# K-Ar Ages and Palaeomagnetic Studies on Rocks from the East Coast of Lützow-Holm Bay, Antarctica**

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# 南極リュツォ・ホルム湾東海岸付近産出の岩石のK-Ar年代と古地磁気学的研究

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## 要旨

第7次南極観測隊により，南極Lützow-Holm湾の東海岸およびオングル島の露岩中より，新たに数種の試料（片麻岩）が採集された．従来この地域の年代決定および古地磁気学的研究は独立に行なわれていたが，今回は同一試料について K-Ar 年代および自然残留磁気測定を行ない，次のような結果を得た．

K-Ar 年代は大体4億年前後の値を示すが，これらは従来の Rb-Sr 法，U-Pb 法による5億年の値よりやや若い値を示す．しかし，この地域の地質が複雑なこと，今回用いられた試料と以前に年代決定が行なわれた際に用いられた試料との相対的関係が不明等のことにより，この差が試料の差によるものか，あるいは方法による差かは断定できない．ただこの地域が高度の変成作用を受けたという立見・菊地（1959）の報告を考慮すると，4～5億年の値は，この地域における変成時期を示すと考えるのが妥当である．

同一試料を mafic な部分（主に黒雲母，角閃石）と，felsic な部分（主に長石，石英）とに分けて K-Ar 年代を求めると，前者が後者よりも古い値を示し，全岩による測定はそれらの中間の値を示す．Mafic な部分のAr保持が高いということから，この場合には mafic な部分による年代が最もその値に近いと考えられる．

また，Lützow-Holm 湾を含む Queen Maud Land 付近の年代測定結果をも考慮すると，この地域の大部分は Cambrian 以後の年代を示すことが予想される．

この年代決定に用いられた試料についての自然残留磁気測定の結果は，この時期の磁極の位置はほぼ赤道上，西径約150°付近に存在することを示す．この結果は，以前永田・清水（1959; 1960）および永田・山合(1961)によって得られたものとほぼ一致する．

## 1. Introduction

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In the last decade, a number of radiometric age determination and palaeomagnetic studies of Antarctic rocks have been undertaken (WEBB, 1962; WEBB and WARREN, 1965). However, there are few cases in which both radiometric age determination and palaeomagnetic studies were carried out on the same samples. It seems also desirable in Antarctica that palaeomagnetic studies are made on the rock samples, whose absolute age is determined by the radiometric method, for the purpose of systematic research of the palaeomagnetic field in Antarctica and possible relative movements of the Antarctic Continent in geologic time.

Several rock samples were collected in the Syowa Station area on the east coast of Lützow-Holm Bay, Antarctica during the period of the 7th Japanese Antarctic Research Expedition, 1965–1966. Prior to this research, rocks in this region were dated by Rb–Sr method (NICOLAYSEN *et al.*, 1961) and U–Pb method (SAITO *et al.*, 1961). Palaeomagnetism was also studied (NAGATA and SHIMIZU, 1959;

