Jour. Korean Inst. Mining Geol.
Vol. 26, No. 2, p. 187-191, 1993.

Fission Track Zircon Ages of the Igneous Rocks in the Hamyang-Geochang Area, South Korea

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ABSTRACT: FT dating of twelve zircon concentrates was carried out on the igneous rocks in the study area.

The FT results from this study are younger than those of Rb-Sr or K-Ar by 20Ma, probably, due to the different closing temperature of the minerals. The obtained ages are 161± 11 Ma to 150± 10 Ma for the gneissose granodiorite and the Geochang granodiorite. It is estimated that the intermediate and basic rocks were formed at twice: one from 148± 13 Ma to 144± 8 Ma, and the other from 122± 8 Ma to 104± 7 Ma. In the case of the Gajo granite, the age is 96.5± 5.7 Ma to 95.4± 6.4 Ma.

Although considering the fact that the FT age is younger than the K-Ar age, it is likely that the magmatism in the Jurassic period was most intense in the area, which was associated with the Daebo orogeny.

INTRODUCTION

In the southwestern part of the Ryongnam massif, some igneous rocks which have different age had intruded the Precambrian gneiss complex. The intrusion age for the igneous rocks has been mostly determined by the K-Ar and Rb-Sr dating (Kim, 1971; Choo, 1986; Hong et al., 1988; Kim et al, 1989).

But the fission track (FT) age of each rock in the area has been seldom reported. Various additional kinds of data, as well as interpretations of the intricated Mesozoic magmatism of the study area will be necessary.

In this study, FT dating is carried out for zircons of twelve rock samples from the area. And the result of FT dating will be compared with previously published K-Ar and Rb-Sr ages.

GENERAL GEOLOGY

The Mesozoic plutonic rocks in the area are mainly composed of the gneissose granodiorite, the Geochang granodiorite, the intermediate and basic rocks, and the Gajo granite. The gneissose granodiorite and the Geochang granodiorite are covered with the Cretaceous sedimentary rocks along their eastern boundary.

The gneissose granodiorite, showing weak gneissosity, is scattered irregularly in the area, except the northern part. The Geochang granodiorite is mainly exposed in the northern part, the intermediate and basic rocks mostly in the southern part, the Gajo granite in the northern part of the area. The intermediate and basic rocks have been devided into the gabbro, the diorite, and the syenite (Geological and Mineral Institute of Korea, 1973). The intrusion age and the correlation among these intermediate and basic rocks are not obvious yet. The Gajo granite intruded all rocks above mentioned, shows many small rocks of irregular shape.

The igneous rocks in the area belong to the calc-alkaline rock series, the I-type (magnetite series) rock suits, and compressional rock suits. The rocks are interpreted to have originated in an calc-alkaline liquid which could be produced by the partial melting of the lowest crust or upper mantle.

EXPERIMENTAL PROCEDURE

The FT dating procedure was carried out using the external detector method on zircon crystals separated by panning. After crushing a rock sample, some mineral particles were sifted through a sixty-mesh sieve and washed with water. The separation of zircon concentrates from these mineral particles was effectively carried out using several beakers, a magnet bar, and a sieve of a hundred mesh under dry conditions.

About thirty zircon crystals were mounted on a PFA sheet (D=15 mm, T=0.5 mm) on a hot plate

