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FLUORINE IN SOUTH AUSTRALIAN UNDERGROUND WATERS

BY

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(Consultant Geologist)

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A. General statement.

It has been found, within comparatively recent years, that certain characteristic symptoms exhibited by both human beings and domestic animals are due to chronic fluorine intoxication. These symptoms include dental abnormalities and, where the fluorosis is more serious, osteosclerosis (especially of cancellous bones). The dental changes are seen not only in 'mottled enamel', which is an affection in which the teeth become chalky, opaque and discoloured, but also in the malformation of the teeth in size, shape and position. These symptoms of chronic fluorosis depend on the dose, the time factor, the animal species, the age of the individual, the composition of the diet, and perhaps on other factors.

Fluorosis has been observed to occur in many parts of the world and has been studied particularly in the United States of America, the Argentine, Northern Africa (Algeria, Morocco and Tunis), and in Iceland. Symptoms characteristic of chronic fluorosis in human beings are reported from all the continents and from many oceanic islands.

It appears certain that most cases of fluorine intoxication arise from ingestion through the gastro-intestinal tract; but gaseous fluorine compounds may be absorbed through the lungs. Thus, while most cases of fluorosis are traceable to the presence of appreciable proportions of fluorine in drinking water, other cases have been traced to the absorption of fluorine in factories where fluoric dust is produced. Also, in areas where grazing animals feed near these factories they may be affected. Thus stock grazing near superphosphate works in France, Germany, and Italy, and near aluminium plants (using cryolite) in Italy, Norway and Switzerland are reported to have suffered from fluorosis. These alternative possible sources of intoxication must be borne in mind when the effect of fluorine in waters is being studied.

Nevertheless it has to be borne in mind that the presence of fluorine in water is not wholly objectionable, provided that the amount does not exceed a safe limit. So it appears that fluorine behaves like many other substances which, although toxic when taken into the body in appreciable amounts, are beneficial when much smaller quantities are absorbed. This aspect is discussed more fully later in connexion with the attempts being made to overcome the ravages of dental caries.

As will be seen in a later part of this report the amount of fluorine that suffices to produce serious effects upon men and animals is so small that it is necessary to determine the quantities present in suspected sources of fluorosis in parts per million. One part per million is the equivalent of only 0.07 grain per imperial gallon, and yet this small proportion constitutes a critical level of concentration in water imbibed by children, as is explained below. Very many analyses of water, although carried out in sufficient detail for the determination of the other less toxic ions and radicles in solution, do not show the amount of fluorine present; and it was therefore necessary to obtain a set of samples and to have the fluorine content determined for the purpose of this investigation.

B. The occurrence of fluorine in nature.

Fluorine is very widely distributed in rocks, soils, waters, and in very many organisms both animal and vegetable, although generally in small proportions. The commonest fluorine-bearing mineral carrying a high proportion is fluorite or fluorspar, CaF_2, with 48.9 per cent. A higher percentage, 54.4, is present in cryolite, $3NaF.AlF_3$, but this mineral is not so common. The silicate mineral topaz may carry 20.7 per cent of fluorine, but it also is comparatively rare. Many other silicates, such as members of the mica family (especially lepidolite and phlogopite) and tourmaline, carry very small amounts of fluorine. Larger proportions are present in the widely-distributed mineral apatite which is present in very many rocks, and in all occurrences of phosphate rock. In South Australian phosphate rock deposits, of both the calcic and the aluminous varieties, the fluorine content has been found to range from 2.2 to 3.4 per cent (vide S.A. Geol. Survey Bulletin No. 7, pp. 32-33).

Fluorine is discharged from many volcanic vents and has been found in relative abundance in waters of regions where volcanoes are active, as for example near Naples and in Iceland.

The ocean carries a small proportion of fluorine, in amounts ranging from 0.3 to 0.8 parts per million in samples taken at different places.

Chemical investigations have shown that fluorine is present in very many plants, and that the range of the proportions carried is extremely wide.

Hence it follows that fluorine finds its way into practically all natural waters, whether these occur on the earth's surface or are stored underground.

C. The Distribution of Fluorine in South Australian Underground Waters.

In order to obtain a broad view of the distribution of the fluorine content of the subterranean waters that have been tapped in many places over an immense area within South Australia it was decided to select for testing the waters drawn from boreholes and springs located in the major geological units. Thus the samples analysed were drawn from the several artesian basins and in a few cases from ground water basins. In all selected cases there has been an actual or potential large draught.

In the case of the Great Artesian Basin, in the north-eastern sector of the State, samples were obtained from the principal aquifer of Cretaceous-Jurassic age, both where an eastern and also a western source were known from earlier hydrological and chemical investigations to exist (vide Bulletin No. 23, G.S.S.A. p. 60); and in addition from the marginal and suspended basins adjoining or overlying the main aquifer (vide Bulletin No. 23, G.S.S.A. Plate II).

The analyses of these samples are set out in the accompanying tables, and the following features are revealed by a study of these results, so far as concerns the fluorine contents of the waters:-

1. The highest fluorine content by far is that of the carbonated water of eastern origin in the principal aquifer of the Great Artesian Basin, where the average figure for the boreholes tested is 4.1 parts per million, and where there is a complete absence of permanent hardness (vide Tables I. A-C).

