reduction was detected at lower temperatures. We consider these contributions to the oxygen yield to be negligible.

The predicted output from a lunar oxygen plant thus depends on the ilmenite and TiO_2 contents of the soil. In most lunar soils almost all the TiO_2 is incorporated in ilmenite [1]. The maximum oxygen yield therefore will equal 20% of the TiO_2 content if only ilmenite is reduced, and 25% if further conversion to Ti_4O_7 occurs. Lunar soil 78221 contains 3.84 wt% TiO_2. The maximum predicted oxygen output from a plant using this feedstock is just under 1% of the total input mass. The output from a high-Ti soil such as 75061, with 18.02 wt% FeO and 10.38 wt% TiO_2 [4], is 2.6%.

Concentration or beneficiation of ilmenite would increase the process yield, but not the overall yield. An output of 2.6% means that 38 tons of lunar soil would be required to produce one ton of oxygen. By terrestrial standards this is a small amount of feedstock. A single medium-sized dump truck can hold 40 tons and can be loaded in under 10 min with a front-end loader [6].

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NORTH MASSIF LITHOLOGIES AND CHEMICAL COMPOSITIONS VIEWED FROM 2–4-mm PARTICLES OF SOIL SAMPLE 76503. Kaylynn M. Bishop, Bradley L. Jolliff, Randy L. Korotev, and Larry A. Haskin, Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis MO 63130, USA.

In this work, we identify the lithologic and compositional components of soil 76503 based on INAA of 243 2–4-mm particles and 72 thin sections from these and associated 1–2-mm particles (76502) [1]. We present a statistical distribution of the major compositional types as the first step of a detailed comparative study of the North and South Massifs. The soil sample was collected well away from any boulder and is more representative of typical North Massif material than any single large rock or boulder sample. So far, our examination of the 76503 particles has provided a better definition of precursor igneous lithologies and their petrogenetic relationships [2]. It has enabled us to refine the nature of mixing components for the North Massif <1-mm fines [3]. It has confirmed the differences in lithologies and their proportions between materials of the North and South Massifs; e.g., the North Massif is distinguished by the absence of a 72275-type KREEP component, the abundance of a highly magnesian igneous component, and the absence of certain types of melt compositions found in the South Massif samples.

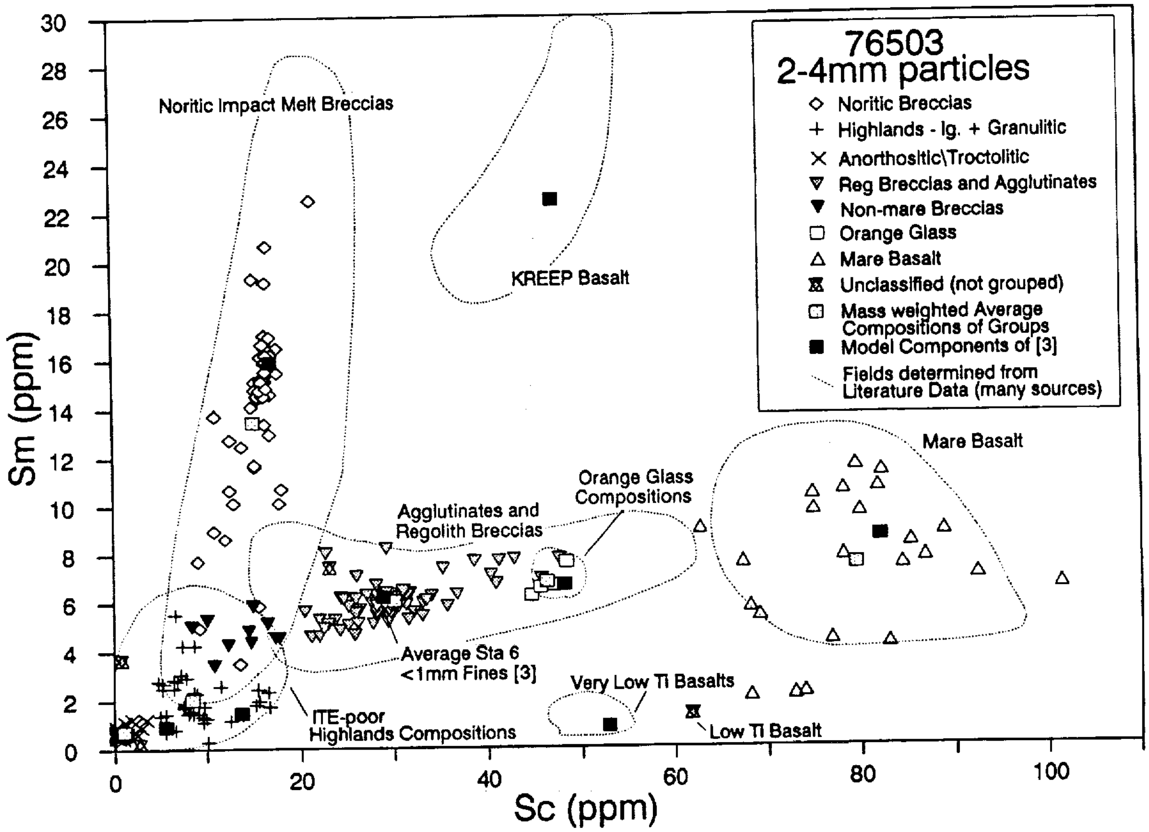
Results: On the basis of chemical compositions and binocular microscope observations, sample 76503 comprises 30 wt% dark glassy-matrix breccias, regolith breccias, and agglutinates; 29% highland igneous fragments and granulitic breccias; 24% noritic melt breccias; 13% high-Ti mare basalt; 1.5% orange glass regolith breccias and vitrophyre, 0.4% (1 particle) VLT basaltic breccia, and 2% unclassified.

