MEASURES OF CHONDRITE EQUILIBRATION. Harry Y. McSween, Jr. and Robert E. Grimm, Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996

Mineral compositional variations are the most useful measures of equilibration in chondrites, though other means, e.g. feldspar grain size (1), matrix compositions (2), or thermoluminescence (3), may be more sensitive in certain temperature ranges. Percent mean deviation (PMD) is the statistical parameter widely used to assess Fe-Mg variability in olivines and low-Ca pyroxenes, the predominant minerals of chondrites. PMD, which is similar to the statistical parameter coefficient of variation, is defined as:

$$PMD = 100\ (\delta_{\overline{Fe}}/\overline{Fe}),$$

where $\delta_{\overline{Fe}}$ is the average deviation from $\overline{Fe}$, the mean $\overline{Fe}$ content (wt. %). The PMD parameter has several serious drawbacks relative to standard deviation δ.

For gaussian distributions, as appropriate to equilibrated chondrites, PMD decreases drastically (for a given kurtosis value) with increasing $\overline{Fe}$ (Fig. 1). This is because $\overline{Fe}$ in olivine and pyroxene increase progressively with petrologic type (4). Thus δ is a better measure of variability because it is unaffected by $\overline{Fe}$. The sensitivity of PMD to changing kurtosis also decreases at higher $\overline{Fe}$ values (changing slopes of gaussian curves in Fig. 1).

In non-gaussian distributions, such as are observed in some partially equilibrated chondrites (usually type 4), PMD is less effective than δ in discriminating between populations with different skewness (Fig. 1). PMD also decreases with increasing Fe in skewed distributions.

The reason for increasing $\overline{Fe}$ in olivine and pyroxene in higher petrologic types is not understood; however, the $\overline{Fe}$ values mimic increases in total $\overline{Fe}$ in the bulk meteorites in this sequence (5 and data summarized by 6). Thus increasing $\overline{Fe}$ in olivines and pyroxenes probably reflect equilibration with changing bulk compositions. The decrease in variability of mineral compositions is a metamorphic effect, but changes in $\overline{Fe}$ reflect primary differences in composition. PMD serves to mix these two effects.

Use of PMD can lead to erroneous interpretations. It is well documented that PMD of pyroxenes is greater than that of olivines coexisting in the same meteorite. This has been interpreted to mean that pyroxene equilibration lags behind olivine due to slower diffusion (e.g. 7). Although the Fe-Mg diffusion coefficient in pyroxene may be less than that of olivine at the same temperature (6), the much slower diffusion of Ca in pyroxene appears to have reached equilibrium in most meteorites (1). Therefore, the apparent kinetic effects in PMD data may be an artifact of the PMD calculation procedure because of differences in $\overline{Fe}$ between olivine and pyroxene.

Comparison of the degree of equilibration between chondrites of different chemical groups (H, L, LL) is also difficult using PMD. For a peaked gaussian distribution (e.g., that with the highest kurtosis in Fig. 1), olivines having the same δ, i.e. experiencing the same degree of equilibration, would have PMD values of 8.7 for H, 6.7 for L, and 5.6 for LL chondrites, using the olivine $\overline{Fe}$ data of (8), due to the different mean $\overline{Fe}$ contents of olivines in each group. Similar results would also be observed in pyroxenes.

PMD has also been applied to minerals other than olivine and pyroxene, e.g. variability of Co contents of kamacite (3). In view of the systematic variations in Co content of metals among the H, L, and LL groups (9), this application will also produce erroneous comparisons.

CHONDRITE EQUILIBRATION

McSween and Grimm

It is clear that δ is a more useful parameter than PMD for assessing equilibration in chondrites, and the use of PMD should be discontinued. Unfortunately, it is not possible to construct a rigorously correct equation to convert literature PMD values into δ. Empirical conversion factors calculated for H group chondrites are follows, based on linear regressions:

$$\text{olivine: } \delta = 0.249 \text{ (PMD)} + 0.470$$
$$\text{pyroxene: } \delta = 0.166 \text{ (PMD)} + 0.237$$

Data for determination of similar factors for L and LL chondrites are not available.

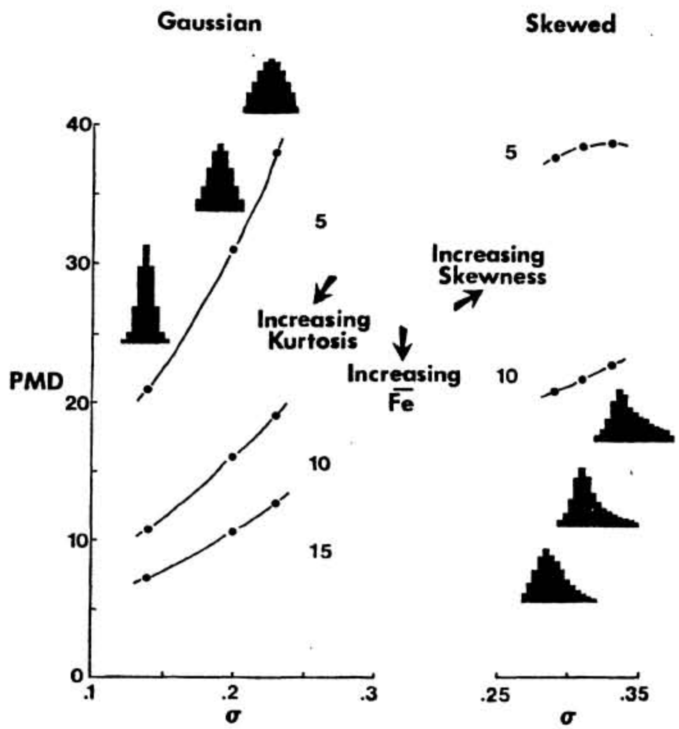

Fig. 1. Calculated values of PMD and δ for the gaussian and skewed populations illustrated (N=100). The various curves show the effect on PMD of changing $\overline{Fe}$ (5, 10, and 15 wt%).

References

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