1949.

WESTERN AUSTRALIA.

DEPARTMENT OF MINES

MINERAL RESOURCES OF WESTERN AUSTRALIA

BULLETIN No. 5

MOULDING SANDS

BY

K. R. MILES, D.Sc., F.G.S., Geological Survey of Western Australia

AND

H. A. STEPHENS, B.Sc., Council for Scientific and Industrial Research, Melbourne

[With twenty-five plates and two text figures.]

Issued under the authority of the Hon. H.S.W. Parker, Minister for Mines

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PREFATORY NOTE.

This bulletin deals with the properties and distribution of some sands considered to be useful as moulding sands. Material was collected from the following localities :—

Bardoc, Kalgoorlie, Tammin, Northam, Marchagee, Collie, Mumballup, Greenbushes and Perth.

The publication does not aim to cover the availability of moulding sands in the whole of Western Australia, but rather to indicate to potential users of this class of material, the physical properties of the sands and the laboratory methods used in testing them. A systematic search for deposits away from those sampled was not undertaken.

The field and laboratory investigations represent a joint effort by the Geological Survey of Western Australia and the Commonwealth Council for Scientific and Industrial Research respectively, the field work being done in 1943 and the laboratory work in the following year.

Publication has been delayed by a post-war accumulation of work at the Government Printing Office.

H. A. ELLIS,
Government Geologist.

27th April, 1949.

CONTENTS.

CHAPTER III.—KALGOORLIE MOULDING SANDS.

CHAPTER IV.—MISCELLANEOUS LOCALITIES.

A.—Collie.

B.—Tammin.

CHAPTER V.—CLAYS.

PLATES.

TEXT FIGURES.

LIST OF TABLES.

SUMMARY.

This bulletin sets out the results of a survey of the moulding sands of Western Australia.

The essential properties of, and the methods of testing moulding sands are first briefly described. The deposits are then divided as follows :—

(a) Perth Moulding Sands.
  1. Free Sands.
  2. Natural moulding sands.
    (i) Guildford.
    (ii) Byford-Cardup.
    (iii) Northam.

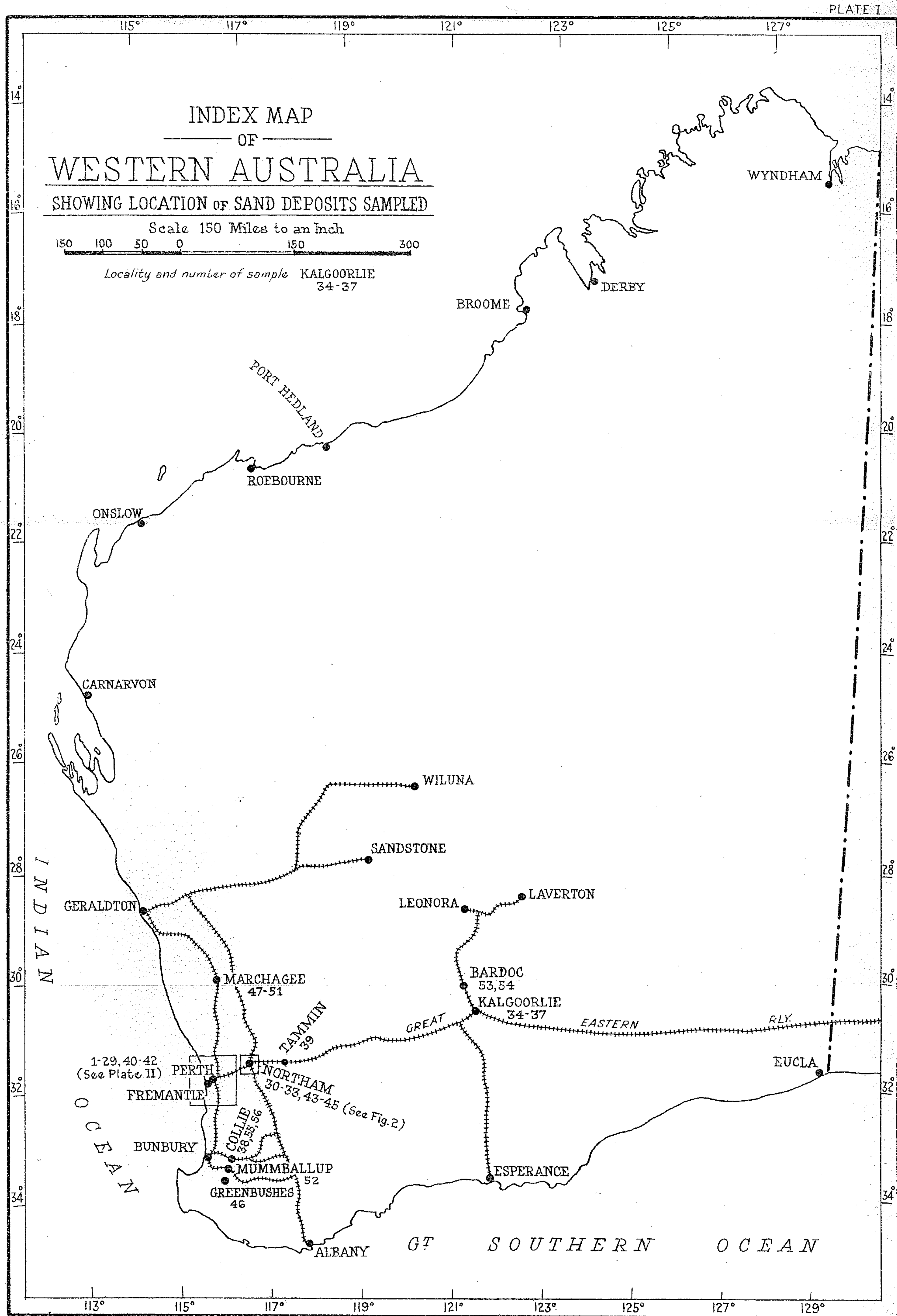
(b) Kalgoorlie moulding sands.

(c) Miscellaneous localities.

After a brief review of the geology of each area, with notes on the geological extent and distribution of the deposits, the pits are described and test results presented.

In a critical discussion it is pointed out that, in the Perth region, the free sands are with few exceptions excellent ; the medium-fine loams from Guildford and Northam are of poor quality and for cast iron could well be replaced by the medium grade loams from Byford and Cardup ; in the Kalgoorlie region the bonded sands are of poor quality and for cast iron could profitably be replaced by synthetic sands based on free sands from Kanowna and Mt. Hunt.

Clays which come from miscellaneous localities and which may prove suitable for synthetic sands have been tested.


INDEX MAP
OF
WESTERN AUSTRALIA
SHOWING LOCATION OF SAND DEPOSITS SAMPLED
Scale 150 Miles to an Inch
150 100 50 0 150 300
Locality and number of sample KALGOORLIE 34-37
115° 117° 119° 121° 123° 125° 127°
113° 115° 117° 119° 121° 123° 125° 127° 129°
14° 16° 18° 20° 22° 24° 26° 28° 30° 32° 34°
WYNDHAM
DERBY
BROOME
PORT HEDLAND
ROEBOURNE
ONSLOW
CARNARVON
WILUNA
SANDSTONE
GERALDTON
LEONORA
LAVERTON
MARCHAGEE
47-51
BARDOC
53,54
KALGOORLIE
34-37
GREAT EASTERN RLY.
TAMMIN
39
EUCLA
1-29, 40-42
(See Plate II)
PERTH
FREMANTLE
NORTHAM
30-33, 43-45 (See Fig. 2)
COLLIE
38,55,56
BUNBURY
MUMMBALLUP
52
GREENBUSHES
46
ESPERANCE
ALBANY
INDIAN OCEAN
GT SOUTHERN OCEAN

Chapter I.

GENERAL INFORMATION.

INTRODUCTION.

Towards the end of 1942, the Western Australian State Committee of the Council for Scientific and Industrial Research requested that assistance be given by the Foundry Sands Section to the foundrymen of Western Australia. After discussion, it was decided that a joint survey of moulding sands in Western Australia should be made by the Geological Survey of Western Australia and the Council for Scientific and Industrial Research, and further that the survey should be sponsored by the Ministry of Munitions. Through the medium of a questionnaire, inquiries were made from foundries in Perth, Kalgoorlie and country districts as to the sources of supply and types of sand used by them. Information so obtained was used as a basis in planning the joint survey.

Field work was commenced in August, 1943, when the authors visited and sampled most of the sand and clay deposits of the Metropolitan Area and Northam District. During this period an inspection was also made of the Marchagee clay deposit, and one of us (H.A.S.) independently visited the Kalgoorlie district. Kalgoorlie sand deposits were further surveyed and sampled (K.R.M.) in March, 1944, and revisited (H.A.S.) in May, 1945. The Collie moulding sands were inspected (K.R.M.) in March, 1944, whilst several areas near Perth were again visited and sampled (H.A.S.) in May, 1945.

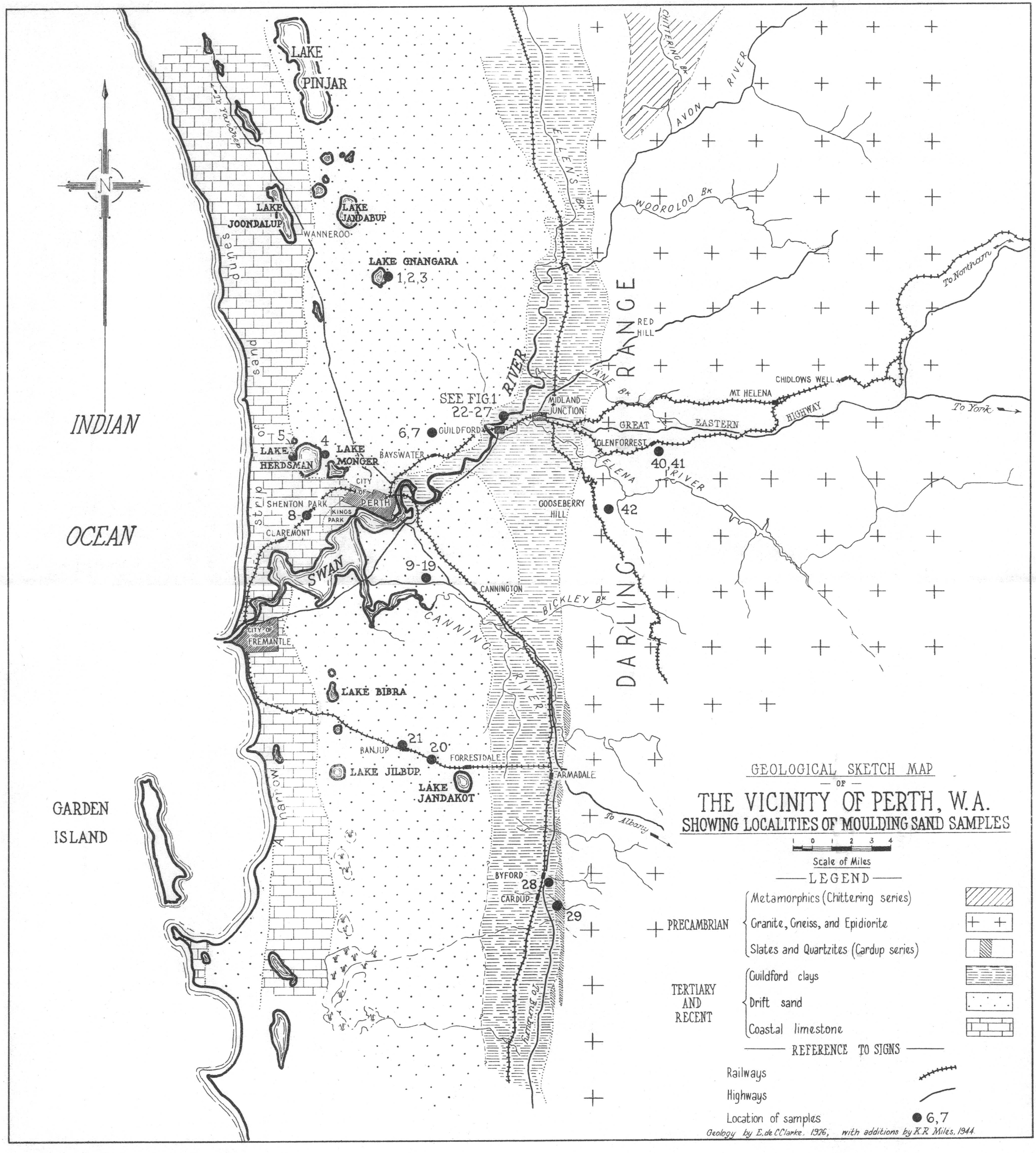
To locate and roughly delineate the deposits, surveying was carried out mostly by means of compass and pace traverses but a detailed plane table and telescopic alidade survey was made of one major deposit. Whenever possible inspections were made in company with the owner or operator of the deposit and samples were taken to include material not only representative of different portions of the deposit, but also representative of particular grades being marketed at the time. With few exceptions, prospecting for new deposits or pit-sampling of areas outside those already worked for foundry sands, was considered beyond the scope of the survey.

Moulding sands are a mixture of silica sand and other materials—principally clay and oxide of iron—which when properly blended and moistened with water can be formed into satisfactory moulds for metal castings. If a sand, as quarried, has sufficient binder to retain its shape after removal of the pattern from the mould, it is termed a "natural" moulding sand; if it requires the addition of a binder, it is termed a "free" sand, and the mixture a "synthetic" moulding sand. The ideal foundry sand consists of quartz grains and binder only. Most natural sands contain varying amounts of alkalies, magnesia and lime; these lower the fusion point of the sand and, if present in more than small amounts, may result in melting of the sand on contact with molten metal. A sand should contain no more than 0.5 per cent. total alkali. For a synthetic sand, a bonding agent such as bentonite or other suitable clay should be blended with the purest high-silica sand of suitable grain size.

Differences in the casting properties of alloys necessitate considerable variations in moulding sands. Engineering castings in iron and steel of heavy section are poured at a high temperature. Such castings require open-textured sands of high refractoriness. For stove and agricultural machinery parts, fine sands may be used to obtain a smooth skin, since the sections are thinner and therefore less gas is evolved on casting. Refractoriness is not quite so important for non-ferrous metals, which are usually cast at a lower temperature. Since the amount of gas evolved is small, fine sand is also used to obtain a smooth skin.

To form the inside shape of hollow castings such as pipes, it is necessary to insert cores in the moulds. The cores are usually made from fine-grained highly-siliceous sands which are held together by an artificial bond such as linseed oil. Cores are baked in an oven at such a temperature that they retain sufficient hardness and strength to maintain their shape without distortion until a thin shell of solid metal has formed. The artificial bond should then burn out, allowing the core to collapse when the casting is removed from the mould. Many aspects of making and baking foundry cores have been discussed by Stephens (1942).

In his classical investigation of British moulding sands during the 1914–18 War, Boswell (1918) placed much importance on the chemical analysis of sands. Analyses were made not only of bulk samples, but also of sized fractions. It was realised, however, that the chemical analysis, while supplying indirect evidence regarding refractoriness, could not hope to predict physical properties; it could not foretell whether a sand would have sufficient plasticity to retain its shape when moulded, nor could it indicate in any way the permeability of a rammed mould. Accordingly, between 1922 and 1924 the American Foundrymen's Association, in co-operation with the National Bureau of Standards and various other bodies, drew up standard specifications for testing the physical properties of sands. These have been revised and enlarged and are published under the title "Foundry Sand Testing Handbook. Standards and Tentative Standards" (A.F.A., 1944). Much work was also done in Great Britain by the Institute of British Foundrymen and


GEOLOGICAL SKETCH MAP
OF
THE VICINITY OF PERTH, W.A.
SHOWING LOCALITIES OF MOULDING SAND SAMPLES
1 0 1 2 3 4
Scale of Miles
LEGEND
PRECAMBRIAN
Metamorphics (Chittering series)
Granite, Gneiss, and Epidiorite
Slates and Quartzites (Cardup series)
TERTIARY AND RECENT
Guildford clays
Drift sand
Coastal limestone
REFERENCE TO SIGNS
Railways
Highways
Location of samples
6,7
Geology by E. de C. Clarke. 1926, with additions by K.R. Miles, 1944.
INDIAN
OCEAN
GARDEN
ISLAND
LAKE PINJAR
LAKE JOONDALUP
LAKE JANDABUP
WANNEROO
LAKE GNANGARA
1,2,3
LAKE HERDSMAN
LAKE MONGER
5
4
6,7
GUILDFORD
BAYSWATER
SEE FIG.1
22-27
MIDLAND JUNCTION
CITY OF PERTH
KINGS PARK
SHENTON PARK
8
CLAREMONT
SWAN
RIVER
9-19
CANNINGTON
CANNING
RIVER
CITY OF FREMANTLE
LAKE BIBRA
21
20
BANJUP
FORRESTDALE
LAKE JILBUP
LAKE JANDAKOT
ARMADALE
BYFORD
28
CARDUP
29
To Albany
To Bunbury
A narrow strip of sand dunes
To Yanchep
ELLENS BK
CHITTERING BK
AVON RIVER
WOOROLOO BK
RED HILL
DARLING RANGE
JANE BK
CHIDLOWS WELL
MT. HELENA
GREAT EASTERN HIGHWAY
To Northam
To York
GLENFORREST
40,41
HELENA RIVER
GOOSEBERRY HILL
42
BICKLEY BK

the British Cast Iron Research Association, and both these societies have established standards. Other European countries have followed the lead. The various specifications differ somewhat, but in degree rather than in principle.

Results of further tests on British sands and clays, bringing Boswell's survey up to date, have recently been published in the first and second reports of the Moulding Materials Sub-Committee of the Steel Castings Research Committee of the Iron and Steel Institute (I.S.I., 1938, 1942).

In conjunction with the research project to develop physical tests, the American Foundrymen's Association sponsored surveys of American moulding sands by the Geological Departments of the various States. A large number of samples were tested for permeability, strength and fineness. The results were published in the various State Geological journals, and in the Transactions of the American Foundrymen's Association for 1924–25 (A.F.A., 1924, 1925).

Some years later, Freeman made a study of moulding sands in Canada. His results are set out in Mines Branch Publication No. 767 (Freeman, 1936), of the Canadian Department of Mines.

In Australia, the Moulding Sands Committee of the Institute of Australian Foundrymen, in conjunction with the Council for Scientific and Industrial Research, has surveyed the deposits of moulding sands used in Melbourne. The results were published by the Institute in 1941 (I.A.F., 1941–42). The Council for Scientific and Industrial Research and the respective Mines Departments have conducted joint surveys of moulding sands in South Australia (Cornelius and Stephens, 1945) and in New South Wales (Stephens and Whitworth, 1948).

A number of foundries in Western Australia use a sand which is more or less satisfactory, and do not check the chemical analysis or the physical properties. More advanced foundrymen, however, have realised the benefits accruing from control of sand quality by means of routine physical tests.

The samples collected were submitted to preliminary examination at the Geological Survey Laboratories and then forwarded to the Foundry Sands Laboratory of the Division of Industrial Chemistry, Council for Scientific and Industrial Research, Melbourne, for physical tests. This bulletin sets out the findings of the survey.

PROPERTIES OF MOULDING SANDS.

The five properties of moulding sands most important in foundry practice, are :—(1) texture and other characteristics of the grain, (2) permeability, (3) cohesiveness or strength, (4) refractoriness, (5) durability.

Texture and Other Characteristics of the Grain.

These form the most important index of moulding sand quality. They have a direct bearing on the permeability, strength and refractoriness of the sand, and in addition, are paramount in determining the "finish" on the casting. Sands with coarser and more even grain size have greater permeability. Strength is governed to some extent by the area of contact; this area is greater in fine sands, which are therefore stronger. Lastly, coarse sands are the more refractory.

Permeability.

When a metal is poured into a mould a large volume of gas is generated and this must find its way out through the walls of the mould. The permeability of a moulding sand is a measure of the ease with which the gas may escape. The gases seeking exit are:—(a) air confined in the mould, (b) steam from the moisture in the sand, (c) steam from the combined water of the clay bond, (d) gases arising from material added (*e.g.*, coal dust) to the sand. On contact with molten metal, the moisture in the sand nearest the casting is volatilised and an enormous amount of vapour is formed, each volume of water producing a minimum of 1700 volumes of steam which must escape through the mould. Permeability depends on the size, shape, smoothness and particularly the size-distribution of the sand grains; on the amount of clay present; on the degree of ramming; and on the amount of water present. When a sand is too dry or too moist its permeability is lowered. It will be seen that many of the Western Australian sands have low permeability caused principally by the high clay content, the uneven size-distribution of the sand grains and the high proportion of fines.

Cohesivenesss or Strength.

A moulding sand must possess plasticity, *i.e.*, it must be capable of being formed into the shape of the mould, and must retain its shape when the pattern is removed. This depends mainly on the nature of the clay or other bonding material such as ferric oxide, and on the presence of water in the correct quantity. Strength is partly destroyed when the hot metal contacts the moulding sand; the effect is more marked with large castings owing to their greater heat content. It is therefore generally necessary to add fresh sand or binder before the sand can be re-used. The strength imparted by the binder depends on the nature and quantity of the clay minerals present. Recent researches have indicated that of the three main types of clay important as binders, the montmorillonite type, which is the base of Wyoming bentonite, produces great strength, the illite type intermediate strength, and the kaolinite type poor strength.

Refractoriness.

Refractoriness of a moulding sand is defined as the ability to withstand heat without "burning on" the casting. The clay substance, especially in those sands which contain active fluxes, lowers the fusion point of the mixture, the temperature of which will depend on both the amount and type of clay. The grain size and surface area of the sand exposed to the action of heat is important, the coarser being less affected than the finer grain. Where the casting is large, or of heavy section, greater refractoriness is required to counteract the sustained heat which penetrates the mould.

Durability.

The durability of a sand is its ability to retain its original physical and chemical properties so that it may be used over and over again. After a sand has been moulded a number of times, it often becomes "dead burned." When this happens, it is incapable of developing suitable strength when tempered, *i.e.*, moistened, and must be discarded.

Moisture.

Moisture is a constituent, and not as is sometimes incorrectly suggested, a property of a moulding sand. Its function is to develop strength and permeability, both of which depend on the amount of water added ; frequently small differences in moisture may result in large changes in the permeability and strength. The percentage of water required to obtain the best results varies from sand to sand, and is dependent on the grain size and grain distribution, as well as the amount and type of bond.

The "optimum" moisture content is the moisture at which maximum strength and permeability are developed.

METHODS OF TESTING.

Sampling.

Precautions were taken to secure representative samples of the sand in the pits. Small lots were obtained from all parts of the face, and these were combined to give a bulk sample of 5 to 10 lb., which was crushed lightly and thoroughly mixed. The sample for the fineness test was obtained by riffling, and the remainder was mixed in a Simpson mill as described below. It must be emphasised that the tests apply only to material similar to the samples tested, and would not necessarily apply to the whole of the deposit, *e.g.*, some pits provide more than one grade of material.

Preparation of Sample.

The sample was prepared for routine tests as follows (the procedure is similar to that of the American Foundrymen's Association but modified slightly to suit the Council for Scientific and Industrial Research laboratory conditions) :—The sand was dried at 105°C. and then mixed dry for two minutes in a laboratory-size Simpson mill. The appropriate quantity of water was then added, and the sand was milled for a further five minutes, emptied on to a six-mesh B.S.S. sieve and riddled into an airtight container. It was allowed to stand for at least 24 hours before testing.

When testing sands at different moisture contents :—

(i) If a higher moisture content was needed, the correct amount of water was added with a spray. The sand was thoroughly mixed by hand, passed through the riddle and allowed to stand for 24 hours before testing.

(ii) If a lower moisture content was needed, a calculated quantity of sand was dried at 105°C., and added to the remainder. The whole was then thoroughly mixed by hand, riddled into an airtight container and allowed to stand for 24 hours before testing.

Where possible, tests were started at a low moisture and the latter then increased rather than at a high moisture followed by a decrease.

Moisture Content.

Sands were tested at three or more appropriate moisture contents, to cover the range within which it was thought their optimum properties would lie.

Testing.

The sands were submitted to the following tests :—(i) fineness, (ii) moisture, (iii) permeability, (iv) green compression strength.

Tests of permeability and strength at varied moisture contents have been styled " routine tests," since these tests are conducted most frequently (once or more per day) for routine control of sands. The grading of sand in a system does not change rapidly, so that the fineness test, though extremely important, is conducted less frequently.

Fineness Test.

A moulding sand may be divided into "sand" (larger quartz particles) and " clay substance " (fine quartz particles and clay). The object of a fineness test is to determine the amount of " clay substance " and the distribution of the different sized " sand " grains.

