ARTICLE

Petrography and Mineralogy of the Morro de La Mina Meteorite.

L. L. Antonello [1]; R. B. Scorzelli [2]; I. S. Azevedo [2]; M. E. Zucolotto [1] and M. F. Lopes [3]

[1] Departamento de Geologia e Paleontologia, Museu Nacional/UFRJ – Quinta da Boa Vista – Rio de Janeiro – Brazil – CEP 20940-040, loiva@acd.ufrj.br, Phone:.(55-021) 568-8262 R.219 [2] Centro Brasileiro de Pesquisas Físicas, CBPF, RJ. [3] Departamento de Ciências dos Materiais e Metalurgia, PUC, RJ.

Abstract

The Morro de La Mina meteorite was found in 1986 in the Atacama Desert, western Chile, presumably in its place of fall. Thin and polished sections were studied under optical microscopy in plane polarized transmitted and reflected light, scanning electron microscopy (SEM/EDS) with dot mapping image and high contrast backscattering electron images, and electron microprobe.

This meteorite presents a chondritic structure with a variety of chondrules embedded in a fine-grained matrix. The internal texture of the chondrules corresponds to the most common ones as barred olivine, radial pyroxene, granular olivine-pyroxene and porphyritic olivine-pyroxene; polysomatic barred olivine, recrystallized annealed olivine and also pyroxene chondrules.

Correspond to those of an H5, weakly shocked, S3 chondrite

Keywords: meteorite - chondrite- radial pyroxene - chondrules - barred olivine- granular olivine- pyroxene chondrules.

Introduction

The Morro de La Mina meteorite was found in 1986 in the Atacama Desert, Antofagasta, Chile, presumably in its place of fall during an investigation of the Imilac strewnfield. One single specimen of 1.4 kg said to have been found and is now in the University de la Serena, Chile (1).

In this paper we characterize the chondritic structure, observing the different chondrules present in a sample of the Morro de la Mina meteorite. This fragment shows strong weathering alteration, certainly due to a severe iron-oxidation process occurred in the warm desert where the meteorite was recovered.

Materials and Methods

Polished and thin sections of the Morro de la Mina meteorite were analyzed microscopically in transmitted and reflected light, by x-ray diffraction, scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS), dot mapping image (Dmi) and high contrast backscattering electron images (BSEi). Electron microprobe investigation (WDS) was also performed.

Results

Petrographic Observation

Under microscope the Morro de La Mina meteorite observation displays a very developed chondritic texture (Figure 1) with the occurrence of many well-defined chondrules showing discernible boundaries relative to the matrix.

The chondrules vary from rounded or elongated shapes to broken and fragmented grains, ranging from 0.2 to 1.8 mm in size.

The matrix consists of chondrules, isolated mineral grains and fragmented grains embedded in a clastic matrix in well-defined patchy areas of different colors, showing finely crystalline to crystalline material. The matrix is composed of olivine, pyroxene, plagioclase, apatite, cristobalite, glass, metallic iron-nickel, troilite, chromite and iron oxides and hydroxides. Opaque mineral veins are also frequent, permeating the matrix.

The chondrules vary considerably in their internal textures, the majority is characterized as radial-pyroxene, barred-olivine, granular olivine-pyroxene and porphyritic olivine-pyroxene, but polysomatic barred-olivine, recrystallized annealed olivine, and pyroxene chondrules are also present.

The radial-pyroxene chondrules are commonly elongated, spherical or with a fine lath of orthopyroxene radiating from an eccentric nucleation point (Figure 2); some exhibit planar fracture and under polarized light undulose extinction, low birefringence with colors in shades of gray; others are also composed of very small crystals. Some pyroxene show complex pyroxene exsolution features; the host is orthopyroxene with lamellae of clinopyroxene. According to the electron microprobe data, there is a small variability of FeO and MgO content in olivine (Fa_{19}) and pyroxene (Fs_{18}) grains, showing an equilibrated state for the iron-magnesium minerals.

