DEPARTMENT OF MINES
SOUTH AUSTRALIA

THE WOOLTANA VOLCANIC BELT, SOUTH AUSTRALIA

by

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ABSTRACT:

Mapping of the Wooltana Volcanic Belt, Northern Flinders Ranges, South Australia, has shown that 2,000 ft. of Willouran trachytic lavas with minor andesites and rhyolites outcrop along the southern margin of the Mount Painter complex and extend southward along the eastern boundary of the ranges two miles beyond Wooltana H.S. They are overlain by Torrensian arenaceous and dolomitic beds and these unconformably by Sturtian glacial beds.

The area has been bisected by a steep reverse fault (Paralana Fault) system, and associated splintering and wrench faulting is combined with tight folding in the north and west. The northern part of the area is regionally metamorphosed.

Copper and asbestos mineralisation is widespread. Gold, uranium and beryllium occur.

Comparison with other recorded Precambrian volcanics in South Australia, both in situ and diapirically emplaced, suggests that the original area of extrusion exceeded 30,000 sq. miles. A general comparison is made with volcanics similar in age and type elsewhere in Australia. A suggested possible common origin with the Gawler Range Porphyry and Moonta Porphyry in South Australia is discussed. The mineralisation of the Adelaide System sediments is suggested to be exhalative-sedimentary in type.

THE GEOLOGY OF THE WOOLTANA VOLCANIC BELT, SOUTH AUSTRALIA

I. INTRODUCTION

I.1. Scope of Work. Acknowledgements

Between July and October 1957 the author mapped the eastern half of the Wooltana one-inch Geological Survey sheet, with particular emphasis on the stratigraphy and structure of, the volcanic rocks and the formations overlying them. A short additional visit was made in October 1959. This paper is a modified version of a thesis (including a map, scale 2000 ft. to 1 inch) submitted to the University of Adelaide in May 1960 for the degree of M.Sc.

Mapping was done on South Australian Lands Department 60-chain vertical air photographs.

Petrographic examination of a large number of specimens was carried out later in 1957 and a proportion of these selected by the author have been described by H.W. Fander, of Australian Mineral Development Laboratories (formerly Parkside Laboratories, Department of Mines), who has written a separate short paper.

The author thanks his Geological Survey colleagues R.P. Coats (who has mapped much of the rest of the sheet), R.C. Horwitz, D. Thatcher, B.P. Thomson and B.P. Webb. H.W.Fander has been especially helpful in the petrology. Professor A.R. Alderman has been an understanding supervisor. Miss A. K. Brook

Mr. W. Rossini and Mr. B. Tink produced elegant copies of the author's original maps. Acknowledgement is due to Mr. & Mrs. J. Ford of Wooltana for hospitality. The author thanks the Director of Mines, South Australia, for permission to submit Departmental work for publication.

I.2. Geography

The area mapped lies in the north-eastern Flinders Ranges, approximately 400 miles north of Adelaide. Wooltana H.S. (139°27'E, 30°25'S) lies 25 miles west of Lake Frome at the foot of the ranges, about 80 miles by road east of Leigh Creek. The mapped area extends south from Wooltana for 6 miles along the scarp to Nepouie Creek, and north for 12 miles to East Painter Creek (Plates I & II). In the north, mapping has been extended westward about 5 miles up the Arkaroola creek to beyond its junction with the Wywyana, but in the south reconnaissance mapping only has been practicable south of Mount Warren Hastings.

This whole area consists mainly of rugged hills with relief up to 2500 feet though predominantly between 500 ft. and 1000 ft. At Wooltana a prominent straight craggy scarp from 300 ft. to 700 ft. high (with Mt. Jacob) overlooks the vast Lake Frome plains. This develops northward into a wider and higher zone of rugged country trenched by the great winding gorge of the Arkaroola Creek. West of it is the open Munyallina valley, widening southwards, itself limited westwards by another scarp beyond which is monotonously rugged country with Mt. Warren

Hastings as its highest point. To the north a most confused topography reflects a complex structure and very broken country extends west of the Barraranna gorge of the Arkaroola (Plate VI) into the granite massif of Mount Painter (Plate VII). The highest peak on the map - Humanity Seat - lies on the east side of this massif; and further east a large embayment, south of East Painter gorge, forms a triangular area of broken ground. This is limited to the north-east by the Lady Buxton Creek on the left bank of which are piedmont fans in course of dissection. Remnants of these overlie the foot of the Wooltana scarp.

The Wooltana district, in common with the rest of the Flinders Ranges, has an arid climate with low and very variable rainfall, having very hot summers and warm winters with cold nights. Rainfall is infrequent and occasionally torrential; though dissection is deep and close, no running streams exist. Streams are ephemeral. Waterholes are confined to the Arkaroola and Wywyana Creeks and are often dry.

The area covers approximately fifty square miles and contains two settlements, Wooltana H.S. and Arkaroola H.S., with a total population of less than 25, all supported by sheep grazing. No mines are active. Motorable tracks are few but a road extends along the foot of the Wooltana scarp, and a rough track connects with Arkaroola through the Munyallina creek gap linking with a track coming north from Balcanoona.

I.3. Previous Work

In comparison with the much more strongly mineralised granite country of Mount Painter to the north, little work has been done on the Wooltana igneous rocks; and nearly all that characteristically by Mawson, with one important paper by Woolnough. A short account, largely recapitulatory, is given in Sprigg's unpublished report (1945) on the wartime reconnaissance survey of Mount Painter. If Woolnough's sketch map of the Wooltana homestead area is excluded, no mapping of any kind was done prior to the author's except in the extreme north where observations were recorded by various Geological Survey officers working on the southern part of the Painter massif.

The first reference to volcanic rocks in the area is in Mawson's short note of 1912 in which he states that 'intrusive basic igneous rocks are of common occurrence in this (NE South Australian) pre-Cambrian series. These are partly coarse and partly fine grained amphibolites and less altered uralitised dolerites and basalts. The latter were observed to be amygdaloidal at an outcrop on the Arkaroola Creek ...'

In his 1923 paper Mawson amplifies this account, especially mentioning vesicular basalts just north of the gorge, and adding that 'other parts of the formation were brecciated in a manner which suggested a possible tuffaceous character. The metamorphism which these rocks have undergone obscures their features.' (p.380) A coarse-grained amphibolitic rock from the same area is compared with the copper-bearing actinolite-rich rocks of Yudnamutana. More space is given to vesicular lavas - 'amygdaloidal melaphyres' - from Paralana station (now a northern part of the Wooltana property) which he had not seen in the field. These he considered to be recrystallised amygdaloidal basalts and noted their close resemblance to chloritised basalts from the Blinman South mine described by Benson (1909).

The 1926b paper of Mawson is the most important, but suffers from lack of a geological map; by chance the chosen line of section crossed what is now known to be the northern end of an outcrop of post-volcanic pre-glacigene sediments, reduced at this point to a thin representative of an arkosic conglomerate. Here it is peculiarly difficult to distinguish in the field either from one of the many varieties of glacigene beds or from an igneous agglomerate, and was classed by Mawson as the latter. He therefore concluded that the volcanics were 'either contemporaneous with the glaciation or preceded it with no great intervening time break' (p. 200). This was a reasonable inference from an examination of the section alone but it is odd that in crossing from Wooltana H.S. to the eastern end of the section line Mawson failed to investigate the prominent crags of the folded sediments immediately overlying the volcanics, and the angular unconformity made by these sediments with the glacial sequence, there most beautifully displayed. Even after further visits, one of which is mentioned in the only succeeding paper (Sturtian Tillite of Mount Jacob and Mount Warren Hastings, 1949) the very existence of these beds seems to have been unrecognised, in spite of the fact that the area immediately north of the homestead is the one place along the scarp where they form the whole of the lower part of the scarp and where no volcanics outcrop.

W.G. Woolnough spent a short time at Wooltana in 1926 principally in reconnaissance of the Lake Frome basin in search of salt on behalf of Brunner, Mond & Co. He was evidently unaware of Mawson's discoveries and separately described the Precambrian geology with particular emphasis on the volcanics. He too regarded them as directly under Sturtian glacials and drew a rough geological sketch map of the area in the immediate vicinity of Wooltana H.S. He noted the existence of bedded dolomites north-west and south-west of the homestead, both of which he grouped with the volcanics, regarding the latter as a merely local interruption of an essentially sedimentary series, and confined the volcanics to the area west of the homestead.

II. GENERAL STRATIGRAPHY AND STRUCTURE

II.1. Introductory - Geological Environment

The Northern Flinders Ranges are defined here as those north of Blinman. They form a wide zone of tightly folded Precambrian and Cambrian rocks, with a triangular outcrop, widest in the north. The essential structure is of east-west folds in the central zone, with north-west folds in the west and north-east folds in the east, all characteristically asymmetrical. Much associated faulting, including major thrusts, complicates the picture. It is further complicated by the presence in the north-east of the outcrop of the oldest rocks, which form the Mount Painter - Freeling Heights massif and its extension north. The shape of the outcrop of this massif and the alignment of the boundaries between the Archaean sedimentary and granitic bodies within it further demonstrate the dominance of north-easterly trends; but clearly it has acted as a block more resistant to deformation than the Proterozoic and Cambrian beds wrapped around it, and has had a strong influence on the details of their deformation.

On the west and south of the massif lower Proterozoic rocks overlap it unconformably. West of Freeling Heights in the Yudnamutana area these are predominantly sediments, though strongly metamorphosed. Near Umberatana calc-silicate rocks with possible volcanics appear. In the south the sequence is essentially volcanic with subsidiary sediments. It is this southern section which is known as the Wooltana Volcanic Belt.

