K-Ar Dating of Some Rocks from the Schirmacher Oasis, Dronning Maud Land, East Antarctica

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ABSTRACT

Geochronological studies were carried out on nine rock samples collected from the Schirmacher Oasis region of the Dronning Maud Land, east Antarctica. Four of these samples belong to the crystalline basement forming part of the east Antarctica shield while the other samples are from the dolerite dykes occurring in the region. Various ages obtained for these two groups of rocks reveal valuable information on the evolution of the Dronning Maud Land and on the palaeo-relationship of Antarctica with Africa.

INTRODUCTION

Radioactive dating of rock plays a significant role in determining relative sequences of various formations and geological events in a conclusive manner. For a continent like Antarctica, where a geological interpretation on a continentwide basis is hindered due to scarcity of rock exposures, the radiometric age determination becomes even more important.

So far, over 1000 radiometric ages have been reported for Antarctic rocks. Detailed reviews of these studies are available in the publications by Webb (1962), Angino and Turner (1963), Picciotto and Coppez (1963), Ravich and Krylov (1964), Woollard (1970), Krylov (1972) and Oliver, et al., (1983). An areal distribution of some significant radiometric ages and their frequency of occurrence are shown in Figs. 1 and 2. From these figures it is evident that the erogenic history of Antarctica involves several periods of diastrophism with repetitive activity in some areas. The most widespread orogenic activity in Antarctica extended from middle Cambrian time through most of the Devonian period (350-550 m.y.) with a peak towards the end of Ordovician period (450 m.y.) which corresponds to the Taconic Revolution in North America. In the context of the evolution of East Antarctic platform, several workers have termed this tectonic event as Ross Orogeny. According to Woollard (1970): Rocks of this age are found from the Wohlthat Mountains (72°S lat., 10°E long.) in the Indian Ocean quardrant right on around the outer boundary of eastern Antarctica to McMurdo on the opposite side of the continent as well as in the Thiel Mountains and Pensacola Mountains in the interior of the continent. Indirect evidence for this orogeny also exists in the Trans-Antarctic Mountains and the Ellsworth Mountains where Cambrian fossils have been found in metamorphosed corbonate rocks.

GEOLOGICAL SETTING OF THE SCHIRMACHER OASIS

The Schirmacher Oasis, covering an area of approximately 30 sq. km. (lat. 70°44'30"-70°46'30"S and long. 11°22'40"-11°54'00"E), is composed of the Precambrian crystalline basement of the East Antarctic platform (Ravich and Kamanev, 1975; Grikurov, et al., 1976). The polymetamorphic granulite and amphibolite facies rocks (Ravich and Solovien, 1966) are dominated by gamet-biotite gneiss and pyroxene - bearing granulites (schists), amphibolites and other metabasites, migmatites