The barred-olivine chondrules are often composed of a single crystal of olivine with plates or bars arranged in parallel rows, and set in a glassy matrix. Often the chondrules is boarded by a rim of the same material, and the olivine plates as well as the rims have the same colors under polarized light, suggesting a single crystal oriented in the same direction (Figure 3). The single crystal oriented at different angles exhibits a of combination of colors under crossed polars. In reflected light these chondrules show a low reflectivity in gray (Figure 4).

Porphyritic olivine-pyroxene chondrules show a composition of small and large crystals of olivine, pyroxene, fragments of relic barred-olivine chondrules, and opaque minerals.

Granular olivine-pyroxene chondrules as well as the rim are composed of a nearly equal mixture of both minerals olivine and pyroxene in anhedral crystals. Some olivine is colorful (Figure 7).

Mineralogical Composition

The essential minerals are the ferromagnesians, pyroxene and olivine, and the metal phase Fe-Ni, mainly kamacite, plessite and taenite (Figure 5). The accessory minerals are troilite, chromite, glass, plagioclase, cristobalite and apatite. The secondary minerals formed during terrestrial weathering are hematite (Figures 7-3) and iron hydroxides such as goethite and lepidocrosite.

Pyroxene: orthopyroxene is dominant, and the clinopyroxene appears in a very low amount. Orthopyroxene is found in chondrules and in the matrix; in transmitted plane polarized light is pale brown and no pleochroic; some grains show exsolution lamellae, the host is supposed to be orthopyroxene and the lamellae are clinopyroxenes. Microprobe analysis gave a low value for iron content, according to a very magnesium-rich mineral (En_{82}; Fs_{17}; Wo_1).

Olivine: most olivine grains are in the matrix and some are greenish yellow with weak pleochroism, high refringence and birefringence. The chondrules of olivine are easily distinguishable by crystal shape and interference colors. In the barred olivine since the crystals are oriented randomly or with twinned components oriented at different angles on the slide, many different interference colors are seen; when crystals are all oriented in the same direction on the slide they have the same interference colors under polarized light (Figure 3). In some areas they are poikilitically enclosed within the pyroxene grains. From electron microprobe analysis the olivine is also magnesium-rich (Fa_{19}; Fo_{81}).

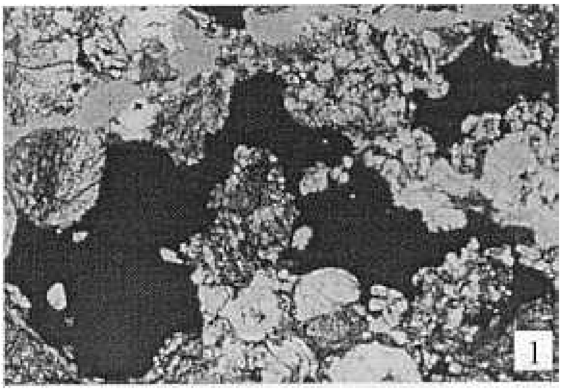
Orthopyroxene and olivine exhibit the same shock features as undulose extinction, development of clinoenstatite lamellae parallel to (100), fractures and fragmented chondrules. Small amounts of nickel, chromium, and calcium are present in these ferromagnesian minerals (Figures 7, 8).

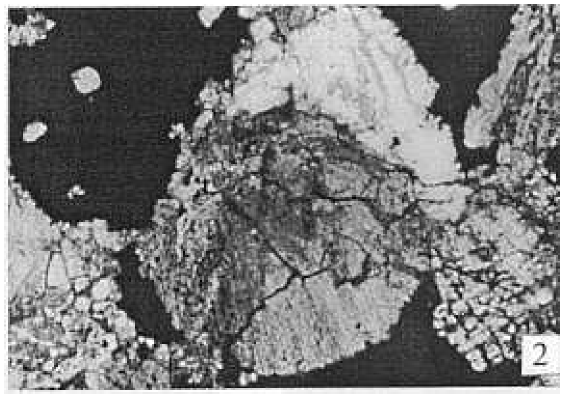
Iron-nickel: Etched samples (nital 2%) show that iron-nickel phases are composed by kamacite, taenite, and plessite, occurring in large xenomorphic grains, some rimmed by thin and no-uniform layers of iron oxides or hydroxides from terrestrial origin, of bright white color in reflected light (Figure 5). SEM images are shown in Figures 8b1.

