REPORT TO ENTERPRISE EXPLORATION COMPANY PROPRIETARY LIMITED

ON

PART I

THE GEOLOGY OF GOSSE'S BLUFF, (N.T.) AND VICINITY

AND

PART II

A GEOLOGICAL RECONNAISSANCE IN THE AREA BETWEEN HUGH RIVER AND CENTRALIAN RAILWAY, DEEP WELL SIDING
AND MARYVALE HOMESTEAD, N.T.

by

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The first and major part of this report contains the description and interpretation of the peculiar structure of Gosse's Bluff. It is shown that nothing older than Upper Ordovician formations appears in the core of the pound-like mountain range and that the whole structure is most likely due in the first place to an acid igneous plug which, solidified, subsequently resisted even major orogenic forces, thus causing the sharply uprighted attitude of the strata which form the rim of the pound. The hard igneous core of the structure is hidden at depth, probably with its top less than 1,500 feet below surface, but some of the apophyses from the plug have reached near-surface beds of the then unfolded configuration and are now found in small outcrops immediately to the south and southwest of Gosse's Bluff in the form of re-exposed plugs and dykes which are involved in the tight folding expressed in the Late Ordovician Mareenie Sandstone.

The structural characteristics of the Bluff suggest that its present form - excluding post-tectonic erosion - is the result of (a) doming by diapiric igneous intrusion, (b) subsequent involvement in a major orogeny during either Silurian or Devonian times and (c) final shaping by north-south directed and on other, regional, evidence believed to be strong epeirogenetic tectonics.

It is the writer's opinion that Gosse's Bluff is not and never has been an evaporite diapir.

In the second part of the report it is shown that a major and as yet not properly recognized orogeny affected Central Australia during the Later Procambrian, i.e., after the deposition of the Collenia-rich Bitter Springs Limestone and before the Subcambrian sedimentary cycles transgressed over a surface with rather strong relief whose peaks and ridges consisted of tightly folded Bitter Springs Limestone and older formations such as the Heavitree Quartzite. That is why one finds direct contacts between Bitter Springs Limestone and almost any one of the Subcambrian and
Cambrian formations, the contacts being basically simple onlaps, not faults as is currently believed.

Across the Rodinga area all of the Ordovician and much of the Cambrian sequence was not deposited. Bitter Springs Limestone and even Heavitree Quartzite have been re-exposed. Younger sequences are over most of the area preserved only in synclinal configurations which reflect depressions in the pre-Subcambrian surface that have been further compressed during the Siluro-Devonian orogeny. Evaporite deposits are unlikely to occur throughout this region.
INTRODUCTION

Gosse's Bluff (or Gosse's Range) is a conspicuous, isolated, pound-like mountain structure jutting out of the rolling downs some 40 miles west of Hermannsburg Lutheran Mission and about midway between the EW-trending MacDonnell Ranges in the north and the WNW-striking Krichauff Ranges in the south. At first sight the pound appears subcircular (diameter of 3-4 miles), but it is in fact subtriangular. Cartographically and structurally the roughly equilateral triangle’s base line is formed by the EW-trending southern rim of the pound.

The rim rises from 400 to 600 feet above the central part of the pound. The whole structure sits astride the apical region of a long (15 to 20 miles) broad, EW-trending rise. This morphological whale-back surmounts the bottoms of the EW-trending valleys on its north and south flanks by 300 to 500 feet. Since Gosse's Bluff crowns the apex of the whale-back its highest rim elevations are as much as 1,000 feet above the lowest areas in its surroundings along Ruddalls Creek. In terms of absolute altitude the highest points of the rim are a little more than 3,000 feet above sea level. It is noteworthy that the morphology of the rim at or just below this altitude shows clear evidence of an ancient peneplain.

The regional uniqueness of the Range as well as its apparently diapiric geometry naturally invited speculations about its origin. The most favoured interpretation has lately been to regard it as the surface expression of an evaporite plug at depth. However, since little was known about the geology of the area, such an interpretation remained entirely speculative even after the occurrence of salt diapirs in Palaeozoic formations of the Kimberley Subdivision of Western Australia had been established by deep drilling in the quest for oil.

Having been assigned by Enterprise Exploration Co. Pty., Ltd., to the task of detailed study of the Gosse’s Bluff area - with special reference to the evaporite-plug idea - and of a reconnaissance of apparently similar structures in the Rodinga area, 40 to 60 miles south of Alice Springs,
as from April 20th 1959, the writer arrived in Alice Springs on April 21st and was met there by one of Enterprise's own geologists, Mr. G.W. Patterson and his field assistant, Mr. N. Gaden.

Of the time between April 20th and the date of the completion of the actual fieldwork (June 5th) 22 days were spent in the area of Gosse's Bluff, 3 days on comparative stratigraphical studies in the Areyonga Valley of the Krichauff Ranges and the Stokes Pass region in the western Macdonnell Ranges, and 6 days on the reconnaissance in the Rodinga area (towards the end of the field period).

As Mr. G.W. Patterson, having fallen ill during the week of my arrival in Alice Springs, was unable to take any further part in the survey, Enterprise's geologist P. Searle was seconded to assist me. He arrived at the Gosse's Bluff camp on May 6th and remained, together with Mr. N. Gaden, to the end of the survey. The party was equipped with a complete flying-camp set and had first one, later (as from 6th May) two Willy's 6-cyl., 4x4 utilities at its disposal.

Fieldwork had to be interrupted for a few days in May because of substantial rainfalls, but this did not extend the survey period beyond the intended 6 weeks because such a few days' break had by that time become necessary anyway for compilation of results, drafting of maps, and repairs to the vehicles and to the radio equipment.

At the end of the field period the party accompanied Mr. C. L. Knight, Chief Geologist, to Gosse's Bluff for a demonstration of the survey's results and discussion of the interpretation submitted with this report. Mr. Knight and the writer then returned to Melbourne on June 5th. During the remaining days until June 10th the writer completed this report.

The writer wishes to express his sincere thanks to Messrs. H. F. King and C. L. Knight for entrusting him with this most interesting assignment, and to Messrs. G.W. Patterson, P. Searle, and N. Gaden, for their able assistance and good companionship in the field.
PART I

THE GEOLOGY OF GOSSE'S BLUFF, N.T., AND VICINITY

(Plates 1 - 7, Appendix II).
All formations taking part in the actual Gosse's Bluff structure are of Upper Ordovician age. In order to study formations older than Upper Ordovician, one has to travel several tens of miles either to the north (MacDonnell Ranges) or the south (Krichauff Ranges). Of the post-Ordovician formations which have a bearing on the interpretation of the Gosse's Bluff structure one is sedimentary and of Lower Carboniferous age, the other is igneous and its age Silurian or Devonian as far as can be judged from indirect evidence.

Post-Palaeozoic formations play a minor role in these regions. They consist of sheets of terraced gravels, of pediment deposits, and other terrestrial sediments, and will not be described here.

The following description of the formations in the Gosse's Bluff area is kept rather brief because, apart from generally ascertaining their nature and age, the main subject of the survey was the study of the structural characteristics and relationships of the Bluff, with a view, of course, to the possibility of it being an evaporite plug.

A. UPPER ORDOVICIAN

(in ascending order)

The "Stokes Formation"
(Nos. 2-4 of legend Plate 1, and Plate 6)

The name "Stokes Formation" is here used in a more restricted sense than is currently done by other students of Centralian stratigraphy (the name is not published yet). For reasons explained below I prefer to exclude what I call "Luther Limestone" and "Gosse Shale" from "Stokes Formation" (also loosely called "Walker Creek beds").

In this restricted sense the Stokes Formation consists of a sequence of calc-siltstones interbedded with limestones of varying types and with occasional thin, sandy beds. It is the oldest of the formations exposed at Gosse's Bluff and forms - crushed, squeezed and imbricated in itself - the low bare hills in the centre of the pound. Its lower portion is not exposed.
According to the palaeontologists of the Bureau of Mineral Resources (Canberra) the formation belongs in the Upper Ordovician. This may or may not be correct - it could still be Mid-Ordovician. I suspect that BMR age determination to be based on the rich fauna of the next younger sequence, the Luther Limestone, which I prefer to keep separate because of its disconformable relationship to the Stokes Formation. The latter's fossil fauna appears to be very poor, the only identifiable forms are some gastropods, 200 to 300 feet, representing an upper portion of the formation, are exposed inside the Bluff. Because of tectonic complications a more precise figure cannot be given.

