Hodge-Smith, T., 1932. Geological and mineralogical observations in Central Australia. *Records of the Australian Museum* 18(8): 415–442, plates liii–lv. [13 September 1932].

doi:10.3853/j.0067-1975.18.1932.746

ISSN 0067-1975

Published by the Australian Museum, Sydney

GEOLOGICAL AND MINERALOGICAL OBSERVATIONS IN CENTRAL AUSTRALIA.

By

T. HODGE-SMITH,
Mineralogist, The Australian Museum.

(Plates liii-lv; Figures 1-12.)

Introduction.

By the invitation of the Mica Corporation of Australia Limited, and the generous assistance of a number of donors, I was enabled to accompany Messrs. J. Dale and R. Barlow on an expedition to Central Australia. Our method of transport was by motor lorry, and altogether we travelled 850 miles in Central Australia. Entering the Territory from Queensland at about latitude 21° 51′ south, we travelled 25 miles south along the Queensland-Central Australia border fence to Tobermory Station, and then in a general west-by-south direction for 204 miles to Oorabbra Water Holes. From here we changed direction to approximately south-west. Crossing the Marshall and Plenty Rivers, and passing over the Hart Range, through Arltunga, we reached Alice Springs in the MacDonnell Range, a further distance of 180 miles. Returning to the Hart Range, we established a camp and remained in these ranges for a period of four weeks. It will be obvious that any work carried out is purely in the nature of reconnaissance, and all that can be hoped for is that these notes may add a little to our knowledge of this very remote and exceedingly interesting area. I am greatly indebted to Assistant Professor W. R. Browne for much valuable help in their preparation and for petrological determinations, and to Mr. R. O. Chalmers for the chemical analyses carried out by him.

The period of my sojourn in Central Australia was from the 12th October, 1929, to the 1st December, 1929. The maximum shade temperature recorded was 104° F. at 4 p.m. for several days, while the minimum temperature was 71·6° F. on the night of the 4th November. During the month of October it rained for six consecutive days, which, I understand, is a very rare happening for that time of the year. A week prior to our leaving the Territory, heavy rain set in, which was largely responsible for our returning somewhat earlier than we had intended. Once the wet season sets in, travelling is almost impossible.

The average yearly rainfall for the Hart Range area is under ten inches, and the country presents a very arid appearance. The vegetation is distinctly desert in type, except along the river courses, where the eucalypts are represented by several species, especially the Bloodwood (*E. terminalis*) and the Red Gum (*E. rostrata*). Elsewhere the acacias, particularly the mulga and gidyea, predominate. A coarse wiry grass covers many of the flat sandy valleys.

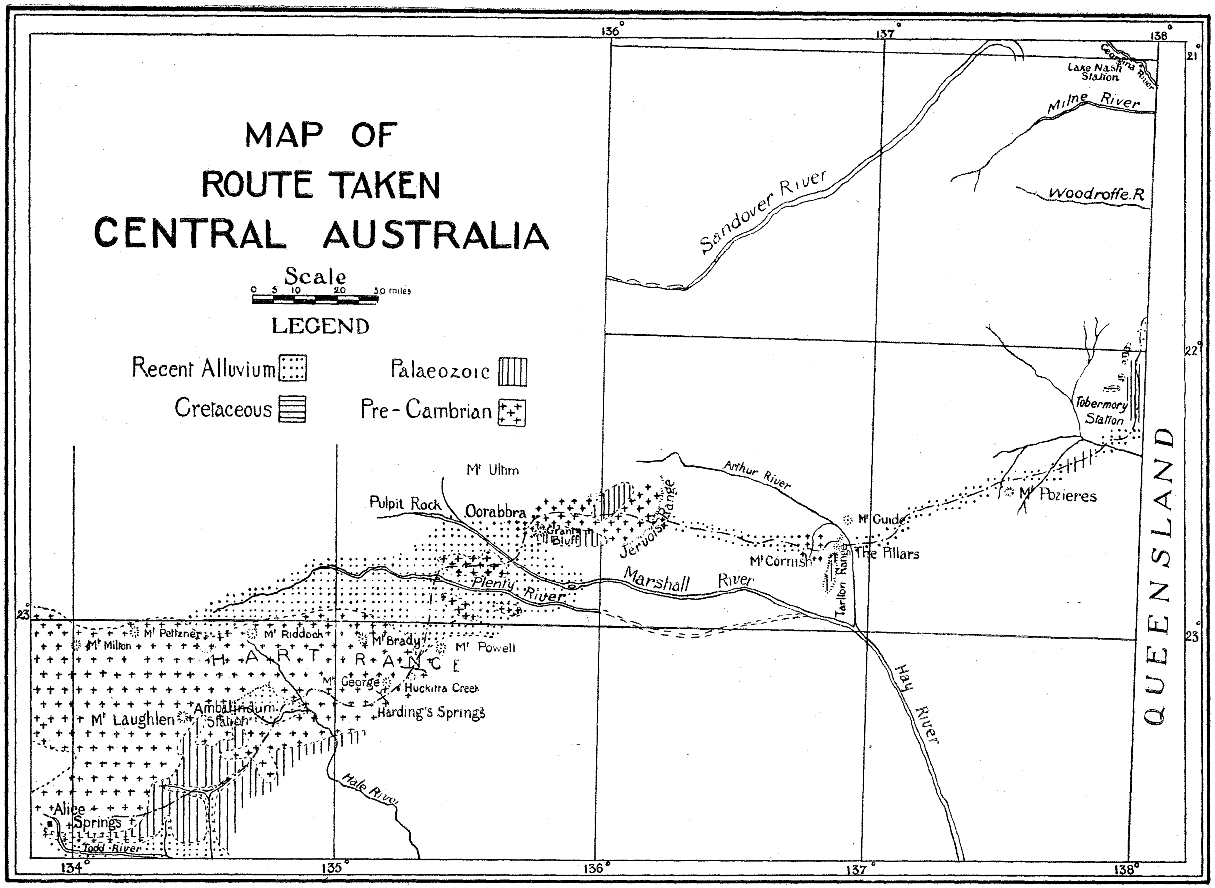

MAP OF
ROUTE TAKEN
CENTRAL AUSTRALIA
Scale
0 5 10 20 30 miles
LEGEND
Recent Alluvium
Palaeozoic
Cretaceous
Pre-Cambrian
136°
137°
138°
21°
22°
23°
134°
135°
Lake Nash Station
Georgina River
Milne River
Woodroffe.R
Sandover River
Tobermory Station
QUEENSLAND
Mt Ultim
Pulpit Rock
Oorabbra
Arthur River
Jervois Range
Mt Guide
Mt Pozieres
Mt Cornish
The Pillars
Tarlton Range
Plenty River
Marshall River
Hay River
Mt Peltzner
Mt Riddock
Mt Brady
Mt Powell
Mt Milton
H A R T R A N G E
Mt George
Huckitta Creek
Harding's Springs
Mt Laughlen
Ambalindum Station
Hale River
Alice Springs
Todd River

Figure 1.

Previous Work.

Several expeditions and exploring parties have traversed various parts of Central Australia, and a number of reports have been published. Only those papers that deal either directly or indirectly with the area under discussion are referred to. I have been unable to find anything dealing with the geology of that area which lies between the Queensland border and Jervois Range.

The first important contribution to the geology of Central Australia is the report of the geologists of the Horn Expedition.[1] They recognized the pre-Cambrian as consisting of metamorphosed sediments, rocks of doubtful origin, including a great part of the gneisses, and eruptive rocks. To the mica-bearing dykes they gave the name of "Oolgarna" granite. Other eruptive rocks of this complex include diorite, gabbro, dolerite, olivine dolerite, epidote rocks, and amphibolite. The absence of Cambrian rocks was noted, and the Ordovician strata were stated to lie unconformably directly on the pre-Cambrian.

In 1896 Mr. H. Y. L. Brown[2] visited the Arltunga Goldfield and the Hart Range Mica-fields, and travelled north across the Plenty and Marshall Rivers to Oorabbra, thus covering a good deal of the area described in these notes. He classifies the pre-Cambrian as Archæan. The limestones and quartzites at Heavitree Gap, as well as those of the Ooramina Range, are designated Cambrian. He recognizes a second series of Palæozoic rocks on the Finke River as Lower Silurian. He describes the auriferous diggings and reefs of Arltunga and the mica claims of the Hart Range.

In 1914 Dr. C. Chewings[3] wrote on the stratigraphy of Central Australia, giving the age of the quartzites and limestones near Arltunga as Cambrian, as he had discovered *Cryptozoon* in the limestone.

In the same year Mr. R. Lockhart Jack[4] visited the Musgrave and Everard Ranges. He describes the pre-Cambrian sediments and oldest plutonic rocks as being both intruded by a very great development of granite, designated the Everard Range type. He regards the pegmatites as being injected during the consolidation of the granite magma, and states that many of them are exceedingly quartzose. The latest members of the pre-Cambrian complex consist of an extensive series of basic dykes. He also recognizes two younger formations, the Cambrian and the Ordovician.

In 1925 Dr. L. K. Ward[5] agreed with the opinion of the geologists of the Horn Expedition regarding the absence of the Cambrian, pointing out that "the *Cryptozoon* specimens occur on the same stratigraphical horizon as *Orthis leviensis*". In regard to the pre-Cambrian complex he states: "Quartz veins, some containing tourmaline, traverse the gneisses at many places, and are probably related genetically to the pegmatites. Less common are the intrusive amphibolites. The youngest and least altered members of the pre-Cambrian group at Alice Springs are the intrusive dykes of gabbroid character."

---

1 Tate and Watt.—Report of the Horn Expedition, iii, Geology and Botany, 1896.
2 Brown, H. Y. L.—Reports on Arltunga Goldfield, etc., South Australia, 1897.
3 Chewings, C.—Trans. Roy. Soc. S. Austr., xxxviii, 1914, pp. 41-52.
4 Jack, R. Lockhart.—Geol. Surv. S. Austr., Bull. 5, 1915.
5 Ward, L. K.—Trans. Roy. Soc. S. Austr., xlix, 1925, pp. 61-84.

In 1928 Dr. C. Chewings[6] again wrote on the stratigraphy of Central Australia, referring to the auriferous White Range quartzites and the Heavitree Gap quartzite as being of the same age, probably Cambrian. He regards them as downfaulted remnants of sediments that originally overlay the pre-Cambrian.

Sir Douglas Mawson and Mr. C. T. Madigan[7] have given the name Arunta Complex to the older pre-Cambrian rocks, and the strata resting unconformably on this complex they regard as post-Aruntan and pre-Ordovician, dividing them into two series, the Pataknurra Series and the Pataoorrta Series. They prove that these rocks are stratigraphically below the Ordovician beds of the Horn Valley.

Geology.

It will be seen from an examination of the section, purely diagrammatic, along the route taken (Figure 3) that there are two geographically and geologically distinct areas, and it is proposed to describe these two areas separately. The first area comprises the country between the Queensland border and Jervois Range, and the second extends from Jervois Range to Arltunga in the White Range.

