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ISOTOPIC AGE DETERMINATIONS ON PRECAMBRIAN ROCKS OF THE CARPENTARIA REGION, NORTHERN TERRITORY, AUSTRALIA.

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ISOTOPIC AGE DETERMINATIONS ON PRECAMBRIAN ROCKS OF THE CARPENTARIA REGION, NORTHERN TERRITORY, AUSTRALIA.

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I. McDougall*, P.R. Dunn +, W. Compston *, A.W. Webb+,
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ABSTRACT

A sequence up to 40,000 feet thick of unmetamorphosed and only slightly deformed sedimentary and volcanic rocks occurs in the Carpentaria Province of Northern Australia. Metamorphic and granitic rocks form the basement to this sequence, and K-Ar and Rb-Sr age measurements show that the basement granites are about 1,800 ± 50 m.y. old. Associated in space and time with the granitic rocks are acid volcanics which form the basal unit in the overlying sequence. Glauconites in sedimentary rocks from this succession yield dates ranging from 1,600 m.y. in the Tawallah Group, the second lowest unit, to about 1,390 m.y. in the Roper Group, the uppermost unit. Plagioclase and pyroxene from dolerites intrusive into the Roper Group give K-Ar dates ranging from 1,100 to 1,280 m.y.; the older date provides a younger limit to the age of the Roper Group. Following slight folding the Wessell Group was deposited unconformably on the Roper Group; a single glauconite from the topmost formation of the Wessell Group yields concordant Rb-Sr and K-Ar dates of 780 ± 20 m.y.

The results generally are internally consistent and provide much information, not previously available, as to the age of the Precambrian rocks in this region. Correlation with other Precambrian sequences in Australia now becomes possible as more dates are measured on rocks from other areas.

Three alternatives are offered for the subdivision of Precambrian time in Australia; (i) the adoption of an arbitrary time-scale independent of rock sequences, (ii) the adoption of the Canadian system of nomenclature, and (iii) the definition of standard time-rock units for use throughout Australia. The third alternative is strongly recommended and such time-rock units should be bounded by horizons that are amenable to accurate and precise dating by isotopic methods. By the judicious choice of several sequences it should be possible to obtain a satisfactory time scale for all Precambrian rocks in Australia. Part of the sequence developed in the Carpentaria Province is proposed as a time-rock unit to be known as Carpentarian.

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* Department of Geophysics and Geochemistry, Australian National University, Canberra, A.C.T.

+ Bureau of Mineral Resources, Canberra, A.C.T.

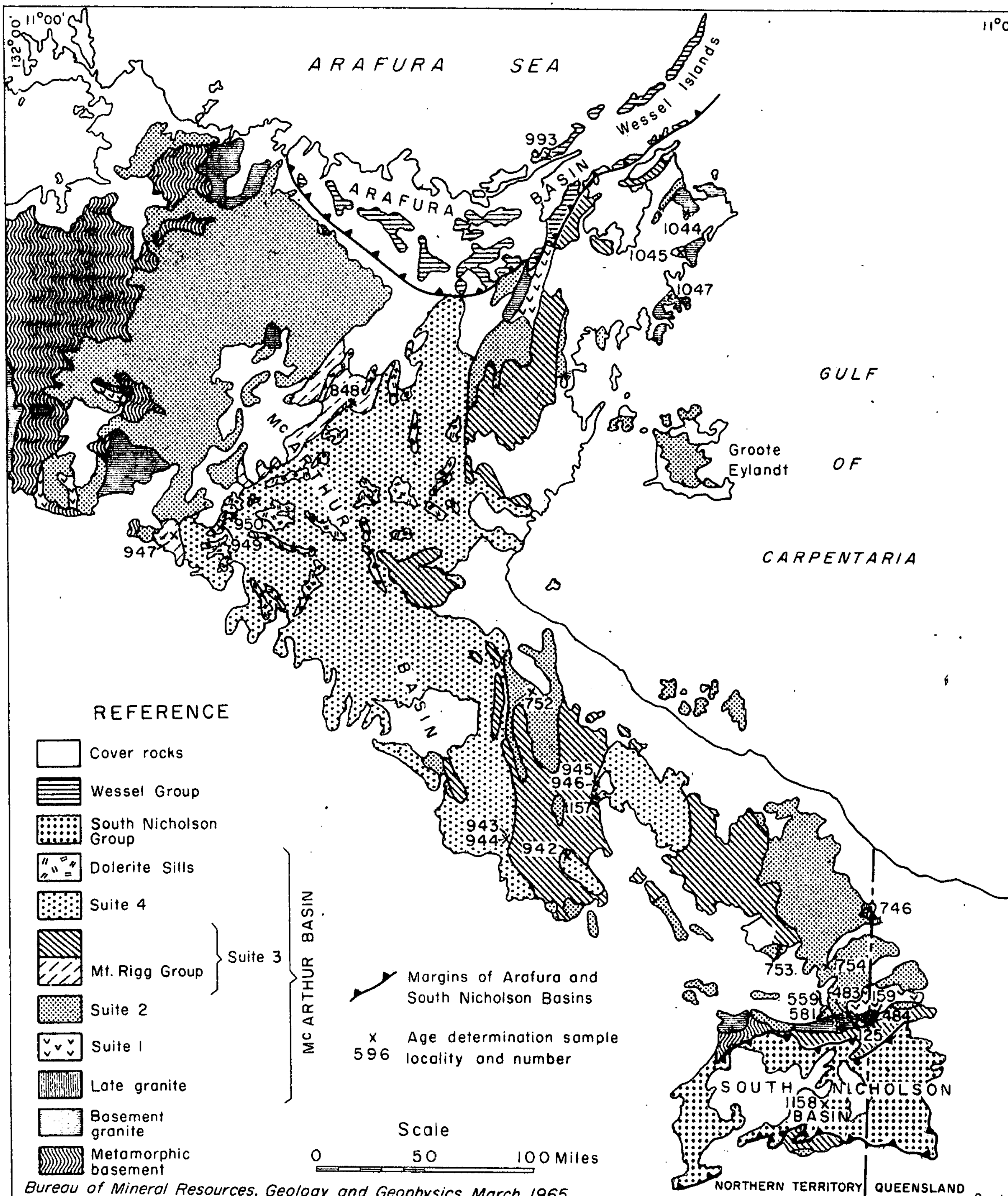

Fig.1 Distribution of major rock units and age determination sample localities, Carpentaria Province, N.T.

