of the State, and may closely resemble those in which values were rapidly lost in depth, it would be decidedly premature to recommend the erection of a crushing plant here until at least one of the rich bodies had proved to carry its values down to at least the water level.

(5.) *Report upon the May Queen G.M.L. 852 (Yilgarn Goldfield), with regard to the loss of the reef due to faulting.*

Acting upon instructions dated November 9th, 1910, I placed myself in communication with Messrs. Liddle and Domley, the owners of the above property, which is situated about 14 miles to the southward of Southern Cross.

After crossing the lake to the southward of the above township the auriferous belt is traversed for a distance of 14 miles, the schistose amphibolites being for the most part covered by a thin deposit of soil, but occasionally patches of mica indicate the presence of granitic dykes, or tracts of dark-red clay with weathered fragments of massive greenstone basic dykes.

At the mine itself the weathered amphibolitic schists are found to extend downwards as far as the bottom workings with so little change that it is probable that at least another 40ft. will have to be sunk before the solid rock will be met with at or near the ground water level.

The reef does not outcrop, but was located by small but rich flat stones after which trenching, and costeen proved a small vein striking nearly north and south to extend for a distance of about 100ft.

To the southward of this it is lost, being apparently displaced by a series of granitic dykes which cross it at an acute angle. This reef, which averages about 6in. in width, may be said to underlie to the westward, but so slight is the dip that it is still in the shaft at a depth of 100ft.

This reef has been driven at the No. 1 or 60ft. level for a distance of 70ft. At the No. 2 or 100ft. level the stone was very rich, and was tracked for about the same distance as in the No. 1 level in a northerly direction, but at the shaft bottom it is sharply cut off by a fault which strikes north-west and south-east and dips to the eastward.

In the northern portion of the bottom level a winze has been sunk to a depth of 30ft. in which the fault was met with at a depth of 15ft., below which the reef was lost; whilst in a crosscut a little north of the winze driven west the fault line was cut at a distance of 20ft., followed a little farther on by a large barren white quartz reef which is exposed upon this side of the auriferous vein at the surface. This would appear to indicate the absence of the small rich vein upon the western side of the fault, but to my mind it is inconclusive in so far that the crosscut was driven at a point some 20ft. above the fault intersection of the vein.

I would therefore advise that a crosscut should be driven at the bottom of the winze in a westerly direction, when if the large barren reef is first cut, it may be safely concluded that the small rich one has died out upon the slide, and further exploiting may be discontinued.

Several crosscuts have been driven in an easterly direction for a considerable distance in barren country, but since this work was executed upon the same side of the fault as the reef already exists, it was not to be expected that it would be cut again.

By crosscutting at the winze bottom the vein, if it exists, should be cut in something less than 20ft. from it, since the main barren reef located in the 100ft. level crosscut was met with at 40ft. from that level upon the western side of the fault, and since it lies about 20ft. to the westward of the outcrop of the small veins. In my opinion there is a very good prospect of the rich vein being cut upon the western side of the fault, which appears to be quite normal, making a clear cut of the reef which is a fissured plane, judging from the walls.

CHAS. G. GIBSON, Assistant Geologist.

(6.) *Some Notes on the Principal Geological Features of the Kalgoorlie Goldfield.**

The importance of Kalgoorlie, which has been responsible for more than one half of the total gold yield of the State, renders some reference to its salient geological features necessary, by way of preface to the series of articles on mining practice, for experience in most mining fields of the globe has shown that many mining failures have been due rather to a want of knowledge, or true appreciation of, structural geology than to any lack of engineering training.

General Topography.—The chief topographical feature of the Kalgoorlie goldfield is a main central ridge of hills trending roughly north-north-west and south-south-east, and reaching its maximum altitude in Mt. Gledden—better known as Maritana Hill—which rises to a height of some one hundred and fifty feet; the ridge has a length of about four miles and dies out in a southerly direction just beyond the south end of what are known as the "Boulder Belt" mines. On each side of this central ridge are wide flats draining southerly and extending laterally on the eastern side for, say, five miles, and on the western for about three. On the east side of the eastern valley is another rather more conspicuous ridge of hills also trending roughly north-west and south-east and having a maximum altitude of possibly a couple of hundred feet; along this ridge of hills are situated the mining centres of Boorara and Waterfall (Golden Ridge). The western flats are also in their turn flanked by a low ridge of hills, less conspicuous at their northern end but well defined at their southern. Both the eastern and western valleys—if they may be termed such—drain, as before stated, southerly into the extensive salt lake or marsh known as Gnumballa or Hannan's Lake, which starts but a short distance south of the Boulder Mines and trends away in a south and south-westerly direction for many miles. On the western side of this salt marsh and some three miles to the south of the Boulder mines is a small conspicuous clump of hills, having their highest point in Mt. Hunt, the most prominent landmark in the district, which rises to a height of possibly some four hundred feet. These hills are more or less connected—by a westerly extension—to the main western ridge.

The town of Kalgoorlie is situated on the western fall of the main central ridge northwards from its middle point, and the mines are along the line of the ridge, the "Golden Mile" being at its southern end, the underlying rocks of the valleys being—as will be explained later—non-auriferous, or practically so.

General Geology.—The original rocks of the Kalgoorlie district were of sedimentary origin, viz., shales, soft sandstones, grits, conglomerates, etc.—with possibly interbedded lava flows—laid down horizontally in probably pre-Cambrian time on a gneissic or granite floor; these were by earth movement afterwards tilted into their present highly inclined posi-

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tions and subsequently intruded by large masses of basic and ultra-basic igneous rocks (amphibolites, quartz diabases, porphyrites, peridotites, etc.), these in turn being intruded by a small series of later acidic rocks (quartz and felspar porphyries). Slight further earth movement has then taken place causing considerable shearing and faulting of the rocks, the former (the shearing) resulting in the formation of the lines along which the auriferous lodes of the field occur.

The accompanying geological map which embraces the main mining portion of the field shows the present relative extent and position of the more important of the various classes of rocks found on the field. These may in a general way be grouped under the following nine heads:—

(1.) The Ancient Sediments (shales, sandstones, grits, conglomerates, etc.).
(2.) The Calc-schists.
(3.) The fine-grained Amphibolites (representing the older "greenstones").
(4.) The Quartz-diabases.
(5.) The Coarse-grained Amphibolites (later or intrusive "greenstones").
(6.) The Peridotites (intrusive ?).
(7.) The Porphyrites.
(8.) The Quartz and Felspar Porphyries (newer intrusives).
(9.) The Recent Deposits (sands, loam, laterite, etc.).