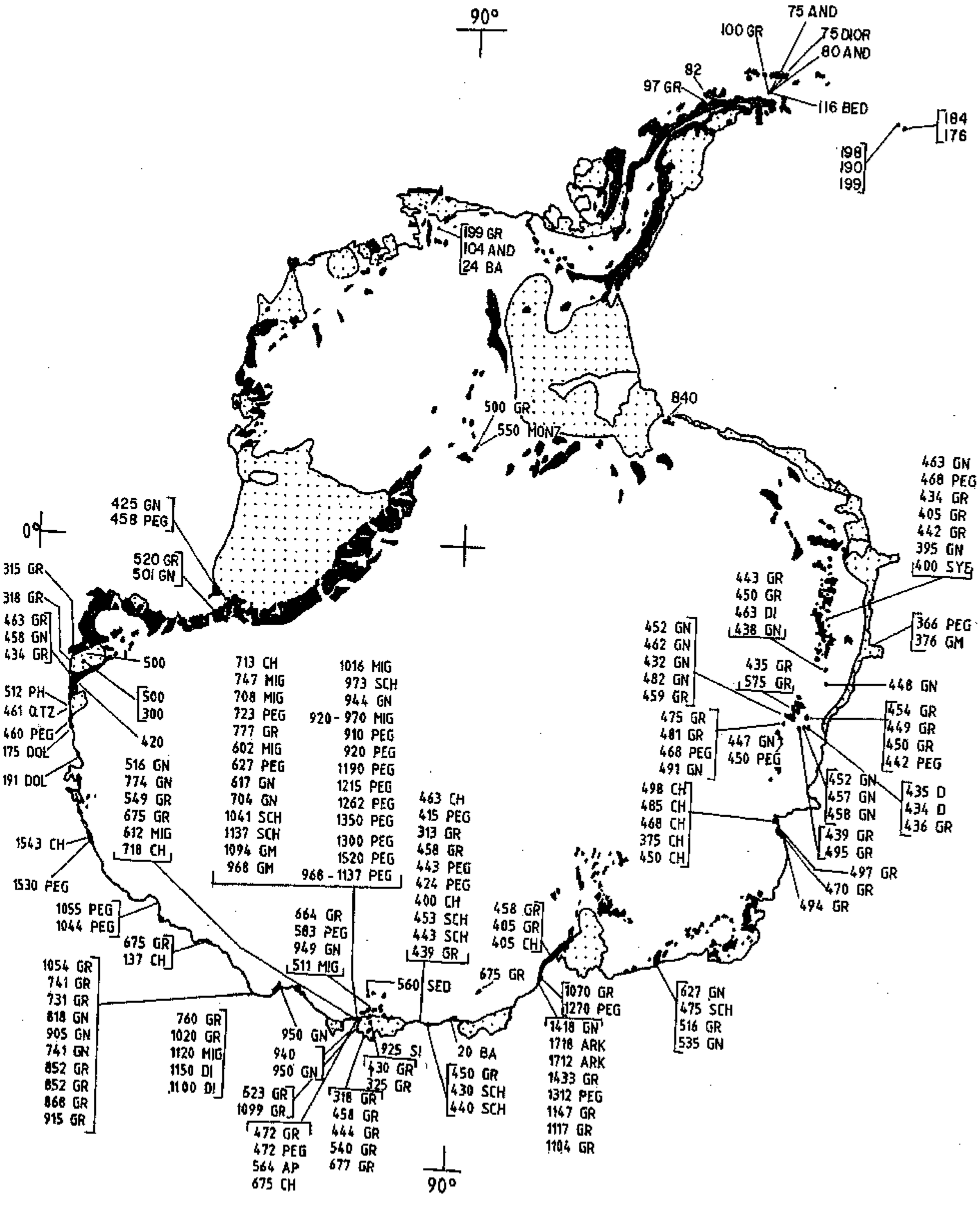

Fig. 1. **Distribution Radioactive Ages - Antarctica. (After Woollard, 1970)**

and mylonites. The area is traversed by numerous pegmatite and aplite dykes and by a number of younger dolerite dykes. Minor intercalations of impure marbles and calc-silicate rocks are also reported (Grew, 1978, 1982; Wand, 1983).

A number of workers (Klimov, et al., 1964; Ravich, 1972; Kamanev, 1972, 1982; and Ravich and Kamanev, 1975) have identified the Schirmacher Oasis as belonging to the "East Antarctic Charnockite Province". The significance of charnockites lies in the fact that they are restricted to the Precam-