The fineness test was conducted according to the methods of the American Foundrymen's Association with minor modifications to suit the Council for Scientific and Industrial Research laboratory conditions. Fifty grams of sand were placed in a " sand wash jar " (Plate III.), 500 ml. of 0.15 per cent. sodium hydroxide solution were added, and the contents were stirred mechanically for five minutes with an impeller speed of 7,000 r.p.m. Water was then added until the total height was six inches. After settling for 10 minutes, five inches of the liquid were removed by a siphon. This process of adding water, settling and siphoning was repeated until the liquid remaining after settling was perfectly clear. The first two settling periods were ten minutes (in order to avoid difficulties arising from increased viscosity and apparent density of the clay-water suspension), after which the intervals were five minutes.

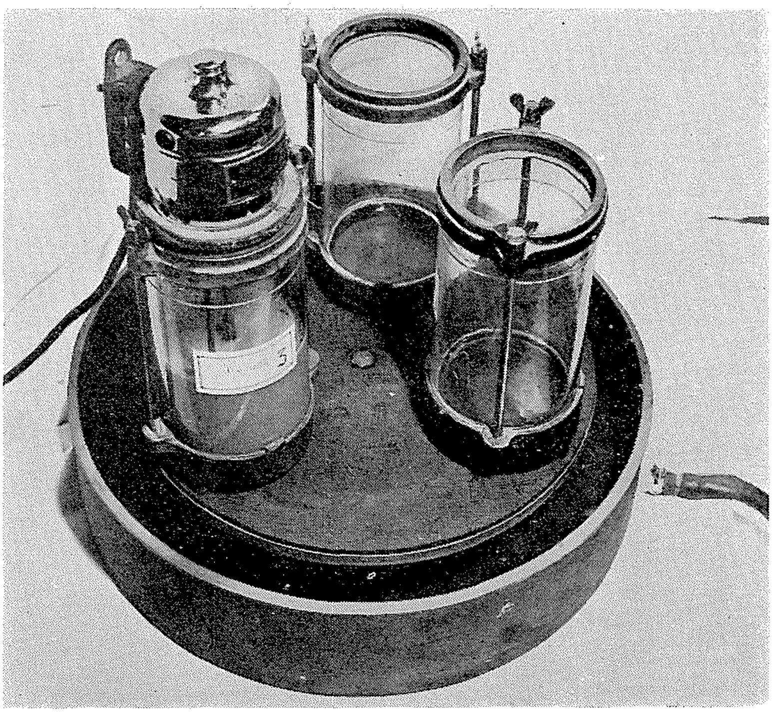


PLATE III.
Clay Washing Apparatus.

To obviate changes (caused by variations in viscosity with temperature) in the size of particle settling, a simple heater to provide water at a temperature of 27 ± 2°C. has been installed. Observations have shown that the temperature in the laboratory varies from 28°C. in summer to 10°C. in winter, with consequent variation in the viscosity of water from 0.84 to 1.31 centi-poises : thus at maximum laboratory temperature particles of 20-micron size would settle whilst in winter only 23-micron particles could fall. Distilled water was not used since this has been shown to be unnecessary by reason of the extreme purity of Melbourne tap water.

The American Foundrymen's Association clay substance* (which did not settle faster than one inch per minute) remained suspended and was removed. The sand remaining in the jar was dried and weighed and the percentage of clay substance was calculated from the loss in weight.

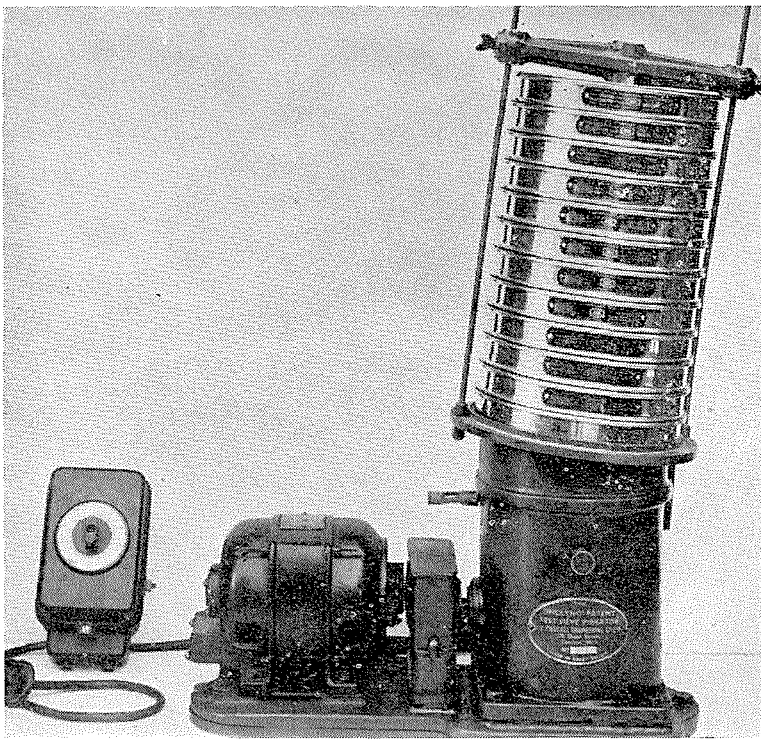


PLATE IV.
Inclyno Sieve Shaker.

The dried sand was placed in the top of a nest of sieves (listed in Table 1), and shaken for 30 minutes on an Inclyno shaker (Plate IV.). Statistical tests have shown that sieving for 30 minutes on the Inclyno shaker is equivalent to 15 minutes sieving on the Rotap—the standard American Foundrymen's Association machine. The amount remaining on each sieve after shaking, was weighed and expressed as a percentage of the weight of the *original* sample.

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* A.F.A. clay is defined as "*that earthy portion of foundry sand which, when suspended in water, fails to settle at a rate of 1in. per minute and which consists of particles less than 20 microns (0.02mm.) in diameter.*" At 27°C. spherical particles of quartz 0.02mm. in diameter would settle at the above rate. (A.F.A. 1944.)

(a) *The A.F.A. Grain Fineness Number.*—This represents the approximate mesh number of the A.S.T.M. sieve through which the sample would just pass if its grains were of uniform size. This number is calculated as follows :—

(1) The percentages of sand remaining on the various sieves are multiplied by the appropriate factors listed in Table 1.

(2) The products are added.

(3) The resultant total is divided by the sum of the percentages remaining on the sieves.

(4) The dividend is the A.F.A. grain fineness number.

Tyler sieves, which conform to A.S.T.M. standards for aperture and wire diameter but have slightly different mesh numbers, were used for these tests. The numbers of the Tyler sieves, together with the equivalent A.S.T.M. sieves, and the fineness factors, are set out in Table 1, which also shows the calculation of the fineness number of a W.A. sand. (Sample No. 29—Medium loam. Cardup.)

TABLE I.—DATA FOR CALCULATING A.F.A. GRAIN FINENESS NUMBERS.

A.S.T.M. Sieve No.	Equivalent Tyler Sieve No.	Factor.	Fineness Calculation.	
			Percentage Material Remaining on Sieve.	Product.
6	6	3	0.0	0
12	10	5	0.2	1
20	20	10	0.6	6
30	28	20	3.4	68
40	35	30	15.6	468
50	48	40	32.0	1,280
70	65	50	16.0	800
100	100	70	6.4	448
140	150	100	3.6	360
200	200	140	2.0	280
270	270	200	1.0	200
Pan	Pan	300	2.6	780
Total Percentage of Sand Grade			83.4	
Total Product				4,691

A.F. Grain Fineness No. .... $= \frac{\text{Total product}}{\text{Total percentage}} = \frac{4,691}{83.4} =$ 56.

(b) *The A.F.A. Grain Fineness Classification.*—Sands are arranged in classes according to their grain fineness numbers. These classes are set out in Table 2.

TABLE II.—A.F.A. GRAIN FINENESS CLASSIFICATION.

Grain Class.	Grain Fineness No.
No. 1	200 to and including 300
No. 2	140 to but not including 200
No. 3	100 to but not including 140
No. 4	70 to but not including 100
No. 5	50 to but not including 70
No. 6	40 to but not including 50
No. 7	30 to but not including 40
No. 8	20 to but not including 30
No. 9	15 to but not including 20
No. 10	10 to but not including 15

In reporting fineness tests, the percentage of the "sand" grade remaining on three adjacent sieves is recorded ; this is a good criterion of uniformity, a sand with 75 per cent. or more of its grain on three adjacent is considered even.

(c) *The A.F.A. Clay Content Classification.*—The A.F.A. has set up eight arbitrary zones into which clay contents are classified. These are set out in Table 3.

TABLE III.—A.F.A. CLAY CONTENT CLASSIFICATION.

Clay Class.	Clay Content Zone (Per cent. of Clay Substance.
A	0.0 to, but not including 0.5
B	0.5 to, but not including 2.0
C	2.0 to, but not including 5.0
D	5.0 to, but not including 10.0
E	10.0 to, but not including 15.0
F	15.0 to, but not including 20.0
G	20.0 to, but not including 30.0
H	30.0 to, and including 45.0

In the latest edition of the sand specifications (A.F.A. 1944) the American Foundrymen's Association has deleted the classifications for clay content and grain fineness. These have been retained in this report, as it is considered that useful information is obtainable from them.

(d) *The A.F.A. Grain Shape Classification.*—The four terms—angular, sub-angular, rounded and compound—have been adopted for describing grain shape (Plate V.). Compound grains consist of two or more grains cemented together in such a manner that they fail to break apart in the clay substance test. The grain shapes were classified by comparison with photographs of standard sands.

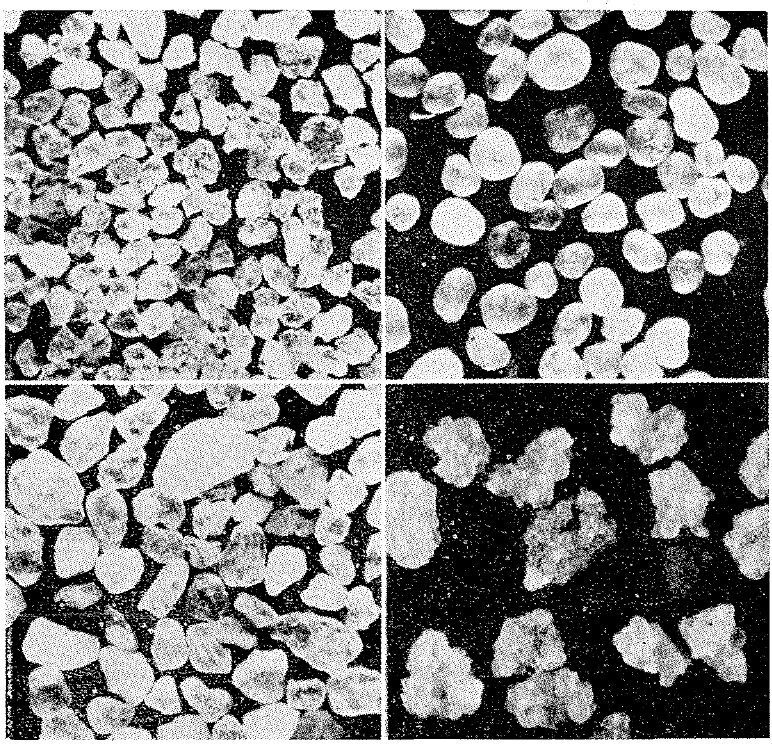


PLATE V.
American Foundrymen's Association Standard Grain Shapes.

(e) *Definition of Terms.*—Throughout the report there are such terms as " active clay," " silt " and " fines." Since their use by different writers varies, it is opportune to define their meaning for purposes of this report :—

" *Active Clay* "—The upper limit of the particle size of A.F.A. " clay substance " is 20 microns, but since the size of dispersed clay is usually less than two microns, some of this

" clay substance " must be fine silt which has no significant bonding power. Without further tests, it is not possible to gauge accurately the true percentage of clay. However, by considering the fineness test as a whole one may estimate the amount of binder. Thus the " clay substance " of a fine sand with a high proportion of minus 270 mesh material would include a large quantity of silt, whereas the " clay substance " of a medium grade sand with a low content of minus 270 mesh material would represent very nearly the true clay content. The estimated proportion of true clay has been styled " active clay,"

" *Silt.*" —" Silt " has been used for material passing the 270 mesh sieve, together with the " clay substance " estimated as lying between 20 microns and two microns.

" *Fines.*"—Some writers regard " fines " as minus 100 mesh material. The authors consider this unsound. With such a classification the major part of a fine sand would be " fines." Foundrymen rightly associate the term " fines " with grains which, though they may improve the skin of the casting slightly, serve to block pore spaces and reduce the permeability. To designate the major part of any sand " fines " is clearly illogical.

The term "fines " must therefore be considered an elastic one, the size varying with the nature of the sand. Thus for a coarse sand, minus 70 mesh material might be considered " fines " ; for a medium sand, minus 100 or minus 150 mesh ; for a fine sand, minus 270 mesh The term has been used in such a manner in this report.

Moisture.

The approximate moisture content was checked immediately after preparation of the sample. Final determinations were made by the standard method ; a 50 gram sample was dried for one hour at 105°C., and the loss in weight was determined.

Permeability and Green Compression Strength.

Tests for permeability and green compression strength were performed on an A.F.A. test piece, which is a rammed cylinder two inches in diameter and two inches high. The sand was rammed on an A.F.A. standard rammer by three blows from a 14 lb. weight falling through two inches (Plate VI.).

(a) *Permeability.*—The permeability of a moulding sand is a measure of the ease with which gases may escape through the mould. The venting qualities vary directly with permeability.

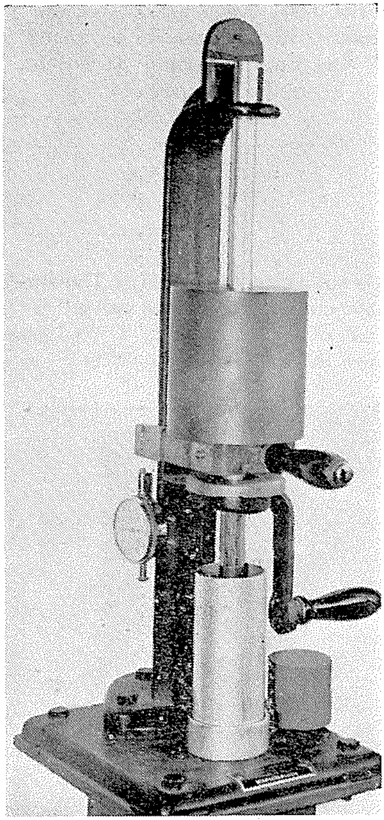


PLATE VI.
Rammer for Forming Test Specimen.

Permeability is measured by determining the rate of flow of gases through a test piece under a measured pressure. Unit permeability is defined as the number of c.c. of air which will pass per minute through a cube of sand, of side one cm., under a pressure of one gram per sq. cm. It may be calculated from the formula :—

$$P = \frac{V \cdot h}{p \cdot a \cdot t}$$

Where—P is the permeability,
V is the volume of air passing (c.c.).
h is the height of the specimen (cm.).
p is the pressure (g./sq. cm.).
a is the cross sectional area of the specimen (sq. cm.).
t is the time (min.)

In performing the test, 2,000 c.c. of air are passed through the standard test specimen (which is two inches (5.08 cm.) high and two inches in diameter, *i.e.*, approximately $3\frac{1}{7}$ sq. in. (20.27 sq. cm.) in area). The formula therefore reduces to :—

$$P = \frac{2{,}000 \times 5.08}{p \times 20.27 \times t}$$

$$= \frac{501.2}{p \times t}$$

The apparatus is shown in Plate VII. The specimen is placed over the mercury seal in the cup " A " and the valve " B " opened. The time taken by the 2,000 c.c. of air in the bell " C " to pass through the specimen, and the pressure in the manometer " D " are measured.

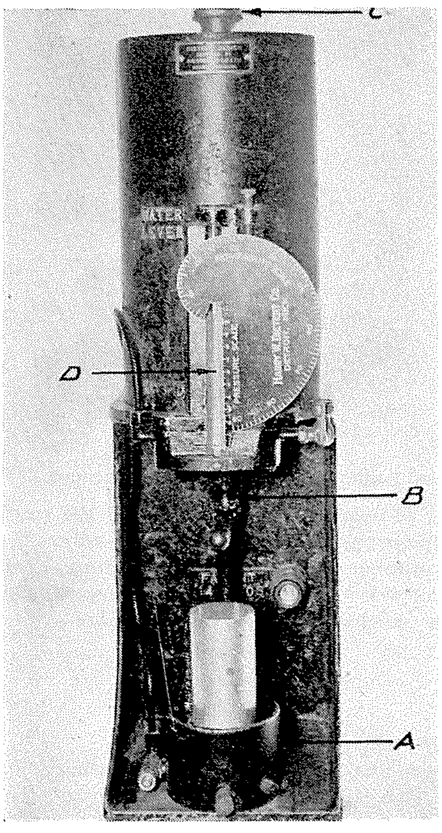


PLATE VII.
Permeability Apparatus.

Base permeability is the permeability of packed dry sand grains containing no clay or other binder. In preparing the specimen, screens to hold the sand in place are inserted in the container before ramming.

(b) *Green Compression Strength.*—After permeability had been determined, the standard test piece was removed from the container, placed in a compression machine and broken by applying a load of 30 ± 10 lb./sq. in./min. uniformly to its ends. The strength was calculated from the load at the breaking point.

The apparatus is the Universal Sand Strength Machine (Plate VIII.). In this machine, the specimen is placed between two compression heads, one of which fits into a " pusher " arm (A) and the other into an arm

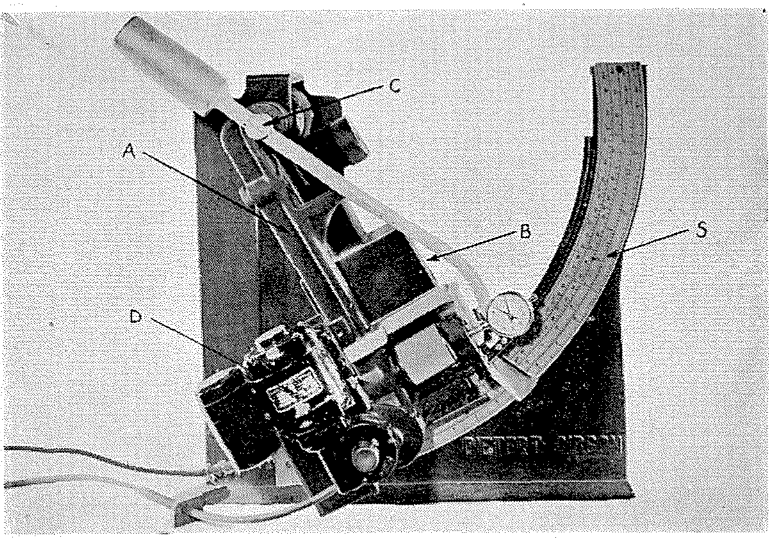


PLATE VIII.
Universal Sand Strength Machine.

attached to a dead-weight (B), which pivots about the axis (C). A motor (D) raises the " pusher " arm, thus causing the specimen to raise the dead weight until the loading exceeds the strength of the sand. The motor is geared so that the weight is raised at a speed designed to apply the standard loading of 30 lb./sq. in./min. The strength is read directly from the scale (S).

A description of the testing apparatus has been published previously by Stephens (1941). A comprehensive account of the tests has been published by the American Foundrymen's Association (A.F.A., 1944).

ACKNOWLEDGMENTS.

Our sincere thanks are due to the following :—Members of the staff of the Ministry of Munitions, Perth, for handling the questionnaires ; Mr. R. A. Hobson. of the Geological Survey, for visiting and sampling certain of the pits and for preparing Fig. I. ; Dr. I. W. Wark and others for reading and criticising the paper ; and particularly to the members of the Foundry Sands Section who performed the routine tests and assisted in checking the results and compiling the tables.

Finally, we wish to thank the many suppliers of sand and clay who afforded the opportunity for visiting their deposits, and the foundrymen of Western Australia for their enthusiastic co-operation, criticism and suggestions.

Chapter II.

PERTH MOULDING SANDS.

Before proceeding to a description of the individual deposits of the Metropolitan Area it may be of advantage to readers to have some idea of the general geology and physiography of the country in the neighbourhood of Perth.

GEOLOGY AND PHYSIOGRAPHY. *

The city of Perth on the banks of the Swan River lies on a stretch of relatively low lying flat or gently undulating country, known as the Swan Coastal Plain. This plain is bounded on the Western side by the Indian Ocean and on the Eastern side by the scarp of the Darling Range, which is in reality the western boundary of a plateau or peneplain of high land extending many hundreds of miles to the eastward. Thus the vicinity of Perth can be divided for convenience of description into the two main physiographic elements, the Darling " Range " highland or Peneplain and the Swan Coastal Plain or " sunk land."

The Darling " Range " (Peneplain).

It is now generally recognised that the so-called Darling Range is in reality the escarpment or edge of an old high land plateau or peneplain which has been formed by the downward displacement or sinking of the country to the west of the scarp line, either by faulting or by folding. The line of the Darling Scarp is traceable in a north-south direction for over 200 miles from near the southern coast to beyond Gingin, north of Perth (Jutson, 1934, p. 84). North of this it gradually fades out into rolling plain country. The summit level of the Darling Scarp, *i.e.*, the summit level of the Darling Peneplain, is remarkably uniform and maintains an average of between 800 and 950 feet above sea level.

The Darling Peneplain is capped by laterite and is dissected by a number of deep youthful river valleys carved out since the formation of the scarp. The most important of these are the valleys of the Swan

* In preparing the following notes the writer has drawn freely from the summary, "The Geology and Physiography of the Neighbourhood of Perth, Western Australia," by E. de C. Clarke, from the handbook "Science in Western Australia," written for 18th meeting, Aust. Assocn. for the Adv. of Science, held in Perth, 1926.

and its tributaries, the Helena and Canning. Active erosion by these rivers and their tributaries has resulted in the wearing back or retreat of the scarp line to some distance east of the original fault plane or monoclinal fold axis, which is now completely hidden under detrital soil and the products of recent erosion.

The geology of the Darling Peneplain is of some interest since it is from the products of weathering and erosion of the rocks forming the peneplain that the existing moulding sand deposits of the Metropolitan Area have ultimately been formed. These rocks are mainly crystalline and are geologically very old (viz., Pre-Cambrian). They consist principally of massive or gneissic granite and several varieties of acid and basic gneiss—all rocks consisting essentially of the minerals quartz and felspars, with varying proportions of the micas muscovite, sericite and biotite, lesser amounts of hornblende, epidote or zoisite, and the minor constituents magnetite, apatite, zircon and rutile. In that portion of the Darling Range immediately east of Perth and thence southwards, granitic rocks predominate, but further northward, in the valley of the Chittering Brook, a south flowing tributary of the Swan (Avon) River, gneisses and schists become abundant. These rocks are frequently characterised by an abundance of mica and contain many of the rarer metamorphic silicate minerals such as garnet, kyanite, sillimanite, andalusite, staurolite, anthophyllite, diopside and chlorite. This belt of ancient metamorphics extends eastwards from Chittering to Clackline, Toodyay (here known as the Jimperding Series) and Northam, and thence southwards towards York and Beverley.

Running in a narrow broken strip along the western edge of the Darling Fault Scarp from near Gosnells southwards through Kelmscott, Armadale, to Byford, Cardup and Mundijong, is a thin series of steeply west-dipping, slaty sediments believed to be younger than the adjacent granitic rocks, but still probably of Pre-Cambrian age (Prider, 1941, p. 51).

Intruding all the previously mentioned rocks are numerous basic dykes which cut the granite and associated rocks in an irregular interlacing network. These dykes consist of dolerite and epidiorite and are characterised by a relative abundance of the iron-bearing minerals augite, hornblende, epidote, ilmenite and magnetite, which on weathering yield a very dark red-coloured soil.

As already mentioned the summit of the Darling Peneplain is capped by laterite which forms a mantle a few feet thick covering all other rock types. Until recently the generally accepted view was that this laterite was a chemical deposit formed by leaching of the underlying rocks and deposition of the leached salts (hydrated oxides of aluminium and iron) from ground water drawn to the surface by capillarity and there evaporated (Simpson, 1912). It has the appearance of a compacted pisolitic gravel.

A further suggestion is that laterite or " duricrust " is the result of a weathering process during a period in which the climate was much wetter and more tropical than at the present day (Prescott, 1931). Under such conditions chemical decomposition of the rock surfaces would have been relatively rapid and the dissolved portions together with some finely divided clayey material, would be carried down into the subsoil and there deposited as a hard pan similar to the " coffee rock " described below. A change in conditions to a very arid climate is believed to have followed, during which the leached sandy top-soil was stripped away by wind erosion leaving the hard pan of laterite exposed.

