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COMMONWEALTH OF AUSTRALIA.

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SUMMARY OF THE GEOLOGY OF THE HAY RIVER 4-MILE SHEET, NORTHERN TERRITORY.

by

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LIST OF CONTENTS

INTRODUCTION

At least three quarters of the area covered by the Hay River 4-Mile Sheet lies within the confines of the Simpson Desert as defined by Madigan (1938). On this Sheet there are no permanent residents; both Marqua and Tobermory cattle stations which are headquartered on the adjoining Tobermory 4-Mile Sheet (to the north), hold grazing licences in the eastern part of the Hay River Sheet and station personnel make periodic visits to that part. In the remainder of the area there are very few travellers.

In the areas held under Grazing Licence a network of tracks leads to bores and dams and a little-used track leads from Gnallan-a-gea Bore along the Field River to the waterhole known as 'Salt Lake'. On the remainder of the Sheet there are no tracks but suitable vehicles can easily travel along the Hay and Plenty Rivers to gain access to the southern part of the area. Journeys to the east and west of these streams is made extremely difficult by the presence of high, parallel sand ridges which persist northwards to about the latitude of Mt. Winnecke.

Supplies of water are not restricted to those obtained from bores and dams; in good seasons, water may be obtained from several waterholes in the Field River and a soakage in the Hay River some 5 miles north of Mt. Winnecke holds water for a short period after heavy rains. The explorer Winnecke obtained water from several native wells along the course of the Hay River (Winnecke, 1884) and he estimated that one near Lake Caroline yielded 1000 gallons per day.

Spinifex grows profusely on most parts of the Sheet area. The courses of the Plenty, Hay and Field Rivers are lined with eucalypts; these get smaller and more spindly downstream. Low mulga, gidyea, and beefwood trees and numerous varieties of stunted shrubs comprise the remainder of the vegetation.

Records of rainfall do not exist. The average annual rainfall probably does not exceed 10 inches and most of this comes from heavy storms at infrequent intervals. The climate is one of short winters and long, very hot summers.

During 1959, Surveyors from the Department of Interior obtained levels along the Hay River as far as Lake Caroline, and from Aroota Bore to Lignum Dam via Yardida Bore. These levels show:

(i) The land falls, along the course of the Hay River, from 761 feet (above mean sea level) near 23° 00' to 520 feet (above mean sea level) in the vicinity of Lake Caroline.

(ii) The elevations at Aroota Bore, Yardida Bore and Lignum Dam are 652, 573 and 571 feet above mean sea-level respectively.

Mt. Winnecke, Mt. Barrington, Mt. Knuckey and Mt. Gardiner are prominent topographic features, rising generally 200 to 300 feet above the level of the surrounding plain country. Between Desert Bore and Gnallan-a-gea Bore there is a

series of prominent ridges of sedimentary rocks, and north-east of Mt. Winnecke there are a few sharp peaks of metamorphic rocks. Elsewhere on the Hay River Sheet outcrop is either very low or forms low mesas. Many of the sand ridges attain a height of about 35 feet.

GEOLOGICAL INVESTIGATIONS

Before 1958, geological investigations were few and were limited to brief reconnaissance surveys, made mainly in the north-eastern part of the Sheet. Several officers of the Bureau of Mineral Resources, including Condon, Casey, Noakes, Opik and Smith, visited this area at various times between 1953 and 1958. References to the geology of the central part of the Hay River Sheet were made by Winnecke (loc.cit.) and by Madigan (1929 and 1938); in addition to a brief ground reconnaissance, Madigan flew across the southern part of the Sheet.

In 1958, geologists of Frome Broken-Hill Pty. Ltd. mapped part of the Hay River Sheet; the scope of the operations and the results attained are unknown to the present author.

In 1959 a field party from the Geological Branch of the Bureau of Mineral Resources, Geology and Geophysics mapped the Hay River Sheet. The field party consisted of K.G. Smith, D.R.G. Woolley, R.R. Vine, D.J. Forman and A.R. Jensen. In addition to ground surveys, an aerial reconnaissance was made over some of the inaccessible parts of the Sheet. Two facets of the investigation have been reported separately; these concern traverses along the Hay and Plenty Rivers (Smith and Vine, 1960, unpubl.) and mica-bearing pegmatites (Forman and Smith, 1960, unpubl.).