The Area Between the Queensland Border and Jervois Range.

This area is mostly flat, with an elevation of 400 to 600 feet above sea-level (aneroid readings). Relief is afforded by a number of flat-topped hills and ridges rising not more than fifty feet above the level of the surrounding country, and the Tarlton Range, with a north-by-west and south-by-east trend, standing approximately 200 feet above the level of the plain. The greater part of our route passed over plains consisting of loose sandy loam of a red colour, which presented great difficulties to the motorist, proving in wet weather an almost insuperable barrier. The sandy loam very effectively covers all outcrops, except at a place nine miles north of Tobermory Station, where limestone, dolomite, quartzites and sandstones are seen striking from north-east and south-west to east-north-east and west-south-west, with a dip of 20° westerly.

The flat-topped hills and ridges are composed of limestones, marls, sandstones, and conglomerates. They are nearly always capped with porcellanite, which does not show any well-marked junction with the underlying limestone, and varies in thickness from a few inches to as much as eight feet. It is a hard compact material, white to pale grey in colour, forming a very jagged surface, and is the typical duricrust of Dr. W. G. Woolnough.[8] There is definite evidence of the porcellanite replacing the limestone and marls on which it rests, and there can be little doubt that the siliceous solutions responsible for deposition and replacement of the limestone have come from below the latter.

The beds forming the flat-topped hills and ridges are horizontal or almost so, a few dips obtained measuring 2° south-west approximately. The limestone is somewhat arenaceous, merging into marls and calcareous sandstones. It is usually fine-grained, and of a light buff colour. A few miles east of Mount Guide a very coarse conglomerate was seen immediately underlying the limestone. It consists

[6] Chewings, C.—Trans. Roy. Soc. S. Austr., lii, 1928, pp. 62-84.
[7] Mawson, D., and Madigan, C. T.—Quart. Journ. Geol. Soc., lxxxvi, 1930, pp. 415-429.
[8] Woolnough, W. G.—Geol. Mag., lxvii, 1930, pp. 123-132.

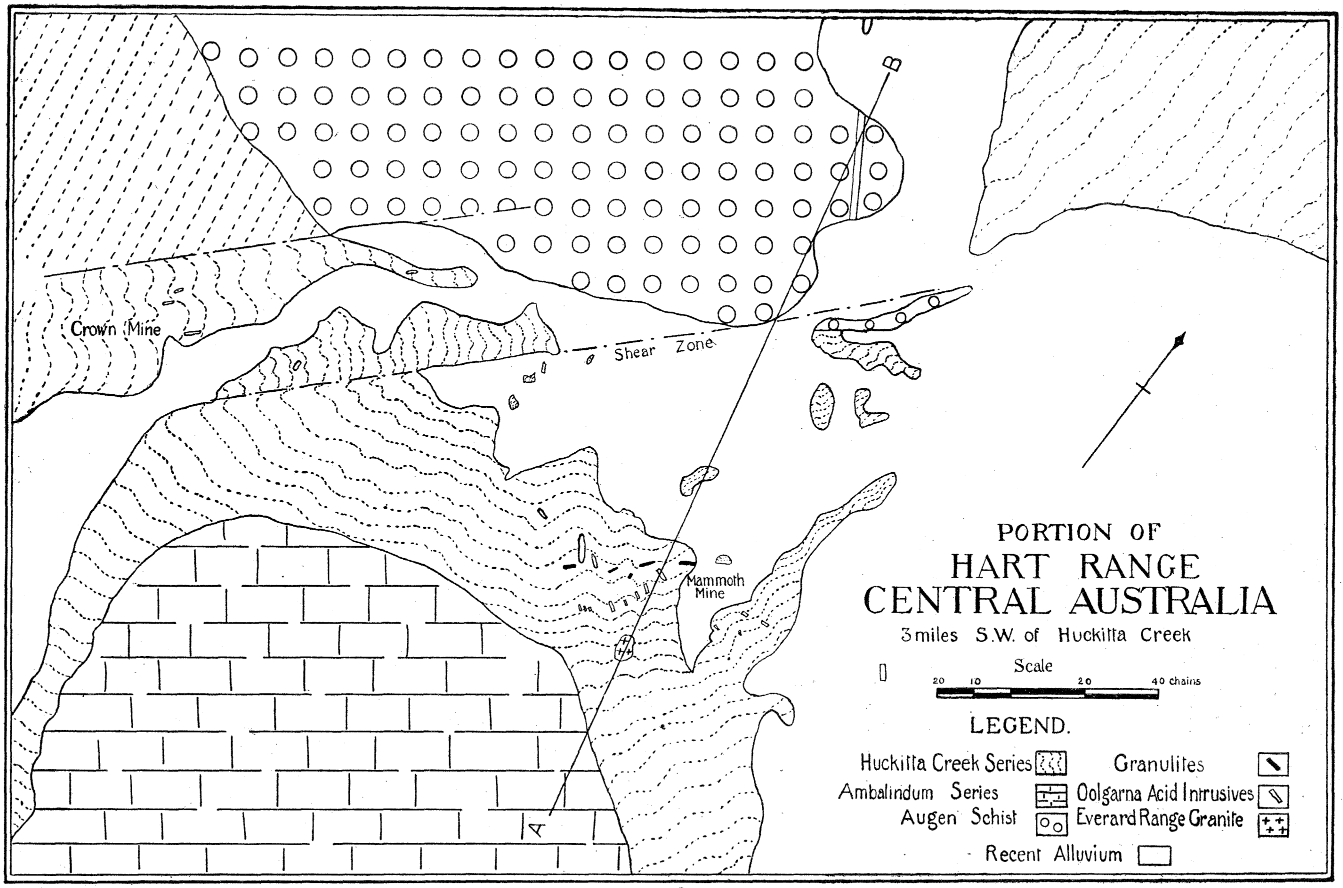

Crown Mine
Shear Zone
Mammoth Mine
A
B
PORTION OF
HART RANGE
CENTRAL AUSTRALIA
3 miles S.W. of Huckitta Creek
Scale
20 10 20 40 chains
LEGEND.
Huckitta Creek Series
Ambalindum Series
Augen Schist
Granulites
Oolgarna Acid Intrusives
Everard Range Granite
Recent Alluvium

Figure 2.

of boulders of white quartz, measuring up to as much as eighteen inches in diameter, set in a matrix of very ferruginous sandstone.

Although very many of these hills and ridges were examined, no traces of fossils were found, so that it is impossible to assign any age to the rocks. Lithologically they bear a distinct resemblance to the Rolling Downs formation of Central Queensland. They appear to lie unconformably on the tilted beds near Tobermory Station, and may possibly be of Cretaceous age. There is no evidence whatever as to the age of the tilted beds. So far as I am aware, there has

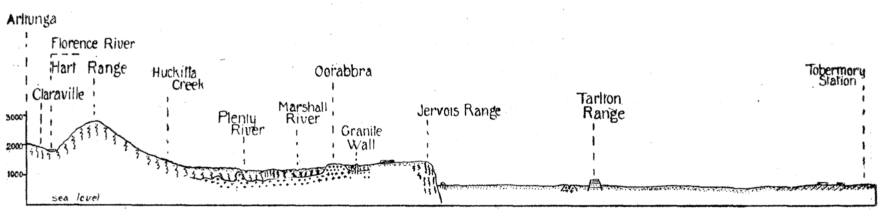


Fig. 3. Diagrammatic Section along the line of Route from Tobermory to Arltunga to Central Australia

Legend

Pre-Cambrian { Schists & Gneisses; Everard Range Granite }
Palaeozoic
Cretaceous?
Recent Alluvium

been no work carried out in this area. At the beginning of 1895, Mr. H. Y. L. Brown[9] travelled from Powell's Creek to Alexandria and back. This area is approximately one hundred and fifty miles due north of the area under review, and appears to be the same flat type of country. Brown mentions the presence of basaltic rocks overlying the sandstone a short distance north of Renner's Springs, and the presence of agate in the soil, probably derived from this basalt. In the area traversed by me there was no sign of basaltic rocks or agate. The country described by Brown is of greater elevation than the country under review, being "from 900 to 1,000 feet above sea level (barometer)". He groups the rocks of that area in the following series:

(1) Recent and Tertiary deposits.
(2) Quartzites, sandstones, grits, conglomerates, and shales.
(3) Limestone, shale, marl, calcareous sandstones, etc.
(4) Quartzite, sandstone, slate, etc., of Lower Palæozoic age.

The basaltic rocks overlie the sandstones of the second group, and it would appear that this series is entirely absent from the area under review. I suggest that the flat-topped hills and ridges represent residuals of Brown's third series, while the tilted limestones, quartzites, sandstones, etc., seen near the Queensland border represent his fourth series, which he considers of Lower Palæozoic age. There is a possibility that these rocks may be even older; further work may show that they are Nullagine in age.

The Tarlton Range is 134 miles west of the Queensland border, and although we passed through a narrow gap in this range, circumstances did not permit

[9] Brown, H. Y. L.—Report on Northern Territory Explorations, Adelaide, 1895, pp. 22-27.

of us making any examination. In passing through we had a particularly trying time, taking five days to travel eighty miles, and it was decided to leave any examination until our return. Unfortunately, on our return a very heavy thunderstorm overtook us, and the whole country was more or less covered with a sheet of water, so that it was necessary to travel at full speed through this in order to reach safety before the water soaked in and made travelling impossible. The range is quite narrow and flat-topped, rising steeply from the plain to a height of about 200 feet (by inspection only). It trends approximately north-by-west to south-by-east, and is composed of horizontal rocks which have the appearance of being somewhat old, probably Palæozoic. We passed through the northern end of the range, and here denudation has proceeded to such an extent as to form a number of mesas, such as Mt. Guide and Goyder's Pillars.

Some eleven miles to the west of this range, in the vicinity of a tributary of the Arthur River, an outcrop of a coarse pink granite with gneiss and bands of hæmatite schist was passed over. The felspar of the granite is microcline, and both muscovite and biotite are present. There can be little doubt that this is an inlier of pre-Cambrian rocks.

There is, in my opinion, little possibility of finding artesian water in this country by boring. Although most of the rocks are concealed by the covering of sandy loam, the presence of crystalline rocks of probably lower Palæozoic age, or even older, in the eastern part of the area, and of undoubted pre-Cambrian rocks in the western section, precludes the possibility of the presence of any porous strata capable of carrying artesian water.

At the little mining settlement at Jervois Range a very prominent outcrop of pre-Cambrian schists and gneisses is seen. They have a general north-and-south trend just here, but a few miles further south they turn to the south-west. The outcrop rises about 100 to 200 feet above the level of the plain, and owes its prominence to the fact that the schists and gneisses have been injected by great masses of white quartz, and also possibly to the fact that they have been injected by mineralizing solutions carrying the sulphides of copper and lead. The ore-bodies consist of a number of relatively small lenses arranged more or less *en echelon* with their longer axes lying in the general direction of the outcrop, that is, approximately north-and-south. The schists and gneisses are very much folded and twisted.

