15th International Congress of the Geological Society of Greece
Athens, 22-24 May, 2019 | Harokopio University of Athens, Greece
Bulletin of the Geological Society of Greece, Sp. Pub. **7** Ext. Abs. GSG2019-380

First report of Fe inclusions in olivine: olivine from the magnesite-hosting ultramafic rocks of Gerakini, Chalkidiki, Northern Greece

E. Tzamos[1,2], , G. Grieco[3], E. Pagona[4], A. Papadopoulos[2], M. Bussolesi[3], M. Mitrakas[4], A. Zouboulis[2]

(1) North Aegean Slops SA, Thessaloniki, Greece, tzamos@chem.auth.gr
(2) Laboratory of Chemical and Environmental Technology, Section of Chemical Technology and Industrial Chemistry, School of Chemistry, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
(3) Department of Earth Sciences, Università degli Studi di Milano, via Botticelli n.23, 20133, Milano Italy
(4) Chemical Engineering Department, Schoolf of Engineering, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece

Magnesite ore deposits are closely associated with ophiolitic ultramafic rocks -more specifically dunites and chartzburgites. Dunites consist mainly of olivine (>90% v/v), whereas in chartzburgites the main mineral phases are olivine and pyroxenes (ortho- and clino-). These rocks can be altered at several extents due to serpentinization, and their primary minerals are altered to different mineral phases (mainly serpentine) but even in cases of extended serpentinization, relics of the primary minerals remain unaltered.

The mineral olivine belongs to the orthorhombic crystal system have a general chemical formula: X_2SiO_4, where X=Mg, Fe. The ratio of magnesium to iron varies between the two endmembers of the solid solution: forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4). Compositions of olivine are commonly expressed as molar percentages of forsterite (Fo) and fayalite (Fa).

Synthesis of olivine in laboratory experiments has shown that, depending on the physico-chemical conditions, Mg and Fe can be substituted in small extend by other bivalent cations (e.g. Zn, Ni, Mn) (Nord *et al.*, 1982, Annersten *et al.*, 1982, 1984a, 1984b, Ericsson *et al.*, 1986).

Geologically, Gerakini area belongs to the ophiolitic sequence of Western Chalkidiki. In Gerakini the –serpentinized- ultramafic formations hosts numerous magnesite ore deposits. Currently, magnesite is being mined at Gerakini by the company “Grecian Magnesite SA”.

The main scope of this work is to provide new data about Fe inclusions found in olivine grains from the Gerakini ultramafic rocks. This is the first such report in Greece and –to the best of our knowledge- worldwide.

For the present study several rock samples (serpentinized dunites and chartzburgites) were taken from the Rachoni open pit mining site located at the Gerakini mining district. Thin-polished sections were mounted from each sample and were examined both in optical microscope (transmitted and reflected light). Mineral chemistry was determined with a JEOL 8200 electron microprobe equipped with a wavelength dispersive system (SEM-WDS). The system was operated using an accelerating voltage of 15 kV, a sample current on brass of 15 nA, a counting time of 20 s on the peaks and 10 s on the background. A series of natural minerals were used as standards.

In one of the studied samples (W5), the examination in the SEM revealed a very rare phenomenon: olivine grains in one particular area of the examined section had inclusions (Figure 1). EDS and WDS analyses from the inclusions showed that they consist solely of Fe.

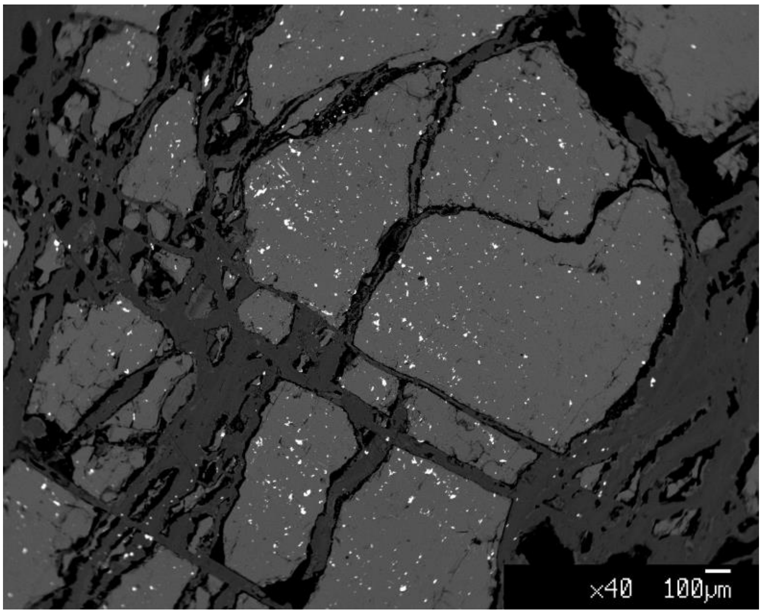

Figure 1. Back Scattered Electron (BSE) image from sample W5 showing Fe inclusions (white) in olivine relics (light grey). Dark grey is serpentine matrix.