It may be noted that in many places within the Darling Ranges the concentration of aluminium oxides in the laterite is sufficient for the material to be classed as low grade bauxite or aluminium ore. In other places hydrated iron oxides (limonite) predominate and the material is of value for its iron content. At Clackline such material has been quarried as a flux. At Wundowie similar deposits are being developed for the manufacture of " charcoal iron."

The Swan Coastal Plain.

In the Swan Coastal Plain can be recognized several distinct geological elements. Progressively westward from the edge of the Darling Scarp these are (i) the Foothill Zone, (ii) The Clay Zone, (iii) The Drift Sand Zone, (iv) The Coastal Limestone Zone (Woolnough, 1918). (*See* Geological Sketch Map, Plate II.)

(i) *The Foothill Zone.*—West of the Darling Scarp there is, in many places, an abrupt slope, falling immediately and steeply down to the Swan Coastal Plain. Elsewhere, particularly near the outlets of the larger streams there is an area of successively low hills. At the foot of these hills the short, steep-grade, rapid streams flowing down from the youthful valleys of the plateau, and carrying with them weathered detritus of both granite and dolerite, have had their velocities checked on reaching the plains and have been forced to deposit their sediment as short flat alluvial fans. They have thus built up an almost continuous deposit of ill-sorted soil and rock detritus forming a fertile foot hill zone.

(ii) *The Clay Zone.*—Immediately west of this foothill zone is a narrow continuous level tract of very irregular width, which runs for many miles north and south along the foot of the Darling Scarp. This is known as the Clay Zone (or Guildford Clays) (Aurousseau and Budge, 1921) and consists of red clays and sandy clays, gravels, sandstones and some calcareous marls, interbedded in impersistent horizons to form a distinct series which is thought to extend to considerable depths over the whole coastal plain. This series is said to dip very gently to the south and west and has an average width of exposure of three to four miles, though in the vicinity of Guildford in the valley formed at the junction of the Swan and Helena Rivers the exposed section of Clay Zone is considerably wider. The Guildford Clays are overlain to the west by drift sand. They are, like all other rocks outcropping on the Swan Coastal Plain, geologically youthful. Although there is little evidence of their actual age it is now generally believed that they represent a piedmont deposit, *i.e.*, a water-borne foothill deposit, formed subsequent to the relative uplift resulting in the formation of the Darling Scarp. As the Darling Scarp was possibly formed in late Mesozoic or early Tertiary times (Woolnough, 1919, p. 394), *i.e.*, somewhere about 20–30 million years ago, the Guildford Clays can probably be regarded as early or mid-Tertiary, say Miocene or Pliocene in age, viz., 8–10 million years old.

In the Guildford and Upper Swan Districts, where the Swan and Helena rivers cross this Clay Zone, a number of distinct terraces (four in all) have been recognised in their banks. These terraces indicate recent periods of relative still stand and then renewed uplift of the land or sinking of the sea (Aurousseau, 1921). In these terraces, consisting of clay and loam, sorted, resorted and deposited by a meandering stream which has been subjected to periodic rejuvenation, moulding sands of considerable importance to Metropolitan foundrymen have been found.

(iii) *The Drift Sand Zone.*—Westward of the Guildford Clay Zone is a broad zone of drift sand which has an average width of about 10 miles and gives place to outcrops of coastal limestones and recent beach sand. This sandy plain upon which the city of Perth is situated, is gently undulating and is characterised by low sand dunes fixed by vegetation. In chance hollows between these dunes, reaching to within a few feet of the underlying Guildford Clays, are small swampy areas and ponds in various stages of growth and extinction. In winter during wet seasons, with the rise in ground water level these swamps become filled with brown-coloured peaty water.

The sand in this plain varies in grain size and is usually white or grey-coloured at the surface, merging into a pale to bright yellow sand at depths from three to five feet below the surface. At various places and at varying depths are found one or more successive layers or lenses of dark brown iron stained bands, known as "coffee rock." This consists of sand grains cemented by hydrated oxide of iron (limonite) to form a relatively hard gravelly layer in the otherwise incoherent sand. These "coffee rock" bands probably mark old surface levels of ground water in which iron oxides leached by waters percolating downward through the sand have been collected after long periods of still stand. Later, possibly as a result of evaporation by capillarity and consequent retreat of the ground water level, this iron oxide has become sufficiently concentrated to reprecipitate.

Towards the western edge of the Drift Sand Plain, in a zone running north and south and a little east of the Coastal Limestone, there are a number of shallow but more or less permanent lakes, the most important of which are Lakes Joondalup, Gnangara, Herdsman, Monger, Bibra, Jilbup and Jandakot. Some of these lakes contain economic deposits of diatomite, whilst the shores of Lake Gnangara contain high grade glass sands and valuable core sands.

(iv) *The Coastal Limestone Zone.*—Between the western edge of the drift sand zone and the coast is a narrow conspicuous belt of hills facing the coast and projecting seaward as rocky headlands honeycombed with large and small cavities. These hills are composed of calcareous dune sands cemented superficially in many places into dense travertine (" capstone "), and below the surface more sporadically into a cavernous limestone in which are embedded irregular " nigger heads " of hard limestone formed amongst the less solid sand. Good exposures of this coastal limestone are visible in Mt. Eliza, Perth, and at Buckland Hill near Fremantle, and form the steep cliffs overhanging the lower reaches of the Swan River. The lower beds of the coastal limestone underlying the dune limestone are often richly fossiliferous and are of marine origin.

There is no definite boundary between the coastal limestone and the drift sand on the east nor between the limestone and recent calcareous beach and dune sand which form the actual coast line on the west. The coastal limestones are believed to have been formed in Upper Kainozoic (Pleistocene) time that is, possibly less than 5–6 million years ago (Maitland, 1926).

Cores from sub-artesian bores indicate that the coastal limestone series and the underlying Guildford clays upon which Perth has been built rest (probably unconformably) upon a series of shales, sandstones and limestones believed to be of Cretaceous and Jurassic Age. These beds are the source of a considerable supply of sub-artesian water which has been obtained from wells sunk to depths varying from 450 to 2,000 feet.

THE SAND DEPOSITS.

Moulding sands in the Metropolitan Area fall naturally into two principal classes ; 1. Free Sands (unbonded sands) for core sands, synthetic sands, etc. ; 2. Natural bonded sands or loams. The distribution of deposits of these two classes of material in the vicinity of Perth is naturally dependent upon the distribution of the geological elements of the Metropolitan Area as already outlined in the foregoing pages. Deposits of free sands at present being utilised are confined to the Drift Sand Zone described above, while natural bonded moulding sands have been obtained mainly from the Clay Zone situated along the foot of the Darling Peneplain or from recent river loams upon the Peneplain itself.

1. Free Sands (Unbonded Sands).

Deposits of free sands examined in the Metropolitan Area listed according to locality from North to South are :—

(i) Lake Gnangara, Wanneroo.
(ii) Herdsman Lake.
(iii) Bayswater.
(iv) Shenton Park.
(v) Cannington.
(vi) Banjup-Jandakot.

(1) *Lake Gnangara, Wanneroo.*

Location.—Lake Gnangara is situated about 11 miles due north of Perth, its southern end lying exactly three miles almost due east of the 12 mile post on the Perth-Wanneroo-Yanchep road.

Description.—The lake is less than a mile long and $\frac{1}{2}$–$\frac{3}{4}$ of a mile wide, covering an area of 287 acres. The surrounding country consists of fixed dune sand covered by a moderate vegetation of timber and undergrowth, here and there sloping downwards to swampy depressions. Lake Gnangara is covered by a permanent body of fresh water, whose level is subject to seasonal variations. Other permanent fresh water lakes occur in the belt of sand dune country extending northwards from Wanneroo.

The north-western shore of the lake carries a deposit of diatomaceous earth, covered by a growth of reeds. The reed beds extend eastwards towards the centre of the lake and southwards forming a narrow edging to the western shore.

On the eastern side of the lake the reeds give way to a clear water-filled channel whose eastern shore line consists of a beach of fine white sand with a very scanty growth of reeds and scattered thin patches of dried diatomaceous earth. This white sand consists of over 98 per cent. silica and is eminently suited for the manufacture of high grade glass. It extends around the eastern shore of the lake for nearly a mile and stretches from a narrow beach ranging from 0 to 30 feet wide, along the floor of the lake for several chains.

Where tested the depth of this white glass sand varied from six inches to two feet, with an average of about one foot. It grades downwards to a dark red-brown to almost black sand, coloured by organic material. It is reported that in places on the floor of the lake the sand overlies diatomaceous earth, and it is claimed that in the summer sand can be dug from as far as three chains in from the high water shore line.

Assuming an average width of $2\frac{1}{2}$ chains along a shore length of $\frac{3}{4}$ mile, and an average depth of one foot, the available clean sand in this deposit amounts to a little less than 25,000 tons. It is claimed, however, that more clean sand is continually being washed into the lake. The rate of this alleged seepage is unknown.

PLATE IX.

Glass Sand. East Side, Lake Gnangara.

Sand generally similar to the white beach sand but less perfectly graded and a dark grey colour from included organic matter, extends eastwards of Lake Gnangara for some distance. forming a ridge approximately 50 feet high and probably half a mile in length. The proportion of organic matter decreases rapidly a few feet below the surface.

The late Dr. E. S. Simpson has described the washed beach sand as " a very superior glass sand as regards both composition and grain. It has been proved to yield a colourless glass of great brilliancy," and has commented on the adjacent grey sand, that " it should be suitable for the production of the best plate glass."*

* Letter, Government Mineralogist and Chemist to N. G. Hill, 20 Queen Street, Perth, dated 19/6/1919.

Partial chemical analyses of typical sand from this area were made at the Government Chemical Laboratory (1918) and are as follows :—

Partial Analyses on Ignited Sand from Lake Gnangara.

	A.	B.	C.
	%	%	%
Fe_2O_3	0.028	0.040	0.082
SiO_2	99.64	99.81	over 99
CaO	*Nil*	*Nil*	*Nil*
Al_2O_3	....	0.14	....
TiO_2	....	0.007	....
Loss on ignition	0.07	0.08	2.39
Colour of ignited sand	White	White	Light red

A. Average sample, lower ridges along beach, over 300 yards. East side of Lake Gnangara.

B. East side of Lake Gnangara.

C. Lake Gnangara, 2 chains east from lake, halfway up slope.

Operator.—The Lake Gnangara glass sand deposits are held under mineral claim and operated by C. Leach and Sons, of Wanneroo. Mr. Leach advises that the deposit has been worked intermittently for over 40 years, the sand having been utilised in local glass and pottery manufacture, by several foundries as a core sand, and by several firms for sand blasting and engraving. It is estimated that in the last few years an average of somewhere near 500 tons per annum have been taken from the deposit which has been worked by hand shovel.

Test Results.—Samples Nos. 1, 2 and 3, chosen in the presence of the supplier are representative of the three grades sold, *viz.*, coarse, medium-fine and fine. It is evident from the tests however, that there is little difference between Samples Nos. 2 and 3 so that only two grades need be considered.

Sample No. 1 is clean and evenly graded and has high base permeability. It is used satisfactorily for cores for heavy iron and steel castings and if bonded with a suitable clay would form an excellent synthetic sand for those classes of work.

Samples Nos. 2 and 3 are a grade finer. They are both clean and are extremely well graded. They are excellent core sands for cast iron and are also used for non-ferrous work owing to the lack of a suitable fine grained free sand. In addition they are highly satisfactory bases for synthetic sands for green-sand iron and steel castings.

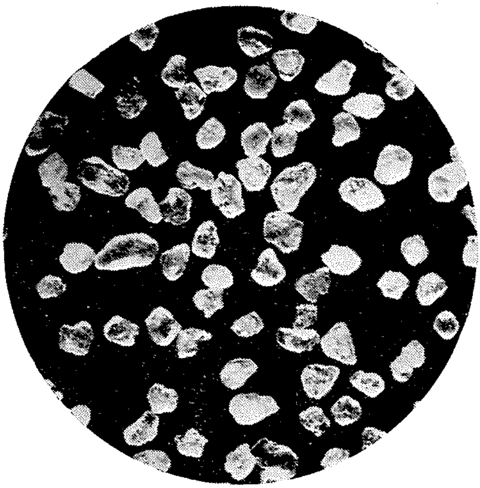


PLATE X.
Washed Sand Grains. Medium Grade
Unbonded Sands, Lake Gnangara.
(Mag. X 12.)

Sample No. 1.—COARSE-MEDIUM SAND—LAKE GNANGARA. (SUPPLIER'S "COARSE" GRADE).

Fineness Test.

A.F.A. clay substance	0.1%
A.F.A. grain fineness number	36
A.F.A. grain class	7
A.F.A. clay class	A
"Sand" remaining on three sieves	86% on 35, 48 and 65 mesh
A.F.A. grain shape	Sub-angular.
Base Permeability	310

REMARKS

Clean. Evenly graded.

Sample No. 2.—MEDIUM SAND—LAKE GNANGARA (SUPPLIER'S "MEDIUM-FINE" GRADE).

Fineness Test.

A.F.A. clay substance	0.2%
A.F.A. grain fineness number	50
A.F.A. grain class	5
A.F.A. clay class	A
"Sand" remaining on three sieves	100% (99.8%) on 48, 65 and 100 mesh (91% on 48 and 65 mesh)
A.F.A. grain shape	Midway between sub-angular and angular.
Base Permeability	180*

Remarks.

Similar to sample No. 3.

* Sufficient sand for one specimen only.

Sample No. 3.—MEDIUM SAND—LAKE GNANGARA (SUPPLIER'S "FINE" GRADE).

Fineness Test.

A.F.A. clay substance	0.1%
A.F.A. grain fineness number	49
A.F.A. grain class	6
A.F.A. clay class	A
"Sand" remaining on three sieves	100% (99.8%) on 48, 65 and 100 mesh (96% on 48 and 65 mesh).
A.F.A. grain shape	Midway between angular and sub-angular.
Base Permeability	190

Remarks.

Extremely clean and even.

(ii) *Herdsman Lake.*

Following a suggestion that sand from Herdsman Lake might prove suitable for cores, the area was visited and sampled in May, 1945.

Location.—Approximately 4½ miles north-west of the centre of Perth city, the lake is skirted on its northern side by the main Scarborough Beach Road and to the south by Grantham Street which links up with the Boulevarde, the main highway to City Beach.

Description.—The Lake itself, a more or less circular depression about 1½ miles in diameter, has been drained and is now dry, reed filled, and split up into farms. Sand can be seen on the roadway which skirts it. Limited quantities only are available on its eastern side, Sample No. 4 being obtained from a bank on the east side of Harborne Street, eight chains south of Dodd Street. Considerable quantities of sand could be obtained from the western side. Sample No. 5 was taken from about 100 yards west of Herdsman Parade at a point about 1.8 miles north of Reserve Street. Here the sand is covered by six inches of top soil and extends down for an undetermined depth. The sample was obtained from one hole from six to eighteen inches below ground level. In the lower lying areas in this vicinity ground water level is only a few feet below ground level during wet seasons.

Operator.—No sand for foundry use has been dug from this locality.

Test Results.—Sample No. 4, from the east side of the Lake is a coarse medium grade of core sand which if available in larger quantities would be suitable for steel or heavy iron castings. It is particularly clean and is even. Sample No. 5 from the west side is discoloured yellow and contains 3.2 per cent. of clay substance. It is of similar grade, but is not as even.

Sample No. 4.—COARSE-MEDIUM SAND—EAST SIDE OF HERDSMAN LAKE.

Fineness Test.

A.F.A. clay substance	0.3%
A.F.A. grain fineness number	38
A.F.A. grain class	7
A.F.A. clay class	A
" Sand " remaining on three sieves	88% on 35, 48 and 65 mesh.
A.F.A. grain shape	Sub-angular.
Base Permeability	245

Remarks.

Clean and even.

Sample No. 5.—COARSE-MEDIUM SAND—WEST SIDE OF HERDSMAN LAKE.

Fineness Test.

A.F.A. clay substance	3.2%
A.F.A. grain fineness number	41
A.F.A. grain class	6
A.F.A. clay class	C
" Sand " remaining on three sieves	78% on 28, 35 and 48 mesh.
A.F.A. grain shape	Sub-angular, smaller grains angular.
Base Permeability	185

Remarks.

Discoloured. Not as even as sample No. 4. Base Permeability lower.

(iii) *Bayswater.*

Location.—The Bayswater sand pit lies slightly over $1\frac{1}{4}$ miles due north of Bayswater Railway Station and about 30 chains north-north-west of the intersection of Beechboro and Collier Roads, and faces the south side of Broadway about 30 chains from its intersection with Beechboro Road.

Description.—The pit has been dug into a ridge of dune sand which on the western side merges into rolling sand hill country but which to the east and south-east slopes rapidly down to low-lying swamp land. The main pit forms an amphitheatre 40 yards long by 25 yards wide whose entrance faces north-east. From the entrance the floor of the pit slopes gently downward to the southern face which is about 20 feet high. The sand in this face is pale yellow and shows traces of grading and false bedding. It varies somewhat in grain size, but is fairly well rounded. On the south-western face of this pit about 6–8 feet below the surface is a band of dark brown coloured coffee rock. The sand grains cemented together to form the pebbles of this rock are somewhat coarser than in other parts of the pit. The band is probably about three feet wide but is laterally discontinuous.

No estimate was made of the quantity of sand available in this deposit but it would appear that the southern and western faces of the main pit could be extended for a considerable distance, yielding at least 15,000 tons of sand. Overburden consists of about 18 inches of sand dark with humus, covered by very scanty vegetation.

To the immediate south-east of the main pit is an old subsidiary pit about 20 yards in diameter whose floor was at the time of inspection (August, 1943) covered with water. Portion of the eastern wall of this old pit is capped by a narrow band of very coarse quartz grit.

Operator.—The pit was opened up by Messrs, Bell Bros. in 1937. The bulk of the sand has been used in the building trade or sold for top-dressing lawns, but for two or three years one or two of the local foundries were supplied with core sand.

Test Results.—Two samples were obtained—Sample No. 6 from the south side and Sample No. 7 from the west side. Both are coarse-

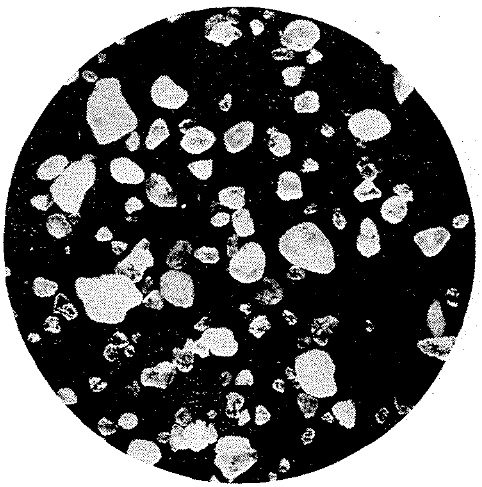


PLATE XI.

Washed Sand Grains. Medium-Coarse Unbonded Sand, Bayswater. (Mag. X 8.)

medium in size, and are clean and evenly graded. Sample No. 6 is slightly finer than Sample No. 7 and as might be expected, has a lower base permeability. Both sands are sufficiently open for cores for the heaviest grade of casting made in Perth.

Sample No. 6.—COARSE-MEDIUM SAND—SOUTH SIDE, BAYSWATER PIT.

Fineness Test.

A.F.A. clay substance	0.7%
A.F.A. grain fineness number	39
A.F.A. grain class	7
A.F.A. clay class	B
" Sand " remaining on three sieves	84% on 35, 48 and 65 mesh.
A.F.A. grain shape	Sub-angular, tending to rounded.
Base Permeability	300

Remarks.

Clean, even sand. Slightly finer than sample No. 7.

Sample No. 7.—COARSE-MEDIUM SAND—WEST SIDE, BAYSWATER PIT.

Fineness Test.

A.F.A. clay substance	0.5%
A.F.A. grain fineness number	33
A.F.A. grain class	7
A.F.A. clay class	B
" Sand " remaining on three sieves	87% on 28, 35 and 48 mesh.
A.F.A. grain shape	Mixture of rounded and sub-angular.
Base Permeability	400

Remarks.

Clean, even sand. High base permeability.

(iv) *Shenton Park.*

Location.—This deposit forms the western bank of a cutting extending from 3 miles 73 chains to 4 miles 9 chains Railway distance from Perth Station and some three hundred yards on the Fremantle side of Shenton Park Railway Station.

Description.—The bank of the cutting has an average height of about 15 feet. Overburden consists of less than two feet of dirty sand with light vegetation. The sand appears fairly even, medium grained, light yellow in colour, but here and there deepens to an orange yellow colour. Occasional boulders of sandy limetsone are exposed in the face and more frequently in the floor of the cutting (the level of the railway line).

This cutting can probably be dug back for an average depth of about 14–15 feet to within a few yards of the western boundary of the railway property, which adjoins a road. This amounts to a width of nearly one chain of sand still available, or for the whole cutting about 30,000 tons of clean sand.

Operator.—This deposit owned and operated by the W.A. Government Railways, provides silica sand for cores and also for admixture with loam for moulding sands in the foundries at the Railway Workshops, and at the State Engineering Works.

Test Results.—The sand is poorly graded. The majority of grains are of similar size to the sand from Lake Gnangara, but the uneven distribution results in an increase in fineness number from 50 to 66 and helps to lower the base permeability from 190 to 145. The sand contains 5.9 per cent. of clay substance, 5.3 per cent. of which is less than five microns in size and must therefore be regarded mainly as "active" bond. The resultant strength of 2–3 lb./sq. in., would be advantageous. In general, however, the writers consider that this sand is not as suitable as other medium-grade free sands.

SAMPLE No. 8.—MEDIMUM SAND—SHENTON PARK.

FINENESS TEST.

A.F.A. clay substance	5.9%*
A.F.A. grain fineness number	58
A.F.A. grain class	5
A.F.A. clay class	D
"Sand" remaining on three sieves	66% on 48, 65 and 100 mesh
A.F.A. grain shape	Angular, tending to sub-angular.
BASE PERMEABILITY	145

ROUTINE TESTS.

Moisture. %	Permeability.	Green Compression Strength. lb./sq. in.
2.1	165	2.9
3.1	160	1.6

REMARKS.

Not as even as sample Nos. 2 and 3.

* Clay Substance < 0.005 mm. $= 5.3\%$.

(v) *Cannington*.

Location.—This sand deposit is bounded by Cannington Lots 16, 17 and 18 facing Braibrise Road off Fremantle Road, some 4½ miles south-east of Perth.

Description.—The country hereabouts consists of rolling dune sand covered by low scrub. Lots 16, 17 and 18 form an area about 10 chains long and 15 chains wide. At the time of inspection in August, 1943, the sand pit consisted of a long narrow quarry about 40 yards long by 10 yards wide entered from the southern end and running approximately north and south. The working face at the north end was about 15 feet high and 20 feet wide at the top, whilst the floor of the pit sloped downwards to the face. Overburden of dirty soil and roots of scrub was about 2½ to 3 feet thick.

There was no distinct evidence of either bedding or grading of the sand in the exposed faces of the pit. Near the centre a thin bed of coffee rock was exposed in the floor. This rises gently to the west, but it probably lenses out to the north and east.

To the west of the pit the ground rises steadily some 40–45 feet to the crest of a ridge running east of north at about 10-12 chains from the pit. As a result a large tonnage of very easily quarried sand should be available.

Adjoining the sand pit to the south-west, on the other side of Braibrise Road is another sand pit with a plant for the production of sand bricks. The sand in this pit seemed similar to that from top of the pit already described. Portions of the western side of this pit are apparently floored on a band of coffee rock.

Operator.—At the time of the original inspection by the authors, lots 16, 17 and 18 were owned, and the pit operated by Mr. E. A. Williamson of Nedlands. Latest information (May, 1946, see below) is that the deposit is now owned and operated by F. A. Moore of Victoria Park. The greater part of the sand dug from this pit has been used for building construction, but lately at least one foundry has been obtaining regular supplies of sand both for cores and as a base for a synthetic steel moulding sand. At the present time all the sand is dug with hand shovels.

Test Results.—Samples Nos. 9 and 10 were chosen in the presence of a representative of the supplier as typical of the sand supplied from the top and lower parts of the main pit. Sample No. 9 is a clean well graded coarse-medium sand of high base permeability and similar to the sand from the west side of the Bayswater Pit. It should be quite satisfactory for cores for heavy castings. Sample No. 10, though clean is poorly graded, the size of the majority of the grains ranging from 20 mesh (0.03 in.) to 100 mesh (0.006 in.). This results in an increase in fineness (to 55), a lowering of base permeability (to 90) and an inferior surface on cores for small castings. Care would have to be taken that the two grades were not mixed.

