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EXPLANATORY NOTES TO ACCOMPANY THE FREW RIVER 1:250,000 GEOLOGICAL SHEET, NORTHERN TERRITORY.

by

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CONTENTS

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SUMMARY

The area covered by the Frew River Sheet lies in an arid part of the Northern Territory, south-east of the township of Tennant Creek. The Davenport Range occupies the south-western part of the Sheet area and the remainder consists of plains which, in the eastern half of the Sheet, are waterless, trackless, uninhabited desert. The western half of the Sheet area is sparsely inhabited by pastoralists engaged in raising beef cattle. When tungsten prices are high, the population is greatly increased by miners working on the Hatches Creek Wolfram Field, which lies in the south-western part of the Sheet area. This Field has been idle since 1957, but since mining began, in 1913, about 3000 tons of tungsten concentrates, 69 tons of copper and 6 tons of bismuth, valued at about £1,306,000 have been won.

Precambrian sedimentary and igneous rocks crop out in the Davenport Range and in a few localities in the desert. The Lower Proterozoic Warramunga Group crops out poorly along the northern fringe of the Davenport Range and is overlain unconformably by a younger Lower Proterozoic sequence named the Hatches Creek Group. The Hatches Creek Group consists of about 20,000 feet of strongly folded and faulted psammites with interbedded lavas and pelites. The Group has been intruded in turn by gabbro, porphyry, and granite. The age of the granite has been determined as 1480 million years.

Marine Cambrian sediments unconformably overlie Precambrian sedimentary and igneous rocks exposed in the Davenport Range, and probably occur in the subsurface beneath most of the plains area of the Sheet. The Cambrian outcrops are low and discontinuous; their thickness is unknown but probably does not exceed 1000 feet. They may have some petroleum potential but no subsurface assessment has been made, and the availability of water from vughy carbonate rocks indicates that prospects may be poor.

A few small outcrops of ? Tertiary sediments crop out in the desert. Quaternary sand cover is extensive in the plains, and low, broad dunes abound in the desert.

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INTRODUCTION

The area of the Frew River Sheet is bounded by the meridians of 135° and 136°30' of East Longitude and by the parallels of 20° and 21° South Latitude. The Sheet covers an area of about 7,000 square miles. The eastern half is uninhabited desert; the remainder is sparsely populated and supports a beef cattle industry. When tungsten prices are high, the population is greatly increased by miners on the Hatches Creek Wolfram Field, which covers an area of about 20 square miles in the south-west part of the Sheet area. This Field has been idle since 1957 but about 100 people lived there in 1956, and about 200 in 1941. A large force of Chinese labour was employed between 1942 and 1944, when the Commonwealth Government operated the mines.

The nearest township is Tennant Creek, about 170 miles north-west of the Hatches Creek Wolfram Field; Alice Springs lies about 300 miles south-west of the Field. Access to the western part of the Frew River is by an earth-surfaced road which leaves the sealed Stuart Highway at a point 54 miles south of Tennant Creek and proceeds via Kurundi homestead (on the Bonney Well Sheet) to Hatches Creek, with a branch to Epenarra homestead. From Hatches Creek the road proceeds south-west via Murray Downs homestead (on the Barrow Creek Sheet) to rejoin the Stuart Highway at a point 24 miles north of Barrow Creek settlement. A network of tracks leads to watering places on Epenarra Station, in the north-western quadrant of the Sheet area, but there are no roads or tracks in the eastern half of the Sheet.

There are no scheduled surface mail services to any part of the Sheet area, and no telephone service is available. Epenarra Station (and Hatches Creek, when mines are operating) are ports of call on regular mail, passenger and freight services operated by Connellan Airways from Alice Springs. Epenarra Station operates a transceiver linked with the Alice Springs Base Station of the Royal Flying Doctor Service, and similar transceivers are operated from Hatches Creek when mining is in progress.

The climate is one of long, hot summers and short, mild winters. Summer temperatures frequently exceed 100°F for periods of weeks. Occasional frosts occur in winter but generally the nights and early mornings are cool and most of the days are warm. The average annual rainfall in the western part of the Sheet area is 12 inches; most of this falls between October and March, but winter rains occasionally occur. In the western half of the Sheet area, several streams contain large waterholes which are used for pastoral and domestic purposes, but these supplies are unreliable and are augmented by water from bores. The eastern half of the Sheet area is waterless.

The most abundant vegetation is spinifex, which flourishes over most of the Sheet area. Other vegetation is generally sparse, and consists of mallee and acacia in the desert, and mulga and eucalypt in the Davenport Range.

The Frew River Sheet area is covered by each of two sets of air photographs. One set, at a scale of 1:50,000 approximately, was taken by the Royal Australian Air Force in 1947 and the other set, at a scale of 1:80,000 approximately, was taken by Adastra Airways Ltd. in 1963. A photo-mosaic, at an approximate scale of 4 miles to 1 inch, a planimetric map, at a scale of 4 miles to 1 inch, and a slotted template assembly at (old) photo-scale of 1:50,000, have been prepared by, and are available from, the Division of National Mapping, Department of National Development, Canberra.

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GEOLOGICAL INVESTIGATIONS

Early exploring and prospecting expeditions were led by Brown (1895, 1896, 1903), Davidson (1905) and George and Murray (1907) to the western part of the Sheet area These expeditions were unsuccessful from a prospecting aspect but they provided early information on geology. A member of Davidson's party found specimens of wolfram in the Hatches Creek area but the mineral was not identified correctly until 1913. Mining then began on the Hatches Creek Wolfram Field. Oliver (1916) inspected the mines and his report on the Field provided the only reliable information available until 1937.

Officers of the Aerial, Geological and Geophysical Survey of Northern Australia (A.G.G.S.N.A.) made a brief reconnaissance of the Hatches Creek Wolfram Field in 1937, and took aerial photographs of it from a height of 12,000 feet. This work was followed in 1940 by a detailed survey of the mines and a regional survey of the surrounding area; new air photographs, taken from a height of 5,000 feet, were used for this survey (A.G.G.S.N.A., 1941).

War-time inspections of the Hatches Creek Wolfram Field were made by Knight (1943), Raggatt)1943) and Sullivan (1943). Sullivan (1951) examined the Treasure Mine at Hatches Creek and later (1953) published a report on the whole Field. Hossfeld (1954) made numerous references to the geology of the Hatches Creek area and Jensen (1955) reported on the treatment of ore from the Pioneer Mine on the Hatches Creek Wolfram Field.

