THE GEOLOGY OF THE CADNIA SHEET

by R. GRASSO.

A thesis to be submitted for the degree of Master of Science.

1960.

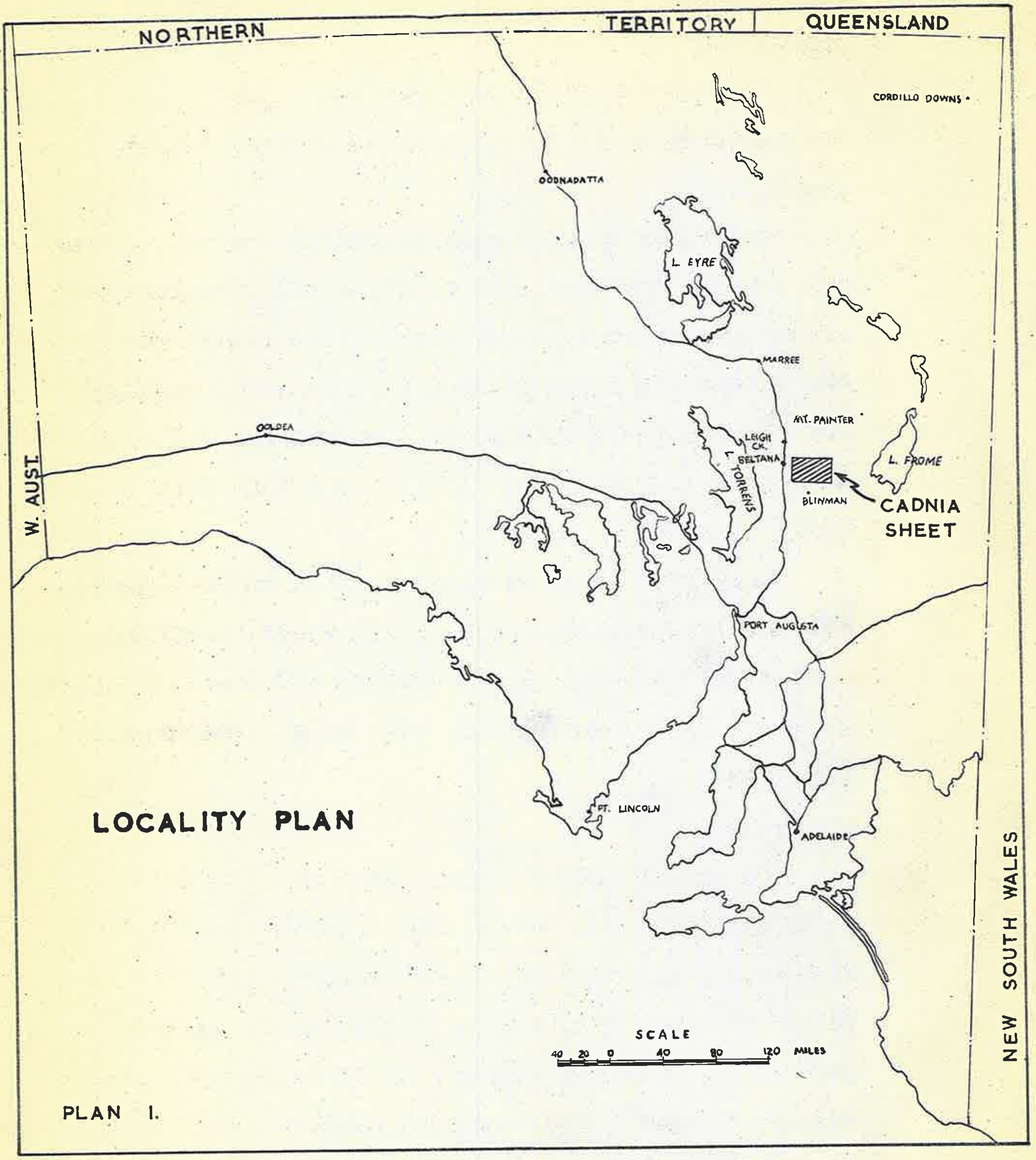
CONTENTS. PAGE.

LIST OF PLANS AND ILLUSTRATIONS

Abstract

The Cadnia military sheet covers portion of the northern Flinders Ranges; the area is composed of Proterozoic and Cambrian rocks which have been deformed into dome and basin structures. These have resulted from several forces; it is thought that they are due to pressures from the south and from the north, in conjuction with an east-west compression. Dolerite outcrops occur in the major crush zones, and are apparantly genetically associated with the emplacement of the copper orebodies.

Geomorphologic studies indicate that lineaments, are related to faulting and jointing. The old mines were found to be unworthy of further investigation; but limonite masses were found which warrant more detailed prospecting. During the field survey, attractive limestones were collected; and were judged to be suitable for terrazzo chips. These could prove important to the Terrazzo Industry.


NORTHERN
TERRITORY
QUEENSLAND
CORDILLO DOWNS
OODNADATTA
L. EYRE
MARREE
MT. PAINTER
LEIGH CK.
BELTANA
L. TORRENS
L. FROME
BLINMAN
CADNIA SHEET
OOLDEA
W. AUST.
PORT AUGUSTA
PT. LINCOLN
ADELAIDE
NEW SOUTH WALES
LOCALITY PLAN
SCALE
40 20 0 40 80 120 MILES
PLAN 1.

INTRODUCTION.

Explanation

The study of the Cadnia military sheet was undertaken as basis for a Master of Science thesis.

Location

The Cadnia sheet covers an area of over 500 square miles in the northern part of the Flinders Ranges. Its north-east corner is about 50 miles south-west of Mt. Painter and located about 400 road miles north of Adelaide, (fig.1.) between the 138°30'E and 139°00'E longitude, and the 30°45'S and 31°00'S latitude.

Type of Geology

Except for a few small outcrops of Tertiary pebble-beds and some shallow alluvium, the entire sheet has well exposed outcrops of Proterozoic and Cambrian rocks, which are folded and faulted into basins and anticline structures.

The Problem

The object of the investigation was to produce a photogeological plan of the area extracting as much information as possible from the photographs. The interpretations were then to be checked during a field investigation and the limitations of photogeological mapping in that type of terrain, using standard (1 inch : 60 chains) photographs, were to be established. Emphasis was to be placed on structure.

General

Actual field mapping was limited to 61 working days. Photogeological interpretations were checked, and areas which were not subject to reliable interpretation were mapped. The old mines were investigated and economic rocks and minerals were noted and appraised.

During the field study about 600 locality notes were made, over 400 specimens were collected and fossils (of lower Cambrian age) were found. Resulting from the rock collection 84 thin sections were cut, inspected and compared. Ore minerals were microscopically studied, while coloured shales, limestone and dolomites were inspected for their economic importance.

Previous Investigations

Dickinson (1944) mapped an area of about half a square mile in the vicinity of Sliding Rock mine, and in the same publication he discusses the economics of the Lady Lehmann mine. Sprigg (personal communication) has worked in the areas adjacent to Sliding Rock mine, Mt. Stuart and The Main Gap. No information is available of any other work which may have been done in the area, except for a few short reports in the South Australian Mining reviews, connected with the progress of various mines.

Howchin (1922), Mawson (1942) and Howard (1951) have published work on areas south of the Cadnia sheet, while staff of the Geological Survey of South Australia have mapped 4 military sheets (Angepena, Serle, Copley and Myrtle to the north and north-west of the area.

Acknowledgements

The writer is indebted to Prof. E.A. Rudd for suggesting the project and for his supervision. The co-operation of the Geological Section of the Dept. of Mines in arranging transport and camping facilities is greatly acknoledged, while many thanks are passed to Mr. E. Brock who assisted during the field investigation. Dr. A.W. Kleeman, Mr. R.C. Sprigg, Mr. R.B. Wilson and Mr. B. Fitzpatrick were particularly helpful at all times, and the writer wishes to acknoledge the great number of ideas that he gained from discussions with them. Sincere appreciation is expressed to Dr. B. Daly for his many suggestions and for the constant help throughout the project. Special thanks to the directors of Geosurveys of Australia Limited, for the extensive use of their Woodville Laboratories, and for permission to include their Copley and Parachilna geological sheets.

Geography

The area is so remote from the larger cities, that known geography is simple. The only towns near the area are Beltana to the west and Blinman to the south---both small towns, each having only a few homes. There are only three station homesteads within the actual sheet boundaries, and only the most obvious peaks and the larger creeks have names.

Accessibility

There are no rail or sealed roads running through the area. The old railway line to Leigh Creek passes Beltana, about 12 miles west of the western boundary of the Cadnia sheet. The main road follows the railway to Beltana, where a track can be taken to enter the area. Because of the small number of homesteads, graded roads are few; even tracks leading to dams, well and bores, are limited in number and therefore much of the field investigation had to be done on foot.

Climate

The climate is a mixture of continental-subtropic and mediterranean types with an annual rainfall varying from 8 to 10 inches over different parts of the area. Most of the rain falls during February, March, June, November and December, but summer rains are most important and are often accompanied by violent thunder and electrical storms. During summer, winds appear to be influenced by the Monsoons of northern Australia; and the area experiences a cöntinental type climate having high day temperatures but cool nights. The winter is cold and windy and is affected by the Mediterranean climate of southern Australia.

Vegetation

Except for local gardens at station homesteads, all the vegetation in the area is of natural origin and offers some scope for geobotanical studies. Native Pine (Callitris spp) almost invariably is limited to rugged slopes of "Pound" quartzite and to a less degree on "A.B.C" quartzite outcrops. Wild Tobacco (Nicotiana spp.) thrives on Cambrian limestones and does well in the vicinity of Irish Well. Mulga grows well on tillite and Wild Rhubarb favours the flat depressions caused by erosion of grey and chocolate Marinoan shales and slates. Gum and Tee trees are wide spread and are generally associated with creeks. Salt Bush, (Atriplex spp.) Wild Marigolds and other small shrubs are widespread throughout the area, and while they may prefer some particular formation, they are not limited to it.

Drainage

During the dry seasons there are only a few flowing creeks. These carry water originating from springs and which eventually disappear down stream in porous rocks. With the exception of a few superimposed streams, such as the Wirrapowie and Pinda creeks, the area has a subsequent drainage system.

The central basin is drained by the Narina creek and its tributaries, which when followed down stream, becomes the Wirrapowie creek and later discharge into Lake Frome as the Bendieuta creek. Because of the enormous catchment area, (over 300 square miles in the Cadnia sheet alone) rapid but temporary flooding often occurs during rainstorms.

In the north eastern part, tributaries of Sliding Rock and Warrioota creeks drain the area. The creeks are extensively controlled by quartzite outcrops and take advantage of fault lineaments. They unite near Beltana and flow into Lake Torrens as Warrioota creek.

Tributaries of Breakfast Time and Blackfellows creeks are the main watercourses of the south western area. Both of these are structurally controlled by the complex geology of that area. They eventually join and flow into Lake Torrens as the Breakfast Time creek.

The main water divides are "Pound" quartzite ranges which cut the Cadnia sheet into two irregular collecting grounds; that which is drained by creeks flowing west into Lake Torrens, and the other whose water flows into Lake Frome. The actual creek directions are largely influenced by geology.

Hydrology

Much use is made of natural springs by the station owners and shallow wells usually produce sufficient water for stock purposes; consequently only a few bores have been sunk to test the underground water supply.

In the Sliding Rock Mine area, enormous quantities of potable underground water have been proved by the fact that during the past 13 years, about 100,000 gallons of water per day have been pumped to Leigh Creek, The water must be trapped in fault zones, as the country rock is massive, nonporous limestone. The large quantity of water that is available, gives us an indication of the space that faulting has created. ~~to accomodate the large volume.~~

An untested area which should possess much water is the Narina basin. Since there are natural springs in the south east part of the basin, it is possible that water at shallow depth would be available anywhere in this section, where springs indicate that the water comes from stratigraphic beds rather than fractures. The natural topographic slope of this large catchment area, is to the south east and therefore any water which penetrates the surface, will tend to flow in that direction; especially since in the catchment area, it is aided by flat east-dipping strata. Water should also be availmble (at slightly greater depth) nearer the centre of the basin where most accumulation takes place. There, the aquifers must be saturated to cause water to flow in the south east, where reversal of dip brings the aquifers to the surface.

As most of the wells inspected were located at the intersection of creeks and faults, it is probable that small quantities of shallow underground water can be obtained practically anywhere along watercourses; especially if wells are sited in fault zones.

While the quality of most underground water is excellent, there are a few wells whose waters are only suitable for stock. All these were found to have been sunk in the Marinoan quartzite and shale formation. Apparantly the best drinking water comes from Cambrian limestones, in which most of the deeper bores have been located. Since wells are sunk to a depth of less than 40 feet, (often under 15 feet) station owners bore for water only when shallow wells have failed. An inspection of wells, which have been excavated in practically every rock type, indicates that in search for new water supplies, the only rocks to avoid are those of the Marinoan quartzite and shale formation, immediately below the "A.B.C" quartzite. If deep boring is to be done, then the site should be picked by a geologist or by someone that understands the structural enviroments and fluid movements in that area.

Geomorphology

Most of the terrain is mountainous and therefore, "The average elevation of the land" does not have much significance. However, to get an idea of the topography it is best to note that peaks stand about one or two thousand feet above the valleys which in turn are about 2,000 feet above sea level. The topography is classified as "Young".

The present land forms are the result of the Australia-wide movements, which were active during the Pliocene-Pleistocene times, and known as the Kosciuskan epoch. During that tectonic period, most of the movements responsible for the present shape of the Flinders Ranges were produced; but as the Adelaide Geosyncline has experienced minor and major movements since early Cambrian times, it appears that while movements have periodically taken place since then, a major rejuvenation along the old lineaments occured during the Kosciuskan epoch, giving us the present land forms. Movements along some lineaments have continued right up to the present; and in many places elevation is keeping ahead of peneplanation. The Mt. Stuart north-east scarp is a very good example showing considerable movement during fairly recent times. Here a scarp, which rises about 500 feet above the adjacent land within a horizontal distance of about 400 feet, indicates that only little slope-debris has accumulated on the lower side of the fault, and that uplifting has progressed faster than peneplanation.

Black Range on which stands Mt. Hack (3,700 ft.) forms an east-west elevated mass overlooking the lower country to the south. The range is of "Pound" quartzite formation having a northly dip. Near Mt. Hack, bedding dipping at 25° causes the harder quartzite bands to protect the softer underlying sandstone members against rapid erosion. West of Mt. Hack the dip steepens considerably and at Black Range Spring it is 80°. Here very little cap-protection is

DIAGAMATIC SKETCH OF THE NARINA BASIN

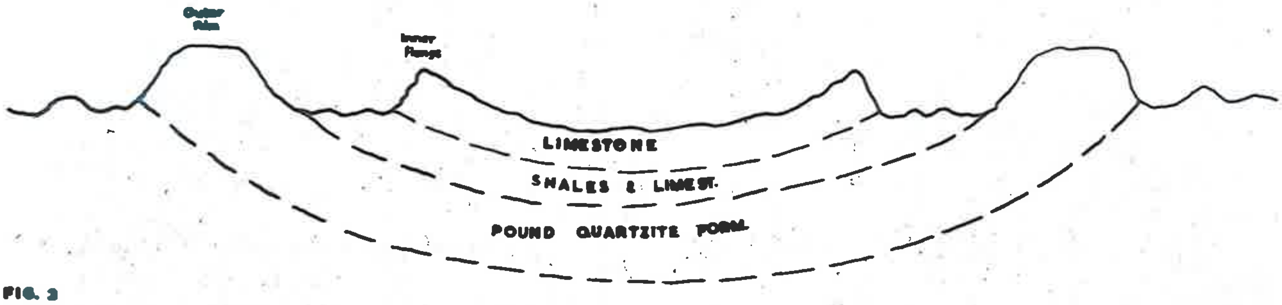


FIG. 2

offered by the harder quartzite members, and the marked change in dip is accompanied by a drop in elevation of about 500 feet. Further, sheer cliffs under Mt. Hack, which have been produced by original faulting and which now, due to cap-protection, expose impressive geological sections hundreds of feet thick, are proof of the relationship of this geomorphological phenomenon to mountain building.

The central portion of the Cadnia sheet is a geological basin which incorporates two topographic basins, one inside the other. Fig. 2. The outer rim is "Pound" quartzite formation and is far more massive and spectular than the inner limestone flange. Patawarta Hill (3060 ft.) is the highest point on the outer rim, while Mt. Tilley and Ben Lomond are two of the Highest peaks on the inner flange. The strong geological control that has influenced the develop ment of the land forms is obvious by studying the geological plan. In the main, the forms have been dependent on structure environments and on the properties of the rocks that have been involved. The outer quartzite rim follows the regional strike and is merely the "Pound" quartzite outcrop. Its medium geological dip and its rather hard character have resisted erosion much more that the adjacent softer rocks, which have weathered to levels up to 1,000 feet below the quartzite. In going towards the centre of the basin the beds dip at a lower angle, creating favourable conditions for hard-band, shallow-dip cap-protection. This is the case in the second rim where a thin, hard, limestone, which in other areas has only a minor effect on physiography, has protected the underlying sediments, giving rise to the elevated flange averaging about 200 feet above the soft rocks separating the two rims.

Between the basin and the Mt. Stuart uplifted area, the topography is very uneven and land form variations correspond to variations is rock formations. A low, relatively even valley, which geologically is occupied by a soft shale formation between the "A.B.C." quartzite and dolomite sediments, can be followed practically all the way around the anticline by its low physiographic features. Similarly, limestone beds nearer the centre of the anticline can be traced by the typical jagged hills, which are characteristic of interbedded limestone and shale formations. The Mt. Stuart uplift is delineated on the west by a north-east fault, along which recent movement has caused a very pronounced scarp. On the downthrow side of the scarp, the topography is semimature and outcrops take the form of rounded hills, except where low dipping quartzites or geological processes are responsible for elevated masses.

In the north-east, the Irish Well syncline shows changes in morphology and is an ideal area for photogeological interpretation. Throughout this syncline the various limestone members can be traced by the patterns they impart to the

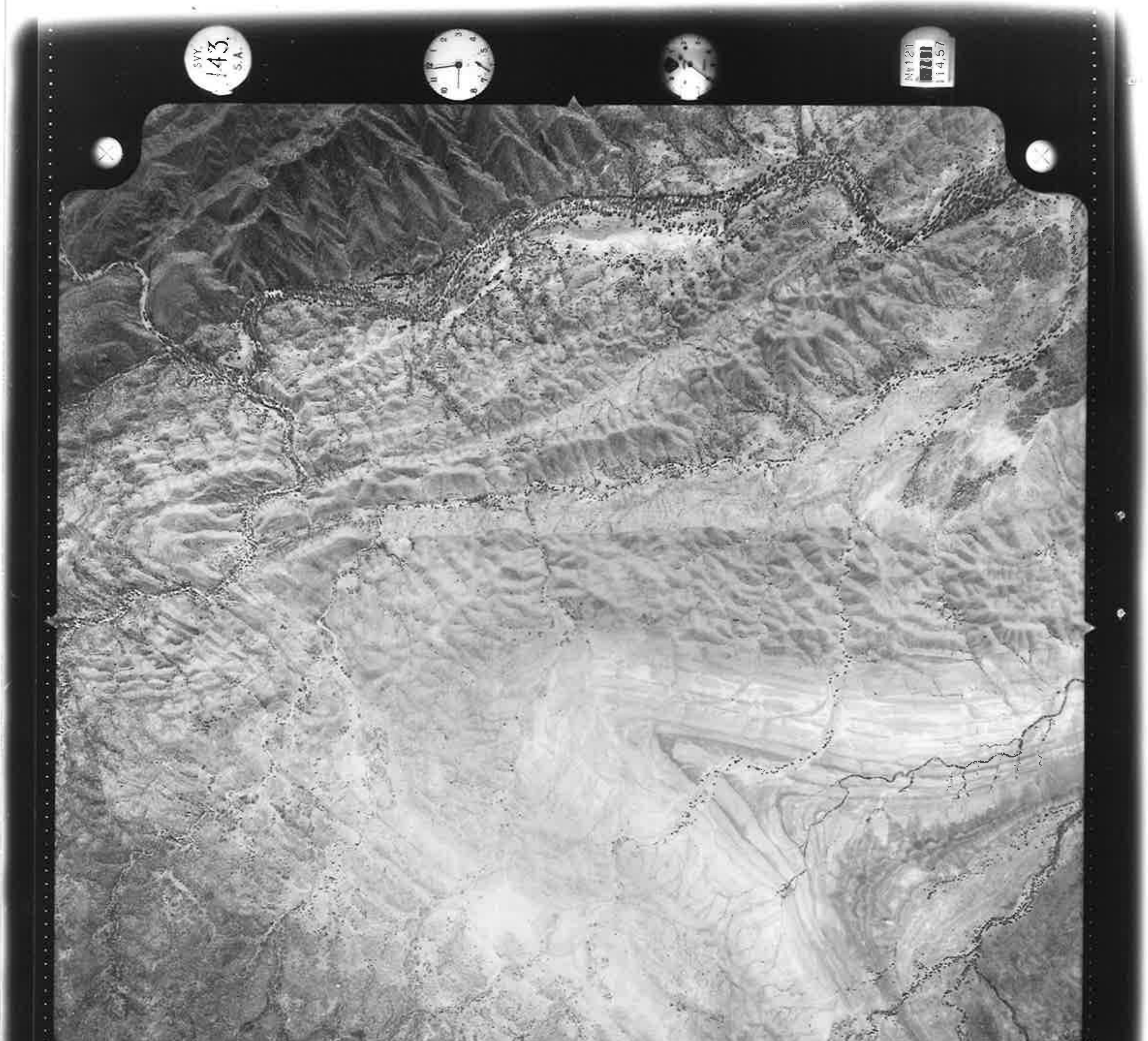


PHOTO. I

topography. Geomorphology here is a very important mapping aid, because the limestones (even the argillaceous ones) are all very similar in appearance, and would be very difficult to map using field methods alone. On the other hand, quite accurate mapping was possible by concentrating on geomorphology during interpretation. Photograph No. 1. shows some of the outcrops of the Irish Well syncline.