SAMPLE No. 9.—COARSE-MEDIUM SAND—TOP OF FACE, MAIN PIT, CANNINGTON.

FINENESS TEST.

A.F.A. clay substance	0.3%
A.F.A. grain fineness number	31
A.F.A. grain class	7
A.F.A. clay class	A
"Sand" remaing on three sieves	89% on 28, 35 and 48 mesh.
A.F.A. grain shape	Rounded, smaller grains tending to sub-angular.

BASE PERMEABILITY 360

REMARKS.

Clean, even sand. High base permeability.

Sample No. 10.—MEDIUM SAND—BOTTOM OF FACE, MAIN PIT, CANNINGTON.

Fineness Test.

A.F.A. clay substance	0.4%
A.F.A. grain fineness number	55
A.F.A. grain class	5
A.F.A. clay class	A
"Sand" remaining on three sieves	63% on 48, 65 and 100 mesh
A.F.A. grain shape	Finest grains angular, medium grains sub-angular, coarsest grains rounded.
Base Permeability	90

Remarks.

Poorly graded. Low base permeability. Not so satisfactory as other medium grade sands.

To obtain more accurate information as to the variation of the sand, the main pit was visited in May, 1946, by Mr. R. A. Hobson of the Geological Survey of W.A., and a further set of eight samples were collected from near the present face of the pit (vertical depth approximately 18 feet). Test results were as follows (depths measured down the face) :—

Sample No.	Description.	Fineness Test.				Base Permeability.
		A.F.A. Clay Substance.	A.F.A. Grain Fineness No.	Per cent. of "Sand" Grade Remaining on Three Sieves.	A.F.A. Grain Shape.	
		%				
11	Coarse-Medium Sand (0–3 ft.). Main Pit, Cannington.	0.5	31	90% on 28, 35 and 48 mesh	Rounded	405*
12	Coarse-Medium Sand (3–6 ft.). Main Pit, Cannington.	0.3	31	90% on 28, 35 and 48 mesh	Sub-angular, tending to rounded	375†
13	Coarse-Medium Sand (6–9 ft.). Main Pit, Cannington.	0.5	36	82% on 28, 35 and 48 mesh	Sub-angular, tending to rounded	295*
14	Coarse-Medium Sand (9–12 ft.). Main Pit, Cannington.	0.4	36	80% on 28, 35 and 48 mesh	Sub-angular, tending to rounded	240†
15	Coarse-Medium Sand (12–15 ft.). Main Pit, Cannington.	0.4	38	75% on 28, 35 and 48 mesh	Sub-angular	200†
16	Coarse-Medium Sand (12–18 ft.). Main Pit, Cannington.	0.3	39	72% on 35, 48 and 65 mesh	Sub-angular	185†
17	Medium Sand (18–21 ft.). Main Pit, Cannington.	0.3	40	71% on 35, 48 and 65 mesh	Sub-angular	175†
18	Medium Sand (21–24 ft.). Main Pit, Cannington.	0.2	43	71% on 35, 48 and 65 mesh	Sub-angular	145†

* Sufficient sand for one specimen only.

† Sufficient sand for two specimens only.

The sand at the top is generally similar to Sample No. 9. It is clean, medium-coarse (fineness 31), evenly distributed, rounded in grain and has high base permeability. From the top downwards the sand becomes progressively finer and less uniform. The grain shape changes gradually to sub-angular and the base permeability decreases. At floor level the sand has a fineness of 43 and only 71 per cent. remains on three adjacent sieves.

Sample No. 19 from the top of the face of the sand-brick pit is a similar grade to Sample No. 9 but it is not as even and in consequence the base permeability is much lower (185 compared with 360). This sand would therefore not be so suitable as the sand from the top of the face of the main pit.

SAMPLE No. 19.—COARSE-MEDIUM SAND—TOP OF WESTERN FACE, OLD SAND-BRICK PIT, CANNINGTON.

FINENESS TEST.

A.F.A. clay substance	0.4%
A.F.A. grain fineness number	35
A.F.A. grain class	7
A.F.A. clay class	A
"Sand" remaining on three sieves	78% on 28, 35 and 48 mesh
A.F.A. grain shape	Rounded. Smaller grains sub-angular.
BASE PERMEABILITY	185

REMARKS.

Not as even as Sample No. 9.

(vi) *Banjup-Jandakot.*

Location.—An inspection was made of a strip of country running along portion of the railway line from Armadale to Fremantle, particularly between Forrestdale and Jandakot sidings, about 10-11 miles due south of Perth. All of this area lies within the Drift Sand Zone described above.

Description.—The country is flat to gently undulating dune sand sloping down to low lying swampy areas and lakes, some of which are of considerable extent, such as Lake Jandakot, Banjup, Jilbup, Bibra.

Two samples were taken—No. 20 from a low railway cutting between Banjup and Forrestdale Sidings (near Telegraph Post No. 503) and No. 21 from a disused sand pit north of the road and directly opposite Telegraph Post No. 473, near Banjup Siding. The sand in this old pit appears typical of that throughout the district—white, grading down to pale yellow with occasional thin bands of coffee rock. Faces of sand 20–25 feet high are exposed in the western side of the quarry.

Ridges of sand dunes of various heights, covered with sparse scrub and occasional trees, are abundant immediately north of the road between Banjup and Jandakot Sidings and it is probable that suitable sand could be obtained from any part of this higher ground.

Operator.—Portion of the area inspected is on W.A. Government Railways property. The sand from the disused pit was probably used for building but the writers have no record of the operator. To their knowledge no sand from this vicinity has been used in foundries.

PLATE XII.
Dune Sand. Near Banjup Siding.

Test Results.—Sample No. 20 is not very even. The main grains are similar to Sample No. 21, but the sand contains finer material which not only increases the fineness number but also helps to lower base permeability. This sample was taken from the surface ; it is possible that a more even sand would be obtained if a well-defined pit were opened.

Sample No. 21 is evenly graded and clean. It has a fineness intermediate between the coarse-medium sands from Bayswater and Cannington and the medium grade sands from Lake Gnangara and should therefore be suitable as a core sand for heavy-medium work.

SAMPLE NO. 20.—MEDIUM SAND—RAILWAY CUTTING BETWEEN BANJUP AND FORRESTDALE SIDINGS.

FINENESS TEST.

A.F.A. clay substance	0.6%
A.F.A. grain fineness number	50
A.F.A. grain class	5
A.F.A. clay class	B
" Sand " remaining on three sieves	72% on 35, 48 and 65 mesh
A.F.A. grain shape	Sub-angular.
BASE PERMEABILITY	100

REMARKS.

Lack of uniformity results in lowered base permeability.

SAMPLE No. 21.—MEDIUM SAND—DISUSED PIT, NEAR BANJUP SIDING.

FINENESS TEST.

A.F.A. clay substance	0.3%
A.F.A. grain fineness number	41
A.F.A. grain class	6
A.F.A. clay class	A
"Sand" remaining on three sieves	88% on 35, 48, and 65 mesh
A.F.A. grain shape	Sub-angular.
BASE PERMEABILITY	250

REMARKS.

Clean, even sand. High base permeability.

General Remarks on Unbonded Sands.

The core sands used in Perth and Fremantle are, with few exceptions, clean and well graded. They are highly satisfactory for steel and general cast iron work. However, for improved finish on non-ferrous and light iron castings (*e.g.*, stove plate), and for synthetic mixtures, a sand of fineness number twice that of the Lake Gnangara sand would be advantageous. No such sand was discovered during the survey and it is unlikely that it is to be found in a locality sufficiently close to Perth to be used economically.

2. NATURAL MOULDING SANDS.

As already mentioned, deposits of natural moulding sands or loams so far utilised in Perth have been found only in the Clay Zone at the foot of the Darling Range Peneplain or within the Peneplain itself. The deposits examined and sampled were situated in the following localities :—

(i) Guildford,

(ii) Byford-Cardup,

(iii) Northam District.

Several other localities within the Clay Zone were inspected but no search was made for other deposits of loam within this belt.

(i) *Guildford.*

Location.—This deposit is on the property of Mr. H. Hamersley, of Guildford, and is situated about 100 yards east of West Swan Road and ½ mile on a bearing N. 25° W. from the East Guildford Railway Station.

Description.—The loam forms portion of a broad flat river terrace about 30 chains wide and 20–24 feet above the level of the Swan River. To the northward this terrace runs flat for about 60 chains and then gently rises a further 15 feet to a higher terrace at Caversham. Westward of the deposit the ground slopes gradually towards Bennett Brook,

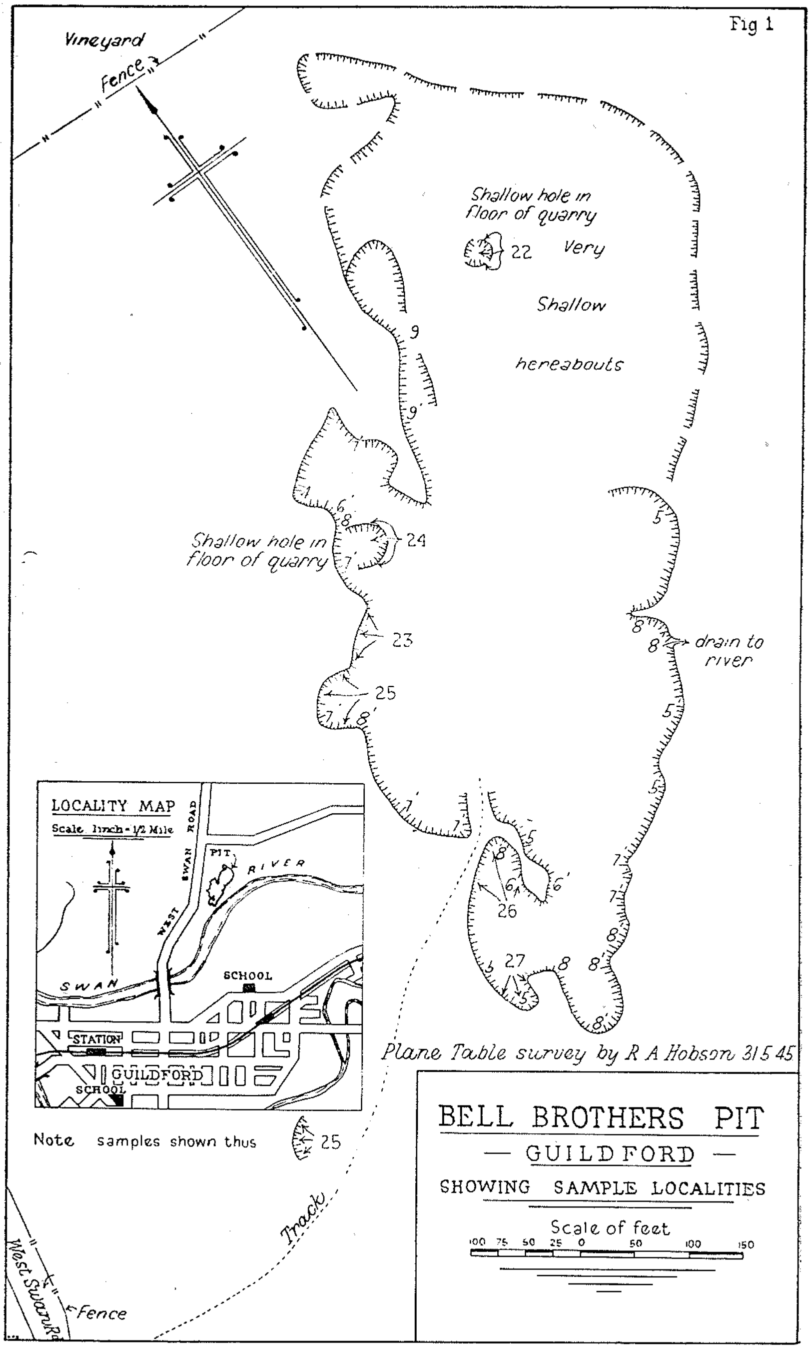


Fig 1
Vineyard
Fence
Shallow hole in floor of quarry
22
Very
Shallow
hereabouts
9
9
Shallow hole in floor of quarry
24
23
25
drain to river
26
27
LOCALITY MAP
Scale 1inch = 1/2 Mile
WEST SWAN ROAD
PIT
RIVER
SWAN
SCHOOL
STATION
GUILDFORD
SCHOOL
Note samples shown thus 25
Plane Table survey by R A Hobson 31.5.45
BELL BROTHERS PIT
— GUILDFORD —
SHOWING SAMPLE LOCALITIES
Scale of feet
100 75 50 25 0 50 100 150
Track
West Swan Rd
Fence

TABLE IV.

PERTH MOULDING SANDS.

Unbonded Sands.

Sample No.	Description of Deposit.	Fineness Test. Per Cent. Remaining on Tyler Sieve No. 6	10	20	28	35	48	65	100	150	200	270	Pan	A.F.A. Clay Substance.	Total.	A.F.A. Grain Fineness No.	A.F.A. Grain Class.	A.F.A. Clay Class.	Per Cent. of "Sand" Grade Remaining on Three Sieves.	A.F.A. Grade Shape.	Base Permeability.
1	Coarse-Medium Sand. Lake Gnangara	0·0	0·0	0·8	11·8	34·0	38·4	13·6	1·2	0·0	0·0	0·0	0·0	0·1	99·9	36	7	A	86% on 35, 48 and 65	Sub-angular	310
2	Medium Sand. Lake Gnangara	0·0	0·0	0·0	0·0	0·2	12·8	78·2	8·4	0·0	0·0	0·0	0·0	0·2	99·8	50	5	A	100%* on 48, 65 and 100 (91% on 48 and 65)	(a)	180†
3	Medium Sand. Lake Gnangara	0·0	0·0	0·0	0·0	0·2	16·4	79·8	3·6	0·0	0·0	0·0	0·0	0·1	100·1	49	6	A	100%* on 48, 65 and 100 (96% on 48 and 65)	(a)	190
4	Coarse-Medium Sand. East Side of Herdsman Lake	0·0	0·0	0·6	8·8	30·6	45·4	11·3	1·6	1·0	0·2	0·0	0·2	0·3	100·0	38	7	A	88% on 35, 48 and 65	Sub-angular	245
5	Coarse-Medium Sand. West Side of Herdsman Lake	0·0	0·0	1·4	15·6	31·2	29·0	9·8	4·6	3·2	0·8	0·2	0·8	3·2	99·8	41	6	C	78% on 28, 35 and 48	Sub-angular (b)	185
6	Coarse-Medium Sand. South Side, Bayswater Pit	0·0	0·0	0·6	9·0	28·8	38·4	16·0	5·4	1·0	0·0	0·0	0·0	0·7	99·9	39	7	B	84% on 35, 48 and 65	Sub-angular (c)	300
7	Coarse-Medium Sand. West Side, Bayswater Pit	0·0	0·0	3·2	20·2	37·8	29·0	6·6	2·0	0·6	0·0	0·0	0·2	0·5	100·1	33	7	B	87% on 28, 35 and 48	(d)	400
8	Medium Sand. Railway Cutting, Shenton Park	0·0	0·0	1·2	6·0	12·0	21·6	22·0	18·6	9·0	1·8	0·4	1·4	5·9	99·9	58	5	D	66% on 48, 65 and 100	Angular .... (e)	145
9	Coarse-Medium Sand. Top of Face, Main Pit, Cannington	0·0	0·0	3·4	31·8	37·0	19·6	4·6	1·8	0·8	0·2	0·0	0·2	0·3	99·7	31	7	A	89% on 28, 35 and 48	Rounded (f)	360
10	Medium Sand. Bottom of Face, Main Pit, Cannington	0·0	0·0	3·6	8·2	11·6	23·6	24·0	15·2	9·2	2·4	0·6	1·2	0·4	100·0	55	5	A	63% on 48, 65 and 100	(g)	90
11	Coarse-Medium Sand. 0–3 ft., Main Pit, Cannington	0·0	0·0	2·4	30·4	39·8	20·0	4·8	1·4	0·4	0·0	0·0	0·2	0·5	99·9	31	7	B	90% on 28, 35 and 48	Rounded	405†
12	Coarse-Medium Sand. 3–6 ft., Main Pit, Cannington	0·0	0·0	3·0	28·6	38·4	22·4	5·0	1·6	0·6	0·0	0·0	0·2	0·3	100·1	31	7	A	90% on 28, 35 and 48	Sub-angular (c)	375‡
13	Coarse-Medium Sand. 6–9 ft., Main Pit, Cannington	0·0	0·0	3·0	20·2	31·8	30·0	9·6	3·0	1·2	0·4	0·2	0·2	0·5	100·1	36	7	B	82% on 28, 35 and 48	Sub-angular (c)	295†
14	Coarse-Medium Sand. 9–12 ft., Main Pit, Cannington	0·0	0·0	3·0	19·6	30·0	30·2	11·4	3·8	1·2	0·2	0·0	0·2	0·4	100·0	36	7	A	80% on 28, 35 and 48	Sub-angular (c)	240‡
15	Coarse-Medium Sand. 12–15 ft., Main Pit, Cannington	0·0	0·0	3·2	17·6	26·8	30·8	14·2	4·8	1·8	0·4	0·0	0·2	0·4	100·2	38	7	A	75% on 28, 35 and 48	Sub-angular	200‡
16	Coarse-Medium Sand. 15–18 ft., Main Pit, Cannington	0·0	0·0	3·2	15·4	24·8	31·0	16·0	6·2	2·4	0·4	0·0	0·2	0·3	99·9	39	7	A	72% on 35, 48 and 65	Sub-angular	185‡
17	Medium Sand. 18–21 ft., Main Pit, Cannington	0·0	0·0	3·4	15·0	24·4	30·8	16·2	6·6	2·6	0·4	0·0	0·2	0·3	99·9	40	6	A	71% on 35, 48 and 65	Sub-angular	175‡
18	Medium Sand. 21–24 ft., Main Pit, Cannington	0·0	0·0	3·2	11·6	20·2	30·2	20·4	9·4	3·8	0·8	0·2	0·2	0·2	100·2	43	6	A	71% on 35, 48 and 65	Sub-angular	145‡
19	Coarse-Medium Sand. Top of Western Face, Disused Sand-brick Pit, Cannington	0·0	0·0	4·8	27·4	28·0	22·6	9·8	4·0	2·0	0·6	0·2	0·2	0·4	100·0	35	7	A	78% on 28, 35 and 48	Rounded (h)	185
20	Medium Sand. Railway Cutting between Banjup and Forrestdale Sidings	0·0	0·0	0·4	5·4	17·2	30·4	23·6	14·4	6·4	1·0	0·2	0·4	0·6	100·0	50	5	B	72% on 35, 48 and 65	Sub-angular	100
21	Medium Sand. Disused Pit near Banjup Siding	0·0	0·0	0·2	5·4	27·2	43·2	16·8	5·0	1·4	0·2	0·0	0·2	0·3	99·9	41	6	A	88% on 35, 48 and 65	Sub-angular	250

* 99·8 per cent. † Sufficient sand for one specimen only. ‡ Sufficient sand for two specimens only.

(a) Midway between angular and sub-angular.
(b) Smaller grains angular.
(c) Tending to rounded.
(d) Mixture of rounded and sub-angular.
(e) Tending to sub-angular.
(f) Smaller grains tending to sub-angular.
(g) Finest grains angular, medium grains sub-angular, coarsest grains rounded.
(h) Smaller grains sub-angular.

whilst to the immediate east are the cliff-like banks of the Swan. The pit from which the loam is obtained has a maximum depth of nine feet (average about 5–6 feet), and covers an area of about an acre.

Overburden waste at the pit is seldom more than three or four inches, whilst the next foot of soil, containing a limited amount of organic material, has a ready sale as garden loam. The moulding loam varies from a very heavy chocolate coloured material to a sandy yellow-brown loam. The floor of the pit is uneven. Near the centre of the western side it has been dug to about eight feet, where a weakly-bonded yellowish sand is exposed. It is not known to what depth this yellow loam extends, nor whether it is underlain by other beds of more strongly bonded clay, though this is probable. In any event the depth to which quarrying would be practicable in this terrace is limited by the river level to little more than 20 feet. The boundaries of the pit as surveyed by R. A. Hobson in May, 1945, are shown in Figure 1. Probable reserves are 70,000 tons.

Operator.—This deposit has been operated by Messrs. Bell Bros., of Guildford, for 30 years and has been the source of a large proportion of the natural bonded moulding sand used in most Perth and Fremantle foundries.

Test Results.—Six samples (the location of which are marked on the plane table survey (Fig. 1)) were obtained from the pit in May, 1945. For discussion, the samples may be divided into three groups :—

(1) Sample No. 22.
(2) Sample No. 24.
(3) Samples Nos. 23, 25, 26 and 27.

Sample No. 22 from a bank at the north-west end of the pit is supplied only to one large foundry. It is very "heavy" and contains 49 per cent. of clay substance, some of which is fine silt. In addition it is uneven and though 50 per cent. of the "sand" passes the finest sieve it contains coarser grains (in approximately equal amounts) from 70 to 270 mesh. As a result of the fine grain size, the uneven distribution and the high clay content, the permeability is very low. The strength, however, is high. Tests were conducted at moisture contents from eight to 11 per cent., but the material felt too dry for moulding until 10 per cent. of water had been added. The permeability would probably be improved by the addition of floor sand (*see* later).

Sample No. 24 from a heap on the floor of the quarry is also heavy but not as clayey. The grains are unevenly distributed ; the bulk of them vary from 70 to 200 mesh, but fines increase the fineness number and decrease the permeability. The strength is high. If a heavy grade is required this sand would be much more suitable than Sample No. 22.

Samples Nos. 23, 25, 26 and 27 are, in general, similar, but Sample No. 26 is slightly heavier and slightly finer than the others. All are poorly graded and though the majority of grains average approximately 100 mesh, smaller amounts of very fine material cause an increase in fineness number and a decrease in permeability. The maximum permeability occurs at approximately 5 per cent. moisture, and is in the neighbourhood of 50. At 6 per cent. this has dropped to 35–40 and the decrease is then gradual over a range of 2–3 per cent. moisture. Sample 26 is slightly stronger than the rest, but in general, the strength of the samples is not high and the sand would require to be rammed fairly hard.

A permeability of 50 is a little low for medium to heavy iron work and it would be preferable to replace the Guildford loam with a loam of the Byford type (Samples Nos. 28, 29) for this class of casting.

At the pit the loam appears to vary considerably, and certain foundrymen in co-operation with the supplier have therefore specified the section of the pit from which their loam is to be dug. The tests have shown, however, that no great harm would accrue if it were obtained from another section, provided care was taken to exclude the heavier grades, unless the latter were specially desired.

The writers would like to make two observations on the tests :—

(i) One of the major difficulties of a survey of this type is that it is only possible to test the material " as mined " and

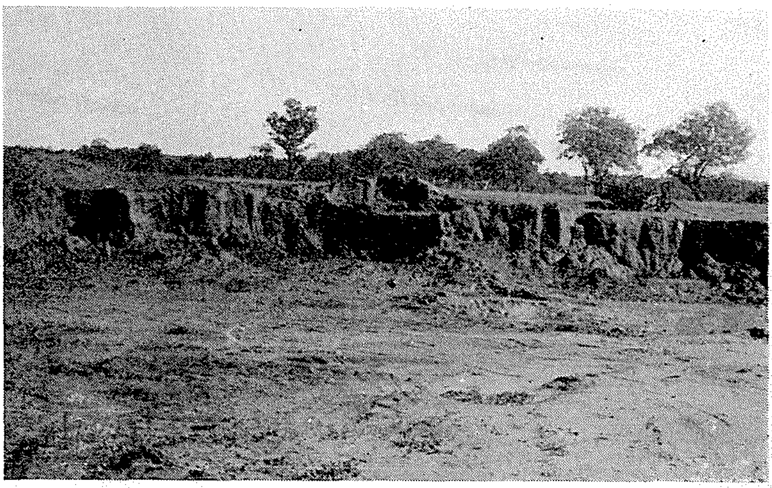


PLATE XIII.

Loam. Bell Bros. Pit, Guildford.

that it is not possible to predict the effect (favourable or otherwise) of diluting the raw sands with sands from the floor. This may be particularly important for the heavier grades of Guildford loam, since addition of floor sand may cause a considerable increase in permeability.

(ii) Sands with high clay content are extremely difficult to test since they tend to "ball" during preparation. Care was taken to prevent this, but some "balling" did occur, especially when testing at high moisture contents. The writers do not consider that this "balling" influenced the results.

