evidence from the Hadean Jack Hills that are strongly suggestive of an S-type origin, albeit potentially for a minority of the population. 1 in 75 Hadean zircon grains contain primary muscovite[6], 1 in 39 yield high aluminium contents[7], and 1 in 5 show[8] elevated $\delta^{18}O$, all suggesting sedimentary origins. Further investigations of zircon falling into the ambiguous, low-phosphorus region of Burnham and Berry's discriminant diagram may help clarify the two origins and their relative abundances in the Hadean zircon population.

Burnham and Berry[2] offer an alternative conceptual model for the origin of Earth's oldest crust with the help of elemental ratios in ancient zircon grains. Comparative studies of zircon trace element contents throughout the geologic record may shed light on the diversity of Hadean igneous processes, and additionally help to understand changing crustal conditions over Earth's history. ❐

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ECONOMIC GEOLOGY

Ocean and ore


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Before the majestic Himalayan Mountains rose, the ancient Tethyan Ocean spanned the gap between India and Eurasia. Tethys evolved in two main stages: more than 400 million years ago, the Palaeo-Tethyan Ocean formed a basin that was almost isolated from the world ocean circulation; as Palaeo-Tethys was gradually destroyed by subduction, a new ocean basin — Neo-Tethys — opened in its wake.

Because of the isolation of Palaeo-Tethys the waters became highly anoxic. Thick layers of black shale accumulated on the seafloor. Neo-Tethys, in contrast, was connected to the neighbouring Panthalassa Ocean — a precursor to today's Pacific Ocean. Replenished with more oxygen-rich waters, oxidized sediments accrued at the seafloor.

Over time, the entire Tethyan Ocean was consumed by subduction. The anoxic shales and oceanic lithosphere that once floored the Palaeo-Tethys sank beneath the Eurasian continent during the Permian and Jurassic. Later, in the Cretaceous and Cenozoic, subduction of the more oxygenated sediments and lithosphere of the Neo-Tethys followed suit.

Jeremy Richards and Celâl Şengör (*Geology* http://doi.org/b6x7; 2017) now suggest that the transition from the subduction of reduced Palaeo-Tethyan to more oxidized Neo-Tethyan sediments and rocks may have influenced ore formation in southern Eurasia. Porphyry ore deposits form when an oceanic plate subducts beneath a continent. Dehydration of the subducted plate and sediments triggers the formation of magma that can transport and concentrate metals into economic-grade deposits in magmatic and volcanic systems in the overlying continental crust. However, porphyry copper deposits only form from oxidized magmas.

Rich copper porphyry deposits are scattered along a vast swathe of land that stretches from Europe's eastern Mediterranean, through Iran and across to the Himalaya and Tibetan Plateau. The majority of these ore deposits formed during and after Cretaceous times (from about 84 million years ago and later), coincident with the subduction of the Neo-Tethyan ocean basin below the continent. Older ore deposits are rare.

Richards and Şengör argue that any magmas formed in response to subduction of the oxygen-starved sediments and seafloor of the Palaeo-Tethys basin were too reduced to transport metals. To test this idea, they used a compilation of existing geochemical data to analyse the composition and trace-element ratios of magmatic rocks preserved throughout southern Eurasia. It turns out that the rocks that formed during subduction of the Palaeo-Tethyan seafloor are indeed largely oxygen poor and barren of metals. In contrast, those magmatic rocks formed during the Cretaceous and later — as seafloor from the Neo-Tethys Ocean was subducted — have higher oxygen contents and are rich in metals.

It seems then that the generation of economically viable ore deposits may have ultimately depended on the oxidation state of ancient Earth environments.

AMY WHITCHURCH