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Fe-Mg-Ni-O (Iron-Magnesium-Nickel-Oxygen)

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Extraction of nickel laterite ores requires an understanding of the phase equilibria of this quaternary system. For the first time, [2009Rha] reported experimental results of the isothermal equilibria between 1600 and 1200 °C in the MgO-FeO-Fe_2O_3-NiO region.

Lower Order Systems

Updates on the Fe-Mg-O and Fe-Ni-O systems appear in this issue. The phase equilibria with emphasis on the metal-rich region of these ternary systems were reviewed earlier by [1989Rag1] and [1989Rag2], respectively. In the Mg-Ni-O system, the monoxides MgO and NiO (bunsenite) form a continuous *B*1-type cubic solid solution. The most recent update on the Al-Fe-Ni system is by [2009Rag].

Quaternary Phase Equilibria

With starting powders of 99.98% Fe_2O_3, 99.99% MgO, 99.99% NiO, 99.99% Fe, and 99.8% Ni, [2009Rha] prepared pellets of powder mixtures, which were broken into smaller pieces and annealed in air between 1600 and 1200 °C for 72-168 h and quenched. The approach to equilibrium was achieved from two opposite directions, by employing both more-oxidized and more-reduced starting compositions. The final phase compositions were measured

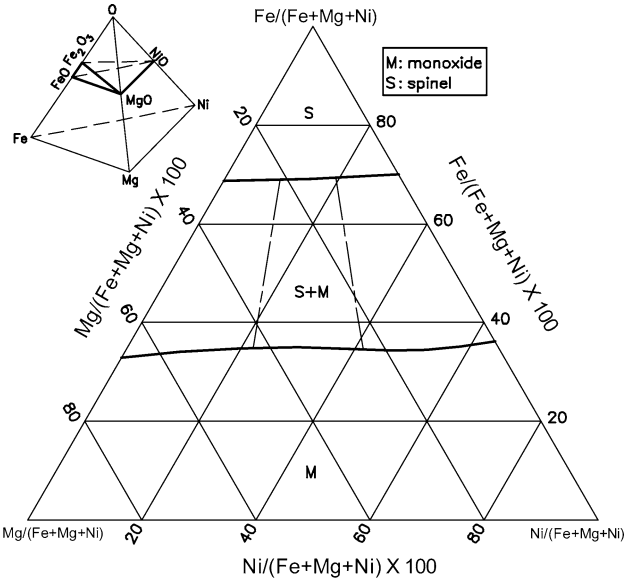

Fig. 2 Fe-Mg-Ni-O isothermal equilibria in air at 1500 °C projected on to the Fe-Mg-Ni plane [2009Rha]

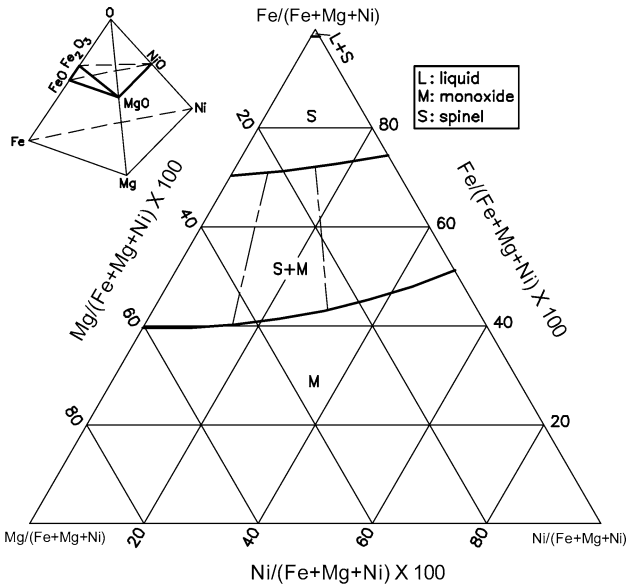

Fig. 1 Fe-Mg-Ni-O isothermal equilibria in air at 1600 °C projected on to the Fe-Mg-Ni plane [2009Rha]

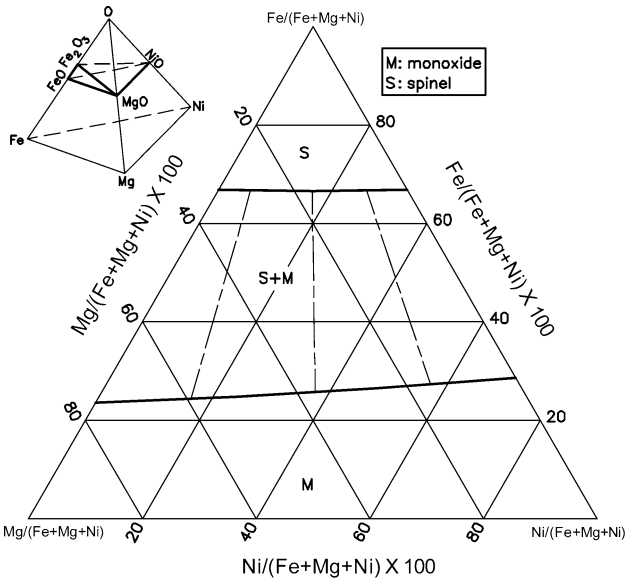

Fig. 3 Fe-Mg-Ni-O isothermal equilibria in air at 1400 °C projected on to the Fe-Mg-Ni plane [2009Rha]

