SANIDINITE FACIES METAMORPHISM OF APOLLO 16 SAMPLE 65015.

A.L. Albee, A.J. Gancarz, and A.A. Chodos; Division of Geological and Planetary Sciences, Calif. Inst. Tech., Pasadena, Calif., 91109

Sample 65015 was collected at station 5, ~ 4.5 km northeast of South Ray Crater. The 1802gm block has the highest reported K (4000ppm), U (3ppm), and Th (10ppm) content of the Apollo 16 samples [1]. It is a prime example of a BaUKREEPTh-rich polymict rock formed prior to 3.93 b.y. [2], which has undergone partial, but extensive recrystallization and reequilibration by sanidinite facies metamorphism at 3.93 b.y. following the Imbrium Event.

The sample was studied in two polished thin sections (~81mm^2 and ~26mm^2). About 5% of the rock consists of rock and mineral clasts, predominantly angular plagioclase (0.1-0.5mm), set in a finer-grained metaclastic matrix. These larger clasts also include a 0.4mm "ball" of Fe-metal, an equant 0.6mm grain of olivine, and about 28 lithic fragments (0.1-1.0mm), including polygonal anorthosite (14), intersertal basalt (7), gabbroic anorthosite (3), and devitrified plagioclase glass (4). This variety of clasts indicates a polymict origin.

The matrix consists of plagioclase, high-Ca pyroxene, olivine, Fe-metal, and troilite grains, poikilitically enclosed in a polygonal mosaic of larger (0.3-0.7mm) low-Ca pyroxene grains. The irregular boundaries between these pyroxene grains typically contain more abundant plagioclase grains, especially the larger, more-angular clasts, poikilitic ilmenite grains, and irregular troilite and Fe-metal grains. The low-Ca pyroxene grains are peppered with blocky plagioclase grains (≤ 0.1 mm) and with olivine and high-Ca pyroxene inclusions, both of which are markedly embayed.

The table gives the mode (1603 points), "average" mineral compositions, and calculated bulk chemical composition as determined by the electron microprobe [3]. The "average" plagioclase composition is An_{93}, but observed compositions range from An_{88} to An_{97}. There are no major compositional differences between the larger clasts and the smaller grains. Many clasts have a core of uniform composition, bordered by a discontinuity, which is marked by a string of tiny olivine granules, and overgrown by a lower An-content rim. High-Ca pyroxene and olivine occur as partially-resorbed clasts with only a limited range in composition. The "average" olivine composition is $Ca_{.01}Fe_{.48}Mg_{1.49}Si_{1.01}O_{\sim 4}$ and the "average" high-Ca pyroxene is $Ca_{.64}Fe_{.29}Mn_{.01}Mg_{.97}Cr_{.02}Al_{.12}Ti_{.05}Si_{1.90}O_{\sim 6}$. The olivine has a higher Fe/Mg than the high-Ca pyroxene, suggesting derivation from independent igneous rock sources. Low-Ca pyroxene ("average" $Ca_{.11}Fe_{.57}Mn_{.01}Mg_{1.28}Cr_{.01}Al_{.04}Ti_{.02}Si_{1.95}O_{\sim 6}$) shows a greater range of composition than high-Ca pyroxene and olivine.

K-rich areas are irregularly dispersed in very fine patches, but are commonly associated with ilmenite. The areas are too small for accurate analysis but the "average" analysis contains normative troilite, corundum, and quartz. No isotropic areas were found and the K-rich areas appear to be devitrified glass. Whitlockite is very abundant and occurs as slender needles up to 40μm in length. No apatite was found. Fourteen grains were analyzed for Y_2O_3 (2.33± 0.29 wt%), Ce_2O_3 (2.34±0.32 wt%), La_2O_3 (0.86±0.24 wt%), and Nd_2O_3 (1.39±0.25 wt%). Other REE were calculated assuming a chondritic abundance pattern. The rock has a high REE content (see table) and the absence of apatite indicates a low Cl and F content.

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SANIDINITE FACIES METAMORPHISM

ALBEE, A. L.

Ilmenite occurs as irregular poikilitic grains and as smaller laths. The larger grains have a uniform composition (38analyses) with an extremely high MgO content (5.06±0.35wt%) and low ZrO_2 content (0.05±0.06 wt%), and contain exsolution lamellae of rutile and Cr-spinel on different crystallographic planes, and tiny baddeleyite grains. The high MgO content suggests homogenization of ilmenite grains containing armalcolite cores [4] which was followed by exsolution of Cr-spinel, rutile, and baddeleyite. The globules of Fe-metal are uniform in composition and contain: Ni=5.44±0.85wt%, Co=0.21±0.07wt%, and P=0.14±0.04wt%; 20 analyses. The composition falls slightly outside the meteoritic range.

A most important characteristic of rock 65015 is that it has undergone partial, but extensive sub-solidus recrystallization and reequilibration. This is suggested by the texture, including the polygonal mosaic of poikilitic, low-Ca pyroxene, and is corroborated by Rb-Sr isotopic studies [2]. An internal isochron indicates that most phases equilibrated at 3.93±0.02 b.y., but that the large plagioclase clasts did not equilibrate at that time [2]. Lower-An rims on plagioclase clasts, embayed relic clasts, and subhedral form of the finer-grained plagioclase enclosed in the low-Ca pyroxene matrix--all indicate a reaction relationship between clasts and surrounding matrix. The texture suggests that this is a metaclastic rock and that the low-Ca pyroxene did not crystallize from a melt.

