	100W110 (bottom water)	33:41
78	95W120 (top water)	36:46
78	95W120 (bottom water)	32:34
2	Stockyard	38:46
3	Island	44:45
39	Hoodoo	35:42

Class 1: These waters have a very high to high percentage of chloride and sodium and many are fairly high in sulphate. The percentage of bicarbonate and hardness-forming constituents is medium to low.

The lowest binomial symbol, 8:8, is from Willowra Soak where groundwater recharge is obtained entirely from metamorphic rock west of Ingallana Creek. Slightly higher values are recorded for water obtained from the kunkar and calcrete along Ingallana Creek (Crows Nest Well, Brown Yard Well, Sandfords Well, bores 80 and 81). Hoodoo Well is an exception to the latter group and contains mixed water of Class 3. This is probably the result of local recharge from flood water in Ingallana Creek, but as individual water analyses from this area have been collected over a period of five years positive conclusions can not be drawn.

The highest values of the Class 1 binomial symbol are for waters outside the Ingallana Creek area, obtained entirely from metamorphic rocks below a cover of Tertiary sand and silt. The bores are west and south-west of Willowra Homestead (Pilooman, Midway, Syphon, No. 24 Dud, No. 22 Dud).

High values are also recorded for bores 91 and 93 which are entirely in Tertiary sands at the southern end of the main Tertiary basin. As these waters show characteristics similar to water obtained from metamorphic rocks it is concluded that recharge to the area of these bores comes from the metamorphic rocks to the east and south-east (Plate 6). The high values of the binomial symbol for these waters, together with the decrease in total dissolved salts westward, is probably due to mixing with a small amount of Class 2 water moving through the Tertiary channel sands to the west. That such mixing exists is shown by the Class 3 waters in bores 90 and 92.

Water from Willowra homestead bore, in Quaternary and Tertiary sediments, collected on 1st December 1958, has characteristics of Class 1 with a binomial symbol of 44:41. Water sampled on 1st March 1960 shows characteristics of Class 2 (42:56). During the same period there was a rise in water level in the bore of 40 feet. It is suggested that during periods of drought groundwater from metamorphic rocks flows into this bore, either from an area to the south-west or from the south-east. This idea is supported by the occurrence of mixed (Class 3) waters in Stockyard and Island bores on 1st December, 1958.

Class 2: This class consists of the alkali-carbonate waters, which have a high percentage of bicarbonate and sodium and a relatively low chloride content. The highest binomial symbol, 61:89, is for Barkly Bore, south-west of Mount Barkly, which on geological and geomorphological grounds has been considered to be near the recharge area for the main Tertiary basin.

Class 2 water is obtained from aquifers in weathered bedrock only in the following bores: 82, 83, 99, 106 and 107. All of these bores occur in a narrow zone, between bores 99 to 83, which closely follows the line marking the limit of saturated sediments. Along this zone Tertiary aquifers are in contact with permeable zones of the deep weathering profile.

The occurrence of Class 2 water in the deeply weathered rocks in this zone suggests that local recharge occur from the Tertiary aquifer. With increasing distance from the contact zone and farther into the area of outcropping weathered rock the (Ca + Mg) percentage in the water is sharply reduced and the bicarbonate percentage less drastically reduced, giving rise to the lowest binomial symbol in this Class (18:49 in bore 98.75W85).

Class 3: Waters in this class have relatively high percentages of chloride, bicarbonate and sodium, that is, a combination of the features of Classes 1 and 2. The content of total dissolved salts reaches as high as 1500 p.p.m.

The original investigation bore at 100W95 (73) did not reach the base of the Tertiary aquifer. A favourable water analysis was obtained showing Class 2 water (24:69) and a total dissolved solids content of 713 p.p.m. A production bore alongside bore 73 (bore 115) passed through the base of the Tertiary aquifer and 75 feet into the underlying weathered basement rock, where aquifers were also intersected. The water from the production bore has a total dissolved salts content of 1546 p.p.m. and belongs to Class 3 (28:29). The Tertiary aquifer is therefore receiving recharge through the main Tertiary basin, and the underlying aquifers in the deep weathering profile are recharged with water from an area of metamorphic rocks, probably to the south-east.

