FeO/MnO RATIOS OF LUNAR METEORITE MINERALS.

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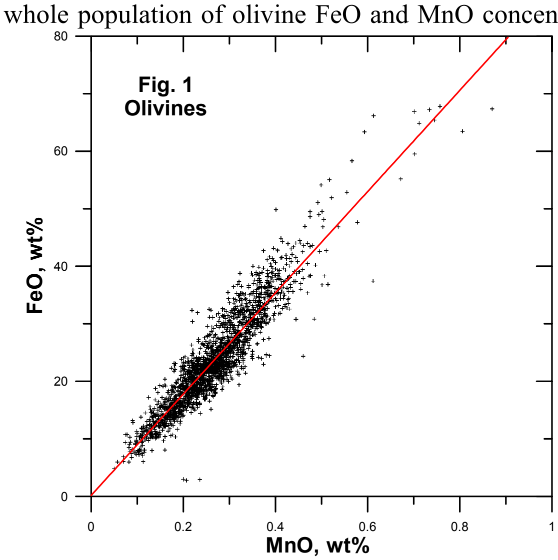
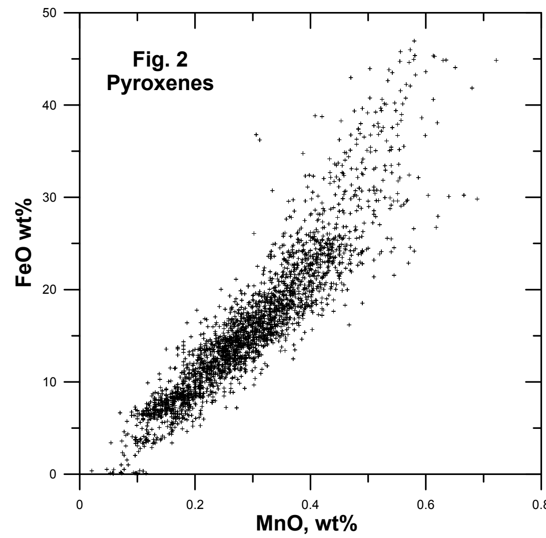
Introduction: The Fe/Mn ratio of meteoritic minerals and rocks is widely used to classify meteorites of planetary origin [e.g., 1-3]. In general, Fe^{2+} and Mn^{2+} have similar ion radii and, hence, a similar geochemical behavior that is, however, sensitive to redox conditions. It is believed therefore that the Fe/Mn ratio of planetary rocks reflects redox conditions in the solar nebula during accretion of planetary bodies or redox conditions during planetary differentiation, magmatic and metamorphism processes. Here we report on Fe/Mn ratios of lunar meteorite minerals. The study is based on our data base including numerous electron microprobe analyses of lunar meteorites collected in Oman.

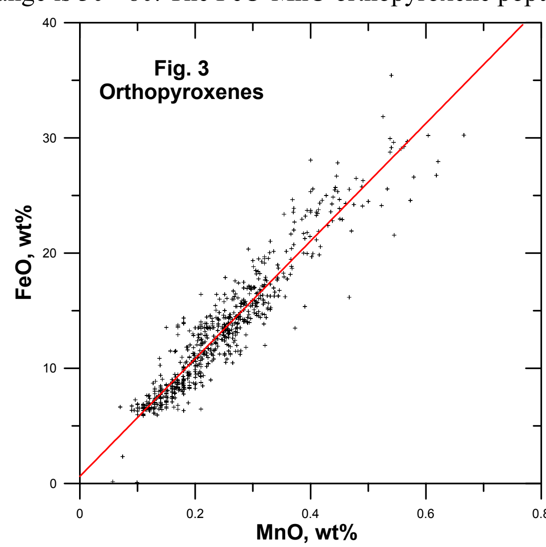
Results: The FeO vs. MnO (wt%) correlation for **olivines** (2145 analyses) is shown on Fig. 1. The correlation is strong (R^2=0.86) and the intercept of the regression line is statistically not distinguishable from zero. The mean olivine FeO/MnO (wt.) ratio is 89+/-0.3 (1 σ), s.d. = 12, the main range is 60 - 120. Note that the FeO/MnO wt. ratio is practically equal to the atomic one that is usually considered [e.g., 1-3]. The whole population of olivine FeO and MnO concentrations is homogeneous. There are only a few grains which do not belong the lunar population because they have very low Fe contents and Fe/Mn ratios.



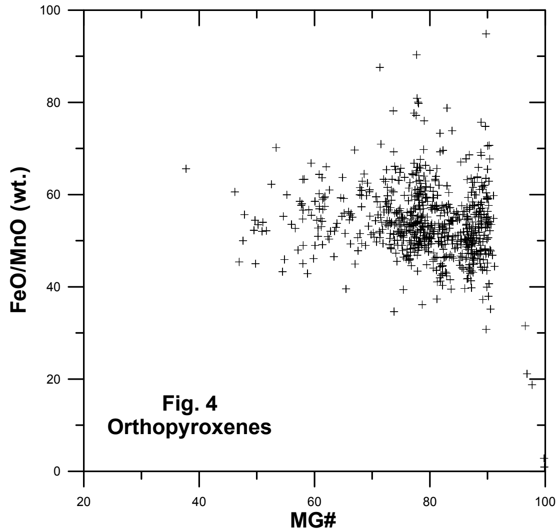
In **pyroxenes,** FeO and MnO are also correlated (Fig. 2) but the regression is not linear. In contrast to [1-3], we found that the Fe/Mn ratio of pyroxenes is a function of their MG# and Ca content.

