60. $^{40}Ar/^{39}Ar$ AGES OF BOULDERS DRILLED AT SITE 439, LEG 57, DEEP SEA DRILLING PROJECT

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ABSTRACT

The $^{40}Ar/^{39}Ar$ stepheating dating method was applied to parts of three boulders recovered at Site 439, DSDP Leg 57. All the samples gave a well-defined isochron. The isochron ages agree with each other within the experimental uncertainties and give a mean value of 21.4± 1.0 Ma.

INTRODUCTION

Site 439 was drilled near the edge of the deep sea terrace, just landward of the inner trench slope of the Japan Trench (40°38′N, 143°19′E). We recovered boulders of acidic igneous rock which formed a 48-meter-thick breccia-conglomerate unit. This unit unconformably overlies Cretaceous claystone and is itself overlain by Oligocene sandstone. Judging from the interface between the two units (Fujioka, this volume), there appears to be no significant time gap between the conglomerate unit and the sandstone. However, the unconformity between the conglomerate unit and the underlying Cretaceous sediment suggests a considerable time gap. Although the stratigraphic relation suggested the early Oligocene for time of deposition of the conglomerates, the age of the acidic volcanic rock from which the boulders derived had to be determined by radiometric dating. This latter information is vital to understanding the origin of the Oyashio landmass, remnants of which were uncovered during Leg 57.

For our $^{40}Ar/^{39}Ar$ stepheating dating analysis we examined the top, middle, and bottom levels of the conglomerate unit.

RESULTS

The experimental data are represented both in age spectra and isochron plots (Figures 1-3). Table 1 presents the analytical data, a statistical evaluation of the precision of the experimental data, the *y*-intercept of the isochron, and correction factors for interfering Ar isotopes, which were determined on monitored CaF_2 and K_2SO_4 irradiated with the samples.

Sample 439-32-2, 61-62 cm

This sample is from an andesite boulder. As Figure 1 demonstrates, the age spectrum exhibits not a plateau but a staircase-type spectrum. However, the experimental data fit reasonably well an isochron (SUMS/[n −2] = 3.87) with an intercept $^{40}Ar/^{36}Ar$ value of 303.5 ± 4.1, which gives an isochron age of 21.2 ± 0.7 Ma. The total fusion age of this sample is 22.8 ± 0.7 Ma, which is slightly older than the isochron age and suggests the presence of excess ^{40}Ar.

From earlier studies on $^{40}Ar/^{39}Ar$ systematics for artificially disturbed samples, we were able to conclude that the isochron age, if defined, would usually represent the original age of the sample in spite of disturbances in the age spectrum (Ozima et al., 1979). Hence we suggest that the isochron age of 21.2 ± 0.7 Ma represents the original age of the andesite boulder. This conclusion seems to be supported by the agreement among the $^{40}Ar/^{39}Ar$ ages (see Discussion).

Sample 439-33-1, 18-19 cm

This sample is from a rhyolite boulder. The experimental data fit an isochron (SUMS/[n −2] = 1.57) with an intercept $^{40}Ar/^{36}Ar$ value of 325.8 ± 8.9, which is significantly higher than the atmospheric Ar isotopic ratio. The age spectrum shows a slightly down-staircase type, reflecting an intercept $^{40}Ar/^{36}Ar$ value higher than the atmospheric value. The total fusion age is 23.4 ± 0.8 Ma, which is significantly older than the isochron age — that is, 20.3 ± 1.2 Ma. We consider the isochron age as the most accurate geological age of the sample for the same reasons cited immediately above. Once again our conclusion seems to be supported by the agreement in isochron ages for the three boulder samples.

Sample 439-36,CC

This sample is from a dacite boulder. It shows an age plateau consisting of 800°C and 950°C fractions, which constitute about 55 per cent of the total ^{39}Ar released, and assigns a plateau age of 22.5 ± 1.4 Ma. The experimental data fit reasonably well an isochron (isochron age, 22.7 ± 1.4 Ma) with an intercept $^{40}Ar/^{36}Ar$ value of 312.4 ± 14.8. Both the isochron and plateau ages agree well with each other, but they are younger than the total fusion age (24.9 ± 1.1 Ma). Because we suspect the presence of excess ^{40}Ar, we suggest 22.7 ± 1.4 Ma as the most accurate geological age of this sample.