Easy Bore, at 100W100, has Class 3 water (28:39) and is in a similar stratigraphic position to bore 115 except that the Tertiary aquifer is in direct contact with the aquifer in the weathered rock, consequently there is a free movement of groundwater from the weathered bedrock into the Tertiary sediments.

Contours of the Total Dissolved Salts in the Groundwater

Contours are shown in Plate 6. No attempt has been made at this stage to contour separately the three classes of groundwater. It must, therefore, be emphasised that in the area of Easy Bore, in particular, the contours combine water qualities from two aquifers;

(1) In Tertiary sediments, containing good quality water.

(2) In the underlying deep weathered bedrock, containing poor quality water.

From a study of the contours of the total dissolved salts in groundwater the following conclusions are drawn:

(a) Good quality water moves along the zone of high permeability in the main Tertiary basin south of the homestead.

(b) Local recharge of poor quality water, from the underlying weathered rocks to the main Tertiary basin, occurs in the area south-east of Easy Bore and south-east and east of bore 92.

(c) Good quality water flows along the perched zone of high permeability associated with the present course of the Lander River south-west of the homestead.

Suitability of Groundwater for Irrigation

Water quality standards related to irrigated agriculture are subject to many influencing factors. the most important of which is the nature of the soil. A system for the classification of irrigated waters has been developed by the United States Department of Agriculture (Richards, 1954). It is based on sodium adsorption ratio (S.A.R.) and conductivity. Four divisions (S1, S2, S3, S4), are used to indicate water of low, medium, high and very high salinity. A low salinity, high-sodium water would be classed as C1-S3. A water so classified is then assessed in relation to the type of soil to be irrigated.

In the Tertiary aquifer south of Willowra homestead all water analyses excepting one are in classes up to and including C3-S2. Most analyses fall into the class C3-S1, although the general pattern is that C3-S1 water occurs on top of C3-S2 water within the one aquifer. The production bore (115) on site 100W95 is an exception, and has water of class C4-S1. The abnormally high salinity is caused by poorer quality water entering the bore from an aquifer in the weathered rock below the Tertiary aquifer.

Water in classes up to and including C3-S2 can be used for irrigation on well-drained, coarse-textured soils of good permeability. The soil at Willowra consists of up to five feet of aeolian sand and silty sand of medium to coarse texture and thus satisfies these conditions.

Much of the underground water occurring along Ingallana Creek and north of the Homestead is of classes C4-S2 to C4-S4 and is generally considered unsatisfactory for irrigation purposes except under very special conditions and special soil management. The same conditions apply to class C4-S1 water.

Richard's classification of irrigated waters has not been fully tested in Central Australia. A summary of the use of water for agriculture in the Northern Territory is given by Jephcott (1956). He concludes that the nature of the soil is more important than the water quality and that an open, porous, sandy soil can support growth despite watering at a high saline level. Jephcott considers lucerne to be a resistant crop capable of tolerating water with up to 2000 to 2500 p.p.m. total dissolved salts.

The Annimal Industry Branch, Northern Territory Administration, at Alice Springs has for the last five years successfully grown lucerne at their experimental Desert Block on Hamilton Downs Station, 60 miles north-west of Alice Springs. The soil there is similar to that at Willowra and is irrigated using water with 1859 p.p.m. total dissolved salts. The water is classified as C4-S3, with 67 percent sodium hazard.

Perry et al. (1963), referring to the Alice Springs area, consider that water up to C4 quality can be used for salt-tolerant crops and, provided the salt content of the soil is kept low by over-irrigation, water of low and medium sodium hazard (S_1, S_2) could be used safely for irrigation.

CONCLUSIONS

All groundwater from the Tertiary aquifer in the Willowra Basin can be safely used, in accordance with accepted practice, for irrigated agriculture on the soil which occurs in the area. Some groundwater from aquifers within the weathered bedrock may be suitable for irrigation of salt-tolerant crops.