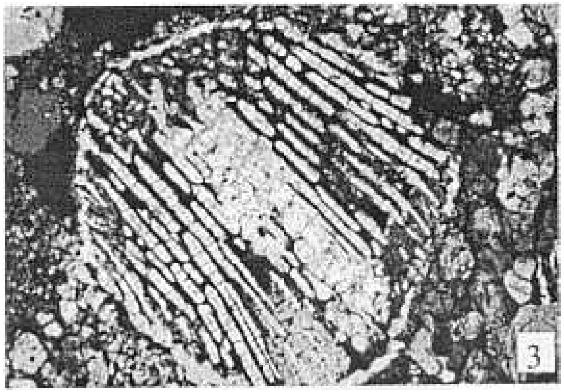
Troilite: This opaque mineral (FeS) occurs in minor amount, and contains nickel and chromium as trace elements (Figures 7kl). Grains are polycrystalline and some exhibit, under polarized light, undulose extinction, others are crosscut by cracks. The characteristic color is bright orange-brown and the reflectivity is slightly higher than that for the iron-nickel minerals. Sulfide minerals such as troilite are the principal shock-indicating are the main features in meteorites.

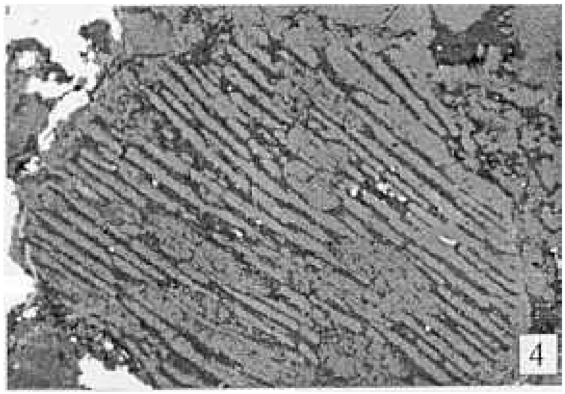
Chromite: Occurs as coarse rounded grains light gray in reflected light, and the DMi of figure 8d1 shows the distribution of chromite elements (Figure 7c).

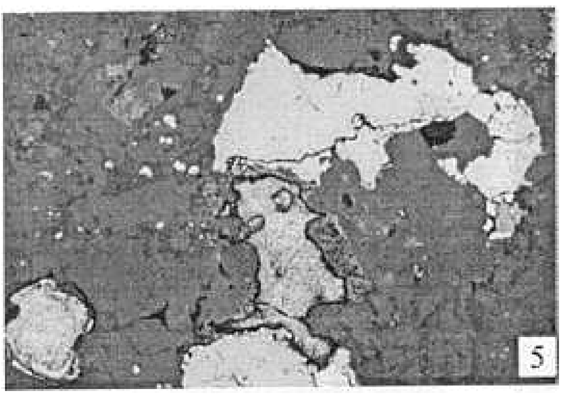
Plagioclase: Occurs as very rare grains in the matrix, usually colorless in plane-polarized light, and with multiple lamellar albite twins visible under crossed polars.











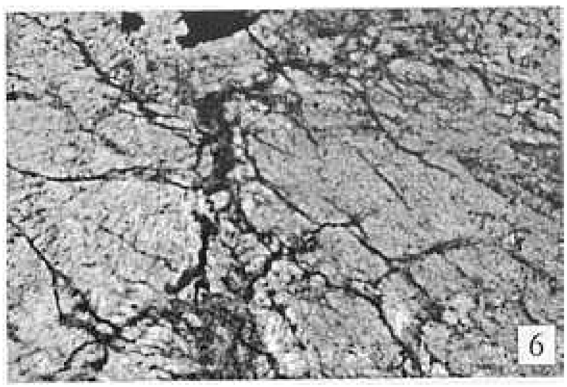


Figure 1 –Photomicrograph of a thin section of the Morro de la Mina meteorite in transmitted, crossed polarized light overview showing the chondritic texture with abundant chondrules, mostly of ferromagnesian silicates (olivine and pyroxene). Visual field 2.5mm wide;