At the time of our visit, mining operations had commenced, and three shafts were in the process of making, but the greatest depth reached was only eighty-three feet at the shaft known as Hanlon's Reward. In this shaft, sunk on the outcrop of one of the lenses of ore, galena was passed through to forty feet, but from here to the bottom of the shaft was muscovite-sericite schist impregnated with chalocpyrite. One notable feature of the lode, or rather lodes, was the scarcity of oxidized minerals. Unaltered galena was seen right on the surface outcrop, although the copper minerals appeared to have suffered a greater amount of alteration.

The primary minerals are represented by chalcopyrite, galena, pyrite (cobaltiferous), also magnetite in the form of a dyke cutting the lodes. The secondary minerals consist of cerussite, pyromorphite, chalcocite, covellite, malachite, azurite, sphaerocobaltite, limonite, and manganese oxide. The non-metallic minerals include quartz, felspar, mica, sericite, fluorite, and garnet. These minerals will be described under the heading of mineralogy.

The outcrop lies less than half a mile to the east of the Jervois Range scarp, and runs parallel to it. This scarp rises very steeply to a height of 800 feet above the plain. It has suffered very little dissection, and we were able to climb on to the tableland only by a very narrow steep gorge a few miles to the south of the mining settlement. I think there can be little doubt that it is a typical fault-scarp separating the pre-Cambrian shield of Central Australia from the plains to the east. It reminded me of the Mundi Mundi fault-scarp, which marks the western limit of the Broken Hill pre-Cambrian shield and separates it from the plains to the west.

THE AREA BETWEEN JERVOIS RANGE AND ARLTUNGA.

The whole area consists of a plateau ranging from 1,400 to 2,000 feet above sea-level. Leaving the Plenty River and travelling in a general south-west direction, we crossed three ranges, the Hart Range, the White Range, and the MacDonnell Range, although the latter is outside the area under review. The highest peak in these ranges is Mt. Heughlin, 4,756 feet above sea-level, situated in the MacDonnell Range. A few peaks were found to be over 3,000 feet above sea-level.

The rocks of this area have been divided into four distinct series, as follows:

(*a*) Recent alluvium and secondary limestone.
(*b*) Early Palæozoic quartzites, sandstones, limestones, etc.
(*c*) Pre-Ordovician and post-Aruntan Series.
(*d*) The pre-Cambrian (Arunta) complex.

(*a*) THE RECENT ALLUVIUM AND SECONDARY LIMESTONE.

Between the Jervois Range and the Hart Range a great deal of the country is covered by recent alluvium consisting of a red to buff-coloured sand. In the mountainous country these sands are confined to the valleys and are often characterized by an abundance of garnet crystals and fragments. Some of the creek beds are composed of a white sand, with here and there patches of garnet sand of a peculiar red colour. This is particularly noticeable in the Florence River.

A peculiarity of many of the valleys in these ranges is the wide flat base of alluvium bounded on either side by steep rocky ridges. The monotony of the flat base is relieved here and there by small inliers of rock forming very low hills. All the creek beds are broad and shallow, and are seen meandering along these valleys in exactly the same manner as a mature river. The only evidence obtained as to the depth of the alluvium was at a spot some twenty-five miles south-west of Claraville on the road to Alice Springs, where a well was in the course of construction and had not reached rock bottom or water at fifty-five feet. This structure points to a very much increased rainfall in former times, when the streams were capable of carving out deep valleys. With the present day low rainfall the streams are incompetent to carry away the alluvium so that there has been a gradual silting up of the valleys.

At the eastern extremity of the Hart Range dissected alluvial fans were seen very similar to those described by Mr. E. C. Andrews,[10] formerly Government

---

[10] Andrews, E. C.—Geol. Surv. N.S.W., Mem., Geology No. 8, 1922, p. 25.

Geologist, and a Trustee of this Museum, at Broken Hill. In a small gully some four miles south of Huckitta Creek a deposit of travertine was seen forming fan-like masses along the sides of the gulley. It was obviously derived from a bed of altered limestone found near the top of the hills on either side of the gully. A deposit of secondary limestone occurred forty-five feet below the surface at the well previously referred to.

(*b*) EARLY PALÆOZOIC QUARTZITES, ETC.

To the north of the Marshall River a number of flat-topped mesas form a conspicuous part of the landscape. Unfortunately, I was unable to get more than a distant view of these hills except in one case in the vicinity of Oorabbra, when I was only able to make a hasty inspection. I can only say that here they consist of quartzite, sandstone and possibly limestone, and that they are horizontally bedded, resting unconformably on the Arunta Complex. No fossils were obtained, but from their lithological characters the rocks appear to be much older than those found east of Jervois Range, with the possible exception of the Tarlton Range. It is quite impossible to say what is their relation to the pre-Ordovician and post-Aruntan series further to the south. In spite of the fact that they both rest directly on the Arunta Complex, I am inclined to the opinion that the rocks of the mesas to the north of the Marshall River are somewhat younger than those exposed in the Arltunga district, but a good deal of work would be required to determine this relationship.

It is of interest to note that Mr. H. Y. L. Brown divides these beds into two series. One small outcrop marked in by him in his map, to the south of the Plenty River, is incorrect. This particular outcrop certainly belongs to the Arunta Complex, and has produced quantities of mica.

(*c*) THE POST-ARUNTAN AND PRE-ORDOVICIAN SERIES.

Sir Douglas Mawson and Mr. Madigan[11] have proved very conclusively that the Heavitree quartzite belongs to this series and not to the Ordovician as suggested by Dr. Ward.[12] It is the basal bed of the series and lies unconformably on the Arunta Complex with a steep dip southwards. These beds are also met with in the White Range, where they are again seen dipping steeply to the southward. As excellent descriptions of these rocks have been given by the writers previously referred to, and as nothing new can be added, it would be useless to repeat such descriptions here.

(*d*) THE PRE-CAMBRIAN (ARUNTA) COMPLEX.

This great complex consists of intensely metamorphosed rocks of igneous, sedimentary, and doubtful origin. It is proposed to make a tentative classification of the complex as follows:

i. The Huckitta Creek Series consisting of schists and gneisses of both sedimentary and igneous origin.

ii. The Ambalindum Series consisting of altered limestone and schist.

---

[11] *Loc. cit.*
[12] *Loc. cit.*

iii. The Everard Range Granite.
iv. Oolgarna Acid Intrusives (Oolgarna Granite).
v. The Augen Schist.

i. *The Huckitta Creek Series.*—All the rocks of this series have been subjected to both thermal and dynamic metamorphism. In some localities they have been intensely folded, particularly where they are associated with the Augen Schist.

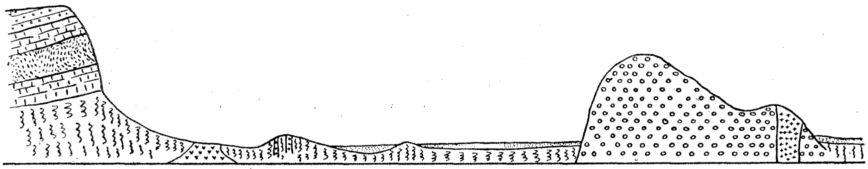


Fig. 4. Section along A.B. in Fig 2.

Recent Alluvium
Ambalindum Series { Quartzite, Quartz Schist, Altered Limestone
Huckitta Creek Series
Everard Range Granite
Oolgarna Acid Intrusives
Augen Schist

In other localities they show remarkably little evidence of any folding. A number of measurements taken over a distance of about sixty miles from Oorabbra to Harding Springs at localities where the schists and gneisses have suffered least contortion, show a variation of strike from north 7° west to north 5° west, while the dip varies from 20° to 35° easterly.

To the west of the Crown Mica Mine is an area of schists and gneisses with little or no contortion which dip at a remarkably low angle. An unsuccessful effort was made to determine the relation of the bedding-plane to the plane of schistosity. The schists very easily split along the plane of schistosity, and it is probable that this plane is parallel to the bedding-plane.

A small area some thirteen square miles in extent to the south-west of Huckitta Creek Road Crossing was selected for mapping as showing the main features of the Arunta Complex. Reference to this map (Fig. 2) will show in the vicinity of the Mammoth Mica Mine an area of the Huckitta Creek Series which is intensely folded and intruded to the north by the Augen Schist. A well marked shear zone passes through this area with a north-east strike and appears to have involved the Augen Schist as well as the Huckitta Creek Series. There is evidence of one or perhaps two minor faults striking parallel with the main shear zone. This fault can be clearly seen in the Augen Schist, where it has a vertical throw of not less than 500 feet, and an almost vertical dip. As the junction line between the unfolded and folded schists is continuous with the strike of the fault in the Augen Schist, it seems fairly certain that this fault is continued into the Huckitta Creek Series.

In the field the most striking feature of the rocks of the Huckitta Creek Series is the almost universal development of felspar. Many of the schists and gneisses show augen structure, and in every case examined the "eyes" proved to consist of felspar. Many of the rocks are highly garnetiferous, although crystals of garnet seldom exceed an inch in diameter and are often very much smaller.

No systematic attempt has been made to determine the original character of the schists and gneisses, as much field work and many chemical analyses besides petrological examinations would be required. The disconcerting way in which a typical gneiss will gradually change along its strike to a typical mica schist, would render any conclusions reached after a visit such as this one was purely a matter of guesswork.

While many of the rocks undoubtedly consist of mixed rocks, and many are of doubtful origin, there are a few types which permit of classification.

Rocks of sedimentary origin consist of biotite-schists, biotite-sillimanite-schists, sillimanite-gneisses, and altered limestones.

The biotite-schists are mostly garnetiferous, though a few coarse types appear to be devoid of garnet. The garnets vary considerably in size and also in quantity, but these two characters do not appear to bear any relation to each other. One of the biotite-schists in the vicinity of the Mammoth Mica Mine contains stretched quartz pebbles measuring up to a foot or more in length, with a maximum diameter of only about two inches, and represents a metamorphosed conglomerate.

The biotite-sillimanite-schists are invariably garnetiferous, and they vary from fine to medium-grained rocks. The garnets generally occur plentifully in small to medium-sized crystals. The colour of the rock varies from dark to pale grey. A little muscovite is sometimes present in these rocks.

The sillimanite-gneisses are pale grey rocks which are sometimes rather friable, and, like the other rocks, they often contain garnet.

The altered limestone consists of a compact very pale grey rock showing slight schistose structure. It is composed of calcite, diopside, scapolite, sphene, quartz, and a little biotite. It is best seen at Huckitta Creek, but is also found about three-quarters of a mile west of the Mammoth Mica Mine.

The igneous rocks of this series are of two types, acid and basic. The acid type consists of gneisses and aplite which are intercalated with the schists and follow the contortions of those rocks. They are sill-like masses varying in width from a few inches to a few feet in thickness. Many of these sills taper off along the direction of their strike, and thus resemble the lenses of granite gneiss seen at Huckitta Creek. There can be little doubt that some of the gneisses are genetically related to the Everard Range Granite, though some, particularly the garnetiferous gneisses, appear to belong to a much older intrusion. It is possible that some of the acid rocks of igneous origin included in the Huckitta Creek Series should rightly belong to the Acid Intrusives, but they are placed here tentatively because of their occurrence.

