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GEOLOGY OF THE STOW REGION, NORTHERN TERRITORY

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P.G. STUART-SMITH, R.S. NEEDHAM, & L. BAGAS*

*NORTHERN TERRITORY GEOLOGICAL SURVEY

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INTRODUCTION

The Stow Region, which includes all of STOW* and part of SNOWDROP, lies between latitudes 13°30' and 14°00'S and longitudes 132°30' and 133°06'E, and is about 250 km southeast of Darwin (Fig. 1). Most of the area is covered by the Gimbat Pastoral lease. The only access is provided by an unsealed road from El Sherana in the northwest (an abandoned mining town) to Gimbat homestead and beyond to the abandoned Sleisbeck uranium mine, in the centre. The road connects with roads leading west and north to Pine Creek and Jabiru, respectively.

Early investigations were mostly reconnaissance trips or reports of mineral occurrences, listed by Walpole (1962) and Walpole & others (1968). In 1954 and 1955, the area was mapped by a BMR survey as part of a regional evaluation of the Katherine--Darwin region. The Mount Stow 1-mile Sheet area, covering the southern half of STOW, was published in 1958, and part of the northwest of the region was included in a 1:12 000 geological map of the South Alligator River area (Walpole & others, 1968, Pl. 31).

The area was mapped by BMR and NTGS in 1981, using 1:25 000 colour air photos, as part of a semi-detailed (1:100 000- scale mapping) investigation of the Pine Creek Geosyncline which

commenced in 1971, following the discovery of uranium mineralisation in the Alligator Rivers Region north of STOW. The geology of adjacent Sheet areas is described by Stuart-Smith & others (1984 -- MUNDOGIE), Stuart-Smith & Bagas (in prep. -- RANFORD HILL), and Needham & others (in prep. a & b -- Edith River and Yeuralba Regions).

Exploration, particularly since the late 1960's, has been concentrated on prospecting principally for uranium, gold, tin, and base metals. Reports of company activities are lodged with the Northern Territory Department of Mines and Energy, Darwin.

Climate and physiography

The Stow region is within the monsoonal climatic zone and has an average annual rainfall of about 1500 mm, most falling during November to April.

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* The names of 1:100 000 Sheet areas are printed in capitals.

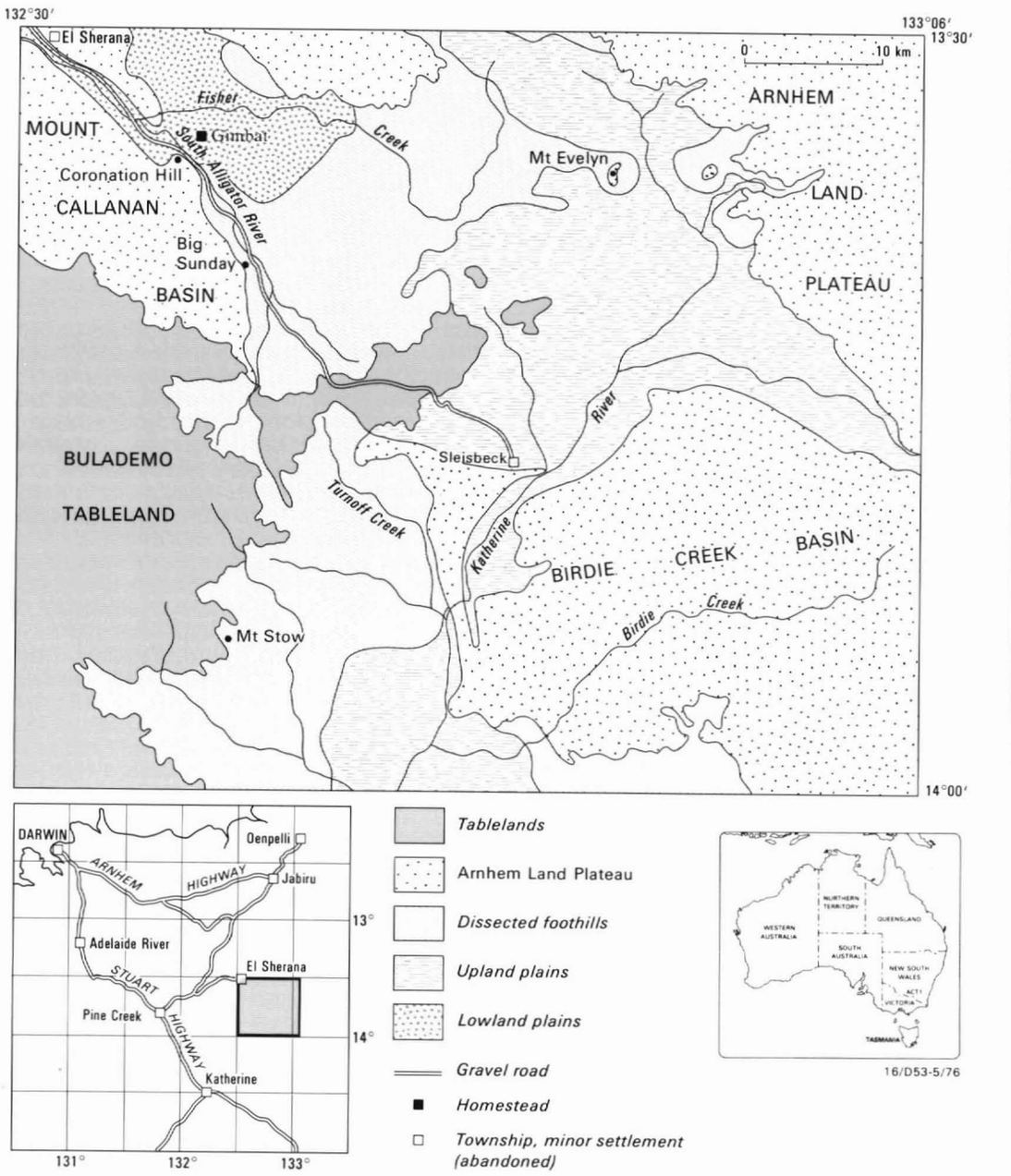

Figure 1. Location and physiography

The area straddles the divide between the catchments of the South Alligator River and Katherine River, respectively flowing north and southwest. The main physiographic units are the Upland Plains, Lowland Plains, Dissected Foothills, Arnhem Land Plateau, and Tablelands (Fig. 1). The physiography of part of the area is described by Walpole (1962), and Story & others (1976).

The Upland Plains are undulating low hills and alluvial plains between 200 and 240 m ASL developed over peneplaned and deeply weathered Early Proterozoic rocks in the Katherine River catchment. Thin gravelly loams, skeletal soils or sandy alluvial soils are covered by a eucalypt woodland of tall deciduous, mixed or scrubby open forest, and grasses. The plains possibly represent the remnants of a mature landsurface most likely of Tertiary age, modified by relatively recent erosion and alluviation.

The Upland Plains are being actively eroded from the west, where west of the nickpoint, bouldery granite hills, steep resistant strike ridges and hills of Early Proterozoic metasediments and volcanics, and intervening undulating rubble strewn rises form the Dissected Foothills. These rocks are mostly deeply weathered and partly covered by thin skeletal soils, gradational gravelly to sandy soils. Vegetation is mostly tall to stunted semi-decidous eucalypt woodland and tall to medium-high perennial grasses.

Downstream from the dissected foothills, generally below 100 m ASL, alluvial Lowland Plains are composed of sandy soils and gravelly loams overlying deeply weathered Early Proterozoic rocks. Alluviation was probably of Quaternary age, but recent rejuvenation has incised the drainage system. Stable organic-rich sediments in the headwaters of many creeks are being actively incised and eroded. Mixed open forest and grasses predominate, with patches of tall deciduous forest.

The most prominent physiographic feature is the Arnhem Land Plateau, which ranges between 300 and 450 m ASL and is bordered by cliffs up to 200 m high. The plateau is developed mainly on Middle Proterozoic sandstone and locally on late Early Proterozoic sandstone and felsic volcanics. It is sharply dissected; the main watercourses form gorges up to 100 m deep, and tributaries are commonly incised along fault or joint-controlled gorges. The plateau has been eroded into a row of flat-topped to rounded hills along a 15x3 km belt between El Sherana and Coronation Hill. Peak elevations decrease from over

320 m ASL near El Sherana to about 250 m at Coronation Hill. These hills divide the lowland plains into an wide upstream plain, with dendritic drainage, and a narrower downstream channel plain confined by strike ridges of metamorphic rocks. Vegetation on the plateau is sparse consisting of patches of tall open forest or annual grasses confined to pockets of deep sandy soil, mainly in gorges and along the escarpment.

The Bulodemo Tablelands form an extensive flat plain in the west, between 300 m and 370 m ASL. The plain overlies flat-lying poorly consolidated Mesozoic sands, and consequent rapid erosion of these rocks is re-exhuming the underlying irregular topography of the Dissected Foothills and forming steep dissected slopes or scarps up to 40 m high along the plain's edge. The sands are a major aquifer and numerous permanent springs issuing from the surrounding scarps feed the South Alligator and Katherine Rivers. Dense, tall open forest, and spinifex grow upon a thin veneer of predominantly thick sandy skeletal soils, humic silty alluvium, and Tertiary lateritic red earths.

Rock terminology and classification

Sandstone/arenite classification follows that by Packham (1954)* and that of limestone by Folk (1959). The term quartzite is used for sandstones consisting chiefly of quartz grains that have either been recrystallised by metamorphism or solidly cemented by silica, so that the rock breaks through individual grains rather than around them.

Although the Early Proterozoic geosynclinal sediments are metamorphosed to greenschist facies, the prefix meta- is only used where the rocks show visible metamorphic mineralogy or fabric in hand specimen. Mineral prefixes used in metamorphic rock terms (e.g., schist) are listed in order of increasing abundance.

Granitoids and pyroclastic rocks are classified according to the nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks, respectively by Streckeisen (1973) and Schmid (1981). Laterite terminology follows that described by Williams (1969). Proportional estimates of rock units within

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* Although more recent and widely applied sandstone classifications are available, this scheme was used during most of the fieldwork in the Pine Creek Geosyncline and also in this commentary to avoid confusion with previous publications.

formations are field estimates only.

Palaeoenvironmental interpretation

Palaeoenvironmental interpretation of the Early Proterozoic rocks is limited owing to the lack of fossils, the effects of metamorphism, and poor exposure. Lithological associations and some sedimentary structures enable distinctions between high and low-energy environments, as well as between shallow and deep water (respectively above and below wave base) deposits. In addition, chemically reduced environments are indicated by pyritic and carbon-rich rocks.

ACKNOWLEDGEMENTS

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REGIONAL SETTING

The Stow region lies in the southeastern part of the Pine Creek Geosyncline; its geology has been described by Needham & others (1980). The geosyncline contains Early Proterozoic metasedimentary rocks resting on Archaean gneissic and granitic basement, the latter being exposed in the west and in the northeast. The metasediments represent a preserved basinal sequence up to 14 km thick (Needham & others, 1980), out of a possible original thickness of up to 20 km (Ferguson, 1980), which at about 1870 Ma was folded and metamorphosed mostly to greenschist facies, and in places to amphibolite facies, during the 'Top End Orogeny'. This event began with the intrusion of a large granite, subsequently migmatised, in the northeast.

The Early Proterozoic geosynclinal strata (mainly shale, siltstone, slate, sandstone, conglomerate, carbonate rocks and greywacke) were also intruded by pre-orogenic intrusions of dolerite and syn- to post-orogenic felsic intrusions and post-orogenic mafic intrusions. On these rest, with marked unconformity, mildly deformed late Early Proterozoic syn- to post-orogenic felsic volcanics and sediments, largely undeformed Middle Proterozoic continental sediments, and Mesozoic epicontinental sediments.

The regional setting of the Stow region is shown in the accompanying map. Early Proterozoic geosynclinal strata are metamorphosed to lower greenschist facies and deformed into steep, tight, mainly horizontal, northwest-trending folds. The region contains the type areas of the late Early Proterozoic felsic volcanic units, which are intruded by probably coeval granites. The essentially flat-lying Middle Proterozoic and Mesozoic strata conceal older units over almost half the region.

STRATIGRAPHY

EARLY PROTEROZOIC GEOSYNCLINAL STRATA

The stratigraphy of the Stow region is summarised in Table 1. The age of the Early Proterozoic geosynclinal sequence is between 2470 and 1870 Ma (Page & others, 1980). An age of 1880 Ma on Mount Bonnie Formation tuff (Page, 1983) further restricts the deposition of the South Alligator and Finniss River Groups to between 1880 and 1870 Ma. Older parts of this sequence (the Namoona and Mount Partridge Groups) were probably deposited after 2000 Ma (Page & others, 1980).

NAMOONA GROUP

The oldest sequence is the Namoona Group, divided into the Masson Formation and Stag Creek Volcanics. Elsewhere in the Pine Creek Geosyncline correlatives of the Masson Formation rest either on the basal Early Proterozoic Kakadu Group or on the Archaean to Early Proterozoic Rum Jungle and Nanambu Complexes (Needham & others, 1980). Within the mapped region, the group is unconformably overlain by the Mount Partridge and El Sherana Groups and is thrown against the Edith River Group along the South Alligator Fault. Contacts are mostly covered by recent talus or Quaternary alluvium. Outcrop of the group is confined to the northwest, where it forms a 1 km-wide belt extending for about 10 km northwest from near Pul Pul Hill (GR 384989).

Masson Formation (Bnm)

Only about the top 400 m of the 2800+m thick Masson Formation (Stuart-Smith & others, 1984) crop out in the extreme northeast of STOW, where it intertongues with the Stag Creek Volcanics. The formation mainly consists of about 220 m of interbedded coarse poorly sorted dolarenite and pyritic quartzite both forming beds up to 1 m thick and exposed as low strike ridges. The beds comprise a northeasterly younging sequence which dips

TABLE 1: SUMMARY OF STRATIGRAPHY OF THE STOW REGION

		Unit	Rock Types	Relationships	Thickness (m)
QUATERNARY		(Qa)	Silt, sand, gravel and clay		
		(Qa1)	Silt, clayey silt		
		(Qs)	Unconsolidated sand		
		(Qf)	Black and brown silt and clay		
TERTIARY TO QUATERNARY		(Cz)	Skeletal soils, gradational red soils and yellow earth soils		
		(Czt)	Rubble composed of sandstone, volcanic and metasedimentary rock fragments, sand		
		(Czs)	Unconsolidated sand, ferruginous and clayey sand		
		(Czl)	Nodular and concretionary ironstone		
TERTIARY		(Teb)	Massive brown ferruginous ill-sorted and poorly consolidated kaolinitic sand	Comprise a conformable sequence in isolated fault-bounded basins, unconformable over older units	<500
		(Tew)	Massive white ill-sorted and poorly consolidated kaolinitic sand		
			UNCONFORMITY		
CRETACEOUS		(K)	Undivided quartz sandstone and conglomerate		
		(K_3)	Reddish to brown, yellow ferruginous friable fine to coarse quartz sandstone	Flat-lying conformable sequence unconformable over older units	40
		(K_2)	Massive, friable and kaolinitic, fine to coarse white quartz sandstone and minor siltstone		
		(K_1)	Limonitic very coarse quartz sandstone, conglomerate and breccia		
			UNCONFORMITY		
MIDDLE PROTEROZOIC	Kombolgie Formation	(Phk_2)	Medium to coarse well-sorted buff clayey quartz sandstone, commonly cross-bedded and ripple marked		300
		Nungbalgarri Volcanic Member (Bhn)	Deeply weathered ferruginous amygdaloidal mafic volcanic		<1
		(Bhk_{2b})	Brown siltstone, basal intra-formational breccia	Comprise a conformable sequence, itself unconformable on older units; slight angular unconformity on Pep, major angular unconformity elsewhere	<2
		Birdie Creek Volcanic Member (Bhb)	Altered massive, and in places amygdaloidal basalt		150

MIDDLE PROTEROZOIC	KATHERINE RIVER GROUP	Kombolgie Formation	Mount Callanan volcanic Member (Ehc)	Massive amygdaloidal basalt, banded vitric tuff	100
			(Ehk_1)	Massive poorly-sorted fine to coarse and pebbly quartz sandstone, well-sorted fine to medium-grained quartz sandstone, basal polymictic boulder conglomerate. Tabular cross-bedding and ripple marks common. Minor siltstone.	<1000
			UNCONFORMITY		
			Oenpelli Dolerite (Pdo)	Porphyritic olivine dolerite, minor quartz dolerite and granophyre	Lopoliths and dykes intruding Pdz and older sediments unconformably overlain by Phk_1 250
EARLY PROTEROZOIC			Malone Creek Granite (Pgm)	Undivided alkali feldspar granite	Concentrically zoned pluton. Intrudes Pfb, Pdz, Pbc, and Pbp
			(Pgma)	Fine porphyritic pink alkali feldspar granite	
			(Pgmb)	Fine to coarse even-grained to porphyritic alkali feldspar granite	
			(Pgmc)	Fine even grained chloritised pink to greenish pink alkali feldspar granite with abundant quartz and greisen veins	
			Grace Creek Granite (Pegb)	Slightly porphyritic grey-green medium-grained granite	Zoned subvolcanic intrusion gradational with Pep. Unconformably overlain by Phk_1, and younger sediments
			(Pegc)	Porphyritic pink-grey medium-grained granite	
			(Pegd)	Porphyritic grey-pink microgranite, layered in places	
	EDITH RIVER GROUP		Plum Tree Creek Volcanics (Pep)	Massive pink to purple rhyodacitic ignimbrite, minor rhyolite and tuff	Conformably overlies Pek and unconformably overlies older units where Pek absent. Unconformably overlain by younger sediments. Transitional with Pegd 500
			Kurrundie Sandstone (Pek)	Massive purple clayey medium to coarse lithic quartz sandstone, polymictic pebble and cobble conglomerate, massive to laminated white, pink and brown, fine to coarse quartz sandstone, minor brown micaceous sandy siltstone	Unconformably overlies older units. Conformably overlain by Pep 350
			UNCONFORMITY		