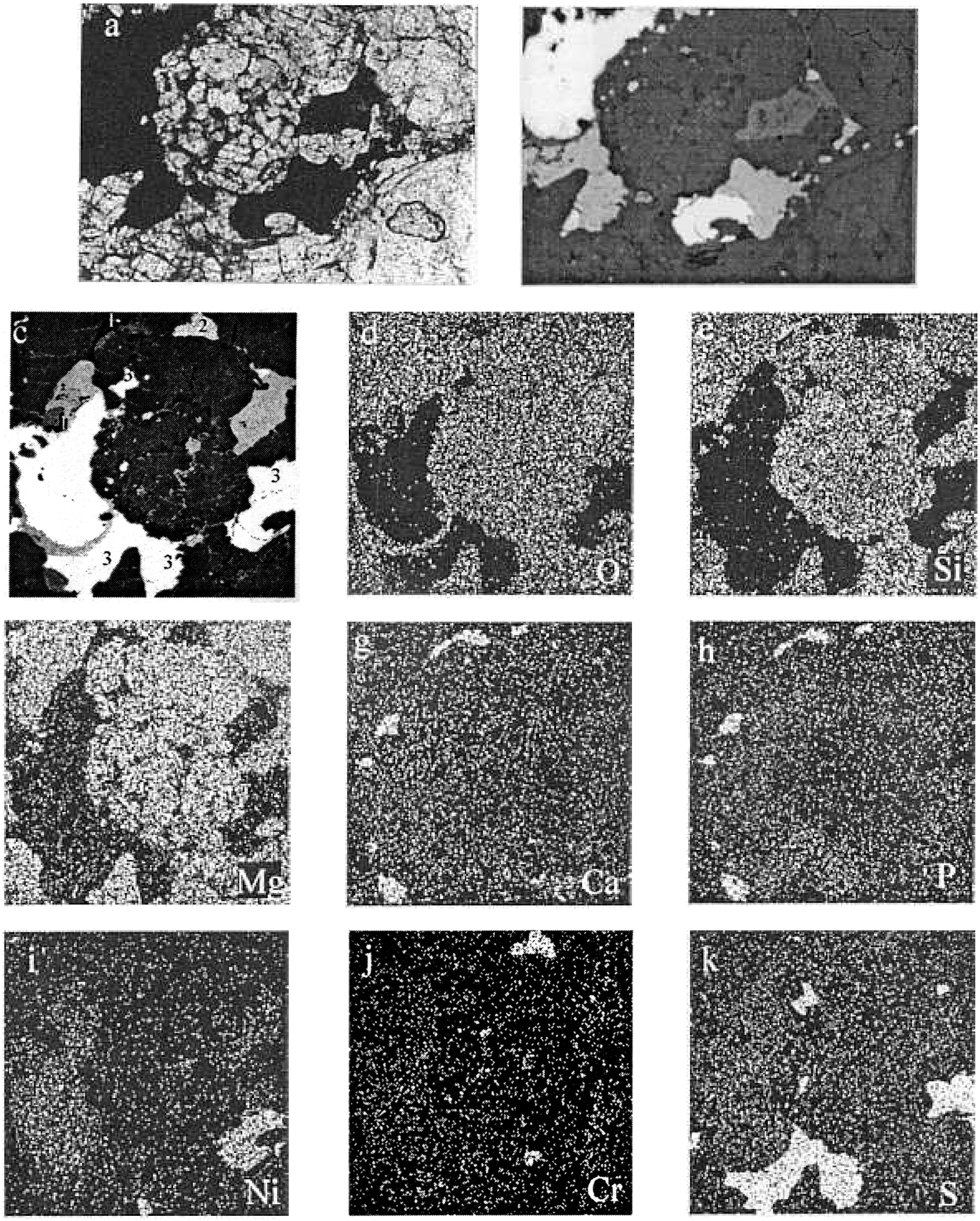
Figure 2 –in transmitted crossed polarized light showing a very fine-grained radial-pyroxene with fan shape and undulose extinction. Visual field 1.55 mm wide;

