Petrography and Mineral Chemistry of 49 Equilibrated Ordinary Chondrites from the Atacama Desert, Chile

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INTRODUCTION

The Atacama Desert in northern Chile, South America, offers optimal conditions for meteorite accumulation due to its persistent hyper-arid climate, which has remained stable for approximately 25 million years [Dunai et al., 2005]. This unique environment has led to exceptionally high meteorite densities per square kilometer and the discovery of meteorite populations with terrestrial ages averaging 710,000 years [Hutzler et al., 2016, Drouard et al., 2019]. Since 2017, numerous international expeditions, alongside a few Chilean efforts, have actively searched for meteorites in the region. However, a key challenge faced by Chilean meteoritic researchers is the lack of access to microprobe laboratories, essential for the precise classification and analysis of meteorite samples.

MATERIALS AND METHODS

This study focuses on the petrography, mineral chemistry, and classification of 49 equilibrated ordinary chondrites collected during a 2020 Spanish scientific expedition in the Atacama Desert, Chile. The chondrites were classified into chemical-petrographic types, and their degrees of shock metamorphism and weathering were assessed. The sample set includes 32 H-group chondrites (two H3, three H4, twenty-three H5, and four H6), 16 L-group chondrites (one L3, three L4, nine L6, and three L6 melt), and one LL-group chondrite (LL6).

RESULTS

A petrographic classification of shock metamorphism degrees of ordinary chondrites was put forward by Stöffler et al. (1991) and has since been widely used. According to their classification, seven shock metamorphism degrees (S1–S6 and shock melted) were defined, based on the shock effects in the main silicate components, as recognized by thin section microscopy. The characteristic shock effects of each shock degree are (see Table 1): S1 (unshocked)-sharp optical extinction of olivine; S2 (very weakly shocked)-undulatory extinction of olivine; S3 (weakly shocked)-planar fractures in olivine; S4 (moderately shocked)-mosaicism in olivine; S5 (strongly shocked)-isotropization of plagioclase (maskelynite) and planar deformation features in olivine; and S6 (very strongly shocked-recrystallization of olivine, sometimes combined with phase transformations (ringwoodite and/or phases produced by dissociation reactions). S6 effects are always restricted to regions adjacent to melted portions of a sample which is otherwise only strongly shocked. According to this data, we classified the shock degrees of 49 Atacama Desert ordinary chondrites. The shock metamorphism degrees of the 49 chondrites are S1 (five meteorites), S2 (32 meteorites), S3 (five meteorites), S4 (four meteorites), and S5 (three meteorites).

CONCLUSION

Our results suggest that the relative abundances of H, L, and LL groups in the Atacama Desert differ from global trends. Notably, the L-group chondrites represent the majority of heavily shocked specimens. In contrast, the H-group includes only four heavily shocked meteorites, and the LL group contains one. The distinct shock metamorphism degrees observed between the H and L groups may reflect differences in the surface properties of their parent bodies.

Table 1. Shock metamorphism degrees of Atacama chondrites (modified from Stöffler et al., 1991).

Shock Degree	Silicates Olivine - Pyroxene - Plagioclase	Local Effects	Results
S1	sharp optical extinction and irregular fractures	none	5
S2	undulose extinction and irregular fractures	none	32
S3	planar fractures undulose extinction and irregular fractures (a few ringwoodite)	opaque shock veins, incipient formation of melt pockets	5
S4	planar fractures weak mosaicism ringwoodite maskelynite	opaque shock veins and melt pockets interconnecting	4
S5	planar fractures strong mosaicism ringwoodite maskelynite (a few (Mg, Fe)SiO3-glass)	pervasive melt pockets and shock veins	3
S6	in or near the shock induced-veins, solid state recrystallization of silicates	pervasive melt pockets and shock veins	0

REFERENCES

Dai, D., Liu, S., & Liu, X. (2018): Chemical-Petrographic Types and Shock Metamorphism of 184 Grove Mountains Equilibrated Ordinary Chondrites. Minerals. **8(6)**, 240.

Dunai, T.J., González López, G.A., Juez-Larre, J. (2005): Oligocene–Miocene age of aridity in the Atacama Desert revealed by exposure dating of erosion-sensitive landforms. Geol. **33**, 321-324.

Drouard, A., Gattacceca, J., Hutzler, A., Rochette, P., Braucher, R., Bourlès, D., Aster Teman., Gounelle, M., Morbidelli, A., Debaille, V., Van Ginneken, M., Valenzuela, M., Quesnel, Y., Martínez, R. (2019): The meteorite flux of the past 2 my recorded in the Atacama Desert. Geol. **47**, 673-676.

Fritz, J., Greshake, A., Fernandes, V.A. (2017): Revising the shock classification of meteorites. Meteorit. Planet. Sci. **52**, 1216–1232.

Hutzler, A., Gattacceca, J., Rochette, P., Braucher, R., Carro, B., Christensen, E.J., Cournede, C., Gounelle, M., Ouzaa, N.L., Martínez, R., Vlanezuela, M., Warner, M., Bourles, D. (2016): Description of a very dense meteorite collection area in western Atacama: Insight into the long-term composition of the meteorite flux to Earth. Meteorit. Planet. Sci. **51**, 468-482.

Lu, R., Miao, B., Wang, G., Dai, D., Lin, Y., Ouyang, Z., Li, C. (2004): Classification of 24 New Ordinary Chondrites from Grove Mountains, Antarctica. Acta Geol. Sin. **78**, 1052–1059.

Miao, B., Lin, Y., Ouyang, Z., Zhou, X. (2003): Type distribution pattern and pairing of ordinary chondrites from Grove Mountains, Antarctica. Chin. Sci. Bull. **48**, 908–913.

— & Wang, D. (2009): Classification of Grove Mountains meteorites and its significance. Chin. J. Pol. Sci. **20**, 97–109.

Stöffler, D.; Keil, K.; Scott, E.R.D. (1991): Shock metamorphism of ordinary chondrites. Geochim. Cosmochim. Acta, **55**, 3845–3867.

Valenzuela, M., Oliveros, V., Menzies, A., Pinto, G., Corgne, A., Alvarez, S., Beltrán, T., Echevarría, R., Revillard, A., Salazar, N., Soto, K., Ulloa, B. (2021): QEMSCAN® as a new tool for classification: First results in ordinary chondrites from Atacama Desert, Chile. 84th Annual Meeting of The Meteoritical Society 2021 (LPI Contrib. No. 2609) 6281.