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THE CAVES ON THE MARGIN OF THE NULLARBOR PLAIN AND THEIR RELATION TO UNDERGROUND WATER SUPPLIES

In Mid-Tertiary time there were many deep embayments of the southern coastline of Australia during a period when the sea level was relatively higher or the land lower than it is today. Of these embayments, that which covered the Nullarbor Plain was second in extent only to the great gulf into which the Darling Lachlan, Murrumbidgee and Murray Rivers discharged their waters by separate channels. The submergence was probably a gradual one.

On the Pre-Cambrian rocks which constitute the ancient continental nucleus of the western half of Australia were deposited a series of normal sediments - sandy shale, galssy quartzose sand and gravel, and clay that it lignitic in part - in relatively shallow beds These were covered by a considerable thickness (335ft. at Robert's Well) of clay containing Miocene marine fossils. On this clay was deposited the typical Miocene limestone similar to that which accumulat in other portions of the Tertiary coastal seas along the southern margin of the Australian continent. This limestone attins a maximum thickness of 570ft. at Guinewarra, but is not so thick in the eastern and northern portions of the plain. Above the limestone there is a very thin mantle of reddish soil and there is at no place any great thickness of this cover, so that is difficult to find places at which retentive tanks can be excavated.

The surface of the plain is not absolutely level, but the undulations are broad and the slopes very gentle. There is, however, a gradual rise from the south coast towards the interior. On the coast the cluffs are from 200 to 265 ft. in height along an unbroken lone from eht Head of the Bight to Wilson's Buff at the far south-western corner of the State (save for a short stretch of sand at Merdayerrah Sandpatch, near the western limit), and the plateau rises gradually to a height of about 500ft. where it is traversed by the Transcontinental Railway.

The plain or plateau has on its northern and eastern boundaries the sandy dues that cover the large portion ofWestern Australia and South Australia. The sand composing these dune ridges is partly calcareous, and the dunes habe become fixed by the solution and redopesition of carbonate of lime. They are also clad with vegetation.

The treeless portion of the Nullarbor Plain, whence the name is derived, does not extend to the southern coast. There is a vegetation embracing shrubs and trees - including acacias, mallees of more than one variety and sandalwood - that occupies a belt between 15 and 20 miles in width between the treeless area and the sea. The best pastoral country lies within this belt, which receives a higher annua rainfall than the treeless plain.

The Cave Systems.

The limestone which outcrops over the whole of the treeless plain and the sparsely timbered belt to the southward is traversed by cavities due to the selective solution of portions of the calcareou rock. This feature is exhibited by limestone regions in all parts of the world. The whole country is more or less caverous and is consequently extremely porous; and there are consequently no surface channels conveying rainwater to the sea. All the rain that falls is lost by absorption and evaporation, and there is no superficial drainage system extending for more than a very short distance.

The cavities assume many forms, some of the most characteristic beimg the blowholes which are three feet or less in diameter and the subterranean extensions of which cannot be explored. They acquir their name from the wind currents that blow inwards or outwards according to the barometric conditions. Air enters the cavities when the barometer is high and issues again when the barameter fails.

With a steep barometric gradient the air movements may be accompanied by a roaring noise. There are many of these blowholes.

The larger cavities are om most cases marked by shallow depressions within which the massive limestone is bare of soil or vegetation. One or more openings lead to chamgers hollowed out by the solution and removal of part of the limestone. In a few place stalactites hang from the roofs of the chambers and stalagmites have been built up on the floors, but these ornamentations are comparativ ly rare. For the most part the cavern roofs are fairly smooth, and the chambers have large dimensions laterally, although not lofty. It is noticeable that many of these chambers have been dissolved out of the rock at depths of between 20 and 50 feet from the surface but that no passages leading downwards to lower levels can be seen. It is inferred that the enlargement of such chambers has taken place during a long pause between stages of the uplift of the region. There have been many stages in the uplift of the Murravian Tertiary gulf, marked in each case by the stranding of the coastal dunes. Hence the southeastern part of south Australia is character-ized by a series of low dune ridges parallel with the coast and separated by flat country. On the Nullarbor plateau no such ridges are to be seen, but the cavities formed by the solution of the limestone appear to indicate a similar history - with the raising of the land relatively to the sea by a series of steps or stages with long intervals between the times of movement. For the active solution of limestone does not usually extend downawards far below the water level of the period, and this water level is controlled by the relief of the land. Where porous limestone rocks exist and the sea is distant but a few miles, the water table must be a surface sloping gently downwards towards the coast and coinciding at its lower limit with mean sea level.