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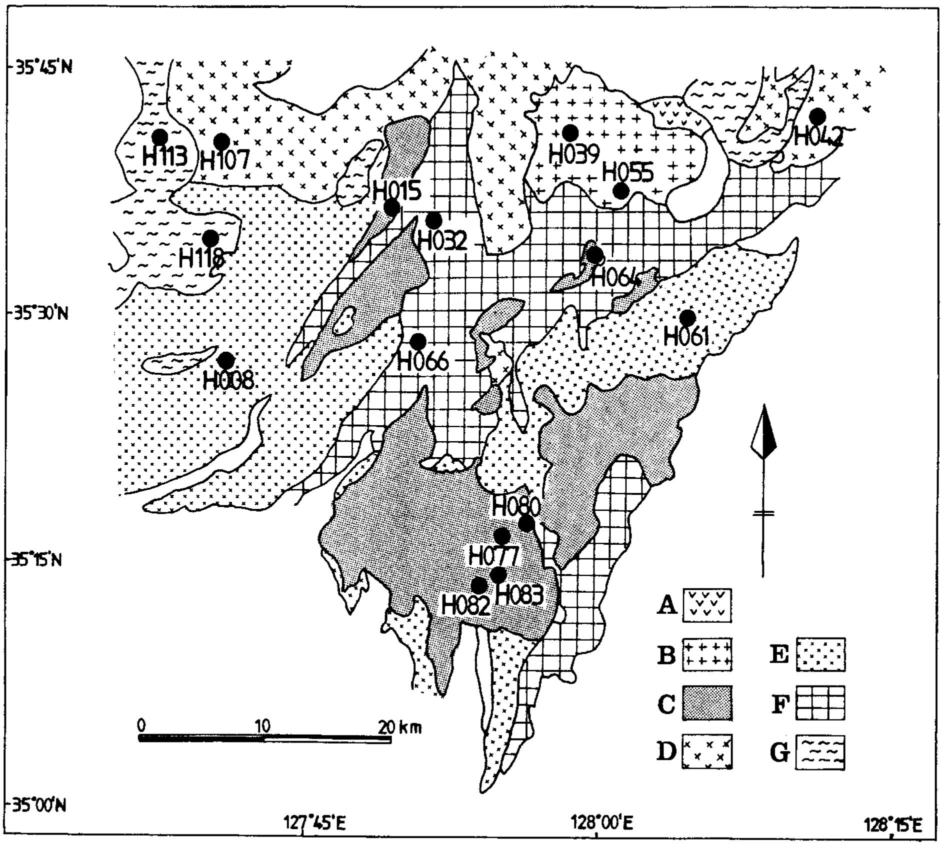

Fig. 1. Geological map of the study area and sampling localities. A; intermediate volcanic rocks, B; Gajo granite, C; intermediate and basic plutonic rocks, D; Geochang granodiorite, E; gneissose granodiorite, F; Jirisan gneiss complex, and G; Sobaegsan gneiss complex.

at 350°C. After polishing the sheet, spontaneous tracks were etched in a NaOH+KOH solution at 230°C for 20~24 hours.

The thermal neutron fluence was evaluated using the standard glass of SRM 962a from NBS. The thermal neutron fluence was;

$\Phi=\Phi_k\ (\rho_{mu}/\rho_{mk})$

Φ_k=known thermal neutron fluence
=$(4.37\pm 0.09)\times 10^{14}$

ρ_{mk}=track density of the mica of the known thermal neutron fluence
=$(9.06\pm 0.26)\times 10^{5}$

ρ_{mu}=track density of the mica of the unknown thermal neutron fluence
=$(8.39\pm 0.13)\times 10^{5}$

The values determined using copper foil, $(4.37\pm 0.09)\times 10^{14}\,\mathrm{n\cdot cm^2}$, were chosen for the known thermal neutron fluence and its standard deviation in this study (Hurford and Green, 1982).

Both mica sheets (known and unknown fluence) were etched in a 46% HF solution at 25°C for 30~45 min. The standard error of the thermal neutron fluence is;

$E\phi=(1/N_{mk}+1/N_{mu}+E\phi_k^2)^{1/2}$

N_{mk}=total number of tracks counted on the mica irradiated with the known thermal neutron fluence

N_{mu}=total number of tracks counted on the mica irradiated with the unknown thermal neutron fluence

$E\phi k$=relative standard error of the known thermal neutron fluence (standard deviation divided by the mean)

A fission track age for a set of grains can be calculated from the following equation which is slightly modified after Fleisher et al. (1965):

Table 1. Analytical data of the fission track dating of the igneous rocks in the Hamyang-Geochang area.

