^{39}Ar–^{40}Ar-CHRONOLOGY OF THE TAURUS LITTROW REGION II: A 4.28 b.y.
OLD TROCTOLITE AND AGES OF BASALTS AND HIGHLAND BRECCIAS. T. Kirsten and
P. Horn, Max-Planck-Institut für Kernphysik, Heidelberg/Germany.

The ^{39}Ar–^{40}Ar method was applied to date rocks 70215 and 77017 and a variety of lithic fragments from 2-4 mm coarse fines. A summary of the results is given in Table 1. - Ages of mare basalts are consistent with previously reported ages for Apollo 17 basalts (1,2,3,4). Cessation of mare volcanism occured about contemporaneously at Taurus Littrow and at Mare Tranquillitatis (5). Exposure ages of 70215 and 78503,13B are typical for Camelot-ejecta (1, 4,6). - In this Abstract we will refrain from any further discussion of all but one sample. We focus our attention on the unique lithic fragment 78503,13A (Table 1). This fragment, about 3 mm in size, consists of essentially one single olivin poikocryst (43 vol.-%) with equant to lath-shaped anhedral to subhedral plagioclases (51%) with slightly rounded corners and anhedral (4%) pyroxenes as chadacrysts (Fig. 1). The accessories (2 %) are enclosed within the plagioclases and only very rarely within the olivine. Accessories are troilite associated with sometimes spherulitic iron, ilmenite, rutile, whitlockite, spinel, baddeleyite and zirconolite. The latter is remarkably abundant relative to its occurrence in other lunar rocks (El Goresy, private communication); occasionally it is euhedral with no signs of magmatic corrosion. The grain-sizes of the chadacrysts are $\leq$ 100 microns and sometimes form larger aggregates while the accessories are in most cases < 20 microns. It should be pointed out that our sample contains no late-stage crystallisation interstitials in which zirconolites normally reside (7) - here they occur within the plagioclases as free floating particles. - The absence of any reaction rims or overgrowths and the apparent homogeneity of the minerals (awaiting confirmation by microprobe-analysis, in preparation) is suggestive either of slow cooling (if the material crystallized from a melt) or of high-grade metamorphism during an extended period of time. Lunar zirconolites indicate formation temperatures of about 1400-1450°C (8). The fact that some of our zirconolites are strongly euhedral is indicative of their primary nature. After final crystallisation the rock was not subjected to any shock; the cracks diverging from the corners of plagioclase chadacrysts seem to be the result of some thermal shrinkage of the host olivine.
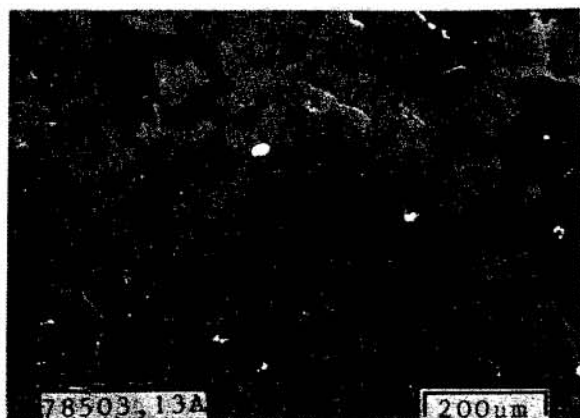

78503,13A   200μm

Fig. 1: Photomicrograph of troctolite in interference-phase-contrast; partly crossed polarizers. Plagioclase is dark grey; brighter grey is olivine and pyroxene (patch lower left); white: troilite and iron.

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A 26 mg split from the troctolite was used for ^{39}Ar-^{40}Ar dating after it had
been slightly etched in a HF+H$_2$SO$_4$-solution to reduce a possible admixture of
solar wind. The ^{39}Ar-^{40}Ar release pattern is shown in Fig. 2. The 600°C-frac-
tion is most likely affected by a residue of contaminant air-argon. A plateau
is defined for the fractions released between 900°C and 1200°C. It comprises
71% of the total ^{39}Ar released and yields an age of 4.28+0.03 b.y. The
1500°C fraction has a larger error due to the high blank correction and is
not used in our further argumentation. The plateau in the ^{40}Ar-^{39}Ar-ratio is
parallelled by a very constant K/Ca-ratio (within 4%). Even over the whole
range of temperatures, the K/Ca-ratio varies only from 0.012 to 0.007. This
indicates that only one single mineral phase has contributed to the ^{39}Ar and
^{37}Ar release, coinciding with the observation that a late-stage potassium
rich mesostasis − a phase often responsible for low apparent ages at low tem-
peratures − is absent. Our troctolite sample has lost only 2.7% of its radiog.
^{40}Ar. The Ar release pattern, the modal analysis and the K and Ca-contents
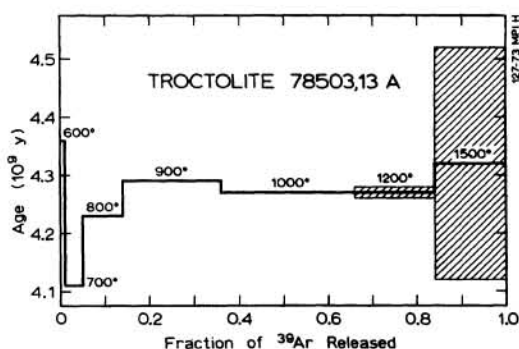lead us to conclude that plagioclase alone contributes to the released Ar