	Big Sunday Formation (Pbb)	Fine to coarse and pebbly volcanolithic greywacke, green shale, devitrified vitric tuff and vitric crystal tuff, altered amygdaloidal basalt, rhyolite and ignimbrite. Minor micaceous siltstone, sandy siltstone, phyllite, slate, and fine quartzite	Conformably overlies or faulted against Pbp. Unconformably overlain by Pek and younger sediments	500
EL SHERANA GROUP	Pul Pul Rhyolite (Pbp)	Altered purple to pink rhyolitic ignimbrite, minor agglomerate and glassy black rhyolite, rare siltstone and shale	Highly angular unconformity on older units, Conformable on Pbc. Intruded by Pgmc	1300
	Coronation sandstone (Pbc)	Clayey purple very coarse pebbly quartz sandstone, massive polymictic cobble conglomerate at base, interbedded shale, siltstone, greywacke, minor felsic and mafic volcanics	Highly angular unconformity on older units. Conformable over Pbs. Intruded by Pgmc	750
	Scinto Breccia (Pbs)	Pink siliceous phosphatic hematitic sandy chert breccia	Unconformably overlies silicified dolomite of Psk and Psp	
		UNCONFORMITY		
EARLY PROTEROZOIC	Zamu Dolerite (Pdz)	Massive medium to coarse grey quartz dolerite and foliated amphibolite	Occurs as sills intruding Psp, Psb and Pfb	2000
FINNISS RIVER GROUP	Burrell Creek Formation (Pfb)	Foliated fine to coarse meta-feldspathic greywacke, chlorite muscovite quartz schist, phyllite and phyllitic siltstone	Conformably overlies Psp and Psb. Unconformably overlain by Pbc and Phk_2	2000
SOUTH ALLIGATOR GROUP	Kapalga Formation (Psp)	Foliated fine to medium meta-feldspathic greywacke grey to brown phyllite, silty phyllite, siliceous phyllite, metasiltstone, biotite quartz schist. Minor BIF and hematitic siltstone with chert bands, lenses and nodules; minor argillite, chlorite schist, massive silicified dolomite, metadololutite, and para-amphibolite.	Faulted against Psk, conformably ovelain by Pfb and Psb. Interfingers with Psb	1200
	Shovel Billabong Andesite (Psb)	Massive greenish-grey altered pitchstone, variolitic andesite and minor microdiorite.	Conformably overlies and interfingers with Psp. Conformably overlain by Pfb in places.	100 - 200
	Koolpin Formation (Psk)	Hematitic metasiltstone and phyllite commonly with chert bands, lenses and nodules. Dark grey graphitic phyllite and phyllitic siltstone, silicified dolomite. Lenses of stromatolitic dolomite, rare medium quartz greywacke.	Faulted against Ppm, Psp, Pfb and Pdz. Unconformably overlain or faulted against Pbc and Pbp	<1000

			UNCONFORMITY		
EARLY PROTEROZOIC	MOUNT PARTRIDGE GROUP	Mundogie Sandstone (Ppm)	Very coarse sericitic foliated quartzite and minor pebble conglomerate, lenticular cross-bedding common. Minor carbonaceous silty phyllite.	Unconformably? overlies Pnm and Pns. Unconformably overlain by younger sediments and volcanics.	100
			UNCONFORMITY		
	NAMOONA GROUP	Stag Creek Volcanics (Pns)	Massive pale green altered intermediate to mafic flows and breccia. Minor green fine to coarse altered vitric tuff at base.	Overlies and intertongues with Pnm.	600
		Masson Formation (Pnm)	Coarse dolarenite, pyritic quartzite, brown silty phyllite	Oldest unit in region, intertongues with Pns.	400

steeply to the northeast, and in places is overturned to the southwest. The sandstones are overlain by about a 190 m of brown silty phyllite, consisting of a lower unit and an upper unit, respectively 60 m and 130 m thick, separated by a 550 m thick tongue of Stag Creek Volcanics. A prominent cleavage in the phyllite mostly parallels bedding and dips steeply to the southwest.

The formation is a shallow-water facies probably distal to the arkosic, dolomitic and partly evaporitic sequences of the Kakadu Group, Beestons Formation, Celia Dolomite and Cahill Formation around the Archaean basement complexes elsewhere in the Pine Creek Geosyncline (Needham & Stuart-Smith, 1984).

Stag Creek Volcanics (Bns)

The Stag Creek Volcanics overlie and intertongue with the Masson Formation. They are poorly exposed, deeply weathered and mostly covered by thick skeletal soils and other Cainozoic deposits. In STOW the unit consists of 50 m of basal, green, fine to coarse, altered vitric tuff, overlain by 550 m of interlayered massive pale green altered intermediate to mafic flows and auto-breccia. The flows and volcanic breccia clasts consist mainly of recrystallised fine tremolite/ actinolite aggregates and minor clinozoisite and carbonate. Rare altered plagioclase phenocrysts are present.

The Stow region outcrops are the most southerly of this unit. Farther northwest in MUNDOGIE, it is more extensive and is 1000 m thick, comprising also interbedded tuffaceous shale and greywacke, siltstone and phyllite (Stuart-Smith & others, 1984; Foy & Miezitis, 1977).

The Stag Creek Volcanics represent the earliest-known volcanic episode in the Pine Creek Geosyncline, and their distribution close to the South Alligator Fault suggests that the major northwesterly faults may have acted as coduits for the rising magmas. Stuart-Smith & others (1984) indicated subaqueous extrusion, with the breccias forming by autobrecciation of flows.

MOUNT PARTRIDGE GROUP

Epiclastic sediments of the Mount Partridge Group overlie either unconformably or disconformably older units in the Pine Creek Geosyncline (Needham & others, 1980). The Mundogie Sandstone, a fluvial sequence of sandstone and minor conglomerate

and pelitic rocks, is the base of the group and is the only member of the group in Stow region. The Wildman Siltstone, present elsewhere in the geosyncline where it overlies the Mundogie Sandstone (Needham & others, 1980), is probably absent from the area owing to either faulting or erosion prior to deposition of the South Alligator Group.

Mundogie Sandstone (Bpm)

Distribution. The Mundogie Sandstone crops out in the northwest as a prominent semi-continuous northwesterly strike ridge up to 50 m high, trending from 3 km southeast of Coronation Hill (GR 406965) into adjoining MUNDOGIE (Fig.2). It also forms a small inlier in late Early Proterozoic volcanics and Cretaceous sediments about 8 km southeast of Big Sunday (GR 457889).

Stratigraphic relations. The formation is part of the generally northeast-facing geosynclinal sequence in which dips are steep (commonly >70°), vertical, and locally overturned. The bedding-parallelism and intensity of the structural grain imposed upon these rocks results in the apparently conformable relationship between units. Northwest of Coronation Hill, the formation overlies the Masson Formation and Stag Creek Volcanics. The contact is not exposed; however, the converging bedding indicates a high angular unconformity. In the same area, the contact with the overlying Koolpin Formation is not exposed, but steeply dipping bedding-parallel faults and shears in the Koolpin Formation suggest that it is probably faulted. The Koolpin Formation unconformably overlies older rocks elsewhere in the geosyncline.

Near El Sherana and Coronation Hill, and in the inlier southeast of Big Sunday, the Mundogie Sandstone is unconformably overlain, with high angularity, by or faulted against the El Sherana Group. Unconformable contacts with the Coronation Sandstone and Pul Pul Rhyolite (El Sherana Group) are well exposed at GR 309053 and GR 316046, respectively.

Lithology. Strongly foliated, very coarse sericitic quartzite is predominant, with minor interbeds of chert pebble conglomerate up to 1 m and carbonaceous silty phyllite up to several metres thick. The quartzite was originally a feldspathic sandstone or arkose in which the feldspar has been altered to sericite.

Bedding is steep, commonly overturned to the southwest and mostly parallel to the foliation which is marked by flattened

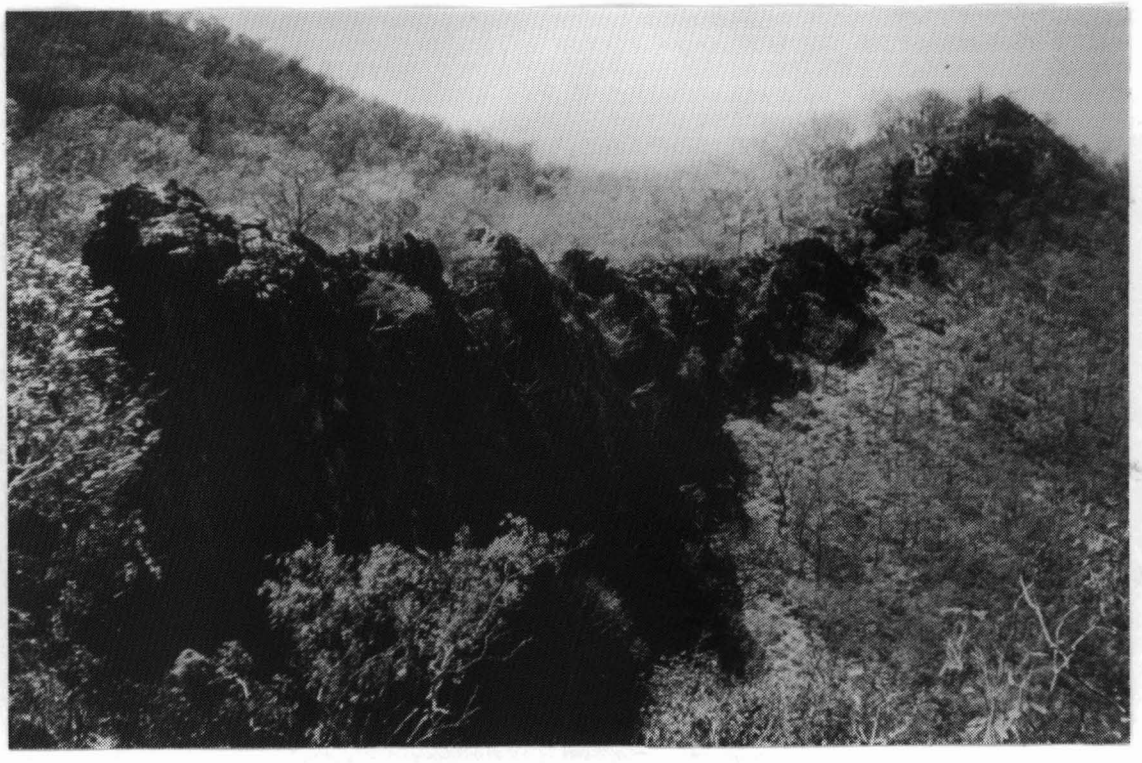

Figure 2. Typical strike ridge exposure of the Mundogie Sandstone. The formation consists predominantly of strongly foliated, very coarse sericitic quartzite. Like other Early Proterozoic geosynclinal units in the region, bedding mostly parallels a steeply dipping metamorphic foliation

pebbles (<2 cm) and quartz grains and micaceous foliae. Lenticular cross-beds are widespread in the quartzite and limited measurements indicate a current direction to the east-southeast.

Remarks. The formation is about 100 m thick in the Stow region, which is the southernmost and thinnest development of the unit in the geosyncline. The sandstone was deposited as coalesced alluvial fans flanking an Archaean provenance to the north (Stuart-Smith & others, 1980; 1984).

SOUTH ALLIGATOR GROUP

An incomplete sequence of the South Alligator Group, represented by the Koolpin Formation, Shovel Billabong Andesite, and Kapalga Formation, is exposed in the north. Other units of the Group found elsewhere in the geosyncline (the Gerowie Tuff and Mount Bonnie Formation) are absent, owing to either early thrusting, faulting, or to facies changes. Throughout large areas of the geosyncline, the distinctive and extensive Gerowie Tuff, in the middle of the South Alligator Group, is used principally to discriminate the Koolpin Formation at the base of the group from the lithologically similar Mount Bonnie Formation at the top. East of the Fisher Fault, where the tuff is absent, this subdivision of the South Alligator Group is not possible. Consequently, rocks have been grouped into the Kapalga Formation, probably laterally equivalent to both the Koolpin and Mount Bonnie Formations. This correlation is based on both the greywacke in the Kapalga Formation and flows of Shovel Billabong Andesite within it. Elsewhere in the geosyncline, greywacke in this group is confined to stratigraphic intervals higher than the Gerowie Tuff (i.e., in the Mount Bonnie Formation); and the Shovel Billabong Andesite lies stratigraphically close to and beneath the tuff in the Koolpin Formation (Needham & Stuart-Smith, 1985a).

The South Alligator Group is characterised by iron-rich carbonaceous and dolomitic pelitic sediments, and volcanics, which rest unconformably on older rocks. The group is conformably and transitionally overlain by the Finniss River Group. Its depositional age is defined by U/Pb zircon ages of about 1880 Ma (Page, 1983) from tuffs of the Gerowie Tuff and Mount Bonnie Formation.

Koolpin Formation (Bsk)

Distribution. The Koolpin Formation forms a line of rugged

hills flanking the South Alligator River in a 1-km wide northwest-trending belt from 4 km southeast of Coronation Hill into MUNDOGIE. As in MUNDOGIE, the apparent thickness of 1000 m is probably over twice its true thickness owing to repetition by extensive faulting, shearing, and tight to isoclinal folding. In adjoining RANFORD HILL, where the effects of faulting and folding are less, a more accurate stratigraphic thickness of about 350 m has been determined (Stuart-Smith & Bagas, in prep.).

Stratigraphic relations. The formation appears to unconformably overlie or has been faulted against the Mundogie Sandstone to the southwest, and is thrown against the Kapalga Formation, Burrell Creek Formation, and Zamu Dolerite to the northeast by the Fisher Fault. Contacts are not exposed owing to extensive talus and thin skeletal soil cover. The formation is unconformably overlain by and in places faulted against the Coronation Sandstone and Pul Pul Rhyolite of the El Sherana Group. Discontinuous bodies of Scinto Breccia are developed over silicified dolomite lenses within the Koolpin Formation and probably represent a paleo-regolith locally developed on the pre-El Sherana Group surface above carbonate lenses in the Koolpin Formation.

Lithology. The lithologies of the formation in order of abundance are metasiltstone and phyllite, graphitic phyllite and siltstone, crystalline dolomite, dolarenite and dololutite, and greywacke. No internal stratigraphy can be determined owing to structural complexity.

Hematitic metasiltstone and phyllite, with grey or black chert bands, lenses and nodules, are predominant, forming about 50% of the formation. In places, particularly on ridge tops, these rocks are capped by a supergene gossanous hematitic and limonitic ironstone to a depth of about 5 m. At greater depths (e.g., in drillhole located at GR 441791) they are pyritic, carbonaceous and dolomitic (A. MacKinnon-Love, Urangesellschaft Australia Pty Ltd, personal communication, 1981).

Dark grey graphitic phyllite and phyllitic siltstone are poorly exposed as bleached or ferruginous rubble (forming beds up to 20 m thick), but probably comprise about 40% of the formation. Exposures are mostly limited to mine workings where they are mainly extensively sheared, chloritic and hematitic.

Lenses of dolomite, silicified in places, are common and comprise less than 10% of the unit. The largest of these, a lens

of steeply northeast-dipping laminated to massive stromatolic dolomite (the 'Pul Pul Bioherm'), up to 400 m thick and 1500 m long, occurs 1 km southeast of Pul Pul Hill. According to Muir & Jackson (1978), the lens consists of two lithologies which alternate in beds 2 to 3 m thick:

(1) Ripple marked, slumped and flaser-bedded dololutite and dolarenite with some quartz segregations and abundant evidence of pressure solution, and

(2) Stromatolitic dolomite, with stratiform, domal and columnar forms. The small domes (5 cm x 1 cm*) are often capped by small columns 2--5 mm in diameter and up to 2--3 cm high, some are branching. The dome and column units, up to 15 cm thick, are finely laminated and grey with cream column interspaces. They are interbedded with grey or cream blebby (?sparry) dololutite beds about 15--20 cm thick which contain no obvious internal lamination.

Other stromatolites discriminated by Muir & Jackson include larger domes up to 20 cm x 15 cm, small domes 5 cm x 1 cm with possible radiating gypsum casts, stratiform stromatolites containing possible scattered small prismatic pseudomorphs after gypsum, and large unbranched slightly divergent columnar stromatolites (4 cm x 1 cm) with a column height of 15 to 20 cm in one bed at the top of the sequence.

Quartz is commonly concentrated in the dolomite lens as zoned cross-cutting veins and in veins parallel and subparallel to bedding. Well-developed crystalline quartz is present, together with elongated blades which may represent vadose alteration of early diagenetic blade chert (Muir & Jackson, 1978). Later deformation has resulted in faulting, brecciation, remobilisation and segration of quartz into coarsely crystalline irregular bodies. In one area, irregular patches of dolarenite in dololutite were ascribed to soft-sediment deformation (Muir & Jackson, 1978).

Rare medium-grained quartz greywacke forms a massive bed about 1 m thick within chert-banded hematitic metasiltstone, about 200 m west of the Koolpin uranium mine, extending as a continuous horizon for about 1 km to the southeast. The rock is

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*The first figure in stromatolite measurements is diameter and the second is the synoptic or lamina height; all figures are averages.

similar to the volcanilithic greywacke in the Mount Bonnie, Kapalga and Burrell Creek Formations, and its presence in the Koolpin Formation may indicate a lateral eastwards transition into the more greywacke-rich Kapalga Formation. The stratigraphic position of the bed cannot be determined; however, it is included in the Koolpin Formation as it is only a minor constituent -- greywacke, together with shale, are the dominant rock types in the Kapalga Formation.

Remarks. The Koolpin Formation is a basin-wide transgressive sequence deposited in fresh to slightly brackish water under chemically reducing acid conditions, indicated by coaly and pyritic strata (Crick & others, 1980). Interbedded clastic carbonate rocks with dolomite lenses, which contain several intertidal forms of stromatolite, suggest high-energy, shallow-water environments (Crick & others, 1980). The carbonates probably represent bioherms which intertongue with the pelitic rocks (Walpole & others, 1968) containing in places small prismatic carbonate pseudomorphs after gypsum, demonstrating hypersalinity. The unique bioherm in the South Alligator Valley, equivalent to lateral lithological changes in the South Alligator Group, may indicate a palaeo-basin margin.

