Inhospitable climate fosters gold ore formation

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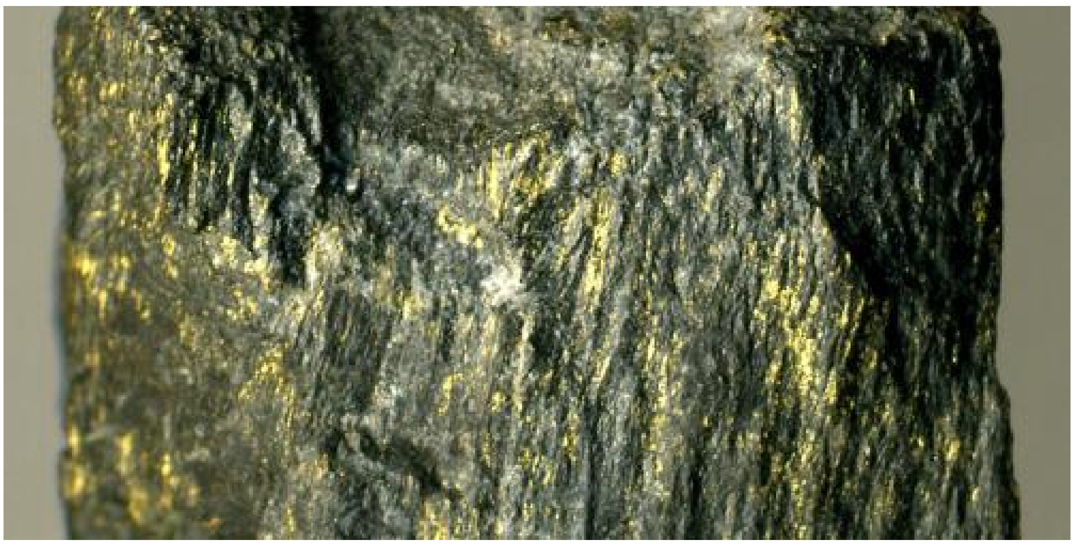


The richest gold ore in Witwatersrand is found in thin layers rich in carbon, plating fibres of ancient microbial life forms. Credit: James St. John / Wikimedia Commons

South Africa's Witwatersrand is the site of the world's largest and richest gold deposit. In order to explain its formation, ETH professor Christoph Heinrich took a look back into the Earth's early climatic history.

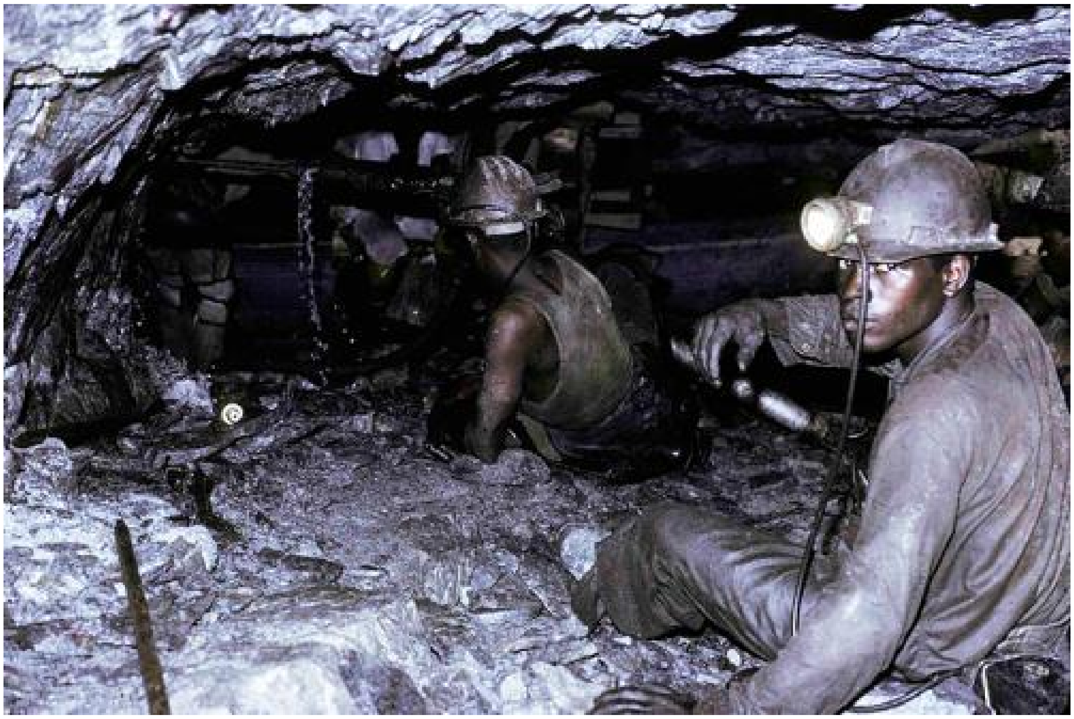
The Witwatersrand Basin in South Africa holds the world's largest gold deposits across a 200-km long swathe. Individual ore deposits are spread out in thin layers over areas up to 10 by 10 km and contain more gold than any other gold deposit in the world. Some 40% of the precious metal that has been found up to the present day comes from this area, and hundreds of tons of gold deposits still lie beneath the earth. The manner in which these giant deposits formed is still debated among geologists. Christoph Heinrich, Professor of Mineral Resources at ETH and the University of Zurich, recently published a new explanation in the journal *Nature Geoscience*, trying to reconcile the contradictions of two previously published theories.

