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$^{40}Ar/^{39}Ar$ ISOTOPIC DATING THE BIOTITES FROM THE IGNEOUS AND METAMORPHIC ROCKS OF THE ZHONGSHAN STATION AREA*

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Abstract The Zhongshan Station of China is located in the Larsemann Hills, East Antarctica. Low pressure granulite facies gneisses together with late granites are outcroped in the region. Three biotite samples from a garnet segregation, a syenogranite and a granite-pegmetite were measured with $^{40}Ar/^{39}Ar$ incremental heating technique. Biotites from the garnet segregation give an $^{40}Ar/^{39}Ar$ plateau age of 504±1Ma. Biotites from the syenogranite yield an $^{40}Ar/^{39}Ar$ plateau age of 494 ± 1 Ma. Biotites from the granite-pegmatite give an $^{40}Ar/^{39}Ar$ plateay age of 486±1Ma. They verify 500 Ma thermal event called "Pan African event" by previous K-Ar and Rb-Sr data. They are cooling ages of the biotites when the paleogeotherm of the area droped to the K-Ar closure temperature for biotite.

Key words Larsemann Hills, biotite, $^{40}Ar/^{39}Ar$ isotopic, dating, early Paleozoic, Pan African event

Geologic Setting

The Zhongshan Station of China is located in the Larsemann Hills, East Antactica (Fig. 1).

Most of rocks outcroped in the region are composed of low pressure granulite facies gneisses as well as less deformed granites (Fig. 2, Stüwe *et al*, 1989)

Much like some other high grade metamorphic tertains of East Antarctica Shield, the first obtained isotopic data by K-Ar and Rb-Sr methods gave the ages around 500 Ma (Picciotto and Coppez, 1963; Ravich *et al.*, 1965; Craddock, 1972). Because these samples came from high grade metamorphic terrains in East Antarctic Shield, which were regarded as Archaean to middle Proterozoic in age by many geologists (Craddock, 1972)

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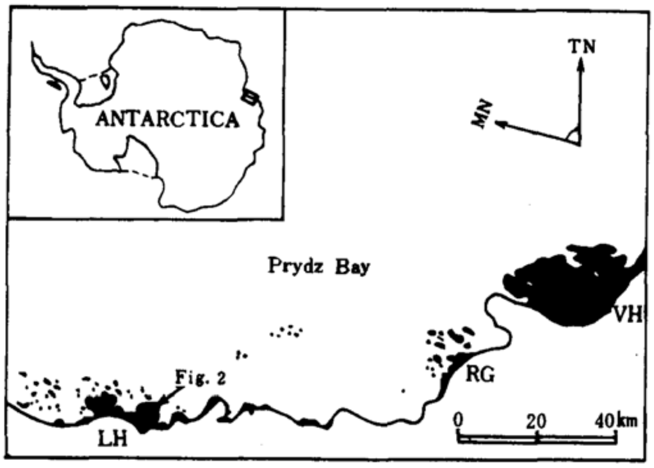

Fig. 1. Map showing the location of the Larsemann Hills. LH: Larsemann Hills, RG: Rauer Group VH: Vestfold Hills.

during 1960's and 1970's based on their metamorphic grades, most geologists now seriously suspect that these samples have suffered radiogenic Ar loss and have been resetted their Rb-Sr system by a late metamorphic thermal event. In order to verify these K-Ar dating data gained in 1960s and more detailed experimental procedure for $^{40}Ar/^{39}Ar$ dating. We give the present paper with detailed $^{40}Ar/^{39}Ar$ dating results.

The three samples given in this paper were collected from Mirror Peninsula, Larsemann Hills. The first one is the metamorphic rock almost identical with garnet segregations described by Stüwe *et al* (1989). Although it is surrounded with gneisses, the rock sample itself have no foliation, and its garnets are idiomorphic. The second is the syenogranite. A dyke of the granite crosscuts gneisses in Broknes Peninsula, while the body of that is transitional to less foliated gneisses in northern Mirror Peninsula. The last is a granite-pegmatite which intruded the syenogranite. Zircon samples from the syenogranite have yielded $^{207}Pb/^{206}Pb$ ages around 550Ma (Zhao *et al.*, 1992). The evidence shows that the three samples are ascribed to later regional thermal event.