As in any other area, the morphology of the Cadnia sheet has been mainly dependent on geology and climate. Although geological influences are varied for each particular locality, it is obvious that the rock type, dip and strike of sediments, folding, faulting and jointing all play their own parts in forming the local topography. Therefore in photogeological investigations all these factors, which are incorporated in geomorphology must be considered, as the topography of any particular formation can appear very similar to that of an entirely different formation under special geological influences.

Photogrammetry

/The photographs used are 7" x 7" double weight, matte-surfaced contact prints. They were taken from an average height of 18,400 feet using a camera whose focal length was 114·57 m.m. The area was completely photographed between 11 a.m. and noon on the ninth day of October 1954. The scale of the photographs is approximately 1 inch to 60 chains.

Five runs were necessary to cover the area, and 85 photographs were used. The direction of flight was approximately east-west. The overlap in the east-west direction is good; (about 60%) but that between adjacent runs is uneven and sometimes lacking.

A slotted template plot was made, but no survey information was available and the plot was not controlled.

A N-S cross-section was made of the area. (Section No. 3.) The vertical scale is not exaggerated and shows a true relationship between height and horizontal distance. For the purpose of this section, the elevations of 45 points were calculated by aerotriangulation. Mt. Hack was used as datum; and its elevation was assumed to be 3,700 feet above sea level.

Photogeology

In preparing the photogeological interpretation, a study was made of the topographic properties of the area. This involved the study of land forms and vegetation, from

CAINOZOIC		LIMESTONES AND DOLOMITES	
CAMBRIAN		SANDSTONE AND QUARTZITES	
PROTEROZOIC	MARINOAN SERIES STURTIAN SERIES	SHALES AND SILTSTONE	

Scale 1": 60 Chains approx.

PHOTO. 3

which the geology was translated. The technique was a subconscious combination of geomorphological and geobotanical characteristics, which involved the study of elevations, shapes, patterns, lineaments and tone. Stratigraphic boundaries were followed along similar-looking topography; the structure was established, reconstructed and later checked by field mapping.

Only slight difficulty was experienced in establishing a fairly accurate geological plan from pure photogeology. (See Photo No.3.) The three basic rock types, quartzite, shale and limestone were identified satisfactorily on the photographs and were generally followed over long distances. However, considerable difficulty was met in deformed areas such as Nuccaleena, Pinda Creek and Roebuck Ranges, where severe faulting has produced small disconnected outcrops. Most of the geology of these local areas was compiled from field information, because it was found that the small outcrops could not be followed over great distances; they all seem to have topography uncharacteristic of any special rock type; bedding could not always be traced; and to make matters worse, complicated fault systems prevented the construction of stratigraphic successions, from which identification may have been possible by the process of elimination.

Trend lines, (afterbedding) were among the most important information that was extracted from the photographs.

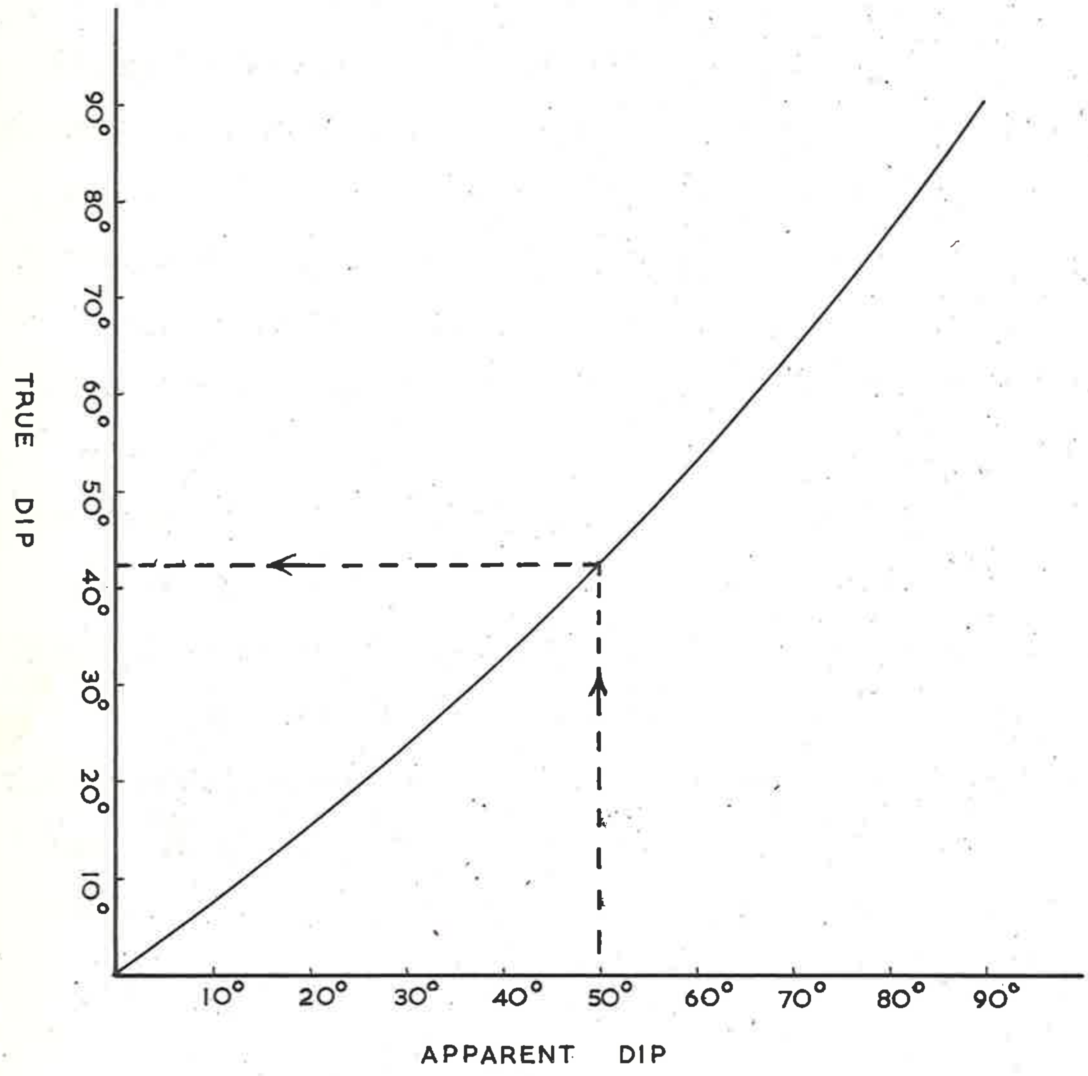


FIG. 12 STEREOSCOPIC CURVE

FOR EXAGGERATION OF 1·32

Bedding can be easily recognised on all rock types of moderate outcrop, except shales; further, many excellent dip slopes appear on the photographs, which are suitable for photogeologic dip measurements. The vertical exaggeration of the photographs for a " Sirius " standard mirror stereoscope was calculated to be 1·32. Using this value, Fig. 12. was prepared, which gives the relationship between the apparant angle, as estimated under a " Sirius " standard mirror stereoscope, and the true angle, as may be measured in the field. All dip measurements that were field-checked were found to be accurate within 10 degrees. While this does not appear to be ~~too~~ very accurate at first sight, it must be understood that the accuracy rests on the ability to estimate the size of an angle in three dimensions. Three accurate dip measurements were also made using a stereocomparagraph. These were deduced from first principles viz. $\tan \text{angle} = \frac{dh}{dx}$ where dh is the vertical distance between points A and B, dx is the horizontal distance between the same points. the values were checked with field readings which were up to 3 degrees different. The discrepency is considered as negligible; especially since it is most likely that the true values would be nearer to those calculated rather than the measured ones.

Because it is generally known that some creeks flow, for at least part of their courses, along fault lines, it was

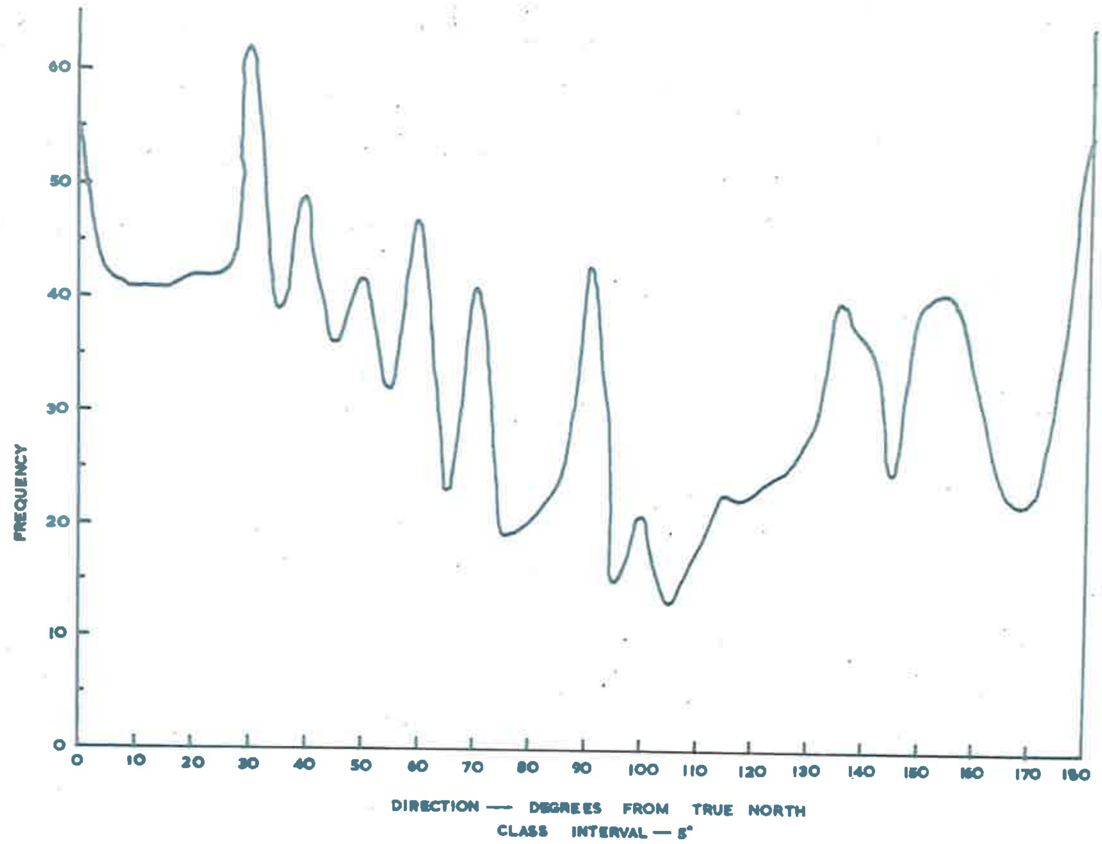


FIG. 13 FREQUENCY PLOT OF LINEAMENT DIRECTIONS (BASED ON 1204 READINGS)

decided to investigate the most obvious lineaments of the area. Consequently the directions of 1207 lineaments were each measured to the nearest 5 degrees. They were then segregated into groups at 5 degree intervals, and a plot of frequency against direction was made. (Fig. 13.) The resulting curve was then compared with similar curves plotted for faulting and for jointing; the study indicated that there is a strong connection between topographic lineaments, faulting and jointing.

As the results of this section of the research are connected with the structure of the area, a more detailed discussion will be undertaken later in this report.

THE PRECAMBRIAN SUPPOSED STABLE NUCLEI

(After Hills)

FIG. 4

UPPER PROTEROZOIC

LOWER PROTEROZOIC

PRECAMBRIAN SEAS (After David)

FIG. 5

GEOLOGY

The Geosyncline Setting

The area can be regarded as being situated in a central position within the Adelaide geosyncline, which has been traced from Kangaroo Island, through the Peake and Denison Ranges to Central Australia. Fig.4. shows the reconstructed position of the Adelaide geosyncline with respect to the neighbouring Precambrian shields. The south-western edge of the geosyncline was flanked by the eastern extremity of the West Australian or Yilgarn shield, while Willyama and some of the granitized rocks to the north of Broken Hill, formed part of the eastern margin. The enviroments in the northern parts of the geosyncline are obscure, but it is not unreasonable to visualize that the geosyncline crossed Central Australia and occupied most of north-west Australia, as is shown in fig. 5. In studying that part of the geosyncline south of Marree, a structural plan shows that deformation of the geosyncline was probably brought on by forces coming from the present Murray basin, and which were directed towards the Lake Torrens area.

Contemporaneous with this movement or a little earlier, structural activity was experienced in the Marree-Murnpeowie district, introducing southerly directed forces. The Cadnia and Blinman areas seem to be situated at the extremities of both sets of forces, and have been distorted less than areas to the north and south where stronger forces have produced greater movements.

The General Geology

The regional geology of the Cadnia sheet is not extremely complicated. Apart from a few small areas which have been severely broken, the geology was established without much diffiøulty. The main rocks of the area are of late Sturtian to early Cambrian age. There are a few flat-top remnants of Tertiary beds, but apart from these, and some alluvium, there is nothing to represent the span of time from the Cambrian to the present. It is possible that post Cambrian sediments originally existed; and that they have all weathered away. However, the Triassic coal deposits at Leigh Creek and at Quorn, which lie unconformably on Precambrian sediments, are indications that most of the known part of the geosyncline was land during middle and upper Palaeozoic times. ?

A study of formation thickness shows that in the Cadnia sheet, there is fairly good representation of lower Cambrian beds. The "Pound" quartzite attains a thickness of over 4,000 feet, while the limestones above it are over 10,000 feet thick in the Irish Well syncline. The dolomite shales immediately below the "Pound" quartzite have wide lenses of solid limestone which are sometimes greater than 100 feet thick, but the "A.B.C." quartzite, which compares favourably in thickness with the "Pound" quartzite near Quorn, is poorly represented in the Cadnia sheet. In places it is so thin, that it cannot be identified. The Marinoan chocolate and grey slates and quartzites attain a thickness of over 9,000 feet; while thick lenses of limestone are interbedded with shales at the top of the Sturtian. The middle and lower Sturtian is poorly represented; unfortunately, the few areas that contain Sturtian beds are so fractured, that diffuculty was experienced in establishing a stratigraphic column.

In the western margin of the Cadnia sheet there are some outcrops of " Duricrust." These are not related to normal sedimentation and are remnants of Tertiary silicification.

Some of the crush zones which contain dolerite dykes also contain unusual calcareous rocks. These have been classified by Webb as diapiric outcrops of Willouran sediments. However, the writer collected rocks showing gradations from a normal limestone to a dolerite and therefore assumes that the unusual rocks are doleritic contaminations of the calcareous "Country rock."

Stratigraphy

The stratigraphy of the area has been deduced on a regional basis, and while an infinite amount of work could still be done in studying the finer details of sedimentation, it is felt that the information already extracted, has produced a generalized but useful representation of the stratigraphy in this part of the Adelaide geosyncline.

The Proterozoic Era

The Sturtian Series

Tillites are the oldest sediments that outcrop in the Cadnia sheet. Severe faulting has affected each of the areas in which tillites were found. North-east of Warraweena H.S., impressive outcrops of boulder tillite are faulted against "Pound" quartzite formation, which is some 15,000 feet stratigraphically above them. Near the Main Gap in the Pinda creek, there are outcrops of both boulder and fluvioglacial tillite. These are also faulted; and it is thought that the tillite in the southern margin of the adjacent crush zone, has been torn from the outcrops near Pinda creek. In this area the fluvioglacial tillite is an argillaceous sandstone associated with quartzite, limestone and slates; but unfortunately, faults have cut out most of the upper Sturtian formations. Another tillite locality was found south-east of Moolooloo H.S. where small

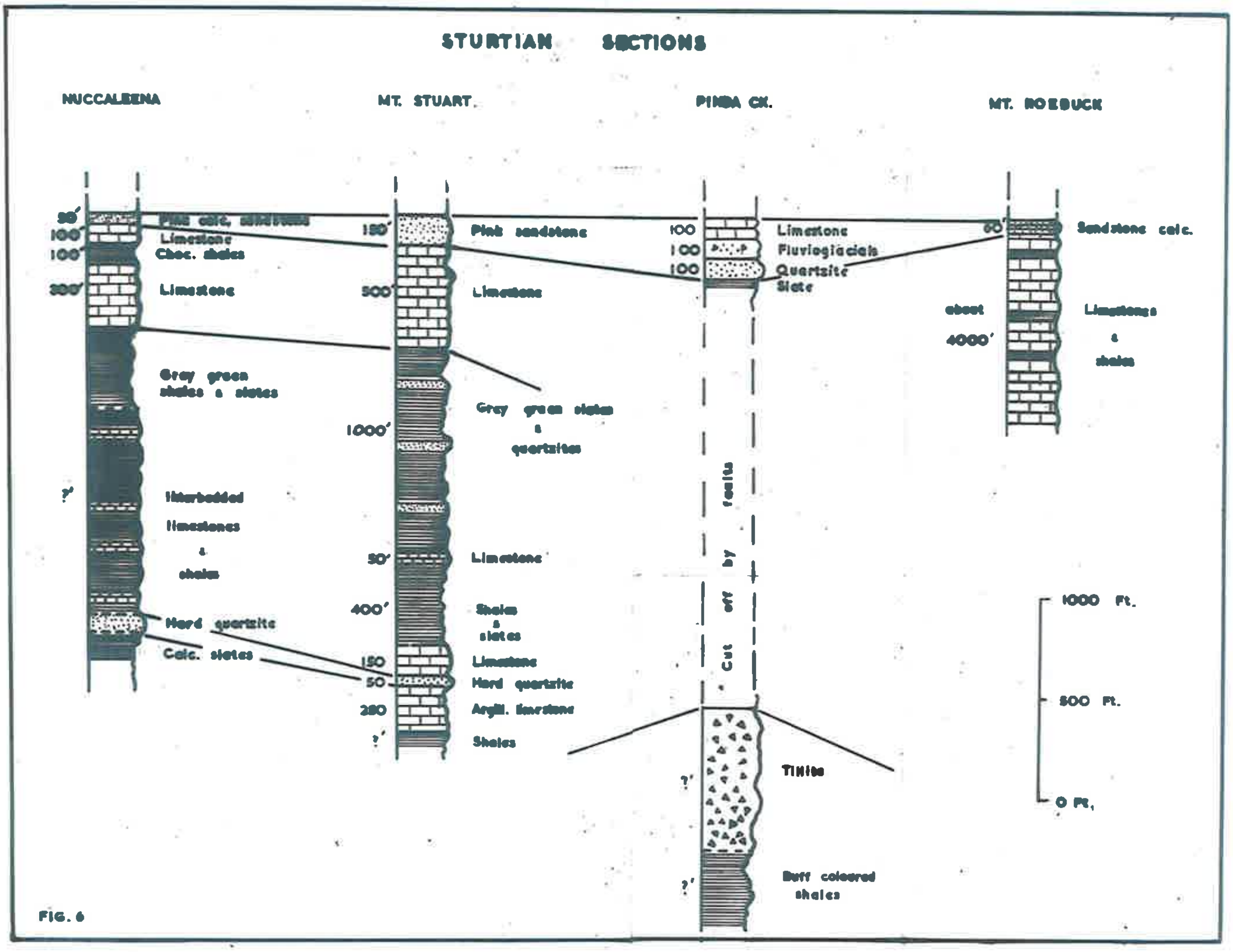

STURTIAN SECTIONS
NUCCALEENA
MT. STUART.
PINDA CK.
MT. ROEBUCK
100'
100'
Limestone
Choc. shales
300'
Limestone
Grey green shales & slates
?'
Interbedded limestones & shales
Hard quartzite
Calc. slates
150'
Pink sandstone
500'
Limestone
Grey green slates & quartzites
1000'
50'
Limestone
400'
Shales & slates
150
Limestone
50
Hard quartzite
280
Argill. limestone
?'
Shales
100
Limestone
100
Fluvioglacials
100
Quartzite
Slate
Cut off by faults
?'
Tillite
?'
Buff coloured shales
60'
Sandstone calc.
about 4000'
Limestones & shales
1000 Ft.
500 Ft.
0 Ft.

