15.—MINERALOGY OF THE DONNYBROOK SANDSTONES, WESTERN AUSTRALIA.

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INTRODUCTION.

Sandstones, Permian or Triassic in age (Maitland, 1939), outcrop along the western edge of the Darling Plateau in the vicinity of Donnybrook (Lat. 33° 10′ S. Long. 116° 10′ E.) about 130 miles south of Perth, Western Australia.

It has been supposed on lithological grounds that these sandstones, known as the Donnybrook sandstone (Saint-Smith, 1912), are a remnant of the Collie Coal Measure Series which are Permian (Maitland, 1939, p. 185), but there is as yet no supporting palaeontological evidence although farmers in the district have discovered fossil footprints, not yet identified, in the upper part of the formation. Beyond some lithological resemblance to the Coal Measure series at Collie and the occurrence of some poorly developed thin beds of coal, there is nothing to show that the Donnybrook sandstone formation is of the same age as the Collie beds; however, both appear to be of estuarine or lacustrine origin and to have been laid down on an uneven, eroded surface of the Pre-Cambrian complex. There is apparently no continuity between the two formations.

The Donnybrook sandstone formation varies from coarse, unevenly graded and bedded sandstone with pebble bands near the base, to fine-grained, evenly bedded, ripple-marked sandstones with clay partings towards the top. The beds dip at about 4° to the south-west. The thickness is not definitely known, but bores have penetrated it to a depth of 200 feet (Maitland, p. 183).

The Donnybrook sandstone forms flat-topped hills, covered by laterised sandy soils, to the west, north and south of Donnybrook. Laterite (duricrust) above the sandstones is distinguishable from that formed from the Pre-Cambrian rocks by its abundant quartz grains.

The distribution of the Donnybrook sandstone is shown in Figure 1 where the formation is seen to overlap the edge of the Pre-Cambrian shield, indicating that the sandstones were in part laid down on an eroded surface of Pre-Cambrian rocks (Forman, 1936, p. 4). The Pre-Cambrian rocks immediately to the north-west of Donnybrook are at a much higher level than the sandstones. A range of sandy hills, known to be underlain in some parts by sandstone, occurs to the south-south-west of Figure 1, suggesting a continuation of the formation in this direction. The contact of the sandstone with the Pre-Cambrian just west of Nannup, about 30 miles south of Donnybrook, is similar to that at Donnybrook. Economically these sandstones are of importance, for the finer, evenly-bedded types provide an easily-worked, durable building stone.

In 1897 gold was discovered in the Donnybrook sandstones which were worked until 1906, yielding about 850 ounces of gold from 1,650 tons. The gold is thought to have been derived from small quantities in the surrounding Pre-Cambrian rocks (Maitland, p. 181) and to have been deposited from solution in the sandstones. An unsuccessful attempt was made about ten years ago to recover gold from the Pre-Cambrian rocks near where the old mines are situated in the sandstones.

Various reports, dealing with the distribution of the Donnybrook sandstone, with its use as a building stone (Simpson, 1917), with the possibility

