Radio-isotope dating sheds light on ancient deposits

Randall Parrish

Keyworth

Volcanogenic massive sulphide deposits, termed VMS in the trade, host some of the most important sources of the metals copper, lead, zinc and silver on the earth. For the most part, they have formed in the vicinity of large submarine volcanic centres with associated hydrothermal systems. The discovery and documentation of the spectacular submarine vents, hot springs, and metalliferous 'black smokers', with their very unusual associated colonies of life forms, has focussed widespread public attention on these submarine volcanic environments. The rates of formation of mineral sulphide deposits on the ocean floor has been studied using these active modern examples.

These types of deposit are found throughout the geological record, with some of the largest systems ever recorded being the oldest. One of the best preserved and largest, a real giant in its class with 150 million tonnes of ore, is the Kidd Creek Deposit, which is found in the Abitibi Greenstone Belt of Ontario, Canada. The largest deposit of this type in the United Kingdom is the Parys Mountain deposit in Anglesey, North Wales, which has up to 10 million tonnes of copper-zinc-lead-silver ore. More often than not, these deposits have been strongly deformed by tectonic processes, and consequently they have very complicated stratigraphical and structural relationships which obscure their original shape, form and size. In the Precambrian deposits like Kidd Creek, where there are no fossils, determining the age and duration of hydrothermal and volcanic activity and elucidating many of the complex stratigraphical relationships relies strongly on radioisotope geochronology. This is mainly the very high-precision method of uranium-lead dating of the mineral zircon. It is interesting to ask whether such giant deposits like Kidd Creek are unique to the Precambrian, and whether the rates of volcanic and hydrothermal processes were different in the distant past.

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The Kidd Creek deposit, like many other VMS deposits, is characterised by a bimodal rhyolite-basalt volcanic association, with important breaks in volcanic activity occupied by deposition of sedimentary material. Current interpretations of the tectonic setting of this volcanic belt invoke a plume origin for many of the volcanic rocks, which include the world-famous spinifex olivine-bearing komatiites. Plume-related volcanism is thought to have occurred in a back-arc environment and was certainly accompanied by significant crustal extension and rifting in the submarine environment.

Rhyolitic volcanic rocks contain zircon, a mineral which crystallises from the magma and which is used for high-precision geochronology. Because of the unique attributes of the uranium-lead decay system which has two coupled radioactive decay schemes (^{238}U-^{206}Pb and ^{235}U-^{207}Pb), it is currently possible to date rocks to ± 500 000 years when the rocks are 2 700 million years old. Analytical precision at this level permits the dating of individual lava flows, enabling geochronology to resolve complex stratigraphical relationships. The technique has only recently been comprehensively applied to deposits of this type, but its impact has far-reaching consequences for our understanding of the genesis of these ore bodies and the development of strategies which mineral exploration consortia use in locating new ore reserves.

The figure shows the presently understood age and original stratigraphical relationships of the Kidd Creek deposit. Several new insights arose from a recent very detailed isotopic dating programme. The main ore bodies, which occur in distinct centres over an original area of at least 2 km^2, developed in distinct episodes of time from 2716.0 ± 0.5 to 2711.5 ± 1.2 million years ago. It is possible to calculate that the rate of deposition of massive sulphides was about 10–100 tonnes per year, which is quite similar to the ore deposition rate

Black Smoker, Main Endeavour Hydrothermal Vent Field on the Endeavour Segment of the mid-ocean ridge at 47˚57'N, 129˚6'W. The sulphide minerals that precipitate from hydrothermal solutions venting from black smokers are metal bearing, with copper, zinc, manganese, etc.
© Woods Hole Oceanographic Institution, J R Delaney, principal investigator, University of Washington; picture taken by camera mounted on hull of the ALVIN.

Black smoker at 9˚50' N on the East Pacific Rise. It consists of a sulphide mound with several actively venting chimneys. © Woods Hole Oceanographic Institution, Deep Submergence Operations Group, Dan Fornari.

