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Early Proterozoic migmatitic basement in the Kalkadoon-Leichhardt Belt of the Mount Isa Inlier, northwestern Queensland

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Tightly folded migmatitic rocks, intruded by 1860 Ma granite and younger felsic and mafic dykes, are exposed in a band 95km long and up to 10km wide along the western part of the Kalkadoon-Leichhardt Belt. The migmatites are considered to represent the basement underlying Proterozoic cover rocks, the oldest of which are Ma felsic extrusives (Leichhardt Volcanics) about 1860 Ma old. The migmatites include thinly banded gneiss with mainly concordant leucosomes (metasediments), non-banded gneiss with wispy leucosomes (metavolcanics), and nebulitic granitic gneiss (meta-intrusives). Metamorphism and deformation of the migmatites took place before the intrusion of a cross-cutting granite dyke dated at 1860±32 Ma by U-Pb zircon. Another U-Pb zircon age, 1850±16 Ma, obtained for a migmatitic metadacite, is anomalously young, although within experimental error of a preferred migmatisation age of 1860-1870 Ma. Uplift rates of 2-5 mm a year are implied, to account for the inferred brief interval between migmatite formation and ensuing felsic volcanism.

Introduction

Migmatitic metasedimentary and meta-igneous rocks, extensively exposed in the western part of the Kalkadoon-Leichhardt Belt, are considered to represent part of the basement underlying Proterozoic cover formations of the Mount Isa Inlier (Blake, 1987). The basement comprises rocks which were deformed and metamorphosed before emplacement of granites of the Kalkadoon Batholith and extrusion of comagmatic Leichhardt Volcanics, the oldest cover rocks, at around 1860 Ma.

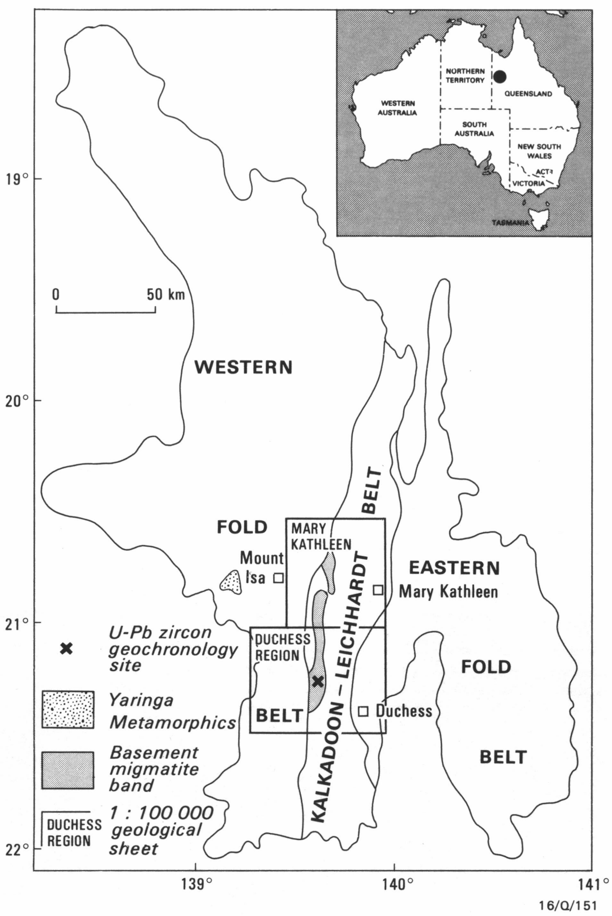

Figure 1. Generalised geology and locality map of the Kalkadoon-Leichhardt Belt of the Mount Isa Inlier.