A continuance of supplies from this deposit will depend on confirmation of the estimate of probable reserves of suitable loam, especially on the western flank of the existing pit. The deposit is considered to be of sufficient importance to merit thorough testing either by digging shallow pits or by boring with a clay spear. It is recommended

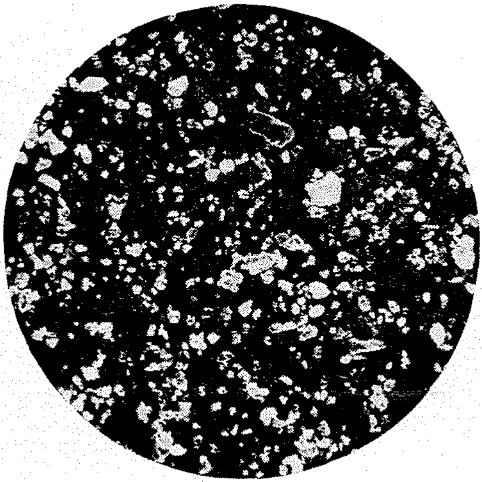


PLATE XIV.

Washed Sand Grains. Medium-Fine Loam, Guildford.
(Mag. X 12.)

that the entire western area be systematically sampled on a grid, set at, say, 50 foot intervals. The floor of the present pit is also well worthy of further investigation by boring to water level.

Sample No. 22.—FINE LOAM—BELL BROS. PIT, GUILDFORD.

Fineness Test.

A.F.A. clay substance	48.8%
A.F.A. grain fineness number	194
A.F.A. grain class	2
A.F.A. clay class	*
" Sand " remaining on three sieves	38% on 100, 150 and 200 mesh (68% on 200, 270 mesh and pan).
A.F.A. grain shape	Angular.

Routine Tests.

Moisture. %	Permeability.	Green Compression Strength. lb./sq. in.
8.0	2.8	23.2
9.1	6.1	23.2
9.8	11.9	20.2
11.1	19.8	13.9

Remarks.

Uneven. Poor permeability.

* Not covered by A.F.A. Classification (too high).

Sample No. 23.—MEDIUM-FINE LOAM—BELL BROS. PIT, GUILDFORD.

Fineness Test.

A.F.A. clay substance	13.0%
A.F.A. grain fineness number	120
A.F.A. grain class	3
A.F.A. clay class	E
" Sand " remaining on three sieves	58% on 100, 150 and 200 mesh
A.F.A. grain shape	Angular.

Routine Tests.

Moisture. %	Permeability.	Green Compression Strength. lb./sq. in.
5.2	51.0	8.0
6.2	39.0	6.6
6.9	42.0	5.2
8.1	37.0	4.5

Remarks.

Poorly graded. Weak.

SAMPLE No. 24.—FINE LOAM—BELL BROS. PIT, GUILDFORD.

Fineness Test.

A.F.A. clay substance	22.9%
A.F.A. grain fineness number	158
A.F.A. grain class	2
A.F.A. clay class	G
" Sand " remaining on three sieves	55% on 100, 150 and 200 mesh (55% on 200, 270 mesh and pan)
A.F.A. grain shape	Angular.

ROUTINE TESTS.

Moisture.	Permeability.	Green Compression Strength.
%		lb./sq. in.
5.0	19.7	19.8
6.1	20.3	14.9
7.1	23.7	11.5
8.2	25.0	9.1
9.2	22.9	8.2
10.0	23.3	8.0
10.8	19.5	7.2

REMARKS.

Not as " heavy " as, and generally more satisfactory than Sample No. 22.

SAMPLE No. 25.—MEDIUM-FINE LOAM—BELL BROS. PIT, GUILDFORD.

FINENESS TEST.

A.F.A. clay substance	13.0%
A.F.A. grain fineness number	116
A.F.A. grain class	3
A.F.A. clay class	E
" Sand " remaining on three sieves	59% on 100, 150 and 200 mesh
A.F.A. grain shape	Angular.

ROUTINE TESTS.

Moisture.	Permeability.	Green Compression Strength.
%		lb./sq. in.
5.2	54.0	8.4
6.0	44.5	6.4
7.1	43.5	5.3
7.9	42.0	4.5

REMARKS.

Similar to Sample No. 23.

SAMPLE No. 26.—MEDIUM-FINE LOAM—BELL BROS. PIT, GUILDFORD.

FINENESS TEST.

A.F.A. clay substance	17.8%
A.F.A. grain fineness number	135
A.F.A. grain class	3
A.F.A. clay class	F
" Sand " remaining on three sieves	67% on 100, 150 and 200 mesh
A.F.A. grain shape	Angular.

ROUTINE TESTS.

Moisture.	Permeability.	Green Compression Strength.
%		lb./sq. in.
5.2	45.0	13.1
6.1	40.0	9.5
7.0	36.5	7.2
8.0	37.0	6.0
9.0	34.5	5.3

REMARKS.

Generally similar to Sample No. 23 but slightly stronger.

SAMPLE No. 27.—MEDIUM-FINE LOAM—BELL BROS. PIT, GUILDFORD.

FINENESS TEST.

A.F.A. clay substance	14.3%
A.F.A. grain fineness number	128
A.F.A. grain class	3
A.F.A. clay class	E
"Sand" remaining on three sieves	69% on 100, 150 and 200 mesh
A.F.A. grain shape	Angular.

ROUTINE TESTS.

Moisture. %	Permeability.	Green Compression Strength. lb./sq. in.
5.1	46.0	7.7
6.2	37.5	5.6
6.9	38.0	4.7
8.1	35.0	4.1

REMARKS.

Similar to Sample No. 23.

(ii) *Byford-Cardup.*

(a) *Byford Pit.*—Location.—On the property of Mr. A. Gordin at about ¼ mile east of the Perth-Bunbury Road and some 50 yards south of Hills Road, Byford, five miles south of Armadale and 24 miles by rail from Perth.

Description.—The pit is located on rather sandy well timbered ground which rises gently to the south. To the east, the country slopes steadily upwards towards the foot of the Darling Scarp. Laterite gravel mantles the soil a hundred yards east of the pit and in the higher ground a short distance further east gives place to outcrops of granite, together with a band of slates and quartzites of the Cardup Series.

The sand pit is entered from the northern end and its floor slopes gently southwards. It is approximately 80 feet long with a maximum width of 55 feet, and at the time of inspection the maximum height of the southern face was about 12 feet. Overburden other than the trees includes sparse scrub, rubble and roots, and extends downwards for about three feet. The sand throughout the pit is fairly even grained, light orange brown in colour, and has only a weak bond.

Similar country extends southwards for many chains of gradually rising ground so that a large tonnage of sand should be available.

Operator.—This deposit has been opened and operated privately in the last few years by Hoskins Foundry, Perth.

(b) *Cardup Pit.*—Location.—Situated on Mr. Evans' property, about 250 yards south of the old Cardup Brick Works, nearly a mile east of the Perth-Bunbury Road and about 1¼ miles south of the Byford pit described above.

Table V.

PERTH MOULDING SANDS.

Guildford Loams.

Sample No.	Description of Deposit.	Fineness Test. Per cent. remaining on Tyler Sieve No. 6	10	20	28	35	48	65	100	150	200	270	Pan.	A.F.A. Clay Sub-stance.	Total.	A.F.A. Grain Fine-ness No.	A.F.A. Grain Class.	A.F.A. Clay Class.	Per cent. of "Sand" Grade Remaining on Three Sieves.	A.F.A. Grain Shape.	Routine Tests. Mois-ure. %	Per-mea-bility.	Green Com-pres-sion St'gth. lb./sq. in.
22	Fine Loam. Bell Bros. Pit, Guildford	0·0	0·0	0·2	0·2	0·4	1·2	2·6	5·0	6·8	8·0	4·8	22·4	48·8	100·4	194	2	*	38% on 100, 150 and 200. (68% on 200, 270 and Pan)	Angular	8·0 9·1 9·8 11·1	2·8 6·1 11·9 19·8	23·2 23·2 20·2 13·9
23	Medium-Fine Loam. Bell Bros. Pit, Guildford	0·0	0·0	0·0	0·6	2·0	6·0	11·4	17·8	18·0	14·4	5·8	11·2	13·0	100·2	120	3	E	58% on 100, 150 and 200	Angular	5·2 6·2 6·9 8·1	51·0 39·0 42·0 37·0	8·0 6·6 5·2 4·5
24	Fine Loam. Bell Bros. Pit, Guildford	0·0	0·0	0·2	0·2	0·6	2·0	5·0	11·0	15·6	16·0	7·4	19·2	22·9	100·1	158	2	G	55% on 100, 150 and 200. (55% on 200, 270 and Pan)	Angular	5·0 6·1 7·1 8·2 9·2 10·0 10·8	19·7 20·3 23·7 25·0 22·9 23·3 19·5	19·8 14·9 11·5 9·1 8·2 8·0 7·2
25	Medium-Fine Loam. Bell Bros. Pit, Guildford	0·0	0·0	0·0	0·4	2·0	6·6	11·6	18·2	19·6	13·8	4·6	10·4	13·0	100·2	116	3	E	59% on 100, 150 and 200	Angular	5·2 6·0 7·1 7·9	54·0 44·5 43·5 42·0	8·4 6·4 5·3 4·5
26	Medium-Fine Loam. Bell Bros. Pit, Guildford	0·0	0·0	0·0	0·2	0·4	1·8	5·6	15·4	22·4	17·8	6·8	12·0	17·8	100·2	135	3	F	67% on 100, 150 and 200	Angular	5·2 6·1 7·0 8·0 9·0	45·0 40·0 36·5 37·0 34·5	13·1 9·5 7·2 6·0 5·3
27	Medium-Fine Loam. Bell Bros. Pit, Guildford	0·0	0·0	0·0	0·2	0·4	2·0	7·0	18·0	23·6	17·6	6·2	10·6	14·3	99·9	128	3	E	69% on 100, 150 and 200	Angular	5·1 6·2 6·9 8·1	46·0 37·5 38·0 35·0	7·7 5·6 4·7 4·1

* Not covered by A.F.A. Classification (too high).

Description.—The deposit consists of a layer of unknown depth of reddish brown sandy loam, which probably overlies and is partly derived from the decomposition of the band of slates whose southern extension passes through the old Cardup Brick Works quarry.

The " pit " is very irregular in shape and consists of a shallow excavation having a maximum depth of about four feet, and averaging about three feet. A number of large trees are growing both within and around the edges of the pit, the loam having been dug from the intervening clear spaces.

Operator.—This pit is worked intermittently by the owner of the property, but had not been worked for two years prior to the date of inspection. No estimate was made of the quantity of sand still available in this locality, but it was considered to be small.

Byford-Cardup Sands—Test Results.—Sample No. 28 contains 12½ per cent. of clay substance. It is even (79 per cent. of " sand " on three adjacent sieves) and the content of fines is small. The permeability is high and maximum permeability is developed at a low moisture content. For moulding the loam must be strengthened, either by the addition of clay or by mixing with Guildford loam ; the former is preferable.

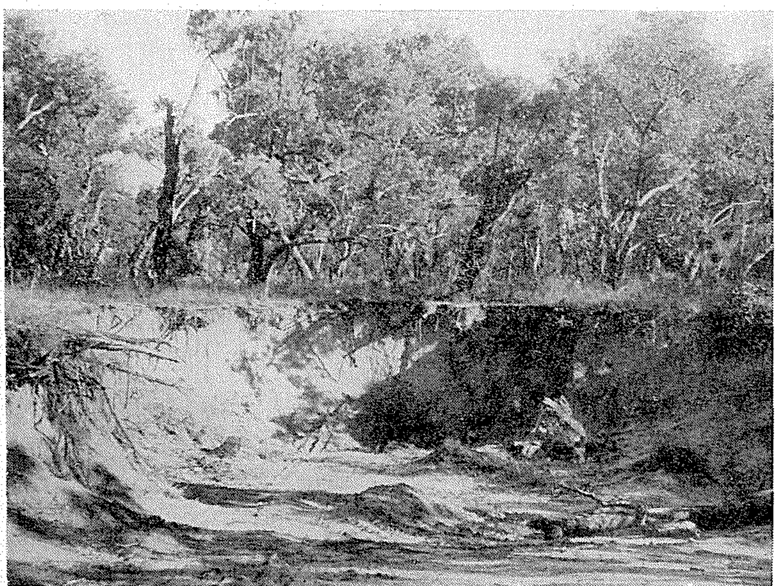


PLATE XV.
Loam. Gordins Pit, Byford.

Sample No. 29 from the Cardup pit is slightly finer and not quite as even. It also contains more fines and more clay substance ; in consequence the permeability is reduced to approximately half that of the Byford loam. In general, therefore, this loam is not quite as satisfactory as Sample No. 28. It would also need to be strengthened for moulding.

The Byford-Cardup type loams have given excellent results in the few foundries in which they are used. Initial difficulties due to

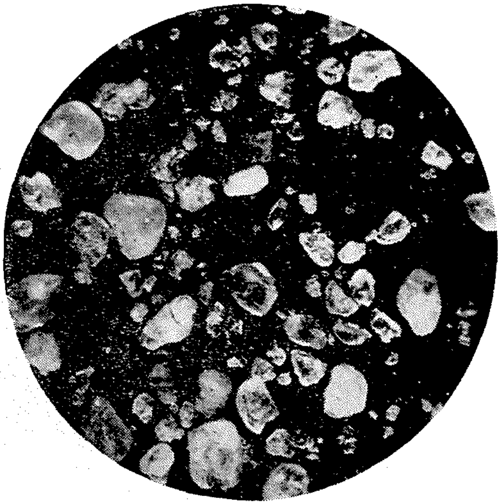


PLATE XVI.
Washed Sand Grains. Medium Loam, Byford.
(Mag. X 12.)

difference in the " feel " of the loam are easily overcome and advantage may be taken of the lower moisture content needed to develop optimum properties. It is probable that other deposits similar to the two pits sampled occur in the Byford-Cardup district.

Sample No. 28.—MEDIUM LOAM—GORDIN'S PIT, BYFORD.

Fineness Test.

A.F.A. clay substance	12.4%
A.F.A. grain fineness number	46
A.F.A. grain class	6
A.F.A. clay class	E
" Sand " remaining on three sieves	79% on 35, 48 and 65 mesh
A.F.A. grain shape	Sub-angular, finer grains angular.

TABLE VI.

PERTH MOULDING SANDS.

Byford-Cardup Loams.

Sample No.	Description of Deposit.	Fineness Test.																			Routine Tests.		
		Per cent. remaining on Tyler Sieve No.												A.F.A. Clay Sub-stance.	Total.	A.F.A. Grain Fine-ness No.	A.F.A. Grain Class.	A.F.A. Clay Class.	Per cent. of "Sand" Grade Remaining on Three Sieves.	A.F.A. Grain Shape.	Mois-ure.	Per-mea-bility.	Green Com-pres-sion St'gth.
		6	10	20	28	35	48	65	100	150	200	270	Pan.										
																					%		lb./ sq. in.
28	Medium Loam. Gordin's Pit, Byford	0·0	0·0	0·8	7·6	27·8	30·2	11·2	4·2	2·2	1·4	0·4	1·6	12·4	99·8	46	6	E	79% on 35, 48 and 65	Sub-angular, finer grains angular	4·2 4·9 5·9	275 270 230	9·7 6·2 4·8
29	Medium Loan. Evans' Pit, Cardup	0·0	0·2	0·6	3·4	15·6	32·0	16·0	6·4	3·6	2·0	1·0	2·6	16·8	100·2	56	5	F	76% on 35, 48 and 65	Sub-angular, finer grains angular	5·1 6·0 6·8 7·9	130 145 150 105	9·3 6·8 5·8 4·6

TABLE VII.

PERTH MOULDING SANDS.

Northam Loams.

Sample No.	Description of Deposit.	Fineness Test.																			Routine Tests.		
		Per cent. remaining on Tyler Sieve No.												A.F.A. Clay Sub-stance.	Total.	A.F.A. Grain Fine-ness No.	A.F.A. Grain Class.	A.F.A. Clay Class.	Per cent. of "Sand" Grade Remaining on Three Sieves.	A.F.A. Grain Shape.	Mois-ure.	Per-mea-bility.	Green Com-pres-sion St'gth.
		6	10	20	28	35	48	65	100	150	200	270	Pan.										
																					%		lb./ sq. in.
30	Medium-Fine Loam. Burlong Pool	0·0	0·6	2·4	2·4	2·4	4·4	8·8	16·4	18·4	15·6	5·8	12·2	10·8	100·2	120	3	E	56% on 100, 150 and 200	Angular	4·0 5·0 5·9	35·5 36·5 36·0	5·3 3·8 3·5
31	Medium Free Sand. 1·2 miles South of Northam Railway Station	0·0	0·0	0·6	4·0	11·2	22·8	24·0	18·4	10·2	3·8	1·2	2·0	1·6	99·8	63	5	B	66% on 48, 65 and 100	Angular	Base Permeability 105		
32	Medium-Fine Loam. North End of East Face of Pit, Spring Hill	0·0	0·2	0·6	0·8	1·6	4·2	7·8	13·2	17·2	16·4	5·8	16·2	16·1	100·1	138	3	F	56% on 100, 150 and 200	Angular	4·1 5·0 6·0	25·0 24·1 24·6	9·4 6·9 5·4
33	Medium-Fine Loam. North End of West Face of Pit, Spring Hill	0·8	6·6	7·8	3·4	4·8	9·6	10·0	11·0	12·2	11·2	4·6	9·2	8·9	100·1	93	4	D	38% on 100, 150 and 200	Angular	3·2 4·1 5·0	59·0 39·5 39·0	4·0 4·1 3·4

Routine Tests.

Moisture.	Permeability.	Green Compression Strength.
%		lb./sq. in.
4.2	275	9.7
4.9	270	6.2
5.9	230	4.8

Remarks.

High permeability as result of uniformity and low clay content. For economy of new sand additions, it would be best to strengthen slightly with bentonite.

Sample No. 29.—MEDIUM LOAM—EVANS' PIT, CARDUP.

Fineness Test.

A.F.A. clay substance	16.8%
A.F.A. grain fineness number	56
A.F.A. grain class	5
A.F.A. clay class	F
"Sand" remaining on three sieves	76% on 35, 48 and 65 mesh
A.F.A. grain shape	Sub-angular, finer grains angular.

Routine Tests.

Moisture.	Permeability.	Green Compression Strength.
%		lb./sq. in.
5.1	130	9.3
6.0	145	6.8
6.8	150	5.8
7.9	105	4.6

Remarks.

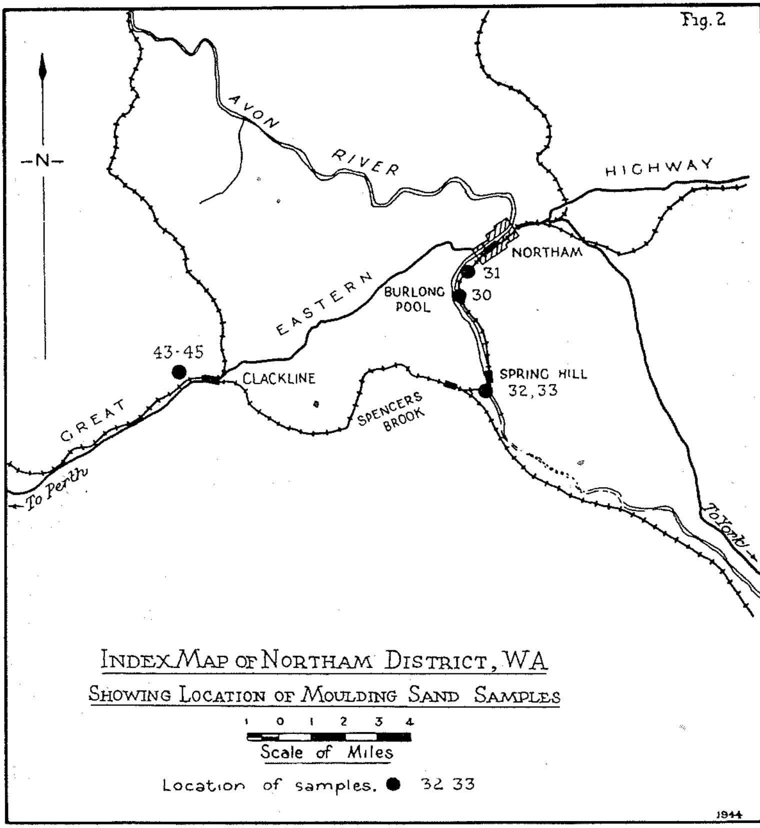
Not as even and permeability not as high as Sample No. 28. Similar remarks to Sample No. 28 apply as regards strength.

(iii) *Northam District.*

(a) *Burlong Pool.*

Location.—This deposit is situated about two miles by road south-west of Northam, and 64½ miles by rail from Perth. It forms portion of a terrace on the eastern bank of the Avon where the river widens into a broad pool (Burlong Pool). The pit lies immediately west of the railway line (the Great Eastern Railway). (*See* Fig. 2).

Description.—The terrace at this point has a width of about three chains. East of the railway line the country rises into low broken hills in which outcrops of granitic and gneissic rocks are exposed. The pit is roughly rectangular, about 50 yards long by 40 yards wide and has an average depth of 2 feet 6 inches. The southern face which borders on private farm land is about four feet deep. A sample hole dug in the floor of the pit disclosed a rather gritty layer.



This loam has apparently been derived from the decomposition of the granite, metamorphic and basic rocks of the district, the material having been transported by the Avon River and deposited in terraces and flood plains during the course of the existing cycle of erosion. Similar loam suitable for moulding sand probably occurs in numerous places along the banks of the river in this area. At Burlong Pool, the amount of suitable loam to the immediate north of the pit is very limited, and though there is a fair depth on the southern side, this is on private land.

About half a mile north of Burlong Pool, approximately 1.2 miles by road south-west of Northam Railway Station a deposit of unbonded silica sand is exposed in several shallow pits. This is probably a residual granitic soil from which the clay material has been washed out. This deposit lies just west of the road and is some 12 chains up the slope from the Avon River. The sand has probably been used mainly for building but a sample was collected to test its suitability as a core sand.

Operator.—The Burlong Pool deposit was owned and operated for many years by the Western Australian Government Railways for use in the foundries at the Midland Junction Railway Workshops. About five years previous to the date of inspection however, the pit was abandoned in favour of the Spring Hill deposit.

PLATE XVII.
Loam Pit, Burlong Pool.

(b) *Spring Hill.*

Location.—This deposit is located on the western bank of the Avon River, just south of the railway bridge about 61¼ miles by rail from Perth and some quarter of a mile west of Spring Hill Siding, one mile east of Spencer's Brook. (*See* Fig. 2).

Description.—The deposit is very similar to that at Burlong Pool and forms a low terrace of dark red loam in a cleared field flanking the river. At the time of the inspection the pit was approximately 75 yards long by 30 yards wide, the depth averaging 4 feet to 4 feet 6 inches, being greatest on the northern face on the edge of the road where 5–6 feet was exposed and least on the southern face where 3 feet was exposed. The floor of the pit was a discontinuous seam of sandy grit, and on the northern end of the western face the loam graded into a gritty band 3 feet above the floor. There were also thin lenses of gritty material near the centres of the east and west faces.

Similar open, flat to gently sloping country extends for a considerable distance south of this deposit on the west bank of the River and it is expected that abundant similar grade moulding sand would be available along this bank.

Operator.—The Western Australian Government Railways had been operating the Spring Hill deposit for moulding sand for five years prior to the date of inspection, this site apparently having been selected for its convenience and economy of working.

Northam District Sands—Test Results.—Sample No. 30 from Burlong Pool has a fineness of 120. It is poorly graded ; the majority of grains are 70–140 mesh, but it contains both coarse sand and fine silt. Some silt is also included in the 10.8 per cent. of clay substance. The strength is poor. Though slightly weaker, this loam is similar, both in fineness and distribution, to the lighter grades of Guildford loam.

The unbonded sand (Sample No. 31) has a fineness of 63 but is poorly graded. It would not be suitable as, and would be more costly than the drift sands at present used in Perth.

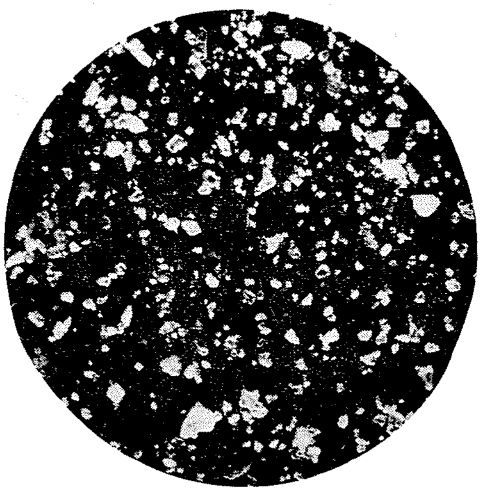


PLATE XVIII.

Washed Sand Grains. Medium-Fine Loam, Northam District. (Mag. X 12.)

