Rb–Sr dating of granite at Windarra and Mount Boreas, near Laverton, Western Australia

by J. C. Roddick[1] and W. G. Libby

Abstract

Rubidium–strontium whole-rock dates on the Windarra granite and the Mount Boreas Adamellite were reported in the Explanatory Notes for the LAVERTON and DUKETON 1:250 000 geological map sheets published by the Geological Survey of Western Australia. Because of the limited size of the Notes, and in anticipation of more extensive discussion elsewhere, the dates were published without supporting analytical data. Furthermore, examination of data not available at the time of publication of the Notes for LAVERTON indicates that the samples from the Windarra granite contained granite of two different ages. The analytical data, published herein, support a revised date of 2538 ± 45 Ma for the Windarra granite and confirm the published date of 2430 ± 30 Ma for the Mount Boreas Adamellite.

Both suites have been deformed, supporting independent arguments that the recorded dates may reflect metamorphic updating. However, the $^{87}Sr/^{86}Sr$ initial ratio of the Windarra granite is near the interpreted $^{87}Sr/^{86}Sr$ ratio of the late Archaean mantle, suggesting that the reported date is near the age of extraction from the mantle and thus has not been substantially updated from the time of emplacement.

A full interpretation of these dates awaits anticipated U–Pb zircon dating.

KEYWORDS: Geochronology, Rb–Sr, Laverton, Duketon.

Whole rock Rb–Sr dates on granite were reported in the Explanatory Notes accompanying the 1:250 000 geological maps of LAVERTON[2] (Gower, 1976) and DUKETON (Bunting and Chin, 1979). The date measured for the Windarra granite on LAVERTON was 2615 ± 25 Ma. Mapping of DUKETON and associated dating established that the Mount Boreas Adamellite, from which one of the Windarra samples (Geological Survey of Western Australia (GSWA) sample 37808) was drawn, is younger than the date of the remaining Windarra samples. The date (2480 ± 30 Ma) of the Mount Boreas Adamellite was published in the Explanatory Notes accompanying DUKETON (Bunting and Chin, 1979) but the Windarra date has remained uncorrected.

This paper has two purposes: to report the corrected date of the Windarra granite and to record the analytical data and procedures used for dating both the Windarra and the Mount Boreas plutons.

Tragically, in the period between planning this note and its realization J. C. Roddick was accidentally killed. His work is the essence of the paper. He performed all of the analyses and the section on experimental procedures is his alone. The discussion of data and the table of data are largely as he wrote them. The responsibility for accuracy in the compilation of the paper, however, rests with W. G. Libby.

Geological setting

The name Windarra granite is used here informally for the granitic rocks dated in the LAVERTON Explanatory Notes, following the usage of Gower (1976) who referred to them as tonalite and granodiorite in the Windarra area. Mount Windarra Homestead is about 15 km west of Laverton.

The Windarra granite lies in the southern and eastern part of an extensive area of granitic rocks that extends south-southeastward from DUKETON through to LAVERTON, and comprises a lobe that terminates in a broadly rounded contact with deformed supracrustal rocks in south-central LAVERTON. The relationship between the granite lobe and the enclosing supracrustal rocks is probably intrusive.

The Mount Boreas Adamellite is an area of granite occupying the core of this lobe. It was named by Bunting and Chin (1979) for Mount Boreas near the central-northern border of LAVERTON. The samples dated in the DUKETON notes are from Mount Boreas.

Granitoid rocks similar to the Mount Boreas Adamellite were mapped by Bunting and Chin (1979) in a belt 2–25 km wide

[1] This paper is dedicated to the memory of J. C. Roddick, Geological Survey of Canada.
[2] Capitalized names refer to standard 1:250 000 map sheets.

extending from the northern part of LAVERTON north-northwestward across DUKETON, a distance of 130 km. An isolated outcrop of similar granite near the central-west margin of KINGSTON (Bunting, 1980) may extend the length to a total of nearly 200 km.

