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BEACH SAND HEAVY MINERALS NEAR BUNBURY, WESTERN AUSTRALIA

by

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SUMMARY

Beach sand heavy minerals occur in highly concentrated deposits adjacent to the coastline at Bunbury, where they are at about present sea level, and within a sandy coastal plain or lowland at Capel and Yoganup, 3 and 9 miles island respectively, where they are at 60 to 150 feet above sea level. The deposits are essentially of ilmenite, for which they are being exploited, and in addition they contain small proportions of rutile and zircon, and of monazite, which the operating companies propose to recover as a by-product. The minerals originated in the Precambrian granitic terrain which forms the landward boundary of the coastal plain. They were concentrated by wave and surf action on former beaches, in Recent times at Bunbury and during the Pleistocene at Capel and Yoganup.

Estimates are given of the composition and reserves of the deposits, and in particular, of the reserves and probable future production of monazite. The possibility of additional discoveries in the future are discussed.

Some details of the leases and treatment plants of the operating companies are given as Appendices to the report.

INTRODUCTION

During December, 1957, the writer accompanied Mr. J. Webb of the Australian Atomic Energy Commission and Mr. G. Low of the Western Australian Geological Survey on an investigation of the reserves of heavy mineral held under lease in the Bunbury-Capel area, Western Australia, and of the potential monazite production of the separation plants in the area. The deposits and treatment plants were inspected and a little sampling was done. Discussions were entered into with officers of the companies who provided copies of sampling data, plans and sections. A report (Gardner, 1958) was written in January, 1958, to summarize the information available.

The present report is more extensive than the earlier one and discusses the occurrence and origin of the deposits, as well as the reserves and potential monazite production. As a result of work done at Canberra since January, partly in the laboratory of the Bureau of Mineral Resources, on samples obtained from the area, small amendments have been made to figures of reserves and of possible monazite production.

GEOLOGICAL BACKGROUND

The deposits occur in a sandy coastal plain about 10 miles wide, flanked on the east by higher country that consists mainly of Precambrian granite, gneiss and metamorphic rocks. The surface elevation ranges from a few feet above sea level at the coastline to about 180 ft. at the landward margin. (Levels in the Capel and Yoganup areas were taken from survey data of Westralian Oil Ltd. This is based on railway datum which was stated by Public Works Department, Perth, to be 97.5' above Mean Low Water).

OCCURRENCE AND ORIGIN

General

Deposits occur (Plate 1) at Bunbury two to three hundred feet back from the ocean beach, a few feet above sea

level; at Capel 2½ to 3 miles inland and about 60 feet above sea level; and at Yoganup, 9 miles inland and about 150 feet above sea level.

The Bunbury deposit is partly exposed in a pit that has been opened up by Cable (1956) Ltd. adjacent to their separation shafts in the leases of Westralian Oil Ltd. north of the townsite, and in a working pit adjacent to the separation plant of Western Titanium Ltd., south of the townsite. The shafts were not open for inspection during the investigation of December, 1957, but the material excavated had been placed near the shafts in heaps each of which represents 1 foot of sinking. These gave a fairly clear picture of the deposit and provided a convenient means of sampling. The working pit excavated by Western Titanium Ltd. extends over several acres and the deposit at that locality is well exposed. In the Yoganup area Westralian Oil Ltd. have investigated the deposit by shaft sinking. The 1-foot samples at the shafts were available for inspection, but the shafts, as at Capel, were not open.

Bunbury

At Bunbury the heavy minerals occur on a former ocean beach about 300 feet east of the present one in a narrow sand-spit or sand-bar that separates Leschenault Inlet from the sea. Presumably they were separated from the common beach sand by the action of the surf during stormy weather and deposited on the upper part of the beach, as has been observed in eastern Australia (Gardner, 1955). The earlier beach line is marked by a large, grass-covered sand ridge, a former foredune, that runs along the eastern or landward side of the deposit.

The deposit has been opened up over a length of a few hundred feet and an exposed width of 100 ft. The actual width is greater since the deposit extends beneath the foredune, which must be left intact in order to protect a railway line on its landward side. In the pit grey to black sand approximately 8 ft. thick is exposed. From the surface to 3 ft. or so bands of heavy black sand up to a few inches thick alternate with bands of grey and white sand. Below 3 ft. little if any white sand is visible and the deposit appears to contain at least 80% heavy mineral.

Capel

The Capel deposit extends over a distance of 13 miles, including barren sections, approximately parallel to the coastline. It lies beneath the western side of a broad, low sandridge, that resembles a foredune, covered by trees and scrub. North of Capel Townsite on the leases of Westralian Oil Ltd. (Plate 3) the deposit has been tested by auger sampling and pitting. From the surface down to a depth of about 10 ft. the sand is pale reddish-yellow. Below this it is darkened by black minerals, which are present in high concentration in the bottom 3 to 8 ft. Nearly all the sand is loose. South of the Townsite a fairly extensive pit has been opened up at the separation plant of Western Titanium Ltd. (Plate 4). From the surface down to about 6 ft. the sand is loose and dull yellow-brown in colour. Below this it is partly cemented or indurated by iron oxide deposited between the grains. The greater part breaks up in a jet of water used for hydraulic mining of the deposit, but tabular and irregular masses up to several feet and exceptionally 20 feet maximum dimension remain intact. The deposit rests on loosely cemented white

sand and marl, which has a westward slope appropriate to that of a beach, and contains occasional pebbles and cobbles that exhibit the flattening typical of beach abrasion. It is clear that this deposit was formed in the same way as the Bunbury deposit. The cementing or indurating iron oxide may have been deposited initially at a time when the lower parts of the terrain existed as coastal swamp-lands at a slight elevation above sea level. Its upper level remains at a constant depth from the surface and apparently indicates a former water table. Subsequently the water table has been lowered and much of the iron oxide has been redistributed. Some of it has been removed locally by leaching and redeposited to form imperfect tubules that are reminiscent of tubular and vermiform structures in laterite. Heavy minerals occur in small amount in the loose sand within 6 ft. of the surface. They become more abundant downwards, and within the last 4 ft. (at the site inspected) form highly concentrated black sand. The leaching and re-deposition of the cementing material has resulted in a crude vertical lineation in the indurated portions of the deposit. Where the proportion of heavy mineral is relatively high, say 50% or more, the heavy and the light fractions of the sand appear to have segregated into vertically elongated ropes and pods. The indurating material seems to have been deposited in the light sand and to be practically absent from the heavy minerals.

Yoganup

The deposit (Plate 2) extends north-westwards for a distance of about 10 miles, approximately parallel to the coastline and 9 miles from it. Breaks occur where it is cut by the valleys of the Capel and Ludlow Rivers and tributaries. The land surface slopes gently towards the north-west and has little topographic relief. An appreciable steepening of the gradient at the edge of the coastal plain marks a subdued scarp named the Whicher Range. The deposit has been tested by auger sampling and shaft sinking. From the surface down to depths of 2 to 10 feet the sand is yellowish-brown in colour. Below this it is darkened appreciably by heavy mineral, and the bottom 2 to 4 ft. from some of the shafts is quite black. Below a depth of about 10 ft. the sand is irregularly indurated by ferric oxide. Typically rounded beach pebbles and cobbles occur below the heavy mineral, suggesting that it is essentially a beach sand deposit. The grain size of the heavy minerals is noticeably smaller than in the Capel deposit, and this may indicate that some of the Yoganup heavy mineral has been derived from re-working of earlier dune deposits.

As the sand of the Yoganup deposit was not seen in situ, the distribution of the cementing material is not as well known as is that of the Capel deposit, in the pit of Western Titanium Ltd. The material dumped around the shafts suggests that it has been subjected to considerably more leaching and re-distribution. Much of the sand is free from cementing iron oxide while other small masses contain a high proportion of it in the form of hard dense irregular concretionary masses. Some of it occurs as rounded or pisolitic concretions.

The surface rocks above the Whicher scarp are lateritized. Detrital laterite in the form of loose pisolites has drifted down the slope of the scarp and has intermingled with sand above the Yoganup deposit, and covered portions of the eastern part of the deposit. This is visible in a quarry from which the detrital laterite has been removed for use as road materials exposing black sand in the bottom.

AGE

The Bunbury deposit is Recent in age. The Capel and Yoganup deposits reached their present elevation either by uplift of the land or depression of the sea level. It is suggested that they were deposited during interglacial stages of the Pleistocene glaciation, when the sea level was considerably higher than it is at present. With the information available, it appears possible that the Yoganup and Capel deposits date back to the Mindel-Riss and Riss-Warm interglacials respectively. However, further speculation should await verification of the elevation of the deposits.

SAMPLING

The compositions of deposits stated in terms of heavy mineral constituents in Table 2, are those of independent samples taken by the writer in December 1957. They agree closely with the Company statements of composition with the exception of the figures for monazite in some cases.

Samples were taken at following localities: (see plate 1 for location of deposits).

Bunbury Deposit	From plant, including head feed to plant direct from pit.
Capel Deposit	From heaps of sand around shafts on leases of Westralian Oil Ltd. The Company representatives stated that each heap represented 1 foot of sampling. From working pit and plant of Westralian Oil Ltd.
Yoganup Deposit	From heaps of sand around shafts. The Company representatives stated that each heap represented 1 foot of sinking.
Yoganup Extended Deposit Tutanup Deposit	Not sampled.