In 1956, a field party from the Geological Branch of the Bureau of Mineral Resources, Geology and Geophysics, mapped the south-western part of the Frew River Sheet area during a programme of regional mapping of the whole Davenport-Murchison Range area (Smith, Stewart & Smith, 1961). Currently with the regional programme, G.R. Ryan of the Bureau made a detailed investigation of the mines and surface geology of the Hatches Creek Wolfram Field (Ryan, 1961). Smith and Condon (1958) made an aerial reconnaissnace of the eastern and northern parts of the Frew River Sheet area.

Walpole and Smith (1961) discussed the geological implications of the results of age determinations made on granites from a large part of the Northern Territory, including the Frew River Sheet area : the ages were determined by Hurley et.al., (1961) at the Massachusetts Institute of Technology.

Mapping of the Frew River Sheet area was completed by K.G. Smith and E.N. Milligan, of the Bureau of Mineral Resources, in 1963. On this survey, helicopter transport was used to examine outcrops in the desert areas of the Sheet.

Several investigations of water supply have been made by the Bureau's Resident Geologists at Alice Springs, and they have supplied most of the water bore data presented in Table 2 of these Notes.

GEOPHYSICAL INVESTIGATIONS

In 1956 the Geophysical Branch of the Bureau conducted airborne scintillograph and magnetometer surveys, from a D.C.3 aircraft, over the south-western part of the Frew River Sheet area, during a survey of the Davenport and Murchison Ranges (Map G 281-4). In the same year a small area south of the Hatches Creek Wolfram Field was surveyed with scintillograph equipment carried in an Auster aircraft of the Geophysical Branch (Livingstone, 1957). Mulder (1960) used an Auster aircraft chartered by the Geophysical Branch to make closer examination of the more promising radioactive anomalies detected during the 1956 D.C.3 survey.

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PHYSIOGRAPHY

Mabbutt (1962, pp 162-165) divided the lands of the Alice Springs area (which includes the Frew River Sheet area) into three physical regions: one of these, the 'Northern Plains and Uplands' covers the Sheet area and has two subdivisions - the 'Northern Plains' and the 'Northern Uplands' Each subdivision contains several units but of these the '<u>North-Eastern Plains</u>' and the '<u>Davenport Range</u>' together cover the Frew River Sheet area.

The '<u>North~~ern~~-Eastern Plains</u>' occupy all of the eastern and north-western part of the Sheet. Most of this is desert, with numerous low sand dunes, and sand-covered plains surrounding low outcrops of Precambrian, Palaeozoic and Cainozoic sediments The plains slope north and east from the Davenport Range and are about 850 feet above sea level in the north-western part of the Sheet area, 800 feet in the north-east, and 850 feet in the south-east. Several streams, all rising in the Davenport Range, drain the northern and central-eastern part of the plains but all except the Frew River 'flood out' within a few miles of the Range. There are no streams in the eastern third of the Sheet area.

The '<u>Davenport Range</u>' occupies the south-western quadrant of the Sheet area and consists of prominent ridges with bevelled crests, separated by wide, flat valleys whose floors are generally about 150 feet below the crests of the ridges. Most of the ridges in the Davenport Range have a north-west trend, but in the Frew River Sheet area this trend is not so pronounced, and it changes from ~~north-west to~~ north-west to north-east in the locality of the Hatches Creek Wolfram Field. The plane of the bevelled crests is about 1500 feet above sea level in the Hatches Creek area and slopes gently northwards to a height of about 1100 feet above sea level in the Epenarra region.

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STRATIGRAPHY

The stratigraphty of the Frew River Sheet area is summarized in Table 1. Archaean rocks do not crop out and are not evident in the shallow subsurface data which is available. The oldest rocks are sediments of the Lower Proterozoic Warramunga Group which crop out in the northern part of the Davenport Range; a younger sequence of Lower Proterozoic rocks - the Hatches Creek Group - is inconformable on the Warramunga Group and forms most of the Davenport Range in the Frew River Sheet area. The Hatches Creek Group crops out also in a few localities on the plains but most of the outcrop there is of Cambrian age and in addition there are small areas of Cainozoic rocks.

Basic and acid igneous rocks intrude the Hatches Creek Group in the Frew River Sheet area but have not been observed to intrude the Warramunga Group there; however, in areas of better outcrop on the adjoining Bonney Well Sheet Smith Stewart & Smith (1961) have mapped basic and acid rocks which do intrude the Group.

The Hatches Creek Group and the Pedlar Gabbro have been named from the Frew River Sheet area but the Warramunga Group and two Cambrian units have been named from adjoining Sheet areas.

PRECMABRIAN

Lower Proterozoic. The Warramunga and Hatches Creek Groups, and intrusive igneous rocks, are of Lower Proterozoic age. The Warramunga Group is older than the Hatches Creek Group and although the contact between thetwo is not exposed on the Frew River Sheet area an unconformity separates them on the adjoining Bonney Well Sheet (Smith, Stewart & Smith, 1961).

The Warramunga Group has been named by Ivanac (1954) in the Tennant Creek area, but formations in it have not been defined. Smith, Stewart & Smith (1961) traced the Group from the Tennant Creek Sheet area south-east to the Frew River Sheet. The outcrops on the Frew River Sheet occur in small areas on the northern fringe of the Davenport Range, where they form low peaks and mesas consisting of yellow, red and purple, thin-bedded, micaceous sandstone, greywacke and siltstone. The beds are strongly contorted and the information available from outcrop is insufficient to determine thickness and regional strike. Numerous narrow quartz viens cut the beds, but there is no evidence of either contact or regional metamorphism.

The minimum age of the Warramunga Group is about 1600 million years; this is the age of a granite which intrudes the Group in the Tennant Creek area and has been determined by Hurley et.al., (1961), using the K/A method. Walpole and Smith (1961) regard this age as being at the top of the lower of two subdivisions in the Lower Proterozoic. Since igneous rocks are not known to intrude the Warramunga Group in the Frew River Sheet area, no age determinations are available for the outcrops there.

The Hatches Creek Group has been named by Hossfeld (1954) from the Hatches Creek area. Smith, Stewart and Smith (1961) modified Hossfeld's definition slightly. The scope of surveys in the Davenport Range area has not permitted formal definition and naming of formations within the Hatches Creek Group and therefore the name does not conform to the Australian Code of Stratigraphical Nomenclature However, the Group name is in common usage and has been allowed to stand.