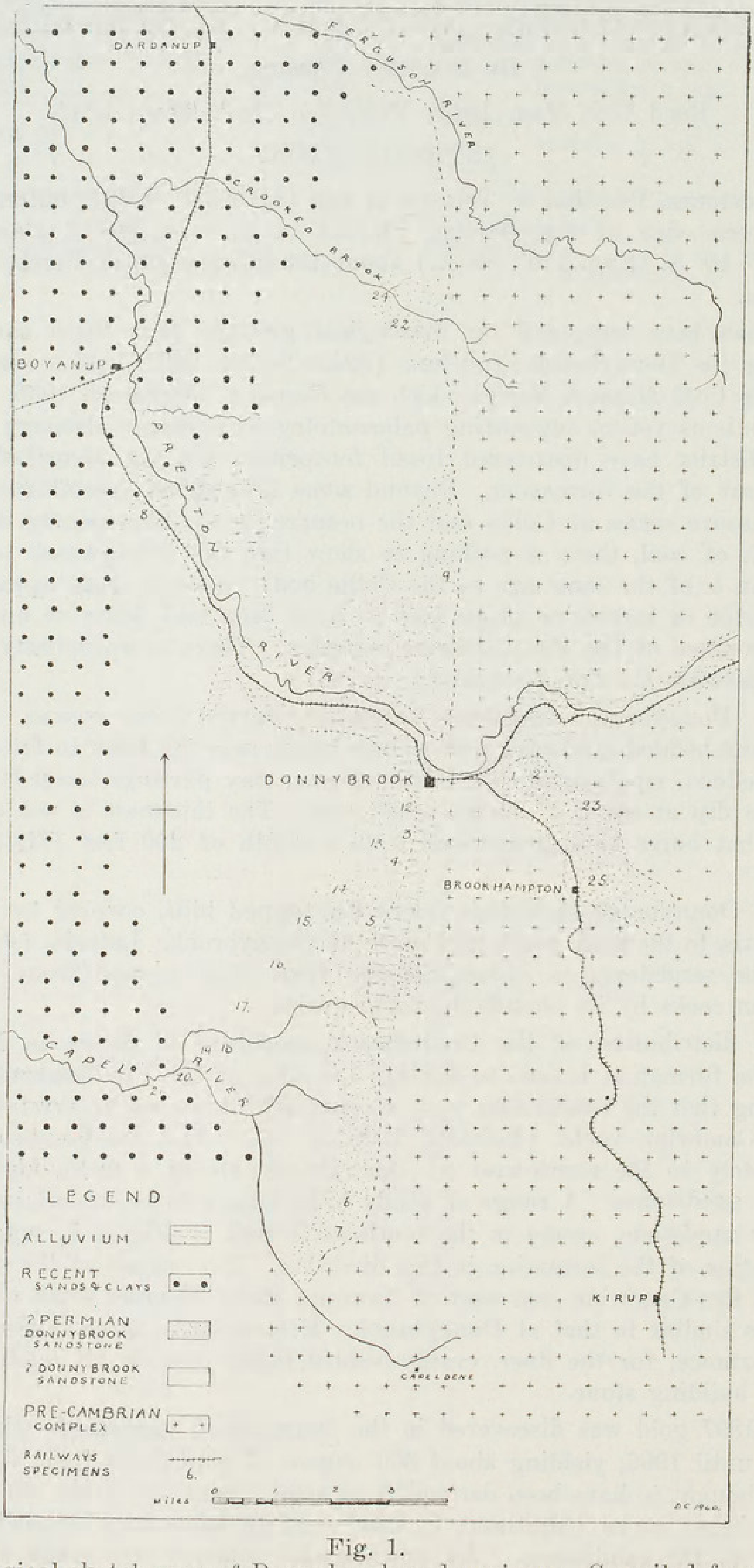

Fig. 1.

Geological sketch map of Donnybrook and environs. Compiled from Lands Department Lithos. 411/80, 414/80, and Plate I., Bull. 44, Geol. Survey, W.A., 1912.

of finding workable coal seams in the district, and with the occurrence of gold have been summarised by Gibb Maitland (1939) but actually there is little detailed knowledge either of the sandstones or of the Pre-Cambrian complex, which lies to the east, north and south of the sandstones (Figure 1). The Pre-Cambrian is represented predominantly by gneisses at Donnybrook, and, in the valley of the Preston River, there are numerous pegmatite dykes some of which carry large crystals of beryl and tourmaline; garnetiferous gneisses, associated with mica schists, are also common. Granite occurs farther to the east.

The soils overlying the Donnybrook sandstones are generally sandy, forming sand-plains. In places, however, the clay in some parts of the formation is sufficient to give a loamy soil with a clay sub-soil evidently well suited to the requirements of Jarrah (*Eucalyptus marginata*) which provides timber for the mills near Donnybrook and Nannup. The sand-plain, lying as it does in a region of 35-40 inch annual rainfall may constitute a distinct type in the sand-plains of Western Australia, and the investigation given below was begun several years ago when the writer was examining the heavy minerals of sandplain soils generally. The results for some other types of sand-plain have already been published.