Samples

1. Garnet segregation (F22103)

The sample F22103 is a garnet segregation from eastern Friendship Peak, southern Mirror Peninsula (Fig 2.). The cores of segregation garnets are up to 10 cm in diameter. The garnets account for 14% in volume of the rock sample, K-feldspar 17%, plagioclase 54%, biotite 10%, quartz 3%. The magnetite, ilmenite, zircon, rutile and apatite are subordinate. The biotite seperated from the sample F22103 is fresh, up to 5 mm across. Its chemical composition is listed in Table 1.

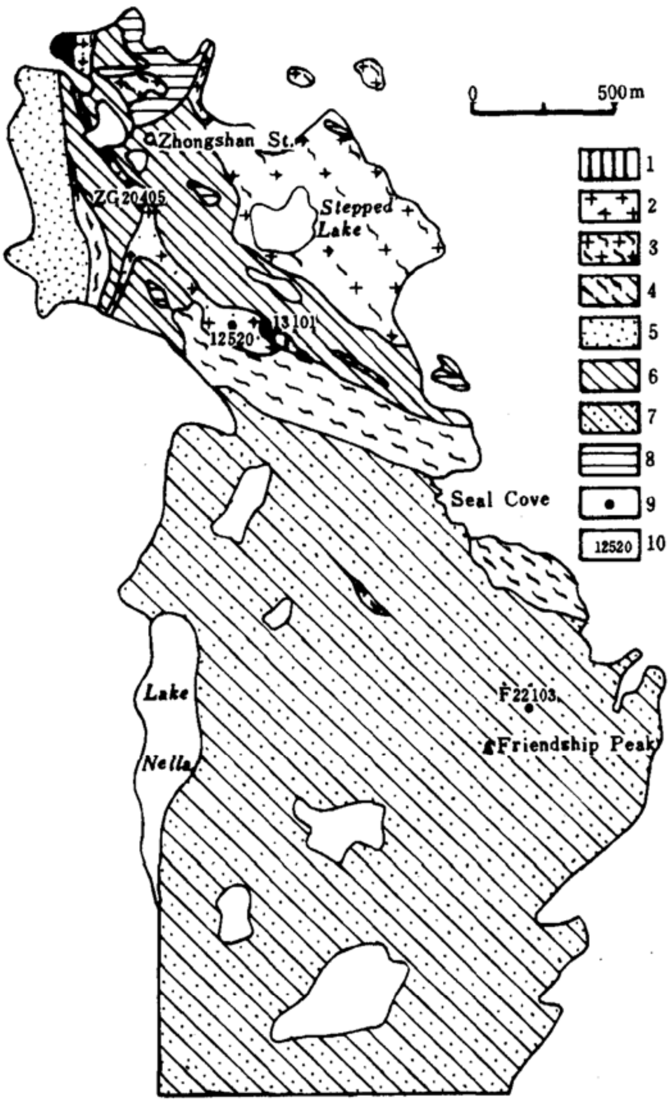

Fig. 2. Geologic map of the Mirror Peninsula region, showing sampling localities. (1) Granite-pegmatite, (2) Syenogranite, (3) Gneissic leucocratic granite. (4) High-Al-Fe-gneisses, (5) Migmatite, (6) Striped migmatite, (7) Heterogeneous migmatic gneisses, (8) Two Pyroxene gneisses, (9) Sampling locality, (10) Sample No.

2. Syenogranite(12520)

The sample 12520 is the biotite syenogranite. It is undeformed to less deformed, medium to coarse grained, with a hypidiomorphic granular texture. It composed mainly of quartz 25%, K-feldspar 50%, plaagioclase 18%, and biotite 5% with garnet 2%. The magnetite, ilmentite, pyrite, allanite , antiperthite, monazite, apatite and zircon are of accessory minerals. The biotite from sample 12520 is up to 4 mm across. No late alteration can be found in the sample. Its chemical composition is given in Table 1.

3. Granite-pegmatite(13101)

The sample 13101 is the granite-pegmatite, and came from just west of The Progress Ⅱ Station (USSR), where the granite pegmatite intruded the syenogranite. It contains quartz (30%), feldspar (62%), biotite (7%), with accessory minerals of garnet, magnetite, ilmenites, pyrite, zircon, and apatite. The biotite of the sample 13101 is up to 30 mm, and without late alteration. Its chemical composition is shown in Table 1.

Table 1. Microprobe analysis of the biotites from the inneousrocks of the Zhongshan Station area, East Antarctica.