FIG. 6

outcrops were found in a creek bed. Since thesd are just outside the sheet boundary and appear to have been uplifted by igneous activity, no detailed work was done to account for their freak stratigraphic position.

Above the boulder tillite, there is a thick formation of grey and green slates. It was impossible to give a reliable estimate of the thickness for these slates, because all the areas visited were severely broken. However, by comparison with equivalent beds outside the area it appears that the thickness can be as much as 4,000 feet. In the top half of the slate formation, sandstones and limestones lenses are often sandwiched within it; one of them, a 50 foot band of very hard quartzite resembling some of the coarser varieties of the "A.B.C." quartzite, has been used as a "Marker bed." Near the top of the Sturtian series, limestone lenses become prominent and in the Mt. Stuart area they measure about 500 feet in thickness. Chocolate slates often separate the limestone members. The very top of the series is marked by a sandy horizon about 100 feet thick. It outcrops as a pink coloured sandstone which is sometimes calcareous, and which often contains particles of varying grain size. This sandstone is a wide-spread feature and marks the close of the Sturtian period. Fig.6. shows the correlation of sections throughout the area.

THE MARINON SERIES (generalized)

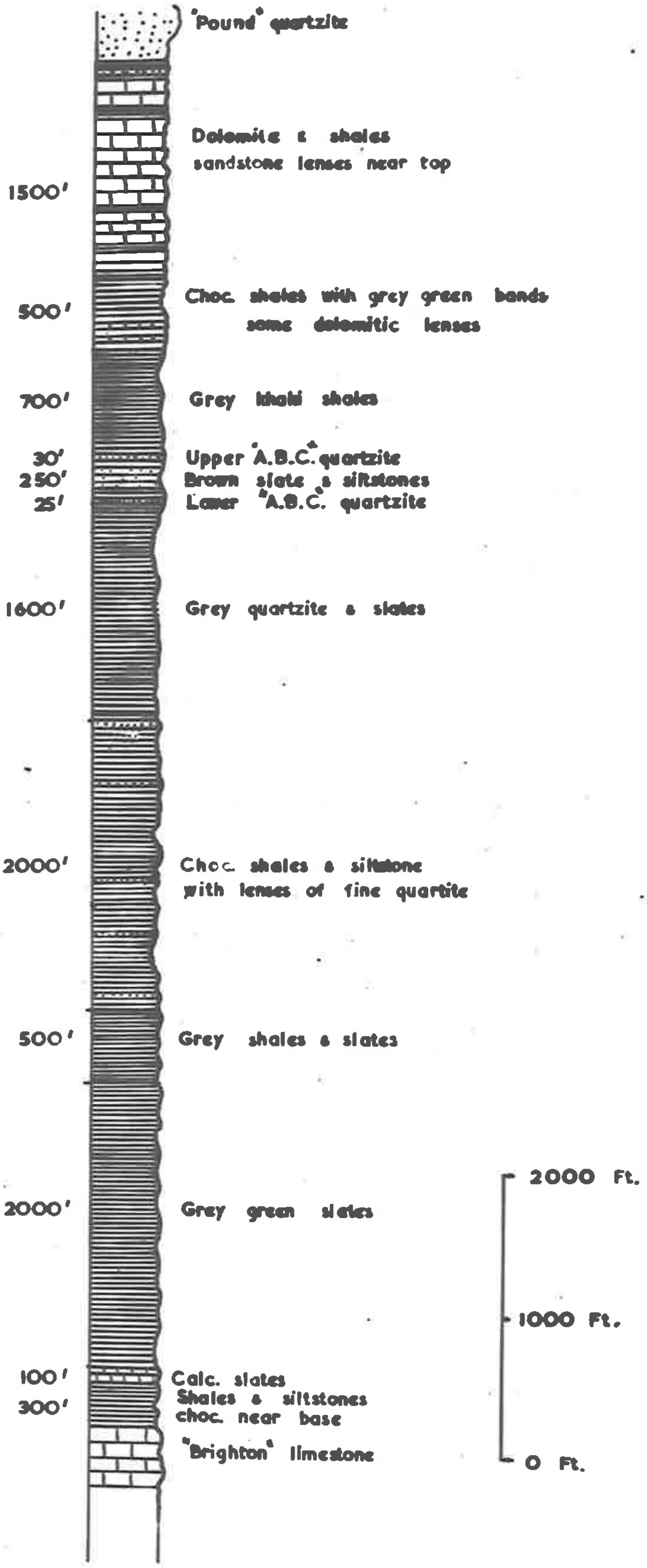


FIG. 7

The Marinoan Series

About a third of the Cadnia sheet is covered by Marinoan beds. These are far less deformed than the underlying Sturtian; consequently the stratigraphy, which has been deduced from reliable sections, gives an accurate picture of Marinoan sedimentation. The Marinoan series is characterized by red-bed conditions, while the underlying Sturtian is essentially a glacial and fluvioglacial succession. There is no visible unconformity between them and the division is based on major changes in lithology. (fig.7.)

Immediately on top of the Sturtian, there is a 200 foot horizon of chocolate and khaki-green slates. These together with the overlying grey-green beds are easily weathered into valley-type depressions hundreds of feet deep. The grey-green sediments which are sometimes separated from the underlying beds by a calcareous horizon, consist of jointed and well bedded slates approximately 2,600 feet in thickness. These pelitic rocks indicate that deposition must have occured while the landmasses which fed the geosyncline were of low elevation. This formation is characterized by its green colouration; and except for the top 500 feet which are grey shales and slates, the rest are essentially of green colour. Following this period of pelitic sedimentation, the presence of 2,000 feet of interbedded siltstones, slates and shales indicated that the adjacent landmasses were gradually being elevated. also marked climatic changes occured which account for the chocolate colouration of all the sediments of this period. Above this formation, there is a 1,600 foot horizon of interbedded quartzites and slates. These are mainly grey in colour; and show a progressive increase in grain-size as the top is approached. Apparantly elevation of the nearby land masses increased, and the interbedded quartzites are indications of occasional abrupt movements. The overlying "A.B.C." quartzite formation acts as a protective cap for these softer rocks which produce a very irregular and cavernous outcrop. The thickness of the "A.B.C." formation varies considerably even within the Cadnia sheet. However, it appears that it is thickest near Artimore, where it is composed of a grey-brown slate and siltstone horizon sandwiched between two quartzite members. The lower quartzite is about 25 feet thick and is separated from the upper 30 foot band by approximately 250 feet of slates and siltstones. The behaviour of this formation is so erratic that conditions of sedimentations must have varied considerably throughout the geosyncline. its presence marks a general, but irregular upheaval of the contributing landmasses. Above the "A.B.C." formation there is a 1,200 foot zone of khaki-grey and chocolate slates and shales. These are fairly uniform in appearance, composition and grain-size, and are overlain by about


UNCONFORMITY
PHOTO 2
Scale 1: 60 Chains approx.

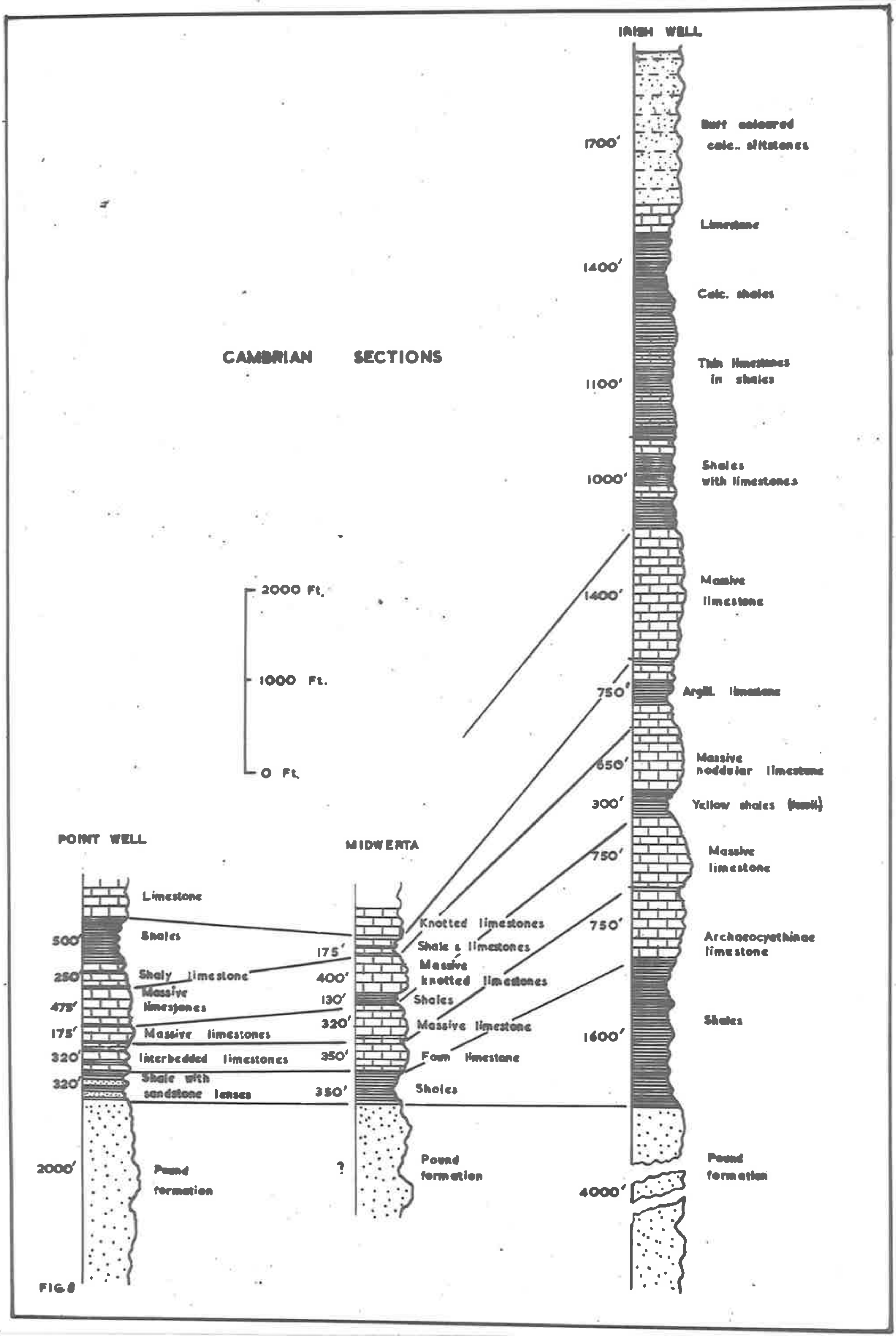
1,500 feet of dolomitic shales. After the "A.B.C." sediments were deposited, there was a long period of time in which only fine sediments entered this part of the geosyncline. The adjacent land must have been eroded to a peneplain; the slow "run off" must have caused considerable Chemical decomposition. Resulting from this, much soluble material was introduced into the geosyncline, and eventually precipitation of carbonates commenced. As time went by, more soluble material entered, and precipitation increased. Gradually precipitation became the more important sedimentary process and occasionally there would be a period when almost no argillaceous material was being introduced, and the clear-water conditions resulted in the precipitation of almost pure limestones. At this stage another mountain building phase was initiated; portions of the actual geosyncline were slightly effected as can be witnessed by the unconformity in the Pinda creek area. See photograph No. 2.. Probably resulting from a revival of mountain building in the adjacent landmasses, some of the geosynclinal slopes were increased sufficiently to start submarine slides. The carbonates which were the last sediments deposited suffered most; in their journey down, they were broken up, intermixed and reposited as "synthetic" clastics. They now outcrop as "brecciolated" dolomites, being made up of different coloured fragments of varying sizes. These dolomitic shales mark the end of Marinoan sedimentation and close the Proteroic era.

The Cambrian Era

Cambrian sediments are well represented in this area, where over half the area of outcrop is of Cambrian age. Recently, Dr. M.F. Glaessner identified Proteroic fossils in the "Pound" quartzite formation. This means that the "Pound" quartzite is of Proterzoic age and should have been discussed in the last section. However, since no positive steps have yet been taken to adopt the results of this discovery, the writer intends to continue using the old classification until the correct age is universally adopted.

Overlying the Marinoan dolomitic shales there is a large thickness of over 4,500 feet of quartzite members interbedded with a few thin shale horizons. The formation is well represented throughout the geosyncline and appears to be due to the major mountain building phase which was active at the close of the Proterozoic era. During the deposition of the "Pound" formation only shallow water existed on the western side of the present Flinders Ranges and consequently only a thin veneer of sediments was deposited there. This has been proved in the Wilkatana area, where drilling has shown a direct passage from fosiliferous limestone to the Marinoan chocolate formation; with the upper Marinoan beds and "Pound" quartzite formation missing. Apparantly the position of the geosyncline had moved east during late Marinoan times causing a regression over the western margin of the syncline. The regression must have been due to the uplifts that caused rejuvenation; and because the western margin of the geosyncline was uplifted, it would appear that the elevated mass contributing to the "Pound" quartzite sedimentation, must have been situated in the western side of the geosyncline. This means that the bulk of the sediments that gave rise to the "Pound" quartzite formation came from the west. (the eastern extremities of the West Australian shield.)

Above the quartzite formation there is what has been termed the "transition beds" these vary in thickness; but in the Irish Well syncline they are 1,600 feet thick. In the main, these are white, yellow, buff or grey shales that are easily weathered and which outcrop as ochreous beds containing limonitic concentrations. The horizon is famous throughout the state as a favourable bed for copper and manganiferous deposits. Near the base of this formation there are several thin bands of quartzite only a few feet thick. These are probably the final members of the "Pound" quartzite formation that were deposited before peneplanation restricted sedimentation to ~~pelites.~~ the pelitic type. Following peneplanation, trangression over the western margin of the geosyncline was



CAMBRIAN SECTIONS
2000 Ft.
1000 Ft.
0 Ft.
IRISH WELL
1700'
Buff coloured
calc. siltstones
Limestone
1400'
Calc. shales
Thin limestones
in shales
1100'
Shales
with limestones
1000'
Massive
limestone
1400'
750'
Argill. limestone
650'
Massive
noddular limestone
300'
Yellow shales (fossil)
750'
Massive
limestone
750'
Archaeocyathinae
limestone
Shales
1600'
Pound
formation
4000'
POINT WELL
Limestone
500'
Shales
250'
Shaly limestone
Massive
limesjones
475'
175'
Massive limestones
320'
Interbedded limestones
320'
Shale with
sandstone lenses
2000'
Pound
formation
MIDWERTA
Knotted limestones
175'
Shale & limestones
400'
Massive
knotted limestones
130'
Shales
320'
Massive limestone
350'
Foam limestone
350'
Shales
?
Pound
formation

FIG 8

considerable. Reef building was extensive and spread westward as the sea trangressed inland. Erosion was slow and chemical decomposition became important. The biological process of reef building, together with the chemical precipitation of carbonates became the main contributors to sedimentation. There were periods when very little argillaceous material was introduced from the adjacent peneplains and the resultant sediments were fairly pure limestones. Occasionally for short periods, greater quantities of argillaceous sediments were received, forming the thin bands of shale between the limestone sediments. These limestone-producing conditions continued for a relatively long time; but eventually signs of rejuvenation were indicated by the deposition of a sandy and calcareous siltstone which lies above the limestone succession. Further sediments were then introduced, but as this sandy and calcareous siltstone is the youngest Palaezoic member that outcrops in the area, no study was made of the nature of the overlying sediments. Fig. 8. shows a correlation of various Cambrian sections.

The Cainozoic Era

The Tertiary

In the eastern portion of the area there are several flat top hills which invariably lie adjacent to "Pound" quartzite outcrops. They are covered with scree material from the "Pound" outcrops and appear to be the remnants of some former ground level. These flat tops are composed of scree, pebbles and sandy material; they are up to 100 feet above the level of the average country. Invariably they slope away from "Pound" outcrops, indicating that they were gradual slopes adjacent to "Pound" outcrops during Tertiary peneplanation.

Silicification

Following the Tertiary peneplanation, a major, state wide period of silicification occured. In the western portion of the sheet, two localities of silicified rocks were found. An extensive outcrop which was followed for over 300 feet occurs near Breakfast Time creek, where silicification roughly followed the topography. The other locality is in the south-west corner where silicification does not appear to be connected to topography or stratigraphy. The presence of these Tertiary duricrusts signifies that in the western portion of the area little erosion has taken place since Tertiary peneplanation. Also the flat tops in the east, give some idea of the amount of erosion that has occured since rejuvenation. An estimate would be of the order of 150 feet in the east and possible under 50 feet in the west.

Igneous Activity

Only dolerite-type igneous rocks have been found in the area. While all known dolerite localities are in crush zones within pre-Cambrian rocks, it was noticed that the extensions of some of the faults leading to the crush zones also cut "Pound" quartzite and Cambrian limestones. Elsewhere in the state, intrusions and structural deformations have been given a lower Palaezoic age; however, in the Cadnia sheet we can only say that the intrusions were emplaced after Marinoan sedimentations and possibly after the deposition of the Cambrian limestones. Also since intrusive outcrops are limited to pre-Cambrian rocks, it would seem that during igneous activity the intrusives only penetrated the deeper sediments and did not reach the overlying younger ones. Allowing 15,000 feet for all Cambrian sediments, including the younger members that have been erroded, and say 5,000 feet for any other sediments which may have been deposited before diastrophism was effective, a figure of 20,000 feet is reached. This would be the maximum thickness of sediments that would have covered the intrusives, if we assume that the dolerites were early products of orogenisis. However, if igneous activity was a late stage process, we must account for the erosion that may have taken place prior to intrusion. Howard (1951) came to the conclusion that much erosion must have taken place before the intrusives of the Blinman dome were emplaced. If this is true, about 8,000 feet of sediments could be erroded off before the dolerites were intruded; even then, they would still be covered by about 12,000 feet of sediments. The two figures, 20,000 and 12,000 give us the limits to where intrusions were originally emplaced. The 20,000 feet also gives us an idea of the depth at which the "Pound" quartzite was deformed.