MINERALOGY OF THE DONNYBROOK SANDSTONES.

The specimens examined fall into two groups, actual rock specimens, and soils derived from the weathering of the sandstones. The sandstones were examined by thin section as well as by concentrating the heavy minerals.

The sandstones were crushed until a large quantity of the material passed an 85 B.S. sieve (approximately 70 I.M.M.), the finest particles were washed out, the sample dried, and about 10 to 15 grams were separated in bromoform. The soils were sieved in a similar way and the clay grade of material washed out before bromoform separation. A few of the sands were treated with HCl to remove ferruginous coatings from the grains, but most of them were white or almost white in the natural state so that acid treatment was unnecessary. The heavy residues were not weighed so that no percentage figures are available, but it was found that the residues were fairly large and would have, in all probability, been at least 1 per cent. of the sand separated. Before mounting, magnetite was removed from each residue.

In thin section the Donnybrook sandstone is seen to be a medium to fine-grained rock consisting of about 75 per cent. quartz; the remainder is felspar, both oligoclase and microcline, kaolinite or other clay mineral supplying the binding. The quartz grains are rounded to sub-angular in shape and often show re-growth at the edges; such grains were also found in some of the soils directly derived from the sandstones. The felspars in the sandstones are somewhat kaolinised.

The heavy mineral assemblages contain the following minerals:— magnetite, ilmenite, leucoxene, zircon, tourmaline, rutile, sphene, epidote, zoisite, garnet, amphibole, chlorite, anatase, monazite, kyanite, sillimanite, staurolite, spinel, and muscovite. The suites are rather similar throughout as is shown in Table 1, where the relative abundance is indicated.

Notes on Individual Minerals.

Magnetite, ilmenite, and leucoxene require no comment except to state that all are rather abundant in the residues, particularly magnetite and ilmenite.

TABLE 1.

Heavy minerals in the Donnybrook Sandstones and Derived Soils.

Sample Nos. ...	1	2	3	4	5	6	7	8	9	12	13	14	15	16	17	18	19	20	21	22	23	24	25	4005*
Magnetite	+				+			A+	S	A+	+	+	+	A+	A+	A+	A+	A+	A+	A+	A+	A+	A	+
Ilmenite	+	+	A	A	+	+	+	+	+	+	A+	A+	A+	A	A	A	A	A+	A+	A	+	+	A	+
Leucoxene	+	+	+	+	+	+	+	+	A	+	+	A	A	+	+	+	+	+	+		+	+	+	+
Zircon	+	A	+	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Tourmaline	+	+	+	+	+	+	+	+	+	S	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Rutile	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	A	+	+	+
Anatase						+	+	+	+		S				+					+				+
Sphene	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+
Monazite					+	+		+	+							S								+
Epidote	+		+	+	+	+	+			+		S					S	+	+	S		+		+
Zoisite		+	+																					
Amphibole	+		+		+	+	+			+	S	+	S		+	S		S		+	+	+		
Chlorite	+		+							+						+		S	S					
Garnet	+		+														S					S		
Kyanite	+	+	+			+		+		+	S	S	S	+	+	S	+	S	S	+	S	S		
Staurolite								+		+	S		+	+	+	S		+	+	+		S	+	
Sillimanite		+						+				+	S	S	+		S	S	S	S		S		
Spinel		+											S		+		+							
Muscovite ...																							S	

*5005 is a residue of a sandstone from one of the main quarries; specimen examined by R. A. Hobson some time ago.
A+ = very abundant; A = abundant; + = present, up to 5%; S = scarce, a few grains only.

