FURTHER FORAGING FOR PRISTINE NONMARE ROCKS. Paul H. Warren and John T. Wasson, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90024, USA.

The majority of lunar highlands rocks are confused mixtures of unrelated materials created by meteorite impacts. Consequently, petrologists concerned with assessing accurately the compositional properties of the original lunar crust are increasingly focusing their attention mainly on those rare nonmare rocks that seem to be pristine, i.e., endogenously igneous or monomict brecciated [e.g., 1,2,3,...8].

In previous papers [1,2,3], we have (a) attempted to assess various characteristics that may tend to indicate whether or not a given sample is pristine; (b) attempted to utilize these characteristics to cull out of all samples described in the literature those which appear to be pristine, and to review the implications of the petrologic tendencies among pristine rocks for large-scale lunar models; and (c) worked at adding to the uncomfortably small number of known pristine nonmare rocks via new studies of promising (but unproven) nonmare materials. In what follows we report fresh progress along the lines of (c).

Except (perhaps) for an exquisitely preserved, unambiguously plutonic texture (i.e., something that unfortunately is very seldom observed among nonmare rocks, <u>including</u> pristine ones), by far the most generally dependable diagnostic is a determination of very low levels of one or more siderophiles, because both meteoritic projectiles and the lunar regolith have far higher concentrations of most siderophiles than do pristine lunar rocks, and there is empirical evidence indicating that most polymict breccias have a meteoritic or regolith component. A trustworthy siderophile datum $<3x10^{-4}$ times CI chondrites is excellent evidence for pristinity. Except for Ni such elements are rarely determined, however, and Ni in pristine rocks is rarely as low as the others, except in monomineralic anorthosites. In Table 1 are listed new data for siderophiles Au, Ge, Ir, Ni and Re, as well as data for 16 other (mainly lithophile) elements. Many of our analyses of Ir and Ni are not yet complete. Nonetheless, the data we already have include 7 cases of Au $<3x10^{-4}$ times CI (<0.048 ng/g); and 2 cases of Au $<5x10^{-4}$ times CI together with Ge $<3x10^{-4}$ times CI (<11 ng/g). There is also one case where Au is $\sim 22x10^{-4}$ times CI, but Ge is $\sim 2x10^{-4}$ times CI (15306,23).

An incompatible element pattern fractionated relative to KREEP is another diagnostic favoring pristinity [1,9]. All of our samples that seem pristine based on their siderophiles also feature sizeable incompatible fractionations, and 4 of the 5 that have high siderophiles (14150, 14264, 15306,27 and 60010) feature virtually zero fractionation (with the possible exception of a volatile incompatible such as K). 66035c is a glaring exception among the high siderophile samples. Its La/Lu ratio is only 0.47 x KREEP's. In fact, 66035c also has a plutonic, cumulate texture, only slightly obscured by brecciation (Fig. 1). In this case, it appears that the usually dependable siderophile diagnostic is somewhat misleading. This is not without precedent: dunite 72417 contains 2.55 ng/g Au, 3.13 ng/g Ir, etc. [10], and yet is obviously pristine [11].

<u>Thumbnail descriptions of selected (all at least possibly pristine) samples:</u>

<u>14160,106</u>. Our 26 mg was taken from the larger of two fragments which comprised 14160,88 (total mass 0.20 g). Texturally it is a typical cataclastic, slightly granulitic anorthosite; but its provenance (the Fra Mauro region) and Na content (reflected in the plagioclase composition,

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An_{81-83}) and Eu content (Table 1), are truly unique.

14172c, 14303c, and 14305c. All are small (<1cm) clasts of anorthositic troctolite, with uniformly magnesian ($\sim Fo_{87}$) olivines. Based on siderophiles and incompatibles, 14172c and 14305c are both pristine; and their textures, while extremely brecciated, are consistent with pristinity. 14303c might also be pristine, but it has a highly annealed, granulitic texture and a relatively high Ge concentration. It probably is another of what [12] refer to as granulitic impactites (loosely translated = "semi-pristine rocks").

15002,575. Our 35 mg came from a 0.33 g fragment found in the Station 8 drill stem. It is a fairly typical cataclastic textured (Fig. 2) ferroan anorthosite, except that it comes from a site other than Apollo 16.

15455c3. Although this comes as the third probably pristine clast from 15455 to be analyzed for major and minor elements, it is by far the largest clast in 15455, and has been known to be a pristine rock of unusual composition (anorthositic norite) for some time [1,3]. It was recently dated by the Rb-Sr technique at 4.52 ± 10 Gyr [13]. Our incompatible data agree fairly well with those of [13].

61224,11. See the abstract in this volume by U. Marvin and P. Warren.

