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REGIONAL GEOLOGY OF THE PRECAMBRIAN ARUNTA BLOCK

By

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INTRODUCTION

The Arunta Block is a region of igneous and metamorphic rocks exposed between Alice Springs and Barrow Creek (Fig. 1) as a result of at least two periods of uplift; the first ~~took place~~ in the Proterozoic (after the period of regional metamorphism at about 1700 m.y. - see below), and the second ~~took place~~ in the Palaeozoic, reaching a climax in the Early Carboniferous. The rocks of the Arunta Block are subdivided in this report into three groups, shown in the inset in Figure 1, based on their areal distribution, metamorphic character, and (where known) their stratigraphic position. Figure 1 has been adapted and revised after Forman and Shaw (1973) to show the distribution of granulite, amphibolite, and greenschist facies rocks, and granite.

Granulite and Amphibolite Facies Rocks of the Central Zone

These rocks crop out in the central zone of the Arunta Block, and comprise several sequences of rocks which have been intruded by granite and mafic igneous rocks, and metamorphosed to the amphibolite and granulite faceis. They are considered to be the oldest rocks in the Arunta Block, for the most part, but include some younger rocks.

Amphibolite Facies Rocks of the Southern Zone

These rocks occupy a broad area which is separated from the granulites and related rocks of the central zone to the north by a complex east-trending deformed zone shown as a fault south of Mount Hay in Figure 1. The

