Metalliferous sediments in the Semail ophiolite, Oman

Reconnaissance of their potential in geochemical exploration for volcanogenic massive sulfide deposits

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Introduction

Seafloor "black smoker" volcanogenic massive sulfide (VMS) deposits are important resources of Cu, Zn, Au and the critical metals Co, In, Ga, Ge, which are vital components of electricity-based energy systems. Reliable methods to explore for VMS deposits are essential to the "green" energy revolution.

VMS deposits often form in open-ocean seafloor far from sources of detritus and at depths greater than the CCD. There, the deposits are surrounded by regionally extensive beds of metalliferous sediments, also known as umbers. In on-land ophiolites, umbers present a much larger target for exploration (many km^2 in extent) than the VMS deposits themselves (typically 0.1 km^2). It is therefore worth evaluating umbers for their potential in exploration for VMS deposits. We are carrying out such an evaluation in the Semail Ophiolite in Oman (Fig. 1).

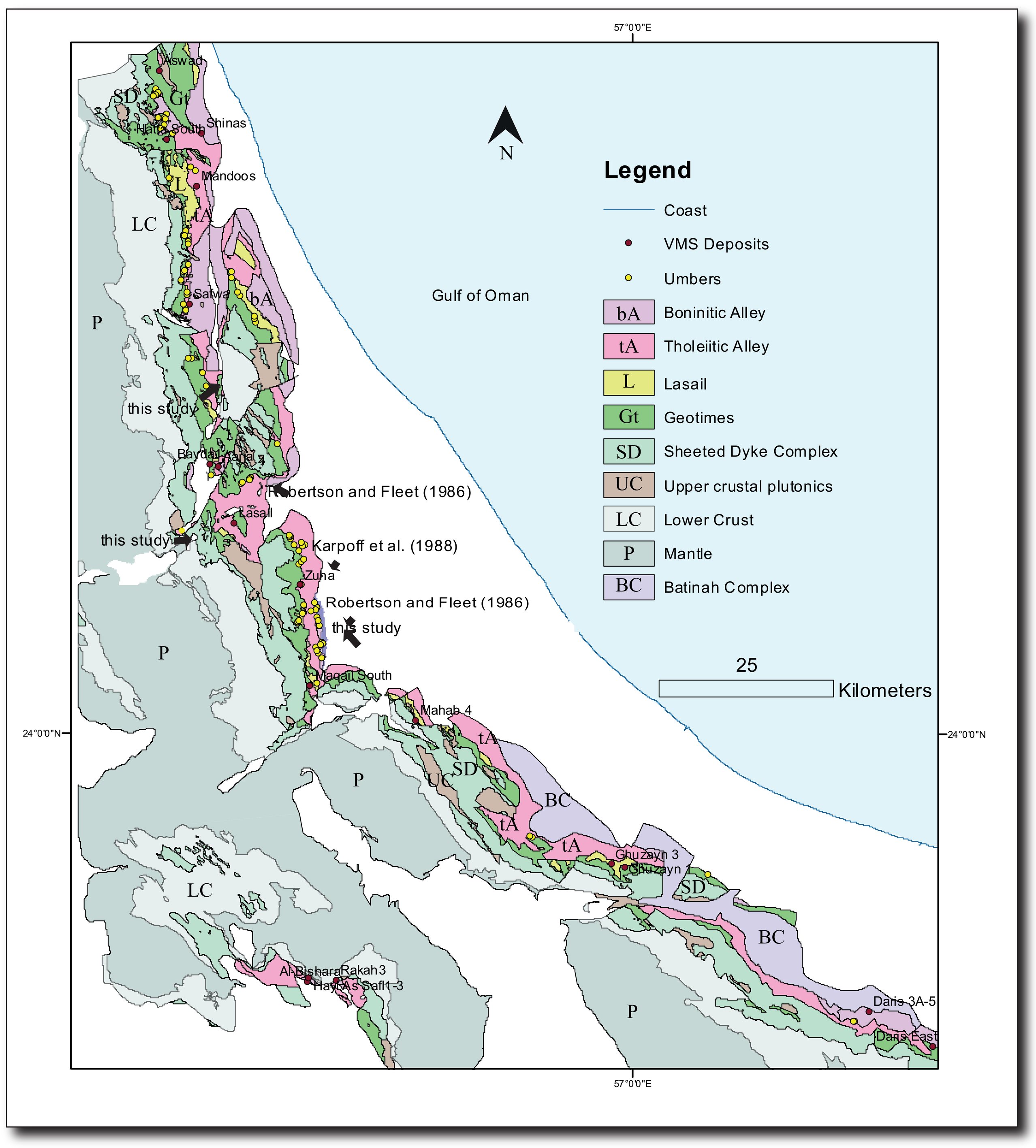


Fig. 1: Geological map of the Semail Ophiolite, Oman (Belgrano et al., 2019), showing known VMS deposits and umber occurrences.

Formation of Umbers

The formation of umbers from the "smoke" of seafloor hydrothermal vents can be divided into 10 steps (Fig. 2). These show that umbers are a combination of element inputs from vent fluids, from solutes dissolved in seawater, and from siliceous plankton tests that sink below the CCD. The differences in solubilities of these elements suggests that umber composition may vary with distance from the black-smoker vents.