Shovel Billabong Andesite (Bsb)

Distribution. Distinctive dull greenish grey massive altered pitchstone, variolitic andesite, and microdiorite of the Shovel Billabong Andesite crop out in the northwest around Gimbat homestead and in the northeast between Mount Evelyn and the Arnhem Land Plateau.

Exposures consist of extensively jointed and fractured pavements, and low sandy rises with scattered rubble. A thick reddish brown soil is developed on the andesite, as is the case with the basic igneous rocks in the area.

Statigraphic relations. The Shovel Billabong Andesite forms a discontinuous conformable unit 100 to 200 m thick, between the Kapalga Formation and the Burrell Creek Formation. In places (e.g., 3 km north of Gimbat homestead), it interfingers with the Kapalga Formation, and in view of its extent, thickness, and almost ubiquitous variolitic quench textures, it probably has a number of thin flows. Owing to poor exposure, the relationship between pitchstone, variolitic andesite and microdiorite is not clear; they are probably gradational, with microdiorite in the centres of thicker flows.

Lithology. The pitchstone and variolitic andesite are aphanitic, dull greenish grey, massive and fractured similar to the Shovel Billabong Andesite in MUNDOGIE (Stuart-Smith & others, 1984). They contain microphenocrysts of plagioclase, mostly altered to albite, epidote, quartz and white mica, in a pale brown altered glassy groundmass. The groundmass contains crystallites, secondary sphene, quartz, biotite, chlorite, epidote, prehnite, and in the variolitic andesite, actinolite/chlorite pseudomorphs of clinopyroxene?. The crystallites form swallow-tailed, sheaf-like, radiating or feather-like clusters, and in MUNDOGIE Bryan (1962) described them as monoclinic pyroxene. In the Stow region most are too altered for identification but they probably include pyroxene, feldspar and hornblende.

The microdiorite is a coarser phase of the variolitic andesite, with deformed idiomorphic plagioclase phenocrysts (up to 4 mm across) in a fine groundmass of plagioclase, acicular actinolite, minor K-feldspar, quartz, sphene, and epidote. Actinolite commonly forms prismatic clusters probably pseudomorphous after augite phenocrysts which are preserved in MUNDOGIE (Stuart-Smith & others, 1984).

Remarks. The Shovel Billabong Andesite was considered by early workers to be intrusive and part of the Zamu Complex (later renamed Zamu Dolerite). Bryan (1962) noted that it was too thick to be a single intrusion and suggested it was "a segregation of the magma that was intruded separately as a series of very small masses that chilled quickly". Walpole & others (1968) mapped the unit as Zamu Complex and suggested that it was intruded before the main mass of dolerite, presumably into a cooler and possibly aqueous environment. However, the absence of field evidence in STOW and MUNDOGIE (Stuart-Smith & others, 1984) supporting a multiple intrusive origin, leads to the conclusion that the considerable thickness of quenched magma formed as multiple subaqueous extrusions. The marked stratigraphic control, and the close stratigraphic and geographic association of the unit with other felsic volcanics (the Gerowie Tuff in MUNDOGIE), also supports an extrusive origin.

Kapalga Formation (Bsp)

Apart from minor flows of Shovel Billabong Andesite, the Kapalga Formation is the only unit of the South Alligator Group east of the Fisher Fault. It is distinguished from both the

Koolpin Formation and Finniss River Group by the presence of interbedded chemical sediments with a dominantly shale--greywacke sequence. The absence of tuffaceous material distinguishes it from the otherwise lithologically similar correlative Mount Bonnie Formation, which is the youngest unit of the South Alligator Group in other parts of the Pine Creek Geosyncline.

Distribution. The Kapalga Formation is poorly exposed as low strike ridges, or within erosion gullies, and is mostly covered by thin skeletal and rubbly soils. It crops out in three areas: between Gimbat homestead and Koolpin Creek, northeast and northwest of Mount Evelyn, and north of Sleisbeck.

Stratigraphic relations. In the Gimbat locality, the formation is in contact with the Koolpin Formation along the Fisher Fault. In the other two areas, it is the oldest unit present, forming the cores of anticlines. In all three areas, it is conformably overlain by the Burrell Creek Formation, and is either faulted against or unconformably overlain by the El Sherana Group and Kombolgie Formation. The unit is extensively intruded and hornfelsed by the Zamu Dolerite and Oenpelli Dolerite. As the Kapalga Formation is the oldest unit cropping out east of the Fisher Fault its true thickness is indeterminable. An estimated maximum thickness of about 1200 m is nearly equals the total thickness of the South Alligator Group in adjoining RANFORD HILL (Stuart-Smith & Bagas, in prep).

Lithology. In STOW, the formation comprises an interbedded sequence of metafeldspathic greywacke, metapelites (commonly iron-rich), banded iron formation, and dolomitic sediments.

Foliated fine to medium-grained metafeldspathic greywacke probably comprises about half of the unit and consists of poorly sorted subangular to subrounded quartz, with minor chert and feldspar grains and shale clasts, in a recrystallised and mostly foliated matrix of biotite, muscovite, sericite and quartz. The greywacke is very poorly exposed and is indistinguishable from those in the overlying Burrell Creek Formation.

Meta--pelites include grey to brown phyllite, silty phyllite, siliceous phyllite, pale green argillite, metasiltstone, dark green chlorite schist, and biotite-quartz schist. These rocks, although similar to pelites in the Burrell Creek Formation, tend to be more iron-rich. They commonly contain iron-rich chlorite, secondary iron oxides and in places late syntectonic magnetite porphyroblasts. Banded iron formation and hematitic siltstone

with chert bands, lenses and nodules, although probably less than 10% of the unit, are the main outcropping rock types, forming low strike ridges near Mount Evelyn and Sleisbeck. The banded iron formation consists of laminated chert and hematite/magnetite-rich bands, commonly with the iron oxides partially filling cubic casts, most probably after pyrite. At the Sleisbeck open-cut the hematitic siltstone is pyritic and carbonaceous at shallow depths.

Minor dolomitic sediments crop out mostly near Gimbat homestead. Vuggy massive silicified dolomite, with specular hematite, forms a lens about 400 m long about 6.2 km northwest of the homestead. Interbedded chloritic dolomite breccia and metadololutite (now a banded carbonate--chlorite--epidote--tremolite rock) crop out 1 km north of the homestead. A para-amphibolite, 8 km northwest of Mount Evelyn (GR 657004), consists of banded foliated actinolite, K-feldspar and quartz, and is probably a metamorphosed laminated impure dololutite.

Remarks. Like the Mount Bonnie Formation west of STOW, the Kapalga Formation contains greywacke and dolomitic, pyritic and carbonaceous sediments, which represent a transition between the chemically reducing acid shallow-water environment characteristic of the South Alligator Group and the higher energy deeper-water pre-orogenic turbidite facies of the Finniss River Group.

FINNISS RIVER GROUP

Burrell Creek Formation (Bfb)

Distribution and stratigraphic relations. The Burrell Creek Formation (the only member of the Finniss River Group), is the youngest and most widespread of the Early Proterozoic geosynclinal sequence in the Stow region. It is exposed mostly on low rubbly rises and in creek beds in the southwest. Kombolgie Formation sandstone unconformably overlies the Burrell Creek Formation, which is best exposed in the footslope of the sandstone escarpment and where it is intruded and contact-metamorphosed by the Malone Creek Granite in the headwaters of Fisher and Gimbat Creeks. Most of the formation is covered by thin skeletal soils, Cainozoic sand and laterite or Quaternary alluvium associated with the Katherine River and its tributaries.

Near Gimbat homestead, and northwest and northeast of Mount Evelyn, the Burrell Creek Formation appears to conformably overlie the Kapalga Formation, although the contact is not

exposed. Southeast of Coronation Hill, the unit is thrown against the Koolpin Formation, and is elsewhere unconformably overlain by the El Sherana Group, the Edith River Group, the Kombolgie Formation or undivided Cretaceous sediments. In places, the contacts with the El Sherana Group and Kombolgie Formation are faulted.

In the north, the formation is intruded by extensive pre-orogenic sills of Zamu Dolerite and post-orogenic lopoliths and dykes of Oenpelli Dolerite. Contact-metamorphic effects are apparent close to the Oenpelli Dolerite, but in the case of the Zamu Dolerite have been overprinted by regional metamorphism. Minor northwest-trending dykes of porphyritic alkali feldspar syenite and granite, and quartz breccias cut the formation near the northeast margin of the Malone Creek Granite.

Lithology. The formation consists of interbedded fine to coarse meta-feldspathic greywacke, chlorite--muscovite--quartz schist, phyllite and phyllitic siltstone. Owing to the lack of suitable marker horizons, the thickness of the unit is difficult to determine but is probably about 2000 m.

Fine to coarse meta-feldspathic greywacke occurs throughout the sequence as massive thin to thick interbeds, which are mostly strongly foliated and are graded in places. The greywacke typically consists of poorly sorted, flattened and recrystallised quartz, chert, K-feldspar and minor plagioclase in a weak to strongly foliated matrix of quartz, muscovite, biotite/ chlorite, granular epidote, iron oxide and minor tourmaline and carbonate. Where contact metamorphosed by the Malone Creek Granite, the greywacke is silicified with no noticeable mineralogical or textural changes.

Brown to greyish green chlorite--muscovite--quartz schist, phyllite and phyllitic siltstone are typically laminated to thinly bedded and strongly foliated, and probably comprise about 50% of the formation. Within the contact-metamorphic aureole of the Malone Creek Granite they are partly recrystallised and contain altered porphyroblasts of cordierite.

Remarks. The Burrell Creek Formation is a turbidite sequence formed in a subsiding basin at the close of deposition within the Pine Creek Geosyncline (Stuart-Smith & others, 1980). The absence of conglomerates, common in the unit in areas west of the region, is consistent with the general easterly fining of the sequence across the Pine Creek Geosyncline and a predominantly

westerly source (Walpole & others, 1968).

PRE-OROGENIC INTRUSIONS

Zamu Dolerite (Bdz)

Distribution. Sills of Zamu Dolerite (Ferguson & Needham, 1978) are well exposed in the north as low rubble-strewn ridges or as prominent bouldery hills up to 160 m high, particulary in the Zamu Creek area, where the dolerite was first described (as the Zamu Complex; Walpole, 1962). Elsewhere, especially in the northeast, the presence of the dolerite at shallow depth is indicated by deep reddish brown soil and scattered rubble.

Stratigraphic relations. The unit intrudes the Kapalga and Burrell Creek Formations and the Shovel Billabong Andesite. Contact effects are absent owing to overprinting by later regional metamorphism. The dolerite is invaded by the Malone Creek Granite and the Oenpelli Dolerite, and is unconformably overlain by El Sherana Group, Kombolgie Formation and Cretaceous sediments.

The sills are up to 2000 m thick and are folded with the enclosing Early Proterozoic rocks about subhorizontal axes. There are probably only two or three major sills repeated several times by tight folding. In some places the intrusions are discordant, bifurcating and forming an interlaced pattern (e.g., in the Fisher Creek area east of the Malone Creek Granite).

Lithology. The main rock type is massive, medium to coarse, grey, quartz dolerite. It has a typical intersertal fabric of plagioclase, clinopyroxene, and mesostasis. Clinopyroxene (typically colourless augite) occurs as ragged subprismatic crystals which are marginally altered to actinolite, hornblende, chlorite, sphene and carbonate. Idiomorphic plagioclase crystals, mostly labradorite, are strongly altered to white mica and prehnite, and are partly enclosed by clinopyroxene. The mesostasis forms up to 5% and consists of graphic intergrowths of quartz and K-feldspar, anhedral quartz, minor euhedral K-feldspar, magnetite, biotite, and rare apatite. Epidote, sphene and carbonate are common secondary minerals present.

The quartz dolerite is, in places, altered to amphibolite, where regional metamorphic amphibole is the dominant mafic mineral present. On the margins of the intrusions, where conversion to an amphibolite is complete, the dolerite is mostly

recrystallised to an amphibolite of weakly to strongly foliated fibrous actinolite, chlorite, ribbon quartz, sphene, and epidote.

Remarks. The Zamu Dolerite probably intruded into undeformed strata as conformable bodies in a single igneous event at about 1880--1870 Ma, involving one parent magma. Ferguson & Needham (1978) concluded that the intrusions are part of a major Early Proterozoic tholeiitic suite in the Pine Creek Geosyncline. The intrusions are orthopyroxene-normative and their major and trace-element chemistry closely parallels the trends of other continental tholeiitic suites.

SYN- TO POST-OROGENIC FELSIC VOLCANICS AND SEDIMENTS

Two groups of Early Proterozoic volcanic (mainly felsic) rocks and associated sediments have recently been recognised beneath the Middle Proterozoic Kombolgie Formation (Needham & Stuart-Smith, 1985 a & b). The units of these groups were previously regarded as Middle Proterozoic (Carpentarian) in age and combined into the "Edith River Volcanics" (Walpole & others, 1968). The older El Sherana Group (1860 Ma) lies unconformably beneath the younger Edith River Group (1850 Ma, Needham & others, 1985). The Malone Creek Granite and probably related porphyritic alkali syenite and alkali granite dykes intrude the El Sherana Group, but are not seen to intrude the Edith River Group.

EL SHERANA GROUP

The El Sherana Group crops out mainly in the west around the base of the Mount Callanan Basin and the western margin of the Birdie Creek Basin. In the northeast, it forms small outliers on Early Proterozoic metasediments and dolerite and in places is exposed at the footslope of the Arnhem Land escarpment.

The group, named after the El Sherana uranium mine (GR 314051), was described by Needham & Stuart-Smith (1985b). In STOW, it is a conformable sequence up to 2650 m thick of flyschoid and fluvial sediments and volcanics, and is divided into the Scinto Breccia, Coronation Sandstone, Pul Pul Rhyolite, and Big Sunday Formation. Tight to open folds, which are more clearly evident in the sediments, are mainly north-trending and subhorizontal, parallel to major faults in the region.

Scinto Breccia (Bbs)

The Scinto Breccia was originally described by Walpole & others (1968) as the "Scinto Breccia Member" of the "Edith River Volcanics". Owing to its distinctive lithology (and genesis therefore), it has been elevated to formation status (Needham & Stuart-Smith, 1985b). The name is derived from the Scinto group of uranium mines near El Sherana, and the type section is at Cliff Face mine (GR 355026), where the Scinto Breccia unconformably overlies the Koolpin Formation.

The breccia, up to 100 m thick, is pink, siliceous, and phosphatic in most places, composed of angular blocks of silicified dolomite, quartzite, rare phyllite and altered rhyolite in a hematitic coarse poorly sorted sandy to highly silicified matrix. The breccia is irregularly distributed, commonly resting upon silicified dolomite of the Koolpin or Kapalga Formations. In places, such as near the Cliff Face prospect, it interfingers with or is conformably overlain by the Coronation Sandstone, and near the peak of Coronation Hill appears to have slumped over this sandstone from a position initially above Koolpin Formation carbonate.

About 14 km south-southwest of Sleisbeck near the Katherine River, discontinuous outcrops of red and white siliceous quartz--hematite breccia are tentatively included in the Scinto Breccia. The relationship of the breccia to nearby outcrops of Big Sunday Formation and Plum Tree Creek Volcanics is uncertain owing to poor exposure. In places, moderately dipping disrupted bedding features and "ripple marks", possibly sedimentary or tectonic in origin, indicate that the breccia may be developed over thinly bedded silicified dolomite possibly within the Big Sunday Formation. Four costeans on one of the northernmost outcrops expose a massive hematite/magnetite lode about 15 m wide within the quartz hematite breccia.

As the Scinto Breccia occurs at the base of the El Sherana Group chiefly over older carbonate rocks, it most probably formed *in situ* as a regolith during a weathering episode represented by the unconformity at the base of the El Sherana Group (Walpole & others, 1968; Needham & Stuart-Smith, 1985 a, b). Local reworking of the breccia, in places, is indicated by interfingering relationships with the Coronation Sandstone.

Coronation Sandstone (Ebc)

The Coronation Sandstone forms a valley-fill sequence up to 750 m thick of mixed sediments and volcanics in the far northwest, where it is faulted against and unconformably overlies older Early Proterozoic rocks (Fig.3). It laps up against and, locally, is draped over northwest-trending ridges of the older rocks. The unit is irregularly distibuted and is mostly confined to the valley of the South Alligator River between Coronation Hill and El Sherana. It also crops out as lenses beneath the Pul Pul Rhyolite on the northwest and southeast margin of the Malone Creek Granite, and as small outliers farther to the east and north. In many places, the formation is absent and the Pul Pul Rhyolite, which conformably overlies it, rests directly on the Early Proterozoic metasediments. Locally, the Coronation Sandstone conformably overlies or interfingers with the Scinto Breccia, and is overlain unconformably by the Middle Proterozoic Kombolgie Formation (Fig.4).

The Coronation Sandstone was originally described by Walpole & others (1968) as the "Coronation Member" of the "Edith River Volcanics". It was elevated to formation status and emplaced within the El Sherana Group by Needham & Stuart-Smith (1985a,b). The name is derived from Coronation Hill (GR 406965) where the type section is located.

The formation consists of a wide variety of sediments and volcanics including sandstone, conglomerate, brown and purple shale, siltstone, sandy siltstone, greywacke, tuff, ignimbrite, rhyolite, agglomerate and mafic volcanics. The rock types grade into one another over short distances reflecting the original restricted extent of lava flows and the rugged palaeo-topography. Sandstone is the most definitive lithology in the formation (as this lithology does not occur in any other part of the El Sherana Group), and was thus incorporated in the stratigraphic name.

Purple very coarse to pebbly, cross-bedded, poorly sorted, clayey and feldspathic sandstone lenses up to 75 m thick are concentrated near the base of the formation. Up to three lenses are present east of El Sherana, which define a paleo-valley filled with a 750 m-thick sequence of alternating fluvial deposits and felsic flows. Massive polymictic cobble or boulder conglomerate beds up to 15 m thick are associated with the lenses at the base. The boulders are typically well-rounded and consist of altered penecontemporaneous felsic volcanics, volcanilithic sediments, and locally derived Early Proterozoic metasediments.