S. N. \ C. C.	SiO_2	CaO	FeO	Na_2O	MgO	Al_2O_3	K_2O	TiO_2	Cr_2O_3	MnO	Total
F22103	34.78	0.04	15.38	0.49	11.85	16.29	10.06	5.25	—	—	94.14
	38.81	—	16.25	0.09	12.86	11.90	8.58	4.82	—	0.14	96.45
12510	34.22	0.00	17.25	0.18	9.46	14.77	9.70	5.09	3.18	1.28	95.08
13101	36.11	0.00	13.20	0.14	10.37	14.54	10.01	4.07	3.14	3.41	95.00

C. C. :Chemical composition, S. N. : Sample No.

Experimental Technique for $^{40}Ar/^{39}Ar$ Dating

The samples studied were packed with aluminium foils in 4~5 mm diameter and loaded into small aluminium cylinders with dimensions of 5~6mm (diameter) and 28~30 mm (length), marking sample position in cylinders. About 20~30 cylinder were vertically sealed into a glass container with dimensions of 30 mm (diameter) and 35 mm (height). The glass container was covered with a sheet of cadmiun (thickness 0.5 mm) to shield the samples from thermal neutrons, and then it was placed into an Al can that could be placed in the reactor. These samples were irradiated in the core of irradiation facility H_4 of the 49—2 Reactor in Chinese Academy of Atomic Energy Sciences. The can is retated twice per minute to decrease horizontal change of neutron flux. Immediate fast neutron flux is $5.8\times10^{12}n/(cm^2 \cdot s)$, irradiation duration is 59.7 hours, and accumulative fast neutron flux is $1.2\times10^{18}n/cm^2$.

K-Ar standard biotite ZBH—25 (Fangshan, Beijing)with a K-Ar age of 133.5 Ma was used as "flux monitor". Variation or irradiation parameter J-value with the position of monitor is so signifiacnt (Fu, 1989) that we have to correct J-value for sample position in the reactor. The measured results show that the correlation between J-value and longitudinal distance (within 30 mm) is linear at the same horizontal position, and the slopes are approximately the same within the error range. Based on this linearity correlation, the J-value of the unkown sample, whose longitudinal distance is known, can be calculated by interpolated and extrapolated the line. By means of this calculating method, the error of the J-value of unkown sample can be about ±1%.

CaF_2 of optical pure and K_2SO_4(G. R.) with the samples were irradiated, fused, and measured with mass spectrometer MM—1200. Interfering isotopic corrected factors are (Fu *et al.*, 1987):

$C_2 = (^{36}Ar/^{37}Ar)_{Ca} = (2.40 \pm 0.24) \times 10^{-4}$;

$C_4 = (^{39}Ar/^{37}Ar)_{Ca} = (8.09 \pm 0.10) \times 10^{-4}$;

$C_3 = (^{40}Ar/^{39}Ar)_{Ca} = (4.78 \pm 0.24) \times 10^{-3}$;

Incremental heating experiments were performed on the mass spectrometer MM—1200, where the pressure is about 10^{-7} Pa. In the extraction system, the sample is heated with electron bombardment furnace, and purified with titanium sponge furnace. The tempreture of every step is lasted for about 1 h. Argon isotope is analysed in static analysis at emission current 100 μA. The computer HP—9845(B) controls the peak jumping, treats data for $^{40}Ar/^{39}Ar$ dating, and yields age spectrogram, isochron diagram and so on.

The constants used in calculating age are: the decay constants of ^{40}K by K-electron capture $\lambda_e = 0.581 \times 10^{-10}$ year^{-1}, and the decay constant of ^{40}K by β-emission $\lambda_\beta = 4.962 \times 10^{-10}$ year^{-1}, the error in age is given by 1σ.

Experimental Results

We measured sample biotite F22103 with $^{40}Ar/^{39}Ar$ incremental heating technique and obtained analytical data which are listed in Table 2. The data for sample biotite F22103

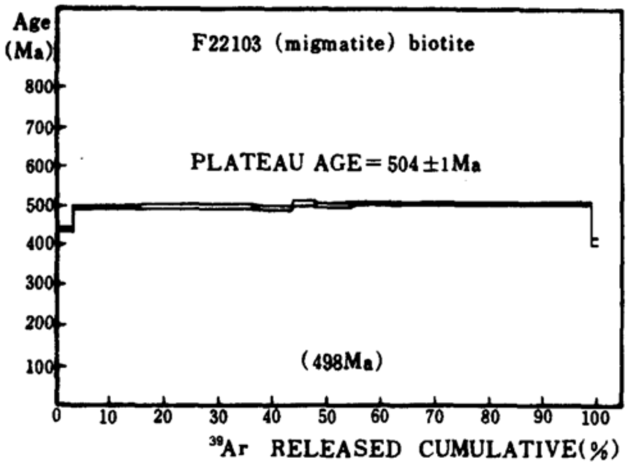

Fig. 3. $^{40}Ar/^{39}Ar$ age spectrum for biotite F22103.