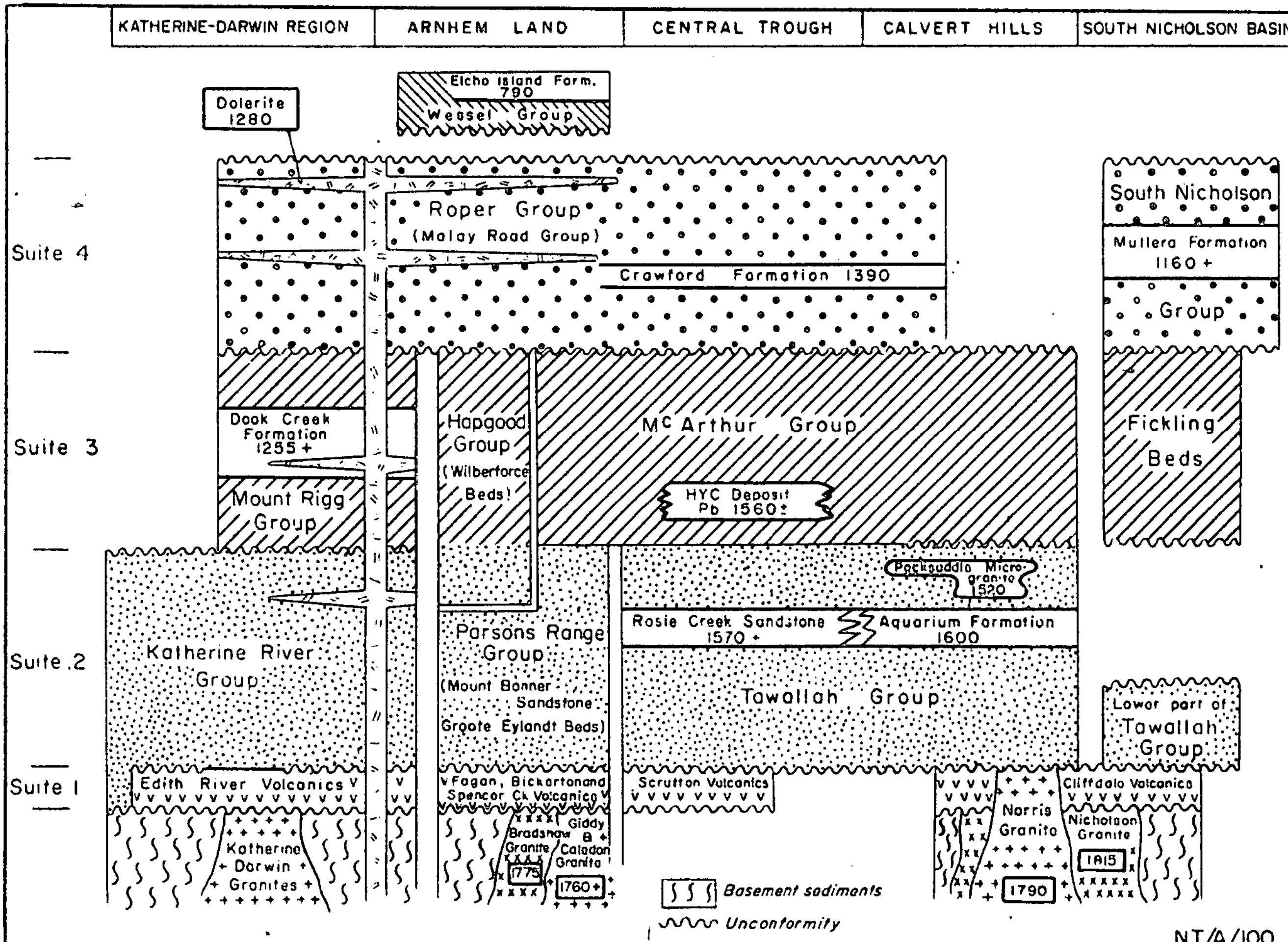

Fig. 2 Diagrammatic relationships of rock units showing relative positions and approximate ages of dated units (age in millions of years.)

INTRODUCTION

Isotopic methods of dating rocks are of particular importance when dealing with the Precambrian, since prior to the development and application of these methods placing of Precambrian sequences even approximately in the geological time-scale was extremely difficult.

In this paper we report isotopic age determinations by the K-Ar and Rb-Sr methods on Precambrian rocks of the Carpentaria Province* of Northern Australia. Dates have been measured on samples from an area of nearly 200,000 square miles; hence this study is of a reconnaissance nature. However, an attempt has been made to collect and date samples that are critical to the geological history of this region.

This work is the result of close collaboration between officers of the Bureau of Mineral Resources, who have carried out the geological mapping and the collection of samples, and the Department of Geophysics and Geochemistry, Australian National University, where the isotopic dating measurements were made. Sample localities and brief petrographic notes on the rocks are given in the appendix.

GEOLOGY

The geology of the Carpentaria Province is described in several bulletins by Dunn, Smith & Roberts (in prep.), Roberts, Dunn & Plumb (in prep.) and Walpole, Randal & Dunn (in prep.). These will be issued by the Bureau of Mineral Resources. Although these bulletins form the basis for the discussion of the geology described below, they have not yet been published and so, where necessary, reference is also made to the available explanatory notes that accompany the relevant 1:250,000 geological maps. The stratigraphy is summarized in Figure 2.

The Carpentaria Province includes an area of Precambrian deposition that extends from the north of Arnhem Land to the Northern Territory - Queensland border (about 190,000 square miles). It is mainly occupied by the McArthur Basin which contains up to 40,000 feet of sediments but also includes the smaller South Nicholson Basin to the south and the younger overlapping Arafura Basin to the north (Fig. 1).

The rocks deposited in the three basins are unmetamorphosed and, in general, only gently folded; they are, however, extensively faulted and steep dips occur near many of the faults. Basement rocks are metamorphics and granites. Much of the south-western part of the Province is overlain by Cambrian and Cretaceous sediments.

Basement rocks to the McArthur and South Nicholson Basins crop out in three main localities: in an east-trending area (the Murphy Tectonic Ridge) across the Queensland border (Roberts et al., 1963); in the north-west portion of Arnhem Land (Dunnet, 1964; Plumb & Roberts, 1964); and in the Katherine-Darwin region in the north-west of the Province (Walpole, 1962; Randal, 1962).

* Carpentaria Province is used in this paper in place of Carpentaria Proterozoic Province as defined by Dunn, Smith & Roberts (in prep.). The names are synonomous but we prefer not to use the term Proterozoic in the light of our discussion of Precambrian nomenclature.

In the Queensland border area the basement rocks consist of isoclinally-folded schists and gneisses (Murphy Metamorphics) intruded by the Nicholson Granite. These rocks are unconformably overlain by a moderately folded sequence of acid volcanic rocks, the Cliffdale Volcanics, which are themselves intruded by the Norris Granite. In Arnhem Land the basement rocks crop out along the eastern coastline and in an inlier 80 miles west of the coast. The rocks consist of syntectonic garnetiferous granite, gneissic granite, gneisses and schists (Bradshaw Granite and Mirarrmina Complex) which appear to have been intruded by post-tectonic granites (Giddy and Caledon Granites). A sample was taken from each of the post-tectonic granites and another sample was obtained from an outcrop mapped as Bradshaw Granite. A detailed examination of the third sample shows that it is not typical of the usual Bradshaw Granite type and is more closely akin to the post-tectonic granites. The basement to the McArthur Basin in the Katherine-Darwin region consists of folded sediments of low metamorphic grade which have been intruded by basic rocks and granite. No samples from the Katherine-Darwin basement were obtained for this survey but Hurley et al (1961) have made K-Ar determinations on the granites and Leggo and Compston (pers. comm.) are now making Rb-Sr determinations on the same samples.

The rocks of the McArthur Basin were deposited unconformably on the basement. Although placed in a number of groups the rocks may be attributed to four fundamental rock suites deposited in succession throughout the basin; they are:

<u>Suite 4.</u>(the youngest). Shale - siltstone-sandstone sequence. Includes the Roper Group and Malay Road Group.

<u>Suite 3</u>. Carbonate - lutite sequence. Includes the McArthur, and Mount Rigg Groups, the Wilberforce Beds (and part of the Habgood Group).

<u>Suite 2</u>. Arenite - volcanic - carbonate sequence. Includes the Tawallah, and Parsons Range Groups, the Mount Bonner Sandstone, the Groote Eylandt Beds and parts of the Habgood Group and Katherine River Groups.

<u>Suite 1</u>.(the oldest). Acid volcanic assemblage, with associated granites. Includes the Cliffdale, Edith River, Scrutton, Fagan, Bickerton and Spencer Creek Volcanics.

The volcanic rocks of Suite 1 occur in a number of separate localities but they are correlated on their lithology and stratigraphic relationships. These rocks seem to have been deposited mainly in the more mobile parts of the basin, and heralded the development of the basin as a whole. For this study no dating was undertaken on the volcanics, although Leggo and Compston are at present measuring Rb-Sr ages on the Edith River Volcanics from the Katherine-Darwin region. However, an approximate age for the Cliffdale Volcanics is given by the dates on the Norris Granite, which is thought to be comagmatic with the volcanics.

The arenite-volcanic-carbonate sequence of Suite 2 generally overlies the acid volcanics unconformably, but in the Katherine-Darwin region some of the volcanics appear to interfinger with the overlying sandstone. We are mainly concerned with this suite in the southern part of the McArthur Basin where it is represented by the Tawallah Group, which has a maximum thickness of about 18000 feet in the central trough portion of the Basin. Webb et al. (1963) made K-Ar age determinations on glauconite from the Aquarium Formation and Rosie Creek Sandstone. These two formations crop out in different areas but both are composed mainly of glauconitic and feldspathic sandstone and siltstone and are considered to be equivalents (Plumb & Paine, 1964; Smith, 1964; Roberts, et al., 1963). The results of Rb-Sr determinations on the glauconites are recorded here. The glauconitic formations overlie up to 12000 feet of sandstone and interbedded volcanics and dolomite of the Tawallah Group. The Masterton Formation, the topmost formation in the group, and about 1500 to 2000 feet above the glauconitic formations, contains a local rhyolitic member (Hobblechain Rhyolite Member) which grades laterally into the Packsaddle Microgranite (Roberts et al., 1963). A Rb-Sr date has been obtained on the Microgranite.