II.2. Lower Stratigraphic Boundary of Wooltana Volcanic Belt

It is not proposed here to discuss the Painter massif, the mapping of which has recently been completed by the author's colleagues and in which he has played a negligible part. It has now been shown that everywhere on the south side of the massif quartz-felspar and quartz porphyries outcrop over a belt usually 1-2 miles wide. They are regarded as of Archaean age, and extend from the Arkaroola Creek above its junction with the Wywyana to the Arkaroola Bore and Humanity Seat, the contact with the Wooltana rocks being tectonic and marked by very strong development of pegmatites and a gigantic quartz reef. The contact is broken by a major thrust - the Paralana fault - being stepped north on the east side and emerging from the ranges north of East Painter Gorge. The eastern part of this stretch is an unconformity, and the contact can be traced through a small outcrop two miles east on the piedmont slope, where it appears again to be non-tectonic.

South and east of the Humanity Seat area no lower boundary can be traced on the ground because of overlap by poorly exposed Mesozoic beds and an extensive further overlap of Cainozoic sediments. No relevant information is obtainable from the wide network of bores on the plains, and it must be assumed that the downfaulting to the east is on a major scale.

II.3. Upper Stratigraphic Boundary of Wooltana Volcanic Belt

The accompanying geological map shows that stratigraphically there are marked differences in the thicknesses of the sequences on either side of the Paralana fault. On the east side the igneous rocks form a belt widening northward and lying east of, and stratigraphically below, a strong development of the Lower Glacial Sequence which is accepted as of Sturtian age. The map shows also, however, that overlying the volcanics there is an arenaceous-carbonate sequence present only near Wooltana in the south, but extending from the area east of Eagle Crag northwards for several miles. Both at Wooltana and at Woolnough Crag this is seen to be folded, and unconformably covered by the glacial sequence. Although very variable in facies along the strike, and varying a good deal vertically, it is demonstrably arenaceous in its lower part, with a characteristic dark arkosic grit, and dolomitic in its upper part.

The volcanics and this arenaceous-carbonate sequence are therefore clearly pre-Sturtian in age.

Towards the Paralana Fault intense folding, faulting and crushing make mapping difficult, but the essential features remain, though the arenaceous part of the sequence increases in thickness very greatly.

West of the fault all the rocks are much more metamorphosed and thicknesses are again increased. The author's interpretation on the map is based on a recognition of the Sturtian boundary, two miles up the Wywyana Creek from the Arkaroola-Umberatana track; the great arkose immediately north of the track being correlated with the arkosic grit of Wooltana and the equall massive wide outcrops of dolomites south of the track with the overlying dolomites. The phyllite sequence below the Arkaroola arkose is, therefore, a thickened and metamorphosed equivalent of thin purple shales and quartzite found locally at Wooltana and north of Groan Creek; and below it are dark green schistose rocks with amygdaloidal lavas, much metamorphosed but undoubtedly equivalent to the Wooltana igneous rocks.

The more metamorphosed rocks of the Humanity Seat area are much less readily identified by lithology and they are structurally almost completely separated from those to the south. On the evidence of the unconformity north of East Painter Gorge they might be expected to be the equivalent of the volcanic sequence and the overlying rocks. The author, approaching them first from the east, saw little resemblance; but careful mapping from the south across the Barraranna Gorge showed that the arenaceous sequence extends north into the gradually more mylonitised rocks of Humanity Seat itself, and a lithological boundary in phyllitic beds has been mapped to the east of the peak. Still lower in the sequence is an actinolitic marble almost certainly equivalent to one low in the volcanic sequence. The author has since discovered that 'possible ash beds' were recorded within the lower less phyllitic sequence by Sullivan (according to Sprigg, 1945).

II.4. The use of the term 'Willouran'

In the past, the whole sequence below the glacial beds would have been described as Torrensian. In recent years the term Willouran has been used for rocks in the Copley - Witchelina area which are stratigraphically below the Copley Quartzite. This is regarded as equivalent to the great arkose of the Arkaroola H.S. area. While such a division is easily applicable to that part of the Wooltana Volcanic Belt lying west of the Paralana Fault it is less easily applied to the area to the east.

In the west a considerable thickness of phyllites, apparently conformable with the arkose, lie between it and the volcanics. The boundary between the phyllites is in part faulted but in any case metamorphism makes recognition of its character difficult. In the tightly folded central and northern area, east of the fault, the phyllite sequence is little less thick and its base is again difficult to interpret. But south of the triangular area between the Lady Buxton Creek, the fault running south-west from the Lady Buxton Mine, and the Torrensian outcrop (i.e. what is hereafter described as the 'triangle of volcanics'), and in the whole of the scarp zone, the arkose is itself very much thinner, rather less persistent, and is underlain by apparently conformable thin quartzites or shales which rest on an eroded surface of the volcanics. Thus the marked break is here within what is strictly a Willouran sequence.

It would therefore have been easier to place all the rocks below the Sturtian in one Group, but to avoid confusion in relation to published maps a division into Willouran and Torrensian has been introduced and the break placed at the base of the arkose as elsewhere.

II.5. Willouran Series: Wooltana Volcanic Group

The Wooltana Volcanic Group in its 'type' area, the Mount Jacob scarp zone, comprises lavas, tuffs and agglomeratic tuffs with associated quartzites and shales. The lavas are almost entirely sodic trachytes; some andesite occurs. Tuffs are much less common than lavas and are mostly found in the south, where a porphyritic sodic rhyolite bomb rock is locally common enough to produce agglomeratic tuff. Tuff has been recorded which is indurated, though not welded.

Dykes are rare. Rocks having the appearance of dykes in outcrop, but in reality well post-volcanic and associated with later tectonic movements, being either clastics or vein-rocks, are very common.

Associated sediments are of minor importance. In a sequence of approx. 400 ft. south of Wooltana H.S. green shales occur, maximum thickness 30 feet, at or towards the top of the sequence. One mile north of the H.S. and again north of Copper Mine Creek very characteristic red, often current-bedded quartzites occur. These are lens-like in the south but in the north can be traced for long distances. They are everywhere less than 20 feet thick. (Since the map was drawn a bore at Wooltana H.S. has shown 200 ft. of red quartzitic sandstone under the volcanics).

Subdivision of the Wooltana Volcanic Group is thought to be impracticable, because of rapid horizontal and vertical variability.

In this scarp zone alteration of the rocks is very common and while the type of alteration is usually clear, the pattern shows nothing but a consistent irregularity. The typical unaltered trachytes are Mawson's 'amygdaloidal melaphyres' - hard dense, fine-grained dark purple rocks with salmon pink or white amygdales, or occasionally vesicular. They outcrop prominently, forming scarp edges and minor gorges. Rocks mineralogically little different, but physically altered, occur as a purplish grey or greenish grey crumble on lower ground between the outcrops of unaltered but brecciated trachyte cemented by pink and white quartz veins, which is common near the major faults and in the south-east part of the 'triangle'.

The small outcrop of igneous rocks south of the Barraranna Gorge has similar rock types, though near the fault they are mylonitized.

West of the Lady Buxton Fault lavas are confined to a small area near the Barraranna Gorge. Most rocks are green, fine grained and tuffaceous, with increasing scapolitization northwards. The proportion of shaly material is difficult to estimate. The sequence contains argillaceous limestones near the base, which become actinolitic marbles to the north, and a red quartzite higher in the succession which may be correlatable with one of those of the scarp zone. North of East Painter Gorge, chlorite-magnetite schists occur.

West of the Paralana Fault metamorphism, tight folding, and faulting make determination of original rock types very difficult. True lavas are known to occur only in a small area in the south-west. Green schists are common, some with quartz blebs possibly amygdaloidal in origin. The evidence suggests a predominantly tuffaceous sequence between two actinolitic marbles which coalesce westwards and open again west of the Arkaroola Water Hole revealing another, smaller, outcrop of metamorphosed, mostly tuffaceous volcanics.

The Humanity Seat rocks are phyllites, with very minor volcanism.

II.6. Overlying Sediments of Willouran and Torrensian Series

In the scarp zone these rocks outcrop in two distinct areas: a short section of the scarp between Mawson Bluff and Wooltana H.S. and a much longer section extending from a point half a mile south-east of Woolnough Crag northwards around to the tightly folded Barraranna Gorge area.

The short outcrop thickens from nil at the south end of Mawson's Bluff to about 200 ft. at the maximum in the first creek north of the homestead, west of which it is lost by folding under the Sturtian. The basal member is a red quartzite (shaly at Wooltana) rising in the south through purple shales and current bedded quartzitic sandstone to an arkosic conglomerate grit which in the north rests disconformably on the basal quartzite. Above this very characteristic grit (which is equated with the basal Torrensian to the west) bedded dolomites outcrop in the south; in the thickest section they have a light brown mudstone at the base. There is much minor horizontal variation.

The sequence rests on an eroded surface of volcanics.

The longer outcrop has essentially the same characteristics, with similar horizontal variation within a general sequence beginning with quartzite passing up into purple shales and arkosic grit. Above the arkosic grit and north of Woolnough Crag a sequence of shales, flaggy sandstone, shales with minor dolomites becomes regular, with the flaggy sandstone very thick in the north east. The overlying beds, purely dolomitic in the south, contain much shaly and silty material. Pre-Sturtian folding in the Woolnough Crag area results in Sturtian resting unconformably on arkosic grit in the bed of the Arkaroola Creek.

Accurate subdivision in the Barraranna Gorge area is not easy, especially north-east of the Gorge where there is tight folding and much faulting. The flaggy member above the arkosic grit is apparently much thicker here and dominates the outcrops. In the tightly folded but unfaulted area south-west of the Gorge the sequence can be established, though very careful mapping was necessary as squeezing of incompetent members is common. Towards the north characteristic purplish ribbon-banded, ripple-marked quartzites become dominant below the thickened arkosic grit (and form the rocks in the sharp bend of the Gorge itself) and can be followed across the Arkaroola immediately east of the Paralana Fault into the Humanity Seat area; slightly further nrth in the immediate vicinity of the peak they are mylonitized and no very obvious lithological correlation is possible.