Mineralization

The very limited information that is available makes it difficult to establish the age or ages of mineralization. However, since the youngest primary ores occured in Cambrian limestone at Sliding Rock mine, it appears that mineralization must have been post dolerite intrusion. (the youngest dolerites are found in pre-Cambrian rocks, whereas the youngest primary ore exists in Cambrian limestone.) Further, chalcopyrite particles have been identified in some of the dolerites; indicating that mineralization was closely related to dolerite intrusions. Perhaps the ore bodies correspond to the top extremities of the doleritic masses; and would have represented a later phase of the magmatic emanations responsible for the intrusions. Although the various copper mines and diggings are located in rocks of different ages, it seems probable that they are all related to the same period of mineralization. There is no evidence to support more than one period of ore deposition.

Veins of Barytes have been found in Sturtian sediments. These are the redeposition of material previously extracted by magmatic waters from older sediments. No age determination is possible, but the emplacement could be associated with the same process as the copper mineralization.

As the mines will be described in detail later, no further mention will be made here regarding the origin of ore deposits.

Petrology

As dolerite intrusions form the only igneous rocks outcropping in the Cadnia sheet, petrology is almost entirely limited to that of sedimentary rocks. Both clastic and nonclastic sediments are wide spread, and form over nine tenths of the outcropping rocks.

Clastics

Practically all gradations of rudaceous, arenaceous and argillaceous sediments have been found in the area, including tillites, grits, sandstones, siltstones and shales. Often these occur in association with clastic or nonclastic limestones.

Nonclastics

These are mainly represented by the chemical and biochemical limestones which often have variable amounts of clastic impurities. They are all fine grained, and some have slightly recrystallized. A few limited outcrops of chalcedonic silification occuring in the western part of the sheet are further examples of nonclastic rocks.

Rocks of the Sturtian Series

Although the tillites are composed of a wide assortment of fragments, slide 341 indicates that there are abundant quartz fragments cemented in a clay-and-siliceous groundmass. The size of the fragments vary from ground-mass-particle size, to boulders many feet in diameter. The assortment of fragments is great; ranging from slate and siltstone to quartzites, breccias and even granites. Slide 538 represents a weathered fluvioglacial horizon in the Pinda creek area. It shows fragments of variable grain size composition cemented in a clay and ferruginous groundmass. The bottom of the upper Sturtian limestones is represented by slide 114. This is a thin section of a siliceous limestone lens containing subangular fragments of quartz and feldspar embedded in a limestone groundmass. The grains vary in size but average at about 0·2 m.m. diameter. Slide 183 is one of a more siliceous lens and can almost be classed as a calcareous quartzite. It is made up of subhedral quartz about 0·1 m.m diameter embedded in a calcareous groundmass. The rock shows signs of slight metamorphism and recent weathering has produced iron stains. Slide 116 from a different area, represents a similar limestone and appears to be closely related to the same horizon as the previous examples. The hieroglyphic limestone is recognised by its peculiar weathering and is thought to be equivalent to the Brighton limestone. It forms the top part of the Sturtian limestone and is represented by slides 122, 167, 124, 24, 140 and 140B. This horizon has an assortment of limestone lenses, most of which are metamorphosed and the thin sections show an abundance of recrystallised calcite. Quartz fragments, together with small amounts of clay minerals, are almost invariably present; but the quantities and grain sizes of the quartz particles change considerably from lens to lens. Immediately above the hierogyphic limestone there is a thin band of chocolate siltstone which is represented by slide 524. This clastic sediment has subangular quartz grains about 0·04m.m. diameter in a clay-ferruginous groundmass. The sandy bed marking the close of the Sturtian is characterized by slides 160, 162, 305A and 523. This sandstone is of special interest, not only because it closes the Sturtian period of sedimentation, but also because throughout the area it is characterized by its dirty pink colour. Under the microscope the thin sections show a "porphyritic" texture; large, well rounded quartz grains are embedded in a finer groundmass of angular quartz. Fragments up to 1 m.m. diameter have been measured which are surrounded by a variable sized groundmass averaging about 0·08 m.m diameter. This member is here correlated with Mawson's Elatina tillite.

Rocks of the Marinoan Series

Near the base there is a formation of interbedded slates and siltstones. Slide 311 represents a slaty horizon near the base of the series, and shows minute grains of quartz cemented in a ferruginous groundmass of clay minerals. Slide 22 is a thin section of a grey-green slate and it too, is siliceous. It is cut perpendicular to bedding and shows stratified layers of small quartz and feldspar grains. These are less than 0·01 m.m in diameter, and are surrounded by finer quartz grains and clay minerals. Progressing upwards, the grain size increases slightly, as is displayed by slide 283. The angular quartz grains of this slate are between 0·01 and 0·02 m.m diameter and stratification is enhanced by ferruginous bands between the quartz and clay layers. As the grain size increases, thin beds of fine quartzite are interbedded with the siltstones. Slides 31, 10, 9, 7, 20, 195, 80, 79, 291 and 19 are thin sections representing the various interbedded siltstones, while slides 8 and 310 are typical of the fine-grained quartzites interbedded between some of these siltstones. The siltstones, which range in colour from chocolate to khaki are all characterized by subangular quartz grains varying from 0·01 to 0·06 m.m diameter. Most have ferruginous layers in the clay groundmass which

quartzites which have been slightly metamorphosed show subhedral grains of quartz up to 0·2 m.m diameter. Weathering has produced cavities which are now filled with pseudomorphic limonite.

Overlying the silty horizon there is the "A.B.C" quartzite formation. The lower quartzite is represented by slides 332, 11 and 285A, which show metamorphosed clastic fragments of subhedral quartz. The grain size varies, and although occasional grains are up to ½" in diameter, an average is of the order of 0·3 m.m. Slides 285B, 548 and 13 typify the upper "A.B.C." quartzite which resembles the lower member, except for its finer grain size, and slighter metamorphism. The close of the Proterozoic is marked by dolomite lenses interbedded between grey and chocolate slates. Slide 369 represents a lower arenaceous lens containing grains of recrystallized dolomite up to 4 c.m. diameter in addition to subhedral quartz and clay impurities. Slide 1 is a thin section of the chocolate siltstone band at the base of the main dolomite horizon. The slide shows a ferruginous and almost argillaceous composition, containing minute fragments of quartz and clay minerals. The main dolomite horizon is represented by slides 255B, 40, 72 and 43, Recrystallization has taken place in most cases, and crystals of about 0·5 m.m diameter are common. Most of the lenses contain at least traces of quartz and clay impurities.

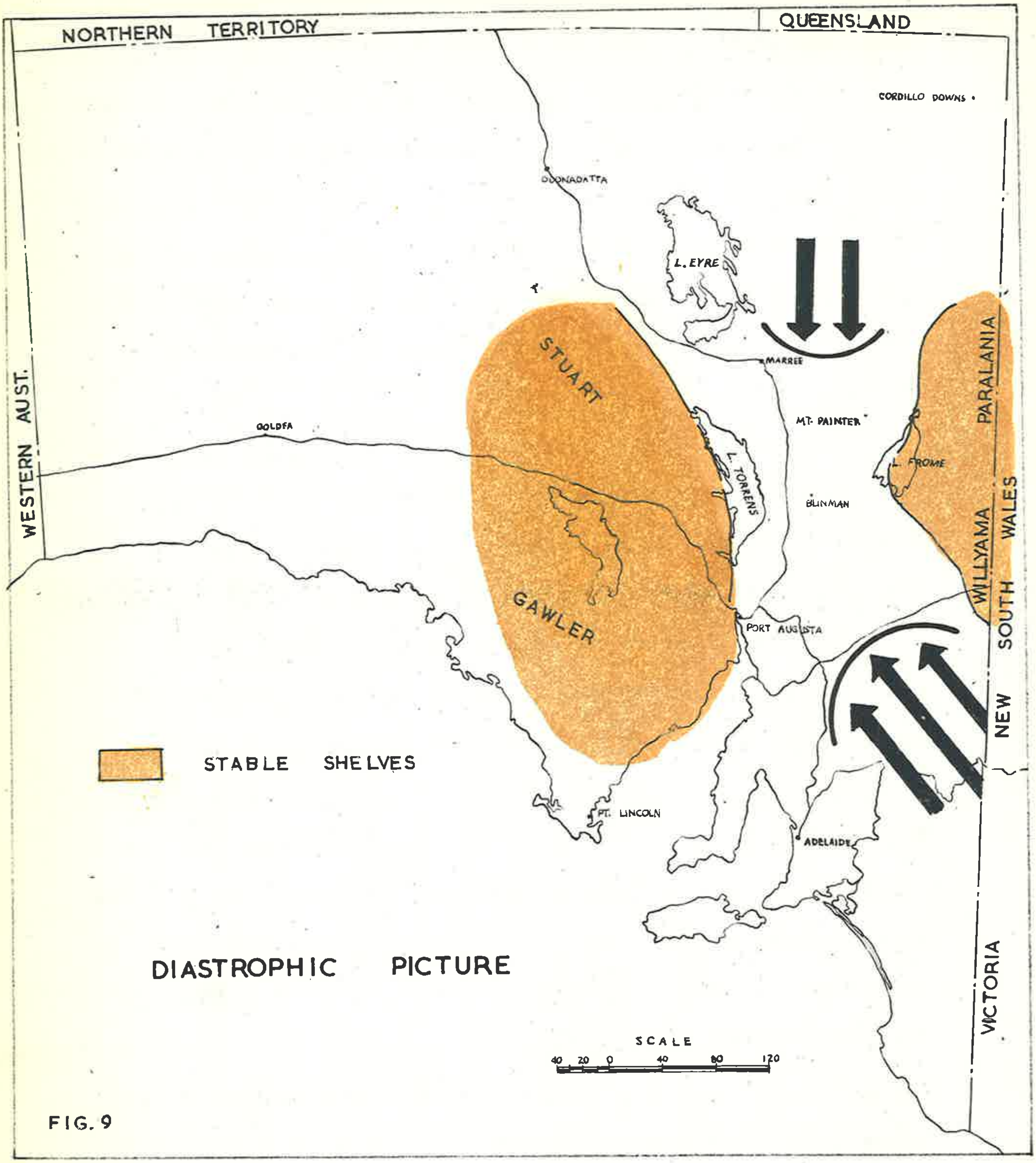
Rocks of the Cambrian Succession

The "Pound" quartzite formation is regarded as the base of Cambrian sedimentation, and is represented by slides 270, 469A, 307 and 362. The formation is generally fine grained and has quartz fragments averaging 0·2 m.m diameter. Apart from a few feldspar pieces, and a little calcareous and ferruginous cement, the quartzite is almost entirely composed of quartz grains. The slides indicate that only slight metamorphism has taken place, and that mixed sedimentary conditions produced both well rounded and subangular fragments. Only two slides (Nos.54 and 236) were cut of the limestones above the "Pound" formation. Both are characterized by the fine grained texture, the calcite veins and the iron staining. Although hand specimens are dark grey in colour, the limestones appear to be fairly pure. Since the colouring material could not be seen under the microscope, it is thought that it must be some very fine matter such as carbon, which was deposited during sedimentation.

The Dolerites

Two thin sections were cut for comparison; and while slide 41 perhaps nears the composition and texture of a true dolerite, the other(slide 37) bears no resemblance. The main minerals represented in slide 41 are hornblende, olivine, basic plagioclase, augite and secondary iron oxides. The minerals are interlocked and form a holocrystalline rock displaying a subophitic, relic texture. Obviously much alteration has taken place, and even the plagioclase shows signs of sericitization. Slide 37 shows extensive weathering. Even the original doleritic texture has been destroyed. The slide shows ferruginous stains throughout. Practically all the olivine has been altered and the resulting secondary iron oxide has masked most of the other minerals. Plagioclase, augite and chlorite are the main minerals, apart from iron oxides which constitute about 20% of the rock.

A complete list of the rocks and thin sections (arranged in stratigraphic order) that will accompany this report, is given in appendix 1.



NORTHERN TERRITORY
QUEENSLAND
CORDILLO DOWNS
OODNADATTA
L. EYRE
MARREE
STUART
GAWLER
PARALANIA
WILLYAMA
MT. PAINTER
L. FROME
L. TORRENS
BLINMAN
OOLDEA
WESTERN AUST.
NEW SOUTH WALES
PORT AUGUSTA
STABLE SHELVES
PT. LINCOLN
ADELAIDE
DIASTROPHIC PICTURE
VICTORIA
SCALE
40 20 0 40 80 120

FIG. 9

STRUCTURE

Diastrophism

On a regional basis the structure of the Cadnia sheet is not extremely complicated, and the rocks are less deformed than those of the areas to the north and south. The area is located at the extremities of two opposing forces (fig. 9.) and therefore during mountain building, it was affected less than the areas that were closer to the deforming forces. Plan 20 shows the Geology surrounding the Cadnia Sheet.

Since only minor amounts of detailed mapping have been done within the geosyncline, it is difficult to clearly establish diastrophism. However, it seems necessary to have had the action of at least two forces (fig. 9.) either contemporaneous or at different times. Folding and faulting of the sediments suggest that the geosynclinal rocks have behaved as a blanket over a moving basement. Diastrophism produced basement instability, which caused the overlying blanket of sediments to move, wrinkle and fracture. It is likely that the basement had a complicated mode of movement; but the most important forces appear to have resulted from the present Murray Basin and from the Marree-Murnpeowie district. The overlying blanket of sediments, in attempting to accomodate the basement rearrangement, was folded into a series of wave-like structures fronting the moving part of the basement. This effect can be clearly seen by studying a structural map of South Australia, where estimates from the defolding of the sediments show that some of the rocks have been folded and pushed for horizontal distances of over 100 miles. Further, while basement movement was taking place, resistance was offered by the Stuart-Gawler and the Paralania-Willyama stable blocks.(fig. 9.) It is thought that as the "Blanket" was forced through the constriction, a reaction-force equivalent to compression from the stable blocks became effective; causing fold axes to develop roughly perpendicular to the compression. These folds are especially noticed adjacent to the stable blocks, where the pressure was greatest. The Cadnia and the Blinman sheets are in an area intermediate between these blocks and consequently have not suffered extensively because of this east-west compressive force.

From the foregoing discussion it appears that two main opposing but independant forces accompanied by an indirect east-west compression have been responsible for the present structure of the rocks in the Cadnia sheet.

It is believed that the intrusions themselves, did not cause major structural deformation. Instead, deformations such as the Blinman Dome and the Lady Lehmann crush zone, resulted indirectly from basement movements. Intrusive material took advantage of any structural weakness that resulted from the "Blanket" accomodation of the sediments.

In the Cadnia sheet, deformation of the Adelaide geosyncline commenced to be effective at the end of the Proterozoic era. (cf. the unconformity below the "Pound" quartzite in the Pinda creek area). However, major ruptures and contortions were not experienced till post Cambrian times. Perhaps most movements took place during the middle Palaezoic era; but as there are no Palaezoic rocks in the Cadnia sheet younger than Cambrian, the assumption is based only on the literature. Field evidence indicates that deformation has continued since the close of the Proterozoic era to the present time. However, while there have been phases of greater activity, (cf. the Koscioskan orogeny) general diastrophic conditions have persisted continuously up to the present time. It is difficult to decide whether this persisting diastrophism has resulted to any appreciable degree from north forces; (Marree-Murnpeowie district) but on the other hand, the bending of the Narina fault, and structures in the Blinman Dome, are proof of continual pressures coming from the present Murray Basin.

In summing up the diastrophism of the rocks in the Cadnia area, it appears that crustal movements, produced opposing forces from the Marree-Murnpeowie district and from the present Murray Basin. These indirectly caused reaction- forces between the stable Stuart-Gawler and Paralania-Willyama blocks, which produced faults and cross folds in the existing structure. Further pushing from the present Murray Basin area has bent some of the early faults and has modified folding. It is thought that the present Murray Basin pushing,has continued right up to the present time.

Folding in the Cadnia sheet area

The writer is of the opinion that the nature of the basin and dome structures in the Cadnia sheet area, supports the theory of east-west compression resulting from the Stuart-Gawler and Paralania-Willyama constriction.

The Narina basin in the central parts of the sheet, covers an area of over 200 square miles. The deepest part of this shallow basin contains about 7,000 feet of Cambrian limestones which lie on massive "Pound" quartzite formation. The quartzite forms a massive and competent support which has resisted the southern forces. Its competency can be judged by appreciating the folded portions of the Narina fault. The part of the fault that has bent is that which lacks the buried support of the "Pound". The rest of the fault is almost a straight line which has been protected from distortion by the large extent of resistent quartzite. The fault actually bends immediately as it leaves the protection of the buried quartzite.

To the north-west of the Narina Basin the beds form the Mt. Stuart anticline. This structure is cut off in the west by the Mt. Stuart fault which has interrupted the western side of an otherwise complete dome. The anticline continues westwards across the fault and can be recognized in the rocks of the Bobmoony's Hut area.

The Cock's Comb anticlinal structure is an unusual example of cross-folding. The south western continuation of the Irish Well syncline has been cross-folded by an anticline which has influenced the present structure more than the original syncline. "Pound" quartzite caps most of the structure protecting it from rapid erosion. The associated Irish Well syncline resembles a small scale model of the Narina Basin. It too, has been protected from severe folding and faulting by its strong "Pound" quartzite formation.

In the south-east corner, the Jubilee anticline extends to the end of the sheet. Although its eastern limb is well within the Arrowie sheet, the anticline can be traced northwards, where, it is connected with the faulted anticlinal structure of the Mt. Roebuck area.

The Point Well syncline has been modified extensively by the folded part of the Narina fault. It is the northern extension of a flat, elongated basin which is centered in the Blinman sheet. The Woodendinna syncline is likewise the northern portion of another basin. This is a well rounded structure centered almost on the southern edge of the sheet; its gentle nature is typical of slightly deformed rocks. A comparison of the shapes displayed by these two synclines is an indication of the enormous structural opposition offered by the "Pound" quartzite formation. The Woodendinna Basin was protected at depth by a thick slab (?2,500 feet thick) of quartzite which was competent enough to forbid excessive deformation of the overlying sediments. The Point Well syncline is in direct contrast to this; for after the Narina fault had displaced the rocks, the northern part of the syncline abuted incompetent sediments. These offered only slight resistance to deforming forces and consequently have been moved northwards.

In the western part, near the southern border, the northern extension of the Blinman Dome can be traced for several miles before dip reversal in the west, causes a minor syncline. Directly north of the dome, the beds flatten out and structural interpretation is difficult; however, it appears that a slight dip reversal must take place about 4½ miles north of the sheet border.

The Breakfast Time anticline forms the eastern extension of a dome structure centered in the Beltana sheet. While the axis of the anticline indicates that pressure has been received from the west, it is probable that forces from the north and south were mainly responsible for the nearby faults. This part of the structure, which would otherwise have been a normal dome, has been elongated by movements along these faults.

Black Range, on which stands Mt. Hack is an east-west syncline in the northern portions of the sheet. The structure is an example of deformation resulting from northern forces. Perhaps the relatively stable slab below the Narina Basin has acted as a stop, against which sediments have been pushed and deformed.

Faulting

Most of the faults that have been studied in the rocks of the Adelaide geosyncline have been high angled ones. Although the Flinders Ranges owe their existance to the abundance of high angle thrust faults, shears are also present; and while they have not influenced topography as much as the thrusts, their presence sometimes causes enormous displacements in the stratigraphic sequence of the beds.

Some of the faults have produced brecciated zones while others have developed as wide areas of disjointed blocks of sediments. Part of these crush zones often contain doleritic intrustions which occur as masses, dykes or as irregular bodies.

Perhaps the most spectacular rupture is the Narina fault. This extends for a length of over 25 miles is the Cadnia sheet alone, and appears to be essentially a thrust fault. The dip of this fault cound not be measured; but by comparing horizontal distances between "Pound" quartzite outcrops in the northern block, with the equivalent distances in the southern area, it can be shown that the northern block has been elevated with respect to the southern one. Further, the fault must have a <u>north</u> dip in order to account for the crustal shortening produced by the north-south forces. The pressures, particularly from the south, were presistent and gradually bent the south-west part of the fault around the quartzite extremity. Along the eastern part of the folded fault, further deformation was restricted by the massive underlying quartzite; however, in the west, pressures complicated the structure and included shearing along the original thrust plane. North of Artimore, where thrusting has been followed by shearing, a brecciated zone developed. The country rock, being dolomitic, has been broken and contorted; dolomite, calcite and siderite veins, as well as dolerite intrusions are very common. Further westward, bending has progressed to the extent that the original fault direction has been turned about 135°, and strikes north before being disguised in the elongated crush zone between Patawarta gap and

Lady Lehmann mine. This crush area is likewise characterized by abundant dolerite dykes and contorted veins of recrystallized dolomite. The large number of diggings in these zones indicates that many ~~valueless~~ fruitless efforts were made in prospecting for copper. In the north-eastern parts, the fault bifurcates, and near Bullock Head Gap it displaces portion of the "Pound" quartzite. Where it branches, the main fault continues as the southern one of the two, while the minor, more northern fault appears to be a "Splinter". Similar faulting occurs further east, near the border of the sheet, where another fault branching off the main one, causes considerable displacement. The main Narina fault has bent at these bifurcations, in response to the slight release in pressure caused by the post-main fault "Splinters".