LABORATORY WORK

General

Samples were examined at the Canberra laboratory of the Bureau of Mineral Resources. They were weighed and then carefully panned to remove the lighter minerals: the samples were too few in number to warrant setting up the laboratory Wilfley Table, which was at the time adjusted for other work. The heavy mineral concentrate was dried and weighed. Where more than one sample was available from a deposit, a composite sample was made from the separated heavy concentrate. This was quartered down to approximately 100 grams and weighed. Compositions were determined by electromagnetic separation on a Frantz Isodynamic Separator, followed by grain counting. At a moderately low magnetic intensity the bulk of the sample, consisting of ilmenite, was separated. Because of iron staining of the zircon in the concentrate, the remainder was warmed with dilute hydrochloric acid. The cleaned concentrate was subjected to a high intensity magnetic field which separated out the

monazite, tourmaline, and a little garnet and leucoxene. This monazite-rich concentrate was weighed and the percentage monazite was determined microscopically by grain counting.

Determination of Monazite

The concentrate obtained by the method just described contains 70 to 80% monazite. In determining the percentage monazite by grain counting no allowance was made for relative grain sizes and specific gravities. The sands are well sorted and the grains of each mineral are sensibly uniform in size. The monazite has a notably higher specific gravity than the other minerals but this is more than offset by a relatively small grain size.

Experience has shown that the percentage by weight of monazite is slightly, though not appreciably, over-estimated by applying the grain-count method to a high grade monazite concentrate. Estimations of the weight percentage of monazite by grain counting the initial mixed concentrate, which is low in monazite, does result in significant errors, as shown in Table 1.

Table 1

Comparison of monazite percentages obtained by grain counting (a) Initial Concentrate from a Beach Sand, (b) High Grade Monazite Concentrate obtained by Magnetic Separation of (a).

Sample	(a) Heavy concentrate separated from beach sand. Ten fields counted, covering approx. 800 grains.	(b) Concentrate containing 70-80% monazite obtained by magnetic separation of (a). Approx. same number of grains counted as in (a).
Composite of Capel concentrates	0.55	0.41
Composite of Yoganup concentrates	1.1	0.90

COMPOSITION

Table 2 summarizes the heavy mineral composition of samples obtained from the deposits in December, 1957. The heavy mineral content ranges from 19 to 44 per cent. By far the most abundant heavy mineral is ilmenite which is present in the heavy concentrates in proportions that range from 74 to 93 per cent. About 1% rutile is present in all concentrates.

The compositions of the Bunbury and Capel concentrates are substantially the same, apart from a relatively high proportion of garnet at Bunbury. Monazite ranges from 0.35 to 0.5 per cent. The Yoganup concentrates contain distinctly higher proportions of zircon, leucoxene, and monazite.

In all cases, the compositions are typical of sands derived directly from granitic terrains. The Yoganup area is closest to the source of the heavy minerals, and this

probably explains the increased proportions of monazite and zircon, which having the highest specific gravities tend to lag behind the other minerals during transport. The Yoganup deposit is distinctly older than the others and the increased leucoxene may have resulted from weathering of some of its ilmenite since it was deposited.

MONAZITE CONTENT

General

Table 3 summarizes the various estimates of the monazite content of the several deposits. Estimates made by Cable (1956) for the Bunbury deposit and Westralian Oil Ltd. for their part of the Capel area agree with B.M.R. estimates.

Western Titanium

Western Titanium's estimates for their portion of the Capel deposit are considerably higher than the B.M.R. estimates. A mineragraphic report by Baker and Edwards (1956) of C.S.I.R.O. gives the monazite content of samples from Plantation and Websters area (see appendix 4) as 0.8% and 0.6% respectively and presumably this is the source of the figures quoted in Table 3. It is stated that the concentrates were examined in clove oil mounts under the petrological microscope, and grain counts were made to determine the approximate relative proportions of the various minerals present. "The samples are not sized, and the degree of natural sorting varies from sample to sample which adds to the approximate nature of the measurements". Table 1 of this report shows that straight grain-counting of Capel concentrates gave 0.55% monazite, whereas grain-counting of a monazite-rich concentrate separated from the same Capel concentrate gave 0.41% monazite. The same reduction factor (0.75) applied to the concentrates examined by Baker and Edwards reduces the monazite content of the two areas to 0.6% and 0.45%.

Applying the same factor to the figure of 1.08% quoted in Table 3 for the northern leases of the Company gives a monazite content of 0.75% for them.

An unpublished report by the South Australian Mines Department on a 6-ton sample was discussed at the separation plant in December 1958. The localities of the sample and monazite content are stated to be:

Sample	Monazite	
A Surface	0.5%	Stated to be as mined.
B Intermediate depth	0.5%	
C Deep mineral	0.2%	

From sample B, 98% of the heavy minerals and 53% of the original weight were recovered over spirals. Magnetic separation of the heavy minerals gave 14% tailings with 4.3% monazite.

Examining the figures -

A simple calculation shows that the heavy mineral concentrate contained 0.6% monazite. This suggests that the percentages listed for samples A, B, and C refer not to the sand as mined but to the heavy mineral concentrate. The average is 0.4%.

TABLE 2

Composition of Samples from Beach Sand Deposits, Bunbury-Capel Area, W.A.

Company	Heavy Mineral in Sample. Wt. per cent. & lb. per cu. yd.	Percentage Composition of Heavy Mineral Concentrate						
		Ilmenite	Leucoxene	Zircon	Rutile	Monazite	Garnet	Other Minerals
Cable (1956) Ltd. Bunbury	* 43.9% 1437	90.7	1.6	2.3	0.8	0.5	3.8	0.3 Epidote, hypersthene, green spinel, staurolite, biotite.
Western Titanium Ltd. Capel	** 41.7% 1265	91.6	0.2	6.0	1.8	0.35	-	Trace of tourmaline, corundum and green spinel.
Westralian Oil Ltd. Capel	/ 19% 539	93.2	1.1	3.8	1.3	0.4	-	0.2 Garnet and epidote.
Yoganup	// 28% 824	77.9	8.0	12.1	1.1	0.9	-	Trace of garnet and tourmaline.

* Numerous grab samples taken from the feed to the plant 18/12/57.
Note: Other samples tested yielded 0.4% monazite. See also "Notes on Plant Sampling".

** Channel sample down face of deposit, length 13 ft. The percentage composition is that of the feed to the separation plant on 17/12/57.

/ Composite sample from dumps around 21 shafts.

// Composite sample from dumps around 8 shafts.

TABLE 3.

Estimate of Monazite Content of Concentrates

Deposit	Figure Supplied by Company	B.M.R. Estimate	Remarks
Bunbury Cable (1956) Ltd.	Technician states monazite content of sand ranges from 0.06 to 0.4%.	0.4%	Assumed that Company figure refers to sand as mined.
Capel Western Titanium Ltd.	Ranges from 1.0% in northern leases through 0.8% down to 0.6% in southern leases*. Northern leases 1.08%. (Stated in Prospectus).	0.4%	B.M.R. samples of head feed to plant and of a channel sample from pit face.
Westralian Oil Ltd.	0.5% ≠ In bulk sample 2000N to 5000N 0.4% ø	0.4%	B.M.R. sample is a composite sample from 21 shafts.
Yoganup	Report dated 5/10/57 by Warman Equipment Co. 0.6%. Length of 7000 ft, at southern end of deposit 2% ø	0.9%	B.M.R. sample is a composite sample from 8 shafts.
Yoganup Extended	0.66%	Not sampled	
Tutunup	From 0-14' depth 0.86%; 15'to27' 0.66% ø Bulk sample 1.3% ø	Not sampled	

* Letter to A.A.E.C., 8/10/57.

≠ Letter to A.A.E.C., 24/6/57.

/ø Figure stated during discussion in Company office, December, 1957.

Samples obtained in December, 1957, from this area and from Westralian Oil leases farther north on the same deposit contain the following proportions of monazite, determined in Canberra laboratory of the Bureau of Mineral Resources.

Sample	Monazite in Heavy Concentrate
Western Titanium Ltd.	
Pit sample	0.4%
Feed to separation plant	0.35%
Westralian Oil Ltd.	
Composite sample from 21 shafts	0.4%

From these figures, it is concluded that in Western Titanium leases monazite amounts to approximately 0.4% of the heavy mineral concentrates. However, the independent samples quoted in the Table above which contain this percentage of monazite, are representative of the working pit in December, 1957, and of Westralian Oil's leases farther north. A slight possibility remains that the remainder of Western Titanium leases contains a higher proportion of monazite. This can only be resolved by check sampling, which could be done effectively by churn drilling and casing.

Westralian Oil, Yoganup

Estimation of monazite by the company is on the basis of P_2O_5-content of concentrates. The figures for Yoganup Extended and Tutunup, north-easterly and south-westerly from Yoganup on the same deposit are 0.66% and 0.76%. A figure for Yoganup given by Warman Equipment Pty. in a report dated 5th October, 1957, is 0.6% but this is obviously too low. The Bureau figure of 0.9% is considered to be reliable. A sample over a length of 7,000 ft. of the southern end of the Yoganup area, examined by Hudson, C.S.I.R.O., is stated to contain 2% monazite. This is obviously too high.