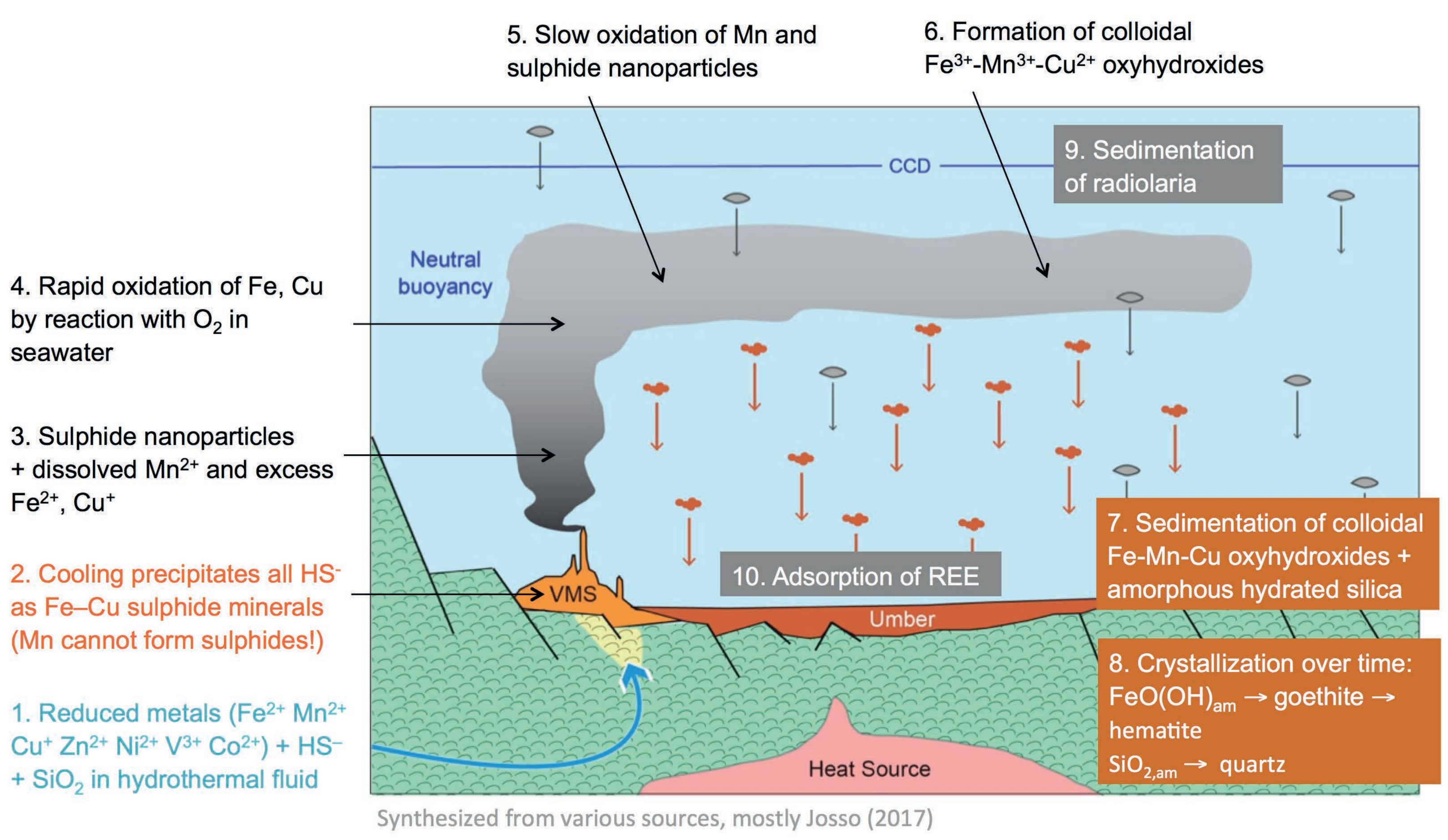


Fig.2: Schematic illustration of formation of umber rocks. Modified after Josso (2017).

Aims of Study

1) Test the idea that spatial zonation in the chemical composition of umbers may serve as a vector to the associated VMS deposits.

2) Compare our results to previous studies in Oman and elsewhere, to establish