Of the gneisses which differ from the normal granite gneiss, which is sometimes garnetiferous, the following may be mentioned.

The aplitic gneisses are very fine-grained rocks of pale pink colour with occasional phenocrysts of felspar. The banding in these rocks is often on a very fine scale.

A quartz-biotite gneiss consists of fairly coarse bands of quartz with a little biotite and biotite with very little quartz.

The quartz-mica-diorite gneiss is always a dark coloured rock with fine banding and much biotite. This rock is not so acidic as the other rocks.

The granite that occurs in these sill-like masses is really indistinguishable from the Oolgarna granite. It is coarse-grained, and may be either pink or grey in colour according to the colour of the felspar, which is mostly microcline.

There are three different modes of occurrence of the rocks of igneous origin of basic type. They occur as sill-like masses similar to those of the acid types, as dykes cutting across the schists and gneisses, and in one case as a boss-like mass.

The sill-like masses consist of amphibolites and hornblende schists, which are sometimes garnetiferous. In addition there is a very striking gneiss consisting of narrow bands of the black hornblende alternating with reddish bands of felspar. In the hand specimen the amphibolites and hornblende schist are fairly compact rocks, varying in colour from greenish-black to grey. They are typically schistose in structure and occasionally contain phenocrysts of felspar.

The dykes of metamorphosed basic igneous rock cut across the schists and gneisses, and vary in width from a few inches to about two feet, and in length from about a foot to as much as half a mile. It is remarkable the number of times these basic dykes were found in close proximity to the dykes of the Acid Intrusives, and yet in no case were they seen in actual contact. Another peculiar feature was that the dykes of the two series were more often than not at right angles to each other.

These rocks are very compact and tough, with a more or less bluish-black colour. In the hand specimen they sometimes have the appearance of ordinary fresh basalt, though more frequently they have a somewhat felted appearance. Phenocrysts of felspar are often present in these rocks.

From the field evidence alone these rocks would not be placed in the Huckitta Creek Series. They would be considered much younger than this series. Where they occur in areas of contorted schists and gneisses the dykes have been unaffected by the folding. Petrological evidence, however, clearly shows that these basic dyke rocks have been subjected to high-grade thermal metamorphism comparable to that which produced the sillimanite schists and have thoroughly recrystallized to granulites; for this reason they must be considered ancient and therefore have been placed in this series.

The boss-like mass of metamorphosed basic igneous rock covers many acres, forming a prominent peak rising to 2,730 feet above sea-level (barometer), about one mile west of the Crown Mica Mine.

ii. *The Ambalindum Series.*—The name proposed for this series is the name of the station property on which they occur. The series is represented by an isolated block of rocks to the south of the Mammoth Mine, covering an area of approximately six square miles, and has a thickness of at least 500 feet, probably more, and dips gently to the south-west. The basal bed of altered limestone rests with marked discordance on the rocks of the Huckitta Creek Series. It was not possible to determine whether this was really an unconformity or whether the series owes its present position to overthrust faulting. Figure 4 shows the relation of these rocks to those of the other series.

The topmost bed consists of quartzite, often rich in garnet, and, like the remainder of the series, is intruded by very acid rocks which probably belong to the Acid Intrusives. There are two beds of limestone separated by a band of schist. The limestone has been entirely recrystallized, and in a number of places saccharoidal structure is well developed. Often it is rich in diopside, scapolite, grossularite, sphene, and quartz. The schist between the two beds of altered limestone is in the main a quartz schist. It appears to have suffered more contortion than the limestone. It contains a band of quartz-garnet-magnetite rock which follows the contortions of the schist. This band is about eight inches wide, and because of its dark colour stands out prominently in the quartz schist. A similar rock to this has been described by Professor W. R. Browne[13] from Broken Hill, New South Wales. He places it tentatively among the older basic igneous rocks of the Willyama Series.

One of the quartz veins in the quartz schist was found to contain a very small amount of chalcopyrite, with the consequent green copper staining. A small shaft had been sunk on this, but had been abandoned. It is of interest to note that the auriferous reefs of the White Range also carry copper minerals.

iii. *The Everard Range Granite.*—This granite forms a great bathylith, and outcrops in numerous places over a very wide area some thousands of square miles in extent. It was given the name of Everard Range Granite by R. Lockhart Jack[14] in his description of the Musgrave and Everard Ranges in 1915. The best outcrop and the most extensive one examined is situated at Oorabbra, some forty miles west of the Jervois Range Mining Settlement. It is a gneissic granite, but the gneissic structure varies considerably. In areas where the Huckitta Creek Series has been subjected to more intense metamorphism the granite more nearly approaches a typical gneiss, and in some very disturbed areas it is quite possible that outcrops of this rock were not recognized for this reason.

At the road crossing at Huckitta Creek the gneissic granite is definitely intrusive into the Huckitta Creek Series, and typical *lit-par-lit* injections (Plate liv, fig. 4) are to be seen here, the granite occurring as lenses in the schists along well defined zones.

The granite is generally coarsely crystalline, and is sometimes porphyritic, the phenocrysts being microcline. Muscovite is always present and only rarely biotite. Quartz is found in less quantity than the felspar.

iv. *The Oolgarna Acid Intrusives.*—These have been divided into two series mainly because of their different appearance in the field. As a matter of fact, it seems fairly certain that both series represent the same phase of igneous activity, and their appearance and mineral constitution are due largely to the nature of the rocks they have intruded. They have been called pegmatites, while the geologists of the Horn Expedition designated the mica-bearing dykes as the Oolgarna Granite. In addition to both pegmatite and granite dykes there are quartz dykes and dykes which include more than one type of rock, and for this reason it is thought advisable to extend the term Oolgarna Granite to Oolgarna Acid Intrusives, which is more comprehensive in its application.

(*a*) *The Granite Dykes.*—Some of these dykes are of enormous size with very prominent outcrops. One dyke (Plate liii, fig. 5), which can be traced for nine miles in a straight line, is about twenty feet wide and rises sixty feet above

---

[13] Browne.—Geol. Surv. N.S.W., Mem., Geol. No. 8, 1922, Appendix I, p. 338.
[14] *Loc. cit.*

the level of the surrounding plateau. In other cases they are less than a foot in width, and persist only for a chain or so in length. They are found intruding all the rocks of the Arunta Complex.

The granite is always coarse-grained and sometimes extremely so. Usually it is pink in colour, but may also be light grey, the colour being controlled by the felspar present, which is microcline. Both muscovite and biotite are present, though generally either one or the other predominates.

(*b*) *The Quartz and Pegmatite Dykes.*—These dykes vary in size from an inch or so to more than two chains in width, and from a few inches to as much as quarter of a mile in length. They can be numbered by the thousand.

Like the granite dykes, they consist principally of quartz and felspar, mostly microcline, with such minerals as mica, tourmaline, beryl, apatite, garnet, and diopside. Some of these accessory minerals seem to be controlled to a large extent by the nature of the rock intruded. For instance, where the dykes cut typical mica-schists they invariably contain large crystals of mica, often of considerable commercial value, and it is only under such conditions that payable mica is found. Diopside has been found only where they intrude altered limestones.

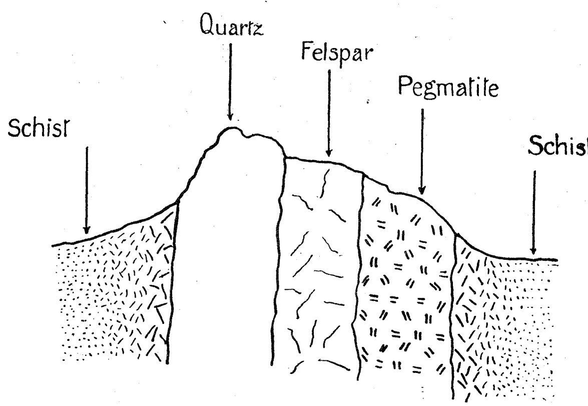


Fig. 5.—Diagrammatic section through a typical dyke of the Oolgarna Acid Intrusives, Hart Range, Central Australia.

A typical section of one of these dykes (Fig. 5) was seen at Lindsay's Mica Mine, eight miles south-by-west of Harding Springs. The dyke is divisible into three distinct vertical zones separated by fairly sharp walls. On the hanging wall side coarse pegmatite is found carrying a fair quantity of mica, the central zone is composed of massive felspar, while the footwall side of the dyke consists of massive white quartz. The two latter zones carry only a minor amount of mica, but at their contact some of the largest books of mica have been found. Elsewhere dykes occur which do not show this vertical zoning, but they always consist of one or other of the zones. Sometimes only two of the zones are represented.

Although the junction with the country rock is always well defined, the dykes have had a profound effect on that rock in many places. This is best seen where they had intruded mica-schists. Almost invariably the mica of the schist has been recrystallized adjacent to the walls of the dyke. In one case the miner had not bothered to work the mica-bearing dykes, but had contented himself with working the recrystallized mica of the schist. There is no sharp line of demarcation between the recrystallized mica and the unaltered schist, but merely a gradual diminution in size of the mica from the dyke wall outwards.

The mica of the dykes may be muscovite or biotite or both, and is usually associated with beryl, apatite, tourmaline, and garnet.

It is suggested that the dykes owe their present position to the interaction of plutonic solutions with the country rock, and perhaps to a less extent to assimilation. Their occurrence in thousands, many of which are quite small, and arrangement without any common orientation, together with the fact that their mineral content varies with the country rock in which they are found, would lend support to this view.

It is difficult to imagine how such chemical reaction would be responsible for the formation of the vertical zones in the resultant dykes. It is suggested that the zoning is due to two separate igneous emanations, the first rich in felspar molecules, and the second highly siliceous. Assuming that the felspar dykes were first formed, the effect of a highly siliceous solution would be to set up a reaction between the silica and the felspar resulting in the formation of muscovite. It is significant that the largest books of muscovite mica are found along the junction of the quartz and felspar. In suggesting two igneous emanations it is not suggested that there was any great time break between the two. There can be no reason for doubting that the two are genetically related and belong to the same igneous phase.

The reason for assuming that the two divisions of the Oolgarna Acid Intrusives are of the same age and of the same igneous phase, is based largely on the similarity of their felspar content, and the frequent occurrence of graphic granite in both. In only one case in the field was a possible relation between the granite dykes and the pegmatite dykes noted. In this instance a granite dyke in the Augen Schist was separated from a pegmatite dyke in the schist and gneisses by alluvium, but the two were in exact alignment, and it is probable that they were continuous beneath the covering of alluvium.