West of the Paralana Fault the very much thicker

Willouran sequence of monotonous phyllites rises to a still stronger development of the Torrensian arkosic grit well displayed in the gorge of Boulder Creek immediately east of Arkareola H.S. The homestead itself stands on shales and westward the thicker equivalent of the flaggy sandstone outcrops as another massive scarp. Beyond this is a very thick sequence of carbonate beds mapped in detail only along the Wywyana.

II.7. Sturtian Series

No detailed study of the Sturtian Series has been made, but its outcrop has necessarily been mapped and much information about the lower and upper parts of the sequence was recorded.

The Series was examined for the first time in this area by Mawson (1949), who gives detailed descriptions along an east-west section near Mount Jacob. It is necessary to add that much lateral variation in lithology occurs, and that Mawson's belief in the significance of the colours of tillites seems misplaced.

In the scarp zone the Series varies a great deal in rock type. In the southernmost area a basal boulder tillite is found, beautifully displayed in a narrow gorge a quarter of a mile west of Merinjina Well (Plate VIII), rising into what is probably a fluvioglacial conglomerate with sub-rounded pebbles and boulders almost entirely of quartzite, and mostly of about 6" to 1' in size. The basal tillite is strongly purplish or green due to its content of volcanic detritus.

At Wooltana the same sequence is seen, but immediately to the north and for several miles to beyond the Arkaroola Creek the lowest member is invariably a tillite very rich in rectangular blocks of dolomite, with other erratic material quite subordinate or absent. This highly characteristic rock is the material forming the massive feature named by the author Mawson Bluff, which appears in the photograph in Mawson's 1926b paper. At this point the member is thickest (100 ft.) and is a yellowish or buff tillite weathering dark brown. In the creek on the north side of the Bluff it rises into a purple tillite containing a much higher proportion of non-dolomitic material with the red bomb porphyry very prominent. (In all the lower tillite containing volcanics, the bomb porphyry is predominant among volcanic erratics; most of the other volcanic types have contributed principally to the matrix.) This member shows much box weathering and is less prominent in outcrop. Above it is greener in colour and gives way to about 300 ft. of green and whitish shales. These are capped by the massive fluvioglacial conglomerate, forming great scars on the crest of the range. The matrix of this is mostly quartz sand (rather than rock flour) and the boulders nearly all fine-grained or medium-grained quartzites, usually purple-stained with prominent current bedding. The rock is so indurated that commonly the joint planes cut cleanly through the boulders.

North of Woolnough Crag, which is formed of it, this latter member occupies nearly the whole sequence; the outcrop is all high ground.

In general, the fluvioglacial conglomerate forms the major part of the Sturtian outcrop, but the uppermost Sturtian along the eastern side of the Munyallina valley is again a definite tillite, with magnificently facetted boulders. In the north it is intensely brecciated, and at the 'tear-off' north of Boulder Creek, where the top and the bottom of the Series approach very closely, so much so that it is almost unrecognizable.

The Sturtian west of the Paralana Fault is confined to the area south of the Arkaroola H.S. - Umberatana track. It has been examined in detail by the author only along a section up the Wywyana Creek, where there is no sudden onset of massive glacial beds but an introduction of thin tillitic beds repeated and gradually giving place to massive fluvioglacials which to the south are more developed and form the rugged mass of which the highest point is named Mount Warren Hastings.

III. DETAILS OF STRUCTURE

III.1. Paralana Fault System

The major structural feature of the area mapped is the Paralana Fault. This is a break which produces an almost complete repetition of the sedimentary and igneous formations, bisecting the area approximately meridionally.

It is a complex fault. Because for much of its length it is a duplicated strike fault its existence was not clearly established until the wartime reconnaissance survey when air photographs became available for the first time. Previously recognition was much more difficult because the area of major topographic change on the west side of the Munyallina Valley, which was of course noted both by Mawson and Woolnough, coincides with the eastern member of the fault, west of which is a narrow repetition of carbonate beds of similar lithology to some of those in the valley; this together with similarity of strike and dip allayed suspicion. Neither Mawson nor Woolnough in 1926 - both crossing westwards - so much as suspected the existence of a fault.

In Mawson's 1948 paper the existence of the fault is recognised and it is shown on Sprigg's reconnaissance map (1945) though the Wooltana Volcanic Belt on that map is left very much in the air in relation to the rest of the area.

Here we may regard the Paralana Fault System as beginning in the south at Italowie Gorge (see fig. 2) on the Balcanoona 1-mile G.S. sheet where a double fracture throws the Lower Glacial mass on the west against upper Sturtian on the left bank of the emerging creek, with repeated upper Sturtian between the two fault members. Here they dip at a high angle. At this point the main mass of Sturtian Lower Glacials on the west side is torn off, re-appearing in the area north-east of Arkaroola H.S. - a tear with an offset of 20 miles. Calculations based on cross sections drawn through the centre of the Munyallina valley show that the throw-down to the east is of the order of 25,000 ft. assuming a dip of the fault plane of 70°, and 22,500 ft. at 80°.

The eastern fault member is clearly exposed on the north bank of the Balcanoona Creek 4 miles west of Balcanoona H.S., 250 yards north of the track to Grindle's Hut, immediately east of where the creek leaves the gorge through the tillite. Here it is a low angle thrust, but ¼ mile further west the western member is a high angle reverse fault, throwing Lower Glacials against upper Sturtian (on the east). The western splinter is much steeper and less clearly exposed.

North of Balcanoona Creek the north-easterly trending fault system is offset westwards by north-south splinters which isolate Mount McTaggart. From there the eastern member extends for seven miles in a straight line, with the western member about half a mile from it in the south but approaching more closely northwards. This is the area where Mawson and Woolnough made their reconnaissances, the 'Cave Hill dolomite' of Mawson (1934) lying between the faults and forming a very prominent east-facing scarp. To the east are upper Sturtian beds which in the south include the Upper Glacial Sequence. West of the double fault the Lower Glacials are very near in the south but the unconformity between them and the upper Torrensian swings away northwards leaving a wide outcrop of the latter beds east of Mount Warren Hastings.

A mile north of the point where the Wooltana - Arkaroola track cuts through the 'Cave Hill dolomite' the faults are again splintered, with a direction change to north-north-east to north. For several miles north the fault is a single high angle stretch thrust (dip 70°-80^{0}) but in the vicinity of Boulder Creek and to the south a narrow zone of upper Sturtian is duplicated, and at the north end of this duplication massive quartz-iron 'blows' occur on the left bank of Boulder Creek.

From here north the fault system as a whole is much more complex because of intense splintering and wrench faulting on the east side and to a smaller extent on the west side in the reverse direction. The Paralana Fault proper however remains exceedingly clear-cut extending across the Arkaroola Creek up-stream from the Barraranna Gorge into the Humanity Seat massif, passing west of the peak, north of which it peters out into a complex system before developing <u>en echelon</u> as the Paralana Fault of the 'type area' from north of East Painter Gorge to the Yudnamutana Gorge mouth and Paralana Hot Springs. At the point it crosses the Arkaroola, the break is so clean cut and lacking in any local brecciation (and this is true of much of its length) that it is not surprising that Mawson failed to see it (Mawson 1923); here by relative northward displacement of the eastern block against the Painter massif volcanics of similar facies on each side of the fault approach very closely.

III.2. Splinter Faults and Thrusts. Folds

Associated with the Paralana Fault System are several major splinter-faults and thrusts, which cannot be discussed without the associated folds.

The most important of these faults extend as a fan in a north-east quadrant from the tightly folded area one mile north-east of Arkaroola H.S. Here, a tremendous compression on the east side of the Paralana system has been relieved by

(a) overthrusting by the volcanics in the axial core, and the overlying arenaceous-dolomitic Group, on to the upper Sturtian;

(b) development of three tight anticlines with squeezing-out or severe thinning of the less competent (largely calcareous) beds in the arenaceous-carbonate Group;

(c) (in the southern part of the Barraranna Gorge) minor over-thrusting from the north-west, with petty wrench faults (all too small to show on the map);

(d) overturning of the quartzites of the Barraranna Gorge at their contact with the volcanics at its northern end.

This is the situation in the 'corner' of the structure. Beyond, the faulting and folding extends well north of East Painter Gorge and affects the area around the upper reaches of Groan Creek. The major thrust, (a) above, is probably continued north-eastward as the Lady Buxton Fault (unless that fault is <u>en echelon</u> to it). On the west side of this the volcanic group is very tightly folded anticlinally with an overturned east limb. On the east side the volcanics of the 'triangle' are for the most part folded more openly but in the south-west corner of the 'triangle' the arenaceous-carbonate group is tightly folded anticlinally, with a curious shallow synclinal keel of quartzite between the principal anticline and a subsidiary lying east of it, the two amalgamating north-eastward. Strong wrench faults with very prominent slickensides showing horizontal movement are associated with this folding.

To the east and south of this complex system of folds and faults numerous wrench faults affect the remainder of the country mapped. These are nearly all dextral on the west side of the Lower Glacial outcrop (some of these carry through to the east side) and sinistral on the east side; further south sinistral faults become dominant. Many extend for several miles and have little throw, but cumulative throw is considerable. They have caused narrow zones of intense brecciation. Only the major faults have been mapped. Innumerable minor wrench faults exist and explain the ubiquitous brecciation in the volcanics. In the glacials they lead to much weathering-out of the rounded pebbles and boulders of the fluvioglacial beds, where they are not so indurated as to form one solid mass. In the arenaceous-dolomitic group the effect is seen in the shattering of the quartzites and in the dolomites shattering on an almost microscopic scale is everywhere apparent.

As described below in the Woolnough Crag-Vermiculite valley area these wrench faults are associated with what appear to be normal faults which in turn may be associated with the major downthrow limiting the ranges to the east (See also III.3).

