PYROXENE MINERALOGY OF MARTIAN METEORITES: MAJOR AND MINOR ELEMENT SYSTEMATICS. J.J. Papike (jpapike@unm.edu), J.M. Karner, C.K. Shearer, P.V. Burger. Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico 87131.

INTRODUCTION: Pyroxene is arguably the most abundant mineral on the surface of Mars and the most valuable as a recorder of igneous petrologic and geochemical processes. In a major synthesis of silicate minerals in martian meteorites we have selected 19 representative meteorites, from a suite of over 40. All contain pyroxene and are discussed here. Our past papers have documented the many ways that pyroxenes can be used as probes of Solar System Processes e.g. [1-5]. The pyroxene data presented here consists of over 1000 new, high quality EMP data that passed several stoichiometric and charge balance tests: 1) Oxide sums between 98 and 102, 2) Tetrahedral cation sums between 1.98 and 2.02 afu, M1 and M2 cations sums between 1.98 and 2.02 afu., and charge balance (discussed below) between –0.03 and +0.03 of a charge. We collected new data because we wanted this study, in comparative planetary mineralogy, to use data collected by the same person, on the same instrument, using the same standards, and using the same data reduction techniques. This is very important when we are pushing detection limits for minor elements and estimating ferric iron which is in relatively low abundance.

QUADRILATERAL COMPONENTS (QUAD): The systematics of pyroxene quadrilateral components (Wo-En-Fs) are shown in Figure 1. The Olivine-phyric and Lherzolitic martian basalts have similar trends. The trends start with low-Ca pyroxene (orthopyroxene or pigeonite) and zone up to augite. The pyroxene crystallizes after olivine, which in most cases is cumulus, with the exception of olivine in Y 980459. The trajectory from low-Ca pyroxene to augite is likely caused by delayed nucleation of plagioclase so the that the activity of Ca increases in the melt and thus drives the pyroxene to higher Ca contents. Pyroxene-phyric martian basalts involve more evolved melts than either Olivine-phyric or Lherzolitic and likely have experienced previous olivine and chromite fractionation. The pyroxene crystallization trajectories are of two types: The Los Angeles, NWA 3171, and Shergotty meteorites have two pyroxenes (augite and pigeonite) coming on the liquidus which then zone to higher Fe contents. QUE 94201 starts with pigeonite crystallization, which then zones to augite, and then zones across the quadrilateral to pyroxferroite (see for example [6]). The Clinopyroxenites (i.e., Nakhlites), usually show a single pyroxene trend from Mg-rich augite to more Fe-rich augite. The pyroxene in ALH 84001 (Orthopyroxenite) shows a tight cluster of points in the orthopyroxene field, reflecting long annealing time or subsolidus equilibration. Thus a single pyroxene grain in the martian regolith, analyzed by EMP, could reveal the difference between several different basalt liquid compositions from which it crystallized.

OTHERS COMPONENTS: The elements that we measured (or estimated) that fall into this group are, Na, Cr, Fe^{3+}, ^{IV}Al, ^{VI}Al, and Ti. We include Mn^{2+} with the QUAD components. All OTHERS components have valence states different from the divalent cations they replace (Ca, Mg, Fe^{2+}, Mn^{2+}) or Si^{4+} and thus require charge balance couples when entering the pyroxene crystal structure. For each of the OTHERS substitutions the following charge balance equation applies: Charge balance deficiencies $Na^{1+} + {}^{IV}Al^{3+}$ = Charge balance excesses $Cr^{3+} + Fe^{3+} + {}^{VI}Al^{3+} + 2Ti^{4+}$. For example, one viable charge balance couple would be $Na\text{-}Fe^{3+}$ (acmite) for Ca-Mg (diopside). We found that the most important charge balance couples for pyroxene in the 18 martian meteorites are: $Fe^{3+}\text{-}{}^{IV}Al$, $Ti^{4+}\text{-}2Al^{IV}$, and (R^{3+}, $Ti^{4+}\text{-}{}^{IV}Al$) where $R^{3+} = Cr^{3+}$, Fe^{3+}, and $^{VI}Al^{3+}$. In the last couple, the charge contributions from Cr^{3+}, Fe^{3+}, $^{VI}Al^{3+}$, and Ti^{4+} are approximately equal. We also calculated the percent of OTHERS substitutions = (Al, Na, Cr, Fe^{3+}, Ti)/4 X 100 for each pyroxene grain. The amount of OTHERS in martian pyroxenes varies from about 1 to 4%. This means that previously determined pyroxene QUAD phase relationships, for the pure system, are applicable to martian pyroxenes. We also estimated the ferric iron content of the pyroxenes using the method of Droop [7]. We find that ferric iron is generally low, ranging from approximately 0.05 to 1.57 Fe_2O_3 wt.% or 0.01 to 0.045 afu. Thus the total iron, as ferric, ranges from 1 to 10%. There is no clear correlation between estimated ferric iron content and previous estimates of fO_2, nor should there be. Many things affect the incorporation of ferric iron into pyroxene including the amount of Ca in the pyroxene M2 site with D (Fe^{3+}) higher for augite than pigeonite.