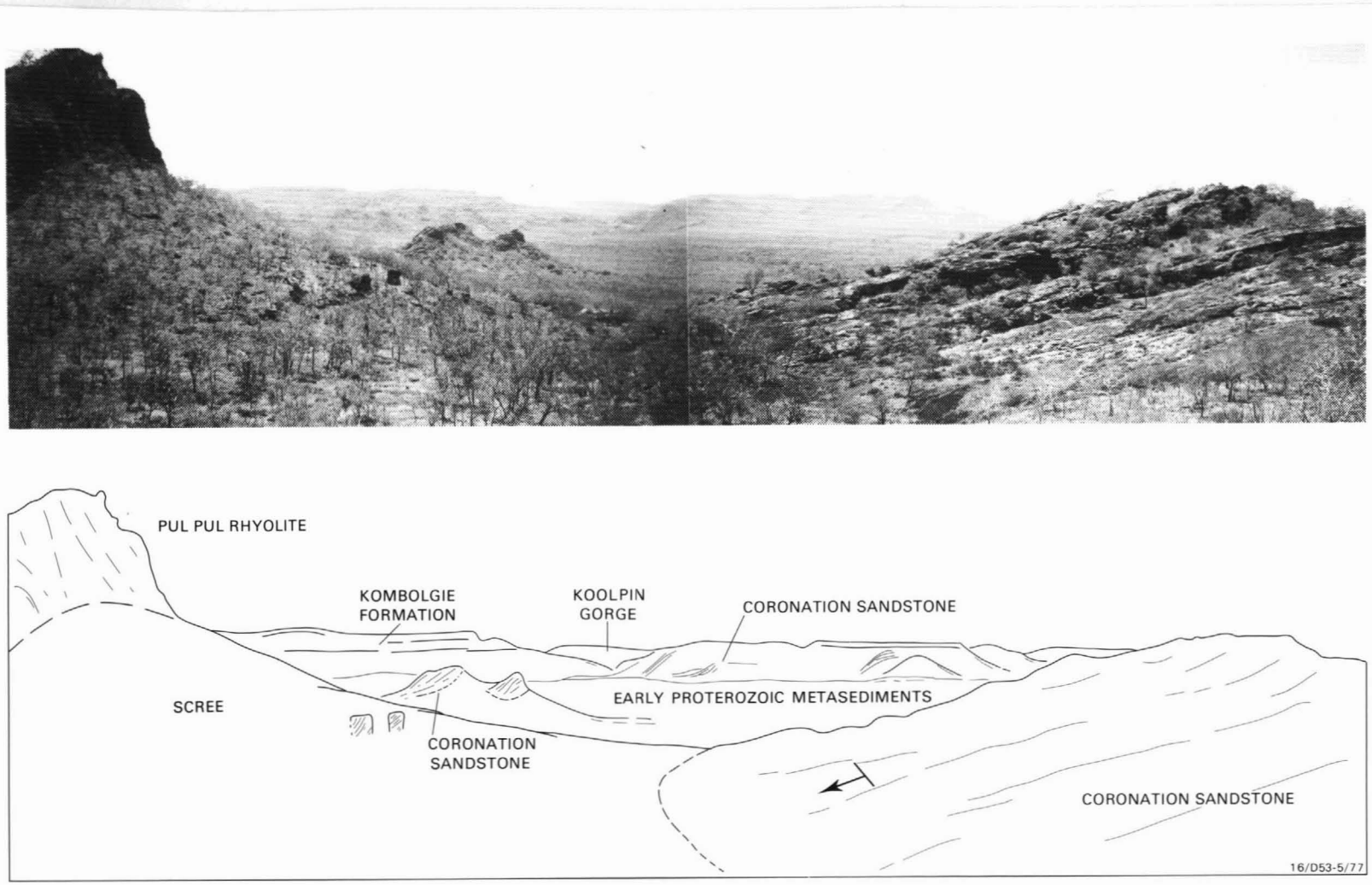

Figure 3. Panoramic view looking east to the Koolpin Gorge from the El Sherana West--Monolith prospect track. In the right foreground and centre left, gently dipping pavements of sandstone of the Coronation Sandstone form two separate valley--fill sequences up to 750 m thick sparated by Early Proterozoic metasediments. The angular unconformity between the flat-lying Kombolgie Formation and more steeply dipping Coronation Sandstone can be seen in the distance.

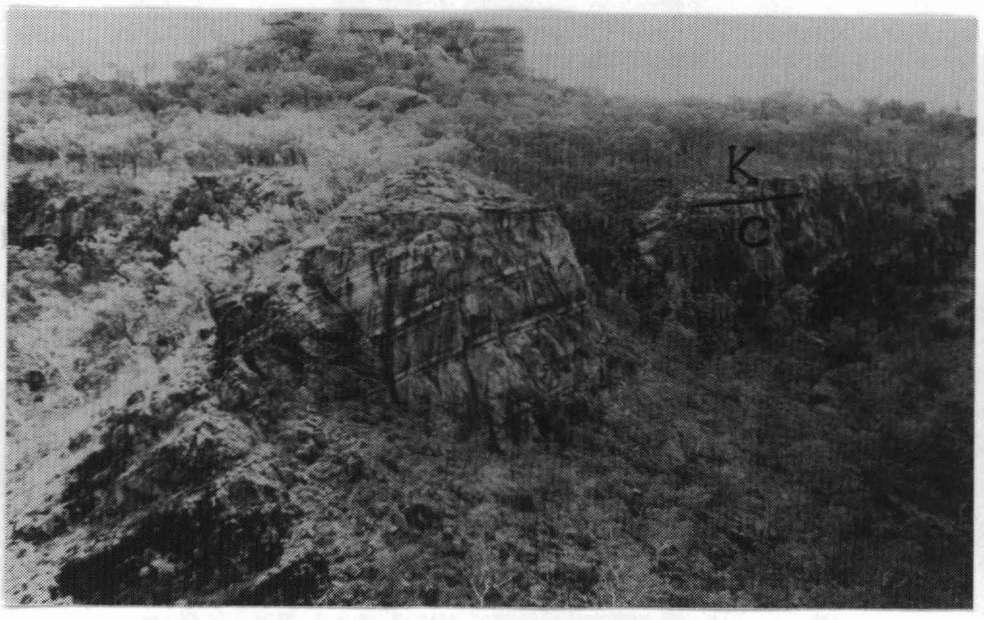

Figure 4. Angular unconformity between the gently dipping Early Proterozoic Coronation Sandstone (C) and the flat-lying Middle Proterozoic Kombolgie Formation (K).

Boulders of foliated quartzite are ubiquitous at GR 310050, where the conglomerate rests on the Mundogie Sandstone, and boulders of dolomite, dolarenite and basalt clasts are widespread in conglomerate lenses interbedded with basalt south of Pul Pul Hill near the 'Pul Pul Bioherm'. Pebbles and angular clasts of foliated feldspathic greywacke, phyllite, carbonaceous phyllite, phyllitic siltstone, silicified dolomite, and vein quartz are also common throughout the region.

Recessive, interbedded brown and purple shale, siltstone, sandy siltstone, micaceous greywacke green cherty lithic tuff, felsic and mafic volcanics form the remainder of the unit. They are normally poorly exposed between sandstone lenses, except around the Malone Creek Granite where the sandstone lenses are minor or absent and felsic and mafic volcanics are predominant. The felsic volcanics, which include massive and fractured purple and green ignimbrite, siliceous pink rhyolite and agglomerate, typically have quartz and minor alkali feldspar phenocrysts, and are extensively silicified and altered to chlorite, carbonate, epidote and sphene. Drusy cavities filled with these secondary minerals are common. The mafic volcanics are also extensively altered to quartz, carbonate, chlorite, epidote and iron oxides. They are characteristically slightly porphyritic with minor phenocrysts of tabular plagioclase and subprismatic hornblende or augite in places. The mafic minerals are mostly altered to chlorite or actinolite and the feldspar is carbonated. Feldspar laths and minor colourless clinopyroxene are the only primary minerals in the groundmass, which typically has a orthophyric and subtrachytic fabric. Amygdales containing epidote, carbonate and sulphide are present in places.

The Coronation Sandstone is a fluviatile valley-fill sequence, deposited at about 1860 Ma in a developing graben. The floor of this structure consisted of a strike ridge topography which was most pronounced northwest of Coronation Hill (Needham & Stuart-Smith, 1985b). The sediments were derived from the older Early Proterozoic metasediments and contemporaneous, mainly felsic, volcanics.

Pul Pul Rhyolite (Ebp)

The Pul Pul Rhyolite, originally described as the "Pul Pul Rhyolite Member" of the "Edith River Volcanics" (Walpole & others, 1968) has been elevated to formation status and placed within the El Sherana Group (Needham & Stuart-Smith, 1985b). The rhyolite is named after Pul Pul Hill, a prominent peak in the

South Alligator Valley (GR 383990). It is well exposed as rocky ridges around the western and southern margins of the Malone Creek Granite, and extends discontinuously along the South Alligator Valley northwest through El Sherana into adjoining MUNDOGIE.

The Pul Pul Rhyolite consists of an extensive 1300 m-thick sheet of rhyolitic purple to pink ignimbrite and minor agglomerate, concoidally fractured devitrified black rhyolite, and rare interbeds of siltstone and shale, which conformably overlies the Coronation Sandstone, and in places overlaps it to rest unconformably on Pine Creek Geosyncline metasediments. It is overlain conformably by the Big Sunday Formation and unconformably by the Kombolgie Formation, and is intruded and hornfelsed by the Malone Creek Granite. Near Big Sunday, the unit is also invaded by northeast-trending dolerite dykes and a small stock of porphyritic alkali feldspar granite probably cogenetic with the Malone Creek Granite. The rocks are flow-banded and columnar jointed, and the ignimbrite is altered.

The ignimbrite and black rhyolite typically contain crystal fragments of quartz, alkali feldspar, plagioclase and rare chloritised mafic minerals in a weakly fluidal altered siliceous base with rare zircon, biotite, tourmaline and patchy secondary calcite, chlorite, epidote and sericite. Rock fragments commonly present in the ignimbrite and agglomerate include pitchstone, spherulitic rhyolite, chloritized mafic rocks and rare greywacke and phyllite, and measure up to 10 cm.

Rare thin interbeds of shale and siltstone are exposed in the El Sherana area and east of the Malone Creek Granite. They consist chiefly of chlorite, sericite, iron oxides and quartz, and are possibly reworked tuffaceous epiclastic sediments.

Big Sunday Formation (Bbb)

The Big Sunday Formation is the youngest unit of the El Sherana Group in STOW and was previously mapped by Walpole & others (1968) as Masson Formation, Burrell Creek Formation and undivided "Edith River Volcanics". The unit is probably a lateral equivalent of the Tollis Formation, which is widespread to the west and south in RANFORD HILL (Stuart-Smith & Bagas, in prep), Edith River Region (Needham & others, in prep.-a) and Yeuralba Region (Needham & others, in prep.-b).

The formation is exposed in the South Alligator Valley

between 3 km southeast of Coronation Hill and 7 km south of Big Sunday, in the Mount Stow area in the southwest and in the Turnoff Creek area. It is named after Big Sunday a prominent hill (GR 457890) 2 km northwest of the type section (GR 480875 (bottom) to GR 472867 (top)). The northwest-trending Palette Fault separates an ignimbritic upper part of the section from a basalt--greywacke lower part at GR 476870.

In the type area, the formation consists of a lower 280 m-thick sequence of interbedded fine to coarse and pebbly, micaceous, feldspathic, volcanilithic greywacke, green shale, devitrified vitric tuff and vitric crystal tuff, and minor micaceous siltstone, sandy siltstone and fine quartzite, and an upper unit at least 200 m thick, of interlayered amygdaloidal dark green basalt and flow-banded massive pink and purple rhyolite and ignimbrite. It rests here conformably on the Pul Pul Rhyolite with a well-exposed contact and is unconformably overlain by the Kurrundie Sandstone, which forms the base of the Mount Callanan Basin to the west. It is also unconformably overlain by Cretaceous sediments at the headwaters of the South Alligator River, and intruded by small bodies of alkali feldspar syenite and granite (probably comagmatic with the Malone Creek Granite) along the trace of the Palette Fault. This fault downthrows the formation against the Pul Pul Rhyolite.

Extensive deeply weathered, low-lying rubbly exposures of mixed felsic volcanics and sediments in the Turnoff Creek area have been included in the Big Sunday Formation, although their relationship with the adjacent units is unclear. They are unconformably overlain by the Kombolgie Formation of the Birdie Creek Basin and are surrounded by Plum Tree Creek Volcanics to the west. The contact with the volcanics approximates the course of the northern part of Turnoff Creek and appears disconformable. Differing phototones, geomorphology and the wide variety of lithology included in the Big Sunday Formation, differentiate the unit from the overlying Plum Tree Creek Volcanics. Felsic volcanics found include interbedded flow-banded red grey and brown rhyolite, commonly with numerous angular clasts of pelitic rocks and minor tuff, laminated to massive red or grey rhyolite with quartz and alkali feldspar phenocrysts, and light grey silicified rhyolitic breccias. Sedimentary rocks include fine to medium-grained greywacke interbedded with siltstone, phyllite, slate and argillite. The argillite crops out mainly west of Turnoff Creek and the Katherine River as prominent near-meridional ridges. It is faulted against the Plum Tree Creek Volcanics to the west and dips steeply to the east. Minor chert-

banded ferruginous siltstone also occurs in the vicinity of the Turnoff Creek/Katherine River confluence and appears to be folded disharmoniously, indicating possible soft- sediment deformation. The relationship between the sediments and felsic volcanics rocks is not clear; it is possible, owing to lithological similarities, that they may be inliers of the South Alligator Group.

In the Mount Stow area in the southwest, about 500 m of interbedded black to greenish grey devitrified vitric tuff, greywacke, and minor volcanilithic pebble conglomerate and siltstone are openly folded about northwest-trending subhorizontal axes. The sequence is unconformably overlain by, or faulted against, the Plum Tree Creek Volcanics, unconformably overlain by Cretaceous sediments, and downthrown against the Burrell Creek Formation to the southwest by the Lambell Fault. Although the sequence is similar to the Mount Bonnie Formation in the South Alligator Group found in adjacent areas, its younger age is indicated by the phyllite and foliated greywacke pebbles within the volcanilithic conglomerate which is itself massive and unfoliated.

EDITH RIVER GROUP

The Edith River Group crops out in STOW around the eastern margin of the Mount Callanan Basin in the west, and around the western margin of the Birdie Creek Basin in the south. It overlies the Early Proterozoic geosynclinal metasediments, and sediments and volcanics of the El Sherana Group, with marked angular unconformity, and is faulted against them in places. It is unconformably overlain by the Middle Proterozoic Kombolgie Formation and flat-lying Cretaceous sediments, mostly with a moderate to shallowly angular contact; in many places the contact with the Kombolgie Formation is sheared or disconformable. Contacts are obscured in most places by talus derived from overlying Kombolgie Formation, or by unconsolidated Cainozoic sand deposits in low-lying areas. In STOW, the group includes the basal Kurrundie Sandstone and the more extensive Plum Tree Creek Volcanics.

Kurrundie Sandstone (Bek)

Apart from a cluster of small outliers 8 km southeast of Big Sunday, the Kurrundie Sandstone is restricted to west of the South Alligator Fault, where it crops out as a prominent strike ridge at the base of the Mount Callanan Basin. It unconformably overlies the Namoona and El Sherana Groups and is faulted against

them northwest of Coronation Hill by the South Alligator Fault. The unconformable contact with the El Sherana Group is exposed about 1 km north of Big Sunday, but mostly the contact is covered by talus. Dips steepen progressively northwestwards from less than 5° at the headwaters of the South Alligator River up to 80° near El Sherana, close to the South Alligator Fault. The sandstone is conformably overlain by the recessive Plum Tree Creek Volcanics.

The Kurrundie Sandstone consists mostly of massive clayey medium to coarse, lithic quartz sandstone, strikingly coloured purple, interbedded with polymictic pebble and cobble conglomerate, massive to laminated white, pink, and brown, fine to coarse quartz sandstone, and minor thinly bedded micaceous brown sandy siltstone. Clasts in the conglomerate (up to 20 cm across) and lithic sandstone include quartz, chert, felsic volcanic rock fragments, phyllite, foliated quartzite and feldspar. The clasts were probably derived locally from the underlying Early Proterozoic metasediments and volcanics. The matrix of both rocks is mostly clay and iron oxides with minor authigenic quartz.

The sequence ranges in thickness from 60 m near Coronation Hill to a maximum of 350 m south of Big Sunday. A thickness of at least 120 m can be measured in the far northwest near El Sherana, where an incomplete section is exposed. The two areas of thickest development near El Sherana and south of Big Sunday, also have more pebbly and conglomeratic horizons, possibly indicating the entry points of major fluvial systems, probably from the east into the Mount Callanan Basin. Limited measurements of tabular cross-beds indicate a westerly current in STOW.

Plum Tree Creek Volcanics (Bep)

The Plum Tree Creek Volcanics forms the bulk of the Edith River Group in STOW, cropping out in the northwest beneath the Kombolgie Formation escarpment along the eastern flanks of the Mount Callanan Basin and in a large inlier south of Sleisbeck. Outcrop is good and ridges, tors and pavement outcrops are common. In the south the unit is cut by rectilinear joint sets with major 180°,090°--100°, 050°, and 140°--170° trends. The easterly trends, with few exceptions, coincide with dolerite dykes, which also intrude along faults within the Kombolgie Formation. The southeasterly and some northerly trends are commonly expressed as quartz breccia-filled faults which crop out

as low strike ridges. Flow-banding or bedding dip directions are difficult to determine over much of the area, but where present are less than 20°, indicating that the unit is probably subhorizontal. In the northwest, along the margin of the Mount Callanan Basin, beds dip up to 70° to the southwest.