The Kalkadoon-Leichhardt Belt is the northerly trending tectonic unit separating the Western and Eastern Fold Belts of the Mount Isa Inlier (Fig. 1). Each of these three tectonic units contains some basement or probable basement outcrops, but consists predominantly of Proterozoic cover and granite (Blake, 1987). The cover comprises of sediments and bimodal volcanics which can be assigned to three major sequences (Fig. 2). The oldest, cover sequence 1, is represented by the Leichhardt Volcanics of the Kalkadoon-Leichhardt Belt. Cover sequence 2, unconformable on basement and cover sequence 1, ranges in age from about 1790 Ma to about 1750 Ma or possibly younger; it includes the Bottletree Formation (1790±9 Ma) and overlying Haslingden Group of the Western Fold belt; the Magna Lynn Metabasalt, Argylla Formation (1783±5 Ma), and Mary Kathleen Group exposed in the eastern part of the Kalkadoon-Leichhardt Belt; and most or all of the stratigraphic units in the Eastern Fold Belt. Cover sequence 3 overlies cover sequence 2 and older rocks disconformably or with an angular unconformity; it includes the Carters Bore Rhyolite (1678±3 Ma) and the Mount Isa Group (1670±20 Ma) of the Western Fold Belt. The cover sequences have been intruded by granites ranging in age from about 1860 Ma to about 1500 Ma and by mafic dykes of various ages, and together with intrusives and previously deformed basement rocks, were extensively deformed and regionally metamorphosed to greenschist and amphibolite facies between about 1620 Ma and 1550 Ma. The dating of the igneous and metamorphic events in the region is based on extensive U-Pb zircon and Rb-Sr geochronology (e.g., Page, 1978, 1983; Page & others, 1984; Page & Bell, 1986).

Outcrops of basement migmatite and nebulitic granitic gneiss extend for about 95km along the west side of the Kalkadoon-Leichhardt Belt, in a band up to 10km wide (Fig. 1). Those in the south, in the Duchess region 1:100 000 geological sheet, were mapped as undivided Tewinga Group by Bultitude & others (1982), whereas those to the north, in the Mary Kathleen 1:100 000 geological sheet, were included within the Leichhardt Metamorphics and Kalkadoon Granite by Derrick & others (1977). On the 1:500 000 geological map of the Mount Isa Inlier and environs and in the accompanying Bulletin (Blake, 1987), the migmatitic metasediments and metavolcanics are assigned to a new unit, the Kurbayia Migmatite, but the nebulitic gneiss, which appears to be confined to the Mary Kathleen Sheet, has not been distinguished from Kalkadoon Granite.

Along its western boundary the migmatite band is generally strongly deformed, but in several places the Kurbayia Migmatite and cross-cutting Kalkadoon Granite can be seen overlain unconformably by the Bottletree Formation of cover sequence 2. This formation of 1790 Ma-old felsic and mafic volcanics, and interlayered conglomeratic, arkosic, and greywacke-type sedimentary rocks, underlies the Haslingden