On the tributary of the Arthur River, about forty miles east of Jervois Range mining settlement, we passed over an outcrop of coarse pink granite very similar in appearance and mineral content to the granite dykes of the plateau. Hematite schist was found associated with the granite. It is entirely surrounded by alluvium, but one is justified in placing it tentatively with the Oolgarna Acid Intrusives.

A few miles west of the Jervois Range mining settlement is a considerable area of tourmaline granite, or perhaps more correctly quartz-tourmaline rock. However, nothing can be said in regard to its relationship with the other rocks. It is placed with the Oolgarna Acid Intrusives provisionally, simply because it does not show any trace of metamorphism, and is similar to some of the quartz-tourmaline dykes of the Marshall River. The tourmaline is the black schorl variety.

v. *The Augen Schist.*—Augen schists occur in the Huckitta Creek Series, but these are not included under this heading. The rock referred to forms a very prominent outcrop (Plate liv, fig. 1) rising to as much as nine hundred feet above the surrounding country, and has been traced for a distance of fifteen miles in a general north-east and south-west direction. Megascopically it has the appearance of a true schist and does not show any of the banding of a gneiss. The "eyes" of this augen schist consist of crystals of microcline, many of which exceed two inches in length.

It is intruded by the Oolgarna Acid Intrusives, but its relation with the Everard Range Granite is quite obscure, as no actual contact with the granite was seen. It definitely intrudes the Huckitta Creek Series, and it is noticeable that where this rock is developed the Huckitta Creek series has been folded to a greater extent than elsewhere.

The Age of the Various Divisions of the Arunta Complex.

From the above description of the various rocks comprising the Arunta Complex, it will be seen that the Huckitta Creek Series represents a vast system of sedimentary rocks with their accompanying igneous rocks, which together have suffered intense though somewhat variable metamorphism. With one possible exception there can be no chronological subdivision of these rocks, as any differences may be due entirely to variation in degree of metamorphism. They are the oldest rocks of the Complex, and are regarded as being of Lower pre-Cambrian or Archæozoic age, being the equivalents of the Yilgarn Series of Western Australia, and the Willyama schists of Broken Hill, N.S.W.

The exception referred to above are some small dyke-like masses of gneiss which may be primary. They may possibly represent the frayed margin of a deep-seated synchronous bathylith. If this suggestion is correct, these gneisses will still be very ancient and should be included in the Archæozoic, though they will be younger than the other members of the Huckitta Creek Series.

It is probable that the Augen Schist belongs here. It intrudes the Huckitta Creek Series, and is intruded by the Oolgarna Acid Intrusives, but its relation to the Everard Range Granite is quite obscure.

The granite gneisses and the Augen Schist are probably the equivalents of the granite gneisses, gabbros, and pegmatites of Archæozoic age of the Barrier Ranges, New South Wales, and the granite gneisses of Western Australia.

In regard to the Ambalindum series, it can only be stated that it is older than the Oolgarna Acid Intrusives. Whether it is Archæozoic or Proterozoic is impossible to determine on the evidence available.

The Everard Range Granite is considered as probably Proterozoic in age and the equivalent of the Late Mosquito granite of Western Australia, and the Mundi-Mundi granite of the Barrier Range of New South Wales. It is of interest to note that north of the Marshall River lenses of ilmenite and rutile were found associated with this granite in the neighbourhood of the largest outcrop of granite seen on this visit. In South Australia at Olary and elsewhere the titanium-rich intrusives of the Houghton magma are also considered as Proterozoic in age. It has been suggested that the silver-lead-zinc deposits of Broken Hill, New South Wales, although occurring in Archæozoic rocks, are in part homotaxial with the Late Mosquito granite. There can be little doubt that the silver-lead-copper deposits of Jervois Range should be correlated with the metalliferous deposits of Broken Hill.

The Oolgarna Acid Intrusives are younger than the Everard Range Granite, and it is probable that they represent the last phase of that intrusion, and they are therefore placed tentatively in the Proterozoic.

The following table gives a tentative correlation of the Central Australian pre-Cambrian rocks with those of Western Australia and New South Wales.

Age.	Western Australia.	New South Wales.		Central Australia.
Proterozoic.	Nullagine Series.	Torrowangie Series.		
	Stirling Range and Mt. Barren Series.			Oolgarna Acid Intrusives (?)
	Late Mosquito granite.	Mundi-Mundi granite.		Everard Range granite.
	Mosquito Series.			Ambalindum Series (?).
Archæozoic.	Kalgoorlie Series.	Willyama.	Granite-gneisses, pegmatites, and grabbros.	Augen Schist granite-gneisses.
	Yilgarn Series.		Schists.	Huckitta Creek Series.

Mineralogy.

The following list of minerals is not intended to be in any way a complete list of minerals occurring in Central Australia. It is merely a list of minerals collected by the party or brought under my notice during our sojourn in Central Australia.

Gold.—The occurrence of gold, alluvial and reef, in the White Range in the vicinity of Arltunga has long been known and an excellent description of the various occurrences is given by Mr. H. Y. L. Brown.[15] I was not able to examine any of the occurrences, but I was shown a number of gold specimens, including alluvial nuggets weighing up to approximately five pennyweights, brought in by aborigines. The gold that I saw is somewhat paler than that typical of the eastern States. According to Brown, it is alloyed with silver.

Galena.—This mineral occurs at Jervois Range in lenses as already described. It is the massive cleavable variety but nothing in the nature of crystals was seen. It is argentiferous, assaying up to ten ounces of silver per ton. Galena is also found in the auriferous reefs at Arltunga, but does not appear to exist in any quantity.

Chalcocite.—The Green Parrot Shaft, Jervois Range, passes through a lense of ore which consists largely of massive chalcocite.

Covellite.—This mineral occurs as a coating on chalcopyrite, which impregnates the muscovite-sericite schist at Jervois Range.

Bornite.—A small lense of massive bornite was seen at Jervois Range.

Chalcopyrite.—This mineral is found at Jervois Range as small segregations or eyes and as impregnations in the schist. One of the "eyes" measured eight

[15] Brown, H. Y. L.—Reports on Arltunga Goldfield, etc., South Australia, 1897.

inches in length and three and a half inches along the greatest diameter. It is also found associated with galena and pyrite.

In the auriferous reefs at Arltunga, and a small reef four miles south-west of the road crossing at Huckitta Creek, small disseminated grains of chalcopyrite are found in quartz.

Pyrite.—This mineral was found only sparingly at Jervois Range. Blowpipe tests carried out proved that it is in part cobaltiferous.

Fluorite.—This mineral was found only at Jervois Range, where it occurs as crystalline incrustations associated with crystals of quartz. Unfortunately I did not see the mineral *in situ* and the specimens were all badly broken. The colour varies from purple to heliotrope.

Quartz.—Although there are a great number of very large masses of pure white quartz occurring between Jervois Range and Alice Springs, no really good specimens of quartz crystals were obtained. Small prismatic crystals of colourless quartz were seen associated with fluorite at Jervois Range. At the junction of the Florence and Hale Rivers a small prismatic crystal was found in a vugh in a boulder of limestone.

Hematite.—A band of micaceous hematite is associated with a coarse pink granite near a tributary of the Arthur River, some eleven miles west of the Tarlton Range. An excellent specimen of mammillary hematite, said to have come from 179 miles south-east of Alice Springs, was secured.

Magnetite.—A band of massive magnetite was seen cutting one of the lenses of ore at Jervois Range. A small band, varying from one to three inches in thickness, striking parallel to the schist was found in garnetiferous mica-schist near the Mammoth Mine, four miles south-west of the road crossing at Huckitta Creek.

Ilmenite.—This mineral was found associated with a little rutile a few miles north of the Marshall River. It occurred as pressure lenses in schist and as detrital material.

Rutile.—Only a very small quantity associated with the ilmenite was found. It was a reddish-brown colour.

Manganese oxide.—Some gossanous manganese oxide was found on the outcrop of one of the lenses of ore at Jervois Range. A small band of pisolitic pyrolusite (?) associated with quartzite was obtained at a well some twenty-four miles west of Tobermory Station.

Calcite.—Some small crystals measuring up to two millimetres in diameter were found lining a vugh at the same locality as the pisolitic pyrolusite. Only two forms were present, $b(11\bar{2}0)$ and $f\cdot(11\bar{2}2)$. A small piece of Iceland spar was picked up in a creek close to an outcrop of altered limestone near the Mammoth Mine. The numerous outcrops of limestone and altered limestone have already been described.

Dolomite.—A bed of dolomite, associated with limestone, some twenty-six miles south-west of Tobermory Station, is the only occurrence met with.

Cerussite.—At Jervois Range cerussite was found at the surface to a few feet below. It occurs both massive and reticulated, associated with fibrous malachite in quartz. Some of the massive material is a steel grey colour, otherwise it is white in colour.

Sphærocobaltite.—Only one specimen of this mineral was obtained from the outcrop of Jervois Range lode, and this constitutes the first record of this mineral in Australia. It occurs as a thin coating on malachite and azurite. The surface of the coating is more or less mammillary, with, in places, a tendency to crystalline structure. It has a vitreous lustre, a rose red colour, and is translucent. The hardness is nearly 5. It effervesces freely in warm acid. In the closed tube it turns black and no water is given off. Unfortunately there is not enough material to carry out a quantitative chemical analysis. The mineral does not show any tendency to alteration as indicated by Dana.[16] The rock which is coated by the mineral contains cubes of cobaltiferous pyrite.

Malachite.—Jervois Range was the only locality at which this mineral was collected. It is associated with earthy limonite, chalcocite, sphærocobaltite, cerussite, azurite, and quartz. It occurs incrusting fibrous, and as slender prismatic crystals grouped as radiating or diverging.

Azurite.—Like malachite, with which it is mostly associated, azurite was found only at Jervois Range. It occurs as crystalline crusts and veins, but no crystals were obtained sufficiently good to measure. It is also found earthy.

Bismutite.—One specimen of this mineral was given to me at Alice Springs as coming from west of that town. The bismutite occurs in quartz and is a yellowish-green colour. The lustre is mostly vitreous, but sometimes dull.

Felspar.—Very large masses of felspar occur in the dykes of Oolgarna Acid Intrusives. Very crude stout prismatic crystals of microcline weather out from the Augen Schist, but they are quite unsuitable for measurement. As previously pointed out, felspar occurs in enormous quantity as a constituent of many of the rocks of the Arunta Complex. The different species of felspar arranged in their approximate order of abundance are as follows: Microcline, perthite (mostly microperthite), plagioclase, and orthoclase. A few chains west of the Mammoth Mica Mine is a small dyke containing some typical moonstone.

The microcline from a dyke three miles north of the Mammoth Mine was analysed by Mr. R. O. Chalmers, with the following result:

SiO_2	65·21
Al_2O_3	19·62
Fe_2O_3	Trace
CaO	Absent
MgO	Absent
Na_2O	3·65
K_2O	11·99
	100·47
Specific gravity	2·58

[16] Dana, E. S.—System of Min., 6th edition, 1892, p. 280.

