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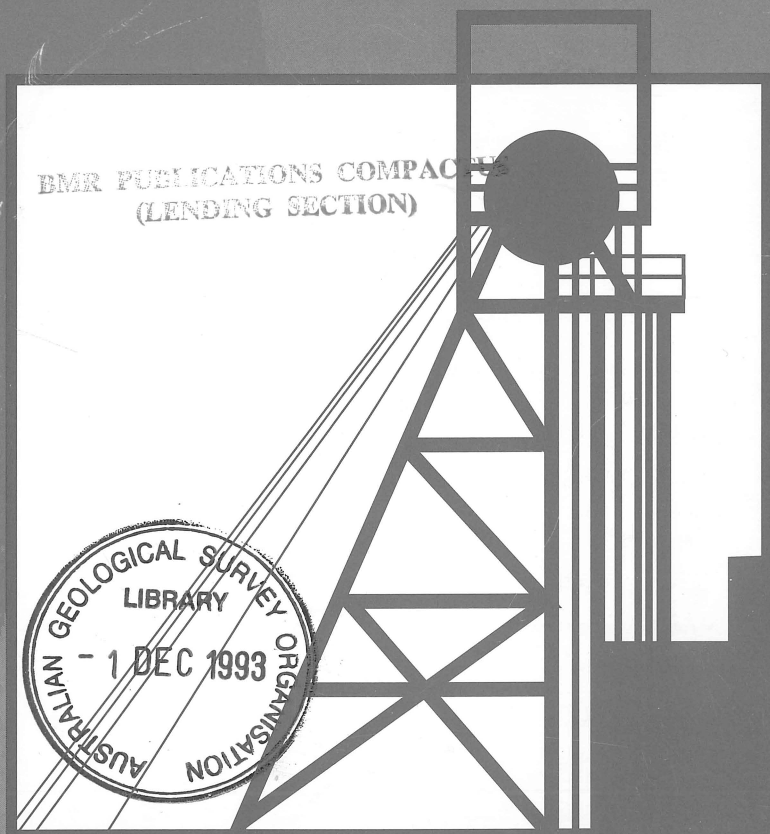
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Final report on the geology of Vaughan 1:100 000 map sheet (Mount Doreen 1:250 000 sheet), Arunta Block and Ngalia Basin, Northern Territory by D H Blake



Record 1993/28

MINERALS AND LAND USE PROGRAM

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Final report on the geology of Vaughan 1:100 000 map sheet (Mount Doreen 1:250 000 Sheet), Arunta Block and Ngalia Basin, Northern Territory

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D H Blake

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

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SUMMARY

This research forms part of the Kimberley–Arunta NGMA project undertaken jointly by the Australian Geological Survey Organisation and the Northern Territory Geological Survey. The National Geoscience Mapping Accord, endorsed by the Australian (now Australian and New Zealand) Minerals and Energy Council in August 1990 is a joint Commonwealth/State/Territory initiative to produce, using modern technology, a new generation of geoscientific maps, data sets, and other information on strategically important regions of Australia over the next 20 years.

Mapping of the Vaughan map sheet was carried out in 1990 and 1991 by the Bureau of Mineral Resources (now Australian Geological Survey Organisation), in collaboration with the Northern Territory Geological Survey, as a contribution to the geological updating of the Mount Doreen 1:250 000 Sheet area for the Kimberley–Arunta NGMA.

The Vaughan map sheet covers parts of the Palaeoproterozoic and Mesoproterozoic (early to middle Proterozoic) Arunta Block and, to the south, the Neoproterozoic (late Proterozoic) to Carboniferous Ngalia Basin. The oldest rocks exposed, mapped as Lander Rock beds and Nicker beds, were folded and metamorphosed to mainly upper greenschist/lower amphibolite facies probably at around 1880 Ma, during the Barramundi Orogeny. The Lander Rock beds in the far north were intruded by Yumurrpa Granophyre before being overlain by the Reynolds Range Group (?1810 Ma), represented by Mount Thomas Quartzite and Pine Hill Formation. This group was folded into an isoclinal synclinal and metamorphosed to greenschist facies, probably during the Strangways Orogeny (1780-1750 Ma), before being intruded by Wabudali Granite. To the south there are intrusions of Buger Creek Granite, Ethel Creek Granite, granites of the Carrington and Southwark Suites, metadolerite, and rare lamprophyre.

The rocks of the Arunta Block predate the Ngalia Basin succession, which comprises, from oldest to youngest, the Neoproterozoic Vaughan Springs Quartzite (subdivided into the Bigrlyi Sandstone, Treuer, and Eva Springs Sandstone Members), Albinia Formation, and Mount Doreen Formation, the probably Ordovician Djagamara Formation, and the late Devonian to Carboniferous Mount Eclipse Sandstone. The Ngalia Basin succession was affected by folding, faulting, and thrusting at around 300 Ma, at the end of the Alice Springs Orogeny. Faults marked by ridge-forming quartz veins in the Arunta Block postdate granite, but their age relative to the Ngalia Basin succession is uncertain.

Tungsten and minor copper mineralisation occurs in Wabudali Granite at Wilsons Find in the far north and uranium mineralisation is present in Mount Eclipse Sandstone at Bigrlyi prospect near the northern margin of the Ngalia Basin in the east. The area is considered prospective for gold deposits of the types being mined at The Granites and Tanami to the north, as well as for small deposits of other metals.

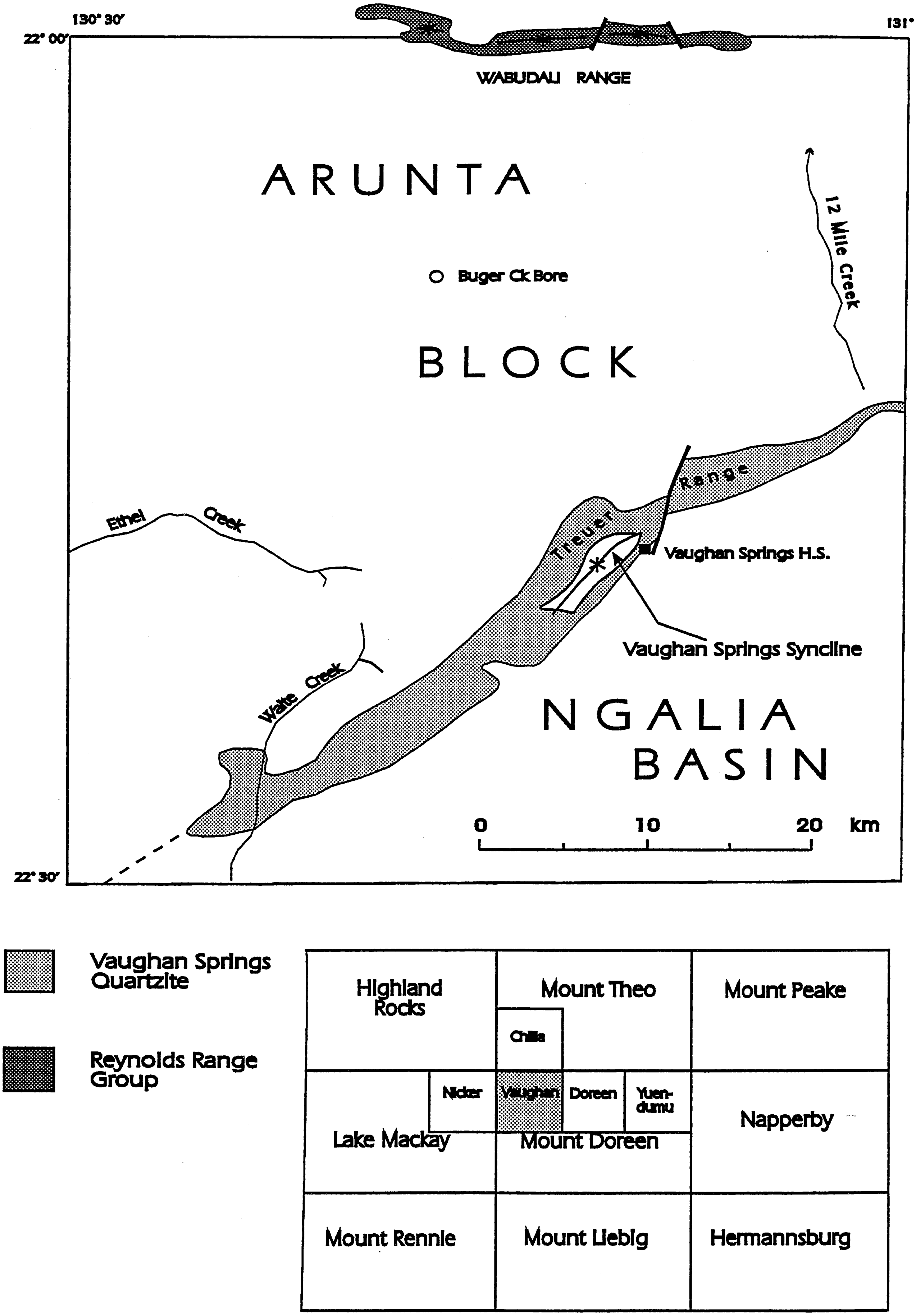

Fig. 1. Locality map, Vaughan 1:100 000 Sheet area.

INTRODUCTION

A detailed reconnaissance survey of the geology of VAUGHAN (upper case indicates 1:100 000 sheet area) and adjoining parts of Lake Mackay and Mount Theo 1:250 000 sheet areas to the west and north (NICKER and CHILLA 1:100 000 sheets, respectively), was undertaken by D.H.Blake in 1990 (Blake, 1991a) and 1991, with some additional observations by C.Edgoose (NTGS) in 1990, and R.D.Shaw (BMR) in 1991, as part of the Kimberley–Arunta Project, under the National Geoscience Mapping Accord. The aims of this project are:

- to determine, through systematic mapping, the nature, timing, and distribution of significant geological events in and between the west Arunta, The Granites–Tanami, and east Kimberley areas of the North Australian Craton, and to determine the extent of prospective basement beneath thin cover;
- to describe styles of mineralisation that can be used as predictive exploration models; and
- to provide geological and mineral resource information necessary for land use decisions.

The Kimberley–Arunta project was started in 1990 and is due to be completed in 1995.

VAUGHAN is bounded by latitudes 22°00' and 22°30' and longitudes 135°30' and 131°00', and occupies the northwestern part of Mount Doreen 1:250 000 sheet area (Fig. 1). It covers part of the early to middle Proterozoic Arunta Block in the north and part of the late Proterozoic to Palaeozoic Ngalia Basin in the south.

NTGS geologists (C.Edgoose and D.N.Young) mapped the DOREEN and YUENDUMU 1:100 000 map sheets to the east of Vaughan in 1990 and 1991, and also in 1991 (with A.Camacho), the southern half of the Mount Doreen 1:250 000 sheet. R.D.Shaw investigated the structural geology of the Mount Doreen area in 1991 (Shaw, in prep.).

The only permanent habitation in VAUGHAN is Vaughan Springs homestead on Mount Doreen station: this homestead is connected to the Tanami Road to the east by graded roads and tracks. The climate is semi-arid tropical, with an average annual rainfall of less than 250 mm. Spinifex and mulga dominate the vegetation. Ridges, rounded hills and tors of Proterozoic and Palaeozoic rocks are separated by plains covered with Quaternary sediments. Some sand dunes are present in the south. The local relief is less than 100 m except in parts of the Wabudali Range in the far north and the Treuer Range of central VAUGHAN. The main drainage channels are those of the north-flowing 12-mile Creek in the east, the west-flowing Ethel Creek in the west, and the southwest-flowing Waite Creek in the southwest.

The Mount Doreen and Lake Mackay 1:250 000 sheet areas were included in the regional geological mapping of the Ngalia Basin by BMR between 1967 and 1969 (Wells, 1972; Nicholas, 1972; Wells & Moss, 1983). Both sheet areas were covered by an airborne magnetic and radiometric survey, 1.6 km line spacing, in 1976. The Mount Theo 1:250 000 sheet was geologically mapped by BMR in 1972 (Stewart, 1976), but has yet to be covered by airborne geophysics.