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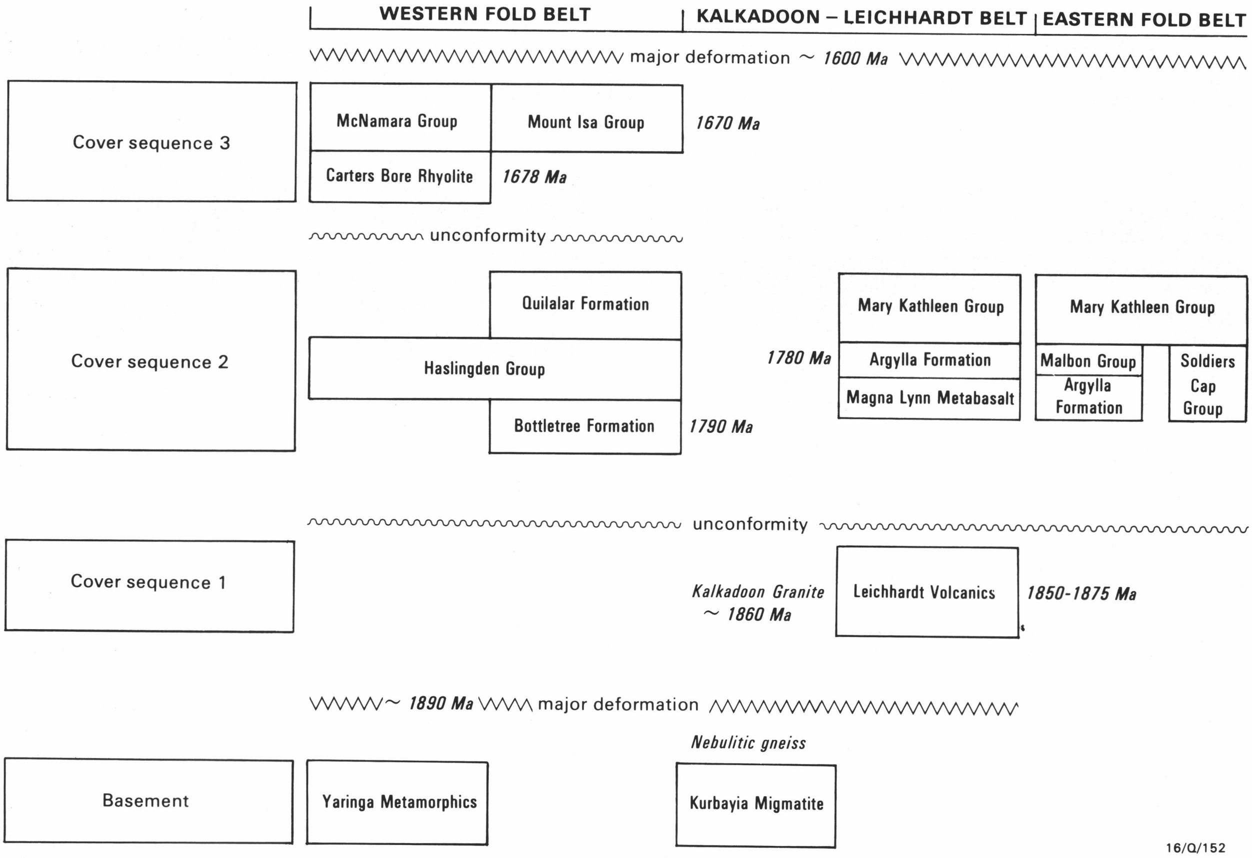

Figure 2. Generalised stratigraphic scheme for the Mount Isa Inlier.

Group conformably (e.g., Blake & others, 1984) or disconformably (e.g., Derrick & Wilson, 1981). It clearly postdates the migmatite-forming event affecting the basement.

In the east the migmatite band is bounded for most or all of its length by a major fault or shear zone which separates it from the Leichhardt Volcanics of cover sequence 1: no migmatitic rocks occur farther east and no Leichhardt Volcanics, a formation consisting solely of felsic extrusives, have been recognised within the migmatite band. The migmatitic basement and adjacent Leichhardt Volcanics are intruded by identical phases of Kalkadoon Granite, and were probably at similar depths in the crust when the Kalkadoon Granite was emplaced. Hence, migmatitic basement may underlie the Leichhardt Volcanics, the base of which is not exposed. Farther east the Leichhardt Volcanics are overlain disconformably by the Magna Lynn Metabasalt and Argylla Formation of cover sequence 2.

The migmatite band is cut by numerous faults and shear zones, mainly with northerly trends, and, in places, the migmatitic rocks and younger intrusives have been rendered schistose.

Kurbayia Migmatite

The Kurbayia Migmatite (defined by Blake, 1987) is made up largely of thinly banded grey gneiss with mostly concordant leucosomes (Fig. 3). Then gneiss is fine to medium-grained and consists predominantly of biotite, muscovite, quartz, microcline, and sodic plagioclase, with abundant myrmekite. The banding is commonly folded in complex disharmonic style (Fig.3). The persistence of individual bands along strike and the presence of texturally and compositionally distinctive marker bands indicate that, in the main, the banding represents primary sedimentary layering (i.e., bedding). This banded micaceous gneiss, therefore, is considered to be metasediments. Variations in composition, from richly micaceous to largely

Figure 3. Disharmonic folding in thinly banded migmatitic gneiss (metasediment), Kurbayia Migmatite. Exposure 2 km north northwest of U—Pb zircon dating site, in the Duchess region 1:100 000 geological sheet area.

quartzofeldspathic, and the local association with metavolcanics, suggest that the protoliths ranged from pelitic and greywacke-type sediments to volcaniclastic and tuffaceous deposits.