The corresponding sequence at Stokes Pass measures 500 to 600 feet, whereas near Areyonga Native Settlement in the Krichauff Ranges only 100 to 300 feet are left, the reduction being partly due, however, to tectonic squeezing in the area of the great Areyonga upthrust.

A typical profile through the Stokes Formation is shown in Plate 6. It will be noticed that three subdivisions have been separated on the map and the sections. These subdivisions are somewhat vague, however, i.e. they are not easily identified by the "uninitiated" and they should not be regarded as formally recognizable members of the formation. This not particularly successful attempt at subdividing the Stokes Formation arose from the necessity to unravel the many tectonic complications in the core of the pound. In this regard the vague subdivisions were useful although it is admitted that they are "felt by the experienced" rather than physically definable.

The youngest of the three subdivisions, for example, is characterized by frequent limestone interbeds, some of the most conspicuous among them being oolitic. The middle subdivision is predominantly calc-siltstone with some calc-sandstone beds; limestones are scarce. The nature of the oldest subdivision - which is not shown in detail on Plate 6 - is not clearly recognizable but it was necessary to establish it for a sequence of calc-siltstones interbedded with minor limestones which does not quite fit into the two younger subdivisions. It appears in places in situations which suggest that it is a sequence older than the middle subdivision, although not much different from the latter.

The upper boundary of the Stokes Formation is a disconformity surface at the base of the conspicuous basal member (a brown, coarsely crystalline echinodermal breccia
or "Spatkalk") of the Luther Limestone. The lower boundary towards the presumably underlying "Stairway Sandstone" is not exposed at Gosse's Bluff.

The "Luther Limestone"
(Nos. 5-6 of legend Plate 1, and Plate 6)

This name is applied to a very distinct sequence, 200 to 300 feet thick, of thin-bedded, richly fossiliferous grey and brown limestones which follows disconformably upon the Stokes Formation. I surmise that it is the Luther Limestone to which the BM palaeontologists' age determination "Upper Ordovician" applies.

Specific identification of the various elements of the fossil fauna of the Luther Limestone (trilobites, nautiloids, pelecypods, gastropods, polyzoans, echinoderms) has not been possible in the limited time at my disposal, but by direct field comparisons of the Luther Limestone fauna with that of the older "Horn Valley Beds" and that of the limestones in the "Stokes Formation" at Stokes Pass itself I have proved to myself beyond doubt that the latter - not the Horn Valley limestones - correspond to the Luther Limestone at Gosse's Bluff.

It would be possible to subdivide the Luther Limestone further on the base of the occurrence of certain genera and species. There are definite zones of predominance of particular types of fossil populations (e.g. "Orthis Zone", "Trilobite Zone", etc.) and these have been found to follow each other in the same order both at Gosse's Bluff and at Stokes Pass. No further elaboration of this observation is necessary here, but the recognition of such features may ultimately help other students working in the area.

The basal few feet of the Luther Limestone form a most conspicuous marker horizon which I call the "brown spatkalk". It is an echinoderm breccia, i.e. a coarsely crystalline limestone, made up of fragments of echinoderms. The basal 4-5 feet of this marker horizon is distinctly olive brown both on fresh and on weathered surfaces. In this form of "brown spatkalk" the echinodermal limestones do not occur anywhere else in the section, although echinoderms as such are common in the sequence. For that reason the "brown spatkalk" is an invaluable guide bed for the elucidation of the rather complicated tectonics in the centre of the pound. It is noteworthy that it occurs in the same sequential position and with the same lithology also at Stokes Pass in the western Macdonnell Ranges.
The existence of a basal disconformity must be inferred firstly from the observation that the "Orthis Zone" in one section (Plate 6) is directly overlying the basal "brown spatkalk" whereas in other, nearby outcrops, it is separated from it by up to 40 feet of fossiliferous limestones from which orthids appear to be absent. Secondly, the sedimentary environments of the Stokes Formation and the Luther Limestone were evidently rather different, and the change from one to the other is sudden, not transitional. The break between the two sequences may or may not represent a significant interval of non-deposition. Yet as long as there is evidence of some break it seems preferable not to apply an age determination gained from the Luther Limestone fauna to the Stokes Formation.

The upper boundary of the Luther Limestone towards the Gosse Shale is nowhere exposed, but in two places, where outcrops of basal parts of the latter and top parts of the Luther Limestone are no more than 10 or 15 feet apart, there are no signs indicating a transitional nature of the contact between the two formations. Again the onset of a new sedimentary environment appears to have been sudden, although in this case the contact need not be disconformable.

The "Gosse Shale"
(No. 7 of legend, Plate 1).

This name is introduced for a sequence of non-calcareous red and green shales and slightly fissile mudstones, estimated to be from 400 to 600 feet thick when tectonically undisturbed. This sequence overlies the Luther Limestone and it has previously been included in what is called "Stokes Formation" (or "Walker Creek beds") by earlier investigators.

In its uppermost 50 feet the Gosse Shale changes gradually but quickly into calcareous, shaley, red siltstones which in turn soon become interbedded with red, calcareous silty sandstones indistinguishable from what is known as Mareonio Sandstone. This may indicate that the Gosse Shale represents the opening chapter of a new sedimentary cycle in this region, i.e. that after a quiet, neritic phase (Luther Limestone), without significant deposition of land-derived clastics, the region is suddenly again placed under the influence of near-shore environments. This change would be characterised first by argillaceous, then by silty, and finally by sandy sediments. However, one cannot exclude the possibility that the mudstone phase of the Gosse Shale after the Luther Limestone might indicate an initial deepening of the previously neritic trough environment and that the near-shore conditions take eventually effect without the re-appearance of a neritic phase on the "return-trip", i.e. that the rate of
shallowing of the trough was much faster than that of the previous deepening. In this case there would, of course, be no disconformity between Luther Limestone and Gosse Shale.

The "Mareenie Sandstone"
(Nos. 8-11 and 712 of legend, Plate 1)

The Mareenie Sandstone is a thick (5,000 feet or more) sequence consisting chiefly of red, buff, and whitish, more or less silty, medium grained, often crossbedded partly calcareous sandstones. The uppermost quarter of the sequence is softer, fine grained and even shaley, and seems at least locally to be separated from the older part of the sequence by an erosional unconformity whose conspicuousness has become emphasized in places by the strong tectonic movements that have affected the Bluff. This softer series, in concert with the Gosse Shale, is responsible for much of the morphology of the rim of Gosse's Bluff, because one accompanies the inside, the other the outside, of the rim which, itself, consists of the main mass of the harder Mareenie Sandstone proper.

The sequence (Plate 1) develops out of the silty top portion of the Gosse Shale and begins with rather soft, red-brown silty sandstones in which case-hardening rarely reaches deeper than one-sixth to one-quarter of an inch. These red sandstones soon show lateral and vertical facies changes into less silty, i.e. more evenly grained and therefore more porous, whitish varieties which are commonly case-hardened to a depth from the surface of one inch or more because of their increased porosity. These whitish sandstones, standing near-vertical in the rim, therefore form the sharp crests and peaks which characterize the inner part of the rim structure. In the upper half of the sequence the whitish types of the Mareenie Sandstone disappear except for occasional minor lenses. The external part of the rim structure therefore consists almost exclusively of the softer, red, sandstones, and not surprisingly they are the ones which show remnants of an ancient peneplain (now at 2,900 to 3,300 feet above sea level) which decapitated the uprighted Gosse's Bluff structure as a whole, i.e. removed its higher structural elements.

I could not find any fossils in this series or in the Gosse Shale. From finds in other areas it is, however, believed (BMR opinion) that the Mareenie Sandstone is still chiefly within the Ordovician. Its total range, i.e. its youngest beds, cannot be demonstrated in the Gosse's Bluff area because the next younger formation, the carboniferous Pertnjarra Conglomerate, was deposited unconformably over the uprighted and thereafter partly eroded structures formed by the Mareenie sequence.
B. LOWER CARBONIFEROUS

The "Pertnjarra Conglomerate"
No. 13 of legend, Plate 1).