Bunting and Chin (1979) have described the granite in some detail. It is a distinctive red, and is medium- to coarse-grained. Fluorite is abundant and can commonly be readily recognized macroscopically in the field.

The sample localities for both the Mount Boreas Adamellite and the Windarra granite are shown in their simplified geological setting in Figure 1.

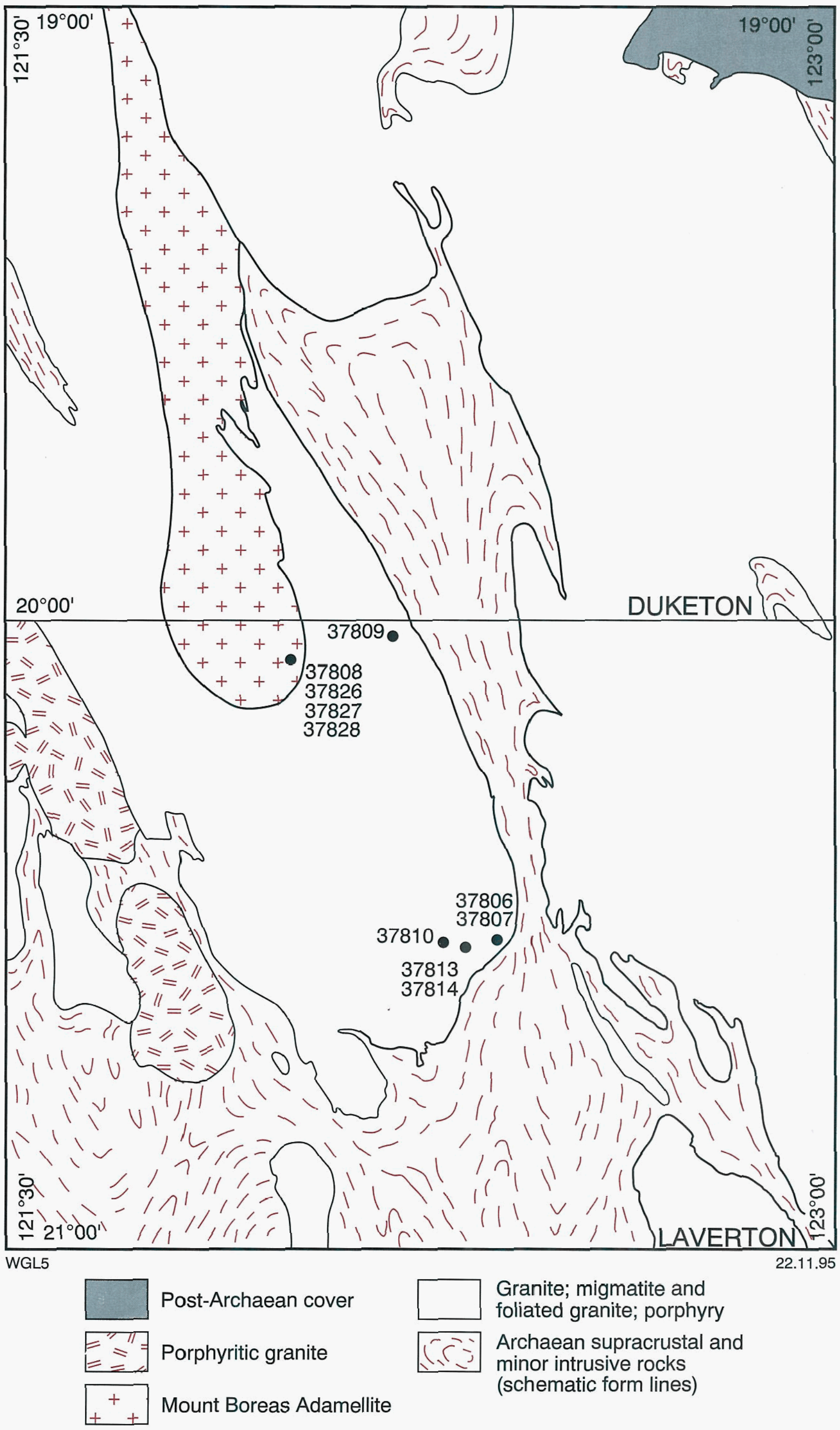

Figure 1. Geological map showing the location of dated samples of Mount Boreas Adamellite and Windarra granite. Simplified from Gower (1976) and Bunting and Chin (1979)