Map production

VAUGHAN and adjoining part of NICKER to the west were mapped using vertical colour aerial photographs at about 1:25 000 scale taken in 1972. RC9 black and white photography flown in 1971, nominal scale 1:80 000, were used for mapping the southernmost part of CHILLA to the

CAINOZOIC	Homestead beds (Ta)
	Alice Springs Orogeny (~300 Ma)
	NGALIA BASIN
PALAEOZOIC	
LATE DEVONIAN TO CARBONIFEROUS	Mount Eclipse Sandstone (Pzt)
ORDOVICIAN	Djagamara Formation (Od)
NEOPROTEROZOIC	Mount Doreen Formation (paq)
	Albinia Formation (paa)
	Vaughan Springs Quartzite:
	Eva Springs Sandstone Member (pae)
	Treuer Member (pat)
	Bigrlyi Sandstone Member (pab)
	Major Unconformity
	ARUNTA BLOCK
MESOPROTEROZOIC	*Mafic dykes*
	Ethel Creek Granite (pge)
	Southwark Granitic Suite (pgp)
	Wabudali Granite (pgw)
PALAEOPROTEROZOIC	Mafic dykes
	Strangways Orogeny (1750-1780 Ma)
	Carrington Granitic Suite (pgf)
	Buger Creek Granite (pgb)
	Reynolds Range Group:
	Pine Hill Formation (prp)
	Mount Thomas Quartzite (prt)
	Gneissic granophyre (pgy)
	Barramundi Orogeny (~1880 Ma)
	Nicker Beds (pls)
	Lander Rock Beds (plr, plm)

Fig. 2. Stratigraphic chart, Vaughan 1:100 000 Sheet area.

north. Field data and photo-interpreted geological boundaries were plotted onto transparent overlays on the aerial photographs and then compiled on photoscale topographic bases. The resulting compilation sheets have been digitised and entered into an ARC/INFO GIS (Geographic Information System). Digital copies of the map can be purchased from the Australian Geological Survey Organisation (formerly BMR).

OUTLINE OF GEOLOGY

The stratigraphy, intrusive activity, and deformational history of the Vaughan area are summarised in Fig. 2. A solid geology map, omitting the Cainozoic sediments which cover most of Vaughan, is shown in Fig. 3: this map is based on exposed features and on an interpretation by R.D.Shaw of airborne magnetics and radiometrics (1.6 km line spacing), and Bouguer gravity data (BMR, 1992). Correlations of rock units in VAUGHAN with units in other parts of northern and central Australia are shown in Table 1.

The oldest rocks of the Arunta Block exposed in the area are assigned to the *Lander Rock beds* and *Nicker beds.* These units consist of greywacke, siltstone, sandstone, and minor mafic and felsic volcanics, which have been deformed and regionally metamorphosed mainly to upper greenschist or lower amphibolite facies, although higher grade migmatitic rocks are present locally. In the far north the Lander Rock beds are intruded by *gneissic granophyre* and overlain unconformably by the *Reynolds Range Group,* comprising quartz sandstone of the *Mount Thomas Quartzite* and sandstone, siltstone, carbonates, and basalt of the *Pine Hill Formation.* This group was folded into a major upright isoclinal syncline and metamorphosed to mainly greenschist facies, probably during the Strangways Orogeny at around 1760 Ma, before being intruded, together with the Lander Rock beds, by *Wabudali Granite.* To the south the Lander Rock beds are intruded by granites of the *Carrington* and *Southwark Suites, Buger Creek Granite,* and *Ethel Creek Granite.* These granites are cut by mafic dykes and displaced by faults marked by ridge-forming quartz veins.

The Arunta Block is overlain in the south by the Ngalia Basin succession, represented by the late Proterozoic (Neoproterozoic) *Vaughan Springs Quartzite, Albinia Formation* and *Mount Doreen Formation,* and the Palaeozoic *Djagamara Formation* and *Mount Eclipse Sandstone.* These units were affected by folding, faulting, and thrusting at the end of the Alice Springs Orogeny, about 300 Ma ago.

Since the Alice Springs Orogeny the area has been part of a tectonically stable craton subjected to subaerial erosion and deposition, and now consists of residual hills and ridges rising above extensive plains covered with a veneer of Cainozoic sediments.

ROCK UNITS OF THE PROTEROZOIC ARUNTA BLOCK

Lander Rock beds

Named after Lander Rock, Napperby 1:250 000 Sheet area; defined in Stewart & others (1980).

Map symbols. plr, plrb, plrs, plm.

Distribution. Arunta Block north of the Ngalia Basin.

Thickness. Probably several thousand metres; base not exposed, and no underlying unit known.

Topography. Forms low ridges and hills and undulating terrain where not concealed by Cainozoic sediments.

Lithology. Greywacke and siltstone with minor sandstone and basaltic lava; metamorphosed to

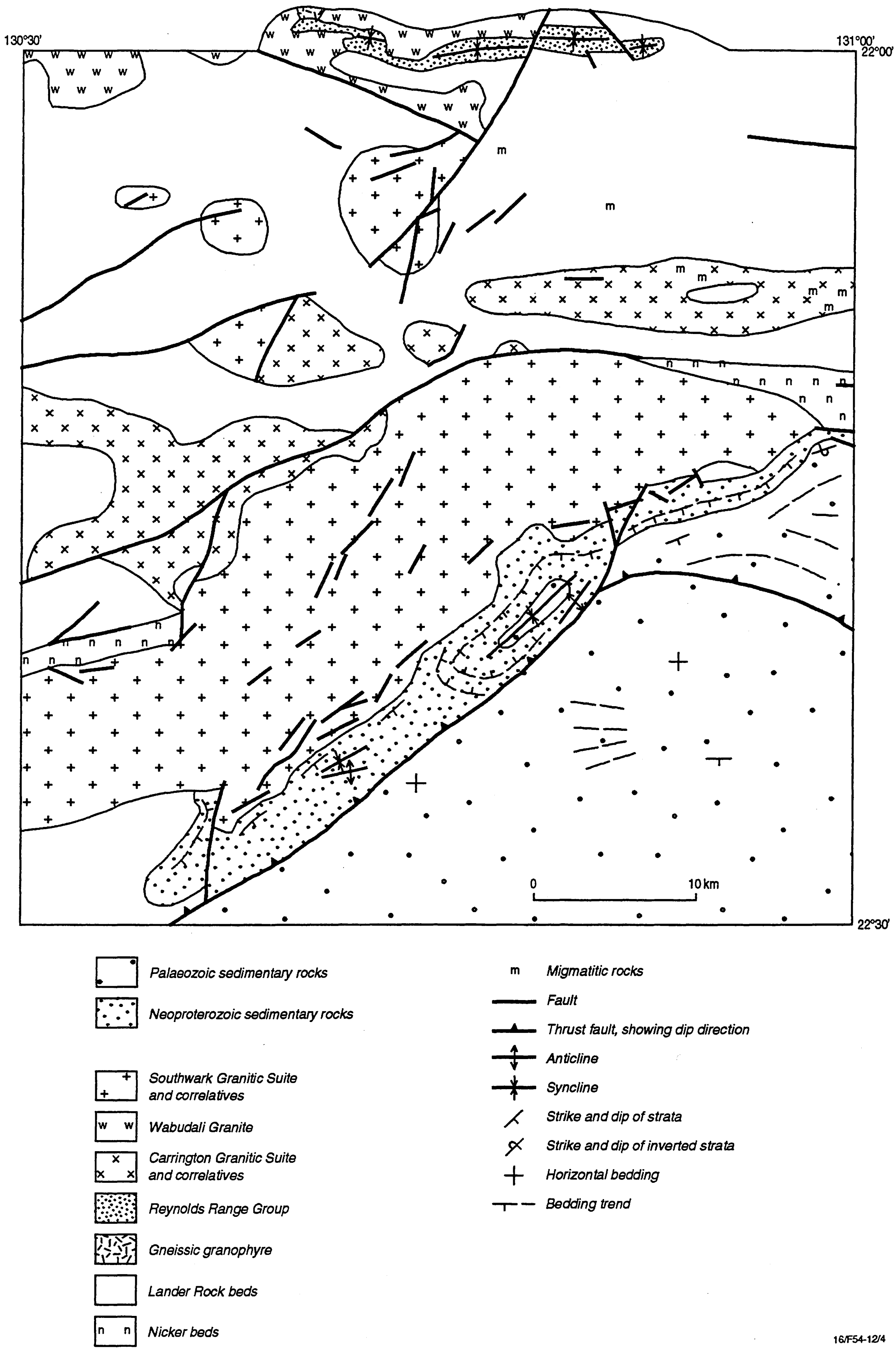

Fig. 3. Solid Geology map Vaughan 1:100 000 Sheet area.

TABLE 1. Correlations of Proterozoic and Palaeozoic units in Vaughan with other units in northern and central Australia.

Vaughan map sheet	Amadeus Basin and northern Arunta Block	Davenport province of Tennant Creek Inlier	The Granites–Tanami Region	East Kimberley Region
Alice Springs Orogeny	Alice Springs Orogeny (~300Ma)			Alice Springs Orogeny?
Mount Eclipse Sandstone	Pertnjara Group		Pedestal beds	Mahoney Group
Djagamara Formation	Larapinta Group			Moonlight Valley Tillite
Mount Doreen Formation	Olympic Formation			
Albinia Formation	Bitter Springs Formation		Redcliff Pound Group	Bungle Bungle Dolomite?
Vaughan Springs Quartzite	Heavitree Quartzite		Redcliff Pound Group	Mount Parker Sandstone?
Southwark Granitic Suite	*Yarunganyi Granite* (1567 ± 6 Ma)			
Wabudali Granite		*Elkedra Granite?*		
Strangways Orogeny	Strangways Orogeny (1780-1750 Ma)			
Carrington Granitic Suite (1779 ± 6 Ma)	*Carrington Granitic Suite*	*Devils Marbles Granite*		
Reynolds Range Group	Patmungla beds (1799 ± 9 Ma) Reynolds Range Group	Hatches Creek Group (1830–1800 Ma)	Mount Winnecke Formation	Kimberley Group
Gneissic granophyre				
Barramundi Orogeny	Barramundi Orogeny (~1880 Ma)	Barramundi Orogeny (~1860 Ma)	Barramundi Orogeny	Barramundi Orogeny (<1870>1850 Ma)
Lander Rock beds and Nicker beds	Lander Rock beds	Warramunga Group (1870 Ma)	Tanami Complex	Halls Creek Group (1900–1870 Ma)

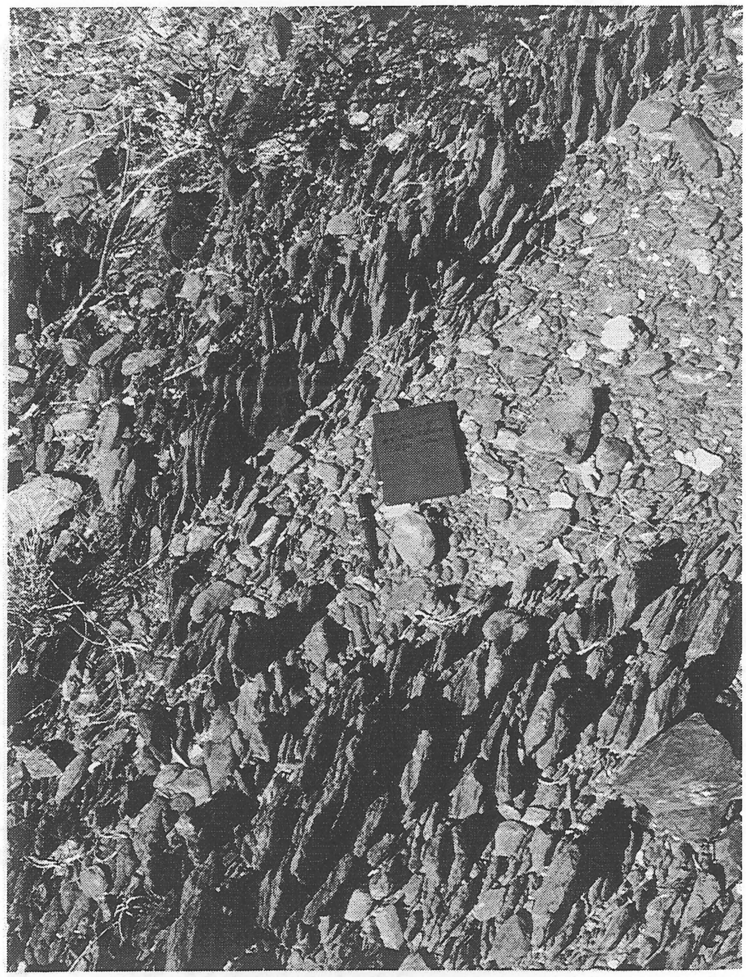

Fig. 4. Lander Rock beds south of the Wabudali Range (at GR Vaughan 788647): interbedded metagreywacke and metasiltstone with cleavage at a high angle to bedding in the core of a fold. (R.D.Shaw)

schist, quartzite, amphibolite, and locally migmatite; cut by numerous quartz veins, some of which predate deformation.