Since the Pertnjarra Conglomerate does not partake
in the Gosse's Bluff structure a detailed lithological
description is not deemed necessary. Suffice it to state
that it is in this area a gritty to pebbly, soft, red,
sandstone rather than a conglomerate or gomphite. It
occurs to the north of the Bluff between Areyonga road and
Ruddalls Creek where its thickness may be less than 500
feet (see sections Plate 2). Farther north towards the
western Macdonnell Ranges it is, however, reported to be
several thousands of feet thick.

The age of the Pertnjarra Conglomerate has long
been a controversial topic among the geologists who have
worked in Centralia. Only a few weeks ago, however, the
problem seems to have been solved by the discovery of stem
fragments of lepidodendrid trees in seemingly equivalent
beds in the Tempe Downs region south of the Krichauff
Ranges by a field party of Frame-Broken Hill Pty. Ltd.
I have inspected this material and am convinced that
these lepidodendrids compare best with the stem fragments
that are found in the Harris Sandstone of the Carboniferous
system in the Carnarvon Basin of Western Australia. In
Australia lepidodendrids are known only from the Upper
Devonian and the Lower Carboniferous. In Permian floras
they are absent.

The main significance of the Pertnjarra Conglomerate
with regard to the Gosse's Bluff structure lies in its
markedly unconformable contact with the Mareenie Sandstone
and the fact that an important post-Carboniferous folding
phase is now established in addition to a Siluro-Devonian
one, because together with the Pertnjarra Conglomerate the
unconformity surface at its base has also been folded.
This makes it clear that the Gosse's Bluff structure has
been going through at least two tectogenic events.
C. THE IGNEOUS SUITE OF "MT. PYROCLAST"

(Siluro-Devonian ?)

About three miles south of the southern rim of the Bluff there is a group of low hills which sit astride a broad rise in the country between Gosse’s Bluff and the Krichauff Ranges. In this manner they reach actually to an altitude of perhaps 2,500 feet above sea level or slightly more. Because of my early working hypothesis, which surmised a strongly resistant body immediately south of Gosse’s Bluff, this area was carefully studied although - with the exception of the hills - there are few outcrops.

It was at once noticed that this group of hills consisted of rocks of an entirely different type from those occurring in Gosse’s Bluff, and closer inspection revealed what, without laboratory inspection, anybody would call a volcanic suite. The most conspicuous of the hills, i.e. Mt. Pyroclast, has the typical appearance of a re-exposed plug. It consists of a rocky pimple protruding from a fairly steeply sloped, conical hill. In other words, it looks like an igneous plug surrounded by scoria slopes. However, these slopes show rocks with contact phenomena such as altered and baked sandstones (Marconic), brecciated and heavily silicified sandstones, and odd materials such as coarse grained marbles which suggest that the original position of the plug was still below surface and it is only erosion which has exposed it. Several heavily silicified and brecciated "dykes" radiate on echelon fashion west and northwestward from the main plug along or near the axis of what I think is a tight and slightly southward overturned anticline (see Plate 7). These "dykes" eventually come very close to the southwestern rim of Gosse’s Bluff and some such heavily silicified sandstones, not brecciated though, occur even within the western rim.

The whole suite has been submitted to a specialist in igneous petrology and his report is attached (Appendix II).

The main significance of the discovery - the first in Central Australia - of such a post-Ordovician igneous suite is that it gives the igneous diapir theory on the origin of Gosse’s Bluff very much more weight. In fact, it may almost be said that it makes the theory irrefutable. However, there are (Iran) salt diapirs which have become intruded by magmas. They are rare and in most cases where igneous rocks occur in salt diapirs they have come up passively with the salt just like other, non-igneous, fragments and slivers.
A. The Regional Setting of the Gosse's Bluff Structure.  
(Plate 7)

The current concept on the structural attitude of the Cambro-Ordovician series west of Hermannsburg and between the Macdonnell and the Krichauff Ranges is that of a simple, wide, syncline, between two more strongly folded anticlinoria. Consequently, the Gosse's Bluff structure had to be regarded as an isolated, post-tectonically diapiric phenomenon, which produced locally vertical and overturned attitudes in regionally sub-horizontal or, at the most, only gently clinched strata. This concept has also served as basic assumption for the calculations and interpretations of the geophysicists of the Frome-Broken Hill Pty, Ltd, and their consultant from the Bureau of Mineral Resources. It was then logical too to suspect that apart from Gosse's Bluff there might be other diapiric structures both within the Hermannsburg "syncline" and in other, similarly broad, tectonic depressions in the Amadeus Trough.

It is now clear that with regard to Gosse's Bluff and its vicinity this concept is not correct. In fact, wherever the patchy exposures of Cambro-Ordovician series are good enough to allow of reliable dip and strike readings, the strata still show very steep attitudes over distances of several miles away from Gosse's Bluff. Although the scarcity of such good exposures prevents the detailed study of the hidden tectonics of the area one cannot escape the conclusion that what was regarded as a little disturbed "wide syncline" is in reality a very strongly folded region in which even so unexpectedly diapiric a structure as Gosse's Bluff need not be considered as particularly strange.

The regional setting of Gosse's Bluff is that of a steeply up-squeezed dome, surrounded by a tight synclinal zone which east and westwards gradually mergers with the neighbouring, generally elongate (non-domal) structures. Although its superficially circular, i.e. meridionally seemingly non-compressed, geometry does not at first sight suggest it, the meridionally compressive forces expressed in the elongate neighbouring anticlines and synclines have also played heavily over the Bluff, as will be seen from the remarks on the central structure itself.

No doubt there must have been a good reason for the partial failure by the N-S directed tectonic forces in
succeeding to squash the Bluff area into a tight, elongate anticline similar to the others in the region. This reason cannot have been the presence of a salt plug - but I will return to this question later.

An important feature of the regional setting is the fairly complex zone immediately to the south and southwest of the Bluff. With regard to the direction of the meridional tectonic forces (at least their latest phases) which worked over the Bluff, this structurally complex zone must be regarded as "in front" (foreland) of the central structure. In other words, it seems to have been the "piece de resistance" responsible for certain characteristic features in the main object of this report.

As shown on Plate 7 this complex zone is interpreted as a curved "en echelon"-couple of steep and elongate anticlines which are overturned to the southwest and south. They are separated from the Bluff by a tight syncline, an outlier of which causes the "en echelon" apposition of the anticlines.

It is in this complex zone where one encounters the acid intrusives. They have broken through - or appear to have done so - axial parts of the westerly of the two anticlines and they appear to be responsible for the complexity of the whole zone. The interpretation of this apparent paradox will be presented later on.

Admittedly, the extent of the tectonised area around the Bluff represents as a whole no more than a quarter of the distance between the Macdonnell and the Krichauiff Ranges, North of the Bluff, from Ruddalls Creek onward, the presumably folded Cambro-Ordovician is hidden beneath the vast sheet of Lower Carboniferous conglomerates and the terraced post-Palaeozoic gravels. To the south and southwest, beyond the complex, intruded zone, there are only very poor outcrops in sandhill country. It is not possible, I think, to elucidate the tectonics of this area further by ordinary surface geological methods. There is, however, to my mind little doubt that the concept of a "wide syncline west of Hermannsburg" can no longer be upheld even though its incorrectness has been demonstrated over no more than a quarter of the area in question. That the anticlinal tectonic zone of the Bluff extends also over a considerable distance westward and eastward is indicated by the morphological "whaleback" which I have mentioned already in the introduction.
It seems also to be reflected in the drainage pattern which consists of a pair of west-east directed creeks, one (Hucknalls Creek) a few miles north, the other at a similar distance south from Gosse's Bluff. I suspect both creeks follow synclinal zones which have found morphological expression because their axial zones contain the soft, silty, series of the upper part of the Mareenie Sandstone sequence.

B. The Structure of Gosse's Bluff.  
(Plates 1, 2, 3, 4).

Gosse's Bluff appears now as a diapiric structure of subtriangular outline, the upper part (now mostly eroded away) of which has been pushed and overturned across the southern "base line" (represented by the southern rim) of the triangle. This base line is at right angles to the meridionally directed regional tectonic forces which have been responsible for the distortion of the originally cylindrical or elliptic geometry of the structure. There is no doubt that the Bluff is a result of more than one phase of movement, diapiric and/or tectonic.