Two samples were obtained from the pit at Spring Hill—Sample No. 32 representative of normal quality loam and Sample No. 33 representative of the " gritty " material. Sample No. 32 is generally similar in grain size to Sample No. 30, though a slight increase in clay substance and fineness (138 compared with 120) cause a decrease in permeability and a slight increase in strength. Sample No. 33 is very poorly graded. The grains range from almost silt to coarse grit which would have a detrimental effect on the skin of the castings. The permeability is little higher than that of Sample No. 32 but the strength is only half as great. Care should therefore be taken to exclude this gritty material.

The Northam sands are generally similar to the lighter grades of Guildford loam. It is difficult to understand why they are used in preference to the latter.

Sample No. 30.—MEDIUM-FINE LOAM-BURLONG POOL.

Fineness Test.

A.F.A. clay substance	10.8%
A.F.A. grain fineness number....	120
A.F.A. grain class	3
A.F.A. clay class	E
"Sand" remaining on three sieves	56% on 100, 150 and 200 mesh
A.F.A. grain shape	Angular.

Routine Tests.

Moisture. %	Permeability.	Green Compression Strength. lb./sq. in.
4.0	35.5	5.3
5.0	36.5	3.8
5.9	36.0	3.5

Remarks.

Poorly graded. Weak.

Sample No. 31.—MEDIUM FREE SAND—NORTHAM DISTRICT.

Fineness Test.

A.F.A. clay substance	1.6%
A.F.A. grain fineness number	63
A.F.A. grain class	5
A.F.A. clay class	B
"Sand" remaining on three sieves	66% on 48, 65 and 100 mesh
A.F.A. grain shape	Angular.
Base Permeability	105

Remarks.

Poorly graded. Not as suitable as Perth core sands.

Sample No. 32.—MEDIUM-FINE LOAM—NORTH END OF EAST FACE OF PIT, SPRING HILL.

Fineness Test.

A.F.A. clay substance	16.1%
A.F.A. grain fineness number	138
A.F.A. grain class	3
A.F.A. clay class	F
" Sand " remaining on three sieves	56% on 100, 150 and 200 mesh
A.F.A. grain shape	Angular.

Routine Tests.

Moisture.	Permeability.	Green Compression Strength.
%		lb./sq. in.
4.1	25.0	9.4
5.0	24.1	6.9
6.0	24.6	5.4

Remarks.

Similar to Sample No. 30 but contains more clay substance which is main cause of lowered permeability.

Sample No. 33.—MEDIUM-FINE LOAM—NORTH END OF WEST FACE OF PIT, SPRING HILL.

Fineness Test.

A.F.A. clay substance	8.9%
A.F.A. grain fineness number	93
A.F.A. grain class	4
A.F.A. clay class	D
" Sand " remaining on three sieves	38% on 100, 150 and 200 mesh
A.F.A. grain shape	Angular.

Routine Tests.

Moisture.	Permeability.	Green Compression Strength.
%		lb./sq. in.
3.2	59.0	4.0
4.1	39.5	4.1
5.0	39.0	3.4

Remarks.

Very poorly graded. Inferior to Sample No. 32. Care should be taken that the " gritty " band is excluded.

Chapter III.

KALGOORLIE MOULDING SANDS.

GEOLOGY AND PHYSIOGRAPHY.

The chief topographical feature in the immediate vicinity of Kalgoorlie and Boulder townsites is a central ridge of low hills trending roughly north-north-west and south-south-east and reaching a maximum altitude in Mt. Gledden, better known as Maritana Hill, which rises to a height of about 150 feet. This ridge has a length of about four miles, and dies out in a southerly direction just beyond the south end of the Boulder mines, giving way to flat salt marsh or lake country which is broken again at about three miles south of Boulder by a small conspicuous clump of hills having their highest point in Mt. Hunt, which rises to a height of from three to four hundred feet.

To the immediate west and east of the central ridge are wide flats having a general southerly drainage. The town of Kalgoorlie is situated on the western fall and northwards of the centre of the main central ridge. The gold mines are concentrated along the line of the ridge, the famous " Golden Mile " being at its southern end.

Surface exposures of primary rock in the vicinity of Kalgoorlie are very infrequent, and where in evidence are often completely bleached and decomposed by weathering to considerable depths. The underlying rocks are all Older Pre-Cambrian and are now highly folded and tilted. They consist essentially of a series of metamorphosed sediments and interbedded fine grained basic lavas (Older Greenstones), intruded by large masses of coarser grained basic and ultrabasic rocks now largely altered to amphibolites (Younger Greenstones), and also cut by later dykes of intermediate and acid rocks—prophyrites and porphyries.

Recent deposits mantling the now highly weathered Pre-Cambrian formations consist of a ubiquitous layer of loose sand and loam, with iron stone, gravel and frequent scattered deposits of travertine. The banks of the salt lake areas, particularly on the sides opposite the direction of the prevailing winds are often covered by low mounds of drift sand or occasionally, powder gypsum.

Ferruginous laterite or ironstone conglomerate frequently occurs as a thin capping overlying the low hills and ridges. A large part of the low lying soil covered country is underlain at a depth varying from a few inches to several feet by a thin layer of impure, often nodular travertine (limestone). This travertine is formed by the lime originally contained in the underlying rocks dissolving and subsequently being deposited at the surface by evaporation. Its presence complicates the quest for suitable moulding sands in this district.

THE SAND DEPOSITS.

The greater part of the sand and loam which covers the country in the immediate vicinity of Kalgoorlie consists of residual soil derived from the underlying rocks by weathering *in situ.* These underlying rocks being, for the greater part, relatively high in iron, alumina, lime, magnesia and the alkalies, and relatively deficient in free silica (quartz), it is not surprising that the resulting soils are usually dark red iron-rich loams having a relatively high content of clay substance. No good naturally-occurring clean silica sand of grain size suitable for core work has so far been located near Kalgoorlie.

As a result of inspections in August, 1943, March, 1944, and May, 1945, four deposits from the following localities were examined and sampled :—

(i) North-West of Kalgoorlie (Ora Banda Pipe Track).
(ii) Kalgoorlie Racecourse.
(iii) Mt. Hunt.
(iv) Kanowna.

Kaolinitic clay for daubing pots and ladles at the Kalgoorlie Foundry has been obtained from the dumps of several old shafts in weathered (kaolinised) greenstone scattered about the vicinity of the Foundry.

(i) *North-West of Kalgoorlie.*

Location.—Red sand has been obtained from a locality to the north-west of Kalgoorlie township. This is situated on the edge of the road following the Goldfields Water Supply Department pipe track running from west of Kalgoorlie to Ora Banda via Black Flag.

It is located at approximately 4¼ miles on a bearing N. 60° W. from Kalgoorlie Railway Station at the intersection of the road and the eastern boundary fence of W. Horan's pastoral lease, and near the eastern boundary of the (now voided) No. 2 State Forest Reserve.

Description.—The country in the vicinity of the deposit rises gently to the north-west for some 100 yards to a travertine-covered mound about 15–20 feet above the general level. The land is here lightly timbered with mallee gum and sparse scrub. A small amount of sand has been dug here and there over an area of a few hundred square feet. The surface sand consists of drift to a depth of three to six inches. Below this is moulding sand to a depth of 40 inches ; beneath the moulding sand is heavy red clay unsuitable for foundry purposes. No attempt has been made to work a face of sand in this deposit.

A second site in this district was also worked for a limited period. The location of the deposit was about three miles westward of the deposit described above and about seven miles on a bearing N. 65° W. from Kalgoorlie Railway Station. The deposit formed portion of the bank of a small clay pan flat, and consisted of 18 inches to two feet of red loam, underlying six-nine inches of loose sand, and overlying heavy clay with nodular travertine. About 55 tons of sand had been supplied to the Kalgoorlie Foundry up to February, 1944, but the deposit was abandoned later in favour of the Racecourse sand described below.

Operator.—The deposit has been worked for and under the direction of the Kalgoorlie Foundry by contract carters. Up to October, 1943, when the site was relinquished, only a limited amount (probably about 20 tons) had been dug.

(ii) *Kalgoorlie Racecourse.*

Location.—Red sand is now obtained from a property on the western side of the Kalgoorlie Racecourse.

Description.—The sand is dug from an ill defined pit 5–10 yards from the roadway. After the surface of sandy soil, which contains roots and other organic matter has been removed, dark-red coloured loam is dug to 12–18 inches, at which depth it grades into heavy clay. Great care would have to be taken to prevent the mixing of clay or overburden with the loam. Owing to the nature of the deposit, the available tonnage would be small.

Operator.—The sand is dug under a similar arrangement to that for the last deposit.

(iii) *Mt. Hunt.*

Location.—Mt. Hunt lies about seven miles south-south-east of Kalgoorlie Railway Station, just east of the Boulder-Celebration Road. The sand deposit is situated to the immediate east of the road and about $\frac{1}{2}$ to $\frac{3}{4}$ mile on a bearing 240 degrees from the Trig. Station on Mt. Hunt.

Description.—This deposit consists of a large dune of light-brown drift sand at the western foot of the Mt. Hunt ridge. To the westward the country slopes down to a broad dry lake-filled valley from which the sand has been derived. The main portion of the dune is approximately five chains long (in a north-south direction) and three chains wide, and at its centre has a maximum thickness of 15 feet. The sand overlies decomposed bed rock (completely weathered greenstone, including pillow lavas), clean wind-swept floors of which are exposed to the immediate north of the dune. The sand is sparsely overgrown with scattered mallee and spinifex. It contains grains of iron oxide.

At the time of inspection three pits having faces from four to 12 feet in height had been dug and about one fifth of the whole deposit had been removed—probably for building construction, top dressing of lawns, etc. Little, if any, of this deposit has hitherto been used for moulding sand. Assuming an average depth of five feet of sand in the central portion of the dune it is estimated that between 8,000 and 10,000 tons of clean sand should be still available.

Operator.—The sand for moulding purposes has been dug under an arrangement similar to that for all deposits worked in the Kalgoorlie district.

(iv) *Kanowna.*

Location.—Kanowna township is situated 12 miles north-east of Kalgoorlie. The sand deposit, the main tailings dumps of the old White Feather Gold Mine, lies approximately one mile north-east of the old Kanowna Railway Station.

Description.—This sand deposit consists of the accumulated remains, after crushing and treatment, of a considerable part of the "Kanowna Main Reef" which has been mined for gold. The "Kanowna Main Reef" consisted of an auriferous quartz reef associated with carbonated porphyries, intruded into a series of metamorphosed sedimentary rocks, especially conglomerates.

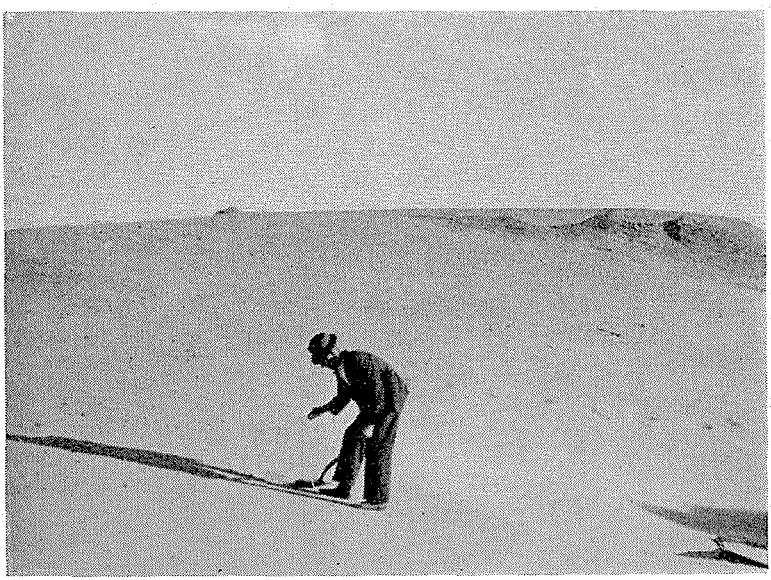


PLATE XIX.

Tailings Dump, White Feather Mine, Kanowna.

The main portion of this dump which is about three chains in diameter and has a maximum height of 25 feet, consists of a strong creamy-white, sandy clay. The dump, which is at least 30 years old, has been continuously exposed to wind action tending to remove the fine clayey material and to sort the coarser sand grains. Consequently a deposit of coarser grained sand particles has accumulated on the northern and eastern slopes of the dump, the sides opposite to the prevailing winds. These sand fragments, which as a result of crushing are extremely angular in form, consist largely of quartz and possibly a little felspar, but also include some carbonates (calcite, mesitite and ankerite) together with numerous grains of green chrome mica (fuchsite).

The amount of thoroughly sorted coarse sand available varies considerably with the seasons and with the direction and intensity of the prevailing winds. There are in the slopes of the dump, no defined boundaries between the clean, sorted coarse sand suitable for foundry work, and the finer tailings which contain such quantities of clay as to be unsatisfactory for general core work. Consequently strict supervision should be exercised during the digging of sand from this dump. The monthly production of sand from November, 1943, to February, 1944, was, according to figures supplied by Kalgoorlie Foundry, Ltd., slightly less than $7\frac{3}{4}$ tons.

Operator.—Winnowed material has now been obtained from this dump for many years (probably 15–20 years) by contract carters for the Kalgoorlie Foundry, where it is used as core sand.

Kalgoorlie Sands—Test Results.—The bonded sands (Samples Nos. 34 and 35) are of similar grade but are uneven, the sand grains being distributed from 35 mesh (0.016 in.) to 270 mesh (0.002 in.). This causes both lowering of permeability and a poor surface finish on the castings, and necessitates a liberal use of black-wash finishing. Sample No. 34 has 11 per cent. of clay substance and a permeability of 50. The decrease of the permeability of Sample No. 35 to less than 20 is mainly caused by an increase in clay substance to 25 per cent. This increase in clay substance however results in generally higher strength (at three per cent. moisture the strength of Sample No. 34 is 19.2 lb./sq. in. but the sand is too dry to be moulded satisfactorily), so that less new sand need be added to the heap.

The free sand from Mt. Hunt (Sample No. 36) is of similar grade to the bonded sands but somewhat more even (68 per cent. of "sand" on three adjacent sieves compared with 59 per cent. and 47 per cent.). The base permeability is 37. The synthetic sand formed by bonding with $3\frac{1}{2}$ per cent. of bentonite and $1\frac{1}{2}$ per cent. of dextrin however, has a permeability of 105–110 and should be suitable for medium grey iron castings. The Mt. Hunt sand could probably be washed and graded easily (*see* later).

The windblown sand from Kanowna (Sample No. 39) is clean and of similar fineness to the other Kalgoorlie sands. It is poorly graded, but could be easily washed and screened to produce two uniform grades suitable for cores or synthetic sands. To simulate practical conditions for such a treatment, 5,000 grams (11 lb.) of sand were washed with an upward current of water flowing at a rate of 10 inches per minute ; 7.4 per cent. of silt was removed. The remainder was sieved on a 10 inch diameter 65 mesh screen for four minutes. Sixty per cent. of over-size and 40 per cent. of under-size were obtained (Sample Nos. 37A and 37B) ; both samples are evenly graded, the fineness of the over-size being 46 and of the under-size 11.

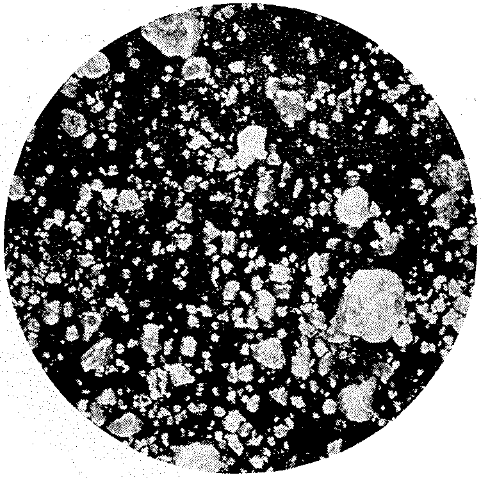


PLATE XX.
Washed Sand Grains. Fine-Medium Loam, Kalgoorlie.
(Mag. X 12.)

The sands at present used in Kalgoorlie are poor and alternative sources are not available without transport over long distances. Better use could be made of the sands, however, and much of the black-wash finishing could be eliminated if the foundries installed sand conditioning plant with screening equipment designed to separate grades suitable for heavy and light castings. Furthermore, the replacement of loam by synthetic sand would be advantageous.

SAMPLE No. 34.—FINE-MEDIUM LOAM—BLACK FLAG ROAD, KALGOORLIE.

FINENESS TEST.

A.F.A. clay substance	11.8%
A.F.A. grain fineness number	87
A.F.A. grain class	4
A.F.A. clay class	E
"Sand" remaining on three sieves	59% on 48, 65 and 100 mesh
A.F.A. grain shape	Sub-angular, stained with iron oxide.

ROUTINE TESTS.

Moisture. %	Permeability.	Green Compression Strength lb./sq. in.
3.0	51	19.2
4.1	51	10.0
4.8	54	7.6
6.1	52	5.7

REMARKS.

Poorly graded. Too dry for satisfactory moulding at three per cent. moisture.

SAMPLE No. 35.—FINE-MEDIUM LOAM—RACECOURSE, KALGOORLIE.

FINENESS TEST.

A.F.A. clay substance	25.1%
A.F.A. grain fineness number	91
A.F.A. grain class	4
A.F.A. clay class	G
"Sand" remaining on three sieves	47% on 48, 65 and 100 mesh
A.F.A. grain shape	Sub-angular, stained with iron oxide.

ROUTINE TESTS.

Moisture. %	Permeability.	Green Compression Strength. lb./sq. in.
5.2	3.8	18.7
5.9	5.6	14.4
7.2	8.7	11.2
8.1	13.7	9.6
8.8	19.3	10.1

REMARKS.

Similar grade to Sample No. 34. High clay substance is main cause of lower permeability and higher strength.

SAMPLE No. 36.—FINE-MEDIUM FREE SAND—MT. HUNT.

FINENESS TEST.

A.F.A. clay substance	5.2%
A.F.A. grain fineness number	83
A.F.A. grain class	4
A.F.A. clay class	D
"Sand" remaining on three sieves	68% on 65, 100 and 150 mesh
A.F.A. grain shape	Angular, slightly stained with rion oxide.

BASE PERMEABILITY 37

ROUTINE TESTS.

Moisture.	Permeability.	Green Compression Strength.
%		lb./sq. in.
2.0	28.5	Too weak to test
*3.5	110	5.3
*4.2	105	4.7

REMARKS.

Uneven. Permeability higher in synthetic sand.

* Bonded with 3½ per cent. bentonite, 1½ per cent. dextrin.

SAMPLE No. 37.—FINE-MEDIUM FREE SAND—KANOWNA.

FINENESS TEST.

A.F.A. clay substance	1.1%
A.F.A. grain fineness number	86
A.F.A. grain class	4
A.F.A. clay class	B
"Sand" remaining on three sieves	61% on 48, 65 and 100 mesh
A.F.A. grain shape	Angular.
BASE PERMEABILITY	41

REMARKS.

Not very even. Could be washed and graded easily (*See* Samples Nos. 37A, 37B).
Carbon Dioxide (Schrotter method) = 4.6%.

SAMPLE No. 37A.—FREE SAND—KANOWNA—OVERSIZE.

FINENESS TEST.

A.F.A. clay substance	*
A.F.A. grain fineness number	46
A.F.A. grain class	6
A.F.A. clay class	....
"Sand" remaining on three sieves	87% on 35, 48 and 65 mesh
A.F.A. grain shape	Angular.
BASE PERMEABILITY	275

REMARKS.

Even. High base permeability.

* Not determined (silt removed from original material before screening).

SAMPLE No. 37B.—FREE SAND—KANOWNA—UNDERSIZE.

FINENESS TEST.

A.F.A. clay substance	*
A.F.A. grain fineness number	111
A.F.A. grain class	3
A.F.A. clay class	....
"Sand" remaining on three sieves	89% on 100, 150 and 200 mesh
A.F.A. grain shape	Angular.
BASE PERMEABILITY	51

REMARKS.

Even. High base permeability.

* Not determined (silt removed from original material before screening).

TABLE VIII.

KALGOORLIE MOULDING SANDS.

Sample No.	Description of Deposit.	Fineness Test. Per cent. remaining on Tyler Sieve No. 6	10	20	28	35	48	65	100	150	200	270	Pan.	A.F.A. Clay Substance.	Total.	A.F.A. Grain Fineness No.	A.F.A. Grain Class.	A.F.A. Clay Class.	Per Cent. of "Sand" Grade Remaining on Three Sieves.	A.F.A. Grain Shape.	Base Permeability.	Routine Tests. Moisture.	Permeability.	Green Compression St'gth.
																						%		lb./sq. in.
34	Fine-Medium Loam. Pit four and a half miles along Black Flag Road from Kalgoorlie	0·0	0·0	0·2	1·2	4·4	15·0	20·2	16·6	13·2	9·6	3·4	4·6	11·8	100·2	87	4	E	59% on 48, 65 and 100	Sub-angular (a)	....	3·0 4·1 4·8 6·1	51 51 54 52	19·2 10·0 7·6 5·7
35	Fine-Medium Loam. Racecourse, Kalgoorlie	0·6	0·4	2·2	3·2	5·8	10·6	12·6	12·2	10·4	8·0	2·8	6·4	25·1	100·3	91	4	G	47% on 48, 65 and 100	Sub-angular (a)	....	5·2 5·9 7·2 8·1 8·8	3·8 5·6 8·7 13·7 19·3	18·7 14·4 11·2 9·6 10·1
36	Fine-Medium Free Sand. Mt. Hunt	0·0	0·0	0·0	0·6	2·8	13·0	24·2	24·2	15·8	7·8	2·6	4·0	5·2	100·2	83	4	D	68% on 65, 100 and 150	Angular (a)	37	2·0 †3·5 †4·2	28·5 110 105	‡ 5·3 4·7
37	Fine-Medium Free Sand. Kanowna	0·0	0·0	0·0	0·4	6·2	18·8	21·6	19·8	14·4	8·6	3·4	5·8	1·1	100·1	86	4	B	61% on 48, 65 and 100	Angular	41	....	....	....
37A	Free sand. Kanowna. Washed and screened through 65 mesh sieve. Oversize	0·0	0·0	0·2	0·4	12·2	33·6	41·2	12·0	0·2	0·0	0·0	0·0	*	99·8	46	6	....	87% on 35, 48 and 65	Angular	275	....	....	....
37B	Free Sand. Kanowna. Washed and screened through 65 mesh sieve. Undersize	0·0	0·0	0·0	0·0	0·0	0·2	1·0	33·4	35·2	20·6	6·0	3·6	*	100·0	111	3	....	89% on 100, 150 and 200	Angular	51	....	....	....

(*a*) Stained with iron oxide. * Not determined (*see* text). † Milled with 3½ per cent. American Bentonite plus 1½ per cent. Dextrin. ‡ Too weak to test.

TABLE IX.

MISCELLANEOUS LOCALITIES.

Sample No.	Description of Deposit.	Fineness Test. Per cent. remaining on Tyler Sieve No. 6	10	20	28	35	48	65	100	150	200	270	Pan.	A.F.A. Clay Substance.	Total.	A.F.A. Grain Fineness No.	A.F.A. Grain Class.	A.F.A. Clay Class.	Per cent. of "Sand" Grade Remaining on Three Sieves.	A.F.A. Grain Shape.	Routine Tests. Moisture.	Permeability.	Green Compression St'gth.
																					%		lb./sq. in.
38	Fine-Medium Loam. Collie	0·0	0·0	0·2	0·2	1·0	4·6	12·8	21·4	17·2	9·6	3·4	6·4	23·1	99·9	104	3	G	67% on 65, 100 and 150	Angular	5·2 6·0 6·9 7·9 9·0 9·8	20·0 28·0 34·5 38·0 52·0 40·5	21·5 15·1 12·2 9·5 8·8 7·9
39	Medium Sand. Tammin	0·0	0·0	3·8	7·8	10·8	14·8	14·8	13·6	11·0	6·4	2·2	3·8	10·8	99·8	72	4	E	49% on 48, 65 and 100	Angular	3·0 4·0 4·9	81 75 73	15·3 6·0 4·8

Chapter IV.

MISCELLANEOUS LOCALITIES.

A.—COLLIE.

GEOLOGY AND PHYSIOGRAPHY.

The Collie Basin of coal measures lies 100 miles slightly west of south from Perth within the southward extension of the Darling Range or "Peneplain" in a depression some 15 to 20 miles eastward of the Darling Fault Scarp. This basin is some 600 feet above sea level and is drained by the upper branches of the Collie River which winds a tortuous path westwards. Collie township lies on the Collie River towards the northern end of the basin.

