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THE GOSSES BLUFF CRYPTO-EXPLOSION STRUCTURE

by

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ABSTRACT

Recent drilling and geological mapping has shown Gosses Bluff to be an undoubted crypto-explosion structure with a minimum diameter of ten miles. It consists of a central uplifted dome surrounded by a ring of breccia. Shatter cones are extremely well developed; glassy material is common and quartz grains frequently show fracturing and strain lamellae. Bentonitic clays were encountered subsurface in the breccia.

Evidence is available to support both crypto-volcanic and astrobleme (impact)hypotheses for the origin of the structure but at the present time there is more to support the extra- rather than the intra-terrestrial origin.

INTRODUCTION

Gosses Bluff is a large circular structure situated approximately 120 miles west of Alice Springs. It forms a very prominent topographic feature (Figs.1 - 2) rising to approximately 800 feet above the general level of the Missionary Plain.

As little detailed information was available on the geology of the Gosses Bluff area (with the exception of an excellent map of the central part by Brunnschweiler, 1959), a limited shallow drilling programme of two weeks duration was undertaken in June 1966. Due to unfortunate delays whilst awaiting the arrival of spare parts, the drilling programme finally lasted a month without being completed. One deep hole (500 feet) and seven shallow holes (21 - 31 feet) were drilled, using a Mayhew 1000 rig. A total of 14 cores were obtained, with an overall cored footage of 85 feet out of a total drilled footage of 700 feet.

The writer sited all the holes and was responsible for the on-site logging of Hermannsburg (BMR) No.1 Well. There was no well-site geologist for the other seven holes.

Approximately two weeks were spent in geological mapping in and around Gosses Bluff; the cuttings of all seismic shot holes in the area were also examined in the field, in an effort to ascertain the sub-surface geology. A geological map (Plate 1) was subsequently prepared.

Preliminary petrographic studies on the core were made by the writer and by G.Schmerber of the Institut Francais du Petrole. P.Duff of the Petroleum Technology Laboratory of the Bureau of Mineral Resources carried out laboratory tests on the bentonite and also core analyses. B.Timms of the Australian Mineral Development Laboratories was responsible for the silicate and trace element analyses.

PREVIOUS INVESTIGATIONS

The first geological investigation of Gosses Bluff was made in 1956 by Prichard and Quinlan (1962). They considered the structure to be of diapiric origin, with the Bitter Springs Formation the mobile unit. This view was further supported by McNaughton et al., (1966), and the diapiric hypothesis has been widely accepted. Brunnschweiler (1959) suggested that it was formed by the injection of an acid igneous plug which subsequently resisted orogenic movements, but in general, this hypothesis was not supported by subsequent geophysical work. It was the recognition of a shatter cone in Gosses Bluff in 1964 by K.A.W.Crook which first threw serious doubt on the diapiric hypothesis; Crook and Cook (1966) showed that Gosses Bluff has many of the features of a crypto-explosion structure (Dietz, 1959) such as shatter cones, strain lamellae (Carter, 1965), a central uplifted area and the presence of glassy material. Subsequently D.A.McNaughton (pers.comm.) found some breccias which he regarded as tuffaceous, in a stream section on the west side of Gosses Bluff; on this and geophysical evidence he considered (McNaughton & Huckaba, 1966) that the structure is of crypto-volcanic origin. Crook and Cook (1966) were unable to say whether the explosive force was of intra-terrestrial (crypto-volcanic) or extra-terrestrial (astrobleme) origin. Cook (1966) suggested that Gosses Bluff lies on a broad structural trend of continental dimensions; if this is so, it would tend to support an intra- rather than an extra-terrestrial origin.

A variety of geophysical surveys have been carried out in the vicinity of Gosses Bluff. Richards (1959) undertook both gravity and magnetic surveys for the Frome-Broken Hill Company; he regarded the results as consistent with a salt-dome hypothesis. Lonsdale and Flavelle (1963) made a regional gravity survey and Young and Shelley (1966) a regional airborne magnetic and radiometric survey. A detailed seismic survey by Moss (1964) indicated the presence of a rim syncline. Further seismic and gravity work by Geophysical Associates (1965) suggested that Gosses Bluff is situated on the crest of a north-east trending anticline approximately 20 miles long.

Prior to the present investigations, one exploratory well had been drilled at Gosses Bluff - Gosses Bluff No.1 (Pemberton and Planalp, 1965). This well, which was sited in the centre of structure, was drilled to a total depth of 4535 feet. The well was in very steeply dipping Larapinta Group sediments throughout and encountered no salt (the well-site was chosen on the assumption that Gosses Bluff was a salt dome).

STRATIGRAPHY

General

Approximately 7000 to 9000 feet of sediments are exposed at Gosses Bluff. No formation older than the Stairway Sandstone is exposed, but the sequence in nearby areas and the aeromagnetic work of Young and Shelley (1966) suggest that there are 10,000 - 15,000 feet of Palaeozoic and Upper Proterozoic sediments in normal sequence below the Stairway Sandstone in the Gosses Bluff area.

TABLE 1

The stratigraphy of Gosses Bluff

PROBABLE EQUIVALENT FORMALIZED UNIT		INFORMAL UNIT	THICKNESS (feet)
		Quaternary Qa Qs Qt Qc Tertiary Tc	500'
		"Gossite" Breccia Br & br	500'
PERTNJARA GROUP (?Carboniferous-Devonian)	Brewer Conglomerate and/ or Hermannsburg Sandstone	Pz(5)	possibly sev. thous. feet
	Hermannsburg Sandstone	Pz(4)	1-2000(?)
	Upper part of Parke Siltstone	Pz(3)	1-200
	Middle sandstone unit within the Parke Siltstone	Pz(2)	1000-1500
	Lower part of the Parke Siltstone	Pz(1)	200
(Devonian-?Silurian)	Mereenie Sandstone	Pzm	100-1500
LARAPINTA GROUP (Ordovician)	Carmichael Sandstone & Upper part of Stokes Siltstone	O1(2)	500-1500
	Lower part of Stokes Siltstone and upper part of the Stairway Sandstone	O1(1)	500+
LARAPINTA GROUP (Ordovician - Cambrian)	Lower part of the Stairway Sandstone Horn Valley Siltstone Pacoota Sandstone	Not exposed but probably present subsurface	3-4000?
PERTAOORRTA GROUP (Cambrian)	Numerous formations - mainly sandstone & siltstone minor carbonates		5000?
(Upper Proterozoic)	Pertatataka Formation		2000?
	Areyonga Formation		1000?
	Bitter Springs Formation		2000+
	Heavitree Quartzite		1000
(Archean)	Crystalline basement		

The exposed and the probable sub-surface sequence at Gosses Bluff is shown in Table 1. The formalized rock units of the Amadeus Basin sequence proved to be unsuitable mapping units at Gosses Bluff and therefore an informal sub-division of rock units was used. These informal units and their probable "formalized" equivalents are given in Table 1.

Gosses Bluff Sequence

Larapinta Group

Unit O1(1)

This, the oldest unit exposed, only crops out in the centre of Gosses Bluff. It is made up of sandstone, siltstone and limestone. The sandstone is grey, white or pale brown fine to coarse grained, phosphatic in part, thin to thickly bedded, moderately resistant to weathering, forming fairly prominent bands; some of the sandstones are bimodal (Fig.11). The poorly exposed siltstone is green or pale brown in outcrop but black or dark grey subsurface; it is commonly sandy, and thin bedded or laminate. The limestone is grey or pale brown, thin bedded, sandy in part, moderately resistant to weathering and commonly fossiliferous. The limestones are most common at the top of the unit. The base of the unit is not exposed; the contact with the overlying O1(2) is probably conformable.

Unit O1(2)

This unit only crops out in the centre of Gosses Bluff and even here it is very poorly exposed. It consists predominantly of red and green siltstone and mudstone, shaley and micaceous in part. This unit was given the informal name of Gosses Shale by Brunnschweiler (1959). Towards the top of the unit, interbeds of red-brown silty sandstone become more common. The unit is overlain probably disconformably by the Mereenie Sandstone.

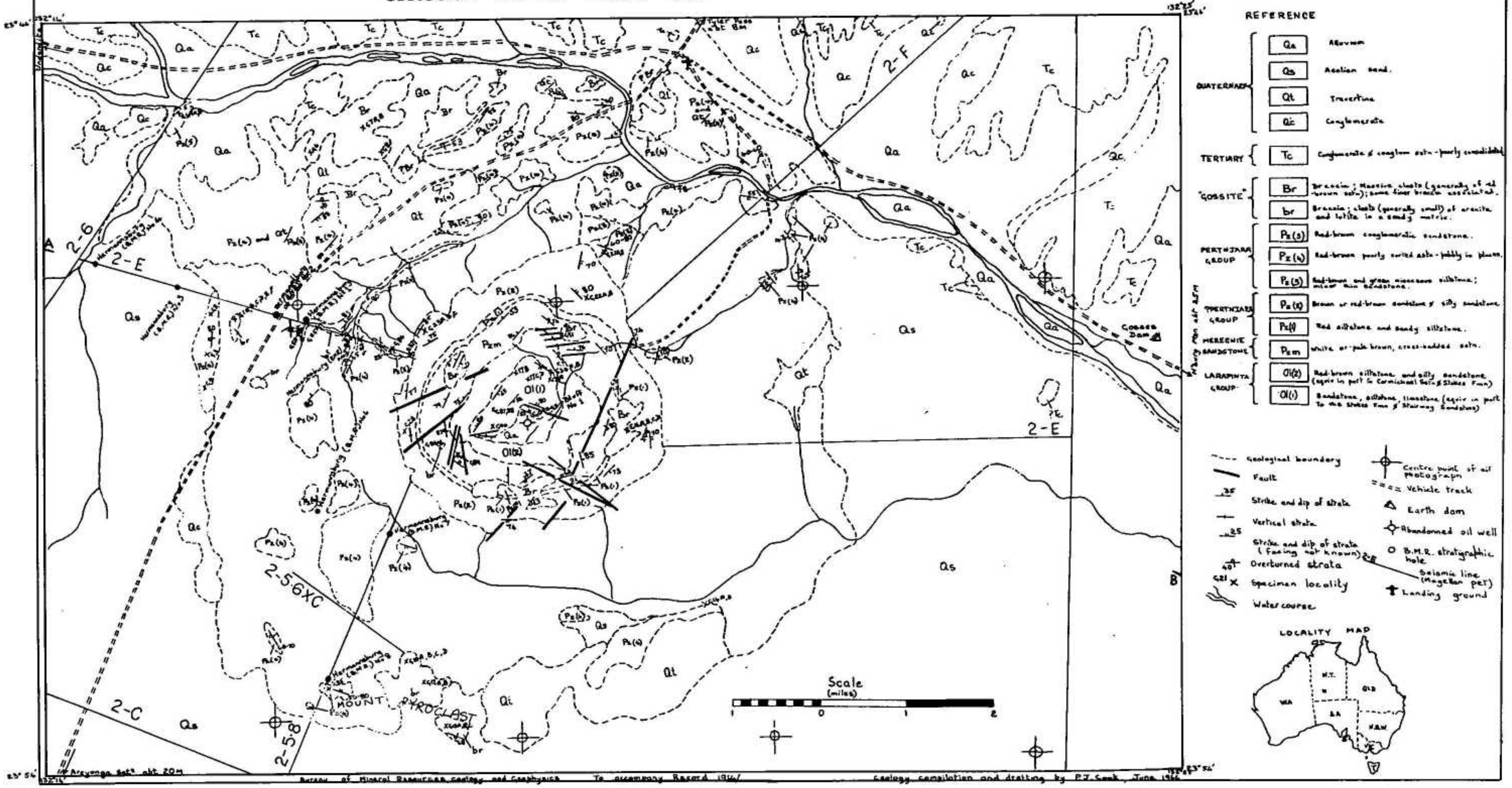
Mereenie Sandstone

Unit (Pzm)

This is the only rock unit which is identical with the same rock unit in areas outside Gosses Bluff. It is composed of white or pale brown, fine grained, friable, thin to thickly bedded strongly cross-bedded sandstone. The only fossils present in this unit in the Gosses Bluff area and elsewhere are vertical worm tubes. The unit is exposed in the inner part of the rim of Gosses Bluff, where it forms a very prominent escarpment. It also occurs as massive blocks, unconformably overlying Pertnjara Group sediments (see Fig.3 and Fig.5) and possibly as clasts within the "Gossite" Breccia. The Mereenie Sandstone is overlain with apparent conformity by unit Pz(1) of the Pertnjara Group.

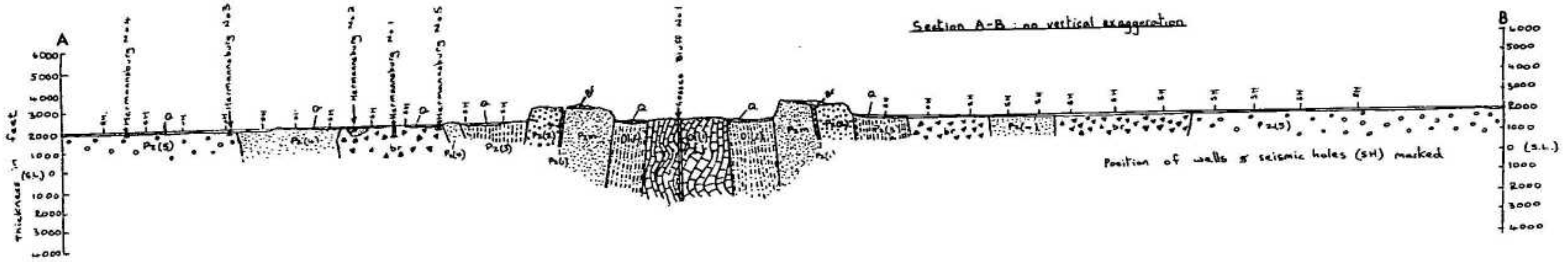
PLATE 1

GEOLOGICAL MAP OF GOSSES BLUFF



Bureau of Mineral Resources Geology and Geophysics   To accompany Record 1966/   Geology compilation and drafting by P.J. Cook, June 1966

Section A-B : no vertical exaggeration



Pertnjara Group

Unit Pz(1)

This unit, which is only 100 - 200 feet thick, consists of red-brown and chocolate-brown siltstone and mudstone, shaly in places, micaceous in part and very poorly exposed, and forms a well defined strike valley, which can be traced round the rim of the Bluff. This rock unit is lithologically similar to the lower part of the Parke Siltstone of the Pertnjara Group. Unit Pz(1) is overlain apparently conformably by Unit Pz(2).

Unit Pz(2)

This unit is 1000-1500 feet thick; it is well exposed and forms a prominent scarp round the outer part of the rim of Gosses Bluff (see Fig.2). It is mainly pale brown, dark brown or red-brown sandstone; fine to medium grained, moderately sorted, silty, thin to thickly bedded and commonly quite strongly silicified. A fragment of an unidentified arthrodire (J.G.Tomlinson, pers.comm.) was found in approximately the middle of this unit, on the eastern side of the rim of Gosses Bluff. Fish fragments have been found in a sandstone lens within the Parke Siltstone of the Mereenie Anticline area and it is possible that Unit Pz(2) is a thick equivalent of this sandstone lens. The fish fragment indicates that this unit is undoubtedly Devonian. Unit Pz(2) is overlain apparently conformably by Unit Pz(3).

Unit Pz(3)

This unit is estimated to be 1000 - 2000 feet thick. It is poorly exposed in a few places, mainly in the banks of creeks, outside the rim of Gosses Bluff and is mostly covered by talus (Fig.2). The unit consists of chocolate-brown, purple and grey micaceous shaley lutite. There are minor sandstone lenses in places. It is probably overlain by Unit Pz(4) but poor outcrop obscurs the relationship of these two units. It is suspected that Unit Pz(3) is equivalent to the upper part of the Parke Siltstone of the Mereenie Anticline area.

Unit Pz(4)

This unit consists of chocolate brown or dark brown, silty, poorly sorted, fine to coarse grained, thin to thickly-bedded, cross-bedded sandstone pebbly in part, and minor red-brown siltstone. The field relationship of this unit is rather uncertain; it crops out as large, but generally discontinuous bodies and contacts are never exposed. Brunnschweiler (1959) regarded this unit as a "tectonic repetition" of unit Pz(3) (referred to as "red Mereenie sandstones" by Brunnschweiler); whilst such an idea is not impossible it is considered unlikely as the two units are lithologically different. It is however possible that most (and perhaps all) of the outcrops of this unit are not in situ and that they are enormous blocks. The probable position of this unit above the equivalent of the Parke Siltstone and also its lithology suggests that the unit should be equated with the Hermannsburg Sandstone of the Pertnjara Group.

Unit Pz(5)

This unit is only known from one small outcrop in the north-west corner of the area (Plate 1), in the banks of Undandita Creek. It is thought to be present sub-surface elsewhere around Gosses Bluff from inspection of the seismic shot hole cuttings. The unit consists of grey-brown feldspathic poorly sorted, fine to coarse grained, thin to medium bedded, cross-bedded conglomeratic sandstone with pebbles and cobbles which are up to 3 inches in diameter and are composed mainly of vein quartz, metaquartzite and silicified sandstone. The relationship of this unit to the probable underlying unit Pz(4) are uncertain at the present time. The lithology of this unit is comparable with that of some of the coarser bands of the Hermannsburg Sandstone or with some of the less coarse beds of the Brewer Conglomerate of the Pertnjara Group.

Breccia (Br and br)

Although two units of "Breccia" are mapped, it is probable that there is a complete gradation in size from the fine breccia (br) with clasts only one or two inches in diameter to massive breccia (Br) with clasts tens of feet across. At least some, and possibly all, of the matrix of the massive breccia is composed of the fine breccia (br). The fine breccia is best seen near Hermannsburg (BMR) No.1 (see Figs. 6, 7), where it is continuously exposed for a distance of about 1 mile in the creek bank. Fine breccia also crops out approximately 1 mile west of Hermannsburg (BMR) No.1 and also at Mount Pyroclast. There is also a small outcrop of breccia (br) in the south-west corner of Gosses Bluff (unconformably overlying Mereenie Sandstone) and also on the east side of the bluff unconformably overlying vertically dipping Pertnjara Group sediments (Pz(2)) and overlain by a massive block of Mereenie Sandstone (Fig.5).