It will not be necessary to describe the structure in extenso because all relevant details are recorded on the map and in the sections. When studying these, not too much emphasis should be laid on the dip-and-strike map (Plate 4) because the data recorded there are a selection chosen to illustrate the general appearance of important parts of the study. In actual fact things are not as simple. There is continual and often most confusing changing of dips and strikes all over the structure, but the variations are essentially "variations on the vertical theme", some with more, others with less significance. It is those with more significance that have been selected for the presentation contained in Plate 4. A field sketch which depicts an elucidating area in the overturned Mareenie Sandstones of the southern rim is shown on Plate 3.

The significant features of the structure are:

1. The closed, internally subtriangular, externally more subcircular, outline in a region where the general tectonic style is that of elongate, meridionally compressed structures. Note, however, that the very steep and vertical attitudes as such in the strata are not unusual.
2. The leaning-over to the south of the whole structure.

3. The southward diving, overturned, fold formed by the rim formation throughout the southeast to southwest sector and the weakening - except for an upright S-fold - of that same structural feature throughout the northern half of the rim, indicating "caved-in roof" features.

4. The tectonically disharmonic behaviour of the rim formations with regard to the formations in the centre of the pound. This is expressed in the absence of significant faulting in the rim as compared with the slicing and imbricating that affects the sequence from Stokes Formation up to Gosse Shale in the core.

5. The absence in the core of any formations that are older than the Stokes Formation.

6. Occasional strong cross-structures occur in the rim, but they are not tectonic. They result from original, large scale crossbedding in the Mareenie Sandstones.

**GEOLOGICAL HISTORY AND INTERPRETATION OF GOSSE'S BLUFF**

The analysis of the stratigraphical, the structural and the morphological features of the Gosse's Bluff structure and its environs results in the following considerations:

1. The Bluff structure cannot be due to a single cause such as a one-phase diapiric activity. It is a result of at least two, most probably three, independent phases of movement, each one of individual character:

   (a) Although some disconformities are evident within the Cambro-Ordovician sequence there are no indications of regional orogenic movements before the end of the time interval, which is represented by the Mareenie Sandstones. A major orogeny
took place, however, thereafter, yet before the deposition of the carboniferous Pertnjarra Conglomerate, i.e. either in Silurian or Devonian times. This orogeny is responsible for the major structural pattern prevailing in the central regions of the Amadeus Basin, i.e. the west to northwest trending compressional belts of that area. For the different pattern observed in the eastern extensions of the Amadeus Basin see Part II of this report.

(b) Another significant phase of movements took place after the deposition of the early carboniferous Pertnjarra Conglomerate, yet before the Mesozoic(?), terraced, gravels were spread over the country. This second phase appears to have been epiorogenic rather than truly orogenic. It produced large scale warping and basement block faulting rather than compressional folding. However, in places (e.g. Macdonnell Ranges) it was still capable of uprighting and even overturning the strata. Naturally, some normal folding was associated with this phase too, but it stands no comparison with the tight structural pattern that had arisen after the Siluro-Devonian phase. The gentle folding of the second phase is illustrated by the anticline expressed in Pertnjarra Conglomerate in the northwest corner of the map (Plates 1, 4, also 2 and 7). It is obvious that the post-Carboniferous movements have helped in tightening even more the earlier structures.

(c) A third type of movement must be surmised from the peculiar geometry of Gosse's Bluff itself. There can be little doubt that the character of this movement is to some extent diapirc and that it seems to be restricted to this particular region (see also Part II of this report). The question is, of course, what the driving force of this diapir was. As will be seen presently, the possibility that this force is, or ever was, a rising salt plug, is very remote. Much more likely the diapirc geometry is due to an ancient acid intrusive.
2. An important aspect of the analysis concerns the mutual relationships between these three tectonic phases. By this are meant direct inter-reactions. The Siluro-Devonian and the post-Carboniferous phases are, of course, separate events and the analysis can only be concerned with the relationship of the diapiric movement to one or the other of the compressional phases. The possibilities and their significance with regard to the salt plug concept are:

(a) 1st Assumption: The diapiric phase is older than the Siluro-Devonian orogenic phase.

This assumption implies a plastic mass having penetrated upwards through a sedimentary column of many thousands of feet of thickness which was still lying undisturbedly sub-horizontal and had as its youngest member the Harranear Sandstone. If this is the case, the Bluff cannot be a salt plug because the very strong Siluro-Devonian phase of compression would easily and surely have squashed such a plastic mass into the same shape as that of all neighbouring anticlinal structures. It could, however, well have been an igneous diapir which had become solidified before the onset of the orogenic movements. The igneous plug would then have defied squashing by the Siluro-Devonian as well as by the post-Carboniferous tectonic phase. This course of events provides good explanations for other features of the structure and is, in my opinion, the most likely one. However, before ultimately returning to it as the best possible explanation of the Gosse's Bluff structure, I will have to analyze the other possibilities, such as -

(b) 2nd Assumption: The diapiric phase is a correlative of, i.e., roughly contemporaneous with, the main orogenic movements in the Siluro-Devonian.

This assumption is to my mind a very weak one because - whether the diapir be igneous or evaporite - it seems impossible that the plastic rising mass should have retained its subcylindric plug geometry when all around it far less plastic material became squashed into tight folds. It is, of course, well known that tectonic movements can help a diapir along but,
at the same time, they definitely affect the shape of the diapir. It is only in brachy­anticlines (Iran) where the shape of diapirs remains more or less unaffected by the comp­ressional forces. In tighter anticlines (Rumania) the diapirs spread along the axis of the structure. In the case of the Amadeus Basin one might expect a diapir to retain its cylindrical shape had it come up in the centre of, for example, the Palm Valley Brachyanticline not, however, in tightly folded areas such as the neighbourhood of Gosse's Bluff.

(c) 3rd Assumption: The diapiric phase is younger than the Siluro-Devonian orogeny but still older than the post-Carboniferous epeirogenetic phase.

This implies that the plastic mass has risen through the tightly folded Cambro-Ordovician sequence. The most common location of diapirs which have to find a way up through folded sequences is on lines of structural weaknesses, e.g. broken anticlines and synclines, thrust planes, various types of faults, etc. Famous examples of that type of diapiric activity are those of the northern ranges in the Sahara (Tell Atlas). The main characteristics of such areas - apart from the predetermination of the diapir geometry by zones of structural weakness - are to be found in their unbelievable complexity and the absence of simple cylindrical diapirs.

Considering the structural pattern in the Gosse's Bluff region one should expect a diapir to appear in the weak apical zone of an anticline (or syncline) and in the shape of an elongate, lense-like, squeeze-out rather than in the form of a starkly triangular to subcircular plug.

If one further keeps in mind that the post-Carboniferous, epeirogenetic, movements resulted in additional meridional compression, one fails to understand why this diapir should have retained a non-compressed shape - unless the force behind the diapir was much mightier than a "passive" salt plug could ever hope to be. Yet even then, e.g. in the case of a high pressure intrusive, one would expect it to be to some degree affected in its geometry by the pre-existing structural pattern, especially in areas which are as tightly folded as the one we are talking about. There is no indication of such features in the Gosse's Bluff area - in other words, the 3rd assumption is also not likely to be the correct one.
(d) **4th Assumption:** The diapir originated during or after the post-Carboniferous epeirogenic phase.

Here again one should surely expect the diapir to have taken a shape that is somehow in keeping with the tight structural pattern in the area. What was said under 2(b) and 2(c) applies in principle also to this 4th assumption, although to a lesser degree because there was no further compression which affected the region.

Summing up the discussion on the four possibilities one cannot but conclude that the least likely of the causes of the diapiric movement at Gosse’s Bluff is salt.

3. Even more serious arguments against a salt plug origin of Gosse’s Bluff are provided by the following observations:

(a) that there is not the slightest indication of rocks which are older than the Stokes Formation having been brought to the surface anywhere, and

(b) that the rim of the structure is near-vertical and overturned whereas the core, although sliced and imbricated, does not reflect the attitude of the rim. In other words, the Bluff is not a true piercing structure.