2. The sulphated water of western origin in the same aquifer (vide Table II) carries a much smaller proportion of fluorine without exception, average 0.7 p.p.m. The lower fluorine content gives further confirmation of the previously-known different origin of the western waters with predominant sulphates and the eastern waters with an excess of carbonates.

3. The fluorine content of the water in the marginal and suspended basins bordering upon or overlying the Great Artesian Basin is low, average 1.1 p.p.m., and is comparable with that of the sulphated water of western origin in the main aquifer. (vide Table III). Here too the fluorine content is consistent with the other dissolved matter in the water in indicating an origin distinct from the water in the main aquifer.

4. The fluorine present in the other artesian basins where tested (Murray River, Adelaide Plains, and Walloway), with averages of 0.9, 0.9, and 1.3 p.p.m. respectively, is low compared with that in the Great Artesian Basin's main aquifer (vide Tables IV and V).

5. The ground water basins of Eyre Peninsula (Uley-Wanilla and Flinders) carry water with a low fluorine content, average 0.9 p.p.m., (vide Table V).

It is noteworthy that the highest fluorine proportions, in the water of eastern origin drawn from the main aquifer of the Great Artesian Basin, are comparable with those recorded in Queensland rather than in New South Wales, as might have been expected from the fact that the principal source of the artesian water is the northern State.

The variability of the fluorine of the deep artesian water in South Australia cannot yet be readily explained. The samples that have been examined fail to show a progressive and consistent increase of fluorine towards the margin of the aquifer, although the boreholes at Marree carry more fluorine than those at Kopperamanna, Mungeranie and Mt. Gason. Yet the extreme marginal springs at Mundowdna, where a concentration by evaporation might have been expected, are not so highly charged with fluorine as the borehole water at Marree, which is only 12 miles away.

In the case of Paralana Hot Spring, near Lake Frome, the high (5.5 parts per million) fluorine content may be due, in part at least, to the leaching of fluorine by the hot carbonated water from the shattered gneissic rocks whence the water emerges on the extreme faulted margin of the basin.

It has been noted by G.W. Bond that in South Africa only those waters which contain sodium carbonate or bicarbonate carry amounts of fluorine exceeding 1 part per million, and that the fluorine is present as sodium fluoride, since there is no permanent hardness (vide Geol. Survey Memoir No. 41. "A geochemical survey of the underground water supplies of the Union of South Africa", pp. 43 and 171). Although some South Australian underground waters, such as those in the Murray River Basin at Naracoorte and Bordertown, contain slightly more than 1 part of fluorine per million, the facts recorded in South Africa are in harmony with those recorded in South Australia with respect to the water of eastern origin in the main aquifer of the Great Artesian Basin (vide Tables I A-C). Only one water of western origin, at Pedirka, is exceptional in this respect. (vide Table II).

Whether the hot carbonated water of the Great Artesian Basin has derived its fluorine content from irregularly-dispersed fluorine-bearing minerals in the aquifer cannot be determined from the existing knowledge about the aquifer. So far as is now known there are no phosphatic horizons in the water-bearing beds, which are regarded as being essentially of lacustrine origin. Nor is there any knowledge of any Tertiary or post-Tertiary volcanic foci beneath the greater part of the area covered by the Great Artesian Basin, although there are places on its eastern margin where volcanic activity has occurred in comparatively late geological time. Proof has yet to be given of any genetic relationship between the fluorine in solution and these marginal volcanic rocks. To the writer it appears unreasonable to attribute a magmatic source to the fluorine in conformity with the arguments of those who, despite the abundant evidence to the contrary, have urged that the artesian water has a plutonic origin.

In the case of the suspended aquifers overlying or marginal to the Great Artesian Basin (vide Table II) the only relatively high fluorine figures are those relating to the Meteor and Wooltana No. 22 boreholes. As regards the Meteor borehole it is to be borne in mind that faulting is considered to have permitted the rise of the deeper water into a shallow aquifer far above the level of the main aquifer (vide Geol. Survey S.A. Bulletin No. 14, Plate III, section G-G). In regard to the No. 22 borehole on Wooltana Station it is noteworthy that this borehole is so close to the extreme margin of the basin that it seems possible that water from the lower aquifer may have caused contamination through upward leakage by way of the marginal fault.

D. <u>The safe limit of fluorine in water used by human beings and stock.</u>

As a result of investigations in many parts of the world during recent years it has come to be accepted that the limiting figure for water that is used continuously by a community that includes young children and that is the sole source for drinking purposes, should be less than 1 part of fluorine per million. A very low figure (0.7 parts of fluorine per million) should be specified as the limit in respect of localities where climatic conditions cause increased body losses so that exceptional amounts are imbibed. Adults can use water with a somewhat higher fluorine content, for a time at least, without suffering ill effects; but are apt to show a mottling of the enamel of their teeth if the fluorine content rises to 1.5 parts per million, and more marked signs as the proportion of fluorine rises.

It is to be remembered always that concentration takes place if the water suffers evaporation by exposure to the sun's rays in a tank, trough, or channel, or by cooking, so that a harmless water may thus be rendered toxic.

Serious dental fluorosis has been observed at the townships of Julia Creek and Thargomindah in Queensland where the water carries 2.4 and 3 parts per million respectively, and in many other individual localities where higher proportions exist. Where the figures rise to 5 parts per million the teeth of young children who have no alternative source of water are affected very seriously indeed.