Figure 3 – in transmitted crossed polarized light showing a barred-olivine chondrule with bars and rims of olivine single crystal set in glass. Visual field 1.55mm wide;

Figure 4 – in parallel polarized reflected light showing the low reflectivity of barred-olivine chondrule.Visual field 0.77mm wide;

Figure 5 – polished and etched (nital 2%) section in reflected light showing metallic iron-nickel, plessite (stained), kamacite and taenite (white), and troilite (brownish yellow) and chomite (gray), outlines of chondrules of ferromagnesian silicates (olivine and pyroxene) (dark gray). Visual field 1.55mm wide;

Figure 6 – in parallel transmitted light, showing thin and no –uniform layers of iron oxides and hydroxides of terrestrial origin such as goethite, lepidocrosite and hematite. Visual field 0.77mm wide.



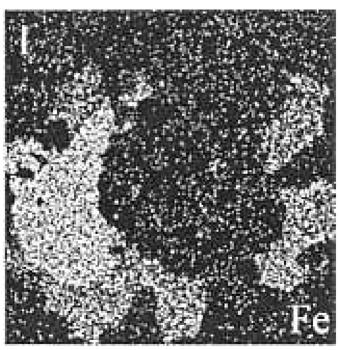
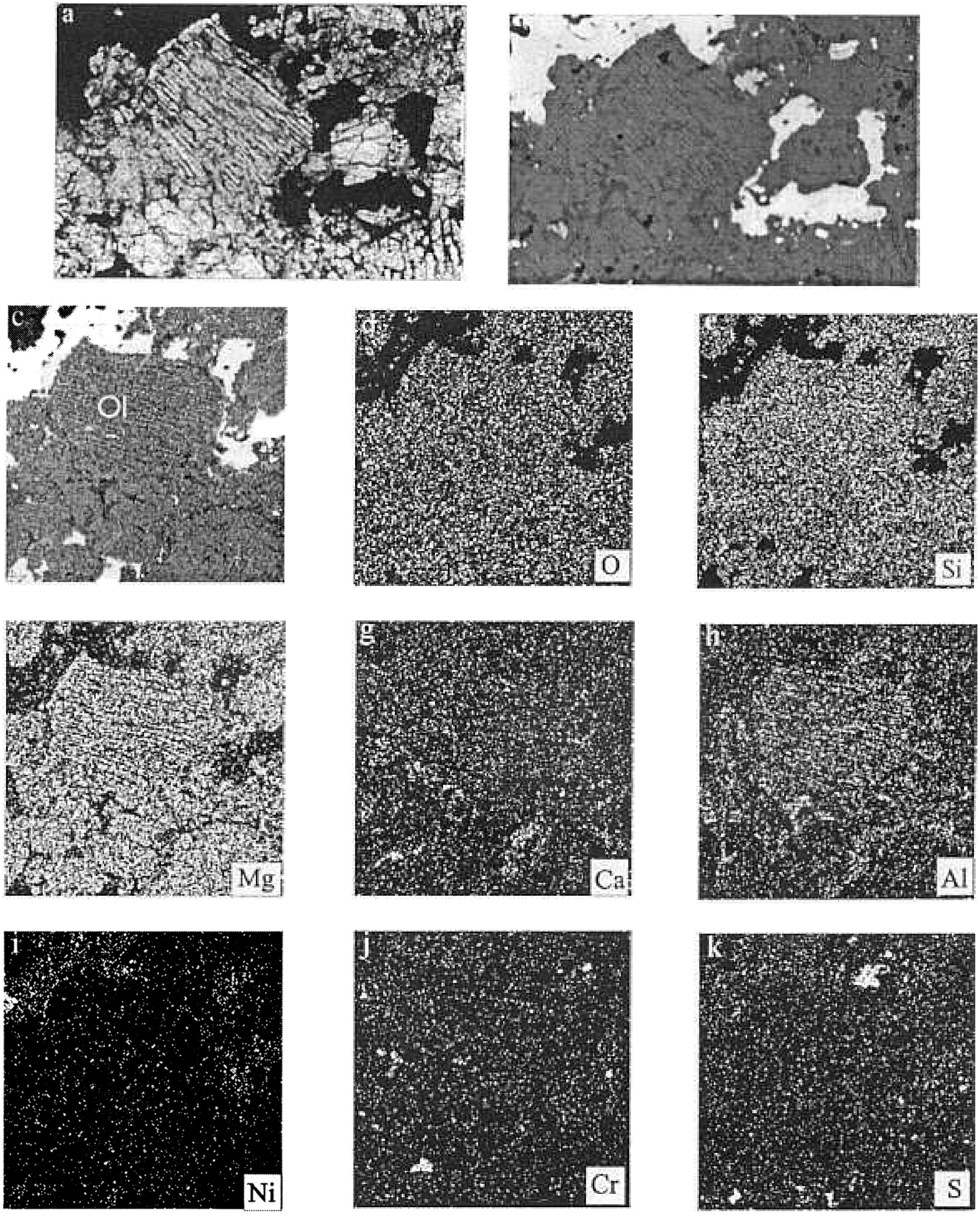