All salt plugs which possess such strongly and evenly uprighted rims have, or have had, salt masses in their core at or above the level of the rim, i.e., the salt itself and on its way up to the surface has created the "angry" attitude of the rim. Vice versa, if the salt mass is still well down at depth there is no reason why there should be such an astonishing rim structure. At best there might be at this stage a simple anticlinal structure because the influence of the rising salt would be beginning to make itself felt. A similar course of events can be envisaged in the case of the diapiric force being igneous — again complete uprighting of the rim would only take place when the diapir is about to, or has broken through to the surface. Good examples of this are the acid volcanic plugs in the Peak Downs area of Central Queensland, which have uplifted the
sandstones of the Middle Bowen series into near-vertical attitudes.

The absence of any fragments of older Ordovician, of Cambrian and/or Precambrian rocks in the centre of the Bluff is of similar significance with regard to the astonishing attitude of the rim. It is clear that the core formations are only fractured, but they have never been pierced by a diapiric mass. Again one comes up against the question why the rim should have such an "angry" attitude, although it is obvious that the tectonic force which caused it cannot have been an uplifting, piercing, diapir.

If the Gosse's Bluff consisted of the fractured central portion alone, the hypothesis of a salt dome at depth would be quite acceptable. However, the uprighted and overturned rim structure spoils this hypothesis. Another interpretation must be sought.

4. Before proceeding to the final interpretation of the Gosse's Bluff phenomenon a word may be said about the regional possibilities of source beds of evaporites. It has been suggested that the Precambrian Bitter Springs Limestone (and dolomite) might in places include evaporite deposits. In spite of the occurrence of "bitter springs" in a few places within this carbonate sequence, however, it is most unlikely that it contains evaporites.

There are two reasons. Firstly, as is shown in the second part of this report, there is the fact that a major orogeny affected the Precambrian sequence after the deposition of the Bitter Springs Limestone. This leaves no possibilities of such ancient evaporite deposits being preserved for the purpose, so to speak, of subsequently piercing the Cambro-Ordovician formations. Secondly, the great abundance in the Bitter Springs sequence of algal reefs - Collenia carpets - points to a normal neritic depositional environment rather than to a hypersaline lagoonal or intracontinental salt lake environment. The idea of evaporite deposits in these Precambrian beds should, I think, be discarded at least in such areas where orogenic movements are evident before the transgression of the Subcambrian-Cambrian-Ordovician sequences.

If we are to look for source beds we must under these circumstances search the Subcambrian and Cambrian.
The most likely sequence would then be the Subcambrian Pertatataka Formation in which I have noticed minor occurrences of primary gypsum in the Olive Creek area west of Rodinga (see Part II of this report). These occurrences are similar to the gypsum deposits in the Cretaceous of the Artesian Basin in Queensland and South Australia and do not impress one as indications of major evaporite deposits. However, in view of the very scanty knowledge of the stratigraphy and palaeogeography of these early Palaeozoic systems in Centralia any further elaboration of these questions would be mere speculation and—certainly with regard to the Gosse's Bluff study—rather pointless.

The conclusion has become inescapable, I think, that Gosse's Bluff is a multiphased structure with a solid, not plastic, core. This means it is not, and has never been, caused by a salt diapir. This is where one has to return to the "1st assumption" (2(a) on page 18) because it seems to be the only one which explains all the major characteristics of the structure reasonably well.

The course of events can then be described as follows:
The Cambro-Ordovician sequence (including the Mareenie Sandstone) in the Bluff area was intruded by a boss of the acid igneous suite of the "Mt. Pyroclast" type. This intrusion took place either before or at the latest during the early phases of the Siluro-Devonian orogeny. By the time the latter arrived at its major compressive phases the intrusive body had become solidified enough to resist being moulded into similarly tight folds as arose all around it. Concurrently, however, the same resistant igneous boss would have caused the surrounding formations to become uprighted against it under lateral compression because pressure release could under such circumstances only have gone upwards all around the igneous core at depth. This mechanism also explains the tectonic disharmony between the rim formations and the formations in the centre of the pound.

Most of the lateral pressure was released into the angry uprighting of the rim. This left a "pressure shadow" more or less vertically above the igneous core. Within this protected area the compressive forces would naturally not lead to the astonishing attitudes shown by the rim, although a moderate amount of folding, puckering, and imbrication would, of course, still have to be expected and is indeed found to be present.
The central area of low pressure was also responsible for the caving-in of what must once have been the roof of the structure (consisting of Mareenie Sandstone) as far as the latter can be reconstructed in our sections (Plate 2).

By the end of the Siluro-Devonian orogeny the Gosse's Bluff structure was in its main outlines already established. Whether the "extras", i.e. southward inclination, overfold, and subtriangular outline are results of the same orogeny or of a less powerful but still fairly strong post-Carboniferous epeirogeny is disputable. I believe it rather likely that these "extras" are due to the later epeirogenetic phase.

It must in this context be remembered that the present morphological isolation of the structure is post-Palaeozoic in origin. The wide depressions to the north and to the south must be thought as having been filled in to the level of the remnants (on the rim) of the previously mentioned ancient peneplain in order to conform with the situation in about mid-Carboniferous times, i.e. after the deposition of the Pertnjarra Conglomerate. Under these conditions there can be little doubt that the epeirogenetic forces had ample opportunity to work directly over the uprighted Bluff and thereby create minor, secondary, sets of structural peculiarities. It is noteworthy that all of these have one characteristic in common - they are all due to forces which acted meridionally from north to south.

With the presentation of this multiphase theory I conclude the tectonic analysis and interpretation of the Gosse's Bluff structure.
PART II

A GEOLOGICAL RECONNAISSANCE IN THE AREA BETWEEN

HUGH RIVER AND CENTRALIAN RAILWAY, DEEP WELL SIDING AND

MARYVALE HOMESTEAD, N.T.

(Plate 8).
STRATIGRAPHY

Whereas in the Gosse's Bluff area only Upper Ordovician and younger formations are exposed, the picture changes markedly as one moves east towards the Centralian Railway although (if one had to rely on airphotos alone) such an astonishing change is rather unexpected. In the area between Hugh River and Railway, south of Deep Well Siding, Ordovician formations do not occur at all, the whole region showing only outcrops of Cambrian and Precambrian rocks which are in a few small areas cloaked by isolated outliers of Cretaceous beds of the Great Artesian Basin type. The formations occurring in the Rodinga area are briefly described in ascending order below:

A. PROTEROZOIC

It should be noted that the formations described under the heading "Proterozoic" here do not, i.e. no longer, belong to what is currently called "Upper Proterozoic", or "Late Precambrian" alias "Adelaide System". Formations which fall under these latter concepts are listed here under the heading "Subcambrian". The Proterozoic formations below are considerably older and would probably fall into the category of what is currently called "Middle" or even "Lower Proterozoic".

The "Heavitree Quartzite" (Chewings)

What I believe are equivalents of this well known subdivision appear in the core of the big anticlinal nose five miles NW of Maryvale Homestead (ca. 60 miles south of Alice Springs). The formation there shows the typically dense quartzite lithology with conchoidal fracture which is very characteristic of the formation at its type locality. Moreover, it is with slight disconformity overlain by a sequence of massive Collenia-limestones and dolomites which can only be likened to the Bitter Springs Limestone of the Macdonnell Ranges.

The appearance of Heavitree Quartzite nearly 60 miles south of Alice Springs (like some other things in this report a new discovery in Centralian geology) will
no longer appear very surprising when one has digested the whole contents of this reconnaissance report. It will be shown that these discoveries mean no more than that a Late Proterozoic land surface is found partially exhumed throughout this region.

The "Bitter Springs Limestone" (Joklik)

This is the long famous sequence of Collenia-limestones which is so widespread in Central Australia. Besides the usually conspicuous Collenia colonies this sequence is characterised by its massive (despite thin-bedded members), rugged and dough-like contorted, rough-surfaced, olive-brown to ochre-brown appearance in outcrop. Its lower beds are commonly silicified limestone breccias. In the upper part a number of layers occur with slump structures and primary breccias.