The fine breccia consists of angular, or more rarely, sub-rounded clasts of white, grey, red-brown, and pale brown sandstone and red-brown or green siltstone and mudstone in a matrix of friable fine grained sandstone. The clasts are extremely variable in size ranging from less than an inch to several inches in length. As mentioned previously, there is probably a complete gradation up into breccia with clasts tens of feet across. The bedding and banding which is present in many of the clasts always appears to be randomly orientated. In places there are thin "veins" (generally only one or two inches thick) of green ?bentonitic clay within the breccia. These are particularly evident near Hermannsburg (BMR) No.1 and appear to be in the form of thin, gently dipping sheets; they may be the expression of a poorly developed bedding within the breccia. Alternatively they could represent small scale thrust sheets. Green clayey bentonitic material also occurs as small "blebs" within the breccia.

At Mount Pyroclast the matrix of the breccia is glassy, and there are crystals of zeolites in places; there are well developed flow structures (Fig.8), and many of the clasts are bent and drawn out. Most of the clasts are of white or pale brown ?glassy material; some are dark grey and have a pumice-like appearance (Fig.13). At Mount Pyroclast (actually three discrete peaks) the breccia crops out as isolated pinnacles, regarded by Brunnschweiler (1959) as igneous plugs; outcrops are however too sparse for the relationship of these rocks to the surrounding country rock to be ascertained.

Initially some difficulty was experienced in deciding whether breccias exposed in the rim of Gosses Bluff were formed by the event which produced Gosses Bluff or whether they were composed of scree material produced by Tertiary or Quaternary erosion, and which was subsequently cemented. The criteria adopted for distinguishing between the two types was that more angular and lutaceous clasts are present in the explosion breccias; lutaceous clasts are almost completely absent from the scree breccias due to the ease with which they are eroded.

The massive breccia (Br) is particularly well developed in the area approximately three miles north-west and north of the centre of Gosses Bluff. Here the massive breccia covers an area of several square miles. There are also four fairly large areas of massive breccia exposed near the summit of the rim of Gosses Bluff.

The massive breccia may be considerably more extensive than is indicated on the outcrop map as it is difficult or impossible to establish whether a large outcrop of Pertnjara Group is a massive block in the breccia or is in a normal undisturbed sequence (see Plate 2 and Fig.4). In the area to the north and north-west of the Bluff the blocks are up to at least 50 feet in length and it is only by measuring numerous dips and strikes that it can be established that the orientation of the blocks is completely random. It is considered unlikely that this is due to complex folding, as the folding would be unbelievably chaotic; it is much more reasonable to regard the random orientation as being the result of brecciation rather than of folding.

The clasts are invariably composed of red-brown or pale brown sandstone, generally of Pz(5) though some of the clasts may be of Pz(2) and possibly Mereenie Sandstone. The outline of the blocks is difficult to establish because of their size but they appear to range from angular to sub-rounded. The matrix is never exposed; it is covered by travertine in many places, suggesting that the matrix may itself be calcareous.

The massive breccia exposed in the rim of the uplifted centre of Gosses Bluff is similar in character to that exposed outside the bluff except that it is rather better exposed and is probably composed entirely of clasts of Mereenie Sandstone. These sheets of rim breccia cover large areas (Fig.3); they are up to 50 feet thick and contain individual clasts up to 100 feet in length and 20 feet thick.

Brunnschweiler (1959) regarded these sheets as nappes; however the orientation of the clasts within the sheets is completely random (ranging from horizontal to vertical, to overturned horizontal) and there can be little doubt that they are the result of explosion and brecciation rather than folding. In places, the rim breccia is underlain by a thin layer of fine breccia (br) (Fig.5). The breccia sheets on the rim everywhere overlies Pertnjara Group sediments with a strong angular discordance. No outcrop of massive rim breccia unconformably overlying Mereenie Sandstone was found.

Tertiary and Quaternary

Little time was spent in the field in mapping these deposits. Quaternary sand (both aeolian and alluvial), travertine and conglomerate, commonly overlie the breccias (Br and br). In one area north-west of Gosses Bluff Tertiary conglomerates overlie breccia (Br). Nowhere do Tertiary or Quaternary sediments appear to have been involved with the Gosses Bluff explosive event.

RESULTS OF DRILLING

The graphic logs of the eight shallow holes drilled in the vicinity of Gosses Bluff are given in Appendix 1. The main information obtained from the holes is summarized here briefly. The positions of the various wells are indicated on the geological map (Plate 1).

Hermannsburg (BMR) No.1

Total depth 500 feet.

The hole is thought to have been in breccia (br) throughout. Clasts are generally small, but are up to 5 feet across in places. The core 490' - 496' (the bottom four feet 496 - 500' were lost) taken at the bottom of the hole is composed entirely of sandstone. It is therefore not impossible that the total thickness of breccia (i.e. 490 feet) was intersected and that the bottom sandstone is the underlying non-brecciated unit; it is however considered more likely that the sandstone is merely a large clast within the breccia and that the total thickness of breccia was not penetrated.

Bright green bentonite (see Appendix II) is common in the cores and cuttings and was detected over a considerable vertical interval. It occurs as vugs, irregular patches, lenses, veins and thin bands or beds (Fig.20). Vugs of calcite and ?zeolites are common in many of the cores. A notable feature is that much of the core, in particular the sandy matrix of the breccia, is calcareous; this contrasts sharply with the clasts which are generally non-calcareous. The clasts are mainly of brown or grey-white sandstone though clasts of lutite are also fairly common. Clasts range from angular to sub-rounded (Fig.15,16). In places the breccia has the appearance of having been injected into a sandstone host-rock (Fig.17, 18) whilst at a depth of 423' (core 6) the breccia showed positive graded bedding.

One unexpected feature shown by some of the larger clasts was that dip measurements taken on either the direction of elongation of the clast or on laminae within the clast showed a definite tendency to fall within the range 35° to 45° (the actual direction of dip is unknown as the core was not orientated). The dominant dip of the bands of bentonite may also fall within this range of 35° to 45°. Shatter cones were common throughout; their apices showed no obvious preferred orientation.

Hermannsburg (BMR) No.2

Total depth 28 feet.

The two feet of core taken at the bottom of the hole is entirely composed of greyish pink Pz(4) type of sandstone, dipping at about 40° and containing many shatter cones.

Hermannsburg (BMR) No.3

Total depth 30 feet.

Five feet of core from the bottom of the hole consists of grey and brown mottled, silty sandstone and is regarded as being unit Pz(5).

Hermannsburg (BMR) No.4

Total depth 30 feet.

The five feet of core taken at the bottom of the hole consists of greyish brown to yellowish grey fine to medium grained, silty, poorly sorted feldspathic sandstone. Regarded as a sandstone of the Pertnjara Group (Pz(5)).

Hermannsburg (BMR) No.5

Total depth 27 feet.

The two feet of core taken at the bottom of the hole is composed of breccia consisting of angular and sub-rounded clasts of arenite and lutite. There are some vughs containing ?zeolites and also a few irregular patches of bentonite (Fig.19).

Hermannsburg (BMR) No.6

Total depth 31 feet.

The six feet of core from the bottom of the hole is made up of breccia, with a high percentage of sandy matrix and only a few clasts. The clasts are small, angular, and composed of either arenite or lutite.

Hermannsburg (BMR) No.7

Total depth 30 feet.

The six feet of core from the bottom of this well consists of greyish red thin bedded or laminate siltstone and mudstone with numerous shatter cones.

Hermannsburg (BMR) No.8

Total depth 21 feet.

The core interval of 16-21 feet is composed of pale red fine-grained poorly sorted sandstone. The sandstone is silty in part and contains a few thin siltstone laminae. The core is cut by numerous very fine fractures, some of which show a small displacement (in the order of ½ to 1 inch). Shatter cones are fairly common.

PETROGRAPHY

The petrography of many of the rocks from the Gosses Bluff area is dealt with rather more fully in Appendix IV. Crook and Cook (1966) also summarize unusual petrographic features of rocks from Mount Pyroclast.

Perhaps the most significant feature of many of the thin sections from Mount Pyroclast and from outcrop and sub-surface breccia is the presence of abundant glass. The glass is generally devitrified but in places there are droplets and spindles of ?lechatelierite of a type similar to that described from Kofels, Austria (Milton, 1964, Fig.2). In some of the glassy rocks from Mount Pyroclast (see Fig.14) there are "ghosts" of round ?quartz grains. Definite quartz grains with diffuse margins possibly due to partial melting, are also present in several of the thin sections. Many of the quartz grains show evidence of strain; strain lamellae (Fig.12) are particularly well developed and have been shown by Crook and Cook (1966) to be parallel to the basal (0001) plane; Carter (1965) regards this as a good criteria for meteoritic impact. Grains are also commonly fractured and shattered (Fig.11) again suggesting shock. One specimen of Mereenie Sandstone from the uplifted rim of Gosses Bluff was made up of very closely packed quartz grains (contrasting markedly with the well rounded grain normally seen in Mereenie Sandstone) which were also strongly fractured; the fractures were not influenced by the grain boundaries. This suggests that the grains were subjected to two forces, first a compressional force which impacted the grains and then a tensional force which produced the fractures.

Thin sections of the bentonitic clays were examined but the rock proved to be too fine grained for any textural or mineralogical information to be obtained.

A specimen from the eastern peak of Mount Pyroclast was observed in hand specimen to be made up of rounded granules with scattered platey crystals. Thin section examination showed the crystals to be the zeolites heulandite and laumontite. A green mineral suspected to be chlorite is present in this and many other rocks, occurring as both ?grains and as diffuse patches. Chloritic material has been reported from other crypto-explosion structures.

STRUCTURAL FEATURES OF GOSSES BLUFF

General

The most prominent structural and physiographic features of the Gosses Bluff crypto-explosion structure are the uplifted rim and central core (Figs. 1 and 2). Within this uplifted area, which has a diameter of approximately 4 miles, dips are invariably steep, particularly in the rim where they range from 70° to 70° overturned.

Dips are a little less steep in the centre with some as low as 55° in places. The steep dips continue to some considerable depth; Pemberton and Planalp (1965) record that dips range from 60° to 90° (possibly with some overturning) throughout most of the Gosses Bluff No.1 well. Larapinta Group sediments in the core of the structure are tightly folded in many places (see Plate 1, Brunnschweiler, 1959). There is extensive faulting in both the core and the rim (see Plate 1); in order to simplify the geological map many of the faults are not shown as their displacement is small. As mentioned previously, the features in the rim which Brunnschweiler (1959) regarded as nappes, are now considered to be flat-lying or gently dipping sheets of explosion breccia overlying steeply dipping Pertnjara Group sediments (Fig.3).

Outside the central uplifted area outcrop is poor and the structural picture is confused. Up to three miles out from the rim of Gosses Bluff (at Mount Pyroclast) overturned dips of 48° were measured in outcrops of sandstone. Overturned dips were recorded from many other outcrops surrounding the Bluff. The structural picture is particularly complicated to the north and north-west with major variations in dip and strike between adjacent sandstone outcrops. This structural complexity around the Bluff is interpreted as being due to each discrete sandstone outcrop being a massive clast within the breccia. It is very much simpler to explain the rapid variation in dip and strike by the "breccia hypothesis" than by invoking extremely complicated folding. In addition blocks up to 100 feet long and 20 feet thick are known from undoubted breccia in the rim of Gosses Bluff, so that the sizes of the outcrop are not too great for them to be clasts. These large sandstone outcrops are surrounded by fine grained breccia (br) in places and it is therefore reasonable to regard them as rather large clasts within the breccia.

The outer limit of the zone affected by the event which produced Gosses Bluff is uncertain; there is however a small outcrop of Pertnjara Group (Pz(5)) located approximately 6 miles north-west of the centre of Gosses Bluff, which is dipping at 45° and does not contain any shatter cones. Shatter cones were also absent from the silty sandstone in the cores from the Hermannsburg (BMR) No.3 and 4 wells. The last fragment of breccia in shot-hole cuttings was found approximately 5 miles west of the centre of Gosses Bluff on seismic line 2-E. These pieces of rather tenuous evidence suggest that the Gosses Bluff crypto-explosion structure has a minimum diameter of 10-12 miles; later work may show that in fact the structural effects of the explosive event were also felt in Unit Pz(5) and that the structure is very much greater than 12 miles across.

The probable form of the structure is shown in Plate 2. The main features are the topographically low central core approximately $1\frac{1}{2}$ miles in diameter, with fairly steeply dipping sediments surrounded by a prominent rim of very steeply dipping sediments which is itself surrounded by an annulus of breccia approximately 3 miles wide and of unknown thickness (though at least 500 feet in Hermannsburg (BMR) No.1).

In a recent communication to the writer, Mr.E.Krieg (pers.comm.), has observed that there are anomalous drops of the seismic horizons in the Missionary Plains area around Gosses Bluff (Geophysical Associates, 1965). The delay is in the order of 0.06 milliseconds. These breaks are consistent with a thin shallow, low velocity layer. This layer underlies an area of about 1000 square miles; it is approximately circular in shape, with a diameter of about 25 miles. Gosses Bluff is not situated in the centre of this area but about 3 miles from its perimeter so that it is by no means certain that the low velocity layer is related to Gosses Bluff. It is however an indication that the breccia or the affected area may have a diameter of 25 miles.

Shatter cones

Shatter cones are remarkably well developed at Gosses Bluff and the area is probably one of the best in the world for their study.

The shatter cones are geographically extremely widespread; they are present in the centre of Gosses Bluff, in the rim, and up to 5 miles out from the centre - a limit which may be related to lack of outcrop rather than to an absence of shatter cones. They occur in all rock types - sandstone, limestone, siltstone and mudstone, either as individual (Fig.9) or multiple (Fig.10) cones and range in length from less than one inch to up to several feet.

Shatter cones are extremely well developed in very steeply dipping (to vertical) sandstone (Fig.9) on the east side of the rim, where they show a strongly developed preferred orientation with the apices pointing upwards parallel to the bedding plane. Elsewhere the shatter cones commonly have their axis parallel to the bedding plane. In some areas however the apices showed random orientation, with, for instance three or four different orientations of shatter cones on a single hand specimen. A thorough quantitative study of the shatter cones will be necessary to establish or refute the existence of a preferred orientation of shatter cones about Gosses Bluff.

Shatter cones are fairly common subsurface. They occur in the Gosses Bluff No.1 exploratory well down to 3,000 feet, throughout the Hermannsburg (BMR) No.1 Well (500 feet total depth) and in the cores of the Hermannsburg (BMR) Nos.2, 7 and 8 wells.

THE ORIGIN OF GOSSES BLUFF

Previous ideas on the origin of crypto-explosion structures

The term "crypto-explosion structure" was first suggested by Dietz (1959) for circular or near-circular structures having the appearance of craters or filled craters and for circular structures apparently formed by localized but strong vertical uplift. As the term carries no genetic connotation it is a useful one for problematical structures of the Gosses Bluff type.

A number of crypto-explosion structures have been recognised - the Ries Dome of Germany, the Vredefort Dome of South Africa, the Bosumtwi Crater of West Africa, the Sierra Madera structure of Texas, some of the craters of the Canadian shield, and a number of structures which occur along a line running through the Tennessee Kansas Missouri and Illinois area of the United States. To this list may possibly be added the Sudbury Loppolith. Undoubtedly Gosses Bluff shows all the features of a bona-fide crypto-explosion structure; the writer also considers that some of the Flinders Range "diapirs" may be crypto-explosion structures, from the form of their breccia and also from a report by R.Dalgarno (pers.comm.) of shatter cones in the Blinman Dome.

The problem posed by all such structures is whether the source of the explosion is intra or extra-terrestrial.

Branco and Fraas (1905) regarded the Ries Dome as a crypto-volcanic structure because of its association with an area of volcanic activity. On the same grounds Bucher (1936, 1963), Amstutz (1964) and numerous other workers have suggested that the crypto-explosion structures of the middle West, such as the Wells Creek Basin, the Decaturville Dome etc. are also crypto-volcanic.

Other workers, notably Dietz (1959, 1961, 1963) regard the same structures as astroblemes (Greek for "star-wound") or impact structures. Shoemaker and Chao (1961) regard the occurrence of coesite (a high pressure polymorph of silica) in the Ries Dome as good evidence for an impact origin . Carter (1965) considers that the presence of basal strain lamellae in quartz is good evidence of an impact origin for structures such as the Vredefort Dome. The presence of shatter cones in the structures is also widely accepted as evidence of impact origin (Dietz, 1959). Dence (1965) considers that these and other criteria (particularly the form of the craters) suggest an extra-terrestrial origin for the Canadian craters. Possibly in part a reaction to the over-enthusiastic acceptance of the impact hypothesis some workers (e.g. McCall, 1965) have suggested that seemingly undoubted meteorite craters such as Meteor Crater Arizona, and Wolf Creek Crater, Western Australia, are of crypto-volcanic origin.

Few workers have suggested diapirism as a possible mode of formation for such structures, with the exception of granitic diapirism for the Vredefort Dome and possibly diapirism in some of the structures of the Middle West of the United States (Amstutz, 1964).

It is therefore widely accepted that these circular structures are of explosive origin, the argument is mainly one of whether the explosion is due to impact or crypto-volcanism. The volume of literature on the subject suggests that impact origin is the one most widely favoured at the present time.

The origin of the Gosses Bluff crypto-explosion structure

This subject has already been covered quite comprehensively by Crook and Cook (1966). Their points will only be mentioned briefly whilst new evidence from the recent fieldwork will be dealt with in more detail.

One of the basic difficulties in determining the origin of Gosses Bluff is the lack of a suitable model from which to extrapolate criteria. What one worker accepts as a good example of a meteorite crater from which impact criteria may confidently be extrapolated, a second worker will regard as an excellent crypto-volcanic structure. With the exception of small craters, such as the Henbury Meteorite Craters, the writer knows of no single large explosion structure for which there is unanimity on the origin.

A diapiric origin for Gosses Bluff is now regarded as most unlikely. Features such as shatter cones, strain lamellae and hundreds of feet of breccia have not been described from any salt dome; they are all features which suggest a violent event rather than the slow tectonic processes of diapirism. It is however possible that subsequent to the explosive event, some movement of salt (from the Bitter Springs Formation) took place either along lines of weakness established by fracturing or as a "rebound" effect. Such diapirism, if it did take place, would have been purely a secondary effect which played little or no part in the establishing of the Gosses Bluff Structure as we see it today, although it might have modified the form of the geophysical anomalies (particularly bouguer anomalies) associated with Gosses Bluff.