The Ancient Sediments.—These consist of shales, soft sandstones, mica and talc schists, grits, and conglomerates. They are of very considerable extent and are found on both sides of the main complex of igneous rocks, the belt on the western side being of by far the greater development and interest. This belt starts some four miles west of Kalgoorlie and has a width of roughly ten or twelve miles, its general trend being north-north-west and south-south-east; how far northerly it runs is not known, as everything is hidden in this direction by an extensive covering of loose sand and loam; southerly it is known to extend beyond Wollubar—some twenty miles from Kalgoorlie—but appears to be narrowing down in this direction, and probably does not run much farther. The rocks of this series are mostly soft banded sandstones, but they also comprise shales, mica-schists, grits, and conglomerates; they have a prevailing strike of, roughly, 25 degrees west of north, and dip steeply to the west. Good natural sections of these sediments can be seen along the small "breakaways" forming the western edge of the lake country some six miles south-west of Boulder; good examples—more especially of the sandstones—are also seen in some of the old mine workings near Binduli and in one or two old shafts on the eastern foot of the conglomerate ridge two to three miles farther west—or rather south-west. An interesting variation from the soft sandstones is seen about a mile on the western side of this ridge and half a mile south of the Coolgardie road; here there is a considerable development of a hard compact laminated sandstone carrying a large percentage of black mica (biotite) in small flakes, and closely resembling in general appearance a fine-grained biotite gneiss.

The most interesting feature, however, in connection with these sedimentary rocks is the occurrence of a well-defined series of coarse conglomerates interbedded in the sandstones and grits. These have their greatest development at a point some eight and a half miles south-west of Kalgoorlie, where they form a well-marked ridge trending roughly north-north-west and south-south-east and extending for several miles both ways; this ridge is crossed near its north-western end by the main Coolgardie road at a point a little more than seven miles from the Kalgoorlie Post Office. There are at least three main bands of conglomerate in the series, and taken together with the intervening bands of soft sandstone, they have a maximum thickness of well over a thousand feet. They are steeply inclined and dip with the enclosing rocks, *i.e.*, at an angle of seventy-five to eighty degrees to the west. The matrix of the conglomerate beds proper is a fairly soft, slightly micaceous sandstone, practically identical with the surrounding rock, while the pebbles and boulders—rarely more than six inches in diameter—consist of banded and jasperoid quartz, black cherty quartz, hard white quartz, quartzite, quartz and felspar porphyry, felsite, granite, etc. The pebbles, etc, are as a general rule set fairly closely together in the matrix and are well waterworn and rounded; they have, however, since their deposition been—together with the enclosing beds—subjected to considerable pressure and shearing, and usually split fairly readily in one direction; were it not for this defect they would probably prove of considerable value for use as pulverisers in tube mills. (There is, however, one place where pebbles of hard flinty quartz are especially numerous and apparently less ready to split than usual; this spot is in a small ravine on the eastern side of the ridge about a mile and a half south-west of the Coolgardie Road and less than half a mile on the north side of the Boulder-Kurrawang Road; it might be worth investigation by local metallurgists.)

An interesting fact to note here is that in the neighbourhood of Mt. Squires, in the Warburton Range district, Mr. Frank Hann, the well-known bushman and explorer, has reported the occurrence of large bands of vertically-bedded conglomerates running for miles and forming a steep, well-defined ridge of hills. This is the only similar occurrence that the writer has heard of in Western Australia, and from Mr. Hann's description and from seen specimens of the contained boulders, he (the writer) is inclined to the belief that these beds are similar to the Kalgoorlie ("Kurrawang") conglomerates, and, if so, it may be that other rocks in the district are also similar to those at Kalgoorlie, and that if a second "Golden Mile" is to be found this may be the district in which it is to be looked for, more especially as auriferous "greenstone" (amphibolite, etc.) country is known to occur in the Warburton district.

On the eastern side of the main central Kalgoorlie ridge is a second series of sedimentary rocks; these occupy the valley between the Kalgoorlie and Boorara ridges and have a lateral extent of some three to four miles; the general trend of the belt is roughly north-west and south-east, and it runs in these directions for a considerable number of miles, its exact limits not being known. The rocks of this series—in keeping with all the others on the field—strike about thirty degrees west of north and dip steeply to the west: they consist for the most part of shales, soft sandstones, and grits. A good section of what appears to be the western edge of the series can be seen in the old Phœnix brick pits just on the southern side of the Kanowna Road and about two miles from the Kalgoorlie Post Office.

A third series of sedimentary rocks is also found on the eastern side of the Boorara ridge, extending from Kurramia almost to Kanowna, or roughly four miles; this belt also runs approximately north-west and south-east, and the rocks are very similar to those of the Binduli-Kurrawang—or western—series, viz., soft sandstones, grits, and conglomerates; they strike in the prevailing north-north-west to north-west direction, and as usual dip steeply to the west. The conglomerates of this series differ from those of the western in that they are of much less extent and not so well defined; the beds are also much more weathered. A section showing the conglomerate bed can be seen in a small cutting about a mile and a half along the Kurramia wood line; the band is here about a hundred feet thick and is interbedded with soft sandstones; the pebbles and boulders are mostly of hard blue quartz with quartz and felspar porphyries, the latter being greatly weathered.

All the sedimentary rocks of the district are, for all practical purposes, non-auriferous, and therefore of no great economic importance.

The Calc-schists.—These, as can be seen from the map, form the eastern portion of the main auriferous series and, next to the quartz-diabases, are the most important series on the field. The rocks are essentially fine-grained, but vary somewhat in colour and general appearance; typically they are dark grey on fresh fracture, with a somewhat blotchy appearance, and are characterised by numerous minute veins of calcite running through them in all directions; they break readily in almost any direction and frequently show a slight development of scaly chlorite along the cleavage planes—when these are present. A less typical type is darker, finer grained, more compact, harder, and does not exhibit the same amount of schistosity; it is merely a less sheared and less altered form; this type differs but little in hand specimens from some of the finer grained chloritic diabases.

These rocks were probably originally a basic lava flow, possibly at one time interbedded with the sedimentary series; owing to the extreme alteration that has taken place in them their original structure has been almost completely obliterated, and they now consist essentially of an indefinite mixture of chlorite and carbonates, with only occasionally traces of their original crystalline form left; in addition to the chlorite and carbonates, microscopic investigation shows the following minerals to be present in small quantities:—sericite, albite, zoisite, quartz, ilmenite, rutile, and iron ores.

In their original form the interlacing and interlocking of the original mineral fibres and crystals would give a certain degree of toughness to these rocks, but, owing to the almost total obliteration of this structure by replacement of the original minerals by finely crystalline and non-crystalline carbonates, this toughness has been destroyed and the rocks fracture readily, and this fact, together with their general comparative softness, makes mining operations in them comparatively easy and cheap; moreover, owing to the less frequent occurrence of joint planes and "heads" this class of country after opening up stands much better than much of the quartz-diabase and amphibolite country.

