

## **Mineralization in a Neoproterozoic Accretionary Orogen: Insights from the Arabian-Nubian Shield**

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The Arabian-Nubian Shield is a north-south belt of folded, sheared, thrust, and mostly moderately metamorphosed Neoproterozoic rocks at the northern end of a larger orogenic belt referred to as the East African orogen. The shield developed during a ~350 million year cycle of crustal growth (~870–550 Ma) bracketed by the breakup of Rodinia and the assembly of Gondwana. Nd model ages are mostly close to the U-Pb Neoproterozoic crystallization ages of the Arabian-Nubian Shield rocks and  $\epsilon\text{Nd}_t$  initial ratios are positive (+2–+8), indicating that the Arabian-Nubian Shield rocks are juvenile. As such, extending 3,500 km north-south and 1,500 km east-west, the Arabian-Nubian Shield constitutes Earth's largest tract of juvenile Neoproterozoic crust. The Arabian-Nubian Shield comprises large amounts of tholeiitic to calc-alkaline volcanic rocks and tonalite-trondhjemite-granodiorite (TTG) intrusive rocks forming Tonian-Cryogenian oceanic arcs, a variety of marine to continental late Cryogenian-Ediacaran volcanic-sedimentary basins, and voluminous late to posttectonic late Cryogenian-Ediacaran calc-alkaline and alkaline granitoids. Tectonically, it developed through a multiphase period of Neoproterozoic orogeny that involved amalgamation and suturing of the arc terranes, emplacement of the younger granitoids and volcanosedimentary basins, and the eventual accretion of the Arabian-Nubian Shield westward with continental rocks of the Archean-Neoproterozoic Saharan Metacraton at the time of peak metamorphism, followed by the onset of orogenic collapse. Eastward, the Arabian-Nubian Shield faced an ocean or was flanked by younger Neoproterozoic terranes. Geodynamically, therefore, even though postaccretionary metamorphic and magmatic events continued until ~525 Ma, the Arabian-Nubian Shield did not lie between converging continents, and represents an accretionary orogen, unlike the rocks of the East African orogen farther south in the Mozambique belt or the Alpine-Himalayan Tethyan belt, which are collisional orogens.

As a direct result of its tectonic development, the Arabian-Nubian Shield contains both mineral deposits typical of arc rocks in convergent margins and those associated with late to posttectonic deformation and magmatism. Arc-related occurrences are preeminently VMS and are commonly economically enhanced by the presence of gold-enriched weathered caps. Less abundant arc-related occurrences include epithermal gold, BIF, and podiform chromite. Recent exploration reveals indications of porphyry Cu-Au associated with potassic-propylitic-argillic alteration in Sudan and at a few locations in Saudi Arabia. The preeminent late to posttectonic Arabian-Nubian Shield deposit type is orogenic gold, which is found throughout the shield, has been mined for over 7,000 years, and is now being extensively worked at industrial-scale and informal artisanal mines. The deposits typically consist of gold-bearing quartz-carbonate veins in shear zones and extension gashes related to periods of high heat flow and hydrothermal activity during the closing stages of Arabian-Nubian Shield assembly. Late and posttectonic A-type granites and pegmatites possibly related to melting, assimilation, storage, and homogenization (MASH) zones associated with slab tear or lithospheric delamination contain deposits of Ta-Nb-Sn, REE-U, and Sn-W. In comparison with the Tethyan orogen, the Arabian-Nubian Shield has a

greater prevalence of arc-related VMS and orogenic gold, but differs in an apparent lack of porphyry Cu-Au, although this may change in the light of ongoing exploration, MVT, and SEDEX Pb-Zn deposits.