It has been found that in the United States of America there are localities in which there is an inverse relationship between fluorine concentration (up to 0.9 or 1.2 parts per million) and the incidence of dental caries, as determined by the examination of many hundreds of children who have imbibed fluorine-bearing water continuously for their first 8 years. Hence sodium fluoride has been added to some waters that are naturally deficient in fluorine. There is considered to be no danger of the retention of fluorine in osseous tissue if the concentration is kept under close control, since the human body is able to dispose, by normal excretory processes, of larger quantities than are required to place a check on dental caries. As an alternative to the addition of sodium fluoride to the water supply, recommendations have been made in America for the direct application of this compound to the teeth, by weekly treatment of children from the age of 3 to give protection to the early teeth and again at the ages of 7, 10 and 13 to protect the later teeth. Lengthy and widespread observation is required before safe conclusions can be drawn from these concerted efforts to reduce the incidence of caries, since there is a small proportion in most communities that exhibits natural immunity to caries, and diet (particularly the consumption of sweet carbohydrate foods) has an undoubted effect.

So far as stock are concerned the effect of fluorine in water are similar, and young animals are most readily affected. This matter has been examined, with experimental support, by Dr. A.W. Peirce of the Animal Health and Nutrition division of the Council for Scientific and Industrial Research, with results set out in his paper on "Chronic Fluorine Intoxication in 'Domestic' Animals", which appeared in 'Nutrition Abstracts and Reviews', Vol. 9, 1939-1940.

Further experiments on sheep using drinking water with known proportions of fluorine, rising to 20 parts per million, are still in progress. The teeth of the sheep drinking water with 10 parts per million are very clearly affected, but during 3 years of observation there has been no significant difference in the mean wool production.

It would seem that stock are less susceptible than human beings to water that is sufficiently high in fluorine content to affect the latter, but much more information is required before safe limits can be drawn. Hitherto no evidence has been seen by the veterinary branch of the South Australian Department of Agriculture of any fluorosis in the stock of this State.

E. <u>Corrective measures designed to prevent fluorosis.</u>

The most obvious way of avoiding fluorosis in stock - to refrain from the use of the tainted water - is in many cases impracticable, on account of the unreliability of rainfall that is low over a considerable part of the Australian continent where occupation by the pastoralist depends largely upon the use of artesian water by the stock. Even where every advantage is taken of the existence of temporary surface supplies, there are long periods when no alternatives to the artesian water exist. It is not possible to indicate any feasible treatment of bore water in sufficient quantities to satisfy the needs of large flocks and herds. Yet it is advisable to adopt every possible measure to avoid concentration by evaporation.

In the case of human beings stress must be placed on the need to conserve, for drinking and cooking purposes, every gallon obtainable from roof catchments.

Several attempts have been made, especially in Queensland, to devise methods of extracting the fluorides present in the artesian water or, at least, to reduce them to a point below the toxic level.

The most promising method so far tried out in Queensland would seem to be treatment of the water by percolation through degelatinised bone, and regenerating the spent bone by boiling in dilute caustic soda solution and then washing out the alkali. Neutralization of the alkali with hydrochloric acid or an aqueous solution of carbonic acid might be necessary.

Aluminium sulphate precipitation with subsequent alkali treatment has been found to be unsuccessful in some cases. Hydrated aluminium oxide has been used in Canada and success for the method has been claimed. Activated carbon has been regarded as impracticable for reasons of cost. The lime-soda treatment was found to show promise but was expensive and needed skilled supervision.

A South African authority, G.W. Bond, writing in 1946, was inclined to think that treatment of the water by synthetic resins was the most promising curative measure, the removal of both cations and anions being effected by these 'organic zeolites', but stated that the process was not then fully developed. This matter is being further investigated.

F. Acknowledgments.

In the preparation of this report the writer is indebted to many individuals for information and literature; especially to Mr. H.R. Marston and Dr. A.W. Peirce of the Division of Biochemistry and General Nutrition, C.S.I.R.O., University of Adelaide; to the Secretary and Dr. Montgomery White of the Fluoride in Waters Committee of the Lands Department in Queensland; to Dr. Neil E. Goldsworthy, Director of the Institute of Dental Research, Sydney; to Professor H.K. Ward, Professor of Bacteriology and to Miss Pamela Jones of the Department of Biochemistry, University of Sydney.

The collection of samples for analysis has been facilitated by the co-operation of Mr. H.R. Marston, the pastoral companies, the Enterprise Exploration Coy. Pty. Ltd., the Department of Lands, the Engineering and Water Supply Department, the Commissioners of Railways for the Commonwealth and South Australia, as well as to the officers of the Department of Mines in South Australia.

The analyses set out in the accompanying tables were made by Mr. T.W. Dalwood, departmental Analyst and Assayer.