whether our vectors are applicable to umbers in general, or just to umbers in Oman.

Results

Mineralogical studies and geochemical analysis findings as follows:

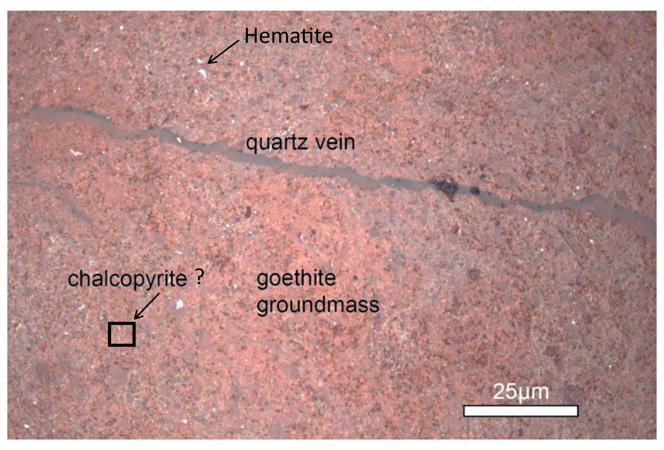
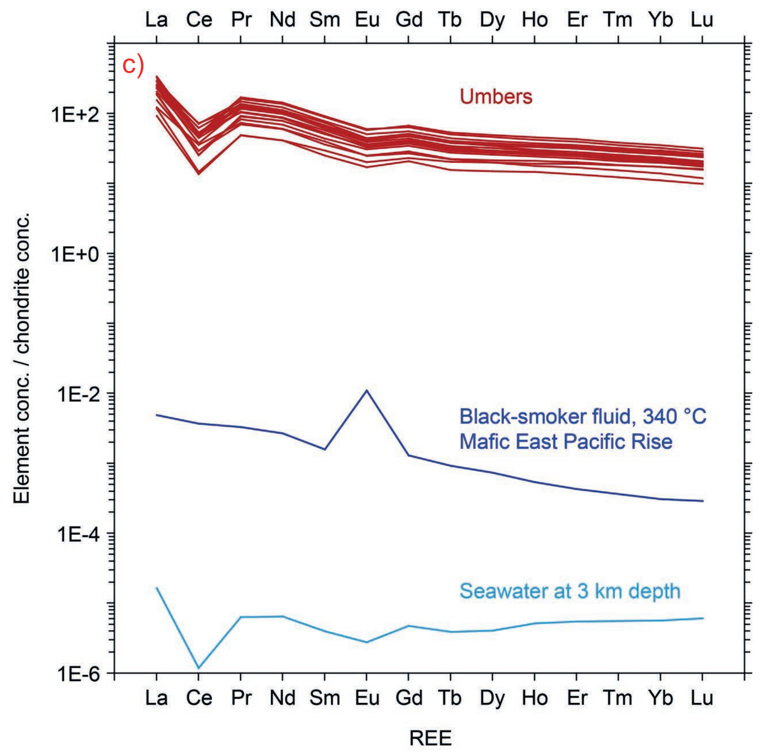


Fig. 3: Microphotograph of an umber in reflected light.

Table 1. Mineralogy of studied umber samples.