Concurrently with the geological investigations, officers from the Geophysical Branch of the Bureau made reconnaissance gravity traverses along the Hay River and from Aroota Bore to Yardida Bore and to Lignum Dam. The requisite levels for the gravity survey were obtained, in 1959, by Surveyors from the Department of the Interior.

GEOLOGY

On the Hay River Four-Mile Sheet there are outcrops of Archaean metamorphic rocks, Lower Proterozoic granite and pegmatite, and sediments of Upper Proterozoic, Cambrian, Ordovician, ? Permian, Cretaceous and Tertiary ages.

(i) Precambrian Metamorphic and Igneous Rocks

(a) ARCHAEAN

Outcrops of rocks of this age have been mapped only in the north-eastern quadrant of the Sheet. They occur in small peaks and low, lateritised ridges north-east and north-west of Mt. Winnecke; no outcrops of Archaean rocks have been mapped, on this Sheet, south of the latitude of Mt. Winnecke.

The rock types include biotite schist, muscovite schist, cordierite schist, meta-quartzite, meta-conglomerate, quartz-feldspar-biotite gneiss, quartz-feldspar-muscovite-gneiss and quartz-hornblende gneiss. The rocks have been intruded by granite and by pegmatites. Outcrops are too

sparse to allow a delineation of regional structure, but numerous local folds were observed. The rocks are much fractured and the dominant sets of fractures trend north-west; there is a complementary set of fractures which trends north-east.

There is no direct evidence of the Archaean age of the rocks. The lithologies and the degree of regional metamorphism are similar to those mapped on the adjoining Tobermory Four-Mile Sheet (Smith & Vine, 1960, unpubl.) and on the Huckitta Four-Mile Sheet (Joklik, 1955, Smith et al. 1960, unpubl.); on the Huckitta Sheet the metamorphic rocks belong to the Arunta Complex, which has been intruded by granites of Lower Proterozoic age (Walpole, Hurley and Smith, 1960, in press).

(b) LOWER PROTEROZOIC

Rocks which are assumed to be of Lower Proterozoic age consist of granite and of pegmatite. The outcrops are in two separate areas which are:

(a) to the north and north-east of Mt. Winnecke

(b) to the east of Mt. Barrington.

In (a) granite and pegmatite intrude Archaean metamorphic rocks; and are overlain unconformably by un-metamorphosed Cambrian and ? Permian sediments; in (b) no Archaean rocks have been mapped and therefore the intrusive nature of the granite has not been proved.

In area (a) several different types of granite have been mapped. They include coarse-grained, porphyritic granite, coarse-grained, even-textured granite, medium-grained, even-textured granite and some thin dykes of aplite. In area (b) the granite is more uniform in lithology and consists mainly of medium to coarse-grained, even-textured, quartz-feldspar-muscovite granite.

In area (a) pegmatites are abundant; few have been mapped in area (b).

The age of the granite bodies is assumed to be Lower Proterozoic. No age determinations, based on radio-activity methods, are available for these granites. The age of numerous granites in Central Australia has been determined by the Potassium-Argon ratio method; the samples thus tested included three from the Huckitta Four-Mile Sheet and their age conformed to the pattern of a general result ranging from 1400-1500 million years for one suite; a second suite was slightly older. The age (1400-1500) x 10^6 years, on current practice of the Bureau of Mineral Resources, Geology and Geophysics, is Lower Proterozoic. In Central Australia there are no known granites which intrude rocks of Upper Proterozoic age. The age of the granite on the Hay River Sheet is tentatively regarded as Lower Proterozoic.

(ii) Sedimentary Rocks

(a) UPPER PROTEROZOIC

In rocks of this age the Field River Beds and the Grant Bluff Formation have been mapped. The sediments have not been metamorphosed.

The Field River Beds (new name)

The name is taken from the Field River, which flows through outcrop of the Beds. On the May River Sheet, outcrops of the Field River Beds are restricted to the north-eastern and eastern parts. Outcrops of the basal unit of the Beds generally form low, rounded hills but lenses of arenites in the unit form higher hills. Higher, arenitic parts of the succession form prominent ridges; between some of these ridges there are low outcrops of poorly-outcropping dolomite.