Suite 3 conformably overlies Suite 2 in the central trough of the McArthur Basin but unconformably overlies Suite 2 on the platform areas adjoining the trough. In the trough the carbonate-lutite sequence has a maximum thickness of about 15,000 feet but is only 1,000 feet thick or less in the platform areas. The two groups in this suite with which we are concerned are the McArthur Group and the Mount Rigg Group; the McArthur Group consists for the most part of dolomite, dolomitic shale, and siltstone, sandstone and chert; a reef complex has been delimited (Smith, 1964) and numerous stromatolites and some sponge spicules (Dunn, 1964) attest to the existence of various forms of life. These Precambrian fossil forms have not yet provided a suitable correlation with the time-scale and the only isotopic age estimate for material from the McArthur Group was made by Richards (1963) on a single sample of galena from an apparently syngenetic lead deposit in the Amelia Dolomite near the bottom of the Group. The Mount Rigg Group constitutes a platform phase of Suite 3; it is only about 4000 feet thick and consists mostly of dolomitic sediments, chert and sandstone. This group crops out in two nearby but separate areas - the correlation of the rocks in the two areas is based on lithology and stratigraphic relationships. A sample of glauconitic dolomite from the Dook Creek Formation in one area was used for age determination whereas a galena sample from a lead deposit in the same Formation in the other area has previously been analysed by Richards (1963); the lead deposit is close to a later dolerite dyke (Roberts & Plumb, 1964).

Suite 4 is represented mainly by the Roper Group which is unconformable on the Suite 3 rocks; the unconformity is not noticeably angular and only appears to involve complete erosion of an underlying formation in the mobile trough areas of the McArthur Basin. The Roper Group averages about 6000 feet thick with a local maximum of about 15000 feet, and has a dominant siltstone and shale lithology with prominent sandstone units; oolitic ironstone occurs in the upper part of the Group. The Crawford Formation occurs within 1500 feet of the base of the Group; it contains a widespread glauconitic sandstone from which six samples were obtained from different localities within an area of about 3000 square miles in the McArthur River region (Smith, 1964).

After the deposition of Suite 4 rocks and before the sediments were folded and faulted, they were intruded by dolerite sills in the northern part of the Basin. The dolerite intrudes suites 2, 3 and 4 in a number of sills each averaging 200 feet thick (Dunn, 1963). It is tholeiitic and commonly is altered, possibly deuterically. Samples were taken from sills intruding the Roper and Mount Rigg Groups. The isotopic dating places a younger age limit on the Roper Group.

The South Nicholson Basin occurs to the south of the basement rocks in the Queensland border area. (Smith & Roberts, 1963, Roberts et al., 1963). It is bounded by rocks that have been equated with Suites 2 and 3 in the McArthur Basin, although there is no remaining link between the sequences on either side of the basement. The South Nicholson Group in the South Nicholson Basin is correlated with the Roper Group - the lithologies are similar (amongst other things both contain oolitic ironstone deposits) and the three main formations in the South Nicholson Group are equated with the four lower formations in the Roper Group. The formations in the South Nicholson Basin are very much thicker (19000 feet total) than their Roper Group counterparts. A sample of glauconitic siltstone from the Mullera Formation, the centre of the three, was taken for age determination.

The Arafura Basin laps on to the McArthur Basin in the north of Arnhem Land and the sediments (Wessel Group) unconformably overlie those of Suite 4. The Wessel Group consists of shallow-dipping shale, siltstone and sandstone with a total thickness of over 4500 feet. The basal sandstone contains worm burrows (*Scolithus*). A sample of glauconitic fine-grained sandstone was taken from the topmost formation, the Elcho Island Formation.

The three basins were formed on an unstable shelf and the sediments are mostly shallow-water types. Warping and faulting associated with the actual development of the basins can account for many of the large-scale structural units. Post-depositional folding was very gentle, producing dips of about 10° in the McArthur Basin, but in the South Nicholson Basin dips up to 40° are found. Faulting is common, and some faults have throws of many thousands of feet; locally beds are overturned against the faults. The folding and faulting has not produced any metamorphic effects and there is little evidence that the great depth of burial (up to 40000 feet in places) has produced more than a fissility in some of the more argillaceous sediments. Authigenic feldspar, glauconite and mica have been formed in some sediments and some of the dolomitic rocks have been silicified, probably diagenetically. Contact effects of the dolerite intrusions are confined to a few feet in the adjacent sediments.

METHODS AND CONSTANTS USED

Argon was determined by isotope dilution with measurement of isotope ratios in a Reynolds-type mass spectrometer. The techniques have been described previously (McDougall, 1963; 1964). Potassium measurements were made flame-photometrically by the method developed by Cooper (1963). Argon determinations generally are reproducible to better than 2 percent, and potassium measurements are reproducible to better than 1 percent. The probable error at the 95 percent confidence interval for a complete K-Ar date is about ± 2.5 percent. The constants used in the K-Ar age calculations are : $\lambda\beta = 4.72 \times 10^{-10}\ yr^{-1}$; $\lambda e = 0.584 \times 10^{-10}\ yr^{-1}$; and $K^{40} = 1.10 \times 10^{-2}$ atom percent. According to Aldrich & Wetherill (1958) these decay constants may only be regarded as accurate to about ± 3 percent.

Rubidium and strontium were determined by isotope dilution; the isotope ratios were measured on a Metropolitan Vickers MS 2 - SG mass spectrometer. Details have been described previously (Compston et al., 1965). The present day Sr^{87}/Sr^{86} ratio was calculated from the mixture of tracer and sample Sr, and in some cases measured directly. The Sr-tracer was enriched in both Sr^{86} and Sr^{84}, which provided an internal standard isotope ratio so that it was possible to eliminate variable mass discrimination. All results were normalized to a Sr^{88}/Sr^{86} ratio of 8.387. The amounts of Rb and Sr are measured to an accuracy of about ± 1 percent. For individual samples, the uncertainty in the measured age is strongly dependent on the amount of enrichment in radiogenic Sr^{87}. For the glauconites and muscovites, enrichment generally was sufficiently high to provide an age with an uncertainty of about ± 2 percent. In all other cases, the uncertainty has been controlled and assessed through measurements made on cogenetic groups of mineral or total-rock samples. Constants used in the calculations are $\lambda = 1.39 \times 10^{-11}\ yr^{-1}$ equivalent to a half-life of 5×10^{10} years, and Rb^{85}/Rb^{87} of 2.600. The uncertainty in this decay constant may be as high as 6 percent in the direction of lowering the half-life, and this must be borne in mind when comparing the Rb-Sr dates with the K-Ar dates on the same rocks. It is pointed out, however, that agreement between the two methods seems only to be possible in the case of the Nicholson-Norris granites when the greater half-life is used, lending support to the hypothesis that this is more nearly the correct value.

USE OF GLAUCONITE IN ISOTOPIC DATING

As glauconite has been used extensively in this study a brief description of this mineral and its genesis is necessary. Glauconite occurs almost exclusively in marine sediments, usually as small green pellets. It is a dioctahedral mica although structurally it is more like biotite, which is tricotahedral (Burst, 1958; Deer, Howie & Zussman, 1962). Glauconite is a K, Fe, Al, Mg mica which contains excess water. The available evidence strongly favours the view that glauconite forms by marine diagenesis in shallow water at a time of slow sedimentation (Burst, 1958). Hence, as an authigenic mineral it should be ideal for K-Ar and Rb-Sr dating of the sedimentary rocks in which it occurs.

