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$^{40}Ar/^{39}Ar$ age-spectrum data for the Buffalo Hump mining district, Clearwater Mountains, central Idaho

By

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The report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

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Introduction

The Buffalo Hump mining district, Idaho County, west-central Idaho, is one of seven lode-mining districts in the Clearwater Mountains north of the Salmon River and south of the Middle Fork of the Clearwater River (fig. 1). Gold-bearing quartz veins and their country rocks in the district have been the subject of an $^{40}Ar/^{39}Ar$ age-spectrum dating study. The purpose of this report is to present the analytical techniques employed in that study and to compile the resultant $^{40}Ar/^{39}Ar$ age-spectrum data. The interpretation of these data is presented in Lund and others (1985).

Geologic setting

Upper greenschist to amphibolite facies metasedimentary rocks and amphibolites in the Buffalo Hump district were multiply deformed and metamorphosed prior to the emplacement of the Idaho batholith (Lund, 1984; Lund and others, 1985). These metamorphic rocks are now preserved in roof pendants within the batholith. In this area, the oldest pluton of the Idaho batholith is hornblende-biotite tonalite. The tonalite discordantly cuts the foliation in the metasedimentary rocks. Both tonalite and metasedimentary rocks are cross-cut by muscovite-biotite granite. Auriferous quartz veins were precipitated in north-northeast-trending fractures that cut the batholith and the metasedimentary units. The veins range up to 10 m in width and are composed mainly of coarsely crystalline, milky white quartz exhibiting uncommon banding and open-space filling. The quartz vein material appears to have been deposited, brecciated, and re-introduced several times. Sulfide mineral associations vary from deposit to deposit and they may include pyrite, galena, chalcopyrite, tetrahedrite, sphalerite, and molybdenite. Gold and silver are present mainly as finely dispersed inclusions in the sulfide minerals and as fine-grained free grains in oxidized zones. Alteration around the veins is limited to minor sericitization.

