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The Mineral Chemistry and Classification of New Ordinary Chondrites Collected in Antarctica

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Abstract: Petrography and mineral chemistry of ninety-eight ordinary chondrites from Grove Mountains, Antarctica, have been studied, in order to assign their chemical-petrographic types. The chemical-petrographic types of these meteorites are presented below: 36 H-groups (21 H4, 9 H5, 6 H6) and 62 L-groups (25 L5, 37 L6). The compositions of olivines and low-Ca pyroxenes in the all these ordinary chondrites have similar composition, respectively, reflecting some degree thermodynamics equilibration in them. The weathering degrees of all the ordinary chondrites, consisting of predominant weathering degrees of W1, suggest lightly weathered among them. More than 30% meteorites experienced severe shock metamorphism, as indicated by the presences of shock-induced melt veins and pockets. These heavily shocked meteorites provide us with natural samples for study of high-pressure polymorphs of minerals.

Antarctica is the most concentrated region with meteorites. Since 9 different types were found in Yamato Mountains in 1969, Japan, USA, some countries of Europe have been searching for meteorites with the results of total more than 30000 meteorites [1][2]. In 1998, Chinese Antarctic Research Expedition (CHINARE) had found the first 4 meteorites in Grove Mountains. Subsequently, CHINARE has carried out 4 expeditions in the region in order to look for meteorites in 1999/2000, 2002/2003, 2005/2006, 2009/2010 austral seasons with the big collection of more than 11000 meteorites which makes China to be one of the biggest countries with Antarctic meteorites. This work focuses on mineral chemistry and petrology of 98 meteorites collected in Grove Mountains, then further to classify them and discuss the features of weathering and shock metamorphism of these meteorites.

1. Samples and Analysis methods

In order to avoid the samples to break and to save them, all samples first were capsuled with exposy resin, then were cut into thin slices with thickness of 1 mm and ground to make the standard thin slices with 30 microns thick. Chondrule structure, matrix recrystallization, mineral assemblages, grain size of feldspar, shock effects and weathering degree etc are observed and studied by reflective and transmission microscopy, at the same time mineral types are identified. Under the back scattered images and reflective micrographs, the modal contents of minerals especially Fe-Ni alloy and sulfides are estimated and calculated by the graphic statistics software.

The work was carried out with the JSM-6460LV scanning microscopy accompanied with Energetic spectroscopy in the national key lab of environmental geochemistry, the institute of geochemistry, Chinese Academy of Sciences. The representative mineral compositions are quantitatively analysed by the Energetic spectroscopy. The accelerated voltage is 25 keV, the working distance is 15 mm, the live time is 100 seconds. In order to make sure the stability of the instrument, the scanning electronic microscopy was cooled by adding liquid nitrogen more than 8 hours before it began to analyse. The high voltage of the filament was been open for two hours. Meanwhile, in order to keep the precise, the Energetic spectroscopy is demarcated by the mineral compositions of both GRV 023595 and GRV 024130 analysed by the EPMA-1600 electronic microscopy. By comparing the analyses, the SEM data are almost close to the EPMA data. Although they are somewhat lower than the EPMA data, the classification range of ordinary chondrites by SEM is the same to those by EPMA [3].

2. Classification of chemical-petrographic types

Based on the olivine Fa value, the pyroxene Fs value and iron metal contents, 98 ordinary chondrites, which include 36 H-group chondrites and 62 L-group chondrites, are classified.

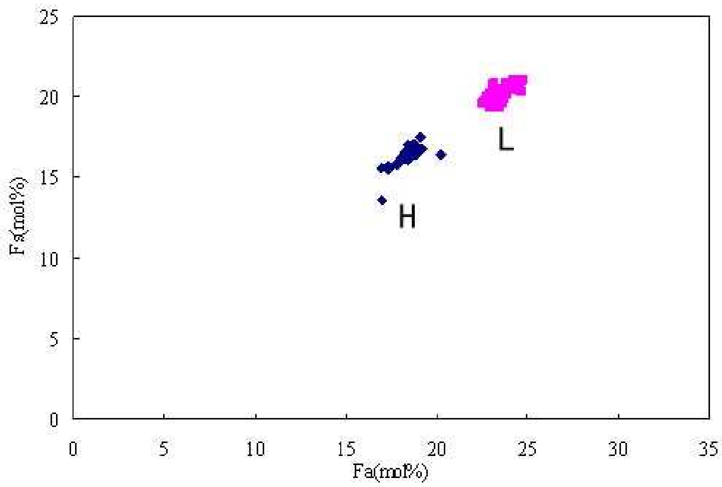

Fig. 1 The plots of olivine Fa and pyroxene Fs of 98 ordinary chondrites, "♦" and "■" represent H groups and L groups repectively.

2.1 High metal groups (H)

The H group meteorites enrich in Fe-Ni alloy and sulfides, and have the typical feature of low FeO content in olivine and pyroxene. The range of average Fa of olivine is 16.9-20.2 mol%, and the range of average Fs of low-Ca pyroxene is 13.7-17.5 mol%. There are some distinct differences in the chondrule texture of 36 H chondrites, suggesting that they were experienced thermal metamorphism in their parentbody, so that they are classified into different petrologic types which include 21 H4, 9 H5 and 6 H6.