Continuing from the premise that any salt diapirism was purely a secondary (and probably minor) event, evidence for a crypto-volcanic or impact origin is now considered.

Shatter Cones

These structures are extremely well developed and occur over a considerable area. The present writer does not accept the view that shatter cones are necessarily a good criteria of impact origin. Shatter cones have been formed experimentally by impact (Shoemaker et al., 1963), but no shatter cone has been found in an undoubted meteorite crater. Bucher (1963) describes a shatter cone in a piece of coal which is most unlikely to have come from an explosion structure. Both these factors make shatter cones a somewhat uncertain criteria of impact origin. The writer does however consider that in most cases they are good criteria of a violent, and probably explosive (source unspecified) event.

Strain Lamellae

Basal strain lamellae (Carter,1965) would appear to be rather more reliable criteria of impact than shatter cones. They have been described from both crypto-explosion structures and also from what most workers would regard as a good example of an impact structure, Meteor Crater, Arizona. Experimental wok on their origin would also support impact as a likely mechanism of formation. Their value as criteria for impact can be questioned only because with the exception of Carter (1965), basal strain lamellae have not been systematically sought in areas away from crypto-explosion or impact structures. However, in spite of this, the presence of strain lamellae at Gosses Bluff is more in favour of an impact origin than against it.

Geophysical Anomalies

There is no magnetic or radiometric anomaly associated with Gosses Bluff so that it is most unlikely that the structure was formed by the injection of a volcanic plug; however, the possibility of a purely gaseous injection with no basic lava cannot be excluded.

A negative bouguer anomaly is closely associated with Gosses Bluff. Such an anomaly may be attributed to the presence of salt which moved into the structure as a secondary process following the primary explosive event. It may also be due to a fairly deep-seated granitic body. Alternatively, hyper-velocity impact producing brecciation of rocks will lower the specific gravity of the rocks in the crater to produce the bouguer anomaly; Iness et al. (1964) have found negative bouguer anomalies over some of the Canadian crypto-explosion structures (interpreted by them as meteorite craters).

Dr.D.A.McNaughton of Magellan Petroleum Corporation revealed in recent discussions that Professor Nettleton considered that the negative bouguer anomaly associated with Gosses Bluff can be most satisfactorily explained by a disc-like, near surface body of low density. The description of Nettletons hypothetical body appears to correspond remarkably closely with the sheet of breccia which is now thought to surround Gosses Bluff.

The seismic work of Moss (1964) and Geophysical Associates (1965) showed that there is a rim syncline surrounding Gosses Bluff; they also found a considerable area of "no-records" surrounding the structure. The writer interprets this "no-record" area as being the region of outcropping or near-surface breccia; it is highly likely that such a breccia would result in poor seismic records. The rim syncline is a structural feature which is commonly associated with diapirs but Dence (1965) also regards it as a typical feature of many of the larger Canadian meteorite craters. A seismic survey of the whole of the Missionary Plain area by Geophysical Associates (1965) showed that Gosses Bluff is situated on the axis of a north-east trending anticline running from the Gardiner Range to the western Macdonnell Ranges, a lateral extent of approximately 30 miles. They also suggested that there was thinning of units about Gosses Bluff, and considered this was evidence in favour of structural growth during sedimentation. The writer considers this explanation unlikely; seismic records are poor in this area and there may in fact be no thinning, however if the thinning is real it can be attributed to the shearing out of units along low-angle thrust planes - such a thrusting is known to take place around the Weaubleau Crypto-explosion structures of the middle west of the United

States (Snyder at al., 1965). There would seem to be no doubt of the validity of the anticlinal trend. The "impactist" can rationalize this either by assuming that the meteorite fell on a pre-existing trend (highly unlikely - but nevertheless this appears to have happened at Meteor Crater, Arizona), or by considering the anticline to have been formed by rebound following impact (the extremely elongate form of the anticlinal trend makes this explanation rather unlikely though not completely impossible.

The location of Gosses Bluff on an anticlinal axis is completely compatible with a crypto-volcanic hypothesis, as crypto-vulcanism would be closely related to the regional tectonics, and therefore it would be logical for Goases Bluff to be located on pre-existing structural trends.

The anomalous drops of the seismic horizons observed by Krieg (pers.comm.) to occur in the vicinity of Gosses Bluff cannot be used in the determination of the origin until the precise nature of the low velocity layer is known.

Therefore whilst most of the geophysical work is of no help in pointing to the source of the explosive event, the location of Gosses Bluff on a regional anticlinal trend, as shown by seismic work, favours an intra-terrestrial origin.

Location on a major fracture zone

Cook (1966) suggested that Gosses Bluff may be located on a major fracture zone of continental dimension (termed the Fitzroy-Spencer Fracture Zone). Should further work in other areas show this suggestion to be correct then it would be further evidence in favour of crypto-vulcanism. However the present lack of information makes it impossible to use this evidence either for or against intra-terrestrial origin.

Petrography

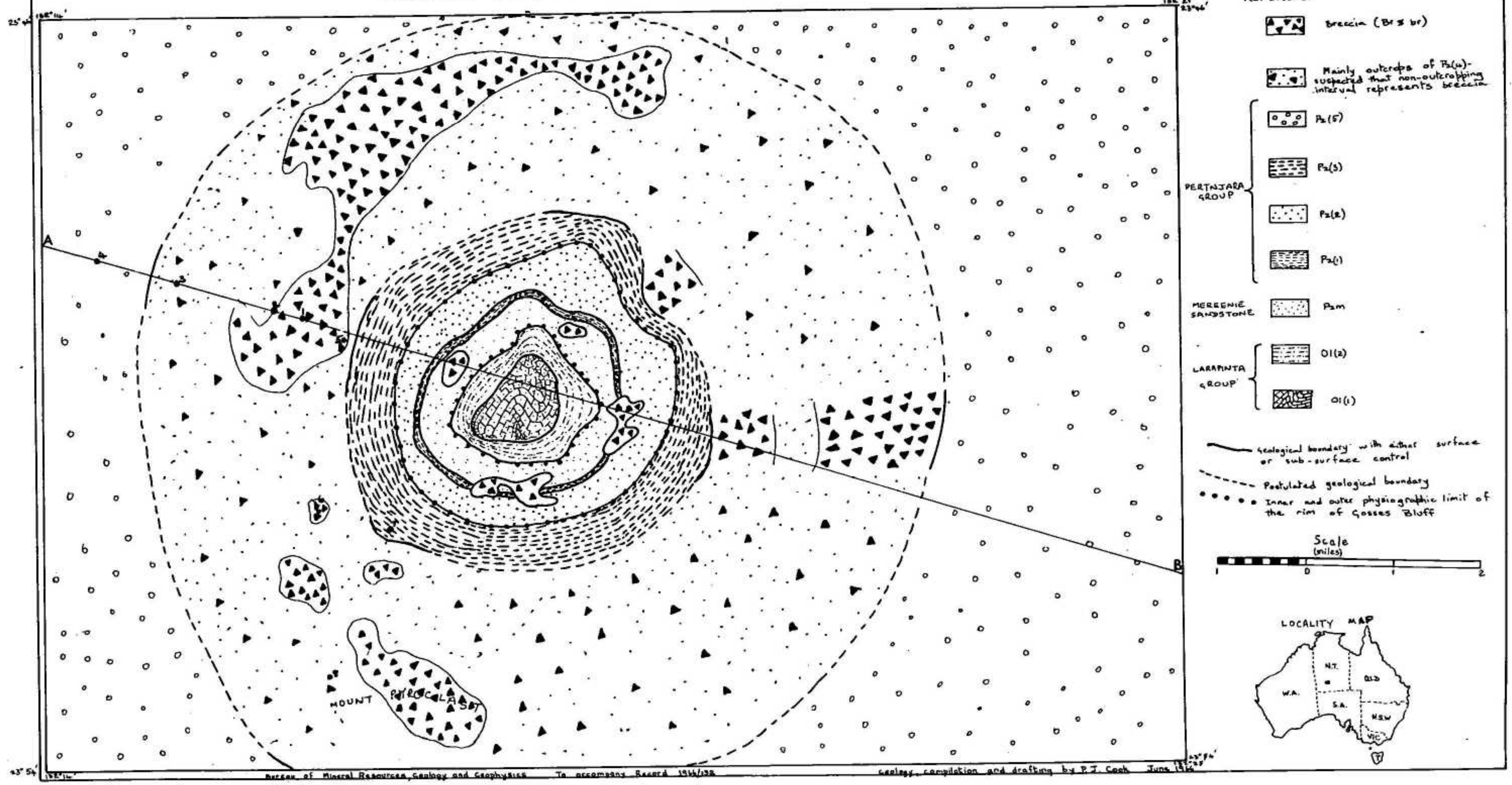
Thin sections of many of the rocks from the Gosses Bluff area contain obvious evidence that they have been involved in a violent event. The evidence includes the strain lamellae mentioned earlier (seeFigs.11, 12), the severe shattering of many of the quartz grains (see Fig.11), and the severe impaction of adjacent quartz grains in some of the sandstones. The presence of abundant glass, the corroded nature of many of the quartz grain boundaries and the flow structures in some of the glassy rocks (see Fig.8, 14, 17, 18) are evidence that the rocks were temporarily molten. The combination of extreme shock and heat can occur during either crypto-volcanism or impact, but whether the extreme shock and heat indicated by the petrography can be generated by crypto-volcanism is open to question.

Breccia

The nature of the breccia, particularly its massive form in places, again testifies to the very violent nature of the event which produced Gosses Bluff. The extreme angularity of most of the clasts suggests that the material has undergone little transport. However,

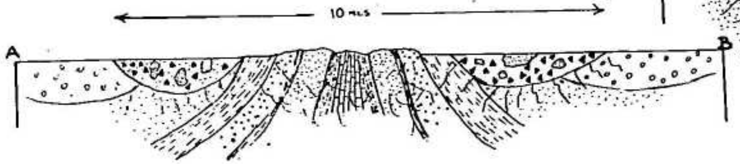
PLATE 2

SPECULATIVE GEOLOGICAL MAP

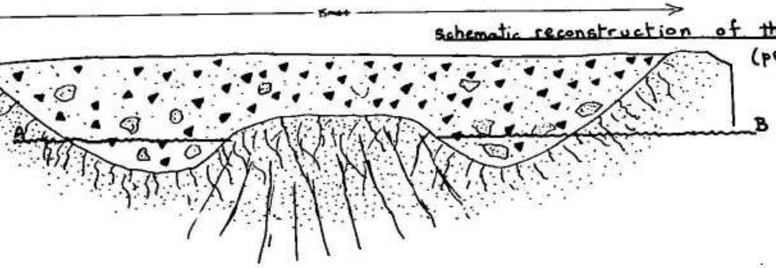


Bureau of Mineral Resources, Geology and Geophysics To accompany Record 1966/132 Geology, compilation and drafting by P.J. Cook June 1966

Schematic cross-section A-B.



Schematic reconstruction of the Gosses Bluff crater (presuming an extra-terrestrial origin)



the presence of a few rare rounded clasts and one case of graded bedding may indicate that part of the breccia was water-lain, possibly being washed into the explosion crater from the side-walls.

The tendency in the cores for clasts to dip at angles of between 35° and 45° may be significant; the dip may be depositional and its steepness suggests that it is deposition on a sub-aerial scree slope rather than sub-aqueous.

Therefore it appears that in addition to clasts falling back into the crater, some may have been washed in and others may have slipped down the scree slopes on the sides of the crater.

Abundant glass and also the presence of ? flow structures suggest that the breccia was at least partly molten.

To the authors knowledge no shatter cones occur in the matrix of the breccia or continue across from one clast to the next, although they are common in individual clasts; this suggests that the main shock preceded the development of the breccia but gives no clue to the origin. However an examination of the clasts reveals a dearth of any exotic rock types (with the exception of glass) and all the clasts are identical with one or other of the sandstones, siltstones, mudstones and limestones making up the sedimentary sequence around Gosses Bluff. There are no clasts of igneous rocks and this would seem to be contrary to what would be expected for a crypto-volcanic origin.

Mineralogy.

The presence of glass is not genetically diagnostic in itself, but X-ray analysis of a glass from Mount Pyroclast showed it to be composed only of silica. It is unlikely that volcanic glass would be composed only of silica, but a silica glass could be readily produced from a quartz arenite by extreme shock.

The presence of zeolites at Mount Pyroclast and bentonitic clays in the Hermannsburg (BMR) wells is perhaps some of the strongest evidence available in favour of crypto-volcanism; these are both mineral forms which show a close association with volcanism throughout the world. However, the possibility that both of these can also form by the weathering of impact glass etc. cannot be ignored.

The form of the structure

Though Plate 2 is described as a "speculative geological map" the surface and subsurface geological information and also the seismic and gravity data are completely compatible with the picture of a central uplifted area surrounded by an annulus of breccia. The limits of the breccia shown in Plate 2 are minimum limits and further work may well show that in fact they are very much greater; perhaps corresponding to the region of low seismic velocities recognized by Krieg (pers.comm.).

The cross section A-B on Plate 2 is a schematic representation of the explosion structure; there seems little doubt that this form is closely comparable with that found by Dence (1965) in several of the larger Canadian craters. There is also every reason to believe that

Dence's reconstruction of the form of the Canadian craters (based on very much more sub-surface information than is available for Gosses Bluff) is equally valid for the Gosses Bluff crypto-explosion structure. If the reconstruction A-B is accepted then this crater form may most easily be produced by the shock from above rather than from below.

A consideration of which rock units are most strongly affected by the explosive event reveals that the sandstone of the Pertnjara Group (Pz(4)) is the most affected and is one of the youngest units present in the Gosses Bluff area, this contrasts with the Stairway Sandstone (the oldest unit exposed) which has not been brecciated nor made over to glass. As the most disturbed rocks were presumably nearer the sources of the explosion than the least disturbed, then the older rocks were further away from the explosion than the younger rocks. As the rocks can only have been in normal succession prior to the explosion, this strongly suggests that the source of the explosion was from above rather than from below.

Conclusion

Crypto-volcanism is supported by the location of Gosses Bluff on the axis of a north-east trending anticline, and the presence of bentonite and zeolites.

Impact is supported by the presence of basal strain lamellae, the silica glass, the evidence of very extreme heat and shock, the complete absence of volcanic clasts in the breccia, the probable form of the crater and the fact that the stratigraphically highest rocks have been most affected, indicating shock from above rather than below.

By treating the evidence as objectively as possible, i.e. by not extrapolating criteria from questionable explosion structures, it is possible to suggest evidence in favour of crypto-volcanism and impact. The writer has previously suggested (in Crook and Cook, 1966, and Cook, 1966) that Gosses Bluff is crypto-volcanic; however the evidence obtained from the most recent work is more in favour of impact than of crypto-volcanism though the data is insufficient to prove or disprove either theory conclusively.

ACKNOWLEDGEMENTS

The writer thanks the staff of the Resident Geologists Office, Alice Springs, for their help during the field season.

Dr.D.A.McNaughton, Consulting Geologist, spent some considerable time in discussions and his information and ideas were most valuable.

The staff of the Alice Springs office of Magellan Petroleum Corporation, and particularly Mr.A.Froelich, Mr.E.Krieg and Mr.K.Williams, all gave valuable assistance which is greatly appreciated.

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FIG.1
View of Gosses Bluff from the air, looking south. The low hills in the foreground (area marked Br) are mainly composed of breccia. M.P. - position of Mt.Pyroclast. Photograph by J.E.Zawartko.

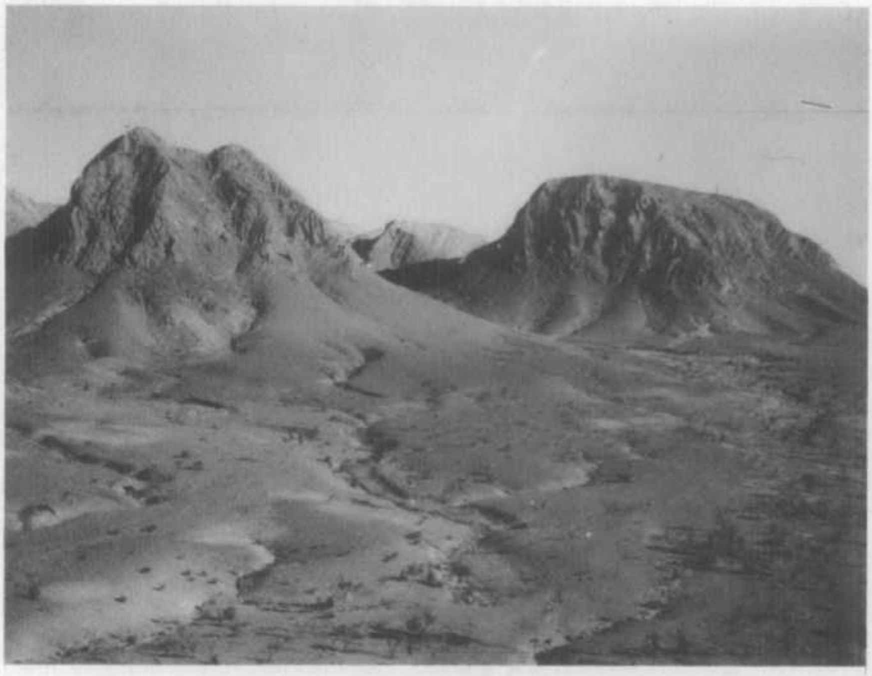


FIG.2
View of the outside of the Gosses Bluff rim (north-western part), composed of sandstones of the Pertnjara Group (Pz(2) - dark) with Mereenie Sandstone (Pzm - light) visible in the distance. The highest point on the rim rises 600 to 800 feet above the plain.

FIG.3
East side of Gosses Bluff. Vertically dipping sandstone of the Pertnjara Group (Pz(2)) overlain by a flat-lying massive breccia sheet (light in colour - marked Pzm) composed of massive blocks of Mereenie Sandstone.

