New chemical and physical data on keilite from the Zakłodzie enstatite achondrite

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ABSTRACT

Keilite, (Fe,Mn,Mg,Ca,Cr),S, from the Zakłodzie enstatite achondrite is described. Forming xenomorphic grains up to 0.5 mm in diameter, the keilite is associated with troilite (or pyrrhotite), Fe-Ni metal, an (Fe,Zn,Mn)S phase, enstatite (with relict forsterite in cores), plagioclase and accessory schreibersite, oldhamite, graphite, sinoite, and an SiO2 polymorph. It is brittle and possesses a good cleavage similar to that of galena, parallel to (001), (010), and (100). X-ray diffraction structural data reveal the following: cubic space group Fm3m, α = β = γ = 90°, a = 5.1717 (18) Å, unit-cell volume V = 138.32 (8) Å³; D = 3.958 g/cm³; Z = 4. The chemical formula based on 63 electron microprobe point analyses is: (Fe0.437, Mn0.336, Mg0.203, Ca0.060, Cr0.019, Zn0.001)S1.000. Compared with previously described keilites from enstatite chondrites, the Zakłodzie keilite is richer in (Mn,Ca,Cr)S and poorer in the Fe- and Mg-end-members and, consequently, it is nearer to alabandite and oldhamite. This is the first detailed description of keilite from a meteorite that is not an enstatite chondrite.

Keywords: Meteorite, keilite, sulfide, XRD data, chemical data, enstatite achondrite, Zakłodzie

INTRODUCTION

Keilite, (Fe,Mg)S, first described as niningerite, (Mg,Fe)S, was discovered in enstatite chondrites by Keil and Snetsinger (1967). It was only in 2002 that keilite was characterized as an Fe-dominant analogue of niningerite and named after Dr. Klaus Keil (Shimizu et al. 2002). In that publication, the main structural, physical (including optical), and chemical features of the mineral were described, keilite being approved as a new mineral by the Commission on New Minerals and Mineral Names of the International Mineralogical Association in 2001 (IMA 2001-053). Keilite was reported first from enstatite chondrites: Abee and Adhi-Kot (type EH4), and Saint-Sauveur (EH5) (Shimizu et al. 2002). The latter authors also listed other meteorites in which keilite had been found: LEW 88180 (EH5), RKP A80259 (EH5), LEW 87119 (EL6), LEW 88714 (EL6), Y-791790 (EH4), Y-791811 (EH4), Y-86760 (EH4 melt), and Y-8404 (EH5) (classifications from Grady 2000). Furthermore, similar Fe-Mn-Mg sulfides have been described by Lorenz et al. (2003) from the phlogopite-bearing enstatite achondrite NWA 1235.

The chemical composition of keilite, like that of niningerite, indicates strongly reducing conditions of crystallization during which lithophile elements (e.g., Mg) were incorporated into sulfides instead of silicates (Keil 1968; Lin and Kimura 1998).

We found a mineral suspected to be keilite during chemical, mineralogical, and petrological investigations of the Zakłodzie enstatite meteorite (Przylibski et al. 2003, 2005). In an earlier paper (Karwowski et al. 2001), this phase was described as alabandite. At that time, only the chemical composition typical of keilite could be confirmed, there not being enough material to determine other structural and physical characteristics of this mineral. Further results of detailed investigations, which have shown this mineral to be keilite, are given in this paper.

The classification of the Zakłodzie enstatite meteorite remains controversial. In the recent publication on the mineralogy, petrology, and classification of this meteorite, Przylibski et al. (2003, 2005) discussed various hypotheses concerning its origin, e.g., considering Zakłodzie as an ungrouped enstatite-rich meteorite (Wlotzka et al. 2000—vide Grossman 2000), an EL7 enstatite chondrite (Stepniowski et al. 2000; Manecki and Łodziński 2001), or an enstatite achondrite (Stepniowski et al. 2000; Karwowski et al. 2001). Another widely held view is that of Burbine et al. (2000): the Zakłodzie meteorite is an impact-related melt. The latter interpretation does not allow assignment of Zakłodzie within the meteorite classification system. Przylibski et al. (2003, 2005), based on detailed observation, interpretation, and discussion of textures and mineral compositions, proposed another hypothesis that explained the observed features better, including published results of isotopic age determinations (K-Ar dating and 4He concentration time method) on the parent body (Patzer et al. 2002). Przylibski et al. (2005) classified Zakłodzie as a primitive enstatite achondrite, and proposed that the stone represents a new group of meteorites, similar to the primitive achondrites: lodranites, winonaites, and acapulcoites defined previously. Because the Zakłodzie meteorite is not an E chondrite (Przylibski et al. 2005), this paper is the first report of keilite from a meteorite other than an enstatite chondrite. We are continuing our research efforts to clarify the remaining interpretative controversies.