PETROLOGIC AND MINEROCHEMICAL INVESTIGATION OF ACAPULCOITES, WINONAITES AND LODRANITES: NEW EVIDENCES FROM IMAGE ANALYSIS AND EMPA DATA. V. Moggi-Cecchi[1], S.Caporali[1] and G. Pratesi[2,3], [1]Museo di Scienze Planetarie, Provincia di Prato, Via Galcianese, 20/h, I-59100 Prato, Italy, e-mail: v.moggi@pratoricerche.it, [2]Museo di Storia Naturale, Università degli Studi di Firenze, I-50121 Florence, Italy, [3]Dipartimento di Scienze della Terra, Università di Firenze, Via La Pira, 4, I-50121, Florence, Italy, e-mail: gpratesi@unifi.it

Introduction

Primitive achondrites still lack a comprehensive and exhaustive classification due to the high compositional and textural variabilità and the low number of samples available. These meteorites are transitional products between chondrites and differentiated meteorites and include all those meteorites deriving from chondritic ancestors that suffered a medium-grade thermal metamorphism and partial fusion, as indicated by the presence of relic chondrules. The main parameter used for their classification is the isotopic composition of oxygen, sometimes affected by terrestrial contamination, especially for what concerns desertic samples. The availability of univoque minerochemical and textural parameters may provide an useful tool to solve classificative and genetic problems relatied to these achondrite groups [1,2]. In order to determine these parameters a detailed modal, textural and minero-chemical analysis on both the matrix and the chondrules of a set of 18 meteorites belonging to primitive achondrites has been performed and the results have been compared with literature data [1,2,3,4,5,6,7,8,9] on these and other primitive achondrites.

Instruments and methods

Optical microscopy and imaging have been been performed at the laboratories of the Museum of Planetary Sciences of Prato by means of a Axioplan-2 polarizing optical microscope equipped with Axiocam-HR camera and Axiovision 4.1 software. SEM-EDX X-ray maps have been perfomed at the Chemistry Department of the University of Florence by means of a SEM equipped with EDX analyzer and a Noran System Six software. EMPA-WDS analyses have been performed at the Padova laboratories of the IGG – CNR (National Council of Research) with a Cameca Camebax Microbeam microprobe.

Experimental results

Textural features: a conventional modal analysis based on optical microscope images is not particularly suitable for this group of meteorites due to the fine grained texture of some of them, which doesn't allow an accurate determination of the grain size. The modal analysis of the mineral phases has been therefore obtained by means of the image analysis of the X-ray maps perfomed on the investigated meteorites. The very high resolution of X-ray-maps (below 10 μm) allows to detect also very small grains (mean size < 70 μm), therefore including them in the count. All the samples show an extremely variable modal composition: silicates account for 50 to 80 % of the total volume, with olivine and orthopyroxene as major phases. Opaque phases are mainly represented by troilite and Fe,Ni alloys. Interesting results have been obtained plotting the troilite/silicates ratio (in vol. %) versus the total silicate vol. % (Fig. 1).

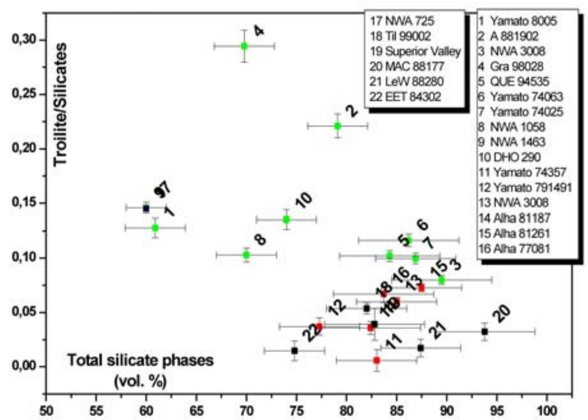

Figure 1: plot of troilite/silicates ratio vs. the total amount of silicates; green squares are coarse grained meteorites, red squares are fined grained; numbers 1 to 16 correspond to this work data; numbers from 17 to 22 are literature data.

This diagram shows a general trend of troilite depletion related to the enrichment of the silicate fraction. This trend is more clear if the overall texture is considered: coarse grained meteorites displaying an equigranular texture with marked 120° triple junctions are located in the bottom right portion of the plot, while fine-grained meteorites with relic chondrules plot in the upper left portion.