The geological results obtained from the drilling programme suggest that the thickest Tertiary aquifer and the highest porosity occur in the vicinity of Easy Bore. Further investigation bores along an east-west line through Easy Bore should be drilled to delineate the width and variation in thickness of the Tertiary aquifer so that final production bores can be located at the point of greatest thickness. If the aquifer thickness and porosity do not vary to any great extent in these investigation bores the final production bore should be sited as far west of Easy Bore as possible, in order to be away from the poor quality water in the metamorphic rocks south-east of Easy Bore.

The investigation and production bores should not penetrate the deep weathering profile but should be completed at the base of the Tertiary sediments. This will prevent the inflow of poor quality water from aquifers in the weathered rock into the Tertiary aquifer. For the same reason it is desirable that the production bore (115) on site 100W95 should be plugged at a depth of 75 feet.

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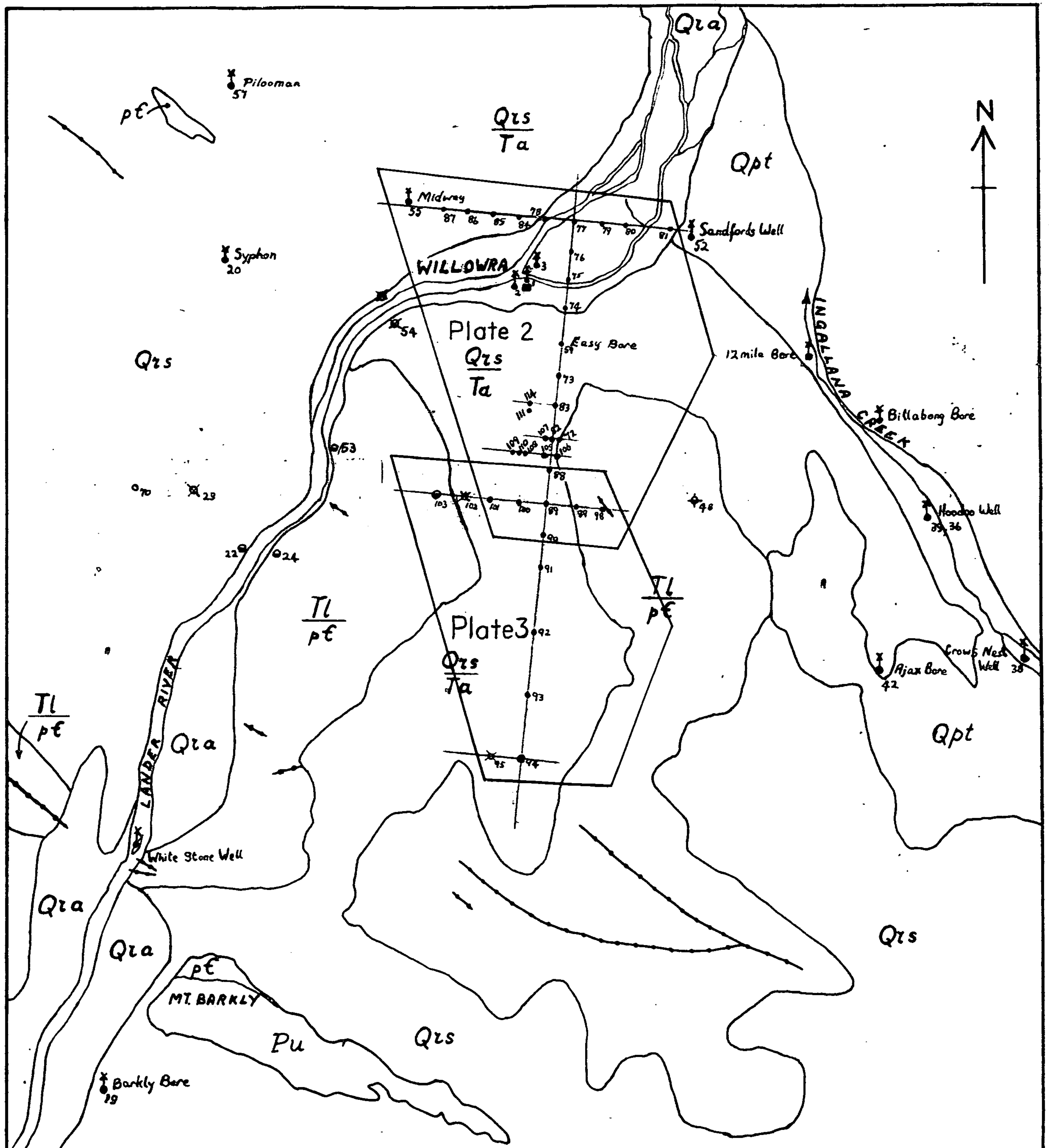
Geology of the Willowra area

