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GEOLOGY AND AUSTRALIA'S ARID ZONE

by

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INTRODUCTION

Australia's arid zone has been defined, mainly on a basis of isohyets, in the Arid Zone Newsletter for 1956; the zone covers parts of all mainland States, and in terms of latitudes and longitudes is roughly bounded by latitudes 17°S. and 31°S. and by longitudes 113°E. and 146°E. The significance of this definition is that the arid zone covers some three quarters of the continent, so that a review of the geology of the arid zone in its broadest aspects must deal with the continent as a whole.

A review of current geological knowledge may be regarded as a basic requirement for the consideration of problems of the arid zone because geology is a significant factor in the distribution of underground water and mineral deposits, and commonly of soils. The soils of the arid zone in general appear to show a closer link with climate rather than with geology, although in places like the Barkly Tableland the association is clear even on a grand scale. But the association is clear and consistent between geology and underground water and mineral deposits, and the review will attain added significance if we can relate geology to these features of the arid zone.

For this purpose, rocks may be divided into two broad categories - igneous and metamorphic rocks, inferring strong folding and alteration of any original sediments, and unaltered sediments principally of the sedimentary basins. The igneous and metamorphic rocks provide most of the metalliferous provinces, but have very restricted storage for underground water in cracks and joints. The sedimentary basins, on the other hand, provide major storage of water in permeable beds, and are potential sources of petroleum but not usually of metals. Broad geological sub divisions of the Arid Zone with notes on groundwater and mineral prospects are set out in Table 1.

GEOLOGY OF THE ARID ZONE

It is useful to divide the continent into three structural units and review the geology by tracing the development of each unit as it concerns the Arid Zone. The western and central parts of the continent covering Western Australia, Northern Territory and South Australia and parts of Western Queensland and New South Wales are referred to as the Australian Precambrian Shield, which has been relatively stable since Precambrian time; the dissected

uplands of Eastern Australia are referred to as the Tasman Geosynclinal Zone, and are the products mainly of Palaeozoic sedimentation and orogeny. Between these uplands and the Precambrian Shield lies the irregular belt of lowlands of the Central East Depression which was the site of deposition in Mesozoic and Tertiary time. The greater part of the arid zone lies on the Shield and about a quarter on the Central East Depression; the arid zone impinges on the Tasman Geosynclinal Zone only in central Queensland.

The rocks of the Precambrian Shield may be divided for our purposes into three sub-divisions - the igneous and metamorphic rocks of the Archaean and Lower Proterozoic, the little-altered sediments of the Upper Proterozoic basins, and the sediments of the post-Precambrian sedimentary basins which contain Palaeozoic, Mesozoic, and, in places, Tertiary deposits.

The granites, greenstones, gneisses, and schists of the Archaean, and less-altered but folded rocks of the Lower Proterozoic, form the basement of the Shield; they account for some two-thirds of geological time, and in outcrop cover about a third of the Shield within the arid zone and a quarter of the arid zone as a whole.

The origin and development of these basement rocks are very imperfectly known, and do not concern us; we should note, however, that the wide areas over which these rocks c rop out contain the main metalliferous provinces of the arid zone, but provide small, commonly saline and unreliable supplies of water.

By Upper Proterozoic time the older folded and metamorphosed rocks were becoming a fairly stable basement and the pattern of sedimentation began to change; the troughs or geosynclines of earlier times largely gave place to broad basins in which little-altered sediments and lavas are still preserved. Upper Proterozoic sediments, mainly sandstone, dolomite, limestone, shale glacigenes and red beds, cover a little more than 20% of the Shield within the arid zone or 17% of the arid zone as a whole. Two of the Lower Palaeozoic basins in Central Australia, the Amadeus and Officer basins, were legacies from the late Proterozoic.

Although, in general, Upper Proterozoic sediments were not folded or intruded by igneous rocks, restricted fold belts occur in the Kimberleys (Yampi Sound) and in the Adelaide Geosyncline; the rocks commonly are more compacted than those of the younger sedimentary basins. They contribute little to the arid zone; they store water in fractures or in permeable beds but the potential is considerably lower and less consistent than that of the younger basins. With the exception of iron ore and some uranium, asbestos and manganese they carry few mineral deposits and have poor prospects for oil.

A new phase in the evolution of the continent commenced in the Palaeozoic; eastward of the Shield a major meridional depression - the Tasman Geosyncline - developed and persisted throughout the Era. The complex development of this geosyncline, with its changing pattern of troughs and ridges does not concern the arid zone, during the Palaeozoic, basinal depressions or embayments were developed on the Shield

to initiate sedimentation in the Carnarvon, Canning, Daly and Georgina Basins. Deposition in the Eucla Basin began in Cretaceous time.

Sedimentation continued into Lower Palaeozoic time in the Adelaide Geosyncline and in the Amadeus and Officer basins; these depressions, together with the Georgina and Daly Basins received little or no sedimentation after the Lower Palaeozoic but the western basins persisted into the Mesozoic and the Carnarvon and Eucla Basins persisted into Tertiary time. Sedimentation in the Canning Basin spread far to the south-east in Permian time.

