Absolute Age of Euxenite from Antarctica

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南極地方産ユークセン石の絶対年令

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要　　旨

南極地方 Lützow-Holm Bay の東海岸，Skallen 地区に見出された花崗岩ペグマタイト中の強放射性鉱物，ユークセン石の年令決定を鉛法により行ない，Pb-206/U-238，Pb-207/U-235，Pb-208/Th-232，Pb-207/Pb-206 の比を測定することによって年令を算出した．従来，しばしば異常な値を示すと考えられている Pb-208/Th-232 の比を除けば，他の三つの比から得られる年令は相当によい一致を示し，平均約 470×10⁶ 年程度である．

最近 AHRENS らは著者の一人（立見）とともに，南極地方の同一地域から産する黒雲母の年令をルビジウム－ストロンチウム法により決定したが，その年令は約 500×10⁶ 年であって，ユークセン石の年令とほぼ一致する．従来，多くの研究者により，南極地方産の岩石や鉱物の年令が報告されているが，それらは主として，カリウム－アルゴン法によって測定されたものであり，現在までにユークセン石のような強放射性鉱物を用いて行なった年令のデータは見当らないようである．

現在までに集められたデータによれば，南極地方の基盤岩類の一部をなす白榴岩相に属する岩石の年令は少くとも２つのグループに分れるようである．グループ A は Lützow-Holm Bay の東海岸，Mirny 地区，McMurdo Sound の西側に産する岩石で，約 500×10⁶ 年の年令を持ち，グループ B は Knox Coast および Budd Coast に産する岩石で，約 900～1100×10⁶ 年の年令を持っている．

本研究を含めたいくつかの研究によって，南極地方に古生代のチャーノッカイトの産出することが確められた．従来，チャーノッカイトは先カンブリア紀に特有の岩型と考えられていたものである．

Mode of occurrence of the euxenite

A strongly radioactive mineral, euxenite, was found in a granitic pegmatite occurring as irregular shaped body of about 5×10 m in size in dioritic gneiss in Skallen district on the east coast of Lützow-Holm Bay, Antarctica (ca. 69°38′S, 39°18′.5E). Some properties of the mineral were already described by N. HAYASHI and K. NAGASHIMA (1961).

Geology of the region was surveyed by one of the authors (T.T.) in 1957 (TATSUMI

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and KIKUCHI, 1959). The entire region surveyed consists of various kinds of metamorphic rock. Hornblende-pyroxene dioritic gneiss, having a close petrographic resemblance to the intermediate charnockite from other continents, occurs widely. Quartzofeldspathic gneisses characterized by the mineral assemblage pyralspite-biotite are also found extensively. Bands or lenses of basic metamorphic rock are often intercalated within both types of the gneisses mentioned above, while some marbles and quartzites are also distributed. The basic metamorphic rock is equivalent in its petrographic features to the basic charnockite. Some biotite-granitic gneiss and granite intrude into other gneisses. Pegmatites of various mineral compositions occur as lenticular masses, irregular shaped bodies and clear-cutting veins in all of the above described rocks.

Based on their petrographical features, these are correlated with the rocks forming basement in other regions of East Antarctica.

Chemical and isotopic analyses

Aggregate of the mineral collected from the pegmatite includes small amounts of some other minerals such as keilhauite*. Handspecimen was first crushed into grains of about 0. 5mm in diameter, and then the mineral grains other than euxenite were picked out easily under a binocular.

The concentrates thus obtained were ground into fine powder and subjected to chemical and isotopic analyses. The chemical constituents except lead were determined by NAGASHIMA as described in his paper, while the lead content was determined on a separate portion by one of the authors (K.S.). Since quantitative recovery of lead from the euxenite by conventional separation method was extremely difficult, isotope dilution technique using a spike of stable lead was applied to the analysis of lead. From another portion of the sample, the lead was separated as lead iodide. It was converted to lead tetramethyl (SATO and SAITO, 1960) and then introduced into a mass spectrometer (CEC 103C) for the isotopic analysis.