All the age data are compiled in Table 2. We see that the ages we suggest for the three samples are concordant within the experimental uncertainties. This conclusion is in agreement with the observation that the boulders derive from a single volcanic activity (Fujioka, this volume), though each sample represents a different stage in

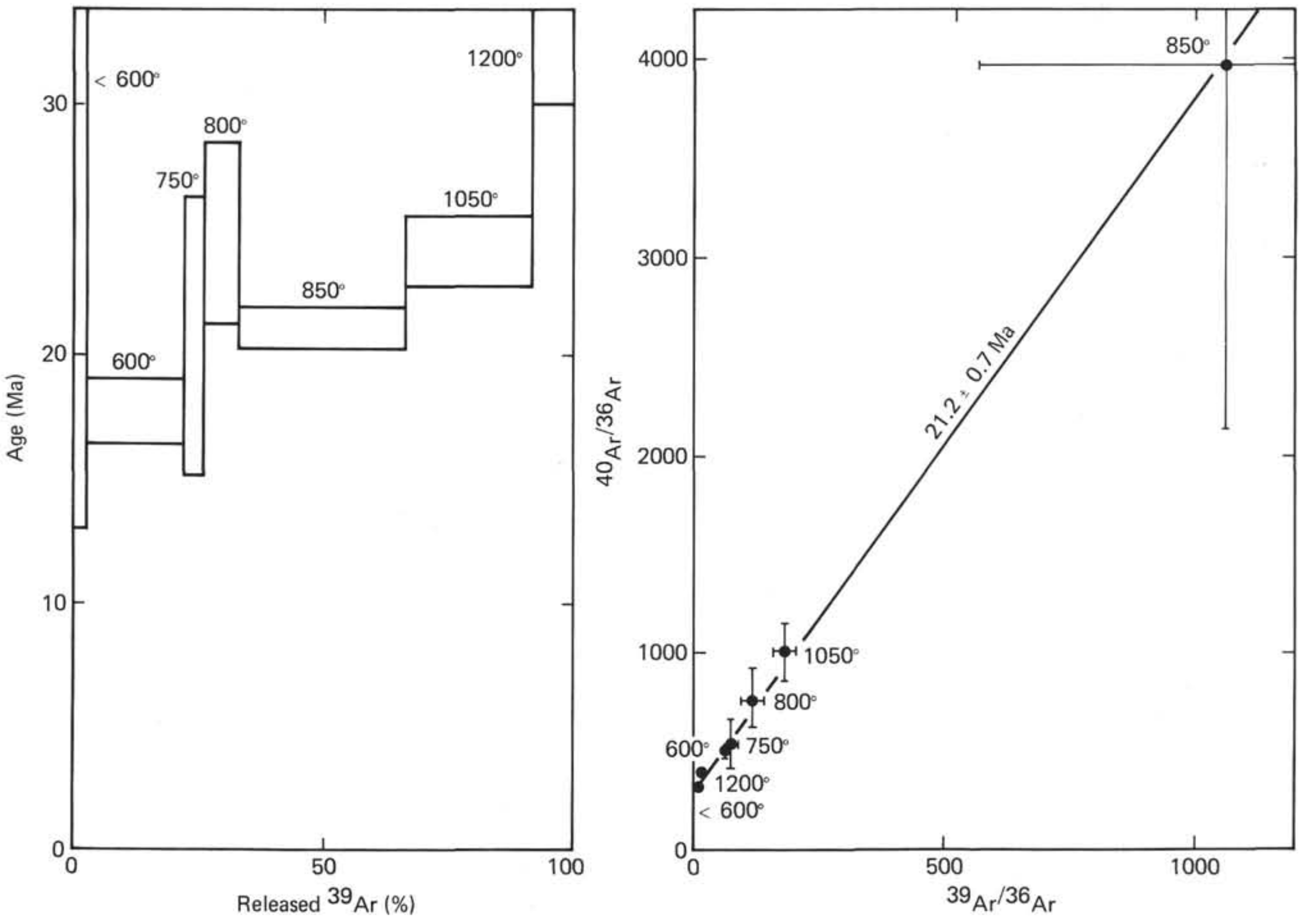

Figure 1. *Sample 439-32-2, 61–62 cm. Apparent age spectrum* (left) *and isochron plot* (right). *The spectrum was constructed with the assumption of the atmospheric trapped Ar. The band area (spectrum) and bar (isochron) represent 1σ error for the apparent age and the isotopic ratio.*

the igneous activity. We conclude that 21.4 ± 1.0 Ma represents the age of the acidic igneous rocks from which these boulders derive.