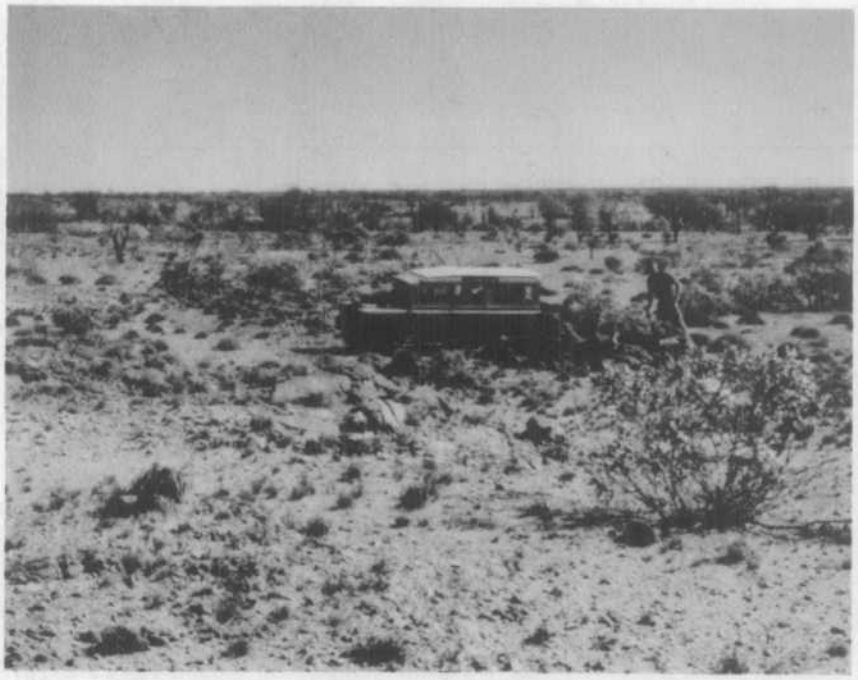


FIG.4
Poorly exposed breccia outcropping approximately five miles north-west of the centre of Gosses Bluff. The low outcrops (outlined) are large blocks set in a fine-grained calcareous matrix.

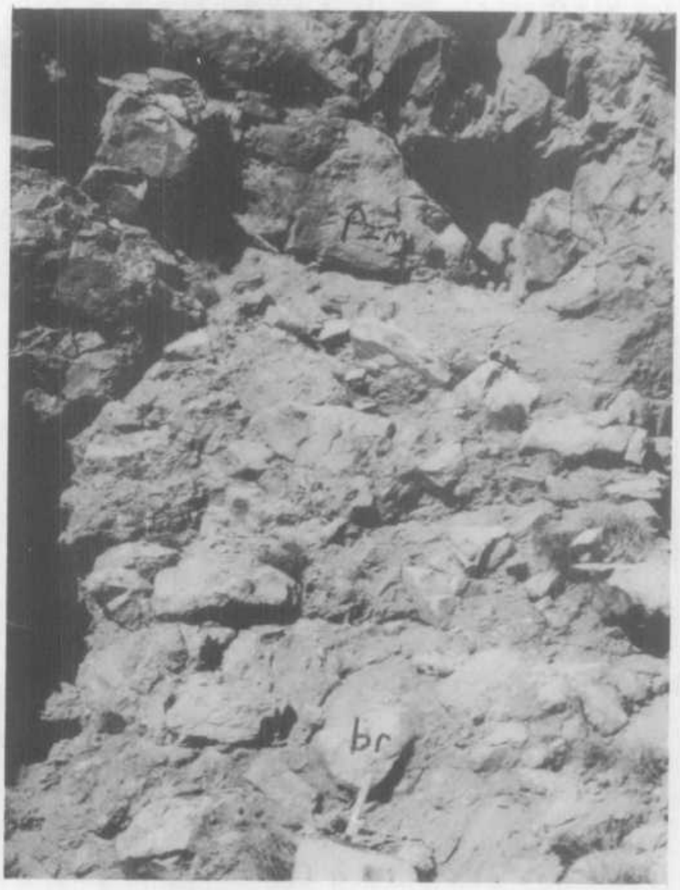


FIG.5
Breccia (br) exposed near the summit of the east side of the rim of Gosses Bluff. This breccia occurs between a massive block of horizontal Mereenie Sandstone (Pzm) and vertical (in situ) beds of the Pertnjara Group (Pz(2)) which it overlies, but which are not visible in the photograph.

FIG.6
Coarse breccia composed of clasts of siltstone, mudstone and sandstone set in a sandy matrix. Exposure in the creek bank near the site of Hermannsburg (BMR) No.1.

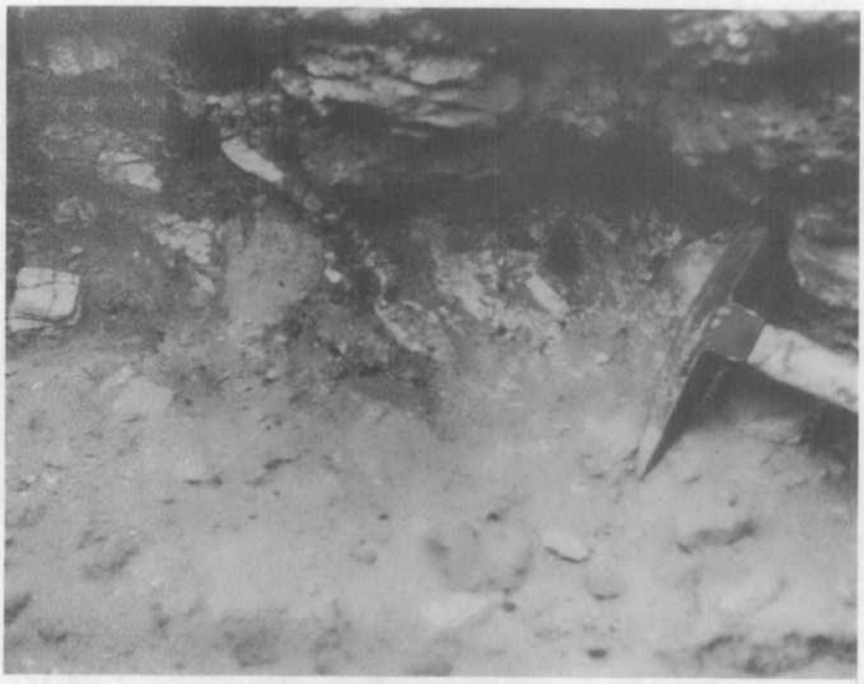


FIG.7
Breccia composed of angular clasts of dark-coloured siltstone, and mudstone and light coloured sandstone, set in a sandy matrix. Exposure approximately three miles north-west of the centre of Gosses Bluff.

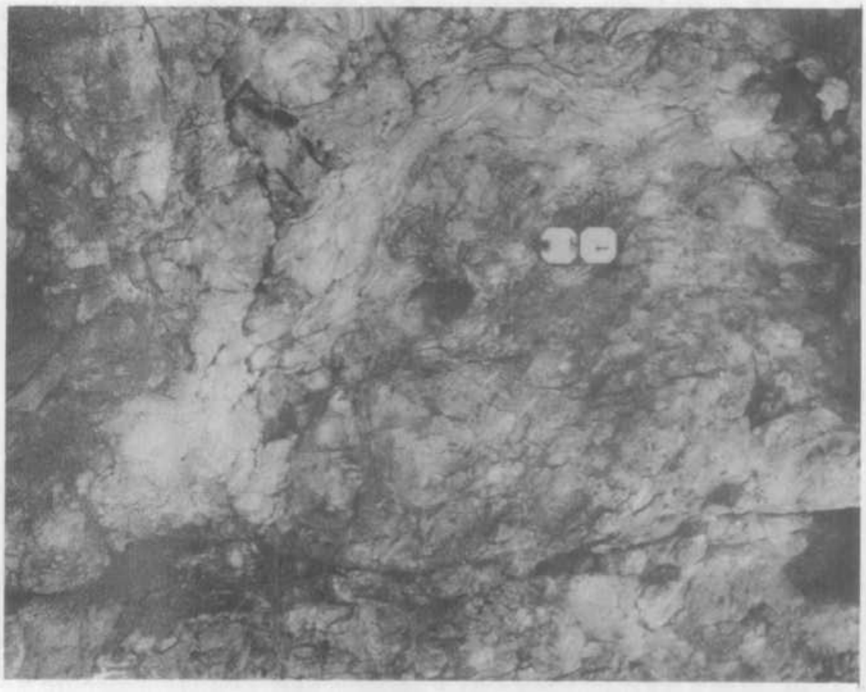


FIG.8
?Flow banding in a "glassy" breccia at Mount Pyroclast south of Gosses Bluff. The scale is given by the Brunton Compass.

FIG.9
Impression of single, well developed shatter cone at Mount Pyroclast south of Gosses Bluff.

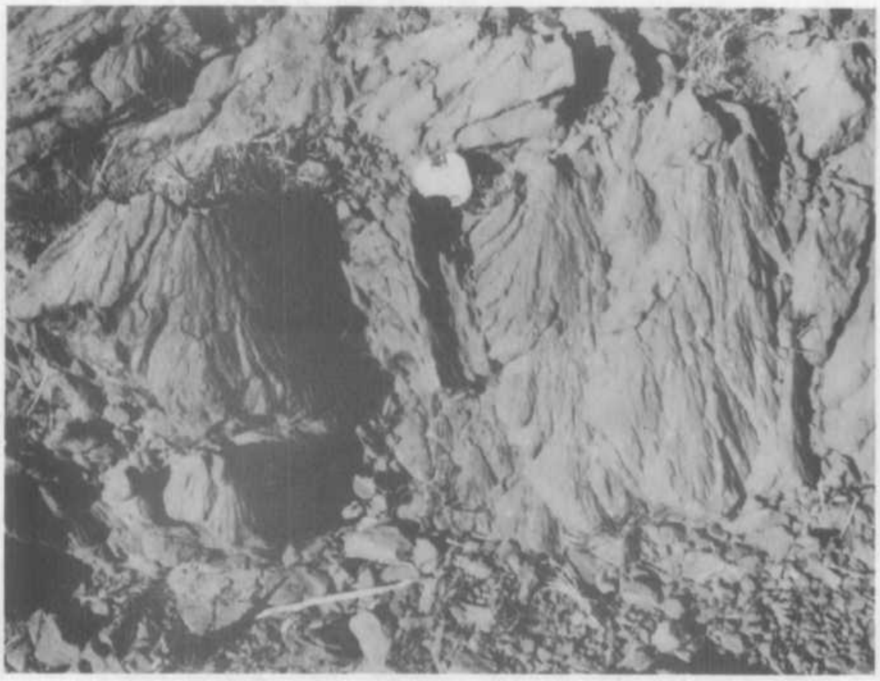


FIG.10
A "swarm" of shattercones in sandstone of the Pertnjara Group (Pz(2)). East side of the rim of Gosses Bluff. Scale given by the Brunton Compass.

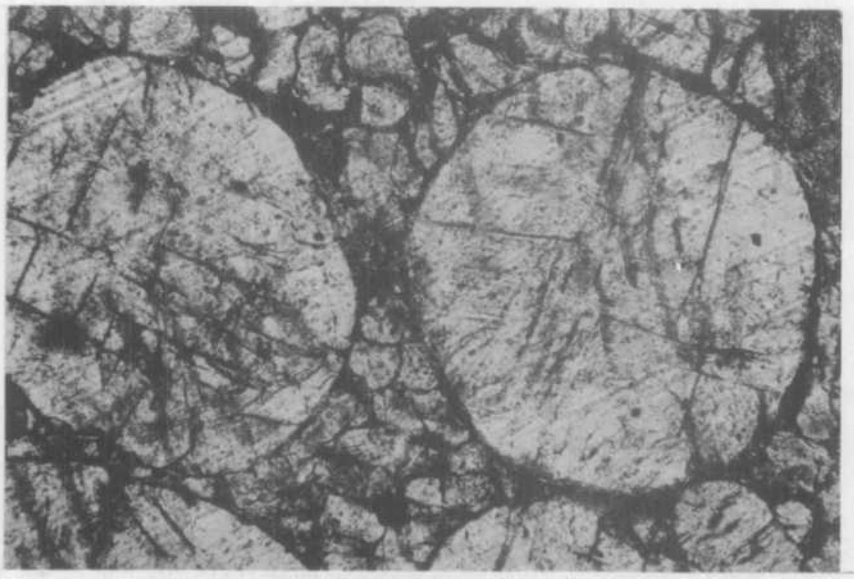


FIG.11
Shattered quartz grains in Stairway Sandstone equivalent (Ol(1) from the centre of Gosses Bluff.

FIG.12
Strain lamellae on the surface of a quartz grain from the Stairway Sandstone equivalent (Ol(1)) present in the centre of Gosses Bluff.

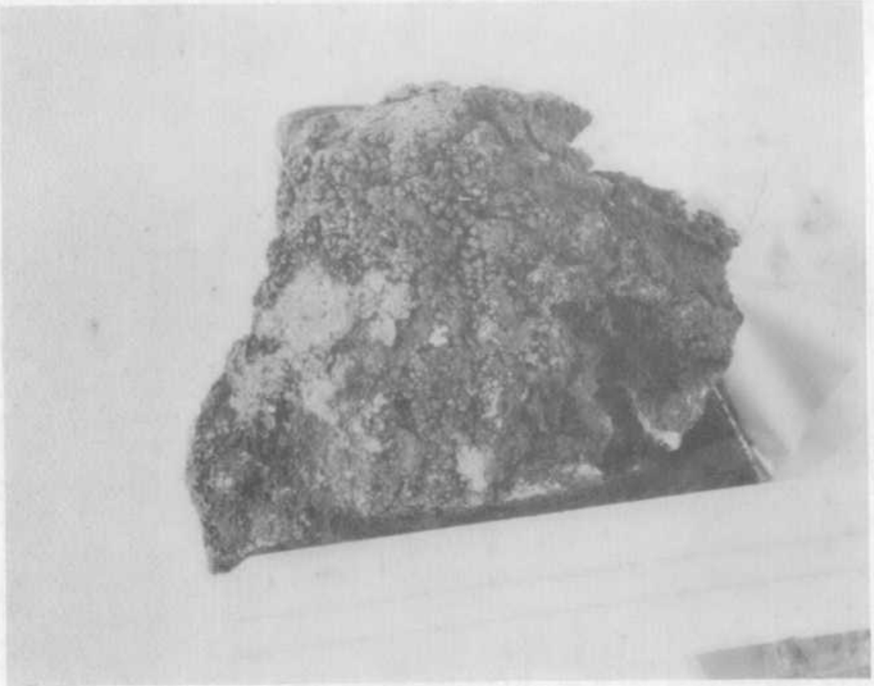


Fig.13 Specimen of glassy zeolitic rock with rounded granules which possibly represent moulds of vesicles in the originally molten rock (?). The specimen is from the eastern peak of Mount Pyroclast. Scale is marked in inches.

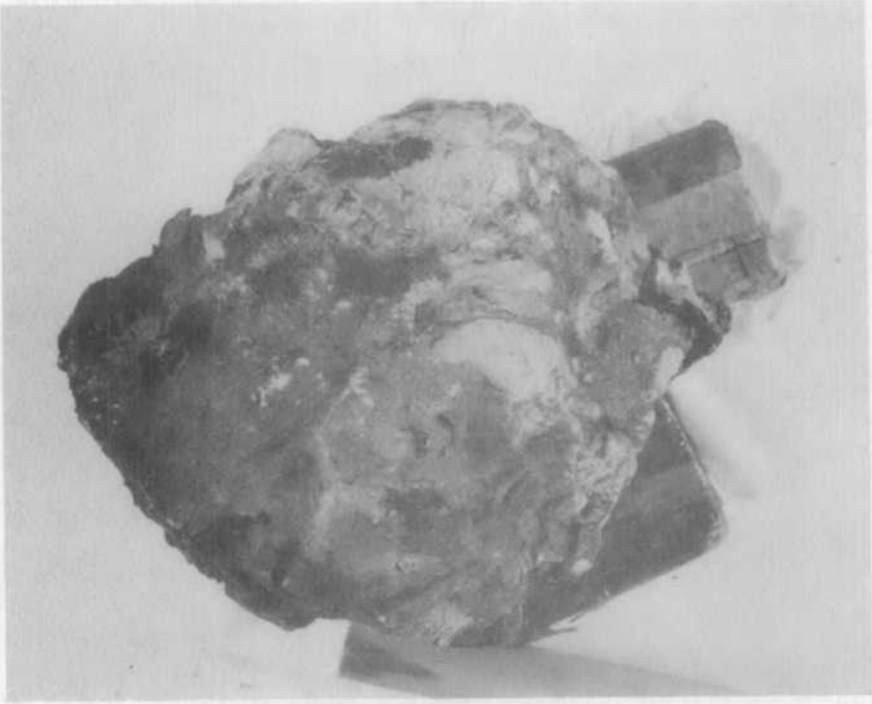


FIG.14 Specimen of breccia from Mount Pyroclast with a dark glassy matrix (exhibiting flow structures in places) with light coloured clasts of fractured and deformed quartz sandstone. Specimen is approximately 6 inches across. Compare this specimen with the photograph of suevite from the Ries Dome, Germany, given by Shoemaker and Chao, 1961, Fig.2.

FIG.15 Typical specimen of breccia. Core from Hermannsburg (B.M.R.) No.1 Well, depth of 348 feet. Scale is marked in inches.

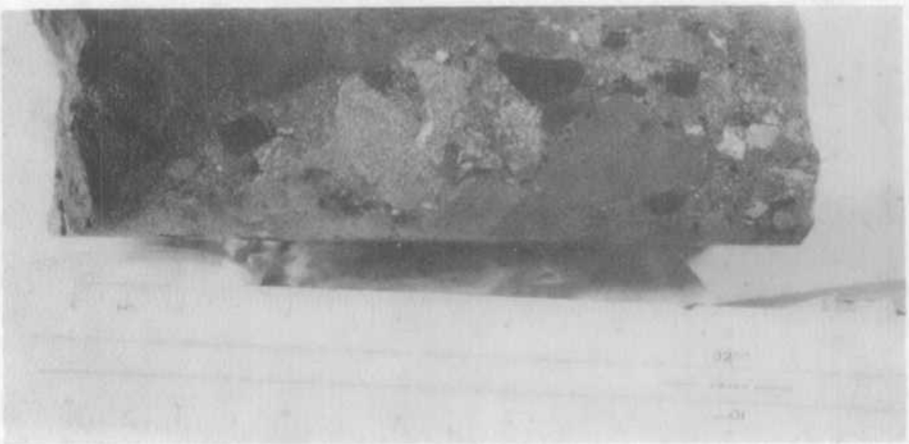


FIG.16 Specimen of breccia showing a clast of dark coloured mudstone with sub-rounded outline. Core from Hermannsburg (B.M.R.) No.1. Depth of 348 feet. Scale is marked in inches.