Diopside.—Beside occurring as disseminated grains in altered limestones (Ambalindum Series), this mineral is found in granular masses associated with quartz forming veins in the altered limestone. The colour is pale green and the mineral belongs to the coccolite variety of diopside.

Beryl (Figure 6).—This mineral has been found only in the Oolgarna Acid Intrusives, and is generally associated with mica, sometimes as inclusions in the mica crystals. Very large crystals have been recorded from Central Australia, but the largest seen by me was 22·5 cm. in diameter. Unfortunately, it had been broken, but I was informed that it was about two feet (60 cm.) in length. Beryl of gem quality appears to be almost entirely absent. One beautiful crystal some 8 cm. in diameter and 17 cm. in length was in the main of gem quality. The colour of the mineral varies considerably, from various shades of green to ultramarine and pale greyish-blue to almost white. The only forms present on the crystal were two prisms and a basal plane.

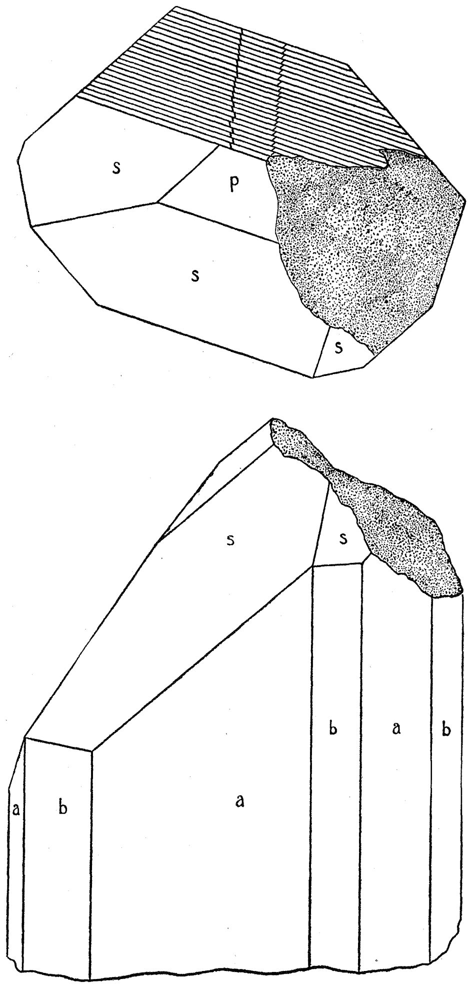


Fig. 6.—Beryl, Hart Range, Central Australia. *Forms.*—$a(10\bar{1}0)$, $b(11\bar{2}0)$, $s(11\bar{2}1)$, and $p(1\bar{1}01)$.

Only one crystal was found with terminal faces other than the basal plane. It was somewhat distorted and broken, measuring 11 mm. × 15 mm. × 36 mm. It was measured on a two-circle goniometer. The following forms were present: $a(10\bar{1}0)$, $b(11\bar{2}0)$, $p(10\bar{1}1)$, and $s(11\bar{2}1)$. Of the prism forms, $a(10\bar{1}0)$ gave good signals, while $b(11\bar{2}0)$ gave a very bad signal or no signal at all, with the exception of one face which gave a fair signal only. Of the pyramids, $p(10\bar{1}1)$ is represented by two faces and $s(11\bar{2}1)$ by five; the signals of the faces of these two forms are only fair. The crystal is prismatic in habit, one-half distorted by the alteration of the prism and pyramid faces.

The following table gives the measured and calculated ϕ and ρ angles:

Form.	Measured.				Calculated.				Error.	
	φ		ρ		φ		ρ		φ	ρ
	°	′	°	′	°	′	°	′	′	′
$a(10\bar{1}0)$	0	0	90	0	0	0	90	0	0	0
$b(11\bar{2}0)$	29	56	90	0	30	0	90	0	4	0
$s(11\bar{2}1)$	29	57	45	3	30	0	44	56	3	7
$p(10\bar{1}1)$	0	31	29	48	0	0	29	57	31	9

Garnet.—This mineral is found in great profusion in the rocks of the Arunta Complex, particularly in the schists and gneisses of the Huckitta Creek Series.

In the schists and gneisses good crystals are rare; more often they are distorted, fragmental, or rounded. The icositetrahedron $q(211)$ is the commonest form, less often the rhombic dodecahedron $d(110)$, and only rarely the combination of these two forms is found. Except in a very few restricted localities, the garnet is not of gem quality, being opaque with a brownish-red colour. Crystals up to 40 mm. are common.

Both the opaque and gem varieties have been analysed with the following result:

	Opaque variety.		Gem variety.
SiO_2	39·23	..	38·33
Al_2O_3	23·54	..	21·52
Fe_2O_3	3·24	..	1·11
FeO	27·75	..	31·95
MgO	5·69	..	5·87
CaO	1·23	..	0·95
MnO	0·19	..	0·15
	100·87	..	99·88
Specific gravity	4·08	..	3·98

Analyst: R. O. Chalmers.

From the above results it will be seen that the two varieties occurring in the schists and gneisses are almandite.

In the Oolgarna Acid Intrusives the garnet is similar in habit to that found in the schists and gneisses, but more often approaches gem quality, when it often exhibits the rhombic dodecahedral parting. It was in one of these dykes at the mica mine of Mr. J. Lewis, about twenty miles south-west of the Plenty River road crossing, that the largest crystal of garnet was found. It measures approximately 27 cm. in diameter. Though somewhat distorted, the rhombic dodecahedron $d(110)$, the icositetrahedron $q(211)$, and the hexakis octahedron $x(321)$ were easily recognizable. The crystal was black on the outside and very dark red to nearly black on fresh fracture. The faces on one side of the crystal were lost in removing the crystal from the quartz and felspar in which it was embedded.

As inclusions in the mica of these dykes the garnet (Figure 7) was often tabular parallel to a face of the icositetrahedron $q(211)$. These crystals varied in size from a millimetre in diameter to as much as 18 mm. The colour varied from red to brownish-red and many of them were perfectly clear.

Two of these crystals were measured on a two-circle goniometer and found to give only fair signals. The forms present were the rhombic dodecahedron *d*(110), and the icositetrahedron *q*(211), while the hexakis octahedron *x*(321) was represented by one exceedingly small face in one crystal. They owe their peculiar habit to the conditions under which they were formed. All the faces are striated in conformity with the cleavage of the mica in which they are enclosed. The tabular faces are always parallel to the direction of the cleavage of the mica, and are striated parallel to the edges *q*:*q* and *d*:*d*.

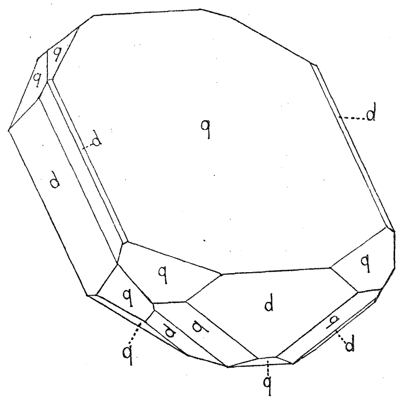


Fig. 7.—Garnet found as inclusions in mica, Hart Range, Central Australia, drawn in the conventional position showing the peculiar habit, tabular to the icositetrahedron. *Forms*: *d*(110) and *q*(211).

Grossularite was found as brown crystals in the altered limestone of the Ambalindum Series.

Cyanite.—A fragment of a crystal was given to me as coming from the mica fields. It is transparent except in the centre, where the colour is a deep blue; elsewhere the colour is pale green.

Anthophyllite.—Only one specimen of this mineral was secured, and this was given to me as a specimen of asbestos coming from a locality eleven miles up Huckitta Creek from the road crossing. It has the typical appearance of asbestos, and the longest fibres in the specimen are 22·5 cm. in length, but they are somewhat brittle. The mineral was analysed by Mr. R. O. Chalmers with the following result:

SiO_2	57·10
Al_2O_3	0·37
FeO	8·94
CaO	1·52
MgO	28·08
Loss on ignition	3·56
	99·57
Specific gravity	3·00

Epidote.—Only a very little of this mineral was seen in the various localities in the Hart Range. It is the usual yellowish-green variety associated with quartz and felspar of the Oolgarna Acid Intrusives.

Tourmaline.—This mineral (Figure 8) is of fairly wide distribution in the Arunta Complex. It is found in the Hart Range in the Oolgarna Acid Intrusives, sometimes as inclusions in crystals of mica, and the schist of the Huckitta Creek Series. At Jervois Range it occurs in immense quantities as black schorl associated with quartz. On the Marshall River it is found in beautiful crystals; though I was unable to visit the locality, some very fine specimens were kindly

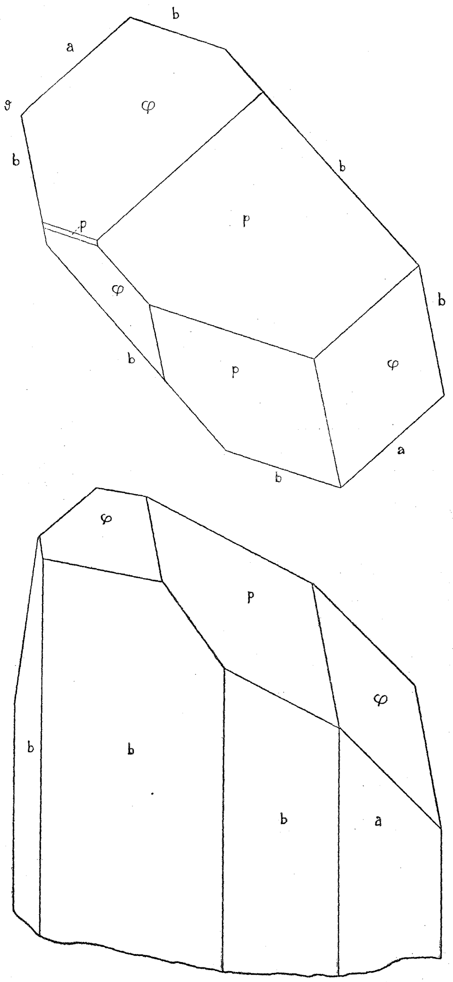


Fig. 8.—Tourmaline, Marshall River, Central Australia. *Forms*: $a(10\bar{1}0)$, $b(11\bar{2}0)$, $\theta(41\bar{5}0)$, $p(1\bar{1}21)$ and $\phi(\bar{2}\bar{2}41)$.

given to me by Mr. Lewis. In one of these specimens the tourmaline was associated with apatite, muscovite, quartz, and felspar, so that it evidently occurs here in the Oolgarna Acid Intrusives. The colour of the mineral is invariably black.