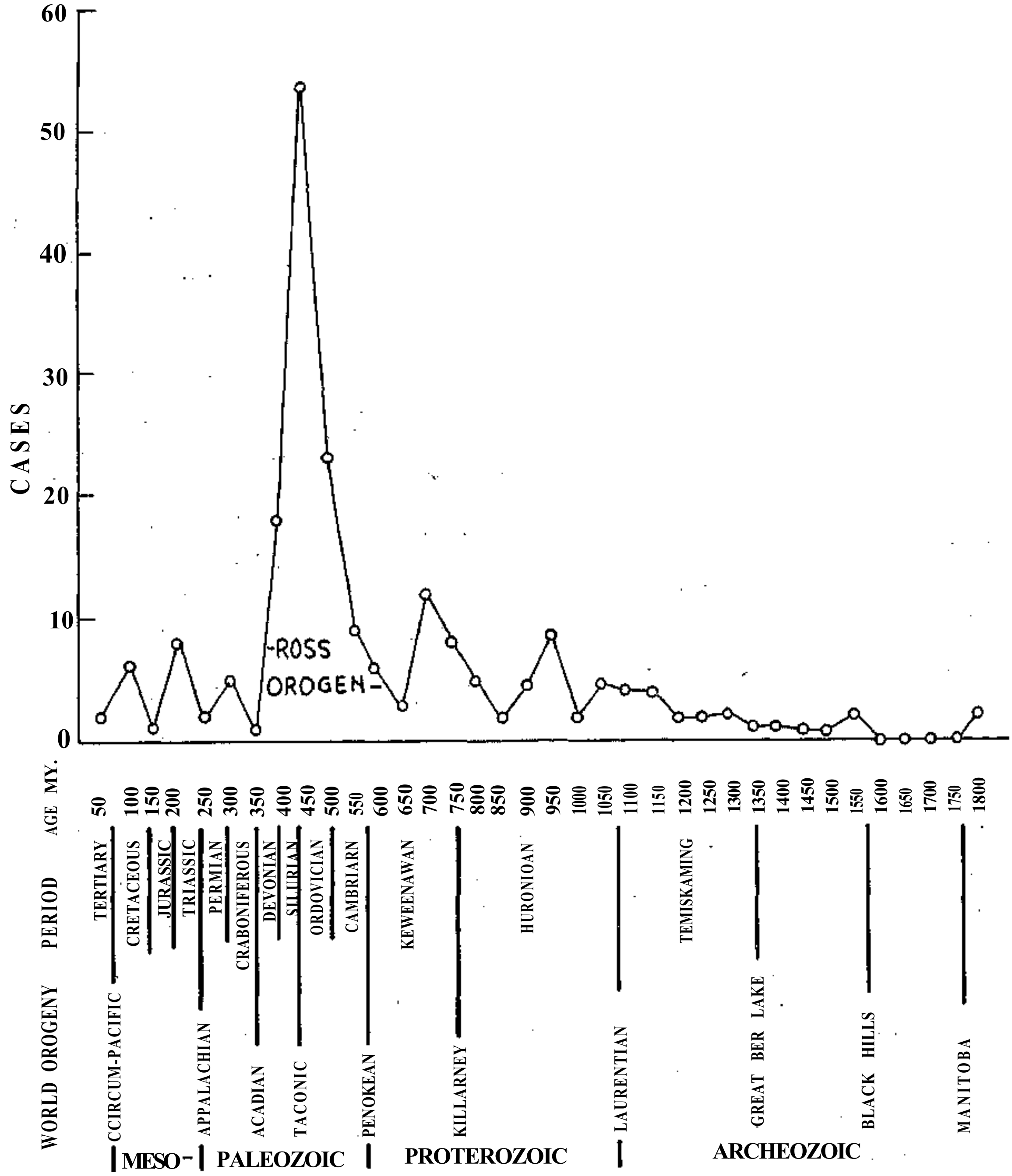

Fig. 2. **Frequency of occurrence and radioactive rock dates in Antarctica (After Woollard, 1970)**