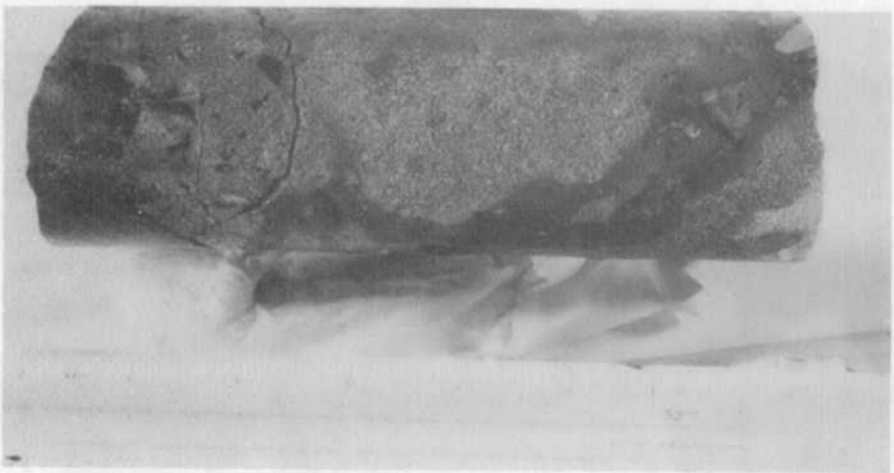


FIG.17 Specimen of breccia showing a large clast of sandstone with a fairly smooth margin. The finer breccia has the impression of having flowed around the larger clast. Specimen from Hermannsburg (B.M.R.) No.1, depth of 347 feet. Scale is marked in inches.

FIG.18 Breccia again looking as if it has flowed. Note the feathered outline to the dark clast of mudstone. Specimen from Hermannsburg (B.M.R.) No.1, depth of 347 feet. Scale is marked in inches.

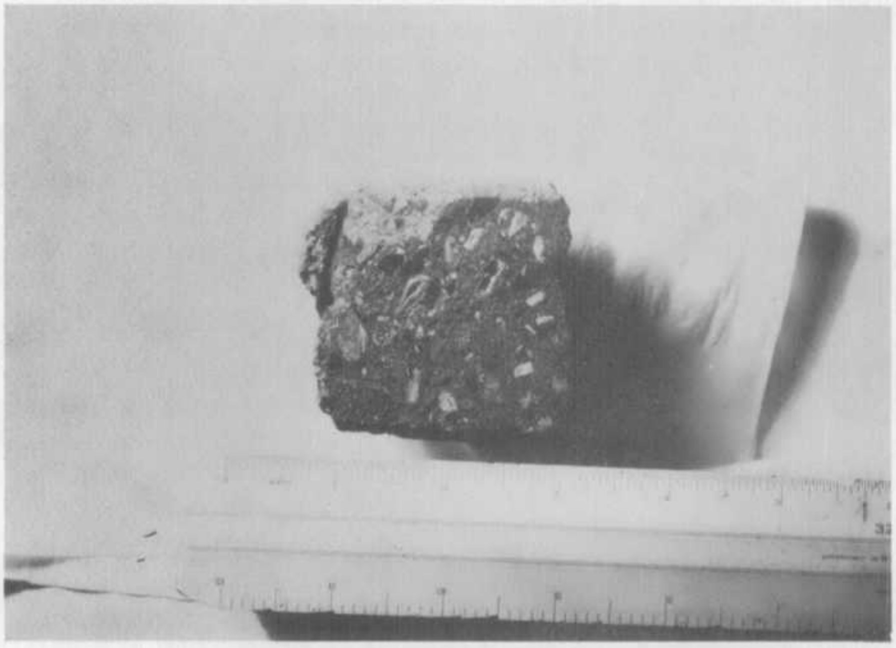


FIG.19 Specimen of breccia with clasts of sandstone, siltstone and claystone. Many of the light patches are composed of bentonitic clay. Specimen from Hermannsburg (B.M.R.) No.5, depth of 27 feet. Scale is marked in inches.

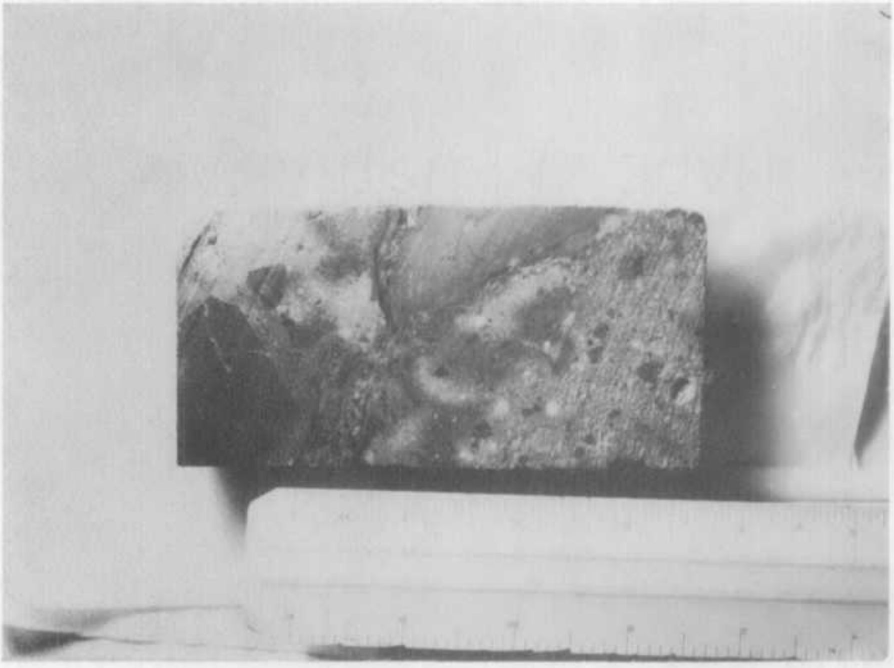


FIG.20 Breccia with extremely angular fragments of sandstone, siltstone and mudstone. In the middle of the core is a lens of bentonitic slay, with an irregular crenulated boundary. Specimen from Hermannsburg (B.M.R.) No.1, depth of 97 feet. Scale is marked in inches.

APPENDIX 1

SHALLOW DRILLING AT GOSSES BLUFF

by

P.J.Cook

Shallow Drilling Programme

The results of the shallow drilling are summarized in the graphic log sheets. The following abbreviations are used in the log sheets.

Grain size: sstn - sandstone
stst - siltstone
mdst - mudstone
vf - v fine grained
f - fine grained
m - medium grained
c - coarse grained

Colour:

A rock colour chart (Goddard, 1963) was used for comparison with standard colours. The colour abbreviations are those of the accepted standard form.

N4 - medium dark grey
N8 - very light grey
N9 - white
5B9/1 - bluish white
5G6/1 - greenish grey
5GY6/1 - greenish grey
5R4/2 - greyish red
5R6/2 - pale red
5R8/2 - greyish pink
5YR3/4 - moderate brown
5YR4/4 - moderate brown
5YR6/1 - light brownish grey
5YR6/4 - light brown
5YR7/2 - greyish orange pink
5YR8/1 - pinkish grey
5YR5/2 - pale brown
10R3/4 - dark reddish brown
10R4/2 - greyish red
10R5/4 - pale reddish brown
10R6/2 - pale brown
10R7/4 - moderate orange pink
10R8/2 - greyish orange pink
10Y6/2 - pale red
10Y7/4 - moderate greenish yellow
10Y8/2 - pale greenish yellow
10YR7/4 - greyish orange
10YR8/2 - very pale orange
10GY7/2 - pale yellowish green

Lithology:

Most terms used are self-explanatory. The term "talc" was used in the field for green very fine grained soft clayey material which occurred in thin beds, veins and vugs. Subsequent analysis by P.Duff showed the "talc" to be bentonite (see Appendix II).

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

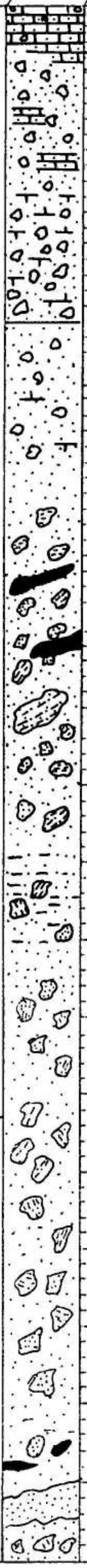
GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966

HOLE NO 1 ANGLE vertical BEARING ELEVATION 2500

LOCATION Gosses Bluff FOUR MILE Hermannsburg LATITUDE 23° 49' S LONGITUDE 132° 17' E

TOTAL DEPTH 500' DEPTH TO WATER TABLE Approx 230'



WEATHERING	CASING	CORE SIZE	LIFTS	CORE RECOVERY	DIP	COLOUR	TEXTURE	LITHOLOGY
WEATHERED	6					5R6/2	stst	Pale red siltstone with large chips of travertine (approx equal amounts
							stst	Chips predominantly siltstone with only v rare travertine
UNWEATHERED						5R4/2		A few siltstone chips - all chips extremely small.
		1½"		3%		5R6/2 and N8		Breccia - arenite & lutite clasts in a sandy matrix. Some 'blebs' of "talc". Calcareous.
		1½"		10%		5R4/2 10R7/4	stst	Sandy siltstone - a few ?clasts. - sample possibly representative - may represent a single clast. Calcareous.
						5R4/2 and 10R7/4	stst	A few chips of sandy siltstone - slightly calcareous.
						5R8/2 5R4/2 and 10YR7/4	vf	70% of chips are silty sstn. 20% claystone & 10% sandy siltst Calcareous.
						10YR8/2 to N8 with N4 and 5R6/2	vf sstn & stst	Predominantly v.f. sandstone and siltstone. Minor claystone. Vuggy in part. Non-calcareous.
						5YR8/1 minor 5R4/2 and 5YR6/1	stst & v fn sstn.	Predominantly sandy siltstone & silty sandstone - v friable; some vugs. Minor mudstone & claystone Slightly calcareous. A few chips of ?breccia.
						5YR8/1 minor 5R4/2 N8 and 5YR6/4	vf sstn	Predom silty sstn & sandy siltst Up to 20% mudst & clayst. Very few chips - sample probably represents a v friable interval. Calcareous.
		1½"		7%		5R8/2 minor 10R4/2 and N9	stst & v fn sstn	Angular clasts of arenite & lutite in a silty sstn or sandy siltst matrix. Calcareous. 'Blebs' of "talc".
		2½"	1	100%	?30°	10GY7/4 10R4/2 and	vf	Very friable sstn band (? glassy) Breccia - angular clasts up to 2"

DRILL Mayhew 1000

DRILLER E. H. Cherry

COMMENCED 18-6-66

COMPLETED 6-7-66

REMARKS

Drilling with air.
Drilling soft or very soft.

LOGGED P. J. Cook

SAMPLED P. J. Cook

ASSAYED

SHEET 1 OF 5

To accompany Record 1966/132

N.L.K.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966
HOLE NO 1 ANGLE vertical BEARING ELEVATION 2500
LOCATION Gosses Bluff FOUR MILE Hermannsburg LATITUDE 23°49'S LONGITUDE 132° 17'E
TOTAL DEPTH 500' DEPTH TO WATER TABLE Approx 230'

WEATHERING	CASING	CORE SIZE	LIFTS	CORE RECOVERY	DIP	FOSSILS	BEDDING	GRAPHIC LOG	FOOTAGE	COLOUR	TEXTURE	LITHOLOGY	SAMPLE INTERVAL	SAMPLE NUMBER	% P_2O_5 SQ	% P_2O_5 Q
			▨						100	5R8/2		forms majority of core. "Talc" present				
									110	10R6/2 minor 5R8/2 some 5R4/2 10R6/2 with 5R8/2 and 5R4/2	vf	Chips predom v fn sstn with 5-10% shaley lutite. A few chips of breccia. Also a few chips of "talc" in upper half of interval. Calcareous.				
									120	10YR8/2 minor 5R6/2 and 5R4/2	vf sstn-c stst	Mainly extremely friable sstn or stst. Minor fn stst and mdst. A few chips of breccia. Calcareous.				
									140	5R4/2 minor 10Y7/4	vf	Predominantly v. friable sstn; minor lutite; a few chips of breccia and "talc"				
		2½	2	100%	30° and 47°				150	5R6/2 minor 10Y6/2 vminor 5B9/1	vf matrix	Predominantly breccia - large clasts with v fn sstn matrix. Also have white (?zeolitic) vugs. Bands of green "talc". Sandy matrix calc. Shatter cones well developed.				
										5YR5/2 and N8	vf	Friable, calcareous sstn				
									160	5YR5/2 to 5YR4/4 minor N4 and 5YR3/4	vf	80%+ brown friable sstn; 5% mudstone; 10% hard, laminate stst. 1-2% grey (N8) v friable sstn. Calcareous.				
									170	5YR5/2 with minor 5YR3/4	vf	90%+ brown sstn with numerous white & green specks; calcareous 5-10% brown mdst; non-calcareous. A few small shatter cones present.				
									180		fn stst	Very few chips - mainly crumbly stst, but with minor brittle mdst.				
									190		c stst - vf sstn	Very few chips - probably a very friable sstn/stst interval. Calcareous. Some "talc" present.				
									200							

DRILL Mayhew 1000
DRILLER E.H. Cherry
COMMENCED 18-6-66
COMPLETED 6-7-66

REMARKS
Drilling with air.
Drilling fairly soft.

LOGGED P. J. Cook
SAMPLED P. J. Cook
ASSAYED
SHEET 2 OF 5

To accompany Record 1966/132

NLK

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966

HOLE NO 1 ANGLE vertical BEARING ELEVATION 2500'

LOCATION Gosses Bluff FOUR MILE Hermannsburg LATITUDE 23° 49' S LONGITUDE 132° 17' E

TOTAL DEPTH 500' DEPTH TO WATER TABLE Approx 230'

200 210 220 240 250 260 270 280 290 300

WEATHERING	CASING	CORE SIZE	LIFTS	CORE RECOVERY	DIP	FOSSILS	BEDDING	GRAPHIC LOG	FOOTAGE	COLOUR	TEXTURE	LITHOLOGY	SAMPLE INTERVAL	SAMPLE NUMBER	% P_2O_5 SQ	% P_2O_5 Q
										5YR5/2 and 5YR4/1	c stst - vf sstn	Few chips - probably a v friable interval.				
		2½"	3	100%	?45°					5R8/2	vf	Homogeneos calcareous sstn. Suspect is a large block. Shatter cones common.				
										5R8/2 minor N8	vf matrix	Breccia - sstn matrix (calc) - with arenite & lutite clasts. White (?zeolite) vug				
										5YR6/4 minor 5YR4/1	c stst - vf sstn	Predom brown sstn or siltstone; soft, friable, calcareous. A few chips of brownish-grey mdst.				
										5YR6/4	vf	No chips - only v.f. sand - grains poorly rounded, mod to poorly sorted. Calcareous. Sand slightly damp.				
										5YR6/4 minor 5YR4/1	c stst - vf sstn	As in interval 214'-220'				
										5YR5/2 and 5YR3/4	mdst & vf sstn	Approx equal amounts of pale brown friable sstn and hard, laminate mdst. Very few chips.				
										5YR4/4	vf	No chips - only v fn sand. Probably a very friable interval. Calcareous.				
										5YR6/4						
		2½	4	100%	?38°					10R6/2		Breccia - arenite & lutite clasts up to 7"				
					?43°					10R6/2 minor 5G6/1	vf	Homogeneous sstn with a single siltstone band. Shatter cones common.				
										10R4/2	mdst	Mainly mdst - some siltst & sstn interbeds.				
					?42					5YR6/1 & N8	vf	Fractured & brecciated sstn. Calc.				
													no sample			
										10R4/2 minor 5R8/2	stst & mdst	Chips mainly of hard laminate lutite; minor silty sstn.				
										5R4/2 minor 5YR8/1	mdst	Laminate, non-calc mudstone; minor friable, fn to v fn, silty, calc sstn. A few schlieren of "talc". Some shatter cones.				

DRILL Mayhew 1000

DRILLER E. H. Cherry

COMMENCED 18-6-66

COMPLETED 6-7-66

REMARKS

Drilled with air to 280' but water located at about 230' necessitated change to drilling with fluid. Drilling fairly hard.

LOGGED P. J. Cook

SAMPLED P. J. Cook

ASSAYED

SHEET 3 OF 5

N.L.K.