ACKNOWLEGEMENTS: This research was funded by a NASA/ Cosmochemistry grant to JJP.

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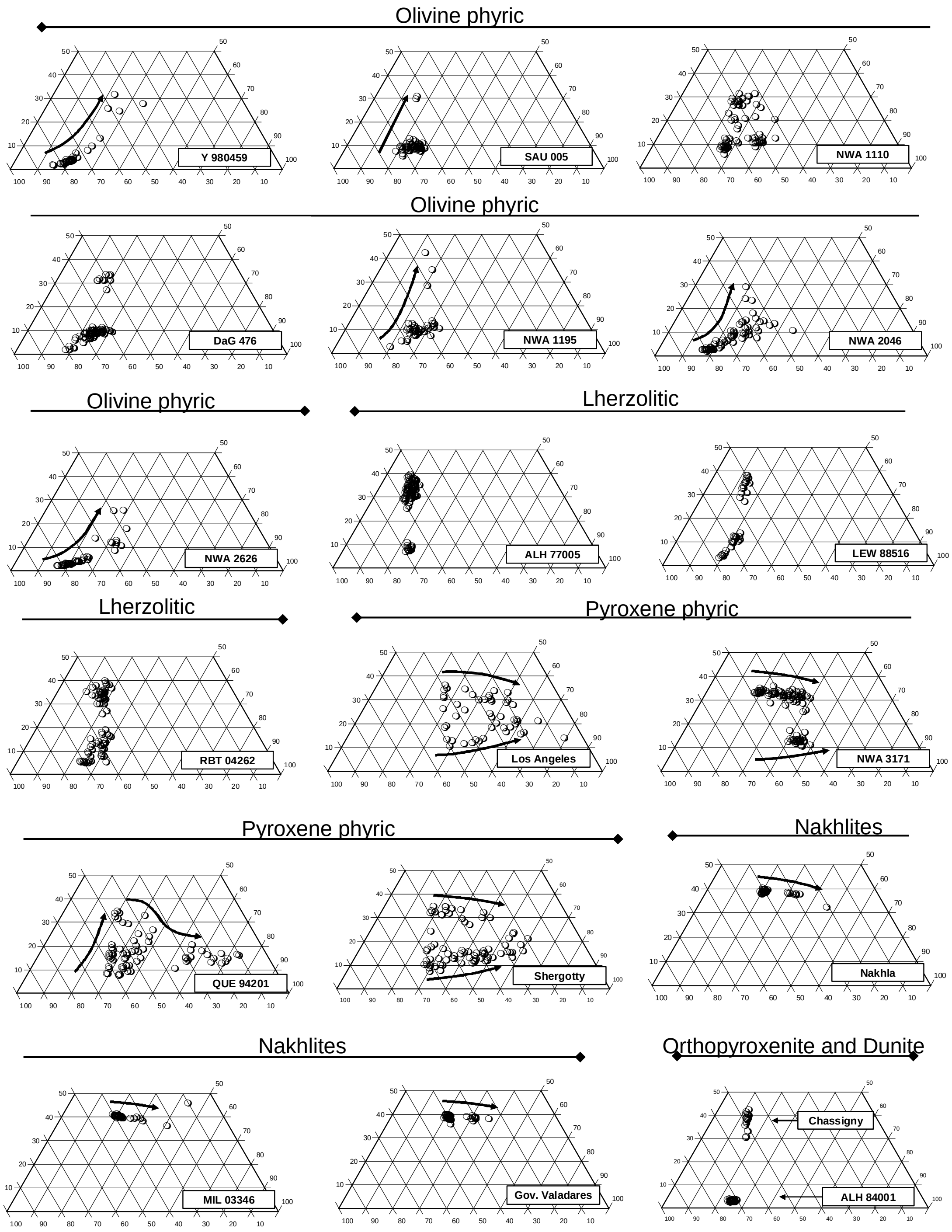
Olivine phyric
Y 980459
SAU 005
NWA 1110
Olivine phyric
DaG 476
NWA 1195
NWA 2046
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NWA 2626
Lherzolitic
ALH 77005
LEW 88516
Lherzolitic
RBT 04262
Pyroxene phyric
Los Angeles
NWA 3171
Pyroxene phyric
QUE 94201
Shergotty
Nakhlites
Nakhla
Nakhlites
MIL 03346
Gov. Valadares
Orthopyroxenite and Dunite
Chassigny
ALH 84001
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