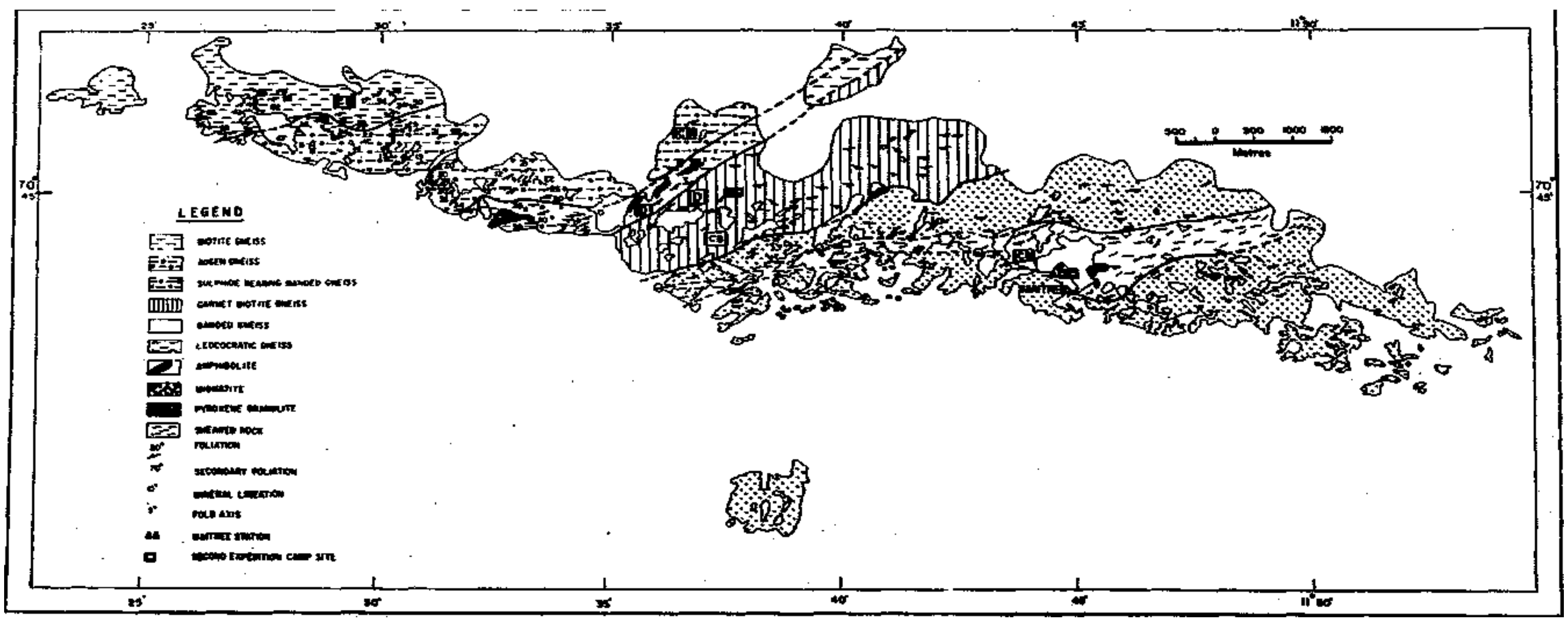

Fig.3. **Location of studied samples with Geology — Schirmacher Landmass, Antarctica.**

brian shield and the crystalline basements of the platforms, and are particularly widespread within the Gondwanian platforms: Indian, African, Antarctic, Australian and South American. These rocks are related to the ancient Precambrian epoch, when regional metamorphic and ultrametamorphic transformation of rocks near the boundary between the 'basalt' and 'granite' layers of the crust were typical (Ravich, 1972). A precise determination of the age of these rocks is therefore very important to understand the paleo-relationships of East Antarctica-Dronning Maud Land in particular, with other Gondwanian platforms having charnockites of comparable age and composition.

The dolerite dykes in the Schirmacher region have a general strike direction of NW-SE to N-S and mostly dip steeply to NE, E and ESE directions. The thickness of these dykes varies from a few centimetres to approximately 10 metres in rare cases. The exposed strike length of the dykes is usually less than 500 m. According to Kaiser and Wand (1985) the dolerites in the region are usually fresh and the XRF analysis has revealed that they have a tholelitic composition. In a K-Ar dating study of 9 basalt dykes from the Schirmacher Oasis and Wohlthat regions, Kaiser and Wand (1985) found that these dykes belonged to the different generations of basalt intrusion- an upper Carboniferous (approximately 300 m.y.) and an upper Jurrasic to lower Cretaceous one (approximately 170 m.y.). A number of workers (Smith and Hallam, 1970; Scrutton, 1973; Cox, 1978) have suggested that the widespread occurrence of Mesozoic tholelitic lavas and sills and dykes in Antarctica is generally related to the break up of Gondwanaland. A precise determination of the age of these tholelitic dykes, therefore, assumes great significance in the study of pre-breakup relationships of various Gondwanian landmasses.

COLLECTION OF SAMPLES

Keeping in view the geochronological significance of various rock types as described in the preceding section, a number of samples were collected from the Schirmacher Oasis region. To estimate the age of the rocks forming the crystalline basement (CB), the biotite gneiss, garnet biotite gneiss and banded gneiss samples were collected from the locations marked CB in Fig. 3. Similarly, the locations of dolerite dyke samples are marked as D in Fig. 3. While collecting the samples precaution was taken to collect only unweathered (petrographically fresh) and hydrothermally unaltered samples. To make further sure that these samples are suitable for K-Ar age-determination studies, thin sections (slides) of the samples were examined under microscope. After examining all the samples, only 4 samples from the CB group and 5 samples from the D group were found to be suitable for the radiometric age determination.