66035c2. This is not the first possibly pristine clast we have studied from 66035 [3]. This 1.7 cm clast has ferroan anorthosite mineral compositions (plagioclase uniformly $\sim An_{96.5}$, inverted pigeonite uniformly $En_{56}Fs_{42}Wo_3$ except for lamellae that are $En_{40}Fs_{18}Wo_{42}$) but its modal (and normative) plagioclase is only 55% (see also [14] -- the exsolution lamellae were coarse enough to be spotted with a binocular microscope). This is probably just a few atypical cm^3 from the ferroan anorthosite stratum of the original lunar crust, however (cf. portions of 60025 [2]).

67635, 67636 and 67637. These are all small (2.3-7.2 g) rake samples from the rim of North Ray crater. They are all very similar: cataclastic, ferroan anorthosites, all containing exceptionally sodic plagioclase (for ferroan anorthosites), the most extreme case being 67637 (mean: $An_{94.3}$). Virtually all other Apollo 16 anorthosites have 96 < mean An < 97 (see Fig. 14 in [3]).

Fig. 1. 66035c2. (both fields = 2.2 x 1.9 mm) Fig. 2. 15002.

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Table 1. Concentrations of 21 elements in nonmare clasts (c) and small rocks (r); µg/g except Na, Mg, Al, Si, Ca, Ti and Fe, mg/g, Ge, Ir and Au, ng/g, and Re, pg/g. Underlined data have uncertainty limits greater than normal [2]. Note: This data set will be considerably augmented for our Proceedings paper.

	Na	Mg	Al	Si	K	Ca	Sc	Ti	Cr	Mn	Fe
r14150,15	5.10	90	79	226	390	64	19.5	9.3	1420	870	78
r14160,106	12.3	0.9	175	224	1470	118	0.64	<0.7	45	37.4	2.0
c14172,11	2.80	93	128	201	440	92	2.99	<0.9	251	356	31.7
c14264,15	6.64	75	80	228	7900	66	22.4	12	1300	1030	79
c14303,194	3.01	71	143	203	710	103	3.88	<1.2	261	267	24.6
c14305,264	3.22	69	148	204	630	102	1.78	<0.8	140	241	22.0
r15002,575	2.59	3.4	185	207		135	1.55	<0.8	82	94	5.6
c15306,23	3.16	78	95	221	420	72	16.3	11	2790	1040	69
c15306,27	3.67	28	147	214	1640	114	8.8	2.6	642	520	36
c15455,228	3.28	42	143	223	690	106	5.33	0.6	1180	376	22.6
r60010,3217	3.29	53	130	211	1050	100	8.0	3.8	830	510	46
r61224,11	6.78	77	70	237	140	83	20.8	2.4	1990	1230	77
c66035,18	1.65	53	104	220	170	90	23.1	1.6	1400	1280	85
r67635,3	4.17	1.0	184	210	150	135	0.34	<0.8	15.2	49	2.0
r67636,2	3.83	10.6	174	208	140	126	1.00	<0.9	60	224	15
r67637,2	4.41	3.4	182	207	160	134	0.96	<0.8	34.8	83	5.4

	Co	Ni	Ge	La	Sm	Eu	Lu	Re	Ir	Au
r14150,15	36.7		310	70	30.5	2.3	3.3	600		4.6
r14160,106	6.3		11	11.7	1.60	7.7	0.071	31		0.060
c14172,11	28.8		17	7.9	2.61	2.34	0.25	<34		0.030
c14264,15	24.3	220	286	99	39.8	2.2	4.26	440	6.0	5.3
c14303,194	23.4		30	31.7	12.0	2.32	1.15	<37		
c14305,264	19.0		12	5.6	1.56	2.72	0.130	<87		0.016
r15002,575	6.2		3.8	0.51	0.127	0.88	0.020	11.5		0.026
c15306,23	28.7	26	8.9	21.4	6.93	1.05	1.13		0.61	0.36
c15306,27	17.2	29	27	16.0	9.18	1.24	0.81	63	1.54	0.21
c15455,228	27.2		56	4.8	1.74	1.38	0.17	6.3		0.023
r60010,3217	57	780	1270	21.4	9.4	1.31	0.89	1910	20	20
r61224,11	23.6	8.3	4.3	1.47	0.87	1.43	0.16	12.6	0.15	0.079
c66035,18	19.5		195	1.88	0.89	0.68	0.18	99		0.80
r67635,3	1.5	1.2	2.6	0.33	0.089	1.05	0.0047	7.2	0.027	0.024
r67636,2	5.0	3.6	5.4	0.40	0.099	1.17	0.0061	18	0.17	0.022
r67637,2	3.8	1.6	1.7	0.40	0.135	1.18	0.0134	32	1.2	0.020

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