DISCUSSION

The size and angularity of the clastics, the monolithologic character of the deposit, and the difficulty of transport from Honshu or Hokkaido islands suggest strongly that the boulders came from a nearby source — probably from the Oyashio ancient landmass (Scientific Staff of Leg 57, 1978). This feature was located only about 90 km from the present Japan Trench axis, whereas the present volcanic arc is about 300 km from the Trench. Present subducting process theory does not explain the existence of volcanic activity so near the Trench axis, because 90 km is too short a distance for the subducting plate to reach a depth where magma can be generated. The radiometric ages obtained for the boulders coincide with the climax of large-scale volcanic activity known as the "green tuff movement" (Tanaka, 1977), which occurred over much of the northern half of Honshu Island during the early Neogene. The eruption rate is estimated to have been more than five times as intense as at present (Sugimura et al., 1963). It is tempting to speculate that the volcanic activity in the Oyashio landmass is a part of the green tuff movement.

From the lithologic sequences at Sites 438 and 439 and from the multichannel seismic record, it is assumed that the Oyashio landmass began to subside in the late Oligocene (Scientific Staff of Leg 57, 1978). Present age results suggest that the intrusion of acidic rocks from which the conglomerate unit at Site 439 derived occurred at nearly the same time as the landmass began to subside. It may be that the subsidence triggered the volcanic activity or vice versa.

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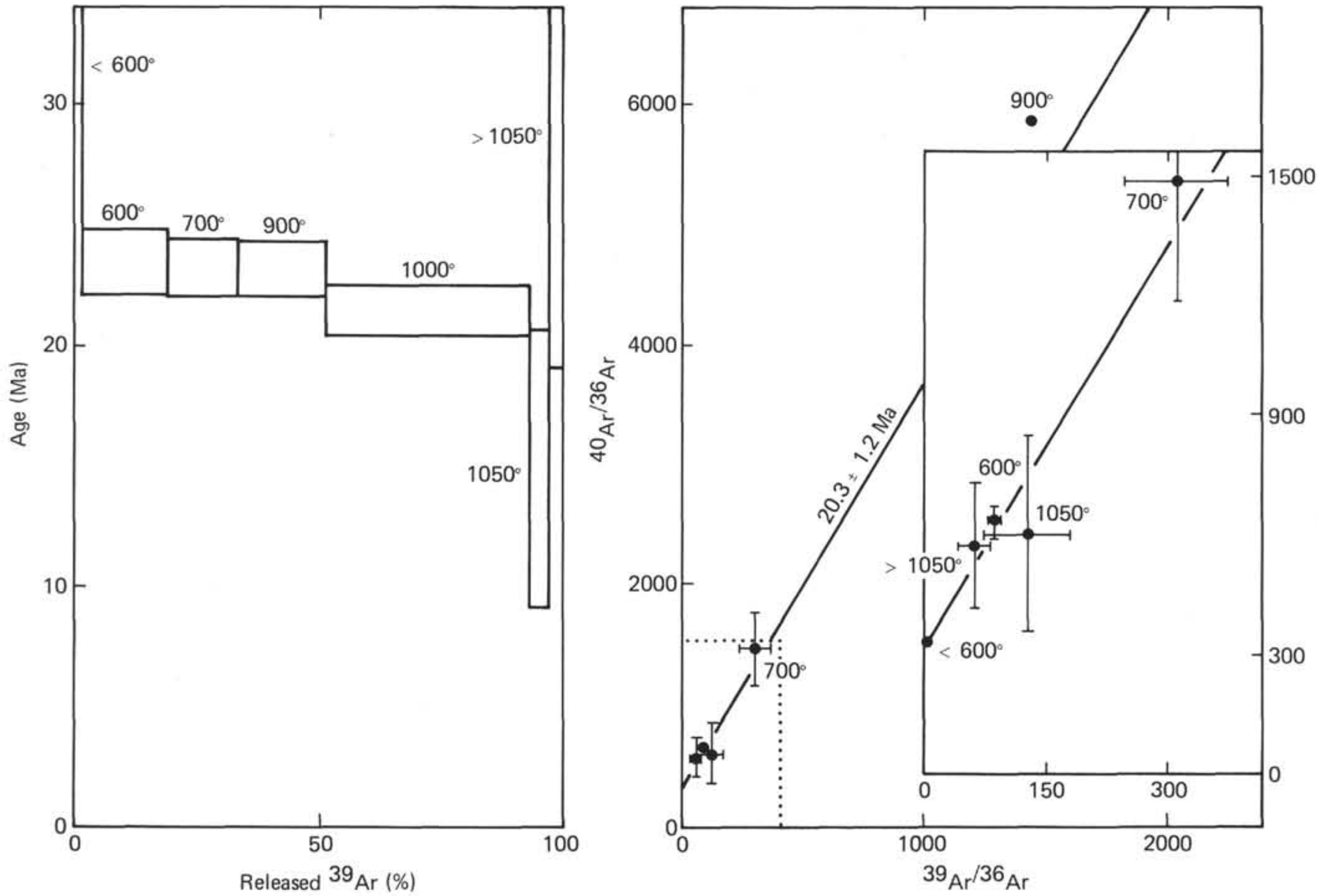