EXPERIMENTAL TECHNIQUE

The K-Ar isotope dating method is based on radioactive decay of the isotope K^{40} to Af^{40}. For age calculations we require the quantity of K^{40} and Af^{40} in a rock sample. The samples belonging to the CB group were first crushed and biotite pieces were isolated for the purpose of age determination. In case of dolerite dykes (D group samples) the whole-rock technique was used. Samples were crushed to 30 to 40 mesh size for argon extraction and approximately 150-200 mesh size for potassium analysis. These samples were then sieved and washed in distilled water and acetone. Potassium analyses were carried out using a flame photometer that yielded results of ± 1 percent of accuracy. Argon extraction and purification was done on all metal ultra high vacuum line, in which a blank of 10^{-8} cc STP of Ar^{40} was obtained at 1400°C. Samples were heated to 1300°C using electron bombardment heating. The extracted gas was mixed with a calibrated amount of spike (Ar^{38}) and purified at different stages using Titanium sponge at 600°C, Titanium sublimation pump and a SAES getter. All the active gases were removed at the above stages and the argon was absorbed in charcoal finger kept at liquid air temperature. The argon was released by heating the charcoal finger to room tempera-

ture and was allowed into the MS 10 mass spectrometer through a leak valve (Fig. 4). Isotopic analyses of argon were done in the mass spectrometer working under static mode. The constants used in this work are those given by Steiger and Jager (1977).

RESULTS AND INTERPRETATION

The ages obtained for the nine samples are given in Table I. The ± figures are standard deviations of analytical precision calculated using the formula derived by Cox and Dalrymple (1976). It may be seen that the group of rocks forming the crystalline basement show much higher ages (between 411 m.y. to 608 m.y.) as compared to the intrusive dolerite dykes which show a range of 97 to 178 m.y. The implication of these ages in the context of tectonic evolution of the Dronning Maud Land and the break-up of Gondwanaland is presented below:

(a) Crystalline basement

A comparison of the ages obtained for the crystalline basement rocks with those given in Fig. 2 immediately reveals that these rocks can be directly correlated with the period (Devonian to Cambrian) representing the most widespread orogenic activity in Antarctica. The absolute ages of crystalline rocks from East Antarctica, based on the whole rock analysis as well as individual minerals have been reported by a number of workers (Ravich and Krylov, 1964; Picciotto and Coppez, 1963,1964; Deutsch et. al., 1964; Woollard, 1970, etc.). A compilation of ages of such rocks from the regions in the immediate vicinity of the Schirmacher Oasis is presented in Table II.