Sections of the outcrop sequence are located in two areas:

(a) between Black Stump Dam and Gnallan-a-gea Bore

(b) about two miles east-north-east of Desert Bore.

The sequence, in descending order, consists of:

5.	565 feet of	red, flaggy dolomite; red, laminated siltstone; brown, coarse-grained, cross-bedded, pebbly arkose and grey, coarse-grained, cross-bedded, quartz greywacke;
4.	730 feet of	yellow and grey, thin and medium-bedded dolomite with thin interbeds of yellow dolomitic siltstone;
3.	250 feet of	brown, coarse and medium-grained, cross-bedded pebbly arkose with thin interbeds of brown, medium-grained, micaceous greywacke;
2.	240 feet of	green shale with interbeds of green, dolomitic arkose; medium-bedded dolomite and medium-bedded, purple, dolomitic arkose;
1.	1,775 feet of	green siltstone with "tillitic" texture; with lenses of grey and purple, medium-grained quartz greywacke, boulder beds, and hard, laminated, green siltstone.
	3,560 feet	thickness of Type Section of the Field River Beds, whose base is nowhere exposed.

The full thickness of the Field River Beds cannot be measured because of lack of exposure between units; it is estimated that a thickness of about 2,000 feet is either concealed or crops out too poorly to permit measurement. The gaps in measurement occur mainly between units 1 and 2, 3 and 4, and 4 and 5.

The relationships between the units of the Field River Beds is not clear; unit 1 is considered to be related genetically to glaciation and there may be a disconformity between this unit and the succeeding one. Such a break has not been mapped in the field and for the present the whole sequence is included in the Field River Beds.

Sedimentary sequences at Mt. Knuckey, Mt. Gardiner and south of 'Salt Lake' are tentatively placed in the Field River Beds. At these localities there are sequences of arenites which resemble, in part, the topmost 250 feet of the Field River Beds, but which are very thick. On the eastern

side of the Hay River Sheet green siltstone of unit 1 of the Field River Beds persist to at least 23°30' South Latitude, but the stratigraphic relationship between them and the sequences at Mts Knuckey and Gardiner and at Salt Lake is not evident in the field.

A section was measured at Mt. Knuckey; on the northern side of the strong ridges which form Mt. Knuckey there is an estimated thickness of 1,200 feet of poorly-outcropping arenites and concealed beds which are not included in the measured section.

At Mt. Knuckey, the measured section, in descending order consists of:

Sand and sand ridges over

770 feet of	grey and brown, medium-bedded, medium to coarse-grained, hard (silicified) silty quartz sandstone, cross-bedded in part; some beds have strong ripple marks; interbeds of pebble conglomerate, and some thick sets of brown, friable, cross-bedded, coarse-grained quartz sandstone;
590 feet	mainly concealed by sand; occasional thin exposures of hard (silicified) grey, silty quartz sandstone whose dips (25° to the south) are conformable with those of the thick units above and below;
910 feet of	mainly grey and brown, medium-grained, silicified, medium-bedded, cross-bedded, silty quartz sandstone with some thick interbeds of medium-grained, friable, brown quartz sandstone and thin interbeds of laminated, fine-grained, micaceous, blue-grey quartz sandstone; some beds of all units have asymmetric ripple marks.
2,270 feet	thickness of part-section, underlain by an estimated 1,200 feet of poorly-outcropping (10%) coarse-grained, pebbly arkose and medium-grained, grey quartz sandstone, and concealed beds.

Near 'Salt Lake' another lithology, namely of hard, blue, medium and coarse-grained pyritic quartz sandstone was mapped. It is not impossible that part, at least, of the sequences at Mt. Knuckey, Mt. Gardiner and 'Salt Lake' belong to the Grant Bluff Formation (described in the next section) but there is no proof of this, and for the present the sequences are included in the Field River Beds.

The Grant Bluff Formation

This Formation has been named and defined from the area of the Huckitta Four-Mile Sheet (Smith, Smith, Woolley and Pulley, 1960, unpubl.). The Type Section is located in the Elyuah Range and there it is 530 feet thick. The thickness of the Formation increases eastward and on the Tobermory Four-Mile Sheet it is 1,500 feet thick.

