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Chlorite–Carbonate Mineral Chemistry Constraints on the Hydrothermal Evolution of a Fault-Controlled Eocene Copper System (Tokat, Türkiye)

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The western region of Almus (Tokat, Türkiye) is located along the İzmir–Ankara–Erzincan Suture Zone (IAESZ), which formed after the closure of the northern segment of the Neotethys Ocean. During the Middle Eocene, post-collisional magmatism generated volcanosedimentary strata with structurally controlled, epigenetic quartz-vein–type copper mineralization. Prior research indicated that copper enrichment is present in secondary quartz veins (average thickness ~70 cm) cross-cutting Eocene volcanic rocks and volcanic breccias within an extensional tectonic framework [1]. The ore paragenesis includes bornite, covellite, pyrite, and magnetite in the hypogene stage, and goethite, malachite, and azurite in the supergene stage [1].

XRD analysis confirms pyrite, arsenopyrite, and malachite; however, arsenopyrite As/S ratios are very low (0.00047–0.00239), indicating limited replacement and reducing its geothermometric relevance. This study examines the chemistry of chlorite and carbonate minerals to improve the understanding of fluid characteristics and hydrothermal evolution.

EPMA analysis indicates Fe-rich chlorite with Fe/(Fe+Mg) ratios of 0.77–0.87, total iron of 0.36–6.61 wt% and magnesium of 0.05–1.93 wt%, yielding Fe-dominant compositions. These results indicate precipitation from Fe^{2+}-enriched hydrothermal fluids under reducing conditions at moderate temperatures, rather than low-temperature propylitic alteration, implying elevated iron activity and substantial fluid–rock interaction along fault-controlled pathways.

Carbonate mineral chemistry distinguishes Ca-dominant calcite and Fe–Mg-enriched carbonate phases, indicating fluid evolution during vein formation, possibly linked to decreasing temperature and changes in redox conditions; Fe-bearing carbonates record late-stage fluid alteration and carbonate-dominated closure of the vein system.

Integrating structural controls, pyrite chemistry, and chlorite–carbonate EPMA studies suggests that the Almus Cu mineralization originated from a Fe-rich magmatic-hydrothermal fluid traversing extensional faults within Eocene volcanic formations and evolved from a metal-bearing, reducing hydrothermal phase to a carbonate-rich sealing phase. Chlorite–carbonate mineral chemistry provides constraints on fluid composition, redox state, and evolutionary pathways in structurally controlled volcanic-hosted copper systems, thereby elucidating the role of crustal geofluids in ore production.

References:

[1] Yalçın, C., Kumral, M., Kaya, M., & Karaman, M. (2022). Geology and geochemistry of copper mineralization of volcanic rocks due to quartz veins in western part of Almus (Tokat-Turkey). European Journal of Science and Technology, (34), 5–9.