display an age spectrogram which is approximately a straight line (Fig. 3). The plateau age is 504.43±1.38 Ma. We obtained the intercept $(^{40}Ar/^{39}Ar)_i$ 289.41±13.23 and isochron age 501.85±7.20 Ma (Fig 4).

The $^{40}Ar/^{39}Ar$ analytical data for the biotite sample 12520 are listed in Table 2. An age spectrogram which is presented in Fig. 5 is approximately a straight line, whose plateau age is 494.39±1.26 Ma. $^{40}Ar/^{39}Ar$ isochron diagram as shown in Fig. 6 yields the intercept $(^{40}Ar/^{36}Ar)_i$ 292.18±3.79 and the isochron age 495.38±4.63 Ma which is the same as the plateau age within error.

Table 2. $^{40}Ar/^{39}Ar$ analytical data for incremental heating experiments biotites of the metamorphic and igneous rocks from the Larsemann Hills, East Antarctica.

Release temp. ℃	$(^{40}Ar/^{39}Ar)m$	$(^{36}Ar/^{39}Ar)m$	$(^{37}Ar/^{39}Ar)m$	$^{40}Ar^{*}/^{39}Ar$	$^{39}Ar(mol) \times 10^{-14}$	Apparent age (Ma)	^{39}Ar-Cam (%)
Sample 13101: Weight=54. mg J=0. 01103							
570	42. 8414	0. 0540	0. 0662	26. 8796	157. 16	468. 420±4. 46	6. 3
670	33. 7231	0. 0194	0. 0206	27. 9914	354. 36	485. 40±4. 90	20. 5
750	31. 8507	0. 0128	0. 0107	28. 0526	537. 76	485. 33±4. 70	42. 0
830	31. 7119	0. 0122	0. 0090	28. 0895	544. 93	486. 89±4. 71	64. 3
910	38. 3420	0. 0355	0. 0343	27. 8528	160. 04	483. 29±4. 37	70. 7
1000	44. 4695	0. 0558	0. 0389	27. 9805	152. 16	485. 23±4. 95	76. 8
1075	37. 2457	0. 0311	0. 0238	28. 0635	219. 38	483. 50±5. 24	86. 2
1200	33. 7379	0. 0189	0. 0206	28. 1595	330. 45	487. 95±5. 03	99. 5
1042	80. 2106	0. 2701	0. 6457	0. 4498	11. 44	8. 93±63. 62	100. 0
Total						482. 48	100
Total without 570 and 1420℃						485. 84±0. 58	93. 2
Sample 12520: Weight=46. 3. mg J=0. 01108							
570	45. 6779	0. 0661	0. 1028	26. 1492	172. 02	459. 00±8. 99	8. 53
670	31. 5999	0. 0102	0. 0125	28. 5791	658. 66	496. 27±4. 40	41. 3
750	32. 3925	0. 0135	0. 0183	28. 3945	407. 94	493. 47±4. 37	61. 6
830	37. 0871	0. 0293	0. 0310	28. 4200	227. 77	493. 86±4. 38	73. 0
910	42. 7704	0. 0494	0. 0676	28. 1605	117. 30	489. 91±4. 99	78. 8
1000	50. 9506	0. 0769	0. 0746	28. 2321	94. 41	491. 00±4. 93	83. 7
1075	37. 6719	0. 0313	0. 0355	28. 4212	178. 11	493 87±4. 46	92. 6
1200	40. 0536	0. 0378	0. 0337	28. 8718	342. 59	500. 71±4. 98	99. 7
1042	290. 4318	0. 9788	0. 8686	1. 4232	5. 36	24. 68±79. 53	100. 0
Total						490. 46	100
Total without 570 and 1420℃						494. 39±1. 26	91. 2
Sample 22103: Weight=47. 4. mg J=0. 01111							
570	57. 5836	0. 1111	0. 1513	24. 7592	67. 55	438. 38±5. 83	3. 1
670	37. 8714	0. 0320	4. 6517	28. 4247	264. 96	495. 10±4. 60	15. 6
760	34. 3969	0. 0199	0. 0165	28. 5270	439. 47	496. 65±4. 48	36. 4
830	36. 9421	0. 297	0. 0468	28. 1588	156. 79	493. 36±4. 48	43. 7
910	48. 7618	0. 0666	0. 0719	29. 0820	83. 93	505. 08±4. 62	64. 5
1000	41. 4977	0. 0430	0. 0469	28. 7786	146. 02	500. 48±4. 91	54. 6
1075	38. 4004	0. 0313	0. 0370	29. 1400	209. 85	505. 96±4. 62	64. 5
1200	31. 8807	0. 0092	0. 0087	29. 1438	731. 46	506. 02±4. 56	99. 0
1420	108. 7074	0. 2899	0. 2865	23. 0683	20. 98	411. 61±9. 28	100. 0
Total						498. 27	
910—120 1420℃						504. 43±1. 36	55. 3