Sample Name	Spontaneous track density (×10⁶/cm²)	Number of spontaneous count	Induced track density (×10⁶/cm²)	Number of induced count	Neutron fluence (×10¹⁴)	Age and standard error(Ma)
Gj-H039	4.40±0.11	1506	1.12±0.06	384	4.05±0.13	95.4± 6.4
Gj-H055	5.36±0.12	2119	1.35±0.06	534	4.05±0.13	96.5± 5.7
IB(s)-H077	4.91±0.12	1672	1.15±0.06	391	4.05±0.13	104 ± 7
IB(s)-H082	Impossible to date because zircon is cloudy					
IB(d)-H015	5.84±0.16	1357	1.26±0.07	293	4.05±0.13	113 ± 8
IB(d)-H064	7.07±0.17	1695	1.41±0.08	337	4.05±0.13	122 ± 8
IB(g)-H083	9.19±0.18	2633	1.55±0.07	444	4.05±0.13	144 ± 8
IB(g)-H080	8.23±0.24	1214	1.35±0.10	199	4.05±0.13	148 ±13
Gc-H107	10.14±0.18	3007	1.59±0.07	471	4.05±0.13	155 ± 9
Gc-H042	8.79±0.18	2516	1.35±0.07	387	4.05±0.13	158 ±10
HGn-H008	9.62±0.20	2408	1.56±0.08	390	4.05±0.13	150 ±10
HGn-H061	9.55±0.20	2205	1.44±0.08	332	4.05±0.13	161 ±11

Table 2. Data of the K-Ar ages and the Rb-Sr ages of the igneous rocks.

Rock	K-Ar dating			Rock	Rb-Sr dating		
	Age(Ma)	Mineral	References		Age(Ma)	Mineral	References
IB(d)	179±9	hornblende	Kim et al.(1989)				
Gc	178±9	hornblende	Kim et al.(1989)	Gc	370±30	whole rock	Choo(1986)
HGn	179±5	biotite	Kim(1986)	HGn	200±5	whole rock	Kim et al.(1989)
HGn	179±0.5	muscovite	Kim(1986)	HGn	203±5	whole rock	Kim et al.(1989)
HGn	179±0.9	biotite	Kim(1986)				

$A=(1/\lambda_d)\ \ln\ (1+\lambda_d\lambda_f^{-1}\ \sigma\ I\ NsNi^{-1}\ \Phi)$

A = fission track age in years

λ_d = total decay constant for ^{238}U ($1.55125\times10^{-10}yr^{-1}$; Jaffey et al., 1971)

λ_f = decay constant for spontaneous fission of ^{238}U ($7.03\times10^{-17}yr^{-1}$; Robert et al., 1968)

σ = cross section for inducing fission of ^{235}U with thermal neutrons ($582.2\times10^{-24}cm^2$; Mughabghab and Garber, 1973)

I = present-day atomic ratio $^{235}U/^{238}U$ (7.2527×10^{-3}; Cowan and Adler, 1976)

Ns = total number of spontaneous tracks counted

Ni = total number of induced tracks counted

Φ = thermal neutron fluence ($n\cdot cm^{-2}$)

Substituting the values for constants, the equation would be rewritten:

$A=6.45\times10^9\ \ln\ (1+9.32\times10^{-18}\ NsNi^{-1}\ \Phi)$

An equation to calculate the standard error of the age is as follows:

$S_A=A(1/Ns+1/Ni+E\phi^2)^{1/2}$

The zeta values for SRM 612a glass have been determined using the TRIGA MARK II reactor from Rikkyo University, according to the standardization

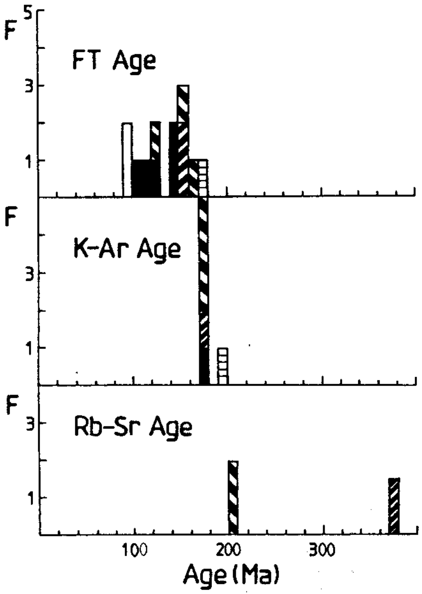

Fig. 2. Frequency of radiometric ages for the igneous rocks in the study area. F; Frequency.

from the International Fission Track Working Group (Hurford, 1990). The standard zircons used were separated from the 27.8± 0.7 Ma Fish Canyon Tuff (FCT), 16.2± 0.2 Ma Buluk Member Tuff (BMT), and 58.7± 1.1 Ma Tardree Rhyolite (TR). The average of 9 zeta values obtained and its standard deviation is 340± 21.