Experimental techniques

The experimental procedures used are similar to those described by Chappell et al. (1969) with a few minor changes. Some samples were analysed for rubidium and strontium by X-ray fluorescence spectrometry (XRF) using background measurements for mass-absorption corrections (Table 1). The other samples were analysed by mass-spectrometric isotope dilution using a mixed ^{85}Rb and ^{84}Sr tracer. All strontium samples were corrected for variable mass discrimination in $^{87}Sr/^{86}Sr$ by normalizing $^{88}Sr/^{86}Sr$ to 8.3752. Analyses of the standard NBS stoichiometric $SrCO_3$ salt SRM 987 on the mass spectrometer (MSZ with Cary 31 electrometer) during this study gave a $^{87}Sr/^{86}Sr$ value of 0.71023 ± 0.00005 (standard deviation of population). NBS 70A potassium feldspar analyzed during the course of the work has values of 522 ppm Rb and 65.4 ppm total Sr by isotope dilution. All XRF results were compared and adjusted to these values. Blanks were sufficiently low (Rb 1.0 ng; Sr 3.0 ng) to provide negligible correction in most cases. The ^{87}Rb decay constant used is $1.42 \infty 10^{-11}$ a^{-1}. The regression technique of McIntyre et al. (1966) was used and tests of significance associated with the isochron interpretation were made at the 95% level of confidence. The T-multiplier was applied to the estimated errors in X and Y, as suggested by Brooks et al. (1972), rather than on the basis of the number of samples regressed. In assigning errors to the regression points, the coefficient of variation for the $^{87}Rb/^{86}Sr$ ratio is taken as 0.5% (McIntyre et al., 1966) and the coefficient of variation for the $^{87}Sr/^{86}Sr$ ratio is taken as 0.01%.

Results

Six samples of Windarra granite define a Rb–Sr isochron within the estimated error limits (MSWD = 0.84). The age is 2538 ± 45 Ma (2σ) with an initial $^{87}Sr/^{86}Sr$ of 0.7019 ± 3.

Table 1. Rb–Sr data for the Windarra granite and the Mount Boreas Adamellite

Sample	*Latitude*	*Longitude*	*Rb (ppm)*	*Sr (ppm)*	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
Windarra granite						
37806 (a)	28°30'30"	122°23'20"	49.6	286	0.5008	0.72012
37807 (a)	28°30'30"	122°23'20"	47.7	250	0.5512	0.72218
37809 (a)	28°01'00"	122°12'20"	45.7	537	0.2454	0.71092
37809	28°01'00"	122°12'20"	45.9	541	0.2450	0.71085
37810 (a)	28°30'35"	122°17'50"	39.7	397	0.2886	0.71250
37813 (a)	28°31'00"	122°20'00"	51.0	258	0.5712	0.72294
37814 (a)	28°31'00"	122°20'00"	44.2	362	0.3527	0.71488
37814	28°31'00"	122°20'00"	44.4	363	0.3536	0.71504
Mount Boreas Adamellite						
37808 (a)	28°03'10"	122°01'10"	277	230	3.516	0.83348
37808	28°03'10"	122°01'10"	278	229	3.542	0.83301
37808	28°03'10"	122°01'10"	278	229	3.546	0.83310
37826 (a)	28°03'10"	122°01'10"	270	200	3.940	0.84541
37827 (a)	28°03'10"	122°01'10"	296	201	4.311	0.85749
37827P (a)	28°03'10"	122°01'10"	524	64.1	25.68	1.60996
37828 (a)	28°03'10"	122°01'10"	318	168	5.558	0.90288
37828	28°03'10"	122°01'10"	319	169	5.561	0.90320

(a) Analysed for Rb and Sr by X-ray fluorescence, others analysed by isotope dilution; see text.