Figure 2. *Sample 439-33-1, 18–19 cm. Symbols and notations are the same as for Figure 1.*

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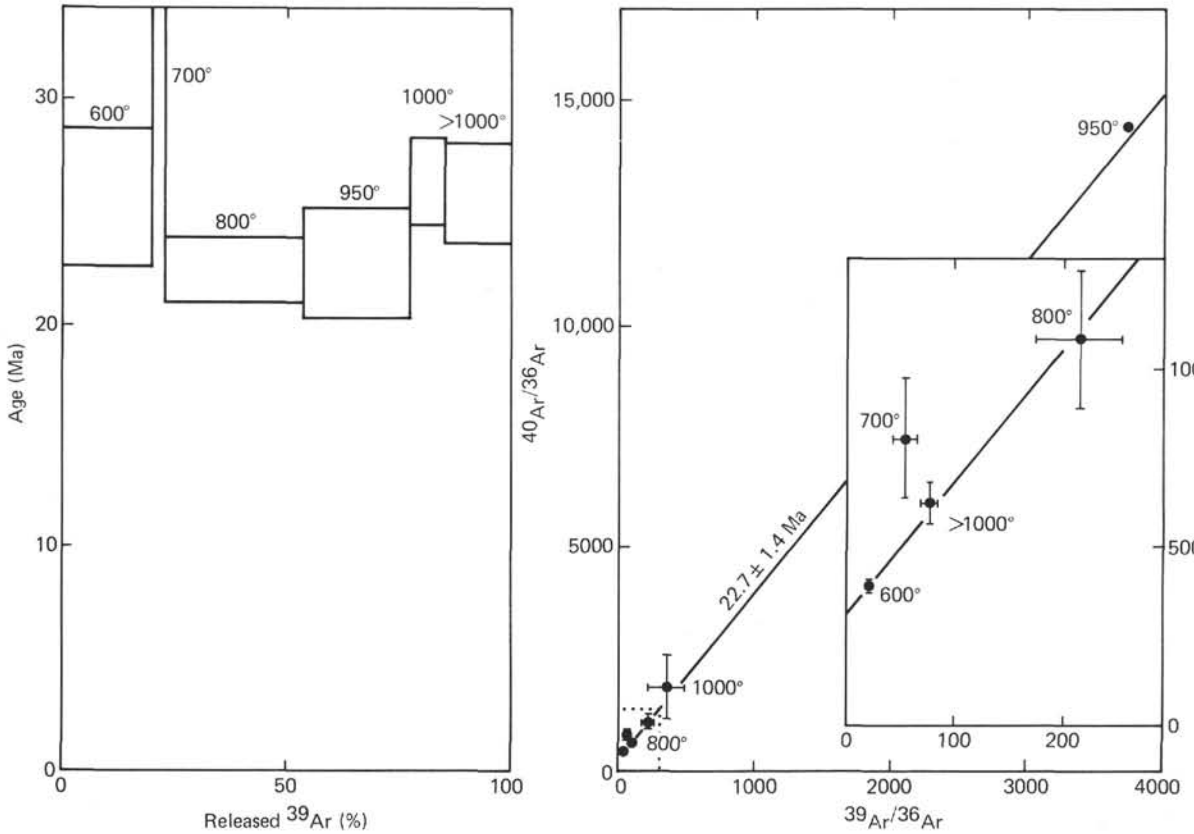

Figure 3. *Sample 439-36,CC. Symbols and notations are the same as for Figure 1.*