Other rock types present include: grey non-banded gneiss with wispy leucosomes (Fig. 4) and overall dacitic composition (e.g., about 65% SiO_2), pink quartzofeldspathic gneiss which in some cases has contorted flow-banding vaguely preserved; and amphibolite intricately veined by leucosome material. The main foliation in these rocks, that marked by the leucosomes, is commonly complexly folded and also crenulated, like the migmatitic foliation in the banded metasediments. The non-banded felsic gneiss is finer grained than nebulitic granitic gneiss in the eastern part of the migmatitic zone, and is regarded as metavolcanics, although the felsic gneiss may include some high-level intrusions. The agmatitic amphibolite may represent either or both mafic lavas and mafic minor intrusions.

Figure 4. Granite dyke cutting migmatitic metadacite (metavolcanic), Kurbayia Migmatite. Exposure near the U-Pb zircon dating site, in the Duchess region 1:100 000 geological sheet area.

One sample of dacitic migmatitic gneiss (metadacite), from northwest of Duchess (Fig. 1), has been chemically analysed; it plots within the field of the Leichhardt Volcanics on variation diagrams for TiO_2, P_2O_5, Zr, Nb, and Y against SiO_2. This metadacite, which has also been isotopically dated (see below), contains aggregates of actinolitic amphibole, possibly pseudomorphing pyroxene, scattered anhedral megacrysts of andesine, which may be remnant phenocrysts (Bultitude & others, 1982), together with biotite, quartz, microcline, and minor calcite, epidote, muscovite, tourmaline and zircon; some myrmekite is present.

The early folds in the Kurbayia Migmatite, those that are cut by, and hence predate, veins of Kalkadoon Granite, are somewhat irregular in orientation, but have overall east-west trends except where they have been tightly refolded about northerly trending axes during a deformation postdating granite intrusion.

Nebulitic gneiss

In the Mary Kathleen Sheet area the eastern part of the migmatite band is a complex of mainly nebulitic granitic gneiss and Kalkadoon Granite; migmatitic metasediments of Kurbayia-type are largely restricted to xenoliths, some more than 1m across, in Kalkadoon Granite. The nebulitic gneiss is medium-grained, and shows streaky banding, (Fig.5). It consists essentially of quartz, microcline, sodic plagioclase, and variable amounts of biotite, and contains abundant myrmekite. Small angular fine-grained mafic xenoliths are commonly present. The banding, which results from variations in colour index, but not in texture, ranges from well-marked to barely discernible, and in places is tightly folded (Fig. 5). Contacts between bands are gradational.

The nebulitic gneiss is cut by, and also occurs as inclusions within, phases of Kalkadoon Granite similar to those intruding Kurbayia Migmatite to the west. It is considered to represent heterogeneous, xenolithic granite which was deformed and in places partially melted at the same time as the Kurbayia Migmatite, prior to intrusion of Kalkadoon Granite.

Conditions of migmatite formation

The presence of leucosomes consisting of quartz, microcline, and plagioclase, the abundance of myrmekite, and the complete recrystallisation of the protoliths of the Kurbayia Migmatite and nebulitic gneiss, indicate anatexis/ partial melting during regional metamorphism to middle or upper amphibolite facies. This implies pressures of probably at least 4 kb and temperatures of 600–700°C during migmatite formation. However, mineral assemblages now present in the basement rocks are indicative of upper greenschist and lower amphibolite facies, as is also the case for adjacent Kalkadoon Granite and mafic dykes. These assemblages are attributed to subsequent regional metamorphism during 1550–1620 Ma tectonism.