Minerals identified so far	Identification methods				Wt.% in rock (XRD)
	TLM	RLM	RAMAN	XRD	
Quartz (SiO_2)	+	-	+	+	7 – 75
Hematite (Fe_2O_3)	-	+	+	+	1.5 – 52
Goethite (FeOOH)	+	+	-	+	10 – 30
Calcite ($CaCO_3$)	+	-	+	+	2.5 – 18
Chalcopyrite (CuFeS2) ??	-	+	-	+	rare
Macfallite (sorosilicate) ($Ca_2Mn^{3+}_3(SiO_4)(Si_2O_7)(OH)$)	-	-	-	+	8 – 14
Okhotskite (pumpellyite group, no Al) ($Ca_2Mn^{2+}Mn^{3+}_2[Si_2O_6OH][SiO_4](OH)_2(OH)$)	-	-	-	+	3.5

Abbreviations: TLM= Transmitted Light Microscopy, RLM= Reflected Light Microscopy, XRD= X-Ray Diffraction



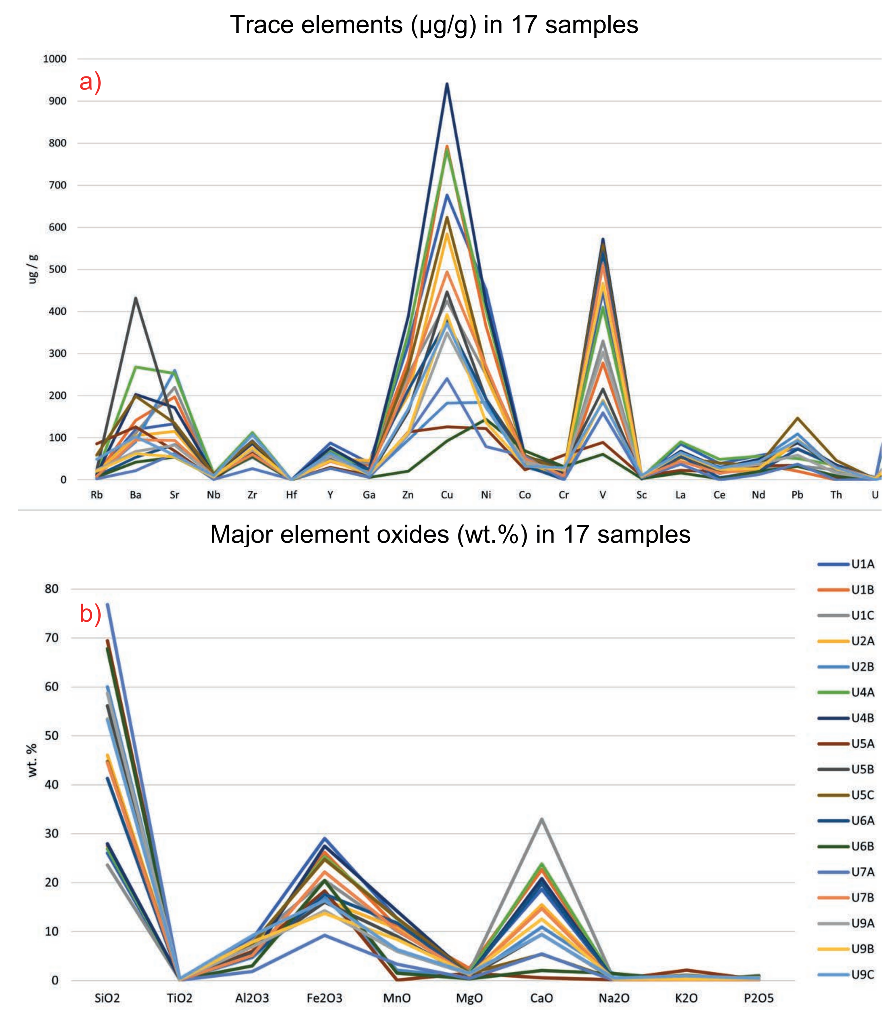


Fig. 4: a), b) Variable Si, Fe, Cu, Zn concentrations from XRF anaylsis may be useful vectors if spatially zoned with respect to VMS deposits. c) Rare earth element pattern normalised to chondrite (Douville et al. (1999)