On the Hay River Sheet the Grant Bluff Formation crops out at Mt. Winnecke, at Mt. Barrington and in an area about two miles south of Desert Bore. At Mt. Winnecke, a part-section has been measured; neither the base nor the top of the Formation is exposed, and there are two intervals where outcrop is completely concealed. A summary of the sequence at this locality, in descending order, is:

Sand over

874 feet of	grey, hard, flaggy, fine and medium-grained, micaceous quartz sandstone, glauconitic in part and with numerous worm trails and some mud pellets;
	Concealed interval;
118 feet of	grey, thick-bedded, cross-bedded, coarse-grained pebble conglomerate;
520 feet of	grey, medium and thin-bedded, medium-grained quartz sandstone with some mud pellets and worm trails; and some interbeds of grey, flaggy, micaceous quartz sandstone;
	Concealed interval;
178 feet of	grey, hard, laminated, medium-grained quartz sandstone with some ripple marks and mud pellets and some thin interbeds of very coarse-grained quartz sandstone.
1,690 feet	thickness of part-section.
	Base not exposed

In the Desert Bore area another part-section was measured in the Grant Bluff Formation. The thickness here is 1,575 feet and in addition to the typical grey quartz sandstone as recorded at Mt. Winnecke the Formation includes many beds of laminated, micaceous siltstone with worm trails.

The age of the Grant Bluff Formation is regarded as Upper Proterozoic but some of it could be of Lower Cambrian age. No determinations of age have been made on glauconite from the Formation. On the Huckitta Sheet the Grant Bluff Formation is conformably overlain by the Mt. Baldwin Formation (Smith et.al., 1960, loc.cit.) which contains Lower Cambrian archaeocyathids in its upper part; the position of these fossils in Lower Cambrian stratigraphy has not yet been determined.

(b) CAMBRIAN

The Marqua Beds (unpublished name)

The oldest Cambrian sediments exposed on the Hay River Sheet are the Marqua Beds. These have been named and defined on the adjoining Tobermory Sheet (Smith and Vine, 1960, unpubl.) where the Type Section is 675 feet thick and the age of the Beds ranges from lower Middle Cambrian to middle Middle Cambrian (Opik, pers.comm.).

On the Hay River Sheet the Marqua Beds crop out only in a few small areas in the northern part, between the Hay and Field rivers. The outcrops are poor and discontinuous, and no sections have been measured in them. The lithologies include fine-grained flaggy blue limestone, medium-grained, flaggy, buff sandstone, and blue chert. From the blue chert and the sandstone, Middle Cambrian trilobites have been collected; from northern continuations of the outcrops of blue limestone, trilobites and brachiopods have been collected in the southern part of the Tobermory Sheet (Smith & Vine, 1960, loc.cit.).

The Marqua Beds rest unconformably on various units of the Upper Proterozoic Field River Beds, on Lower Proterozoic granite and on Archaean metamorphic rocks.

The Arrinthrunga Formation

This Formation, of Upper Cambrian age, has been named and defined on the Huckitta Four-Mile Sheet (Smith, Woolley and Vine, 1960, unpubl.); it crops out on the Tobermory Four-Mile Sheet (Smith & Vine, 1960, loc.cit.) where its thickness is 1,350 feet. On the Hay River Sheet, the formation crops out only in the north-eastern corner. Here the Formation is exposed on continuations of both the Craigie Fault and the Toomba structure (Named by Smith and Vine, 1960, loc.cit.); it is poorly exposed and no sections have been measured in it. It consists of dolomite, algal dolomite and limestone. The age of the Formation is known to be Upper Cambrian because elsewhere it overlies the Marqua Beds and is overlain by fossiliferous sediments of Upper Cambrian age.

(c) ORDOVICIAN

Along the upturned (western) edge of the Toomba structure there are a few thin outcrops of the Ninmaroo and Nora Formations (unpublished names; refer Smith and Vine, 1960, loc.cit.), strong outcrops of the Carlo Sandstone, and poor outcrops of some of the Mithaka Formation. The Carlo Sandstone forms the prominent ridge named the Toomba Range.