These samples are all from within an area of about 25 km^2 except for GSWA sample 37809, which is 60 km from the others. The good fit of this sample to the others supports the mapping and geochemical grouping of this remote sample with the others.

The Mount Boreas samples are all from within a few hundred metres of each other. One sample has a medium-grained pegmatite zone and this pegmatite was analysed as a separate sample (37827-P). All five samples define an isochron with slight scatter (MSWD = 3.1) and an age of 2430 ± 30 Ma (model 3). The initial $^{87}Sr/^{86}Sr$ ratio is 0.7075 ± 23. The pegmatite sample appears to have the same age and initial ratio as the other samples because exclusion of it from the regression, though increasing the error estimates, does not change the age significantly (2405 ± 140 Ma). Isochrons on both the Windarra and Boreas samples are plotted in Figure 2.

The initial $^{87}Sr/^{86}Sr$ of these two bodies places some constraints on their evolution. The initial ratio for the Windarra isochron (0.7019 ± 0.0003) is close to the upper mantle value at the body's indicated age of 2540 Ma. This suggests derivation from material ultimately derived from the mantle, or crustal material with a short history (<100 Ma). In contrast, the Mount Boreas Adamellite has a much higher initial $^{87}Sr/^{86}Sr$ of 0.7075 ± 0.00023 indicating that it has been derived from older crustal material. This conclusion is in agreement with the field and geochemical evidence that the Mount Boreas Adamellite is post-tectonic and highly fractionated.

Petrography

The Windarra granite is a deformed biotite granodiorite that commonly contains euhedral plagioclase, now saussuritized to albite, with microcline, set in a variably deformed groundmass of quartz and probably less feldspar. Accessories include prominent titanite in large (0.25 mm) grains that constitute about 1% of the rock, much less abundant magnetite, and large (0.3 mm) but uncommon grains of euhedral zoned allanite. Carbonate, sericite, and chlorite are secondary minerals in some samples. Discrete epidote constitutes less than 1% of the rock, in addition to saussuritic epidote. Chlorite has replaced all of the biotite in some of the more heavily altered samples (e.g. GSWA sample 37814) and sericite in some plagioclase grains ranges in size up to 0.5 mm.

Deformation is variable, limited in some samples to grain-boundary abrasion resulting in a thin microgranular mortar between the coarse quartz and feldspar grains. Elsewhere (e.g. GSWA sample 37807) the rock has been severely deformed, forming rounded porphyroclasts of plagioclase and greatly elongated composite quartz lozenges in a matrix of equant 0.05 mm quartz grains, with some feldspar and strongly oriented, elongate biotite.

Some of the samples that show an intermediate degree of deformation (e.g. GSWA sample 37810) emulate a porphyry. In these samples euhedral plagioclase porphyroclasts are set in a microgranular groundmass of quartz and feldspar. A lower degree of development of this texture in other samples indicates that the coarse plagioclase grains of the pseudo-porphyries are porphyroclasts and that the fabric is tectonic.

The Mount Boreas Adamellite is much less deformed than the Windarra granite. It is an allotriomorphic granular biotite monzogranite. Plagioclase, where determined, is albite, but saussuritized cores and prominent euhedral oscillatory zoning indicate that the composition on crystallization was more calcic.