The Fine-grained Amphibolites.—These are found on the western side of the northern portion of the coarse-grained amphibolite, at Somerville, about two miles along the Coolgardie Road, and also on the eastern side of the calc-schist belt. portions of these areas are shown on the accompanying map. In places they very closely resemble the rocks of the calc-schist series, and with them probably belong—in the main—to an older series of "greenstones," being possibly a closely related lava flow or intrusion.

Typically, the rocks of this series are of a dark-green colour, mostly massive, and very fine-grained; they consist apparently almost entirely of light-green hornblende and chlorite with occasionally small crystals of felspar. A microscopic examination of them shows their constituent minerals, in a typical specimen, in addition to the hornblende, chlorite, and felspars, to be calcite, epidote, and various iron ores; in some specimens the hornblende has entirely disappeared and is replaced by greenish chlorite.

As far as known this series is to all intents and purposes non-auriferous, and therefore of no great economic importance.

The Quartz Diabases.—The series of rocks to which the name "quartz-diabase" has been given is by far the most important on the Kalgoorlie goldfield, as it is within them that nearly all the principal ore-bodies at present being worked are found.

The rocks vary greatly in general appearance according to the amount of foliation, shearing and chemical alteration that they have undergone. The type rock is massive and fairly coarse-grained; it has a mottled appearance, being dark-green in general colour with white porphyritic felspars—or what were originally felspars—and occasional fair-sized blebs of colourless quartz, a good deal of this probably being of secondary origin. Under the microscope the rock is seen to consist essentially of plagioclase felspar, quartz and chlorite, the quartz and felspar frequently showing micro-pegmatitic structure, while the chlorite probably represents the remains of original augite; in addition there are present ilmenite (largely altered to leucoxene), calcite, apatite, and saussurite.

Another variety is much finer grained with—in hand specimens—no sign of porphyritic felspars, and with the quartz blebs developed to a much less degree; on microscopic examination, however, this rock proves to be only a modification of the previous one. Both these types are found massive and are also found subjected to all degrees of foliation, schistosity and chemical alteration.

The quartz-diabases are as a series very closely allied to some of the coarse acid amphibolites and in all probability were originally derived from the same magma.

Several interesting forms of extreme alteration are found in the diabases, one of the chief ones being the occurrence of the so-called "graphitic-slate" bands. These are of fairly common occurrence and are sometimes found up to well over a hundred feet in thickness, the more usual width being two to six feet; they are frequently of considerable persistence in strike and have been known to occur down to a vertical depth of well over two thousand feet; they are also known on the other hand to extend only a comparatively few feet both longitudinally and vertically. In places these so-called "slates" exhibit a very marked and regular fissility and in hand specimens exactly resemble true sedimentary slates or shales. The present article is too short to permit of a close investigation in detail of the question, but the writer, after a careful examination of the bands, can allow no other explanation than that they are merely highly-sheared bands of country rock, the graphite being deposited subsequent to the shearing and being probably formed as the result of the decomposition of hydrocarbons derived from deep-seated sources. The bands are occasionally closely associated with the ore-bodies and in these cases, owing to the graphitic material becoming mechanically mixed with the ore, they cause some annoyance to the metallurgist.

In many instances the bands are non-graphitic, and in these cases they still more closely resemble true slates, especially nearer the surface, where they are slightly weathered; occasionally slight secondary silicification has gone on and the bands then closely resemble fine-grained phyllites.

They likewise occur in the calc-schists, in both the coarse and fine-grained amphibolites, and also to a less extent in the porphyrites.

The second interesting modification occurs as the result of the extreme carbonating of the rocks, whereby they are converted into a mixture of lime, iron and magnesium-carbonates, together with a certain amount of original and some secondary quartz. This form of alteration is extremely common and often occurs over considerable widths—150 feet and more; it is—as is to be expected—most marked where the shearing of the rocks is most pronounced, and in almost all cases is found to occur to a greater or less degree in the immediate proximity of the lodes; frequently it can be noticed taking place on both sides of a main fault-line or cleavage plane, the carbonating being most intense near the fault—or cleavage—and gradually dying out on both sides until the rock reaches its normal state. In its extreme form the carbonated rock is white to pale pink on fresh fracture, but it very rapidly changes on exposure to a dull pink owing to the oxidation of the ferrous carbonate present; in texture it varies from a fine-grained compact variety with very little quartz to a coarse variety with large quartz blebs, this latter variety when seen by candle light underground having at first glance very much the general appearance of a pink granite or syenite. All gradations can of course be obtained from the coarse carbonated type to the typical diabase. A highly schistose variety of the carbonated rock is sometimes found along the lode-channels or where secondary shearing has taken place; this is usually creamy-white in colour and has a somewhat greasy appearance and feel, owing to the large development of sericite along the cleavage-planes; in some of its forms this sericite-carbonate schist is locally known as "fish rock." Splendid examples of this carbonating of the diabase are to be seen in certain of the deeper workings of the Lake View, the Perseverance and the Ivanhoe mines—in fact in almost all the workings within this class of rocks. In the Ivanhoe mine towards the end of the main east crosscut at the 1669-ft. level is to be seen a splendid example of the various changes from the normal green mottled diabase to the coarse white to pink carbonated type.

For exactly the same reasons as with the calc-schists, mining operations in the carbonated diabases are easier and cheaper than in the normal rock; along the same crosscut very often can be seen cuts that have been fired in both classes of rock; in the carbonated variety the cuts will be shot out right to the extreme end of—and even slightly beyond—the holes, while in the tougher normal rock often as much as eight or nine inches of the hole will be left in the face.

In addition to the main fault-lines—which will be referred to later—the diabases are crossed by numerous small secondary faults, fissures and cleavages; these dip at all angles and run in all directions, though the prevailing strike of them is roughly at right angles to the strike of the main faults, and they are probably in most cases induced fissures caused by pressure along these main lines; they are found crossing the lodes as well as the country, but as a rule do no harm beyond the fact that by their intersection with each other or with well-developed shear-lines, they sometimes cause considerable falls of rock to take place in the stopes and—to a less extent—in the drives.

The Coarse-grained Amphibolites.—These are really of two types, (*a*) the basic and (*b*) the felspathic or acid; they are, however, for all practical purposes inseparable, and the latter variety is simply an acid eastern side of the calc-schist belt; portions of these western side of the northern area, the change from one to the other being a gradual one. Typically, the felspathic variety is a coarse-grained green and white mottled rock—coarser grained than the typical quartz-diabase—showing large irregular crystals and blebs of felspar intermixed with dark green crystals of hornblende and chlorite; the two being present in apparently approximately equal proportion; frequently a little clear quartz is also present. In some of its varieties this acid type very closely resembles some of the quartz-diabases, the two, as before stated, being probably originally derived from the same magma.