PLATE 1



REFERENCE

QUATERNARY

RECENT

Qra	*Alluvium*
Qrs	*Aeolian sand*

PLEISTOCENE

Qpt	*Kunkar*

TERTIARY

Ta	*Alluvium*
Tl	*Laterite*

PROTEROZOIC

Pu	*Conglomerate, sandstone and quartzite*

ARCHAEAN

pЄ	*Schist and gneiss*

WATER BORES

- 60 *Dry hole, with reference number*
- *Bore with inadequate supply*
- *Bore with adequate supply*
- *Bore equipped with windmill*
- *Quartz reef*
- *Geological boundary*
- WILLOWRA *homestead*

Scale

0 4 8 12 MILES

Resident Geologist's Office, Alice Springs. 1963.

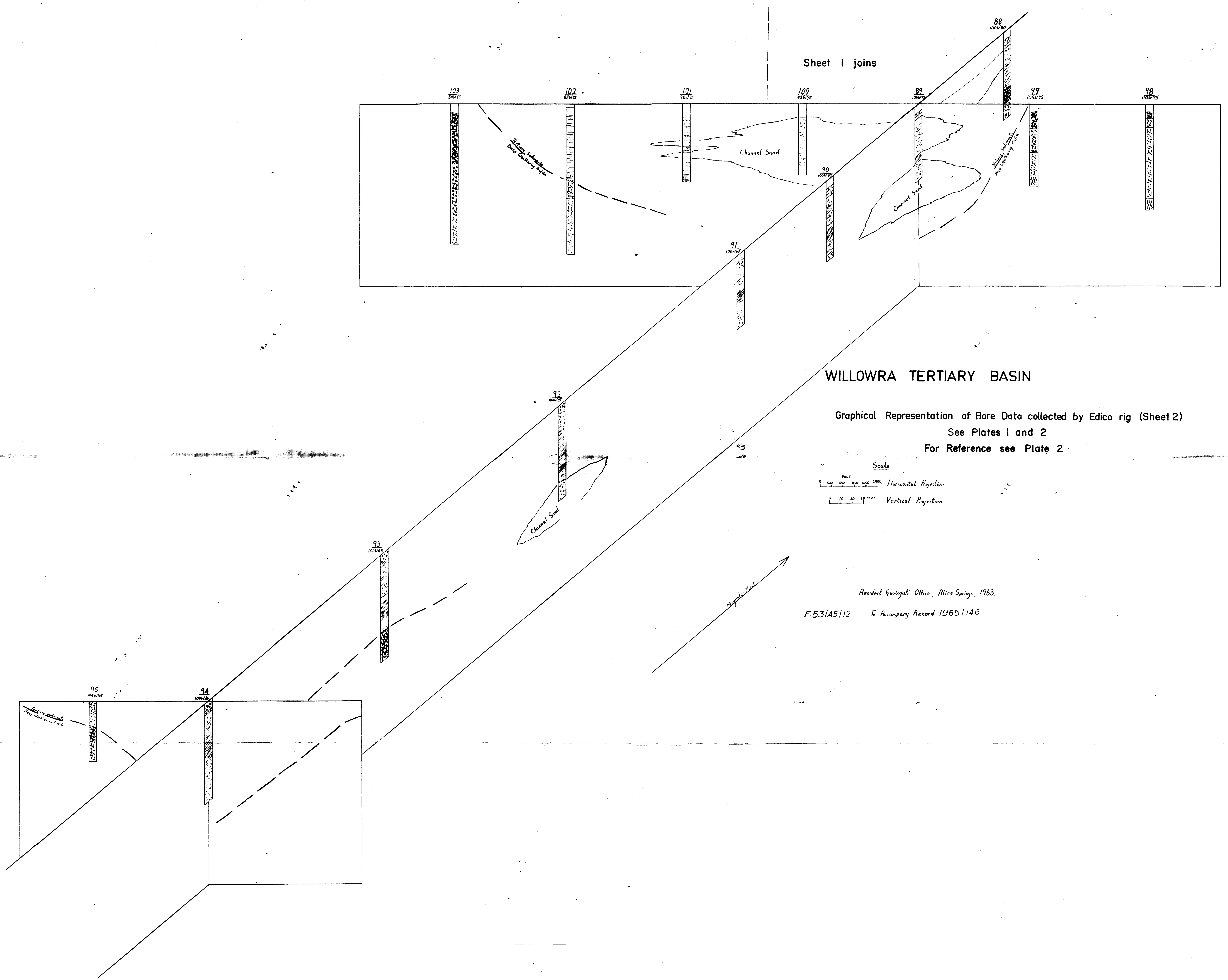
F53/A5/6

To accompany Record 1965/146

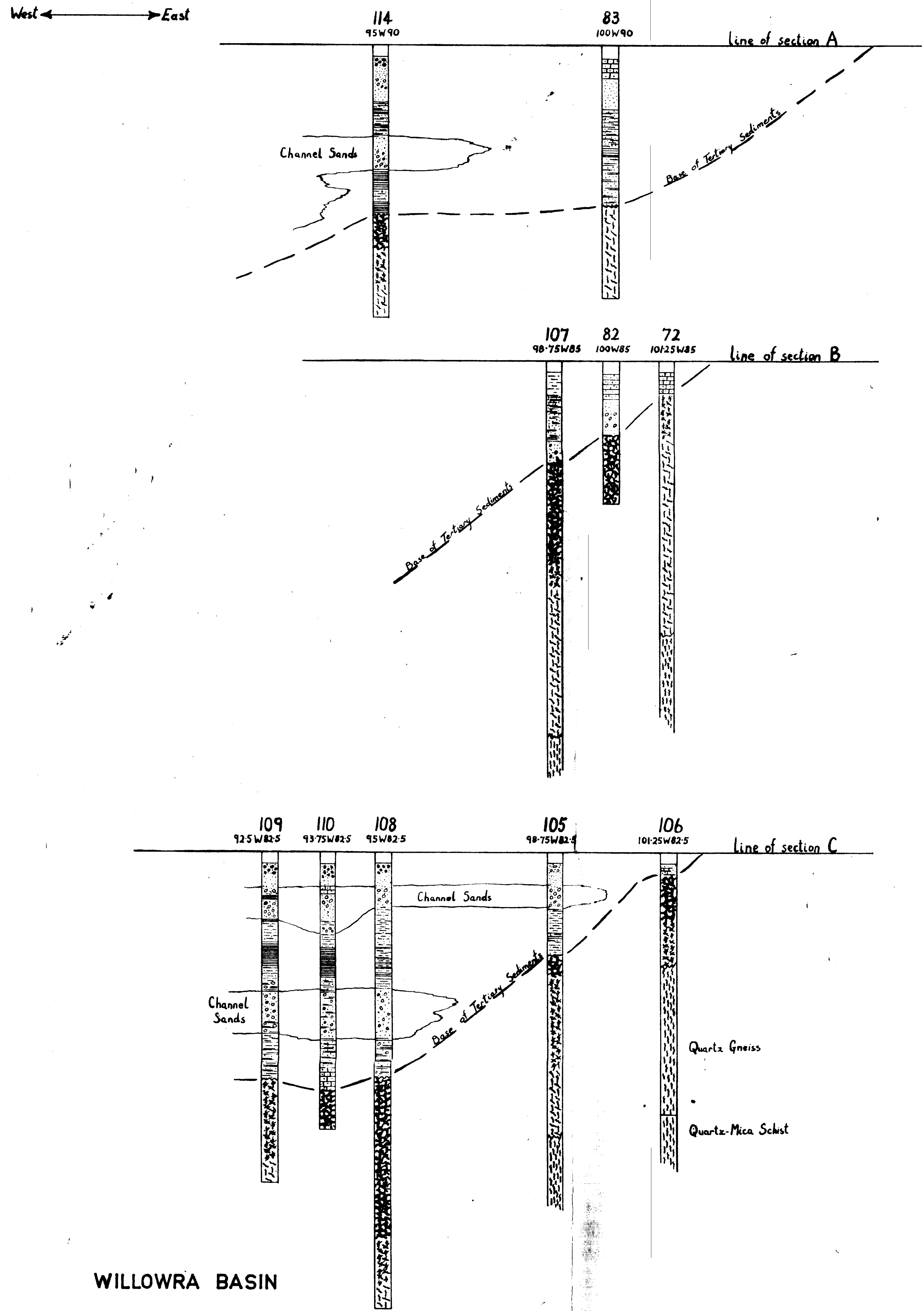
PLATE 2


WILLOWRA BASIN
Graphical Representation of Bore Data collected by Edico rig (Sheet I)
See also Plates I and 3
Reference
Soil
Ferruginised Detrital Laterite
Calcrete
Sandstone
Sand
Coarse Sand and Gravel
Clay
Silt
Sandy Silt and Silty Sand
Ferruginous zone
Mottled zone
Pallid zone
Deep Weathering Profile
Gneiss and Schist