Comprehensive studies on K-Ar dating of glauconites include papers by Amirkhanov et al. (1957), Amirkhanov et al. (1959), Evernden et al. (1961), Polevaya et al. (1961) and Hurley et al. (1960). Dates by the Rb-Sr method also were reported by Hurley et al. (1960). These studies show that in favourable cases the measured dates are close to the expected age, but that commonly the results obtained by both dating methods are too low because of loss of radiogenic daughter products. Laboratory experiments show that liberation of radiogenic argon from glauconite commences at about 200° C. (Evernden et al., 1960; Polevaya et al., 1961), and Evernden et al. concluded that appreciable argon loss may occur at a temperature as low as 100° C. if this temperature were maintained for a period of a few million years. Temperatures of this order may be expected at quite shallow depths in a depositional basin. Although glauconite occurs as pellets which may be several millimeters in diameter, thin sections show that these pellets consist of aggregates of extremely small crystals, and Grim (1952) stated that these crystals are commonly about 1 μ in size. The fine grainsize undoubtedly is a contributing factor to the ease with which radiogenic daughter products are lost. However, the main reason for leakage of argon (and presumably Sr also) from glauconite at low temperatures appears to be the result of marked lattice changes during loss of combined water above about 200° C. (Polevaya et al., 1961, p. 299). Hence, in most cases isotopic dates on glauconites must be regarded as only reliable minimum ages for the enclosing sediments.

Of the numerous K-Ar dates published on glauconite only two give dates that undoubtedly are too old. These were reported by Lipson (1958) who suggested that the anomalous older ages may have resulted from occluded older material in the glauconite pellets. Although glauconite forms authigenically the possibility that it may be eroded from an older formation and redeposited must be considered. As glauconite is a relatively unstable mineral, erosion and transportation normally would be expected to destroy it. However, Allen et al. (1964) reported the presence of derived glauconite in the Cretaceous Wealden of England, but K-Ar age measurements in these glauconites indicate that a penecontemporaneous origin is a possibility. The glauconites in the sedimentary rocks of the Carpentaria Province are considered to be truly authigenic; no evidence has been found that suggests that they were derived from older sediments.

Glauconite was separated from the sedimentary rocks by the usual techniques employing heavy liquids and a magnetic separator. The concentrates generally are better than 98 percent pure, but in some cases up to 10 percent of iron-stained quartz occurs which could not be removed. Special care was taken to ensure that the glauconite concentrates were free of detrital micas and feldspars.

DATING OF BASEMENT ROCKS

Measurements by the K-Ar and Rb-Sr methods were made on samples from the Nicholson and Norris Granites in the south of the region, and on samples from the granitic rocks of the Arnhem Land coast in the north. Analytical details of the K-Ar measurements are given in Table 1; those for the Rb-Sr measurements are listed in Table 2.

(a) Nicholson and Norris Granites

The K-Ar dates on the Nicholson Granite range from 1790 to 1840 m.y. and average 1815 m.y., and those on the Norris Granite range from 1760 to 1825 m.y. and average 1790 m.y.. The average for the Nicholson Granite and that for the Norris Granite are not significantly different, although the younger average date for the latter agrees with the field relationships. These dates provide minimum ages for the time of emplacement of the granites but they may approximate closely to the true ages. The spread in measured age is 3 percent for the Nicholson Granite samples and 4 percent for the Norris Granite specimens. As the 95 percent confidence interval for the K-Ar measurements is about 2.5 percent, the spread in ages is slightly greater than the experimental error. This spread is probably the result of some argon loss by diffusion, which would lower the measured age.

The Rb-Sr data on the Nicholson Granite Sample No.559 support the interpretation that the mean of the K-Ar dates for this granite is the true age of emplacement to within experimental error. The common Sr content of Sample No.559 is sufficiently low for the total rock data alone to define an accurate value for the age. The maximum possible age is about 1770 m.y. using an assumed minimum value for the initial Sr^{87}/Sr^{86} ratio of 0.705. A reasonable upper limit for this ratio is 0.715 in which case the total rock age becomes 1745 m.y., showing that the age is not particularly dependent on the initial Sr^{87}/Sr^{86} ratio chosen. Duplicate analyses of muscovite from this sample yield Rb-Sr dates of 1770 and 1835 m.y., in reasonable agreement with the total rock age. The difference between the duplicates on the muscovite is somewhat greater than the experimental error, but unfortunately lack of material prevented investigation of the reason for this. The good agreement of the result from muscovite A with the total rock date suggests that muscovite B may be in error or that there is a variation in the Sr^{87} concentration in the mineral itself. The 1770 m.y. date for this granite by the Rb-Sr method is 2.5 percent lower than the mean of the K-Ar dates at 1815 m.y., but this is regarded as satisfactory agreement and indicates that the granite was emplaced about 1790 ± 30 m.y. ago.

The indicated Rb-Sr ages of both K-feldspar and total-rock from Sample No.558 from the Norris Granite are sensitive to the value for the initial Sr^{87}/Sr^{86}. For the total-rock the maximum possible age is 1910 m.y., using an initial Sr^{87}/Sr^{86} of 0.705, and a date of 1705 m.y. is found if the value is taken as 0.715. Corresponding dates for the K-feldspar are 1810 m.y. and 1715 m.y. respectively. By using the isochron plot the indicated age for the combined K-feldspar and total-rock data is 1725 m.y. with an initial Sr^{87}/Sr^{86} of 0.713. However, this date appears to be significantly younger than the average of the K-Ar dates at 1790 m.y., and suggests that there has been some leakage of radiogenic Sr from the K-feldspar. For both the Nicholson and Norris Granites it is clear that further Rb-Sr dating is necessary using total-rock samples to enable the true age of emplacement to be determined.

Summarizing, the K-Ar and Rb-Sr data indicate that the Nicholson Granite was emplaced at 1790 ± 30 m.y., and from the K-Ar data it appears that the Norris Granite was intruded at a time that is experimentally indistinguishable from that of the Nicholson Granite. As the Cliffdale Volcanics are younger than the Nicholson Granite but older than the Norris Granite, then their extrusion must have occurred at about 1790 ± 30 m.y.. It is most desirable to make Rb-Sr total-rock measurements on a suite of samples from the volcanics to obtain a precise age for their formation.

(b) Arnhem Land Basement

Measurements were made by the K-Ar method on micas separated from three granitic rocks of eastern Arnhem Land, and one of these samples also was dated by the Rb-Sr method. The K-Ar dates all agree at 1760 ± 20 m.y. and provide a minimum age for the time of crystallization of these rocks.

The sample of Bradshaw Granite that was dated is a coarse-grained adamellite, which shows little evidence of deformation or recrystallization; quartz and biotite in this rock are essentially unstrained. The measured K-Ar date on biotite possibly records the time of emplacement of the Caledon Giddy Granites rather than the time of original crystallization of the Bradshaw Granite.

The Caledon Granite sample dated contains quartz which has slight undulose extinction, but the Giddy Granite sample is essentially unstrained and seems to be a typical post-tectonic granite. A Rb-Sr measurement on biotite from the Giddy Granite gives a date of 1825 m.y., which is some 3.6 percent greater than the K-Ar date. This difference is a little greater than that expected from experimental error and may indicate that some loss of radiogenic argon from the biotite has occurred. The Rb-Sr total-rock measurement on this sample gives a maximum possible age of 1895 m.y., using 0.705 as the initial Sr^{87}/Sr^{86} ratio, and agreement with the Rb-Sr biotite date of 1825 m.y. is obtained for initial Sr^{87}/Sr^{86} equal to 0.720. The K-feldspar date is about 1740 m.y. based on replicate analyses when the latter value for the initial ratio is used. Hence the data appear to be slightly discordant due to some geological effect, but on the basis of the biotite data it can be stated confidently that the age of this granite is 1825 ± 50 m.y..

The K-Ar and Rb-Sr data on the Nicholson and Norris Granites and the granites of Arnhem Land confirm the geological correlation of these basement rocks, and indicate that they all were emplaced close to 1800 m.y. ago.

(c) Ewen Granite

About 160 miles south-south-east of the Murphy Tectonic Ridge in Queensland the Ewen Granite crops out, and is intrusive into the Argylla Formation (Carter et al., 1961). Richards et al. (1963) reported K-Ar dates of 1775 m.y. on biotites from two samples of this granite and as this age is similar to that found in the present study on the Nicholson and Norris Granites further Rb-Sr measurements were made on the Ewen Granite.