Orthopyroxenes (Wo<5%, 672 analyses) are very similar to olivines in FeO-MnO relationships (Fig. 3). The oxide contents are strongly correlated (R^2=0.89) and the regression line passes through the origin. The FeO/MnO mean is 54+/-0.3 (1 σ), s.d.=8, the main range is 30 - 80. The FeO-MnO orthopyroxene population is homogeneous and the oxide contents do not depends on other compositional parameters including MG# (Fig. 4).



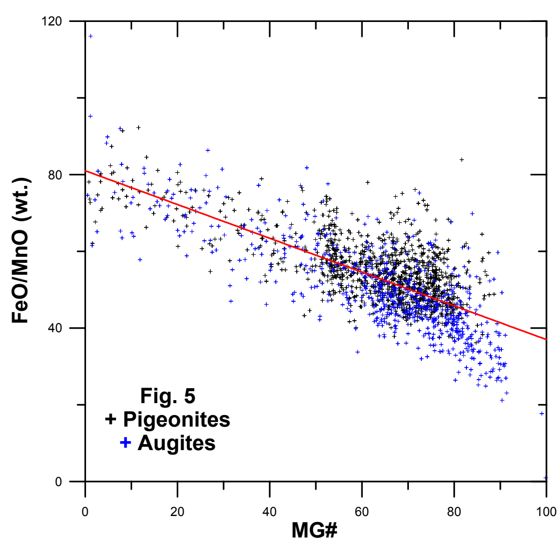


Pigeonites (Wo 5-20 %, 1056 analyses) and *augites* (Wo>20 %, 662 analyses) have complicated Fe/Mn characteristics. The FeO/MnO ratio of pigeonites does not correlate with Ca but is negatively correlated with MG#. Augites show negative correlations of FeO/MnO with both Ca content and MG#. Significantly, augites and pigeonites form a united trend in the FeO/MnO vs. MG# projection (Fig. 5)

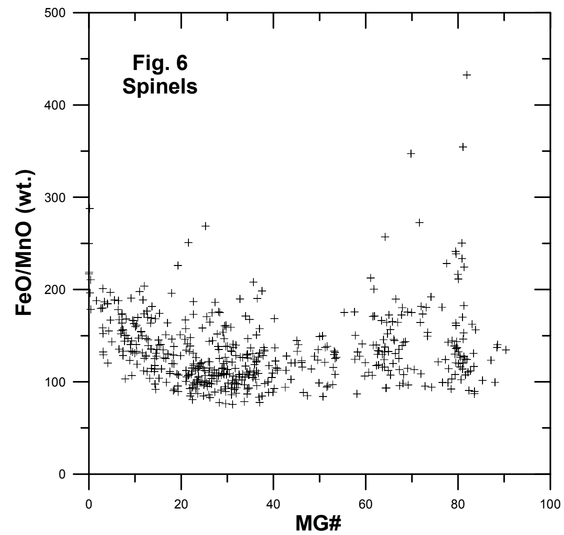


within the FeO/MnO range from 20 to 100. This trend can be approximated by a line: FeO/MnO = -0.44*(MG#) + 81 but obviously the real function is not linear. The Mn enrichment of Ca,Mg-rich pyroxenes can be explained by a complete solid solution between kanoite ($MnMgSi_2O_6$) and diopside but not hedenbergite [4}.

Spinels (498 analyses) do not reveal a simple FeO/MnO distribution. The main group of spinel com positions at MG#>20 has an approximately constant FeO/MnO ratio of about 135 although there are spinels with high FeO/MnO ratios mainly at high MG# (Fig. 7). Spinels contain <20 wt% TiO_2 and >10 wt% Al_2O_3 and belong mostly to the spinel-chromite suite. Spinels



containing >20 wt% TiO_2, i.e. >50 % of the ulvöspinel



component, show a negative correlation between MG# and FeO/MnO.

Discussion: The study demonstrates that FeO/MnO ratio of olivines and orthopyroxenes is the most important characteristic to identify lunar meteorites. In these phases the ratio is least variable and does not depend on other element contents. The FeO/MnO ratio of pigeonites and augites is also useful for meteorite classification but only at certain MG# values. In general, the Ca-rich pyroxene Fe/Mn ratio cannot be used as a classification parameter. FeO/MnO ratio of spinels varies significantly but in the range of chromite-spinel compositions the ratio can be used as a supporting classification criterion. A whole rock FeO/MnO ratio depends on proportions of mafic phases, which have different FeO/MnO ratios, as well as a whole-rock MG# value and, therefore, the ratio is less significant for meteorite classification than those of olivine and orthopyroxene.

There are rare mafic silicate grains which have Fe/Mn very different from that of common lunar minerals. As a rule, such grains have extremly low FeO/MnO ratios and high MG# (Fig. 1,4,5]. Some of them are likely of extralunar origin and could be projectile relics of the heavy ancient bombardment or interplanetary dust. Other non-fitting grains with low Fe/Mn could be the product of Fe^{2+} reduction during melting, crystallisation and metamorphism in the lunar crust. Fe-free and very low Fe/Mn enstatites and diopsides found in a gabbro-norite clasts of Dho 301 [5] give evidence for such a reduction processes

References: [1] Papike J. J. et al. (2003) *Am. Mineralogist* 88, 469-472. [2] Karner J. et al. (2003) *ibid*, 806-816. [3] Karner J. et al. (2006) *Am. Mineralogist* 91, 1574-1582. [4] Robinson P. et al. (1980) In Pyroxenes. *Rev. in Mineralogy*, v.7. [5] Nazarov M. A. et al. (2002) *LPS XXXIII,* #1293.