The prevailing 'placer gold' theory states that the gold at Witwatersrand was transported and concentrated through mechanical means as metallic particles in river sediment. Such a process has led to the gold-rich river gravels that gave rise to the Californian gold rush. Here, nuggets of placer gold have accumulated locally in river gravels in the foothills of the Sierra Nevada, where primary gold-quarz veins provide a nearby source of the nuggets.

But no sufficiently large source exists in the immediate sub-surface of the Witwatersrand Basin. This is one of the main arguments of proponents of the 'hydrothermal hypothesis', according to which gold, chemically dissolved in hot fluid, passed into the sediment layers half a billion years after their deposition. For this theory to work, a 10 km thick blanket of later sediments would be required in order to create the required pressure and temperature. However, the hydrothermal theory is contradicted by geological evidence that the gold concentration must have taken place during the formation of host sediments on the Earth's surface.

Rainwater rich in hydrogen sulphide

Heinrich believes the concentration of gold took place at the Earth's surface, indeed by flowing river water, but in chemically dissolved form. With such a process, the gold could be easily 'collected' from a much larger catchment area of weathered, slightly gold-bearing rocks. The resource geologist examined the possibility of this middle way, by calculating the chemical solubility of the precious metal in surface water under the prevailing atmospheric and climatic conditions.



Hard and dangerous labour: The mines provide no place to stand. Credit: Prof. C. Heinrich

Experimental data shows that the chemical transport of gold was indeed possible in the early stages of Earth evolution. The prerequisite was that the rainwater had to be at least occasionally very rich in hydrogen sulphide. Hydrogen sulphide binds itself in the weathered soil with widely distributed traces of gold to form aqueous gold sulphide complexes, which significantly increases the solubility of the gold. However, hydrogen sulphide in the atmosphere and sulphurous gold complexes in river water are stable only in the absence of free oxygen. "Quite inhospitable environmental conditions must have dominated, which was possible only three billion years ago during the Archean eon," says Heinrich. "It required an oxygen-free atmosphere that was temporarily very rich in hydrogen sulphide – the smell of rotten eggs." In today's atmosphere, oxygen oxidises all hydrogen sulphide, thus destroying gold's sulphur complex in a short time, which is why gold is practically insoluble in today's river water.

Volcanoes and bacteria as important factors

In order to increase the sulphur concentration of rainwater sufficiently in the Archean eon, basaltic volcanism of gigantic proportions was required at the same time. Indeed, in other regions of South Africa there is evidence of giant basaltic eruptions overlapping with the period of the gold concentration.

A third factor required for the formation of gold deposits at Witwatersrand is a suitable location for concentrated precipitation of the gold. The richest deposits of gold ore in the basin are found in carbon-rich layers, often just millimetres to centimeters thick, but which stretch for many kilometres. These thin layers contain such high gold concentrations that mining tunnels scarcely a metre high some three kilometres below the Earth's surface are still worthwhile.

The carbon probably stems from the growth of bacteria on the bottom of shallow lakes and it's here that the dissolved gold precipitated chemically, according to Heinrich's interpretation.

The nature of these life forms is not well known. "It's possible that these primitive organisms actively adsorbed the gold," Heinrich speculates. "But a simple chemical reduction of sulphur-complexed gold in water to elementary metal on an organic material is sufficient for a chemical 'gilding' of the bottom of the shallow lakes."

The gold deposits in the Witwatersrand, which are unique worldwide, could have thus been formed only during a certain period of the Earth's history: after the development of the first continental life forms in shallow lakes at least 3 billion years ago, but before the first emergence of free oxygen in the Earth's atmosphere approximately 2.5 billion years ago.

More information: Heinrich C: "Witwatersrand gold deposits formed by volcanic rain, anoxic rivers and Archaen life." *Nature Geoscience*, advanced online publication, February 2nd 2015. DOI: 10.1038/ngeo2344

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