Impact melt lithologies (noritic breccias) are rich in incompatible trace elements (ITE) (Fig. 1) and include very fine-grained crystalline and poikilitic impact-melt breccias, glassy matrix breccias, and regolith breccias and agglutinates that include only impact melt breccia lithologies. The latter may have developed in the regolith higher on the North Massif or prior to the introduction of mare materials into the soil. On the basis of Sc, Cr, Sm, and Eu concentrations, noritic melt lithologies from 76503 and matrices from station 6 and 7 boulders differ significantly from those of stations 2 and 3, except boulder 2, station 2. Among particles from sample 76503, evidence of more than one melt group is lacking (Fig. 2). Most of the melt breccias are tightly clustered compositionally and fall within the field of North Massif melt breccia compositions defined by analyses from the literature (Fig. 2). Those melt breccias having compositions outside this field contain clasts of highland material having low concentrations of ITEs; thus their compositions are displaced toward those of highland igneous lithologies and granulitic breccias.

Highland lithologies that have low ITE concentrations include fragments of shocked and unshocked anorthositic troctolite, anorthositic norite, gabbroic anorthosite, and granulitic breccias of generally anorthositic-norite or anorthositic-gabbro compositions. Coarse single crystals or clumps of several crystals of plagioclase are common in the 2–4-mm range. These are compositionally very similar to plagioclase in 76535 troctolite [4]; however, we believe these, and perhaps 76535 also, are members of a more anorthositic body [2]. We find no igneous particles whose compositions suggest affinity to ferroan-anorthositic suite igneous rocks. Granulitic breccias are generally more pyroxene rich than the samples having igneous textures, and, although they have low ITE concentrations, many are substantially contaminated by meteoritic siderophile elements.