Part of the Ninmaroo Formation, all of the Kelly Creek Formation and part of the Nora Formation are not present on the Hay River Sheet; their absence is attributed to faulting, along the western side of the Toomba structure, which has caused Ordovician sediments to be downthrown to the east. The presence of the Nora Formation in the Toomba structure has been established by fossils and that of the other Formations cited, either by lithology or continuity with formations on the Tobermory Sheet.

No sections were measured in the Ordovician sediments, but a section through the Carlo Sandstone was measured about ½ mile east of the boundary between the Hay River and Mt. Whelan Four-Mile Sheets. Here the Formation is 280 feet thick, but the base is not exposed.

(d) ? PERMIAN

The Tarlton Formation

This Formation, which was named and described (Condon & Smith, 1959) from a Type Locality in the Tarlton Range, crops out in numerous localities in the northern and eastern parts of the Hay River Sheet. The Formation is believed to be of terrestrial glacial origin. No direct evidence of its age is yet available; specimens of fossil wood have been obtained from the Formation but they are generally poorly-preserved and no specimen of definite Permian age has yet been identified.

Sediments of the Tarlton Formation crop out in isolated mesas and in low rises. The Formation unconformably overlies Archaean, Lower Proterozoic, Upper Proterozoic, Cambrian and Ordovician sediments. Several sections, ranging in thickness from 20 feet to 110 feet were measured. On the Hay River Sheet, no boulder beds were observed in the base of the Formation but there were some bands of pebble and cobble conglomerate. The Formation consists mainly of medium and coarse-grained, cross-bedded silty quartz sandstone, succeeded by white or brown (lateritised) laminated siltstone containing fossil wood.

(e) CRETACEOUS

Small areas of sediments which are considered to be of Cretaceous age crop out in the north-eastern part of the Hay River Sheet, and also in the Lake Caroline area and along the lower course of the Plenty River.

Along the Plenty River the thickest section is 23 feet thick. It consists of a thin-bedded, coarse-grained sandstone with pellets of siltstone and stringers of micaceous sandstone, and interlaminated sandy siltstone. No fossils were found in the sediments; one sample was examined for micro-fossils but none were found in it (D.J. Belford, pers. comm.).

In the Lake Caroline area two sections were measured. At the northern end of Lake Caroline 20 feet of red, yellow and brown shale are overlain by 5 feet of khaki-coloured, medium-grained, cross-bedded quartz greywacke. Specimens of this shale contain Radiolaria (Irene Crespin, pers.comm.). In a mesa on the south-eastern end of another large lake some two miles south of Lake Caroline, 11 feet of sandy siltstone are overlain by 40 feet of medium-grained, finely cross-laminated quartz greywacke. In another mesa in the same area, gypsiferous blue siltstone crops out. Specimens of this siltstone were examined for micro fossils but none were found (Irene Crespin, pers.comm.).

In the north-eastern part of the Sheet, the lithology is fine to medium-grained sandstone with stringers, lenses and beds of siltstone; in some places this unit is capped by a few feet of lateritised coarse-grained, angular sandstone (J.N. Casey, pers.comm.). On the adjoining Mt. Whelan Four-Mile Sheet the sequence contains Rhizocorallium and the Cretaceous age for the beds is established.

(f) TERTIARY

In the north-eastern part of the Hay River Sheet there are several small mesas of impure limestone and chalcedony; these are believed to be of Tertiary age. The sediments are usually horizontal and the thickness ranges from 10 to about 50 feet. These sediments unconformably overlie Precambrian, Palaeozoic rocks. There is no definite evidence of their age but they are correlated with the Austral Downs Limestone (Noakes & Traves, 1954) which crops out in north-western Queensland and in various parts of the Northern Territory, including the Tobermory Four-Mile Sheet.

STRUCTURE

In Archaean rocks, outcrops are too sparse to permit a delineation of regional structure. Several small, local folds are evident but their relationship to regional folding is unknown. There are in general two dominant sets of fractures, one trending north-west and another trending north-east. In some of these fractures, younger Precambrian pegmatites have been emplaced.

The Upper Proterozoic Field River Beds have been affected by numerous faults, some of which have affected the Grant Bluff Formation also; in the north-eastern part of the Sheet, the Field River Beds are faulted against various units of the Palaeozoic sequence.