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L. Keith Ward

TABLE IA. GREAT ARTESIAN BASIN
MAIN AQUIFER - WATER OF EASTERN ORIGIN

Sample Analysed	Two-mile Spring Mundowdna	Station Spring Mundowdna	Railway Borehole Marree	Northern Borehole Marree	Eastern Borehole Marree	Southern Borehole Marree	Callanna Borehole	Lake Billy Borehole Mundowdna	Marian Borehole	Lake Harry Borehole
Date of Analysis	23/12/48	23/12/48	26/10/48	23/12/48	23/12/48	23/12/48	23/12/48	23/12/48	23/12/48	23/12/48
IONS AND RADICLES (Grains per gall.)										
Chlorine, Cl.	53.85	65.65	78.05	215.25	45.50	60.00	27.90	103.46	17.50	18.50
Sulphuric acid, SO_4	1.24	nil	0.45	18.23	0.16	0.16	nil	18.48	nil	nil
Carbonic acid, CO_3	32.55	32.85	33.00	26.25	35.70	36.45	37.95	19.80	34.80	34.95
Sodium, Na	59.97	66.61	73.34	152.80	55.46	65.28	46.78	87.28	37.82	38.36
Calcium, Ca	0.29	0.36	0.86	6.43	0.50	0.54	0.29	3.32	0.11	0.36
Magnesium, Mg	0.09	0.39	0.96	4.39	0.49	0.55	0.04	0.02	0.04	0.01
Total Saline Matter	147.99	165.86	186.66	423.35	137.81	162.98	112.96	232.36	90.27	92.18
ASSUMED COMPOSITION OF SALTS (Grains per gall.)										
Calcium carbonate	0.72	0.90	2.15	16.06	1.25	1.35	0.72	8.29	0.27	0.90
Magnesium carbonate	0.31	1.35	3.33	15.22	1.70	1.91	0.14	0.07	0.14	0.03
Sodium carbonate	56.35	55.38	51.83	10.23	59.60	60.56	66.10	26.11	61.01	60.75
Sodium sulphate	1.83	nil	0.67	26.96	0.24	0.24	nil	27.33	nil	nil
Sodium chloride	88.78	108.23	128.68	354.88	75.02	98.92	46.00	170.56	28.85	30.50
HARDNESS (English degrees)										
Total	1.09	2.50	6.10	34.13	3.27	3.61	0.88	8.37	0.43	0.94
Temporary	1.09	2.50	6.10	34.13	3.27	3.61	0.88	8.37	0.43	0.94
Permanent	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
Due to calcium	0.72	0.90	2.15	16.06	1.25	1.35	0.72	8.29	0.27	0.90
Due to magnesium	0.37	1.60	3.95	18.07	2.02	2.26	0.16	0.08	0.16	0.04
pH value	8.4	7.9	7.8	7.8	7.9	7.8	8.1	7.5	7.8	7.8
FLUORINE (Parts per million)	3.2	3.2	4.4	3.2	4.0	4.0	4.0	2.4	4.0	4.4

TABLE IB. GREAT ARTESIAN BASIN
MAIN AQUIFER - WATER OF EASTERN ORIGIN

Sample Analysed	Clayton Borehole Mundowdna	Sinclair Borehole	Peter's Camp Borehole Lake Letty	Station Borehole Lake Letty	Big Borehole Lake Letty	Crow's Nest Borehole Lake Letty	Dulkaninna Borehole	New Koppermanna Bore hole	Mungeranie Borehole	Mt. Gason Borehole
Date of analysis	23/12/48	17/2/49	13/4/49	23/12/48	23/12/48	23/12/48	17/2/49	6/4/49	26/10/48	26/10/48
IONS AND RADICLES (Grains per gall.)										
Chlorine, Cl	12.00	10.83	14.07	16.20	17.45	21.25	8.13	10.22	5.35	4.80
Sulphuric acid, SO_4	0.45	nil	0.21	0.45	nil	0.12	nil	0.41	1.73	1.36
Carbonic acid, CO_3	33.00	30.30	35.40	37.20	36.75	38.70	29.55	27.00	23.70	23.25
Sodium, Na	32.68	30.25	36.21	39.17	39.40	43.30	27.59	26.71	22.31	21.42
Calcium, Ca	0.21	nil	0.07	nil	0.04	nil	0.29	0.50	0.14	0.14
Magnesium, Mg	0.20	nil	0.04	0.04	0.02	0.11	nil	0.13	nil	nil
Total Saline Matter	78.54	71.38	86.00	93.06	93.66	103.48	65.56	64.97	53.23	50.97
ASSUMED COMPOSITION OF SALTS (Grains per gall.)										
Calcium carbonate	0.52		0.17	nil	0.10	nil	0.72	1.25	0.35	0.35
Magnesium carbonate	0.69		0.14	0.14	0.07	0.38		0.45		
Sodium carbonate	56.88	53.53	62.18	65.54	64.72	67.89	51.44	45.81	41.50	40.70
Sodium Sulphate	0.67	nil	0.31	0.67	nil	0.18	nil	0.61	2.56	2.01
Sodium chloride	19.78	17.85	23.20	26.71	28.77	35.03	13.40	16.85	8.82	7.91
HARDNESS (English degrees)										
Total	1.34	nil	0.33	0.16	0.18	0.45	1.19	1.79	0.35	0.35
Temporary	1.34		0.33	0.16	0.18	0.45	1.19	1.79	0.35	0.35
Permanent	nil		nil	nil	nil	nil	nil	nil	nil	nil
Due to calcium	0.52		0.17	nil	0.10	nil	1.19	1.25	0.35	0.35
Due to magnesium	0.82		0.16	0.16	0.08	0.45	nil	0.54	nil	nil
pH value	8.1	7.9	8.1	8.0	8.1	8.1	7.6	7.6	7.8	8.1
FLUORINE (Parts per million)	4.0	4.0	4.0	3.6	4.0	4.0	4.0	2.2	2.4	2.6