It has been found advisable, in boring for water in this region, to sink a shaft to a depth of about 200ft. and to drill in the bottom of the shaft, in order to overcome the difficulty of maintaining a straight borehole through the cavernous limestone. These shafts exhibit the features of the natural "blowholes" and it has been found that upward and downward currents of air can be detected in accordance with the barometric pressure conditions. Moerover, it has been noted that the air currents are strongest at different depths in differnt shafts, a phenomenon due to the variations in the extent of the natural openings at differnt levels penetrated by the shafts at each place. Possibly there were many stages in the uplift of the Nullarbor plateau, as there were in the southeastern district, and each stage was marked by an enlargement of the caves at or close to the water level and at that stage. So, if different shafts have exposed portions of the cavities dissolved out of the limestone at different levels, the phenomena of the air currents are easily accounted for. Moreover, it does seem probable that the verticle walls of the openings to the deepest caves extend to a horizon (about 90 feet below the surface) that was once near water level, although a subsequent uplift of the plateau has raised the bottom of these open pits far above present water level. It is not possible to make a more definite statement in the absence of more extensive openings.

These deeper caves, known as Koonalda and Warbla, are characterized by tunnel-like cavities with arched roofs and walls marked out by horizontal lines of massive flint as well as irregular concretionary masses of the same material. In the case of the Warbla cave the tunnel descends on an incline from the bottom of the pit that gives access from the surface. It then opens out an rises to a great dome that appears to reach to within 60 or 70 feet of the surface. Beneath the dome there is a great mound of fallen rock, on the slopes of which it is possible to descend to water lev at about 340ft. below the surface.

There is a similar conical mound of fallen limestone near the entrance to Koonalda cave and at its base there is a long tunnel with an arched roof and a relatively level floor extending northwards for many chains and with a westerly branch for a shorte distance. Water was found in the edn of the main and branch tunne at a depth of about 265ft. below the surface.

Another large and deep cave, knon as Weebabbie and possessing similar features, occurs in Western Australia, within a few miles of the South Australian Border. In the bottom of this cave also water level is reached, about 300ft. belot the surface.

Underground water supplies, occurrence and quality.

The examintion of all the records of boring within the limits of this Tertiary basin shows very clearly that there are tw separate waters.

In the southern portion of the basin the upper water occu in the superficial limestone at an average depth below the surface of 220 ft., with a maximum of 290ft. at Albala Karro bore and a minimum of 162ft. at Gilgurabbie bore. This shallowwater struck in the boreholes has been so highly charged with dissolved solids that it is merely recorded as "salt". In a few cases the water has been tested by hydrometer and found to contain too much saline material to be useful in salt-bush country. The figures obtained by the hydrometer are as follow:

Delisser bore, 2¼ ozz; Number 7 bore 5 ozs.; Murrawiginee bore 2¾ ozs; Robert's Well bore 3½ ozs; Number 8 bore 4 ozs; and Albala Karoo bore, 3½ ozs per gallon. The shallow water from the more recently drilled Muddaugna bore has been analysed and found to contain 3.22 ozs. of dissovled solids per gallon.

The boreholes drilled on the East-West Railway line met with shallow supplies but these were not of useful quality, with the exception of the most westernly bores situated respectively at 554miles 49 chains, 566 miles 50 chains and 591 miles 24 chains fr Port Augusta. This is the protion of the line nearest to the western Australian border, which is distant 597 miles 29 chains from Port Augusta. In these three boreholes the shallow water was prov to contain 1.129 ozs. per gallon (at 554 M. 49C); 1.066 ozs. per gallon (at 566M, 50C) and 0.697 ozs. per galon (at 591 M. 24C) Unfortunately no such useful water has been obtained at a shallow depth in the coastal portion of the basin within the limits of South Australia.