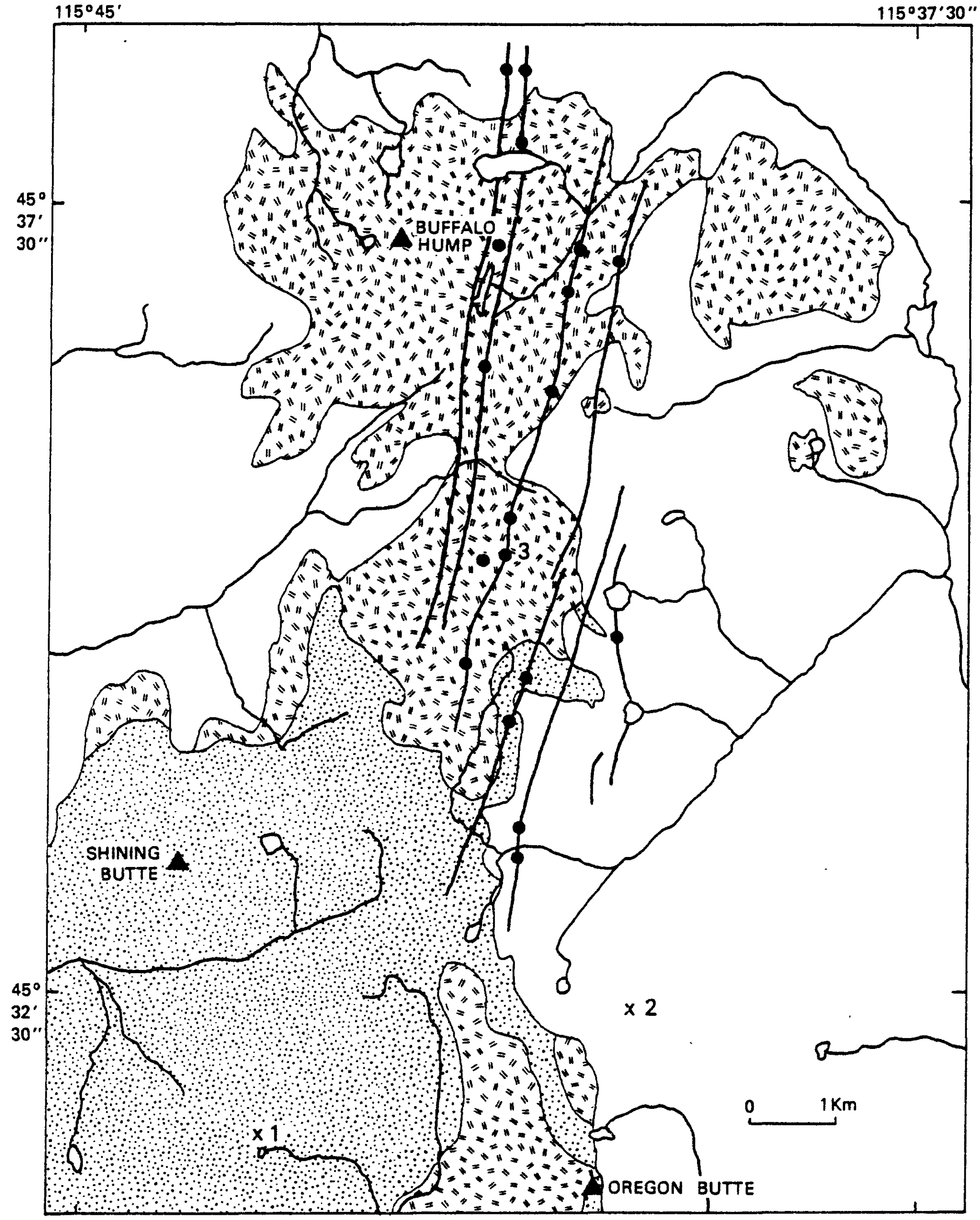

Figure 1--Geology (generalized after Lund, 1984) and vein distribution (after Thompson and Ballard, 1924; Shenon and Reed, 1934) of the Buffalo Hump district showing sample localities. 1. Amphibolite (2KE080) 2. Muscovite-biotite granite (1KE052) 3. Quartz vein (2KE087). Dots are mines along the veins. No pattern = Cretaceous igneous rocks; Double stripe pattern = mixed igneous and metasedimentary rocks; Fine stipple pattern = Middle Proterozoic metasedimentary rocks.

Techniques

Sample collection and mineral separation

Three representative samples from amphibolite (2KE080) in the metasedimentary roof pendant, muscovite-biotite granite (sample 1KE052), and gold-bearing quartz vein (sample 2KE087) were collected in the Buffalo Hump 7 1/2′ quadrangle to define the thermal history and the age of mineralization of the Buffalo Hump district (fig. 1). Thin sections were prepared for each

Sample number	Latitude	Longitude
2KE080	$45^{\circ}31'50''$N	$115^{\circ}43'11''$W
1KE052	$45^{\circ}32'24''$N	$115^{\circ}40'10''$W
2KE087	$45^{\circ}35'14''$N	$115^{\circ}40'53''$W

sample and studied petrographically. Samples for mineral dating were examined to determine the character of hornblende, biotite, muscovite, and K-feldspar with particular attention to grain size, alteration, intergrowths of other K-bearing minerals, presence of overgrowths of other minerals, and structural state of the K-feldspar. The minerals selected for dating were hornblende and biotite from amphibolite, muscovite and microcline from muscovite-biotite granite, and muscovite from the quartz vein.

Samples were crushed, pulverized, sized, and washed in tap water and acetone. Grain size used for mineral separates ranged from 125 to 250 m. Purified mineral separates of hornblende, biotite, muscovite, and microcline were then obtained by techniques using one or more of the following: heavy liquids, magnetic separation, and paper friction. Hand picking was usually necessary to ensure 99.9 percent purity. Mineral separates were then washed in acetone, ethyl alcohol, and distilled water, and dried at $100^{\circ}C$ for 30 to 60 minutes.

$^{40}Ar/^{39}Ar$ analysis

After purification, approximately 0.1 g microcline, 0.1 g biotite, 0.2 g muscovite, and 1.0 g hornblende were loaded into aluminum capsules. The aluminum capsules were stacked in 6 mm (inside diameter) commercial quartz vials to a length that did not exceed 4.2 inches. The sample container was like that described by Dalrymple and others (1981, Exhibit C, fig. 7, p. 9). In this container, 6 quartz vials are systematically disposed around the inside wall of an aluminum canister. Several capsules containing 0.04 g of flux monitor were dispersed throughout each vial. The primary flux monitor for the experiment was hornblende MMHb-1 with percent-K^+ = 1.555 ± 0.001, $^{40}Ar_R$ = 1.624 ± 0.005 x 10^{-9} mol/g, and K/Ar age = 519.5 Ma (Alexander and others, 1978).