TABLE IC. GREAT ARTESIAN BASIN
MAIN AQUIFER - WATER OF EASTERN ORIGIN

Sample Analysed	Arboola Borehole Quinyambie	Culberta Borehole Quinyambie	Paralana Hot Spring Wooltana	Murnpeowie Borehole	Quartpot Borehole Murnpeowie
Date of analysis	21/10/48	22/10/48	22/10/48	23/12/48	28/2/49
IONS AND RADICLES (Grains per gallon)					
Chlorine, Cl	28.49	40.30	25.34	14.28	31.55
Sulphuric acid, SO_4	nil	0.23	11.00	1.41	
Carbonic acid, CO_3	40.95	42.20	9.87	32.55	22.35
Sodium, Na	49.41	56.23	23.53	34.74	
Calcium, Ca	0.20	0.40	3.00	nil	
Magnesium, Mg	0.12	1.01	1.22	0.08	
Total saline matter	119.17	140.37	73.96	83.06	
ASSUMED COMPOSITION OF SALTS (Grains per gallon)					
Calcium carbonate	0.50	1.00	7.49	nil	
Magnesium carbonate	0.42	3.50	4.23	0.28	
Sodium carbonate	71.28	69.09	4.19	57.15	
Sodium sulphate	nil	0.34	16.27	2.09	
Sodium chloride	46.97	66.44	41.78	23.54	
HARDNESS (English degrees)					
Total	0.99	5.16	12.51	0.33	
Temporary	0.99	5.16	12.51	0.33	
Permanent	nil	nil	nil	nil	
Due to calcium	0.50	1.00	7.49	nil	
Due to magnesium	0.49	4.16	5.02	0.33	
pH value	7.9	7.9	8.2	7.6	7.2
FLUORINE (Parts per million	3.8	13.5	5.5	3.6	3.6

TABLE II GREAT ARTESIAN BASIN
WATER OF WESTERN ORIGIN

Sample Analysed	Alberga Borehole	Abminga Borehole	Pedirka Borehole	Oodnadatta Borehole	Hockington Borehole Mt. Dutton	Peake Borehole	Mt. Kingston Borehole	Neill's Water Bulgunnia	N. Well Kingoonya
Date of analysis	27/10/48	26/10/48	27/10/48	26/10/48	20/1/49	20/1/49	20/1/49	6/4/49	26/10/48
IONS AND RADICLES (Grains per gallon)									
Chlorine, Cl	48.07	38.43	35.70	50.82	67.38	68.60	84.35	121.45	43.52
Sulphuric acid, SO_4	26.99	15.31	15.31	22.30	36.87	21.97	1.98	40.20	11.48
Carbonic acid, CO_3	9.45	4.50	5.70	9.90	11.30	11.60	23.10	5.25	8.40
Sodium, Na	43.35	24.55	25.21	41.56	58.84	59.64	72.68	58.70	25.43
Calcium, Ca	5.15	5.50	4.15	4.86	7.51	2.86	0.21	19.44	6.50
Magnesium, Mg	1.11	2.56	2.58	2.16	1.35	0.52	0.24	11.12	3.85
Total saline matter	134.12	90.85	88.65	131.60	183.25	165.19	182.56	256.16	99.18
ASSUMED COMPOSITION OF SALTS (Grains per gallon)									
Calcium carbonate	12.86	7.51	9.51	12.14	18.75	7.14	0.52	8.76	14.01
Calcium sulphate		8.46	1.16					54.11	3.02
Magnesium carbonate	2.45			3.68	0.08	1.80	0.83		
Magnesium sulphate	1.98	11.70	12.77	5.45	6.58			2.53	11.72
Magnesium chloride		0.78						41.55	5.80
Sodium carbonate						10.67	39.22		
Sodium sulphate	37.58		6.36	26.55	46.76	32.49	2.93		
Sodium chloride	79.25	62.40	58.85	83.78	111.08	113.09	139.06	149.21	64.63
HARDNESS (English degrees)									
Total	17.43	24.27	20.98	21.03	24.30	9.28	1.51	94.30	32.07
Temporary	15.78	7.51	9.51	16.50	18.83	9.28	1.51	8.76	14.01
Permanent	1.65	16.76	11.47	4.53	5.47	nil	nil	85.54	18.06
Due to calcium	12.86	13.73	10.36	12.14	18.75	7.14	0.52	48.54	16.23
Due to magnesium	4.57	10.54	10.62	8.89	5.55	2.14	0.99	45.76	15.84
pH value	8.2	7.1	8.0	7.6	7.1	7.0	6.8	7.3	7.6
FLUORINE (Parts per million)	0.5	0.8	1.6	0.7	0.6	0.8	0.4	0.5	0.5