The basic type—which is found at both the north and south ends of the field—is in hand specimens a dark-green coarse-grained rock consisting apparently almost entirely of green hornblende and chlorite.

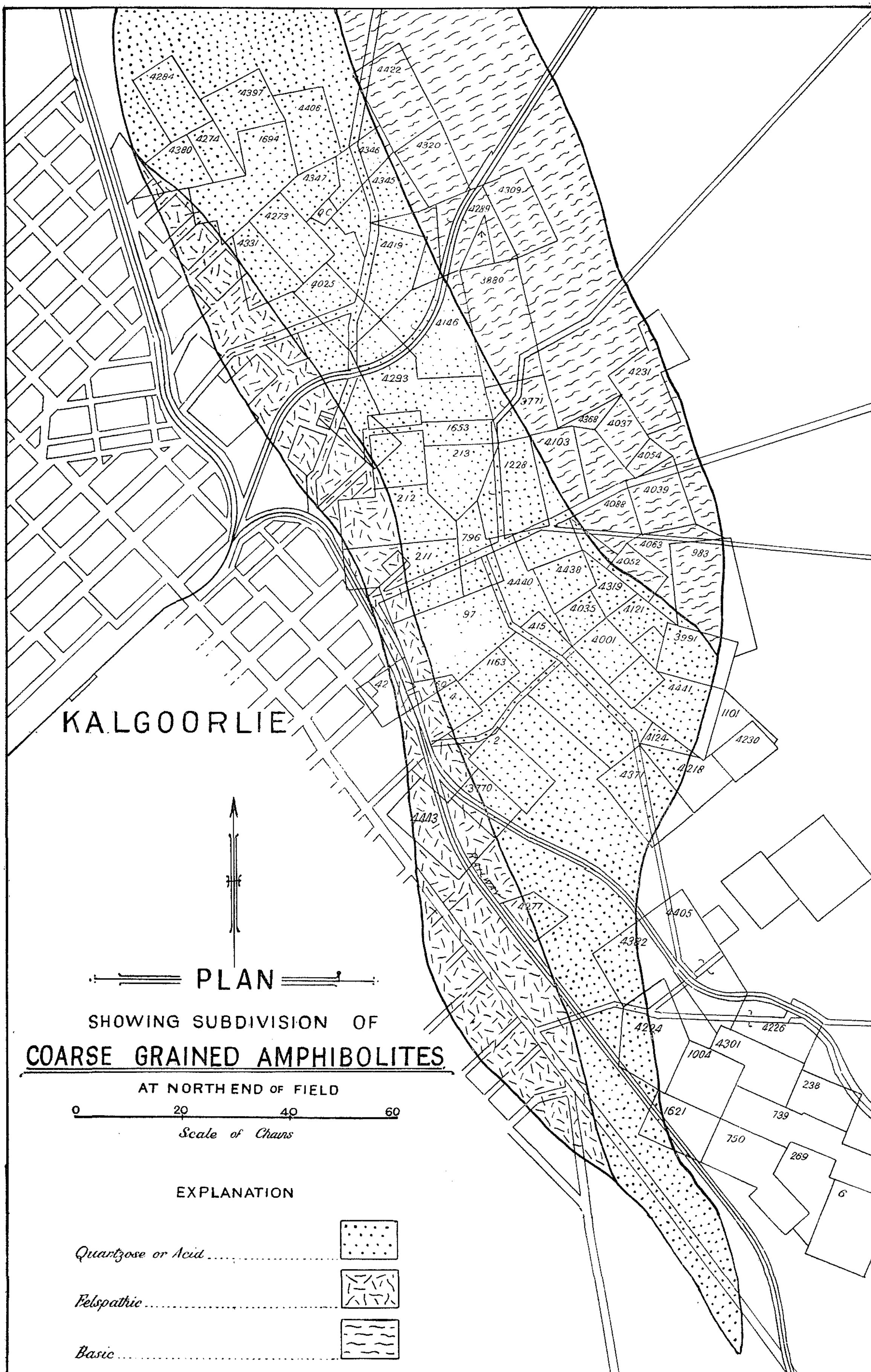
The rocks of both types are generally massive and have not been, on the whole, subjected to the same amount of shearing and alteration as the diabases—though sheared areas do occur, especially to the north-eastern end and in the neighbourhood of Hannan's Hill.

In economic importance certain of the acid amphibolites rank next to the calc-shists, but it is practically only at the north end that they contain any auriferous deposits of commercial value, and even these are of no great importance when compared with those in the diabases. On their western and southern extensions the amphibolites, both basic and felspathic, are practically non-auriferous; the presence of auriferous lodes at the north end may be to a large extent due to the presence of intrusive igneous rocks (peridotites and porphyries) in the neighbourhood.

Coarse-grained amphibolites—principally of the basic variety—occur over a large area to the south of the Boulder Belt in the neighbourhood of Mt. Hunt, and also in the hills forming the ridge further west; these, however, are outside the scope of the present article, sufficient is it to say that they also are for commercial purposes practically non-auriferous.

The Peridotites.—These have their greatest development at the south end of the field along the western edge of Hannan's Lake towards Mt. Hunt, this area being beyond the limits of the map accompanying this article. Several smaller areas of what is in the writer's opinion a carbonated peridotite occur, however, at the north end of the field and the positions of these are shown on the map.

The peridotite at the south end of the field is almost black in colour, is very fine-grained, breaking with a somewhat conchoidal fracture; it has suf-


KALGOORLIE
PLAN
SHOWING SUBDIVISION OF
COARSE GRAINED AMPHIBOLITES
AT NORTH END OF FIELD
0 20 40 60
Scale of Chains
EXPLANATION
Quartzose or Acid
Felspathic
Basic
RHI

fered considerable alteration and in some cases has been altered into a solid serpentine rock. On a small island on the west side of the lake it has, by the action of carbonated waters, been entirely converted into a dark-grey coarsely crystalline rock composed chiefly of carbonates of magnesia, iron and lime.

A little asbestos (var. picrolite) is found here and there in the peridotites, but it is of no great commercial value; scattered over the hills, however, are here and there fair-sized patches of magnesite (carbonate of magnesium) which might possibly be put to some use as furnace linings, etc.

The rock at the north end of the field, which has been mapped as a derivative of the peridotite, is a greyish, fairly coarsely crystalline, carbonated rock, agreeing almost absolutely in analysis with that found at the edge of Hannan's Lake. It is found to be invariably associated with the fuschite- (chrome mica) bearing lodes so conspicuous at the northern end of the field, and it is probably the source from which the fuchsite has been derived, as it is found on analysis to contain a little over one half per cent. of chromic oxide. Especially good examples of these fuchsite lodes can be seen in the Hidden Secret, Fairplay, and Devon Consols leases.

Except for their close relationship to certain gold-bearing lodes at the north end of the field the peridotites themselves can be classed as non-auriferous.