In the Frew River Sheet area the Hatches Creek Group crops out in the Davenport Range and less prominently in a few localities in the desert to the east and north-east. The Group consists of psammites cropping out in prominent, parallel, strike ridges, with softer psammites and lutites and extrusive rocks cropping out in valleys between the ridges. In general the psammites are medium to coarse-grained, thin to medium bedded, cross-bedded, ripple-marked quartz sandstone and quartz greywacke; some dense quartzite occurs in the Hatches Creek area, and beds and lenses of pebble conglomerate occur in the lower parts of the Group. Cross-bedding is not a prominent feature in the Group but ripple marks are abundant throughout. The colour of the psammites is usually either grey, pink or brown, but occasionally blue. The lutites consist of siltstone and shale, and outcrop of these is generally poor. The extrusive members include both basic and acid rocks, with acidic types predominating. Amygdaloidal lavas are abundant in the Hatches Creek area, where they are interbedded with and pass laterally into, psammites. Ryan (1961, p24) has recorded an aggregate thickness of about 3800 feet of acid and intermediate lavas interbedded with psammites in the southern part of the Hatches Creek Wolfram Field. Dallwitz (in Ryan, 1961) has described one igneous member of the Hatches Creek Group as "sericitized and silicified acid porphyry'; Lovering (in Ryan, 1961) has described another as 'porphyritic acid volcanic'. Field evidence indicates that these rocks are members of the Hatches Creek Group.

A basic extrusive member of the Hatches Creek Group crops out near the south-west corner of the Frew River Sheet area. Smith, Stewart and Smith (1961) mapped this member for a distance of about 100 miles in the Davenport Range and although some features suggested that it may be a sill, they considered that the weight of evidence favoured an extrusive origin. The rock is usually dark, fine-grained and strongly epidotised. Walker (in Smith, Stewart and Smith, 1961) has described some specimens of it as dolerite, and others as meta-basalt. The member is younger than the acid extrusive members. In the valley east of Coulter's Waterhole the thickness of the unit was estimated at 2000 feet (Smith, Stewart and Smith, 1961).

The thickness of the Hatches Creek Group has not been measured in any locality. Smith, Stewart and Smith (1961) estimated the thickness of section b - b' at 25,000 feet. Although this estimate is 7000 feet greater than a more reliable estimate made by the same authors at a locality 14 miles west north-west of Hatches Creek (on the Bonney Well Sheet), the section b - b' contains higher beds of the Group, and the preserved thickness of the Hatches Creek Group in the Frew River Sheet area is estimated conservatively at 20,000 feet.

The Hatches Creek Group has been strongly folded and faulted, and intruded by igneous rocks, during a Precambrian orogeny which concluded with the intrusion of granite dated by Hurley et.al (1961) as about 1440 million years. During the orogeny, the Hatches Creek Group was folded into major anticlines, synclines, domes and basins, which trend north-west (Smith, Stewart and Smith, 1961). In the Frew River Sheet area, these major folds are not so apparent, and the regional trend changes from north-west to north-east in the Hatches Creek region, which is the most complex structural area in the Davenport Range. Faulting is contemporaneous with folding of the Hatches Creek group. Only one period of faulting is evident in the Frew River Sheet area, and although some dislocation of tungsten ore bodies (introduced by granite near the end of the orogenic period) is known, it is a minor event. Most of the faults strike east north-east. Ryan (1961) has studied them in detail on the Hatches Creek Wolfram Field where there are a few major fault zones with numerous smaller, parallel faults between them. The horizontal displacement on the Mia Mia Fault is of the order of 5000 feet, but on the smaller faults the displacement is considerably less and varies markedly along the strike. A strong reverse fault, north of the Wolfram Field, strikes north-east and has a vertical displacement of several thousand feet. Beyond the confines of the Hatches Creek Wolfram Field, faults in the Frew River Sheet area are numerous, but most have small displacement.

Regional metamorphism of the Hatches Creek Group is of a very low order, and consists mainly of silicification In a few places, dynamic metamorphism has converted pelites to mica schists, but the most marked metamorphism of the Group is found in confined areas within the Hatches Creek Wolfram Field, where an intrusion of gabbro has caused severe metasomatism and thermal alteration. Dallwitz and Lovering (both in Ryan, 1961) have described several types of metasomatised sediments and of hornfels from the Field.

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Intrusive Igneous Rocks. In the Frew River Sheet area several bodies of igneous rocks intrude the Hatches Creek Group, but do not intrude Cambrian sediments. The intrusive rocks include gabbro and dolerite, with acid differentiates, quartz-feldspar porphyry, and granite. The field evidence for the order of intrusion is that granite intrudes quartz-feldspar porphyry, and that quartz veins carrying tungsten ores cut basic intrusive rocks; the source of these ores is assumed to be granite. No juxtaposition of quartz-feldspar porphyry and basic intrusives has been observed in the field but the basics are considered to be the older because (i) the broad pattern of magmatic differentiation was probably from basic to acid; (ii) the outcrops of basic intrusives bear no apparent relationship to fold structures but quartz-feldspar porphyry has always been emplaced in the cores of domes and anticlines (Smith, Stewart and Smith, 1961) and this emplacement probably took place during an early stage of the folding movement, whereas the random distribution of basic intrusives indicates prior emplacement.

Basic Intrusive Rocks. These crop out in several parts of the Frew River Sheet area and intrude units in the lower half (approximately) of the Hatches Creek Group. Ryan (1961) named the Pedlar Gabbro on the Hatches Creek Wolfram Field, but other individual bodies have not been named All are considered to be of the same general age.

The Pedlar Gabbro is an intrusive complex which crops out in the northern half of the Hatches Creek Wolfram Field. It consists of gabbro, with some dolerite, and granophyre and other late-stage acid differentiates including gabbro pegmatites.

Dallwitz (in Ryan, 1961) has described several specimens of 'potash-soda granophyre' and of 'gabbro pegmatite', and Walker (in Smith, Stewart and Smith, 1961) has described 'metamorphosed dolerite' and 'uralitized and saussuritized gabbro pegmatite', from the Pedlar Gabbro. In hand specimen, the most common rock type in the Pedlar Gabbro is a xenolithic, epidotised gabbro, but many variations resulting from assimilation of the Hatches Creek Group are evident.

Other basic bodies in the Frew River Sheet area consist of epidotised gabbro and dolerite, but acid differentiates have not been recorded.

Porphyry A large mass of quartz-feldspar porphyry crops out in the core of a dome south of the Hatches Creek Wolfram Field. Walker (in Smith, Stewart and Smith, 1961) has described specimens from several similar occurrences of porphyry in other parts of the Davenport Range.