RESERVES

General

Estimates of probable reserves have been made on the basis of Company estimates modified by the results of inspection and check sampling, where practicable. The estimates given here for Cable (1956) Ltd. and Westralian Oil Ltd. are identical with those of Records C1958/1. The figures for Western Titanium Ltd. have been amended. The earlier estimate, based on the Company's 1st Annual Report, 1957, covers the reserves in the Company's northernmost bases. The estimate given below is based on figures supplied by the Company to the Australian Atomic Energy Commission during October, 1957. It covers the total reserves held by the Company in the Capel area.

Method of Calculating

The proportion of mixed heavy mineral in the samples obtained December, 1957, was determined both as

weight per cent and as lb. per cubic yard. The relationship between these two quantities is expressed by the curve of Fig. 1. The sand in situ in the deposits will almost certainly be more densely packed than that in the samples and as a result the quantities of heavy minerals in the deposits, expressed lb. per cu. yd. will be a little higher than shown in Fig. 1. To calculate the approximate tonnage of heavy mineral in a sampled area, the average thickness of deposit was obtained by averaging the thickness obtained in all the boreholes. Average grade through the area was obtained by multiplying thickness by lb. per cu. yd. for each borehole, and obtaining the overall average of lb. per cu. yd. Volume of deposit in cu. yd. was estimated, as product of area x average thickness, and weight of heavy mineral obtained by multiplying this by average lb. per cu. yd. As discussed above, this will probably be a little below the true tonnage.

In making estimates from company figures, grade in weight per cent. was converted to lb. per cu. yd. by using the curve of Fig. 1.

ESTIMATES OF HEAVY MINERAL RESERVES

General

Table 4 summarizes the estimated reserves of heavy mineral. Except in the case of Western Titanium Ltd., as explained above in the introductory paragraph on reserves, the figures are those given in Record C1958/1.

Cable (1956) Ltd.

No statement of reserves has been obtained from the Company, excepting a claim to 250,000 tons concentrates made in February in a letter to Western Australian Mines Department. A rough estimate on the basis of visual examination during the December inspection gives promise of reserves of approximately 20,000 tons heavy mineral per 1200 ft. length along the deposit, or 88,000 tons per mile. This assumes a width of 90 ft., average thickness of 9 ft. and average grade of 40% heavy mineral. A length of 15,000 ft. of deposit would contain the reserves claimed by the company. It would be surprising if the deposit has not a considerably greater length. Except in the vicinity of the separation plant, no boring or sampling had been done up to December, 1957.

Westralian Oil Ltd.

Yoganup Area. The deposits in the Yoganup area comprise three main bodies of heavy mineral, probably separated portions of a once-continuous deposit, termed the Yoganup Extended, Yoganup, and Tutunup Deposits.

Reserves estimated by the Company are:

Yoganup Extended	300,000	tons heavy mineral
Yoganup	634,000	" " "
Tutunup	(400,000	" " " ?)

The total reserves are reported to be 1,300,000 tons heavy minerals, and presumably the Tutunup area contains an estimated 400,000 tons.

TABLE 4

Estimated Reserves of Mixed Heavy Minerals and of Monazite in Beach Sands near Bunbury, W.A.

Company	Reserves in Tons of Heavy Mineral		Monazite in weight per cent of heavy mineral and Reserves in tons.	
	Company Estimate	Remarks	Company Estimate	B.M.R. Estimate
Cable (1956) Ltd. Bunbury	250,000 tons	Probably the deposit contains at least these reserves.	0.4% No figure given	0.4% Probably at least 1,000 tons.
Western Titanium Ltd., Capel.	11,485,000 tons	Probable 6,000,000 tons. See Appendix 3.	Ranging from 0.6% to 1.0%. 86,000 tons. (54-58%, rare earths, 6.14% thorium oxide).	0.4% Probably 24,000 tons.
Westralian Oil Ltd. Capel	3,100,000 tons	May be a little high but substantially correct.	0.5%. Company doubts whether it can be economically recovered. 23,400 tons. Distribution of reserves not indicated.	0.4% 12,000 tons.
Yoganup	600,000 tons	Appears reasonable	0.6 to 2%	0.9%; 5,400 tons
Yoganup Extended*	300,000 tons	Appears reasonable	0.66%	0.6%(?); 1,800 tons(?)
Tutunup*	400,000 tons	Appears reasonable	0.66-0.86%	0.7%(?); 2,800 tons (?)

* Not sampled by B.M.R.

The Company has sunk 9 shafts in the Yoganup area (Plate 2), and the material excavated has been kept adjacent to the shafts in small dumps, each representing 1 foot depth. These dumps were sampled during December, 1957, and the samples were examined in the B.M.R. Laboratory, Canberra. The average thickness of heavy mineral bearing sand is 19.6 ft. and the average heavy mineral content is 824 lb/cu. yd. (approximately 28% by weight).

On the basis of these figures the quantity of heavy minerals in the area outlined by the shafts amounts to a possible 713,000 tons. This exceeds the Company's estimate (600,000 tons). However, close boring and sampling with a power auger has disclosed the presence of a narrow barren strip within the area (shown on Plate 2). There seems no reason to doubt the Company's own estimates of reserves.

Capel Area. The Company has sunk 35 shafts in the Capel area (Plate 3), and as at Yoganup the sand excavated has been placed in small dumps, each representing 1 foot of sinking.

The dumps at 21 of these shafts were sampled by the writer during December, 1957. On the basis of assay results obtained at B.M.R. Laboratory, Canberra, following are estimates of quantities in the area that contains the shafts.

Average thickness sampled - 19.6 ft.

Average content of heavy minerals - 539 lb. per cu. yd. (approx. 19% by weight).

Possible reserves of heavy minerals in area sampled - 1,323,000 tons.

The shafts sampled extend over 11,000 ft. length of the deposit.

According to the Company's records, high grade samples were obtained from eight other shafts over an additional length of 5,000 feet, to the north.

This probably gives reasonable grounds for increasing the figure of possible reserves by something like 5/11, viz. to more than 1,900,000 tons heavy mineral.

Since the shafts do not provide samples for the full width of the deposit it appears quite likely that the total possible reserves exceed 2,000,000 tons. The Company's estimate amounts to 3,100,000 tons and it is considered that this is substantially correct.

Western Titanium Ltd.

The Company's estimate of 11,485,000 tons of heavy mineral is based on the results of sampling by means of a power-driven auger. This sampling method is not satisfactory. Heavy minerals tend to fall down the uncased hole and "salt" the auger sample after the auger has in fact passed through the bottom of the deposit.

During the investigation of December, 1957, it was not practicable to carry out any adequate check sampling of the deposits. The only samples obtained were one from the working pit and one from the feed to the magnetic separation plant taken on 17/12/1957. However, some basis for appraisal

of the estimate of reserves can be found (a) by comparison with reserves in the nearby leases of Westralian Oil Ltd., which are apparently on an extension of the same deposit, (b) by comparison of the thickness of deposit exposed in the pit with the thickness shown on the Company's sampling plan, and (c) by making an estimate of reserves based on the Company's sampling data.

(a) Westralian Oil Ltd. estimated reserves of 3,100,000 tons over a length of 3 miles in their leases situated about 3 miles north-west of Western Titanium's leases (Plate 1). Check sampling by the Bureau indicates that this estimate is substantially correct, though probably a little high. Accepting Westralian Oil's estimate this gives reserves of 1,000,000 tons per mile. Western Titanium claim reserves of approximately $3\frac{1}{2}$ million tons over a length of less than $1\frac{1}{2}$ miles in their northern leases (Plate 4, MC517,516). This exceeds 2,000,000 tons per mile.

(b) The average thickness of the deposit shown in Western Titanium's boring plan is 29 ft. and the average grade is 46.6% by weight heavy mineral. In the working pit, where the deposit is completely exposed, its thickness is about 15 ft. A channel sample taken on 17/12/57 was examined at the Bureau of Mineral Resources laboratory. The heavy mineral content is:

From To	lb. per cu. yd.	Wt. per cent.
0 - 6'	1,099	36.4
6'-10'	1,508	47.6
10'-13'	1,274	44.3
Average 0-13'		41.7

(c) Using the Company's figures of thickness and weight per cent heavy mineral obtained from auger samples throughout the leases the reserves in sands containing 6% or more by weight of heavy mineral are estimated to total 5,283,000 tons. Details are given in Appendix 3.

Paragraphs (a) and (b) suggest that the Company's estimate of reserves may be double the actual reserves, viz. may be about 6,000,000 tons heavy mineral. The independent estimate based on Company sampling data is lower than this figure. It was calculated after converting Company's figures of weight per cent to lb. per cu. yd. using the curve of Fig. 1. However, the paragraph entitled "Method of Calculating" points out that the figure for lb. per cu. yd. is probably a little low, and hence the 6,000,000 tons is likely to be a better estimate.