Correlatives of the Kurbayia Migmatite

Several other units exposed in the Mount Isa Inlier and nearby are regarded as either basement or possible basement predating the Proterozoic cover sequences (Blake, in 1987), and hence are possibly similar in age to the Kurbayia Migmatite. One such unit, the partly migmatitic Yaringa Metamorphics in the west of the Inlier (Fig. 1), was metamorphosed and deformed at around 1890 Ma (Page, in Blake & others, 1983; Page & Williams, in press); it is overlain unconformably by much less deformed and metamorphosed sedimentary rocks of the McNamara Group of cover sequence 3. Other possible correlatives are: the Murphy Metamorphics to the northwest, which were deformed and metamorphosed before being intruded by granite (Nicholson Granite), probably similar in age to the Kalkadoon Granite (Page & others, 1984); the Sulieman Gneiss, Kallala Quartzite, and Saint Ronans Metamorphics, exposed in the far southwest of the Mount Isa Inlier; the May Downs Gneiss, which crops out between the Yaringa Metamorphics and Mount Isa; the Plum Mountain Gneiss in the southeast of the Kalkadoon-Leichhardt Belt; and the Double Crossing Metamorphics in the south of the Eastern Fold Belt.

Igneous rocks intruding migmatitic basement

The basement migmatites in the west of the Kalkadoon-Leichhardt Belt are intruded by phases of Kalkadoon Granite and by northerly trending felsic and mafic dykes. These intrusions postdate the migmatite-forming event and associated deformation; however, they have been foliated and recrystallised to varying degrees as a result of subsequent deformation and metamorphism. The foliation in the intrusions, like the late foliation evident in the migmatites, is typically subvertical and northerly-trending.

Phases of Kalkadoon Granite intruding the migmatites include medium-grained diorite, fine to medium-grained tonalite, porphyritic and non-porphyritic granodiorite, and granite and leucogranite (Fig. 4) which are mainly medium-grained. These form veins and larger irregular bodies that cut across the complex folds and early foliation developed in the migmatites. The dominant mafic mineral present in all phases is biotite, which occurs as recrystallised aggregates, in some cases pseudomorphing amphibole (Wyborn & Page, 1983). At most localities where different phases of Kalkadoon Granite are juxtaposed, the more mafic phase appears to be the older; leucogranite, for example, very commonly occurs as veins cutting the other granite phases. However, this may not always be the case, as in places the granitic rocks intruding the migmatites form net-veined complexes in which pillow-like inclusions of tonalite or granodiorite are enclosed in and veined by leucocratic granite: either the two contrasting phases were emplaced together or the more mafic phase is younger (e.g., Blake, 1981).

Thirty kilometres northwest of Duchess (Fig. 1) the Kurbayia Migmatite and adjacent Kalkadoon Granite are cut by dykes of grey fine-grained felsic porphyry. These dykes are identical in chemical composition (both major and trace elements) to nearby porphyritic felsic volcanics in the overlying Bottletree Formation, and are probably comparable in age (1790 Ma).

Many mafic dykes intrude both the Kalkadoon Granite and the migmatitic basement rocks. They range from amphibolite consisting largely of green hornblende and either oligoclase or andesine, indicative of amphibolite facies metamorphism, to retrograde biotite or chlorite schist.

Geochronology

Two samples from within the band of migmatites in the Duchess region 1:100 000 geological sheet (at GR 558510, Fig. 1) have been the subject of a U–Pb zircon geochronological study. One of the samples is of migmatitic metadacite assigned to the Kurbayia Migmatite. The metadacite has wispy quartzofeldspathic segregations (leucosomes) which are generally parallel to a strongly aligned east-west fabric (foliation) and represent an anatectic/ metamorphic product. The other sample is of medium-grained granite from a dyke, one of several up to 1m wide, cutting the metadacite (Fig. 4). These granite dykes postdate the east-west fabric, but show a weak north–south foliation.

Zircons from the migmatitic metadacite were isotopically measured initially using conventional U–Pb techniques (Page, 1983). A somewhat scattered grouping of the 7 reported data points was considered to reflect a complex crystallisation history for the zircons. As 4 of the 7 data points formed a perfect discordia line, the preferred interpretation was that the metadacite had an igneous crystallisation age indicated by the upper concordia intercept — 1866 $\pm$ 5 Ma. This interpretation was influenced by the close correspondence of this age to igneous crystallisation ages of 1850 to 1870 Ma determined for the Leichhardt Volcanics exposed east of the migmatite band.