Fresh surfaces show a dense, tough, greyish, more or less dolomitic and cherty limestone which is very resistant to weathering. The roughness of weathered surfaces is due to chemical weathering which produces deep grooves separated by knife-sharp ridges ("Karst" features). In addition, this chemical weathering leaves behind the numerous chert concretions and the silicified Collenia colonies as sharply protruding knolls.

The Bitter Springs Limestone pokes through the Subcambrian and Cambrian formations in many places throughout the reconnoitred area. Some of these "islands" are quite large and allow of partial reconstruction of the ancient regional tectonics which belong to the Proterozoic - not the Siluro-Devonian - orogenic history, although the younger of these two orogenies has, of course, remodelled the older trends to some extent.

The Bitter Springs Limestone follows conformably or only slightly disconformably upon the Heavitree Quartzite. Its thickness must be very variable because of strong folding and subsequent erosion after its deposition and before the transgression upon it of the Subcambrian and Cambrian sequence. The latter is, of course, quite unconformable on the Bitter Springs Limestone. The Proterozoic orogeny left a rather rugged land surface behind and that is why any one of the Subcambrian and Cambrian formations up to the Pacoota Sandstone can be found in direct depositional contact with Bitter Springs Limestone. These basically depositional contacts did naturally take up some movement during later orogenic phases because they are discontinuity surfaces in the affected rock masses. They should, however, not be shown - as is often done - as proper tectonic faults.
B. SUBCAMBRIAN

Under the heading SubCambrian are here described all those formations which lie unconformably transgressive upon the Proterozoic (mostly on Bitter Springs Limestone), i.e. are younger than the Proterozoic orogeny, but in which recognized Cambrian fossils are still absent. The term "SubCambrian" is deliberately meant to imply that all these formations are much more closely connected with the Cambrian history and palaeogeography than with the Proterozoic as is currently contended.

The "Pioneer Formation" (Pritchard 15)

This yet unofficial but commonly used name (I would prefer "Pioneer Conglomerate") is being applied to the basal and largely psephitic subdivision of the transgressive Sub-cambrian sequence. In some areas (western Macdonnells, Areyonga Valley) it is reported to show tillitic lithology. In the Rodinga area where it is known so far from two localities - near the road about three miles NNW of Bokhara and much more prominently in the previously mentioned big anticinal nose NW of Maryvale Homestead - the conglomerate pebbles (mostly quartzite and silicified limestones, some gneisses) are all well rounded and polished. They show no signs of glacial environment and represent here simply a basal transgression conglomerate, as would be expected to be formed at the beginning of such a major transgressive cycle. The upper part of the formation shows diminished grain size, i.e. it consists of first gritty, then of ordinary medium grained, quartzitic sandstones.

The thickness of this basal formation must be expected to vary considerably. In the ancient depressions it may easily reach as much as 3,000 feet. The greatest thickness I have seen on the reconnaissance is in the northern (partly overturned) limb of the anticline NW of Maryvale, where it is about 2,000 feet. NNW of Bokhara there is scarcely more than 200 feet of it between the central ridge of Bitter Springs Limestone and the Pertatataka shales.

The Pioneer Formation lies, as said before, regionally unconformable upon the Proterozoic and it is overlain conformably - except for localised irregularities caused by draping over highs in the Proterozoic relief - by the argillaceous Pertatataka Formation.
The "Pertatataka Formation" (Hadijan)

This is a sequence of micaceous, dark coloured, slates and shales with some primary gypsum, also of micaceous red shales and shaley sandstones, and of very soft, light coloured, fissile mudstones which contain in places "uprooted" (remanie) chunks of Callelia which are derived from the Proterozoic. Limestone layers have been reported from this sequence elsewhere but in the Rodinga area I have not noticed any. The thickness varies regionally. In the ancient depressions west of the Railway between Deep Well Siding and Rodinga it may reach more than 2,000 feet, whereas in the eastern part of the Maryvale anticline the formation, sandwiched synclinally between Pioneer Conglomerate (south) and a protruding ridge of Bitter Springs Limestone (north), measures 1,200-1,400 feet at the most.

The Pertatataka Formation may be found conformably upon the Pioneer Formation or unconformably transgressing the Bitter Springs Limestone, as for example 4 miles SW of Bokhara or in the area south of Olive Creek. In the latter case there is commonly a shale/chert breccia at the base of the Pertatataka, the chert fragments obviously being derived from the adjacent Bitter Springs Limestone.

Between the Pertatataka and the Arumbera Sandstone - if the latter is present - there is conformity, but the Arumbera Sandstone may be absent and in that case a distinct disconformity exists at the contact to the Pertacorta limestones (e.g. see on air photos source area of Olive Creek ca. 3 miles WSW of Bokhara).

The "Arumbera Sandstone" (Pritchard MS)

This is the "Chocolate Sandstone" of older authors; a very prominent formation in the MacDonnell Ranges but apparently patchy or absent south of latitude Bokhara as far at least as Maryvale. This pinch-out which is also indicated in the behaviour of other Subcambrian and Cambrian formations shows that the Rodinga region was a very shallow submarine threshold right through to late Ordovician time, especially after the depressions in the Proterozoic surface had been filled by the first-comers among the Subcambrian formations. In fact, it is likely that this area was never much below sea level after the Late Cambrian Pacoosta Sandstone had been deposited, rather thinly, over it.
In the only locality in our area where equivalents of the Arumbera Sandstone occur (two sharp and low ridges of steeply north dipping, dark, ferruginous sandstone 3½ miles north of Bokhara) the formation has a thickness of the order of 1,000 feet. It is conformably overlain there by the Pertaoorta formation.

C. CAMBRIAN

The "Pertaoorta Formation" (Madigan)

This is the widespread sequence of late Lower Cambrian and Middle Cambrian limestones and calc-shales the age of which is established by trilobites, gastropods, brachiopods and archeocyathinids. *Collenia* has disappeared long before and the characteristic algal genus is *Girvanella*.

Even in the absence of fossils this Cambrian carbonate sequence is rather easily recognized by its broadly banded (limestone-shale regular interbedding) outcrop pattern, its softer, lighter coloured, crystalline (cystids?) limestones, some of them oolitic, the absence of the weird contortions so characteristic of the Ditter Springs Limestone, and its over wide areas gently clined attitude.

The thickness of the formation varies probably in the same way as does the Pertatataka series, i.e., it may vary from 1,200 to 2,500 feet depending on the configuration of the ancient relief (or what was left of it after the Subcambrian series had filled the depressions) over which it was laid down.

Where the Arumbera Sandstone is present the whole sequence from the Pertatataka up to the top of the Pertaoorta Formation appears to be conformable. Elsewhere the Pertaoorta carbonate sequence lies disconformably, or even with slight angular unconformity (near source of Olive Creek) upon the Pertatataka. With very pronounced unconformity it transgresses, of course, upon protruding ridges of the Bitter Springs Limestone (e.g., west of upper Olive Creek).

The "Tacoota Sandstone" (Madigan)
(Including "Transition beds" - Pritchard MS)

This is the well known pipe-rock, i.e., the widespread *Scolithec* sandstones of Late Cambrian and probably earliest
Ordovician age (also known as "Tempe Sandstone" - Bell MG). Even without the vertical worm pipes the Pacoota Sandstone is in our area usually well distinguishable from other sandstones, especially older ones, by its even grain, its softness, its argillaceous matrix, and its finely glittering and sparkling appearance caused by tiny particles of mica and probably feldspars.

The formation attains a thickness of up to 3,200 feet west of the Rugh River and in the Bhoddell Ranges, but in the Rodinga area - because of original pinch-out over the "Rodinga threshold" and subsequent erosion - there is nowhere more than 1,200 to 1,500 feet and commonly far less of the sequence preserved.

The basal portion (100 to 200 feet) of the Pacoota Sandstone is shaley and commonly very heavily ferruginised (partly to medium-grade iron ore). This basal sequence is rather unlike what is called "Transition beds" in areas farther west (e.g. Waterhouse Range).

The contact between the Pertaaorta limestones and the Pacoota Sandstone appears to be disconformable here. The Pacoota transgresses the areas from which the limestones are absent and it seems that the very heavy ferruginisation at the contact to the Pertaaorta may be the result of an interval of intense, local, terrestrial weathering in early Ordovician or Late Cambrian times - not surprising when it is considered that this region sits on the "Rodinga threshold".