RESULTS AND DISCUSSION

The results of the FT dating are listed in Table 1. The FT dating of age unknown igneous rocks, i.e. the intermediate and basic rocks in the area, was especially evaluated. The zircon crystals from the Precambrian gneiss complex had such a high spontaneous track density that it was impossible to count the tracks.

The ages were calculated to be 161± 11 Ma to 150 ± 10 Ma for the gneissose granodiorite and the Geochang granodiorite. The FT results from this study (Table 1) are younger than those of Rb-Sr or K-Ar (Table 2) by 20 Ma, probably, due to the different closing temperature of the minerals. The closing temperature of zircon is 175± 25℃ in the FT dating, and the temperatures of muscovite are 350± 50℃ in K-Ar dating, 500± 50℃ in Rb-Sr dating respectively. It may be that the age data do not indicate an intrusion age, but indicate the age of mineral at the time of the closing temperature (the Petrological Subcommittee of the Geological Society of Korea, 1988).

It was estimated that the intermediate and basic rocks were formed on two occasions; one from 148± 13 Ma to 144± 8 Ma, and the other from 122± 8 Ma to 104± 7 Ma. The previous geochronological study of the intermediate and basic rocks was not reported yet, and the FT results could not be compared with any other data. It is difficult to conclude the age of the intermediate and basic rocks by only the FT results, taking into account the world-wide occurrence, the geographical distribution, and the correlation to the intermediate and basic rocks of the anorthosite. The added data for the intermediate and basic rocks must be determined by another methods such as the K-Ar and Rb-Sr dating.

In the case of the Gajo granite, the age is 96.5± 5.7 Ma to 95.4± 6.4 Ma.

Above FT results from this study, during the Mesozoic era, could originate in sporadic magmatism, cooling, and denudation of the crust. Although considering the fact that the FT age is younger than the K-Ar age, it is likely that the magmatism associated with the Daebo orogeny in the Jurassic period was most intense in the area, because the Jurassic rock bodies are the widest in geographical distributions.

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Manuscript received 19 June 1992

咸陽-居昌 地域, 火成岩類의 저어콘 휫션트랙 年代

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요 약 : 연구 지역내 화성암류로부터 얻은 13개의 저어콘에 대한 휫션트랙 연대가 측정되었다.

본 연구에서 얻은 휫션트랙 저어콘 연대는 Rb-Sr법 또는 K-Ar법에 의한 선행연구의 결과보다 약 2천만년 정도 젊게 나타났다. 이는 아마 측정 대상 광물의 연령보존온도가 각기 다른 때문인 것으로 보인다. 소백산편마암복합체는 자발핵분열비적의 밀도가 너무 높아서 측정이 불가능했으며, 편마상화강섬록암과 거창화강섬록암은 161± 11 Ma~150± 10 Ma로 나타났다. 연구 지역내 중성 및 염기성암류는 148± 13 Ma~144± 8 Ma와 126± 9 Ma~104± 7 Ma의 2차례에 걸쳐 형성된 것으로 생각된다. 가조화강암의 연대는 96.5± 5.7 Ma~95.4± 6.4 Ma로 나타났다.

중생대에 있어서, 이러한 휫션트랙 저어콘 연대의 측정 결과는 단속적인 마그마활동, Cooling 또는 지각의 상승 및 삭박작용 등이 주된 원인으로 작용되었을 것이다. 휫션트랙의 연대가 K-Ar법 보다 젊게 측정되었음을 감안해 보더라도, 본 지역은 쥬라기때 대보 조산운동과 관련하여 가장 격렬한 화성활동을 겪었던 것 같다.