ESTIMATES OF MONAZITE RESERVES

General

Estimates of reserves of monazite are given in Table 4. They are calculated from figures of reserves of heavy minerals and of monazite content of the heavy minerals, and this provides two possible chances for differences between Company estimates and those made during the investigation of December, 1957.

Cable (1956) Ltd.

Monazite reserves amount to 0.4% of heavy mineral reserves, which should total at least the 250,000 tons claimed by the Company. This indicates at least a probable 1,000 tons monazite.

The Company Technician stated during discussions in December, 1957, that the monazite contains 5.5% thoria and less than 50% rare earths. The thoria figure is much lower than that quoted by Western Titanium and Westralian Oil for the Capel and Yoganup areas, although presumably the monazite originated from the same source. It is suggested that check analyses should be made of the Bunbury monazite.

Western Titanium Ltd.

The figures of reserves given in Table 4 are higher than those stated in Records C1958/1 (24,000 tons compared with 16,000 tons) but are much lower than the Company estimate for two reasons:

(a) The estimate of reserves of heavy minerals adopted here is much lower than the Company estimate. This is discussed above under "Estimate of Heavy Mineral Reserves".

(b) The percentage monazite considered to be present in the heavy mineral concentrate is a good deal lower than the Company's figure. This is discussed above under "Composition Monazite", and the slight possibility is mentioned that the monazite content of the deposit as a whole may be higher than that of the samples examined.

Westralian Oil Ltd.

The figures of Table 4 are the same as those given in Records C1958/1. It is considered that the sampling of the Capel and Yoganup areas (excluding Yoganup Extended and Tutunup) during December, 1957, was adequate to give a reliable estimate of monazite content.

POSSIBLE ANNUAL PRODUCTION OF MONAZITE

General

Estimates of possible annual production of monazite are summarized in Table 5. In the case of Westralian Oil Ltd., the figure is a little higher than that given in Record C1958/1. High percentage recoveries of monazite by C.S.I.R.O. metallurgical laboratory, Melbourne, from the non-magnetics remaining after separation of ilmenite have been reported by both Western Titanium and Westralian Oil, and Table 5 gives production figures if the high recovery is attained. However, the experience of the east coast beach sands industry throws a great deal of doubt on the likelihood of such high recovery. The matter could probably be resolved by requesting an independent investigation by C.S.I.R.O. of concentrates supplied, say, by A.A.E.C.

Cable (1956) Ltd.

Monazite in tailings from the separation plant, stated to contain 1.46% monazite are being stockpiled. A sample of the tailings from the electrostatic separators, taken in December, 1957, was found at B.M.R. laboratory to contain 3.2% monazite. The reported low contents of thoria

rare earths is discussed under "Estimates of Monazite Reserves".

Considering the relatively low proportion of monazite in the sands, and the presence of much garnet, which will hinder separation, it is doubtful whether the 50% figured in Table 5 can be recovered as a high-grade concentrate. Possible annual production of high grade monazite concentrate using the data of Tables 2 and 5 is

$$\frac{80,000}{1} \times \frac{100}{90.7} \times \frac{100}{9} \times \frac{.4}{100} \times \frac{50}{100} \text{ tons}$$

$$= 196 \text{ tons.}$$

Western Titanium Ltd.

Since the quantity of garnet in the deposit is small a possible recovery of 60% monazite as high-grade concentrate is assumed. Annual production using the data of Tables 2 and 5 is:

$$\frac{100,000}{1} \times \frac{100}{91.6} \times \frac{100}{90} \times \frac{.4}{100} \times \frac{60}{100}$$

$$= 291 \text{ tons.}$$

A recovery of 90% of the monazite from the non-magnetic tailings is reported by C.S.I.R.O. This would increase the figure for annual production of monazite by 50%, viz. would raise it to 436 tons. It is considered very unlikely that this recovery could be attained in the form of high grade monazite concentrates.

Alternative estimates of probable annual monazite production based on plant throughput as stated by Company representatives are given in Appendix 4. They are summarized as follows:

Production of non-magnetics 16,000 lb. per hour.

Contains 25% to 30% of the heavy minerals.

Monazite Content of non-magnetics	Annual monazite production	
	60% Recovery	90% Recovery
1.66% *	Range 253 to 300 tons	379 to 450 tons
1.78% /	271 to 322 tons	406 to 482 tons

* Derived from figure of 4.3% monazite in non-magnetics separated by South Australian Mines Department as 14% by weight of heavy minerals. (See "Composition. Monazite").

/ Derived from figure given for non-magnetics in Appendix 1, Table 2, i.e. $2.3 \times \frac{77.4}{100}$

The estimates given earlier, viz. 291 tons at 60% recovery and 436 tons at 90% recovery fall within the ranges of the alternative estimates.

TABLE 5

Possible Annual Production of Monazite, Bunbury-Capel Area, W.A.

Company and Possible Annual Ilmenite Production	Ilmenite in mixed heavy min. conc. %	Ilmenite recovery (est.) %	Monazite in mixed heavy min. conc. %	Recovery of monazite (Est.) %	Recovery of monazite Annual Production Tons
Cable (1956) Ltd. 80,000 tons	90.7	90 *	0.4	50	196 tons
Western Titanium Ltd. 100,000 tons	91.6	90 *	0.4	60 90 ≠	291 tons 436 tons
Westralian Oil Ltd. 100,000 tons	77.9	90 *	0.9	60 85 ≠	770 tons ≠ 1,091 tons ≠
TOTAL					1,257 tons 1,723 tons ≠

* Recovery at December, 1957, was approximately 70-80%. If plant is installed to treat non-magnetic fraction, e.g. for recovery of monazite, probably at least half the ilmenite in it will be recovered, giving a total of about 90% recovery.

≠ Western Titanium quoted a reported 90% recovery and Westralian Oil 85% recovery of monazite by C.S.I.R.O. Metallurgical Research Laboratory. Experience of east coast producers suggests that this high recovery as high grade monazite concentrate is unlikely.

Westralian Oil Ltd.

The Company doubts whether monazite can be recovered economically from the Capel deposit. They plan to start mining at Yoganup, where the monazite content is higher. Using the data of Tables 2 and 5, annual production is:

$$\frac{100,000}{1} \times \frac{100}{77.9} \times \frac{100}{90} \times \frac{.9}{100} \times \frac{60}{100}$$

= 770 tons.

The Company reports a recovery by C.S.I.R.O. of 85% of the monazite from Yoganup mixed concentrates, reputed to contain 2% monazite. This recovery would increase the annual yield of monazite to 1,091 tons. However, the comment given above regarding the reported high recovery from Western Titanium's concentrates applies here, viz., it is thought very unlikely that this high recovery could be attained in the form of a high grade concentrate.

The production figures given in Table 5 are possible only if Yoganup sands exclusively are mined. If some production is from the Capel leases the yield of monazite, if it can be recovered economically, will be much lower. Per ton of Capel concentrate treated, it would equal the yield estimated for Western Titanium Ltd.

POSSIBLE FUTURE DISCOVERIES

It is possible that new deposits may be discovered by prospecting areas that have the same position relative to the coastline and same height above sea level as known deposits, and by prospecting at other heights above sea level that have been found favourable elsewhere for deposition of beach sand minerals. In either case the work is likely to be hampered in that in many properties the mineral rights are vested in the landholder.

The deposit at Bunbury may be one of a number of similar ones at or near the present shoreline, deposited a little above usual high tide level. On the east coast similar deposits occur commonly up to several hundred feet, and exceptionally up to nearly half a mile inland. The locality of the deposit is marked by a former foredune which developed at the top of the beach.

The Capel deposits were deposited on several old parallel beaches within a width of a few hundred feet of one another. The old foredune is clearly visible, although its continuity is broken by coastal streams that have cut channels across it. Broad low dune ridges of similar aspect have been noticed a considerable distance north of Bunbury, and these may be worth prospecting.

The Yoganup sands were deposited on a shoreline that existed along the Whicher Scarp. Other beaches must have occurred at the same level both to the north and to the south. They are considerably older than the other deposits at lower heights above sea level. The foredunes that marked the former shorelines have been eroded and obliterated

by drainage from the adjacent country to the west, which is underlain by solid rock.

Deposits at other heights above sea level possibly occur within the coastal plain. Along the east coast of Australia the major deposits are those of the Bunbury type, which rise little above sea level and occur up to several hundred feet inland. Two other series of deposits with considerable reserves usually in part indurated, occur inland and their bottom levels are about 5 ft. and 10 ft. above present high tide level. As these deposits are apparently associated with the high sea levels of the Pleistocene glaciation, it is possible that a series of deposits occurs at about 20 ft. above present high tide level.

Railway datum in the Bunbury area is 95 ft. above mean low water, viz. approximately 100 ft. above high tide level. Hence the reduced levels of the bases of the deposits will be approximately on Railway datum:

		Level with respect to present sea level
100 ft.	e.g. Bunbury deposit	0
105 ft.	Known in east coast (Expected a short distance inland from the deposits of the Bunbury type).	+5'
110 ft.	Known on east coast	+10'
120 ft.		+20'
160 ft.	Capel deposits	+60'
250 ft.	Yoganup deposits	+150'

REFERENCES

BAKER, G., and EDWARDS, A.B., 1956 - Gravity concentrates from beach sands at Capel, Western Australia. C.S.I.R.O., Mineragraphic Rep. No. 657.