Three crystals from the Marshall River were chosen for measurement on a two-circle goniometer. The following seven forms were recognized: $a(10\bar{1}0)$, $b(11\bar{2}0)$, $\eta(21\bar{3}0)$, $\omega(31\bar{4}0)$, $\theta(41\bar{5}0)$, $p(11\overline{21})$, and $\phi\cdot(\bar{2}\bar{2}41)$. In one crystal a steep scalenohedron is present giving ϕ and ρ angles of 13° 47′ and 85° 32′, which corresponds to an unrecorded form $(21{\cdot}7{\cdot}\overline{28}{\cdot}1)$, the calculated ϕ and ρ angles of which are 13° 54′ and 85° 37′. The following table gives the results of the measurements made:

Form.	Measured.				Calculated.				Error.	
	φ		ρ		φ		ρ		φ	ρ
	°	′	°	′	°	′	°	′	′	′
$a(10\bar{1}0)$	0	0	90	0	0	0	90	0	0	0
$b(11\bar{2}0)$	30	0	90	0	30	0	90	0	0	0
$\eta(2\bar{1}\bar{3}0)$	20	3	89	27	19	6	90	0	57	33
$\omega(31\bar{4}0)$	13	45	90	0	13	54	90	0	9	0
$\theta(41\bar{5}0)$	11	6	89	57	10	53	90	0	13	3
$p(11\bar{2}1)$	0	4	27	25	0	0	27	20	4	5
$\varphi'(\overline{22}41)$	0	3	46	5	0	0	45	47	3	18
$(21{\cdot}7{\cdot}\overline{28}{\cdot}1)$	13	47	85	32	13	54	85	37	7	5

Mica.—Muscovite and biotite were the only two species of this group of minerals that were definitely recognized in the area, and it is proposed to describe them separately.

Muscovite.—Beside being a constituent of many rocks of the Arunta Complex, muscovite is found as crystals or "books" in the very acid dykes of the Hart Range and Plenty River area. The crystals vary in size from a few millimetres to as much as a metre or more in diameter. In the large books no definite crystal outline is developed, but in the smaller ones the cross-section is mostly hexagonal, though often the form *b*(010) is very poorly developed, giving the crystal an orthorhombic appearance. The larger crystals are usually stout tabular in habit, while the smaller ones are frequently prismatic with the prism zone tapering toward the basal plane and strongly striated horizontally. The basal plane is invariably rough, and when exposed to the surface is generally much weathered.

The colour of the muscovite varies considerably, there being various shades of reddish-brown, amber, and green. The optical axial angle varies with the colour as follows:

Colour of the Muscovite.	2E.
Amber	64° 20′
Reddish-brown	68° 15′
Green	73° 55′

In addition to the usual perfect basal cleavage, there is occasionally a cleavage or parting parallel to a clino-pinacoid. On splitting this type of mica, narrow strips are produced instead of the usual plates or leaves, and this variety is known on the field as ribbon mica.

Gliding planes produced by pressure have been noted only rarely, and when present correspond approximately to the planes $\rho(205)$ and $\zeta(135)$, accurate measurement being impossible owing to the formation of fibrous mica along these planes.

A highly polished plane occurred in one crystal of mica quite different from any of the partings or gliding planes described above. It lay in the zone [100], and the angle between it and the basal cleavage is 8° 30′. It is probably a vicinal face.

Another feature produced by pressure, not infrequently observed, is the regular rippling of the mica in directions parallel to the prism faces *m*(110), with a further irregular line of rippling at the angle where the two sets of ripples meet. The ripples are quite distinct and can be felt by the fingers. It often happens that hematite is deposited along the ripples, thus emphasizing the effect. A book of mica, say, ten centimetres thick, may show no sign of this structure until being split, when it will be found to be affected in a small central zone only.

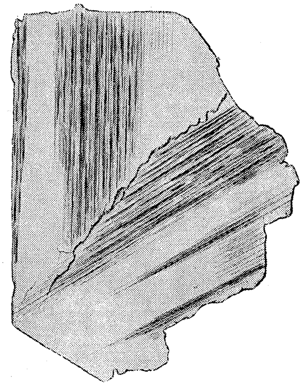


Fig. 9.—Mica, Hart Range, Central Australia, showing rippling parallel to the prism.

What may be regarded as an intergrowth with biotite was seen in only two specimens. The central portion of a small crystal was composed of muscovite followed by biotite and again by muscovite (Figure 10).

Crystals of muscovite are often included in larger crystals of the same mineral. An examination of a large number of specimens proves that the orienta-

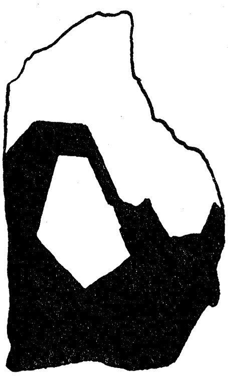


Fig. 10.—Mica, Hart Range, Central Australia, showing intergrowth of muscovite and biotite.

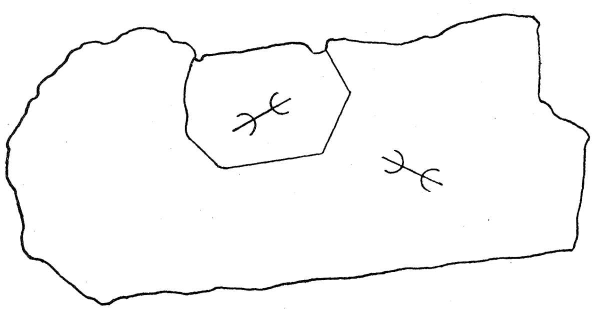


Fig. 11.—Mica, Hart Range, Central Australia, showing the relation of the optical orientation of the included crystal to the host.

tion of the included crystal may bear any relation to that of the host. Occasionally the basal cleavage of the two may be parallel, but it is found that the optical axial planes of the two as observed in a number of cases bear no constant relation to one another, though in one case (Figure 11) the relative positions of the two axial planes are suggestive of twinning according to the mica law. Otherwise no actual twinning has been recognized.

One of these included crystals, measuring 11 mm. by 18 mm. by 24 mm. along the *a*, *b* and *c* axes respectively, was translucent in the direction of the horizontal axes, the colour by transmitted light being green. This interesting crystal was included in a crystal of reddish-brown muscovite measuring approximately 28 cm. in diameter, and was the only one of its kind that was observed.

Crystals of biotite are sometimes included in the same manner as those of muscovite. Quartz is another common inclusion, and is generally in the form of flat plates lying parallel to the direction of cleavage of the mica. Often these plates are extremely thin, but they have been found up to 1 cm. in thickness. The quartz may also occur in more or less irregular masses with no relation to the cleavage of the mica whatever. When beryl is found as an inclusion it is invariably associated with these irregular masses of quartz. Other inclusions noted include garnet, tourmaline, and apatite. Magnetite in the form of regular dendritic markings, so common in mica, is often present.

Biotite.—The occurrence of this mineral is the same as that of muscovite. The books of biotite seldom show any crystal outline, but are more in the nature of foliated masses from which it is impossible to split thin plates. Books up to 50 cm. were observed, but the largest cleavage plate obtained measured 19·5 cm. by 15·5 cm., and, so far as my observations went, this was a unique specimen.

Chrysocolla.—This mineral occurs in enamel-like masses and veins impregnating the country rock, and also associated with chalcopyrite, malachite, and cuprite near the Green Parrot Shaft, Jervois Range.

Apatite.—I can find no previous record of this mineral, although it occurs fairly frequently in the Oolgarna Acid Intrusives of the Hart Range. The best specimens were collected from two localities, one eight miles south of Harding Springs, and the other sixteen miles north of the same locality. In the former case it was not seen *in situ*, but Mr. Mace, the owner of a mica mine there, showed me several pieces measuring up to 5 cm. in diameter, one of which he presented to the museum. This material is bottle green in colour, translucent, with a vitreous lustre. It has well developed prismatic and basal cleavages. It was thought to be olivine or green felspar by the miners on the field. The chemical composition is as follows:

CaO	54·88
MnO	1·72
P_2O_5	41·85
F	Absent
Cl	1·34
H_2O	0·36
	100·15
Specific gravity	3·17

Analyst, T. H.-S.

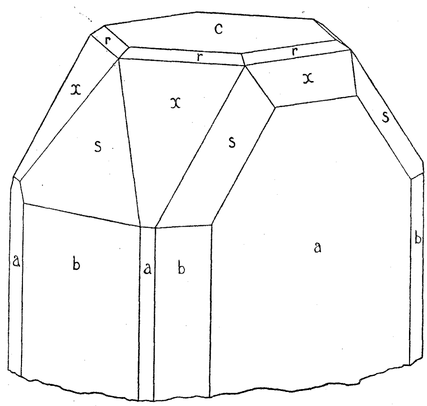


Fig. 12.—Apatite, Hart Range, Central Australia. *Forms*: *c*(0001), *a*(10$\bar{1}$0), *b*(11$\bar{2}$0), *r*(10$\bar{1}$2), *x*(10$\bar{1}$1), and *s*(11$\bar{2}$1).

From the above analysis it will be seen that the mineral belongs to the chlorapatite variety, with a notable amount of manganese present. This is remarkable, as the manganese-bearing apatites appear to be generally rich in fluorine, which is entirely absent in this mineral.

From the latter locality two small crystals were obtained associated with mica of a pegmatite dyke. The crystals measured 10 mm. by 8 mm. by 10 mm., and 6 mm. by 7 mm. by 7 mm. The prisms $a(10\bar{1}0)$ and $b(11\bar{2}0)$ were present and the forms $r(10\bar{1}2)$, $x(10\bar{1}1)$, $s(11\bar{2}1)$, and $c(0001)$ comprised the single termination in each case. Both crystals were measured on a two-circle goniometer and except for the prisms and basal plane, the signals were bad, merely serving to identify the forms present. This appeared to be due to an exceedingly fine etching of the faces. The arrangement of the prism faces is peculiar in that it produces a rectangular cross-section of the crystal rather than the usual hexagonal form.

Pyromorphite.—This mineral was found only on the surface just north-west of Hanlan's Reward Shaft, Jervois Range, where it was exposed more or less to the action of atmospheric weathering. It occurred as groups of prismatic crystals deposited on a ferruginous somewhat gossanous rock. Much of the pyromorphite was weathered on the surface only to a light brown to almost black colour. The true colour varies from yellow to yellowish-green. No crystals were suitable for measurement, and the only termination noted was the basal plane.

Niter.—I was able to secure two specimens of this mineral, although I did not visit the locality, which is south of Mt. Zeil and 120 miles due west of Alice Springs. Its mode of occurrence, origin, etc., has been fully described by Sir Douglas Mawson,[17] so that any comment would only be in the nature of repetition.

Summary.

From the Queensland border (lat. 21° south) to Jervois Range the country is essentially plane relieved only by flat-topped hills of level-bedded Cretaceous (?) rocks, and the Tarlton Range of possibly Palæozoic rocks. Otherwise the rocks are mostly covered by alluvium, but near the Queensland border Palæozoic rocks dipping to the west were seen. Beyond the Tarlton Range pre-Cambrian rocks appear here and there through the alluvium.

Jervois Range is a steep fault scarp separating the plane country from the Central Australian Plateau which consists of pre-Cambrian rocks, the Arunta Complex, flanked to the north and south by Palæozoic rocks, with occasional outliers on the plateau itself.