Granite. Outcrops of granite are of small areal extent in the Frew River Sheet area. They intrude beds which are stratigraphically low in the Hatches Creek Group, and they have a random distribution which is not related to the folding pattern of the Group One outcrop of muscovite-biotite-granite occurs about 6 miles south of the southern limit of the Hatches Creek Wolfram Field; veins of greisen emanating from the granite cut quartz-feldspar porphyry. This is the closest granitic outcrop to the Hatches Creek Wolfram Field, and a northern extension of the granite may have been the source of the tungsten ores there. Hurley et.al. (1961)

used the K/A method to determine the age of this granite as 1480 million years.

Walker (in Smith, Stewart and Smith, 1961) described a specimen from the granite outcrops near the headwaters of Hanlon's Creek as an 'aplitic granite'. The third outcrop of granite mapped on the Frew River Sheet consists of muscovite-biotite-microcline granite. Although the age of only one granite in the Frew River Sheet area has been determined, it is considered that all of them are similar in age: the results of Hurley et al. (1961) showed an approximate equivalence in the ages of several granite bodies of the Davenport Range in adjoining Sheet areas.

PALAEOZOIC

Cambrian. The only Palaeozoic rocks exposed are of Cambrian age. ~~of Cambrian age.~~ They crop out in a few localities within the Davenport Range, and in numerous places on the plains to the north and east of it. The Davenport Range forms part of the western margin of the Georgina Basin, and the Cambrian sediments in the Frew River Sheet area are part of the Lower Palaeozoic succession in the north-western part of the Basin. From the Frew River Sheet area the Cambrian sediments extend north and east to the Barkly Tableland, where several Cambrian units have been mapped (Noakes and Traves, 1954; Opik, 1956, Randal and Brown, 1962; Randal and Nichols, 1963); they extend south in the subsurface to the adjoining Elkedra Sheet area (Milligan, 1963) and south-east to the adjoining Sandover River Sheet area (Nichols, 1964).

The exposed Cambrian rocks are divided into three units. Two of these contain lower Middle Cambrian fossils (A.A.Opik, pers comm.) but the third is apparently unfossiliferous. None of the Cambrian units has been either metamorphosed or tectonically disturbed.

The oldest unit is the Gum Ridge Formation, which was named by Opik (in Ivanac, 1954) in the Tennant Creek area. Isolated outcrops of this Formation can be traced south-east from Gum Ridge to the Frew River Sheet area (Smith, Stewart and Smith, 1961) where the formation has been deposited unconformably on the Warramunga Group, the Hatches Creek Group, and Lower Proterozoic granite. The surface lithology consists of chert, shale, sandstone and conglomerate. Limestone and dolomite have been recorded in cuttings from water bores on Epenarra Station, but no fossils have been found in this subsurface material. In the cross-section on the Frew River Sheet, the carbonate beds have been included in the Gum Ridge Formation, but part of them could belong to a younger Cambrian formation.

The Gum Ridge Formation crops out poorly in the Sheet area and is confined to the western half. Within the Davenport Range, small outcrops of boulder conglomerate crop out in valleys; the boulders are well-rounded and set in a laterised, sandy, feldspathic matrix. The thickness of the beds ranges from 10 to 50 feet. Smith, Stewart and Smith (1961) placed these beds in the Upper Proterozoic, but recognised the possibility of a Cambrian age for them. It is now considered that the weight of evidence favours a Middle Cambrian age, and the conglomerate is placed in the Gum Ridge Formation. Pebbly, ripple-marked sandstone, chert and weathered shale crop out in the northern fringe of the Davenport Range, and on the plains to the north. The thickness of individual outcrops ranges from 15 to 75 feet. A few hyolithids have been found in these outcrops, but the occurrence of the trilobite Redlichia in mesas about 8 miles west of Epenarra homestead establishes the age of the Gum Ridge Formation there as lower Middle Cambrian (A.A.Opik, pers comm.).

The Wonarah Beds, which crop out poorly in the north-eastern part of the Sheet area, are slightly younger than the Gum Ridge Formation (Opik, 1957). The Beds were named informally by Opik from the Wonarah area of the Northern Territory, at latitude 19°55'S, longitude 136°21' approximately. From Wonarah, outcrops of the unit can be traced south to the Frew River Sheet area (Randal and Nichols, 1963).

The base of the Wonarah Beds is not exposed in the Frew River Sheet area, the top has been eroded, and no subsurface data on the thickness are available. Outcrops are low and small, and the beds are almost horizontal. Surface lithologies are chert, oolitic chert, and silicified coqinite, and the maximum thickness exposed is about 50 feet. Trilobites (Xystridura and others), brachiopods and hyolithids contained in the Wonarah Beds in the Sheet area establish a lower Middle Cambrian age (Opik, pers comm).

The third Cambrian unit has not been named. It crops out poorly in the central-eastern and south-eastern part of the Frew River Sheet area, and consists of low outcrops of near-horizontal dense grey dolomite and brown oolitic chert which are unfossiliferous. The thickness of the outcrops ranges from 2 to 15 feet. These Cambrian outcrops have been mapped as a separate unit because the outcrop lithology differs from each of the named units but is similar to unfossiliferous beds which are widespread over the northern two-thirds of the south-easterly adjoining Sandover River Sheet (Nichols, 1964). There the beds have not been named, but their Cambrian age is known because of their stratigraphical position.

The un-named beds on the Frew River Sheet could belong to the Wonarah Beds, or be a time-equivalent of them, but because poor outcrop and lack of fossils prevents confirmation of this, they are at present referred to undifferentiated Middle Cambrian

The thickness of Cambrian sediments underlying the plains area of the Frew River Sheet is unknown, but is expected to vary markedly because of the uneven surface of deposition. Considerable variations in depth to magnetic basement along the 20th parallel are indicated by an aeromagnetic survey of part of each of the Alroy and Tennant Creek Sheets (Faessler, 1963). Bore records show thicknesses of up to 500 feet of carbonate sediments in the Epenarra region, and the Bureau of Mineral Resources cored 739 feet of unfossiliferous carbonates in the Anitowa area, about 15 miles south of the southeastern corner of the Frew River Sheet (Milligan, 1963). A maximum thickness of about 1000 feet seems likely in the nothern part of the Frew River Sheet but the thickness may be slightly greater in the southern part.