Folding in this eastern area is much less common, the only important example being in the upper reaches of Groan Creek, where the dips in the upper Torrensian arenaceous beds suggest a syncline plunging west. It is not certain whether this is not partly to be explained by local thickening of the arenaceous beds. The faulting on the north-east side of this area is also abnormal in its north-westerly alignment but this again may be connected with the faulting limiting the ranges, which elsewhere is offset by north-westerly trending faults.

North of the Barraranna Gorge another major thrust, also duplicated, develops from a fold in the upper Torrensian and extends parallel to the Lady Buxton Fault to East Painter Gorge entrance and beyond. This dips much less steeply than the Paralana Fault (and the Lady Buxton Fault); brecciation is common and intense in the vicinity of East Painter Gorge. At the southern end of this structure the phyllites of the Humanity Seat block are extremely tightly folded and overturned.

To the north the actinolitic marble of the Humanity Seat block appears to be faulted against the higher beds; there is a marked difference of strike. Beyond, structures in the East Painter Gorge area are very confused.

West of the Paralana Fault very strong faulting occurs along the southern margin of the Painter Complex, principally along NE-SW lines. Tremendous quartz blows exist. A crude <u>en echelon</u> pattern of wrench faults affects the volcanics and sediments. Tight folding has taken place. Two major synclines in the upper Torrensian are clearly established. (These fade southwards and there is no good evidence to date them, even in part, as pre-Sturtian). A little north-east of the junction of the Arkaroola and the Wywyana folding is extremely sharp and excellent boudinage is seen. Strong cleavage, elsewhere not prominent, leads to weathering of the phyllites into angular blocks. The zone between these two synclines is far from simply anticlinal, however, and repeated examination on the ground and of air photographs has failed to establish a satisfactory detailed structure. Variations in thickness of the volcanics and metamorphism make this difficult.

Further west, structures are simpler. They are finally cut by overlap of the higher beds on to the Painter Complex.

A minor splinter east of Arkaroola H.S. may partly account for the gold mineralisation at the Golden Rule Mine (Lively's Find) (see below, V.2)

<u>III.3. Dyke-like Features</u>

Two types of dyke-like features occur both of which are regarded as of tectonic origin.

The first are brown-weathering linear wall-like bodies which occur in two areas, the southern part of the scarp zone and the eastern part of the area west of the Lady Buxton Fault, both north and south of East Painter Creek. (In the latter area some confusion may arise if it is not recognised that for about half a mile south of the Lady Buxton mine one has in fact been used as a wall, with debris of similar material piled on top or built on to the end as a dry stone wall extension. This is apparently an early shepherd's work.)

In the scarp zone these bodies are 5-20 feet wide and extend continuously (or with minor breaks) across the area in a north-north-easterly direction irrespective of the formations outcropping. They reach 15 ft. in height, usually 5-10 feet, and form strong landscape features. They are apparently vein bodies of calcite, dolomite and quartz, rather ferruginous. No other mineralisation had been noted.

In the Lady Buxton area the bodies are similar but north of East Painter Creek they are folded.

In both areas the bodies are regarded as veins developed along wrench faults or associated fractures (including, perhaps, north of East Painter Creek, gaps between tightly folded formations).

The second type of dyke-like bodies is confined to the southern end of the scarp zone south of Wooltana H.S. These are bodies with no differential relief, usually only 5-10 feet wide, and dark or light grey in colour. In places these cut the tuffaceous shales, i.e. they post-date at least the lavas of the south. They are not, however, volcanic, though they contain much altered volcanic material. Of two examples collected (T.S. 5272 and T.S. 5275) one is obviously a deeply altered rock, largely calcite and chlorite; the other a strongly mylonitized rock, which Fander thinks might originally have been agglomerate or conglomerate. At the time that these rocks were being examined, other rather similar rocks were collected by R.C. Horwitz from the Arrowie 1-ml. G.S. sheet where he has demonstrated diapiric squeezing of lower Torrensian material through younger rocks along the eastern side of the ranges. It seems possible that these are related bodies, essentially tectonic.

IV. LOCAL DETAILS OF STRATIGRAPHY & STRUCTURE

IV.1. Wooltana H.S. area: southern limit of volcanics to Mawson Bluff

This is the area of volcanics most easily seen, the Volcanic Group here forming a narrow linear outcrop no more than a few yards wide in the extreme south to a little over half a mile in the north. The outcrop is broken immediately north of Wooltana H.S. by the overlying Torrensian arenaceous-dolomitic group.

In this area, especially that part of it south of Wooltana H.S., faulting is a major feature. In addition to major wrench faults, associated with which are numerous massive vein structures cutting the outcrops with strong relief, there is a thorough shattering. The area is also folded more intensely than any other part of the scarp zone. Much of the volcanic material is therefore highly brecciated and is weathered more than elsewhere. Effects due to deuteric alteration are not easily distinguished from alteration consequent upon tectonic shattering and later weathering. Near the eastern edge of the outcrop rock types are commonly difficult to identify.

The scarp here is not more than 200 feet above plain level in the south but rises to about 700 feet in the north.

As the map shows, the area is structurally divided into three parallel zones by what appear to be wrench faults, Each zone is anticlinal, with mild plunge variation, so that several isolated outcrops of volcanic rocks occur. The relationship of this folding and faulting which affects both the Torrensian and the Sturtian, to that immediately north west of Wooltana, which affects only the Torrensian, is not absolutely clear; but there is no doubt that the latter is older: no effect on the tillite north west of Wooltana can be seen, but to the south it is very definite. This folding and faulting with north-easterly or north-north-easterly trends is connected with the major flexing which limits the Flinders Ranges as a whole.

The most characteristic rock type is exemplified by T.S. 3229, an amygdaloidal sodic trachyte (Plate III). This is macroscopically an unusually striking rock, a dense fine-grained dark purplish grey lava with amygdales commonly filled with salmon-pink microcline and usually with white quartz.

Vesicular lavas of similar type occur, more especially in the south. Such lava tops are common but not traceable for more than about 50-80 yards; they are repeated vertically many times. Because of such rapid variation and variably intensive weathering and alteration counting of flows is impracticable. There is a confusion of numerous minor flows.

The fresh apparently unaltered trachyte commonly outcrops adjacent to a crumble of altered rock containing much secondary material. T.S. 3107, for example, is a trachyte containing colourless to pale green amorphous material and calcite. From field evidence there is no doubt that this is essentially the same rock as T.S. 3229, and a gradual change from the one to the other often occurs over a distance of 20 yards.

The third characteristic rock is the epidotised material e.g. T.S. 3099. This occurs as sharply angular fragments about 6" long resembling unweathered talus, much less often as massive outcrops. This is the host rock for tremolite veins up to 4" wide, which are commonly stained green with epidote and are sometimes crumpled.

The many brecciated areas commonly show a rock consisting of a trachyte similar to T.S. 3229 but broken up into very irregular, sometimes crudely rounded masses cemented together by quartz which is often stained and associated with haematite. This material was at first regarded as an agglomerate produced close to its source and altered but once the intense and ubiquitous brecciation was recognised it was appreciated that much of this type of rock is merely a recemented brecciated trachyte; some however is associated with what are almost certainly small vents. The frequency of occurrence of this material makes it difficult to be certain of the existence of pillow lavas, as the only two places where such pillows have been thought to possibly exist are in areas of brecciation. Immediately behind Wooltana homestead strongly cleaved red shales appear to overlie the lavas but they appear to be disconformable. The shales rise through a current-bedded sandstone and shales (40') to the very characteristic arkosic conglomeratic grit.

To the south there is a generally low but very irregular area much cut by thick veins of calcite, dolomite and quartz; further south the ground is higher and is capped by tillite.

A clearer sequence is seen at Merinjina Well, one mile south of Wooltana H.S. The last, wide curve of the creek before entering the plain below Merinjina Well windmill shows very elegantly the swinging outcrop of the folded volcanics under green tuffaceous shales. (These shales resemble part of the Sturtian glacial sequence and there was at first some difficulty in distinguishing them in the field). The faulting of the volcanics against these is clearly seen on the left bank. Upstream for 800 feet is a fine succession of dark purplish grey lavas with vesicular and amygdaloidal tops, all dipping west at 30°-40°, and showing the characteristic crumbly grey and green epidotic variants; these lavas are of the order of 100-150 feet thick. At the repeated boundary with the tuffaceous shales a very fine section is seen on the left bank, from which a suite of specimens was obtained. A sketch of this is given (Fig. 3).

The basal member is a fresh, hard, dark greyish green rock, non-vesicular, very constant in colour and texture, and with a smooth upper surface. This is a micro-diorite (T.S. 5269) slightly coarser-grained and more basic than the trachytes.

It is covered by a succession of interbedded tuffs and clayey sediments and in the lowest tuff is a bomb of porphyritic sodic rhyolite, T.S. 5265, with characteristic glomeroporphyritic chequer-albite.

This rhyolite occurs elsewhere to the south and is very common as debris at the extreme south of the volcanic outcrop; it occurs rarely north of Wooltana but it is widespread as an erratic in the Sturtian glacial beds.

The matrix around the bomb is a lapilli-tuff (T.S. 5266) but the immediately overlying material is an argillaceous silt-stone (T.S. 5270) succeeded by a tuff (T.S. 5268) with similar constituents to T.S. 5266. Overlying these are tuffaceous shales with pebbles of gritty sandstone, and a boulder of current-bedded quartzitic sandstone.

In the extreme south a rock which appeared in the field to be a dyke (T.S. 5272) cutting the volcanics immediately west of the major limiting fault is strongly altered but most probably a volcanic which has been squeezed up through tension cracks associated with the major faulting. A rock thought to be a bomb is described by Fander as a brecciated and mylonitized lapilli-tuff or conglomerate (T.S. 5275). The only other volcanic characteristic of this area is a very dense red jaspery-looking intensely hard rock (T.S. 5271) which is a tuff occurring repeatedly among lavas and owing its colour to abundant haematite. This rock has not been seen in the northern part of the Belt, but much of the tuffaceous material there is comparable though less haematitic.