The Porphyrites.—These are of very considerable extent and for the most part are found underlying the recent deposits of the flats on the west side of the Kalgoorlie ridge and to the south and south-west of Boulder. Typically they are massive, and of a brownish-green to dark-brown ground colour with numerous white porphyritic crystals of felspar and occasionally dark porphyritic hornblende crystals; the microscope shows these porphyritic felspars and hornblende to be set in a slightly greenish very finely crystalline felsitic ground mass, the greenish colouration being due to the presence of a little finely-divided chlorite. Numerous variations from the type specimen occur; one of these is a very fine-grained dark-grey compact variety showing in hand specimens no trace of porphyritic structure, while only a few feet away the rock is mottled in appearance and shows innumerable large white porphyritic felspars set in a dark-grey green to brown ground mass; in this latter type are frequently noticed patches up to two inches in diameter of a pale grey felsitic-looking material; these represent merely more acid portions which have segregated out from the original molten mass on cooling. Other variations, which probably represent segregation on a larger scale, approach very closely in general appearance to quartz and felspar-porphyries. Still another variation is seen on G.M.L. 1923, about three miles south of Boulder Block (Fimiston); here can be seen on a dump a very dark almost black rock of fairly fine texture showing a large development of biotite in small flakes and crystals; it is a biotite-porphyrite and, as far as can be seen, merely a local variation from the general type.

The porphyrites occur as large masses—as shown on the map—and also in the form of small dykes; these latter are found traversing the amphibolites in all directions, but are never at any great distance from the main mass, from which they are evidently only off-shoots.

Sheared examples of the porphyrites occur and in this form it very closely resembles, when weathered, some of the soft sandstones of the sedimentary series, so much so in fact that it is practically impossible to distinguish between the two in hand specimens. At Monument Hill, on a western arm of Hannan's Lake and some three-and-a-half miles south-south-west of Boulder Block, is an example of sheared and weathered porphyrite exactly resembling the sediments of the Kurrawang series; several shafts sunk on it have proved its nature beyond dispute. At Walshe's Quarry about a mile along the Coolgardie road are exposed a series of rocks whose origin is more doubtful; as seen in the face of the quarry these rocks appear to consist of sandstones, soft siliceous slates and shales; they *may* be of sedimentary origin, but the writer, after a careful comparison of them with other rocks of the field, is strongly of the opinion that they are merely sheared and weathered porphyrite.

While on the subject of the porphyrites mention must be made of the "building stone" so much used in Kalgoorlie some years ago for building purposes. This is in its typical form a light-coloured fairly compact, rather fine-grained rock, soft enough to be cut with a knife and closely resembling in general appearance a soft sandstone; it frequently exhibits a red-and-white or brown-and-white banded appearance, this being due to original horizontal weathering of the rock. The greater portion of this stone used in the past has been obtained from the White Cliffs—or Button's quarry, some three miles south-west of Boulder Block; in this case it is simply a much-weathered porphyrite. A very similar class of rock results from the weathering of the massive amphibolites, but not much of this has been used for building purposes

The porphyrites are as a whole non-auriferous.

The Quartz and Felspar Porphyries.—These are found for the most part in the form of narrow dykes intruding the older rocks of the field; they are not numerous and are of no great importance; the felspar-porphyries are the more common type; they are as a rule hard and compact, usually of a pinkish colour and have a very fine-grained felsitic ground-mass, in which are embedded fair-sized porphyritic crystals of felspar.

They form dykes of from ten to forty feet in width and often of considerable length, good examples of which can be seen in the workings of the Hainault, South Kalgurli, Perseverance, Lake View and other mines. These dykes have in many cases been subjected to much shearing and have suffered the same faulting, etc., as the main lodes; they appear to have been intruded prior to the formation of the majority of the lodes and, as far as can be judged, do not seem to have had any marked influence on the deposition of the gold.

A large extent of coarse felspar and quartz porphyry is found in the vicinity of Binduli; here there are two well-defined parallel bands up to a maximum of twenty chains in width running for several miles in a north-westerly and south-easterly direction. This occurrence is of interest principally on account of the presence of large crush breccias at both the southern and northern ends of the main band. The finest of these breccias is seen at the south end, some four miles from the Coolgardie road; here it extends over a width of from ten to twelve chains—the full width of the porphyry—having in a general way much the appearance of a compact coarse boulder conglomerate and being in every way similar to the so-called conglomerates of Kanowna, which in the writer's opinion are nothing more or less than similar crush breccias; by following it in a north-westerly direction it can be seen to pass gradually into, first, a slightly sheared, and finally, into the unaltered porphyry. This breccia has been formed by shearing of the porphyry while it was still probably in a more or less semi-molten condition. The second similar breccia towards the north end of the band cannot be seen on the surface, but it has been exposed in the workings on G.M.L. 3645, a mile and a half to two miles north-west of Binduli.

A similar class of breccia is found within the main porphyrite area, on W.R. 221 about three-quarters of a mile north of Lakeside; here some of the boulders are up to nearly two feet in diameter. No outcrop of this breccia can be seen, but it has been opened up to a considerable extent by mine workings which are now unfortunately inaccessible.

The Recent Deposits.—These consist of loose sand, loam, ironstone-gravel, etc., and are the result of the gradual weathering and breaking down *in situ* of the underlying rocks. They cover by far the greater part of the district, often to a considerable depth, and make accurate geological mapping at times a matter of almost practical impossibility, and what is probably of more commercial importance, they also render surface prospecting extremely difficult.

Included in these "recent deposits" are the laterites, or ironstone-conglomerates, which are such a conspicuous feature of the district. The question of the exact origin of these laterites has at times given rise to considerable argument and even to the present time has not been altogether satisfactorily settled; the belief held by the writer is the fairly commonly accepted one that they have been formed *in situ* by the gradual concentration by atmospheric agencies of ferric oxide derived from the decomposition of the underlying rocks, which in every case have been originally rich in iron compounds.

These recent deposits have not been shown on the accompanying map, which claims only to show the main structural formations.

The Ore Deposits.—The class of deposit worked on the Kalgoorlie field is that to which the term "lode deposit" has been generally applied, for though in a few cases quartz reefs of small size have been opened out, these are always more or less intimately connected with the main class. These lodes have in a general way been well defined as—

"More or less vertical zones of rock usually continuous with the surrounding country and of similar origin, but distinct from it in carrying metallic ores disseminated through them, often in payable quantities, and frequently characterised by strong foliation. They owe their existence to a shearing and faulting action having crushed and foliated portion of the main rock mass in a certain definite direction, producing a more or less well-defined band of rock through which, by virtue of the foliation, mineral bearing solutions can have free circulation. In consequence of this, mineral deposits are formed within the rock, usually, but not necessarily, extending over the whole of the foliated zone and having no definite boundaries horizontally or vertically other than those determined by the decrease of assay values to a point at which they cease to pay working expenses."

