$^{40}Ar/^{39}Ar$ LASER STEP HEATING AGES OF SOME APOLLO 15 IMPACT MELT ROCKS:

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The landscape produced by the ancient bombardment of the highlands is a conspicuous aspect of the Moon. An absolute time-scale for the events that produced the craters depends on isotopic dating of impact melt rocks. Several different histories, ranging from gradually declining bombardment to only late cataclysmic bombardment, have been proposed [1,2,3]; advocates claim that the available isotopic data support their hypotheses. We are attempting to improve the data base for ancient melt rocks by acquiring reliable ages for a greater variety of samples representing more events.

We are measuring $^{40}Ar/^{39}Ar$ age spectra for submillimeter, submilligram fragments using a continuous Ar-ion laser for heating, an infrared radiometer for measuring temperature, and a sensitive mass spectrometer for measuring isotope ratios. The use of very small samples permits us to avoid or minimize the effects of older clasts yet still obtain high-resolution age spectra, and to replicate the measurements to verify the lack of contamination. We can also target small clasts within the melt. Because of the absence of reliable dates from the Apollo 15 highlands site and the critical importance of the Imbrium event in lunar stratigraphy, our initial studies are on 12 melt rocks from that site. The Apollo 15 impact melt rocks are chemically diverse [4,5] and must represent several impact events, ranging from (mostly) pre-Imbrium to post-Imbrium (a KREEP-rich group) in age.

We have obtained replicate age spectra on six melt rock samples with a range of compositions, and on two plagioclase clasts (Table). All of the rocks are very fine grained and contain at least some clastic material [descriptions in 4,6,7]. Four of the samples gave intermediate-temperature plateaus for 50% or more of the ^{39}Ar released that we interpret as representing crystallization (impact) ages.

Four fragments of sample **15304,7,69** gave nearly identical age spectra with well-defined intermediate temperature plateaus for more than 50% of the ^{39}Ar released (Figure). A plagioclase clast from this sample gave a similar age spectrum and an identical plateau age. The weighted mean age of 15304,7,69 is 3,870 ± 4 Ma, which we interpret as the crystallization age.

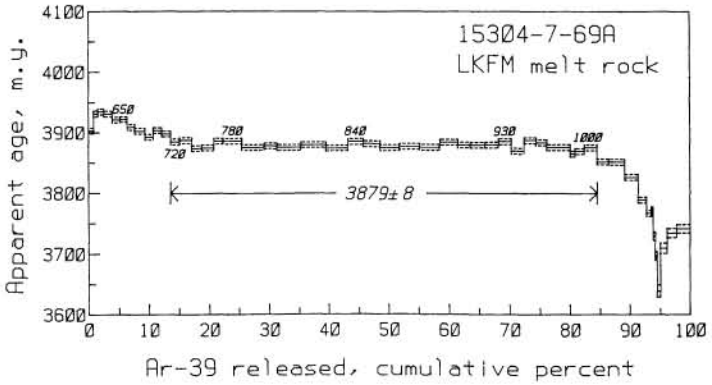

Figure. High resolution $^{40}Ar/^{39}Ar$ age spectrum for melt rock 15304,7 obtained by laser step heating.

Two fragments of sample **15356,9** gave age spectra similar to those of 15304,7,69, with intermediate temperature plateau ages whose weighted mean is 3,836 ± 6 Ma. We consider this age also to be a crystallization age.

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The age spectrum of sample **15308,9** climbs from 2.6 Ga to a fusion step of about 2.85 Ga. The age spectrum of a plagioclase clast from this rock is similar, climbing from about 2.75 Ga to a fusion step of about 3.5 Ga. We conclude that this rock crystallized in, or was affected by, a younger event at about 2.6-2.8 Ga and was incompletely degassed.

Table. Summary of $^{40}Ar/^{39}Ar$ laser incremental heating results

Sample[a]	MgO (%)	Sm (ppm)	Weight[b] (mg)	Spectrum description	Plateau ^{39}Ar (%[steps])	Age (Ma)
15304,7,69	...	25.5	0.62	good plateau	58[22 of 43]	3,862 ± 8
			0.25	good plateau	51[18 of 42]	3,869 ± 8
			0.44	good plateau	71[28 of 51]	3,879 ± 8
			0.260	good plateau	61[20 of 36]	3,872 ± 8
15304,7,69[p]	...	...	*0.234*	fair plateau	68[9 of 21]	3,874 ± 11
15308,9	...	12.3	0.33	increasing	none	
15308,9[p]	...	...	0.29	increasing	none	
15356,9	13.7	14.4	0.16	fair plateau	48[10 of 21]	3,838 ± 8
			0.77	good plateau	50[19 of 43]	3,834 ± 8
15414,3,36	9.0	1.8	0.48	complex	none	
			0.22	complex	none	
15294,6,21	21.5	8.9	*0.066*	good plateau	57[12 of 22]	3,864 ± 8
			0.120	good plateau	64[14 of 22]	3,875 ± 8
15314,26,156	12.8	22.1	*0.062*	fair plateau	60[13 of 24]	3,869 ± 8
			0.089	good plateau	53[10 of 26]	3,869 ± 8

[a] [p], plagioclase clast, others whole rock. [b]Italics, samples weighed before analysis; other weights estimated from diameter of fused glass bead.

The two age spectra of sample **15414,3,36** are complex; they show generally increasing ages and indicate that the sample may have been affected by an impact at about 3,870 Ma.

The age spectra of sample **15314,26,156** resemble those of 15304,7,69, whereas those of **15294,6,21** show some evidence of low-temperature Ar loss. Both samples have good intermediate temperature plateaus at about 3,870 Ma.

The six melt rocks for which we have obtained $^{40}Ar/^{39}Ar$ age spectra provide the first reliable ages for melts from the Apollo 15 site and record major impacts at about 3,870 Ma and 3,836 Ma, and another (local?) impact at about 2.6-2.8 Ga. Given the nature of sampling from a debris pile, assignment of samples and their ages to specific impact events is highly speculative. The data, however, strongly suggest that Imbrium Basin is not older than 3870 Ma and most likely not older than 3840 Ma. So far, reliable ages for impact melts show no evidence for bombardment prior to 4.0 Ga. Instead they are consistent with the hypothesis of a cataclysmic bombardment in the period 3.9-3.8 Ga, during which KREEP was first brought to the lunar surface.

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