TABLE III. GREAT ARTESIAN BASIN
WATERS OF SUSPENDED AND MARGINAL BASINS

Sample Analysed	Homestead Well Cordillo Downs	Cordillo Downs Borehole	Bull's Hole Borehole	Meteor Borehole	Wooltana Station Borehole	No. 9 Borehole Wooltana	No. 22 Borehole Wooltana	No. 27 Borehole Wooltana
Date of analysis	28/2/49	28/2/49	28/2/49	23/12/48	22/10/48	22/10/48	22/10/48	22/10/48
IONS AND RADICLES (Grains per gallon)								
Chlorine, Cl	15.65	80.15	228.20	14.14	13.30	48.60	22.40	37.80
Sulphuric acid, SO_4	0.45	36.17	75.92	0.20	6.16	36.81	17.11	10.43
Carbonic acid, CO_3	18.15	11.70	5.85	35.49	11.34	14.05	15.35	8.60
Sodium, Na	17.41	60.39	108.23	36.32	8.86	30.97	22.34	21.11
Calcium, Ca	3.93	9.01	45.45	nil	4.70	6.10	5.40	7.50
Magnesium, Mg	1.25	3.98	15.05	0.08	3.18	11.60	3.15	3.37
Total saline matter	56.84	201.40	478.70	86.23	47.54	148.13	85.75	88.81
ASSUMED COMPOSITION OF SALTS (Grains per gallon)								
Calcium carbonate	9.81	19.51	9.76	nil	11.74	15.23	13.48	14.34
Calcium sulphate		4.08	107.59					5.98
Calcium chloride			27.33					
Magnesium carbonate	4.33			0.28	6.04	6.91	10.22	
Magnesium sulphate		19.70			7.13	46.13	0.99	7.78
Magnesium chloride			58.93			1.14		7.05
Sodium carbonate	16.23			62.34				
Sodium sulphate	0.67	25.98		0.30	0.70		24.13	
Sodium chloride	25.80	132.13	275.09	23.31	21.93	78.72	36.93	53.66
HARDNESS (English degrees)								
Total	14.95	38.89	175.41	0.33	24.83	62.97	26.44	32.60
Temporary	14.95	19.51	9.76	0.33	18.90	23.42	25.62	14.34
Permanent	nil	19.38	165.65	nil	5.93	39.55	0.82	18.26
Due to calcium	9.81	22.51	113.48	nil	11.74	15.23	13.48	18.73
Due to magnesium	5.14	16.38	61.93	0.33	13.09	47.74	12.96	13.87
pH value	7.5	7.3	8.1	7.6	7.3	8.2	8.3	8.1
FLUORINE (Parts per million)	0.4	0.5	1.3	1.8	0.5	0.9	2.2	1.1