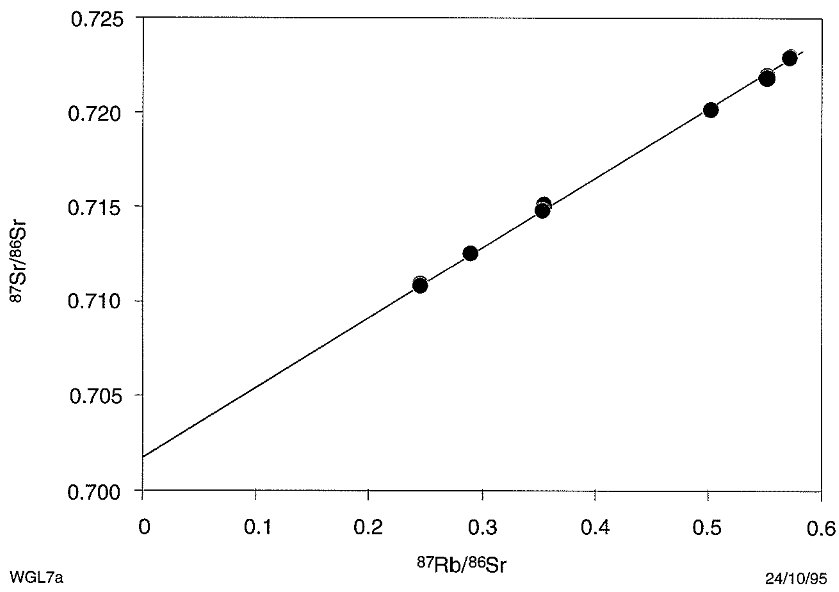

Figure 2. (a)Isochron on six samples of Windarra granite giving a date of 2538 ±45 Ma with an $^{87}Sr/^{86}Sr$ initial ratio of 0.7019 ±3

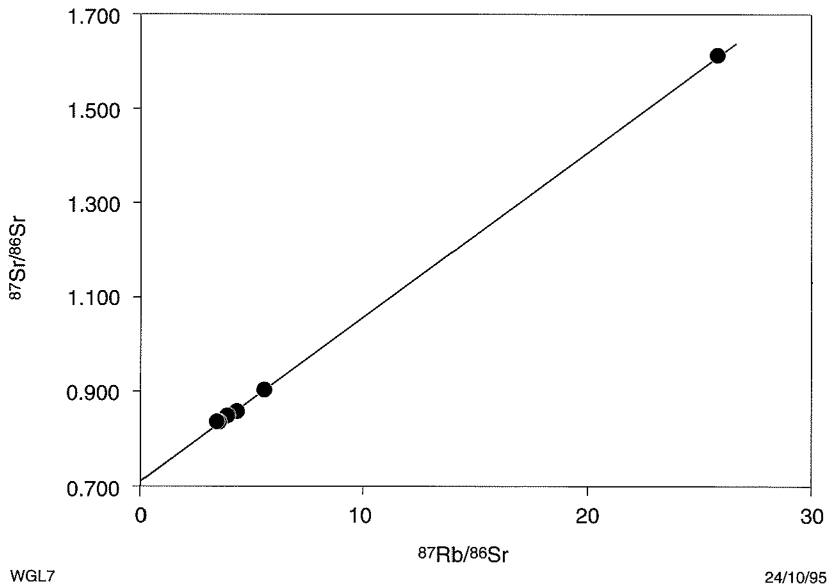

Figure 2. (b)Isochron on five samples of Mount Boreas Adamellite giving a date of 2430 ±30 Ma with an $^{87}Sr/^{86}Sr$ initial ratio of 0.7075 ±23

In some cases a fresh broad albite rim of a grain becomes more calcic toward the core of the grain, but as it reaches oligoclase the calcium component drops abruptly to near zero and the core of the grain is heavily saussuritized albite. The albitization of the core can be attributed to the well-known response of calcium-bearing plagioclase to low-grade conditions, partitioning the plagioclase components between nearly calcium-free albite and a calcium-bearing 'anorthite-substitute' mineral, commonly epidote. The calcic albite near, but outside, the albitized core was probably too calcic to be in equilibrium with the conditions during alteration, but was insufficiently out of equilibrium to trigger a reaction. The more calcic plagioclase in the core reacted, the reaction running completely to the equilibrium phase, albite.

Incomplete microcline grains as long as 7 mm were measured, and much coarser grains probably exist. Magnetite is a common accessory and fluorite is ubiquitous in thin section, and is commonly reported from hand specimens.