The Arunta Complex has been divided into the Huckitta Creek Series, correlated with the Yilgarn of Western Australia; the Ambalindum Series of doubtful age; the Everard Range Granite, forming a bathylith and the equivalent of the Late Mosquito Granite of Western Australia; and the Oolgarna Acid Intrusives, which may possibly represent the last phase of the Everard Range Granite.

At Jervois Range cerussite, pyromorphite, chalcocite, cobaltiferous pyrite, and fluorite were among the minerals collected, while sphærocobaltite constitutes the first record of this mineral in Australia.

[17] Mawson, D.—Min. Mag., xxii, 1930, pp. 231-237.

From the mica-bearing dykes of the Hart Range crystals of beryl, tourmaline, garnet, and apatite have been measured and described. The mica consists of muscovite and biotite, the former occurring in sufficient quantity and quality to be of considerable commercial importance.

EXPLANATION OF PLATES.

Plate LIII.

Fig. 1.—The plane country near the Queensland border at about latitude 21° south. The timber is gidyea.

Fig. 2.—The limestone capping of one of the flat-topped hills found in the eastern part of Central Australia.

Fig. 3.—Goyder's Pillars at the northern end of the Tarlton Range, Central Australia, showing the dissection of the range into mesas.

Fig. 4.—Oorabbra Water Holes. This is the largest outcrop of the Everard Range Granite seen during the Expedition.

Fig. 5.—A dyke of the Oolgarna Acid Intrusives left standing as a result of differential erosion. Near Oorabbra, Central Australia.

Plate LIV.

Fig. 1.—A view of the Hart Range, Central Australia. The larger peak on the skyline is part of the outcrop of the Augen Schist. The section in text-figure 4 is taken through this peak toward the observer. The main Camp was situated in front of the small hill in the centre middle distance.

Fig. 2.—Quartz and pegmatite dykes of the Oolgarna Acid Intrusives cutting through the Huckitta Creek Series near the Mammoth Mine, Hart Range. The dykes are seen as white patches, while on the extreme left of the picture is seen one of the dykes left standing as a wall of white quartz, as a result of differential erosion.

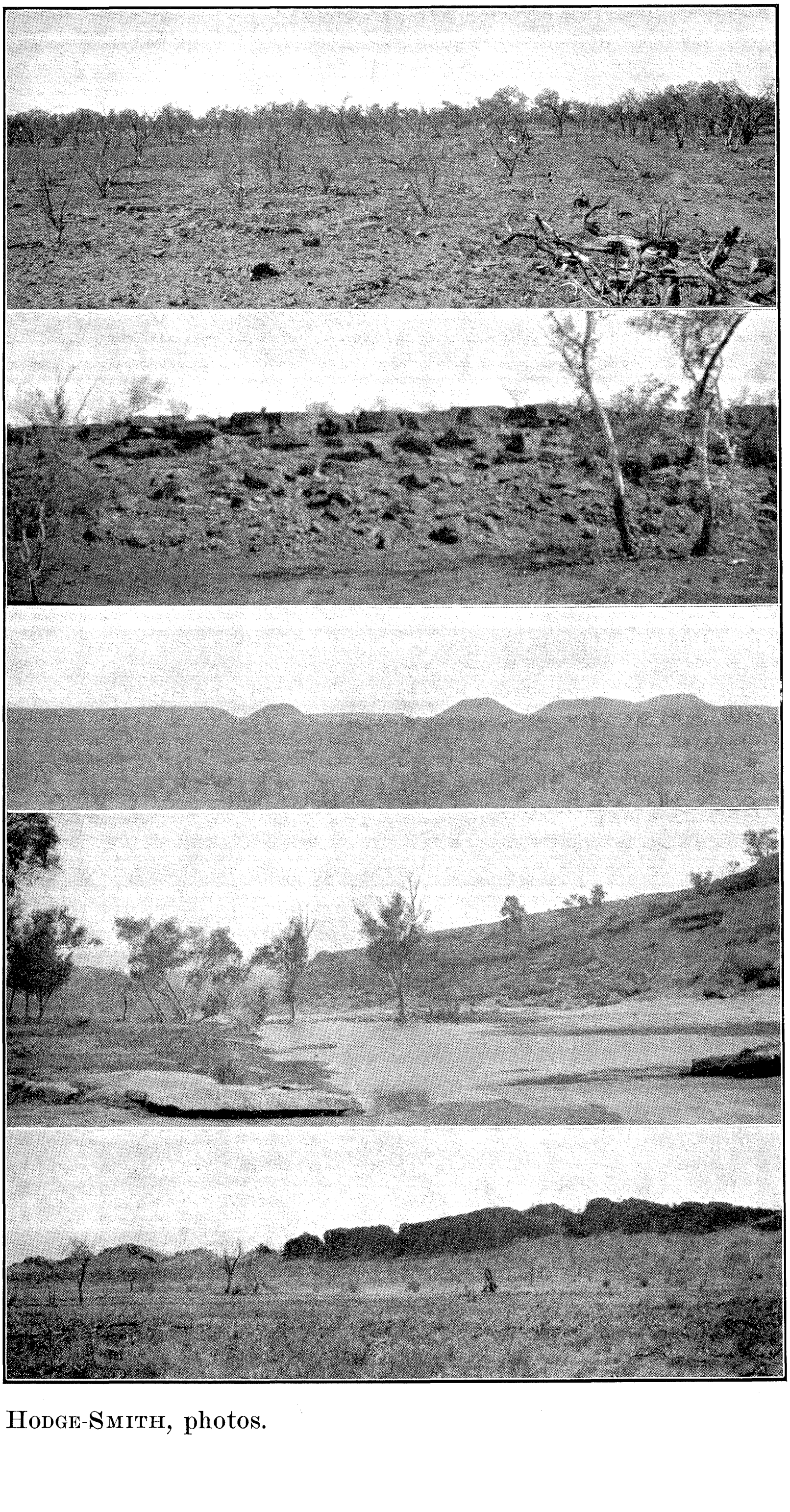
Fig. 3.—A natural east-west section of the Huckitta Creek Series looking north, at the road crossing, Huckitta Creek, Central Australia.

Fig. 4.—An example of *lit-par-lit* injection of gneissic granite, Huckitta Creek, Central Australia.

Plate LV.

Fig. 1.—The Augen Schist showing the "eyes" of microcline. Hart Range, Central Australia.

Fig. 2.—Contorted gneiss, Hart Range, Central Australia.



1

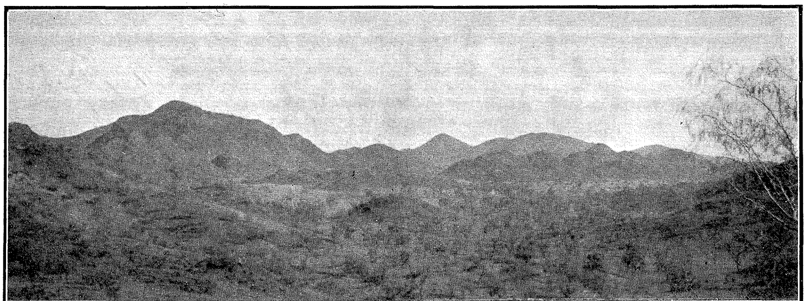
2

3

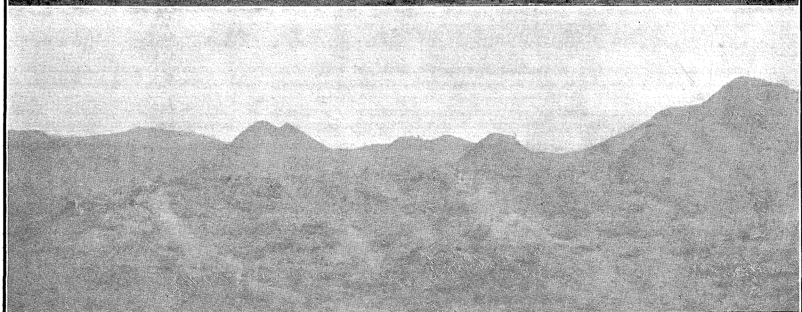
4

5

T. HODGE-SMITH, photos.

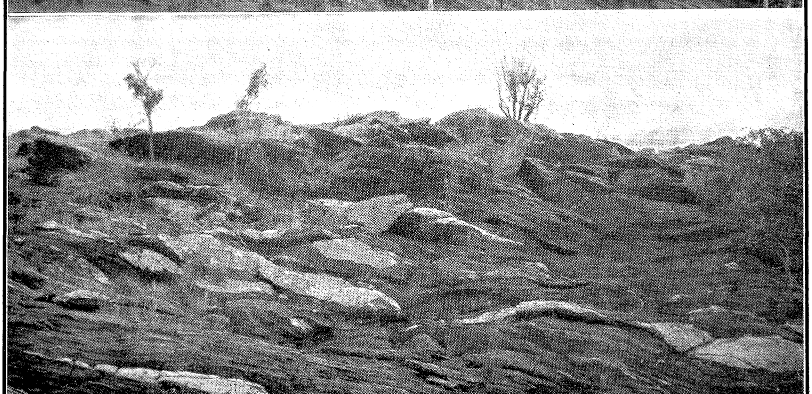


1



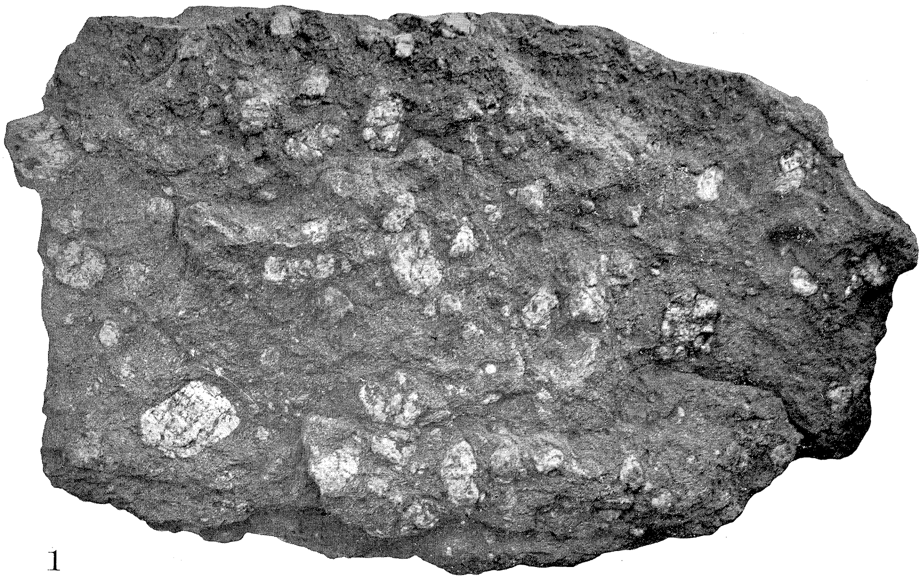
2

3



4

T. HODGE-SMITH, photos.



1

2

G. C. CLUTTON, photos.