The sediments of the Lower Palaeozoic basins consist largely of sandstone, shale, dolomite and limestone and occupy some 15% of the Shield within the arid zone. They are, in places, folded and faulted. The sediments are well compacted and useful aquifers either in fractures or in permeable strata are commonly sporadic; the reliable supplies of the Barkly Tableland are notable exceptions. Outside the Adelaide Geosyncline, Lower Palaeozoic sediments contain no significant metalliferous deposits but they have, in places, oil prospects which have yet to be explored.

The sediments of the western basins include both marine and fresh water deposits and consist mainly of sandstone, shale, calcareous sediments, limestone and glacial deposits. These are the basins with the greatest potential for both sub-artesian and artesian water on the Shield and they also include, the areas most likely to contain commercial accumulations of oil. They occupy mostly 30% of the Shield within the arid zone.

The development of the Shield since the Palaeozoic has one more important aspect as far as the arid areas are concerned. Apart from the major sedimentary basins already mentioned, smaller, and younger basins occur on the Shield; an increasing number of these has been recognised in recent years. In general these result from the infilling and alluviation of broad valleys or minor depressions in Mesozoic or Tertiary time and, in places, commenced with the deposition of marine sands and muds in the last widespread inundation of the Shield in Lower Cretaceous time. In some of these basins, in the Alice Springs area, for example, valley fill, commenced by Cretaceous marine sediments was continued intermittently by continental alluvation in Tertiary time; in other areas, like the Barkly Tableland, low-lying areas were filled, in Tertiary time, with continental sediments and, particularly, with chemically deposited limestone.

Although not of significance in oil search, these minor basins can be very important in arid zone resources because some of them seem likely to provide water of suitable quality, and in adequate quantity, to sustain irrigation. Their areal extent within the arid zone is not yet known.

Having traced the development of the Shield, the geological review of the arid zone is completed by considering the third major structural unit of the continent - the Central-East Depression. This developed in Mesozoic time as a great crustal sag between the fold mountains of the Tasman Geosyncline in the east and the Shield in the west, and became the site, in particular, of the Carpentaria, Great Artesian

and Murray Basins. In the Great Artesian Basin deposition of sands began in lakes and swamps in the Jurassic and was followed by marine sands and shales when the Lower Cretaceous sea flooded most of the Depression and transgressed much of the Shield. Continental conditions recurred in the Basin in Upper Cretaceous time and extended into the Tertiary; marine conditions recurred later in the Tertiary in the Murray Basin.

The importance of these basins in the Central-East Depression, needs no reiteration; the Great Artesian Basin itself forms nearly a quarter of the Australian arid zone. The Basin provides a number of aquifers from which sub-artesian or artesian water is drawn but the major and most widespread aquifers are provided by Jurassic sandstones.

Up to 1950, when detailed investigations of the Western Australian basins began, the Great Artesian Basin was the most studied sedimentary basin in Australia, largely because of its underground water resources; a revitalised oil search in the last decade, however, is now building up new information on the structure and stratigraphy of the Basin which should not only clarify the oil prospects but should aid in establishing the water potential on a firmer basis than has been available in the past.

MINERAL DEPOSITS IN THE ARID ZONE.

Geology directly bears on the potential of the arid zone in providing underground water and mineral deposits; underground water resources are discussed in a following paper but a brief review of mineral deposits in the arid zone is appropriate here.

The importance of mineral deposits in the development of the arid zone is clearly shown by population figures; the writer estimates that roughly 35% of the population is at present directly dependent on mining; over the Shield area, which amounts to $\frac{3}{4}$ of the arid zone, the percentage of population dependent on mining is much higher and probably exceeds 50%. The percentage contribution of mining to the total value of production of the arid zone is more difficult to estimate but judging by the value of production of the main commodities in 1953-4, it is probably of the order of 25 percent; over the Shield area it would be much higher and may well exceed 50%.

Mineral deposits are of course wasting assets and lack the promise of permanent settlement, usually associated with the agricultural and pastoral industries; but most of the settlements in arid areas of the Shield owed their initiation to mining and most of the current major settlements are still directly dependent on mineral deposits - Broken Hill, Mt. Isa, Leigh Creek, Tennant Creek, Yampi Sound, Wittenoom Gorge, Kalgoorlie, Coolgardie etc.

Most of the mineral deposits principally gold, silver-lead and copper, lie in the older Precambrian rocks which crop out over about a third of the Shield within the arid zone; the Upper Proterozoic rocks are comparatively barren but contribute iron, uranium, asbestos and manganese.

The importance of mining activity in the arid zone is not to be measured only by value of production nor by population figures; mining also provides access and local markets which may encourage the establishment of more permanent industries. Although mining communities must be expected to fluctuate and eventually die, the need for intensive investigation over wide areas of potentially mineralised rocks (about 1/3rd of the Shield within the arid zone) is a basis for some optimism; we may expect that in the future, some new mining settlement will eventuate and that some older ones be revived. The search for, and development of mineral deposits will certainly be difficult and costly but Australian prospects are becoming increasingly attractive in the mining world and a significant proportion of the exploration capital available in Australia, from both domestic and overseas sources, will find its way to the Precambrian Shield.