Results and discussion

The results of the chemical analysis and the isotopic analysis of lead are tabulated in Tables 1 and 2. After some correction was made on common lead in euxenite, the ages, Pb-206/U-238, Pb-207/U-235, Pb-208/Th-232 and Pb-207/Pb-206 were calculated as shown in Table 3. Since there is no lead mineral in close association with the euxenite, the isotopic composition of common lead existing in euxenite was assumed to be the same as that of lead ore of 5×10^8 years old. Except for abnormally low Pb-208/Th-232 age, the rest three ages coincide fairly well with each other, giving an average value of 470 m.y. (million years).

The absolute ages of the rocks and minerals from Antarctica determined by many investigators are summarized in Table 4. These absolute ages reported are mainly K-Ar

* Determined by A. KATO through analysis of its X-ray diffraction pattern.

Table 1. Chemical composition of euxenite.

MnO	0.05%
Fe_2O_3	1.07
MgO	0.22
CaO	0.64
ΣCe_2O_3	0.38
ΣY_2O_3	25.26
PbO	0.92
ThO_2	3.20
UO_2	11.49
UO_3	0.64
$(Nb, Ta)_2O_5$	30.76
TiO_2	24.74
SiO_2	0.33
SnO_2	0.11
$H_2O(+)$	0.23
	100.04

ages. It seems that no age data have been available on strongly radioactive minerals from Antarctica.

Recently, AHRENS, NICOLAYSON and BURGER (NICOLAYSON et al., 1961), in collaboration with one of the authors (T.T.), determined the Rb-Sr ages of biotites from the same locality of Antarctica. The age of the biotites was found to be about 500 m. y. It is encouraging to know that the age obtained on the euxenite is nearly identical with that of the biotite mentioned above.

The age obtained in this study, about 470 m. y., means the age of the host rock in which the euxenite was formed. According to the data collected in Table

Table 2. Isotopic composition of lead.

	Pb-204 (%)	Pb-206 (%)	Pb-207 (%)	Pb-208 (%)
Euxenite	0.111±0.009	84.03±0.04	6.27±0.02	9.60±0.04
Common Lead	0.111	1.95	1.71	4.13
Radiogenic Lead		82.08±0.42	4.56±0.27	5.47±0.68

Table 3. Age of the euxenite (unit: 10^6y).

Pb-206/U-238	Pb-207/U-235	Pb-208/Th-232	Pb-207/Pb-206
485±6	468±12	375±27	458±21

Table 4. Age measurements on the rocks and minerals from Antarctica.

Age in m. y.	Method	Mineral and its host	Locality	Author
1. 470	U-Pb	Euxenite from granitic pegmatite in dioritic gneiss	East coast of Lütow-Holm Bay	Saito, Tatsumi, Sato, 1961
2. 500 (mean of 3)	Rb-Sr	Biotites from granitic pegmatites and basic charnockite	ibid.	Nicolayson et al., 1961
3. 468	K-Ar	Biotite from pegmatitic vein cutting charnockite	Mirny region	Ravich, 1958
4. 509	,,	Biotite from xenolith of crystalline schist in charnockite	ibid.	Ravich, 1958
5. 520	,,	Biotite from augitehorn-blende-biotite paragneiss	West side of McMurdo Sound	Goldich et al., 1958
6. 560	,,	Sericite from sericitized sandstone	Mt. Amundsen, Knox Coast	Ravich, 1958
7. 910-920 (mean of 2)	,,	Biotites from pegmatites in gneiss formation	Bunger Oasis, Knox Coast	Ravich, 1958
8. 920-970 (mean of 3)	,,	Biotites from pyroxene schists and garnet schist	ibid.	Ravich, 1958
9. 950-1120 (mean of 3)	,,	Gneiss and quartz diorite	Windmill Islands, Budd Coast	Cameron et al., 1959

Note: Kind of mineral facies of rocks Nos. 6 and 9 are uncertain from original descriptions.

4, ages of granulite facies rocks from Antarctica are divided into at least two groups. Group A, about 500 m. y. in age, includes the rocks from the east coast of Lützow-Holm Bay, the Mirny region and the west side of McMurdo Sound, and group B of about 900–1100 m. y. comprises the rocks from the Knox Coast and the Budd Coast.