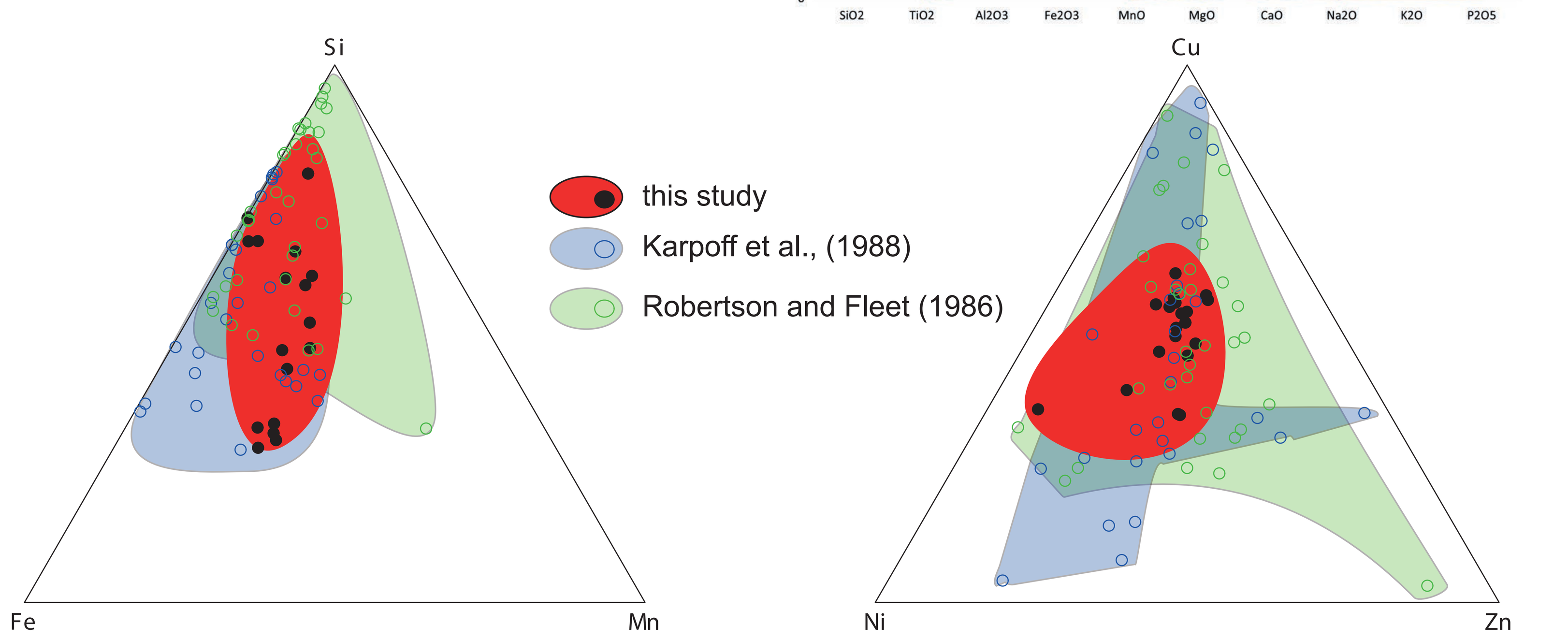


Fig. 5: Relative mass relationships between Fe, Si, Mn and Ni, Cu, Zn concentrations in umbers in different sampling areas of the Semail Ophiolite (see map in Fig. 1).

Discussion

Our results characterize the umbers mineralogically and geochemically, and demonstrate that there is considerable variation in compositions between different samples. We have recognized that some of variation may be due to overprinting of the umbers by late-stage hydrothermal veins (e.g. chalcopyrite and calcite veins), therefore care must be taken when sampling umbers in the field. Potential vectors to test with future samples are Mn/Fe, Cu/Fe and Si/Fe ratios.

Conclusions and outlook

Consideration of formation mechanisms and of the spread in compositions of the analysed umbers suggest that systematic chemical variations in umbers can be expected with distance to VMS deposits. Therefore, our next steps are to;

- Analyse a new set of samples that have been collected purposefully at different distances from the same VMS deposit
- Examine the results for systematic spatial zonations
- Evaluate whether these zonations can be useful in exploration

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