CAINOZOIC

Tertiary? Small areas of outcrop of chalcedony and chert in the north eastern quadrant of the Sheet may be of Tertiary age. No fossils have been found in these outcrops and they are referred to Tertiary age because of lithological similarity to fossiliferous Tertiary units on the Barkly Tableland (Randal and Nichols, 1963). The maximum thickness exposed in the Frew River Sheet area is 10 feet.

Quaternary: Soil, sand and alluvium cover about three-quarters of the Sheet area. Within the Davenport Range, soils occupy only small areas but on the plains there are wide expanses of soil and alluvium along the courses of the Frew River and Whistleduck and Teatree Creeks. Data from water bores on Epenarra station show thicknesses of alluvium ranging from 2 to 247 feet. Litchfield (1962) has described the soils within the Davenport Range as "Shallow, Stony, Undifferentiated Soils" and those on the plains as "Red Sands and Clayey Sands". Dunes are abundant in the south-eastern part of the Sheet area; they trend north-west and some are about 20 miles long. The dunes are low and broad and they do not form distinctive features on the ground but are fairly prominent on air photographs. The depth of Quaternary sand cover is unknown.

GEOLOGICAL HISTORY

Precambrian rocks cropping out in the Davenport Range provide reasonable evidence of the geological history in Lower Proterozoic time, and Palaeozoic sediments on the plains together with water bore data and evidence from adjoining areas, enable reasonable deductions of history in Middle Cambrian time. However, the general lack of subsurface data in about three-quarters of the Sheet area precludes deductions of events which may have occurred in Archaean, Upper Proterozoic and Lower Cambrian times.

The oldest outcrops are those of the Warramunga Group. These were deposited in the Warramunga Geosyncline, which was named by Noakes (1956); the boundaries of this Geosyncline have not been determined because of cover, but it trends north-west. The Warramunga Group has been folded and faulted in the Sheet area, but has not been intruded by igneous rocks. Hurley et al.,(1961) have determined an age of 1600 million years for granite which intrudes the Group elsewhere to the north-west. The intrusion of granite closed the orogeny which affected rocks in the Lower of two divisions of the Lower Proterozoic (Walpole and Smith, 1961).

Later in the Lower Proterozoic the Hatches Creek Group was deposited in the Davenport Geosyncline (Walpole and Smith, 1961) where about 20,000 feet of ripple-marked psammites with interbedded pelites and basic and acid lavas, were deposited. The Hatches Creek Group was then strongly folded and faulted, and intuded by igneous rocks. At an early stage of folding, basic rocks intruded the lower half of the Group, in random locations. Later, porphyry was emplaced in the cores of domes; after folding and faulting movements were completed, granite intruded the lower units of the Group, in random locations. One such intrusion may have been responsible for epigenetic ore deposits at Hatches Creek Wolfram Field, and other small ore occurrences in the Sheet area are probably related genetically to granite intrusion. Hurley et al., (1961) determined an age of 1480 million years for a granite which crops out south of Hatches Creek, and the same authors (1961) determined the average age of all granites which intrude the Hatches Creek Group in the whole Davenport Range area as 1400 million years; this dates the close of the younger Lower Proterozoic orogeny.

The next recorded event in the Frew River Sheet area was the deposition of thin marine Middle Cambrian sequences in an epicontinental sea of the Georgina Basin. Sediments were deposited on the uneven surface of Precambrian rocks along the margin of the Davenport Range, but to the north and east of this Range the age of the basement rocks is unknown. Sedimentation was essentially continuous in lower Middle and middle Middle Cambrian time, but Opik (1957) considers that the seas regressed during upper Middle Cambrian. Younger Palaeozoic sediments are unknown in the Sheet area and in adjoining areas, and the Middle Cambrian sediments of the Barkly Tableland, including those of the Frew River Sheet, have not been affected by orogeny sine their deposition.

There is no record of events between Middle Cambrian and Tertiary times. A few outcrops of probable Tertiary age are present in the north-east quadrant of the Sheet. Quaternary sand cover is extensive, and some relatively thick pockets of Quaternary alluvium have been revealed in water bores.

ECONOMIC GEOLOGY

Almost all metal production in the Frew River Sheet area has come from the Hatches Creek Wolfram Field, where ores of tungsten and accessory copper and bismuth have been won. The total recorded value of these ores is about £1,306,000. Small gold and wolfram prospects have been worked on the northern fringe of the Davenport Range, but the search for uranium deposits in Precambrian outcrops has been unsuccessful. All of the metalliferous deposits occur in Precambrian rocks; both Precambrian and Cambrian rocks have been drilled successfully for water but little work has been done to assess the petroleum potential of Cambrian rocks.

Tungsten. Details of the occurrence and production of tungsten ores on the Hatches Creek Wolfram Field have been described fully by Ryan (1961). A Wolfram prospect has been worked 2 miles south-east of Epenarra homestead but details of production, if any, are unknown.

On the Hatches Creek Wolfram Field, mines have been worked intermittently between 1913 and 1957, at times when world demand for tungsten ensured reasonable financial returns from the poorer lodes: Ryan (1961) states that "only a few lodes can support operations at a moderate price". He states also that "official records indicate that 2840 tons of wolfram and scheelite concentrates valued at £1,294,110 were produced between 1913 and 30th June, 1958; but the recording of production before 1940 was unreliable and the actual production is thought to be about 3000 tons".

The tungsten ores occur in steeply dipping quartz reefs, usually ranging from 6 to 18 inches in width, which cut sedimentary and volcanic rocks of the Hatches Creek Group, and the intrusive Pedlar Gabbro. The lodes are concentrated in groups, in shear zones, and Ryan (1961) has recognised sixteen groups. The number of individual mines is large and they cannot be plotted on the Frew River 1:250,000 Sheet; Ryan has plotted them on large-scale maps.

The commonest ore is wolfram, but scheelite is produced from a few mines. Accessories include copper, bismuth, molybdenum, lead, tin, gold and iron, but of these only bismuth and copper have been worked economically. The source of the mineral deposits is believed to be granite but it does not crop out on the Field and has not been reported in the mines. The nearest outcrop of granite is about 4 miles south of the southern extremity of the Field.

Apart from the war-time operations of the Commonwealth Government, most of the mining has been done by individuals and small syndicates. The deepest development to date is about 200 feet but the bottoms of the lodes have not been exposed; future development will require more extensive investigations and deeper workings, which would involve greater capital outlay than previously necessary.

Bismuth Bismuth ores are abundant in tungsten lodes in the northern part of the Hatches Creek Wolfram Field, and are present in minor amounts in the southern part. Native bismuth, bismuthinite and bismutite occur. During the life of the Field 5.58 tons of bismuth, valued at £4,400, have been produced (Ryan, 1961).