The Mt. Stuart fault is of particular interest, not only because movement is suspected to have taken place recently, but also because it was possible to trace the fault to its very limits. The northern end "dies" just before hitting the "Pound" quartzite outcrop about 1 mile south-east of Warraweena H.S.; while its southern end appears to have only slight effect on the "A.B.C." quartzite about 5 miles past the sheet border. As the fault extremities are approached, displacement (vertical plus horizontal) decreases more gradually in the north than in the southern

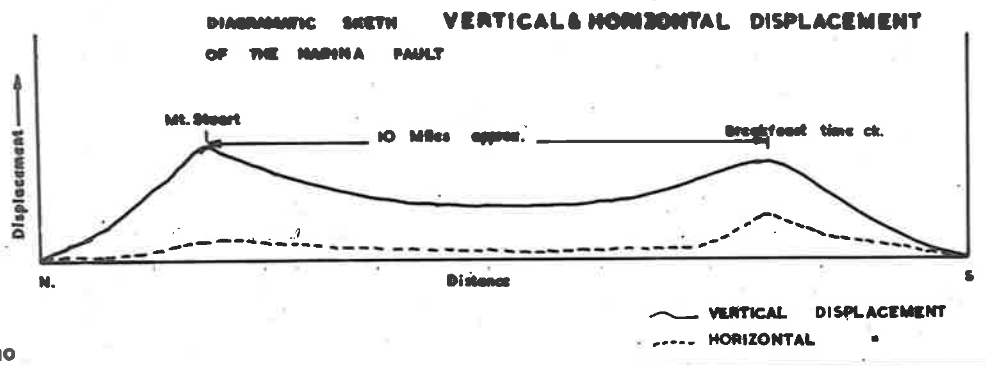

VERTICAL & HORIZONTAL DISPLACEMENT
Displacement
10 Miles approx.
Breakfast time ck.
N.
Distance
S
VERTICAL DISPLACEMENT
HORIZONTAL

FIG. 10

end, where major displacements complicate the geology of the area. A more detailed study of the movements, indicates that along the fault lineament, there are two areas which have experienced major displacements. The Mt. Stuart area has suffered thrusting; while the Breakfast Time creek mevements have also been influenced by a little shearing. Fig. 10 is a generalized plot of the horizontal and vertical displacement along the fault. In the Mt. Stuart area, the presence of a very steep scarp in relatively soft sediments can only be explained by assuming that movements have been active during fairly recent times. The almost linear behavior of the fault irrespective of topography indicates that it must dip at a steep angle. Further, by considering the outcrops on either side of the fault, it can be shown that resulting from thrusting, the west block has moved south in relation to the east block. Therefore, the resultant horizontal movement must have come from the resolved north-south component of the thrust-producing forces. It follows from the north-south compression and the east-block elevation, that the fault must have a south dip. Calcite veins, mylonites and dolerites are abundant in the brecciated zones south-west of Mt. Stuart. Where brecciation occurs in Sturtian limestones, the recrystallized clastics have been contaminated by doleritic intrusions, and have formed unusual, but attractive hybrid rocks. cf. Webb's Willouran sediments. P.19.

The Breakfast Time creek area offers slight structural complication. Basically the structure is that of a faulted dome that has been pinched out into a north-pitching anticline. In the Cadnia sheet, only the pinched out portion is covered; but the remaining sections of the faulted dome can be identified in the Beltana sheet. The southern extension of the Mt. Stuart fault cuts off the western limb of the Breakfast Time anticline, and continues into the Beltana sheet, where it is joined by a branch of the Nuccaleena fault system. In the Nuccaleena area, the rocks are very broken and only the major faults are shown. A fault roughly parallel to the Mt. Stuart fault forms the main lineament; it crosses the Nuccaleena mine and continues south-west into the Beltana sheet, where a branch joins it to the Mt. Stuart fault. In the main area, it is met by an east-west fault which also truncates two "Splinters" coming from the main lineament. About half a mile south of the mine, another east-west fault can be traced westward into the Beltana sheet, where it cuts the previous fault, and continues as the connecting branch between the Mt. Stuart fault and the main Nuccaleena lineament. The system is further modified by two faults whose southern ends "die" in Marinoan sediments; but which meet when followed north. The north-west branch continues into the Beltana sheet until it is cut off by the second east-west fault.

Dolerite floaters were found in some of the creeks associated with the Nuccaleena fault system. Although the actual outcrops were not found, the floaters indicate that the area contains basic intrusions. Mylonites, calcite and siliceous veins are common near the faults and are often associated with wide brecciated areas within calcareous sediments.

Although a little shearing has influenced the structure, the main movements in the Nuccaleena fault system are indicative of thrusting. It is considered that pressures from the south, in pushing the sediments through the Stuart-Gawler and Paralania-Willyama blocks produced gentle folds. Later, as the pressures continued thrust faults were developed cutting earlier formed folds.

In the north the rocks have been folded and faulted quite severely. "Pound" quartzite outcrops are disconnected, displaced and sometimes brecciated. Some of the displacements are so great, that blocks of Sturtian tillite are thrust up against "Pound" quartzite some 15,000 feet stratigraphically above it. Although the Sliding Rock fault is hinged at its western end, considerable displacements are noticed in "Pound" quartzite as the fault crosses the sheet border. It appears that the eastern block has tilted towards the north, and that continued pressures bent the fault eastwards just after it enters the Angepena sheet.

Between Warraweena H.S. and Black Range Spring a fault causes repetition of "Pound" quartzite. The thickening is due to an almost perfect strike fault which gradually cuts across the quartzite, and becomes associated with another folded fault. Displacement along the fault progresses as it is followed north, where it is responsible for bringing Sturtian tillite against Cambrian limestone.

The Lady Lehmann mine occurs in a small area containing dolerites and broken sediments. Here, regional drag-folding and shearing along the western end of the Narina fault has caused considerable local buckling and shattering. The dolerites are fine grained and are associated with the copper mineralization of Lady Lehmann Mine.

The Pinda fault system, centered around the Pinda crush zone, is an example of intense deformation. The main faults surround an area which has been broken and intruded by numerous dolerites. In the southern part of the crush zone, a hill of tillite has obviously been torn off from tillite outcrops some two miles north, and has been turned and transpoarted to its present position. One of the faults continues south-west from the crush zone, passes through the Main Gap, and persists through the Warraweena Gap between the Narina basin and Black Range. Near its western end, as it cuts off the "Pound" quartzite, the fault widens and brecciation extends for over 100 feet. Calcareous veins and mylonites intermingle with contorted fragments of dolomitic material, which being incompetent, has been affected by the fault. To the east, the crush zone narrows and continues eastward as a single fault. It "dies" just prior to hitting "Pound" qaurtzite; but before doing so. it is met by a minor fault from the south which has only slightly displaced the adjacent rocks. The intersection of two major faults forms the northern apex of the triangular-shaped crush zone. Both these faults produce considerable displacements, but that directed towards the north-west, is associated with the formation of a very wide crush zone within the Angepena sheet. The other fault "dies" about three miles north of the sheet border.

The crush zone is genetically related to the Blinman dome. During the early stages of deformation the Cock's Comb structure was connected with the anticlinal structure occupying almost the entire south-east quadrant of the Angepena sheet. The site of the present crush zone appears to have been a structural "high" or the domal part of the two joining anticlines. Continued stresses faulted the rocks and caused uplifting, shearing and general displacement in the crush zone area. Diastrophism was accompanied by numerous doleritic intrusions which slightly enhanced the extent of deformation, and which have since been smashed by the persistent north-south pressures.

In summing up faulting of the area, it is thought that while failure mainly occured in response to the general forces from the south, it was influenced by pressure from the north (especially in the northern part of the sheet) and by the east-west compression. The southern forces have acted more or less continuously up to the present time, and further deformation has since resulted, giving the rocks their present structure. The majority of the faults are thrusts, resulting from crustal shortening; but invariably these are accompanied by at least some shearing, which at times (cf. Western part of the Narina fault) causes major displacements.

Jointing

During the field survey, joints were measured in conjunction with stratigraphic dip readings. The original idea was to use the joints in studying a strain-ellipsoid diagram of diastrophism. However, since it appears that

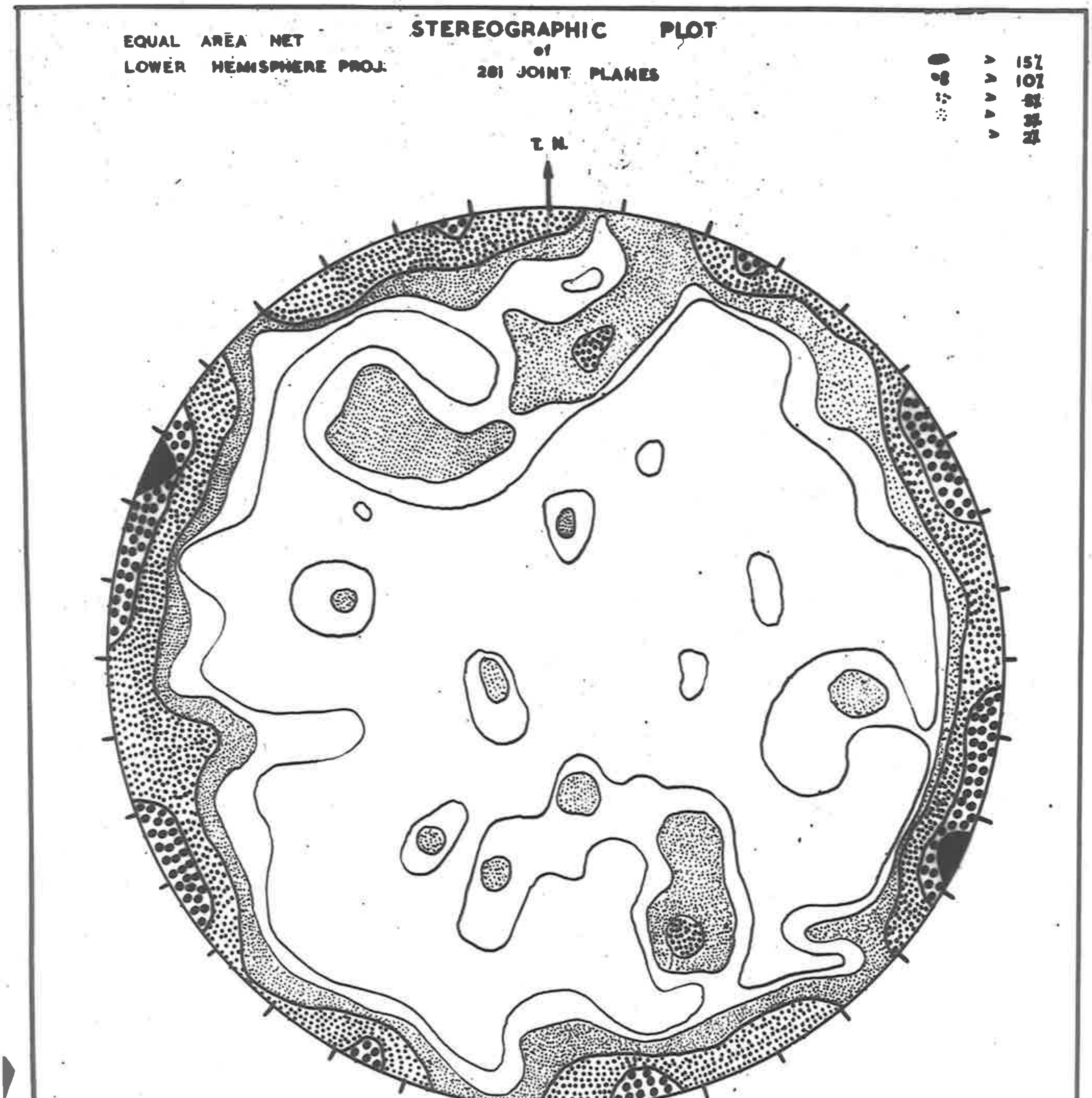

EQUAL AREA NET
LOWER HEMISPHERE PROJ.
STEREOGRAPHIC PLOT
of
281 JOINT PLANES
> 15%
> 10%
T. N.

FIG. 11

deformation was caused by at least two sets of compressive forces acting almost at right angles to each other, it became impossible to orientate a strain-ellipsoid diagram which would cover the whole area; however, it was found that by subdividing the area into structural sections, (eg., The Mt. Hack syncline or the Mt. Stuart's anticline) the orientation of the strain-ellipsoid diagram was possible and the associated structures were in harmony with the diagram predictions.

In all, 281 joints were measured, plotted on the bottom hemisphere of a Schmidt's equal area net, and finally contoured. Fig. 11. shows the result of the plotting. The joints have segrated themselves into groups which are represented by the following joint systems

Main joints (in order of abundance)

Strike	N.26°E.	dip	87°W.	and	E.
"	N.51°E.	"	85°E.	"	W.
"	N.76°E.	"	85°N.	"	S.
"	N.116°E.	"	87°N.	"	S.
"	N.96°E.	"	55°S.		
"	N.66°E.	"	55°N.		

Minor joints (in order of abundance)

Strike	N.55°E.	dip	50°E.
"	N.96°E.	"	25°S.
"	N.6°E.	"	60°W.

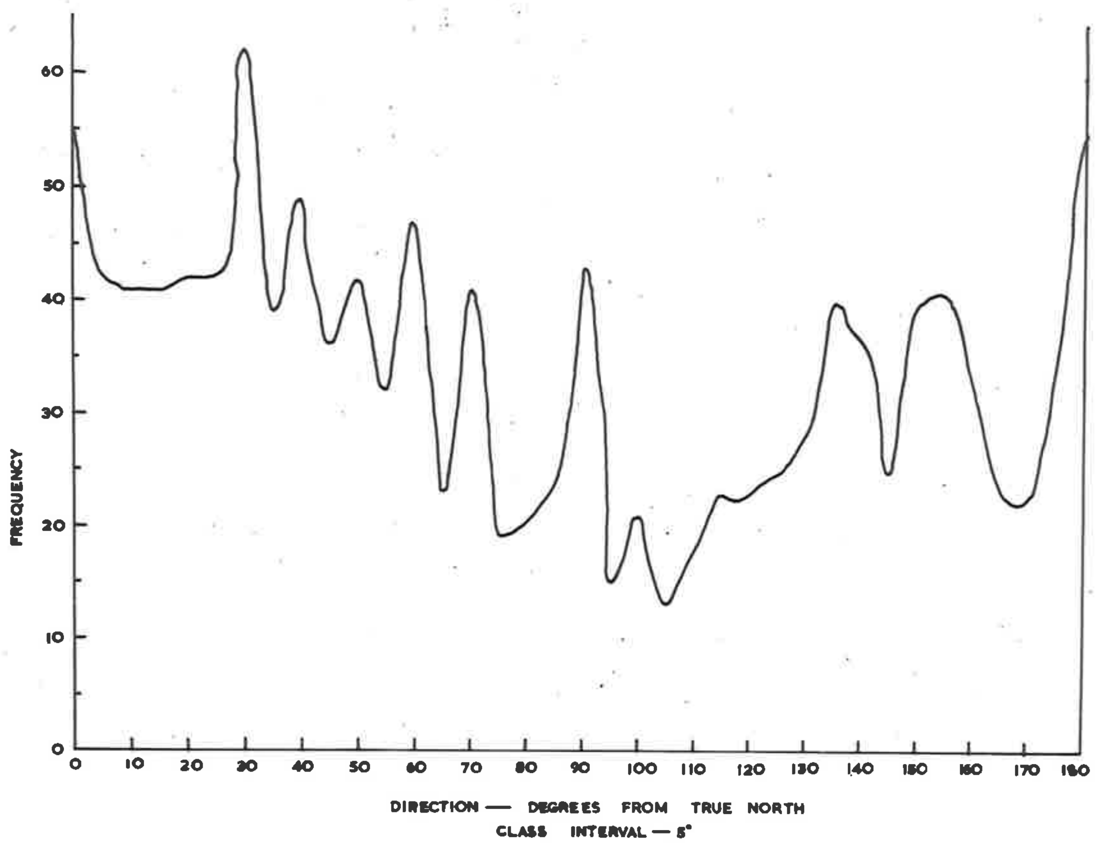


FIG. 13 **FREQUENCY PLOT OF LINEAMENT DIRECTIONS** (BASED ON 1204 READINGS)

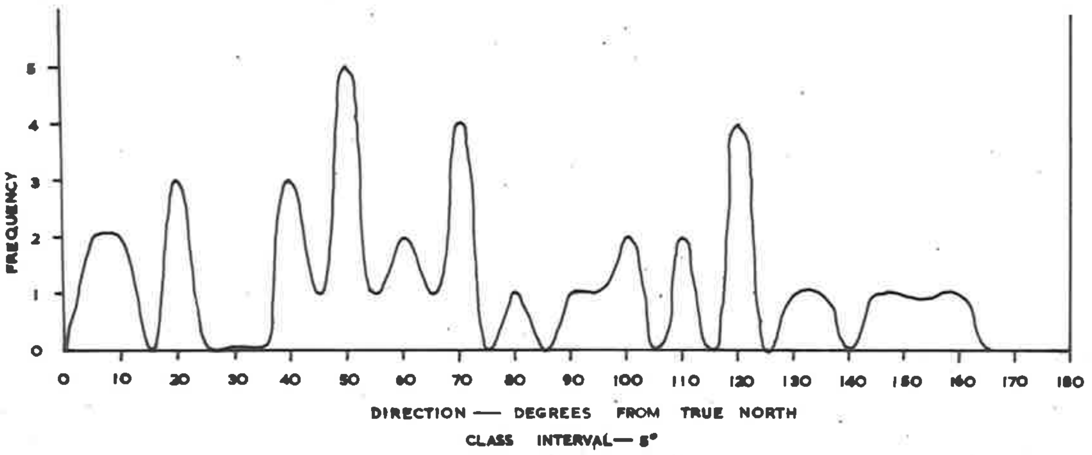


FIG. 14 **FREQUENCY PLOT OF FAULTS DIRECTIONS** (BASED ON 42 FAULT READINGS)

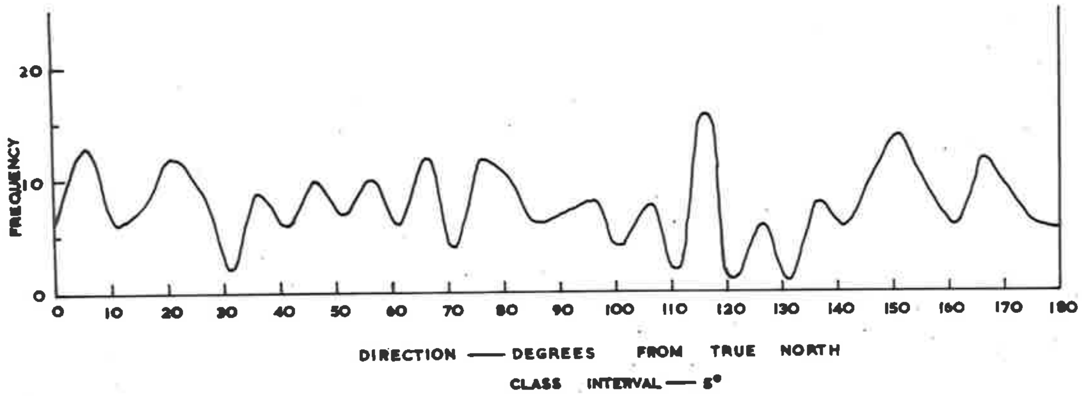


FIG. 15 **FREQUENCY PLOT OF JOINT DIRECTIONS** (BASED ON 281 JOINT READINGS)

Strike	N.81° E.	dip 25° N.
"	N.106° E.	" 40° N.
"	N.126° E.	" 40° N.
"	N.61° E.	" 15° E.
"	N.16° E.	" 40° E.