The volcanics include areas mapped by Walpole & others (1968) as (in the northwest) the "Plum Tree Creek Volcanic Member" of the Kombolgie Formation and (in the south) undivided "Edith River Volcanics" or Grace Creek Granite. The unit was redefined and elevated to formation status by Needham & Stuart-Smith (1985b). The Grace Creek Granite is compositionally similar to the volcanics and is probably an associated subvolcanic intrusion. Contacts between the volcanics and the granite appear gradational and ill-defined. The volcanics rest conformably on the Kurrundie Sandstone and overstep it in the south to rest unconformably on, and in places faulted against, the Burrell Creek and Big Sunday Formations. The contact with the Big Sunday Formation south of Sleisbeck in the Turnoff Creek area is obscure. The volcanics are unconformably or disconformably overlain by the Kombolgie Formation and Cretaceous sediments. Commonly the upper contact is covered by talus from the overlying units. In the far southeast, the volcanics are intruded by northeast-trending dolerite dykes.

The Formation is about 500 m thick, and consists almost entirely of columnar-jointed and rarely flow-banded massive, concoidally fractured, red or pink rhyodacitic ignimbrite. Minor white to pale green rhyolite with minor quartz and feldspar phenocrysts are present in places, and rare pyritic grey tuff is exposed 1.5 km west of the Turnoff Creek/Katherine River confluence. Mafic rocks and clastic sediments in the formation elsewhere (Stuart-Smith & Bagas, in prep; Needham & others, in prep.-a) are absent in the region. The ignimbrite has a distinct weathered pitted surface caused by the preferential weathering of andesine and microcline phenocrysts. Minor phenocrysts of quartz and chloritised hornblende are also widespread. The groundmass is fluidal and consists of microcrystalline quartz, kaolinised feldspar, chlorite and trace amounts of apatite, zircon, sphene and biotite. Variations in the rock are minor and confined to varying proportions of phenocrysts or fine mafic xenoliths which are ubiquitous in the ignimbrite and range up to 25 cm across. Crumbly, mottled, purple, pink and green rocks in a narrow belt exposed close to the Kombolgie Formation contact in the south are a weathering product of the ignimbrite (or in places Grace Creek Granite) and define a paleo-weathering profile beneath the

Kombolgie Formation similar to that described by Needham & others (1980) in the northern Alligator Rivers region. They were interpreted by Walpole & others (1968) as "Edith River Volcanics" resting unconformably on granite.

SYN- TO POST-OROGENIC FELSIC INTRUSIONS

Two granite plutons, the Grace Creek and Malone Creek Granites, invade the syn- to post-orogenic felsic volcanic and sediment sequences. The Grace Creek Granite is probably a subvolcanic intrusion coeval with the Plum Tree Creek Volcanics. The Malone Creek Granite and associated porphyry dykes cut the El Sherana Group and older units; however, there are no contacts with the Edith River Group or Younger strata.

Grace Creek Granite (Beg b,c,d)

South of the Birdie Creek Basin, ignimbrite of the Plum Tree Creek Volcanics surrounds porphyritic grey--pink microgranite (Pegd), pink--grey medium-grained porphyritic granite (Pegc), and slightly porphyritic grey--green medium-grained granite (Pegb) of the Grace Creek Granite. Where very fine or microcrystalline, these granitic rocks are very similar to the Plum Tree Creek ignimbrites, and are red with phenocrysts of feldspar, quartz and chloritised hornblende. Also, they characteristically have xenocrysts of eroded feldspar and xenoliths of mafic volcanics, hornfels, and rare medium to coarse granite.

The groundmass of both the microgranite and granite contains the same accessory minerals as the ignimbrite, but is mostly a fine graphic intergrowth of alkali feldspar and quartz. Owing to the generally very similar appearance, the ignimbrite--microgranite contact has not been precisely located and appears gradational. Farther to the south in YEURALBA, the Grace Creek Granite shows a roughly concentric zoning coarsest near the centre (Needham & others, in prep.-b). The granite is probably a subvolcanic intrusion, comagmatic with ignimbrite of the Plum Tree Creek Volcanics.

Where weathered beneath the Kombolgie Formation, the granite is indistinguishable from weathered ignimbrite of the Plum Tree Creek Volcanics.

Malone Creek Granite (Bgm a,b,c)

The Malone Creek Granite (Raggatt, 1958; Walpole & others,

1968) is an almost circular pluton about 10 km in diameter, which crops out as a rugged bouldery, deeply dissected plateau rising up to 150m above the adjoining plains. The hills form the catchment of Coronation Creek (also known as Malone Creek, from which the name of the granite was derived) which flows westwards into the South Alligator River near Coronation Hill. The creek and its tributaries have mostly followed the prominent northwest and north-trending joints in the granite.

The granite intrudes the Burrell Creek Formation, Zamu Dolerite, Coronation Sandstone, and Pul Pul Rhyolite with a sharp discordant contact. Bryan (1962) described the granite contact with the Zamu Dolerite. Metasediments are contact metamorphosed within a contact aureole about 200 m wide: pelitic rocks contain altered cordierite porphyroblasts and greywacke is silicified. The only noticeable change in volcanic rocks is the presence of aplite and pegmatite veins.

Several discontinuous northeast to east-trending dolerite dykes transgress the granite and the surrounding rocks.

The granite consists of three phases of alkali feldspar granite which form broad concentric gradational zones. Fine to medium-grained slightly porphyritic pink alkali feldspar granite (Bgma) is the centre of the pluton and comprises scattered quartz and K-feldspar phenocrysts, up to 1 cm across, in a fine groundmass of cloudy K-feldspar, about 30% quartz, and 1% biotite. Quartz and K-feldspar are chiefly graphically intergrown. Up to 5% kaolinised plagioclase, and minor allanite and sphene (Walpole & others, 1968), are present in places. Biotite is mostly altered to chlorite, white mica and iron oxides. The middle zone (Bgmb) is fine to coarse even-grained to porphyritic alkali feldspar granite, and commonly contains traces of fluorite, epidote and carbonate. The outer zone (Bgmc) is fine, even-grained chloritised greenish pink alkali feldspar granite, with abundant fluorite, epidote and carbonate; quartz and greisen veins are widespread and K-feldspar phenocrysts are rarely present.

The age of the Malone Creek Granite is uncertain, but its maximum age is constrained by its intrusive relationship with the 1860 Ma old El Sherana Group. Leggo (in Walpole & others, 1968) determined a minimum Rb/Sr age of about 1760 Ma for the granite. Riley (1980) recalculated Leggo's data and indicated an age of about 1780±20 Ma for all the post-orogenic granitoids of the Katherine--Darwin region. Samples of the Malone Creek Granite

collected for age determination in 1979 have so far yielded insufficient zircon to obtain a U/Pb age (Page, BMR, pers. comm., 1986).

Unnamed granite and syenite intrusions

Porphyritic alkali feldspar granite and syenite dykes and stocks, up to 500 m across, are exposed 2 to 3 km distant from the Malone Creek Granite around its southwestern and eastern margins, where they intrude the Early Proterozoic geosynclinal metasediments and El Sherana Group rocks. The intrusions, consisting of K-feldspar and plagioclase phenocrysts in a groundmass of fine-grained K-feldspar, quartz, chlorite, epidote and carbonate, may be genetically related to the nearby Malone Creek Granite.

POST-OROGENIC MAFIC INTRUSIONS

Post-orogenic mafic intrusions in the region include lopoliths and dykes of the Oenpelli Dolerite, and unnamed dolerite dyke swarms. The Oenpelli Dolerite intrudes only Early Proterozoic rocks, whereas the dyke swarms invade both Early and Middle Proterozoic rocks.

Oenpelli Dolerite (Bdo)

The Oenpelli Dolerite crops out in the north on the plains west of Mount Evelyn, and in the floor of narrow gorges in the Arnhem Land Plateau east of Mount Evelyn and north of Zamu Creek mine. In the gorges, outcrops are mostly covered by sandstone talus from the Kombolgie Formation, which unconformably overlies the dolerite. On the plains, the dolerite intrudes the Early Proterozoic metasediments and the Zamu Dolerite. Well-defined narrow contact aureoles form low ridges, but the contact is not exposed.

The Oenpelli Dolerite has been described in detail from areas north of STOW by Smart & others (1976) and Stuart-Smith & Ferguson (1978). It forms symmetrically differentiated layered sheet-like intrusions (probably lopoliths) intruding Early Proterozoic rocks after the 1870 Ma regional metamorphism. The dolerite has yielded a concordant Rb--Sr total-rock and mineral age of about 1690 Ma (i.e., earliest Middle Proterozoic; Page & others, 1980; Page, 1981).

The exposures in the region are probably continuous beneath thin skeletal soil and Quaternary alluvial cover and are part of a sheet-like intrusion up to 250 m thick. The sheet dips shallowly to the northeast and forms the southwestern edge of a large ellipsoidal basin-like structure at least 100 km long by 50 km across. West of Mount Evelyn, three vertical dykes, up to 100 m thick, extend southwesterly up to 2.5 km from the intrusion near a point where its strike swings sharply. The main intrusion consists of symmetrically differentiated layers of olivine dolerite and minor felsic differentiates of quartz dolerite and granophyre.

Stuart-Smith & Ferguson (1978) suggested that the Oenpelli Dolerite forms a major tholeiitic province which has "... evolved by polybaric olivine fractionation during slow, or intermittent, uprise from higher-magnesia magma generated by partial melting within the upper mantle; plagioclase is an additional liquidus phase at shallow-crustal levels". The magma was intruded at 1 to 2 km depth as sheet-like bodies which crystallised from the upper and lower margins towards the centre, where the more felsic differentiates are concentrated.

Unnamed dolerite dykes

Swarms of east-northeast-trending fine-grained dolerite dykes intrude Early and Middle Proterozoic rocks in the southeast, in the Birdie Creek area, and in the north, around the Malone Creek Granite area. The dykes, up to 50 m wide, fill major faults and joints in the Plum Tree Creek Volcanics, Grace Creek Granite, and the Kombolgie Formation. They comprise magnetite-bearing quartz dolerite, showing patchy chlorite and carbonate alteration. Some of the dykes have a strong linear magnetic expression similar to a dyke, dated at 1370 Ma (Page & others, 1980), which transgresses the Ranger orebody in CAHILL.

CONTINENTAL SEDIMENTS

Largely undeformed Middle Proterozoic continental sediments and minor volcanics of the Katherine River Group rest on older rocks with marked unconformity. They form the tablelands, the most prominent physiographic feature in the region.

KATHERINE RIVER GROUP

The only representative of this group in the Stow region is the Kombolgie Formation, which, following modifications to the stratigraphic interpretation of the lower part of the group by Needham & others, (1980), is now its basal unit.

Kombolgie Formation (Bhk)

The Kombolgie Formation forms, respectively, the gently sloping, deeply dissected Arnhem Land Plateau in the north and northeast, and the Mount Callanan and Birdie Creek Basins in the northwest and southeast. All three structures are bordered by escarpments up to 200 m high, commonly flanked by sandstone talus. Bedding dips are mostly shallow to moderate except adjacent to the T-Bone Fault, where locally tightly folded beds dip up to 70^{o}. Local intraformational angular unconformities are present near the fault west of Sleisbeck, indicating syn-depositional movement; the fault forming the northern margin of the Birdie Creek Basin.

The formation overlies with marked angular unconformity all Early Proterozoic rocks (metasediments, dolerite, volcanics and granite), and is overlain by flat-lying Mesozoic deposits and a thin veneer of Cainozoic unconsolidated sand, laterite and alluvium. Along the northern margin of the Birdie Creek Basin, the formation is thrown against older rocks by the T-Bone Fault. Numerous dolerite dykes intrude the formation along a major east-northeasterly joint and fault trend, particularly in the southeast.

In the region, the Kombolgie Formation comprises two unnamed sandstone subunits, separated by a discontinuous volcanic horizon; the latter includes the Nungbalgarri, Birdie Creek and Mount Callanan Volcanic Members. In places, beneath the volcanics, and where they are absent, the unit has siltstone and intraformational breccia. An upper volcanic horizon present in the formation elswhere (Needham, 1984) is not present.

The lower sandstone subunit (Bhk_1) varies considerably in

thickness, being 1000 m thick in the Mount Callanan Basin, 700-1000 m thick in the Birdie Creek Basin, and up to 200 m thick in the Arnhem Land Plateau. In the plateau, the subunit thins to the east and finally pinches out east of Mount Evelyn. It consists of massive, poorly sorted fine to coarse and pebbly, white, brown, pink or purple quartz sandstone, well-sorted fine to medium-grained quartz sandstone, and minor thin interbeds of siltstone, and sandstone and vein-quartz breccia. Tabular cross-beds and ripple marks are widespread. The base is usually marked by a polymictic boulder conglomerate up to 3 m thick with predominantly vein-quartz clasts. Near the Turnoff Creek/ Katherine River confluence a basal conglomerate lens up to 100 m thick and 2.5 km long with rounded to angular clasts of rhyolite, silicified tuff, minor quartzite and vein quartz up to 40 cm across. A similar smaller lens crops out 6 km to the south in which vein-quartz clasts predominate.

Deeply weathered and highly altered mafic rocks of the Nungbalgarri Volcanic Member (Bhn) are confined to the Arnhem Land Plateau. They contain amygdales filled with chalcedony, chlorite and iron oxides, and are poorly exposed as rubble on sandstone pavements about 13 km northeast of Mount Evelyn. The outcrops, truncated by the Gimbat Fault, form the southernmost exposures of the volcanic member, and are less than 1 m thick. Where the volcanics are absent, such as 12 km northeast of Gimbat homestead, and also in places beneath the volcanics, a 2 m-thick brown siltstone unit (Bhk_{2b}) is developed with a basal 5 cm-thick intraformational breccia with sub-angular clasts of quartz, shale, and quartz sandstone in a siliceous sandy matrix.

The Birdie Creek Volcanic Member (Bhb) is the most extensive of the volcanic members in STOW and is confined to the Birdie Creek Basin in the southeast. It is a conformable recessive continuous horizon about 150 m thick, but is mostly covered by skeletal soils and alluvium. It is exposed as low bouldery hills in a valley along the upper reaches of Birdie Creek, and as low weathered exposures along the banks of the Katherine River. The member comprises altered massive basalt, which is amygdaloidal in places. The basalt consists mostly of secondary hematite, chlorite, epidote, chalcedony, albite, carbonate and prehnite, although plagioclase laths and stubby clinopyroxene crystals are commonly preserved. Microcrystalline rounded chlorite aggregates may be pseudomorphs after olivine crystals.

At the base of the Birdie Creek Volcanic Member in the far southeast, large circular depressions in the underlying sandstone

have been attributed to hydroplastic deformation, possibly triggered by shock waves related to earthquakes associated with volcanism (Needham, 1978).

In the northwest, in the core of the Mount Callanan Basin, interbedded amygdaloidal basalt flows and minor graded chloritic vitric tuff of the Mount Callanan Volcanic Member (Bhc) are poorly exposed and deeply weathered. They form a 100 m-thick conformable horizon above the lower sandstone subunit.

The upper sandstone subunit (Bhk_2) of the Kombolgie Formation conformably overlies the three volcanic members. Southeast of Mount Evelyn, it oversteps the lower subunit to rest unconformably on older rocks. It consists of medium to coarse-grained well- sorted, buff, clayey, friable quartz sandstone which is gritty and pebbly in places. Cross-bedding and ripple marks are widespread. Maximum preserved thickness of the unit are 60 m in the Mount Callanan Basin, 100 m on the Arnhem Land Plateau, and 300 m in the Birdie Creek Basin.

The Kombolgie Formation platform sediments were probably deposited as braided alluvial fans (Ojakangas, 1979) from a northwest provenance on a peneplaned, mostly metamorphic, basement. North of STOW, the Nungbalgarri Volcanic Member has yielded an age of about 1650 Ma (Page & others, 1980).

EPICONTINENTAL SEDIMENTS

MESOZOIC

Undivided flat-lying Mesozoic sediments (K) up to 40 m thick form both the Bulademo tableland in the west and remnant veneers in the southeast. They were previously mapped as "Mullaman Beds" by Skwarko (1966), but were later divided into the fluvial to shallow-marine Petrel Formation (Jurrassic to Early Cretaceous) and the Darwin Member of the Bathurst Island Formation (Early to Late Cretaceous) by Hughes (1978).

The Mesozoic sequence in STOW consists of three informal lithogical sub-units: K_1, K_2 and K_3. The lowermost sub-unit (K_1) is restricted to the Mount Stow area where it is up to 5 m thick and comprises of dark brown limonitic and goethitic poorly sorted porous very coarse to pebbly quartz sandstone, cobble conglomerate and breccia. The sub-unit is very similar to the basal part of the Mesozoic in RANFORD HILL (Stuart-Smith & Bagas, in prep), PINE CREEK Stuart-Smith & others, 1986), McKINLAY RIVER

(Stuart-Smith & others, 1986), and MUNDOGIE (Stuart-Smith & others, 1984), and probably forms part of the Petrel Formation (i.e., "Coastal Belt" of Skwarko's "Mullaman Beds").

The middle sub-unit (K_2) ranges up to 10 m thick and consists of massive friable white fine to coarse quartz sandstone. The upper sub-unit (K_3) is similar to K_2, but is yellow or reddish brown owing to the presence of limonite. It ranges up to 25 m thick. Both K_2 and K_3 possibly form part of Hughes' Darwin Member of the Bathurst Island Formation, correlating it with Skwarko's 'Inland Belt' of the "Mullaman Beds".

Skwarko (1961) described Neocomian marine pelecypods and plants, and wood fragments from a sequence similar to K_3, which forms the lowermost exposures of the Mesozoic section along the western edge of the Bulademo Tableland near the headwaters of the Mary River (in RANDFORD HILL, 10 km west of STOW). Claystone, commonly forming the uppermost part of the Mesozoic sequence in areas farther west, is not preserved in this region.

About 10 km south of Big Sunday, the Mesozoic sequence is overlain by up to 500 m of Tertiary sediments in small fault-bounded basins up to 3 km across. Here, the Mesozoic sediments dip up to 14^{o} and are at least 100 m thick. The location of similarly thickened Mesozoic fault-bounded basins in the region (e.g., in RANFORD HILL; Stuart-Smith & Bagas, in prep) indicates Mesozoic (and later Cainozoic) fault reactivation.