This shallow water occurs in the limestone but not at any particular horizon in that formation. It seems probable that the whole of the limestone formation below water level is charged with water on account of the porosity of the rock.

The comparison of aneroid levels taken during two journeys over the basin, in 1921 and 1927, indicates a close relationship between the surface of this shallow groundwater and sea level. T depth of the water level below the surfaceis, of course, influence by the elevation of the surface at each boreshite. But the reduce level of the water table is very close to sea level in each case. There is a gentle seaward slope of the water-table, which indicates a marked degree of porosity for the limestone - a natural result of the open texture of much of the rock andthe existence of solution cavities.

The depth of this water-table below the surface accounts for the absence of water in the shallow caves. The level of the water in the deeper caves (Koonalda, Warbla andWeebabbie) is that of the general water table, and the quality of the main body of water in the caves corresponds in general with that of the general pass of ground water.

The water in the main pool at the endof the northerly tunnel in Koonalda Cave contains a little over 3ozs. of dissolved solids per gallon, according to a hydrometer test and has a salty taste. But the water in the westerly branch of the tunnel is less saline, the hydrometer showing 2¼ ozs. of dissolved solids per gallon.. It is probable that the quality of the water at this place has been imporved by an infiltration of fresh water from the surface . There is a depression on the surface round the Koonalda cave, which will serve to collect the local rainfall, that must rapidlyreach the water-table before it has had the opportunity to become as saline as the general body of groundwater which has absorged a greater quantity of salt and carries this dissolved burden as it moves laterally downwards towards thesea. An individ ual clay-lined pocket in the upper part of the cave floor, a few feet above the general water level, was found to contain a few hundred gallons of water containing 1⅞ ozs. of dissolved solids per gallon. This pocket of water was apparently isolated from the main ground water by the clay; but the water in the end of the western tunnel probably rests upon the more saline water which wil be the normal water remaining after the diffusion of the cream of less saline water. Such occurrences are known elsewhere in South Australia and in the Northern Territory, where attempts to use the top layer of better water have proved dissappointing on account of its limited bulk and consequent rapid removal on baling or pumping

This explanation of the relation of the better water to that which is more saline shows the reason for the differences of salinity observed and reported with regard to the water in

Koonalda Cave at different times. The accession of storm water will temporarily improve the quality of the water, but the slow movement of the groundwater down the slope of the water table, aided by gradual diffusion, will cause a progressive deterioration, until the quality is agin improved by a heavy fall of rail. There is no doubt but that an artificial draft on the underground storage will rapidly remove the better water and that the only reliable supply is that of the general body of saline ground water.

In the deepest part of Warbla Cave, the water expose d contains $3\frac{1}{8}$ ozs. of dissolved solids per gallon by hydrometer test and it is too saline to be useful. Occurring as it does in chalky limestone, this water is portion of the groundwater that can circulate freely through such a rock.

The quality of the water exposed in Weebabbie Cave in Western Australia is rather better, the content of dissolved solids per gallon being $1\frac{7}{8}$ ozs. It also occurs in chalky limetsone, and the better quality of the water is due to the general improvement in the character of the groundwater in the western part of the basin that has been noted above in connection with the bores on the East-West Railway line near the boundary of Western Australia. Possibly groundwater of somewhate similar quality is obtainable at about 300 feet from the surface in the most westerly portion of the coastal s strip lying to the south of the treeless plain in South Australia. Unfortunately the herbage is poor in this district.

The sahllower waters discussed above are separated from other supplies of water, stored under pressure at a considerabley greater depth by a thick deposit of clay or shale. The average thickness of this formation is all the southerly bores is 307ft. wit a maximum of 402feet at Guinewarra. Beneath the clay eor shale is a series of relatively thin beds of sand and gravel separdted by clay seams. The porous sands and gravels consist of rounded grains of glassy quartz that have been derived from a granitic source - the most widely spread foundation rocks of the region.

Some of the boreholes have traversed the whole series of sand, gravel and clay beds and entered the underlying gneissic bedrock, namely Albala Karoo, Guinewarra, and Numbers 7 and 8 bore holes. Borehole Number 6 ended in old slate. The other boreholes lying to the south of the Railway line did not reach bedrock.