Copper. Copper minerals occur in almost every tungsten lode on the Hatches Creek Wolfram Field and are abundant enough in the southern part of the Field to warrant the mining of copper ore Most of the production has come from the oxidized zone and only two mines have reached the primary zone (Ryan, 1961). The recorded production from the Field is about 69 tons, valued at £7148 (Ryan, 1961). Copper minerals have not been reported elsewhere on the Frew River Sheet area.

Gold. Traces of gold have been obtained from shafts at the Crystal Mine, near Hatches Creek, but Hossfeld (1941) rightly concluded from the results of a sampling programme that the prospect would yield very little gold. No production has been recorded.

Tungsten concentrates from some mines on the Hatches Creek Wolfram Field contains small amounts of gold (Ryan, 1961), and gougers have won small quantities near Kurinelli out-station.

Uranium. No ores of uranium have been reported from the Frew River Sheet area. Livingstone (1957) used an Auster aircraft fitted with radiometric equipment to survey a large dome south of the Hatches Creek Wolfram Field; he recorded several radioactive anomalies but these were examined on the ground by prospectors and no deposits of uranium were found. Mulder (1960) used an Auster aircraft to examine some of the radioactive anomalies reported during the Bureau's D.C.3 survey of 1956, and he concluded that none of those in the Sheet area warranted further investigation.

Petroleum Potential.

This cannot be assessed adequately at this time because the sparse surface information has not been supplemented by any subsurface data except that from a few water bores. The available information, from the Sheet area and from contiguous areas, indicates that the marine, fossiliferous Middle Cambrian sequences in the Frew River Sheet area are part of a thin blanket of near-horizontal sediments deposited over a large area in the north-western part of the Georgina Basin. These sediments are unmetamorphosed and have not been tectonically disturbed. The thickness is unknown but probably does not generally exceed 1,000 feet. No oil seeps are known, and no shows of oil and gas have been recorded from water bores. On available evidence the petroleum potential must be considered to be low.

Water. Supplies of water are available from semi-permanent holes in the Frew River, Hatches Creek and Mia Mia Creek. Most of these waterholes are in the Davenport Range and they generally suffice for pastoral purposes there because available grazing land is restricted. The Frew River also contains some large waterholes in its lower course but these are inadequate to support the pastoral industry, and the supplies are augmented by underground water from bores. Thus most of the bores on the Sheet area are in the plains of the north-western quadrant, but two within the Davenport Range are used for pastoral purposes and two are for domestic use at Hatches Creek There are no bores in the eastern half of the Sheet area.

Jones & Quinlan (1962) defined numerous ground-water provinces in the lands of the Alice Springs region, and their Davenport and Barkly Provinces cover the Frew River Sheet area. These authors (1962, p 156) describe the aquifers of the Davenport Province as "fractured quartzites and volcanics of Lower Proterozoic age in complex structures" and state that the availability of water is "moderate, commonly confined to topographically inconvenient locations". Jones and Quinlan (1962, p156) describe the aquifers of the Barkly Province as "Fractures and solution cavities in limestone and dolomite and some porous sandstone, all of Cambrian age", and they state that the availability of water is "Good except near the margin where bedrock is above piezometric surface".

The available data on bores drilled in the Frew River Sheet area are summarized in Table 2. Although there are several unsuccessful bores in the Barkly Province, most of them were abandoned for technical reasons and the results do not negate the statements of Jones and Quinlan (1962) regarding the availability of underground water in the Province. Some of the unsuccessful bores could not be relocated on the ground, and their plotted position on the Frew River 1:250,000 Sheet is approximate.

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TABLE 1

STRATIGRAPHY OF THE FREW RIVER GEOLOGICAL SHEET

Age	Rock Unit	Map Symbol	Lithology	Thickness (feet)	Stratigraphic Relationship	Structure	Fossils	Economic Geology
Quaternary		Qrs.	Sand	~~2-247~~				May contain aquifers
		Qr'a	Soil, alluvium	2-247				May contain aquifers.
Tertiary		T	Chert, travertine	10	Unconformable on Cambrian	Horizontal beds	-	May provide aquifers if sufficiently thick.
Middle Cambrian	Undifferentiated	Ꞓm.	Grey dolomite, brown oolitic chert	2-15 on surface; subsurface unknown		Near-horizontal beds	-	May provide aquifers if sufficiently thick.
	Wonarah Beds	Ꞓmw.	Chert, oolitic chert, silicified coquinite	50 on surface subsurface unknown		Near-horizontal beds	Trilobites (Xystridura) Brachiopods, hyolithids	Sandstone and vuggy dolomite are good aquifers.
	Gum Ridge Formation	Ꞓmg.	Chert, shale, sandstone, conglomerate; Limestone and dolomite in subsurface	10-75 on surface 500 in subsurface	Unconformable on Lower Proterozoic sedimentary and igneous rocks.	Near-horizontal beds.	Trilobites (**Redlichia**) hyolithids.	
Lower Proterozoic		Pg.	Muscovite-biotite granite.		Intrudes Hatches Creek Group, quartz-feldspar porphyry, and by inference, Pedlar Gabbro.			Probable source of tungsten and associated ores at Hatches Creek.
		Pp	Quartz-feldspar porphyry		Intrudes Hatches Creek Group	Emplaced in cores of folds.		
	Pedlar Gabbro	Pb	Gabbro dolerite, with acid differentiates		Intrudes Hatches Creek Group.			
	Hatches Creek Group	Plh	Grey, pink and brown, medium to coarse-grained medium to thin-bedded cross-bedded, ripple-marked quartz sandstone quartz grey wacke and quartzite; siltstone, shale, pebble conglomerate; basic and acid lavas.	20,000 +	Unconformable on Warramunga Group	Strongly folded into anticlines, synclines, domes; strongly faulted.	-	Cut by quartz veins containing tungsten ores. Contains aquifers, tungsten, copper, bismuth ores in quartz veins.
	Warramunga Group	Plw	Yellow, red and purple, thin bedded, sandstone, greywacke and siltstone.	Not available	Base not exposed in Frew River Sheet area.	Strongly folded.	-	

TABLE 2.

