# RUDASHEVSKYITE IN THE WINCHCOMBE CM CHONDRITE: A SULFIDE FROM EITHER NEBULAR CONDENSATION OR METASOMATIC ALTERATION

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**Introduction:** Winchcombe is a Mighei-like carbonaceous (CM) chondrite that fell in England in February 2021. It is a CM2 chondrite, having undergone pervasive aqueous alteration [1] and containing sulfides, which form by condensation in the solar nebula, parent body aqueous alteration and/or thermal metamorphism [2]. Within Winchcombe, we observed a sulfide assemblage made of pentlandite (Pn) and a Zn-Fe sulfide, rudashevskyite (Rud). Zn-sulfides are rarely reported in carbonaceous chondrites, with one other occurrence in Sutter's Mill [3]. We describe this Pn-Rud assemblage as well as its formation, which has implications regarding the parent body of CMs.

**Samples and Methods:** Back-scattered electron (BSE) images, and energy-dispersive X-ray spectra (EDS) and hyperspectral maps of a polished block of Winchcombe (#P30552), were collected using a Carl Zeiss Sigma Variable Pressure Analytical scanning electron microscope (SEM) at the University of Glasgow, and a Zeiss EVO LS15 SEM and a FEI Quanta 650 field emission SEM at the Natural History Museum.

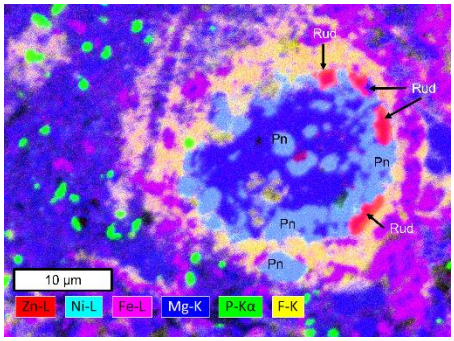


Fig. 1. Zn-Ni-Fe-Mg-P-F EDS net intensity map of the Pn-Rud assemblage in Winchcombe (#P30552). Pn and Rud are labelled. EDS net intensity map was collected using the FEI Quanta 650.

**Results:** The Pn-Rud assemblage is roughly circular and occurs with serpentine. The majority of the sulfides in the assemblage are Pn. Small grains of Rud ≤3 µm in size occur on the outer edge on one side. The area surrounding the assemblage is enriched in F relative to the rest of the meteorite (Fig. 1). The Rud's composition is ~$Zn_{0.5}Fe_{0.5}S$.

**Discussion:** Rud occurs with troilite in enstatite chondrites and iron meteorites as a product of nebular condensation [4]. It is also found in terrestrial hydrothermal deposits [5] and natrocarbonatite lavas [4]. The incorporation of Fe into Zn-sulfides is facilitated by high temperatures, and low oxygen and sulfur fugacities [5,6]. The composition of Rud within Winchcombe is quite similar to the Rud within enstatite chondrites [7] and could have formed under similar conditions. However, the Fe-content of Winchcombe's Rud is also similar to Rud in terrestrial hydrothermal deposits whose conditions differ from enstatite chondrites [4,5]. Additionally, Winchcombe's Rud occurrence differs from that within enstatite chondrites, in that it is associated with Pn instead of troilite [4]. The area around the Pn-Rud assemblage is enriched in F, which can be mobilized and transported during metasomatism [8], however there are few studies on F distribution in meteorites beyond its occurrence in apatite to definitively establish this as why it is concentrated around the assemblage. However, the F is not in apatite and is therefore indicative of reducing conditions [9], like those required for Rud formation, yet Pn forms under oxidizing conditions [2]. Given the volatility of F, its concentration around the assemblage is likely from a late alteration event. If the F and Rud were produced from the same alteration event, then Rud would have likely formed from metasomatic alteration.

**Conclusion:** The Fe content of Rud in the CM2 chondrite, Winchcombe, is indicative of reducing conditions and is consistent with one of two formation scenarios: 1) condensing out of the solar nebula or 2) formation during metasomatism. The area around the assemblage is enriched in F, which supports its formation by metasomatism, and may provide evidence for the process on the CM parent body.

**Future Work:** We will search for more Rud in other carbonaceous chondrites as well as further characterize Rud within Winchcombe through electron microprobe analysis and/or transmission electron microscopy.

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