The total-rock Rb-Sr measurement (Table 2) yields a maximum age of 1800 m.y. for initial Sr^{87}/Sr^{86} equal to 0.705, and 1780 m.y. for initial Sr^{87}/Sr^{86} equal to 0.715. This confirms the interpretation that the K-Ar biotite ages give the time of emplacement of the granite. Rb-Sr measurements also were made on K-feldspar and plagioclase from the same sample, but these revealed a discordancy in indicated age similar to that found in the Giddy Granite, but considerably more pronounced. These data will be discussed elsewhere. However, their interpretation is consistent with the total-rock remaining a closed chemical system, and with an age of emplacement of the granite of 1780 ± 20 m.y.. The similarity in the age of the Ewen Granite with that of the Nicholson-Norris and Arnhem Land Granites strongly supports the correlation of the basal members of the overlying sequences in these areas.

DATING THE CARPENTARIA SEDIMENTARY SUCCESSION

(a) Tawallah Group

Webb et al. (1963) published K-Ar dates on 3 glauconites from the Aquarium Formation and the Rosie Creek Sandstone. These dates ranged from 1480 to 1580 m.y., and provide reliable minimum ages for this part of the Tawallah Group. The spread in measured age was interpreted as being caused by some loss of radiogenic argon. Subsequently Rb-Sr measurements were undertaken on the same samples of glauconite and the results are given in Table 4. A similar age pattern is apparent; the Rosie Creek Sandstone glauconite yields a date of about 1570 m.y., and the two glauconites from the Aquarium Formation give Rb-Sr dates of 1495 and 1590 m.y.. Hence the maximum measured date of 1590 m.y. for the Aquarium Formation must be regarded as a minimum age for this part of the Tawallah Group; possibly it is very close to the true age.

A single total rock sample from the Packsaddle Micro-granite was measured by the Rb-Sr method. The sample consists entirely of quartz and K-feldspar and hence it was not possible to obtain the initial Sr^{87}/Sr^{86} ratio directly. As the enrichment in radiogenic Sr is only moderate (Table 2) the age derived for this rock is critically dependent upon the initial Sr^{87}/Sr^{86} value chosen. Assuming the lowest possible value for this ratio of 0.705 the maximum indicated age is 1520 m.y., based on three analyses. The initial ratio may be as high as 0.715 in which case the indicated age is 1470 m.y.. The older age would be quite consistent with the glauconite dates from lower in the Tawallah Group, but should the lower age be more nearly correct this indicates an extremely long period between the deposition of the Aquarium Formation and the intrusion of the Packsaddle Microgranite. Because the sample of the microgranite is slightly altered it is possible that the date measured is younger than the true age because of some loss of radiogenic Sr by diffusion. Nevertheless the date on the Packsaddle Micro-granite is broadly consistent with the dates obtained on the glauconites.

(b) McArthur Group

No age measurements were made on rocks from the McArthur Group because of the lack of suitable material. Richards (1963) derived a model lead age of about 1560 m.y. from galena from the Amelia Dolomite. However, because the enclosing sedimentary rocks were then regarded as Upper Proterozoic the lead was provisionally classified as a spectacular case of a B-type anomaly, with the lead much older than the host formation (Richards, 1963, p.236). From the preceding discussion of the age results from the Tawallah Group it appears that the model age may approach the true age. Because a model lead age is dependent on several parameters and assumptions, such an age has a margin of possible error of the order of 10 percent.

(c) Mount Rigg Group

A single glauconite from the Dook Creek Formation of the Mount Rigg Group yields a K-Ar date of 1210 m.y. (Table 3), and a Rb-Sr date of 1255 m.y. (Table 4). Loss of both radiogenic Ar and Sr is indicated, as the overlying Roper Group will be shown later to be older than 1300 m.y.. Richards (1963) reported a model lead age of about 1260 m.y. on a single sample of galena from a vein in the Dook Creek Formation. The reliability of this result will not be known until further samples are investigated.

(d) Roper Group

Glauconite was separated from six samples of the Crawford Formation within this Group obtained from four different localities on the Bauhinia Downs sheet. The measured K-Ar dates (Table 3) range from 1100 to 1280 m.y.; this large spread is much greater than the experimental error and indicates that loss of radiogenic argon has taken place. Hence, even the date of 1280 m.y. must be regarded as a minimum age for this formation. Measurements by the Rb-Sr method (Table 4) on five of the glauconites give dates ranging from 1270 to 1390 m.y.. This spread is also greater than experimental error and probably results from leakage of radiogenic strontium. Hence, the oldest date of 1390 $\pm$ 20 m.y. is a minimum age for the Crawford Formation.

(e) Dolerites

Dating of the dolerites which intrude the Roper and Mount Rigg Groups give a younger limit to the age of these groups. Unfortunately the dolerite samples were somewhat altered; nevertheless useful K-Ar dates were obtained (Table 3) on plagioclase and pyroxene from several specimens.

Plagioclase from two dolerites intrusive into the Roper Group yield dates of 1220 and 1280 m.y., and pyroxene from one of these samples gives a date of 1150 m.y.. The difference between the measured ages for coexisting plagioclase and pyroxene shows that some argon loss has occurred, but the results at least show that the Roper Group is older than 1280 m.y., in agreement with the conclusion reached in the preceding section.

Pyroxene and plagioclase from a dolerite that is intrusive into the Dook Creek Formation of the Mount Rigg Group give K-Ar dates of 1205 and 1100 m.y. respectively. The large difference between these dates indicates argon loss; however, the older date is similar to the oldest dates found on the dolerites intrusive into the Roper Group, with which this dolerite is correlated.

It should be noted that the plagioclase concentrates have unusually high potash contents because of the sericitized nature of the mineral. This may have been a deuteric alteration or it may have occurred during the subsequent folding.

(f) Wessel Group

A glauconite separated from the Elcho Island Formation, the topmost unit of the Wessel Group, gives a K-Ar date of 770 m.y. and a Rb-Sr date of 790 m.y. (Tables 3, 4). The dates are in good agreement and are consistent with the younger limit of the Roper Group. However, in the absence of confirmatory evidence the date of about 780 m.y. must be regarded as a minimum age. The Wessel Group was previously considered to be of probable Cambrian age, mainly because of the presence of Scolithus -bearing sandstone. This group is clearly Precambrian.

(g) South Nicholson Group

Glauconite from the Mullera Formation, a unit in the South Nicholson Group, gives a K-Ar date of 1040 m.y., and a Rb-Sr date of 1160 m.y. (Tables 3,4). Some argon loss certainly has occurred. The older date is much younger than dates obtained on the Roper Group, but because of the possibility of loss of radiogenic strontium as well as argon from this single sample of glauconite, the stratigraphic correlation of the South Nicholson Group with the Roper Group may still prove to be correct. The greater degree of deformation in the South Nicholson Group may account for the discrepancy in the K-Ar and Rb-Sr dates obtained on rocks from the two groups.

DISCUSSION

The results from the Carpentaria Province are an excellent example of the application of isotopic age determination methods to a sequence of rocks which, at first sight, seemed to be most unpromising from the dating point of view. In general the results are internally consistent, and although the indicated ages must be regarded as minimum estimates in many cases, the data provide much information as to the age of the rocks in this region.

The stratigraphic succession was well established before the age measurements were made, although hitherto it was not possible to give any estimate of the duration of the period of deposition, nor could correlations be made satisfactorily with other Precambrian sequences in Australia. The measured ages enable us to place the rocks of the Carpentaria Province within the geological time-scale with a reasonable degree of accuracy. The results further show that the sequence from the Cliffdale Volcanics to the Roper Group, of maximum thickness of about 40,000 feet, was deposited during a time interval of the order of 400 m.y.. Although several unconformities occur within the sequence the age data nevertheless suggest that the rate of sedimentation was extremely low.

A slow subsidence of the depositional basin may involve slow lateral changes in sedimentary facies which could produce measurable differences in the time of deposition of widely separated parts of the same lithological unit. Such a situation could in part explain the discrepancies in ages between the Mount Rigg Group and South Nicholson Group and their respective correlates, but the available data are too discordant and too meagre to substantiate such an explanation.