GARDNER, D.E., 1958 - Estimated reserves and monazite content of beach sand deposits near Bunbury, W.A. Bur.Min.Resour.Aust. Records C1958/1.

_____, 1955 - Beach-sand heavy-mineral deposits of Eastern Australia. Bur.Min.Resour.Aust. Bull. 28.

APPENDIX I

Notes on Individual Companies - Mining, Treatment, Future Plans

Cable (1956) Ltd.

Mining

The Company is bulldozing rich concentrates from the deposit and trucking to the plant, a distance of a few hundred feet. Attempts have been made to work the pit by suction dredge, but without success.

Treatment

The treatment process is summarized in Table 1.

Appendix I Table I - Summary of Treatment - Cable (1956) Ltd.

	Composition of Samples taken December, 1957.							
	Heavy Min. Wt. % of sample	Heavy Minerals (see footnotes for other minerals)						
		Il.	Leuc.	Zirc.	Rut.	Mon.	Gar.	Others
Sand as mined	43.9	90.7	1.6	2.3	0.8	0.5	3.8	(1)
Rotary drier								
Magnetic separators -- Tailings stockpiled								
	21.8	48.9	3.2	26.6	6.4	0.5	7.5	(2)
	99 +	98.4		0.1		0.25	1.2	(3)
Electrostatic Separators -- Tailings stockpiled								
	98.5	89.5	0.6	0.4		3.2	6.0	(4)
Pro Product	99.7+	99.7						(5)

Other Minerals

(1) Epidote, hypersthene, green spinel, staurolite, biotite 0.3%.

(2) Epidote 3.2%, pyroxene 2.8%, tourmaline 0.7%, corundum 0.2%.

(3) Leucoxene, epidote, pyroxene, tourmaline 0.05%

(4) Hypersthene 0.3%

(5) Zircon, rutile, leucoxene, monazite, felspar, quartz, carbonate 0.3%.

On the basis of the proportions of ilmenite in the magnetics and tailings from magnetic separation it is estimated that the magnetic fraction contains 82.5% and the non-magnetic fraction 17.5% of the original heavy mineral concentrate. This indicates that the monazite content of the concentrate in the head feed was 0.4%. The

proportions of ilmenite in the conductors and non-conductors from the electrostatic separators suggest that the conductors contain 87.2% of the feed to the electrostatics. The recovery of ilmenite is hence $98.4 \times \frac{82.5}{100} \times \frac{87.2}{100} = 70.8\%$

A large proportion of the ilmenite lost should be recovered if plant is installed to separate monazite and zircon.

Future Plans

A second rotary drier is being installed. Two cone separators are being installed to take the low S.G. minerals from the head feed. This will permit the mining of lower grade sand. Wilfley tables now at the plant, will presumably be used eventually for concentrating the head feed, enabling the cone separators to be used for the tailings from magnetic and electrostatic separation.

Western Titanium Ltd.

Mining

A pit covering an area of several acres is worked by hydraulic mining, the monitors operating at about 50 lb./sq. in. Indurated sand that remains unbroken is pushed aside into dumps by a bulldozer. The sand and water runs down gutters dug in the bottom of the pit to a sump, where it is pumped up to rotating tubular screens, of 40 mesh openings. The over-size (18%) returned to the pit and the -40 sand, reported to be 83% of the feed to the screens, is concentrated over Humphry spirals.

Treatment

A summary of the treatment is given in Table 2.

Appendix I, Table 2 - Summary of Treatment Process, Western Titanium Ltd.

	Compositions of Samples taken Dec. 1957						
	Heavy Min. Wt. %	Heavy Minerals (see F'note for Oth.Min.) Il.	Leuc.	Zirc.	Rut.	Mon.	Others
Sand from pit							
Tubular rotary screen							
Primary spirals							
Secondary spirals							
Cone de-waterer							
Draining, on floor	92.9	91.6	0.2	6.0	1.8	0.35	(1)
Primary magnetics -- Tailings stockpiled							
	77.4	70.3	1.4	22.3	3.7	2.3	(2)
	99.7+	99.7		0.5			(3)
Cleaner magnetics -- Tailings re-circulated (?)							
Product							

Other Minerals

(1) Trace of tourmaline, corundum, and green spinel.
(2)
(3) Monazite, rutile, leucoxene, quartz, carbonates, felspar 0.25%.

Notes on Plant.

The spiral plant consists of 30 primary and 30 secondary spirals. The concentrate from the spirals is pumped to the separation plant, de-watered, and dropped on to the floor in dumps to drain. It is raised by an overloader to a small chute feeding a rotary drier. The dried concentrate is raised by bucket elevator to a battery of 24 Rapid cross-belt magnetic separators, which take out the ilmenite. The tailings containing the monazite are stockpiled.

Production is said to be about 100,000 tons per annum running about 600 hours per month. The total non-magnetics is about 16,000 lb. per hour, and it is stated to contain 25 to 30% of the heavy minerals.

Future Plans

The Company intends to instal shaking tables and electrostatic separators to produce monazite and perhaps zircon.

Westralian Oil Ltd.

The Company proposed to instal a pilot plant to be producing in September, 1958. A full scale plant to be erected later at Capel would have a capacity of at least 100,000 tons ilmenite per annum, and by-product monazite. Initial mining is to be at Yoganup.

APPENDIX 2.

DETAILS OF LEASES AND DEPOSITS

The attached table summarizes lease numbers and surface dimensions, surface dimensions of deposits, and gives an estimate of reserves held by Western Titanium Ltd. The drawings of Plates 2 to 4 show the approximate positions of the deposits in the leases. (The localities of the leases are shown in Plate 1).

APPENDIX 2. LEASES COVERING BEACH SAND DEPOSITS, BUNBURY-CAPEL AREA, WESTERN AUSTRALIA.

Company	Lease No.	Area Acre	Rd.	Pch.	Surface Dimensions of Heavy Mineral Deposit and Reserves, computed from Company Boring Records: Length Chains	Max. Width Chains	Av. Width Chains	Area Acres	Av. Thickness Feet	Av. Grade Wt. %	Reserves Heavy Minerals Tons	
Cable (1956) Ltd. Bunbury (Plate 1)	DC 64	300			No boring had been done up to 18/12/57. ✱ By 18/12/57, the date of inspection, at the south-western extremity of the deposit, in DC 56 an area approximately 500' x 100' had been exposed by stripping. Probably the deposit extends in a narrow strip no wider than 100 ft. parallel to the shoreline of DC 56 and DC55, and possibly DC 63.							
	56	90										
	62	140										
	65	180										
	63	190										
Western Titanium Ltd. Capel (Plates 1 and 4)	S.W. part of Capel town site ⁄	100 (approx.)			50	6	4.5	22.5	22.4	46.7	517,275	Reserves estimated by converting average grade in weight per cent to lb. per cu. yd. using curve included with this report. (Fig. 1)
	MC 516	10	0	8	92	10.5	6.6	60.7	28.9	47.7	1,342,518	
	517	148	0	13								
	524	40	2	18	146	17	10.9	159.1	23.3	22.2	1,655,365	
	528	80										
	527	80										
	526	80	0	39								
	525	68	3	16	24	6.5	3.7	8.9	21.2	19.2	73,383	
	557	200	0	16	29.5	8.5	5.2	15.3	19.6	11.1	110,800	
	558	199	3	23	No deposit							See Appendix 3.
	559	237	0	5	114.5	18.5	11.1	127.1	21	15.4	817,014	
	574	160										
	530	250 (approx.)			127.5	20.5	11.3	144	17.4	15.3	766,967	
	529	200					Total	637.6		Total	5,283,322	
Westralian Oil Ltd. Capel (Plates 1 and 3)	MC 571	106			221.2	24.2	13.4	296.4				Shafts sampled in the Capel area by B.M.R. covered an effective deposit area of 173.9-24.1 = 149.8 acres. Average grade was 538.8 lb/cu. yd. and average thickness 19.6 ft. Tonnage of heavy mineral estimated from these figures is 1,139,388 Assuming that the remainder of the Capel area carries heavy mineral in the same proportions the total would bear the same ratio to this tonnage as 296.4 is to 149.8. It would be 2,254,393 tons.
	546	300										
	608	220										
	638	163										
	548	300										
	647	40 (approx.)										
	549	250										
	646	50										
	576	290										
Yoganup Extended (Plate 1)	MC 587	300			Deposit not examined and data not available.							
	586	300										
	588	300										
Yoganup (Plates 1 and 2)	609	160			108.1	13.3	8.9	96.3				The deposit extends unbroken through MC 618, 619 and about 900 ft. north into MC 617 and 900 ft. south into MC 620. Shafts sampled by BMR covered an effective area of 50.4 acres. Average grade was 824 lb/cu. yd. and, average thickness 19.6 ft. Estimated reserves on the basis of these figures amounts to 586,173 tons. This however is fictitious because seven of the nine shafts were put down in relatively high-grade parts of the deposit (previously ascertained by auger sampling). However, there is no reason to doubt the Company's claim that the deposit contains 600,000 tons heavy mineral.
	582	300										
	581	225										
	617	128										
	618	124										
	619	100										
	620	100										
Tutunup (Plate 1)	621	100			Deposit not examined and data not available.							
	622	100										
	623	100										
	624	100										
	625	100										

a ✱ Up to date of inspection on 18/12/57 the south-western extremity only of the deposit, in DC 56, had been investigated.
⁄ Lease number not available.