South and south-east of Gnallan-a-gea Bore, the upper part of the Field River Beds have been affected by a fault which is here named the Gnallan-a-gea Fault; this fault can be traced for a distance of about 10 miles and horizontal displacement of the beds affected is of the order of 2 miles. In many parts of the lower units of the Field River Beds a pronounced shear cleavage has been developed; in green siltstone with "tillitic" texture wide zones of cleavage have been observed; the cleavage cuts across any boulders contained in the beds and produces numerous parallel fractures in these boulders. The zones of cleavage strike at about 300 degrees and the cleavage planes dip steeply to the south-west. In the area between Aroota Bore and Black Stump Dam there are numerous small quartz-filled faults, striking north-west, which cause small displacements in arkose of the Field River Beds.

The Craigie Fault and the Toomba Structure, named on the Tobermory Four-Mile Sheet (Smith & Vine, 1960, unpubl.) both continue from that Sheet into the north-eastern part of the Hay River Sheet. The Craigie Fault ends some four miles east of Aroota Bore but the Toomba Structure continues onto the Mt. Whelan Sheet in Queensland. On the Hay River Sheet the Toomba Structure is a double fault, with fault junctions between

(a) The Field River Beds and the Arrinthrunga Formation; on the south-eastern extension of this fault plane the Field River Beds may be faulted against Ordovician sediments, but this contact is concealed.

(b) part of the Ninmaroo Formation and part of the Nora Formation. The downthrown side of this fault is on the east. On the Mt. Whelan Sheet, Middle Cambrian sediments crop out along the Toomba Structure (J.A. Casey, pers.comm.), but the Marqua Beds have not been observed along this structure on the Hay River Sheet; if originally present here, they have been faulted out.

Sediments of ?Permian, Cretaceous and Tertiary ages have not been faulted, and except in the Lake Caroline area, they have not been folded. In the Lake Caroline area, gentle rolling folds have been observed but these may be due to basement configuration. The sediments have a regional dip to the south.

ECONOMIC GEOLOGY

(a) Mica

As far as is known, no mica has been mined on the Hay River Sheet. In the area of granite and metamorphic rocks to the north and north-east of Mt. Winnecke, numerous mica-bearing pegmatites were mapped. The geology of these has been reported (Forman and Smith, 1960, unpubl.) and the dimensions, strike, mineral content and location of some of the more promising prospects have been listed in the report. In summary, the size of some muscovite books in the pegmatites would encourage prospectors, but the pegmatites contain mostly potassium feldspars, and such pegmatites, on the Harts Range and Plenty River mica fields, are not good producers of commercial muscovite (Joklik, 1955). The area where the pegmatites crop out is about 30 miles from the nearest water supply.

(b) Underground Water

On the Hay River Sheet there are five water bores, several dud bores, and several sites which will be drilled during 1960. Two bores, namely Aroota and Gnallan-a-gea, have been drilled in alluvium; Noakes and Yardida Bores have been drilled into green siltstone of the lower part of the Field River Beds and Desert Bore penetrated the upper, arenaceous part of those Beds.

The dud bores are in two categories:

(i) those which produced a good supply of water which was too saline for pastoral purposes.

(ii) those which produced little or no water.

As far as is known, all of the dud bores have been drilled in green siltstone of the lower part of the Field River Beds. Those of (i) have been drilled in zones of shear cleavage whilst those of (ii) have been drilled outside these zones.

On the Hay River Sheet, the problem of obtaining additional supplies of water for pastoral purposes, in areas suitable to the pastoralists, is a difficult one. To date, no bores have been drilled along the banks of the Hay River; some bores are scheduled to be drilled along the banks of the Field River, both north and south of Gnallan-a-gea Bore, during 1960.

(c) Petroleum Prospects

About two-thirds of the Hay River Sheet is covered either by sand dunes or by sand plains; most of the outcropping rocks are of Precambrian age. Therefore in the present state of surface knowledge the value of the Hay River Sheet is its contribution to the regional geology of Central Australia and western Queensland, rather than as a location of petroleum prospects.