$^{40}Ar^{*}$: radiogenic ^{40}Ar
one sigma intralabolotory errors

The measured data for sample biotite 13101 are listed in Table 2. An age spectrogram which is approximately a straight line is illustrated in Fig 7, and the plateau age is 485. 84± 0. 85 Ma. $^{40}Ar/^{39}Ar$ isochron diagram is shown in Fig. 8, which yields the isochron age 486. 34±4. 31 Ma and the intercept $(^{40}Ar/^{39}Ar)_i$ 294. 82±1. 59.

Experimental results show that these samples were formed 485—504 Ma ago, and are products of Pan-African Event.

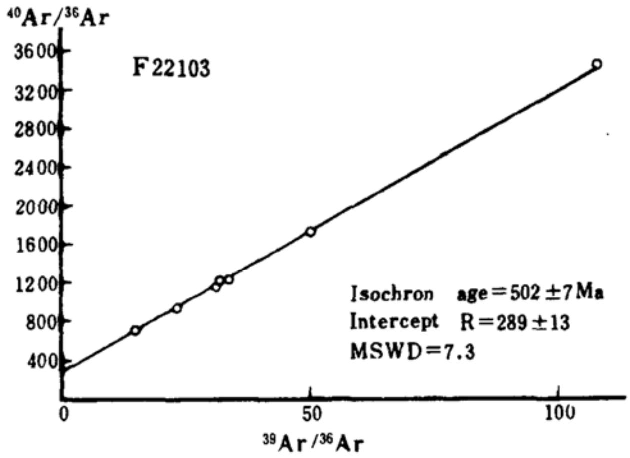

Fig. 4. $^{40}Ar/^{39}Ar$ isochron diagram for biotite F22103.

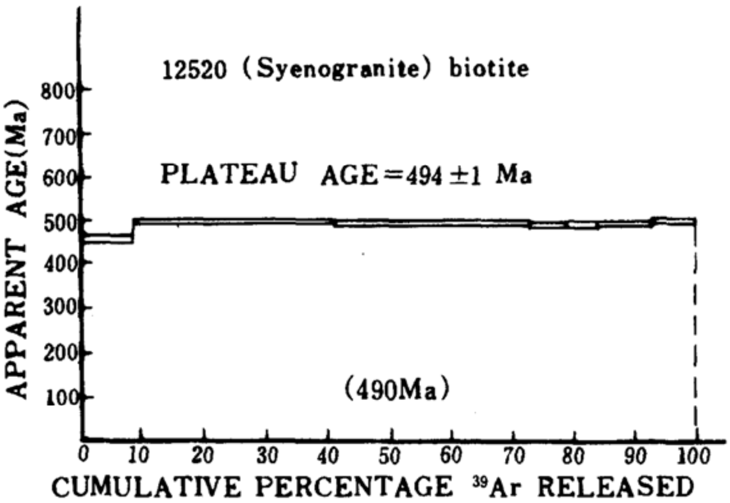

Fig. 5. $^{40}Ar/^{39}Ar$ age spectrum for biotite 12520.

Conclusion

The results of $^{40}Ar/^{39}Ar$ dating of biotites from metamorphic and igneous rocks of the Zhongshan Station region, Larsemann Hills, East Antarctica verify C. 500Ma thermal event, called 'Pan African event' by the previous K-Ar and Rb-Sr data. They are cooling ages for the biotites when thepaleo-geotherm of the Larsemann Hills terrane droped to the K-Ar closure temperature for biotite after the peak granulite metamorphism of this region. Afterward, the K-Ar systems of the biotites have not been disturbed.