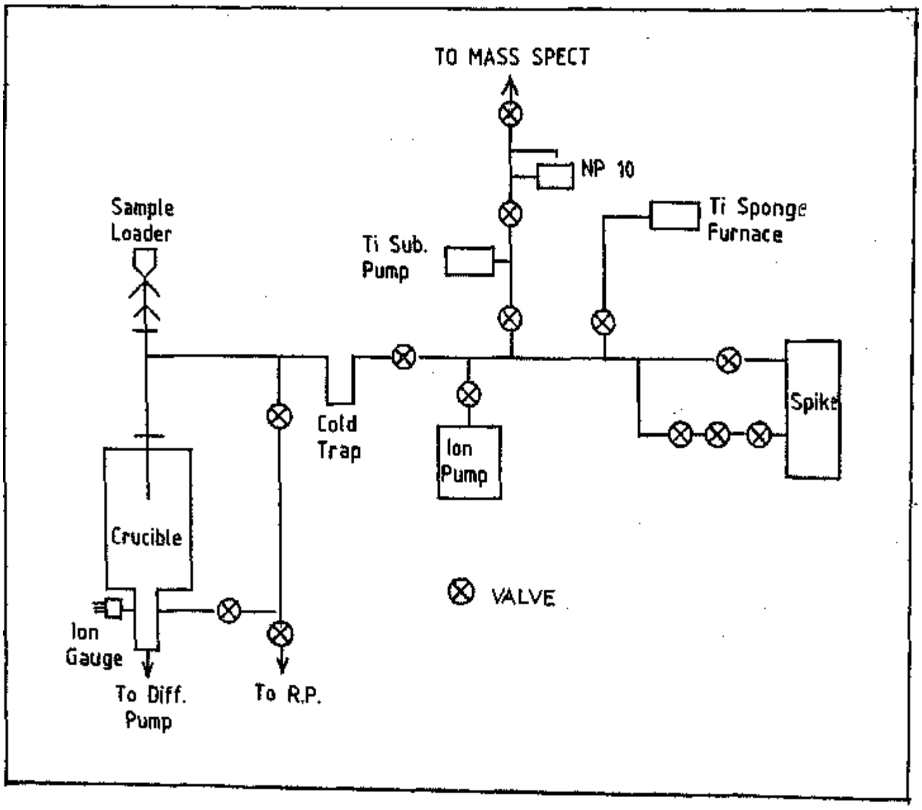

Fig. 4. Argon extraction system

TABLE I

Ages of the samples collected for the present study.

S.No.	Rock or Mineral	Age (in m.y.)
	A. Crystalline Basement	
1.	Biotite Gneiss	608 ± 60
2.	Garnet Biotite Gneiss	526 ± 48
3.	Leucocratic Gneiss	411 ± 40
4.	Augen Gneiss	496 ± 50
	B. Dolerite Dykes	
5.	Dolerite	97 ± 3
6.	Dolerite	165 ± 7
7.	Dolerite	173 ± 8
8.	Dolerite	178 ± 10
9.	Dolerite	160 ± 5

TABLE II

S.No.	Rock or Mineral	Locality	Age (in m.y.)
1.	Slightly migmatized pyroxene amphibolite schist	Schirmacher Oasis(SO)	845
2.	Slightly migmatized pyroxene amphibolite schist	SO	830
3.	Migmatized biotite amphibolite schist	SO	690
4.	Migmatized biotite amphibolite schist	SO	490
5.	Augen-migmatite after plagiogneiss	SO	460
6.	Vein pegmatite	SO	400
7.	Diopside-phlogopite rock	Humboldt regions(HR)	650
8.	Vein pegmatite	HR	485
9.	Biotite from pegmatite vein	HR	475
10.	Quartz diorite	HR	465
11.	Quartz diorite syenite	HR	460
12.	Quartz diorite syenite	HR	450
13.	Phlogopite from diopside phlogopite rock	Wohlthat mountain	530
14.	Altered calciphyre	Petormann Range(PR)	505
15..	Altered calciphyre	PR	500

The ages obtained in the present study (Table I) are similar to those given in Table II and can be interpreted as those belonging to the period of Ross Orogeny.

It may be noted, however, that the distribution of these ages spreads well over a period of about 200 my. covering the entire period corresponding to the Ross orogeny (Fig. 2). According to some workers (McKelvey and Webb, 1962; Allen and Gibson, 1962; Peam, et aL, 1963) this large period can be divided into two distinct subgroups of tectonic activity within the Ross orogeny: (1) Late Cambrian-early Cambrian (510 ± 25 my.) and (2) late Ordovician-early Silurian (440 ± 25 m.y.). The different rocks whose ages are shown in Table I, can thus be interpreted as those belonging to the different sub-groups ofdiastrophism causing various polymetamorphic fades. In this context it is worthmentioning that for the polymetamorphic rocks derived from original basic volcanic rocks, two mineral assemblages are typical (Ravich, 1972): (i) An earlier one of hypersthene and clinopyroxene with basic (partly immediate) plagioclase; (ii) A later one ofamphibole, garnet and biotite with intermediate (partly acid) plagioclase. The abundant amphibolites and gamet-biotite gneisses in the Schumacher Oasis obviously belong to the later stage of the polymetamorphic history of the region. Considering various aspects of the regional metamorphism in the crystalline basement of the East Antarctic platform, Ravich and Krylov (1972) have suggested atleast three to four episodes in the rejuvination of the basement. Though the cause of this rejuvination is yet to be ascertained in a conclusive manner, Ravich and Krylov (1972) have suggested that faulting and repeated metamorphism may be of the greatest importance in addition to the repetitive large scale block movements in the basement of the East Antarctic platform. Such block movements are well evident in a series of large blocks in the crustal section obtained by the deep seismic sounding (Kogan, 1972) in a mobile area of the crystalline basement in the vicinity of the Schirmacher Oasis.