But greater hopes for development of the arid zone appear to rest on oil search which, at present is at a higher level than at any time in the past. Current prospects of commercial concentrations of oil seem brightest in the Carnarvon Basin and in the western portion of the Canning Basin, toward the western end of the arid zone, but prospects in the Georgina and Great Artesian Basin, toward the eastern end of the arid zone, are also encouraging. The discovery of commercial oil would naturally establish settlement but it would also touch off intensified exploration in many basins in the arid zone. The search for petroleum or for metals does not itself establish worthwhile settlement but it can contribute much to general geology and to the knowledge of underground water resources.

SIGNIFICANCE OF RECENT GEOLOGICAL DISCOVERIES

Some recent geological discoveries deserve specific mention because they clearly show the pattern of extending knowledge of the arid zone and of its underground water resources.

In the last five years, the known limits of the Canning Basin have been extended hundreds of miles to the south-east; hundreds of square miles, previously blank on the geological map of the arid zone, are now known to be underlain by Mesozoic and/or Permian sediments with the probability of useful supplies of underground water. The geology of the south-eastern portion of the Georgina Basin is becoming much better known and its aquifers delineated.

Of great importance is the recent recognition of smaller Mesozoic and Tertiary basins which, in places like Wiluna, Tennant Creek and in the Alice Springs area, promise supplies of good-quality water in actual or potential mining areas where the terrain previously seemed most unfavourable for water supply.

Geological knowledge of the arid zone is, then, by no means static; the tempo of geological exploration is likely to increase and will continue to add to our knowledge of the general distribution of underground water resources. However, it is well to remember that much of this work is only reconnaissance as far as underground water is concerned; hydro-geological surveys are needed to establish the detailed distribution, yield and quality of underground water before

realistic planning for the arid zone is possible.

SUMMARY OF CURRENT KNOWLEDGE AND FUTURE PROSPECTS

Three-quarters of the Australian arid zone lies on the Precambrian Shield and a quarter on the Great Artesian Basin where underground water is plentiful although of varying depth and quality. Of that portion of the arid zone which lies on the Shield, a third, consisting of the oldest rocks, has poor water prospects; another 35% has useful supplies in places and the remainder, some 30%, overlies the known, major, sedimentary basins in which the supply of underground water is generally plentiful.

Considering the arid zone as a whole, about half of the area overlies major sedimentary basins and has ample supplies of water for stock; about a quarter of the zone overlies well-consolidated sediments in which water supplies are more sporadic and less reliable and the remaining quarter overlies igneous and metamorphosed rocks in which water supplies are scarce and unreliable. However, prospects of development in this latter section are greatly improved, in some places, by the occurrence of small previously unsuspected basins which are likely to provide good-quality water; the extent and potential of these basins is yet to be determined.

Excluding the Great Artesian Basin, which has no metalliferous deposits, mining has played a major role in the settlement of the arid zone, although largely restricted to a third of the area, it probably supports more than half the present population. Mining settlement, although likely to fluctuate, has prospects of expansion with the gradual intensification of scientific exploration of the Shield and thus is likely to continue to encourage the establishment of more permanent industries.

Oil prospects encourage the hope for additional settlement in the arid zone and certainly the rising tempo of geological exploration will continue to add to the knowledge of geology and water resources.

However, detailed hydro-geological investigations will be needed properly to assess underground water resources. Prospects within the arid zone, as far as underground water is concerned, certainly appear more encouraging than they did five years ago, and should continue to improve in the future; but, despite these improved prospects it seems inevitable that wide areas within the arid zone will remain intractable on present standards because underground water is lacking, too deep or too saline.

TABLE 1

GEOLOGICAL SUB DIVISION AND GROUNDWATER AND MINERAL PROSPECTS OF THE ARIS ZONE

Geological Classification	Approx % of Arid Zone	% of Shield Area within Arid Zone (¾ of Arid Zone)	Groundwater Prospects	Mineral Prospects
Igneous and metamorphic rock. (Archaean or Lower Proterozoic)	25	33	Small unreliable, commonly saline	Provides most of the mineral provinces. No oil prospects
Sediments and lavas of Upper Proterozoic Basins.	17	22	Better than above but sporadic	Some iron, uranium manganese, asbestos, copper, lead-zinc. Very poor oil prospect.
Sediments of Lower Palaeozoic basins.	11	15	Good supplies in places variable salinity	Some oil prospects - little metal prospect (possible lead-zinc).
Sediments of Upper Palaeozoic to Tertiary basins.	47	30	Plentiful; variable depth and salinity.	Major oil prospects - [redacted] - no metals.
Sediments of smaller Mesozoic - Cainozoic basins.	Unknown, extent overlying other units.		High yield, low salinity in places.	No oil or metal prospects.