The Marqua Beds are possible source beds for petroleum, and the Arrinthrunga Formation may be a reservoir formation. But on the Hay River Sheet, outcrops of the Marqua Beds are few and they rest unconformably on Precambrian rocks. The only suitable structure may be the Toomba structure but the presence of sub-surface Marqua Beds in it has not been proved. In any case, such beds would be on, or near, the margin of the Georgina Basin.

The presence or absence of either Palaeozoic or Mesozoic sediments under the sand of the Simpson Desert is speculative. The beds of both the Hay and Field Rivers have been examined at numerous random localities, but no outcrop or debris of near-outcrop has been seen north of latitude 23°45' S. It is known that on the adjoining Illogwa Creek Four-Mile Sheet to the west, outcrops of metamorphic rocks persist to about latitude 23°45' S. and specimens of schist were collected in 1959 by Surveyor Seton (Division of National Mapping) at about this latitude and just west of the western boundary of the Hay River Sheet.

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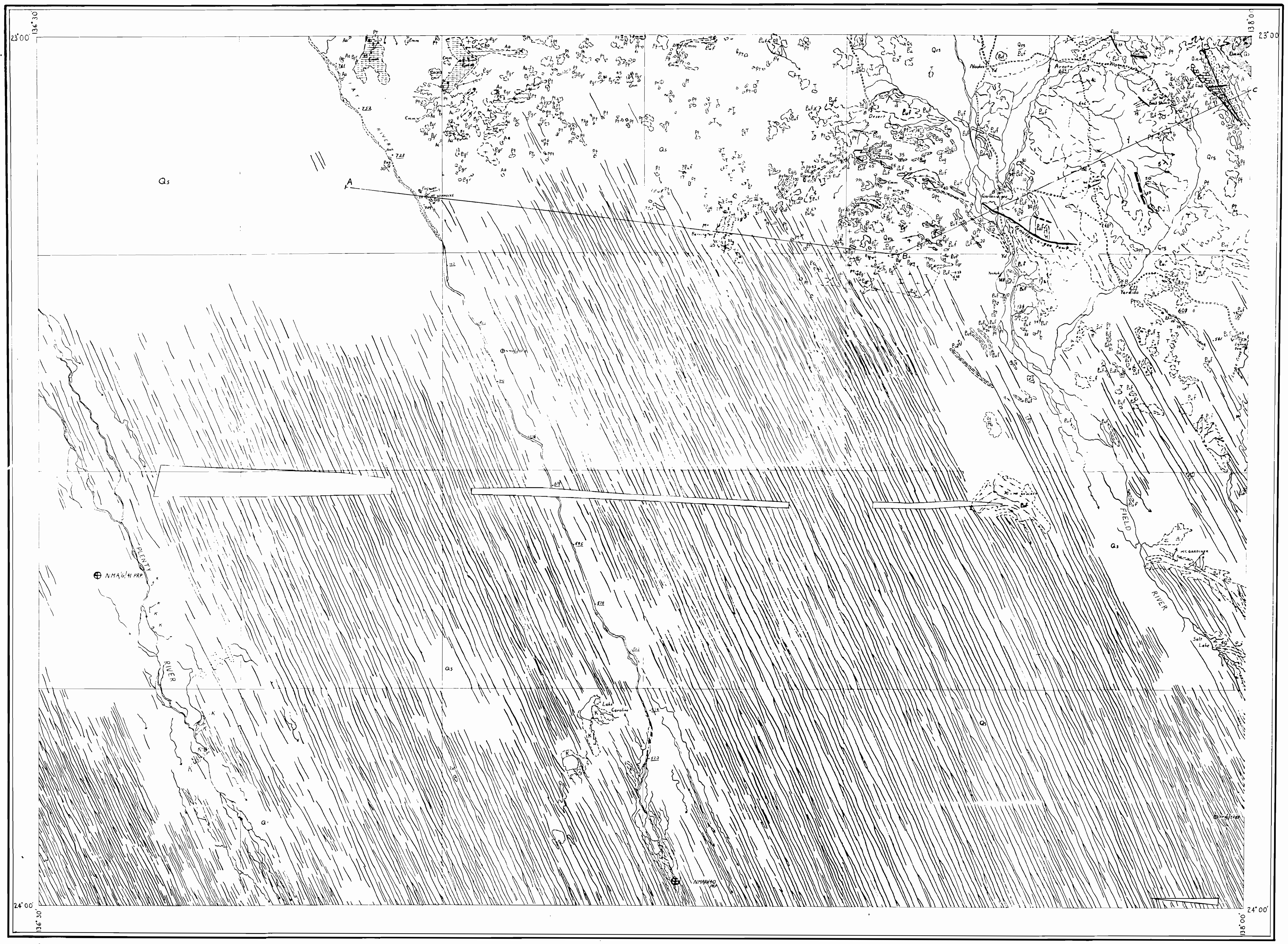
HAY RIVER (4 M)