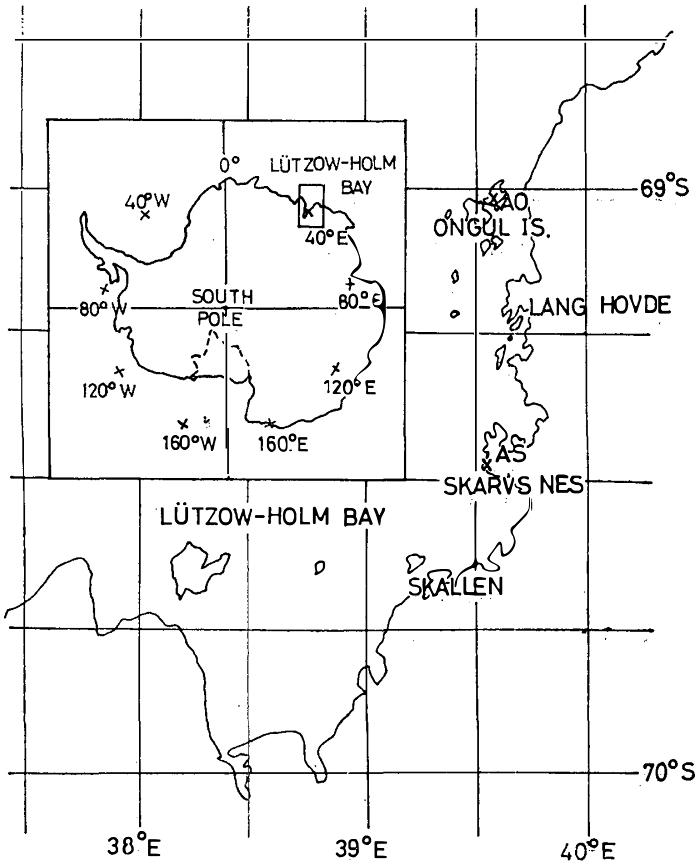


*Fig. 1. Map of the east coast area of Lützow-Holm Bay. AO and AS are the sampling localities.*

NAGATA and YAMA-AI, 1961) on different samples from the same area. In this paper, the results of K-Ar dating and palaeomagnetic studies of the same samples from the Syowa Station area are reported and their geophysical implications are also discussed.

## 2. Geology and Petrography

Samples were collected from the East Ongul Island (69°01′ S, 39°35′ E) and the Skarvs Nes district (69°29′ S, 39°33′ E) on the east coast of Lützow-Holm Bay, Antarctica (Fig. 1). Most parts of this area are composed of high-grade metamorphic rocks (TATSUMI and KIKUCHI, 1959). This fact seems to be important in interpreting the results of age determination and palaeomagnetic studies as will be discussed later. Petrographic descriptions of these samples are given in appendix.

## 3. Experimental Results

### 3.1. K-Ar age determinations

K-Ar ages were determined for samples AO2 and AS using whole rocks. For sample AO2, K-Ar dating was made also for the separated mafic and felsic minerals. Rocks were crushed into −80 to +100 meshes and separated by an isodynamic separator. In mafic and felsic parts, minerals were concentrated more than 95 per cent in purity.

Potassium determination was carried out by a flame photometer with a lithium internal standard. Argon analysis was made by the isotope dilution method on a 15cm radius Reynolds type mass spectrometer. Details of the argon analysis were reported elsewhere (OZIMA *et al.*, 1967). Analytical error in the final K-Ar age is considered to be less than 5 per cent.

### 3.2. Palaeomagnetic measurements

The direction and intensity of NRM of four samples of AO2 were measured by an astatic magnetometer. From the mean value of the directions of NRM, the virtual pole position was estimated for these samples (Table 3).

The A-C demagnetization test shows that NRM of these samples is very stable (Figs. 2 and 3), suggesting that the NRMs are of TRM or CRM origin. The thermomagnetic analysis shows that Curie point is 560°C, suggesting that the magnetic mineral in these samples is almost pure magnetite.

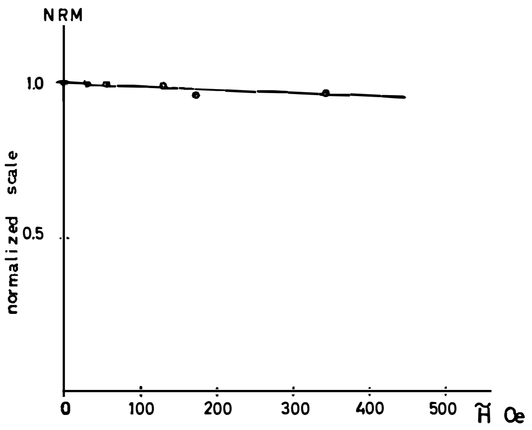


*Fig. 2. Change in the intensity of the remanent magnetization with the demagnetization by alternating magnetic field.*
*Sample: AO2*