The minor joints are insignificant because they cannot easily be connected to diastrophism.

Joints, Faults and Lineaments

As part of the photogeologic study, lineaments were measured, grouped into classes and plotted. Fig. 13. represents the plot of 1207 lineaments; it shows the number of lineaments measured, having a strike direction within a particular class interval. The peaks of the curve represent the directions of lineaments occuring most frequently.

Fig. 14. is a similar curve representing the directions of mapped faults in the area. The directions of 42 faults which were taken directly from the geological map were measured, grouped and plotted; the resulting curve shows the relationship between frequency and fault directions, and also highlights the directions of the most frequently occuring faults.

Similar plotting of the 281 mapped joints produced fig. 15. The joints, whose directions were measured with a magnetic compass, have been corrected for magnetic

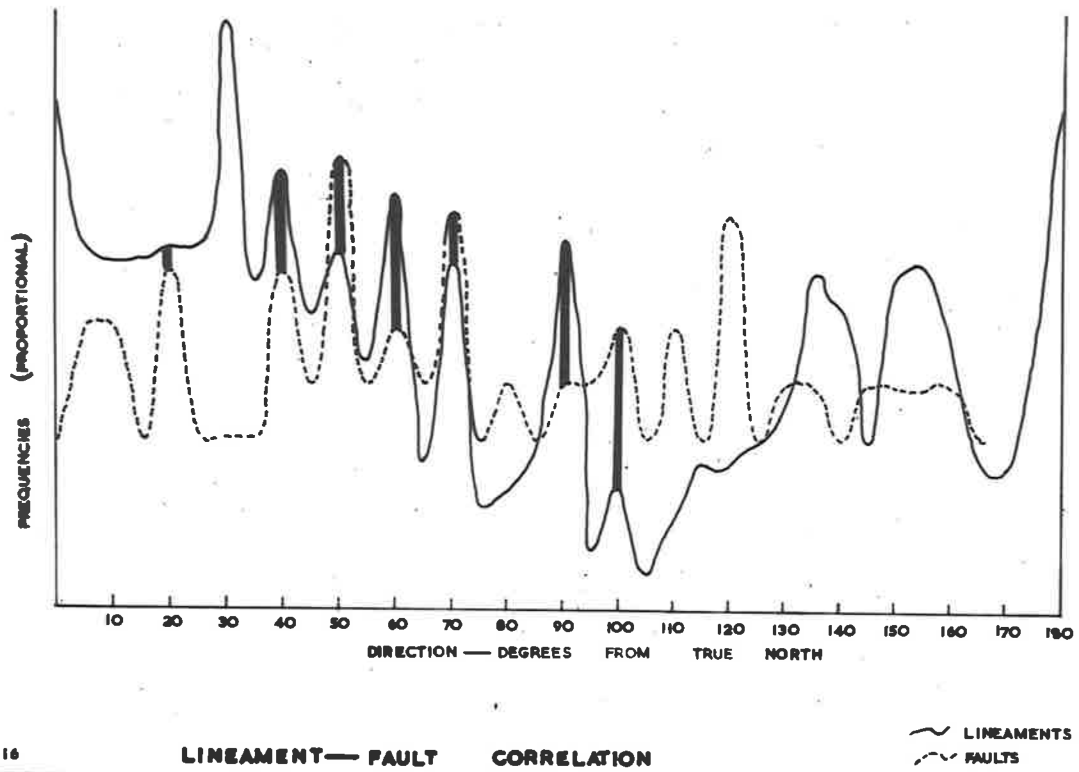


FIG. 16 LINEAMENT— FAULT CORRELATION

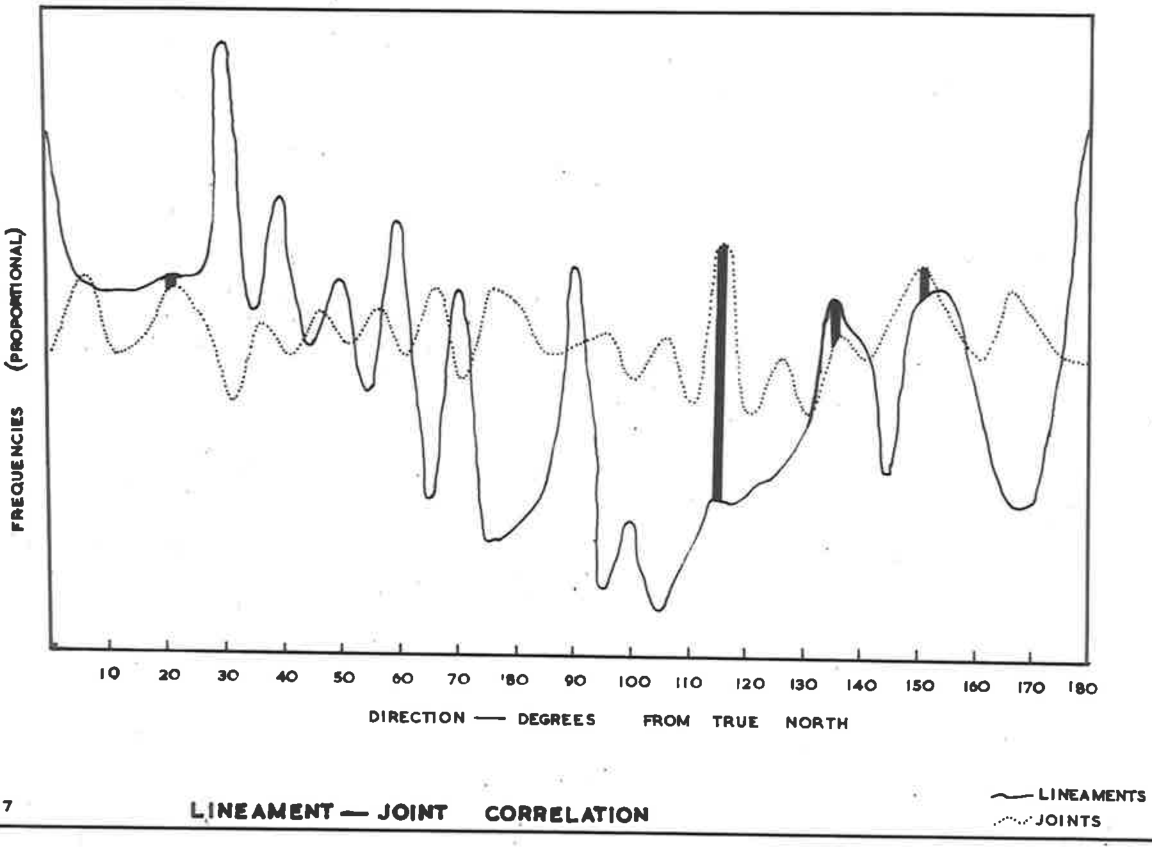


FIG. 17 LINEAMENT — JOINT CORRELATION

deviation; the directions on the resulting curve, (as with the previous ones) are in relation to True North.

The real object of the lineament plot, was to eastablish whether topographic lineaments were mainly related to faulting or to jointing. The results of the study show that both faulting and jointing were responsible for the formation of topographic lineaments. Superinposing fig. 14. on fig. 13. we get the relationship between faulting and lineaments. The resulting fig. 16. shows agreement at the 20°, 40°, 50°, 60°, 70°, 90° and 100° degree peaks; indicating that most lineament directions less than 100° were caused by faulting. A similar superinposition of fig. 15 and fig. 13. shows the relation between joints and lineaments in fig 17. The agreement at the 20°, 115°, 125° and 150° degree peaks tends to prove that at least some topographic lineaments have been produced because of jointing.

Economic Geology

During the geological survey, prospecting for economic minerals was all important. The old mines were investigated, their structural and stratigraphic enviroments were studied, and possible prospects were evaluated. Attention was paid to the non-metallic ores such as marble, dolerite, chalcedony and the coloured ochres.

General

During the copper boom of the last century, mining was inportant in only two areas. The Sliding Rock creek mine must have realized large profits quickly by mining native copper from relatively shallow depths. The mining activities at Neccaleena were at first very economical; high grade ore was mined from the oxidized zone of a tabular orebody, which was soon worked and eventually caused the closing down of the mine. Judging from the development work at Lady Lehmann mine, it is possible that some ore was sent to the Blinman smelters; however, even though there are no records of the mine, it is not likely that a very large tonnage of ore could have been won. An adit in the Mt. Roebuck area indicates that prospecting for barytes proved uneconomical. A small open cut was also made, and a limited amount of barytes was removed from the area. A few tons of manganese ore have been won from small diggings near Narina H.S. where manganiferous outcrops appear to be irregularly bedded with the transition sediments between the "Pound quartzite and the Cambrian limestones.

Description of the Mines

The Sliding Rock Copper Mine

History

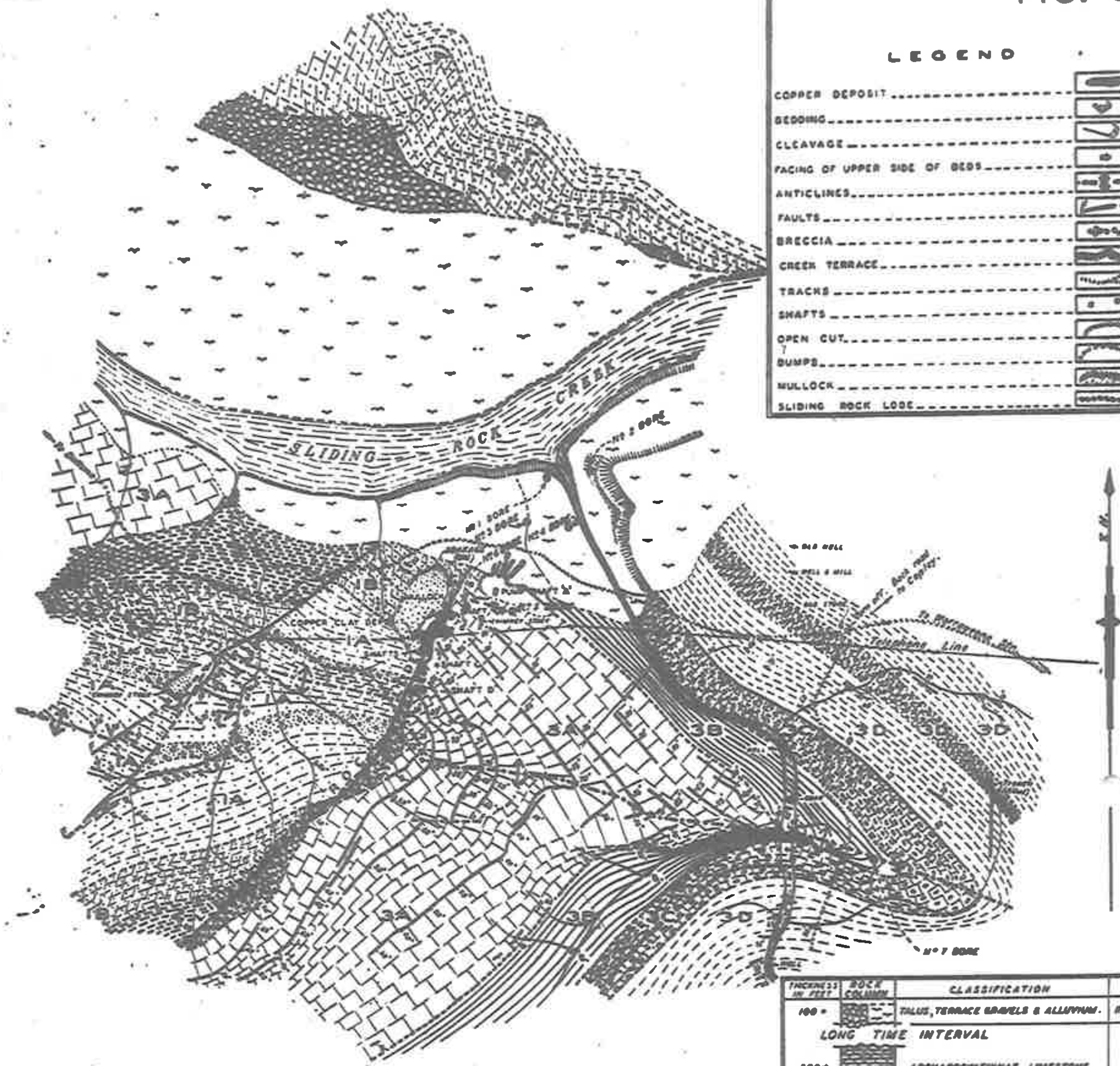
Records go back to 1871 when the mine was purchased by the Sliding Rock Company. Resulting from mining operations, about £100,000 worth of copper ore had been sold by 1877. The only other production recorded was a parcel of 145 tons of ore, equivalent to 5 tons of copper, sold by the Tasmanian Copper Company in 1907.

Water was first struck at 30 feet; and was the main obstacle which necessitated the mine closing down in 1877. During 1899 the Sliding Rock Copper Proprietary took over and sank a new shaft; (361 feet deep) but without sucess. Finally between 1906 and 1907 the Tasmanian Copper Company made an attempt to restart mining; but apart from the 145 tons of ore which was won from an open-cut, no other material was extracted. Since then, the mine has not been reopened; but the Sliding Rock creek mine area has now been withdrawn from the operations of the Mining Act, 1930-1941; and has become a Water Works reserve supplying water to the Leigh Creek coal field.

Mineralization

Although sulphides are found in the deepest part

FIG. 8



LEGEND

- COPPER DEPOSIT
- BEDDING
- CLEAVAGE
- FACING OF UPPER SIDE OF BEDS
- ANTICLINES
- FAULTS
- BRECCIA
- CREEK TERRACE
- TRACKS
- SHAFTS
- OPEN CUT
- DUMPS
- MULLOCK
- SLIDING ROCK LODE

SOUTH AUSTRALIA

DEPARTMENT OF MINES

GEOLOGICAL MAP OF SLIDING ROCK MINE

SCALE

FEET 200 100 0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 FEET

S. B. Dickinson.

DEPUTY GOVERNMENT GEOLOGIST

THICKNESS IN FEET	ROCK COLUMN	CLASSIFICATION	AGE
100 +		TALUS, TERRACE GRAVELS & ALLUVIUM.	RECENT
		LONG TIME INTERVAL	
200+		ARCHAEOCYATHINAE LIMESTONE	LOWER CAMBRIAN
		1600'	
400 +		MANGANIFEROUS SHALE & LIMESTONE (3 D)	
		1200'	
100		CONCRETIONARY LIMESTONE (3 C)	
		1100'	
250		SHALE (3 B)	
		850'	
		DOLOMITIC LIMESTONE (3 A)	
		200'	
200		CLAY SHALE (2)	
		0	
200		WHITE QUARTZITE (1B)	PRE-CAMBRIAN UPPER PROTEROZOIC
		200'	
1000 +		QUARTZITE & SANDSTONE (1A) (QUARTZITE)	
		1200'	
TOTAL 3100 +			

GEOLOGIC COLUMNAR SECTION

of the mine, oxidized ores persist right down to the 210 feet level. Secondary copper mineralization include native copper, malachite, azurite, cuprite, tenorite and chalcocite; but the mine was originally an economical venture because of the abundance of native copper.

No dolerite intrusions have been found near the mine, but it is believed that the Sliding Rock orebody, represents late-stage magmatic emanations associated with the wide-spread emplacement of basic intrusions. It is best classed as a mesothermal deposit.

The orebody is localized in a fault zone which cuts an east-pitching anticline. Dickinson (1944) mapped the area in detail; and because the structural features are well depicted, a copy has been included in this report. The fault seems to have developed because of the sudden steepening of the anticlinal pitch; and merely represents the fractured zones where the bending takes place. The anticline is only a small local feature and is about 30 chains wide; it was formed during the regional deformation of the area, when movement along a major fault (hidden by Sliding Rock creek) dragged the adjacent rocks and formed the small anticline in the mine area. The orebody is up to 25 feet wide. At the surface it dipped at about 60 degrees to the east, with a strike of N. 20 E. Not enough information is available (the mine is inaccessible) to determine the direction and amount of pitch; and although its length has not been defined, its width is more or less uniform with depth. No fossils were found, but it seems that the country-rock is the equivalent of the Archaeocyathinae limestone, which here outcrops as a dense, light-grey, dolomitic limestone.

Origin of the Ore Deposit

The large tonnage of native copper that has been mined from the oxidized zone, requires some genetic explanation. Native copper, although abundant in the blowholes of some basic extrusives, is fairly rare as a secondary mineral. The large quantities found in the Sliding Rock mine, have resulted from freak ore-deposition processes which have reduced some of the copper minerals to the metallic state.

Since hypogene minerals have been found in the deeper parts of the mine, and the orebody follows the fault, mineralization must have occured within the broken fault zone.

During erosion the mineralized part was gradually introduced to an oxidizing medium, where oxygen in the presence of water, chlorides, bromides and iodides gradually oxidized the sulphide minerals to their sulphates. In the Sliding Rock mine the large quantities of indigenous liminite that are associated with the orebody, indicates that the original mineralization must have been pyritic. If this is so, the pyrite would have been the first sulphide mineral to be decomposed by oxidation, and would probably be affected according to the following chemical equations.

(1) $Fe\ S_2 + 7\ O + H_2O = FeSO_4 + H_2SO_4$

(2) $FeS_2 + 15\ O + H_2O = Fe_2(SO_4)_3 + H_2SO_4$

Depending on local conditions such as country-rock, temperature and pressure, some of the ferrous sulphate would have been oxidized to the ferric state.

(3) $FeSO_4 + H_2SO_4 + O - Fe_2(SO_4)_3 + H_2O$

(4) $6FeSO_4 + 3\ O + 3H_2O = 2Fe_2(SO_4)_3 + 2Fe(OH)_3$

Also some of the ferrous and ferric sulphate probably reacted on other sulphides with the production of soluable sulphates. e.g.

(5) $CuFeS_2 + 2Fe_2(SO_4)_3 = CuSO_4 + 5FeSO_4 + 2S$

or

(6) $Cu_2S + Fe_2(SO_4)_3 = CuSO_4 + CuS$

Any excess ferric sulphate would have caused ferric hydroxide which in the presence of copper was deposited as limonite.

(7) $Fe_2\ (SO_4)_3 + 6H_2O = 2Fe(OH)_3 + H_2SO_4$

or

(8) $Fe_2(SO_4)_3 + FeS_2 = 2FeSO_4 + 2S$

The above gives an idea of the probable chemical reactions which were associated with the oxidation of the Sliding Rock orebody. During oxidation, the limestone country-rock would have precipitated most of the transported copper quickly, producing malchite and azurite. However, because of the ore localizing fault, some of the copper sulphate solution trickled down the fault zone to the water table. There, they reacted with primary sulphides (probably chalcopyrite and bornite) producing secondary sulphides which accumulated; and formed the supergene enrichment zone.

(9) $5CuFeS_2 + 11CuSO_4 + 8H_2O = 8Cu_2S + 5FeSO_4 + 8H_2SO_4$

or

(10) $Cu_5FeS_4 + CuSO_4 = 2Cu_2S + 2CuS + FeSO_4$

or

(11) $2FeS_2 + 14CuSO_4 + 12H_2O = 7Cu_2S + 5FeSO_4 + 12H_2SO_4$

The above are only three of the many possibilities which could have produced the secondary sulphides, chalcocite and covellite in the zone of secondary enrichment. Accordimg to Bateman a high ferric to ferrous ratio favours the formation of covellite in preference to chalcocite; and vice versa. Since no covellite has been recorded as occuring in the orebody, it seems that the ferric to ferrous ratio was low; and that relatively small amounts of pyrites existed in the supergene zone. (The amount of ferric sulphate formed depends on the available pyrites.)