The study of the mineral chemistry of olivines from sample W5 (Table 1) did not reveal any notable differences between olivines hosting Fe inclusions and those not. All olivines are high forsteritic and Fo content in both cases has a constant value of 0.90 ($Fo_{0.90}Fa_{0.10}$). Also, NiO content of olivines is rather low (<0.44wt.%), but no Ni alloys were found during the microscopic study of the sections.

Table 1. Mineral chemistry of olivine grains from sample W5. Analyses No 22-26 are from olivines with Fe incusions, whereas analyses No 31-35 are from olivines without inclusions.

Analysis No	**22**	**23**	**24**	**25**	**26**	**31**	**32**	**33**	**34**	**35**
SiO_2	41.59	41.51	41.75	41.30	41.16	41.65	41.75	41.31	41.31	41.74
TiO_2	0.01	0.04	0.05	0.01	0.05	--	--	--	0.01	--
Al_2O_3	--	--	--	0.04	--	--	--	--	0.02	0.02
Cr_2O_3	--	0.01	--	--	--	--	0.04	--	0.04	0.03
FeO	9.04	8.98	8.94	9.03	8.96	9.17	8.97	9.01	8.89	8.94
MnO	0.12	0.15	0.15	0.15	0.10	0.08	0.13	0.11	0.10	0.14
MgO	49.66	50.00	49.58	49.60	49.61	49.73	49.74	49.84	50.06	49.38
NiO	0.36	0.39	0.41	0.44	0.32	0.36	0.29	0.36	0.38	0.39
CaO	0.03	0.03	0.02	0.03	0.03	0.03	0.02	0.01	0.01	0.01
Total	100.82	101.11	100.90	100.60	100.23	101.03	100.93	100.65	100.83	100.65
Fo	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

The Fe inclusions must have segregated from magmas prior to or along with crystallization of olivine. The segregation of these inclusions, although minor amount, could result in Fe depletion in the evolved magmas (Bai *et al.*, 2017). Of course, subsolidus equilibration between olivine and chromite (Mg^{2+} diffusion from chromite to olivine and Fe^{2+} from olivine to chromite at subsolidus temperature) is the most probable factor controlling the olivine chemical composition and its high Fo content.

Conclusions

During the microscopic and mineral chemistry investigation of the studied samples, Fe inclusions in olivine were found in olivine grains of one of the samples. These inclusions must have crystallized prior to or along with olivine grains. The high Fo content of olivines in the studied samples is attributed –mainly- to subsolidus equilibration between olivine and chromite and –to some extend- to the formation of these inclusions.

Acknowledgements

This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE (project code:T1EDK-03543).

European Union
European Regional Development Fund

EPAnEK 2014-2020
OPERATIONAL PROGRAMME
COMPETITIVENESS
ENTREPRENEURSHIP
INNOVATION

ΕΣΠΑ 2014-2020
ανάπτυξη - εργασία - αλληλεγγύη
Partnership Agreement 2014 - 2020

References

Annersten, H., Adetunji, J., Filippidis, A., 1984a. Cation ordering in Fe-Mn silicate olivines. American. Mineralogist, 69(11/12), 1110-1115.

Annersten, H., Ericsson, T., Filippidis, A., 1982. Cation ordering in Ni-Fe olivines. American Mineralogist, 67(11/12), 1212-1217.

Annersten, H., Filippidis, A., 1984b. Cation ordering in Ni-Fe olivines: reply. American Mineralogist, 69(1/2), 164.

Bai, Y., Su, B.-X., Chen, C., Yang, S.-H., Liang, Z., Xiao, Y., Qin, K.-Z., Malaviarachchi, S.P.K., 2017. Base metal mineral segregation and Fe-Mg exchange inducing extreme compositions of olivine and chromite from the Xiadong Alaskan-type complex in the southern part of the Central Asian Orogenic Belt. Ore Geology Reviews, 90, 184-192.

Ericsson, T., Filippidis, A., 1986. Cation ordering in the limited solid solution Fe_2SiO_4-Zn_2SiO_4. American Mineralogist, 71(11/12), 1502-1509.

Nord, A.G., Annersten, H, Filippidis, A., 1982. The cation distribution in synthetic Mg-Fe-Ni olivines. American Mineralogist, 67(11/12), 1206-1211.