Bore Data

Station	Name of Bore	Depth (feet)	Standing Water-level (feet)	Yield (gallons per hour)	Ground water Province (After Jones & Quinlan)	Strata	Remarks
Epenarra	No. 1	480	–	–	Barkly	0-15 Soil 15-75 Sand and clay 75-380 Rock 380-480 Shale and clay	Driller's log only. Hole abandoned for technical reasons.
"	No. 2	352	–	–	"	0-18 soil 18-40 River gravel 40-352 Stones and clay	Driller's log only. Hole abandoned for technical reasons.
"	No. 3 (Beantree)	350	–	200 +	"	No information.	
"	No. 4	280	170	120	"	0-50 Sandy loam 50-52 Quartz 52-55 Sand 55-135 Clay 135-165 Diorite boulders 165-255 " " and clay. 255-260 Diorite boulders 260-278 Clay and diorite 278-280 Boulders.	Driller's log only.
"	No. 5 (Bloodwood)	350	327	2300	"	1-5 Red soil 5-50 White clay and gravel 50-120 Red clay 120-180 Yellow clay 180-250 " " and gravel 250-280 Boulders and clay 280-350 Clay and boulders	 Limestone and chert. Friable sandstone. Limestone and chert. " " " " " " Sandy limestone.
"	No. 5A (Yellow hole)	650	340	300	"	0-50 Red sand. 50-195 Clay with dolomite chips. 195-260 " " " 260-290 Sandy clay with dolomite chips. 290-340 Dolomite 340-425 Dolomite and cherty dolomite 425-505 Cherty dolomite 505-650 Granite	Geologist's log.
"	No. 6	160	–	–	"	Various coloured clay: black clay at 160'.	Driller's log only.
"	No. 7	240	–	–	"	At 175', white crystalline limestone.	Abandoned for technical reasons.
"	No. 7 A.	170	–	–	"	156'6"-170' Cave	Abandoned for technical reasons.
"	No. 9 (Salt)	179	66	300	Davenport	0-135 Sand and clay. 135-165 Quartzite of Hatches Creek Group	Logged by Resident Geologist, Alice Springs.
"	Mulga	?		? at 250'	Barkly	0-247 Soil, sand, clay and gravel. 247-289 dolomitic limestone and dolomite, with chert nodules.	Logged by Resident Geologist, Alice Springs.

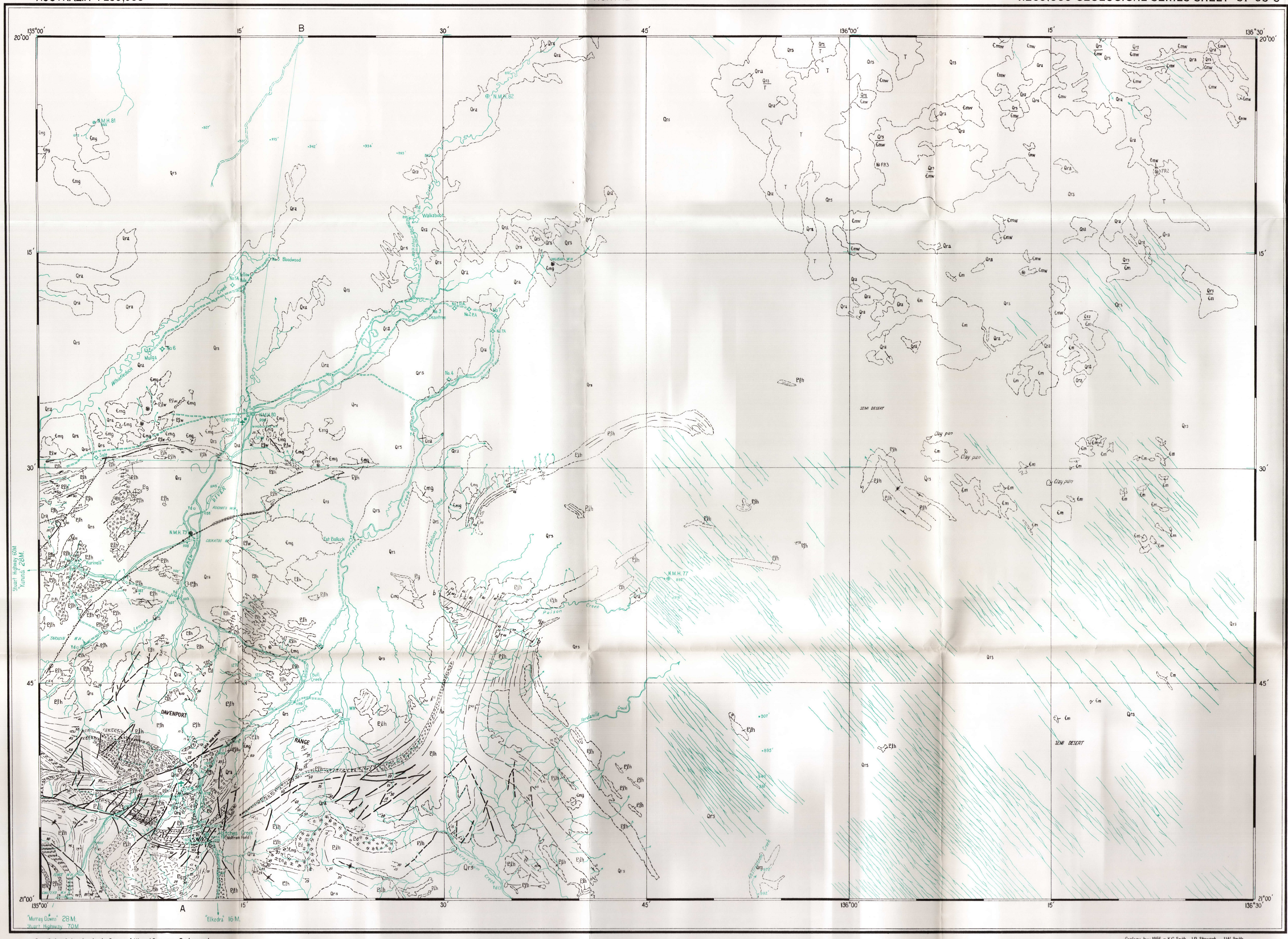
Epenarra	Walkabout	360	285	1800	Barkly	0-150 Sand 150-205 Clay 205-240 Chert and sandstone 240-260 Dolomite 260-325 Limestone and chert 325-328 Sandstone(Aquifer) 328-360 Limestone	Logged by Resident Geologist, Alice Springs.
Kurundi	Bull Creek	187?	90?	No information	Davenport	No information	Saline.
"	- 4 miles N. of Bull Creek Bore.	122'	80'	100	"	Silicified siltstone and sandstone of Hatches Creek Group.	Geological Interpretation. Hole unsuccessful.
"	Fat Bullock	62	40	1500 +	?	0-40 Sand and gravel 40-62 Silicified siltstone	Logged by Resident Geologist Alice Springs.
Police Station Hatches Creek	No. 1 Try	100				0-12 gravel 12-18 Sand and gravel 18-30 Brown, fine sand. 30-50 Quartzite boulders 50-58 Quartzite 58-68 Hard and soft bands of quartzite 68-75 Quartzite 75-100 Biotite.	Unsuccessful Drilled into Hatches Creek Group, 0-75. Note: Both this and the No. 2 try are not shown on the Frew River Geological Sheet; they were drilled in the vicinity of the Police Station but have not been relocated by the Bureau Field Party.
"	No. 2 Try	?87		300		0-5 Soil 5-10 Siltstone 10-35 Sandstone 35-52 Sandstone with thin bars of quartzite 52-65 Sandstone 65-72 Quartzite 72-80 Sandstone with thin bars of quartzite 80-87 Quartzite.	