As erosion progressed, the water table was lowered and the supergene enrichment zone was oxidized. The chalcocite, which was formed during secondary enrichment was oxidized. By this time very little or no pyrite was left; but traces of ferric sulphate must have been available to produce cuprite and tenorite both of which have been won from the Sliding Rock mine. Lindgren quotes the copper mine at Chino, New Mexico, as an example where oxidation of the supergene zone resulted in the reduction of chalcocite to native copper.

(12) $Cu_2S + 3Fe_2(SO_4)_3 + 4H_2O = 2Cu + 6FeSO_4 + 4H_2SO_4$

Although this could be the case at Sliding Rock; it is more likely that the native copper was due to the reduction of cuprite by ferrous sulphate. This assumption is backed by the fact that the ratio of ferric to ferrous was low, and also by the fact that during mining operations, native copper was found to be associated with cuprite.

The copper minerals which formed the orebody occured as streaks and aggregates in a brown clay within the fault zone. Indigenous and transported limonite has filled cavaties in the clay and in the neighbouring rocks; and it appears that before the open-cut existed, the orebody must have had an impressive gossanous capping with limonite mushrooming.

Future Possibilities of the Deposit

As the available records do not contain information relating to the size, shape, yield and grade of the deposit, a reliable appraisal cannot be given without first drilling the orebody. However, although there are no known ore reserves, it is reasonable to assume that the lode extends both in length and in depth beyond the present mine openings. Also the enormous quantities of water that have been recently pumped out of the area, tend to prove that the real "closing-down" of the mine was due to water difficulties.

Speculating a little on the few figures that are given in the Mining Reviews of South Australia, it seems feasible to assume that fair quantities of oxidized 3%-4% ore, should be available below the 150 foot level.

Even if no water difficulty (which apparantly is the main draw-back) existed, the grade would be far from sufficient to off-set the heavy transport costs, that would be involved because of the mine's geographic position. Therefore, it is not likely that anyone will undertake (at least in the near future) the difficult and expensive job of dewatering and restarting the Sliding Rock copper mine.

The Nuccaleena Mine

This mine was worked even before the Sliding Rock deposit, and consequently it is not surprising to find that the few records that are available, contain very little useful information. Prospecting in the vicinity of the original gossan was very encouraging; and a shaft was sunk nearby. Very good returns were soon realized by mining the oxidized zone; but by 1872 the better parts of the known orebody were worked out and this, together with the continued increasing water difficulties caused the mine to close. In 1902 the mine was reopened; and several new shafts and drives were developed. However, it was again abandoned after winning only a few tons of low grade ore.

Another more systematic effort was made by Hunter Bros. in about 1913. Although this venture was backed by a government subsidy, no records of any new development work nor of grades or yields were found in the files of the Dept. of Mines. However, a certain amount of sucess must have been achieved, because operations continued till at least 1920. The Hunter Bros. attempt was concerned with removing ore below the water table; and it appears that much time was spent in reconditioning the existing developments. including the main shaft, which was sunk to the 203 foot level.

It is impossible to estimate the total amount of ore extracted from the mine, but before Hunter Bros. began working the deposit, several thousand tons of good quality ore were mined.

Structural Enviroments

The orebody is located at the intersection of two major faults. It appears to be genetically associated with the resulting shattered zone; in which, it forms irregular bodies.

Later movements, probably connected with the Mt. Stuart-Breakfast Time creek uplift, have caused minor faults which have displaced the orebody. One of these faults was recorded; and is said to have displaced the orebody 10 feet horizontally.

Mineralization

The hypogene minerals forming the orebody are chalcopyrite and pyrite existing together with a quarts-calcite and barytes gangue. Like the Sliding Rock deposit, it has probably originated from mesothermal mineralization associated with basic intrusions. Dolerite floaters have been found in the nearby creek, indicating that basic outcrops probably exist in the immediate vicinity.

Although the oxidized minerals that have been mined are atacamite, malachite, chrysocolla, cuprite and minor amount of native copper, it appears that atacamite-malachite chrysocolla masses, constituted the bulk of the mine ore.

The Origin of the Deposit

The oxidation of the original orebody would have taken place along similar lines as the Sliding Rock deposit; that is, the oxidation of pyrite, and the production of ferrous sulphate, ferric sulphate, sulphuric acid and ferric hydroxide. These solvents would have reacted on the primary copper ores and caused the transportation of copper. As the country rock is a calcareous slate, most of the copper solutions would have been quickly precipitated as malachite and azurite. No supergene sulphides have been recorded; and it seems that only small amounts of cupriferous solutions trickled down deep enough to cause supergene enrichment.

The presence of chrysocolla in the oxidized zone indicates that desert-type conditions must have been experienced during oxidation. Siliceous underground waters were moved towards the surface by capillary attraction and "silicified" the already-deposited oxidized copper minerals. This period of silicification, while being represented by chrysocolla in the mine area, is also supported by the extensive silicified cappings that outcrop in the Beltana sheet, just west of the mine. The silicification was probably associated with the Australia-wide duricrust formation, which was effective during the Tertiary period. The oxidation of the orebody would therefore date back to pre-duricrust formation.

Atacamite, which is a basic copper chloride, is said by Lindgren to develop where wind-borne salt affects normal oxidation products. In the Nuccaleena area the only possibility of salt cantamination is from Lake Torrens. This is quite feasable for the lake is less than 30 miles away, and perhaps was closer during the past. As the lake has been built up by a series of salt-caked clay bands, it is quite possible that during the drier periods, the "Westerlies" could have swept up salt-coated clay particles from the surface of the lake, and transported them eastward. Some of this dust could have easily fallen over the area, and have affected the copper mineralization.

The Nuccaleena orebody is therefore the result of oxidation under relatively dry conditions. High grade ore resulted in the oxidized zone; but at the same time, little or no supergene sulphide enrichment took place at the water table.

Future Possibilities of the Deposit

Since it is not known exactly what was done during the management of Hunter Bros. it is difficult to give a relaible appraisal of the mine. However, practically all the oxidized ore was mined by the early owners; also since no signficant secondary sulphide enrichment existed, it is likely that the Hunter Bros. organisation mined hypogene ore, and probably worked the mine to the economic limit. No big reward can be expected to future operators of this mine.

The Lady Lehmann Mine

The previous copper mines had their own particular peculiarities—The Lady Lehmann is no exception; the absence of a zone of oxidation calls for further explanation

A little development work has been done; including the driving of an adit over 100 feet long, and the sinking of several shallow shafts. Only a small parcel of low grade ore has been recorded as being won from the mine; and this was sent to the Blinman smelters, where it yielded 3·9% copper and 7·3% sulphur.

Structural Enviroments

The orebody extends for a length of over 600 feet; and is located along a fracture zone striking approximately in the north-east direction. The northern end is poorly defined; and is deflected towards the east, where it assumes an almost east direction, before gradually dying out

A clean-cut boundary designates the hanging wall of the lode; but the foot wall cannot be defined, because there is a decreasing gradation in mineralization, as the brecciated-foot-wall rocks are approached.

Mineralization

Primary sulphides exist only a few feet from the surface; there is no zone of supergene enrichment, and only traces of copper carbonate staining have resulted from recent weathering. These sulphides, being associated with much calcite gangue, were probably localized by mineral replacements, within the dolomitic horizon at the top of the Marinoan series.

According to Dickinson (1944), the lode contains from 10% to 15% sulphides; but because of the low chalcopyrite : pyrite mineralization, the ore averages at only 1·70% copper.

Explanation for the Missing Oxidation Zones

The only explanation that can be offered is one concerning rapid uplifting of the area followed by fast erosion. Assuming that this is true, erosion must have been so severe that it kept ahead of oxidation. Supporting this theory is the present rugged nature of the topography, in the vicinity of the mine. However, other factors, including the absence or presence certain chemicals, could have caused this unusual phenomenon.

Future Possibilities of the Deposit

The lode, which has been proved as averaging 3' 6" wide to a depth of at least 50 feet, and for a length of 600 feet, is too poor to be mined by a small organisation which would have to ship the ore away for treatment; while at the same time it is not large enough to warrant the building of a treatment plant in the mine area.

Therefore, unless one or more similar deposits are found nearby, (to be worked collectively) the mine cannot be worked economically.

Encouraging Copper Prospect

During field mapping an area was found which was rich in indigenous limonite. According to Lindgren and Bateman, indigenous limonite results when copper sulphides have been present in the orebody; for then, the precipitation of ferric hydroxide takes place in situ.

The locality, situated in Breakfast Time creek, at the fault intersection; and marked P.I. on the geological plan, appears to be very interesting. There are several dyke-like masses of limonite which perhaps are the remains of oxidized sulphides. A similar limonite "dyke" has been recorded in the Sliding Rock mine, where the relationship between the limonite "dyke" and copper mineralization has been proved.

Although the brief investigation did not reveal any copper staining, the area, in addition to having limonitic outcrops, is so crushed that it is structuraly suitable for mineralization; and therefore warrants a more careful and detailed study.

As one of the wider dykes strikes almost due norhh and dip 40 W., one vertical diamond drill hole placed about 60 feet away, on the hanging side of the "dyke" would test the possible lode at the 50 foot level. If the results prove encouraging, other holes could be drilled to outline the orebody.

Mt. Roebuck Barytes Mine

A small open-cut and an adit have been developed in the mine, and some barytes has been won. The mine appears to have been a small prospeet which proved uneconomical, and was abandoned after a small amount of work had been done.

Orebody

The ore is in the form of veins and lenses which fill the joints and cavities of the country rock; on the surface, they can be seen cutting the enclosing pink calcareous sandstone, forming veins up to a foot wide. The strike and dip of one of the wider veins was found to be, strike N. 35°E, dip 80°E; and reasonably agreed with the strike and dip of the main joint of the area which was measured at strike N 20°E, dip 75°E.

Origin of the Deposit

Although the barytes is in a faulted area, it is not thought that mineralization was associated with hydrothermal solutions. It is more likely that it was a product derived from sedimentation. Its present location, in the cavities of Sturtian beds, must have been due to waters resulting from the weathering of younger rocks.

It may be interesting to note that while the Mt. Roebuck deposit is located in Sturtian rocks, most other South Australian barytes orebodies occur in purple shales of Marinoan series.

Future Possibilities of the Deposit

The known veins are too narrow to be worked individually; and because they are not closely spaced, they cannot be economically mined collectively. While at the surface the ore appears to be reasonably free from iron stains, there is no guarantee that deeper down, oxidized impurities will not reduce the quality of the barytes. Also the geographic position of the prospect would reduce any possible profits considerably, as heavy transport costs cannot be avoided.

In view of these difficulties, it is unlikely that the project will become a profitable mine within the near future.

The Manganese Deposits

Throughout the Flinders Ranges, there is a stratigraphic horizon between the "Pound" quartzite and the Archaecyathinae limestone, which is mineralized. The horizon is manganiferous and often carries copper and lead as well.

Along the Narina road to Blinman, there are many small diggings which have produced minor quantities of pyrolusite. The "holes", which are less than a few feet deep have produced the material from which patches of ore have been hand sorted. Other unworked manganiferous deposits, within this stratigraphic horizon were found near Patawarta Gap and along the track from Narina, leading north to the Claypan bore.

A more attractive price for manganese would probably encourage independent workers to prospect and mine the better sections of this metalliferous horizon.

Ochre Deposits

About 2 miles north of Narina H.S. there are huge outcrops of weathered shales which have been stained by iron solutions. Various colours have resulted from chocolate to yellow which appear to be suitable for colouring cement work. The shales are in the mineralized horizon of the transition beds between "Pound" quartzite and Archaeocyathinae limestone; and have obviously resulted from oxidation of the ferruginous minerals contained in that horizon.

Some of the weathered Sturtian beds also form suitable ochres. Specimen 380 D represents a red-chocolate bed which when crushed would form an excellent mahogany-coloured pigment. Specimen 328 F is a yellow variety. Both specimens were collected from an area about 2½ miles west of Mt. Stuart.

Marblitized Limestones and Dolomite

In view of the fact that limestones and dolomites are so abundant throughout the Cadnia area, a general survey was made for any carbonate material which could be useful to the Terrazzo Industry.

At present, most of the terrazzo chips used in Australia are imported from Italy at a cost of approximately £30. 0. 0. per ton. An investigation of the Italian material reveals that the most important property, which causes its wide-spread demand, is the fine, compact texture resulting from minute calcite recrystallization.

Some of the finger-grained, slightly-metamorphosed limestones and dolomite from the Cadnia sheet, have been cut and coated with "Araldite" plastic, to display their true "polished" appearances.
Specimens 31A, 43, 72, 140, 140B, 206, 236A, 279, 161E and 500 show the varities (by no means complete) which are available.

Samples X are "home-made" terrazzo slabs to prove that these Australian carbonates can also produce attractive terrazzos.

It is most likely that good quality limestones and dolomites, suitable for the industry are available nearer to Adelaide. However, the writer merely wishes to point out, that an opportunity seems to exist for anyone who is prepared to mine suitable carbonates for the Terrazzo Industry.

Localities of "Terrazzo" specimens

Specimen	Location
31A	$\frac{1}{4}$ mile east of Artimore
43	1 mile east of Patawarta Gap
72	$\frac{3}{4}$ mile south of Lady Lehmann Mine
140	2 miles east of Nuccaleena Mine
140B	2 miles east of Nuccaleena Mine
161E	$3\frac{1}{2}$ miles south-west of Nuccaleena (off sheet)
206	$1\frac{1}{4}$ miles north-west of P.I.
236A	$3\frac{1}{4}$ miles east of Artimore
279	1 mile north of Mt. Stuart
500	1 mile north of Irish Well

Summary and Conclusions

It has been deduced that deformation began towards the end of the Proterozoic Era; but was not wide-spread till early Palaeozoic times. The movements, which were related to rearrangements in the basement rocks of the geosyncline, resulted from a combination of two almost opposite forces, together with a transverse compression.

The close relationship between copper orebodies and dolerite intrusions, indicates that a genetic connection exists between them; especially since specks of chalcopyrite have been identified in the dolerite dykes.

Photogeological interpretation of the area was very successful; proving that this type of terrain is quite susceptible to reliable photographic interpretation. Studies concerning lineaments, faulting and jointing, show that the morphology of the area is influenced by faulting and jointing. Because of the large number of lineaments measured, it is concluded that there must be many unmapped faults, (perhaps with only minor movements) which produce lineaments in topography.

The thin sections display slight regional metamorphism; no marked change, apart from calcite recrystallization was noticed in the country rocks near the dolerite masses.

An inspection of the old copper mines shows that no rich extension of the worked out orebodies are likely, and that prospecting may prove successful either near Lady Lehmann mine, or at P.I. The multi-coloured, and slightly metamorphosed limestones and dolomites which outcrop in the area seem to be suitable as terrazzo chips. Their mining could create a profitable industry.

REFERENCES

BANKS M.R. and SPRY H.H. 1954. Stratigraphic Nomenclature in the Precambrian. University of Tasmania.

BROWN H.Y.L. 1908. Record of Mines of South Australia.

DAVID T.W.E. and BROWNE W.R. 1950. The Geology of the Commonwealth of Australia.

DICKENS S.B. 1944. South Australian Department of Mines, Geological survey Bulletin No. 21.

EDWARDS A.B. 1953. Geology of Australian Ore Deposits.

HOWARD P.F. 1951. The Basic Igneous Rocks of the Blinman Dome. Trans. Roy. Soc. S. Aust. vol. 74 (2).

HOWCHIN W. 1925. The Geographic Distribution of Fossiliferous Rocks of Cambrian Age in South Australia with Geological Notes and References Trans Roy. Soc. S. Aust. vol XLIX.

KAY M. 1947. Geosynclinal Nomenclature and the Craton. Bull. Amer. Assoc. Petroleum Geol., 31.

KUENEN P.H. and MIGLIORINI C.Y. 1950 Turbidity currents as a cause of graded bedding. Journ. Geol. vol. 58 (2).

LINDGREN W. 1933 Mineral Deposits.

MAWSON D. 1941. The Wilpena Pound Formation and Underlying Proterozoic Sediments. Trans. Roy.

Soc. S. Aust., vol. 65 (2).

1941. Middle Proterozoic Sediments in the Neighbourhood of Copley. Trans. Roy. Soc. S. Aust., vol. 65 (2).

1947. The Adelaide Series as Developed along the Western Margin of the Flinders Ranges. Trans. Roy. Soc. S. Asst., vol. 71 (2).

MAWSON. D. and SPRIGG R.C. 1950. Subdivision of the Adelaide System. The Aust. Journal of Science., vol. 13 No. 3.

NIGGLI P. 1954. Rocks and Mineral Deposits.

South Australian Department of Mines, Geological survey Bulletin No. 21.

South Australian Department of Mines, Mining Reviews. Nos. 8, 10, 16, 20, 22, 27, 31, 62, 68, 71, 72, 73, 75, 76, 82, 85, 88, 98.

SPRIGG R.C. 1946. Reconnaissance Geological Survey of Portion of the Western Escarpment of the Mount Lofty Ranges. Trans. Roy. Soc. S. Aust., vol. 70 (2).

SPRIGG R.C. 1952. Sedimentation in the Adelaide geosyncline and the Formation of the Continental

Terrace. Sir Douglas Mawson Anniversary Volume. University of Adelaide.

WAHLSTROM E.E. 1955. Petrographic Mineralogy.

WEBB B.P. 1960. Diapiric Structures in the Flinders Ranges, South Australia. The Australian Journal of Science Vol. 22. No. 9.

WEBB B.P. and HORWITZ R. 1959. Notes on the Boundaries of the Marinoan Series of the Adelaide System. The Australian Journal of Science. Vol. 21. No.6.

ROCK CLASSIFICATION	COLOUR OF SPECIMENS	ROCK No.	SLIDE No.	GRAIN SIZE	TYPE OF FRAGMENTS	CEMENT	LOCALITY	REMARKS
Siliceous limestone	Light grey	116	116	Limestone fine quartsO 1m.m.	Angular quartz	Limestone	3 miles S.E. Moolooloo	Quartz exists in layers.
Siliceous limestone	Grey, mottled brown	183	183	Up to O 1m.m. average O 07m.m.	Subhedral quartz	Limestone	½ mile E. Nuccaleena	Iron stained common.
Siliceous limestone	Light grey	114	114	Limestone fine quartz O 2m.m.	Subangular quartz, feldspar	Limestone	4 miles S.E. Moolooloo	Impure limestone with ferruginous material.
Siliceous limestone	Chocolate, light grey bands	290	290	Average O 08m.m. (quartz)	Subangular quartz	Limestone	½ mile S.W. Mt. Stuart	Slightly metamorphosed, and well bedded.
Quartzite	Light cream, Buff, brown	128	128	Up to 1c.m.	Subangular quartzite fragments in minute crystals of quartz ground mass	Silica iron	1½ miles N.E. Nuccaleena	The larger fragments have been silicified.
Tillite	Green-grey	341	341		Subangular quartz	Silica, Clay	2½ miles N.E. Warraweena	Typical tillite.