Based on the recent KULP's tentative geological time scale (KULP, 1960), the age of about 500 m. y. is correlated roughly with an epoch dividing lower and middle Cambrian. In other words, the age of the metamorphosed rocks belonging to group A seems to be Cambrian. The basement complex of East Antarctica is covered by the horizontal Beacon Sandstone Formation probably of Devonian to lower Mesozoic with remarkable unconformity (FAIRBRIDGE, 1952). The lower to middle Cambrian formation in South Australia is affected by the Tyennan orogenesis (end of middle Cambrian or beginning of upper Cambrian) together with the Adelaide System which is overlained concordantly by the former and is thought to belong to upper Proterozoic (DAVID, 1950). Rocks of amphibolite facies were found in this orogenic zone. An Ordovician formation overlies these Proterozoic to Cambrian formations with clear unconformity. The granitic rocks and their derivatives of about 500–550 m. y. are also known in Ceylon (HOLMES, 1955), Cape Province, South Africa and Madagascar (HOLMES and CAHEN, 1955). In South Africa the Cape Granite of this age is covered also by the Table Mountain Series, Cape System, of upper Silurian to Devonian (Du TOIT, 1954). Then, an orogenesis accompanied by high-grade metamorphism and granitic intrusion seems to have occurred widely in many places of the Gondwana land at the time about 500–550 m. y., namely Cambrian in age, as already noticed by A. HOLMES (1955).

On the other hand, an orogenesis which took place around the end of Proterozoic or early Cambrian has been studied also in Eurasia, e. g. the Baikalian folding named by N. S. SHATZKI in 1932 (SHATZKI and BOGDANOFF, 1950) or the Assynt orogenic movement by H. STILLE (1955). Data are so poor at present to clearify the nature of orogenesis of this age in Gondwana that the relation of the orogenesis to that of the Baikalian or the Assytish remains unknown. It seems to be one of the important problems regarding geotectonical development of Antarctica to make clear the geological relationships between the basement complex, so-called Robertson Bay Series (late Proterozoic or early Palaeozoic ?) in South Victoria Land, the Cambrian (?) limestone formation near the Beardmore Glacier and the low-grade metamorphic rocks described by E. F. ROOTS (1953) in the western Dronning Maud Land, etc.

Epoch of about 900–1100 m. y. is one of the great orogenic cycles in the geotectonical development of the Earth's crust, many investigators having obtained coincident numerical data from nearly all of the shields (e. g., Canadian Shield—GASTIL 1960 ; Baltic Shield—POLKANOV and GERLING, 1960 ; Ukraine Shield—VINOGRADOV et al., 1960 ; Urals and Pre-Urals—OVCHINNIKOV and HARRIS, 1960 ; South Africa—HOLMES and CAHEN, 1955 ; Peninsular India—HOLMES, 1955 ; and KRISHNAN, 1960). The rocks of group B from Antarctica belong to this category.

The youngest charnockite and other granulite facies rocks on which absolute age has been determined seem to be those from Antarctica*. So far as known, all of the rocks of this kind from the Baltic and the Ukraine Shields are of 1900–2100 m. y. in age (POLKANOV and GERLING, 1960; SIMONEN, 1960; VINOGRADOV et al., 1960) and those from Peninsular India are thought by M. S. KRISHNAN (1960) to be older than the Closepet Granite (900–1050 m. y.). Australian charnockites are found only in the shield region of the Western Australia (WILSON, 1959), one of them having been determind to be 2880 m. y. in age (WILSON, 1958).

It has been believed for a long time that the charnockite is a characteristic rock type of Precambrian. It seems worth mentioning that the occurrence of Paleozoic charnockits in Antarctica has been ascertained by several investigators including the present authors.

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* K.S. HEIER (1960) described recently the high-grade metamorphic rocks including charnockite and igneous rocks from Langøy, Northern Norway. According to his opinion, the age of orogenesis during which the granulite facies rocks were formed in thought to be early Caledonian (probably Cambrian), although there is no absolute age determination. In Central Pyrenees, hyperthene gneiss belonging to the granulite facies has been recently found and believed to be formed during the Hercynian orogenesis (Westphalian) from the field evidences (SITTER and ZWART, 1959).

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