For the purposes of detailed description the ore-deposits are best grouped according to the various classes of rock in which they are found, viz.:—

(1) Deposits in the quartz-diabases.
(2) Deposits in the calc-schists.
(3) Deposits in the acid amphibolites.

(1) *The Deposits in the Quartz-diabases.*—These may be subidivided into:—

(*a*) The quartzose ore-bodies.
(*b*) The schistose or carbonated ore-bodies.

There is, however, no hard and fast line between the two classes, both being of the same origin and each in part grading imperceptibly into the other. As a general rule, however, the quartzose bodies are more regular both in values and occurrence than the carbonated. Typical bodies of this class are those worked in the western group of mines, viz., the Great Boulder, Horseshoe and Ivanhoe; most of the other mines are on carbonated or schistose bodies.

The essential difference between the two classes lies in the fact that a greater amount of replacement has taken place in the former and the original lode material has been to a large extent gradually replaced by a dark compact cherty looking quartz, while in the latter the alteration is chiefly to carbonates; these ore-bodies always have a more or less banded appearance and the development of the quartzose material is always greater in the central portion of the lode. Within the limits of the lode channels are frequently found small iregular veins of white glassy quartz, usually running at right angles to the strike of the lodes; these rarely carry any appreciable gold values, but very often contain considerable amounts of tourmaline and tennantite (sulpharsenide of copper) in addition to the usual vein minerals; they are of very limited extent, rarely extending for more than a few feet in any one direction, and are evidently of secondary origin, probably marking shrinkage cracks in the lodes proper.

Very frequently the main lodes show signs of secondary movement and of re-opening, especially along the centre line of fissuring; in these cases the middle portion of the lode is much brecciated, the darker original quartz being broken up and re-cemented by a fine-grained intergrowth of white quartz and calcite. This re-opening is also seen in the case of the carbonated lodes, though the re-cementing of the brecciated material is not so noticeable as in the darker quartzose bodies.

In the case of the carbonated lodes their general apearance varies from a more or less solid mixture of carbonates to a very slightly carbonated sericite or chlorite schist; they are much more irregular both in size and in the distribution of the values than the quartzose lodes.

Almost invariably the main central line of the lodes is marked by a small well-defined seam, usually of quartz with carbonates of iron, etc., and generally not more than a quarter of an inch in width; this represents the central line along which the original shearing has taken place, and it can be followed in many cases for long distances; often the lode, *i.e.*, the crushed and altered rock, will die out and this central seam then exists merely as a narrow cleavage running through the comparatively solid country.

Mineralisation of the lodes has of course taken place to the largest extent where the foliation and crushing have been most intense, while in the more solid rock it has taken place only over a very small area extending outwards from the main fissure. As the shearing of the rocks is irregular in its intensity, so also is the extent of the mineralised lodes irregular, the occurrences being to a certain extent lenticular; in some cases—where the shearing has been fairly general—the mineralisation has extended over a width of well over a hundred feet and the whole of this width has carried payable gold values, while at other times along the same lode-line the shearing—and mineralisation—is confined to a width of a few feet; in short, wherever the country has been highly foliated or sheared, there mineralisation has taken place, but in these mineralised bands, though gold is invariably present up to a certain extent, it is not always there in sufficient quantity to pay for working.

Along the main lode-lines in many cases the values are found to occur in irregular lenticular patches even when there is apparently no change in the lode; in other cases the more highly sheared portions throughout which the ores are deposited are themselves lenticular in habit, and as these lenses are irregular both in size and occurrence they cause some slight trouble both in mining operations and in the satisfactory estimation of ore reserves; for example, a level may be driven for some distance on good values, while one stope taken above the drive may see the end of these values; this has actually happened on more than one ocasion. Again, in prospecting for ore-bodies with the diamond drill, this lenticular habit of the lodes is apt to be very misleading owing to the fact that a bore-hole might cut an apparently fair-sized body of ore which on further development will prove to be only an isolated lens of no great length or depth; at the same time it would be equally likely to miss a lens of ore and cut the lode where it had pinched or carried no values .

The lode-channels themselves are very persistent both in strike and in depth and have been frequently known to continue without a break through several leases; the length and frequency of the ore-lenses along the same lode vary greatly; while one lens may be several hundred feet in length the next one may be only twenty feet; frequently however, the persistence in depth of the short lenses is just as great as with the longer ones, though this is not always the case; all the lenses a a rule show a tendency to pitch to the south. The values never cut out entirely along the main lodes, but in those portions of them connecting two ore-lenses they drop to a point at which they cease to be at present payable.

All these mineralised shear zones, or lodes, have a roughly parallel strike, this being approximately north-north-west, and as they are fairly numerous. extensive diamond-drilling or cross-cutting has to be resorted to in order to prove their existence; frequently a low-grade lode will be intersected in a crosscut and a good deal of development work has often to be carried out along it in the chance of meeting with a lens of payable ore, these being of possible occurrence along any lode channel.

With regard to the mineralisation of the ore bodies the principal lode minerals in addition to gold and tellurides (calaverite, petzite, sylvanite, hessite, coloradoite, altaite) are iron pyrites, marcasite, chalcopyrite, tennantite, asbolite, carbonates (of iron, lime, magnesia, etc.), sulphates (of lime and magnesia), iron ores (hematite, magnetite, ilmenite, etc.), tourmaline, chlorite, albite, rutile, etc. Of these the most important is—next to the gold and tellurides—the iron pyrites; this is usually present in fair quantity, and it is invariably found to be the case that the finer-grained it is the higher are its gold contents; frequently a coarse more or less crystalline pyrites is present, more especially on the walls and in the carbonated lodes, and this almost invariably carries no payable values; it has apparently been deposited at a later date and certainly under different conditions from those of the finer-grained auriferous pyrites.

(2) *The Deposits in the Calc-schists.*—No quartzose ore-bodies occur in this series of rocks, the lodes being similar, and behaving similarly in every way, to the schistose or carbonated ores found in the diabases, and the same general remarks apply almost equally well to both. As a general rule, however, they are more patchy in their contents and on the whole of lower grade than the latter class of deposits.