There are no known stratified rocks in the vicinity of Collie, the entire extent of the coal measures (which consist of a series of sandstones, grits and micaceous shales associated with a number of coal seams of Permo-Carboniferous age), being concealed beneath either sandy swamps or ferruginous laterite ridges, whilst the whole basin is surrounded by gneissic granite.* A typical section showing the relationships of the superficial deposits to the coal measures is exposed at the Stockton Open Cut about five miles east of Collie, where a shallow deposit of grey-white sand overlies 10 to 15 feet of compact horizontal ferruginous laterite. Under this grain is a thin pebble bed—a lacustrine conglomerate—which is unconformably underlain by the gently south-dipping coal measures. The superficial deposits are probably late Tertiary in age.

THE SAND DEPOSITS.

Only one deposit—a river loam from near the corner of Christie Street and River Avenue, North-East Collie—is at present used for foundry work at Collie. Other bonded sands from the river bank near an old brick works about a mile south of this were also inspected but owing to the presence of incipient nodules of iron oxide this sand would have to be sifted before use. Some excellent fine, even grained unbonded silica sands suitable for core work were noted on the flats forming the north bank of the river near Minninup Pool, about a mile and a half

* As in other parts of the Darling "Range" this granite is usually more or less covered by a capping of laterite.

south-west of Collie township. However, owing to the small volume of work and the absence of intricate repetition castings, it has been found unnecessary to develop an oil-bonded core sand at Collie.

River Avenue Sand.

Location.—This deposit forms a terrace on the eastern bank of a meander in the Collie River slightly less than a mile north-east of the Post Office. This terrace is bounded on the eastern side by River Avenue and extends from Christie Street at the northern end to Lane Street at the southern end. The deposit is at present being opened up at the northern end opposite Christie Street.

Description.—Soil from the river's edge to about 10 yards up the bank (*i.e.*, eastward) consists of grey clay, which further eastward grades into a very fine yellow loam. Opposite Christie Street this loam is 18–20 yards in width and has an average thickness of 12–18 inches. Below this the clay content increases and the sand becomes too strong for foundry use. Surface vegetation is scanty and providing superficial gravel is brushed away, foundry sand can be dug right from the surface. North of this point the river swings round in a sharp curve to the eastward, cutting off the terrace, but to the south the loam probably extends for 200 yards or less, after which as the river swings sharply westward the terrace narrows rapidly and rises to a laterite-gravel capped ridge. The southern portion of the terrace is sprinkled with trees and a moderate undergrowth.

Operator.—This deposit lies on portion of a Collie Municipal Council Reserve. In recent years sand has been dug by W. Geldert and Sons for iron and brass castings and cores in their foundry. Considerably less than 10 tons are consumed per year.

Sample.—Sample No. 38 was collected and forwarded by Mr. W. Geldert in October, 1943.

Test Results.—The loam is moderately even, 67 per cent. of " sand " remaining on three adjacent sieves. It is a fine-medium grade since the majority of the grains are 70–100 mesh, but the fineness number is increased to 104 by 25 per cent. of " fines." The strength of the sand is high. While the maximum permeability is not low for a sand of this fineness, this maximum is not developed below moisture contents at which the strength has decreased to less than one-half its maximum.

SAMPLE No. 38.—FINE-MEDIUM LOAM—COLLIE.

FINENESS TEST.

A.F.A. clay substance	23.1%
A.F.A. grain fineness number	104
A.F.A. grain class	3
A.F.A. clay class	G
" Sand " remaining on three sieves	67% on 65, 100 and 150 mesh
A.F.A. grain shape	Angular.

ROUTINE TESTS.

Moisture.	Permeability.	Green Compression Strength
%		lb./sq. in.
5.2	20.0	21.5
6.0	28.0	15.1
6.9	34.5	12.2
7.9	38.0	9.5
9.0	52.0	8.8
9.8	40.5	7.9

REMARKS.

Poorly graded. High strength.

B.—TAMMIN.

Sand Quarry.

Location.—North side of the main Perth-Kalgoorlie Road and just west of the cemetery, about one mile west of Tammin township.

Description.—A sample (No. 39) from this quarry was collected by Mr. F. G. Forman, Government Geologist, in February, 1944. The pit had a maximum depth of about seven feet. The country surrounding this deposit for many square miles consists of yellow sand plain sparsely covered with low scrub. It is not known whether any of this sand has so far been used for foundry work ; all the material dug has probably been utilised in the construction of roads, railways and pipe lines.

Test Results.—The sand is yellow coloured and medium grained. It is uneven, being distributed is nearly equal amounts over five sieves from the 35 mesh (0.0165 in.) to the 150 mesh (0.0041 in.), and in consequence the permeability is lowered. Although containing only 10.8 per cent. of clay substance the green strength of the sand is high at three per cent. but falls rapidly with more moisture ; it may require small additions of bentonite when suitably tempered for moulding. The sand has been tried by one foundry which reports that its durability is low.

SAMPLE No. 39.—MEDIUM SAND—TAMMIN.

FINENESS TEST.

A.F.A. clay substance	10.8%
A.F.A. grain fineness number	72
A.F.A. grain class	4
A.F.A. clay class	E
"Sand" remaining on three sieves	49% on 48, 65 and 100 mesh
A.F.A. grain shape	Angular.

Routine Tests.

Moisture.	Permeability.	Green Compression Strength.
%		lb./sq. in.
3.0	81	15.3
4.0	75	6.0
4.9	73	4.8

Remarks.

Uneven. Not promising as moulding sand.

Chapter V.

CLAYS.

Many of the naturally bonded moulding sands of Western Australía are of but average quality ; some are weak and most are poorly graded and have low permeability. On the other hand, the State is richly endowed with clays, and excellently graded free sands are available in the Perth district. The two combined would form synthetic sands well suited for iron and steel castings. The survey of moulding sands was therefore extended to cover certain clays which it was considered might prove useful for synthetic sands.

TESTING OF CLAYS.

In evaluating the suitability of clays, physical tests were conducted on synthetic sands prepared by milling appropriate quantities of clay with a washed silica sand.

The method of preparation was similar to that of the American Foundrymen's Association, but modified slightly to suit laboratory conditions. The clay was ground in a Raymond swing-hammer laboratory mill, and then dried for four hours at 105–110°C. (Certain clays which appeared too hard for the Raymond mill, were ground to —200 mesh in a ball mill). The desired percentage of clay was first mixed dry with the silica sand in a laboratory-size Simpson mill. After the addition of water the mixture was milled as described on page 15. A washed sand of the following screen analysis was used as a base for the synthetic sands :—

WASHED SILICA SAND.

Fineness Test.

Tyler sieve No.	Remaining on sieve. %
35	0 .2
48	17 .4
65	75 .2
100	6 .8
150	0 .2
—150	0 .0
Total	99 .8
A.F.A. grain fineness number	50
A.F.A. grain shape	Sub-angular.

Remarks.

99 .6 per cent remaining on 48, 65 and 100 mesh Tyler Sieves.

Three synthetic sands (usually containing 4, 8 and 12 per cent. of binder) were prepared for each sample of clay. Each mixture was tested at one or more suitable moisture contents.

For comparison, test results for a synthetic sand containing 4 per cent. of American bentonite are shown below.

PHYSICAL TESTS ON SYNTHETIC SAND.

Base Sand.	Clay.*	Moisture.	Permeability.	Green Compression Strength.
	%	%		lb./sq. in.
Washed silica sand	4	1.9	245	8.9
Lake Gnangara sand (Sample No. 3)	4	1.9	280	7.1

* American Bentonite.

THE CLAY DEPOSITS.

Clay deposits of possible value for synthetic sands belong to the two main groups (1) Kaolins, and (2) Fuller's earths or "Bentonites." A number of deposits of group (1) (used in the past as either firebrick or pottery clays), mostly within easy distance of Perth were examined and sampled. These were situated in the following localities :—

(a) Perth-Darling Range District :—
  (i) Glen Forrest.
  (ii) Gooseberry Hill.
  (iii) Red Hill.

(b) Northam District :—
  Clackline.

The only deposit of group (2) examined in the field was at Marchagee. Samples of clays classed as fuller's earths from a number of scattered localities, *viz.*, Collie, Mumballup and Bardoc were made available for testing from the collection of the Government Mineralogist and Analyst.

1. Kaolins.

(a) Perth-Darling Range District (*see* Plate II.).

(i) *Glen Forrest.*

A clay pit on the property of Mr. G. Burkinshaw about three-quarters of a mile south-east of the Glen Forrest Railway Station, 17 miles from Perth, proved to consist of highly kaolinised granite. The pit is 35–40 yards long in a north south direction and 20 yards wide. It has a maximum depth of 12–14 feet. Overburden consists of lateritic gravel with a fair overgrowth of timber. Samples were taken from the northern face (rather gritty) and the southern face (denser but with quartz veinlets).

Clay from this pit has been supplied for some time to one local foundry for the preparation of synthetic steel moulding sand.

(ii) *Gooseberry Hill.*

A disused clay quarry lies 1¾ miles slightly south of east from Gooseberry Hill Railway Siding which is on the Upper Darling Range Railway and about 19 miles by rail from Perth. This quarry is situated on the eastern slope of a laterite-capped, well timbered hill and on the

PLATE XXI.
Kaolin Pit, Gooseberry Hill.

western edge of a steep, northerly-running valley. It consists of two cuttings into the hillside, the face of each ranging from 10 to 15 feet in height. The clay, which in the past has been used for pottery ware, is a clean pure white kaolin obviously derived from the decomposition in situ of granitic rock. The accompanying grit could be removed readily by washing. A brief inspection revealed very large quantities of clay similar to that exposed in the cutting.

(iii) *Red Hill.*

A brief inspection was made of an old clay quarry at Red Hill on the eastern side of the old Newcastle (Toodyay) Road about 17 miles by road from Perth. This is situated in the hilly country half a mile east of the Darling Scarp which here consists of granite intersected by dolerite dykes and capped by laterite. The material in this quarry is partially decomposed granite, but on inspection contained such a high proportion of quartz and incompletely decomposed ferromagnesian minerals, mica, etc., that it was deemed not worth sampling.

Test Results.

All samples contain a considerable proportion of free silica whose size varies from pit to pit ; the following grading analysis of Sample No. 42 is typical.

GRADING ANALYSIS OF SAMPLE No. 42.

A.F.A. Clay Substance.	58 .5%
Tyler Sieve Number.	Per cent. Remaining on Sieve.
6	0 .1
10	0 .5
20	6 .0
28	6 .5
35	5 .8
48	6 .0
65	4 .8
100	4 .2
150	2 .9
200	1 .9
270	0 .9
Pan	1 .8
Total " sand " grade	41 .4
Total	99 .9

All clays are similar. They have low strength* and high percentages would be needed for satisfactory synthetic sands. The strength would be doubled if the true clay were separated by elutriation but would still be unsatisfactory.

SAMPLE No. 40.—DECOMPOSED GRANITE—SOUTH FACE, BURKINSHAW'S PIT, GLEN FORREST.

PHYSICAL TESTS ON SYNTHETIC SAND.

Clay. %	Moisture. %	Permeability.	Green Compression Strength. lb./sq. in.
4	2 .1	190	0 .9
8	3 .1	145	2 .2
12	4 .1	99	3 .9

REMARKS.
Very weak.

* Throughout this section the term " strength " has been used for brevity. It should be understood clearly, however, that " *strength imparted to a synthetic sand mixture* " is implied.

SAMPLE No. 41.—DECOMPOSED GRANITE—NORTH FACE, BURKINSHAW'S PIT, GLEN FORREST.

PHYSICAL TESTS ON SYNTHETIC SANDS.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	1.8	180	To weak to test
8	3.0	130	2.0
12	4.0	90	3.9

REMARKS.

Similar to Sample No. 40.

SAMPLE No. 42.—DECOMPOSED GRANITE—DISUSED CLAY PIT, GOOSEBERRY HILL.

PHYSICAL TESTS ON SYNTHETIC SANDS.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	1.9	200	1.1
8	3.0	155	2.5
12	3.9	105	4.3

REMARKS.

Too weak to use satisfactorily as binder.

(b) *Northam District* (*See Fig.* 2).

Clackline.—The clay pits at Clackline are situated on the north side of the Great Eastern Railway about one mile west of Clackline Station, 50 miles from Perth. The pits occur in a belt of decomposed (kaolinised) interbedded greenstone (?amphibolite) and metamorphosed erosion sediments—quartzite, mica, sillimanite and garnet schists which strike about north-north-west and dip vertically or at a steep angle west, and are intruded by granitic and dolerite dykes. The pits were mapped and the geology of these deposits briefly described by Matheson (1937). This deposit is owned and operated by the Clackline Firebrick Co. for clays for refractory bricks.

The writers made a brief inspection of the Main (South) Pit and collected samples of a greenish clay (decomposed greenstone schist) from an "island" in the centre of the pit and of a creamy coloured faintly spotted clay derived from the decomposition (kaolinisation) of a dolerite dyke some 40 feet wide. A sample of a mid ball clay from the Company's North Pit about 1½ miles further north on the strike of the country was also secured, though the pit was not inspected.

Test Results.—Though stronger than the Darling Range clays, those from Clackline are much weaker than the Marchagee bentonite. A sufficiently strong synthetic sand could be obtained from 10–12 per cent. of clay, but the permeability is much lower than to be expected with a bentonite-bonded sand and refractoriness would also be lowered. Sample No. 45 is slightly weaker than sample Nos. 43 and 44.

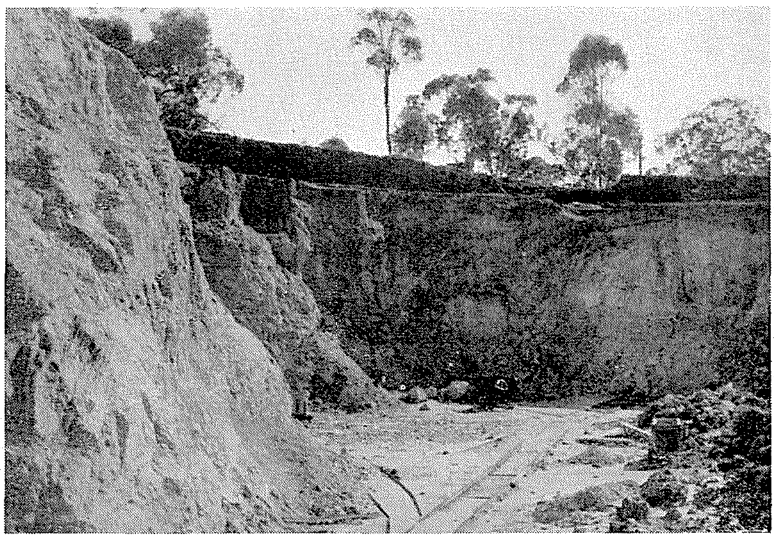


PLATE XXII.

Fireclay Pit, Clackline.

SAMPLE No. 43.—DECOMPOSED GREENSTONE SCHIST—CLACKLINE.

PHYSICAL TESTS ON SYNTHETIC SANDS.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	2.0	215	1.8
8	3.0	175	5.7
12	4.1	130	9.6

REMARKS.

Synthetic sand containing 12 per cent. of clay would have sufficient strength, but permeability would be low.

SAMPLE No. 44.—DECOMPOSED DOLERITE—CLACKLINE.

PHYSICAL TESTS ON SYNTHETIC SANDS.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	2.1	210	1.8
8	3.1	160	5.8
12	4.1	125	10.1

REMARKS.

Similar to Sample No. 43.

SAMPLE No. 45.—MEDIUM BALL CLAY—CLACKLINE.

PHYSICAL TESTS ON SYNTHETIC SANDS.

Clay.	Moisture.	Permeability.	Green Compression. Strength.
%	%		lb./sq. in.
4	2.0	195	1.6
8	3.0	140	5.1
12	4.2	105	8.2

REMARKS.

Slightly weaker than Samples Nos. 43 and 44.

(c) *Greenbushes.*

A sample of fine kaolinitic clay was also received from Greenbushes to test its suitability as a base for core paint. No inspection was made of the deposit.

Test Results.—The strength is in general similar to that of the Clackline clays. With low percentages, the synthetic sands have low strengths, but mixtures containing 10–12 per cent. of clay, would be sufficiently strong for foundry use.

SAMPLE No. 46.—KAOLIN No. M.C. 1—GREENBUSHES.

PHYSICAL TESTS ON SYNTHETIC SAND.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	1.9	200	2.7
8	3.0	150	7.7
12	4.1	125	10.4

REMARKS.

Weak with low percentages of clay. Strength improved with 10–12 per cent. clay.

General Remarks on Kaolins.—Though samples Nos. 43–46 have been classed as kaolins, it would perhaps have been preferable to use the rather loose term "semi ball clay," since they are intermediate in strength between a true kaolin and a bentonite.

Latest overseas practice is to use a fire-clay in conjunction with bentonite. The true kaolins may prove suitable for this purpose, though they are too weak to be used satisfactorily alone.

2. Bentonites.

(a) *Marchagee.*

Location.—Marchagee is situated on the Midland Railway line, 150 miles north of Perth. The clay deposits occur approximately nine miles west of Marchagee Siding. The two principal deposits are located on Mineral Claims 258H and 259H on the south-western corner of Victoria Loc. 5866, and the northern end of Victoria Loc. 7308 respectively. At the time of inspection they were the only two claims held in this area but since then it is understood that two others, viz., M.Cs. 282H and 283H, have been granted.

Description.—In the vicinity of Marchagee and immediately west of the railway line is a belt of Pre-Cambrian metamorphosed sedimentary rocks—quartzites, etc., believed to form a long narrow strip running from near Moora to Yandanooka. To the east of these metasediments is a broad stretch of sandy country containing scattered

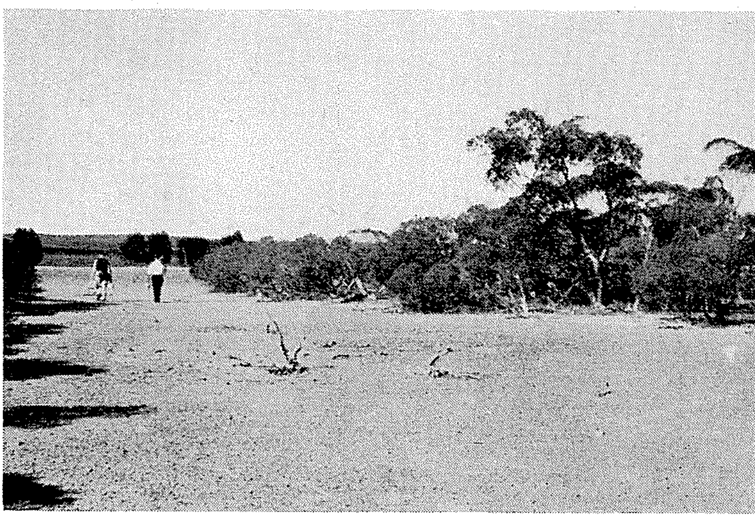


PLATE XXIII.

General View from North end of M.C. 258H, Marchagee.

outcrops of granite. To the west is a belt of sand plain believed to overlie sediments of Jurassic age. West of Marchagee the country is rolling, with low hills capped by ferruginous gravel. About eight miles west of the Siding the country opens out into a flat sandy low lying plain covered with low scrub vegetation, and sprinkled with *travertine* boulders.

The bentonite or colloidal clay deposits occur in a number of clay pans within this sandy plain but approaching the probable contact between the Jurassic sediments and the Pre-Cambrian metamorphic sediments mentioned above.

The principal deposit is located on M.C. 258H and consists of a long narrow, irregular shaped clay pan running in the approximate direction N. 35° W. The clay has an average depth of 2–3 feet and bottoms on sand. It consists of (a) Top Clay, 9–10 inches thick—a greyish clay which is claimed to be a high grade bentonite, (b) Middle Clay (transition layer), 6–9 inches thick—a highly gypseous clay,

PLATE XXIV.

Granulated Surface of Sun-dried Bentonite, M.C. 258H, Marchagee.

(c) Bottom Clay, average thickness 15 inches—a fawn-brown coloured clay very similar in general appearance to (a) but claimed to have inferior swelling properties. All three layers, but particularly (a) and (c) are plentifully sprinkled with small fragments of limestone. The measurements were made whilst the clay was damp. On drying, it is understood that the top clay expands to a thickness of 15–18 inches.

For purposes of computation the clay pan was taken as approximately 25 chains long by one chain wide. Assuming an average thickness of nine inches of Top Clay this should contain a little over 3,000 tons of bentonite. Layer (b), consisting largely of gypsum, is useless as a clay. The Bottom Clay, providing it can be freed from the overlying gypseous layer, and assuming an average thickness of 12 inches should yield approximately 4,000 tons of clean clay.

Twelve to 15 chains south-east of M.C. 258H is a small shallow clay pan covering less than ¼ acre and containing a fair growth of trees and scrub. At the time of inspection this area was wet and boggy, but a sample hole revealed a surface layer about 12 inches deep of clean, apparently good colloidal clay underlain by gypseous material. It is estimated that at least 400 tons of bentonite could be obtained from the surface of this clay pan.

M.C. 259H lies about 1½ miles south-east of M.C. 258H. It encloses a clay pan which at the time of inspection was covered by water and could not be sampled. The clay pan covers an area of at least 1½ acres. It was claimed that the top four inches of clay in this deposit was useless as a colloidal clay, but that beneath this was a layer, about 12 inches thick, of fair grade bentonite, underlain by a hard layer of ferruginous cement. Assuming an average thickness of 12 inches of workable clay in this deposit it should yield at least 2,500 tons of bentonite.

Thus in the deposits of bentonite inspected at Marchagee there is an estimated yield of about 10,000 tons. However, in this and adjacent districts, there are tracts of country geologically and physiographically similar to that described, and it is probable that other similar bentonite-bearing clay pans occur in this region.

No conclusions were reached during the brief inspection as to the origin of the bentonite in these deposits. The location of the clay pans close to the apparent boundary between supposed Jurassic and Pre-Cambrian rocks may have some significance, the clay having been washed out of overlying Jurassic and possibly Cretaceous formations, transported by a system of internal drainage and deposited in shallow depressions where drainage may have been checked against the abutting Pre-Cambrian rocks, possibly during a period of Cainozoic erosion.

Operator.—M.Cs. 258H and 259H are held by Messrs. W. G. Fennell and F. R. Bryant, of Marchagee, on whose farm land the claims are located. The material is dug during the summer months when thoroughly dry, and railed to Perth where the preparation of the crude bentonite for the market, and marketing of the final product is in the hands of Mr. Eric E. Rendle, of Perth. Bentonite has so far been dug from M.C. 258H only, operations having commenced in 1942. Reported production to November, 1943, is 175 tons.

Test Results.—The samples from the north-west end and centre of M.C. 258H are similar, with a strength approximately two-thirds that of American bentonite. The sample from the south-east corner is weaker and has a strength approximately half that of American bentonite. There was little difference in strength between the top grey coloured clay and the bottom fawn clay at the north-east end.

The sample from the small clay pan (M.C. 259H) 12–15 chains south-east of M.C. 258H has a strength approaching that of American bentonite. The strength of the mixture containing six per cent. of clay and two per cent. of water appears particularly high but, though

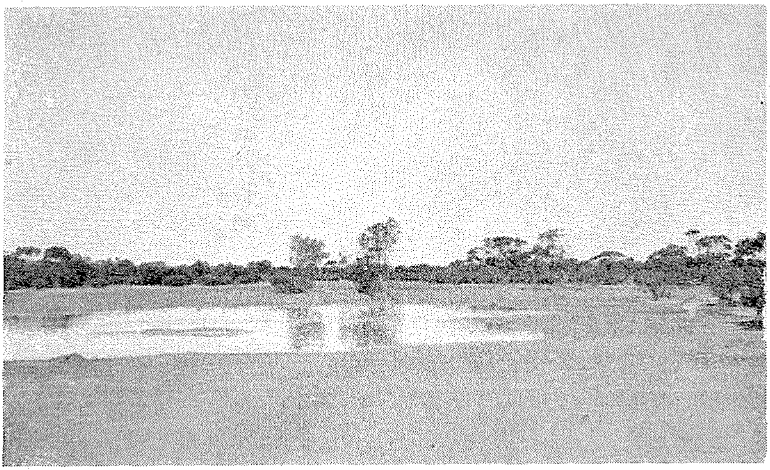


PLATE XXV.

Centre of Clay Pan, M.C. 258H, Marchagee.

this moisture gives optimum strength, the sand is too dry to be worked satisfactorily. It should again be emphasized that at the time of the inspection M.C. 259H was wet and boggy and the sample therefore had to be obtained from one hole only at the surface.

The raw clays contain variable amounts of free silica which would be partly removed during commercial processing ; batches of clay purchased from suppliers may therefore be slightly better than the survey samples which were ground without separation of free silica.