Zircon: Zircon is a prominent constituent in all the residues. Colourless, worn grains predominate, and many of these have large inclusions of bubbles and rods; zoning is not a common feature, but occasionally finely-zoned grains occur. Purple zircon is rare, odd grains only being recorded from specimens 6, 13, 18, 25, and 4005. The most deeply coloured grains are pleochroic from a brownish-purple to deep purple and are similar to those found in other sediments in south-western Australia. Purple zircon is known as an accessory in some of the Pre-Cambrian gneisses. Tawny or brownish zircons, possibly derived from the same source as the purple, were obtained in specimens 1, 3, 12, 13, 15, and 16. Most of the zircon grains are more or less rounded but some sharp-edged crystals also occur. The rounding indicates considerable transport, and possibly more than one cycle of sedimentation.

Tourmaline occurs in a variety of colours such as bright yellowish-brown, grey, pinkish-grey, or pinkish-brown, and blue, the latter being scarce. Although tourmaline is a noticeable constituent because of its colour, it does not make up a great part of each residue and little significance can be attached to it except to note that some of the grains are well-rounded and spherical, and hence are probably survivals, along with the rounded zircon, from other cycles of sedimentation.

Although the Pre-Cambrian rocks in the Preston Valley to the east of, and not far from, Donnybrook are comparatively rich in tourmaline, yet it is not a major constituent of the Donnybrook sandstone residues. This is one reason for believing that the Donnybrook sandstones have not been derived from local sources.

Rutile is a fairly prominent constituent. The grains are generally robust and rounded, and of deep reddish-brown colour. In some specimens yellowish-brown grains are also present, but these show very few signs of wear and transport. Yellowish-brown, broken, geniculate twins are found occasionally.

Anatase: As shown in Table 1, anatase is present in about one-third of the specimens. The grains generally vary from steel-grey to pale yellow in colour, but occasionally steel-blue ones are to be found. Both the tabular and octahedral habits occur, the tabular being the more common. Anatase is present only in very small amounts and it must be regarded as an authigenic constituent for the grains are euhedral, unworn, and sometimes two or more small crystals are joined together.

Sphene is fairly plentiful in angular, colourless fragments of "chunky" appearance. It is a constituent of practically all the specimens examined.

Monazite in pale yellowish-green worn grains is characteristic of a number of residues. Its presence is to be expected where granitic material has been incorporated in a sediment.

Epidote and zoisite: Epidote in pale yellowish-green, somewhat worn grains occurs in about three-quarters of the specimens, but zoisite was only recorded in two residues, Epidote never makes up a large part of any residue, and is usually restricted to a few grains.

Amphibole is present in about the same amount as epidote or less and often there are only one or two grains to each slide. The amphibole is the bright bluish-green variety common to the hornblende schists and epidiorites of the Pre-Cambrian complex. That it is not present in greater quantities indicates that greenstones were not being actively eroded during the formation and deposition of the Donnybrook sandstones, for it is a resistant mineral and not easily broken down by weathering. Its scarcity also suggests derivation of the Donnybrook sandstones from older beds or from a terrain which was almost entirely granitic.

Garnet is angular to somewhat rounded, colourless grains is one of the minor constituents, for it occurs as odd grains only in four of the residues. Garnetiferous gneisses were evidently not present to any appreciable extent in the eroded terrain, and the scanty garnet in these residues could have been passed on from a pre-existing sediment.

Kyanite, sillimanite, and staurolite: These metamorphic minerals occur in the majority of the specimens, kyanite being the most prominent. The kyanite grains are usually well-worn, some being almost round, but others are merely broken fragments with "steps" due to breaking along cleavages. Staurolite occurs in more than half the residues as bright, brownish-yellow, strongly pleochroic grains, most of which are either angular or sub-angular. The presence of kyanite, sillimanite, and staurolite indicates that at some time Pre-Cambrian meta-sediments contributed material to the Donnybrook sandstones, but in view of the scarcity of these minerals, with the exception of kyanite, it is unlikely that they were derived directly, i.e. these minerals have come to the Donnybrook sandstones via some earlier sediment. No sources for these minerals are known in the Donnybrook district, but, as mentioned previously, there is little detailed knowledge of the Pre-Cambrian complex in the vicinity.