Special, though brief, mention must, however, be made of one particular ore-body occurring within the calc-schists, and this is the remarkable "Oroya shoot." The ore-body in this case was in the form of a pipe or chimney whose cross-section, though irregular, approximated in a general way to a more or less flattened oval having in places a maximum diameter of roughly a hundred feet. The general pitch of the "pipe" was at a very flat angle to the south, with, at the same time, an underlay to the west. It has been worked from the surface down through the following leases:—Brown Hill, Iron Duke, Oroya and Australia East, or for a total length of over three-quarters of a mile; at the point where it appears to have died out it had reached a vertical depth of about twelve hundred feet. Immediately on the east side of the pipe is a well-defined body of highly sheared rock dipping at an angle of forty-five to fifty degrees to the west; the ore appears to have lain on or close to this shear line, dipping with it and at the same time pitching away, as before stated, very flatly to the south. In several places the hanging and foot walls—if they may be termed such—of the ore body are formed by well marked fault or fissure lines, and these, taken in conjunction with the main underlying shear plane, have probably had a good deal to do with the deposition of the values. Occasional small patches—or "droppers"—of ore run out from the main body; these are of very limited extent and are generally formed on an intersecting cleavage of fissure plane.

(3) *The Deposits in the Acid Amphibolites.*—Lodes similar in origin and general character to those in the diabases and calc-schists also occur in certain of the acid amphibolites, but they have not as a general rule so far proved of any very great importance.

The main point of difference between this class of rocks and the diabases and calc-shists is the occurrence within them of small rich quartz veins and leaders. These have been worked to the greatest extent in Hannan's Reward and on Cassidy Hill; they are never of any great size, rarely exceeding a foot in thickness and more usually ranging from a mere thread up to only two inches; they are confined to certain well-defined belts of sheared rock and are never found beyond the limits of the sheared zone, running at right angles to the general trend of this; although consequently never of any great length, they are fairly persistent in depth. In the big lode on Hannan's Reward, which near the surface exceeds a hundred feet in thickness, these leaders were especially numerous and some of them were phenomenally rich. At first merely the leaders themselves were taken out, but subsequently the whole lode formation—which itself carried a little gold—was worked, the high grade of the quartz veins being sufficient to bring the grade of the whole formation up to payable limits.

It is from these quartz leaders that the bulk of the alluvial gold obtained in the neighbourhood of Hannan's Hill was originally derived.

Another class of deposits found in the amphibolites of the north end are the contact bodies referred to previously as occurring alongside the peridotite dykes. These are merely mineralised zones of sheared and altered rock, and must be classed as "lodes"; they are, however, irregular, following to a considerable extent the boundaries of the peridotite; they are also of comparatively small size and their gold contents are very erratic, although at times extremely high. They are characterised as a rule by their bright-green colour, this being due to the presence of finely divided fuchsite, whose occurrence has already been referred to. Lodes of this description are typically represented in the Hidden Secret and Fairplay mines.

While on the subject of the lodes generally, brief mention must be made of the large banded and jasperoid quartz reefs occurring in certain portions of the field. These are found principally in the amphibolites, and especially at the south end in the neighbourhood of Mt. Hunt. They are of a dark banded and jasperoid quartz, often carrying a large percentage of hematite and sometimes magnetite, and are the result of extreme alteration and silicification of well defined sheared bands of rock; they are very persistent in strike, sometimes extending for over a mile in length and are of large size occasionally reaching as much as fifty feet in width; near Mt. Hunt they are particularly numerous and can be seen in places rising from the ground to a height of 40 or 50 feet. Although small auriferous quartz leaders are at times associated with them, the jasperoid lodes themselves appear to be practically non-auriferous.

The Faults.—Faulting of the lodes has been fairly common, more especially in the quartz-diabase and calc-schists areas; the main system runs approximately parallel to the general strike of the lodes and the faults dip at an angle of 40 to 45 degrees to the west. The faults of this system are "reversed" faults, and are due to overthrusting of the western portion of the belt; contrary to the usually accepted idea of reverse faults, they do not duplicate the lodes. Occasionally, however, normal or easterly-dipping faults do occur, but they are much less usual than those with a westerly dip. The displacement caused by both classes of faults varies considerably, usually, however, ranging from ten to forty feet. As a general rule the faults of the main system are very persistent not only in strike but also in dip, and can readily be followed down from level to level; they are usually marked by a seam of calcite or gypsum, or a "dig," varying from half an inch up to as much as four inches in width, and in the latter cases almost always act as water channels. Occasionally values are found along the fault-lines between the two portions of the lode, these sometimes extend over a width of as much as two feet; but, as a general rule, values are not found in appreciable quantity along the fault lines.

The numerous small fissures, or "heads" or "floors," which are found crossing the lodes and country in almost every direction, but chiefly at right angles to the main lines, are evidently part of a secondary system induced by these main lines; as a general rule they cause no displacement.

The chief effect of the main faults is, by their presence, to lessen the apparent amount of ore "in sight" between any two levels by causing, as a result of the overthrusting upwards of the upper portion, the formation of a vertical—as well as horizontal—gap between the two portions of the faulted lode.

Another effect of the faulting is represented by the following occurrence which actually took place in the Great Boulder Main Reef G.M. An inclined bore-hole from the No. 14 level cut what appeared to be two separate ore bodies; subsequent development, however, proved the supposed second body to be merely the faulted portion of the original one, the bore-hole thus having passed through the same lode twice; equally well also might it have passed through the gap between the two portions and thus have apparently proved the non-existence of the lode below the level bored from.

Conclusion.—With regard to the permanency of the Kalgoorlie and Boulder lodes it may be at once stated that they are undoubtedly deep seated and will in every probability live at least to the depth to which mining operations can at present be carried; whether or no their gold contents will live with them is a matter on which it is impossible to speak with any certainty, and one which can only be proved by actual development; the best arguments in favour of this, however, that the writer knows of, are the following deep-level developments recently reported by two of the leading mines of the field:—

Golden Horse-Shoe.—Cabled report to London, May 19th 1909: "No. 3 shaft, 2,000 feet level—East branch, No. 3 lode, total width 18 feet, assays 1 ounce 2 dwts. per ton; free gold and telluride showing from wall to wall."

Great Boulder Proprietary.—Cabled report to London, August 25th, 1909: "Prospecting with diamond drill, Edwards' shaft, 2,600 feet level, West—At 108 feet from shaft struck ore, for the first three feet schist intermixed with quartz leaders, the ore is very rich in free gold; assays average 11 ounces per ton. The next three feet similar, but there is no visible gold, assays average 5 dwts. per ton. The next 8 feet consists of pyrites and quartz, assay value 5 dwts per ton; there is quartz in the end of the bore-hole."

Cabled report to London, November 12, 1909: "Edwards' shaft, 2,500 feet level—West crosscut has cut the reef 98 feet from the shaft; it is hard quartz; width of ore 14 feet, and assays 10½ dwts. per ton."

Cable, December 11th, 1909: "Edwards shaft, 2,500 feet level—North end of drive, average assays 15 dwts. per ton; south end, 44 dwts. per ton."

These developments are the deepest on the field and speak for themselves as to the permanency of the lodes and their values.

Addenda.—Since the preceding article was written the author has had the opportunity of carrying out considerable petrological work in connection with the Kalgoorlie rocks. The result of this has been to confirm his original view that the so-called "newer greenstones" all belong to one main intrusive series, consisting originally of plagioclase-augite and quartz-plagioclase-augite rocks of the gabbro or diabase type.