Samples were irradiated at a power level of 1 megawatt in the central thimble of the U.S. Geological Survey TRIGA reactor (GSTR), Denver, Colorado. Total time of irradiation was 37 hours over the period from January 18, 1983, to February 3, 1983. This length of irradiation was chosen to ensure optimum Ar ratios for samples and monitors. After a "cool-down" period of approximately two weeks in the pool of GSTR, the samples were shipped to the Isotope Laboratory, USGS, Reston, Virginia.

Argon analysis was done on a VG Instruments MM1200B mass spectrometer under the supervision of John F. Sutter, USGS, Reston, Virginia. Gas extraction was performed in an ultra-high vacuum extraction system that is on-line with the mass spectrometer. Extractions were not made if pressures were greater than 10^{-8} torr. The aluminum capsules containing the irradiated monitors or samples were dropped into a molybdenum crucible from a sidearm on the extraction bottle. The extraction bottle is constructed of pyrex with internal liners of commercial-grade quartz. Gas was extracted in one step from monitors and in 4 to 14 steps ranging from about $400^{o}C$ to $1,350^{o}C$ from samples. Heating was done using a Lepel radio-frequency generator; temperature was monitored with an optical pyrometer. Each heating step lasted 20 minutes. During heating the gas was collected on a charcoal trap cooled to the temperature of liquid nitrogen. After each step, gas was purified by reaction with hot Cu/CuO, molecular sieve desiccant, and hot Ti foil. The purified gas from each heating step was immediately transferred to the mass spectrometer for analysis. Analyses were performed in the static mode. Isotopes ^{36}Ar, ^{37}Ar, ^{38}Ar, ^{39}Ar, and ^{40}Ar and their baselines were measured by magnetic field switching. Each isotope was collected on a Faraday cup and its intensity was measured on a VG Instruments Integrating digital voltmeter. Five complete sets of intensity data were collected. Data reduction was done on a Hewlett-Packard HP9845 computer that is on-line with the mass spectrometer. Time-zero intensities for each isotope were calculated after baseline corrections were made. Blanks were analyzed each day of analysis and air standards were periodically analyzed to determine the discrimination factor of Ar isotopes in this mass spectrometer. Sensitivity of the mass spectrometer is approximately 1×10^{-17} moles Ar/count.

$^{40}Ar/^{39}Ar$ dates were calculated as described by Dalrymple and others (1981). The age equation is

$$t_u = \frac{1}{\lambda} \ln (JF + 1)$$

where t_u = age of unknown, J is the flux parameter, and F is the corrected $^{40}Ar/^{39}Ar$ ratio. J is determined from measurements on the monitors and can be calculated from the equation $J = (e^{\lambda t_m} - 1)/(^{40}Ar/^{39}Ar)_m$ where λ is the ^{40}K decay constant for decay to ^{40}Ar, t_m is the age of the monitor (519.5 Ma), and m is a subscript for monitor. During irradiation numerous reactions occur beside the production of ^{39}Ar from ^{39}K. Some of these produce isotopes of argon that interfere with the above calculation. Of these reactions, three produce significant amounts of Ar that must be corrected. These are ^{36}Ar and ^{39}Ar from Ca, and ^{40}Ar from K. Corrections are made by measuring production ratios within GSTR. Production ratios for GSTR are $(^{36}Ar/^{37}Ar)_{Ca} = (2.67 \pm 0.017) \times 10^{-4}$ (25 determinations), $(^{39}Ar/^{37}Ar)_{Ca} = (6.73 \pm 0.037) \times 10^{-4}$ (25 determinations), and $(^{40}Ar/^{39}Ar)_K = (0.59 \pm 0.072) \times 10^{-2}$ (4 determinations) (Dalrymple and others, 1981). Dalrymple and others (1981) pointed out that $(^{40}Ar/^{39}Ar)_K$ was difficult to reproduce but that it is a direct function of the integrated fast neutron flux, an inverse function of the age of the sample, and independent of the K/Ca ratio. For the Buffalo Hump samples, if no K-derived ^{40}Ar correction were made, the maximum error in age would be 0.2 Ma. Thus, even if a large error exists in the $(^{40}Ar/^{39}Ar)_K$ production ratio, the error in the calculated age would be insignificant for this study. The production ratios were confirmed for this study. Recently Roddick (1983) noted that in some cases a correction for ^{36}Ar produced from Cl is necessary. Using calculations based on his work and Cl concentrations determined by microprobe analysis (Snee, unpublished data, 1983), it was found that for the Buffalo Hump samples the correction needed for this interference was negligible. The only additional correction made was for the half-life of reactor-produced ^{37}Ar. Thus, the actual $(^{40}Ar/^{39}Ar)_K$ or F was calculated from the relationship