Figure 7: (a) photomicrograph of a thin section showing a granular olivine-pyroxene chondrule, surrounded by opaque and matrix minerals, in parallel polarized transmitted light. Visual field 1.55mm wide; **(b)** previous figure in reflected lightprevious figure in reflected light showing opaque minerals, high reflectivity (white) and ferromagnesian minerals, low reflectivity (dark gray); ;**(c)** backscattering electrons image, showing phosphate (1), chromite (2), nickel-iron (3), ferromagnesien silicates (dark gray); ; **(d to l)** respectively dot mapping image of oxygen in previous c of: Si, Mg, Ca, P, Ni, Cr, S and Fe.



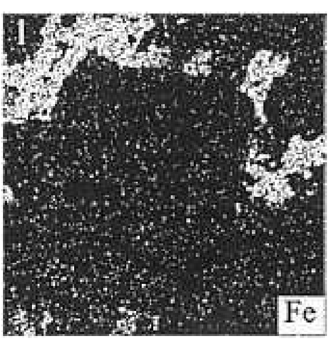


Figure 8: (a) photomicrograph of a thin section showing a granular barred olivine chondrule, surrounded by opaque and matrix minerals, in parallel polarized transmitted light. Visual field 1.55mm wide; **(b)** previous figure in reflected light showing opaque minerals, high reflectivity (white) and ferromagnesian minerals, low reflectivity (dark gray); **(c)** backscattering electrons image; **(d)** dot mapping image of oxygen in previous 8c; **(e)** dmi of silicon in previous 8c; **(f)**- dmi of Mg in previous c; **(g)** dmi of calcium in previous c; **(h)** dmi of aluminum in previous 8c; **(i)** dmi of nickel in previous 8c; **(8)** dmi of chromium in previous 8c; **(k)** dmi of sulfur in previous 7c; **(l)**- dmi of iron in previous 8c.

Cristobalite: Occurs as few clear grains with low birefringence, tentatively identified by peaks on the x-rays patterns.

Glass: Occurs as dark and crypto-crystalline material, probably consisting of devitrified glass almost between the bars in barred olivine chondrules, but also in the matrix. Some grains with high relief and low birefringence that occur surrounding ferromagnesian chondrules (Figures 7d1) could be apatite or merrilite (phosphorus and calcium are detected, and sodium is absent), but according to (2), apatite and merrilite in appearance and optical properties are very similar; they are almost impossible to distinguish one from the other.

The secondary minerals formed during terrestrial weathering from iron minerals are hematite, goethite and lepidocrosite. They occur as thin and no-uniform layers red and brown in color, filling cracks, and stained ferromagnesian minerals. (Figures 6).

Conclusion

Based on textural features together with the mineralogical and chemical data, the meteorite Morro de la Mina from the Atacama Desert, western Chile corresponds to those of an H5-group chondrite, weakly shocked, S3, according to (3).

References

(1) Graham, A.L. (1989). Meteoritics, 24, 59.

(2) Mason, B. (1972). Meteoritics, 7, 309-326.

(3) Stoffler, D., Keil, K. and Scott, E.R.D. (1991). Geochim. Cosmochim. Acta 6, 282-301.