The ages obtained in the present study (Table I) are important not only in the context of the Ross orogeny in the tectonic evolution of the Antarctic platform, but they also provide valuable insights into the palaeorelationships of various Gondwanian platforms. A considerable number of rocks samples from Africa, South America and India have yielded age dates in the range of 450-525 m.y. Frequent and widespread occurrence of the rocks within the time interval 450-550 my. from various localities around the East Antarctic platform suggests "On a speculative basis if nothing else, a relationship between the Antarctic Continent and those other Gondwanaland area..../ (Angino and Tumer,1972).

The range 440-570 my. is the most widespread age group which has been distinctly distinguished in east Antarctica (Dronning Maud Land in particular) and signifying a major tectonic event. It is possible that the rigid epicratonic crystalline basement involving regions of early Proterozoic consolidation reacted to the powerful Ross tectonogenesis by the development of faults and by intense block (uplift) movements. Such block movements may have led not only to the formation Of typical block mountains but also to a considerable isotopic 'rejuvination' of the pre-Raphena metamorphosed rocks to an 'average Ross radiogenic level' of about 500 m.y. (Grikurov, et al., 1972). The limited granitic rnagmatism possessing platform (sub-alkaline) features such as the granite-syenite intrusive formations in the Dronning Maud Land possibly accompanying the block tectonics is alsoproposedbyGrikurov, etal. (1972).

The Ross tectonogenesis is widely believed to have completed the crust over most parts of the east Antarctica (epi-Ross) platform. synchronity of the age of the crystalline basement with that of the period of Ross tectonogenesis signifies the fact that since about this (early-Palaeozoic) period the east Antarctic landmass remained a stable platform and has followed the pattern of the Gondwanian evolution. It is worth nothing in this context that while the rocks of similar isotopic age are widespread throughout the Gondwana continents, they are found rather rarely in Laurantia continents.

(b) Dolerite dykes

The dolerite dykes are widely distributed in east Antarctica right from eastern Wilkes land to the Dronning Maud Land. These basalt (dolerite) predominantly of Jurrasic or Mesozoic age, intrude the crystalline basement and are related to the Ferrar group of dykes that represent the most intense igneous activity in east Antarctica (Ravich and Kamanev, 1965; Grikurov, et. al., 1976).