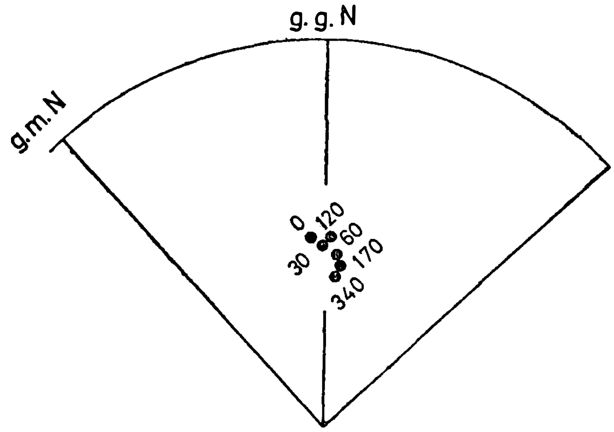


*Fig. 3. Change in the direction of the remanent magnetization with the demagnetization by alternating magnetic field.*
*Sample: AO2*
*g. m. N: Geomagnetic North*
*g. g. N: Geographic North*

## 4. Results and Discussions

The results of K–Ar age determination are listed in Table 1, and the ages determined previously on rocks collected from the same area by the Rb–Sr and U–Pb methods are tabulated in Table 2. As seen in the tables, the K–Ar ages in the present study are generally younger than those determined by the Rb–Sr and U–Pb methods. The geology of this region is very complicated (TATSUMI and KIKUCHI, 1959) and it is not possible to identify whether samples dated in the present study belong to the same geological unit as those studied previously. Therefore, we cannot decide whether the difference in age values are really due to the difference of samples or to the argon loss during the geological period.

As shown in Table 1, the K–Ar ages for different minerals from the same rock AO2 are different : felsic minerals (mostly feldspar and quartz) show the youngest age, whereas the mafic (mostly hornblende and biotite) the oldest age. As it is generally accepted that hornblende and biotite have higher argon retentivity than feldspar (HART, 1964; ALDRICH *et al.*, 1965), the observed pattern of the order of the age values among different minerals may suggest that the difference in the K–Ar ages is essentially due to argon loss from the felsic minerals. In addition, it is interesting to note that the whole rock gives the average ages between those of the felsic and mafic minerals. Considering the high argon retentivity of mafic

*Table 1. K-Ar ages of rocks from the east coast of Lützow-Holm Bay.*

| Sample | Locality | Rock type | $Ar^{40}$ ($\times 10^{-9}$ moles/g) | $\frac{(Ar^{40})air}{(Ar^{40})total}$ (%) | K (%) | $(Ar^{40})/(K^{40})$ ($\times 10^{-2}$) | Age (m. y.) |
|---|---|---|---|---|---|---|---|
| AS | East Coast of Lützow-Holm Bay, Skarvs Nes | Garnet-biotite gneiss (whole rock) | 3.423 | 14.8 | 4.81 (4.90, 4.72) | 2.341 | 363 |
| AO2 | East Ongul Is. | Biotite-hornblende gneiss (whole rock) | 2.351 | 3.3 | 3.08 (3.13, 3.03) | 2.511 | 387 |
| 〃 | 〃 | 〃 (biotite + hornblende) | 2.134 | 11.5 | 2.54 (2.53, 2.55) | 2.764 | 421 |
| 〃 | 〃 | 〃 (feldspar + quartz) | 2.805 | 13.0 | 4.09 (4.07, 4.11) | 2.257 | 350 |

$\lambda_e = 0.585 \times 10^{-10}$ yr$^{-1}$
R = 0.124
$K^{40}/K = 1.19 \times 10^{-4}$ mole/mole