$$F = (^{40}Ar/^{39}Ar) - 295.5\ (^{36}Ar/^{39}Ar - (^{36}Ar/^{37}Ar)_{Ca}(^{37}Ar/^{39}Ar))$$
$$- (^{40}Ar/^{39}Ar)_K \ / \ 1-(^{39}Ar/^{37}Ar)_{Ca}(^{37}Ar/^{39}Ar)$$

after a correction for ^{37}Ar decay was made.

Decay constants used in this study are those recommended by Steiger and Jager (1977). These constants are $\lambda_\varepsilon = 0.581 \times 10^{-10}$/yr, $\lambda_{\beta-} = 4.962 \times 10^{-10}$/yr, $\lambda = \lambda_\varepsilon + \lambda_\beta = 5.543 \times 10^{-10}$/yr, and $^{40}Ar/^{36}Ar$ atmosphere = 295.5.

Dalrymple and others (1981) measured K/Ca ratios by independent techniques on many samples of various ratios that were irradiated in GSTR, Denver. From these data, they determined that

$$K/Ca = (0.49 \pm 0.09)\ ^{39}Ar/^{37}Ar_{Ca}$$

This expression has been used to obtain approximate K/Ca ratios for samples in this study.

The error calculated for the age of each temperature increment is done in the manner described by Dalrymple and others (1981). Plateau ages are the average of all temperature fractions that define a plateau. All contiguous temperature fractions whose ages agree with each other as determined by the Critical Value Test (Dalrymple and Lanphere, 1969) are used in the plateau-age calculation. The error calculated for the plateau age is the standard deviation of the ages of all fractions on the plateau.

$^{40}Ar/^{39}Ar$ age-spectrum data are compiled in table 2.

Figure 2 shows the age-spectrum diagrams for the five dated minerals. These figures show apparent age versus cumulative percent ^{39}Ar released during the experiment. Each horizontal line represents a temperature increment of the experiment. The length of the line corresponds to the percentage of ^{39}Ar released during that heating step. Extraction temperature increases progressively to the right. Plateau ages (T_p) are calculated as discussed above.

Table 1.--$^{40}Ar/^{39}Ar$ age-spectrum data for samples of the Buffalo Hump mining district