To accompany Record 1966/132

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

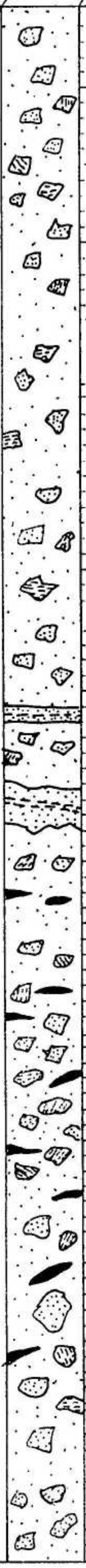
GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966

HOLE NO 1 ANGLE vertical BEARING ELEVATION 2,500'

LOCATION Gosses Bluff FOUR MILE Hermannsburg LATITUDE 23°49'S LONGITUDE 132°17'E

TOTAL DEPTH 500' DEPTH TO WATER TABLE Approx 230'



WEATHERING	CASING	CORE SIZE	LIFTS	CORE RECOVERY	DIP	FOSSILS	BEDDING	FOOTAGE	COLOUR	TEXTURE	LITHOLOGY	SAMPLE INTERVAL	SAMPLE NUMBER	% P_2O_5 SQ	% P_2O_5 Q
								300	10R8/2 minor 5R4/2	vf	80% friable, mod to poorly sorted and rounded, feldspathic, calcareous, silty sstn. 20% hard, non-calc mudstone.				
								310	10R8/2 minor 5R4/2 and 5GY6/1	vf	80% sstn as in interval 300-310 v minor qtz arenite. 20% non-calc siltstone & mudst. A few small fragments of ?opaline material.				
								320	10R8/2 and 5R4/2	vf	Same as interval 310'-320'				
									10R8/2 minor 5R4/2		Same as interval 310'-320' except that lutite now only 10% of total.				
		2½"	5	100%	?61° ?48° ?58° ?52°					vf	Fdspathic sstn - some mdst.				
									5YR7/2 minor	large clasts	Breccia - composed of ang & sub-rnd arenite & lutite fragments. Some calcite vugs. Some "talc".				
									5YR4/4 & 5GY6/1	vf	sstn - v minor lutite. A few thin veins of silic^n near top. Non-calc				
									5YR6/4 & 10R4/2	mdst & vf sstn	Approx equal arenite & lutite Lutite - mdst & v.f. stst; laminate Arenite - slightly calc, friable silty sstn. V minor "talc"				
								360	5R8/2 minor 10R4/2	vf	70% arenite - fairly, silty & poorly sorted. 30% lutite - laminate stst & mdst. up to 3% green "talc"				
								370	5YR6/4 & 10R4/2	v.f. sstn stst & mdst	Approx equal arenite & lutite. Up to 5% "talc". Non-calcareous. A few chips of breccia & also light grey (N8) friable sstn - calc.				
								380	5R8/2 & 5R4/2		Same as interval 370'-380'				
								390	5R8/2 & 5YR6/4 minor 10R7/4		Predominantly arenitic. The greyish pink sstn is hard; the other sstns are soft, friable and calcareous. V minor mdst. A few chips of breccia				
								400							

DRILL Mayhew 1000

DRILLER E. H. Cherry

COMMENCED 18-6-66

COMPLETED 6-7-66

REMARKS

Drilling with fluid.

Drilling very hard.

LOGGED P. J. Cook

SAMPLED P. J. Cook

ASSAYED

SHEET 4 OF 5

N.L.K.

To accompany Record 1966/132

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

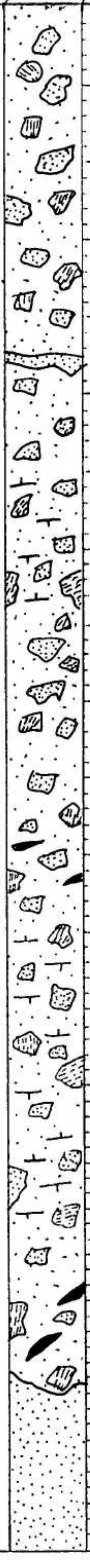
GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966

HOLE NO. 8 ANGLE vertical BEARING ELEVATION 2500

LOCATION Gosses FROM MILE Hermannsburg LATITUDE 23° 49' S LONGITUDE 132° 17' E

TOTAL DEPTH 500' DEPTH TO WATER TABLE Approx. 230'



	WEATHERING	CASING	CORE SIZE	LIFTS	CORE RECOV.	DIP	FOSSILS	BEDDING	GRAPHIC LOG	FOOTAGE	COLOUR	TEXTURE	LITHOLOGY	SAMPLE INTERVAL	SAMPLE NUMBER	% P_2O_5 SQ	Q
400											N8 to 10R4/2 minor 10R7/4 & 5R4/2	vf	60-70% sstn and silty sstn; calcareous. Calcite vugs are common. 30/-40% mdst; non-calcareous. Some chips of breccia.				
420			2½"	6	90%	?45° ?48° ?38° ?42°					5R4/2	vf	Breccia - sstn matrix (silty, calc). Clasts up to 6" - composed of sstn & mdst. Some "talc"				
											5R6/4	s-vf	Fractured slightly calc. sstn				
											5R6/2	vf	Breccia as above.				
											5YR6/4 & 5YR8/1	vf	90% sstn - friable, silty, poorly sorted, calc in part. 10% stst & sandy stst.				
430											5R8/2 minor 10R3/4 & 5G6/1	vf	90% sstn - friable, calcareous, Some intergranular calcite. Vugs of calcite common. 10% mdst with some stst. Some chips of breccia.				
440											5R8/2 minor 10R3/4 & 5G6/1	vf	Same as interval 430'-440'.				
450											5R8/2 5R6/2 5YR4/4	stst & vf mdst	Approx equal arenite & lutite. Sstn - mod hard, silty, poorly sorted. Lutite mainly stst and sandy stst. V minor "talc". Interval calc in part.				
460											5R8/2 & 5YR3/4 minor N9	mainly vf minor mdst	60% sstn; 40% mdst with minor stst. Crystals of calcite fairly common. Interval calc.				
470											5YR3/4 & 5R8/2	mdst minor vf sstn	60% mdst with minor stst. 40% sstn - calcareous. crystals of calcite present				
480											5R8/2 minor 5YR3/4	vf minor mdst	Predom silty, poorly sorted, calc, feldspathic sstn. Minor lutite. A few fragments of talc (of 5GY8/1 and 5Y6/4).				
490			2½"	7	65%	?37° ?57° ?47° ?47°					5YR6/4	vf	Sstn - silty, friable, vuggy porosity, thickly bedded, non-calcareous. Thin lutite (5G6/1) bands at 490'6" and 491'6". ?clay-pellets at 494. Shatter cones v common. Core 496-500 lost				
500																	

DRILL Mayhew 1000

DRILLER E. H. Cherry

COMMENCED 18-6-66

COMPLETED 6-7-66

REMARKS

Drilling with fluid. Drilling fairly soft.

LOGGED P. J. Cook

SAMPLED P. J. Cook

ASSAYED

SHEET 5 OF 5

N.L.

To accompany Record 1966/132

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966

HOLE NO 2 ANGLE vertical ? BEARING ELEVATION 2500 ft

LOCATION Gosses Bluff FOUR MILE Hermannsburg LATITUDE 23°49'S LONGITUDE 132° 16'E

TOTAL DEPTH 28' DEPTH TO WATER TABLE

	WEATHERING	CASING	CORE SIZE	LIFTS	CORE RECOVERY	DIP	FOSSILS	BEDDING	GRAPHIC LOG	FOOTAGE	COLOUR	TEXTURE	LITHOLOGY	SAMPLE INTERVAL	SAMPLE NUMBER	% P_2O_5 SQ	% P_2O_5 Q
0																	
10	WEATHERED ↑																
20	UNWEATHERED ↓																
			2½"	1		40°			░		5R8/2	f-m	Fairly uniform sstn; strongly fractured Fn green specks. Some shatter cones				
30																	
40																	
50																	
60																	
70																	
80																	
90																	
100																	

DRILL Mayhew 1000

DRILLER E H Cherry

COMMENCED 6 - 7 - 66

COMPLETED 6 - 7 - 66

REMARKS

Possibly some deviation of the hole due to steep dip

LOGGED P. J. Cook

SAMPLED M Vowles

ASSAYED

SHEET 1 OF 1

To accompany Record 1966/132

NLK

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

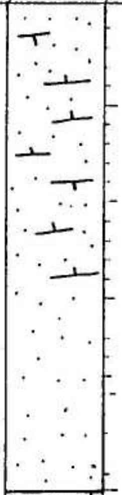
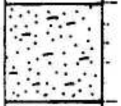
GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966

HOLE NO 3 ANGLE vertical BEARING ELEVATION 2500'

LOCATION Gosses Bluff FOUR MILE Hermannsburg LATITUDE 23° 49'S LONGITUDE 132° 15'E

TOTAL DEPTH 30' DEPTH TO WATER TABLE

WEATHERING	CASING	CORE SIZE	LIFTS	CORE RECOVERY	DIP	FOSSILS	BEDDING	GRAPHIC LOG	FOOTAGE	COLOUR	TEXTURE	LITHOLOGY	SAMPLE INTERVAL	SAMPLE NUMBER	% P_2O_5 SQ	% P_2O_5 Q
												Soft and friable				
		2½"	▨ 1	100%	40°					10R5/4 & 5YR8/1	m-c	Mottled sstn; silty, poorly sorted clay pellets in places.	/			

DRILL Mayhew 1000

DRILLER E H Cherry

COMMENCED 7-7-66

COMPLETED 7-7-66

REMARKS

Easy drilling

LOGGED P J Cook

SAMPLED M Vowles

ASSAYED

SHEET 1 OF 1

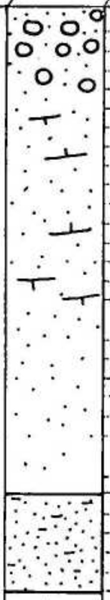
To accompany Record 1966/132

N.L.K.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966
HOLE NO 4 ANGLE vertical BEARING ELEVATION
LOCATION Gosses Bluff FOUR MILE Hermannsburg LATITUDE 23° 48' S LONGITUDE 132° 14' E
TOTAL DEPTH 30' DEPTH TO WATER TABLE



Weathering	Casing	Core size	Lifts	Core recovery	Dip	Fossils	Bedding	Graphic log	Footage	Colour	Texture	Lithology	Sample interval	Sample number	% P_2O_5 SQ	% P_2O_5 Q
												Unconsolidated gravel - cobbles of vein q^tz and q^tzite				
												Travertinous				
												Soft, friable sandstone.				
		2½"	1	100%	70°(?)					5R8/1 5R4/2	f-m	Poorly sorted, feldspthic, mottled in part; lithic grains fairly common.				

DRILL Mayhew 1000
DRILLER E. H. Cherry
COMMENCED 7 - 7 - 66
COMPLETED 7 - 7 - 66

REMARKS

LOGGED P. J. Cook
SAMPLED M Vowles
ASSAYED
SHEET 1 OF 1

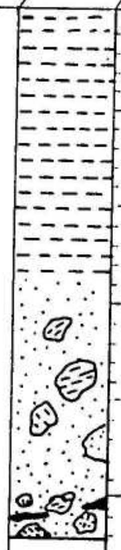
N.L.K.

To accompany Record 1966/132

RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966
HOLE NO 5 ANGLE vertical BEARING ELEVATION 2500′
LOCATION Gosses Bluff FOUR MILE Hermannsburg LATITUDE 23° 50′ LONGITUDE 132° 17′E
TOTAL DEPTH 27′ DEPTH TO WATER TABLE



WEATHERING	CASING	CORE SIZE	LIFTS	CORE RECOVERY	DIP	FOSSILS	BEDDING	GRAPHIC LOG	FOOTAGE	COLOUR	TEXTURE	LITHOLOGY	SAMPLE INTERVAL	SAMPLE NUMBER	% P_2O_5 SQ	% P_2O_5 Q
												Hard siltstone				
												Soft friable sandstone with minor siltstone and mudstone. Lithology fairly varied.				
		2½″	▨ 1	100%						5YR6/4	fn sstn matrix	Vughs, with ?zeolites and 'blebs' of 'talc' are common.	/			

0 10 20 40 50 60 70 80 90 100

DRILL Mayhew 1000
DRILLER E. H. Cherry
COMMENCED 10-7-66
COMPLETED 10-7-66

REMARKS

LOGGED P. J. Cook
SAMPLED M. Vowles
ASSAYED
SHEET 1 OF 1

To accompany Record 1966/132

MLK.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

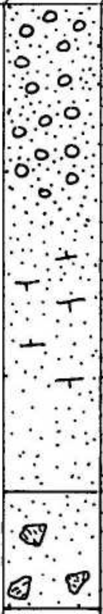
GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966

HOLE NO 6 ANGLE vertical BEARING ELEVATION

LOCATION Gosses Bluff FOUR MILE Hermannsburg LATITUDE 23° 51'S LONGITUDE 132° 17' E

TOTAL DEPTH 31' DEPTH TO WATER TABLE



	WEATHERING	CASING	CORE SIZE	LIFTS	CORE RECOVERY	DIP	FOSSILS	BEDDING	GRAPHIC LOG	FOOTAGE	COLOUR	TEXTURE	LITHOLOGY	SAMPLE INTERVAL	SAMPLE NUMBER	% P_2O_5 SQ	Q
0–25													Unconsolidated gravel				
25–31			2½"	1		45°					10R6/2	fn sstn matrix	20-30% of rock composed of clasts of arenite & lutite; clasts generally angular.				

0 10 20 40 50 60 70 80 90 100

DRILL Maybew 1000

DRILLER E. H. Cherry

COMMENCED 11 - 7 - 66

COMPLETED 11 - 7 - 66

REMARKS

LOGGED P. J. Cook

SAMPLED M. Vowles

ASSAYED

SHEET 1 OF 1

F53/B03/10

To accompany Record 1966/132

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

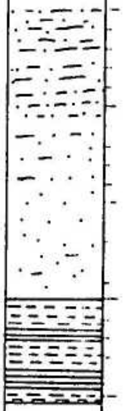
GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966

HOLE NO. 7 ANGLE vertical BEARING ELEVATION 2500'

LOCATION Gosses Bluff FOUR MILE Hermannsburg LATITUDE 23° 51' S LONGITUDE 132° 18' E

TOTAL DEPTH 30' DEPTH TO WATER TABLE



Depth (ft)	WEATHERING	CASING	CORE SIZE	LIFTS	CORE RECOVERY	DIP	FOSSILS	BEDDING	GRAPHIC LOG	FOOTAGE	COLOUR	TEXTURE	LITHOLOGY	SAMPLE INTERVAL	SAMPLE NUMBER	% P_2O_5 SQ	% P_2O_5 Q
0																	
10																	
20																	
			2½"	1	100%	45°					5R4/2	stst & mdst	Thin bedded or laminate; soft; vughs with white filling common. Shatter cones very common.				
30																	
40																	
50																	
60																	
70																	
80																	
90																	
100																	

DRILL Mayhew 1000

DRILLER E. H. Cherry

COMMENCED 12-7-66

COMPLETED 12-7-66

REMARKS

LOGGED P. J. Cook

SAMPLED M. Vowles

ASSAYED

SHEET 1 OF 1

To accompany Record 1966/132

N.L.K.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Shallow Drilling 1966

HOLE NO 8 ANGLE vertical BEARING ELEVATION 2500'

LOCATION Gosses Bluff FOUR MILE Hermannsburg LATITUDE 23° 53'S LONGITUDE 132° 17'E

TOTAL DEPTH 21' DEPTH TO WATER TABLE

WEATHERING	CASING	CORE SIZE	LIFTS	CORE RECOVERY	DIP	FOSSILS	BEDDING	GRAPHIC LOG	FOOTAGE	COLOUR	TEXTURE	LITHOLOGY	SAMPLE INTERVAL	SAMPLE NUMBER	% P_2O_5 SQ	% P_2O_5 Q
		2½	1		70°					10R6/2	f-m	Cut by numerous fine fractures. Bedding poorly developed. Shatter cones are fairly common.				

DRILL Mayhew 1000

DRILLER E H Cherry

COMMENCED 12-7-66

COMPLETED 12-7-66

REMARKS

LOGGED P. J. Cook

SAMPLED M. Vowles

ASSAYED

SHEET 1 OF 1

F53/A3/21

N.L.K.

To accompany Record 1966/132

APPENDIX II

THE OCCURRENCE OF BENTONITE AT GOSSES BLUFF

by

P.J.Cook and P.Duff

Introduction

At the present time bentonite is being keenly prospected for in several parts of Australia; the occurrence of bentonite at Gosses Bluff is therefore of economic interest.

Occurrence

The bentonite (initially given the field name of "talc") was first detected in drill cuttings from the interval 37 - 43 feet in the Hermannsburg (BMR) No.1 Well. Cuttings above 37' were very sparse and the bentonite may also occur at shallower depths. Fragments of bentonite were detected in drill cuttings down to a depth of 490' in the well.

Bentonite is also present in several of the cored intervals, occuring as irregular "blebs", vugs, veins, lenses and bands. At a depth of 97'3" the bentonite occurs as a lens showing marked concentric bands (Fig 20) with the bands ranging from bright green and grey-green to more rarely red-brown, pale brown or white in colour. In general the bentonite is bright green in colour but there is minor brown and white in places. Bentonite was observed in the Hermannsburg (BMR) No.1 well, over the following intervals:

37' - 49'	- cuttings
60' - 70'	- cuttings
90' - 96'	- cuttings
97'3" - 97'5"	- cored band
97'9" - 98'3"	- cored band
98'3" - 110'	- core and cuttings
120' - 140'	-Bentonite very common in cuttings
147' - 147'6"	- cored band
151'3" - 151'5"	- cored band
152'6" - 1528"	- cored band
152'10" - 153'0"	- cored band
also 145' - 155'	- vugs of bentonite throughout cored intervals
190' - 200'	- cuttings
290' - 300'	- cuttings
345' - 353'	- vugs of bentonite in cored interval
353' - 399'	- cuttings
415' - 423'	- irregular patches in cored interval
450' - 460'	- cuttings
480' - 490'	- cuttings

Bentonite was therefore detected over a total interval of 170 feet out of a total depth of 500 feet. This suggests that the bentonite may be of considerable vertical extent.

The lateral extent of the bentonite is rather uncertain at the present time. It is undoubtedly present as vugs in the 2 feet of core obtained from the Hermannsburg (BMR) No.5 Well, but was not observed in the cores of any of the other shallow holes. Fragments of bentonite were only detected in the cuttings of two seismic shot points (one a mile from Gosses Bluff on line 2-F, the other 1½ miles from Gosses Bluff on line 2-5.8). The paucity of bentonite in the seismic cuttings is however to be expected as the cuttings had been subjected to weathering for 12 months previously. No rocks positively identified as bentonitic were observed in outcrop but areas in the vicinity of the Hermannsburg (BMR) No.1 Well (particularly areas thought to be underlain by breccia) were "spongy"; this may be due merely to the presence of travertine, but it may alternatively be a reflection on the swelling properties of an underlying bentonitic rock.

It is suspected that there is a very strong relationship between the bentonite and the breccia.

The properties of the Gosses Bluff bentonite

Samples for analysis were selected from the following depths:

Core No.1	98' 10" to 99'3"	Core No.2	152'4½" to 152'7½"
Core No.2	151' 2" to 151'6"	" "	152'7½" to 153'0"
" "	151'11" to 152'4½"	" "	153'0" to 153'6"

The pieces selected were combined, air-dried and ground before testing. The moisture content of the clay was determined at 23% by weight.