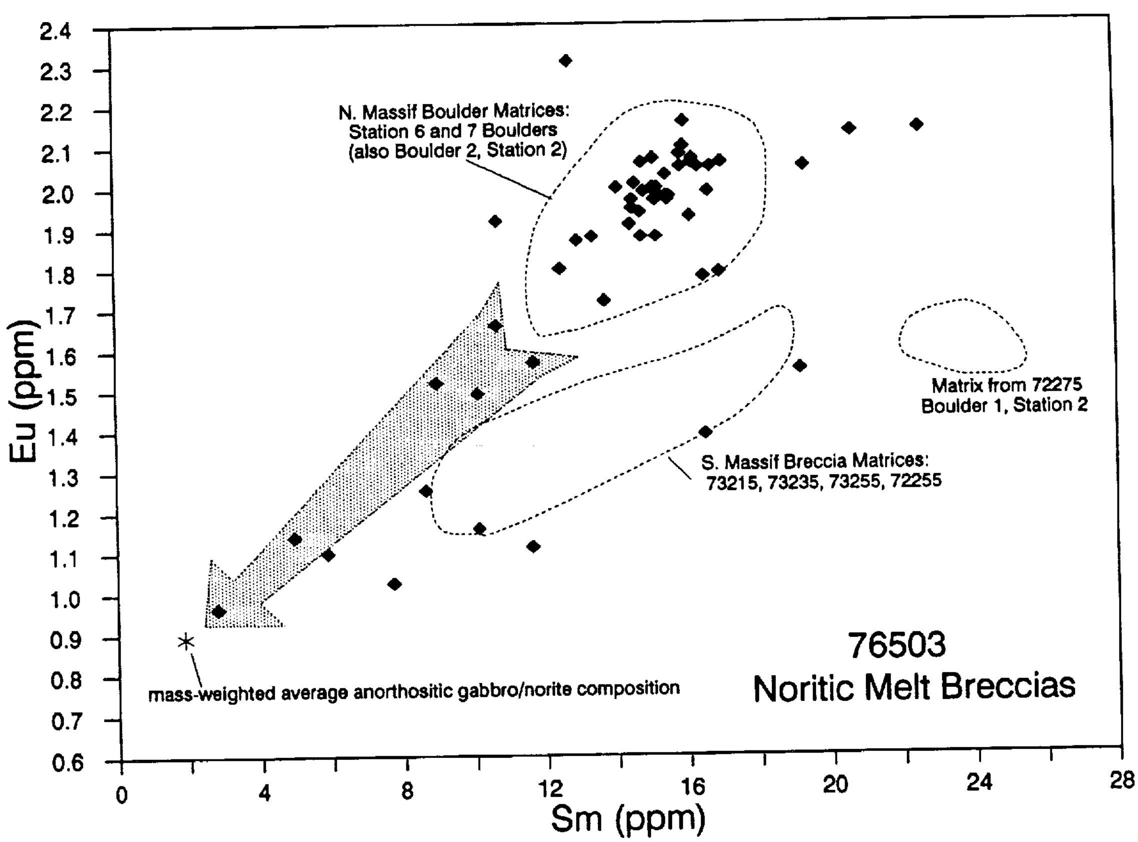
Observations and Implications: Below, we summarize some important features of the distribution of lithologies and compositions of particles in 76503 by comparison to the model distribution of components determined for station 6 <1-mm soil by [3]. Several of these features distinguish this soil from soils of the South Massif. (1) The mass-weighted average composition of the regolith breccias and agglutinates is very similar to the average composition of the station 6 <1-mm fines [3] (Fig. 2). (2) The proportions of components that have been used to model the station 6 soil [3] are similar to the proportions of groups we find in sample 76503 (i.e., the regolith breccias and agglutinates can be well accounted for as a mixture of observed mare basalt and orange glass fragments, noritic melt breccias, and ITE-poor highland lithologies).

The <1-mm fines can be modeled as 51% highlands [36% anorthositic norite and 14% MG component (norite/troctolite mix)], 21% noritic breccia, 21% mare basalt, and 6% orange glass, whereas the proportions of fragments in sample 76503 are 43% highlands, 34.5% noritic breccias, 19% mare basalt, 2% orange glass, and 0.6% VLT basalt (by mass on an agglutinate/breccia-free basis). (3) The proportion of noritic breccias in 76503 exceeds that determined as a mixing component in <1-mm fines by [3]; however, we have included in our particle count noritic breccias whose compositions are skewed toward ITE-poor highland compositions (see Fig 1). Therefore, a portion of the "MG" and "AN" highland components of [3] is taken up in our proportion of noritic breccias. This portion consists of mineral and lithic clasts that, on average, have a composition similar to magnesian granulite or magnesian anorthositic norite [2]. (4) More orange glass was found in the fines model than in the 2–4-mm particles because orange glass particles have a mean size of 40 μm [5] and so concentrate in the finer soil fractions. Particles with orange glass composition in sample 76503 were orange/black glass regolith breccias, not large, individual glass spheres. (5) Magnesian troctolitic



76503
2-4mm particles
Noritic Breccias
Highlands - lg. + Granulitic
Anorthositic\Troctolitic
Reg Breccias and Agglutinates
Non-mare Breccias
Orange Glass
Mare Basalt
Unclassified (not grouped)
Mass weighted Average Compositions of Groups
Model Components of [3]
Fields determined from Literature Data (many sources)
Noritic Impact Melt Breccias
KREEP Basalt
Mare Basalt
Orange Glass Compositions
Agglutinates and Regolith Breccias
Average Sta 6 <1mm Fines [3]
Very Low Ti Basalts
Low Ti Basalt
ITE-poor Highlands Compositions
Sm (ppm)
Sc (ppm)

Fig. 1.



