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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N93-18789 p. 2

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.

in this group range from (1) those with irregularly shaped pyroxene oikocrysts of variable size (generally 0.5–2 mm) to (2) those rocks in which the oikocrysts are subrounded, considerably smaller (<0.4 mm), and less pervasive than in the former. Also, the overall texture in type 2 rocks begins to take on a granulitic appearance. Both the granulitic and the poikilitic rocks have plagioclase crystals with small, round, mafic inclusions, though this is less common in the granulitic rocks. Pyroxene compositions taken from the literature were used to obtain equilibration temperatures. Both the Kretz-Ca [7] and Lindsley and Anderson graphical thermometer [8] methods yield similar temperatures, which range from ~1030° to 1240°C for the two major rock types, with a clustering around 1100°C (Table 1).

Rocks previously thought of as granulites may have formed in more than one way. Samples with a true granulitic texture appear to be metamorphosed polymict breccias, as many authors have argued. If the coarse-grained poikilitic samples are also metamorphic, their larger grain sizes suggest more intense metamorphism, but they have fewer clearly metamorphic triple junctions. In fact, in coarse-grained samples, such as 77017 and 67955, many plagioclase and olivine crystals are subhedral to euhedral. The poikilitic rocks might have formed from melts and then cooled at a range of rates after crystallization to account for observed textural variations among them [16]. The high siderophile elements and rare large, angular, plagioclase grains suggest that melting was more likely to have been caused by impact than endogenous igneous processes. If they actually formed by impact, the similar subsolidus histories of granulitic and poikilitic samples, as implied by two-pyroxene temperatures, suggest similar stratigraphic locations in pre-Imbrium crater deposits; perhaps the granulitic breccias were clasts in impact melts [9]. If grain growth in the granulitic rocks was due to solid-state coarsening (Ostwald ripening) controlled by diffusion at 1100°C at a rate equivalent to that in olivine, then the observed olivine and plagioclase grain sizes (excluding the poikilitic crystals) can be obtained in about 10^4 yr. This is also a sufficient amount of time (at 1100°C) to equilibrate olivine and pyroxene.

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MARE VOLCANISM IN THE TAURUS-LITTROW REGION.

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Introduction: The products of mare volcanism at Taurus-Littrow occur in the form of crystalline basalts and volcanic glass beads. Both categories of sample define a compositionally diverse, but petrogenetically unrelated, suite of magmas derived by partial melting of a heterogeneous, differentiated mantle beneath the region of the Apollo 17 landing site. This abstract is a brief review of what is known and what is not known about mare volcanism at this location on the Moon.

Mare Basalts: The Taurus-Littrow valley lies within a graben that is radially oriented to the Serenitatis Basin [1]. The valley is thought to contain a vertical sequence of mare volcanics up to about 1400 m in total thickness [1]. Although impact gardening has produced a regolith overlying these mare basalts that averages about 14 m thick in the Taurus-Littrow valley [1], individual cratering events may have excavated basalts from depths of about 100 m below the surface [1]. If correct, this would have excavated only about 7% of the estimated thickness of mare basalts. Consequently, about 90% of the basaltic units comprising this section were not sampled. Photogeologic and petrologic constraints on mare volcanics from other areas of the Moon suggest that individual flows are usually less than 30 m thick [2–4]. If applicable to this site, it suggests that the Taurus-Littrow valley contains at least 40–50 individual flow units. Regardless of the correct number, sample analysis initially identified three compositionally [e.g., 5] and isotopically [6,7] distinct high-Ti lavas. This is similar to the number of distinct flow units expected from excavation to depths of 100 m within a sequence of lava flows having an average thickness of about 30 m. Recently, the number of compositionally identifiable flow units has been raised to four [8,9]. These high-Ti lavas are designated types A, B1, B2, and C. In addition, a fifth variety (type D) of high-Ti mare basalt has been reported [10,11] from a drive tube at Van Serg Crater. The ages of these individual flow units are as follows: type A = 3.75 ± 0.02 Ga [9], type B1/B2 = 3.69 ± 0.02 Ga [9], and type C = 3.72 ± 0.07 Ga [7,9]. No isotopi data presently exist on the type D basalt. Therefore, the duration of mare volcanism represented by these uppermost basaltic flows is probably less than, or about equal to, 120 Ma. Comparison of this extrusion rate of 100 m/120 Ma (i.e., about 1 m/Ma) with the time-averaged extrusion rate of mare lavas at Taurus-Littrow (i.e., 1400 m extruded between the time of graben formation by the Serenitatis impact at 3.87 Ga [e.g., 12-14] and the last flow at 3.69 Ga; 1400 m/180 Ma = 8 m/Ma) suggests that volcanic activity was higher during the early part of its volcanic history. Although the 1400-m thickness must include not only lava flows but also landslide deposits from the adjacent mountains, the general conclusion of an initially high volcanic activity seems inescapable.

In sequence of sampled abundance, type B1/B2 basalts are more abundant than type A basalts [8], and type A basalts are more abundant than the type C basalts [8], which have thus far been identified only at station 4. In addition to high-Ti lavas, very low-Ti (VLT) mare basalts also occur as fragments in the Apollo 17 drill core [15–17]. These VLT samples may be exotic pieces of mare basalt ballistically transported from elsewhere within Mare Serenitatis. No radiometric ages have yet been acquired on the Apollo 17 VLT basalts.

Chemical and isotopic data from types A, B1, and C are compatible with petrogenetic models involving closed system fractionation of observed phenocryst phases during emplacement of these magmas [9]. In contrast, type B2 basalts contain variable $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ initials [9] that require more complex processes, such as extensive interaction with, and assimilation of, the lunar crust [9]. The recent subdivision of the type B mare basalts into two distinct groups [8,9] lessens the need for appealing to differing percentages of partial melting in order to account for the range of trace element abundances and ratios noted by earlier investigators [e.g.,18,19].