The only borehole in the East-West railway line that reached bedrock is the deep hole near Fisher (at 482 miles 54 chains from Port Augusta) which pierced some hundreds of feet of a red sedimentary rock and was abandoned at 912 feet from the surface.

The water stored under pressure in the beds of sand and gravel that lie between the thick clay or shale formation and becroc is absorbed on the northern side of the Nullarbor Plain, in the great sandy tract that lies between the treeless plain and the Everard, Birksgate and Blyth Ranges, lying to the south of the Musgrave Ranges. The exact positions of the places where absorption takes place are unkwnon. But it may be deduced from the varying compsotion of the water that conditions along the intake beds are variable from point to point. It is probable that absorption of rainfall is rapid at some places, notabely those near the western boundary of this State, to the north of the district where the quality of the water is best. But to the eastward the absorption may be delayed and the water making its way into the beds of sand and gravel may find opportunity to dissolve salts from saline soil or from overlapping marine limestone beds that may possibly cover the outcrops of the deep water-bearing beds.

Most of the records of boring do not show differences between the pressure under which the water exists in the several beds of sand or gravel, but in a few cases details have been preserved and these (with no exception) indicate the mormal existence of higher pressures in the deeper beds, a natural result of the higher pressures in the deeper beds in the intake area. Thus, in Number 2 bore water struck at 735 feet rose to within 187 feet of the surface. In Mallabie 18ft. 5 inches rose to within 183 ft. of the surface, while that from 846 feet rose to within 116 feet of the surface. So too in Muddaugna bore the water from 787ft. rose to within 190ft. of the surface, while that from 794ft. rose to within 131 feet of the surface. And in the Murrawijinee bore the water from 743ft. rose to within 157 feet of the surface. The single exception is that of Guinewarra bore, where it is recorded that water from 975 feet rose to within 203 feet of the surface and water from 1004 feet rose to within 216 fet of the surface.

It is noetworthy also that the hydraulic surface of the pressure water lies above the ground water table at almost every point where the basin has been proved with boreholes. But at Albala Karoo bore the recorded level of the deeper water is the same as that of the groundwater, and in this case the water came from a porous seam in the main clay or shale, not from the underlying beds And in Number 8 bore the water from 900ft. stood 27ft. below the ground water table, which is 240ft. from the surface.

The average distance above the groundwater table is 57ft., to which the pressure water rises in bores which show this phenomenon.

The quality of the deeper water stored under pressure is rather variable from point to point, and is not good at any place within the South Australian part of the basin. The best water is that at Robert's Well, Muddaugna, White Well and Number 6 boreholes where the salinity is about 1½ ozs. per gallon. The area embracing these boreholes, togehter with the somewhat more saline water of Number 5 and Murrawijinee boreholes, may possibly extend in a north westerly direction towards Cook on the East-West Railway line, where the salinity is 1.849oxZ. per gallon. It would appear that No.2 and Mallabie boreholes lie to the westward of this belt of better water.

An interesting feature has been observed with regard to Robert's Well borehole, concerning the improvement in the quality of the water from a total salinity of 2.08 ozs. per gallon in October, 1886 to that of 1.51 ozs. per gallon in April, 1914. This improvement may be due to the washing out of salit in the beds overlying the sands in the intake area, or to the removal of a relatively stagnang pocket of more saline water entrapped within the water - bearing sands.

<u>Conclusions</u>

It will be clear, from what has been written above, that the cave systems in the Tertiary limestone of the Nullarbor Plain (including also the timbered belt between the treeless plain and the sea) cannot be relied upon to provide the supplies of water tha will be useful for watering sheep. Only the deepest of the caves co contain water, and these underground pools are expsed portions of a general ground water table, the normal salinity of the water being too high fro stock watering. Temporary improvement may be effected by heavy falls of rain. But a supply in this region to be useful must be capable of satisfying the demand continuously throughout the year, on account of the absence of surface waters and the difficulty of finding retentive ground for tanks. The most westerly portion of the State will be found to contain the best supplies of shallow water, so far as quality is concerned, but the prospect of obtaining such supplies to the eastward of Albala Karoo borehole do not appear promising. The deeper artesian caves, since the caves occur in the limestone and the artesian water exists in beds of sand which are separated from the limestone by a great thickness of impervious clay or shale.

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