Fig. 2: ^{39}Ar-^{40}Ar-release pattern
for an Apollo 17 highland rock
with a gas-retention age of
4.28+0.03 b.y.

isotopes. It has been demonstrated (9) that among the lunar rock forming mi-
nerals plagioclase is the one which is most suitable for ^{39}Ar-^{40}Ar dating. We
conclude that the plateau-age of 78503,13A reflects the undisturbed gas re-
tention age of this poikilitic troctolite. It strongly supports previous indi-
cations for the existence of rock fragments which crystallized within the lu-
nar crust before 4.1 b.y. ago (10,11,12). − In our opinion, 4.3 b.y. old rocks
could not have survived on or near the lunar surface because of the high rate
of impacts at that time. These remnants of the ancient lunar crust must have
been stored at depths possibly as large as some tens of kilometers. They may
have been transported to or close to the lunar surface some hundred million
years later by large impacts at a time when the meteorite influx rate had
dropped appreciably. The petrological evidence seems to exclude crystallisa-
tion of our troctolite from an impact melt; more likely it is the product of
plutonism or of regional metamorphism which allowed argon isotopes to equili-
brate. Whether an isotopic system was open or already closed at the time of
the giant impacts is simply a question of depth and the corresponding storage
temperatures. Very likely the rock dated by us has once been one of the un-
equilibrated poikilitic clasts which are abundant in Apollo 16 and 17 high-
land breccias. This very old remnant of the lunar crust has been preserved

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for a longer time period than any other lithic fragment dated so far. Its age has not been altered by the brecciation process and the decomposition of the breccia; the latter may have happened more recently than 290 m.y. ago as indicated by the ^{38}Ar-Ca-exposure age.

It is our opinion that rock ages set only upper limits for the age of impact basins and correlated formations in which the rocks are now found. If our rock is Serenitatis ejecta, the basin forming event has to be younger than 4.28 b.y.; if rock 76055 is also Serenitatis ejecta, the Serenitatis basin has to be as young or younger than 4.05 b.y. (12,13).

TABLE 1

Sample	Rock type	Locality	K (ppm)	Ca (%)	Ca-^{38}Ar exp.age (m.y.)	Plateau-age (b.y)
78503,13A	poikilitic troctolite	Base of Sculptured Hills	785	8.2	290	4.28+0.03
70215,21	fine grained subfloor basalt	50 m E of LM	345	7.2	100	3.84+0.03
78503,13B	fine grained basalt	Base of Sculptured Hills	550	8.1	105	3.82+0.03
74243,4A	fine grained subfloor basalt	S-rim of Shorty Crater	785	7.4	315	3.76+0.03
77017,32A	anorthositic breccia with poikilitic clasts	Base of North Massif	410	9.6	80	4.05+0.03
77017,32B	black glass vein penetrating 77017,32A		475	10.0	90	heavily degassed, rich in Ar$_{tr}$
74243,4C	basaltic hornfels	S-rim of Shorty Crater, adjacent to orange soil	515	7.3	58	3.93+0.08 [1]
74243,4B	med.grained basalt		580	6.75	57	no plateau

Error figures include absolute errors. Plateaus are confined within +0.02 b.y. except 1) which is badly defined. Errors for K and Ca-contents are ≤5%; for exposure ages ≤ 8%.

TABLE 2: Stepwise release of Ar-isotopes from troctolite 78503,13A
Total Gas Released (10^{-8}cc/g)

Temperature (°C)	^{40}Ar$_R$	^{39}Ar$_K$	^{38}Ar$_C$	^{37}Ar$_{corr.}$	^{36}Ar$_T$	K/Ca
600	80.3	0.546	0.290	23.95	0.499	0.01197
700	174.6	1.372	1.170	66.78	0.977	0.01078
800	365.5	2.671	2.548	128.9	1.629	0.01087
900	1188	8.405	8.822	437.5	1.369	0.01008
1000	1486	10.65	11.33	560.3	1.766	0.00997
1200	911.7	6.546	6.852	331.6	1.243	0.01036
1500	834	5.792	9.391	428.3	1.254	0.00710
total	5040	35.98	40.4	1977	8.739	0.010

^{40}Ar$_R$ corrected for reactor-produced ^{40}Ar from K
^{39}Ar$_K$ corrected for ^{39}Ar from Ca
^{38}Ar$_C$ corrected for reactor produced ^{38}Ar and for trapped ^{38}Ar
^{37}Ar$_{corr.}$ corrected for decay after irradiation
^{36}Ar$_T$ corrected for reactor produced ^{36}Ar and for cosmogenic ^{36}Ar.

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