The two main groupings that have been adopted in the article have been made for *economic* reasons and for simplicity in mapping rather than for strictly *technical* purposes. The distinguishing feature of the groups is the relative amount of mass alteration that has taken place in each, this alteration being represented chiefly by the partial or complete molecular change of the original augite in the rocks to hornblende, uralite, and chlorite.

In the case of the so-called "quartz-diabases" molecular alteration—probably largely assisted by the presence of the intrusive porphyries—has proceeded to a much greater extent than in the "amphibolites," the original augite being wholly and completely altered to chlorite. The term "quartz-diabase" has been given to these chloritic rocks in order to distinguish them from the less-altered and less-auriferous rocks, because this is what they appear to have been originally.

The "coarse-grained amphibolites" comprise all the various modifications of the original newer greenstones, exclusive of the above chloritic (quartz-diabase") type, viz., gabbros, pyroxenites, amphibolites, etc. Typical gabbros are not found within the limits of the map published with Part I. of these notes, but are confined to that area of greenstones referred to in the text as the western ridge, and lying immediately behind the Kalgoorlie abattoirs. The "felspathic amphibolites," however, which are found at both the north and south ends of the central area, are derived from these gabbros, through the change of the original augite to hornblende and uralite. All gradations between the two classes are obtainable in the field. A more correct subdivision of the amphibolites referred to in the article, viz., (a) the basic, and (b) the felspathic or acid, would be (a) the quartzose or acid (b) the felspathic and (c) the basic. These have their greatest development over the northern area and are undoubtedly merely differentiations from the one intrusive mass; the quartzose or more siliceous type occupies, as would be expected, the central portion of the mass and gradually merges on both sides into the more basic varieties forming the outer margins, the "basic" being on the eastern, and the "felspathic" on the western margin. The "quartzose" type was probably originally a quartz-gabbro, a slightly acid segregation from the normal type; the "basic" was (in part) a pyroxenite, being a basic segregation from the original mass, while the "felspathic" probably represents the nearly normal rock (gabbro or, in part, diabase). In the case of the "felspathic" type the change of the original augite has been to hornblende and uralite; in the "basic" it has been (largely) to hornblende; and in the "quartzose" it has gone further to uralite and chlorite. This latter type approaches very closely to the "quartz-diabase" series, but the change of the augite to chlorite has not been quite as complete as in that series.

The important facts, however, in connection with the various modifications and alterations of these original gabbros, etc., are as follow:—

(1) The rocks in which the conversion to chlorite of the original augite has been complete, viz., the "quartz-diabase" series, are those which contain all the highly-auriferous lodes.

(2) The rocks in which this conversion to chlorite has been partial, viz., the chlorite "quartzose, or acid, amphibolites" of the north end, contain certain less highly auriferous lodes.

(3) The rocks in which there has been practically no conversion to chlorite, viz., the typical amphibolites, gabbros, etc., of the western group, contain no auriferous* lodes.

From these facts it appears not unreasonable to assume that the gold has originally been held in combination by the ferro-magnesian mineral (augite) and the splitting up of this—to chlorite, etc.—has probably assisted in the liberation and solution of the gold subsequently deposited in the lode formations. That this is so, or that the conditions affecting the conversion of the ferro-magnesian minerals had any connection with those affecting the deposition of the gold is, of course, open to argument, but the fact remains that in the wholly chloritic rocks, and in them alone, are the highly-auriferous lodes to be found.

In the original article the writer, when dealing with the felspar-porphyry dykes, stated that " . . . as far as can be judged, they do not seem to have had any marked influence on the deposition of the gold;" this statement was intended to infer more that they had no immediate effect on the local enrichment of the lodes—which they have not—rather than that they had nothing to do with the general process of mineralisation ,etc. As a matter of fact they have probably had a great deal to do with the mineralisation, etc., of the older lodes, in so far that the presence of magmatic water following on their intrusion has been the direct cause of, or, at least, has largely assisted in, such mineralisation.

L. Glauert, Field Geologist.

(7.) *Further Notes on the Gingin Chalk.*

According to verbal instructions I proceeded to Gingin on the 11th of May, 1910, with a view of continuing my investigations concerning the development, extension, and relationship of the Gingin Chalk, and of making a general survey of similar or allied beds extending to the northward.

The fact that the vegetation had not yet felt the effects of the winter rains considerably improved the conditions of work and facilitated the examination of the district.

Immediately upon arrival I visited the outcrop on One Tree Hill. Since my last visit a considerable amount of work had been undertaken in order to determine the extent and depth of the chalk. Shafts had been sunk to a depth of 10ft. or 15ft. and borings made by means of long augers with a result that the bed was found to have a depth of at least 25ft. to 30ft.

One of the shafts was sunk outside the "chalk" area on the eastern side of the hill, but the rest were found to be within its borders. In two instances a greenish clay, probably Glauconitic, was entered at a slight distance below the surface and found to continue beyond the limit of the bore. The presence of this clay in the bores was regarded as most discouraging by those undertaking the work, but it is my opinion that fears of the chalk thinning out at the centre of the hill are quite groundless. Measurements made around the two unfavourable sinkings show that the chalk is normally developed on all sides.

An examination of the quarry on the southern edge of the hill shows the presence of numerous joints, two of these, which are somewhat wider than the rest, are seen to be filled with a stiff greenish clay very like that met with in the course of the investigations on the hill-top; it seems therefore that the correct explanation of the occurrence is to be found in the presence of other more or less widened joints containing similar clay. I do not consider that any diminution in thickness of the chalk itself will be found to exist at the centre, the bed will be either of constant thickness or gradually tapering.

The quarry itself has been worked at times during the past twelve months, and from new exposures I was able to procure a good collection of specimens, large Pelecypods (Lamellibranchs) from the north face and Ammonites from the western wall, as well as one or two smaller fossils including corals, Brachiopods, etc.†

The exposure on Mole Cap Hill was unchanged, and needs no remarks, but the outcrops two miles along the Bindoon Road and in the valley of the Moonda Brook now give some good sections of the lower portions of the chalk and the underlying glauconitic clay. Similar clays have also been seen in places along the upper valley of the Gingin Brook, at points where the investigations made last year led me to believe they would in all probability be found.

The outcrops on the eastern, southern, and western sides of Ginginup are much more extensive than was at first supposed, and have been traced along the

*In this context the term "auriferous" is meant to imply a grade of ore that may be profitably mined.—C.G.G.

†These specimens are at present in the hands of Mr. R. Etheridge, the Curator of the Australian Museum, Sydney. His report upon the animal life of the chalk should contain most important results and will, I hope, definitely determine the position of the bed in the Cretaceous Formation.