N. Massif Boulder Matrices: Station 6 and 7 Boulders (also Boulder 2, Station 2)
Matrix from 72275 Boulder 1, Station 2
S. Massif Breccia Matrices: 73215, 73235, 73255, 72255
mass-weighted average anorthositic gabbro/norite composition
76503
Noritic Melt Breccias
Eu (ppm)
Sm (ppm)

Fig. 2.

anorthosite appears to be the dominant lithology of the "MG" component and granulitic breccias, the dominant lithology of the "AN" component of [3]. The abundance of the Mg-rich component coupled with the absence of a KREEP component distinguish North Massif soils from South Massif soils.

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REFINING THE GRANULITE SUITE. Janet A. Cushing, G. Jeffrey Taylor, Marc D. Norman, and Klaus Keil, Planetary Geosciences, Department of Geology and Geophysics, University of Hawaii at Manoa, 2525 Correa Rd., Honolulu HI 96822, USA.

Early studies of rocks retrieved from the Moon during the Apollo missions defined a group of rocks as granulites or "granulitic impactites" [1,2]. This included rocks with cataclastic, granulitic, and poikilitic or poikiloblastic textures. Bickel and Warner [3] showed that the "granulites" have bulk compositions that fall into the two major pristine rock groups: the Mg-suite and ferroan anorthosites. Lindstrom and Lindstrom [4] further divided the granulites into four groups based on compositional distinction (Table 1). All these rocks have high contents of siderophile elements, indicating meteoritic contamination and indicating that impacts played a role in their origin. The conventional wisdom for the formation of the granulite suite involves post- "Apollonian" metamorphism of polymict breccias at near-solidus temperatures and low pressures, and for a relatively short period of time [2,5]. Nevertheless, some authors have drawn attention to the igneous appearance of some members of the granulite suite, such as 77017 and 67955 [6].

Petrographic studies indicate that the textures of "granulitic breccias" are significantly varied so as to redefine the granulitic suite into at least two distinct groups. The first group consists of rocks that have true granulitic textures: polygonal to rounded, equant grains that are annealed and have triple junctions with small dispersions from the average 120°. The second group of rocks have poikilitic or poikiloblastic textures, with subhedral to euhedral plagioclase and/or olivine grains enclosed in pyroxene oikocrysts. In some instances, the relationship between the minerals resembles an orthocumulate texture. The rocks

TABLE 1. Classification and data for the granulite suite.

Rock	Comp. Group [4]*	Texture	Equilibrated Minerals?	Mineral Comps.	Ref.	T(°C) (Kretz Ca)
60035	—	poik a	no	—		n/a
67215	sf	poik a	no	—		n/a
67415	sm	poik a	yes	n/a		n/a
67955	sm	poik a	yes	Fo_{76-80} $En_{78}Wo_{3.1}$ $En_{49}Wo_{42}$ An_{92-97}	11	1097
76230	mm	poik a	yes	n/a		n/a
76235	mm	poik a	yes	n/a		n/a
77017	mf	poik a	yes	Fo_{61} $En_{62}Wo_{8.5}$ $En_{46}Wo_{37}$ An_{95}	10,15	1165
72559	sm	poik b	yes	Fo_{81} $En_{80}Wo_{3.7}$ $En_{48}Wo_{44}$ An_{88-95}	12	1031
78527	sm	poik b	yes	Fo_{77} $En_{76}Wo_{4.1}$ $En_{48}Wo_{42}$ An_{95}	12	1089
15418	sf	gran	yes	Fo_{53} En_{65} An_{97}	13	n/a
67915	—	gran	no	—		n/a
78155	mf	gran	yes	Fo_{62} $En_{61}Wo_{9}$ $En_{48}Wo_{30}$ An_{95}	14	1247
79215	mm	gran	yes	Fo_{73} $En_{75}Wo_{2.1}$ $En_{47}Wo_{41}$ An_{93}	1	1070

* sf: strongly ferroan; mf: moderately ferroan; sm: strongly magnesian; mm: moderately magnesian.