*Table 2. Radiometric ages of rocks from the east coast of Lützow-Holm Bay.*

| Locality | Rock type | Mineral | Method | Age (m.y.) | Author |
|---|---|---|---|---|---|
| Lützow-Holm Bay, Skallen district | Granitic pegmatite in dioritic gneiss | euxenite | $Pb^{206}/U^{238}$ | 485 | N. SAITO, T. TATSUMI and K. SATO (1961) |
| 〃 | 〃 | 〃 | $Pb^{207}/U^{235}$ | 468 | 〃 |
| 〃 | 〃 | 〃 | $Pb^{208}/Th^{232}$ | 375 | 〃 |
| 〃 | 〃 | 〃 | $Pb^{207}/Pb^{206}$ | 458 | 〃 |
| Lützow-Holm Bay, Lang Hovde district | Granitic pegmatite in granitic gneiss | biotite | Rb/Sr | 525* | NICOLAYSEN *et al.* (1961) |
| Skallen district | Granitic pegmatite in dioritic gneiss | 〃 | 〃 | 530* | 〃 |
| Skarvs Nes | 〃 | 〃 | 〃 | 510* | 〃 |
| West Ongul Is. | Charnockite lens in granodioritic gneiss | 〃 | 〃 | 500* | 〃 |

* : $\lambda_\beta = 1.386 \times 10^{-11}$ yr$^{-1}$

minerals, the K-Ar ages of the mafic minerals may not be much different from the time when these minerals in the rocks were recrystallized. As shown in Table 1, sample AS shows a considerably young age in comparison with the ages obtained by different dating method for different samples collected from the same area. However, we cannot conclude only from this result whether this young age is due to argon loss in the present sample or to the difference in the samples.

As stated above, the entire region from which the samples were obtained was very intensely metamorphosed (TATSUMI and KIKUCHI, 1959). Therefore, the ages determined in this region should be regarded to represent the ages of the metamorphism. The same conclusion has been obtained by NICOLAYSEN *et al.* (1961).

Before radiometric age determination was made, this region had been considered to be of Precambrian age on the basis of field geology. At present, a number of results of age determination of the rocks from Antarctica are available. So far, no Precambrian ages have been detected by radiometric method for rocks obtained from the Queen Maud Land area (all radiometric ages range from 350 m. y. to 600 m. y.). Considering these results and the radiometric ages determined on the rocks from the east coast of Lützow-Holm Bay, it may be concluded that most of the rocks are not as old as Precambrian, but have the metamorphic ages around 400 to 500 million years.

Palaeomagnetic measurements were made only for sample AO2, since magnetization of sample AS is too weak (less than $10^{-6}$ emu/cc) to be measured. The average values of declination and inclination of the natural remanent magnetization are tabulated in Table 3. In the same table, palaeomagnetic results obtained for rocks from the same area collected by the 1st and the 3rd expedition parties of JARE (Japanese Antarctic Research Expedition) are compared. As the metamorphism in this area was reported to be of high-temperature type (TATSUMI and KIKUCHI, 1959), it is most likely that the magnetic mineral (Curie point = 560 °C) of these samples may have acquired the remanent magnetization (TRM) during the metamorphism. Hence, no bedding correction was made for the estimation of the virtual pole positions. As shown in Fig. 4, the virtual pole is located around the equator in the Western Pacific area. The average intensity of natural remanent magnetization of four samples is $5.4\times10^{-4}$ emu/cc.

The palaeomagnetic data of the Antarctic rocks have been summarized from the table compiled by IRVING (1964) and are plotted in Fig. 5 together with the present result. The most remarkable feature is that only the virtual pole deter-

*Table 3. Palaeomagnetic results of rocks from the Ongul Islands.*

| Author | Locality | Number of specimen | Direction of NRM Declination | Inclination | Virtual geomagnetic pole (uncorrected) | |
|---|---|---|---|---|---|---|
| | | | | | Lat. | Long. |
| NAGATA and SHIMIZU (1959) | East Ongul Is. | 18 | −23° | 51° | 19°N | 163°W |
| NAGATA and YAMA-AI (1961) | Ongul Is. | 5 | −10° | 49° | 9°N | 148°W |
| Present work | East Ongul Is. | 4 | − 7° 00′ | 46°36′ * | 7°N | 147°W |

* All samples have reverse NRM.