CAINOZOIC

Tertiary, Tertiary to Quaternary and Quaternary sediments cover parts of the Tablelands, Lowlands, and the Dissected Foothills. They also form talus slopes adjacent to the Tablelands. The deposits have been divided into the following units: laterite (Czl), sand (Czs), talus (Czt), and Quaternary alluvial sediments (Qf, Qs, Qal, Qa). Where the Tertiary to Quaternary deposits are undivided or consist mainly of skeletal soils, they are designated Cz.

Tertiary

Unnamed massive ill-sorted poorly consolidated kaolinitic sand crops out in three circular basins up to 3 km in diameter, about 10 km south of Big Sunday. The sands have been divided into a lower white unit (Tew), and an upper brown ferruginous unit (Teb), each both about 250 m thick. The sediments dip up to

40° and gravity data indicate that the largest basin, including Mesozoic strata, is about 500 m thick (A. Mackinnon-Love, Urangesellschaft Australia Pty Ltd, pers. comm., 1981). A drillhole in the centre of this basin intersected grey carbonaceous siltstone at 71 m depth, which contained a Middle to Upper Eocene pollen assemblage (A. Mackinnon Love, pers. comm., 1981). The assemblage probably indicates that the sediments were deposited in a fresh-water swamp or lake (Truswell, 1982).

Tertiary to Quaternary

Laterite (Czl) Remnant laterite on Mesozoic and Middle Proterozoic strata form a planar capping at about 320 to 380 m ASL upon the Bulademo Tableland. Generally, the laterite profiles are either detrital or are truncated remnants of the standard laterite profile, according to Whitehouse (1940). Of the laterite types described by Williams (1969) in the Adelaide River-Alligator River area, the following have been recognised: detrital, pisolitic, mottled zone, and concretionary.

Sand (Czs) Coarse unconsolidated ferruginous and clayey quartz sand forms remnants of the 'Koolpinyah Surface' of Story & others (1969), covering parts of the Lowlands and Tablelands. The sand probably are fan deposits (Story & others, 1969) derived from Mesozoic sediments, Middle Proterozoic sandstone, and Early Proterozoic rocks. Clean quartz sand, developed in situ on the tablelands from the Kombolgie Formation and Mesozoic sediments, has most likely formed continually in an erosional environment since the early Tertiary.

Talus (Czt) Talus slopes are widespread around both the Arnhem Land Plateau and the northern margin of the Mount Callanan Basin adjacent to the cliff-forming Kurrundie Sandstone and Kombolgie Formation. The talus deposits comprise extensive aprons of sandstone blocks and minor weathered rubble of Early Proterozoic metasediments and volcanics.

Skeletal soil (Cz) Sandy to gravelly skeletal soil, gradational red soils and yellow earth soils, mostly developed in situ, are widespread particularly in the centre and south over areas of Early Proterozoic metasediments, dolerite, volcanics and granite. Where this soil is thin (<1 m), such as over much of the Kapalga and Burrell Creek Formations, structures in the underlying bedrock can be seen on aerial photographs.

The skeletal soils are an accumulation of loose material by

aggradation upon the 'Upland Plains'. The Katherine River system draining the plains is stable to slightly erosional, whereas the South Alligator system is actively eroding these deposits in the northwest to produce similar colluvial plains near Gimbat homestead (the 'Lowland Plains') at about 100m lower elevation.

Quaternary

Deposition in a continental setting during the Quaternary led to the accumulation of a variety of alluvial units. Alluvial silt, sand, gravel and clay (Qa) occupy the courses and floodplains of the South Alligator and Katherine River systems. Large bodies of unconsolidated quartz sand (Qs) also occur within the channels of the major creeks and rivers. Minor silty levee deposits (Qal) are developed along the Katherine River near Sleisbeck. Black and brown humic soil and clay (Qf) are common in poorly drained depressions at the headwaters of streams, particularly upon the Bulademo Tableland, where springs support perennial growth to produce organic-rich marsh deposits.

METAMORPHISM

All the Early Proterozoic geosynclinal strata have been regionally metamorphosed to greenschist facies at about 1870 Ma and locally contact metamorphosed by the post-orogenic Malone Creek Granite and Oenpelli Dolerite (see Metamorphic and Structural Sketch on map surrounds).

REGIONAL METAMORPHISM

Two regional metamorphic zones are recognised in STOW. Rocks north of the Fisher Fault are higher grade and contain ubiquitous biotite, distinguishing them from the lower-grade rocks elsewhere. This trend is consistent with an eastward increase in metamorphic grade in adjoining MUNDOGIE (Stuart-Smith & others, 1984).

In the higher grade zone, mafic rocks of the Zamu Dolerite and Shovel Billabong Andesite are mostly recrystallised to amphibolite, consisting of actinolite, biotite/chlorite, epidote, prehnite, sphene and carbonate. Igneous textures are commonly preserved, especially in the centre of larger bodies. Primary clinopyroxene is rare and chiefly replaced by chlorite and actinolite. Plagioclase is altered to aggregates of white mica, prehnite, epidote, quartz and albite.

Mafic igneous rocks southwest of the Fisher Fault (mainly within the Stag Creek Volcanics) contain actinolite, epidote and carbonate.

Metasediments in both metamorphic zones are strongly foliated and recrystallised. Clastic grains are deformed and feldspars are mainly altered to white mica aggregates. Muscovite and chlorite are the chief minerals and biotite is present only in the higher-grade zone. Some iron-rich pelites of the Kapalga Formation have late syn-tectonic magnetite porphyroblasts.

Impure carbonate rocks of the Kapalga Formation near Gimbat homestead are recrystallised to a banded amphibolite with dolomite, chlorite, epidote and tremolite. Pyritic, carbonaceous and dolomitic siltstone in the Koolpin Formation intersected in a drillhole 10 km south-southwest of Big Sunday contain dolomite and chlorite.

CONTACT METAMORPHISM

In the northwest, a contact-metamorphic aureole up to 200 m wide surrounds the Malone Creek Granite. Contact effects are limited to cordierite porphyroblasts in pelitic rocks and silicification and recrystallisation of sandstone units. There is no apparent change in volcanic rocks, but in places they are cut by aplite and pegmatite veins radiating from the granite.

Metasediments intruded by the Oenpelli Dolerite are indurated within a well-defined narrow (<50 m wide) contact aureole, expressed topographically as a low ridge. Zamu Dolerite, where hornfelsed by the Oenpelli Dolerite, is extensively altered to actinolite, prehnite and carbonate.

STRUCTURE

At about 1870 Ma, the Early Proterozoic geosynclinal strata and intrusive dolerite (Zamu Dolerite) underwent a major period of deformation which accompanied greenschist facies regional metamorphism ('Top End Orogeny'), resulting in tight to isoclinal folding and extensive faulting. Late Early Proterozoic and Middle Proterozoic rocks are mildly deformed and form fault-bounded basins, namely the Mount Callanan and Birdie Creek Basins. Mesozoic and younger sediments are undeformed except adjacent to a fault 10 km south of Big Sunday, where Tertiary strata dip up to 40^{o}.

FOLDING

Small isoclinal fold noses within chert-banded hematitic siltstone of the Kapalga Formation may represent the earliest deformation. These folds may be the result of a high-strain zone, possibly associated with early thrusts or low-angle fault zones, similar to those identified at the base of the Koolpin Formation in MUNDOGIE (Stuart-Smith & others, 1984; Johnston, 1985). Such a thrust zone could well explain the stratigraphic anomalies east of the Fisher Fault (i.e., absence of the Gerowie Tuff).

The structure of the Early Proterozoic geosynclinal sequence is dominated by regional northwest to west-northwest-trending, subhorizontal, tight to isoclinal folds (Fig. 5). Bedding is commonly parallel to a strong phyllitic to schistose axial plane foliation, which is near vertical or dips steeply to the southwest. This foliation is the dominant structural surface, developed during the peak of regional metamorphism by alignment of muscovite, chlorite, biotite, actinolite, and within clastic sediments, flattened grains and pebbles. In places, quartz segregations form veins parallel to the foliation. Magnetite porphyroblasts in iron-rich pelites have a late syn-tectonic relationship.

The regional folds and schistosity are locally disrupted by south to south-southwest-trending, near vertical, kink cleavage and associated minor small-scale open folds. The timing of this deformation is unknown.

Late-Early to Middle Proterozoic strata of the El Sherana, Edith River and Katherine River Groups form the fault-bounded Mount Callanan and Birdie Creek Basins, and the flat-lying Arnhem Land Plateau. Sediments and volcanics of the El Sherana Group at the base of the basins and, in places, the plateau, are open to tightly folded about subhorizontal northwest to north-trending axes which locally parallel major faults. In the southwest, folds are tighter, limbs commonly dip between 20^{o} and 70^{o}, and an associated slaty cleavage is present in pelitic rocks. The unconformably overlying Edith River and Katherine River Groups are mostly gently dipping to flat-lying or openly folded; local tight folds, with bedding dips up to 80^{o} are related to the South Alligator and T-bone Faults.

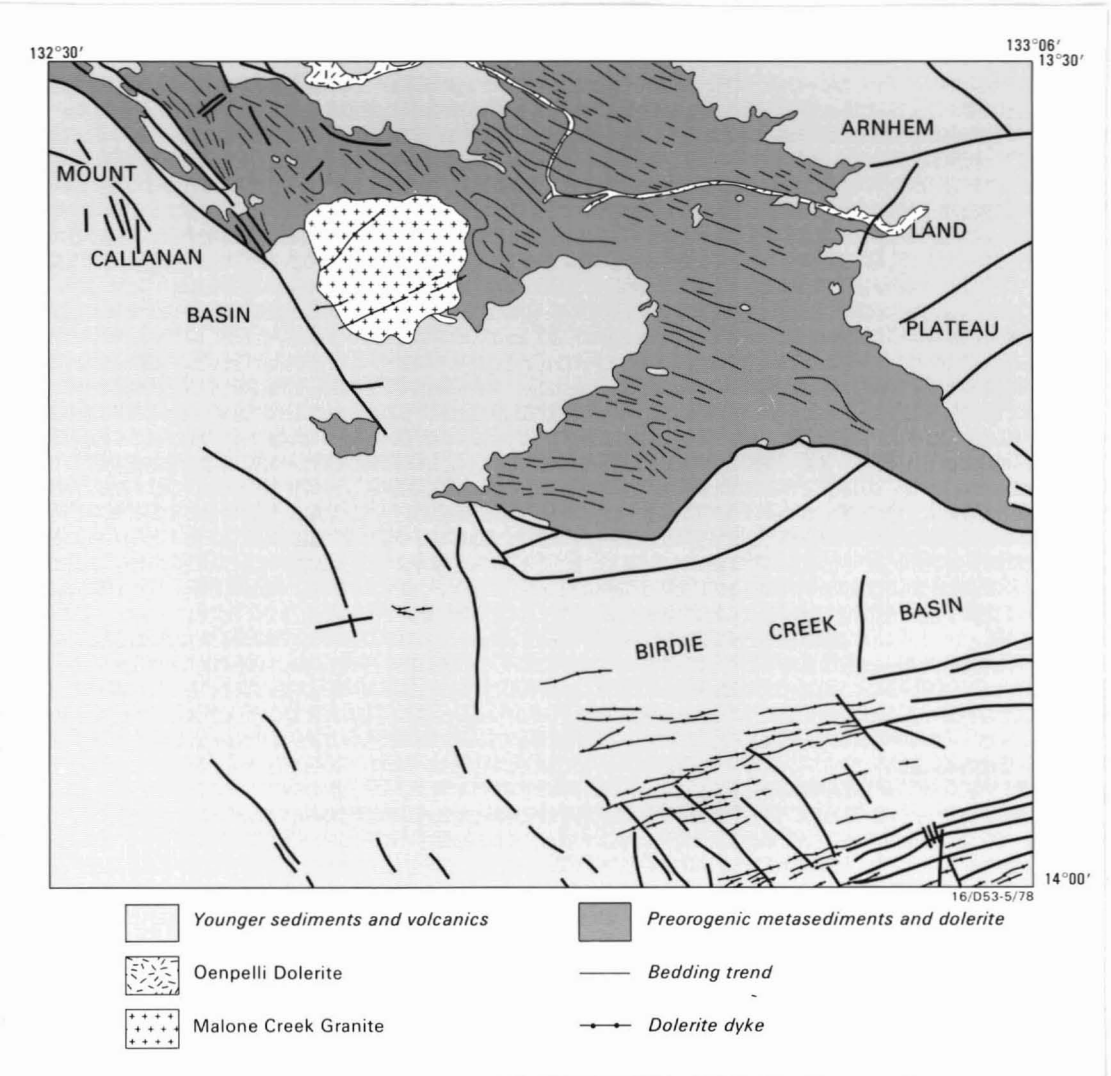

Figure 5. Major structural elements and preorogenic metasediment bedding trends

FAULTING

Apart from possible early thrusts (as discussed on page..) two types of faults are recognised within the region. Several long, and mostly linear, vertical northwest-trending faults cut Early Proterozoic and Middle Proterozoic rocks, particularly in the northwest and southeast. They are mostly quartz-filled and show a history of reactivation since Early Proterozoic time. Facies and stratigraphic changes within the South Alligator Group, across the Fisher Fault, may indicate active movement and possibly down-faulting to the southwest during geosynclinal deposition. Alternatively, these changes may be a result of early thrusting. Dramatic sediment thickness changes suggest that the South Alligator and T-bone Faults were active basin-bounding normal growth faults during deposition of the El Sherana, Edith River and Katherine River Groups (Fig. 6). These faults were also the locus of later movement and associated drag folding, and the intrusion of porphyritic alkali feldspar granite stocks. The location of small Eocene sedimentary basins adjacent to a northwest-trending fault south of Big Sunday indicates possible Cainozoic movement--Mesozoic fault movements have been postulated in adjoining RANFORD HILL (Stuart-Smith & Bagas, in prep).

East-northeast-trending faults are also widespread, particularly in the southeast where they cut the Grace Creek Granite, Plum Tree Creek Volcanics and Kombolgie Formation. The faults have minor vertical displacements and are commonly filled by dolerite. They are post-Middle Proterozoic in age, as there is no evidence of earlier displacement. They do not displace Cretaceous and younger sediments. Joints within the Kombolgie Formation (Fig. 7) parallel these and other major fault directions.

JOINTS

Late Early and Middle Proterozoic strata and granite intrusions are intensely jointed. The joints have largely controlled the drainage pattern, in particular the formation of gorges within the sandstone tablelands. The joint orientations range considerably between the Mount Callanan and Birdie Creek Basins, the Arnhem Land Plateau, and the Malone Creek Granite (Fig. 7). Except for a 350--360^{o} set in the two basins and the plateau, there is no comparably similar orientation between the areas. An east-northeast-trending set in the Arnhem Land Plateau and the Birdie Creek Basin parallels major faults and dolerite

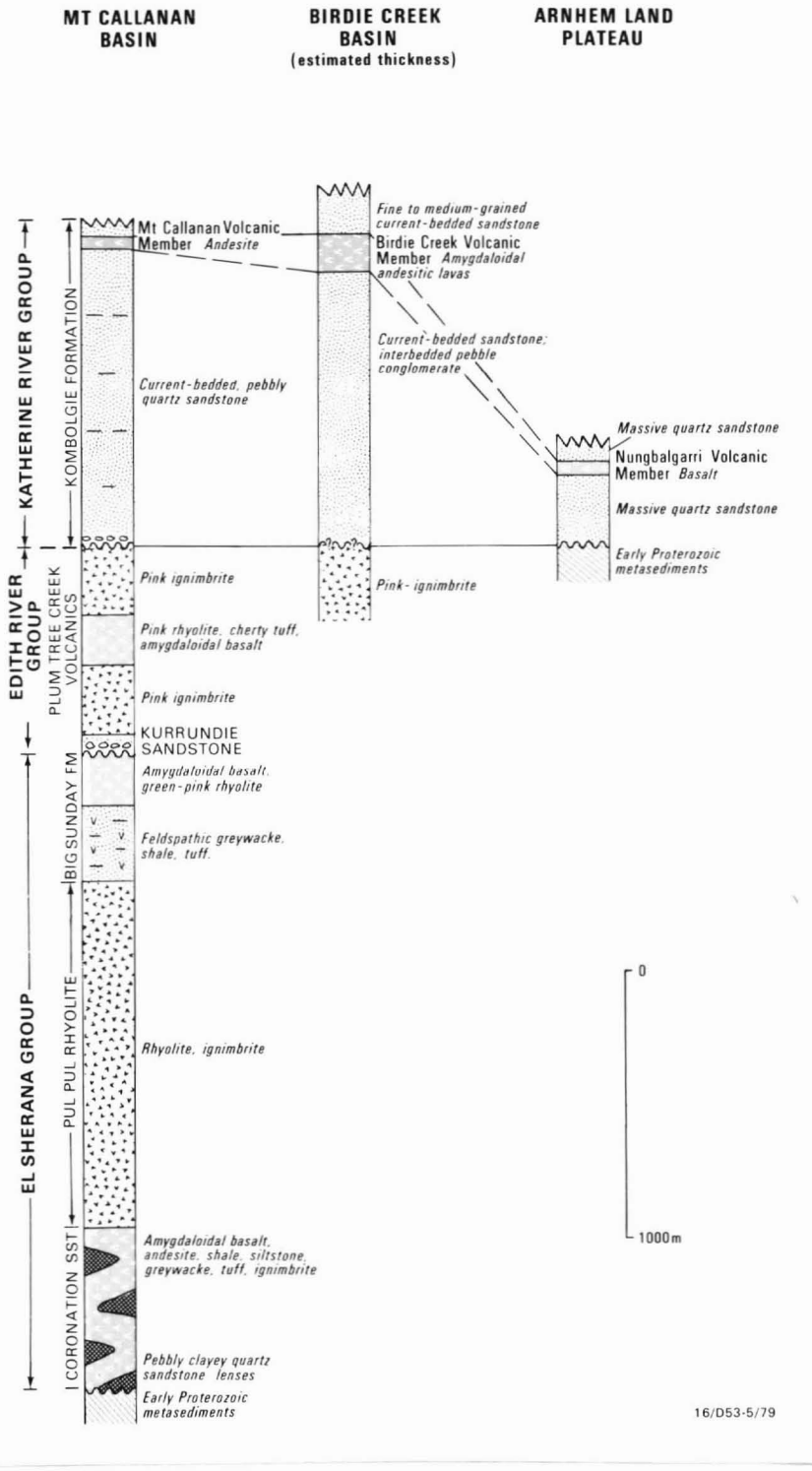

Figure 6. Composite measured sections in the Mount Callanan and Birdie Creek Basins and in the Arnhem Land Plateau, Stow region