plr. Turbiditic metagreywacke and metasiltstone (Fig. 4), thick to thin-bedded, generally schistose, consist mainly of biotite, muscovite, quartz, and alkali feldspar; subordinate variably feldspathic and micaceous quartzite; minor finely banded quartz-tourmaline rock and amphibolitic metabasalt; rare calc-silcate bands. Porphyroblasts of andalusite (in places more than 3 cm long), muscovite, tourmaline, and less commonly garnet and altered ?cordierite, and also fibrolitic sillimanite, are present locally, mainly near granite intrusions.

plrb. Turbiditic beds, as in plr, with interlayered amphibolite, some of which represents amygdaloidal metabasalt flows.

plrs. Massive schist (no discernible banding) in southwest (near GR 657193), unconformably overlain by Vaughan Springs Quarzite: weathered medium-grained muscovite-quartz schist with minor biotite; some irregular leucogranite veins; north-east trending vertical foliation.

plm. Migmatitic metasedimentary gneiss: medium-grained gneiss showing migmatitic layering with complex minor folds (Fig. 5); consist predominantly of quartz + mica (muscovite and/or biotite) ± feldspar; porphyroblastic tourmaline and altered 'andalusite', and also fibrolitic sillimanite and pseudomorphed cordierite, present in places. In migmatite to east, near Yuendumu,

Fig. 5. Migmatite assigned to Lander Rock beds in northwest of area mapped (at GR Nicker 540663).

the migmatitic fabric is superimposed on a foliation formed under conditions of high strain involving disruption and transposition of an earlier compositional layering (Shaw, in prep.).

Deformation. Tightly folded (F1) on outcrop scale, mainly about upright east-west-striking axial planes; axial planar cleavage/schistosity (S1) well developed, strongly refracted by bedding in places (e.g., Fig. 4); minor folds (F1, F2), crenulations (F2), bedding-cleavage intersection lineations (L1) common; quartzite beds locally boudinaged.

Metamorphism. Regionally metamorphosed mainly to upper greenschist or lower amphibolite facies; retrogressed from higher grade (up to granulite facies?) where migmatitic in northwest. Affected by contact metamorphism near granite intrusions, with development of porphyroblastic andalusite, muscovite, tourmaline, and garnet, also fibrolitic sillimanite and possible cordierite (pseudomorphed), in mica schist; some andalusite and garnet porphyroblasts contain folded inclusion trails. Some migmatitic gneiss may be result of contact, rather than regional, metamorphism.

Mineralisation. None known in VAUGHAN; host for some Cu-bearing quartz vein deposits to east.

Relationships. Base not seen. Contacts with Nicker beds faulted or concealed. Overlain, probably unconformably, by Mount Thomas Quartzite of Reynolds Range Group. Intruded by mafic dykes, gneissic granophyre, Wabudali Granite, Buger Creek Granite, Ethel Creek Granite, and granites of the Carrington and Southwark Suites; cut by pegmatite, quartz-tourmaline and quartz veins.

Age. Around 1890 Ma, like the lithologically similar Warramunga Group of the Tennant Creek Inlier and Halls Creek Group of East Kimberley, or older; migmatite mapped as Lander Rock beds near Yuendumu is intruded by cordierite and garnet-bearing granite dated at 1880 Ma (ionprobe U-Pb zircon age–D.Young & others, 1992).

Correlatives. Probably part of the Tanami Complex of The Granites–Tanami region to north, Halls Creek Group to northwest, and Warramunga Group to northeast (e.g., Blake, 1978).

Remarks. No internal stratigraphic sequence determined.

Shown as unnamed Precambrian schist, amphibolite, quartzite, and gneiss on Mount Doreen map of Wells (1972) and Lake Mackay map of Nicholas (1972) and as Lander Rock beds on Mount Theo map of Stewart (1976).

Affected by the Yuendumu event of Shaw (in preparation), which may be correlated with the 1870-1880 Ma Barramundi Orogeny of northern Australia (Page & Williams, 1988), and also by the 1780-1750 Ma Strangways Orogeny and the 400-300 Ma Alice Springs Orogeny: these three deformations appear to have been dominated in the area by east-west trending structures, so consequently were essentially co-axial.

Structural evidence near Yuendumu (Shaw, in preparation) and the presence of inclusions of both migmatite and bedded Lander Rock metasediments in Buger Creek Granite in Vaughan sheet indicate that some migmatite may be older than the Lander Rock beds and could represent underlying basement. However, this is considered unlikely by D.Young (personal communication 1991 and 1992) because migmatites in the Yeundumu and Doreen Sheet areas to the east pass laterally, with only small gaps of no exposure, into less metamorphosed Lander Rock beds.

Nicker beds

Name approved and reserved (18/5/92); named after Mount Nicker, in NICKER, Lake Mackay 1:250 000 Sheet area.

Map symbol. pls.

Distribution. Scattered outcops in Arunta Block north of Ngalia Basin and south of Lander Rock beds exposures in NICKER, VAUGHAN, and DOREEN.

Type section. In east NICKER, across strike of bedding, from GR 515273 south to 517263.

Topography. Low strike ridges and undulating terrain.

Thickness. Probably 1000 m; base and top not exposed; tightly folded.

Lithology. Quartzite, muscovite quartzite, feldspathic quartzite, quartz-muscovite schist, and siltstone, some of which shows graded bedding; schistose porphyritic felsic volcanics and volcaniclastic sandstone; minor mica schist, calc-silicate rock, and ironstone; mylonitic in east, near GR 058448. To east, in DOREEN, may range from migmatitic (e.g., at Pyramid Hill) to only weakly deformed (northeast of Bigrlyi Gap).

Felsic volcanics: exposed in NICKER (near GR 517270), eastern Vaughan (near GR 058448) and in DOREEN (NE of Bigrlyi Gap and at Pyramid Hill); consists of alkali feldspar and partly resorbed quartz phenocrysts in fine-grained heterogeneous groundmass of muscovite, biotite, quartz, and probably alkali feldspar; textures indicate probable fragmental origin.

Deformation and metamorphism. Tightly folded about subvertical axial planes in west, with steeply plunging fold axes; mylonitic in eastern Vaughan. Probably metamorphosed to upper greenschist/lower amphibolite facies in NICKER and VAUGHAN.

Relationships. Contacts with Lander Rock beds faulted or not exposed. Intruded by granite of Southwark Suite. Inferred to be overlain unconformably by Vaughan Springs Quartzite northeast of Bigrlyi Gap in western DOREEN.

Age. Yet to be isotopically dated, though felsic volcanics should be suitable for U-Pb zircon geochronology. Thought to predate Barramundi Orogeny, and may be similar in age to adjacent Lander Rock beds, as both units contain turbidites and have had similar structural history.

Correlations. Tentatively correlated with Lander Rock beds, and hence with the Warramunga Group of the Tennant Creek Inlier, the Tanami Complex of The Granites–Tanami region, and Halls Creek Group of the east Kimberley region.

Remarks. Differs from Lander Rock beds of VAUGHAN in lithology—sedimentary component generally more siliceous and less pelitic, includes porphyritic felsic volcanics—hence may not be a direct correlative.

Amphibolite

Map symbol. dl.

Distribution. Two bodies shown on map, in northwest and northeast.

Topography. Low ridges.

Lithology. Metadolerite and metagabbro.

Northwestern body, centred at GR 745435: fine to coarse igneous textures partly preserved; consists mainly of pale amphibole (some with cores of remnant pyroxene) and partly recrystallised plagioclase; minor pods and veins of anothosite and small irregular patches of carbonate (filling vesicles?); weak to strong east-west trending subvertical foliation. Interbanding with Lander Rock beds metasediments at northern margin indicates unit could be extrusive rather than intrusive, in spite of relatively coarse grain-size; southern margin is cut by granitic veins.

Northeastern body, centred at GR 917558: metagabbro with amphibole and partly altered olivine; inferred to intrude biotite-quartz-feldspar hornfels containing porphyroblastic garnet and andesine.

Deformation and metamorphism. Weak to strong vertical foliation, trending east in western body and east-northeast in eastern body. Probably upper greenschist/lower amphibolite metamorphism.

Age. Similar to Lander Rock beds (1890 Ma?) or younger.

Reynolds Range Group

Named after Reynolds Range, Napperby 1:250 000 Sheet area; defined in Stewart & others (1980)

Map symbol. pr.

Constituent formations. Mount Thomas Quartzite (at base), Pine Hill Formation.

Distribution. Restricted in map area to Wabudali Range of northernmost VAUGHAN and southernmost CHILLA sheets. Further outcrops continue along strike to west in Mount Theo and Highland Rocks 1:250 000 sheet areas, and also in to east, in YUENDUMU 1:100 000 sheet area of Mount Doreen 1:250 000 sheet area. Main outcrop area of group is farther east, in Reynolds Range of Napperby 1:250 000 sheet area.

Thickness. About 1000 m in map area.

Topography. Forms the Wabudali Range: highest point, Mount Singleton, is 844 m a.s.l. and about 250 m above adjacent plains.

General lithology. Quartz sandstone, lithic/feldspathic sandstone, subgreywacke, siltstone, carbonates, basalt.

Deformation and metamorphism. Folded into a major, upright to slightly overturned (to the north), near-isoclinal syncline trending east-west; axial planar cleavage/schistosity generally prominent; locally mylonitic. Regional metamorphism probably up to upper greenschist facies; also affected by contact metamorphism.

Relationships. Overlies (inferred unconformity) Lander Rock beds and gneissic granophyre; intruded by Wabudali Granite, pegmatite veins, and rare metadolerite dykes.

Age. Probably between about 1830 and 1800 Ma, the age of the Hatches Creek Group (R.W.Page, personal communication, 1990)–see following paragraph.

Correlatives. Probably a correlative of the Hatches Creek Group of the Davenport province to northeast (e.g., Stewart & others, 1984; Dirks, 1990). Other possible correlatives are Patmungla beds in DOREEN to east (C.Edgoose, personal communication, 1991), Supplejack Sandstone, Pargee Sandstone and Mount Winnecke Formation in The Granites–Tanami region to northwest (Blake, 1978; Stewart & others, 1984), and Speewah and Kimberley Groups of the Kimberley region farther to the northwest.

Mineralisation. None known.

Remarks. Probably deposited on shallow marine shelf (Dirks, 1990)

Previously mapped as unnamed Precambrian schist and quartzite in Mount Doreen (Wells, 1972), but shown as Reynolds Range Group on Mount Theo map of Stewart (1976).

Mount Thomas Quartzite

Named and defined in Stewart & others (1980); type section in Napperby 1:250 000 sheet area.

Map symbol. prt.

Distribution. Wabudali Range.

Topography. Ridge-forming.

Thickness. 150-400 m.

Lithology. Quartzite (= metamorphosed quartz sandstone): mainly medium-grained, medium to thick bedded; cross-bedding, including prolapsed (Fig. 6) and large-scale high-angle types, commonly evident; locally conglomeratic at base, with pebbles and cobbles of quartzite and vein quartz. Partly mylonitic (along bedding-parallel faults?), thin-bedded to platy, with very low- angle cross-bedding and flattened pebbles, on southern side of Wabudali Range.

Deformation and metamorphism. Steeply dipping on north side and steeply dipping to overturned

Fig. 6. Prolapsed cross-bedding, Mount Thomas Quartzite, Reynolds Range Group, in the Wabudali Range (at GR VAUGHAN 808655).

on south side of major east-west trending syncline; highly compressed and mylonitic along much of southern limb. Variably recrystallised.

Relationships. Overlies Lander Rock beds and gneissic granophyre: the contact, where not a fault, is probably an unconformity, as the formation appears to post-date mesoscale folding in nearby Lander Rock beds south of the Wabudali Range and is much less deformed than immediately underlying gneissic granophyre on the north side of this range. Intruded by Wabudali Granite, pegmatite veins, and rare mafic dykes.

Pine Hill Formation

Named and defined in Stewart & others (1980); type section in Napperby 1:250 000 sheet area.