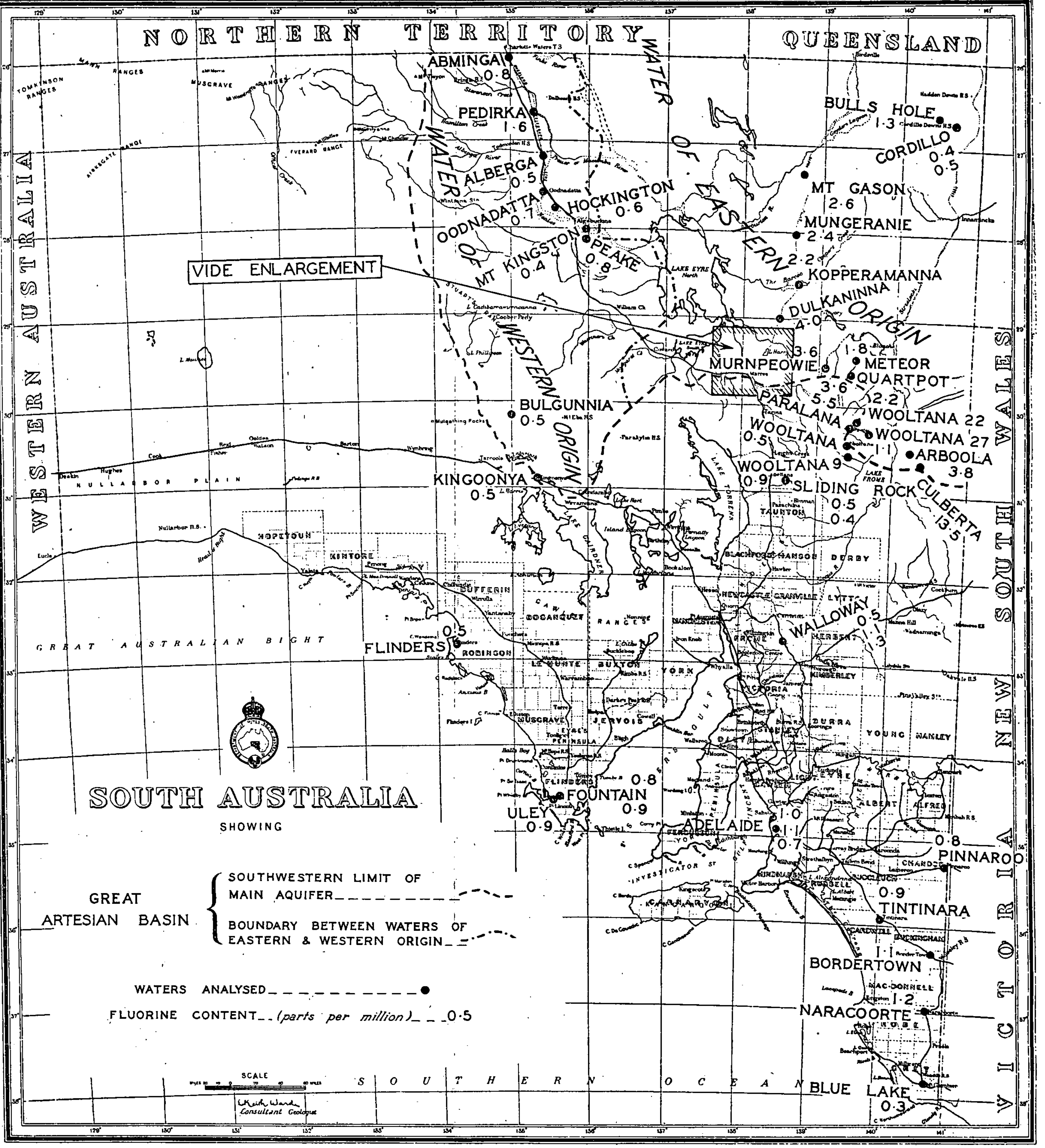
TABLE IV

	MURRAY RIVER ARTESIAN BASIN					ADELAIDE PLAINS ARTESIAN BASIN		
Sample Analysed	Blue Lake Mt. Gambier	Government Borehole Naracoorte	Government Borehole Bordertown	Railways Borehole Tintinara	Government Borehole Pinnaroo	C. R. Pearson's Borehole Sec. 101 Adelaide	A. Smith's Borehole Sec. 413 Yatala	F. L. Klar's Borehole Sec. 436 Yatala
Date of analysis	22/10/48	25/10/48	25/10/48	20/10/48	22/10/48	21/10/48	21/10/48	21/10/48
IONS AND RADICLES (Grains per gallon)								
Chlorine, Cl	7.55	34.83	64.93	28.70	15.75	16.95	25.55	21.95
Sulphuric acid, SO_4	0.29	10.86	11.69	5.84	6.63	4.32	6.34	6.83
Carbonic acid, CO_3	7.65	13.50	15.75	12.75	10.20	15.30	10.35	11.85
Sodium, Na	6.09	27.49	35.23	26.78	13.36	14.70	16.18	14.94
Calcium, Ca	1.86	3.57	8.36	1.14	3.86	3.50	3.72	4.29
Magnesium, Mg	1.42	3.47	7.91	1.64	1.81	3.21	3.76	3.56
Total saline matter	24.86	93.72	143.87	76.85	51.61	57.98	65.90	63.42
ASSUMED COMPOSITION OF SALTS (Grains per gallon)								
Calcium carbonate	4.64	8.91	20.88	2.85	9.64	8.74	9.29	10.71
Magnesium carbonate	4.92	11.47	4.54	5.69	6.21	11.13	6.72	7.63
Magnesium sulphate		0.79	14.65		0.10		7.95	6.73
Magnesium chloride			14.25				0.82	
Sodium carbonate	2.42			12.35		3.78		
Sodium sulphate	0.43	15.13		8.64	9.69	6.39		2.16
Sodium chloride	12.45	57.42	89.55	47.32	25.97	27.94	41.12	36.19
HARDNESS (English degrees)								
Total	10.48	23.19	53.43	9.60	17.09	21.95	24.76	25.36
Temporary	10.48	22.53	26.27	9.60	17.01	21.95	17.27	19.76
Permanent	nil	0.66	27.16	nil	0.08	nil	7.49	5.60
Due to calcium	4.64	8.91	20.88	2.85	9.64	8.74	9.29	10.71
Due to magnesium	5.84	14.28	32.55	6.75	7.45	13.21	15.47	14.65
pH value	7.6	7.5	7.2	8.1	7.7	7.6	8.1	7.7
FLUORINE (Parts per million)	0.3	1.2	1.1	0.9	0.8	1.0	0.7	1.1