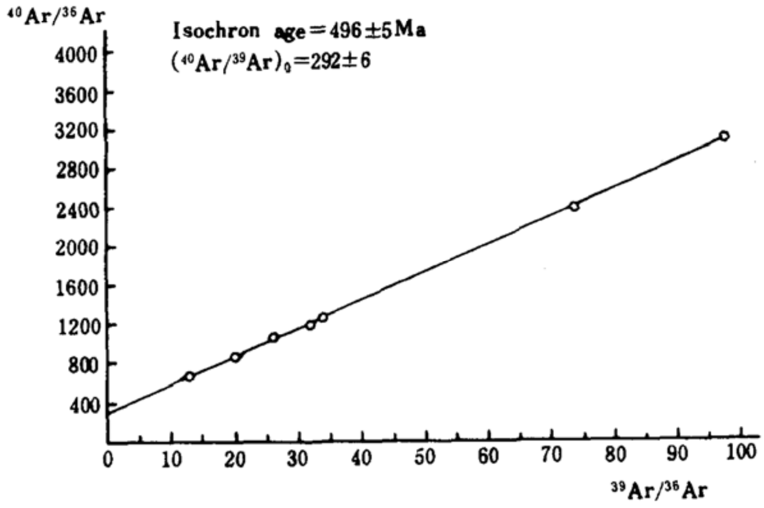

Fig. 6. $^{40}Ar/^{39}Ar$ isochron diagram for biotite 12520.

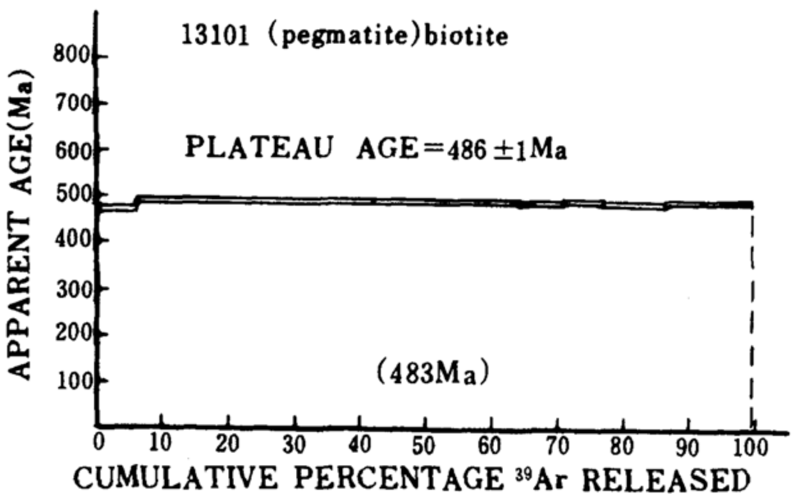

Fig. 7. $^{40}Ar/^{39}Ar$ age spectrum for biotite 13101.

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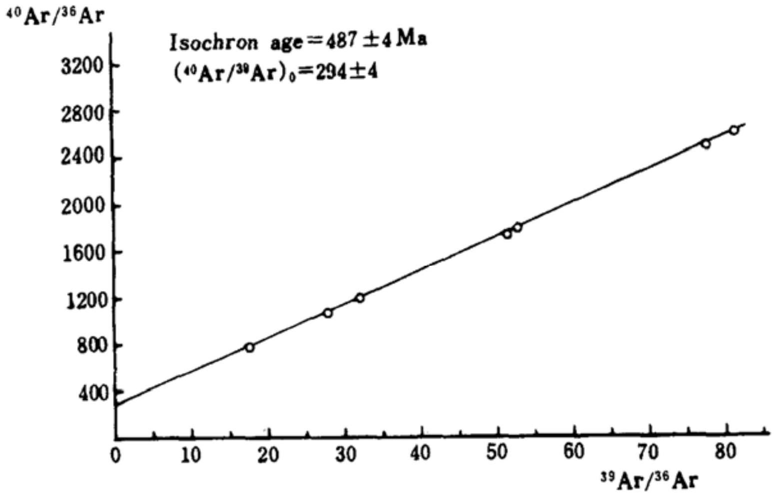

Fig. 8. ^{40}Ar/^{39}Ar isochron diagram for biotite 13101.

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