APPENDIX 3.

Estimate of Reserves held by Western Titanium Ltd., Based on Company's Sampling Data (excluding sand containing less than 6% by weight of heavy mineral)≠

Leases See Plate 3.	Averages: Thickness of deposit (Ft.)	Averages: Grade: Wt. per cent heavy mineral.	Averages: Grade: Lb. per cu. yd. (from Fig. 1)	Area of Deposit (acres)	Reserves of Heavy Mineral (tons)
Loc. 46.	22.4	46.7%	1,425	22.5	517,275*
MC 516 517	28.9	47.7%	1,470	60.7	1,342,518Ø
524 528 527 526	23.3	22.2%	620	159.1	1,655,365
525	21.2	19.2%	540	8.9	73,383
557	19.6	11.1%	315	15.3	110,800
559 574	21	15.4%	425	127.1	817,014
530 529	17.4	15.3%	425	144	766,967
TOTAL					5,283,322 ≠

≠ Sand of grade lower than 6% by weight occupies a very small area and would not appreciably increase the reserves.

* The Company estimate stated in the 1st Annual Report, 1957, is 750,000 tons.

Ø The Company estimate stated in the Prospectus is 3,476,800 tons.

≠ The Company estimate stated in a report to the A.A.E.C. October, 1957, is 11,485,000 tons.

APPENDIX 4.

Western Titanium. Alternative Estimate of Probable Monazite Production.

The Company gives figures of monazite content based on the results of examination of various samples by C.S.I.R.O. Metallurgical Research Laboratory and South Australian Mines Department. A report by the South Australian Mines Department is quoted that magnetic separation of a sample of Western Titanium's mixed concentrate gave 14% tailings containing 4.3% monazite. In discussions at the plant it was stated that to produce about 100,000 tons ilmenite per annum the plant runs approximately 600 hours per month, total non-magnetics is about 16,000 lb. per hour, which contains 25-30% of the heavy minerals, and monazite content of non-magnetics is about 600 lb. per hour.

Examining these figures - assume that the composition of the non-magnetics is as stated in Appendix 1, Table 2. Percentage monazite in the heavy mineral fraction of the non-magnetic is $\frac{600}{1} \times \frac{100}{77.4} \times \frac{1}{16,000} \times \frac{100}{1} = 4.8\%$

Remembering that the figures of plant throughput are in round numbers, it is obvious that the monazite percentage is that stated by the South Australian Mines Department, for non-magnetic tailings which constituted 14%, not 25-30% of the total heavy minerals. If the figure of 4.3% is to be used it should be reduced by a factor that ranges from $\frac{14}{25}$ to $\frac{14}{30}$, say $\frac{14}{28}$ or $\frac{1}{2}$ and the appropriate figure is then 2.15%.

The head feed to the magnetics, from Appendix 1, Table 2, is 93% heavy mineral, 7% quartz, or 85% ilmenite, 8% (other H.M.), 7% quartz.

The non-magnetics consist of the 8 (other H.M.) + 7 Qtz. + x Ilm. and it is 25 to 30% of the total heavy mineral.

A simple calculation shows that x is:

For non-magnetics 25% of H.M. = 15.25
" " " 30% " " = 19.9

The proportion of ilmenite ranges from $\frac{15.25}{23.25}$ to $\frac{19.9}{27.9}$ i.e. 66% to 71%. This compares with 70.3% in the table.

The percentage ilmenite in the total non-magnetics ranges from $\frac{15.25}{30.25} = 50\%$ to $\frac{19.9}{34.9} = 57\%$.

Ilmenite per hour in non-magnetics ranges from $\frac{50}{100} \times 16,000$ to $\frac{57}{100} \times 16,000$.

The ratio of commercial ilmenite produced concurrently with the ilmenite in the non-magnetics ranges from $\frac{85 - 15.25}{15.25} = \frac{70}{15}$ (approx.) to $\frac{85 - 19.9}{19.9} = \frac{65}{20}$ (approx.), hence production per hour of commercial ilmenite ranges from $\frac{50}{100} \times 16,000 \times \frac{70}{15}$ lb. to $\frac{57}{100} \times 16,000 \times \frac{65}{20}$ lb.

Hours to produce 100,000 tons is calculated to range from 6,000 hours to 7557 hours.

Monazite contained in the non-magnetics ranges from $16{,}000 \times \frac{2.15}{100} \times \frac{6{,}000}{2{,}240}$ to $16{,}000 \times \frac{2.15}{100} \times \frac{7557}{2240}$

or 921 tons to 1160 tons.

These figures, however, are subject to three qualifications, each of which progressively reduces them.

(1) It was shown in the paragraph on "Composition. Monazite" that although the head concentrate that yielded the non-magnetics containing 4.3% monazite contained 0.6% monazite, the average monazite content throughout the thickness of the deposit was probably 0.4%. Hence the monazite production should be reduced to $\frac{0.4}{0.6}$ or two-thirds the above, viz. to 614 tons and 773 tons.

(2) The concentrate that yielded the magnetics containing 4.3% monazite must have contained only a very small proportion if any of low specific gravity minerals. This is evident from inspection of Appendix 1, Table 2, in which it is obvious that the heavy minerals being fed to the magnetic separators could not yield such a low proportion of non-magnetics, unless perhaps a large percentage of the zircon went into the magnetic fraction. It must be assumed that the concentrate which yielded the 4.3% monazite reduced to 2.15% was virtually free from low S.G. minerals. Assuming that the same relative proportion of monazite went into the concentrate of Appendix 1, Table 2, its percentage would be close to $2.15 \times \frac{77.4}{100} = 1.66\%$, and the quantity contained in the non-magnetics would be similarly reduced, viz. to 475 tons and 598 tons.

(3) If plant is installed to recover monazite presumably some of the ilmenite contained in the non-magnetic tailings, say 60% of it will be either returned to the ilmenite plant and re-circulated or separated as commercial grade ilmenite. The proportion of additional ilmenite which will be recovered will be $\frac{60}{100} \times 15.25$ and $\frac{60}{100} \times 19.9 = 9$ and 12 (approximately), i.e. the total ilmenite recovered from the head feed, which contains 85 units per cent is 79 and 77. This reduces the quantity of sand as mined to $\frac{70}{79}$ and $\frac{65}{77}$ of the former quantities, and hence the quantity of monazite entering the plant should range from $\frac{70}{79} \times 475$ to $\frac{65}{77} \times 598$, i.e. 421 tons to 500 tons.

The above figures relate to the monazite contained in the non-magnetic fraction. Suppose 60% of it can be recovered as high grade concentrates, actual production will range from 253 to 300 tons per annum. Recovery of 90% , which is considered unlikely, would yield 379 to 450 tons per annum.

Note: The monazite figure given for the heavy mineral fraction of the non-magnetics in Appendix 1, Table 2, is 2.3%. As a percentage of total non- magnetics this equals $\frac{77.4 \times 2.3}{100} = 1.78\%$.