Map symbols. prpl, prpc, prpcb, prpu.

Distribution. Wabudali Range.

Topography. Forms alternating strike ridges and valleys; less resistant to erosion than Mount Thomas Quartzite.

Thickness. Up to 600 m; top not preserved.

Lithology. Ridge-forming metasandstone and recessive metasiltstone at bottom (prpl) and top (prpu), separated by central band of carbonates (prpc) and, in west, metabasalt (prpcb).

Sandstone: friable to silicified; iron-stained to bleached; quartzose to sericitic (muddy?) and also possibly slightly calcareous (pitted weathered surfaces); medium to fine-grained; thick-bedded to laminated; rather rare cross-bedding and slump structures (including prolapsed bedding); generally shows subvertical east-west trending cleavage.

Siltstone: medium to pale grey; schistose to phyllitic; thinly bedded to laminated; interbedded with sandstone; micaceous; andalusite porphyroblasts common close to Wabudali Granite.

Carbonates: calcareous sandstone and siltstone, grey limestone/marble, epidotic calc-silicate rocks, sideritic? ironstone, and ochreous dolomite?; some slump bedding; small folds developed in axial zone of major syncline.

Metabasalt: 0 to more than 30 m thick in middle of formation; amygdaloidal, especially near margins, with quartz, carbonate and some sulphides in amygdales; flow-margin breccias present in places; overlying and underlying sedimentary rocks commonly contain fine-grained basaltic detritus.

Deformation and metamorphism. Exposed in axis of major east-west syncline, which in west plunges at around 20 to east; east-plunging small-scale folds in carbonates at western fold closure; well developed axial planar cleavage. Metamorphic muscovite and biotite in metasiltstone and green amphibole and sodic plagioclase in metabasalt indicate upper greenschist (or lower amphibolite?) facies; andalusite porphyroblasts in metasiltstone attributed to contact metamorphism.

Relationships. Conformable on Mount Thomas Quartzite. Intruded by Wabudali Granite.

Gneissic granophyre

Map symbol. pgy.

Distribution. North side of the Wabudali Range in map area; also on north side of smaller range along strike to west, in CHILLA (Mount Theo).

Topography. Low hills and mounds.

Lithology. Dark greyish, fine-grained strongly foliated rock with small augen of quartz and feldspar. In thin section the augen are seen to be deformed phenocrysts lying in a foliated fine-grained micrographic (granophyric) quartzofeldspathic groundmass with biotite and muscovite.

Deformation and metamorphism. Gneissic to schistose, with east-west trending subvertical foliation/cleavage; steeply plunging lineation (mineral elongation) present in places. Primary igneous minerals highly strained, especially quartz; primary biotite partly altered to chlorite.

Relationships. Contacts poorly exposed. Inferred to intrude Lander Rock beds and to be overlain by (as more deformed than) south-dipping Mount Thomas Quartzite, the basal formation of the Reynolds Range Group. Intruded by mafic dykes, Wabudali Granite, and pegmatite veins related to this granite.

Age. Older than 1800 Ma, as overlain by Reynolds Range Group. Appears to be more deformed than adjacent overlying Mount Thomas Quartzite, but main foliation is parallel to that of the Reynolds Range Group, so emplacement may postdate the Barramundi Orogeny.

Remarks. Represents high-level, possibly subvolcanic, felsic intrusions.

Not distinguished from unnamed granite on Mount Theo map (Stewart, 1976).

Fig. 7. Granite of the Carrington Suite with a metasediment xenolith (S) and several dark mafic enclaves with highly irregular cumulose contacts suggestive of magma mingling (at GR VAUGHAN 986493).

Carrington Granitic Suite

Named after Carrington Bore in northeast VAUGHAN, at GR 970521; name approved and reserved (18/5/92).

Map symbol. pgf.

Distribution. Northeast VAUGHAN, in general vicinity of Carrington Bore; most westerly outcrop at GR 834467, 15 km WSW of bore. Extends east into DOREEN.

Type area. Group of tors 2-3 km south of Carrington Bore, centred at GR 970497, VAUGHAN sheet.

Topography. Forms scattered small kopje-like tors on sand plain; also low ridges.

Lithology. Xenolithic biotite tonalite and subordinate muscovite-biotite granite: weakly to strongly foliated; medium to fine-grained; generally homogeneous and even-grained, but patchily porphyritic, with sparse feldspar phenocrysts up to 1 cm across; quartz invariably strongly strained. Generally contains abundant metasedimentary xenoliths (hornfelsic; bedding commonly discernible) derived from Lander Rock beds; also biotite-rich mafic enclaves (tonalitic), some with crenulate contacts (Fig. 7) suggestive of magma mingling (e.g., Blake, 1991b). Gneissic granite at GR 835467 contains subhedral andalusite. Taken to include schistose to gneissic migmatitic granite north and east of type area.

Deformation and metamorphism. Foliation typically east-west and subvertical, parallel to that in adjacent Lander Rock beds. Variably recrystallised, with highly strained primary quartz; presence of secondary muscovite, chlorite and epidote indicate probable greenschist metamorphism.

Fig. 8. Foliated xenolithic Buger Creek Granite (at GR VAUGHAN 638318).

Relationships. Intrudes Lander Rock beds: contacts range from sharp and cross-cutting to lit-par-lit type, and adjacent country rocks range from hornfels metasediment to migmatitic gneiss. Intruded by foliated mafic dykes and probably by porphyritic granite of Southwark suite.

Age. Dated at 1780 Ma (Young & others, 1992), hence probably postdates Reynolds Range Group.

Remarks. Deformed during Strangways Orogeny. Shown as undivided Precambrian granite on Mount Doreen map of Wells (1972). Occurrence of migmatitic granite assigned to Carrington Suite in northeast suggests two ages of migmatite formation in the area, one at around 1880 Ma (unit plm) and the other significantly younger (Strangways Orogeny at around 1760 Ma?).

Buger Creek Granite

Name approved and reserved (18/5/92); named after Buger Creek, northwestern VAUGHAN.

Map symbol. pgb.

Distribution. Northern central VAUGHAN, south of Buger Creek Bore.

Type area. Tor at GR 713430.

Topography. Forms mainly low tors, gently undulating terrain, and partly concealed spheroidal boulders.

Lithology. Xenolithic grey medium-grained biotite and muscovite (primary)-biotite granite–CI up to 30 (Fig. 8), small feldspar phenocrysts (<2cm) present in places, quartz invariably strained; minor pegmatite, aplite, and microgranite. Xenoliths: bedded metasedimentary rocks, swirly migmatite, fine-grained biotite- rich rocks, and vein quartz (derived from Lander Rock beds and possible older basement).

Deformation and metamorphism. Weakly to strongly foliated; biotite is commonly recrystallised and quartz is highly strained, hence probably greenschist facies metamorphism.

Relationships. Intrudes Lander Rock beds; intruded by mafic dykes and porphyritic granite of Southwark suite.

Age. Probably about 1780 Ma, like petrographically similar granite of Carrington Suite. Postdates main schistosity of Lander Rock beds, as contains disoriented blocks of schistose turbidites, but foliated before being intruded by Southwark granite suite, so probably deformed during Strangways Orogeny.

Remarks. Shown as undivided Precambrian granite on Mount Doreen map of Wells (1972).

Ethel Creek Granite

Named after westward flowing Ethel Creek in northwest VAUGHAN. Name approved and reserved (18/5/92).

Map symbol. pge.

Distribution. Northwest VAUGHAN.

Type area. Tor at GR 698475.

Topography. Low tors, whalebacks, spheroidal boulders.

Lithology. Medium-grained, pale pinkish to greyish biotite granite with scattered tabular feldspar phenocrysts up to 3 cm across; sparse small quartz xenoliths and fine-grained mafic enclaves; rare pegmatite, aplite; not foliated.

Granite: consists mainly of biotite, microcline, andesine, strained quartz, and subordinate muscovite; some myrmekite.

Deformation and metamorphism. Essentially undeformed and only weakly metamorphosed.

Relationships. Intrudes Lander Rock beds; cut by northeast trending mafic dykes.

Age. Postdates folding of Lander Rock beds; may be similar in age to either Buger Creek Granite or to granites of Southwark suite.

Remarks. Not as biotite-rich or as xenolithic as Buger Creek Granite, and apparently not foliated; less porphyritic than granites of Southwark suite.

Wabudali Granite

Name approved and reserved (18/5/92); named after the Wabudali Range, on northern margin of VAUGHAN and southern margin of CHILLA.

Map symbol. pgw.

Distribution. Northern VAUGHAN, southern CHILLA, and northwestern NICKER.

Type area. Western end of Wabudali Range, in CHILLA, where the granite is well exposed as tors and pavements, and is seen to intrude Reynolds Range Group.

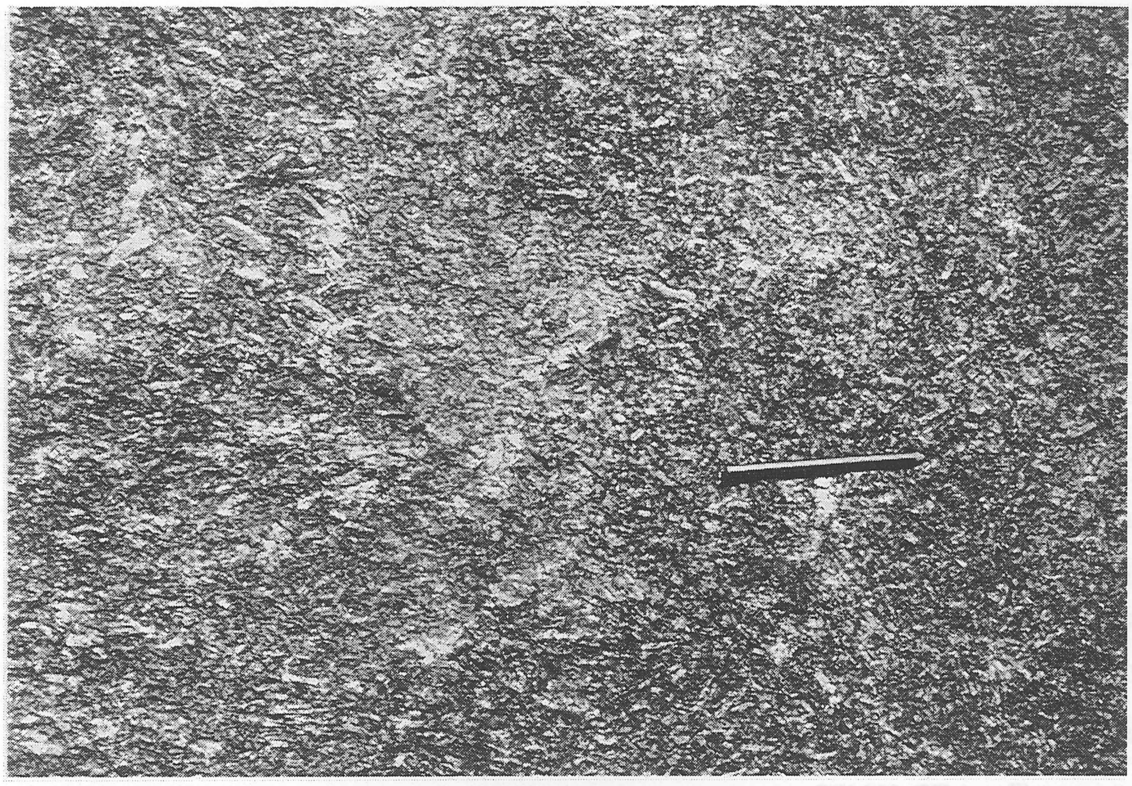

Fig. 9. Wabudali Granite, crowded with tabular feldspar phenocrysts, in the Wabudali Range (at GR VAUGHAN 786662).

Topography. Generally recessive, as mostly friable, but forms some low tors, bornhardts, and pavements, and also rock benches along north side of Wabudali Range. Cut by some ridge-forming quartz veins (quartz-filled faults).

Lithology. Pale medium to coarse-grained biotite-muscovite granite; colour index typically around 5; commonly contains abundant white tabular oligoclase phenocrysts 1-3 cm long (Fig. 9) which in some places show a pronounced swirly flow alignement; quartz invariably somewhat strained. Subordinate even-grained phases and minor aplite and pegmatite. Quartz-feldspar pegmatite veins, some containing tourmaline, common in adjacent country rocks.