AUSTRALIA 1:250,000

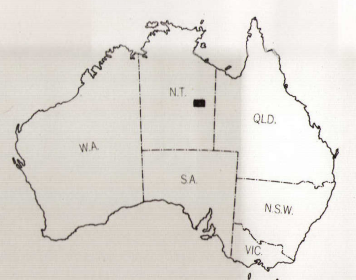
FREW RIVER

NORTHERN TERRITORY

1:250.000 GEOLOGICAL SERIES SHEET SF 53-3



Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force; complete vertical coverage at 1:50,000 scale. Transverse Mercator Projection.



INDEX TO ADJOINING SHEETS

Showing Magnetic Declination

SOUTH LAKE WOODS SE53-9	HELEN SPRINGS SE53-10	BRUNETTE DOWNS SE53-11	MT. DRUMMOND SE53-12	LAWN HILL SE54-9
GREEN SWAMP WELL SE53-13	TENNANT CREEK SE53-14	ALROY SE53-15	RANKEN SE53-16	CAMOOWEAL SE54-13
LANDER RIVER SF53-1	BONNEY WELL SF53-2	FREW RIVER SF53-3	AVON DOWNS SF53-4	MT. ISA SF54-1
MT. PEAKE SF53-5	BARROW CREEK SF53-6	ELKEDRA SF53-7	SANDOVER RIVER SF53-8	URANDANGI SF54-5
NAPPERBY SF53-9	ALCOOTA SF53-10	HUCKITTA SF53-11	TOBERMORY SF53-12	GLENORMISTON SF54-9

ANNUAL CHANGE 1'15"E

Scale 1 : 250,000

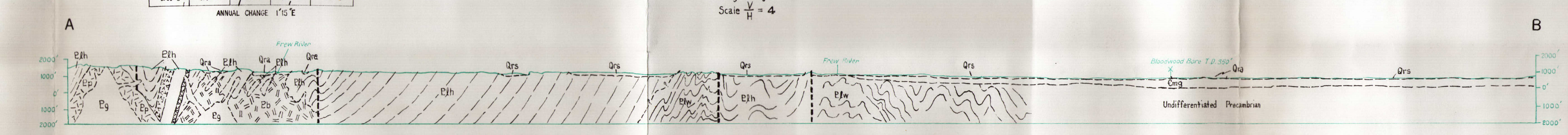
5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

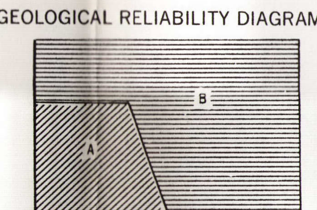
Section A-B

Folding Diagrammatic

Scale $\frac{V}{H} = 4$



GEOLOGICAL RELIABILITY DIAGRAM



A Detailed reconnaissance - numerous traverses with air-photo interpretation

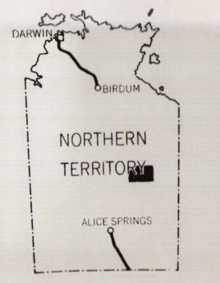
B Helicopter reconnaissance with air-photo interpretation

Geology by: 1956 - K.G. Smith, J.R. Stewart, J.W. Smith and G.R. Ryan.

1963 - K.G. Smith and E.N. Milligan

Compiled by: 1963 - K.G. Smith and E.N. Milligan

Drawn by: N.L. Kruger and G. Matveev



PRELIMINARY EDITION, 1964

SUBJECT TO AMENDMENT

Reference

CAINOZOIC	QUATERNARY		Qrs	Sand
			Qra	Soil and alluvium
	? TERTIARY		T	Chert, travertine
PALAEOZOIC	MIDDLE CAMBRIAN	Undifferentiated	Єm	Dolomite, oolitic chert
		Wonarah Beds	Єmw	Chert, oolitic chert, silicified coquinite
		Gum Ridge Formation	Єmg	Chert, sandstone, shale, conglomerate
PRECAMBRIAN	LOWER PROTEROZOIC		Pg	Muscovite - biotite, granite.
			Pp	Quartz - feldspar porphyry
		Pedlar Gabbro	Pb	Gabbro, with acid differentiates, dolerite
			Pd	Gabbro, dolerite
		Hatches Creek Group	Plh	Grey pink and brown, ripple marked, medium and coarse grained quartz sandstone and greywacke, siltstone, shale, pebble conglomerate
				Basic lava
				Acid lava
		Warramunga Group	Plw	Thin-bedded siltstone and greywacke

Geological boundary

Fault

Where location of boundaries, folds and faults is approximate line is broken; where inferred, queried: where concealed, boundaries and folds are dotted, faults are shown by short dashes

Strike and dip of strata

Horizontal strata

Vertical strata

Prevailing dip of gently folded strata

Anticline

Syncline

Trend lines - Air-photo interpretation

Quartz vein

FR.2 Macrofossil locality with reference number

Mine, W - wolfram Au - Gold

Water bore and windpump

Abandoned bore P.A. position approximate

Well

WH Waterhole

Sand dunes

b—b' Section - thickness estimation

Road

Vehicle track

Fence

"Epenarra" Homestead

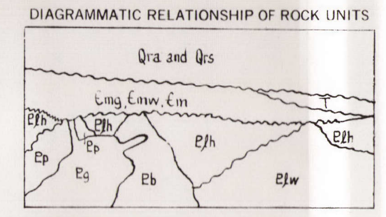
Airfield

Yd Yard

N.M.H.81 Astronomical station

965' Height in feet, barometric — datum, mean sea level

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



FREW RIVER

SHEET SF53-3