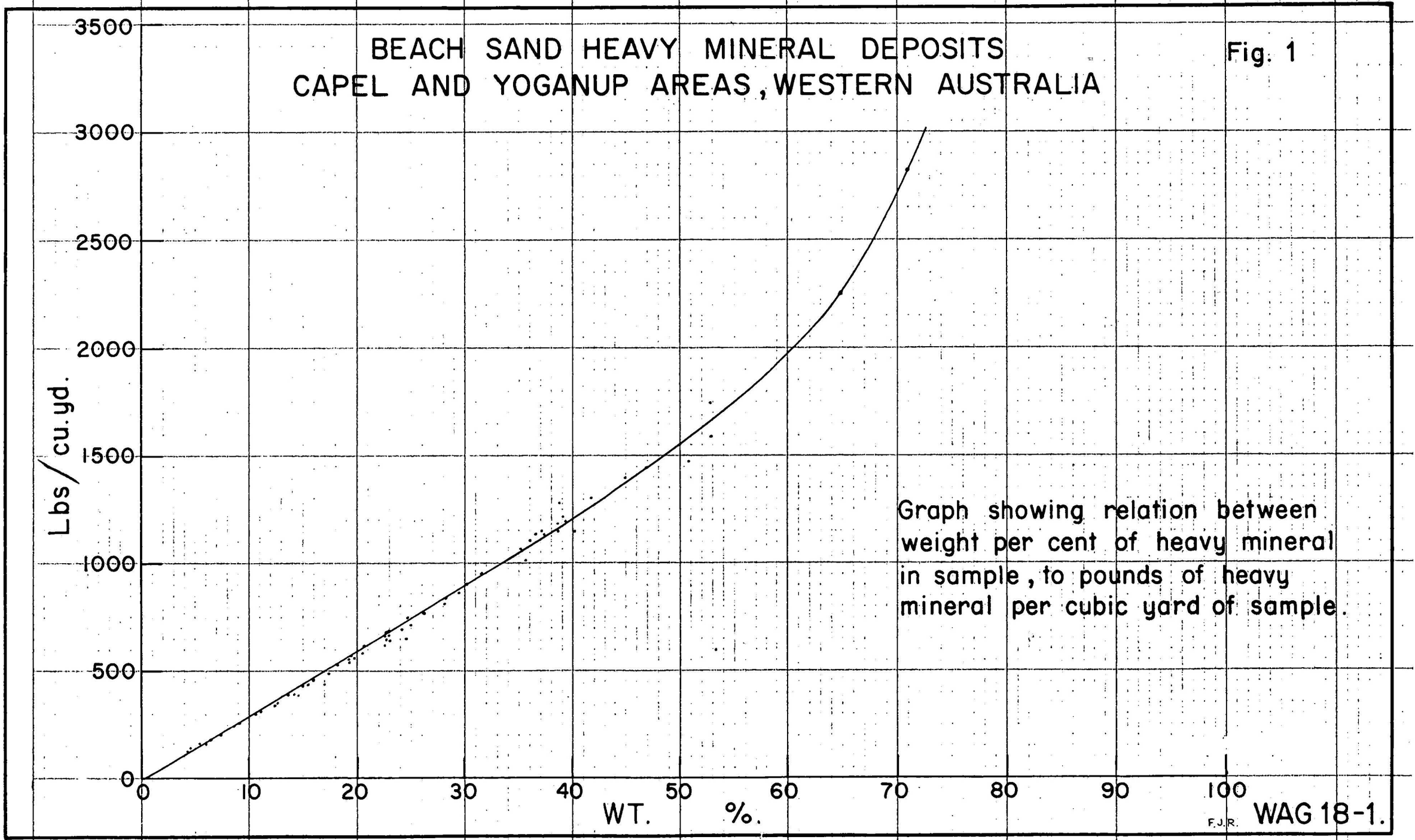
Using this figure in place of the 1.66% derived above would increase the estimate of total monazite in non-magnetics to the range 451 tons to 536 tons and the probably annual production as follows:

60% recovery, range 271 to 322 tons.

90% recovery, range 406 to 482 tons.

BEACH SAND HEAVY MINERAL DEPOSITS
CAPEL AND YOGANUP AREAS, WESTERN AUSTRALIA

Fig. 1



Graph showing relation between weight per cent of heavy mineral in sample, to pounds of heavy mineral per cubic yard of sample.

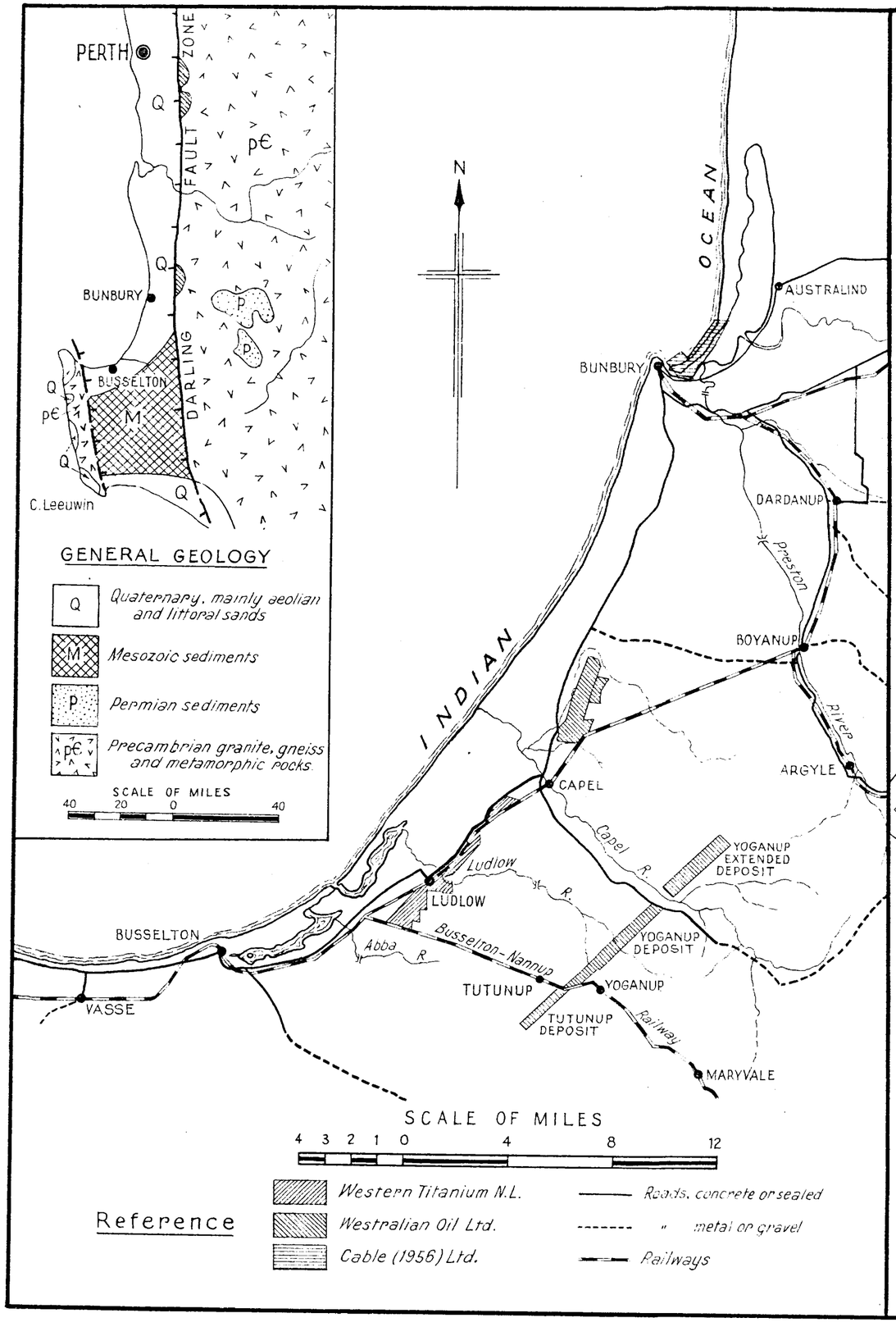
F.J.R. WAG 18-1.

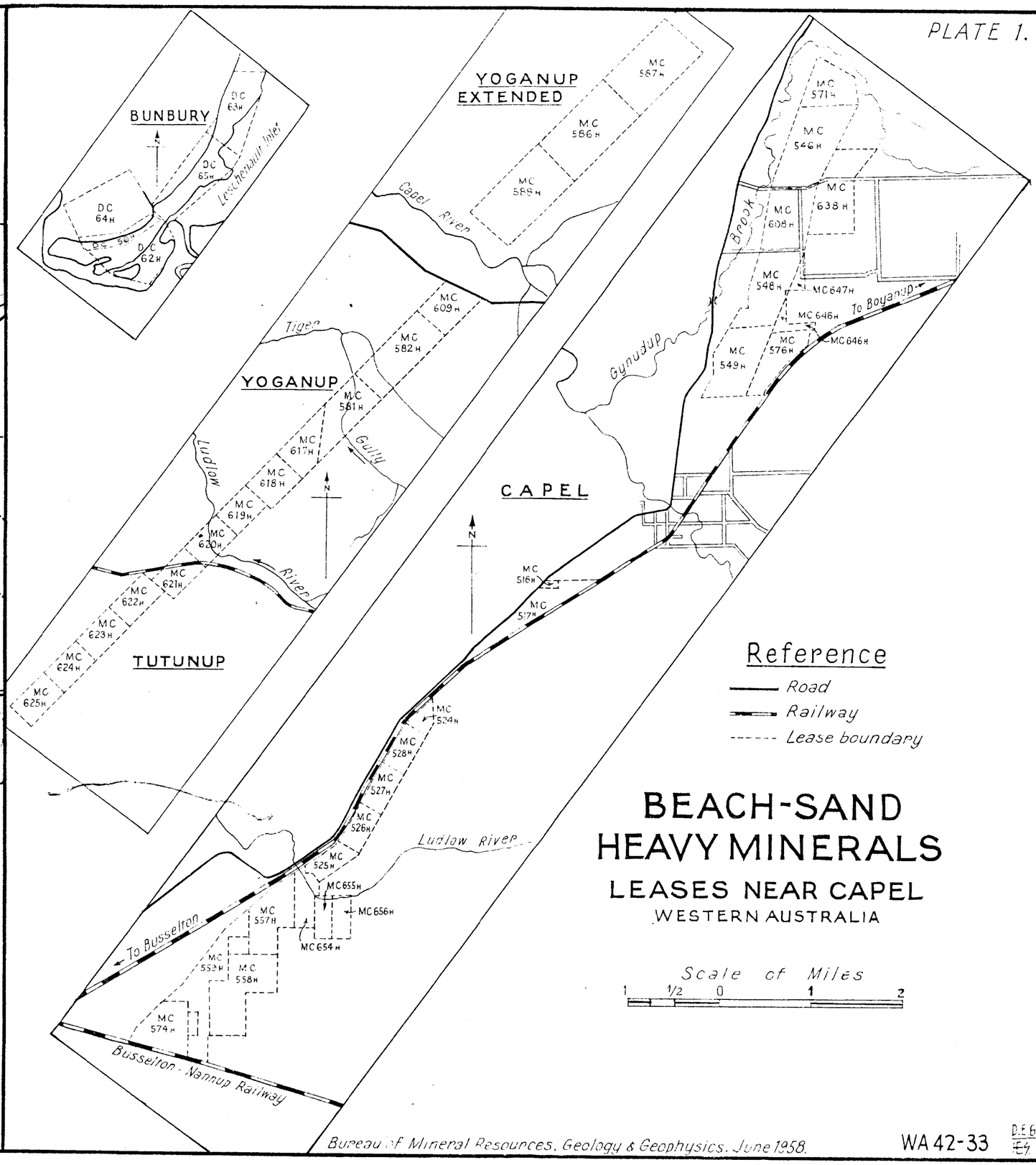
PLATE 1.