Deformation and metamorphism. Generally appears undeformed, but is locally strongly foliated and mylonitic, mainly along faults marked by ridge-forming quartz veins; these faults may be related to the Alice Springs Orogeny. Thin-sections show that primary quartz is invariably highly strained.

Mineralisation. Host to tungsten and copper mineralisation at Wilsons Find, at western end of Wabudali Range in CHILLA (GR 715685): here wolframite, malachite and chryscolla occur with tourmaline in southeast-trending quartz-rich greisen veins up to 2m wide.

Relationships. Intrudes Lander Rock beds, Gneissic granophyre, and Reynolds Range Group– flat-lying to steep intrusive contacts are well exposed along the Wabudali Range, and blocks of quartzite several metres across occur in the granite at the western end of this range. Not seen in contact with granites of Southwark Suite.

Age. Maximum age 1750 Ma: postdates folding of the Reynolds Range Group in the Wabudali Range, so younger than Strangways Orogeny.

Correlations. Possible correlatives to east include granite near Silver King mine in DOREEN.

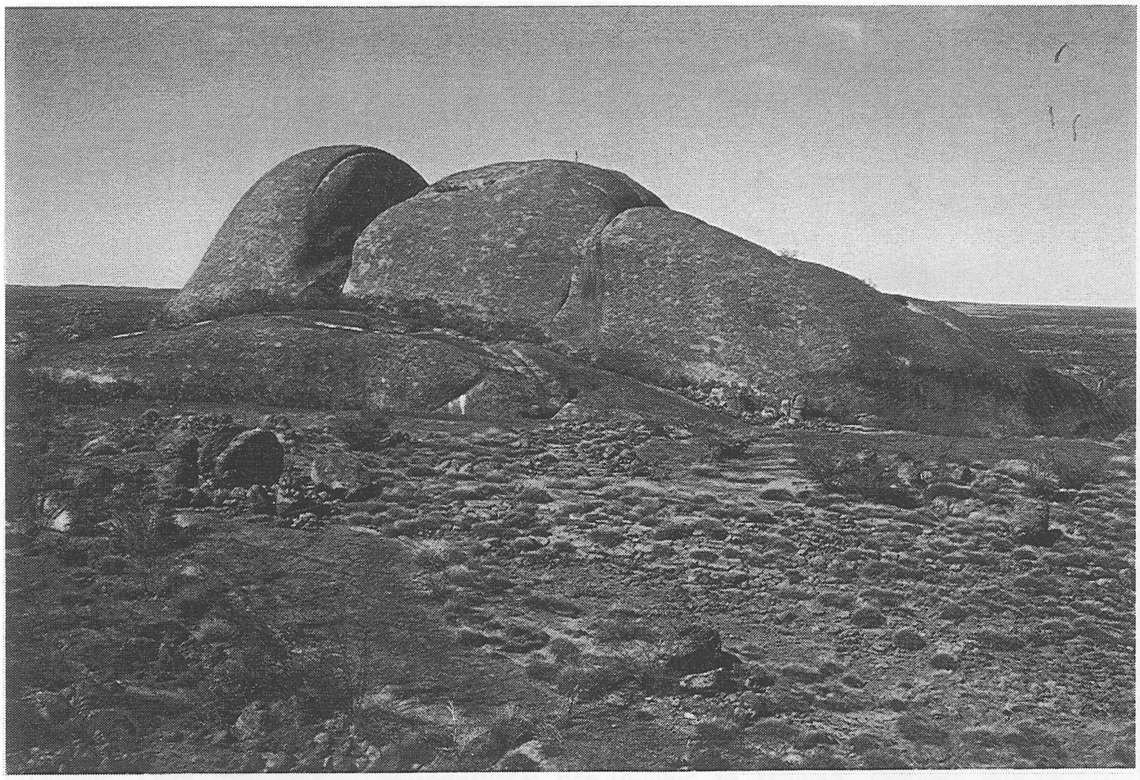

Fig. 10. Granite of the Southwark Suite in central VAUGHAN. Scale given by figure on summit (at GR VAUGHAN 900430).

Remarks. Andalusite porphyroblasts are present in adjacent contact metamorphosed pelitic country rocks, so the granite is probably mesozonal, emplaced at a depth of several kilometres.

Shown as undivided Precambrian granite on Mount Doreen and Mount Theo 1st edition maps (Wells, 1972; Stewart, 1976).

Southwark Granitic Suite

Name approved and reserved (18/5/92). Named after Southwark Bore, 5 km west of Vaughan Springs homestead, at GR 848318, VAUGHAN.

Map symbol. pgp.

Distribution. Widespread north of Ngalia Basin; extends north in VAUGHAN to within 6 km of the Wabudali Range; extends west into NICKER and east into DOREEN.

Type area. Tors and bornhardts in central VAUGHAN, around GR 900430 (Fig. 10).

Topography. Tors, bornhardts, rock pavements and spheroidal boulders.

Lithology. Coarsely porphyritic biotite granite; minor leucogranite, aplite, and, in north (near GR 775570), heterogeneous microgranite.

Porphyritic biotite granite: characterised by generally abundant, pale pinkish, equidimensional, poikilitic phenocrysts of alkali feldspar (microcline) 1 cm and in places up to 10 cm across (Fig. 11), and smaller phenocrysts of equant quartz and white tabular sodic plagioclase in a fine to coarse-grained, pale pinkish to greyish groundmass of mainly quartz, feldspar (microcline and plagioclase), and biotite (commonly in small clots); quartz is variably strained; some muscovite,

Fig. 11. Feldspar phenocrysts in weathered granite of the Southwark Suite (at GR VAUGHAN 898431).

partly secondary, is commonly present, as is secondary chlorite after biotite; dark blue-green amphibole present with biotite at GR 955413; small xenoliths of dark fine-grained biotite tonalite common.

Leucogranite: medium to coarse; typically friable and bleached; widely scattered feldspar phenocrysts up to 2 cm across and small xenoliths present in places.

Heterogeneous microgranite: pale to dark grey biotite microgranite with irregularly distributed microcline and plagioclase phenocrysts; streakily banded in places; occurs as irregular vein-like bodies a few centimeters to over a metre thick cutting porphyritic granite.

Deformation and metamorphism. Not foliated, except near faults, but quartz invariably highly strained; secondary muscovite and chlorite may be related to low grade regional metamorphism during the Alice Springs Orogeny.

Relationships. Intrudes Lander Rock beds and some granite (Pge and Pgf) and mafic dykes; not seen in contact with Reynolds Range Group or Wabudali Granite (Pgw); overlain by Vaughan Springs Quartzite; cut by mafic dykes, lamprophyre (at GR 850453), and quartz-filled faults.

Age. A very similar megacrystic granite to the east, in DOREEN, was dated at 1567 ± 6 Ma (Yarunganyi Granite; Young & others, 1992, in press); predates Vaughan Springs Quartzite and postdates main deformation of Reynolds Range Group.

Correlations. Similar coarsely porphyritic granite extensively exposed in DOREEN and YUENDUMU to east.

Mineralisation. None known.

Remarks. Probably mesozonal to epizonal intrusions.Shown as undivided Precambrian granite on Mount Doreen map of Wells (1972).

Unassigned granite

Photointerpreted outcrops, not visited in field.

Map symbol. pg.

Distribution. Small isolated outcrops in northern VAUGHAN, north of Ngalia Basin.

Topography. Low mounds.

Remarks. Probably either Buger Creek Granite or Southwark Granitic Suite.

Mafic dykes

Map symbol. Dyke symbol

Distribution. Arunta Block north of Ngalia Basin.

Topography. Recessive; poorly exposed. Some dykes show up as thin dark bands on aerial photographs.

Lithology. Dark, fine-grained **metadolerite**: non-foliated to foliated; samples thin-sectioned contain metamorphic sodic plagioclase and green amphibole, but most have igneous textures partly preserved, suggestive of upper greenschist facies metamorphism, and some contain remnants of primary pyroxene.

Lamprophyre: dyke 20 cm thick at GR 850453; consists of fine-grained euhedral biotite and augite in groundmass of altered glass.

Relationships. Metadolerite dykes intrude Lander Rock beds, Reynolds Range Group, gneissic granophyre, Buger Creek and Ethel Creek Granites, and Carrington Granitic Suite; cut by coarsely porphyritic granite (e.g., at GR 757408). Dyke of non-foliated metadolerite cuts gneissic granophyre at GR 726685. Lamprophyre at GR 850453 cuts coarsely porphyritic granite of Southwark Suite.

Age. At least two ages apparent, as some dykes predate and others postdate emplacement of coarsely porphyritic granite. The younger dykes may include equivalents of the Stuart Dyke Swarm to the southeast, dated by Black & others (1980) at about 900 Ma.

Remarks. Most dykes seen are less than 5 m thick.

NGALIA BASIN SUCCESSION

NEOPROTEROZOIC (late Proterozoic)

Siliceous breccia

Map symbol. pas.

Distribution. Hillock at GR 795287, about 1.2 km northwest of Ngalia Basin succession exposed in the Vaughan Springs Syncline.

Description. Recrystallised siliceous breccia: small angular fragments of quartz in very fine-grained iron-stained matrix; no bedding or foliation; some quartz veining.

Remarks. May represent silicified palaeoregolith (silcrete) developed prior to deposition of Vaughan Springs Quartzite.

Vaughan Springs Quartzite

Named and defined by Wells & Moss (1983) to include Treuer Member. Now taken to comprise three members in Vaughan–Bigrlyi Sandstone, Treuer, and Eva Springs Sandstone.

Map Symbols. pay (Bigrlyi Sandstone Member), pat (Treuer Member), pae (Eva Springs Sandstone Member).

Distribution. Along northern margin of Ngalia Basin in VAUGHAN.

Type section. Northwest flank of Vaughan Springs Syncline, about 6 km west of Vaughan Springs homestead (Wells & Moss, 1983): from about GR 843324 (base) southeast to GR 857315 (top), VAUGHAN.

Topography. Sandstone members form the prominent strike ridges of the Treuer Range, Treuer Member forms lower strike ridges, undulating terrain, and, in southwest, cuestas.

Thickness. About 1750 m in type section (Wells & Moss, 1983).

Lithology. Quartz sandstone; subordinate siltstone, feldspathic and micaceous sandstones, shale, claystone, conglomerate.

Deformation and metamorphism. Folded, faulted and thrusted during Alice Springs Orogeny. Bedding attitudes range from flat-lying to vertical to strongly overturned (e.g., east of 12 Mile Creek); strike of bedding generally subparallel to northern margin of Ngalia Basin, except in noses of folds; main fold is the Vaughan Springs Syncline west of Vaughan Springs homestead. Variably recrystallised, but no appreciable metamorphism.

Relationships. Unconformable on Southwark Granitic Suite along north side of Treuer Range; unconformable on schist assigned to Lander Rock beds (unit plrs) in west, overlain concordantly by Albinia Formation and unconformably by Mount Doreen Formation and Mount Eclipse Sandstone.

Age and correlations. Minimum age of 1280 Ma indicated from Rb-Sr and K-Ar measurements on glauconite from Treuer Member (Cooper & others, 1971), but the formation is correlated with ?850 Ma-old Heavitree Quartzite of the Amadeus Basin (e.g., Wells & Moss, 1983); also correlated with basal formations of Redcliff Pound Group in The Granites–Tanami region (Blake, 1978), and possibly with Mount Parker Sandstone of the east Kimberley region.

Bigrlyi Sandstone Member

Name approved and reserved (18/5/92). Named after Bigrlyi Gap, Treuer Range, DOREEN.

Map symbol. pay.

Distribution. Northeast of Vaughan Springs homestead, in eastern VAUGHAN, between GR 927377 and GR 964395; also present along north side of Treuer Range in western DOREEN, northeast of Bigrlyi Gap. Not present in type section of Vaughan Springs Quartzite.

Topography. Forms prominant narrow flat-topped ridge.

Type section. ?In western DOREEN, northeast of Bigrlyi Gap.

Thickness. About 200 m in VAUGHAN.

Lithology. Medium to thick-bedded silicified to friable quartz sandstone; minor interbedded siltstone and sandstone of Treuer Member type.

Deformation and Metamorphism. Bedding has moderate to steep southerly dips; outcrop area cut by several faults. Not metamorphosed.

Relationships. Inferred to overlie granite of Southwark Suite (contact not exposed); grades up (south) into Treuer Member.