H4 chondrites: This type has 21 meteorites, which are GRV 020210, 020216, 020252, 021559, 021561, 021745, 021798, 021890, 022107, 022834, 022977, 022423, 023245, 051566, 051576, 051603, 052403, 053638, 054044, 054494, 054651. The textures and boundaries of the chondrules in these meteorites are distinctive or clearer (Fig. 2 a, b). The glass in most chondrules are devitrified, only a few of chondrules have some primary glass. Some extents of recrystallization occurred in their matrix which show semi-transparent to transparent, and the size of the recrystallized feldspar is about 2 μm across. Fe-Ni alloy and sulfides occur in grain-sized, patched or banded in the matrix or between chondrules. The minerals in the 21 chondrites are relatively uniform in inter- or intra-grains. The Fa of olivine is among 16.9 mol% and 20.2 mol%, the Fs of low-Ca pyroxene is among 15.6-17.0 mol% [4][5].

H5 chondrites: There is 9 meteorites in this group, including GRV020256, 021638, 021938, 022381, 050408, 051959, 052387, 053364, 054080. All these meteorites have chondrules which have easily identified boundaries and are not hard to see the interior textures. The matrix of these meteorites are recrystallized with coarse-sized feldspar grains of 2-50 μm across. Majority of pyroxene are rhombic, only fews pyroxene grains are monocline. The content of pyroxene is less 20 vol%. Olivine and pyroxene are almost homogeneous in composition among intra- or inter grains with the olivine Fa of 17.0 mol% and the low-Ca pyroxene Fs of 13.6-16.8 mol%.

H6 chondrites: This group has 6 meteorites, i.e. GRV 022428, 022859, 024130, 051611, 053655, 054348. The boundaries of chondrules are unclear and their interior textures are hard to see. The matrix is highly recrystallized with coarse-grained feldspar of more than 50μm (usually between 50μm and 100μm). Due to strong thermal metamorphism, olivine and pyroxene are homogeneous in composition.

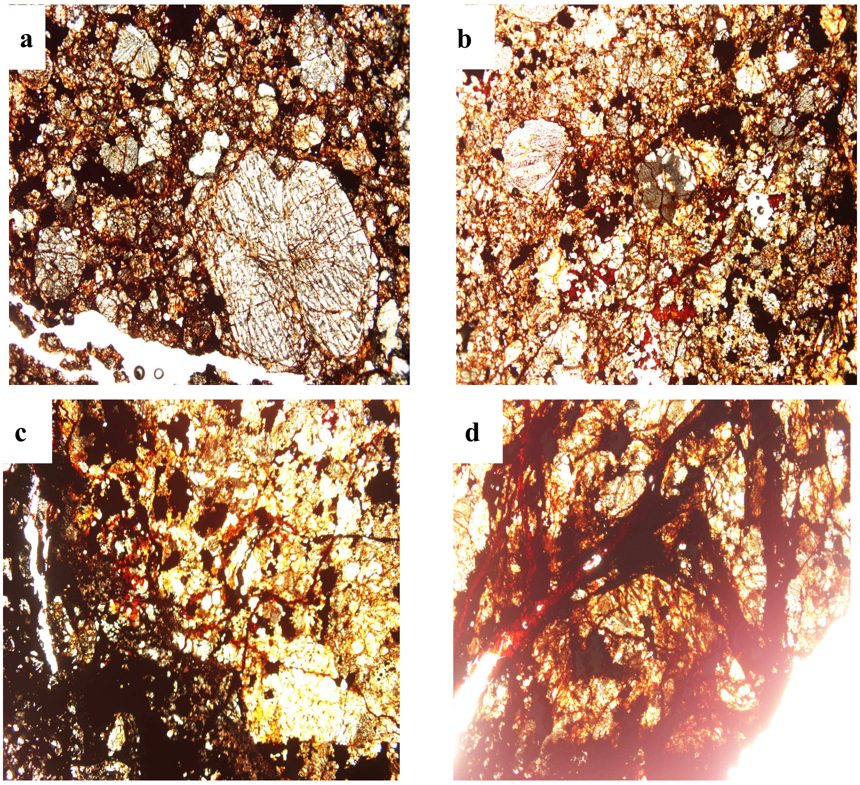

Fig. 2 The photos of interior textures of some H group chondrites under transparent light, a) GRV 054044 (H4); b) GRV 020216 (H4); c) GRV 020256 (H5), the left low corner clearly shows the shock-induced darkness; d) GRV 022381 (H5), in which the shock veins and pockets are seen.

2.2 Low metal group (L)

The L group has 62 meteorites, including 25 L5 and 37 L6.

L5 types: This type meteorites have 25 samples, e.g. GRV 020224, 020310, 020328, 020354, 020576, 021691, 021746.