Temp (°C)	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	F	^{39}Ar (% of total)	$^{40}Ar_R$ %	^{39}Ar (mole x10^{-13})	Apparent K/Ca (mole/mole)	Apparent age (x10^6yr)	Error (1σ x10^6yr)
Sample 2KE080 hornblende; amphibolite; J = 0.008163; wt. = 1.0388g										
550	65.962	5.574	0.2186	1.7797	0.0	2.7	0.0190	0.0929	26.02	30.24
700	50.099	3.858	0.1576	3.8074	0.1	7.6	0.0394	0.134	55.21	10.33
800	115.851	4.294	0.3712	6.4934	0.1	5.6	0.0561	0.121	93.17	19.93
900	63.749	6.192	0.1967	6.1072	0.2	9.6	0.0980	0.0836	87.77	3.21
950	45.918	7.443	0.1388	5.4788	0.5	11.9	0.303	0.0695	78.93	1.75
1000	7.241	5.461	0.007296	5.5013	10.5	76.0	6.50	0.0949	79.25	0.55
1025	6.648	5.108	0.004926	5.5815	15.7	84.0	9.71	0.101	80.38	0.43
1050	7.128	4.967	0.006609	5.5534	9.3	78.0	5.72	0.104	79.98	0.42
1075	7.853	4.855	0.008864	5.6029	6.0	71.4	3.72	0.107	80.68	0.41
1100	7.476	4.795	0.007492	5.6268	6.5	75.3	4.04	0.108	81.01	0.43
1125	6.876	4.847	0.005546	5.6057	9.8	81.6	6.07	0.107	80.72	0.40
1150	6.477	4.859	0.004099	5.6350	15.1	87.1	9.36	0.107	81.13	0.42
1200	6.482	4.835	0.004125	5.6313	23.2	86.9	14.4	0.107	81.08	0.57
FUSE	21.192	4.796	0.05434	5.4998	3.0	26.0	1.83	0.108	79.23	0.68
						Total gas age			80.54	
						Plateau age (1025°-1200°C)			80.77 ± 0.42 Ma	
Sample 2KE080 biotite; amphibolite; J = 0.007930; wt. = 0.0446g										
750	23.175	8.719	0.06056	5.9487	1.8	25.7	0.523	0.0593	83.15	0.97
1050	6.491	0.02517	0.002982	5.6058	65.2	86.4	18.5	20.7	78.46	0.40
1100	7.718	0.2476	0.007440	5.5331	21.9	71.7	6.21	2.10	77.47	0.39
FUSE	10.272	0.8158	0.01631	5.5099	11.1	53.6	3.16	0.637	77.15	0.41
						Total gas age			78.19	
						Plateau age (1050°-1100°C)			78.21 ± 0.40 Ma	
Sample 1KE052 muscovite; muscovite-biotite granite; J = 0.008244; wt. = 0.1812g										
750	6.193	0.003483	0.004020	4.9990	5.4	80.7	5.70	149	72.85	0.37
875	5.597	0.001583	0.001790	5.0626	16.9	90.4	18.0	328	73.76	0.42
925	5.563	0.001199	0.001695	5.0567	27.2	90.9	29.0	434	73.68	0.36
975	5.738	0.004248	0.002372	5.0313	10.3	87.7	11.0	122	73.32	0.39
1015	5.600	0.001481	0.001832	5.0527	13.9	90.2	14.8	351	73.62	0.37
1050	5.582	0.000938	0.001677	5.0807	17.2	91.0	18.3	554	74.02	0.37
1100	6.189	0.005080	0.003657	5.1028	9.0	82.4	9.62	102	74.34	0.37
FUSE	113.488	0.161400	0.375000	2.6939	0.1	2.4	0.133	3.22	39.63	13.22
						Total gas age			73.68	
						Plateau age (875°-1100°C)			73.77 ± 0.35 Ma	
Sample 1KE052 microcline; muscovite-biotite granite; J = 0.007990; wt. = 0.0785g										
400	23.500	0.002487	0.062670	4.9786	0.1	21.2	0.0414	20.9	70.37	3.75
500	34.384	0.006816	0.079350	10.9349	0.1	31.8	0.0485	7.63	151.11	5.54
600	11.282	0.002477	0.011290	7.9403	0.6	70.4	0.295	21.0	110.97	0.73
700	4.656	0.002839	0.002746	3.8413	1.4	82.5	0.763	18.3	54.54	0.41
800	4.661	0.002966	0.002604	3.8881	3.8	83.4	2.00	17.5	55.19	0.33
900	4.422	0.003659	0.001329	4.0266	5.3	91.1	2.82	14.2	57.12	0.29
1000	4.506	0.004886	0.001058	4.1911	13.4	93.0	7.09	10.6	59.42	0.30
1050	4.938	0.004161	0.002086	4.3185	9.7	87.5	5.17	12.5	61.20	0.31
1100	5.632	0.002400	0.004225	4.3796	7.8	77.8	4.13	21.7	62.05	0.31
1150	6.253	0.001847	0.005997	4.4767	7.3	71.6	3.85	28.1	63.40	0.36
1200	7.336	0.001907	0.009676	4.4726	6.9	61.0	3.67	27.3	63.34	0.32
1260	7.425	0.002785	0.009563	4.5957	9.1	61.9	4.82	18.7	65.05	0.37
1300	6.785	0.001727	0.006925	4.7340	19.6	69.8	10.40	30.1	66.98	0.35
FUSE	6.938	0.001007	0.007440	4.7345	15.0	68.2	7.94	51.6	66.98	0.33
						Total gas age			63.52	
						No plateau				
Sample 2KE087 muscovite; quartz vein; J = 0.008244; wt. = 0.1946g										
750	5.405	0.002374	0.002403	4.6888	11.2	86.8	9.87	219	68.42	0.34
875	5.208	--------	0.001205	4.8463	25.5	93.0	22.3	---	70.67	0.38
925	5.149	--------	0.000932	4.8677	25.7	94.5	22.5	---	70.98	0.36
975	5.184	--------	0.001076	4.8598	18.3	93.8	16.1	---	70.87	0.36
1050	5.404	0.000096	0.001618	4.9202	14.4	91.0	12.7	5400	71.73	0.35
1100	7.066	0.001665	0.007393	4.8750	4.5	69.0	3.99	312	71.08	0.36
FUSE	38.805	0.019720	0.011700	4.2187	0.3	10.9	0.303	26.4	61.67	0.91
						Total gas age			70.67	
						Plateau age (875°-1100°C)			70.99 ± 0.40 Ma	