Sub-solidus recrystallization at a relatively low temperature is also suggested by the abundance in ilmenite of rutile, Cr-spinel, and baddeleyite, and by the low ZrO_2 content of ilmenite. In addition, both apatite and whitlockite occur in nearly all lunar igneous rocks, commonly associated with mesostasis. In this rock whitlockite occurs as large crystals not restricted to high-K areas and no apatite was found. This may be the result of Cl and F loss during metamorphic recrystallization with conversion of apatite to whitlockite. Such Cl loss could well be accompanied by loss of volatile $PbCl_2$ [5], especially since lunar apatite and whitlockite are typically high in U and Th and hence radiogenic Pb.

The rock as a whole is high in K, U, Th [1], and Ba, REE, and P (see table) and has a composition similar to "KREEP" fragments [6]. The abundance of such rocks in Apollo 16 soils was estimated by broad-beam analysis for K of 24 2-4mm fragments from stations 4, 8, 10 and 11. About 1/3 of these have a K-content equal to or greater than 65015.

We infer that the most probable protolith of sample 65015 was a glassy agglutinate of mineral and lithic fragments comented by "KREEP" glass which was extensively recrystallized with incipient melting of the interstitial K-rich material during sanidinite facies metamorphism at 3.93 b.y. Such "KREEP"-glass agglutinates are figured by Meyer et al. [6,p.399]. Alternatively, 65015 might be derived by metamorphism of "annealed brecciated KREEP", such as the fragments figured by Meyer et al. [6,p.403]. However, the peculiar nature of the low-Ca pyroxene might be more readily attributed to metamorphism of a glass containing clasts. The variety of lithic clasts indicates that 65015 was not simply derived by brecciation of an igneous rock. Hence, the 4.42 b.y. Rb-Sr isochron, defined by the total rock and plagioclase clast composition [2] cannot be interpreted as the primary age of the protolith.

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SANIDINITE FACIES METAMORPHISM

ALBEE, A. L.

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REFERENCES

[1] P.E.T., Science 179(1973)23; [2] D. A. Papanastassiou and G. J. Wasserburg, Earth Planet. Sci. Letters 17(1972)52 and F. Tera et al., this volume; [3] A. J. Gancarz et al., Earth Planet. Sci. Letters. 16 (1972)307; [4] S. E. Haggerty, Earth Planet. Sci. Letters 13(1972)328; [5] F. Tera and G. J. Wasserburg, Earth Planet. Sci. Letters 17(1972)36; [6] C. Meyer, Jr. et al., Proc. 2nd Lunar Sci. Conf. 1(1971)393.

Phase abundances, "average" phase compositions and calculated bulk-chemical composition of 65015

	plagioclase	low-Ca pyroxene	high-Ca pyroxene	mesostasis	ilmenite	olivine	whitlockite*	Fe-metal**	troilite**	bulk composition
vol %	$57.1_3 \pm 1.8_9$	$28.9_4 \pm 1.3_4$	$6.4_9 \pm 0.63$	$3.6_2 \pm 0.4_8$	$1.2_5 \pm 0.2_8$	$1.1_9 \pm 0.2_7$	$0.7_5 \pm 0.2_2$	$0.4_4 \pm 0.1_7$	$0.1_9 \pm 0.1_1$	
wt %	51.2_2	32.5_5	7.1_5	3.4_2	1.9_2	1.5_1	0.7_8	1.1_5	0.3_0	
P_2O_5	n.a.	n.a.	n.a.	0.06	n.a.	n.a.	40.28±1.39	0.17	0.01	0.3_2
SiO_2	43.76	51.80	51.31	60.43	0.26	38.85	2.29±1.28	0.07	0.06	45.6_2
TiO_2	n.a.	0.78	1.68	0.16	53.58	0.17	n.a.	0.01	n.a.	1.4_1
ZrO_2	n.a.	n.a.	n.a.	<0.01	0.05	n.a.	n.a.	n.a.	n.a.	<0.01
Al_2O_3	36.93	1.27	2.64	21.95	0.13	0.14	1.26±1.21	n.a.	n.a.	20.2_8
Cr_2O_3	n.a.	0.47	0.77	<0.01	0.54	0.07	n.a.	n.a.	0.06	0.2_2
MgO	0.11	24.41	17.61	0.05	5.00	38.28	3.28±0.34	0.02	n.a.	9.9_6
CaO	18.80	2.43	16.18	2.75	n.a.	0.26	39.94±1.12	0.01	0.01	11.9_9
FeO	0.13	18.42	9.30	3.35	39.57	22.25	0.89±0.36	94.98	63.43	9.5_9
MnO	n.a.	0.36	0.20	<0.01	0.32	0.15	n.a.	0.04	n.a.	0.1_4
NiO	n.a.	n.a.	n.a.	0.21	n.a.	0.01	n.a.	4.55	0.04	0.0_7
BaO	0.09	n.a.	n.a.	2.47	n.a.	n.a.	n.a.	n.a.	n.a.	0.1_3
Na_2O	0.60	0.02	0.08	0.73	n.a.	n.a.	0.47±0.13	n.a.	n.a.	0.3_5
K_2O	0.06	n.a.	n.a.	7.73	n.a.	n.a.	n.a.	n.a.	n.a.	0.3_0
S	n.a.	n.a.	n.a.	0.83	n.a.	n.a.	n.a.	n.a.	36.39	0.1_4
Co	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.19	n.a.	<0.01
$\Sigma RE_2O_3 + Y_2O_3$	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	10.71	n.a.	n.a.	0.0_8
Total	100.48	99.96	99.77	100.72	99.45	100.18	99.18	100.04	100.00	100.60

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