Age and correlations. See Vaughan Springs Quartzite.

Treuer Member (of Vaughan Springs Quartzite)

Named and defined by Wells & Moss (1983).

Map symbol. pat.

Distribution. Along northern margin of Ngalia Basin (Wells, 1972) in VAUGHAN: on north side of Treuer Range east of Vaughan Springs homestead, around the sides of the Vaughan Springs Syncline to the west, and forms entire Treuer Range to southwest.

Topography. Strike ridges and valleys, cuestas (in southwest), and undulating terrain along Treuer Range; ridges not as high as those of Bigrlyi and Eva Springs Sandstone Members.

Type section. According to Wells & Moss (1983), about 20km west-southwest of Mount Davenport, i.e., near GR 650170, at western end of Treuer Range in VAUGHAN. More representative section is lower part of the Vaughan Springs Quartzite type section, on northwest limb of Vaughan Springs Syncline, where Treuer Member is inferred to overlie granite of Southwark Suite and is overlain conformably, just southeast of Southwark Bore, by Eva Springs Sandstone Member.

Thickness. Probably up to 500 m; difficult to measure because of folding, faulting and gaps in exposures.

Lithology. Interbedded siltsone and sandstone; subordinate shale, claystone; rare chert; some possible evaporites; conglomeratic sandstone locally present near base in southwest.

Siltsone, shale, claystone: recessive, thinly bedded to laminated, friable, white to pale grey (bleached) or iron-stained; halite encrustations common.

Sandstone: ridge-forming, pale greyish or iron-stained, typically compact and tough, thin to medium-bedded; commonly platy or flaggy, with siltstone or claystone pellet casts on bedding planes; otherwise generally well sorted/even-grained; cross- bedding common, ripple marks less common; feldspathic to quartz-rich, also some micaceous and glauconitic beds (e.g., near GR 980380); quartz overgrowth cement.

Conglomeratic sandstone: poorly sorted, with pebbles and granules of vein quartz and quartzite.

Deformation and metamorphism. Medium to small-scale folding common (see Fig. 16): folds typically upright, open to tight and locally overturned, gently to steeply plunging, with trends

Fig. 12. Dip slope of Eva Springs Sandstone Member, Vaughan Springs Quartzite, on the southeast side of the Vaughan Springs Syncline, with poorly exposed Albinia Formation in the foreground. View from GR VAUGHAN 852287.

subparallel to general bedding; broad open folding in southwest. Does not appear to be metamorphosed.

Relationships. Unconformable on schist assigned to Lander Rock beds (contact exposed in southwest, near GR 656192) and on granite of Southwark Suite (e.g., near GR 697195 and GR 825301); conformable on Bigrlyi Sandstone Member; overlain conformably by Eva Springs Sandstone Member and conformably or disconformably in southwest, west of Waite Creek, by carbonates assigned to Albinia Formation.

Age and Correlations. As for Vaughan Springs Quartzite.

Eva Springs Sandstone Member

Named after Eva Springs on Waite Creek at GR 814279, VAUGHAN; name approved and reserved (18/5/92).

Map symbol. pae.

Distribution. Treuer Range of central and eastern VAUGHAN.

Topography. Forms main strike ridges of Treuer Range (e.g., Fig. 12).

Type section. Central and upper part of the sequence exposed in the type section of the Vaughan Springs Quartzite, from GR 848318 (base, conformable on Treuer Member) to 857315 (top), VAUGHAN.

Thickness. About 900 m in type section (from Wells & Moss, 1983).

Lithology. Medium to thick-bedded quartz sandstone: pale pinkish to pale grey, or bleached, or iron-stained; friable to silicified; mainly medium-grained and well sorted; abundant cross-bedding

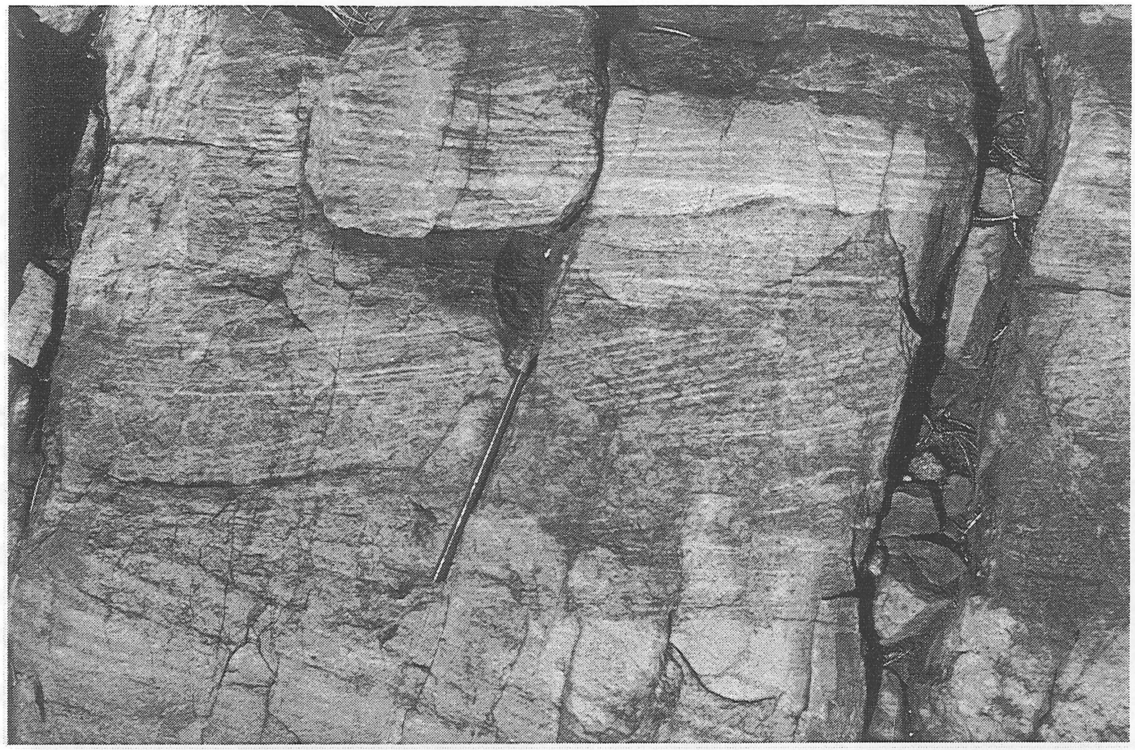

Fig. 13. Cross-bedding in the Eva Springs Sandstone Member of the Vaughan Springs Quartzite (at GR VAUGHAN 887346).

(Fig. 13); ripple marks uncommon; generally no siltstone or claystone pellet casts (in contrast to sandstone of Treuer Member.

Deformation and metamorphism. Forms major folds—Vaughan Springs Syncline and smaller anticline on east side; south facing to east, with moderate to steep dips and, east of 12 Mile Creek, vertical to strongly overturned; brecciated near faults—barite-filled breccia veins at GR 886309. Not noticeably metamorphosed.

Relationships. Conformable on Treuer Member of Vaughan Springs Quartzite. Overlain conformably or disconformably by Albinia Formation, unconformably by Mount Doreen Formation and Mount Eclipse Sandstone.

Age and correlations. See Vaughan Springs Quartzite.

Albinia Formation

Named and defined by Wells & Moss (1983).

Map symbol. paa.

Distribution. Main outcrop is in Vaughan Springs Syncline; also mapped to southwest: in fault zone at GR 662172 and on south side of low ridge near GR 647155 (outcrop too small to show on map).

Topography. Recessive unit; forms low mounds, cuestas, and undulating terrain capped in places by calcrete, but largely covered by Quaternary sediments.

Type section. Southwest part of Vaughan Springs Syncline (Wells & Moss, 1983), from GR 830280 (concealed base, overlying Eva Springs Sandstone) to GR 840287 (where inferred to be overlain by concealed Mount Doreen Formation), VAUGHAN.

Fig. 14. Bedded dolomite and chert (c) of the Albinia Formation in the Vaughan Springs Syncline (at GR VAUGHAN 831280).

Thickness. Possibly up to 500 m in Vaughan Springs Syncline (Wells & Moss, 1983).

Lithology. Grey dolomitic siltstone and shale; stromotalitic dolomite; black chert; thinly bedded to laminated (Fig. 14).

Relationships, correlations, and age. Overlies Vaughan Springs Quartzite (Eva Springs Sandstone Member in Vaughan Springs Syncline, Treuer Member in southwest) conformably or disconformably; unconformably overlain by Mount Doreen Formation. Correlated with Bitter Springs Formation of Amadeus Basin (Wells & Moss, 1983) and possibly with Bungle Bungle Dolomite of east Kimberley region.

Remarks. Distinguishing features are grey colour of dolomitic beds (cf. pinkish dolomite in Mount Doreen Formation) and presence of thin black chert lenses.

Dolomitic beds at GR 662172 assigned to Mount Doreen Formation by Wells (1972), but now regarded as Albinia Formation because grey rather than pink.

Finely banded silicified carbonates exposed near GR 647155 consist mainly of quartz and barite.

Mount Doreen Formation

Named and defined by Wells & Moss (1983)

Map symbol. paq.

Distribution. Vaughan Springs Syncline, and in Treuer Range to east, east of 12 Mile Creek.

Topography. Recessive; generally concealed by Quaternary sediments, but exposed in some gullies.

Type section. In DOREEN (Wells & Moss, 1983).

Thickness. 0 to possibly 350 m in VAUGHAN.

Lithology. Diamictite, dolomite, sandstone, siltstone/shale.

Diamictite in Vaughan Springs Syncline: at base of formation at GR 867327—boulders, commonly striated and faceted, of quartzite in abundant unsorted matrix, characterised by angular quartz and quartzite clasts of all sizes down to submicroscopic; near top of formation—weathered out boulders of granite, gneiss, and quartzite strewn on surface.

Dolomite: exposed east of 12 Mile Creek; typically pinkish, laminated, stromatolitic; some bands with scattered sand to granule size quartz grained and fragments of lamina-banded chert.

Sandstone: forms band a few metres thick at or near top of formation on northwest side of Vaughan Springs Syncline; gritty to pebble (conglomeratic, poorly sorted), with poorly defined bedding planes; quartzose; friable and iron-stained.

Siltstone-shale: at top of formation east of 12 Mile Creek, a few tens of metres thick; reddish-brown, thinly bedded: also in Vaughan Springs Syncline, at GR 872327—weathered, in creek area.

Deformation and metamorphism. Moderately to steeply dipping in Vaughan Springs Syncline; strongly overturned east of 12 Mile Creek. Not metamorphosed.

Relationships. Unconformable on Eva Springs Sandstone Member of Vaughan Springs Quartzite; overlain unconformable by Djagamara Formation in Vaughan Springs Syncline and Mount Eclipse Sandstone east of 12 Mile Creek.

Age and correlations. Late Proterozoic; correlated with youngest glacial formation in Amadeus Basin and possibly also that in Kimberley region (Wells & Moss, 1983).

Remarks. Poorly exposed formation; presence commonly indicated only by recognisable glacial erratics on surface. Diamictite mapped as basal Mount Doreen Formation in Vaughan Springs Syncline (at GR 867327) may be part of Nabarula Formation of Wells & Moss (1983), and weathered shale/siltstone in creek bed to east (at GR 872327) may be part of Rinkbeena Shale of Wells & Moss (1983).

Three members distinguished by Wells & Moss (1983: Mount Davenport Diamictite Member, probably represented by diamictite with granite and gneiss erratics in Vaughan Springs Syncline, Wanapi Dolomite Member, probably represented by dolomite east of 12 Mile Creek, and Newhaven Shale Member, probably represented by shale/siltstone at top of formation east of 12 Mile Creek.

?ORDOVICIAN

Djagamara Formation

Named and defined by Wells & Moss (1983); type section in DOREEN.

Map symbol. Od.

Distribution. Confined in mapped area to Vaughan Springs Syncline.

Topography. Strike ridges.

