COMPARISONS OF CRYSTALLOGRAPHIC AND CHEMICAL CHARACTERISTICS OF PYROXENES BETWEEN LUNAR CRUSTAL ROCKS AND ACHONDRITES, Hiroshi Takeda[1,2], Teruaki Ishii[2] and Arch M. Reid[1], [1]NASA Johnson Space Center, Houston, TX 77058; [2]Mineralogical Institute, Faculty of Science, University of Tokyo, Hongo 113, Japan.

The achondritic meteorites provide a record of igneous processes active early in the history of the solar system. The major mineral in most achondrites is pyroxene, ranging from magnesian orthopyroxene through pigeonite to ferroaugite and ferropigeonite. Similar pyroxenes occur in rocks from the lunar highlands and can provide an insight into a separate but similar set of processes active early in the evolution of the solar system, namely those involved in the formation of the lunar crust.

Both suites of pyroxenes encompass a range of Mg/Mg+Fe ratios and of Ca contents, but low Ca pyroxenes predominate and differentiation trends, expressed by zoned crystals or in suites of related rocks, involve related increases in Fe/Mg+Fe and Ca/Ca+Mg+Fe (1). The crystallographic characteristics of many achondritic and lunar pyroxenes have been interpreted by Ishii and Takeda (2) in terms of a mechanism of inversion and exsolution of pigeonites. The proposed processes include a) decomposition of pigeonite into orthopyroxene and augite at the pigeonite eutectoid reaction point producing blebby augite sharing (100) with the host orthopyroxene, and b) exsolution of augite from pigeonite along the metastable extension of the pigeonite solvus.

The enstatite and hypersthene achondrites are coarse-grained brecciated pyroxenites with orthopyroxenes (En_{100} and En_{75} respectively) that show crystallographic features not found in lunar orthopyroxenes. These include the diffuse streaks along a* that connect reflections of enstatite with clinoenstatite produced by a stress-induced transition from the original enstatite. Coexisting bronzite and twinned clinobronzite, that has inverted from protobronzite, occur in the Steinbach stony-iron meteorite (3) but have not been found in lunar rocks. Diffuse streaks along a*, as in the Johnstown hypersthene achondrite ($Wo_{2.4}En_{79.0}Fs_{18.6}$) have broad maxima where twinned augite spots would be expected. Those have been interpreted (4,5) as the product of Ca-rich Guinier-Preston zones within the orthopyroxene. The presence or absence of augite lamellae on (100) in the hypersthene achondrites appears to be a function of Ca content of the original pyroxene and not totally of cooling rate. Augite reflections are absent from very low Ca pyroxenes such as Steinbach, Mt. Padbury and Shalka, but present in higher Ca pyroxenes such as Ibbenbüren (R. Gooley, pers. comm.).

Comparable orthopyroxenes from lunar highland rocks have been studied in the pyroxene poikiloblastic breccias 77135 and 60315 (6), with compositions $Wo_{3-7}En_{73-83}Fs_{14-20}$, and in orthopyroxenes from igneous anorthositic fragments (7). Similar orthopyroxenes, overgrown by more Fe-rich pigeonite, have been studied in the KREEP basalt 14310 (8). The lunar orthopyroxenes show none of the features, described above, that are characteristic of the achondritic pyroxenes. The sole exception is one grain from the Luna 20 regolith (9) that does show diffuse streaks parallel to a*, indicating the presence of stacking faults.

Achondrites contain inverted pigeonites that in the samples studied in detail, Moore County (2) and Crab Orchard (1), are only partly inverted. The

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Moore County pigeonite (4), partly inverted to orthopyroxene, has two generations of (001) augites, coarse lamellae 0.1 mm thick and submicroscopic exsolution lamellae. Similar pyroxenes have been reported from several anorthositic breccias such as 67075 (10, 11) and as grains from the Luna 20 regolith (9). The host pigeonite composition indicates that the Ishii and Takeda exsolution process (b) must have taken place before inversion.

Inverted pigeonites have also been described from Apollo 14 breccia 14082 (12) and from an anorthositic gabbro clast in breccia 15459 (13). The 15459 inverted pigeonite with augite on (100) was interpreted as a product of the process (a) of Ishii and Takeda. These pigeonites have completely inverted to orthopyroxene, in contrast to the achondritic pigeonites.

Iron-rich pigeonites in eucrites, Juvinas (1) and in eucritic inclusions in mesosiderites, Crab Orchard (1) and Mt. Padbury (2), exsolve ferroaugite on (001) as very regular lamellae at most a few micron wide. The composition of the uninverted pigeonite host (e.g., Juvinas $Wo_2En_{31}Fs_{67}$) is that of a low Ca clinohypersthene, indicating the exsolution process (b) of Ishii and Takeda. These clinohypersthenes display diffuse streaks along a*, interpreted as a preliminary stage in the inversion to orthopyroxene. The only pigeonite of this type recorded in lunar samples is from 14310,90. The results of refinements of this host pigeonite and augite lamellae can be used to explain the Fe-enrichment of the host pigeonite.

These differences in pyroxene characteristics may lead to an understanding of the different environments and the different evolutionary trends in the development of the achondritic parent bodies and of the lunar surface. In both cases we have a suite of breccias that represent a sampling of at least two parent bodies that had differentiated extensively in the surface and near-surface. The differences recorded in the pyroxenes reflect differences in the chemical environment (with the lunar samples being derived from a more aluminous crust), the range of physical environments (reflected in the factors sensitive to temperature, redox state and cooling rate) and the intensity of brecciation and impact metamorphism.

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