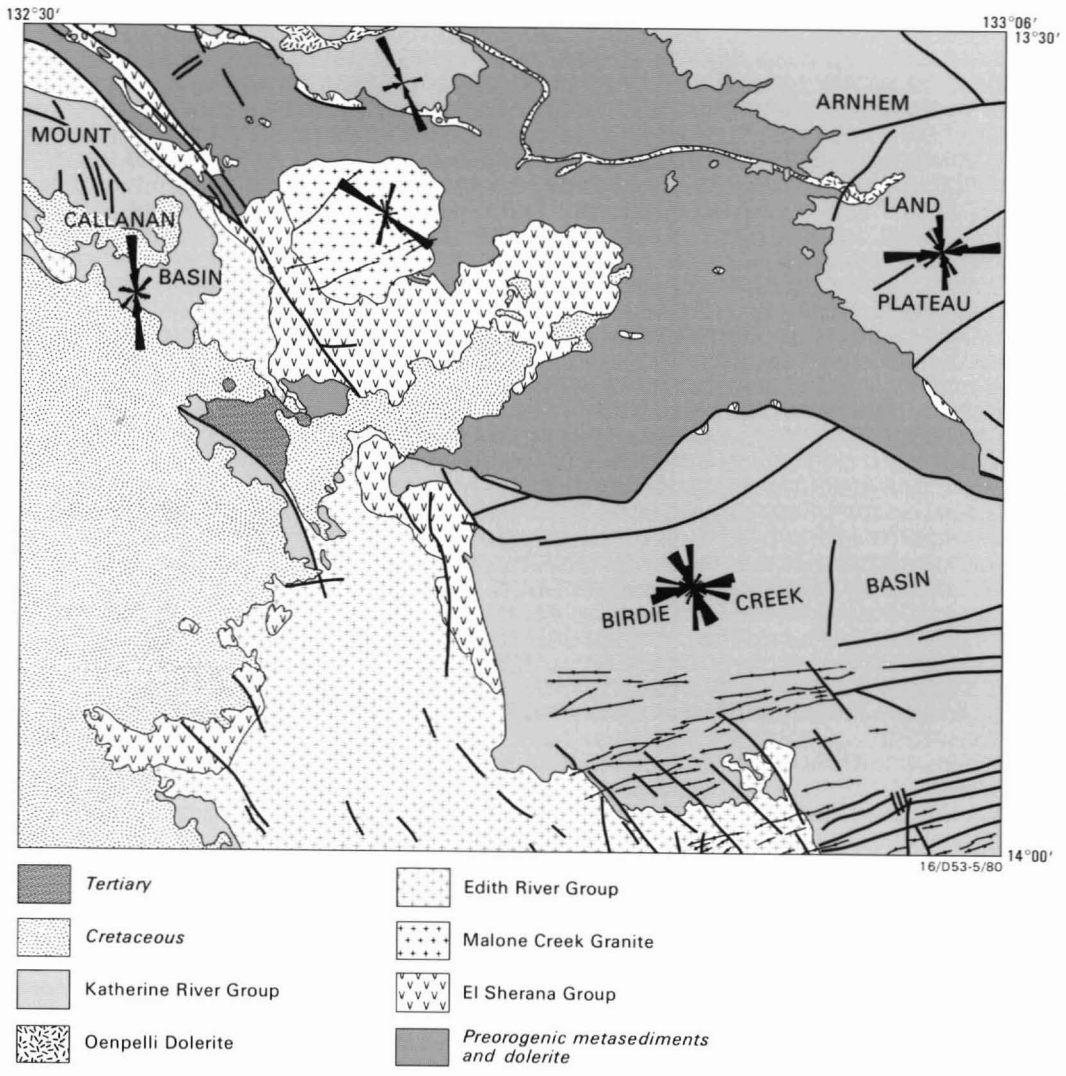

Figure 7. Rose diagrams of joint sets in the Katherine River Group and the Malone Creek Granite

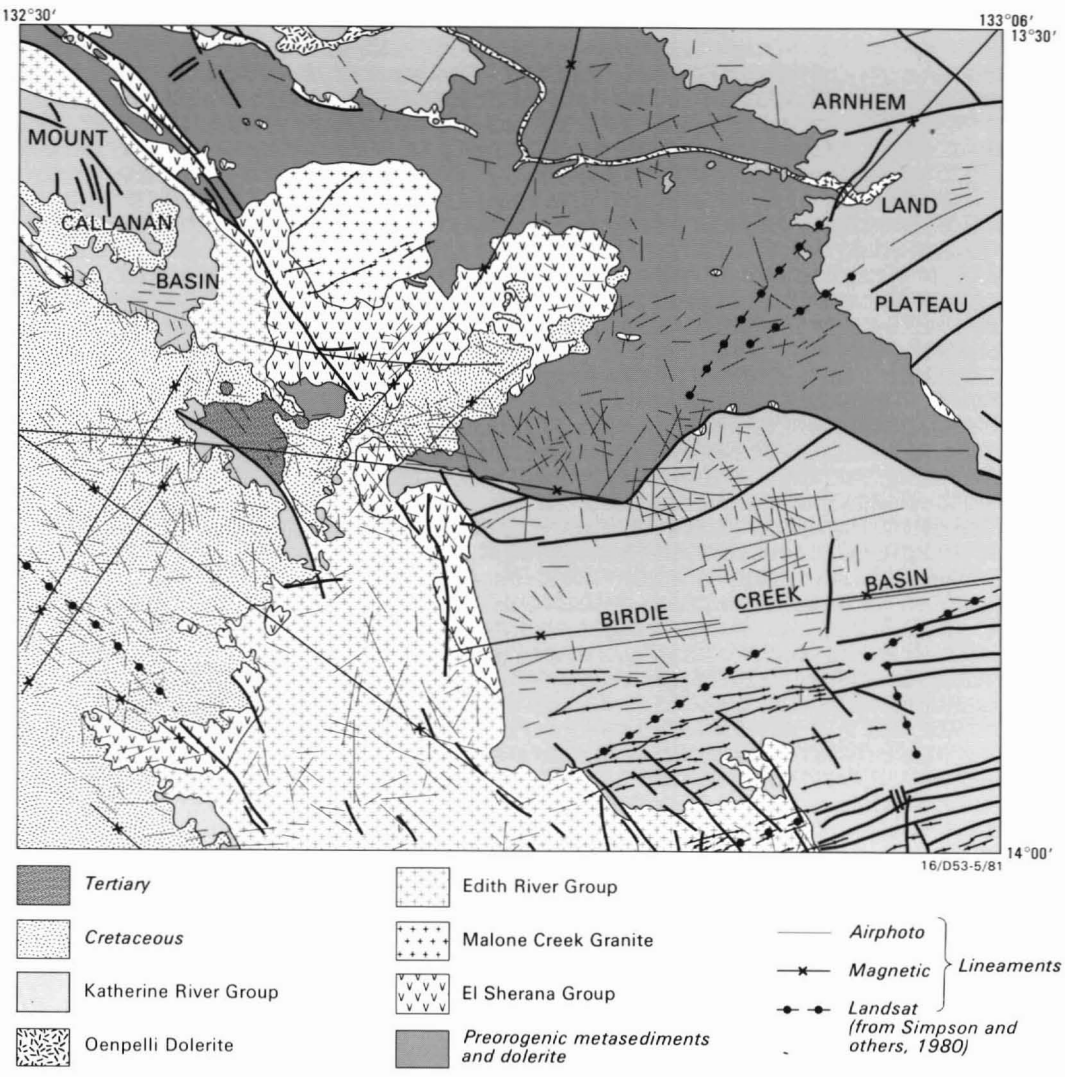

Figure 8. Lineament sketch

dyke swarms in the southwest. The major northwest-trending faults in the region parallel major and minor joints in the Birdie Creek Basin and the Arnhem Land Plateau, respectively.

LINEAMENTS

Airphoto and Landsat lineaments are concentrated in areas of thin Cainozoic sand or residual soil cover, where they mostly reflect the major joint, fault and bedding trends in the underlying rock (Fig. 8). In the west, several northeast-trending Landsat lineaments do not appear to be related to any known structure.

Magnetic lineaments, probably caused by dolerite dykes, trend either northwest or northeast parallel to identical fault orientations. In the southwest, one lineament indicates a northwesterly extension of the Lambell Fault beneath Mesozoic sediments into RANFORD HILL, where it is continuous with the Little Mary Fault.

ECONOMIC GEOLOGY

The Stow region contains most of the South Alligator Valley Uranium Field, forming a belt about 10-20 km wide between the northwest corner of the map area and Sleisbeck. Several of the uranium deposits, mined out from 1952 to 1964, also carried gold, and one is presently being investigated as a potential disseminated fine gold source. The only recorded mineral production outside this belt is from the Zamu Creek lead--silver mine, 11 km east of Gimbat homestead. Scattered, previously undocumented, small trenches in the south are probably related to uranium search in the 1950's.

There was no exploration between 1957 and 1970, but forecasts of increasing uranium demand lead to search for that metal, mainly in the most mineralised part of the South Alligator Valley Uranium Field, northwest of Coronation Hill. Several drillholes tested for extensions of the exhausted mines with disappointing results. Track etch and emanometry surveys were used near faults, in addition to radiometrics, geochemisty and drilling, to test for buried uranium deposits. A deep drillhole investigating a gravity anomaly 10 km south-southwest of Big Sunday intersected Koolpin Formation beneath thickened Eocene and Mesozoic sequences, but failed to detect mineralisation. Interest in the region as a gold district developed in the 1980's, and in 1985 preliminary results were released indicating a potentially

TABLE 2. MINERAL PRODUCTION FROM THE STOW REGION

mine	element(s)	tonnes metal	grade
SOUTH ALLIGATOR VALLEY URANIUM FIELD			
El Sherana West	U	185t	0.8%
	Au	0.007t	
	Ag	minor	
El Sherana	U	226t	0.55%
	Au	0.33t	
Koolpin	U	3t	0.12%
Scinto 6	U	3t	0.15%
Scinto 5	U	22t	0.4%
Palette	U	124t	2.5%
	Au	included in El Sherana prodn.	
Skull	U	3t	0.5%
Saddle Ridge	U	78t	0.2%
Coronation Hill	U	75t	0.3%
	Au	production not recorded	10gm/t
Sleisbeck	U	3t	0.4%
ELSEWHERE			
Zamu Creek	Pb,Ag	20t ore	

economic gold--platinum deposit adjacent to the Coronation Hill U/Au mine. However, restrictions on the processing of Exploration Licence applications and controls on exploration in mining tenements, introduced by Government in relation to proposed extension to the Kakadu National Park over the region, have severely limited the level of exploration since 1980.

The uranium and uranium--gold deposits were located on or close to faults in the Koolpin Formation, commonly where the faults had juxtaposed these rocks with sandstone or volcanics of the El Sherana Group. Primary mineralisation was in the reduced Koolpin Formation and accounted for about 65% of uranium produced from the region. The remainder, from oxidised ore, was hosted mainly by El Sherana Group sandstone or volcanics. The Coronation Hill gold--platinum prospect is, however, mainly

hosted by; altered volcanics of the El Sherana Group; and a different genesis and age than those for the U/Au deposits is indicated.

U and U/Au deposits of the South Alligator Valley Uranium Field

Ten mines have produced a total of 722 tonnes at grades between 0.2 and 2.5% U_3O_8 (Table 2). About 1/3 tonne gold production is also recorded from three mines, (El Sherana and Palette pitchblende concentrates contained about 600 gm/tonne gold; Fisher, 1969), and gold was produced but not recorded at Coronation Hill. Generally, the gold was described as veinlets cutting pitchblende ore, but recent work suggests that fine disseminated gold may have been present but unnoticed.

The principal ore distribution controls are stratigraphy and structure. All deposits are entirely or mainly in carbonaceous shale or ferruginous silty shale of the Koolpin Formation and lie either along a fault, in between faults, or in an intensely faulted zone. All the ore zone faults displace Koolpin Formation against sandstone and/or volcanics of the Coronation Sandstone, although in some cases the juxtaposition of the two formations may not be apparent owing to erosion. Those deposits carrying gold tend to be close to or on the Palette Fault. They are epigenetic, with uranium probably derived by leaching of the felsic volcanics and transported by oxygenated groundwaters in interbedded permeable sandstone beds to chemical reduction sites provided by fault-juxtaposed carbon-rich metasediments of the Koolpin Formation.

El Sherana and El Sherana West

At El Sherana, mineralisation lies in a steeply dipping fault-bounded inlier of Koolpin Formation within Coronation Sandstone and Pul Pul Rhyolite. The ore zone was shallow, extending to about 50 m below surface and 30 m below the unconformity (Fig 9). A down-gradient carrot-shaped oxidised lens mainly in Coronation Sandstone overlay primary ore in Koolpin Formation. In-depth extensions of primary ore in Koolpin Formation about 250 m to the northeast were discovered by drilling self-potential anomalies in a deep valley, and were worked separately as the El Sherana West mine. The open-cut was sunk to extract high near-surface oxidised ore (thought to be only a few metres below the unconformity plane, which has been removed by erosion), and adits driven southeast towards El Sherana intersected several small high-grade bodies. The adits

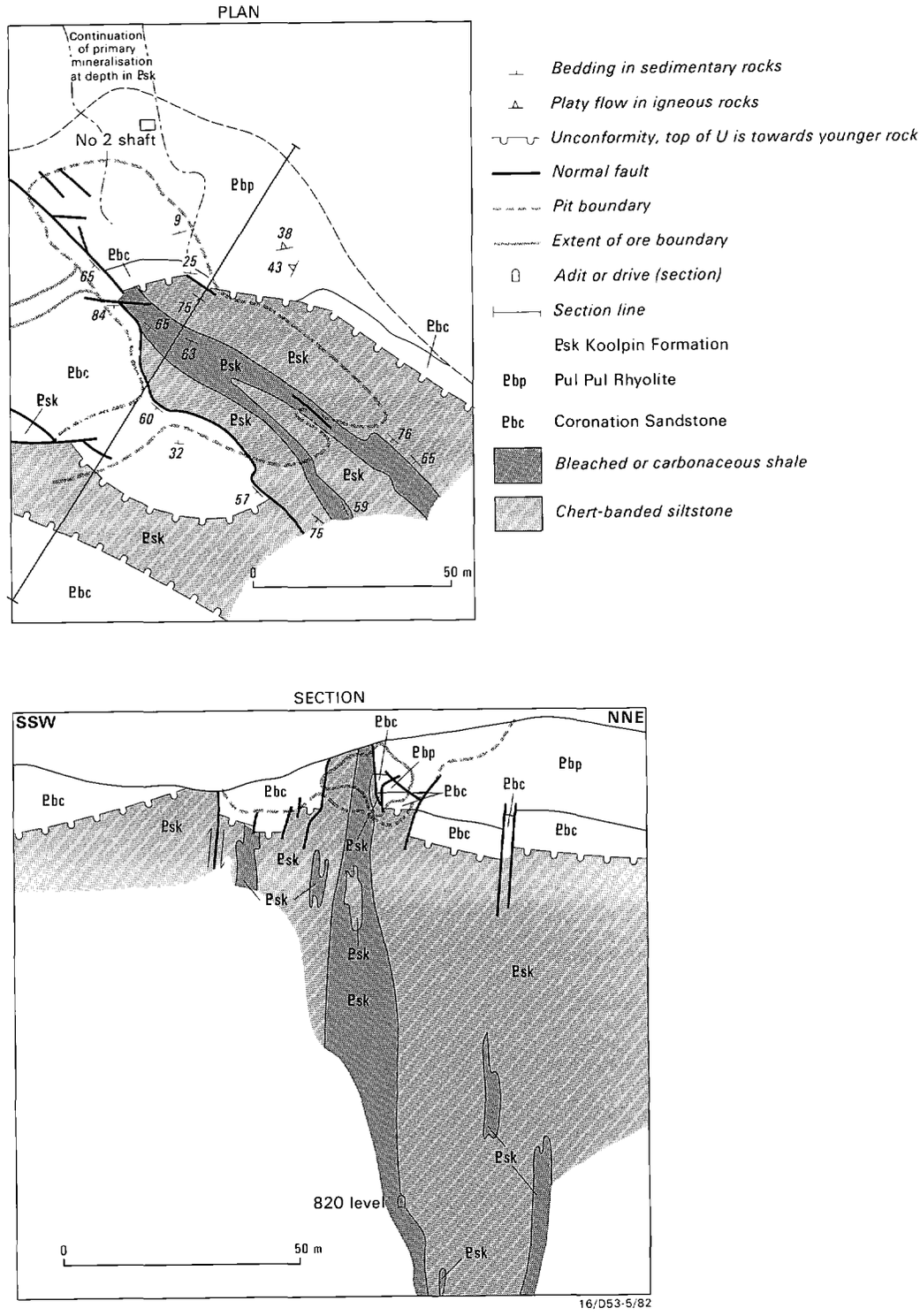

Figure 9. Plan and section of El Sherana mine; section shows in depth projections towards El Sherana West. (modified from unpublished data of United Uranium N.L., 1969)

followed the contact between ferruginous chert-banded siltstone and carbonaceous siltstone, the same favourable ore-bearing horizon established at El Sherana. Mineralisation was known to continue in depth when the mine closed in 1964 (Fisher, 1969).