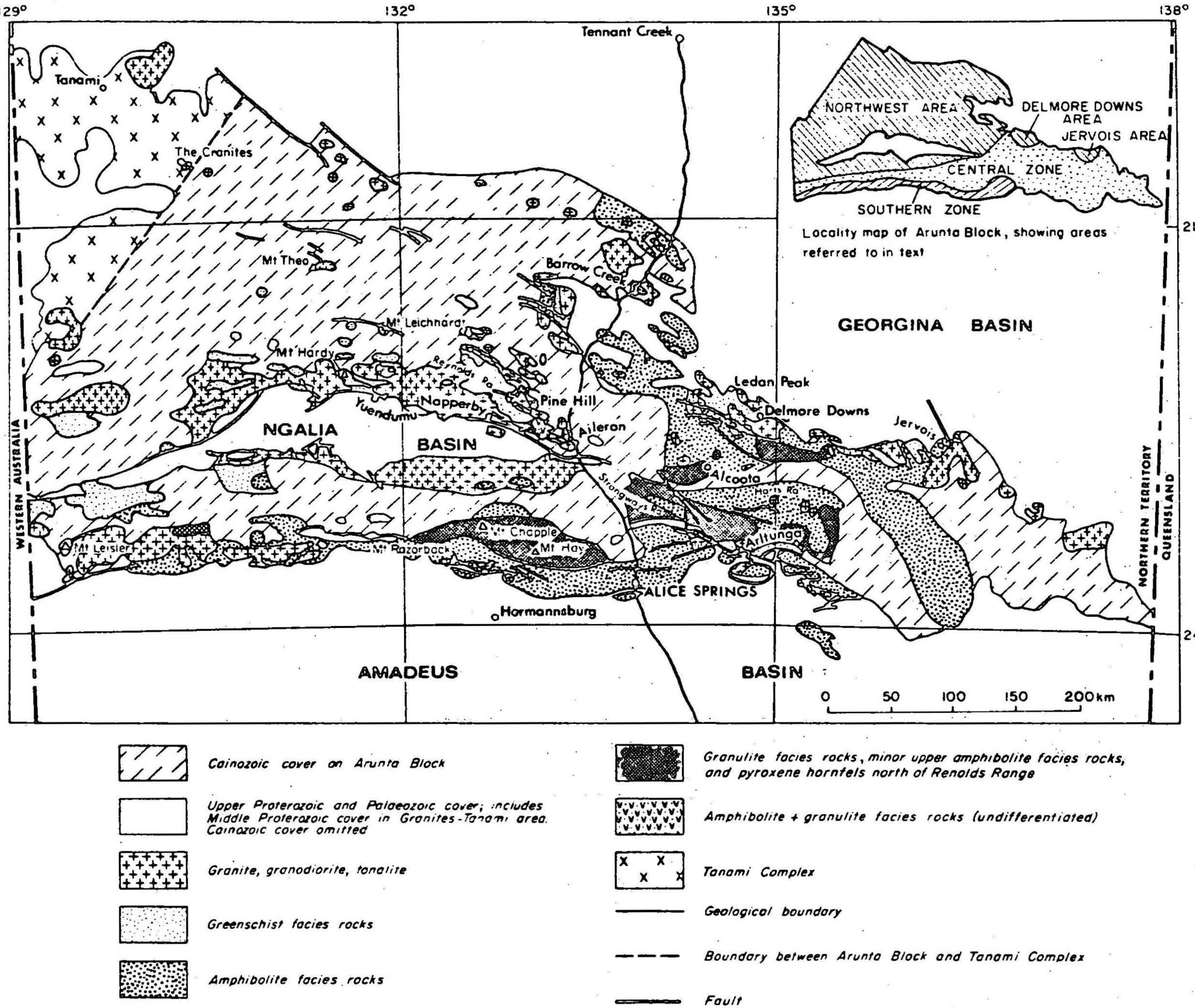

FIG. 1 **REGIONAL GEOLOGY OF THE PRECAMBRIAN ARUNTA BLOCK**
(Distribution of metamorphic rocks modified after Forman and Shaw, 1973)

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rocks of the southern zone consist of pelitic metasediments and felsic gneiss which have been metamorphosed to the amphibolite facies, and extensively migmatized. They are considered to be roughly equivalent to the upper part of the rocks of the central zone, and to the rocks of the northern areas (described below), but no specific correlations can be made.

Greenschist Facies and related Rocks of the Northern Areas

In the northern part of the Arunta Block, rocks of the central zone are overlain by two sequences of generally weakly metamorphosed Precambrian sedimentary and minor volcanic rocks, all of which are intruded by granite. The sequences are best displayed in the Reynolds Range area, where they are separated by an angular unconformity. Rocks very similar to the lower sequence, but for the most part of higher metamorphic grade, also crop out in the Delmore Downs and Jervois areas in the eastern part of the Arunta Block. The lower sequence in the Reynolds Range area is tentatively correlated with the Warramunga Group at Tennant Creek, and the upper sequence with the Hatches Creek Group and with lithologically similar rocks in the Granites-Tanami area (Table 1).

The overlying Upper Proterozoic and younger sequences of the Amadeus, Ngalia, and Georgina Basins are described elsewhere in this volume. They are not intruded by granite, contain very little volcanic rock, and are, for the most part, unmetamorphosed.

Previous Investigations

Early detailed work in the Arunta Block centred on around the Harts Range mica field (Joklik, 1955) and the Jervois copper field (Morgan, 1959a, 1959b;

m.y.	Central Arunta Block and Amadeus Basin	Northwestern Arunta Block and Ngalia Basin	Tennant Creek Block and Georgina Basin	Granites - Tanami Block and Birrindudu Basin
600				
700				
800	Pertatataka Formation 730[1] 760[2] 822[2]	Mt Doreen Formation	Mt Cornish Formation	
900				
1 000	Areyonga Formation	(Mt Doreen Formation?)	Field River Beds (Mt Cornish Formation?)	
1 100				
1 200	Bitter Springs Formation 1170[2] Heavitree Quartzite	Vaughan Springs Quartzite 1280[5]	Rising Sun Conglomerate(?)	Redcliff Pound Group
1 300				
1 400				
1 500				
1 600				Birrindudu Group
1 700	Granite Intr. 1710[3] 1723[4]	Granite Intr.	Granite Intr. 1690[6] Granite Intr. 1760[7]	
1 800	Metamorphism Utopia Quartzite Ledan Schist	Metamorphism Granite intrusion Reynolds Range Group	Hatches Creek Group	Granite intrusion Pargee Sandstone Mt Winnecke Formation
Undated rock units	Unit 10 Alcoota Sheet area Unit 9 Alcoota Sheet area	Mt Stafford Beds Lander Rock Beds	Warramunga Group	Killi Killi Beds Mt Charles Beds