Although there are no euhedral plagioclase grains in the rock, euhedral oscillatory zoning of some coarse plagioclase grains and the existence of euhedral plagioclase embedded in coarse microcline indicate that the unit has retained much of its igneous crystallinity and has not been heavily recrystallized. Nonetheless, some fine grains interstitial to the coarse grains are probably a product of mild deformation. The response to deformation has been the development of a typically irregular and discontinuous mortar of microgranular intergranular quartz, feldspar, and biotite. This is similar to that shown by samples of the Windarra granite but none of the samples from Mount Boreas that have been studied have approached the degree of deformation shown by the Windarra samples.

Discussion

This work confirms the Rb–Sr date of 2480 ± 30 Ma reported by Bunting and Chin (1979) for the Mount Boreas Adamellite. It also indicates that the date of 2615 ± 25 Ma for the Windarra granite should be modified to 2538 ± 45 Ma by application of the $1.42 \infty 10^{-11} a^{-1}$ decay constant for ^{87}Rb and the omission of the spurious Mount Boreas sample, GSWA 37808.

The only other radiometric dating from rocks related to those reported in this paper is from a rock mass in the northeast corner of SIR SAMUEL (northwest of LAVERTON; Figure 3), which has been called the Mount Boreas type granite by Bunting and Williams (1979). The Mount Boreas type granite has been dated by Stuckless et al. (1981) using Pb–Pb whole-rock techniques at 2370 ± 98 Ma, which is even younger than the Rb–Sr date on the type Mount Boreas Adamellite on LAVERTON, although within the limits of reported uncertainties.

These dates are younger than most whole-rock radiometric dates from the Eastern Goldfields (de Laeter et al., 1981) and, in particular, younger than recent U–Pb zircon dating (Nelson, D. R., 1995, pers. comm.). The petrography of the Mount Boreas Adamellite shows that the rock has not only been deformed, but that mortar generated around deformed grains has been finely recrystallized and some minerals altered.

The high $^{86}Sr/^{87}Sr$ initial ratio of the Mount Boreas Adamellite, 0.7075, would conventionally be interpreted as indicating either that the rock has experienced more than a single stage of differentiation from rocks of mantle composition or that, some time after differentiation, the relevant isotopic ratios have been metamorphically homogenized over the extent of the sampling area. Petrographic evidence of metamorphism suggests that the young date of the rock and high initial $^{86}Sr/^{87}Sr$ ratio could reasonably be attributed to metamorphism at some time in the vicinity of 2400 million years ago.

The Windarra granite, however, presents a more difficult case, because the initial $^{86}Sr/^{87}Sr$ ratio is low.

The conventional interpretation of an initial $^{87}Sr/^{86}Sr$ ratio that is near that which the mantle is interpreted to have had at the time of extraction is that the rock has been derived directly from the mantle, or from rock of mantle-like composition, at the given date, and that the date has not been significantly modified by isotopic homogenization since that time. In short, if the $^{87}Sr/^{86}Sr$ initial ratio of the rock is the same as the $^{87}Sr/^{86}Sr$ ratio of the mantle at the date given by the rock, the real age of the rock cannot be older than the recorded date.