Minerochemical features: detailed EMPA analyses of both major and minor elements have been perfomed on selected mineral phases (plagioclase, diopside, orthopyroxene and olivine). Plagioclase displays an albitic composition ($An_{13 \div 24}$ $Or_{1 \div 6}$). Olivine has a forsteritic composition ($Fo_{88\text{-}99}$), with marked differences between the acapulcoites-lodranite (Mg-depleted) and winonaite (Mg-enriched) groups. These data substantially confirm literature data [10] for plagioclase and olivine. As concerns olivine differences between matrix and chondrules our data indicate a compositional equilibrium for both lodranites and acapulcoite - winonaites, thus suggesting a scarce influence of metamorphic grade on olivine composition. Interesting results have been obtained from the analyses of clinopyroxenes: marked differences have been observed among the samples, with winonaites displaying a Mg-rich composition (mean value $Wo_{44}Fs_{50}En_{6}$) and lodranites a Fe-rich one (mean $Wo_{47}Fs_{52}En_{1}$). The analysis of minor elements in clinopyroxene provided the most significative results: a plot of the Cr content of diopside versus Mg# of olivine (Fig. 2) shows two separate clusters of values corresponding to the acapulcoite/lodranite and winonaite groups, in agreement with literature data [7].

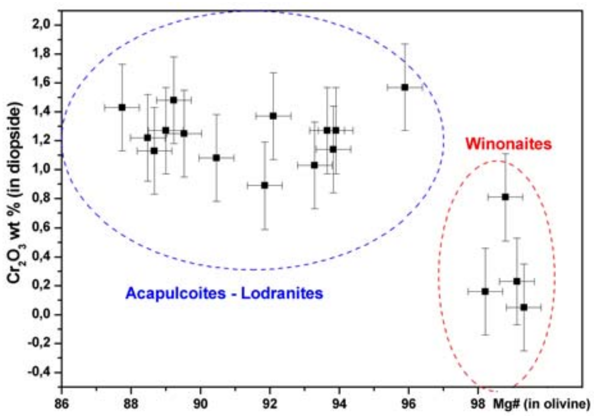

Figure 2: plot of chromium conent in diopside vs. Mg# in olivine.

Other significative data came from the analysis of the reduction state of the selected meteorites: since olivine and orthopyroxene have different solid state diffusion rates a plot of Fe# of orthopyroxene against Mg# of olivine provides a valuable estimate of the reduction state. Fig. 3 displays the results obtained from EMPA data on the samples analyzed compared with literature data: the more reduced meteorites plot in the bottom right corner, while the less reduced ones plot near the top left one. A linear fit applied to the data suggests the existence of three separate clusters corresponding to the three primitive achondrites groups: while acapulcoites follow a negative trend (dip = – 0.6), lodranites show constant Fe# values with increasing Mg# (dip = +0.09) and winonaites show a more marked slope (dip = - 1.4). A possible explanation is, for lodranites, is the slight difference between the reduction state of these meteorites and that of their chondritic precursor, and, for winonites, the existence of a parental body distinct from that of acapulcoites-lodranites, in agreement with the hypotheses by [10] and other authors or, alternatively, a mixing process between primitive materials and more differentiated ones.

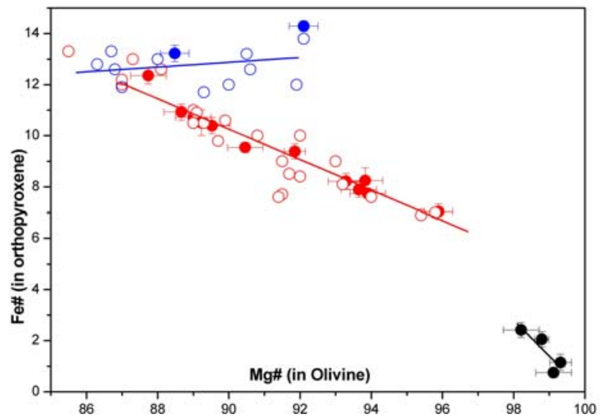

Figure 3: plot of reduction state for the analyzed samples; blue circles are lodranites, red circles are acapulcoites, black circles are winonaites; open circles are literature data

Discussion and conclusions

The accurate modal analysis performed with X-ray maps provides a more comprehensive evaluation of the silicate/sulfide and mafic/sialic silicate ratios, allowing to distinguish lodranites from acapulcoites and winonaites. Minerochemical parameters and the accurate evaluation of the reduction state help in distinguish winonaites from meteorites belonging to the other groups. This combined textural and minero-chemical investigation is therefore a valid tool for an appropriate classification of primitive achondrites.

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