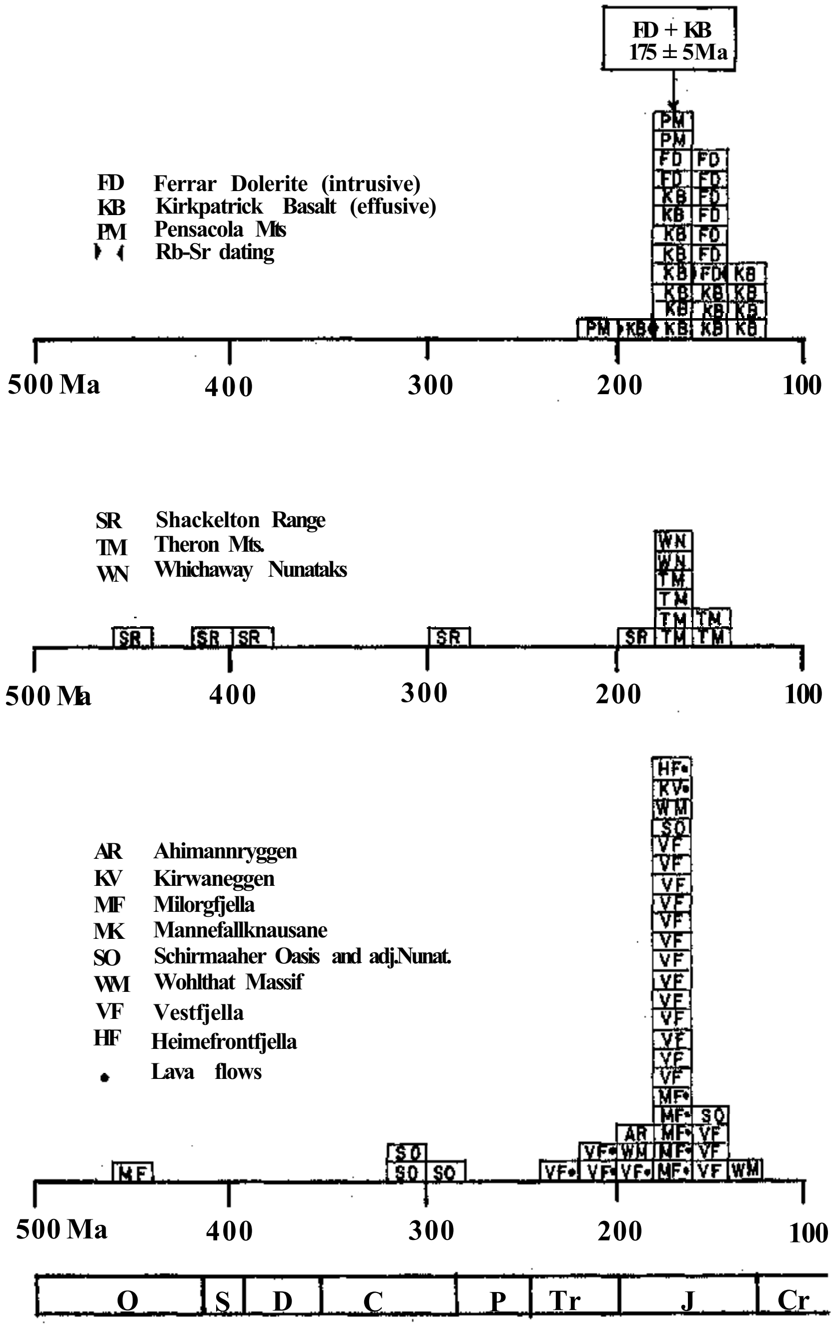

Fig. 5. **Potassium-Argon ages of the studied dolerite specimens compared with those of similar rocks from other regions of Antarctica (After Kaiser et al., 1985)**

TABLE III

K-Ar ages of basalts from Schimacher Oasis (SO) and Wohlthat Region (WR).

S.No.	Locality	Apparent age (m.y.)
1.	SO	302 ± 10
2.	SO	290 ± 4
3.	SO	300 ± 4
4.	SO	154 ± 13
5.	Nunatak (69°S, 12°E)	163 ± 16
6.	WR (boulder)	128 ± 7
7.	WR (boulder)	184 ± 7
8.	WR (boulder)	179 ± 12

In a recent study Kaiser and Wand (1985) determined the ages of eight basalt samples from Schirmacher Oasis and Wohlthat Massif region. These ages are shown in Table III.

A histogram of the ages obtained for various dolerite samples for three different regions of Antarctica is shown in Fig. 5. From the figure it is evident that the most frequent age of 175 ± m.y. corresponding to Ferrar dolerites (intrusives) or Kirkpatrik basalt (effusives), is obtained from all the three regions. Out of the five ages determined for the dolerite samples in the present study, four show ages close to 175 m.y. The fourth sample shows a much younger age of about 93 m.y.

The widespread occurrence of intrusive or effusive basalts (Dolerites) along the margin of the east Antarctic shield is generally associated with the break-up of Gondwanaland (Smith and Hallam, 1970; Scrutton, 1973; Cox, 1978). This concept is supported by the occurrence of basic sills, dyke swarms and lava flows in the southeastern part of Africa revealing striking similarities in regard of enormous quantities and the extensive areas showing magmatic activities in association with basic rocks (Peach, 1985). A number of researchers (Dietz and Holden, 1970; Smith and Hallam, 1970, etc.) have argued that Africa and Antarctica remained together until late Triassic or early Jurassic period. The age obtained in the present study, therefore, indicate that the Dronning Maud Land region of the eastern Antarctic shield was juxtaposed to the Mozambique region of south-eastern Africa. The younger age of 97 m.y. obtained for one sample could signify the post-drift magmatic activity in the region.

CONCLUDING REMARKS

The results presented in this paper clearly indicate that the geochronological studies of the samples from the Schirmacher Oasis region provide valuable information on the evolution of the polymetamorphic crystalline basement forming part of the East Antarctic shield and the palaeo-relationship of Dronning Maud Land and the Mozambique region in east Africa.

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