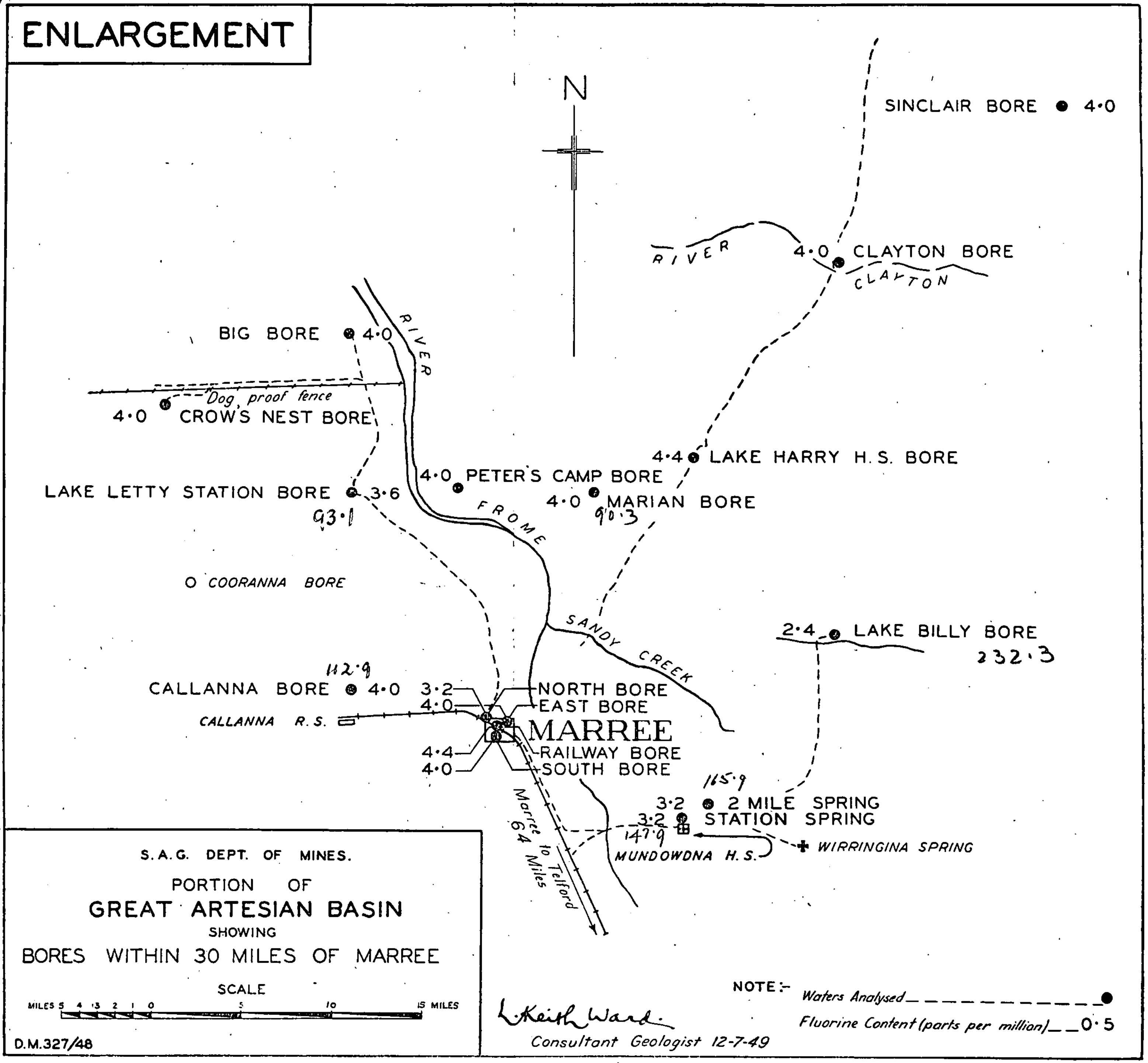
TABLE V

WALLOWAY PLAINS ARTESIAN BASIN — GROUND WATERS

Sample Analysed	Government Borehole Pekina	Brice's Borehole Sec. 68 Walloway	Bright's Borehole Sec. 88 Walloway	Sliding Rock Borehole A.	Sliding Rock Borehole B.	Fountain Springs Wanilla	Fountain Springs Wanilla	No. 1 Borehole Uley-Wanilla	No. 2 Borehole Uley-Wanilla	Pumping Trench Streaky Bay
Date of analysis	27/10/48	25/10/48	25/10/48	25/10/48	25/10/48	21/10/48	27/10/48	21/40/48	21/10/48	26/10/48
IONS AND RADICLES (Grains per gallon)										
Chlorine, Cl	45.62	42.53	43.23	26.88	29.96	9.15	9.75	7.74	7.84	18.97
Sulphuric acid, SO_4	20.74	20.16	21.77	17.94	16.01	2.35	1.60	1.89	1.85	2.18
Carbonic acid, CO_3	13.50	13.65	13.65	16.65	16.50	9.75	9.75	7.65	8.25	10.95
Sodium, Na	29.21	27.79	29.10	17.55	18.94	4.92	5.60	4.66	5.41	10.09
Calcium, Ca	5.36	4.93	4.79	9.36	9.15	5.15	4.57	2.36	2.57	7.65
Magnesium, Mg	7.67	7.54	7.58	5.55	5.44	1.97	1.97	2.34	2.08	1.51
Total saline matter	122.10	116.60	120.12	93.93	96.00	33.29	33.24	26.64	28.00	51.35
ASSUMED COMPOSITION OF SALTS (Grains per gallon)										
Calcium carbonate	13.38	12.31	11.96	23.37	22.85	12.86	11.41	5.89	6.42	18.26
Magnesium carbonate	7.70	8.81	9.11	3.71	3.93	2.87	4.09	5.79	6.18	
Calcium sulphate										1.16
Magnesium sulphate	25.99	24.75	24.50	22.18	20.06	2.95	2.01	2.37	1.49	1.70
Magnesium chloride	0.78				1.02	2.11	1.49	0.74		4.58
Sodium sulphate		0.61	3.28	0.35					0.98	
Sodium chloride	74.25	70.12	71.27	44.32	48.14	12.50	14.24	11.85	12.93	25.65
HARDNESS (English degrees)										
Total	44.95	43.33	43.15	46.20	45.24	20.97	19.52	15.52	14.98	25.32
Temporary	22.52	22.76	22.78	27.77	27.50	16.28	16.27	12.76	13.75	18.26
Permanent	22.43	20.57	20.37	18.43	17.74	4.69	3.25	2.76	1.23	7.06
Due to calcium	13.38	12.31	11.96	23.37	22.85	12.86	11.41	5.89	6.42	19.11
Due to magnesium	31.57	31.02	31.19	22.83	22.39	8.11	8.11	9.63	8.56	6.21
pH value	7.2	7.5	7.4	7.1	7.2	8.6	8.2	8.1	8.1	7.3
FLUORINE (Parts per million	1.5	1.1	1.3	0.5	0.4	0.8	0.8	0.9	0.9	0.5



R. E. POWELL, GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE.



S.A.G. DEPT. OF MINES.

PORTION OF

GREAT ARTESIAN BASIN

SHOWING

BORES WITHIN 30 MILES OF MARREE

D.M.327/48