That many of the glauconites have retained a high proportion of their radiogenic Ar and Sr deserves specific comment. The surprisingly good results found in this study testify to the extremely stable geological conditions that must have prevailed since deposition of the rocks, a fact that was clearly recognized when the region was mapped. It seems that temperatures in the sedimentary rocks are unlikely to have exceeded about 200°C. since their deposition, except near dolerite intrusions and faults. Because some loss of radiogenic daughter products has occurred, and because of the reconnaissance nature of this study, correlation of individual units such as formations is not yet possible using these dating methods on glauconite. There is considerable scope for further work in this direction.

COMPARISON WITH OTHER AREAS

Walpole & Smith (1961) suggested that the granites of the Katherine-Darwin region were emplaced during a single tectonic cycle. K-Ar dates on micas from these granites range from 1520 to 1720 m.y., and average 1630 m.y. (Hurley et al., 1961). The large spread in dates may indicate that emplacement occurred over a long period of time. Alternatively the spread may be because of leakage of variable amounts of radiogenic argon, in which case the grouping of a number of dates at about 1700 m.y. could be closer to the correct age of emplacement of all the granites. The fact that many of the micas used by Hurley et al. (1961) were strongly chloritized tends to support the latter interpretation, and suggests that the dates should be regarded only as minimum ages. Recent Rb-Sr dating of these rocks (Leggo and Compston, pers. comm.) confirms this interpretation. Hence, these granites may not be significantly younger than those elsewhere in the basement of the Carpentaria Province.

Hurley et al. (1961) also reported dates ranging from 1320 to 1630 m.y. on biotites from granites of the Davenport Range region near Tennant Creek in Central Australia. Walpole & Smith (1961) interpreted these results as representing two distinct periods of granite emplacement. The older period was regarded as of similar age to that in the Katherine-Darwin region, and the younger period at about 1400 m.y. was suggested as terminating the so-called Davenportian Series of deposition. Although this later event would correspond to a widespread event in the Mount Isa region (Richards et al., 1963) its validity must remain doubtful because of possible argon loss, as many of the micas used in the determinations were strongly chloritized and show evidence of deformation. Further detailed studies, particularly by the Rb-Sr method, should be made to clarify the position.

The major event, including metamorphism and possible emplacement of granitic rocks, which occurred about 1400 m.y. age in the Mount Isa region (Richards et al. 1963) apparently has not effected the Carpentaria Province, although the unconformity between the McArthur and Roper Group may be related to it.

The metamorphic event at about 1100 m.y. found by Wilson et al.(1960) in Central Australia is not in evidence in the Carpentaria region, except that it may be represented by the unconformity between the Roper and Wessel Groups.

PRECAMBRIAN STRATIGRAPHIC NOMENCLATURE

Proterozoic and Archaean commonly have been employed as time terms for Precambrian sequences in Australia. These terms have undergone continued modification as regards their meaning and use, even in North America where they were first applied. The present status of Proterozoic and Archaean as used by the Canadian Geological Survey for the Canadian Shield is given in several recent publications (Stockwell, 1961; 1963a, b; 1964); a summary of this work is necessary before discussing nomenclature in the Precambrian of Australia.

In the Canadian Shield, with the help of an extensive K-Ar dating programme, the Geological Survey has recognized three major Precambrian orogenies; these are the Kenoran, Hudsonian and Grenville. Recently a fourth orogeny, the Elsonian, has been recognized in the Nain province of eastern Canada (Stockwell, 1964). Folding, metamorphism and emplacement of granitic rocks occurred during these orogenies. The three main orogenies, each of which is followed by a profound unconformity, have been used to define four major Precambrian time divisions, the Archaean, and the Lower, Middle and Upper Proterozoic. Stockwell (1964, p.7) recently suggested that the last three terms be abandoned and replaced by Aphebian, Helikian and Hadrynian respectively.

The K-Ar age determination programme carried out by the Canadian Geological Survey has produced a concentration of dates about the time of each orogeny. A spread of approximately 200 m.y. is found in the measured dates on rocks involved in each of the orogenies. The spread is partly the result of analytical error, partly due to the time span of an orogeny, and partly because of loss of radiogenic argon during later events. Such a large spread in measured dates on each orogeny makes the choice of time boundaries difficult and somewhat arbitrary. The Canadian Geological Survey has chosen a time toward the end of each orogeny to mark the boundary between the major Precambrian sub-divisions. Using dates determined from rocks of the Kenoran Orogeny the boundary between Archaean and Lower Proterozoic (Aphebian) is given as 2390 m.y.; similarly, dates on rocks of the Hudsonian and Grenville orogenies are used to place the boundaries between the Lower and Middle Proterozoic (Aphebian and Helikian) and the Middle and Upper Proterozoic (Helikian and Hadrynian) at 1640 m.y. and 880 m.y. respectively. The Helikian is further subdivided into the Paleohelikian and Neohelikian by the Elsonian Orogeny, the age of which is given as about 1280 m.y.. When additional age measurements are made, particularly by the Rb-Sr method, revision of the age of these boundaries undoubtedly will be necessary.

In Australia the terms Archaean, Lower and Upper Proterozoic commonly have been applied using the degree of deformation and metamorphism to define relative age. Although this may be valid within one basin of deposition, such a method of applying time and time-rock terms inevitably must be highly speculative and misleading, as pointed out by Spry & Banks (1955).

Correlation in the Precambrian of Australia, as elsewhere, has been extremely difficult because of the scarcity of diagnostic fossils and the lack of sufficient isotopic dates. Recently some progress has been made using stromatolites as marker fossils (Edgell, 1964), and this apparently has enabled correlations to be made between sequences in a number of areas in Australia. Marker horizons such as tillites may also prove to be of considerable help in correlation from basin to basin. Nevertheless, it seems that isotopic age determinations will provide the main tool by which detailed and objective correlations can be made in the Precambrian. The development of a satisfactory nomenclature and classification for Precambrian rocks are interrelated problems as stressed by Goldich et al. (1961). With an increasing number of isotopic age determinations now becoming available there seem to be three courses that can be followed in dealing with the nomenclature and correlation in the Precambrian.

It would be possible to set up an arbitrary time-scale with, say, 500 m.y. as a convenient interval, and label the divisions in some simple way. Such a procedure, apart from being at variance with established practice, has the great disadvantage of being divorced completely from the rocks themselves, which are our primary standard of reference, as forcibly pointed out by Hedberg (1961).

The Canadian terms Archaean, Lower, Middle and Upper Proterozoic could be employed in Australia provided that the age limits as currently given by the Canadian Geological Survey are observed. Because these terms have been used in the Australian Precambrian with quite a different meaning it is possible that continued use of them may cause even greater confusion.

A further difficulty in applying the Canadian terms is that the divisions may not be natural ones in Australia. Many authorities (e.g. Gilluly, 1949; Hedberg, 1961) argue strongly against the hypothesis that there are worldwide revolutions at certain periods of time, but Aldrich et al. (1960) and Gastil (1960) showed that from the available age data there is a strong case for worldwide orogenic activity during certain broad periods of time in the Precambrian. Although it may be feasible to use the Canadian system of nomenclature in Australia, it must be expected that the major breaks in Australian sequences will occur at slightly different times than in Canada, and that these breaks may not be found in all sequences.

Perhaps the most unsatisfactory feature of the Canadian scheme is that it is based on orogenies and not on the time represented by a sequence of rocks, the normal stratigraphic practice at least in the Phanerozoic. This brings us to the third alternative for the subdivision of the Precambrian: the use of time-rock units defined in terms of specific rock units in standard sections in Australia. Such a system of nomenclature has the great advantage that it is defined in terms of the rocks themselves. For this purpose we need a number of relatively undeformed sequences of layered rocks, and some of these rocks, preferably near the base and top of such sequences, must be suitable for accurate dating by isotopic methods. The need for a standardized subdivision of the Precambrian in Australia was emphasized at a symposium in the Australian National University in December, 1964. At the symposium Dr. B.P. Walpole, representing the Bureau of Mineral Resources, and Dr. W. Compston, of the Australian National University, presented a chart of Precambrian correlations in Australia, based on published and unpublished data from the Bureau of Mineral Resources, the Australian National University, the Mines Department of South Australia and the Geological Survey of Western Australia. Proposals for the definition of time-rock units to cover at least the so-called Proterozoic in Australia were tentatively made, including the possibility of using part of the sequence in the Carpentaria region as a time-rock unit. A paper describing the chart and giving the proposals for nomenclature is in preparation.