Table I: Possible Proterozoic correlations in southern part of Northern Territory.
Upper Proterozoic correlations between Amadeus Basin and Ngalia Basin from Wells et al. (1972); between Amadeus Basin and Georgina Basin from Smith (1972) (with alternatives shown in parentheses); between Ngalia Basin and Birrindudu Basin supplied by D.H. Blake (BMR, pers. comm.).
Numerals in body of table are Rb-Sr dates in m.y.; superscripts refer to relevant publication, as follows: 1 Compston & Taylor (1969). 2 Wells et al. (1967). 3 R. Bennett (pers. comm. in Cooper et al. (1971)). 4 Armstrong & Stewart (in prep.). 5 Cooper et al. (1971). 6 Riley (pers. comm. in Compston & Arriens, 1968). 7 Riley (1968).

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Robertson, 1959). Reconnaissance studies of the structure of the northern margin of the Amadeus Basin were made in 1961 (Wells, Forman, and Ranford, 1965) and in 1964 (Forman, Milligan, and McCarthy, 1967; Wells, Forman, Ranford, and Cook, 1970). Further detailed work was done between 1968 and 1971 in the Arltunga Nappe Complex on the northeastern margin of the Amadeus Basin (Stewart, 1971a; Forman, 1971; Shaw, Stewart, Yar Khan, and Funk, 1971). In 1967-68, Wells, Evans, and Nicholas (1968) and Evans and Glikson (1969) mapped the basement rocks along the margins of the Ngalia Basin at a scale of 1:250 000. Shaw and Warren (in preparation) mapped the Alcoota 1:250 000 Sheet area in 1970-71. Field parties from the Bureau of Mineral Resources are currently mapping the Reynolds Range area, and, in co-operation with the Australian National University and Queensland University, the Alice Springs and Hermannsburg areas, at 1:100 000 scale.

Generalized Geological Description of Mapped Areas

The following section consists of summaries of the geology of those areas that are best understood, and which are considered to be representative of the major part of each zone.

Granulite and Amphibolite Facies Rocks of the Central Zone

Harts Range Area

In the Harts Range area (Joklik, 1955), the sequence consists of two gneisses of granitic composition, interpreted by Joklik as metasediments that have undergone K-metasomatism, overlain (in part unconformably) by two psammopelitic bodies of gneiss containing minor amounts of amphibolite, calc-silicate rock, and quartzite. All four units have been metamorphosed to the upper amphibolite facies, and are intruded by small bodies of granodiorite. Numerous pegmatites were emplaced during the final stages of metamorphism. Joklik (op.cit.) also described a fifth gneiss unit, the Cadney Gneiss, consisting of quartzofeldspathic gneiss and minor calc-silicate rock, and placed it in the uppermost part of the Harts Range Group, above the two psammopelitic gneisses. Recent work (Rickard and Shaw, 1972) has shown that the Cadney Gneiss consists mainly of calc-silicate rock, a considerable amount of metapelite, and minor quartzofelspathic gneiss. Furthermore, the Cadney Gneiss is partly metamorphosed to the granulite facies, and overlies a sequence of K-feldspar-bearing quartzofeldspathic gneiss and mafic granulite. The stratigraphic relationships of the Cadney Gneiss with the other units are not known.

Strangways Range Area

In the Strangways Range area, a basement of hypersthene-quartz-plagioclase granulite is intruded by a thin sheet of anorthosite-gabbro, and is overlain by a well-layered metasedimentary sequence of partly retrogressed pelitic gneiss (composed of cordierite, hypersthene, garnet, biotite, ± plagioclase or mesoperthite), felsic gneiss (containing garnet, hypersthene, and biotite), and abundant mafic intrusives which are also metamorphosed to the granulite facies (A. Allen, University of Queensland, personal communication). These rocks are overlain by a unit of sillimanite gneiss, and this is succeeded by a thick sequence (correlated with the Cadney Gneiss) of calc-silicate rock, metapelite, and minor amounts of quartzite and marble. South of Mud Tank Bore, the sequence is retrogressively metamorphosed, and intruded by carbonatite (Crohn and Gellatly, 1969).