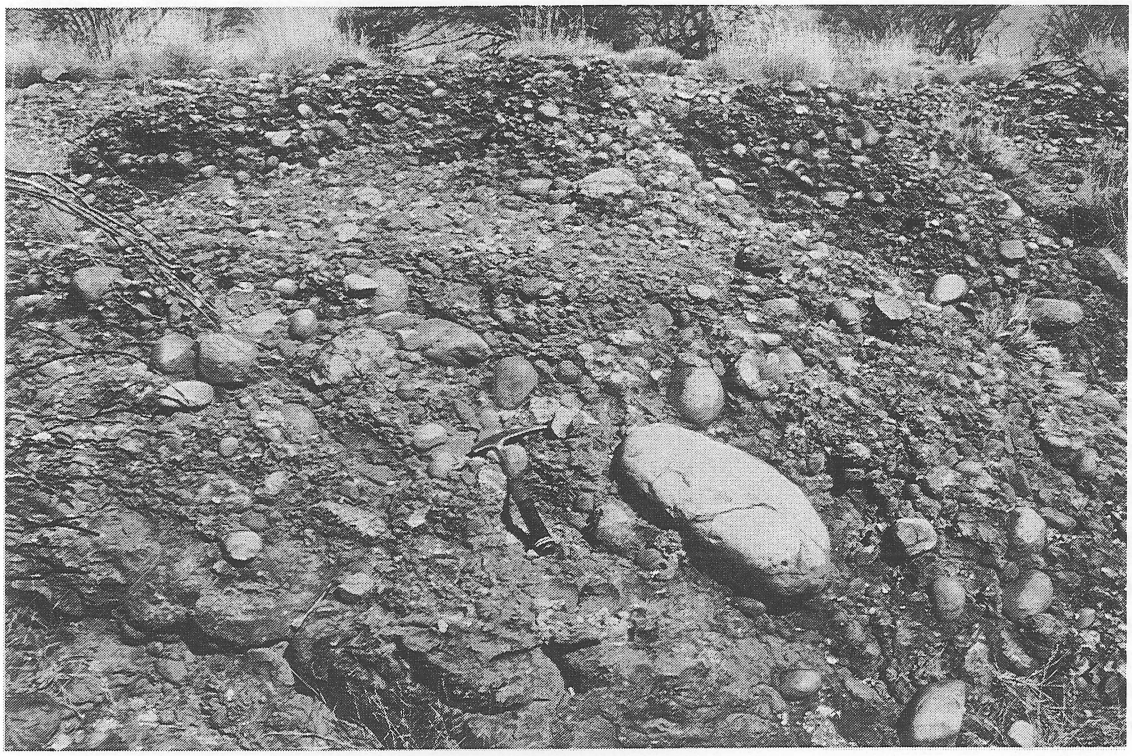

Fig. 15. Quartzite boulder in flat-lying conglomerate of the Mount Eclipse Sandstone (at GR VAUGHAN 789214).

Thickness. About 225 m in Vaughan Springs Syncline (Wells & Moss, 1983).

Lithology. Thin to medium-bedded pale greyish sandstone with abundant mudstone pellets, subordinate darker siltstone; sandstone commonly silicified, platy, ripple-bedded. Glauconitic sandstone identified to east (Wells & Moss, 1983).

Relationships. In Vaughan Springs Syncline overlies Albinia Formation and Mount Doreen Formation and overlain by Mount Eclipse Sandstone. Contacts concealed, but inferred to be low-angle unconformities.

Deformation and metamorphism. Tight fold (Vaughan Springs Syncline) formed during Alice Springs Orogeny; not metamorphosed.

Age and correlations. Possibly early Ordovician, correlated with Cambro-Ordovician sandstones of Larapinta Group in the Amadeus Basin (Wells & Moss, 1983).

Remarks. Probably deposited in shallow marine environment (Wells & Moss, 1983).

DEVONIAN TO CARBONIFEROUS

Mount Eclipse Sandstone

Named and defined by Wells & Moss (1983); type section in YUENDUMU to east.

Map symbol. Pzt.

Distribution. Treuer Range (in centre of Vaughan Springs Syncline) and to south and east.

Topography. Generally recessive in VAUGHAN, but forms some strike ridges, cuestas, and mesas.

Thickness. Greater than 2000 m in central part of Ngalia Basin (Wells & Moss, 1983).

Lithology. Friable to silicified arkosic sandstone: mainly coarse-grained, with scattered rounded cobbles and pebbles, mostly of quartzite but also some of quartz sandstone, vein quartz, and grey limestone; some beds have calcite cement; thin to thick-bedded, commonly cross-bedded. Subordinate boulder and cobble conglomerate (Fig. 15) and siltstone.

Relationships. Overlies Vaughan Springs Quartzite, Mount Doreen Formation, and Djagamara Formation with low angle unconformity; overlain by Cainozoic deposits.

Deformation and metamorphism. Steeply dipping to flat-lying; strongly overturned in Treuer Range near Twelve Mile Creek. Not metamorphosed.

Age. Plant fossils and spores indicate late Devonian to late Carboniferous age (Wells & Moss, 1983).

Correlations. Correlated with Pertnjara Group of Amadeus Basin and possibly with Lucas Formation, Pedestal beds, and Chuall beds of The Granites–Tanami region (Wells & Moss, 1983) and Mahoney Group of Ord Basin (Mory & Beere, 1988).

Remarks. Probably continental formation, deposited mainly in fluvial and piedmont environments (Wells & Moss, 1983).

CAINOZOIC

The Cainozoic units mapped in Vaughan area are based largely on airphoto interpretation using vegetation and geomorphic criteria. Boundaries between units range from sharp and well defined to gradational and highly diffuse, and in many cases are somewhat arbitrary. Many of the areas shown as a single unit are compound in that they consist of two or more types of sediment; for example, areas shown as Qs, aeolian sand, may contain unmapped inclusions of residual sand and silt (Qr) and alluvial sand and silt (Qa).

Homestead beds

Name informal, not submitted for approval.

Map symbol. Ts.

Distribution and topography. Two mesas about 40 m high near Vaughan Springs homestead.

Thickness. At least 40 m.

Lithology. Iron-stained to bleached silicified silty/clayey sandstone and mudstone capped by nodular lateritic ironstone.

Remarks. Flat-lying erosional remnants of extensive Tertiary or older sediments overlapping onto Vaughan Springs Quartzite.

Laterite

Map symbol. Czf.

Description. Ferruginous cappings on low mounds within Ngalia Basin near GR 840140 and GR 960153.

Silcrete

Map symbol. Czs.

Description. Siliceous cappings on mesas and mounds; consist of angular fragments of quartz in amorphous siliceous matrix; developed mainly on granite.

Poorly consolidated gravel and sand

Map symbol. Czc.

Description. Colluvial and fluvial detritus forming incised, now inactive, fans; probably mainly Tertiary rather than Quaternary.

Calcrete

Map symbol. Czk.

Description. Low mounds of inorganic limestone developed on metadolerite in northwest; formed subsurface by evaporation of groundwater, so may be Tertiary rather than Quaternary.

Granitic sand

Map symbol. Qg.

Description. Granitic sand/disaggregated granite with scattered low exposures of rubble granite forming undulating terrain in west, in vicinity of Waite Creek; merges into map units pgp, Qr and Qs.

Lag gravel

Map symbol. Qq.

Description. Residual rubble, consisting largely of vein quartz, on low mounds and flanking low hills; forms thin veneer (?less than 1 m thick) on bedrock–which is mainly Lander Rock beds.

Sand and gravel on active fans

Map symbol. Qc.

Description. Unconsolidated sand and gravel on fans and scree slopes flanking ridges of sandstone and vein quartz.

Sheet-wash sand and silt ("red earth")

Map symbol. Qr.

Description. Sheet-wash deposits of unconsolidated sand and silt on low rises (interfluves) between drainage lines; characteristic airphoto pattern of dark-toned mulga forming closely spaced, irregularly arcuate strips and patches, convex down slope; merges into Qs.

Aeolian sand

Map symbol. Qs.

Description. Unconsolidated sand, largely aeolian, covering plains that are slightly higher than adjacent drainage depressions; includes sand dune country in the south and southeast; merges into Qr and Qa.

Lacustrine silt, clay

Map symbol. Qt.

Description. Fine sediment and possibly some evaporites deposited in claypans; as mapped, includes groups of closely spaced claypans; merges into Qa.

Alluvial sand and silt

Map symbol. Qa.

Description. Unconsolidated fluvial sediments laid down along floodplains and in drainage depressions; merges into Qs and Qt.

DEFORMATION AND METAMORPHISM

Three major periods of deformation and metamorphism are evident in the area. The first was the Yuendumu Event of Shaw (in preparation), which may be correlated with the Barramundi Orogeny of northern Australia (Etheridge & others, 1987). The Barramundi Orogeny has been dated at around 1880 Ma (Page & Williams, 1988). This early deformation affected the Lander Rock beds and Nicker beds, but predated the Reynolds Range Group. The second was the Strangways Orogeny, which postdated deposition of the Reynolds Range Group and emplacement of the Carrington Granitic Suite, but predated intrusion of Wabudali Granite and the Southwark Granitic Suite. The third and last major deformation was the Alice Springs Orogeny, during which the Ngalia Basin succession was deformed. All three deformations appear to have resulted in north-south shortening, and structural trends are predominantly between east-west and northeast-southwest. Because of this patrallism, many structures cannot be readily assigned to a particular deformation.

In the Lander Rock beds and Nicker beds the earliest structures recognised are tight to isoclinal upright folds with wave-lengths commonly less than 1 km, and a generally pronounced penetrative slaty axial-planar cleavage. The folds typically have east-west trends and steep plunges. A bedding/cleavage intersection lineation is commonly developed. This folding predates all granites exposed in the area.

The Reynolds Range Group in northern VAUGHAN and southern CHILLA forms a major tight, upright, boat-shaped syncline more than 20 km long from west to east and up to 2 km across. The southern limb is overturned for much of its length. The fold plunges gently east in the west and more steeply west in the east. An axial planar cleavage is generally well developed, especially in the Pine Hill Formation of the Reynolds Range Group, and a bedding/cleavage intersection lineation is present in many places. The syncline reappears along strike to the west, in CHILLA, and to the east, in YUENDUMU.

The Mount Thomas Quartzite on the southern limb of the syncline shows much thinner bedding than on the northern limb, with low to very low-angle cross-bedding, and has a mylonitic fabric. Although mainly plane-strain deformation is indicated, flattened granules and small pebbles with slightly asymmetrical fabrics suggest some top-to-the-north sense of shear (Shaw, in preparation). This high-strain zone along the southern limb of the syncline is considered by Shaw to have formed during progressive development of the fold, rather than being a later feature, as it is parallel to the axial plane of the syncline and is at the same metamorphic grade as the rest of the Reynolds Group in the area. Crenulations in the core of the syncline and local tight folding of the bedding/cleavage intersection lineation postdate the main fold, but may have formed during the same deformation event. Cross-cutting small mesoscopic kinks could be related to subsequent gentle bending of the main syncline.

Fig. 16a & b. Steeply plunging small-scale folds in the Treuer Member of the Vaughan Springs Quartzite (at GR VAUGHAN 791239).

The syncline and associated cleavage are cut by, and hence predate emplacement of, the Wabudali Granite, and are attributed to the Strangways Orogeny documented in the Arunta Block to the east and dated at 1750-1780 Ma (Black & Shaw, 1992).

Along the northern margin of the Ngalia Basin the Vaughan Springs Quartzite and younger formations of the Ngalia Basin succession form a series of folds trending between east and east-northeast. The largest of these folds is the Vaughan Springs Syncline. There is no associated axial planar cleavage. Small, open to tight, gently to steeply plunging folds characterise the Treuer Member of the Vaughan Springs Quartzite (Fig. 16). These folds are typically a few metres to tens of metres across, close to upright, and aligned parallel to stratigraphic contacts. They may be related to structures in the underlying Arunta Block (Shaw, in preparation). Bedding in the Vaughan Springs Quartzite, Mount Doreen Formation, and Mount Eclipse Sandstone in the Treuer Range near Twelve Mile Creek is strongly overturned, dipping north at angles as low as 20° but facing south. The main folds affect, and hence postdate, the Devonian to lower Carboniferous

Fig. 16b.

Mount Eclipse Sandstone, and were probably formed about 300 Ma ago, at the end of the Alice Springs Orogeny.

Faults

Some of the faults in the area are related to the Alice Springs Orogeny, especially those that affect the Ngalia Basin, but others may be older. The latter include the numerous faults in the Arunta Block marked along parts of their length by ridge-forming veins of recrystallised quartz that is sheared, brecciated, and cut by quartz veinlets, suggestive of several phases of movement; rocks adjacent to these veins are commonly highly foliated to mylonitic. Measured dips on faults range from vertical to about 45^{o}, but most faults appear to be subvertical.