As indicated part of the sequence in the Carpentaria Province seems to be a satisfactory choice for a time-rock unit in the proposed classification. This unit, to be called the Carpentarian, would include the time represented between the extrusion of the Cliffdale Volcanics at the base of the succession and some selected datum level higher in the sequence. The age of the Cliffdale Volcanics is already reasonably well controlled by the Nicholson-Norris Granite ages at about 1790 m.y., but further measurements should be made directly on the volcanics. The choice of an upper boundary to the Carpentaria succession is much more difficult because of the lack of rocks which are suitable for accurate and precise isotopic dating. Rocks containing glauconite are not ideal for defining a time-rock boundary because of the ease with which this mineral loses radiogenic daughter products. Definitions involving the top of a selected rock unit are not practical unless a dateable horizon occurs at this level. Similarly unconformities are inconvenient as time-rock boundaries unless they can be indirectly dated through two dateable rock units which occur immediately above and below the unconformity.

In the Carpentaria Province no ideal horizon is presently available to define the top of a time-rock unit. An upper boundary could be defined using an unconformity, a glauconitic sandstone or the emplacement of the dolerites into the Roper Group, but each of those is unsatisfactory. Preferably a dateable horizon of widespread occurrence in some other succession in the Precambrian of Australia should be used, provided that this can be correlated by dating methods, at least approximately, with the Carpentaria sequence. Such a horizon would constitute the base of the next youngest time-rock unit.

In conclusion, we suggest that standard rock sections should be used to define time subdivisions of the Precambrian in Australia. Time-rock units should be defined for a number of judiciously chosen sequences which cover the whole of the Precambrian. An important factor in deciding upon standard sections is that rocks suitable for isotopic age determination should be present at the base of the sequence, and also the top if possible. Several isotopic dating surveys now in progress should enable the establishment of such a system of nomenclature, to which all Precambrian successions ultimately can be correlated. As a first step we propose part of the Carpentaria sequence as a type section for a subdivision to be called Carpentarian. This time-rock unit is represented by the succession from the base of the Cliffdale Volcanics, which is dated at about 1800 m.y., to a younger limit as yet to be decided.

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APPENDIX

Nicholson Granite

GA 125 : Pandanus Creek near crossing on the old Eva Uranium Mine - Doomadgee track. Calvert Hills 1:250,000 Sheet. Mainly medium-grained, but containing abundant phenocrysts of microcline (up to 6 cm. across), oligoclase (1 cm.), and quartz (1 cm.). The rock shows little straining and no regular orientation.

GA 559 : 16 miles SSW of Pandanus Creek Uranium Mine, west of Fish River. Lat. 17°55'S, Long. 137°13'E.

Hypidiomorphic granular adamellite. Quartz exhibits moderate strain shadows. Plagioclase is extensively altered to sericite. Microcline forms an interlocking mosaic with quartz and plagioclase. The minerals appear to have formed synchronously and there is no indication of feldspathization. Muscovite appears to be of both primary and secondary origin.

GA 581 : 18 mile SSW of Pandanus Creek Uranium Mine, west of Fish River. Lat. 17°55'S, Long. 137°13'E.

Melanocratic medium-grained massive rock containing over 50% hornblende. It is a highly contaminated marginal variety of the Nicholson Granite, probably produced by the feldspathization of the Murphy Metamorphics. Close to this outcrop, foliated biotite gneiss grades into biotite gneiss and biotite schist along the strike. Lit-par-lit intrusions are common.

Norris Granite

Medium to coarse-grained adamellite containing subhedral megacrysts of K-feldspar over 1 cm. in length. Biotite, commonly containing zircon inclusions, is quite fresh.

GA 159 : ¼ mile north of track from Corinda to Norris copper mine, 58 miles from Corinda.

GA 483 : 7 miles SSW of Pandanus Creek Mine, ½ mile north of track to Fish River. Lat. 17°46'S, Long. 137°47'E. Calvert Hills 1:250,000 Sheet.

GA 484 : 8½ miles SE of Pandanus Creek Mine on track to Corinda. Lat. 17°45'S, Long. 137°55'E. Calvert Hills 1:250,000 Sheet.

GA 558 : 10 miles ESE of Pandanus Creek Uranium Mine and 5 miles NNW of Gorge Creek crossing on track from Pandanus Creek Mine to Corinda. Lat. 17°43'S, Long. 137°57'E. Calvert Hills 1:250,000 Sheet.

Ewen Granite

GA 584 : Dobbyn 4-mile Sheet. Dobbyn Run 7, photo 5175, quadrant B, = 2.8", y = 0.5", diag. = 2.8.

The rock is a medium-grained adamellite with megacrysts of microcline up to 2 cm. in length. Quartz shows moderate strain effects. Some megacrysts contain inclusions or "remnants" of plagioclase which are in optical continuity, indicating replacement of plagioclase by microcline.

Packsaddle Microgranite

GA 746 : 10 miles N of Wollogorang Homestead on Redbank Creek. Lat. 17°4'S, Long. 137°56'E. Calvert Hills 1:250,000 Sheet.
Very fine-grained microgranite consisting essentially of small K-feldspar phenocrysts and occasional small quartz phenocrysts in a matrix of these minerals.

Crawford Formation

GA 942 : (B.M.R. reference E53/3/14). Cape Crawford, Bauhinia Downs 1:250,000 Sheet. Lat. 16°38'S, Long. 135°47'E.
From the top of the Crawford Formation. A well-sorted glauconitic quartz sandstone. No detrital micas or feldspars present. Glauconite shows some alteration.

GA 943 : (B.M.R. reference E53/3/15).
On O.T. Downs - Three Knobs track, 1.8 mile E of turnoff to Defence road. Bauhinia Downs 1:250,000 Sheet. Lat. 16°34'S, Long. 135°26'E. Stratigraphically higher than GA 944.
Moderately well sorted glauconitic quartz sandstone. No detrital micas or feldspars present.

GA 944 : (B.M.R. reference E53/3/16).
0.1 mile west of GA 943. Bauhinia Downs 1:250,000 Sheet.
Base of Crawford Formation. Subfeldspathic glauconitic quartz sandstone, poorly sorted, containing illite, microcline and plagioclase. Most glauconite grains are altered.

GA 945 : (B.M.R. reference E53/3/18).
East of track, 19.8 miles north of McArthur River Camp on track to Borroloola. Bauhinia Downs 1:250,000 Sheet. Lat. 16°11'S, Long. 136°04'E.

GA 945 : Position within Crawford Formation unknown. Subfeldspathic glauconitic quartz sandstone. Well-sorted. Illite and K-feldspar present. Glauconite shows slight to moderate alteration.

GA 946 : (B.M.R. reference E53/3/19)
Same locality as GA 945. Very similar to GA 945 in composition and appearance.

GA 1157 : (B.M.R. reference E53/3/7)
2 miles N of McArthur River Camp. Bauhinia Downs 1:250,000 Sheet. Position within Crawford Formation unknown.

Dook Creek Formation

GA 947 : (B.M.R. reference D53/9/8)

Low hills to N of Dook Creek, just N of Beswick Homestead. Katherine 1:250,000 Sheet. Lat. 14°31'S, Long. 135°06'E.
Glauconitic dolomite. No micas or feldspars present.
Glauconite often wholly or partially altered to chlorite.

Mullera Formation

GA 1158 : (B.M.R. reference E53/12/2)
½ mile S of Cleanskin Creek, 13 miles N 13°E of Springvale Homestead. Mount Drummond 1:250,000 Sheet.

Elcho Island Formation

GA 993 : (B.M.R. reference D53/3/17)

On beach, 1 mile NW of Elcho Island Mission. Arnhem Bay 1:250,000 Sheet. Lat. 12°01'S, Long. 135°34'E.