Alcoota Area

In the Alcoota area (Shaw and Warren, in preparation), a sequence of interlayered mafic granulite, felsic gneiss, and pelitic gneiss, with associated small bodies of anatectic granite, is overlain by a sequence which is generally similar except that it lacks mafic rocks and contains small bodies of orthogneiss. This is overlain in turn by a sequence which is included in the greenschist rocks of the northern area (Delmore Downs Area), and is correlated on lithological grounds with the sequence in the Reynolds Range Area.

AMPHIBOLITE FACIES AND RELATED ROCKS OF THE SOUTHERN ZONE

In the Alice Springs and Mount Razorback areas, the rocks consist predominantly of biotite-feldspar gneiss (including garnet-bearing, quartz-rich, and amphibolitic varieties), and probably represent pelitic metasediments. The gneiss has been migmatized over a wide area, and several domes of anatectic granite have formed (R.W. Marjoribanks, Australian National University, personal communication).

Similar rocks between Mount Leisler and Mount Razorback have been intruded by large bodies of gneissic granite and massive granite.

GREENSCHIST FACIES AND RELATED ROCKS OF THE NORTHERN AREAS

Northwestern Area

Greenschist facies rocks shown around the Reynolds

Range in Figure 1 represent two groups of metasediments which are separated by an angular unconformity. The lower group includes two separate sequences which are regarded as lithological variants, although their stratigraphic relationships are not exposed. The more widespread sequence, known as the 'Lander Rock Beds'*,

*Name to be published in a forthcoming BMR Report by Stewart, Warren, Offe, and Glikson.

consists of slate, micaceous schist and sandstone, and a small amount of phyllite (intruded by orthoamphibolite), quartzite, and chert. The other sequence crops out in the north-western part of the area, and is known as the 'Mount Stafford Beds'*; the rocks are banded pelitic hornfels of high metamorphic grade, and are intruded by sills and dykes of metadolerite.

The Lander Rock Beds are unconformably overlain by a sequence of shallow-water marine sediments, the 'Reynolds Range Group'*, which begins with a thin, though extensive, basal unit of conglomerate and arkose (10m), overlain by about 250 m of cross-laminated orthoquartzite with abundant tourmaline laminae, followed by about 700 m of red-brown shale, slate, and sandstone, and lenses of dolomite and limestone. The Reynolds Range Group is intruded and thermally metamorphosed by large sills of acid igneous rock, comprising rhyolite porphyry in the northwestern part of the Reynolds Range, and granite and granodiorite porphyry in the central part of the range; the sills are strongly deformed and retrogressively metamorphosed.

High-grade metamorphic rocks crop out southeast of the low-grade rocks, in the Pine Hill-Aileron area (Fig. 1) and are regarded as equivalents of the low-grade rocks;

slate and orthoquartzite of the Reynolds Range Group pass along strike into pelitic granulite and coarse metaquartzite (respectively), the dolomite and limestone beds are represented by calc-silicate marble and, in one place, forsterite marble (R.G. Warren, BMR, personal communication), and the sills of granitic rock are represented by bodies of felsic granulite. The Lander Rock Beds pass southeastwards into an assemblage of high-grade pelitic gneiss, garnet-biotite quartzite, and mafic granulite. Sapphirine has been found ~~located~~ at several places along the contact of the metamorphosed Lander Rock Beds and Reynolds Range Group (R.G. Warren, BMR, personal communication).

Granite occupies large areas north and south of the Reynolds Range, and has thermally metamorphosed the low-grade metasediments to andalusite-bearing hornfels. The batholith north of the Reynolds Range contains rapakivi feldspars, and has thermally metamorphosed the Mount Stafford Beds to pyroxene hornfels (L.A. Offe, BMR, personal communication). Small dykes and plugs of unaltered dolerite represent the last igneous activity in the area.