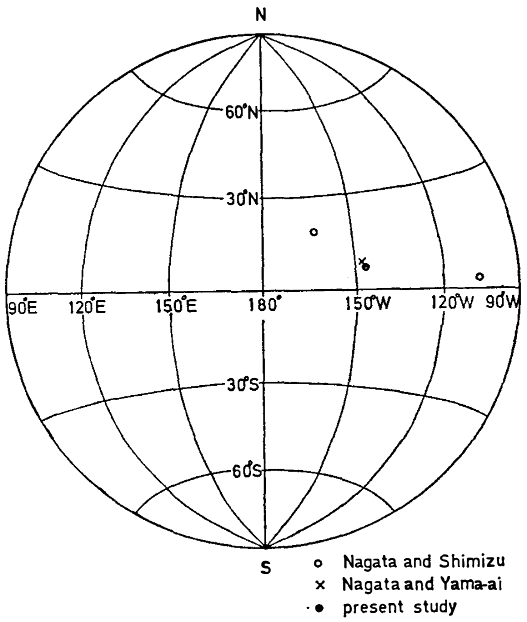


*Fig. 4. Positions of the dipole's north pole. Samples from the Ongul Islands.*

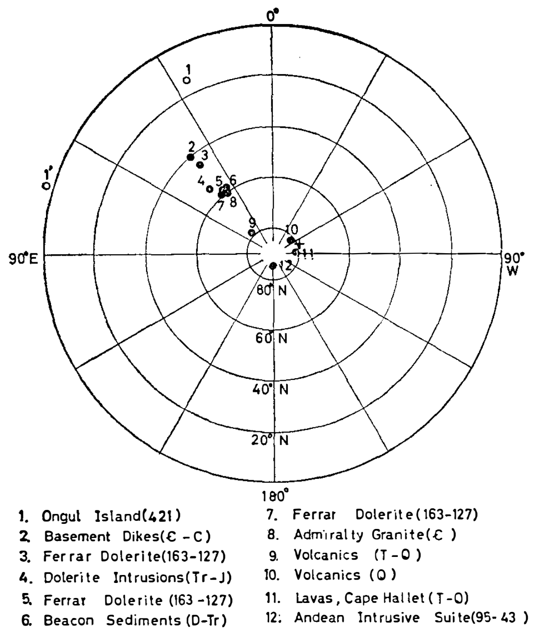


*Fig. 5. Palaeomagnetism in the Antarctic. Cross denotes the present geomagnetic pole.*

mined from the Ongul Islands is situated around the equator, while other virtual poles obtained from rock samples of other areas are located in the middle to higher latitudes. As pointed out by NAGATA and YAMA-AI (1961), it seems that the virtual pole has shifted from the equator to the present position during the geological period between several hundred million years ago and the present time. However, there still remains a possibility of relative displacement of the Syowa Station area against the rest of the Antarctic Continent, because there are some uncertainties in the absolute ages of other data which were estimated simply on the basis of field observations. It is hoped, therefore, that more systematic research of palaeomagnetism will be made on radiometrically dated samples collected from many localities of different geologic ages in Antarctica.

## 5. Conclusions

1. The K–Ar ages of rocks from the east coast of Lützow-Holm Bay range from 400 to 500 million years. It seems likely that the obtained K–Ar ages indicate the time when these rocks were subjected to thermal metamorphism.

2. It is confirmed that biotite and hornblende have higher argon retentivity than felsic minerals. The whole rock age shows the average value between the age

determined for mafic minerals and that for felsic minerals.

3. The virtual geomagnetic pole position determined from rocks of the east coast of Lützow-Holm Bay is situated near the equator.

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## Appendix

*AO2: Biotite-hornblende gneiss*

Samples were collected from the highest elevation in the East Ongul Island. They show clear gneissosity and strong weathering effect on the surface. They are composed mainly of potassium feldspar, plagioclase, quartz, hornblende and biotite. Perthite is observed and potassium feldspar is more abundant than plagioclase. Small amounts of apatite and opaque minerals are observed.

*AS: Garnet-biotite gneiss*

Samples were collected from the Skarvs Nes district, 1 to 2 meters above the sea level. Gneissosity is not very clear. They are composed mainly of potassium feldspar, plagioclase, quartz, biotite and garnet. Perthite is abundant. Opaque minerals are few.

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