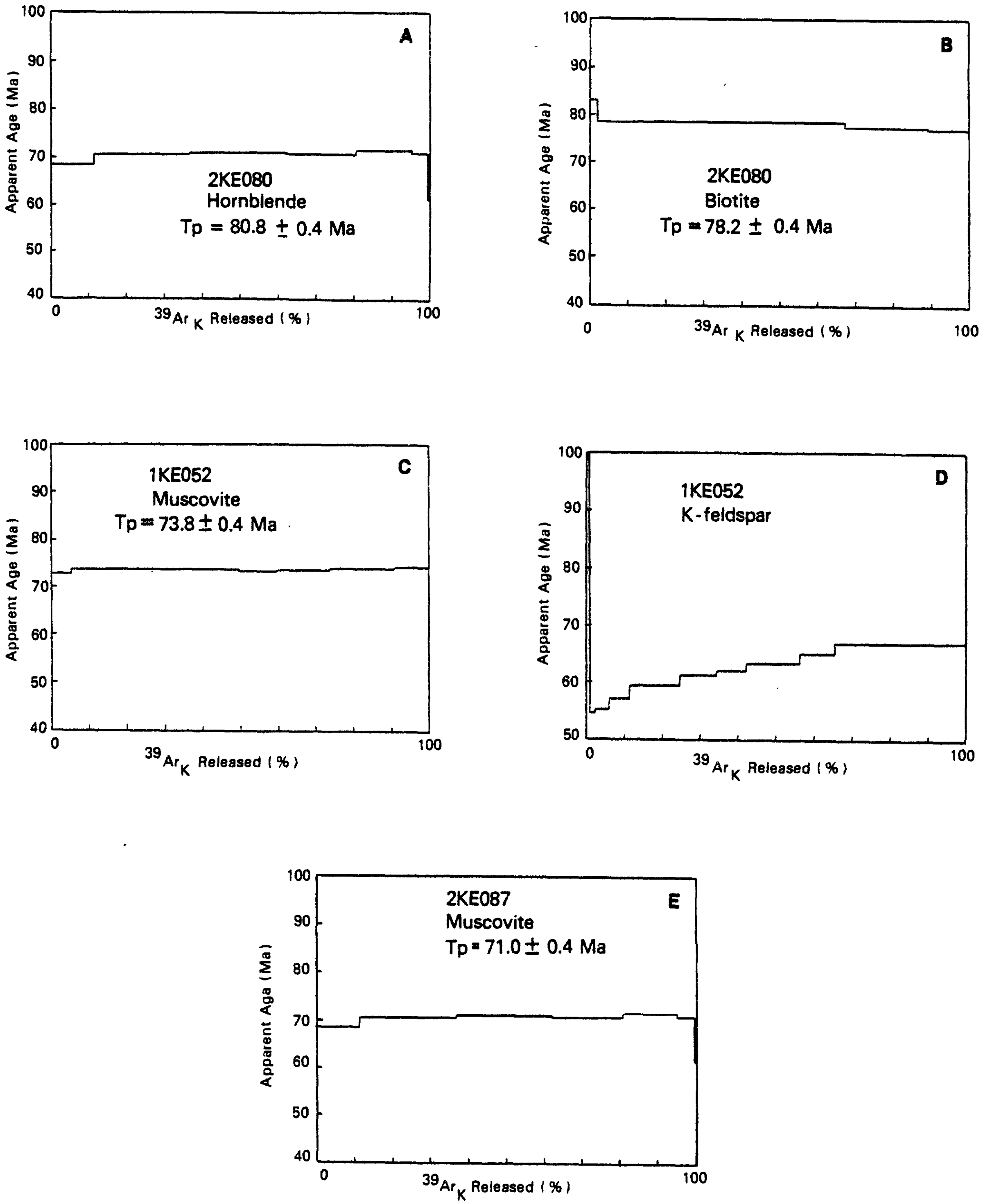

Figure 2--$^{40}Ar/^{39}Ar$ age-spectrum diagrams for samples from the study area. Tp = plateau age. A---Hornblende from amphibolite (2KE080); B--Biotite from amphibolite (2KE080); C--Muscovite from muscovite-biotite granite (1KE052); D--Microcline from muscovite-biotite granite (1KE052); no plateau age defined; E--Muscovite from gold-bearing quartz vein (2KE087).

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