Stratigraphic omissions and low-angle unconformites between units in the Ngalia Basin succession probably result from faulting and tilting associated with early phases of the Alice Springs Orogeny (Shaw, in preparation). Overturned strata in the Treuer Range near Twelve Mile Creek may be attributed to north-over-south thrusting. Similar southward thrusting of the Arunta Block over the northern part of the Ngalia Basin is indicated from seismic evidence, which also shows that the basin is deepest near its exposed northern margin. The best documented large thrust fault is the concealed Waite Creek Fault of western VAUGHAN, which, as summarised by Wells & Moss (1983) and Shaw (in preparation), has an estimated dip of about 25^{o} and horizontal displacement of 11.5 km. Like the main folding of the Ngalia Basin succession, the thrusting took place at the end of the Alice Springs Orogeny, about 300 Ma ago.

Metamorphism

The first two deformations recognised in the area were accompanied by regional metamorphism of low pressure/high temperature type. The Lander Rock beds were metamorphosed to mainly upper greenschist/lower amphibolite facies during the Barramundi Orogeny and also, together with the Reynolds Range Group, during the Strangways Orogeny. Local partial melting and development of migmatite and granulite assigned to the Lander Rock beds in the north indicates that in places the metamorphism reached upper amphibolite to granulite facies. Two ages of migmatitisation may be represented, as has been suggested in the Reynolds Range area in the Napperby 1:250 000 Sheet area by Hand & others (1992), one older and the other younger than the Reynolds Range Group: migmatite near Yendumu is cut by garnet and cordierite-bearing granite, dated at 1880 ± 9 Ma (Ngadarunga Granite; Young & others, 1992), but migmatite in northeast VAUGHAN appears to grade laterally into gneissic granite of the 1780 Ma old Carrington Suite and may be related to the Strangways Orogeny.

The granites and mafic dykes in the area postdate the Barramundi Orogeny, but some, including the granites of the Carrington Suite, were deformed and metamorphosed during the Strangways Orogeny. Although the granites of the Southwark Suite and the Wabudali Granite were intruded after the Strangways Orogeny, they show some metamorphic effects: quartz in the granites is invariably strained, and cross-cutting mafic dykes contain metamorphic sodic plagioclase and green amphibole indicative of upper greenschist or lower amphibolite facies. This late metamorphism may be related to the Alice Springs Orogeny or to one of the deformations that took place in the Arunta Block to the east between about 1550 Ma and 1000 Ma.

The Vaughan Springs Quartzite at the base of the Ngalia Basin succession may have been weakly metamorphosed (partly recrystallised to quartzite) during the Alice Springs Orogeny, but overlying formations do not appear to be metamorphosed.

The development of andalusite, muscovite, tourmaline, and garnet porphyroblasts, and also fibrolitic sillimanite, is restricted to pelitic metasediments of the Lander Rock beds and Reynolds Range Group (Pine Hill Formation) within about a kilometre of granite intrusions, and is attributed to contact metamorphism related to granite emplacement.

GEOLOGICAL HISTORY

The mapping of VAUGHAN and adjoining map sheets indicates the following sequence of major events (see also BMR, 1991).

1. Deposition of the Lander Rock and Nicker beds. These two thick units of sedimentary and subordinate volcanic rocks were probably laid down in deep water. They are lithologically similar to, and probably contiguous with, the Tanami Complex of The Granites–Tanami region to the northwest (Blake & others, 1979), and hence may be correlated with the 1870 Ma-old Halls Creek

Group of the east Kimberley and Warramunga Group of the Tennant Creek Inlier. U-Pb zircon dating of felsic volcanics in the Nicker beds should resolve these uncertainties.

2. *Deformation and metamorphism.* The Lander Rock beds were tightly folded and, together with granophyre in the north and possibly some granite to the south, were cleaved about upright east-west trending axial planes, and regionally metamorphosed, before being overlain unconformably by the Reynolds Range Group (e.g., Clarke & Powell, 1991). This tectonism is probably related to the Barramundi Orogeny of northern Australia, dates for which currently range from about 1890 to 1860 Ma (e.g., Page & Williams, 1988).

3. *Intrusion of felsic magma.* The Lander Rock beds were intruded by porphyritic granophyre in the far north and possibly also by some granite to the south either before or after the Barramundi Orogeny, but before event 4.

4. *Deposition of the Reynolds Range Group.* After uplift associated with the Barramundi Orogeny and a period of erosion, the Reynolds Range Group was deposited in shallow water on a broad shelf or platform. Minor basaltic volcanism accompanied the sedimentation. The group is probably a correlative of the 1830-1800 Ma-old Hatches Creek Group, which unconformably overlies the Warramunga Group in the Davenport province of the Tennant Creek Inlier to the northeast (Blake & others, 1987), and hence part of a major sequence that once covered much of central Australia.

5. *Intrusion of the Carrington Granitic Suite.* Granite belonging to this suite was emplaced at about 1780 Ma (Young & others, 1992), shortly before folding of the Reynolds Range Group. The Buger Creek Granite may be of similar age.

6. *Deformation of the Reynolds Range Group.* Sometime after deposition, but before emplacement of Wabudali Granite, the Reynolds Range Group was folded into a major east-west trending syncline and regionally metamorphosed to greenschist facies. The deformation and local migmatite formation affecting granites of the Carrington Suite probably took place at this time–the Strangways Orogeny.

7. *Granite emplacement.* Large volumes of granitic magma were intruded into previously folded Lander Rock beds, Nicker beds, and Reynolds Range Group, forming the Wabudali Granite in the north and the Southwark Granitic Suite and possibly also the Ethel Creek Granite to the south.

8. *Intrusion of mafic dykes.* This event overlaps with event 7, as some mafic dykes postdate, whereas others predate, emplacement of porphyritic granite of the Southwark Suite. The dykes may include correlatives of the 900 Ma-old Stuart Dyke Swarm exposed in the Arunta Block to the east.

9. *Ngalia Basin sedimentation.* The oldest formation in the Ngalia Basin, the Vaughan Springs Quartzite, is correlated with the ?850 Ma-old Heavitree Quartzite of the Amadeus Basin to the south. Sedimentation continued intermittently until the Carboniferous, the youngest formation preserved being the Mount Eclipse Sandstone. The Ngalia Basin succession is much thinner than the Amadeus Basin succession to the south, and many units in the Amadeus Basin are not represented. Either the missing units were never deposited or they were eroded before the deposition of the Mount Eclipse Sandstone.

10. *Alice Springs Orogeny.* Towards the end of this orogeny, about 300 Ma ago, the Ngalia Basin succession was folded, faulted, and overthrust from the north by the Arunta Block. Many of the mapped faults in the Arunta Block were probably active during this period.

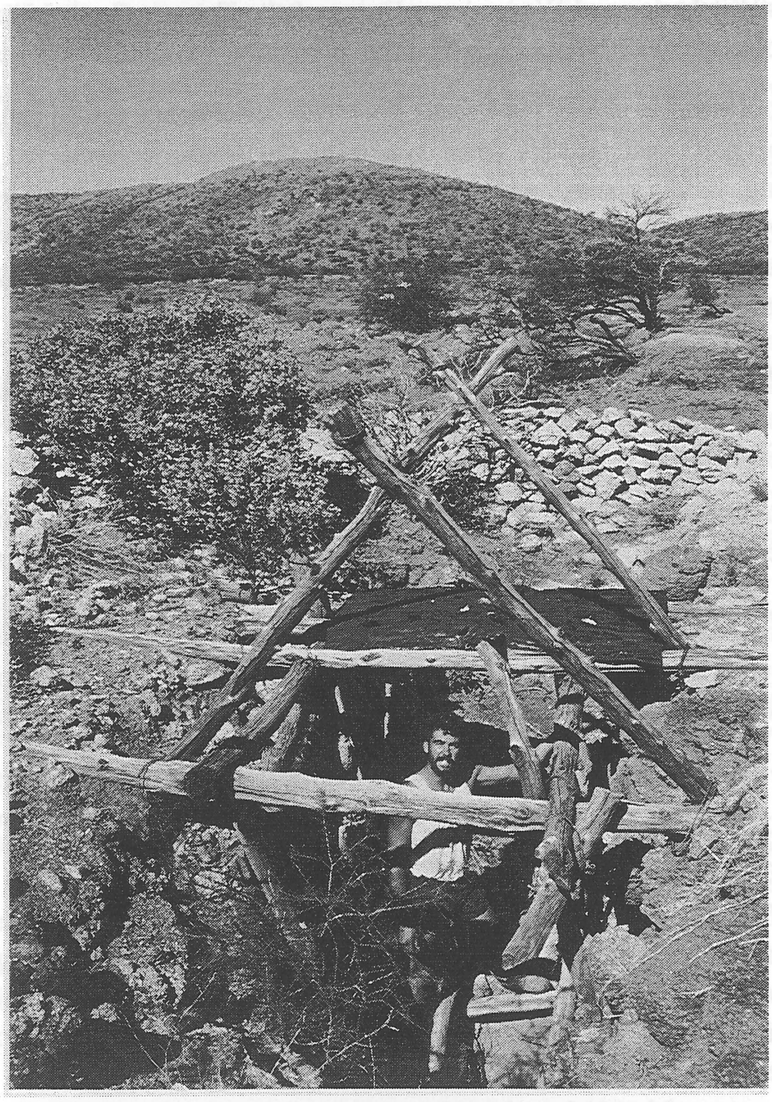

Fig. 17. Part of Wilsons Find tungsten mine, with the Wabudali Range in the background (at GR CHILLA 713687).

11. Denudation. Since the Alice Springs Orogeny the area has been part of a tectonically stable craton. Uplift associated with this orogeny was accompanied and followed by subaerial erosion and deposition, processes which have continued with little interuption to the present day.

ECONOMIC GEOLOGY

The only known exploited mineral deposit in the mapped area is at *Wilsons Find* (Fig. 17) in the Mount Theo 1:250 000 Sheet area (CHILLA) just to the north of VAUGHAN (in the vicinity of GR 715685). Here wolframite with some malachite and chrysocolla occur with tourmaline in a series of southeast-trending quartz greisen veins up to 2 m wide cutting granite (probably Wabudali Granite). The deposit was mined for tungsten during the 1940s, producing about 2 tonnes of concentrate (Stewart, 1976).

VAUGHAN includes the western part of the Bigrlyi uranium deposit, discovered in 1973 (Wells & Moss, 1983; Fidler & others, 1990). The mineralisation consists of uraninite and carnotite lenses in Mount Eclipse Sandstone of the Ngalia Basin succession, near the northern margin of this basin.

For information on water supply, see Wells (1972) and Wells & Moss (1983).

PROSPECTIVITY

VAUGHAN is regarded as prospective for several types of mineral deposits. These include the following.

1. Gold deposits like those found at and near The Granites mine in The Granites–Tanami region to the north (Mayer, 1990). The deposits at The Granites occur in tightly folded metasediments of the Tanami Complex, which are comparable in overall lithology, deformation, metamorphism, and probably age to the Lander Rocks beds of VAUGHAN. Granite intruding the Tanami complex near The Granites mine, and possibly genetically related to the gold mineralisation, may be similar in age to granite of the Carrington Suite in VAUGHAN.

2. Gold deposits like those at the Tanami mine northwest of The Granites (Nicholson, 1990). The gold at Tanami occurs in veins associated with faults cutting little-deformed and little-metamorphosed sedimentary rocks and basalt that may correlate with the Reynolds Range Group of northern VAUGHAN.

3. Small deposits of silver, lead, copper, tungsten, tin, molybdenum, and other metals in granite and related metamorphic aureoles. Such deposits occur elsewhere in the Mount Doreen 1:250 000 Sheet area and in other parts of the Arunta Block.

4. Additional uranium deposits of the Bigrlyi type (Fidler & others, 1990) in Mount Eclipse Sandstone and possibly also in Vaughan Springs Quartzite, in the Ngalia Basin. A likely source for the uranium in these deposits is the Southwark Granitic Suite, which is known from regional radiometric data to be relatively enriched in uranium.

Factors affecting the attractiveness of prospecting in VAUGHAN include the widespread cover of unconsolidated Cainozoic sediments concealing prospective bedrock, lack of detailed airborne magnetic and radiometric data for the Mount Doreen area, and the fact that there are no active mines in this part of the Arunta Block.

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