TABLE 1
Analytical Data, DSDP Site 439

Temperature (°C)	$^{40}Ar/^{36}Ar$ (% error)	$^{39}Ar/^{36}Ar$ (% error)	$^{37}Ar/^{36}Ar$	Apparent Age (Ma)	^{39}Ar Fraction (%)	r[a]
Sample 439-32-2, 61–62 cm (andesite)			J = 0.00341, SUMS[b]/(n – 2) = 3.87 (3.97), Intercept = 303.5 ± 4.1			
<600	304.0(1.4)	1.7(30.3)	1.2	30.8 ± 17.9	1.5	0.09
600	495.0(5.1)	68.9(5.1)	27.5	17.8 ± 1.3	19.7	0.61
750	543.0(22.9)	73.1(22.9)	41.6	20.7 ± 5.6	3.9	1.00
800	758.0(22.7)	114.0(22.7)	74.9	24.9 ± 3.6	6.9	0.99
850	3967.0(46.5)	1062.0(46.5)	1204.0	21.1 ± 0.8	33.3	1.00
1050	1011.0(14.0)	180.0(14.0)	318.0	24.3 ± 1.4	25.6	0.97
1200	395.0(2.7)	18.1(2.9)	27.9	33.7 ± 2.7	9.1	0.86
Sample 439-33-1, 18–19 cm (rhyolite)			J = 0.00338, SUMS/(n – 2) = 1.57 (4.12), Intercept = 325.8 ± 8.9			
<600	332.0(2.8)	2.1(3.8)	0.0	102.5 ± 22.6	1.3	0.68
600	643.0(6.8)	89.1(6.8)	15.9	23.6 ± 1.4	17.7	0.84
700	1494.0(20.4)	311.0(20.4)	78.7	23.3 ± 1.2	14.5	1.00
900[c]	5887.0(–)	1457.0(–)	507.0	23.3 ± 1.5	17.8	1.00
1000[c]	– (–)	– (–)	–	21.5 ± 1.1	41.9	1.00
1050	608.0(40.8)	127.0(40.8)	94.5	14.9 ± 5.7	4.2	1.00
>1050	579.0(27.6)	64.3(27.6)	120.0	26.7 ± 7.6	2.6	1.00
Sample 439-36,CC (dacite)			J = 0.00337, SUMS/(n – 2) = 1.74 (4.12), Intercept = 312.4 ± 14.8			
600	397.0(4.1)	24.0(4.2)	20.0	25.6 ± 3.1	19.6	0.96
700	810.0(21.2)	55.2(21.4)	51.5	55.8 ± 6.9	2.7	0.98
800	1095.0(17.6)	215.0(17.6)	343.0	22.4 ± 1.5	30.7	1.00
950[c]	14410.0(–)	3743.0(–)	7856.0	22.8 ± 2.5	23.4	1.00
1000	1877.0(38.5)	361.0(38.5)	738.0	26.4 ± 2.0	7.7	0.99
>1000	625.0(9.6)	76.9(9.6)	189.0	25.9 ± 2.3	15.9	0.96

Note: Correction factors used are $(^{39}Ar/^{37}Ar)_{Ca}$ = 0.0039, $(^{36}Ar/^{37}Ar)_{Ca}$ = 0.00029, $(^{40}Ar/^{39}Ar)_K$ = 0.031. Errors given in the apparent ages indicate 1σ.
[a] Correlation coefficient (York, 1969).
[b] SUMS = S in York 1969. Figures in parentheses are cut-off values for the confidence limit of 95 per cent (Brooks et al., 1972; Roddick, 1978).
[c] Because of small ^{36}Ar peaks, it was difficult to assign error estimates (at the 900°C, 1000°C fraction of Core 439-33 and the 950°C fraction of Core 439-36). After the correction for Ca-induced ^{36}Ar, ^{36}Ar value became negative (at the 1000°C fraction of Core 439-33). However, these did not affect the apparent ages.

TABLE 2
Summary of ^{40}Ar-^{39}Ar Ages (Ma)

Sample (Interval in cm)	Total Fusion Age[a]	Plateau Age	Isochron Age[b]	Suggested Geological Age
439-32-2, 61–62	22.8 ± 0.7	not defined	21.2 ± 0.7	21.2 ± 0.7
439-33-1, 18–19	23.4 ± 0.8	22.5 ± 0.7[c]	20.3 ± 1.2	20.3 ± 1.2
439-36,CC	24.9 ± 1.1	22.5 ± 1.4	22.7 ± 1.4	22.7 ± 1.4

Note: λ = 5.543 × 10^{-10} y^{-1}, λ_e = 0.581 × 10^{-10} y^{-1}, $^{40}K/K$ = 0.0001167.
[a] Total fusion age = $1/\lambda \ln [1 + J(^{40}Ar/^{39}Ar)_{total}]$, $(^{40}Ar/^{39}Ar)_{total} = \sum_{i=1}^{n} f_i(^{40}Ar/^{39}Ar)_i$.
[b] Isochrons were determined by means of York's method (York, 1969).
[c] Apparent plateau age calculated from the 600°, 700°, 900°, and 1000°C fractions.