Between Wooltana H.S. and Mawson Bluff is the area first described by Mawson (1926b). On the low ground north of the hills occupied by the upper Torrensian the volcanics outcrop poorly under piedmont debris. The reddish sandstones and chocolate shales described by Mawson as below the main igneous formation have not been seen. Eastwards the boundary of the volcanics and the overlapping ?Cretaceous conglomeratic gravels is indefinite. The first major creek to the north-west offers a poor section in the volcanics (though a fine one in the higher beds). Further north the outcrop of the volcanics widens at the expense of the upper Torrensian and the three characteristic rock types mentioned earlier are well seen, in their equally characteristic irregular distribution. The strike is generally north-westerly with a dip south-west of 20-25°, in sympathy with the synclinal folding of the upper Torrensian. In this area interbedded sediments are rare, except in the extreme north where quartzite lenses appear.

IV.2. Mawson Bluff to Copper Mine Creek

This area has been examined in most detail in the south, where the stratigraphy is apparently most complex. A typical section is seen in the creek running from the amphitheatre of Mount Jacob down on the north side of Mawson Bluff.

The southern part is apparently more disturbed than the rest and has much more interbedded sediments, mainly red shales, purplish grey conglomeratic shaly sandstones and minor quartzitic sandstone. As in the south, repeated lava flows are common. The relation between the Sturtian and the volcanics is here apparently only disconformable because of similarity of strike and dip. Immediately north a tight syncline forms a steep hill, volcanics in the hill being faulted against sediments in the creek to the north.

In Red Bank Creek a hard dense unusually reddish rock was noticed near the Sturtian boundary. It is an indurated tuff (T.S. 3213).

The only other rock examined which resembles this is T.S. 3143 from the isolated outcrop of volcanics adjacent to the Paralana Fault between the Barraranna Gorge and Arkaroola H.S., a resemblance not obvious in the field, as the rocks in the latter area are much brecciated and squeezed. In the author's opinion the two types are different, T.S. 3213 being probably indurated by superincumbent strata or baked by overlying lavas, and T.S. 3143 being a tectonically metamorphosed volcanic.

The area between Red Bank Creek and Woodnamoka Creek presents no unusual features, having a little sedimentary material and numerous typical flows. It has two prominent hills, outcrops of massive dense red-brown rock which in the field resembles T.S. 3213 but which has not been examined microscopically.

At Woodnamoka Well typical vesicular and amygdaloidal lavas are beautifully exposed. Epidotized rock is common here, e.g. T.S. 3228. (Plate IV).

Above Woodnamoka Well similar rocks are repeated across all the outcrop.

North from Woodnamoka Well to Copper Mine Creek there is a greater regularity of outcrop, but insufficient time could be devoted to the area to determine whether this is due (as further north) to an increased proportion of intercalated sediments or to some other reason e.g. linear fissure eruptions as against the confused and apparently more explosive conditions of the Wooltana H.S. area. It is probable that both causes combined to give this effect.

IV.3. Vermiculite Valley and Grean Creek area.

This is a large area of westerly-dipping lavas with minor sediments, with clearly defined faults - either normal or reversed, but not wrench faults, - markedly affecting the landscape and producing the fault-angle depression of Vermiculite Valley. It has been subjected to two periods of folding. The first period of folding is illustrated by the existence of a tiny outcrop of volcanics occurring west of the upper Torrensian outcrop, and is unconformable under the Sturtian. The whole of the north-east is gently arched along a north-south axis as is revealed by the present disposition of the Mesozoic (Cretaceous) cover. This latter folding is insufficient to alter the general westerly dip of the volcanics.

Rocks typical of the Wooltana area occur. The typical amygdaloidal lava is most easily seen where the old Paralana mail track crosses the Arkaroola. On the south side up the creek for a quarter of a mile is a beautifully exposed succession of lavas many of which are amygdaloidal sodic trachytes (e.g. T.S. 3220, Plate V), and the recemented brecciated variety is very common a quarter of a mile to the south-west (e.g. T.S. 3094).

On the west of this lava belt of minor rugged hills a continuous outcrop of a thin dark red very dense recrystallised quartzitic sandstone limits the eastern edge of Vermiculite Valley. Two specimens of this have been examined (T.S. 5277 and T.S. 5278), are almost identical and resemble red quartzites from the 'triangle' and the area west of the Lady Buxton Fault. Though it would be unwise to assume that they are all necessarily synchronous they enable the stratigraphy and structure to be disentangled in the three separate areas, in which the outcrop is continuous or almost so.

Vermiculite Valley itself is a generally flat-bottomed valley strewn with debris of piedmont material (which caps some of the volcanic hills) and much weathered volcanic rock. It is an enigma, being like no other part of the volcanic outcrop except the eastern part of the triangle, where, similarly, much weathered volcanic rock exists. One is tempted to regard it as perhaps at one time very temporarily a lake, since drained by a right bank tributary of the Arkaroola about half a mile above the Paralana mail track crossing. A high-level lake Frome (and there is much unpublished evidence of such a former high level) would fill the valley and have marked effects on the rock weathering.

A curious depression, reminiscent of an old mine shaft and dump area so completely washed by rain as to be almost unrecognizable, occurs in the centre of the valley about 100 yards east of a sizeable fault scarp. The material in the 'dumps' is a crumbly crust of grey-green weathered volcanic rock and was sampled as a possibly activatable clay. Mrs. N. Chebotarev examined this and found it to be mostly aggregated vermiculite with much secondary iron mineral. The rock at the foot of the fault scarp to the west (T.S. 5276) was found to be a completely altered fine-grained volcanic.

North of the Arkaroola, Groan Creek is a major left bank tributary, east of which most of the volcanic outcrop is strewn with younger debris; in the south the volcanics are better exposed but very much lateritized on the crests. This is an interesting area not examined in detail. T.S. 3225 from the central part of a flow towards the north end of Groan Creek south-east of its exit from the upper Torrensian is a slowly-cooled trachyte. This rock type is very common in the area, together with typical amygdaloidal trachytes.

IV.4. 'Triangle of Volcanics'

A relatively small but highly confused area of volcanics exists as a triangular area between the Lady Buxton Fault, the upper Torrensian, and the Lady Buxton Creek. This contains all types of volcanics previously described, but tight folding in the south-west, and deep weathering towards Lady Buxton Creek, made identification occasionally difficult. The south-eastern part is intensely brecciated and contains some isolated knobbly hills which are probably vents.

A typical lava (T.S. 3224) from the southern margin is a sodic trachyte; T.S. 3199 from the eastern edge is similar but coarser grained.

A rock from one of the knobs considered to be possible vents is T.S. 3194, another trachyte.

South-westwards these rocks give way to green fine-grained rocks with quartz blebs suggestive of elongated amygdules. Half a mile south-west of the Lady Buxton mine an altered andesite was collected (T.S. 3232).

The northern and north-western part of the triangle has been shown to be anticlinal by following the outcrop of a quartzite comparable with those described above (IV.3).

The proportion of tuffaceous material increases in the north-west, so that the succession tends to resemble that of the area west of the Lady Buxton Fault.

IV.5. Area south of Barraranna Gorge

A small outcrop of volcanic rocks occurs immediately east of the Paralana Fault on the west side of the track running north from Boulder Bore. This is an anticlinal core of rocks brought up by plunge variation. The volcanics are typical Wooltana-type amygdaloidal trachytes with minor tuffs but adjacent to the fault they have been mylonitized.

IV.6. Area west of Lady Buxton Fault and east of Humanity Seat Thrust

A rugged area between the 'triangle' and the Humanity Seat mass extends from Barraranna Gorge to East Painter Gorge. North of the entrance to East Painter Gorge a smaller area of similar rocks exists. This is the northernmost recorded outcrop of the Wooltana Volcanic Group.

These rocks (a) are generally much more tuffaceous than those to the east and south; (b) contain more persistently bedded sediments - dolomites, actinolitic limestones; (c) are tightly overfolded in an anticline along a narrow zone parallel to the fault; and (d) show increasing metamorphism from south to north.

True lavas are seen only in the extreme south next to the overturned sandstones through which the Barraranna Gorge is cut. Most of the area shows bedding on the air photographs.

Three rocks from the south centre of the area are T.S. 3191, a strongly altered basic rock, T.S. 3192, probably an altered trachyte and T.S. 3144 (from the foot of the thrust in the south-west) an extensively altered fine-grained igneous rock.

The rocks of the northern part of the area are very much scapolitised and the question of the existence of spilites was considered. An example is T.S. 3184, a thoroughly scapolitised rock. No detailed study has been made of these rocks but they are at present regarded as comparable with those to the south, altered mainly by regional metamorphism with accompanying metasomatism. Another related rock from about 200 yards north-west of the Lady Buxton Copper Mine was described in the field as a 'scapolitised intrusive or ? spilite' (T.S. 3098). Petrographically this resembles the albite-tremolite rock from Groan Creek (T.S. 3225).

North of East Painter Creek chlorite-magnetite schists are characteristic (T.S. 3149). In the extreme north amphibolitic material appears which is not certainly part of the Group, being possibly part of the Painter Complex.

IV.7. Area west of Paralana Fault

This area, much less readily accessible, has been studied in less detail than the rest. It is intensely folded. True amygdaloidal lavas have been observed in the south-west. The rest of the outcrop would best be described as green schistose calc-silicates, but green quartz-blebbed dense rocks occur in the north which are regarded as metamorphosed amygdaloidal lavas, e.g. T.S. 3214.

Still further west, beyond the Arkareola Water Hole (i.e. 1-1½m. west of the Wywyana Creek) similarly metamorphosed rocks occur, and one specimen from an outcrop surrounded by actinolitic limestone belongs to the amphibolitic facies (T.S. 3174), a very characteristic pink and green felspar-tremolite rock.