Just north of Deep Well Siding the Pacoota Sandstone is disconformably overlain by the Late Ordovician Maroonie Sandstone. Thus the bulk of the Ordovician System is missing, evidently another sign of the "Rodinga threshold" across which most of the Cambrian and Ordovician formations had to wedge out.

The sandstone mountains south of Maryvale have not been visited on this reconnaissance, but they appear to consist of either Pacoota or then Maroonie Sandstone. This might indicate that the "Rodinga threshold" ends south of Maryvale.

D. Mesozoic

Cretaceous. A number of low, flat topped, hills near Rodinga Siding and in the vicinity of Maryvale consist of flat lying, pink, ochre, and white shales which are very similar to the Cretaceous kaolinite shales of the Great Artesian Basin region.
farther south (e.g., Rumbalara). Very similar shales occur, however, in the basal part of the Subcambrian Pertatataka Formation. Care must be taken in distinguishing them. In places this can be done by a diligent search for bedding planes. It will then be noticed that the Pertatataka Shale is always more or less steeply dipping. With some luck one may also find chunks of re-deposited, silicified, Collenia from which all calcareous matter has been weathered away - this again indicates the presence of Pertatataka, not Cretaceous.

However, it must be admitted that to distinguish between these two very similar formations (both are apt to form exactly the same type of "billy" duricrust too) is often an extremely difficult, in places impossible, task. Thus the reader is warned that, what is marked as Cretaceous on the map (Plate 8), may here and there still include Sub-cambrian shales and mudstones.

All Cretaceous is, of course, unconformably transgressing in this region.

TECTONICS

The following interpretation of the results of the Rodinga reconnaissance can only briefly summarize the major novelties. Much more detailed work is needed before a reasonably complete picture can be presented. However, I fear that even this brief account is probably going to whirl up some old dust into the eyes of Centralian colleagues.

From the fact that any one of the Subcambrian and Cambrian formations occurs in some place or other in direct and simply depositional contact with the Proterozoic Bitter Springs Limestone it is quite evident that a major unconformity surface separates the Proterozoic from the Subcambrian and Cambro-Ordovician in these parts - and very likely others - of the Amadeus Basin.

This unconformity can only be the result of an important orogenic phase the existence of which has not yet been duly recognized (only Madigan seems to have had a suspicion of it, but his evidence was not accepted as conclusive). It is this
orogeny of course - not the Siluro-Devonian one - which caused the doubling of the Heavitree Quartzite together with the Bitter Springs Limestone at Heavitree Gap near Alice Springs. It also caused the many imbrications and the weird structural complications between Archean gneisses, Heavitree Quartzite, and Bitter Springs Limestone north and west of the Macdonnell Ranges both east and west of Alice Springs - complications which, one should note well, never involve Subcambrian and later sequences. The mechanism of all these structural complexities had to remain quite inexplicable because the existence of this intervening Proterozoic orogeny escaped recognition.

It is now evident that the eastern part of the Amadeus Basin (east of the James Ranges) is so much eroded down in many areas that the pre-Subcambrian tectonics have been partly re-exposed (as they have always been north and west of the Macdonnell Ranges). With their more or less obviously different trends they confuse the regional picture of the Siluro-Devonian orogenic pattern. Moreover, this tectonic confusion is aggravated by the re-exposure of basically depositional features in the transgressive Subcambrian e.g., in-filled depressions of the Proterozoic relief which pose now as Siluro-Devonian tectonic synclines between "anticlines" which are just as well Proterozoic relief features and as such not necessarily anticlinal in character.

Almost all anticlinal features south of Deep Well turned out to be re-exposed highs of the Proterozoic surface with most of the Cambro-Ordovician sequence - that originally was draped around them - eroded away. What is left between those re-exposed highs of the relief are the equally ancient lows that became synclinally filled in with Subcambrian and Cambrian and which ultimately were only compressed a bit tighter by the forces of the Siluro-Devonian and/or later tectonic movements. Palaeozoic beds younger than Upper Cambrian and earliest Ordovician do not even occur between Deep Well and Maryvale, i.e., on the "Rodinga threshold".

It may in this context be recalled that a similarly prominent unconformity - which I called Elgee (Lincoln Gap) Unconformity in Santos Limited's reports of 1954 - exists west of Port Augusta between two non-metamorphosed Proterozoic series, the Moonable Grits (below) and the Tent Hill Formation. There too the interpretation of it as a major orogenic feature has still to be recognized,
Another point which is of some nomenclatorial importance is the fact that with the recognition of a major orogeny in the later Proterozoic, the term "Precambrian", as currently used in Australian geology, becomes rather meaningless, certainly as far as Central Australia is concerned. One can no longer list everything between the Archean gneisses and the base of the fossiliferous Cambrian under this name or under "Upper Precambrian". In other words, the current concept of "Precambrian" and "Upper Precambrian" has to be restricted.

It is too early yet to work out the geotectonic trends of this new Proterozoic orogeny. Only some of the fragments are known but it should not take long now until the overall pattern emerges. Whether it was a metallogenic period will also have to be worked out in the future.
LEGEND TO PLATE 6

1. Grey shelly limestone.
2. Grey shelly limestone with polyzoans and crinoids.
3. Grey crinoid limestone with gastropods.
4. Grey shelly limestone with pelecypods and gastropods with thin interbeds of crinoidal limestone.
5. Light brown, inside grey crinoidal limestone.
7. Olive green, inside grey, dense, shelly, fine grained crinoidal limestone.
8. Olive green, inside grey, thinly bedded, shelly and crinoidal limestone with small nautiloids.
9. Light brown, inside reddish brown, shelly, partly crinoidal limestone.
10. Light brown, inside grey, shelly limestone with crinoidal interbeds.
11. Light brown, inside rose, shelly limestone with frequent crinoidal interbeds with nautiloids and Orthis.
12. Light brown, inside red-brown, dense, finely crystalline limestone.
13. Pink, inside light brown, thinly bedded, partly shelly limestone with Orthis.
14. Grey to pinkish shelly limestone with Orthis.
15. Grey shelly limestone with Orthis.

Disconformity

17. Yellow-brown, inside patchy red and yellow, dense, finely crystalline, vuggy limestone with minor interbeds of sandy white siltstone and thin beds of limestone with gastropods.
18. Light grey, inside rose, massive limestone, wrinkled surfaces.
19. Yellow, inside grey, finely crossbedded, silty limestone.
20. Yellowish grey, inside rose, massive limestone with wrinkled and pitted surfaces.
21. Pink limestone interbedded with thin bands of yellow brown, silty, limestone and coarsely crystalline crinoidal limestone.
22. Yellow-brown, inside red-brown, dense, vuggy limestone.
23. Pink limestone interbedded with thin bands of silty, white limestone and coarsely crystalline, grey, crinoidal limestone.
24. Light brown, inside pink, limestone with hematite spots.
25. Olive-green, inside purplish green, oolitic limestone.
27. Yellow, inside purplish green, oolitic limestone.
28. White calc-siltstone.
29. Brown, inside yellow, massive, Fe-stained, sub-oolitic limestone.
30. Yellow brown, inside pinkish, dense, tough, finely crystalline limestone.
31. White calc-siltstone.
32. Off-white, greyish inside, silty oolitic limestone.
33. Yellowish white, inside clean white, massive, silty limestone.
34. Yellow-brown, inside red-brown, Fe-dendritic, massive limestone.
35. White, silty, limestone.
36. White, inside yellowish grey, dense, Fe-dendritic limestone.
Appendix I

(ii)

37 Yellow, hematite stained, dense finely crossbedded limestone, silty.
38 White calc-siltstone.
39 Yellow, massive limestone with hematite encrusted vugs.
40 Yellow, inside pinkish white, dense, silty limestone.
41 Yellow, inside white, dense, hard, silty limestone.
42 Brown, inside yellow, fossiliferous (gastropods), lensing limestone.
43 Yellow, inside white, calc-siltstone with, in lower part, interbeds of massive, white, silty limestone.
APPENDIX II

SOUTH AUSTRALIA DEPARTMENT OF MINES
RESEARCH AND DEVELOPMENT BRANCH

26th June, 1959.

