IDENTIFICATION OF CLASTS IN CM CHONDRITE FALL KOLANG WITH S AND CA

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Introduction: Kolang is a CM chondrite that fell in Indonesia in August 2020. This meteorite has experienced a high degree of aqueous alteration (subtype CM2.2) [1] but is also a breccia composed of CM clasts that differ in lithology. It is important to characterize each clast to better understand the history of the whole meteorite and its parent asteroid. Both S and Ca are soluble elements and common constituents of the fluids responsible for the aqueous alteration of carbonaceous chondrites on their parent body [2]. This makes them good tracers of the alteration history of each clast in Kolang, as their distribution will be determined by the conditions at which hydration occurred. The distribution of S and Ca can also test whether or not aqueous alteration occurred in an open system, because if there is significant variation between the clasts it suggests that they were altered by fluids of differing composition.

Samples and Methods: Large area montages of back-scattered electron (BSE) images and Energy Dispersive X-ray Spectroscopy (EDS) data for two thin sections of Kolang (Kolang_01 and Kolang_02), both from the same rock chip, each about 2 cm in size, were collected using a Carl Zeiss Sigma Variable Pressure Analytical SEM, equipped with Oxford Instruments microanalysis (Aztec) at the ISAAC lab at the University of Glasgow. Lithological units in both samples were identified using BSE images together with S and Ca EDS maps.

Results: Kolang_01 contains 13 clasts, while Kolang_02 has seven. Between the two rock slices, five lithologies were categorized in both samples, key features of each are summarized in Table 1. Lithologies vary in metal abundance, however chondrules tend to show similar degrees of degradation and alteration between lithologies.

Table 1. Summary of Ca and S Distribution for Main Lithologies in Kolang.

Lithology	Ca Distribution	Matrix Ca/Si	S Distribution	Matrix S/Si	Other Features
Carbonate & Metal-rich	Matrix lacks Ca, but there are several large grains of Ca-rich minerals.	0.000	Low abundance in matrix. S-rich phases abundant isolated in matrix and in chondrules.	0.187	Contains ~1% isolated metal grains.
Fe-rich/Mg-poor	Low abundance in matrix, some Ca isolated in matrix and chondrules.	0.055	Low abundance in matrix. Some chondrules contain S-rich phases.	0.186	Matrix is Fe-rich. Almost no metal found.
Conventional	Low abundance in matrix, some Ca isolated in matrix and chondrules.	0.066	Moderate abundances in matrix. Some chondrules contain S-rich phases	0.219	Contains less than 1% metal, associated only with chondrules.
Heated	Low abundance in matrix, some Ca isolated in matrix and chondrules.	0.072	Matrix richer in S that for most clasts. S-rich phases abundant both isolated in matrix and in chondrules.	0.356	Matrix shows abundant fracturing, consistent with post-hydration heating. Contains less than 1% metal, associated only with chondrules.
Metal-rich	Moderate abundance in matrix, while Ca-rich grains also occur within chondrules.	0.111	Moderate abundance in matrix. Some chondrules contain S-rich phases	0.235	Contains ~1% isolated metal grains.

Discussion: The clasts displayed distinct differences in Ca and S distribution and abundance, indicating that each clast likely experienced aqueous alteration by different fluids at contrasting conditions and compositions. The clasts have similar degrees of chondrule degradation, indicating that they likely experienced similar degrees of alteration. Only one lithology appears to have experienced post-hydration heating and would have had its S and Ca composition affected by it. As the S and Ca compositions and distributions vary between clasts, the system that altered the clasts was an open system at a scale of at least several centimeters.

Conclusions: The lithologies in Kolang have distinct Ca and S distributions, making them easy to identify. However, clasts also have other features that characterized them, such as textures (i.e., post-hydration heating fractures) and Fe abundance. S and Ca maps can be a powerful tool to delineate clasts, but they should not be relied on alone and is best used in conjunction with other methods for identifying clasts. The variation in the distribution of Ca and S between clasts reflect fluid environments that varied spatially on Kolang's parent body.

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References: [1] King A. J. et al. (2021) *52nd LPSC*, Abstract #1909. [2] Palmer E. E. and Lauretta D. S. (2011) *MAPS* 46: 1587-1607.