These rocks - which are Mawson's (1948) Arkaroola Series - are cut off westwards by the unconformity of higher horizon rocks on the Painter Complex but are thought to be the equivalent of amphibolites near North Well, east of Umberatana H.S., which are at a comparable stratigraphic horizon.

IV.8. Humanity Seat Area.

The Humanity Seat area is quite different from the others described being much higher, more rugged, and essentially an area of phyllites. However, there is little doubt that these phyllites are stratigraphically equivalent to the Volcanic Group on mapping evidence. None of the volcanics noted by Sullivan have been seen by the author, as Sprigg's report on the area, in which this occurrence is quoted, was not seen until field work was completed. The existence of an actinolitic limestone east of the phyllites suggests equivalence with those highly folded in the area west of the Lady Buxton Fault and similar limestones west of the Paralana Fault; and the uppermost very mylonitic rocks adjacent to the Paralana Fault can be followed along strike southwards into upper Torrensian beds.

V. MINERALIZATION

Mineralization is widespread in the volcanics and along structures. The observed minerals of economic interest are those of copper, gold, uranium and beryllium, and asbestos (tremolite). Magnetite occurs in the north and the volcanics are everywhere very rich in haematite. The gold is not certainly associated with the volcanics but is of much interest. Cave guano and ammoniacal cave deposits are known in the carbonate rocks.

V.1. Copper

Minor malachite and azurite showings are numerous, mostly along or near faults. The largest occurrence is at the Lady Buxton mine where mineralization is associated with strong overfolding and thrust and wrench faulting. Magnetite occurs here also, and a quarter of a mile further north.

Woodlamulka mine on Copper Mine Creek has less obvious mineralization. Six shafts were sunk along a shear which is probably related to the wrench faulting described above. The Oraldana, Great Boulder (Great Boulder and Welcome) and Wheal Hancock Mines were all in the vicinity of Boulder Bore, near the Paralana fault and Golden Rule gold mine (q.v.). Several other minor diggings and more showings exist east of Groan Creek, in the high ground west of Vermiculite Valley, in the triangle, and in the 'tear-off' area north and north-east of Boulder Bore. The old shafts 2m. north-east of Boulder Bore are at the junction of the Sturtian glacials with the overlying slates, here a fault. These may be the old Kingsmill Mine. Other minor shows are seen in the Barraranna Gorge (southern part) where they are clearly related to faulting, though Woodmansee and Johnson (1956) suggested that some may be derived from leached volcanics. The same authors recorded bornite in vesicles near the Arkaroola Bore.

The O'Donoghue's Castle mine was on the Paralana fault about 6 miles south-east of Arkaroola H.S. The Nepowie mine (never developed) was adjacent to Nepouie Peak, probably on a wrench fault.

V.2. Asbestos

Tremolite has been dug for at two sites near Wooltana H.S. and most occurrences of tremolite in the scarp zone have obviously been prospected. They are clearly related to faulting, often occurring in fault planes. No important deposits have been seen, though if the occurrences were near to Adelaide some might prove workable.

V.3. Gold

In 1949 three prospectors discovered gold about ¼ mile east of Arkaroola H.S. (Lively's Find; Golden Rule Mine). This is sited almost exactly on the Paralana Fault. 158.85 fine ounces was produced from 77.1 tons of ore dug to 1952. The last working took place in 1954.

The 20 ft. shaft has not been descended by the present writer, and the statement by L.L. Mansfield (Mining Engineer) that the material excavated appears to be a decomposed and faulted dyke has not been verified; only shales having been seen. Petrological examination of this material by A. W. G. Whittle in 1948 and 1949 indicated that the material might be of primary origin, and a report by F.L. Stillwell in 1949 on a specimen described it as a fine-grained syenite-aplite. This suggests that it is either an altered thin remnant of volcanic material preserved along the Paralana fault plane or similar volcanic material as debris in a conglomerate of upper Torrensian age; or mylonitic volcanic material squeezed up locally along the fault plane. Volcanics outcrop ¼ mile north.

V.4. Uranium

Woodmansee and Johnson (1956) refer to scattered evidences of uranium mineralization in small amounts in the area west of Paralana Fault, in the actinolitic marbles, associated with some copper mineralization. They regarded it as unimportant.

V.5. Beryllium

A specimen from the dumps of the Lady Buxton Mine has been described by H. W. Fander as containing massive magnetite with veinlets of malachite and partly altered crystals of phenacite.

V.6. Wooltana Cave

References are often made to the Wooltana Cave. This is the Ammonia Cave of Mawson (1934, map p. 188) and Ammonia Mine of Woolnough (1926). The cave is in massive dolomitic limestone immediately west of the Paralana Fault (east member), near the Wooltana-Arkaroola track and when visited by Woolnough in 1926 contained quantities of liquid wallaby dung. Near the entrance a great heap of bat guano was seen, in which the remains of a large extinct bat-eating bat were discovered, demonstrated to the Royal Society of South Australia by Wood Jones in 1925. The floor of the cave was covered with ammoniacal material later dug for manure, and last worked in 1933.

VI. COMPARISONS WITH OTHER AREAS

VI.1. Areas on margin of Painter Complex

As pointed out in II.1. above, lower Proterozoic rocks overlap unconformably the Archaean rocks of the Painter Complex on the west side as well as on the south.

Near Umberatana, rocks occur 2 miles north-east of North Well (which is on the Arkaroola track 6 miles east of Umberatana) and have been mapped by Thatcher as calc-silicate rocks. Some of these were seen by the author and appeared very similar to the westernmost Wooltana Volcanic Group rocks. They are in a comparable stratigraphic position, below the thick arkose. No detailed examination of the rocks has yet been made.

At Yudnamutana 8 miles east-north-east of Umberatana copper mineralization has long been known to be associated with basic rocks. Mawson (1923) described altered basic intrusives 'post-dating the great quartzite' which at that time he equated (with some hesitation) with that of the Bolla-Bollana (Barraranna) Gorge. He noted much actinolite and tremolite. Recent mapping by Campana, Coats, Horwitz and Thatcher places these rocks in the Willouran; but they are of course a horizon equivalent to that of the Wooltana volcanics. One is described by Mawson as a diabase. A specimen collected by R.P. Coats during mapping has been described by A.J. Marlow as amphibolitic marble, and another from 2 miles east as a pyroxene marble.

A little further round the periphery of the complex, altered basic intrusives were recorded in the vicinity of the Daly (Mawson, Daley) mine, 4 miles east-north-east of Yudnamutana. Mawson described some as 'slightly vesicular', and intruded into 'slaty and calcareous beds', adding that the intruded rocks 'include a remarkable development of actinolite rock and spotted slates in which tremolite is seen to be forming at scattered centres, crystallizing in radial fibrous forms.' This association of rocks is almost identical with that on the opposite side of the massif at the entrance to East Painter Gorge. Again, recent Geological Survey mapping places these rocks in the Willouran. Two miles east of the Daly Mine a scapolitised basic rock was recorded at the Shamrock Mine.

VI.2. Arrowie One-Mile Sheet

In late 1959 mapping by R. Horwitz on the Arrowie one-mile sheet 40 miles south of Wooltana revealed basic rock in breccias apparently squeezed up along the marginal fractures of the ranges near Tea Tree outstation and St. George's Bluff. Three specimens collected by Horwitz were described by Fander as a dolerite, a uralitized dolerite and a sheared uralitized gabbro and it seems likely that these are of Willouran age. They are fragments diapirically emplaced in Marinoan and Cambrian rocks. Other similar associations have been mapped in the area to the west.

VI.3. Blinman Dome and other diapiric structures in the Central Flinders Ranges

The Blinman Dome is a prominent structural feature of the Central Flinders Ranges. Howchin (1907) recorded basic rocks in 'volcanic dykes and necks' near Blinman, where a rich copper deposit was found in 1862 and worked till 1918. Specimens were described by Benson (1909). Howchin (1922) gave further details and also referred to basic intrusions at Big Hill, Wirrealpa, 15 miles east. Dickinson (1944, 1953) described the mine and accepted Howchin's 'intrusions', suggesting that they were however separated from the upper Proterozoic and Cambrian by an unconformity and that they predated the diastrophism which produced the Dome. Howard (1951) studied the district and regarded the structure as an 'early form of ring-dyking' and thought the basic rocks were intrusions following a late stage of the Cambrian to post-Cambrian folding and faulting. He found no unconformity. He did suggest that Benson's 'melaphyres' predated the dolerites and were interbedded with shale and sandstone.

Webb (1960, 1961) recognized diapiric structures in the Flinders Ranges of which the Blinman Dome is one of the largest. Most of the rocks in the diapiric centre are of Willouran type and include lavas. Subsequent detailed mapping by Coats and Webb shows that many of these lavas though often very similar to Wooltana type lavas are rather more basic.

Comparable diapiric structures occur 15 miles east of Blinman near Wirrealpa H.S., 20 miles south near Oraparinna H.S., 40 miles south near Arkaba H.S. and 55 miles south near Worumba H.S. Of these, that at Oraparinna includes large outcrops of amygdaloidal trachyte identical with some Wooltana trachytes. The Worumba area was described by Spry (1951) who recognized uralitized andsaussuritized dolerites and basalts. The present author (1959) noted diorite in crushed dolomitic limestones near Arkaba.

VI.4. Leigh Creek - Angepena area

Benson (1909) refers to a dyke at the Victory mine, 10 miles east of Leigh Creek, Northern Flinders Ranges and describes a specimen as amygdaloidal melaphyre. This was probably from the 'dolerite plugs' mapped by Parkin, Reyner, Pitman and Johns (1953) on the Serle one-mile sheet as intruding the Sturtian south-east of the Victory Mine. Similar dolerite plugs are mapped on the Angepena sheet to the south, by Sprigg and Wilson (1953) at Camp Hill Springs - almost on a fault - and in a great 'crush zone', possibly diapiric north of Mucatoona Hill; and east and north of Leigh Creek and at a node on the North West Fault near Termination Hill by Parkin and King (1952) on the Myrtle Sheet.