ROCK CLASSIFICATION	COLOUR OF SPECIMENS	ROCK No.	SLIDE No.	GRAIN SIZE	TYPE OF FRAGMENTS	CEMENT	LOCALITY	REMARKS
Calcareous sandstone	Flesh-pink dolour	162	162	Up to 0 8m.m. average 0 07m.	Subangular quartz fines) rounded quartz (coarse)	Limestone	3 miles S.W. Nuccaleena	Coarse material exists as bands.
Sandstone-quartzite	Pink, mottles	181	181	Up to 0 15m.m. average 0 08m.m	Rounded quartz	Iron	½ mile E. Nuccaleena	Poorly sorted sandstone. Slightly micaceous.
Quartzite	Light grey to flesh coloured	305A	305A	Up to 0 5m.m. average 0 1m.m.	Angular quartz, feldspar (fines) rounded quartz (coarse)	Limestone	Cockatoo Water	
Quartzite	Flesh to pink coloured	523	523	Up to 0 7m.m. average 0 07m.m.	Subangular quartz (fines) rounded quartz (coarse)	Iron	1 mile S.E. Mt. Roebuck Ba. Mine	Not well sorted.
Sandstone	Buff	538D	538D	Large variation	Angular and rounded fragments	Iron	2 miles N.E. Main Gap	Weathered fluvio-glacials.
Limestone-marble	Off white	24	24	Average 0 3m.m.	Subhedral calcite, quartz, feldspar, sericite	limestone	4 miles S.W. Artimore	Partly marblitized.
Siltstone	Chocolate	524	524	Average 0 04m.m	Subangular quartz	Iron Clay	1 mile S.E. Mt. Roebuck Ba. Mine	Weathered.
Calcareous quartzite		140	140	Up to 0 2m.m. average less than 0 05m.m.	Subhedral quartz	Limestone	1½ miles E. Nuccaleena	
Limestone		140B	140B	Very fine	Subhedral	Limestone	1½ miles E. Nuccaleena	Slightlu metamorphosed.
Siliceous limestone		124	124	Less than 0 01m.m.	Angular quartz	Limestone	2 miles S. Moolooloo	Quartz exists in layers.
Arenaceous limestone	Chocolate	122	122	Average 0 2m.m.	Angular Quartz	Limestone Iron	2 miles S.E. Moolooloo	
Siliceous marble	Mottled flesh coloured	167	167	Quartz 0 6m.m. calcite 0 5m.m.	Anhedral quartz, calcite euhedral	Iron	1½ miles S.W. Nuccaleena	Well metamorphosed.
Quartzite	Light grey, mottled chocolate	133	133	Up to 0 6m.m. Average 0 08m.m	Subhedral quartz, calcite		½ mile N.E. Nuccaleena	Calcite veins.

ROCK CLASSIFICATION	COLOUR OF SPECIMEN	ROCK No.	SLIDE No.	GRAIN SIZE	TYPE OF FRAGMENTS	CEMENT	LOCALITY	REMARKS
Siltstone	Khaki-green	79	79	Fine bands 0 04m.m. coarse bands 0 1m.m.	Subangular quartz, feldspar, muscovite	Clay	Near Hanagan Gap	Typical of fine and coarse members of this formation.
Silstone	Chocolate	80	80	Average0 02m.	Subangular quartz, muscovite	Clay iron	Near Hanagan Gap	Slightly metamorphosed and iron stained.
Quartzite	Chocolate	310	-	Fine			2 miles N.W. Mt. Stuart	Very hard. Ferruginous material has leached out.
Siltstone	Buff	81	81	Aver. 0 01m.m	Subangular quartz, muscovite, sericite	Clay	Near Hanagan Gap	Slightly metamorphosed. Micaceous minerals orientated.
Ferruginous quartzite	Chocolate	195	195	Aver. 0 15m.m	Subhedral quartz	Iron	1½ miles N.W. Mooloolo	Fairly even sized fragments.
Siltstone	Chocolate	397	397	Less than 0 05m.m.	Quartz	Clay iron	1 mile N. Jeffrey's Well.	Two thin sections.
Siltstone grey-wacke	Chocolate	20	-				2 miles W. Artimore	Slightly metamorphosed.
Slate-shale	Khaki-green	283	283	Less than 0 02m.m.	Subangular quartz	Clay iron	1 mile N. Mt. Stuart	Almost a siltstone with ferruginous bands.
Slate	Grey-green	22	22	Less than 0 01m.m.	Minute quartz and feldspar	Clay	4 miles W. Artimore	Typical well bedded slate.
Slate-shale	Grey-green	297	297	Very fine	Minute quartz	Clay	Near Nantillbury	Shows bedding.
Siltstone-shale	Grey-green	311	311	Very fine	Some quartz	Clay, Iron	½ mile N.W. Bobmoony's Hut	
Quartzite	Flesh-pink colour	145	145	Up to 0 8m.m. Aver. 0 15m.m	Anhedral quartz, alcite		1½ miles E. Nuccaleena	A clean quartzite.
				STURTIAN	RIES			
Calcareous sandstone	Flesh colour	160	160	Up to 0 7m.m. Aver. 0 15m.m	bangular quartz (fines) rounded quartz (coarse)	Limestone	2½ miles S.W. Nuccaleena	

ROCK CLASSIFICATION	COLOUR OF SPECIMEN	ROCK No.	SLIDE No.	GRAIN SIZE	TYPE OF FRAGMENTS	CEMENT	LOCALITY	REMARKS
Arenaceous dolomite	Mottled green,grey	369	369	Up to 0 4 c.m. Large variation	Subhedral quartz, shale,dolomite	dolomite	1½ miles N.E.Old Warraweena	Dolomitized lens about 1 ft. wide.
Slate-shale	Green9grey	15	-				1 mile S.W. Artimore	Typical grey-green shale near base of dolomite horizon.
"A.B.C."quartzite upper	Flesh coloured	13	13	Up to 0 2m.m. average 0 1m.m.	Subhedral quartz		1 mile W. Artimore	Typical top "A.B.C." quartzite, showing a mosaic texture. Slightly metamorphosed.
"A.B.C."quartzite upper	Off white	333	-	Fine grained.			1½ miles W. Camel Well	Slightly metamorphosed.
"A.B.C."quartzite upper	Light grey	93	-	" "		dolomite	1 mile E. Lady Lehman Mine	Ferruginous material has been leached out. Associated with fault zone.
"A.B.C."quartzite upper	" "	548	548	Up to 0 4m.m. average 0 1m.m.	Subhedral quartz	dolomite	1 mile S.E. Pinda Springs	Ferruginous material has been leached out.
"A.B.C."quartzite upper	Grey	261	-	Fine grained.			½ mile S. Rock Water Springs	Very well metamorphosed.
"A.B.C."quartzite upper	Light grey	2	2	Up to 0 3m.m. average 0 07m.m	Subhedral quartz	iron,clay	1½ miles S.E. Rock Water Springs	Has more clay mineral than "A.B.C." average.
"A.B.C."quartzite upper	Flesh coloured	285B	285B	Up to 0 3m.m. average 0 1m.m.	Subhedral quartz		2 miles N.W. Mt. Stuart	Metamorphosed, but less than specimen 285A.
Arenaceous slate	Light brown	-	-				1 mile S.W. Artimore	Soft beds between the two "A.B.C." members.
A.B.C." quartzite lower	Flesh coloured	285A	285A	Up to 1 5m.m. average 0 3m.m.	Subhedral quartz		2 miles N.W. Mt. Stuart	Very well metamorphosed.
"A.B.C."quartzite lower	Light grey	11	11	Up to 0 4m.m. average0 2m.m.	Subhedral quartz		1 mile S.W. Artimore	Hard and well metamorphosed.
"A.B.C.quartzite lower	Flesh coloured to light grey	332	332	Up to 1 0m.m. average 0 4m.m.	Subhedral quartz		1½ miles S.W. Camel Well	Very hard and well metamorphosed.
iltstone grey-acke	Brown-grey	19	-				2 miles W. Artimore	Slightly metamorphosed.
Siltstone	Grey-green	-	-				2 miles N.W. Mt. Stuart	

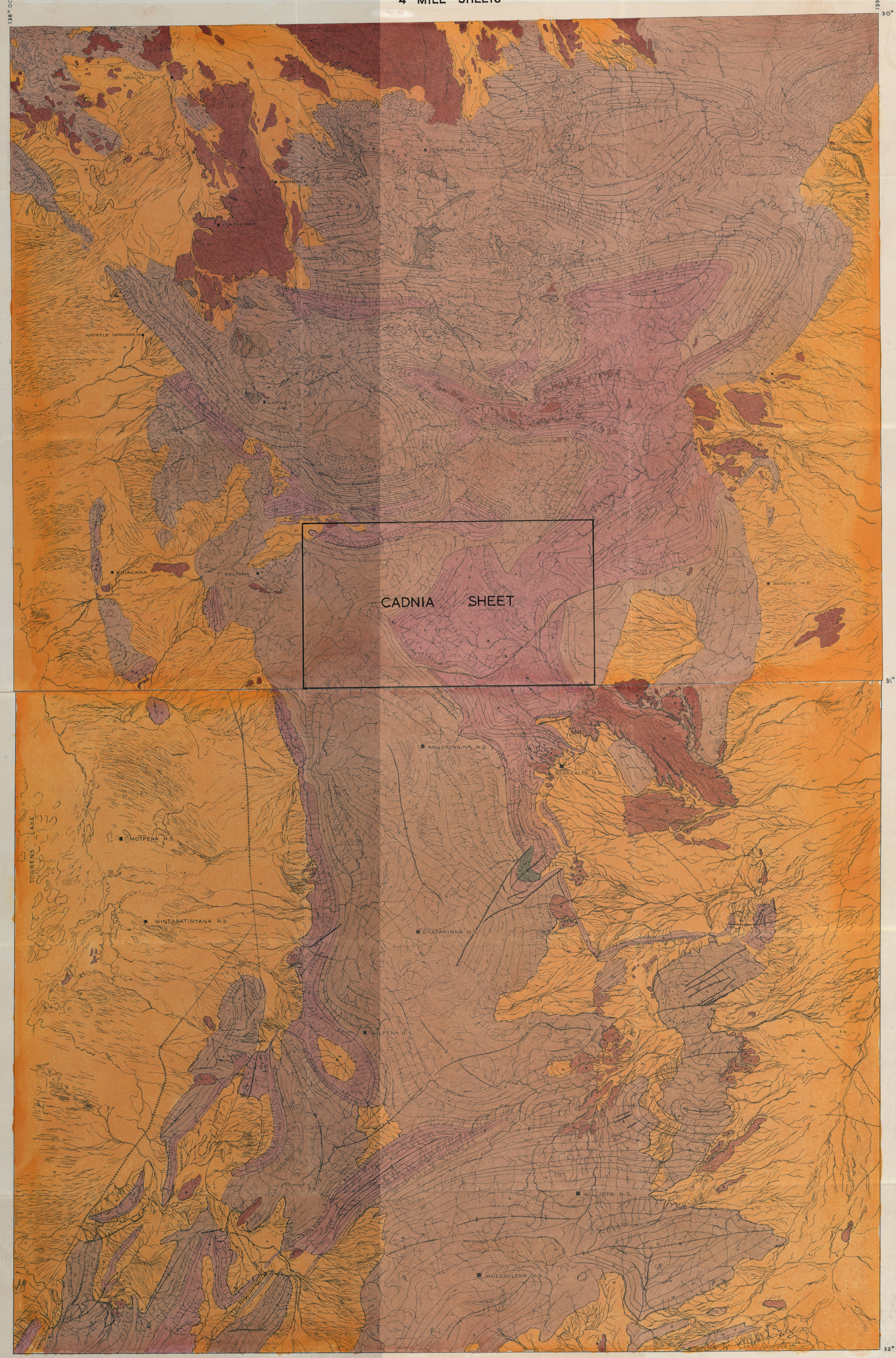
ROCK CLASSIFICATION	COLOUR OF SPECIMEN	ROCK No.	SLIDE No.	GRAIN SIZE	TYPE OF FRAGMENTS	CEMENT	LOCALITY	REMARKS
Quartzite	Light grey	362	362	Up to 0 5m.m. average 0 2m.m.	Subrounded quartz	calcareous	1 mile W. Sliding Rock Ck. Mine.	Calcareous cement fills cavities. weathered.
Quartzite	Flesh coloured to brown	271	-	Fine			4 miles N.E. Old Warraweena	A small porous band below the main "Pound" formation.
Quartzite	Light flesh colour	307	307	Up to 0 5m.m. aver.0 2m.m.	Anhedral quartz		1½ miles S. Sliding Rock	Very porous.
Quartzite		469A	469A	Up to 0 6m.m. aver.0 2m.m.	Anhedral quartz		2 miles N. Narina H.S.	
Quartzite	Buff	270	270	Up to 0 3m.m. aver. 0 1m.m.	Subhedral quartz and feldspar		4 miles N.E. Old Warraweena	A small porous band below the main "Pound" formation.
				MARINOAN	SERIES			
Calcareous slates	Grey-green	-	-				N. of Artimore.	
Arenaceous siltstone	Grey	259	-			Calc.	Near Black Range Spring	Well bedded.
Dolomite	Green-grey	-	-				1 mile N. Artimore	100 foot lenses of massive dolomite.
Calcareous sandstone	Buff-grey	257	-				Near Black Range Spring	Associated with massive dolomites.
Dolomite-marble	Light grey	43	43	Up to 0 5m.m. aver. 0 1m.m.	Recrystallized dolomite	Iron	1 mile N.E. Hanagan Gap	Recrystallozation due to fault movements.
Breccia (micro)	Mottled red, buff, grey	92A	92A	Variable	Subangular quartz, feldspar, mica	Calc.	1 mile N.E. Lady Lehmann	Sediments contaminated and recrystallized. Due to crush zone.
Dolomite	Cream, brown	72	72	Very fine	Recrystallized Siderite, quartz	Siderite	Near Lady Lehmann Mine	Some large grains of siderite. Metamorphism due to crush zone.
Breccia	Cream mottled	40	40	Up to 0 5m.m.	Recrystallized quartz, calcite	Calc.	2 miles N.E. Artimore	In crush zone. Mineralized with hematite.
Dolomite-marble	Pink, green	255A	255A		Recrystallized carbonates	Argill.	Near Rock Water Spring	Brecciolic structure in an undisturbed area.
Dolomitic siltstine	Chocolate	255B	255B	Up to 0 1m.m. aver. 0 01m.m	Quartz, calcite	Argill. calcite	"	Typical choc. dolomite from the base of dolomitic shales.
Breccia	Pink, buff	265	265	Variable	Dolomite, quartz, shale	Dolomitic	3 miles N.E. Old Warrawena	Recrystallized dolomite fragments in fault zone.
Dolomitic siltstone	Chocolate	31B	-			Dolomitic	Near Artimore	Minor dolomite lenses in choc. shales below 255B.
Argillaceous siltstone	Chocolate	1	1	Very fine	Quartz, clay, iron	Iron	2 miles S.E. Rock Water	Typical chocolate siltstone below main dolomite horizon.
Dolomitic shale	Chocolate	-	-				S.E. part of sheet	Chocolate shales from base of chocolate formation.

LIST OF ROCKS AND THIN SECTIONS

ARRANGED IN STRATIGRAPHIC ORDER

ROCK CLASSIFICATION	COLOUR OF SPECIMEN	ROCK No.	SLIDE No.	GRAIN SIZE	TYPE OF FRAGMENTS	CEMENT	LOCALITY	REMARKS
Green-grey silt-stone.	Green-grey	491	-				1½ miles east of Irish well	This formation is mainly calcareous siltstone.
Calcareous silt-stone	Green-grey	493	-				"	"
Calcareous shale	Buff	-	-				-	About 30% of this formation is black limestone. Rest is shale.
Argillaceous limestone	Thin buff shale between black limestone	490	-				½ mile east of Irish Well	Limestone weathers into cigar-shaped fragments and shale into yellow powder.
Calcareous shale	Thin black limestone in buff shale	500	-				1 mile north of Irish Well	Bands of limestone inches thick. About 60% shale.
Arenacous limestone	Grey-black with pink bands	501	-				2 miles north-west of Irish W.	Pink bands are more sandy. Colour due to oxidized iron. About 5% of formation is shale.
Calcareous slate	Grey-black	502	-				2¼ miles N.-W. Irish Well	Argillaceous material with Calcareous cement.
Argillaceous limestone	Black	503	-				3 miles N.-W. of Irish Well	4' bands of massive limestone separated by noddular limestone 3"-4" thick.
Calcareous shale	Grey	504	-				3¼ miles N.-W. of Irish Well.	3"-4" thick fossiliferous lime-stone bands in yellow shale.
Argillaceous limestone	Grey-black	505	-				"	Massive noddular 3' lenses inter-bedded with argillaceous matter fossils?
Limestone	Grey	236	236A				2½ miles W. of Point Well	Some calcite veins. Pink due to iron. Massive.
Limestone	Grey-black	54	54				2 miles N.E. Patawarta	Some calcite grains and iron stains.
Limestone	Grey	506	-				3½ miles N.-W. Irish Well	Highly fossiliferous. Pinnacle studded surface. Limestones separated by thin shale bands.
Shales	Grey, yellow white	-	-				-	Often very Ochrous. Manganese, limonite,a nd copper frequent.

COPLEY & PARACHILNA
4 MILE SHEETS

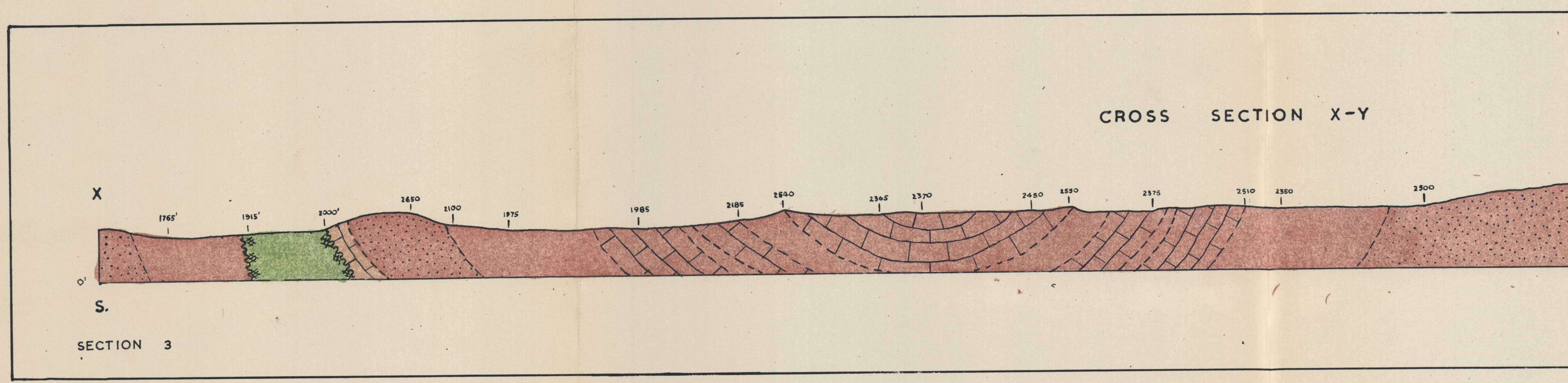


Legend	
CAINOZOIC (QUAT.)	PROTEROZOIC
CAINOZOIC (TERT.)	ARCHAEAN
PALAEOZOIC	

G · H54 · 13
4 mile

PLAN BY GEOSURVEYS AUSTRALIA LTD.

PLAN 20


CROSS SECTION X-Y
X
Y
1765'
1915'
2000'
2650
2100
1975
1985
2185
2540
2365
2370
2450
2550
2375
2510
2350
2500
3560
2826
2700
2435
2825
2582
3143
2582
0'
0'
S.
N.
HORIZONTAL & VERICAL SCALE
1 INCH 60 CHAINS APPROX.
SECTION 3

CADNIA

LEGEND

CAINOZOIC	QUAT.		ALLUVIUM
	TERT.		HIGH LEVEL GRAVELS OF FORMER GEOMORPHIC CYCLES
PALAEOZOIC	CAMBRIAN		BUFF COLOURED CALC. SILTSTONES
			CALC. SHALES
			LIMESTONES & SHALES LOWER L.S. IS ARCHAEOCYATHINAE HORIZON
			"POUND" QUARTZITE FORMATION
PROTEROZOIC	MARINOAN		DOLOMITES & SHALES
			GREY SHALES
			"A.B.C." QUARTZITE FORMATION
			GREY QUARTZITES & SLATES
			CHOC. SLATES & SILTSTONES
			GREY & CHOC. SLATES
	STURTIAN		LIMESTONES & SLATES SANDY NEAR TOP. UPPER MEMBERS ARE THE BRIGHTON EQUIV.
			GREY GREEN SLATES
			TILLITE

- CRUSH ZONES SOME (I) CONTAIN DOLERITE INTRUSIONS
- STATIGRAPHIC SECTIONS
- TRACKS
- OLD MINES
- LITHOLOGICAL BOUNDARY
- BOUNDARY OBSCURE
- TREND LINES
- FAULTS
- FAULTS INFERRED
- STRIKE AND DIP OF BEDDING
- PLUNGE OF FOLDS
- STRIKE AND DIP OF JOINTING
- P. I. ENCOURING PROSPECT No. I
- FOSSIL LOCALITY

SCALE — I INCH: 60 CHAINS

30 30 0 60 120 chains

R. GRASSO. FEB. 1959.

MAP 19