90 Bore Reference Number
100W 75
Scale
Horizontal Projection
Vertical Projection
Resident Geologist's Office, Alice Springs, 1963
F53/A5/8 To Accompany Record 1965/146
Midway Bore (55)
87
86
85
84
78
LANDER RIVER
77
79
80
81
76
75
74
59
Channel Sand
Base of Tertiary Sediments
Deep Weathering Profile
Quaternary
Tertiary
Key bed
Clay member
115 and
112 and 113
117
118
119
116
Line of section A
114
83
Line of section B
107
82
72
113
and
108
111
109
110
Line of section C
105
106
88
100
89
99
98
90
Sheet 2 joins

PLATE 3



Sheet 1 joins
103
102
101
100
89
88
99
98
90
91
92
93
94
95
Channel Sand
Channel Sand
Channel Sand
Tertiary Sediments
Deep Weathering Profile
WILLOWRA TERTIARY BASIN
Graphical Representation of Bore Data collected by Edico rig (Sheet 2)
See Plates 1 and 2
For Reference see Plate 2
Scale
Feet
0 500 1000 1500 2000 2500
Horizontal Projection
0 10 20 30 FEET
Vertical Projection
Magnetic North
Resident Geologists' Office, Alice Springs, 1963.
F.53/A5/12
To Accompany Record 1965/146



WILLOWRA BASIN

Graphical representation of some bore data collected by Portadrill rig

Lines of section from Plate 2 Reference and Scales as for Plate 2

NOTE: Some Edico holes are also shown.

To Accompany Record 1965/146 F 53/A5/9 *Resident Geologist's Office, Alice Springs, 1963.*

To accompany Record 1965/146

PLATE 6

WILLOWRA BASIN

Contours on the Total Dissolved Salts in Groundwater

REFERENCE

- Dry hole, with reference number
- Bore with inadequate supply.
- Bore with adequate supply.
- Bore equipped with windmill
- Bore with inadequate supply unsuitable for stock
- A–A, B–B, C–C, — Lines of investigation bores
- Limit of saturated sediment.
- (990) 80 — Bore with reference number, and total dissolved salts in groundwater (in parenthesis) in p.p.m.
- —600— Contours on total dissolved salts in groundwater, 600 p.p.m.

F 53/A5/11 Resident Geologist's Office, Alice Springs. 23rd July 1963.

To accompany Record 1965/14