VI.5. Willouran Ranges - Witchelina H.S. area

Howchin (1924) described Sturt tillite in the Willouran Ranges west and south-west of Hergott Springs (now Marree). Mawson (1927) gave further details of the geology.

Howchin noted no igneous rocks in situ, but saw many varieties as erratics in the tillite.

Mawson (p. 387) mentioned that a microscope slide of a conglomerate of a 'peculiar-type' at Breaden's Hill showed a fragment of a much-altered ophitic basic igneous rock, suggesting that it may have originated in a dyke located amongst the strata half a mile to the west. He described the beds to the west and names them the Willouran Series, noting a calc-silicate rock between Breaden's Hill and Hogan's Well and a large ophitic dolerite sill, uralitized and epidotized, 'extending for a great distance to the north-north-west' (from near Breaden's Hill). This he said 'is quite like some of the basic igneous types of Wooltana and Blinman.' He noted also vanadium mineralisation (as well as copper).

The published Geological Survey sheets do not cover this area but a specimen collected by R.K. Johns from 4 miles east of West Mount, Witchelina one-mile sheet (and 25 miles south-west of Marree) is an extensively altered medium-grained volcanic similar to those of Wooltana. Specimens from Willouran rocks near Callana H.S. mapped by B.P. Webb include vesicular dacites and microdiorites.

VI.6. Port Augusta - Iron Knob - Whyalla area

40 miles north of Port Augusta, Brunnschweiler (1956) recorded amygdaloidal lavas in Willouran rocks at Depot Creek, Southern Flinders Ranges. These are identical with the typical Wooltana trachytes.

Early in 1960 B.P. Webb, visiting the Whyalla area with R. Whitehead, geologist of Broken Hill Proprietary Ltd., collected similar lavas from a sequence interbedded with sediments unconformably overlying Archaean at Douglas Point, on the coast of Spencer Gulf south-west of Port Augusta.

In mapping the Middleback Ranges Miles (1955) recorded 'Younger Dolerite dykes and possible sills or flows' on the General Geological Map which accompanies his Bulletin. His own descriptions refer only to dykes cutting the Iron Monarch orebody, and he quotes G.H. Taylor's description of a specimen as a 'pyroxene dolerite'. On the map however there is shown an outcrop 3 miles by 2 miles around Old Roopena H.S. (10 miles east of Iron Knob) and in an appendix Taylor describes three specimens from this area as vesicular basaltic lavas. Specimens since collected are scarcely distinguishable in the hand specimen from the most common amygdaloidal trachyte of Wooltana and have been described by Fander as exact equivalents of the Wooltana rocks but far less affected by subsequent changes. The lavas are overlain by a conglomerate mapped as Corunna conglomerate, containing pebbles of volcanics.

VI.7. Mount Remarkable

Mount Remarkable, 30 miles north-east of Port Pirie, forms a precipitous scarp, 2,000 feet above the Willochra Plains. Its structure was examined by Howchin (1916) and found to be complex, there being strong meridional faulting and crushing, the sudden ending of the range being attributed to east-west faults.

In the 'Foot Hills' between the southern end of the scarp ridge and the town of Melrose at its base to the east is an area of crushed limestones and ribbon slates (above a tillite) in which Howchin stated that numerous small plugs and pipes of basic igneous rock, with a few acid types, occur over an area about one mile by half a mile.

E.O. Thiele (1916, in Howchin 1916) described these rocks as of three types: (i) altered dolerites (ii) quartz porphyries (including 'quartz-ceratophyre') (iii) aplites. He compared the first group with the Blinman basic rocks. From his descriptions it seems likely that the 'quartz-ceratophyre' very strongly resembles the porphyritic sodic rhyolite of Wooltana.

It is suggested here from a review of the published evidence that the Mount Remarkable igneous complex is diapiric.

VI.8. Olary Province

Jones, Talbot and McBriar (1962) suggest that rocks mapped on the Plumbago one-mile sheet of the Geological Survey of South Australia by Campana as 'amphibolites, epidotes and skarn rocks' in Archaean rocks are volcanic and that the sequence 'probably represents a spilite - keratophyre assemblage with interbedded shales'. They refer it to the Archaean. The authors kindly showed specimens to the writer; they closely resemble the more metamorphosed Wooltana rocks. It is suggested here that these rocks are of Willouran age. Those near the southern boundary of the Plumbago sheet occupy a syncline and are mapped by Campana as overlying his uppermost Archaean, and unconformably covered by Sturtian. Those of the larger outcrop extending east-north-east from Hughes prospect could be intrusive into Campana's Archaean and are mapped as unconformably covered by the Torrensian Series.

VI.9. New South Wales

Barrier Ranges. According to B.P. Thomson discontinuous outcrops of lavas occur in Adelaide System rocks (Torrowangee Series) from about 30 miles north of Broken Hill for a distance of at least eight miles, continuing to the north (King and Thomson, 1953, p. 547 and personal communication). These occur along a folded and locally faulted zone, which could explain the discontinuity. They were described as altered amygdaloidal and vesicular basalts. A specimen kindly presented by Mr. Thomson was described by M.J. Bucknell as an amygdaloidal quartz andesite.

The lavas overlie thin beds of limestone, sandstone and grit which themselves unconformably overlie the Willyama Series. The contact between the lavas and an overlying tillite (which contains erratics of volcanics obviously of local origin) is disconformable.

West Darling District. In Kenny (1934) lavas (felspar-porphyry and rhyolite), interbedded with sediments which according to Thomson (pers. comm.) are probably of Adelaide System age, are recorded in the Gnalta-Grasmere area (80 miles north-east of Broken Hill). Specimens collected by the present author in 1961 include some closely resembling Wooltana lavas. Green tuffaceous sandstones of similar age are recorded near the Coppermine Range (100 miles north-east of Broken Hill). Porphyry and felsite lava flows occur in the Cootawundy Hills to the south of the Coppermine Range. The distribution of these outcrops has a north-west trend in sympathy with a regional fault direction (the Waratta-Koonenberry Fault of King & Thomson, p. 555) which is associated with gold and copper mineralization.

At Mount Arrowsmith (125 miles north of Broken Hill) andesite and amygdaloidal basalt were recorded by Kenny (p. 51) 'and appear to be arranged as lava flows about a centre of volcanic activity more or less contemporaneous with the upper beds of the Torrowangee Series. These ancient basalts have undergone considerable alteration, epidote being very common in veins and irregular masses within the basic lavas. The general trend of the main structures is north 30 degrees west', parallel to the general direction of the Waratta-Koonenberry Fault.

In the Waratta Ranges (180 miles north of Broken Hill) Kenny recorded flows of felsite and porphyry interbedded with sediments and equivalent in age to those previously mentioned. Possible volcanics of similar age occur in the Scopes Range (50 miles east of Broken Hill).

It is noteworthy that tillites were recorded in the Koonenberry Gap close to the top of the Torrowangee Series.

<u>VI.10. Far North of South Australia - Indulkana Ranges</u>

In the extreme north of South Australia Proterozoic outcrops are rare but west of Granite Downs H.S. in the Indulkana Ranges an area of 'vesicular basalt and melaphyre' has been mapped south of Chambers Bluff by Sprigg, Wilson and Coats (1956) on the Chandler one-mile sheet. These are shown as overlying Sturtian tillite. A smaller area is mapped 20 miles east, near Wantabella swamp, at a similar horizon.

<u>VI.11. Northern Territory</u>

Proterozoic volcanics are widespread in the northern Territory. Hossfeld (1953) gave the name Agicondi Series to rocks assigned to this age, and stated (p. 114) that they consisted originally of 'arenaceous and argillaceous sediments with a considerable amount of tuffaceous material and very few calcareous deposits', the tuffaceous material having been subsequently metamorphosed to schist. Hossfeld regarded certain rocks at Hatches Creek as of this age; these contain amygdaloidal lavas. Tuffs of the Pine Creek district he regarded as suggestive of 'original lavas of intermediate composition, dacites or andesites, but probably the latter.'

Regional mapping by Bureau of Mineral Resources geologists has since confirmed the widespread occurrence of Proterozoic amygdaloidal rocks. Examples of these collected from the Edith River volcanics (Katherine-Darwin region) were stated to resemble Willouran volcanics (Webb 1959). As Fander points out in the accompanying petrological notes, volcanics collected by Bureau of Mineral Resources geologists in the McArthur River Basin on the south-west side of the Gulf of Carpentaria are practically identical with the Wooltana rocks.

Noakes (1957, table p. 224) refers the Wollogorang volcanics of the Gulf of Carpentaria - Barkly Tableland area to a Willouran-Torrensian horizon.

VI.12. Western Queensland - Mount Isa

Knight (1953), discussing the regional geology of Mount Isa, mentions amygdaloidal rocks and tuffs in the Greenstones Group. This is the lowest Group of the Mount Isa Series according to Jones (1953), who places it in the Proterozoic.

VI.13. Western Australia

David and Browne (1950) correlated the Nullagine Series of Western Australia with the upper Adelaide Series (System) of South Australia. The basal bed, 300 feet thick at Nullagine, they accepted as fluvioglacial, quoting a correlation with the Sturtian by Becher in 1898.

Browne states (p. 73) that in the Pilbara Goldfield 'contemporaneous volcanic activity is strongly represented by acid, intermediate and basic lava-flows and pyroclastic rocks. These are in places at the very base of the series, but may be interbedded with the sediments on more than one horizon .... Thick felsite flows are present .... Numerous volcanic vents have been found, surrounded by coarse agglomerates, tuffs and vesicular and amygdaloidal lavas'.

In the Townsend Range a series of that name, equated with the Nullagine Series, includes altered vesicular lavas in its lower part, and lavas are common in the Kimberley Division Nullagine Series. Noakes (1957) refers the Mornington volcanics of the Kimberley Plateau to a lower Torrensian horizon.

