Three-Dimensional Structural Geologic Reconstruction of the Botija Porphyry Cu-Mo (-Au) Deposit, Cobre Panamá District, Panamá

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Botija is one of seven Cu-Mo-Au porphyry deposits in the Cobre Panamá mining district, which has a total resource of 13.6 Mt of Cu. The Botija deposit is a northwest-elongate (2 km by 1 km) and 600 m-thick tabular body that dips 10° to 45° north, an atypical shape for a porphyry copper deposit. Cu- Fe sulfides at Botija are both disseminated and present in hydrothermal quartz veins associated with potassic alteration. These quartz veins are cut by pyrite ± quartz (D type) veins with sericitic alteration selvages. Systematic vein measurements demonstrate that a quartz vein density >0.5 vol % is coincident with >0.5 wt % Cu ore. Quartz veins have two dominant orientation modes (azimuth of strike/right-hand dip) that average 233°/50° NW and 295°/45° NE, and D veins have dominant orientation modes of 295°/73° NE, 260°/69° NW, and 228°/48° NW. Quartz and D veins in numerous porphyry deposits globally occupy near-vertical hydrofractures, and therefore the dip of veins at Botija deposit suggests moderate tilting of 40° south-southeast after mineralization. Geologic mapping of field exposures and drill core has identified a series of west (367°/50°–70ºN), southwest (230°/65º NW), and northeast (314°/75º NE) striking normal and oblique-slip normal faults which displace hydrothermal alteration zones and Cu, Mo, and Au grade contours.

To access the nature of postore displacement three-dimensional numerical models of copper, molybdenum, and gold were created for the Botija deposit using Leapfrog Geo v. 3.1. The closely spaced (≤100 m) drilling at Botija allows construction of rigorous three-dimensional numerical grade models. Grade models were initially constructed as structurally unconstrained interpolants. Faults identified from field work were then added to these models to provide structural geologic constraint. Addition of faults locally increased the accuracy (±10–40 m) of grade contours but did not fundamentally change their shape. Indeed, the location of three-dimensional fault traces spatially coincide with breaks in the unconstrained >0.5 wt % Cu model. The combined use of the fault orientations and the offsets of the three-dimensional grade model, vein density contours, and alteration zone boundaries indicate the Botija deposit has experienced post-mineral northwest-southeast extension, which produced its current elongate geometry. Restoration of the modeled Cu-Mo grade contours along identified faults removes 10° to 15° of tilting to the southeast and produces a single ore shell with an inverted cup-shaped geometry typical of porphyry copper deposits.

The restored grade models of the Botija deposit provide insight into the geologic structural history of the Cobre Panamá mining district. Restoration of additional district-scale faults striking southwest-northeast (050°–060°) removes 25° to 30° of southeast tilting and places the Botija deposit in an upright position. The structural model developed at Botija is inferred to apply to the entire Cobre Panamá district; likely, all the porphyry deposits have been significantly modified by post-mineral normal faulting.