The clay from Marchagee has been used satisfactorily by a number of Australian foundries and the writers consider that for green sands the best grade of clay would prove entirely suitable. However, there has been considerable variation in samples of commercially processed clay received at the Foundry Sands Laboratory, some samples being as strong as American bentonite, but the majority being only half to two-thirds as strong. The variation may be due to two causes :—

1. Variation in the material at the source—variation in clay and methods of mining, contamination with gypseous layer.

2. Variation and lack of control in processing.

It is only by elimination of this variation that the clay can be expected to prove entirely suitable for Australian foundries.

Sample No. 47.—TOP CLAY—N.W. END OF CLAY PAN MARCHAGEE.

Physical Tests on Synthetic Sand.

Clay.	Moisture.	Permeability.	Green Compression Strength.
% 4	% 1.9	245	lb./sq. in. 5.7
6	1.9	250	13.6
	3.0	205	6.9

Remarks.

High strength. Approximately two-thirds that of American bentonite.

Sample No. 48.—BOTTOM CLAY—N.W. END OF CLAY PAN, MARCHAGEE.

Physical Tests on Synthetic Sand.

Clay.	Moisture.	Permeability.	Green Compression Strength.
% 4	% 2.2	245	lb./sq. in. 5.9
6	2.0	270	14.6
	3.0	225	8.5

Remarks.

Similar to Sample No. 47.

Sample No. 49.—TOP CLAY—CENTRE OF CLAY PAN, MARCHAGEE.

Physical Tests on Synthetic Sand.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	1 .9	240	6 .3
6	1 .9	255	13 .8
	3 .1	200	5 .5

Remarks.

Similar to Sample No. 47.

Sample No. 50.—TOP CLAY—S.E. CORNER OF CLAY PAN, MARCHAGEE.

Physical Tests on Synthetic Sand.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4 .0	1 .9	245	3 .9
6 .0	1 .9	255	10 .0
	3 .0	210	4 .8

Remarks.

Not as strong as Samples Nos. 47–49.

Sample No. 51.—SURFACE CLAY—CLAY PAN, 12 CHAINS S.W. OF SAMPLE No. 50, MARCHAGEE.

Physical Tests on Synthetic Sand.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	2 .0	245	8 .4
6	2 .1	250	20 .0
	3 .0	215	9 .6

Remarks.

High strength. *See* text regarding nature of sample.

(b) *Miscellaneous Samples.*

Test Results.—Sample No. 52, Mumballup. This is promising. The strength is slightly lower than that of the better grade samples from Marchagee but is approximately three-fifths that of American bentonite. Six per cent. of clay should be satisfactory for a synthetic sand. This deposit merits further investigation.

Samples Nos. 53 and 54, Bardoc. These are not quite as strong as sample No. 52, but if double the quantity normally used with American bentonite were added, satisfactory synthetic sands would be formed.

Sample No. 55, G.C.L. 5319/31, Collie district. The strength of this is similar to that of the clays from Bardoc.

Sample No. 56, Collie. This is stronger than sample No. 55 and is generally similar to the clay from Mumballup.

SAMPLE No. 52.—FULLER'S EARTH G.C.L. No. 7404—MUMBALLUP.

PHYSICAL TESTS ON SYNTHETIC SAND.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	2.0	230	5.1
6	2.0	195	8.8
8	2.9	190	11.7

REMARKS.

Promising as binder for synthetic sands.

SAMPLE No. 53.—WHITE CLAY—DECOMPOSED GREENSTONE (?)—BARDOC.

PHYSICAL TESTS ON SYNTHETIC SAND.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	1.9	230	3.9
8	2.9	210	8.8
12	4.1	165	10.6

REMARKS.

Strength not as high as Sample No. 52.

Sample No. 54.—CLAY—DECOMPOSED GREENSTONE (?). G.C.L. 3507/30.—BARDOC.

Physical Tests on Synthetic Sand.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	1 .6	235	4 .8
	2 .0	215	3 .0
8	3 .0	220	8 .7
12	3 .9	190	12 .6

Remarks.

Generally similar to Sample No. 53.

Sample No. 55.—CLAY—G.C.L. 5319/31—COLLIE DISTRICT.

Physical Tests on Synthetic Sand.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	2 .0	260	3 .3
8	3 .0	225	8 .7
12	4 .0	180	14 .9

Remarks.

Generally similar to Sample No. 54.

Sample No. 56.—FULLER'S EARTH—COLLIE DISTRICT.

Physical Tests on Synthetic Sand.

Clay.	Moisture.	Permeability.	Green Compression Strength.
%	%		lb./sq. in.
4	2 .0	255	3 .8
6	2 .1	230	8 .4
8	2 .9	220	10 .3

Remarks.

Not as strong as best grades of Marchagee clay, but promising as binder for synthetic sands.

TABLE X.

CLAYS.

Sample No.	Description of Clay.	Tests on Synthetic Sands.											
		Four per cent. Clay.			Six per cent. Clay.			Eight per cent. Clay.			Twelve per cent. Clay.		
		Moisture.	Permeability.	Green Compression Strength.	Moisture.	Permeability.	Green Compression Strength.	Moisture.	Permeability.	Green Compression Strength.	Moisture.	Permeability.	Green Compression Strength.
		%		lb./sq. in.	%		lb./sq. in.	%		lb./sq. ins.	%		lb./sq. in.
....	American Bentonite	1·9	245	8·9	....	....	....	....	....	....	....	....	....
....	American Bentonite (Base sand—Lake Gnangara)	1·9	280	7·1	....	....	....	....	....	....	....	....	....
	(a) *Kaolins.*												
40	Decomposed Granite. South Face, Burkinshaw's Pit, Glen Forrest	2·1	190	0·9	....	....	....	3·1	145	2·2	4·1	99	3·9
41	Decomposed Granite. North Face, Burkinshaw's Pit, Glen Forrest	1·8	180	Too weak to test.	....	....	....	3·0	130	2·0	4·0	90	3·9
42	Decomposed Granite. Disused Clay Pit, Gooseberry Hill	1·9	200	1·1	....	....	....	3·0	155	2·5	3·9	105	4·3
43	Decomposed Greenstone Schist, Clackline	2·0	215	1·8	....	....	....	3·0	175	5·7	4·1	130	9·6
44	Decomposed Dolerite. Clackline	2·1	210	1·8	....	....	....	3·1	160	5·8	4·1	125	10·1
45	Medium Ball Clay. Clackline	2·0	195	1·6	....	....	....	3·0	140	5·1	4·2	105	8·2
46	Kaolin M.C. 1. Greenbushes	1·9	200	2·7	....	....	....	3·0	150	7·7	4·1	125	10·4

	(b) *Fuller's Earths or "Bentonites."*												
47	Top Clay. N.W. of Clay Pan M.C. 258H, Marchagee	1·9	245	5·7	1·9 3·0	250 205	13·6 6·9	....	....	....	....	....	....
48	Bottom Clay. N.W. End of Clay Pan M.C. 258H, Marchagee	2·2	245	5·9	2·0 3·0	270 225	14·6 8·5	....	....	....	....	....	....
49	Top Clay. Centre of Clay Pan M.C. 258H, Marchagee	1·9	240	6·3	1·9 3·1	255 200	13·8 5·5	....	....	....	....	....	....
50	Top Clay. S.E. Corner of Clay Pan M.C. 258H, Marchagee	1·9	245	3·9	1·9 3·0	255 210	10·0 4·8	....	....	....	....	....	....
51	Surface Clay. Clay Pan 12 chains S.W. of Sample No. 50, Marchagee	2·0	245	8·4	2·1 3·1	250 215	20·0 9·6	....	....	....	....	....	....
52	Fuller's Earth, G.C.L. No. 7404 Mummballup	2·0	230	5·1	2·0	195	8·8	2·9	190	11·7	....	....	....
53	White Clay. Bardoc	1·9	230	3·9	....	....	....	2·9	210	8·8	4·1	165	10·6
54	Clay, G.C.L. No. 3507/30. Bardoc	1·6 2·0	235 215	4·8 3·0	....	....	....	3·0	220	8·7	3·9	190	12·6 ....
55	Clay, G.C.L. No. 5319/31. Collie	2·0	260	3·3	....	....	....	3·0	225	8·7	4·0	180	14·9
56	Fuller's Earth. Collie	2·0	255	3·8	2·1	230	8·4	2·9	220	10·3	....	....	....

Chapter VI.

GENERAL DISCUSSION OF WESTERN AUSTRALIAN MOULDING SANDS.

For the purposes of this discussion, the moulding sands of Western Australia have been divided into four groups :—

1. Unbonded.
2. Medium grade.
3. Fine-medium grade.
4. Medium-fine grade.

The grades have been arbitrarily classified as follows :—

Grade.	*A.F.A. Grain Fineness No.*	*A.F.A. Grain Classes.*
Coarse-medium sands	30–40	7
Medium sands	40–70	5 and 6
Fine-medium sands	70–100	4
Medium-fine sands	100–150	3
Fine sands	150–250	1 and 2

It will be appreciated that there must, inevitably, be some overlap. For instance a sand, the majority of which is medium grained, may contain small amounts of finer material which would increase its fineness number from say 65 to 75. Nevertheless this sand would still be classed as medium grade.

The unbonded sands are widely used for all classes of core work and less frequently for synthetic sands. The medium grade sands have been used by some foundries for cast iron work. The fine-medium sands are all from the Kalgoorlie district and are used for iron and brass castings. The medium-fine sands are at present used by most Perth foundries for all grades of iron and brass castings.

There are abundant supplies of silica sands in the Drift Sand Zone which comprises the larger portion of the western half of the Swan

Coastal Plain near Perth. Theoretically, two grades—coarse-medium and medium—are available, but by selecting the locality a uniform sand of any fineness between 31 and 50 may be obtained. With the exception of Sample No. 5 (not used) and Sample No. 8, the sands are not contaminated with clay or earthy matter. Furthermore with the exception of Sample No. 8 (Shenton Park) and Samples Nos. 15 to 18 (lower level Cannington) they are uniform and have high base permeabilities (Sample No. 3 is the most even sand examined in the Foundry Sands laboratory). In consequence of the lack of uniformity in the Shenton Park and Cannington sands the permeability is lowered, *e.g.*, Sample No. 8 has only half, and the lower-level sands from Cannington only three-quarters the permeability of the equivalent Lake Gnangara sand.

The lack of a suitable fine grained unbonded sand for cores for light work has already been noted (page 45). Fine unbonded sands are lacking in most states of the Commonwealth and with the exception of a sand from Noarlunga in South Australia and sands from Northern Tasmania, no deposits sufficiently close to the manufacturing centres are known. Some foundries in other states have attempted to solve the problem either by using a sand-blast dust or by crushing and grading sands, but neither method is entirely satisfactory.

Suitable naturally bonded moulding sands in the vicinity of Perth can be expected only from the narrow belt of country between the city and the foothills of the Darling Scarp, in what has been called the Clay Zone. Further inland upon old terraces in the more mature valleys of the Avon River near Northam some useful moulding sands have been found and it is probable that other deposits of suitable loam may be discovered along the upper reaches of this river. Test results revealed no major differences in grade between the loams from Guildford and Northam.

The medium grade loams in the Byford District have not been used extensively for foundry work. However, they are well graded and have high permeability, and though weak, if strengthened slightly would produce a sand satisfactory for general jobbing cast iron work. The sand from Evans' pit is slightly finer and has a higher clay content, characteristics which combine to cause lowered permeability, as compared with the sample from Gordin's pit. Though weaker, and not quite as even, these sands may be compared with the Oakleigh red sands of the Melbourne District (Table No. XI.). The maximum permeability of the Oakleigh sand is higher than that of Evans' sand, and higher even than that of the slightly coarser grade from Gordin's pit, even though the latter has a lower clay content.

TABLE XI.

COMPARISON OF "BYFORD" LOAM AND OAKLEIGH RED SAND.

FINENESS TEST.

	"Byford" Loam (Evans' Pit).	Oakleigh Red.
Clay Substance	% 16.4	% 16.2
Tyler Sieve No.	Retained.	Retained.
	%	%
6	0.0	0.0
10	0.2	0.2
20	0.6	0.2
28	3.4	0.2
35	15.6	3.3
48	32.0	23.4
65	16.0	42.2
100	6.4	13.2
150	3.6	0.4
200	2.0	0.2
270	1.0	0.2
Pan	2.6	0.2
Total "Sand" Grade	83.4	83.7
A.F.A. Grain Fineness No.	56	51
Per cent. Remaining on 3 Sieves	76% on 35, 48 and 65 mesh	94% on 48, 65 and 100 mesh
A.F.A. Grain Shape	Sub-angular. Finer grains angular	Sub-angular

ROUTINE TESTS.

"Byford" Loam			Oakleigh Red.		
Moisture	Permeability	Green Compression Strength	Moisture	Permeability	Green Compression Strength
%		lb./sq. in.	%		lb./sq. in.
5.1	130	9.3	5.0	295	15.3
6.0	145	6.8	6.1	265	12.0
6.8	150	5.8	6.9	120	7.9
7.9	105	4.6			

The Oakleigh red sands have been successfully used by two of the largest steel foundries in Melbourne. Perth steel foundries are using a synthetic sand, but it is probable that the Byford loams, if strengthened slightly, would prove quite satisfactory. It is difficult to predict, however, whether the change would be economic.

The Tammin sample belongs to the medium grade sands. Its fineness number is 72, but since the grains are distributed over five sieves in nearly equal amounts, the net result is a sand whose permeability is low, and one which would produce a skin inferior to that provided by the Byford loams. The strength is high at the moisture content of 3 per cent., but at the latter the sand is a little too dry for satisfactory moulding and a further increase of one per cent. moisture causes the strength to fall off so rapidly that additions of binder would be necessary.

The medium-fine sands, likewise are of poor quality. The fineness numbers range from 116 to 194, but with the exception of Sample No. 22 the majority of grains are coarser than these numbers indicate ; the higher values are due to smaller amount of finer material. Thus permeability is lowered and the surface finish is not as smooth as the fineness number would lead one to expect. Some foundries obtain sand from Northam, but it is difficult to see what advantage this sand has over the Guildford loams. For cast iron jobbing work, more satisfactory results would be obtained if these medium-fine sands were replaced by the Byford-type loams.

The fine-medium sands are all from the Kalgoorlie district. The bonded sands (Samples Nos. 34 and 35) are mainly residual, the deposits lying in an ancient drainage channel in clay pan country west of the town. They are of poor quality. Whilst the permeability of Sample No. 34 is not low, it must be realised that the majority of grains remain on the 48, 65 and 100 mesh sieves and that a sand of such grading normally has a permeability well over 100. Sample No. 35 is generally similar but is less even and contains more clay. The permeability is therefore lowered considerably.

Owing to the poor quality of the bonded sands from Kalgoorlie and the poorly defined character of the deposits—the sand is limited to a layer of 18 inches—alternative sources of free sand suitable for synthetic sand would be desirable. No naturally occurring high-grade silica sand has so far been found at Kalgoorlie, the chief source at present being an old tailings dump at Kanowna. A free sand from Mt. Hunt is also available but has not been used hitherto. The latter contains 5 per cent. of clay substance and is slightly more even than the bonded sands. When bonded with 3.5 per cent. bentonite and 1.5 per cent. dextrin and at 3.5 per cent. moisture (most suitable for moulding) it had a permeability of 110 which is quite satisfactory for medium-grade iron moulds. The Kanowna sand is a fine medium grade, but only slightly finer than the medium grade Perth sands, the higher fineness number being caused mainly by small amounts of minus 150 mesh material. It is not entirely suitable for heavy iron castings, but by washing and screening could easily be separated into two even grades—a medium grade for heavier castings and a medium-fine grade for light castings.

Western Australia possesses both good quality clays and deposits of well graded unbonded sands. The combination of the two would provide excellent synthetic sands of high permeability and good refractoriness, and whose strength could be controlled by varying the additions of binder. Moreover, synthetic sands may be worked at lower moisture contents. The gas evolved is, in consequence, less and this would allow such sands to be rammed harder without fear of " blowing " or " scabbing."

The clays examined during the survey were of two types—kaolins and bentonites or " fuller's earths." As might be expected the kaolins are weak, though some of them, which might be better classified as " semi-ball clays," would have satisfactory strength if used in larger percentages than is normal with bentonite. The bentonite from Marchagee is strong and if carefully selected and processed is an excellent binder for synthetic sands. Certain of the fuller's earths are also promising and should be developed further.

Where sands are poor in quality, the advantages of a preparation plant cannot be too strongly emphasised. For the larger foundry, a complete sand-conditioning unit consisting essentially of magnetic separator, dryer, screens, mill and aerator, is advisable, but even the smallest foundry can make very good use of a mill and portable aerator. The latter may be employed not only for the preparation of facing sand, but for aerating the floor sand in order to break up lumps and improve the heap. It should be emphasised that, owing to the high moisture content at which it is worked, natural moulding sand is still moist after casting, and cannot be satisfactorily handled by simple screening equipment, though the latter may be quite suitable for synthetic sands which are moulded at a lower moisture content, and are almost dry after casting. A conditioning unit for natural sand should therefore be provided with a dryer.

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Appendix.

LIST OF SAMPLES COLLECTED DURING FOUNDRY SAND SURVEY.

Sample No.	Description.	Map No.
1	Glass sand, suppliers designation "coarse grade." East shore (southern end) Lake Gnangara, Wanneroo	Pl. II.
2	Glass sand, suppliers designation "Medium-fine grade." East shore Lake Gnangara, Wanneroo	Pl. II.
3	Glass sand, suppliers designation "fine grade." East shore Lake Gnangara, Wanneroo	Pl. II.
4	White sand. Bank, east side of Harborne Street, eight chains south of Dodd Street, east side of Herdsman Lake	Pl. II.
5	Yellow sand. Ten chains west of Herdsman Parade at point 20 chains southerly from junction of Herdsman Parade and Liege Street, west side of Herdsman Lake	Pl. II.
6	Unbonded sand, average sample about 10–15 feet. South face main Bayswater Sand Pit, about 1¼ miles due north of Bayswater Station	Pl. II.
7	Sand from below about 10 feet. Western side of main Bayswater Sand Pit. Underlying "coffee" rock seam	Pl. II.
8	Yellow sand, profile sample from bank of Railway Cutting. West side of line, approximately 200 yards south of Shenton Park Railway Station	Pl. II.
9	Top sand. North face of pit, 3–10 feet, Lot 16, Braibrise Road, Cannington (August, 1943)	Pl. II.
10	Bottom sand. West side of north face of pit, about 12–15 feet, Lot 16, Braibrise Road, Cannington (August, 1943)	Pl. II.
11	Unbonded sand. North face, 0–3 feet, Lot 16, Braibrise Road, Cannington (May, 1946)	Pl. II.
12	Unbonded sand. North face, 3–6 feet, Lot 16, Braibrise Road, Cannington (May, 1946)	Pl. II.
13	Unbonded sand. North face, 6–9 feet, Lot 16, Braibrise Road, Cannington (May, 1946)	Pl. II.
14	Unbonded sand. North face, 9–12 feet, Lot 16, Braibrise Road, Cannington (May, 1946)	Pl. II.
15	Unbonded sand. North face, 12–15 feet, Lot 16, Braibrise Road, Cannington (May, 1946)	Pl. II.
16	Unbonded sand. North face, 15–18 feet, Lot 16, Braibrise Road, Cannington (May, 1946)	Pl. II.
17	Unbonded sand. North face, 18–21 feet, Lot 16, Braibrise Road, Cannington (May, 1946)	Pl. II.
18	Unbonded sand. North face, 21–24 feet, Lot 16, Braibrise Road, Cannington (May, 1946)	Pl. II.

Sample No.	Description.	Map No.
19	Top sand, about 0–9 feet. Western side of old Sand Brick Pit, Braibrise Road, Cannington	Pl. II.
20	White sand. South side of low bank (railway cutting) about 12 yards west of T.P. 503 between Banjup and Forrestdale Sidings	Pl. II.
21	Yellow and white sand. Eastern side of disused sand pit, north of road opposite T.P. 473 near Banjup Siding	Pl. II.
22	Heavy loam. Small heap at North end, Bell Bros. Pit, 1 mile north-east of Guildford Railway Station	Fig. 1
23	Medium-fine loam. About centre of west face, Bell Bros. Pit, 1 mile north-east of Guildford Railway Station	Fig. 1
24	Heavy loam. Heap from bottom of pit, just north of sample No. 23, Bell Bros. Pit, 1 mile north-east of Guildford Railway Station	Fig. 1
25	Medium-fine loam. West face just south of Sample No. 23, Bell Bros. pit, 1 mile north-east of Guildford Railway Station. Main supply of moulding sand dug from this face at time of inspection (May, 1945)	Fig. 1
26	Medium-fine loam. South end, Bell Bros. pit, 1 mile north-east of Guildford Railway Station	Fig. 1
27	Medium-fine loam. South end, Bell Bros. pit, 1 mile north-east of Guildford Railway Station	Fig. 1
28	Sandy loam. Average grab sample over south face Gordin's pit, off Hills Road, Byford	Pl. II.
29	Sandy loam. Grab sample from southern faces of Evans' pit, just south of Cardup Brick Works, Cardup	Pl. II.
30	Loam. Pit in terrace on east bank of Avon River at Burlong Pool, about 2 miles south of Northam	Fig. 2
31	Unbonded sand. Pit west of road on east side of Avon River, approximately 1·2 miles south of Northam Railway Station	Fig. 2
32	Loam. North end, east face of pit on west bank of Avon River, about ¼ mile west of Spring Hill Siding, Northam District	Fig. 2
33	Sandy loam (rather gritty). North end, west face of pit west of Spring Hill Siding, about 1¼ chains west of Sample No. 32	Fig. 2
34	"Cemetery" sand. Red sand from 4¼ miles north of Kalgoorlie on Black Flag Road	Pl. I.
35	Red Sand. Property on western side of Kalgoorlie racecourse	Pl. I.
36	"Mt. Hunt" sand. Chocolate sand from Mt. Hunt about 5 miles south of Kalgoorlie on Celebration Road	Pl. I.
37	"Kanowna" sand. Main dump of old White Feather Mine, Kanowna, 16 miles north-east of Kalgoorlie	Pl. I.
38	Moulding sand. One mile north-east of Post Office, Collie	Pl. I.
39	Bonded sand. Quarry about 1 mile west of Tammin on main Perth-Kalgoorlie Road	Pl. I.
40	Clay (decomposed granite). South face (rather gritty), Burkinshaw's Pit, Glen Forrest	Pl. II.
41	Clay (decomposed granite). Northern face, Burkinshaw's Pit, Glen Forrest	Pl. II.
42	White clay (decomposed granite). Southern faces of disused clay pit about ¾ mile east of Gooseberry Hill Railway Siding	Pl. II.
43	Greenish Clay. Decomposed greenstone schist island in Clackline Firebrick Co.'s South Pit, Clackline	Fig. 2
44	Decomposed dolerite (No. 3 Clay). West side of South Pit, Clackline Firebrick Co., Clackline	Fig. 2
45	Medium ball clay. New pit about 1½ miles north of the South Pit, Clackline Firebrick Co., Clackline	Fig. 2

Sample No.	Description.	Map No.
46	Kaolin Clay. Mineral Claim No. 1, Greenbushes	Pl. I.
47	Grey clay (Top Clay), layer about 9 inches thick overlying gypseous layer. North-western end of clay pan, M.C. 258H, Marchagee	Pl. I.
48	Fawn coloured clay (Bottom Clay). North-western end of clay pan, MC. 258H, Marchagee	Pl. I.
49	Top Clay. About centre of clay pan, M.C. 258H, Marchagee	Pl. I.
50	Top Clay. South-eastern end of clay pan, M.C. 258H, Marchagee	Pl. I.
51	Surface clay (wet). Small clay pan approximately 12–13 chains south-east of M.C. 258H, Marchagee. (Clay about 12–15 inches deep)	Pl. I.
52	Clay (Fuller's Earth). Mummballup. (Government Chemical Laboratory No. 7404)	Pl. I.
53	White Clay (decomposed greenstone ?). Bardoc, Broad Arrow Goldfield. (Obtained by Government Chemical Laboratory 1933)	Pl. I.
54	Clay (decomposed greenstone ?). Bardoc, Broad Arrow Goldfield. (Government Chemical Laboratory No. 3507/30)	Pl. I.
55	Clay. Collie. (Government Chemical Laboratory No. 5319/31)	Pl. I.
56	Clay (Fuller's Earth). Collie. (Obtained from Government Chemical Laboratory)	Pl. I.

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INDEX.

Index—continued.

Index—continued.

Index—continued.

Index—continued.

Index—continued.

Index—continued.

Index—continued.

Index—continued.

Index—continued.

Index—continued.