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Characteristics of hydrothermal alteration mineralogy and geochemistry of igneous rocks from the epithermal Co-O mine and district, Eastern Mindanao (Philippines)

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Detailed petrographic as well as hyperspectral analyses using PIMA (Portable Infrared Mineral Analyser) and geochemical (major, trace and rare earth elements) studies were conducted on samples of the epithermal, low sulfidation Co-O mine (47,869 ounces gold produced in 2009 with an average grade of 13.3 g/t gold) and district in Eastern Mindanao (Philippines). The aims of the study were to unravel the petrogenetic origin of the various volcanic (host rocks) and intrusive rocks (potential fluid driver) as well as their relationship and influence on the hydrothermal alteration zoning and fluid chemistry.

The auriferous veins at the Co-O mine were formed during two hydrothermal stages associated with the district wide D1 and D2 deformation events. Gold in stage 1 quartz veins is in equilibrium with galena and sphalerite, whereas in stage 2 it is associated with pyrite. Auriferous quartz veins of stage 1 reflect temperatures below 250˚C or strong variations in pH and fO_2 at higher temperatures, due to potential involvement of acidic gas or meteoric water. Cathodoluminescense studies revealed strong zonation of quartz associated with Au, presumably related to changes in the Al content, which is influenced by the pH. Plumose textures indicate times of rapid deposition, whereas saccharoidal quartz grains are related to potential calcite replacement.

The geology of the Co-O mine and district is dominated by Miocene volcanic rocks (basic to intermediate flows and pyroclastics units), which are partly covered by Pliocene volcanic rocks and late Oligocene to Miocene limestones. The Miocene units are intruded by diorite (presumably Miocene in age). The epithermal mineralization event may be related to diorite intrusions. The geochemistry of all igneous rocks in the district is defined by a sub-alkaline affinity and is low to medium K in composition. Most units are related to a Miocene subduction zone with westward subduction, whereas the younger Pliocene rocks are related to the currently active east dipping subduction zone.

At the Co-O mine the proximal hydrothermal alteration zone is defined by phyllic to argillic alteration displayed in sericitized to carbonated feldspar, quartz and chloritized amphiboles surrounded by a distal alteration halo displaying propylitic alteration. The alteration geochemistry of these hydrothermal altered rocks is defined by an increase in K_2O and Na_2O and decrease in Al_2O_3. However, adularia usually associated with hydrothermal alteration in low epithermal Au quartz veins, has so far not been described, which points to a K-poor magma system. PIMA hydrothermal alteration studies indicate the dominant presence of smectite rather than white mica, which supports the involvement of a K-poor hydrothermal fluid.

The epithermal Co-O mine and district displays low to medium potassic magma series and a hydrothermal alteration mineralogy that is K-poor. However, the Co-O mine hosts significant amounts of epithermal gold mineralization. The recognition of poor K melts and hydrothermal alteration mineralogy associated with distinct low-sulfidation epithermal gold mineralization has important implication for exploration in the Co-O district and, potentially, also in other areas in the Philippines and worldwide.