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Eocene Gold Ore Formation at Muteh, Sanandaj-Sirjan Tectonic Zone, Western Iran: A Result of Late-Stage Extension and Exhumation of Metamorphic Basement Rocks within the Zagros Orogen

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Abstract

A multidisciplinary study including field geology, microstructure analysis, $^{40}Ar/^{39}Ar$ dating, and fluid inclusion microthermometry and Raman spectrometry has been carried out on the Muteh gold deposit located in a greenschist to amphibolite facies metamorphic rock complex of the Sanandaj-Sirjan tectonic zone, Zagros orogen, Iran. The Muteh gold deposit has been previously interpreted as genetically related to Precambrian granitic intrusions, as an exhalative hot-spring deposit related to Paleozoic rhyolitic-acidic tuffs, and to local metamorphic processes.

Host rocks of the gold deposit are predominantly schist and gneiss, and subsidiary amphibolite and quartzite, and are intruded by leucogranites. In the vicinity of the gold deposit, the metamorphic and granitic rocks display a subhorizontal mylonitic foliation, containing a northeast-oriented stretching lineation. Field investigations in one of the producing open pits show that the gold orebodies are controlled by northwest-oriented normal faults and joints, dipping to the northeast and the southwest, and crosscutting the ductile fabric of the host rocks. Both the ductile fabric of the host rocks and the gold ore-controlling brittle structures are interpreted to have formed within a single, continuous extensional event, which started with ductile deformation and gradually changed into brittle deformation. Hydrothermal alteration associated with ore formation consists of quartz, muscovite, pyrite, dolomite-ankerite, and albite, which crosscuts the ductile fabric and overprints the metamorphic minerals of the host rocks. Pyrite is the dominant opaque mineral and is the major phase associated with gold. Chalcopyrite, marcasite, bismuth, galena, sphalerite, and pyrrhotite are subsidiary to rare phases.

$^{40}Ar/^{39}Ar$ incremental-heating and in situ laser-ablation age data reveal a coherent sequence of cooling and hydrothermal events in the metamorphic complex hosting the Muteh gold deposit. Muscovite samples from the alteration zone and from one quartz vein from the orebodies yield $^{40}Ar/^{39}Ar$ ages between 55.7 and 38.5 Ma and show that gold mineralization is the youngest among the different dated events. This Eocene age is consistent with the young structural setting of the gold orebodies revealing an emplacement along northwest-oriented normal faults, which can be correlated with Tertiary extensional tectonic events reported by previous field investigations. The data also indicate that gold ore formation is coeval with magmatism in the adjacent Tertiary Urumieh-Dokhtar magmatic belt and with intrusive activity within the Sanandaj-Sirjan zone, with a $^{40}Ar/^{39}Ar$ age of 54 Ma near Muteh according to our study. The remaining $^{40}Ar/^{39}Ar$ data reveal a Cretaceous to early Tertiary metamorphic, magmatic, and deformation history of the complex hosting the Muteh gold deposit.

The fluid inclusion study showed that distinct fluids were present during the regional geologic evolution predating ore formation and later Eocene gold ore formation. Early regional fluids consist of an H_2O-CO_2-NaCl fluid with subsidiary N_2 and CH_4 that underwent local unmixing. The salinities of the liquid-rich inclusions resulting from unmixing range between 2.2 and 17.5 wt percent NaCl equiv, and those of the CO_2-rich, vapor-rich inclusions range between 2.8 and 7.2 wt percent NaCl equiv. The high salinity of the regional liquid-rich fluids is attributed to metamorphism of evaporite-bearing sedimentary rocks, magmatic intrusions, retrograde hydration reactions, metamorphism of impure marbles, and migmatization. The fluid inclusions spatially associated with the gold veins postdating regional metamorphism and ductile deformation of the host rocks contain a low-salinity aqueous fluid with a dilute, low-density CO_2 component, and maximum salinities between 2.6 and 5.8 wt percent NaCl equiv.

Gold deposition at Muteh occurred during or after late stages of Eocene brittle extension as a result of exhumation of the host metamorphic complex, possibly during magmatic activity in the Sanandaj-Sirjam zone. It is most likely linked to the introduction of a distinct low-salinity, low CO_2 content aqueous fluid during crustal extension. These fluids are younger than, and therefore unrelated to, the highly saline and CO_2-rich, regional metamorphic-magmatic fluids. Our results refute previous models advocating Precambrian to Paleozoic ages of the Muteh gold deposit.

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