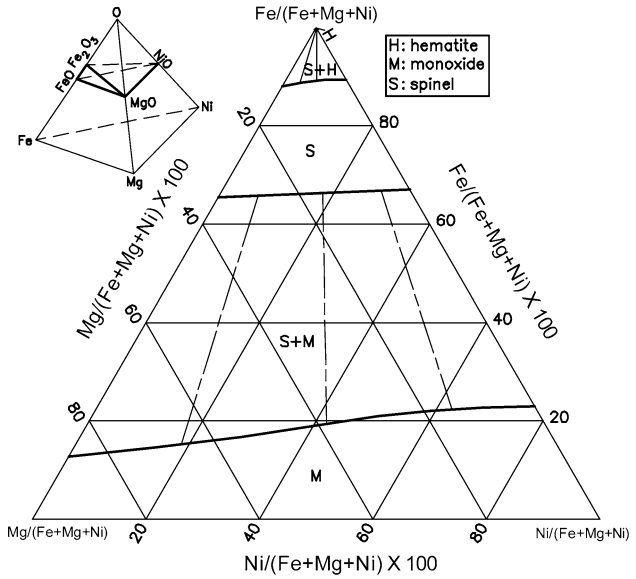

Fig. 4 Fe-Mg-Ni-O isothermal equilibria in air at 1300 °C projected on to the Fe-Mg-Ni plane [2009Rha]

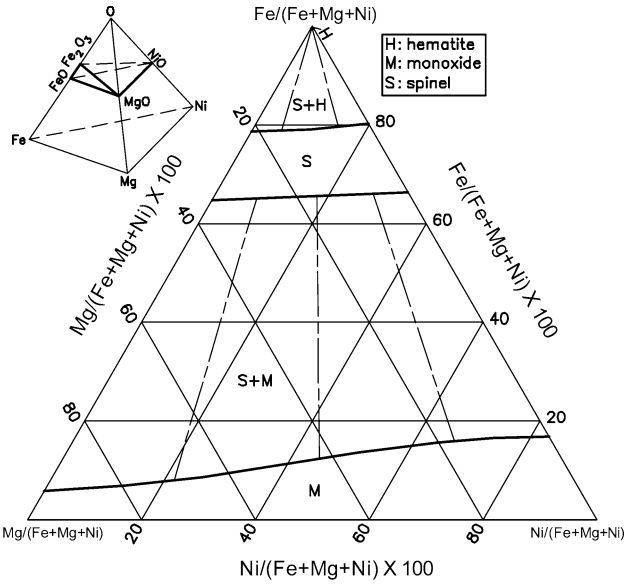

Fig. 5 Fe-Mg-Ni-O isothermal equilibria in air at 1200 °C projected on to the Fe-Mg-Ni plane [2009Rha]

with the electron probe microanalyzer and listed. The relative concentration of ferrous and ferric ions in the phases was not determined.

The isothermal equilibria were plotted as projections on the Fe-Mg-Ni plane, at 1600, 1500, 1400, 1300 and 1200 °C (Fig. 1-5) [2009Rha]. The solubility of Fe in the monoxide phase increases with increasing temperature. At 1600, 1500 and 1400 °C, only the monoxide and spinel phases are stable (except for a small region of liquid near the Fe-rich corner at 1600 °C). At 1300 and 1200 °C, the hematite phase (Fe_2O_3) is additionally present.

References

1989Rag1: V. Raghavan, The Fe-Mg-O (Iron-Magnesium-Oxygen) System, *Phase Diagrams of Ternary Iron Alloys. Part 5: Ternary Systems Containing Iron and Oxygen*, Indian Institute of Metals, Calcutta, 1989, p 170-180

1989Rag2: V. Raghavan, The Fe-Ni-O (Iron-Nickel-Oxygen) System, *Phase Diagrams of Ternary Iron Alloys. Part 5: Ternary Systems Containing Iron and Oxygen*, Indian Institute of Metals, Calcutta, 1989, p 222-231

2009Rha: M.A. Rhamdhani, T. Hidayat, P.C. Hayes, and E. Jak, Subsolidus Phase Equilibria of Fe-Ni-X-O (X = Mg, Al) Systems in Air, *Metall. Mater. Trans. B*, 2009, **40B**, p 25-38