Spinel: Odd grains of green spinel were found in four of the residues. Spinel is commonly present in residues derived from the Pre-Cambrian in the south-western part of Western Australia. These spinel grains are well-worn, but otherwise are typical.

Muscovite: With typical platy habit is only present in one residue.

SIGNIFICANCE OF DETRITAL HEAVY MINERALS IN THE DONNYBROOK SANDSTONES.

It has been stated (Saint-Smith, 1912, p. 21) that the Donnybrook sandstone has been derived more or less directly, with little transport, from the weathering of the Pre-Cambrian rocks upon which it rests. The heavy residues show that this is rather unlikely, for the minerals which are known to be present in the underlying and surrounding Pre-Cambrian rocks are poorly represented in the residues separated from the sandstones. Moreover, a feature which was not known when Saint-Smith's statement was made, is that most of the heavy mineral grains have been rounded by abrasion during transport. Again, although there is a considerable number of minerals in the residues, zircon is the only one of the non-opaque minerals which is present in large quantities, and this suggests that part at least, of the formation was derived from a pre-existing sedimentary series.

The assemblages are dominantly granitic as shown by zircon, tourmaline, sphene, and monazite. Minerals derived from greenstones occur very sparingly, as do the metamorphic minerals of which the most conspicuous is kyanite, the most resistant of these to weathering and abrasion. Andalusite, which generally accompanies these metamorphic minerals, is absent. This suggests some transport of the material, from the place of origin, for andalusite does not seem to be able to survive much abrasion. The almost complete absence of garnet and the scarcity of tourmaline in most of the residues is conclusive evidence that the source was not in the Donnybrook district, for garnetiferous and tourmaline-bearing rocks are plentiful in the Preston Valley, but these rocks were evidently not uncovered when the sandstones were being laid down. The scarcity of amphibole, which makes up a very minor part of the residues, suggests deposition some distance from the source and also possible re-working of a sedimentary series.

The above interpretations of the mineralogy must be regarded as tentative only, for the specimens examined come from a rather small area. It is known, too, that most have come from near the top of the formation, so that a very different picture might be obtained if the lower members could also be examined. Nevertheless, this investigation will, it is hoped, provide a basis for future work on these sediments, and it is also hoped that the Collie Coal Measures may be examined. It has been suggested, on the one hand, that the Coal Measures have been protected in a graben (Woolnough, 1916, p. vi), and, on the other that they were deposited in a separate basin, (Woodward, 1894, p. 548). Examination of the heavy minerals may be expected to indicate which of these theories is correct. If the graben theory is supported, then the heavy minerals may afford a means of correlation between the Donnybrook sandstones and the Collie Coal Measures. If the separate basin theory seems more probable, then it is unlikely that the detrital heavy minerals will be helpful in the correlation of the coal measures with any part of the Donnybrook sandstones. Saint-Smith (1912 p. 22) has suggested that the Donnybrook sandstones are stratigraphically above the Coal Measures; the examination of the detritals in the Donnybrook sandstones suggests the possibility that part of the Coal Measure sandstones was eroded to form the Donnybrook sandstones. Few outcrops, lateritic cappings, and heavy timber make field work difficult. Also, over a considerable part of the area where Coal Measures or Donnybrook sandstone occur, more recent lake beds further obscure stratigraphical details (Woolnough, 1916, 9. v.)

The fact that the latest dissection of the plateau has uncovered and eroded large hills in the Pre-Cambrian along the Preston Valley, and that these hills are higher than most of the Donnybrook sandstone outcrops, suggests that the lake or estuary in which they were laid down had an irregular floor caused by previous erosion, and that some of these older surfaces are now being once again eroded, possibly because of a general uplift of this part of the country. The Pre-Cambrian rocks on the northern side of the Preston Valley may have been a land surface which effectively blocked any communication between the Collie "lake" and the Donnybrook "lake." Erosion appears to have removed a considerable thickness of the Donnybrook formation, and this has contributed to the Tertiary beds in the coastal plain.

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