Recent ion-probe studies of this same zircon population confirm that the 7 conventionally analysed data points do not form part of a simple discordia Pb-loss array (Page & Williams, in press). Indeed, there is now evidence of a pronounced and complex pattern of multiple crystallisation ages. The great majority of zircon grains are in the range 1850–1870 Ma old, a few per cent are inherited grains with $^{207}Pb/^{206}Pb$ ages ranging from 2.1 to 2.9 Ga, and a few per cent have concordant U–Pb ages indicating crystallisation in latest Proterozoic/earliest Paleozoic times. Given this new evidence, the initial age interpretation from the conventional zircon data of 1866$\pm$5 Ma, based on the linearity of 4 of the 7 conventional data points, is not justified. A better interpretation of the conventional analyses, based on all 7 data points, is an age of 1850$\pm$16 Ma (Fig. 6). This is unlikely to be the igneous crystallisation age for the metadacite, though, because:

Figure 5. Fold in streakily banded nebulitic granitic gneiss in the Mary Kathleen 1:100 000 geological sheet area. A fine-grained mafic xenolith can be seen near the hammer handle.

(1) metamorphic overgrowths of about this age have been measured by ion-probe analysis on zircon grains from the same sample of metadacite;
(2) the 1850$\pm$16 Ma date conflicts with new zircon data presented below for the intrusive granite dyke.

The granite dyke studied (sample no. 8320.5012) postdates the dominant east-west anatectic fabric in the metadacite (Fig. 4). Zircons from the dyke are clear stubby euhedral crystals, colourless to pale brown and commonly with a pronounced core/rim structure. The zircon population is high in U (1136 — 2286 ppm, Table 1), and contains a high proportion of common Pb (10–60% of total Pb). The analytical uncertainties are thus larger than usual (0.8% in Pb/U). The Pb–U data are variably discordant in proportion to the amount of common Pb, and do not fit a simple Pb-loss pattern (MSWD = 11.5). The best-fit discordia line through the 8 data points has upper and lower concordia intercepts at 1860$\pm$32 Ma and 250$\pm$75 Ma, respectively (Fig. 6). All except one of the points lie to the right of the 1850$\pm$16Ma discordia line for the metadacite, although the two fitted chords and upper intercept ages are within analytical error.

As the granite dyke cuts the main fabric in the metadacite, the dyke's age of 1860$\pm$32 Ma is regarded as a minimum for the migmatisation and associated deformation event (providing there is no significant inherited component of zircon in the granite dyke), and the 1850$\pm$16 Ma age measured on the metadacite is no longer considered to date igneous crystallisation.

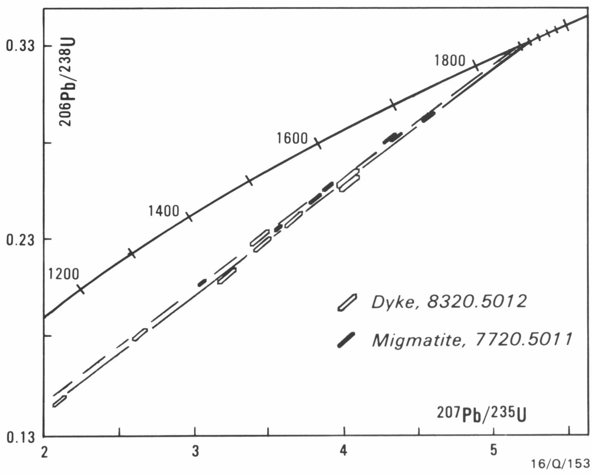

Figure 6. Concordia plot of U-Pb data for migmatitic metadacite (Kurbayia Migmatite) and cross-cutting granite dyke (Kalkadoon Granite) in the Duchess region 1:100 000 geological sheet, showing 2σ error envelopes for the zircon points.

The ion-probe analytical data show that the conventionally determined 1850 Ma result for the metadacite is a mixture of at least 3 zircon age components, of which the dominant one, 1850- 1870 Ma, is considered to correspond to the migmatisation event. The preferred age for the migmatisation, based on the current analytical data, is 1860–1870Ma.

The offset of most of the metadacite zircon points to the left of the chord defining the geologically younger granite dyke zircon data on the concordia plot (Fig. 6) may be due to recent Pb loss from more discordant fractions, and/or to a disproportionate presence of the very young zircon recognised in the ion-probe study. Such factors can explain why the 'averaging' represented by the 1850$\pm$16Ma conventional result, although within experimental error of a migmatisation age of 1850–1870 Ma, is graphically anomalous and marginally younger than given by the post-migmatite granite dyke age.