AUSTRALIA 1 253,440

HAY RIVER

NORTHERN TERRITORY

4 MILE GEOLOGICAL SERIES



REFERENCE

Era	Period	Formation	Symbol	Description
CAINOZOIC	QUATERNARY		Qs	Sand, alluvium, dunes
	TERTIARY		T	Chalcedony, pisolitic impure limestone
			UNCONFORMITY	
MESOZOIC	CRETACEOUS		K	Sandstone, greywacke, siltstone.
PALAEOZOIC	?PERMIAN	Tarlton Formation	Pt	Conglomerate, sandstone and siltstone with fossil wood
			UNCONFORMITY	
	ORDOVICIAN	Mithaka Formation	Omm	Siltstone, sandstone, some coquinite
		Carlo Sandstone	Omo	Sandstone
		Nora Formation	Omn	Siltstone, sandstone, coquinite
		Ninmaroo Formation	Ꞓln	Calcarenite, green siltstone, dolomite, fossiliferous
	CAMBRIAN	Arrinthrunga Fm	Ꞓua	Dolomite, limestone
		Marqua Beds	Ꞓmm	Chert, siltstone, blue flaggy limestone with sandstone lenses, fossiliferous
			UNCONFORMITY	
PRE-CAMBRIAN	UPPER PROT.	Grant Bluff Fm	Pug	Grey fine grained glauconitic sanstone, coarse quartz greywacke siltstone, worm trails.
		Field River Beds	Puf	Boulder beds, green siltstone with tillitic texture, arkose, dolomite, siltstone sandstone
			NONCONFORMITY	
			Pgr	Granite
	ARCHAEAN	Arunta Complex	Aa	Schist, gneiss, metaquartzite

Geological boundary

Anticline, showing plunge

Syncline

Monocline

Fault

Where location of boundary, fold, or fault, is approximate, line is broken, where inferred, queried. Where concealed faults are shown by short dashes.

Strike and dip of strata

Vertical strata

Horizontal strata

Overturned strata

Strike of vertical joints

Sand Dune

Quartz vien

Sand Dune

Fossil locality

National Mapping Astro-fix

Levelled spot height

Hand pump

Water bore

Abandoned water bore, dry

Yard

Dam

Water hole

Swamp

Vehicle track

Geology by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by Division of National Mapping, Department of National Development. Spot heights from levels supplied by the Department of the Interior

Geology by K.G. Smith, R.R. Vine, D.J. Forman, A.R. Jensen.

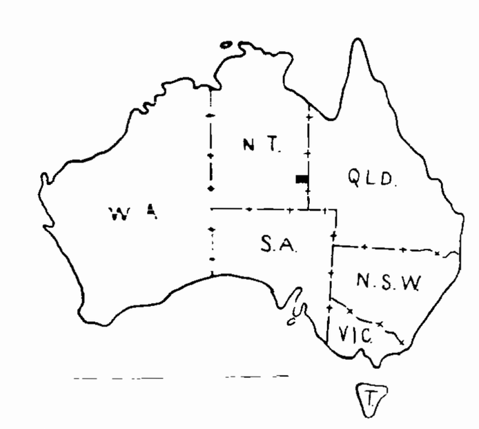
INDEX TO ADJOINING SHEETS

Showing Magnetic Declination

HUCKITTA	TOBERMORY	GLENORMISTON
ILLOGWA CREEK	HAY RIVER	MT WHELAN
HALE RIVER	SIMPSON DESERT NORTH	BEDOURIE

Scale

4 Miles to 1 Inch



Section ABC

Exaggeration 10·56