Giddy Granite

GA 1044 : (B.M.R. reference D53/4/6)
Gove 1:250,000 Sheet. Lat. 12°23', Long. 136°37'. Hornblende-biotite adamellite. Massive, even-grained, fresh biotite and hornblende. Slight strain effects in quartz.

Bradshaw Granite

GA 1045 : (B.M.R. reference D53/4/7)
Gove 1:250,000 Sheet. Lat. 12°37', Long. 136°30'. Biotite-muscovite adamellite. Coarse-grained. Plagioclase and K-feldspar slightly altered. Quartz and biotite show only minor deformation.

Caledon Granite

GA 1047 : (B.M.R. reference D53/4/8)
Gove 1:250,000 Sheet. Lat. 12°53', Long. 136°32'. Hornblende adamellite. Massive adamellite with marked granophyric texture. Quartz shows moderate strain effects. Muscovite occurs in clusters associated with both hornblende and the feldspars. It probably is not of primary origin.

Dolerites

GA 848 : (B.M.R. reference D53/6/4).
Mount Marumba 1:250,000 Sheet. Lat. 13°39'S, Long. 134°21'E. Quartz dolerite. Plagioclase is labradorite and the high K content is due to the sericitized nature of the plagioclase, although there is also minor contamination by K-feldspar. Pyroxene is mainly fresh, with some alteration to amphibole.

GA 949 : (B.M.R. reference D53/9/6)
Maranboy - Mainoru track, 20 miles E of Beswick Homestead. Katherine 1:250,000 Sheet. Lat. 14°30'S, Long. 133°24'E. Dolerite. Plagioclase rather altered. Pyroxene strongly chloritized.

GA 950 : (B.M.R. reference D53/9/7)
Maranboy - Mainoru track, 30.6 miles E of Beswick Homestead. Katherine 1:250,000 Sheet. Lat. 14°26'S, Long. 133°30'E. Medium-grained dolerite. Plagioclase (labradorite) is slightly sericitized and the high K content is related to this, but some K-feldspar also is present as a contaminant. Pyroxene is chloritized marginally, but much of it is fresh.

TABLE 1 : K - Ar Dates on Basement Granitic Rocks

Sample No. (GA)	Mineral	% K		*Ar^{40}/K^{40}	Ar^{40} atm. %	Age(m.y.)	Rock Unit
125	Biotite	7.22 7.25	7.23	0.1823	4.4	1840	Nicholson Granite
559	Muscovite	8.81 8.87	8.84	0.1743	1.4	1790	Nicholson Granite
581	Hornblende	1.033 1.036	1.035	0.1782	5.9	1815	Nicholson Granite
159	Biotite	5.92 5.92	5.92	(1) 0.1794 (2) .1806	0.8 0.8	1820 1830	Norris Granite
483	Biotite	5.51 5.51	5.51	0.1699	1.2	1760	Norris Granite
484	Biotite	5.82 5.80	5.81	0.1727	4.3	1780	Norris Granite
1044	Biotite	6.10 6.09	6.09	0.1702	1.7	1760	Giddy Granite
1045	Biotite	7.39 7.43	7.41	0.1722	1.2	1775	Bradshaw Granite
1047	Muscovite	8.72 8.73	8.73	0.1684	2.3	1750	Caledon Granite

* Ar^{40} - radiogenic argon

Table 2 - Rb-Sr Analytical Data and Derived Ages from Basement Rocks and the Packsaddle Microgranite

Sample No. (GA-)	Rock Unit	Sample	Rb p.p.m.	Sr p.p.m.	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}	Age (m.y.)	Initial Sr^{87}/Sr^{86}
559	Nicholson Granite	Total Rock A	391	24.5	46.09	1.856(M)	1770	0.705
		" " B	391	24.2	46.73	1.853(M)		
		Muscovite A	1060	3.69	829.3	21.34 (C)		
		" B	1060	4.96	618.0	16.67 (C)		
558	Norris Granite	Total Rock A	228	188	3.498	0.7992(M)	1725	0.713
		" " B	227	188	3.476	0.7982(M)		
		K-feldspar A	434	167	7.497	0.8932(M)		
		" B	431	173	7.223	0.8920(M)		
584	Ewen Granite	Total Rock	469	43.7	30.99	1.491 (M) 1.490 (C)	1780	0.715
		Plagioclase	38	43.1	2.52	0.8056(M) 0.8084(C)		
		K-feldspar	982	71.3	39.82	1.680 (C)		
1044	Giddy Granite	Total Rock	330	63.8	14.93	1.104 (C)	1825	0.720
		K-feldspar A	530	77.0	19.91	1.206 (C)		
		" B	529	78.8	19.40	1.198 (C)		
		Biotite	1216	3.35	1050	27.69 (C)		
746	Packsaddle Micro-granite	Total Rock A	214	45.3	13.67	0.991 (C)	1520	0.705
		" " B	215	44.4	14.01	1.009 (C)		
		" " C	215	43.4	14.32	1.011 (C)		

(M) - measured directly

(C) - calculated from mixture of tracer and sample strontium

TABLE 3 : K-Ar Dates on Sedimentary Rocks and Dolerites of the Carpentaria Region.

* Ar^{40} - radiogenic argon

Sample No. (GA)	Mineral	%K			$*Ar^{40}/K^{40}$	Ar^{40} atm %	Age (m.y.)	Rb-Sr Age (m.y.)	Rock Unit
1158	Glauconite	5.18 5.19	5.19		0.0812	1.7	1040	1160	Mullera Fm.
993	Glauconite	6.62 6.68	6.65	(1) (2)	0.0564 0.0592	2.9 3.1	780 765	790	Wessel Group
848	Plagioclase	1.43 1.43	1.43	(1) (2)	0.0888 0.0867	3.1 4.4	1115 1095	-	Dolerite in Dook Creek Fm.
848	Pyroxene	0.040 0.041	0.040		0.0987	23.4	1205	-	
949	Plagioclase	1.44 1.44	1.44		0.1003	4.3	1220	-	Dolerites in Roper Group
950	Plagioclase	1.14 1.15	1.15	(1) (2)	0.1074 0.1067	0.9 1.4	1280 1280	-	
950	Pyroxene	0.113 0.114	0.113		0.0923	23.2	1150	-	
942	Glauconite	5.78 5.76	5.77		0.0911	1.0	1140	1115	
943	Glauconite	5.58 5.55	5.56		0.1071	1.9	1280	1330	Crawford Formation Roper Group
944	Glauconite	5.36 5.34	5.35		0.0989	1.3	1210	1390	
945	Glauconite	5.41 5.39	5.40		0.0891	0.9	1120	1270	
946	Glauconite	5.14 5.14	5.14		0.0875	3.0	1100	1290	
1157	Glauconite	5.66 5.61	5.63		0.1030	0.8	1245	-	
947	Glauconite	5.61 5.66	5.63		0.0986	2.4	1210	1255	Dook Creek Fm.

TABLE 4 - Rb-Sr Analytical Dates on Glauconites from the Carpentaria Region

Sample No. (GA-)	Rock Unit	Rb p.p.m.	Sr p.p.m.	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}	Age (m.y.)	K-Ar Age (m.y.)
1158	Mullera Fm.	377	23.6	45.96	1.458	1160	1040
993	Elcho Id. Fm.	181	6.95	75.18	1.539	790	780
942	Crawford Formation, Roper Group	380	22.4	49.14	1.618	1315	1140
943		481	22.6	61.86	1.846	1310	1280
B		477	23.3	59.11	1.829	1350	
944 A		441	28.5	44.68	1.574	1380	1210
B		441	28.9	43.99	1.575	1400	
945		392	21.3	53.37	1.669	1270	1120
946		364	28.2	37.47	1.389	1290	1100
947	Dook Creek Fm.	354	12.3	83.43	2.180	1255	1210
752	Rosie Creek Ss.	299	4.89	175.6	4.662	1605	1520
		298	3.84	224.8	5.601	1550	
753	Aquarium Fm.	268	7.02	110.5	3.031	1495	1470
754		288	7.87	105.9	3.089	1600	1580
		282	8.94	91.02	2.737	1585	