This group meteorites usually have low metal contents. Except 5 meteorites of GRV 020224, 020576, 052298, 053080 and 053726 have somewhat higher metal contents, the contents of other 20 meteorites are lower than 2.0 vol%. These meteorites have chondrules which have discernable boundaries and interior textures. Their matrix are more highly recrystallized with coarse-grained feldspar of 2-50 μm across. The olivine has the Fa value between 22.6-24.6 mol%, the low-Ca pyroxene has Fs values of 19.3-20.8 mol% [6][7].

L6 types: This type has 37 meteorites, e.g. GRV 020300, 020355, 020589, 021523, 021658. Except 7 meteorites (e.g. GRV 021658) have a little higher metal contents, other meteorites have lower Fe-Ni contents of less than 2.0 vol%. Because these meteorites experienced highly thermal metamorphism, all of them are highly recrystallized. The chondrule texture and their boundaries are unclear and are hard to identify. The secondary feldspar are coarse-grained with the size of more than 50 μm. All this type meteorites have the olivine Fa of 22.8-24.9 mol% and the pyroxene Fs of 19.6-21.0 mol%, which fall into L group.

3. The shock effects and weathering features

(1) 21 H4 meteorites have lighter shock effects. 12 of them have very slightly shock degree of S1, while 8 meteorites have shock degree of S2 [8]. However, GRV 021745 has a little stronger shock effects of S3, i.e. heavily mineral irregularly fragmented, plannar fractures of feldspar, undulose extinction, and local shock pockets. Under the criteria of weathering degree of Wlotzka [9], GRV 054651 has a weathering degree of W2, 20 others of H4 meteorites have W1 weathering degree.

(2) In 9 H5 meteorites, GRV 020256 has the shock effects of shock darkness, shock veins and pockets, plannar fracture of olivine, weak mosaic extinction, suggesting that it has the shock stage of S4. GRV 022381 have more highly shock effects, e.g. planner fractures of olivine, heavily mosaic extinction, popular shock veins and pockets (Fig. 2c, d), indicating it belongs to S5 shock stage. GRV 050408, 051959 and 054080 share lighter shock effects of S2 shock stage, including irregular fractures of minerals, undulose extinction. GRV 053364 has the lowest shock stage of S1. All 9 H5 meteorites have very fresh samples with W1 weathering degree, in which only boundaries of metal or sulfide grain are oxidized.

(3) Among 6 H6 meteorites, GRV 053655 has the lightest shock effects, e.g. normal extinction of olivine and pyroxene, and only irregular fratures, indicating it has S1 shock stage. The shock effects of GRV 022428, 022859 and 054348 include irregular fractures, fews of plannar fracture, undulose extinction, indicating that they have S2 shock stages. But GRV 051611 has a little high shock stage of S3 with effects of some shock veins and pockets. GRV 024130 experienced a little high oxidization of W3 weathering degree, while other 5 meteorites are much fresh with weathering degree of W1.

(4) The 25 L5 meteorites have different shock stages of S1, S2, S3 and S4. GRV 050726 has highest shock stage of S4, due to the strongest shock effects of weak mosaic extinction of olivine, plannar fractures of olivine and feldspar, net-shaped shock veins with local shock pockets. And the 6 meteorites, e.g. GRV 020328, 021691, 021746, have heavy shock effects of undulose extinction, irregular fractures, some plannar fractures, and shock veins and pockets, indicating their shock stages are W3. But the 17 meteorites of this type experienced light shock metamorphism of W2. Only GRV 020354 seems almost not to be shocked with S1. Except GRV 020328 is a little oxidized on the metal and sulfide grains with a weathering degree of W2, other 24 meteorites have fresh samples with weathering degree of W1.

(5) 37 L6 meteorites have the shock stages of various shock stages. Both GRV 021523 and GRV 050037 have the lightest shock effects of S1. The 15 meteorites (e.g. GRV 021658, 021760, 021945) share light shock effects of S2. Due to the presence of heavier shock effects of mineral fractures and fine shock veins, 9 meteorites (e.g. GRV 020589, 021971, 051018) shock stage is classified into S3. And in 9 meteorites (e.g. GRV 020300, 020355, 021759) the much higher shock effects of mosaic extinction of olivine, shock veins and pockets indicate they have the shock stage of S4. However, GRV 023595 and GRV 053583 have the shock stage of S5 with strongest shock effect of popular mosaic extinction of olivine, wide shock veins and pockets. Additionally, all samples of 37 meteorites are quite fresh with the weathering degree of W1.

4. Conclusions

(1) Mainly based on mineral chemistry of olivine and low-Ca pyroxene and petrological features of metal contents, chondrule textures and matrix recrystallization, 98 GRV meteorites classification has been carried out with the result as follows: 21 H4, 9 H5, 6 H6, 25 L5 and 37 L6.

(2) More than 30% meteorites have higher shock effects of above S3, suggesting that they should be experienced heavily shock metamorphism in their parentbody and formed shock veins and pockets, so they are ideal samples to study the high shock-induced minerals and metamorphism.

(3) All the meteorites samples are much fresh with the weathering degree W1. Comparing with desert meteorites, Antarctic meteorites experienced much lighter terrestrial oxidization, suggesting that Antarctica is a good reserve for meteorites.

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