REPORT No. NFRC 20/59

Rock Samples submitted by Enterprise Exploration Co., Pty., Ltd.
Nos. B.90 - G/1-7, B.90 - G/10-12 for identification.

Results of Examination:

The rocks submitted for identification may be divided into two groups. The first group consists of sedimentary rocks, clearly defined and easily identified. The second group, however, forming the bulk of the specimens, is of a highly unusual and problematical nature. Lack of knowledge of field relations is in this particular case a great handicap in the naming of the rocks.

The sedimentary group of rocks includes specimen numbers B.90 - G/1, G/5, G/6, G/10.

B.90 - G/1 (T.S. 4772): A strongly brecciated feldspathic sandstone; rounded grains of quartz, of medium-grained sand-grade, and occasional grains of microcline and plagioclase, are set in a matrix of angular fragments of the same materials, with a dark, very fine-grained ferruginous, siliceous cement. The rock was originally a feldspathic sandstone, with well-sorted and rounded grains. Strong cataclasis has reduced it to a breccia with a mylonitic matrix. A few subangular fragments of dark ferruginous shale also occur.

B.90 - G/5 (T.S. 4784): This rock is very similar to G/1 above; brecciation has not been quite as intense, so that large coherent fragments of feldspathic sandstone have survived. They are set in a matrix of crushed sandstone. The large fragments show that the original rock was well-sorted, medium-grained, and composed of rounded, elongate, somewhat cracked grains of quartz, enlarged by secondary quartz in optical continuity occasional microcline, and well-rounded grains of zircon.
Appendix II

(ii)

B.90 - G/6 (T.S. 4785): This rock is similar to the preceding ones, though there are several differences. Brecciation appears from the hand-specimen to be confined to zones. The rock is not very well sorted and contains a very much higher proportion of feldspars; it is an arkose. Many grains have a thin film of haematite. Accessory minerals are zircon and green tourmaline.

Field evidence will probably indicate whether this rock is a poorly sorted, arkosic version of G/1 and G/5, or whether it is a separate and distinct unit.

B.90 - G/10 (T.S. 4789): This specimen shows the contact between the sedimentary group and the second group to be described below. The sedimentary rock is a strongly ferruginous sandstone showing evidence of stress. The elongate, rounded grains of quartz are cracked and show strain-extinction. Secondary quartz cement is in optical continuity with the grains. Large patches of limonite occur; they may be altered opaques. The contact between this sediment and the pyroclastic group described below is sharp, though the pyroclast has many inclusions of individual sand grains. The impression given is of a loose or unconsolidated sand-surface, upon which the pyroclast was deposited, incorporating some of the loose grains; angular fragments of sandstone and of dark shale are also incorporated.

The pyroclastic group includes all the other specimens; individual specimens are generally similar to one another and give the general impression of representing pyroclastic deposits, most probably welded vitric- and crystal-tuffs of "acid" composition. It is not proposed to describe each rock in detail, but rather to give a general description and comments on variations in type. In hand-specimen it is evident that silicification has played a major part in some specimens; others are extensively replaced by massive calcite; other rocks again carry abundant zeolites. Metasomatism subsequent to deposition has thus been very active in practically every case.

B.90 - G/1 (T.S. 4770, 4771, 4773-78): This suite includes a brecciated feldspathic sandstone already described in the sedimentary group (see above). The other specimens consist of vaguely delineated, grey-polarizing areas with highly-crenulate interlocking boundaries; most thin sections show small groups of thin laths with simultaneous extinction. Blbs and patches of devitrified and isotropic brown glass are abundant. The rocks are silicified and it is thought that the major constituent is quartz and other forms of
silica ranging from microcrystalline to amorphous. The silica has replaced most of the original rock constituents and has been responsible for the simultaneous extinction characteristics of groups and skeletal configurations of laths and microlites. Occasional euhedral opaques are visible.

B.90 - G/2 (T.S. 4770 & 80): In hand-specimen the rocks have an ashy appearance, with scoriaceous and pumiceous fragments. In thin section, T.S. 4770 confirms this; elastic grains and groups of quartz are also in evidence. T.S. 4780 is a rock which has been strongly silicified and zeolitized. Original microlites and laths (? of feldspar) have been replaced, and interstices and vesicles filled with small and large plates of heulandite and chabazite.

B.90 - G/3 (T.S. 4781): In hand specimen the rock appears vesicular and conglomeratic. In thin section it is similar to G/1 above, and contains abundant euhedral opaques scattered throughout. Zeolites and cryptocrystalline and amorphous silica are ubiquitous, interstitially between laths and in cavities.

B.90 - G/4 (T.S. 4782 & 84): Relicts of a pyroclastic rock, similar in type to the others described above, are enclosed in large, mutually-interfering poikiloblasts of calcite, which has almost completely replaced the original rock.

B.90 - G/4 (T.S. 4780 - 87 - 88): The first two sections show strongly zeolitized pyroclasts very similar to the type example, with irregular areas and groups of laths poikiloblastically enclosed in large platy zeolites, notably heulandite. Minute euhedra of ?apatite and ?zircon also occur. The third section is of a highly vesicular rock which is almost entirely opaque and white. The vesicles are lined with a thin layer of cryptocrystalline silica; some vesicles contain single small crystals of apatite, rutile, opaques.

B.90 - G/11 (T.S. 4790): This rock is similar to G/1. Zeolites are not abundant.

B.90 - G/12 (T.S. 4791): This is the same general rock-type. Small, sharply euhedral opaques are scattered
Appendix II

(iv)

throughout, and minute euhedra of unidentified minerals are present. Very occasional well rounded grains of zircon and rutile occur, as well as a few rounded grains of quartz. Zeolites poikiloblastically enclose original rock minerals.

The evidence based on hand specimens and thin sections favours a pyroclastic origin; several specimens are pyroclasts with incorporated detrital material. The rocks may tentatively be classed as welded tuffs and agglomerates.

Examined by: R. A. Doth, and H.W. Fander.

/s/ H. W. Fander,
for: A. W. Whittle,
Chief Mineralogist and Petrologist.
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Title</th>
<th>Source</th>
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<tbody>
<tr>
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LEGEND

Stratigraphic Column of Formations occurring in and near Gosses Bluff, N.T.

- Alkarray
- Permian Conglomerates and pebbly sandstones
- Red Mareenie sandstones and siltstones
  (Part of this sequence is probably a tectonic repetition of two ID Sequence)
- Predominantly red Mareenie sandstones (calcareous, porous, with thick hardened "skin", crossbedded)
- Predominantly off-white Mareenie sandstones (calcareous, porous, with thick hardened "skin", crossbedded)
- Predominantly off-white Mareenie sandstones (calcareous, porous, with thick hardened "skin", crossbedded)
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- Predominantly o
Rock & Fossil Sample Localities
Gosses Bluff, N.T.
LEGEND

10. Alluvium and 'non-investigated'

Creataceous

9. "Rumbalara Formation" (in places possibly = basal Form No 4)

MAJOR UNCONFORMITY (OROGENY)

8. "Marrenee Sandstone" (non-differentiated from Carboniferous on this map)

MINOR UNCONFORMITY (EPEIROGENY)

7. "Pacoota Sandstone" (pipe-rock)

U. Cambrian

6. "Pertjasota Formation" (Lst and asic shales interbedded)

DISCONFORMITY

5. "Arumbara Sandstone"

U.L. & L.M. Cambrian

4. "Pertjasota Formation" (micac. skites, shales, mudstones, chert-breccias)

3. "Pioneer Conglomerate"

DISCONFORMITY

2. "Bitter Springs Limestone" (collenia - lst)

L. Cambrian (Chiefly)

1. "Heavitree Quartzite"

U. Pre-Cambrian (or Earlier)

ENTERPRISE EXPLORATION CO. Pty. Ltd.

GEOLOGICAL RECONNAISSANCE

MAP OF AREAS BETWEEN THE HUGH RIVER

AND THE CENTRALIAN RAILWAY LINE SOUTH

OF DEEP WELL SIDING, N.T.

Sacle 1" = 4 miles

R. O. Brunnschweiler

June 1959

Plan No. X 27/1106

PLATE 8