An age of 1860–1870 Ma for the migmatisation and associated deformation of the basement conflicts, if taken at face value, with field evidence, which suggests that this major tectonic event took place before the eruption of the Leichhardt Volcanics, the oldest cover sequence unit. The Leichhardt Volcanics, extensively exposed to the east of the migmatites, are intruded by phases of Kalkadoon Granite identical to those cutting the migmatites, but neither the volcanics nor the granite appear to have been deformed or metamorphosed to any significant extent until the 1620–1550 Ma period of tectonism that affected all three cover sequences of the Mount Isa Inlier. U-Pb zircon ages of 1875^{+26}_{-19} Ma and 1865$\pm$3 Ma have been obtained for the Leichhardt Volcanics in the Kalkadoon-Leichhardt belt (Page, 1983). Kalkadoon Granite from the southern part of the Belt has been dated at 1856^{+11}_{-9}Ma (Wyborn & Page, 1983) and from the northern part at 1862^{+27}_{-21} Ma (Page, 1978). For the field and geochronological interpretations to be in agreement, the precover migmatite-forming event should be older than these indicated ages. This is possible when the 2-sigma uncertainties on the ages are considered, but it implies that the operative tectonic processes took place over a short time interval — an interpreted maximum age of 1870 Ma for migmatite formation and a minimum possible age of 1862 Ma (from the 1865 $\pm$ 3 Ma determination) for commencement of Leichhardt volcanism allow no more than eight million years for cessation of migmatisation and subsequent uplift and erosion sufficient to bring the migmatites from a depth of around 12 km (4 kb) to within a few kilometres of the surface. This would imply uplift rates in the order of 2–5 mm a year (=10 km in 2–5 million years).

The rapidity of tectonic processes such as envisaged here is comparable to that of the present day in tectonically active regions; for example, in the South Island of New Zealand, uplift rates of up to 17 mm a year have been calculated (Wellman, 1979), and in the Himalayas, some parts have probably been uplifted more than 10 km in less than 10 Ma (e.g., Windley, 1985). Similar rates of uplift in the period 1850–1900 Ma are indicated from the latest geochronological evidence in other Proterozoic terranes of Australia (Page & others, 1984; Needham & others, in press).

Although the stratigraphic age of the basement sequence (Kurbayia Migmatite protoliths) could not be directly determined from this study, the youngest inherited zircon components, from ion-probe data, indicate that the migmatitic metadacite has a maximum age of about 2100 Ma.

Geological history of migmatitic basement

The following sequence of events can be interpreted for the migmatitic basement in the western part of the Kalkadoon-Leichhardt Belt.

1. Sedimentation and penecontemporaneous? felsic (and mafic?) volcanism, forming the protoliths of the Kurbayia Migmatite.
2. Burial of the protoliths to a depth of several kilometres.
3. Intrusion of inclusion-rich granite; possibly also of some mafic dykes.
4. Major tectonism, resulting in metamorphism, partial melting and formation of migmatite, and complex folding of protoliths of the Kurbayia Migmatite. At the same time the inclusion-rich granite was recrystallised and deformed to form nebulitic gneiss. Medium-grained gneissic textures, presence of leucosomes, and abundance of

Table 1. U-Pb analytical data for zircons from a granite dyke (sample 8320.5012) intruding the Kurbayia Migmatite