Test results of a standard 6% slurry are given in the table below: they are compared with sample "E" from the Black Alley Shale near Early Storms and also with Black Alley Shale material from near Springsure, Queensland. The latter results are included as it appears probable that this material will be used commercially.

A further test was carried out wherein the Hermannsburg clay was treated with 2% by weight of soda ash to determine whether the clay could be improved. These results are also included in Table 2.

Tests on bentonitic clay TABLE 2

TEST	Sample E Early Storms	Average of 24 Springsure samples	Hermannsburg (BMR) No.1 samples	Hermannsburg samples + 2% by wt. soda ash
Apparent Viscosity (cp)	3.3	1.8	5	7
Plastic Viscosity (cp)	3	1	2	2.5
Field (lb./100 sq.ft)	0.5	1.8	6	9
Initial Gel " "	0	0	2	5
Ten Min Gel " "	0	2	5	7
Filtrate (cc)	16	45	47	43
pH	9	8	8.5	9.5

Economic considerations

It is evident from the properties given in Table 2 that the Gosses Bluff bentonite is of good quality comparing favourably with bentonite from the Springsure area, and as such merits economic evaluation. It is known that the bentonite has considerable vertical extent in Hermannsburg (BMR) No.1 Well and it is thought that it may also be of appreciable areal extent. If, as is suspected, the bentonite is intimately associated with the breccia then it may occur throughout the ring of breccia which is thought to surround GossesBluff (Plate 2) and which has a minimum area of 60 square miles.

At the present time it is not known whether the bentonite occurs in flat-lying beds which could be readily worked. Much of it probably occurs as irregular lenses and veins which could not be worked; the thickest cored band was only 6 inches thick and in addition, most of the bands appeared to be fairly steeply dipping. Therefore any thorough evaluation of the deposits is likely to be fairly difficult and probably costly, and would necessitate an extensive drilling programme. However, even a limited shallow coring programme would be of considerable assistance in showing whether or not a full-scale exploratory programme is warranted.

APPENDIX III

CORE ANALYSIS RESULTS FROM THE HERMANNSBURG (BMR) WELLS

by

P.Duff

TABLE 3

Analyses of cores from the Hermannsburg (BMR) Wells

Well No.	Core No.	Depth From:- To:-	Lithology	Average Effective Porosity from two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Water Saturation (% of pore space)	Bulk density (100% water saturated)
					V	H	Dry Bulk	Apparent Grain		
1	1	100'4" 100'7"	Claystone Siltstone	* 31	Nil	10	2.01*	2.97	N.D.	?
1	2	149'7" 150'0"	Sandstone	* 27	"	Nil	2.13*	2.87	43	?
1	3	206'11" 2-7'6"	Sandstone	14	"	"	2.35	2.74	24	2.49
1	4	269'1" 269'9"	Sandstone	11	"	"	2.44	2.74	4	2.55
1	5	351'6" 351'11"	Sandstone	13	"	"	2.36	2.71	12	2.49
1	6	422'4" 422'11"	Claystone Siltstone	* 20	"	9	2.19*	2.73	N.D.	?
1	7	495'3" 495'9"	Sandstone	12	"	Nil	2.45	2.79	Nil	2.57
2	1	27'0" 27'7"	Sandstone	9	N.D.	1	2.47	2.72	Nil	2.56
3	1	28'5" 29'0"	"	15	1	1	2.32	2.74	12	2.47
4	1	27'0" 27'8"	"	14	1	1	2.36	2.76	34	2.50
5	1	25'6" 26'0"	"	12	N.D.	Nil	2.41	2.72	36	2.53
6	1	28'11" 29'5"	"	16	1	2	2.33	2.75	11	2.49
7	1	28'7" 29'1"	Sandstone Siltstone	14	1	1	2.45	2.85	10	2.59
8	1	18'4" 18'11"	Sandstone Siliceous	9	N.D.	Nil	2.48	2.71	Nil	2.57

Core Analysis

The porosities and permeabilities were determined on two small plugs (V & H) cut at right angles from the core. Ruska porosimeter and permeameter were used with air, at 30 p.s.i.g., and dry nitrogen, respectively, as the saturating and flowing media. Residual oil and water saturations were determined using soxhlet type apparatus. Acetone test precipitates, the core water salinity, the solubility in 15% HCl and the fluorescence of freshly broken core were checked but all the amounts of these tests were either nil or not present in detectable quantities. Shrinkage cracks occurred in cores 1, 2 and 6 from Hermannsburg (BMR) No.1, due to the presence of bentonitic clay; the values obtained for porosity and dry bulk density for these three cores are therefore unreliable.

Results

The results of the core analyses are summarized in Table 3.

The average value for the dry bulk density is 2.38, which is similar to the average figure of 2.39 given by Richards (1958) for sediments from the Arumbera Creek area. It is noticably lower than the average dry bulk density of 2.53 (Crook and Cook, 1966) in the Gosses Bluff No.1 Well. It therefore appears that the dry bulk density of the sediments (breccia etc.) around Gosses Bluff is a fairly normal value for Amadeus Basin sediments but that it is markedly lower than the average value for sediments in the centre of Gosses Bluff.

The average bulk density of the breccia and the other rocks surrounding Gosses Bluff is 2.52; the average bulk density of sediments in the Palm Valley No.1 Well (the nearest well to Gosses Bluff) is 2.61. This bulk density contrast might be sufficient to account for the negative bouguer anomaly associated with Gosses Bluff (Cook pers. comm.).

APPENDIX IV

THE PETROGRAPHY OF SOME SPECIMENS FROM GOSSES BLUFF

by

G.Schmerber

General

A total of 43 thin sections (28 outcrop samples and 15 samples from the Hermannsburg (B.M.R.) Wells) were examined.

Material referred to as "chlorite" or "chloritic material" was not checked by X-ray analysis, nor was X-ray analysis carried out on material referred to as "glassy" in order to determine its composition more precisely. The term "tuffaceous" is used merely as a textural term and no genetic connotation is implied.

In the description of the samples field numbers are used for outcrop specimens (localities marked on Plate 1) and footages are used for core specimens.

Description

G1A Sandstone from an outcrop of Pz(4) approximately 3 miles west of Gosses Bluff; shatter cones are common at the locality.

Calcareous sandstone: very poorly sorted, rounded to angular and very fine to coarse grained with quartz (60%) with thin primary haematitic coatings and some quartz overgrowth. There is rare sericitized K-feldspar and 10% rounded or subangular sericitized lithics, some of which are rich in recrystallized fine grained quartz. Quartzitic sandstone (partly fused), chert rich specks and haematitic sandy shale are also present. The cement is limonite and haematite, with minor (20%) fine carbonate.

G1B Very strongly weathered pink Pz(4) sandstone. In thin section the sandstone is medium to very fine grained, angular to sub-rounded and poorly sorted. It is made up mainly of quartz with a few grains of K-feldspar and 2-3% chert. The cement is haematitic in part; there is some secondary silicification and up to 30% calcite. Very little chlorite was observed.

Many of the grains in this thin section are fractured and broken.

G2 A typical specimen of Pz(4) sandstone from approximately two miles west of Gosses Bluff.

The specimen is a poorly sorted sandstone; fine to coarse grained, and rounded to angular. Quartz forms 65% (approximately) of the thin section, with minor chert, and altered orthoclase. There are also fragments of haematitic, slightly calcareous claystone and cryptocrystalline slightly haematitic limestone. Some of the lithic fragments have been sericitized or chloritized.

G4 A specimen of typical pebbly Pz(4) sandstone. Coarse grained calcareous sandstone with quartz overgrowth and minor primary haematitic cement. There are some well rounded lithic fragments of limestone and chert. Pyrite is present in places.

G5B Specimen of typical breccia from the creek bank near the site of Hermannsburg (BMR) No.1.

Tuffaceous sandstone - composed of fragments of sandy micaceous haematitic claystone and quartzitic sandstone. There are patches of vesicular glass and also patches of glassy material with some recrystallized quartz.

The matrix is composed of poorly sorted angular quartz grains, black opaque specks, and patches of sericite. The quartz grains throughout this thin section are fractured and broken and show strain lamellae; many of them are also "dusty".

G5D Regarded as pink ?sandstone in the field. In thin section it is considered to be a tuffaceous sandstone of fine to medium grain size. It is poorly sorted and rounded to angular. Quartz grains make up to 60% of the specimen; there are also a few grains of microcline, orthoclase, chert and sericitized lithics. There are pellets of ?chlorite in places. The matrix is glassy, vesicular in places, and also recrystallized in part. Haematite is locally present. There are also small specks of ?chlorite and black opaque material.

The quartz grains in this specimen are commonly fractured, broken and "dusty"; undulatory extinction is extremely common.

G5J Typical Pz(4) sandstone from near the site of Hermannsburg (BMR) No.1.

The specimen is a fine grained, quartzitic sandstone; angular to rounded, fairly well sorted and composed mainly of quartz; there are a few grains of orthoclase, chert, sericitized lithics and ?chlorite.

Haematitic coatings are common on the grains. Secondary silicification is well developed.

G7A A specimen from a large block of conglomeratic sandstone from within massive breccia.

The sandstone is very fine to very coarse grained, poorly sorted, angular to rounded.

The majority of the sand-size grains are quartz; there is minor K-feldspar, chert, muscovite, zircon and tourmaline. Pebbles are up to 4 mms. in diameter and are mainly of medium grained, silicified quartzose sandstone, haematitic shale and limestone. There is interstitial haematite, calcite, and silica in places.

Many of the grains are strongly fractured; the fractures are commonly filled with carbonates.

G8 Specimen from a large block within breccia. Petrographically identical with Specimen G7A.

G10A Sample of breccia from Mount Pyroclast. The specimen could be described as a tuffaceous conglomeratic sandstone. The sand-size material is angular to rounded and very fine to very coarse grained. Clasts which are up to 10 mms. across are composed of quartzitic sandstone, haematitic siltstone and mudstone and richly micaceous siltstone. The matrix is glassy and commonly contains minute specks of black opaque material; chlorite is present in places.

Many of the quartz grains have a "dusty" appearance, strain lamellae are well developed, fractures are extremely common and the grains generally show undulatory extinction.

G10B In outcrop at Mount Pyroclast this rock has the appearance of a white soft, extremely friable sandstone. In thin section the rock appears to be composed mainly of crypto-crystalline (vesicular in part) glassy material with indeterminate black opaque specks in places.

G10C This specimen which is also from Mount Pyroclast has a similar appearance in outcrop to G10B but in thin section appears to be fairly normal sandstone, medium grained, well sorted, angular to rounded. The sand-size grains are mainly quartz, with minor weathered orthoclase, microcline, chert and sericitized lithics. There are a few clasts of very fine to medium grained poorly sorted sandstone.

The matrix is haematitic, chloritic, calcareous or siliceous.

G10D A friable vuggy sandstone from Mount Pyroclast. It is medium grained, well sorted, rounded to angular with the majority of grains composed of quartz. There are a few grains of K-feldspar, chert and sericitized lithics. Specks of unidentified dark opaque material are common. Many of the detrital grains are fractured and broken.

G11 A typical specimen from an outcrop approximately 3 miles south of the rim of Gossesl Bluff. A well sorted, rounded to angular, medium grained sandstone, with detrital grains mainly of quartz but with minor orthoclase, microcline, albite, chert, muscovite and biotite. There are patches of calcite in places. The matrix is haematitic, siliceous and more rarely, calcareous.

Many of the detrital grains are fractured, show strain lamellae and well developed undulatory extinction.

G12A In hand specimen this rock is composed of a dark ?glassy matrix with large white clasts. It is regarded from thin-section examination as a fused sandstone. The boundaries of the quartz grains are very indistinct; they commonly grade into the glassy matrix. There are patches of chlorite in places. This rock has much the same texture as specimen G13B.

G12B This is a white friable rock from Mount Pyroclast. In thin section it is composed mainly of glass which shows a "frothy" sort of texture. There are acicular (?zeolitic? crystals in places. Indeterminate black specks are very common.

G13B The specimen is from the eastern peak of Mount Pyroclast. In thin section it has the appearance of a fused sandstone, with indistinct but apparently well rounded medium grained quartz grains grading into the glassy matrix. There are numerous fine bubbles and black specks within the glassy matrix. Some low birefringence material in the slide may be zeolitic.

G13C The hand specimen of this rock is shown in Fig.13. It contains phenocrysts of the lamellar zeolite heulandite and radial acicular groups and clusters of the fibrous zeolite laumontite. Crystals of pyrite are fairly common. The matrix is probably composed of glassy material.

G16A The specimen is typical of unit Pz(2) on the east side of the rim of Gosses Bluff. It is a quartzose sandstone, with a haematitic cement. It is identical with specimen G27A.

G16B This is a specimen of breccia from the east side of the rim of Gosses Bluff and is from the locality shown in Fig.5. It is underlain by vertical Pertnjara Group (Pz(2)) sediments and is overlain by large horizontal blocks of Mereenie Sandstone (Pzm). From thin section examination, it is regarded as a tuffaceous brecciated sandstone, with clasts up to 20 mms. across, in a matrix of well rounded to angular quartz grains and minor glass. The detrital quartz grains show strain lamellae and are commonly fractured and broken. Strong undulatory extinction is evident.

G16C A specimen of typical Mereenie Sandstone from the east rim of Gosses Bluff. It is an orthoquartzite with most of the detrital grains composed of quartz with a few chert grains. Some of the grains have a thin coating of ?chlorite. Many of the grains show strain lamellae, and are strongly fractured and broken. Many of the grains have been apparently impacted against neighbouring grains.

G17A A limey sandstone (Unit Ol(1)) from the centre of Gosses Bluff. The sandstone is fine grained, very well sorted, angular to rounded with the detrital grains mainly of quartz but with very minor K-feldspar and muscovite. The quartz grains are commonly "dusty" and show well developed strain lamellae. Up to 35% of the rock is calcite cement.

G17C Regarded as a silty sandstone in the field. The specimen is from the centre of Gosses Bluff. In thin section it is seen to be a good example of a bimodal sand, with two well sorted modes of coarse well rounded and fine angular sand (Fig.11). The detrital grains are mainly of quartz but there are a few grains of orthoclase, chert, tourmaline and zircon. The rock is slightly phosphatic (up to 7% P_2O_5); cryptocrystalline apatite occurs as both pellets and isotropic matrix. The matrix is also chloritic in part. The detrital grains are fractured and show good strain lamellae.

G23A A typical specimen of Unit Pz(2) from the rim of Gosses Bluff. It is a very fine to medium grained, angular, poorly sorted sandstone composed mainly of detrital quartz grains, but with minor sericitized orthoclase, microcline and composite quartz grains. The cement is of silica, haematite chlorite and calcite.

The detrital grains are clear but many are fractured; the fractures are commonly filled with chlorite.

G27A A specimen of Pz(2) from the western side of the rim of Gosses Bluff, where it is overlain by breccia. It is a medium grained, well sorted, angular to sub-angular sandstone. The grains are very closely packed. There are a few grains of orthoclase, microcline, chlorite (or glauconite) and chert, but most detrital grains are composed of quartz and show strain lamellae and strong undulatory extinction.

G27B A specimen of the breccia which unconformably overlies specimen G27A; it is regarded as a tuffaceous sandstone from thin section examination. The clasts are up to 25 mms. in diameter, angular, and have very poorly defined outlines; they are composed of quartzose sandstone of a type which commonly occurs in breccias from the Gosses Bluff area. The matrix is composed of poorly sorted quartz grains, chlorite and glass.

Description of sub-surface samples

Hermannsburg (BMR) No.1

98' - 98'1"

Tuffaceous brecciated sandstone with angular clasts up to 20 mms. across. The clasts, which have indented outlines in places, are composed of quartzose sandstone, and micaceous haematitic silty claystone. They are in a matrix of angular medium to very fine grained quartz which have very indefinite outlines grading into the glassy material which forms the bulk of the matrix. The quartz grains are commonly "dusty", strain lamellae are well developed and undulatory extinction is marked.

109'3" - 109'4"

Quartzose and calcareous sandstone composed of medium grained, well sorted, angular to rounded quartz grains; with rare grains of K-feldspar and chert. Some of the grains have poorly defined outlines. Many of the quartz grains are shattered and the fissures filled with chlorite. The cement is mainly chloritic and haematitic.

145'10" - 145'11"

Tuffaceous brecciated sandstone, with clasts of medium grained quartzose sandstone and haematitic mudstone. The clasts are surrounded by poorly sorted angular to rounded, medium grained quartz in a glassy matrix. The quartz grains are "dusty" and have well-developed strain lamellae. Fine specks of an indeterminate opaque black mineral are present in places. Locally, there are patches of calcite and chlorite.

152'9" - 152'10"

Tuff with a few clasts of haematitic claystone and poorly sorted sandstone; there are patches of glassy material within the clasts. The glassy patches both inside and outside the clasts are partly recrystallized. The clasts arē surrounded by a diffuse matrix of glassy material, haematite and chlorite.

Some of the detrital grains have the appearance of having been partially melted, many of them are shattered and fractured and strain lamellae are well developed.

212' - 213'1"

Brecciated tuffaceous sandstone. The clasts are composed of quartz sandstone, haematitic silty claystone, chert (very rare) sericitized and chloritized clasts, the original form of which is unknown, and glass.

The matrix is composed mainly of quartz grains in which strain lamellae, fractures (filled with chlorite) and shattering are common. There is chloritic, calcareous and glassy cement in places. Vugs are partially filled with fibrous crystals (?gypsum or ?zeolite). Tourmaline zircon and glauconite occur as very minor accessory minerals.

266'3" - 266'4"

Brecciated tuffaceous sandstone with irregular, poorly defined clasts up to 15 mms. across. The clasts are composed of medium grained, well sorted quartzose sandstone and micaceous haematitic mudstone.

The clasts are in a matrix of fractured quartz grains and glass, with a few patches of chlorite.

349'8" - 349'9"

Medium grained, well sorted, angular to rounded quartz sandstone with rare detrital grains of sericitized and chloritized lithics, in a matrix of haematite, chlorite, silica and calcite. Few of the grains show strain lamellae and undulatory extinction is rare.

415'2" - 415'3"

Very poorly sorted, brecciated, tuffaceous sandstone, with clasts greater than 20 mms. across. The clasts are composed of well sorted, medium grained quartzose sandstone, haematitic micaceous claystone and sandy claystone, and ?glauconitic sandstone. There are also patches of calcite and glass. The clasts are in a matrix composed of angular to subrounded quartz grains which are shattered, fractured, show strongly undulose extinction and have well developed strain lamellae. The grains are commonly surrounded by glassy material. There are some patches of chlorite and calcite; dark opaque grains are common in places.