Ore consisted of massive segregations, veins, and disseminations of pitchblende, mainly in fractures in cherty ferruginous siltstone and only rarely in carbonaceous beds (Taylor, 1969). In places, the massive pitchblende formed nodules up to 25 cm in diameter, commonly displaying radial and concentric cracks. Gold was found in one specimen in a concentric crack, suggesting it had formed after the pitchblende. Galena and anglesite stringers were widespread, and the lead content of pitchblende ore was locally as high as 5% (Shepherd, 1967). In places, massive pitchblende enclosed fragments or residuals of chert with minor arsenides. Rutherfordine ($(UO_2)(CO_3)$) was the most common secondary uranium mineral (Threadgold, 1960).

Palette

This mine was named after the colourful display of secondary uranium minerals at surface in Coronation Sandstone. The ore zone roughly followed the Coronation Sandstone/Koolpin Formation contact, variously a shallow-dipping unconformity or steep fault. The primary zone consists of veins in shears and fractures, and massive nodules, in carbonaceous shale mostly altered to chloritic shale. The secondary zone consisted of a disseminated halo in weathered carbonaceous and ferruginous banded shale and siltstone of the Koolpin Formation, and Coronation Sandstone. The mine is located near the intersection of several normal and reverse, shallow to steep faults, with the Palette Fault.

Palette was the richest deposit in the region with shoots of massive vein and nodular pitchblende. Some of the nodules showed imperfect radial and concentric cracks (Shepherd, 1967). Significant quantities of gold formed veins up to several millimeters wide in pitchblende, along with minor pyrite, chalcopyrite, galena and marcasite. The ore also contained the exotic minerals clausthalite (PbSe) and coloradoite (HgTe). Pitchblende veins also passed into the sandstone, where the normally cream rock is altered to mottled grey-pink sandstone in which apatite is extensively replaced by phosphuranylite ($Ca(UO_2)_4(PO_4)_2(OH)_4.7H_2O$) up to 8 cm from the vein. The altered sandstone also carries hematite, sericite and minor tourmaline, all probably introduced at the same time as the pitchblende

(Threadgold, 1960).

Phosphuranylite and uranophane ($Ca(UO_2)_2Si_2O_7.6H_2O$) were the most common epigenetic products in a wide range of secondary uranium minerals.

Saddle Ridge

The Saddle Ridge mine lies on a northwest-trending saddle joining a ridge capped by an outlier of Scinto Breccia to the south, and an isolated plateau of Kombolgie Formation sandstone to the north. The deposit was close to two easterly trending cross-faults about 1 km west of the Palette Fault. The faults displace the carbonaceous shale of the Koolpin Formation against altered rhyolite and tuff of the Coronation Sandstone. Mineralisation was irregularly disseminated secondary uranium minerals, mainly metatorbernite ($Cu(UO_2)_2(PO_4)_2.8H_2O$) (Ostle, 1956) in Koolpin Formation. Sooty pitchblende was intersected by drilling about 85 m below the open cut (Shepherd & Grenning, 1961). No gold was recovered. A down-faulted block of Scinto Breccia within the ore body was unmineralised.

Coronation Hill

Uranium was first discovered in the region at Coronation Hill, in 1953--on Coronation Day. Minor green secondary uranium minerals occurred at surface about 200 m south of a small copper prospect associated with a quartz-filled fault.

The deposit occupied an intensely faulted and sheared zone about 250 m southwest of the Palette Fault. Host rocks were initially interpreted as volcanic agglomerate in a volcanic neck, but have been recently described as conglomerate and altered volcanics (mostly rhyolite) of the Coronation Sandstone by Needham & Stuart-Smith (1986). Primary mineralisation was associated with carbonaceous shale of the Koolpin Formation at the bottom of the workings, and higher up with fault slices of carbonaceous material within the conglomerate and rhyolite, and within the conglomerate where carbonaceous shale clasts were abundant. The ore zone formed a vertical cylindrical body about 20 m across with several rich steep shoots and broadened near-surface to a wider oxidised zone. Uranium mineralisation comprised disseminated and patchy sooty pitchblende, and native gold formed veinlets and disseminations mainly in association with pitchblende, but in places also as gold-only shoots.

Scinto 5

Secondary uranium minerals -- mainly torbernite ($Cu(UO_2)_2(PO_4)_2.8\text{-}12H_2O$) -- and minor pitchblende occurred in bleached white and red ferruginous chert-banded shale and grey phyllitic siltstone of the Koolpin Formation. The metasediments are tightly folded, strongly sheared and in places brecciated on an indistinct bedding parallel fault, about 50 m north of an east-striking minor cross-fault. Matheson (1960) indicated that the deposit carried gold, but there is no description of its mode of occurrence or production. Massive and brecciated silicified carbonate caps the ridge immediately north of the opencut. No evidence exists of altered volcanics in faulted contact with Koolpin Formation, as described by Dunn (1960).

Minor uranium mines

Four small mines each yielded 3 tonnes of U_3O_8, as a result of selective mining, where no substantial development was warranted. Mineralisation at Koolpin occurred within a shear zone in Koolpin Formation and consisted of sooty pitchblende and some thin stringers of pitchblende in fractures in black shale and phyllite. The mine lies on a northeast-trending cross fault between the Palette and Fisher Faults, and is about 50 m southwest of a concealed contact with Zamu Dolerite. This contact is possibly faulted, in which case the structure may be a splay off of the Palette Fault converging with the parent fault close to Palette mine. The Skull mine lies 250 m south of Palette on the Palette Fault and comprised of irregular nodular concentrations of mainly pitchblende in shears within Koolpin Formation carbonaceous shale adjacent to the faulted contact with Kombolgie Formation sandstone. Scinto 6 is in sheared altered rhyolite of the Coronation Sandstone and consisted solely of oxidised ore (autunite, torbernite, saleeite ($Mg(UO_2)_2(PO_4)_2.8H_2O$)) forming near-surface patches in the shear zone and adjacent joints. Sleisbeck differs markedly from the other mines of the region in that it lies well away from the Palette Fault (by about 10 km), and is hosted by Kapalga Formation, in a wider variety of lithologies (phyllite, quartzite, mudstone -- Newton 1955; Crick & others, 1980). Although close to a major fault displacing the host rocks against Scinto Breccia and Kombolgie Formation sandstone and basalt, the ore zone rocks are generally unfractured at depth and grade into hematitic fractured quartzite, possibly originally calcareous, near the surface. This rock is phosphatic and probably related to the development of the Scinto Breccia. The uranium

mineralisation was pitchblende at depth, but most was obtained from the breccia in the form of phosphatic minerals. Minor Cu, Ni and As minerals were also recorded.

Uranium prospects

Numerous uranium prospects were located in the 1950's and 1960's with hand-held or airborne geiger-counters. Cliff Face is the only one to contain significant primary mineralisation; pitchblende occurs in carbonaceous lenses in chert-banded siltstone of the Koolpin Formation in a cross-fault close to the Palette Fault, and is surrounded by a disseminated secondary halo. Stockpile 1 and 2 has minor fine-grained pitchblende and yellow powdery secondaries in altered Pul Pul Rhyolite close to small cross-faults. Flying Fox, Palms, Clear Springs, Charvats and Saddle Ridge East are similar to the Stockpile prospects, situated in altered Pul Pul Rhyolite on or close to cross faults. Charvats and Saddle Ridge East are the only two of these to have visible mineralisation, present in the latter as disseminated torbernite, some in vesicles within lava. Minor secondary minerals at Christmas Creek lie in a fault breccia juxtaposing Coronation Sandstone and conglomerate of the Kurrundie Sandstone. Monolith and Koolpin East are sites of anomalous radioactivity in chert-banded Koolpin Formation siltstone close to cross-faults. Matheson (1960) suggested that they may lie on an extension (or splay) of the Palette Fault, which also passed through the Koolpin mine and continued north to Charvats, but there is no evidence of a structure in this position. Costeans in a quartz--tourmaline lode cutting Burrell Creek Formation 11 km east of Big Sunday are related to a minor gold prospect. Other costeans in Big Sunday Formation, 10 km west of Sleisbeck, and in Pul Pul Rhyolite 12 km northeast of Sleisbeck, are probably related to uranium reconnaissance work.

Base metal mines and prospects

Malachite is present in fractures and veins in breccia surrounding a massive quartz lode striking east 100 m north of the Coronation Hill open cut at Callanan's prospect. Four of six holes (totalling about 300 m; put down in 1955) intersected a lode interpreted to be about 60 m long by 13 m wide, extending as a vertical parallel-sided body to about 60 m depth. The lode, however, assayed an average of less than 0.5% Cu and 0.005% U_3O_8 (Zimmerman, 1970).

Small pits near Saddle Ridge and 5.5 km east of El Sherana

have exposed minor chalcocite, chalcopyrite, malachite and azurite below gossan, adjacent to caps of Scinto Breccia, over Pul Pul Rhyolite at Saddle Ridge, and in grey and minor chloritic phyllite and greywacke of the Kapalga Formation east of El Sherana.

The Zamu Creek mine comprised of several subparallel gossaneous veins in siliceous sheared altered dolerite breccia, striking northeast for 50 m along the contact between altered dolerite and a narrow band of Burrell Creek Formation schist, within a large ridge of Zamu Dolerite. About 20 tonnes of Ag-Pb ore was extracted, consisting of argentiferous galena and cerussite.

The Coronation Hill gold-platinum prospect

Recent exploration, following up gold values first obtained during uranium exploration in the mid 1950's in and close to the Coronation Hill U/Au mine, has confirmed the presence of a near-surface gold--platinum deposit in altered volcanics and minor sediments of the Coronation Sandstone east of the Coronation Hill open cut (Noranda Pacific Ltd, 1985). The host rocks are cut by numerous shear zones and faults, and are hematitised, sericitised and silicified with minor pyrite, chlorite and quartz veining in the gold zone. The gold is finely disseminated and generally not visible, even in samples assaying up to 140 g/t. An average grade of 5g/t for 800 000 tonnes ore has been estimated over a surface area of about 500 by 300 m, with extensions likely, particularly to the east and south. Gold-bearing samples (>1g/t Au) average 0.62g/t Pt and 1.33 g/t Pd, indicating a potentially significant platinum-group deposit. The gold concentation appears to have a northerly strike and may be related to northerly trending cross-faults which intersect the Palette Fault about 400 m north of the prospect.

The close relationship between gold and felsic volcanics suggests an epithermal origin at or soon after extrusion of the host rocks. Absolute ages of 500 Ma on the uranium ores of the region suggest no relationship with uranium mineralisation. Gold veins cutting pitchblende in several deposits indicate a late gold mobilisation with the metal source possibly being adjacent gold-rich volcanics in each case.

The genesis of the platinum-group elements (platinum, palladium) in the deposit is enigmatic. No ultramafic rocks are known in the region to support the usual mafic igneous-derivation

or association. Possibly ore genesis was by remobilisation of Proterozoic platinum-group placers by paleo-supergene processes related to one of several late Early Proterozoic unconformities. Alternatively, platinum may have been introduced by hydrothermal fluids related to felsic igneous activity -- an association hitherto undocumented in any platinum deposit.

GEOLOGICAL HISTORY

Most sediment and volcanic deposition, and virtually all of the tectonism, metamorphism and igneous intrusion, is associated with the Early Proterozoic Pine Creek Geosyncline. Apart from minor tectonism and minor Middle Proterozoic, Mesozoic and Cainozoic continental to shallow-marine sedimentation, the area has been relatively stable since the late Early Proterozoic.

Geosynclinal sedimentation took place during the later part of the Early Proterozoic, probably between 2000 and 1870 Ma ago in an intracratonic basin, mainly under alternating continental and shallow-marine conditions which gave way to deeper water at later stages. Marginal sandstone sequences, which rest on Archaean basement (Needham & others, 1980), are not exposed in STOW. Interbedded carbonaceous and carbonate rocks were deposited over these sequences at the basin margins while in deeper parts, including the STOW region, a thicker sequence of fine clastic and chemical sediments of the Masson Formation accumulated. STOW was the locus of submarine intermediate to mafic volcanism (Stag Creek Volcanics) at the end of this stage of sedimentation. Minor warping and planation of these deposits followed, and a sequence of clastic sediments of the Mount Partridge Group formed alluvial fans (Mundogie Sandstone) which were overlain by and were transitional with shallow-marine, possibly subtidal, deposits (Wildman Siltstone). These latter rocks, which include minor chemical sediments, are not present in the Stow region, owing to either faulting or peneplanation, which preceded a shallow-marine transgression and deposition of the South Alligator Group, a sequence of chemical and organic-rich sediments. Volcanism during this stage, at about 1880 Ma, is represented by the Shovel Billabong Andesite. Intercalated ashfalls, in close proximity of the andesite west of the South Alligator Valley, may indicate syndepositional movement and erosion along the Fisher Fault, as they are absent from STOW. The waning stages of this volcanism coincided with an influx of flysch-type sediment of the Finniss River Group, which was possibly related to deepening of the basin heralding the Top End Orogeny.

Sills of Zamu Dolerite were intruded probably near the close of geosynclinal deposition between 1880 and 1870 Ma (respectively the ages of the South Alligator Group tuff and the earliest-known synorogenic granite, both outside the Stow region). Tight folding, faulting and associated low-grade regional metamorphism took place at about 1870 Ma. Following subsequent uplift and erosion, northwest-trending basement fractures were reactivated to form a wide, shallow graben within which a strike-ridge topography developed in the northwest, in the area of the present South Alligator Valley. At about 1860 Ma, after a period of weathering during which the Scinto Breccia formed on carbonate rocks, the valleys were partly filled with coarse fluviatile sediments (predominantly polymictic conglomerate, sandstone and minor shale derived by the erosion of adjacent metasediments) and contemporaneous, mainly felsic, volcanics, of the Coronation Sandstone. Volcanism culminated with the extrusion of massive columnar-jointed ignimbrite sheets and rhyolite flows of the Pul Pul Rhyolite, which filled the graben and extended marginally eastwards onto the surrounding upland areas of Pine Creek Geosyncline metasediments.

Volcaniclastic flyschoid sediments and interbedded volcanics of the Big Sunday Formation later spread across the surrounding uplands, probably over the entire area. Absence of the Big Sunday Formation above the Pul Pul Rhyolite east of the South Alligator Valley suggests that this area was uplifted, following extrusion of the Pul Pul Rhyolite, to form a provenance for the flyschoid sediments. Abrupt thickness variations indicate uplift by faulting along the eastern side of the Mount Callanan Basin.

The El Sherana Group rocks were then folded, uplifted and eroded. The Mount Callanan and Birdie Creek Basins were initiated on the eroded terranne by deepening of the graben through further rifting. The northeastern margin of the Mount Callanan Basin, and the northern margin of the Birdie Creek Basin, are clearly defined by major faults. These probably formed steep active scarps at times, particularly at the initial stages of Edith River Group deposition.

The basal coarse clastic sediments of the Edith River Group (Kurrundie Sandstone) were first accumulated in the Mount Callanan Basin, possibly forming southwestward-thinning coalesced fans flanking the marginal fault scarp (Needham & Stuart-Smith, 1985b). Pebbles and cobbles in conglomerate consist mainly of locally derived rocks from the El Sherana Group. The thickest

developments of conglomerate occur along the northeastern margin of the basin at El Sherana and at Big Sunday, where they possibly mark the entry points of major fluvial systems from the east. The Plum Tree Creek Volcanics extruded over the fluvial deposits at about 1860 Ma. In the south, the volcanic pile was intruded by the subvolcanic Grace Creek Granite, probably at the effusive centre of the Edith River Group.

Although timing relationships are not conclusive, the Malone Creek Granite and associated porphyritic granite and syenite dykes and stocks were probably emplaced after the Edith River Group at the same time as (i.e., 1840-1780 Ma; R.W. Page, pers. comm., 1985) other post-orogenic granitoids in the geosyncline.

A 150 Ma period of uplift and erosion followed during which lopoliths of Oenpelli Dolerite were intruded at about 1690 Ma in the northeast, and were subsequently partly exhumed.

Local high angularity between the Kombolgie Formation and the Edith River Group indicates minor faulting and associated local folding during the erosional interval; the paleoweathering profile in the older rocks indicates a prolonged period of chemical decomposition. In places, the Scinto Breccia was re-exhumed and mechanically reworked during this interval.

The Kombolgie Formation platform sediments originated about 1650 Ma ago as braided alluvial fans from a northwest provenance on a relatively stable, peneplaned, mostly metamorphic basement. The greater thickness of the Mount Callanan and Birdie Creek Basins indicates considerable subsidence during sedimentation, probably by reactivation of bounding faults.

Except for a suite of Precambrian dolerite dykes intruded along the east-northeast fault set, there is no evidence of geological processes in the region for about 1500 Ma after Kombolgie Formation deposition. The region may have been subject to erosion for much of this time during which gold and uranium were concentrated in sructural sites. The metals were probably leachon for much of this time during which gold and uranium were concentrated in sructural sites. The metals were probably leached from late Early Proterozoic felsic volcanics and transported by oxygenated groundwaters in permeable sandstone beds to chemical reduction sites provided by fault-juxtaposed carbon-rich rocks of the Koolpin Formation. Cocentations of platinum-group elements may also have taken place at this time or be related to an earlier phase of hydrothermal activity

associated with the felsic volcanics.

By the Mesozoic, the Proterozoic rocks were exhumed almost to their present extent, at which time extensive continental to shallow-marine sediments had accumulated; the present sandstone scarps of the area possibly formed sea cliffs. Marginal faults in the three basins continued to be periodically active from the Middle Proterozoic onwards, and resulted in basin development and deposition of Mesozoic and Eocene sedimentation in the southern part of the Mount Callanan Basin. The Kombolgie Formation was drag-folded against some of the faults during re-activation.

Since the Mesozoic, the area has remained above sea level and has been subjected to weathering, which has produced laterites and sheet washing of sand derived from older strata. These deposits have been continually modified during the Quaternary by repeated erosional and aggradational cycles in a variety of alluvial environments. Earlier Quaternary base levels, represented by the 'Upland Plains', have over the past 7000 years been progressively eroded from the northwest by the South Alligator River system as a result of Pleistocene coastal emergence.

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