Size (microns) and magnetic susceptibility	*Weight (mg)*	*Concentration (ppm)*			*$^{206}Pb/^{204}Pb$ (measured)*	*Radiogenic ratios*		
		Radiogenic Pb	*Common Pb*	*U*		*$^{207}Pb/^{206}Pb$*	*$^{206}Pb/^{238}U$*	*$^{207}Pb/^{235}U$*
-350 MI	0.88	298.7	119.3	1394.7	139.4	0.10546	0.18155	2.6398
-215 NMI	1.14	263.0	70.1	1135.7	209.3	0.11029	0.21188	3.2219
-150 NMO	0.66	334.6	39.7	1239.3	480.9	0.11119	0.26319	4.0347
-150 MO	1.53	306.2	60.0	1279.0	295.4	0.10987	0.22824	3.4575
-100 NMO	1.12	352.0	42.2	1327.2	491.0	0.11247	0.25961	4.0259
-100 MO	1.06	335.0	55.3	1399.1	346.9	0.10786	0.23135	3.4405
- 80 NMO	0.55	415.1	65.2	1688.5	377.8	0.11040	0.24079	3.6654
- 45 NM	0.25	434.3	241.5	2286.0	96.1	0.10376	0.14710	2.1045

myrmekite indicate that metamorphism reached upper amphibolite facies, implying probable pressures of 4 kb or more. U-Pb zircon data reported in this paper and preliminary ion-probe U-Pb data suggest that the metamorphism probably took place about 1860-1870 Ma ago. Uplift and erosion associated with the tectonism brought the migmatitic basement to within a few kilometres of the surface. This appears to have happened within a period of less than 10 Ma, implying uplift rates of 2-5 mm a year. The tectonism may correlate with 1890 ± 8 Ma high-grade metamorphism in the Yaringa Metamorphics in the western part of the Mount Isa Inlier (Page & Williams, in press), and provide further support for the existence of the continent-wide early Proterozoic event — the 1850-1880 Ma-old Barramundi orogeny — put forward by Etheridge & others (1987).

5. Leichhardt volcanism and intrusion into the basement of the comagmatic Kalkadoon Granite at around 1860 Ma.
6. Subaerial erosion, leading to exposure of Kurbayia Migmatite and Kalkadoon Granite.
7. Deposition of the 1790 Ma-old Bottletree Formation (oldest unit of cover sequence 2 in the Western Fold Belt) unconformably on Kurbayia Migmatite and Kalkadoon Granite in the west. Intrusion into the migmatite and granite of high-level dykes related to felsic volcanics within the Bottletree Formation.
8. Deposition of younger units of cover sequence 2, including the Haslingden Group and Quilalar Formation in the Western Fold Belt, and the Magna Lynn Metabasalt, Argylla Formation, and Mary Kathleen Group in the eastern part of the Kalkadoon-Leichhardt Belt.
9. Period of nondeposition, erosion, and local, mainly mild, tectonism.
10. Deposition in the Western Fold Belt, and perhaps also in the Kalkadoon-Leichhardt Belt, of cover sequence 3 (1680-1670 Ma).
11. Major tectonism between 1620 Ma and 1550 Ma (Page & Bell, 1986), resulting in region-wide deformation and metamorphism of the three cover sequences, 1670-1860 Ma-old granites, and the previously deformed and metamorphosed Kurbayia Migmatite and nebulitic gneiss of the basement. The metamorphism reached amphibolite facies, and was of low-pressure high-temperature type (e.g., Jaques & others, 1982).
12. Some faulting occurred later in the Proterozoic and during the Phanerozoic; however, since about 1500 Ma the Mount Isa Inlier appears to have been a relatively stable part of the north Australian craton (e.g., Blake, 1987).

Conclusions

1. The protoliths of the Kurbayia Migmatite and nebulitic gneiss exposed in the western part of the Kalkadoon-Leichhardt Belt were metamorphosed to migmatite and deformed before the Kalkadoon Granite was intruded at around 1860 Ma and probably before the comagmatic Leichhardt Volcanics were erupted. They can therefore be regarded as forming part of the basement underlying the Proterozoic cover rocks (which are taken to include the Leichhardt Volcanics) of the Mount Isa Inlier. This basement is seen to be overlain unconformably by the 1790 Ma-old Bottletree Formation, but no stratigraphic (non-faulted) contacts with the Leichhardt Volcanics are known.
2. The migmatite-forming event took place between 1860 Ma and 1870 Ma, according to constraints imposed by U-Pb zircon data, or, as suggested by region-wide geological considerations, somewhat earlier — perhaps at around 1890 Ma, when the Yaringa Metamorphics in the west of the Isa Inlier were metamorphosed to migmatite.

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