In the <u>Yuendumu-Mount Hardy</u> area, knowledge of the basement rocks is of a reconnaissance nature only. Most of the area consists of large bodies of granite which intrude schist, phyllite, and quartzite (Wells, Evans, and Nicholas, 1968; Grainger, 1968), and there are also areas of granulite north of Yuendumu. Isolated outcrops of the same rock-types occur in the area between Yuendumu and Mount Theo. The mica schist at Mount Hardy may be a correlate of the Lander Rock Beds. Greenschist facies rocks also occur in the Mount Leisler area, but have not as yet been studied.

Delmore Downs Area

In the area around Delmore Downs homestead, a series of units overlying granulite and gneiss of the central zone are correlated with the sequences in the Reynolds Range area (Table 1). The lowest unit of the series (Unit 9 of Shaw and Warren, in preparation) consists mainly of felsic gneiss characterized by muscovite clots, and resembles some metamorphosed parts of the Lander Rock Beds. Unit 9 appears to be overlain by Unit 10, which is a thin unit of microcline-rich metapelite, calc-silicate rock, and possible metamorphosed basic volcanics (which may include metaspilite). Unit 10 is very similar to the Mount Stafford Beds, and is unconformably overlain by the 'Ledan Schist'*, which consists of quartz, muscovite, tourmaline, and biotite, and the 'Utopia Quartzite'*. The latter two units are correlated on lithological grounds with part of the Hatches Creek Group, and also with the Reynolds Range Group (Table 1). Rocks below the unconformity have been metamorphosed to amphibolite facies (in one place containing the assemblage cordierite-anthophyllite), whereas the rocks above the unconformity appear to have been metamorphosed only to the upper greenschist facies. Large masses of calc-alkaline granite intrude the sequence below the unconformity.

*Name to be published in Shaw and Warren (in preparation)

Jervois Area

In the area around Jervois, the rocks are very similar to the Lander Rock Beds and Mount Stafford Beds, and comprise quartz-muscovite schist with lenses of cordierite schist and andalusite schist, and minor amounts of marble and calc-silicate rock of the amphibolite facies (Robertson, 1959). The rocks grade into sericite schist and phyllite north of the Bonya Mine.

STRUCTURE

The granulite belt of the central zone is separated from the amphibolite facies rocks of the southern zone by a major deformed zone. The western part of the deformed zone south of Mount Hay consists chiefly of mylonite, which contains augen of K-feldspar up to 30 cm long, and is intruded by gabbro; the mylonite has been partly migmatized (R.W. Marjoribanks, Australian National University, personal communication). The eastern part of the deformed zone is similar, though less intensely deformed, and lacks gabbroic intrusions. An extremely steep Bouguer anomaly gradient (150 milligals over 50 km; Langron, 1962; Lonsdale and Flavelle, 1963) is situated parallel to, but north of, the entire western part of the deformed zone; the maximum anomaly is centred 20 km north of the mafic granulites of the Mount Hay area (Fig. 1), which are the densest rocks exposed in the area. This relationship suggests that overthrusting has taken place, and involved a major much ~~portion of~~, if not all of the crust, possibly during the final stages of the main high-grade regional metamorphism at about 1700 m.y. (cf. Forman and Shaw, 1973). North of Alice Springs, the deformed zone has undergone a meridional displacement of about 30 km, and the displacement is associated with a sharp decrease in the Bouguer anomaly values. The deformed zone is further displaced at the eastern end of the Strangways Range by a north-trending cross-fault.

Thrust nappe displacements of at least 10 km southwards have been demonstrated from basement-cover relationships within the amphibolite facies rocks of the southern zone in the Arltunga Nappe Complex (Forman, 1971; Stewart, 1971a; Shaw, Stewart, Yar Khan, and Funk, 1971), and at least 2 km in the Blatherskite Nappe at Alice Springs (Stewart, 1967), all on the northern margin of the Amadeus Basin. The large displacements suggest that part of the steep Bouguer anomaly gradient north of the margin of the Amadeus Basin may be caused by Middle to Late Palaeozoic thrust faulting concomitant with greenschist retrograde metamorphism, which is particularly strong near the thrust faults in the Arltunga Nappe Complex.