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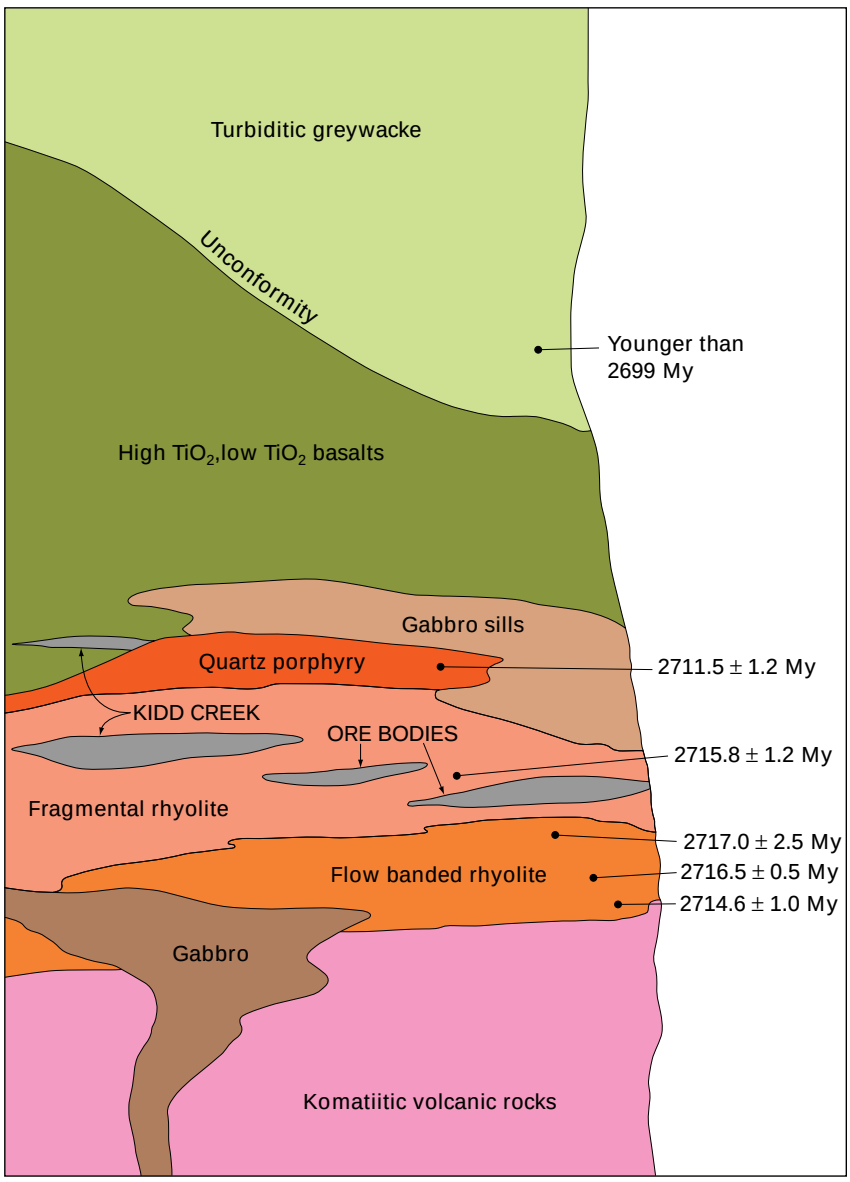
of the 50 000-year-old, five-million-tonne deposit discovered recently on the Mid-Atlantic Ridge under several kilometres of sea water. Such conclusions strengthen the notion that similar hydrothermal processes have operated on the Earth for billions of years. Because individual rhyolitic lava flows can be precisely dated, several volcanic layers have been identified in the outlying region which are the same age as the mineralised ones at the ore deposit. The identification of these layers may help to steer future exploration activity to those stratigraphic horizons known to contain ore nearby, a potentially valuable strategic tool for exploration companies. The dating work at Kidd Creek has also resolved two long-standing controversies. Firstly, the sedimentary greywackes which underlie the south side of the ore body are younger, not older than the Kidd Creek ore body. Secondly, previous dating results (using other radioactive decay systems and minerals) which suggested that the VMS ore deposition might be younger than 2690 million years are now known to be incorrect.

Similar controversies surround many of the VMS deposits of the world, not the least of which is the Parys Mountain deposit in North Wales. By comparison with the significant cost of drilling new exploration holes, the cost of the programme of work outlined above for the Kidd Creek deposit was quite modest. In surprising ways, the isotopic dating programme solved definitively some very controversial issues which had been the subject of debate for decades.



Schematic profile showing stratigraphical relationships at the Kidd Creek deposit.