



## Multivariate statistical analysis of mafic- and ultramafic-hosted seafloor massive sulfides

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Seafloor massive sulfide (MS) deposits on oceanic spreading centers have variable concentrations of base metals (mostly Cu, Zn), precious metals (Au, Ag), critical metals (Co, Ni), and other trace elements. The geological factors that control this geochemical variability are still a matter of debate. In particular, the role of the composition of substrate rocks (specifically mafic vs. ultramafic) has been variably considered to be decisive or subordinate. In a previous study (Toffolo et al., 2020, *Earth Sci. Rev.*), we have investigated these factors by means of robust principal component and factor analysis of chemical data for MS samples from mid-ocean ridges worldwide. We found that a large part of the observed variability is produced by a combination of three independent factors, interpreted to reflect (in order of importance): (1) the temperature of deposition, which controls the relative enrichments in (Cu, Se, Co) vs. (Pb, Sb, Zn, Ag), (2) the ridge spreading rate, which influences the oceanic basement structure and the rock-to-water ratios, leading to opposite behaviors of (Au, Ag) vs. Ni, and (3) zone refining. Unexpectedly, the composition of the substrate did not emerge as a statistically significant independent factor. An important limit of our previous investigation was that literature data were often incomplete, thus limiting the number of samples and of chemical elements for the multivariate statistical analysis. We have now addressed this problem by using statistical imputation techniques and by integrating the database with additional literature and in-house data for present-day deposits on mid-ocean ridges and ancient deposits in ophiolites from different settings (supra-subduction-zone, mid-ocean ridge, ocean-continent transition). As a result, undersampling of ultramafic-hosted deposits was significantly reduced and the number of elements was raised to 11, including Cu, Zn, Pb, Au, Ag, Co, Ni, Se, Sb, Mo and the previously excluded As. The integrated database essentially confirms our previous findings. In addition, deposits in supra-subduction-zone ophiolites show factor scores typical of high deposition temperatures and high rock-to-water ratios, consistent with their formation on infant-arc, slow-spreading centers. The potential influence of other local geological factors will be discussed.