BEACH-SAND HEAVY MINERALS

LEASES NEAR CAPEL

WESTERN AUSTRALIA





Bureau of Mineral Resources, Geology & Geophysics. June 1958.

WA 42-33

D.E.G. 54

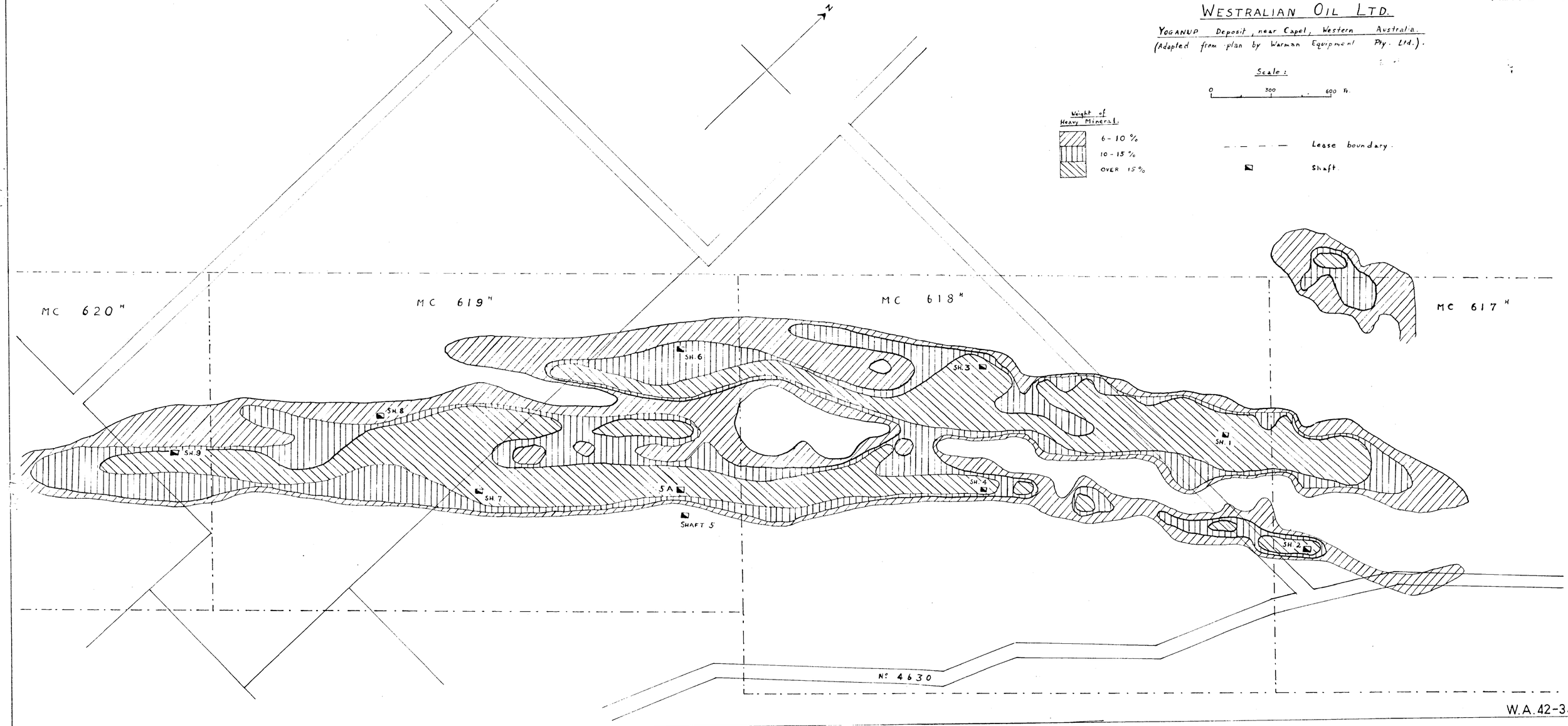
WESTRALIAN OIL LTD.

YOGANUP Deposit, near Capel, Western Australia.
(Adapted from plan by Warman Equipment Pty. Ltd.).

Scale: 0 300 600 Ft.

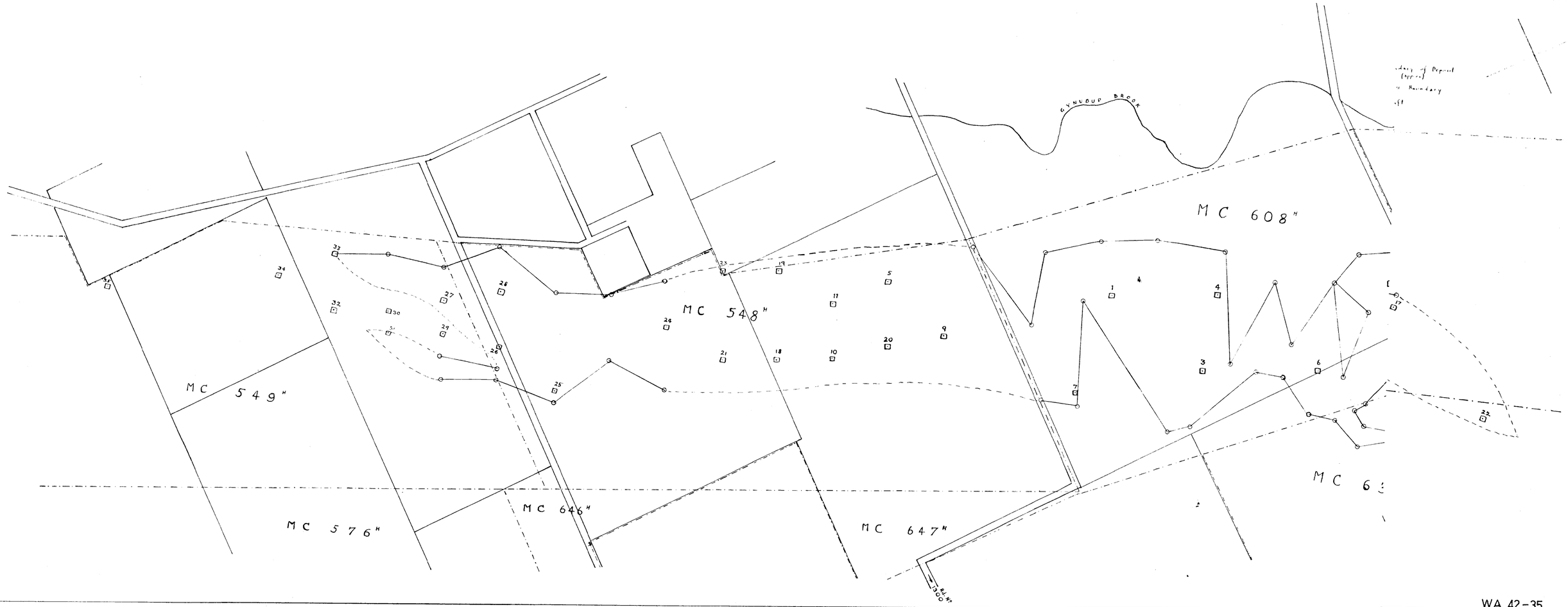
Weight of Heavy Mineral.
6 - 10 %
10 - 15 %
OVER 15 %

Lease boundary.
Shaft.



W.A. 42-34

PLATE 3



W.A. 42-35

WESTERN TITANIUM LTD.

Leases and Heavy Mineral Deposits near Capel, Western Australia.
(Compiled from Company's sampling plans).

Scale:

0 10 20 30 Chains

MC 516
DUNES
CREST
SAND
CLAY
BANK
RAILWAY
MC 517
PT LOC. 46
N

Lease Boundary
Boundary of Deposit

Scale

0 10 20 30 Chains

RAILWAY
ROAD
MC 528H
MC 524H
MC 527H
MC 525H
MC 526H
ROAD
EDGE
SELECTED AREA
STATE FOREST 12

MC 559H
LUDLOW STN.
MC 558H
MC 557H

352
353
ABBA RIVER
RAILWAY
MC 559H
MC 574H
1420

W.A. 42-36