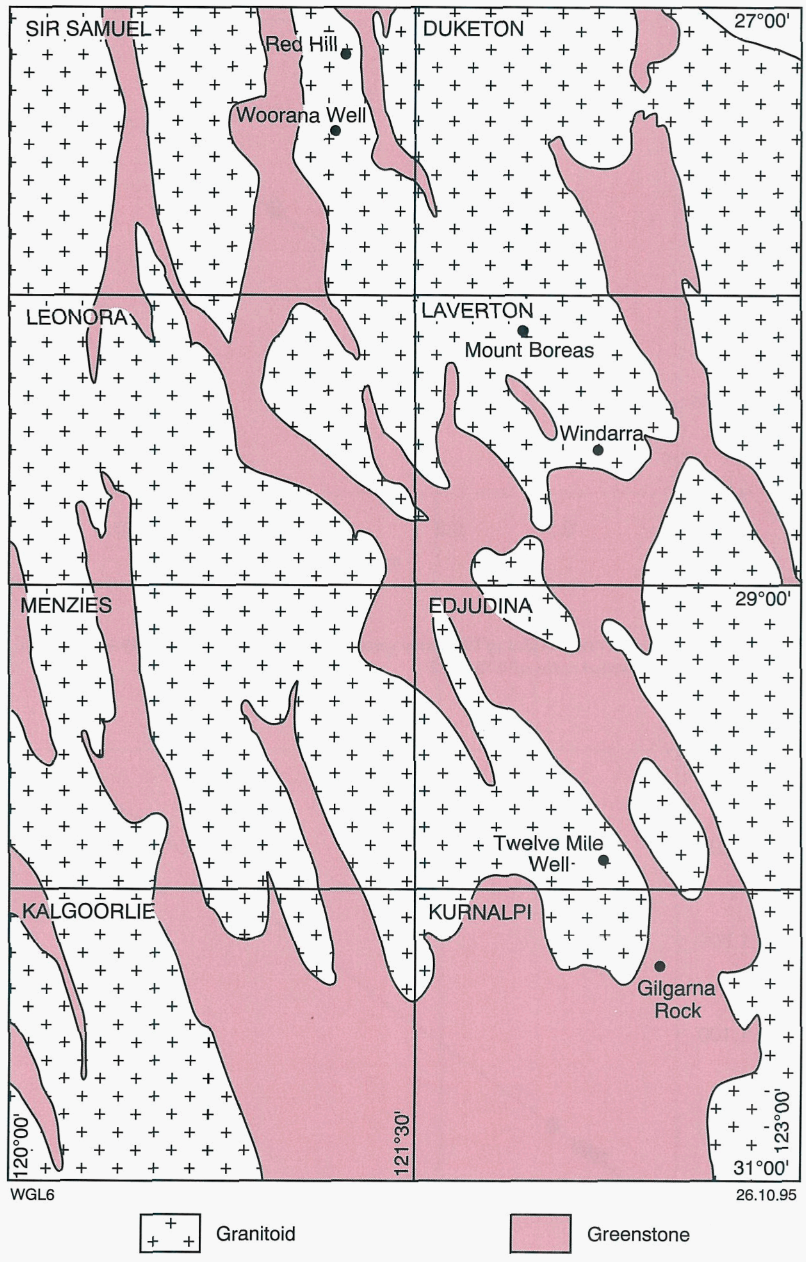

Figure 3. Schematic locality map of the Eastern Goldfields showing the relevant 1:250 000 map sheets

While there is always some uncertainty about the value of both the $^{87}Sr/^{86}Sr$ ratio of the ancient mantle and the initial $^{87}Sr/^{86}Sr$ ratio of the rock body being studied, small differences in the two ratios would not normally be expected to change the measured dates greatly. Thus it is implied above that the date for the Windarra granite approximates the age of intrusion. However, the petrography indicates even more deformation and alteration than that in the updated Mount Boreas Adamellite. Furthermore, it is recognized that the assignment of an emplacement age of 2538 million years to the Windarra granite would be in conflict both with current interpretations of the age of tectonic activity in the Eastern Goldfields and with current confidence in the U–Pb zircon dating technique relative to Rb–Sr whole-rock dating as measures of age of emplacement. It is intuitively appealing, but technically difficult, to interpret the Rb–Sr date on the Windarra granite as a metamorphic date.

A similar problem in the Eastern Goldfields is raised by the alkaline suite at Woorana Well and Twelve Mile Well (Libby and de Laeter, 1981) and at Gilgarna Rock and Red Hill (Johnson, 1991) where most Rb–

Sr dates again cluster around 2500 Ma, again with low $^{86}Sr/^{87}Sr$ initial ratios. As in the case of the Windarra and Boreas rocks, no U–Pb data are yet available to explain these young dates.

These conflicts may soon be resolved as the relevant map sheets may shortly be subjected to reinterpretation involving SHRIMP U–Pb zircon dating of some of the bodies considered here.

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