

Spatial and Temporal Distribution of Gold Deposits in the Urals

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Abstract

During the past 10 years, the Paleozoic Urals mountain belt has been the subject of internationally based, deep seismic, and ancillary geologic studies aimed at improving our knowledge of the lithospheric evolution of the orogenic belt, in general, and its prominent crustal root, in particular. In view of its wide-ranging mineral endowment, especially for gold, this work also provides important keys to help clarify relationships between collisional tectonic processes and gold mineralization. Following an outline of current ideas on the tectonic evolution of the Urals, we present an overview of the distribution of the majority of known gold deposits. This information, together with the available isotopic and geologic age data of associated alteration assemblages, is compared to available geochronological data for various magmatic and deformation episodes. Spatial and temporal relationships suggest that hydrothermal mineralizing processes and the geodynamic evolution of the orogen are linked. In an attempt to analyze the deep structural framework of the orogen, down to the mantle, we have also examined a number of subcontinental- and regional-scale continuous geophysical datasets.

The Urals have been subdivided traditionally into a series of north-south-striking tectonic zones but more recently into three principal tectono-magmatic sectors, which comprise a Suture sector along the Main Uralian fault zone and two sectors with tectonically imbricated island-arc, transitional (viewed as active continental margin), and continental zones. Gold deposits are found in all tectono-magmatic sectors of the orogen. Minor gold occurs in Siluro-Devonian volcanic-hosted massive sulfide deposits, magnetite(-copper) skarns, and porphyry copper deposits. In a number of cases, younger structures (shear zones, faults, and their intersections) have controlled the deposition of higher gold grades. In the Urals, this has led to the concept of progressive concentration of gold during later tectonic overprinting, and the understanding that regional deformation and hydrothermal fluid-rock interaction in the Late Carboniferous to Early Triassic upgraded gold contents of earlier deposits. During the Late Carboniferous to Early Triassic, gold-bearing quartz vein lodes, which effectively encompass the majority of the larger gold deposits in the Urals, were also formed in structural-chemical traps. Some deposits, such as Mindyak that is hosted by tectonic mélanges along the Main Uralian fault zone, are clearly typical late-orogenic lode gold deposits. Others occur within and along the margins of early to middle Carboniferous older granite and, although local orthomagmatic relationships have been described, most recent observations now favor a strong structural control on the lodes and no direct genetic association with granite intrusion. In the two largest gold deposits, Kochkar and Berezhovskoe, gold mineralization was controlled by structural and combined structural-chemical traps in dilational jogs in both shear and contact zones. Locally, gold mineralization has been shown to occur during a change from orthogonal to transpressional compression.

The inferred ages of the lode gold deposits suggest they are mostly coeval with the generally undeformed Permian-Early Triassic younger granites. However, a spatial relationship with gold mineralization has not been observed. The younger granites were formed in an extensional regime following Ural-wide magma generation, caused by a thermal flux attributed to underplating of the crust by mantle-derived mafic magmas. The widespread distribution of this late thermal event, during changes in stress regime, and the involvement of magma-generating mantle processes suggest regional delamination in the lithosphere and concomitant upwelling of the asthenosphere. These processes may have largely occurred prior to the formation of the prominent crustal root of the Urals, which formed during subsequent transpressional convergence. Another, Triassic, Ural-wide phase

of hydrothermal alteration has been recognized, but associated gold deposits have been documented in only two cases. We tentatively attribute this phase to destabilization of the lithosphere of the wider Altai, reflected by the formation of the West Siberian and Central Asian basins, east of the Urals, during the Mesozoic.

The integrated analysis of magnetic, Bouguer gravity, heat flow, and crustal thickness data suggests that a major indenter of the East European craton is responsible for a singular, transcrustal, sidewall ramp in the subsurface of the middle Urals. This ramp may extend into the mantle and formed the principal conduit zone for mineralizing fluids. The world-class Kochkar and Berezovskoe gold deposits are adjacent to this proposed conduit.