VII. CONCLUSIONS

Wooltana area

Mapping of the Wooltana Volcanic Belt shows that at least 2000 feet of lavas and associated pyroclastics of Willouran age outcrop over an area about 15 miles by 5 miles. In the immediate district it seems probable that northwards and westwards they thin and a change to a more sedimentary facies is masked by metamorphism. Southwards and eastwards there is insufficient evidence to state whether they are concealed or absent. The major part of the outcrop lies along an important lineament forming the eastern limit of the Flinders Ranges.

The volcanics are overlain disconformably by Torrensian sediments which near Wooltana are thin or absent but which thicken rapidly to the north and west. These are unconformably overlain by the Sturtian lower glacial sequence, which near Wooltana rests directly on the volcanics.

The area is bisected by a major meridional structure, the Paralana Fault, which has a throw of over 20,000 feet. Intense splinter-faults, wrenches and thrusts are associated with this and caused ubiquitous brecciation. Tight folding occurs in the north and west.

Petrographic examination of the volcanic rocks shows that they are mostly trachytes, with very subsidiary porphyritic rhyolite and some andesite. The trachytes are sodic and unusual in being rich in haematite and are often amygdaloidal or vesicular.

The presence of interbedded though thin sediments of shallow-water type suggests that some flows at least were submarine. No pillow lavas have been found and most of the volcanics are of sub-aerial deposition. Some filled up shallow waters and others were temporarily submerged and covered by water-deposited sediments.

The Wooltana volcanics appear mostly to have been extruded from fissures, of which the main lineament along the Wooltana scarp foot was probably much the most important. Central vents are few and small.

vents are few and small.

The association of volcanics with lineaments often known to be faults, together with the combination of predominantly subaerial effusion with some shallow water sedimentation has been explained experimentally by E.S. O'Driscoll (pers. comm.). In producing domes and basins by shear folding techniques he has demonstrated that the hingeline is a nodal line which combines the zone of maximum weakness with the meeting point of ground, air and water. Further it defines the locus of maximum shear, maximum deformation and maximum rate of change of attitude, with all the attendant maxima of sedimentation rate, turbidites, fracture, brecciation and, in the inclined shear, overturning and thrusting.

Fig. 4

The fissure effusion of the volcanics could therefore be associated either with a prominent scarp due to block faulting or with a lineament showing no marked relief. Any present day relief along such a lineament would have, of course, no necessary relevance to the environment at the time of effusion.

<u>Adelaide geosyncline</u>

The known occurrence of similar rocks <u>in situ</u> and in diapirs elsewhere in the Adelaide geosyncline suggests that either the original area of effusion was very much larger, or that other scattered occurrences exist, mostly now concealed. Because the erosion during and immediately preceding Sturtian time was intense but apparently local, the second suggestion seems more probable.

Even if only the northern half of the geosyncline is considered (i.e. about as far south as the southernmost known related rocks at Mount Remarkable) an area of 30-40,000 square miles may have been affected. Whether this was ever a complete cover of lavas or was in discontinuous but extensive spreads from local centres is uncertain. The Wooltana occurrence could itself be such a local centre, related to the known linear weakness along the Wooltana scarp foot. This could apply also to the Depot Creek (Wilkatana) occurrence, itself on a major fault. The almost invariable occurrence of Willouran volcanics in numerous diapirs at first sight suggests a complete coverage. But as the age of the beginning of doming at Blinman has been shown by Coats (pers. comm.) to be probably contemporaneous with Sturtian deposition, and as this doming may be the first surface expression of diapirism, it is possible that the diapirs are located on centres of volcanic activity which started in Willouran time and continued long after it, rather than local revelations of what lies everywhere below. Although there is no evidence of post-Willouran vulcanism at Blinman, other occurrences exist, e.g. at Chambers Bluff (Indulkana sheet) which could come within this category. There is also no certainty that some necks at Wooltana are not post-Willouran.

Wider Australian Correlations

The occurrence of precisely similar rocks at similar stratigraphic horizons in various distant localities, including Tennant Creek, N.T. (800 miles north-north-west of Wooltana) and Bauhinia Downs N.T. (950 miles north) as well as very similar rocks from almost certainly the same horizon over large parts of Western Australia, western New South Wales and western Queensland is of great interest. Making due allowance for erosional losses in a well-authenticated Australia-wide Upper Proterozoic glaciation and a widespread Permian glaciation, it seems reasonable to postulate an effusion of Proterozoic volcanics of Willouran age comparable, if not so continuous in extent, as the classic flood basalts such as the Deccan Traps, Drakensbergs and Keeweenawans.

Restricting discussion to South Australia and the adjacent areas, lack of knowledge of the basement geology of the great sedimentary basins and of those parts of the massifs masked by Quaternary deposits prevents even an approximate assessment of the real relationships with (for example) western New South Wales.

A major problem in South Australia is the age and structure of the vast area of igneous rocks known loosely as the

Gawler Range porphyry. This not only forms the Gawler Ranges as shown on most maps, but extends far to the north and is known near Kingoonya, at Tarcoola and for 100 miles north. Jack (1917) regarded it as an effusive lying on the Archaean gneisses. No study of the porphyry itself has yet been made. Much confusion about its age has arisen because of the discovery by Jack, repeated by Mawson (1947) of pebbles of Gawler Range porphyry type rocks in an arenaceous formation (Corunna conglomerate) lying east of the porphyry mass and of uncertain relation both with it and with other rocks in the geosyncline, where Sturtian glacial beds contain erratics of similar porphyry; and the discovery by Johns and Solomon (1953) of intrusions of Gawler Range porphyry in that same arenaceous formation.

At the time this paper was submitted in its original form as a thesis, the problem was unsolved. The author suggested then a genetic relationship between the Gawler Range porphyry and the Wooltana and other equivalent volcanics. At that time he was particularly struck by the similarity between the sequence of events in the Erongo complex of South-West Africa (Cloos, 1919) and a possible though unproved sequence in northern Eyre Peninsula. This, together with the petrographic similarity of the 'bomb porphyry' of Merinjina, Wooltana (T.S. 5265) and specimens of Gawler Range porphyry led him to suggest that the Gawler Range porphyry is 'an effusive mass formerly covered by, and possibly lying on, a lava of which the Wooltana and other volcanics are local remnants of the floods spreading further out (possibly, at Wooltana itself, locally more abundant extruded). This porphyry- lava complex could be .... a larger version of the Erongo complex of South-West Africa (Cloos, 1919). It would since have been deprived of its outer skin on the upper surface by erosion. The relatively minor occurrences of porphyry at Wooltana and their apparent equivalents (e.g. at Mount Remarkable) having been derived from a similar ultimate source.' It was further suggested that the intrusions of the Gawler Range porphyry into the Corunna conglomerate were a late phase (it should be noted that these lie well east of the main outcrop of the porphyry) and, following Jack, that the Moonta Porphyry was also genetically related, and was possibly a deeply eroded feeder.

The economic importance of a study on these lines was emphasized, the Wooltana volcanics having copper and gold mineralisation, and considered with the Gawler Range Porphyry to be the ultimate source of the widespread copper mineralisation of the Mount Lofty - Flinders Ranges, and the Moonta Porphyry being known to be the host rock for very rich copper lodes. While the mineralisation actually in the Wooltana volcanics and the two porphyries is of course magmatic (if often structurally controlled) it is suggested that much of that in the Adelaide System sediments is of the submarine exhalative-sedimentary type (Oftedahl, 1958). The widespread distribution of copper and other minerals in sediments known to occur in extensive basins crossed by numerous lineaments along which volcanics occur suggests that gas emission accompanying the volcanic lavas and tuffs caused chemical reaction with seawater which by marine circulation led to mineral deposition far beyond the emission areas.

In 1961 a sinuous traverse of the Gawler Range porphyry outcrop and surrounding areas was made with B. P. Webb and J. Johnson. The discovery that the rocks at Roopena included by Miles in his 'Younger Dolerite' suite are identical with the typical Wooltana amygdaloidal trachytes gave immediate encouragement. The discovery of definite extrusive rocks (volcanic breccia, volcanic glass and tuff) at one of Johns' and Solomon's intrusions and elsewhere followed. It was immediately evident that the 'Gawler Range porphyry', though possessing a very strong identity in that red porphyritic sodic rhyolites are by far the commonest rocks, is nevertheless a great volcanic complex.

In a report on this reconnaissance the fact that the gold and tin mineralization at Glenloth and Tarcoola is closely associated with variants of the typical Gawler Range porphyritic rhyolites was emphasized.

The author's later discovery of huge intersecting circular structures up to 35 miles in diameter (possibly 50 miles) and definite central vents parasitic to these, both associated with major straight lineaments suggests that both circular and straight fissures were the major sources of a vast but quiet effusion of rhyolite lava in the Gawler Ranges, with local explosive central vents. The relationship of this to the Wooltana, Oraparinna, Roopena and other trachytes, though certainly genetic, needs further study.

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APPENDIX

Analyses of Wooltana volcanic rocks by H. W. Sears, Australian Mineral Development Laboratories. Specific Gravities by Geophysical Section, Geological Survey, of South Australia.

	Epidotized trachyte Wooltana: Woodnamoka Well (TS.3228)	Trachyte Wooltana: Triangle of Volcanics. (TS.3194)
SiO_2	53.2 %	59.2 %
Al_2O_3	12.3	11.2
Fe_2O_3	10.92	12.07
FeO	0.73	nil
MgO	2.36	0.73
CaO	15.8	2.02
Na_2O	0.16	0.24
K_2O	0.15	10.2
H_2O-	0.31	0.17
H_2O+	0.84	0.50
CO_2	0.71	2.22
TiO_2	1.42	1.02
P_2O_5	0.13	0.10
SO_3	Nil	Nil
Cl	Nil	Nil
MnO	0.14	0.44
F[illegible]	0.03	-
Specific Gravity	2.86	2.75

All Plates and Figures are Missing