493'6" - 493'7"

Medium grained, well sorted, angular to rounded sandstone. The majority of the detrital grains are composed of quartz which is commonly fractured (the fractures are filled with ?chlorite). There are rare detrital grains of orthoclase, microcline, chert and sericitized lithic fragments. Glauconite, tourmaline and pyrite are present in very small quantities.

Hermannsburg (BMR) No.2

26'9" - 26'10"

Medium to coarse grained, angular to rounded, medium sorted sandstone. Detrital grains are mainly of quartz, microcline, sericitized lithic fragments. Muscovite, glauconite, zircon and tourmaline are present. A few of the quartz grains are fractured. The matrix is haematitic, siliceous and calcareous.

Hermannsburg (BMR) No.3

25'9" - 29'10"

This arenite is very fine to coarse grained, angular to sub-rounded, and poorly sorted. Grains are mainly quartz but with minor orthoclase (sericitized), microcline, muscovite (altered to hydro-muscovite), green biotite, pyrite and zircon. The cement is haematitic, chloritic and calcareous.

Hermannsburg (BMR) No.4

26'9½" - 26'10½"

Very fine to coarse grained, poorly sorted, angular sandstone.

Detrital grains are mainly quartz, with minor K-feldspar, microcline, lithics, muscovite, biotite (commonly replaced by chlorite), tourmaline, zircon and garnet. Some ?glauconite pellets are present. The cement is mainly chloritic or calcareous. This thin section is noticeably lacking in fractures and strain lamellae.

Hermannsburg (BMR) No.5

27' - 27'1"

Tuffaceous brecciated sandstone, with clasts up to 10 mms. across. Clasts are composed of haematitic micaceous claystone, quartz sandstone and patches of glass. The matrix is predominantly glassy, with scattered, poorly sorted, angular and rounded quartz grains; calcite, chlorite and indeterminate black grains are also present in the matrix, though in very small quantities.

The detrital quartz grains are "dusty" and strongly fractured; they have indications of melting on the margins and commonly their outline grades into the glassy matrix.

Hermannsburg (BMR) No.6

28'2" - 28'3"

Tuffaceous brecciated sandstone with clasts up to 30 mms. across. Identical with the specimen from Hermannsburg (BMR) No.5.

Hermannsburg (BMR) No.7

27'9" - 27'10"

Finely laminate haematitic and ?illitic, micaceous mudstone and claystone, with local haematitic concentrations.

There are a few thin sandy laminae composed of fine to medium grained angular to rounded, poorly sorted quartz sandstone, with a few grains of orthoclase, microcline sericitized lithics, and chert.

Many of the detrital quartz grains are fractured (the fissures are commonly filled with chlorite) and strain lamellae are common.

Hermannsburg (BMR) No.8

17'9" - 17'10"

Calcareous lithic arenite. The arenite is fine to coarse grained; it is poorly sorted and grains range from angular to rounded. Most grains are of quartz but a few are of orthoclase, microcline and chert. Lithic grains are of haematitic micaceous claystone, limestone and quartz sandstone. The cement is mainly calcareous, with minor secondary silicification.

APPENDIX V

THE CHEMICAL COMPOSITION OF SOME ROCKS FROM THE VICINITY OF GOSSES BLUFF

by

P.J.Cook

Introduction

The chemical results given here in this appendix did not become available until after the completion of most of the Gosses Bluff report. For this reason the work was not referred to earlier. B. Timms of the Australian Mineral Development Laboratiries, Adelaide, was responsible for all the analyses.

Analytical methods

Oxides:

Silica - complete SiO_2 and total gravimetric
Aluminium - spectrophotometric
Iron - volumetric
Magnesium and Calcium - volumetric and/or atomic absorption
Sodium and Potassium - flame photometer
Water(plus and minus) - gravimetric
Carbon dioxide - acid evolution and gravimetric
Titanium and phosphorus - spectrophotometric

The order of accuracy for the various analyses is indicated by the last place of decimals given in the results, viz. a result expressed as 2.34% is accurate to 0.01%.

Trace elements:

Copper, cobalt, nickel, cromium, vanadium, gallium, manganese, barium, strontium, zirconium, scandium, rubidium, and lithium were all determined by spectrographic analyses. The values give an indication of the order of concentration only, as the method is only accurate to ± 50%.

Results

The results of the analyses by Timms are given in Tables 5 and 6. The location of specimens given in these two tables may be obtained from Table 4.

Silicon: it is evident from these results that all the rocks are highly siliceous; even specimens C and F which have SiO_2 values of 57.2% and 14.4% on recalculation to remove carbonates ($CaO + MgO + CO_2$) are found to have SiO_2 values of 78.3% and 76.9% respectively. These high SiO_2 values suggest that none of the rocks are likely to be volcanic. In particular the breccia from Hermannsburg (BMR) No.1 (specimens G, I and J) have an average SiO_2 content of 78.2% and the glassy rocks from Mount Pyroclast (D and E) have an average SiO_2

content of 81.2%. These results suggest that the breccia is not a volcanic breccia and that the glass is not volcanic. By contrast, the SiO_2 values from the breccia and the glass are comparable with that of the Pertnjara Sandstone (80.6%) from outside the area affected by the Gosses Bluff explosive event. The implication therefore is that the parent material of the glass and the breccia is most likely to be Pertnjara Group sandstones.

The SiO_2 content of the bentonite (74.0%) is somewhat lower than normal but most of this difference is probably attributable to a high water content.

Alumina: Al_2O_3 contents range from 2.50% to 6.90% with the lowest value being recorded in a specimen of $P_2(5)$ sandstone and the highest value in the bentonitic clay (H). There appears to be a tendency for the Al_2O_3 content to be higher in the Mount Pyroclast specimens and breccia than in the Pz(4) and Pz(5) sandstones; this may be due to the incorporation of some lutites in the breccia.

Iron: Fe_2O_3 contents range from 0.05% (in Pz(5)) to 2.15% (in Pz(4)) and FeO ranges from 0.07% in the glassy rock from Mount Pyroclast to 0.91% in the breccia. The Fe_2O_3 is significantly higher and the FeO significantly lower in the two glassy specimens from Mount Pyroclast than in the sandstones and the breccia. The $FeO:Fe_2O_3$ ratios of D and E from Mt. Pyroclast are approximately 10:1 and 25:1; this suggests that the glass was heated to less than 1700°C as it is known that at a temperature of 1700°C (Friedman et al.,1960) ferric iron will reduce to ferrous iron.

There are no abnormally high iron values to suggest that any meteoritic iron has been incorporated into the rocks.

Calcium Magnesium and carbon dioxide: The CaO, MgO and CO_2 contents are extremely variable; the highest values are regarded as being due to the incorporation of limestone and/or dolomite either as clasts, vugs or cement into the rock. The lowest values occur in the glassy rocks from Mount Pyroclast. The reason for this is unknown; it would seem unlikely that such a loss would be entirely due to vaporization.

Sodium and Potassium: The Na_2O content is generally low, with most values falling into the range 0.16% to 0.25%. It is possible that some of the low values may be due to loss of sodium during melting. The K_2O values are very much more variable, ranging from 0.78% in a specimen of $P_2(5)$ sandstone (F) to 4.85% in a glassy rock from Mount Pyroclast (D); this high K_2O content for the glass could possibly be interpreted as an indication that potassic-rich material has been added to normal arenitic sediments in order to produce the present composition of the glass.

Titanium: The TiO_2 content ranges from 0.07% in a sandstone of the Pertnjara Group (K) to 0.34%, also in a Pertnjara Group sandstone. Both the Mount Pyroclast glass and the breccia fall within these limits.

TABLE 4

Sample Numbers, Localities, and Lithology

	BMR Registered* Number	Latitude S	Longitude E	Locality	Lithology
A	66660005F	23°50'	132°17'	Creek near H'burg No.1	Pz(4) sandstone clast -contains shatter cones
B	66660005I	23°50'	132°17'	Creek near H'burg No.1	Pz(4) sandstone -contains shatter cones
C	66660006	23°48'	132°17'	Creek near H'burg No.1	Pz(4) Sandstone - from massive clast
D	66660012A	23°52'	132°18'	Central peak of Mount Pyroclast	Glassy rock with phenoclasts
E	66660013C	23°53'	132°19'	Eastern peak of Mount Pyroclast	Glassy and zeolitic rock
F	66660069B	23°47'	132°16'	5 mls. N.W. of Gosses Bluff	Typical Pz(5) sandstone
G	66660095	23°50'	132°50'	H'burg No.1 212'-213'1"	Breccia
H	66660096	23°50'	132°17'	H'burg No.1 147'3"	Bentonitic rock from within breccia
I	66660097	23°50'	132°17'	H'burg No.1 346'4"	Breccia
J	66660098	23°50'	132°17'	H'burg No.1 213'1"-213'3"	Breccia
K	66660099A	24°00'	132°48'	Palm Valley No.1 693'6"	Typical specimen of Pertnjara Group sstn.
L	66660099B	24°00'	132°48'	Palm Valley No.1 699'	Typical specimen of Pertnjara Group lutite

* The prefix "666600" is replaced by the prefix "G" in the field localities (Plate 1) and in the thin section descriptions.

TABLE 5

Analyses of rocks from the Gosses Bluff area

	A	B	C	D	E	F	G	H	I	J	K
S_iO_2	81.8	79.7	57.2	81.3	81.1	14.4	76.3	74.0	79.4	79.0	80.6
Al_2O_3	4.45	3.90	3.50	6.35	5.00	2.50	5.05	6.90	5.05	4.15	3.75
Fe_2O_3	0.25	0.92	2.15	1.64	1.79	0.05	0.26	0.71	0.73	0.22	0.77
FeO	0.66	0.62	0.50	0.16	0.07	0.35	0.91	0.47	0.69	0.82	0.18
MgO	2.30	3.00	7.80	0.65	2.10	1.01	3.40	5.55	2.85	2.95	2.15
CaO	2.50	3.60	10.30	0.92	1.21	44.5	3.90	2.15	2.80	3.85	3.60
Na_2O	0.21	0.47	0.17	0.25	0.24	0.16	0.23	0.17	0.12	0.18	0.16
K_2O	2.35	1.67	1.37	4.85	2.05	0.78	1.96	2.90	2.20	1.51	1.93
H_2O+	1.20	0.52	0.94	2.80	2.90	0.72	1.21	3.45	0.81	0.94	0.46
H_2O-	0.44	0.73	0.31	0.75	2.75	0.38	0.75	1.41	0.92	0.86	0.88
CO_2	3.35	4.75	15.2	0.24	0.11	34.9	5.40	1.46	3.90	5.05	5.15
TiO_2	0.17	0.23	0.34	0.32	0.26	0.08	0.25	0.34	0.24	0.25	0.14
P_2O_5	0.06	0.10	0.06	0.11	0.12	0.04	0.08	0.11	0.08	0.08	0.07
Totals	97.74	100.21	99.84	100.34	99.70	99.87	99.70	99.62	99.79	99.86	99.84

TABLE 6

The trace element content of rocks from the Gosses Bluff area

	A	B	C	D	E	F	G	H	I	J	K	L
Cu	10	10	10	12	10	5	15	12	8	12	12	15
Co	4	3	5	5	3	1	4	4	4	5	4	15
Ni	3	3	5	4	3	lt 1	5	2	3	4	3	15
Cr	100	8	80	120	15	6	80	30	20	100	150	150
V	10	10	20	30	6	lt 1	12	8	12	12	12	100
Ga	5	5	3	10	3	lt 1	10	10	10	10	10	30
Mn	300	300	80	80	50	1200	200	70	200	200	200	200
Ba	400	300	400	400	50	15	600	500	600	500	20	2000
Sr	50	50	200	100	400	5	150	100	150	150	3	300
Zr	lt 50	lt 50	50	lt 50	lt 50	lt 50	100	50	50	lt 50	lt 50	lt 50
Sc	15	20	30	15	10	5	50	30	30	30	3	100
Rb	100	80	150	200	30	60	100	60	80	30	100	300
Li	150	80	400	250	80	20	150	40	150	120	100	200

lt = less than.

TABLE 7

Comparison of analyses of breccia and glassy rock with possible parent rock (Pz(4)

Oxide	average breccia from Hermannsburg (BMR) No.1 (G,I,&J)	average glassy material from Mount Pyroclast (D&E)	average Pz(4) Sandstone (A,B,&K)
SiO_2	78.23	81.2	80.7
Al_2O_3	4.75	5.67	4.03
Fe_2O_3	0.40	1.71	0.65
FeO	0.81	0.12	0.49
MgO	3.07	1.38	2.48
CaO	3.52	1.07	3.23
Na_2O	0.18	0.25	0.28
K_2O	1.89	3.45	1.98
H_2O+	0.99	2.85	0.72
H_2O-	0.84	1.75	0.68
CO_2	4.78	0.18	4.42
TiO_2	0.25	0.29	0.18
P_2O_5	0.08	0.12	0.08
TOTAL	99.78	100.04	99.92

TABLE 8

Comparison of average trace element contents of various rock types

	average glassy material from Mt. Pyroclast D & E	average Breccia from Hermannsburg No.1 G, H, I & J	average Pz(4) Sandstone A & B	average for australites (Taylor & Sachs, 1964)
Cu	11	12	10	73
Co	4	4	4	15
Ni	4	4	3	30
Cr	68	58	54	75
V	18	11	10	76
Ga	7	10	5	83
Mn	65	140	300	760
Ba	2225	550	350	620
Sr	250	140	50	200
Zr	lt 50	60	lt 50	410
Sc	13	13	17	12
Rb	115	115	90	100
Li	165	165	115	42

lt = less than

TABLE 9

Comparison of Gosses Bluff glass with Darwin Glass

	glassy rock from Mount Pyroclast D	glassy zeolitic rock E	Average composition of Gosses Bluff glass	Average Composition of Darwin Glass (Taylor & Solomon, 1964)
SiO_2	84.6	86.0	85.3	85.70
Al_2O_3	6.60	5.30	5.95	6.64
Fe_2O_3	1.71	1.90	1.81	2.34
FeO	0.17	0.74	0.46	1.66
MgO	0.68	2.23	1.46	0.96
CaO	0.96	1.28	1.12	0.10
Na_2O	0.26	0.25	0.26	0.05
K_2O	5.04	2.17	3.61	1.81
CO_2	0.25	0.12	0.19	0.59
TiO_2	0.33	0.28	0.31	0.12
TOTAL	100.60	100.28	100.44	99.97

Phosphorus: The P_2O_5 shows little variation (particularly if the content is recalculated for excess carbonates), generally ranging from 0.07% to 0.12%; these values are very much lower than those of most igneous rocks but are fairly normal for quartz arenites.

Trace elements: With the exception of specimens F and L, many of the trace element contents are surprisingly constant. This is particularly true for Cu, Co, Ni, Cr, V, Ga and Zr (see Table 8). The greatest variations are shown by Mn, Ba, and Strontium.

The low nickel and cobalt contents contrast sharply with the high Co and Ni recorded from impact glasses associated with undoubted meteorite craters such as the Henbury Craters (Taylor, 1965).

The parent material of the Gosses Bluff glass and the breccia and analogs

The average composition of the two main problematical rock-types are given in Table 7. The two major oxides SiO_2 and Al_2O_3 are very similar in both the breccia and the glass and also in the Pz(4) sandstone. Na_2O, TiO_2 and P_2O_5 are also very similar in the average value of the three rock types. Some of the other oxides show rather more variation, though none are sufficiently large to necessitate the suggestion of different parent material.

Many of the trace elements show an even more marked constancy, particularly Cu, Co, Ni, V, Ga, Zr, Rb and Li. Therefore both the oxide and the trace element contents of the breccia and the glass suggest a common parent material; the chemical composition of the Pertnjara Group (Pz(4)) suggests that it is the parent material. There would appear to be little or no necessity to introduce any volcanic material to account for the glass and the "tuff-like" breccia.

In Table 9 a comparison is made between Darwin Glass and glass from Mount Pyroclast; again the major oxides are extremely similar; this might be taken to imply a common extra-terrestrial origin for the two glasses or alternatively it may be fortuitous resulting from heating (following impact) of two quartzose sandstones. Some of the minor oxides differ quite widely and also there are considerable differences between the trace element contents of Darwin Glass and Gosses Bluff glass.

In a recent paper, Faul (1966) suggested that all tectite fields are related to the position of a major crypto-explosion-structure; Faul postulated that a large crater would be found in central Australia to account for the australites; Gosses Bluff would now seem to be the crypto-explosion of the hypothesis. Comparison of the trace element content of australites with that of Gosses Bluff material would not however support this as most concentrations (except for Cr, Ga, Sc and Rb) are very different. The major oxides also show marked dissimilarities, with australites being poorer in SiO_2 and richer in Al_2O_3 than the rocks from Gosses Bluff. One possible reason for this would be that if the material for australites was derived from Gosses Bluff then it would have been from the youngest rocks, i.e. Pz(5); if Gosses Bluff is an impact structure then this would have been the most affected.

TABLE 10

Comparison of the composition of Pz(5) sandstone and australites

Oxide	Analysis of typical Pertnjara Sandstone Pz(5)	Average composition of australites (Taylor & Sachs, 1964)
SiO_2	78.44	77.70
Al_2O_3	13.60	12.38
Fe_2O_3	0.27	0.63
FeO	1.90	4.27
Na_2O	0.87	1.33
K_2O	4.24	2.36
TiO_2	0.43	0.73
TOTAL	99.76	99.40

A comparison of the composition of Pz(5) (specimen F) with the average composition of australites (Taylor and Sachs) is given in Table 10. The compositions have been recalculated to exclude CaO, CO_2, and MgO because most of this is regarded as being due to travertinous cement in Unit F. In addition H_2O+ and H_2O- have been excluded because of the extremely low water content of australites (the water having been lost during heating). Several of the oxides in Pz(5) and australites are rather dissimilar but Al_2O_3 and SiO_2 are extremely similar. This may be fortuitous or may possibly be due to the parent material for australites being the Pertnjara Group sandstones. However a great many more analyses will be necessary before such a "way-out" theory merits serious consideration.

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