North of the Ngalia Basin in the northwestern area (Fig. 1), seismic data indicate that thrust faulting at the northern basin margin has displaced the basement southwards over cover for at least 12 km along a fault dipping north at 35° (F.J. Moss, BMR, personal communication in Forman and Shaw, 1973), and the basement rocks adjacent to the fault show some retrogression.

The pattern of east-trending deformed zones is partly disrupted in the eastern and northeastern areas of the Arunta Block by major northwest and west-northwest faults.

TIMES OF MAIN OROGENIC EVENTS

Table 1 depicts the more important Precambrian orogenic events in the Arunta Block, and also shows some tentative correlations with events and rock-types of other areas in the southern half of the Northern Territory. The most widespread episodes of metamorphism and related uplift took place in the Proterozoic (at about 1700 m.y.) and in the Middle to Late Palaeozoic.

Principal Precambrian Orogeny

The rocks of the Arunta Block were folded twice and metamorphosed at least once during Precambrian time, before deposition of the Heavitree Quartzite. Granites that intrude metamorphic rocks along the southern margin of the Georgina Basin gave an average K-Ar date of 1440 m.y. (Hurley et al., 1961), and one of them (the Jinka Granite) gave a Rb-Sr total rock and mineral isochron of 1690 m.y. (Riley, 1961, and personal communication in Compston and Arriens, 1968). Four samples of intrusive igneous rocks (granite, adamellite, and two tonalites) from the front of the Arltunga Nappe Complex gave a Rb-Sr total rock age of about 1710 m.y. (R. Bennett, formerly of BMR, personal communication in Cooper et al., 1971), but two other samples (adamellite and granodiorite gneiss) from the same area plot well away from the isochron. A whole rock isochron age of 1723 $\pm$ 23 m.y. has been obtained from seven samples of metamorphic rocks from the autochthonous and root zones of the Arltunga Nappe Complex (Armstrong and Stewart, in preparation). K-Ar dates on muscovite, biotite, and hornblende from the southern (least retrogressed) part of the Arltunga Nappe Complex indicate a minimum age of metamorphism of 1660 m.y. (Stewart, 1971b), and muscovite from the Ledan Schist at the southern margin of the Georgina Basin gave a K-Ar date of 1532 m.y. (Webb, 1972). The dates indicate that ~~emplacement of~~ granitic rocks were emplaced ~~took place at~~ about 1700 m.y., and that the moderate to high-grade regional metamorphism occurred somewhat earlier.

Alice Springs Orogeny

A second major event, involving thrust faulting, folding, and greenschist retrograde metamorphism, was largely restricted to two zones, one along the northern margin of the Amadeus Basin, and another along the northern margin of the Ngalia Basin (Forman, 1968, 1971; Forman, Milligan, and McCarthy, 1967; Wells, Evans, and Nicholas, 1968; Forman and Shaw, 1973). The orogeny folded the cover rocks of both basins. Thirteen K-Ar dates from the root zone of the Arltunga Nappe Complex, including dates from metamorphosed cover rocks, indicate that the orogeny reached a maximum in the Middle Carboniferous or earlier (Stewart, 1971b). Two samples of retrograded tonalite in the root zone of the Nappe Complex have given Middle Carboniferous whole rock-mineral Rb-Sr dates (Armstrong and Stewart, in preparation). A Carboniferous age is probably also applicable to the zone of thrust faulting along the northern margin of the Ngalia Basin.

K-Ar mineral dates from a wide area in the northwestern, central, and eastern parts of the Arunta Block are reset by various amounts, suggesting that a rise in the regional geotherms took place during the Alice Springs Orogeny (<u>cf</u>. Webb and Lowder, 1972). Rocks adjacent to the Amadeus and Georgina Basins show the least amount of resetting. No igneous activity is associated with the Alice Springs Orogeny.

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