Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.38101

The Virginia Witwatersrand-type helium deposit, South Africa: New constraints on the origin and evolution.

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The Virginia helium deposit in the southern Witwatersrand Basin, South Africa, is the only new find in the past 15 years large enough to warrant construction of a dedicated liquefaction plant. The helium is extracted from shallow faults within the 2-4 km thick Witwatersrand Supergroup metasediment/metavolcanic rocks, and the overlying Ventersdorp Supergroup sandstones. Both reservoirs are sealed by near horizontally-bedded Early Permian Dywka diamictite and mudstones, the basal units of a thin veneer of Karoo Supergroup sediments. The helium has been generated in U-rich quartz pebble conglomerates of the basal Dominion Group that formed during a period of extremely low atmospheric oxygen level at 2.8-2.9 Ga, making it a unique natural laboratory for studying how helium deposits form.

The He-rich Virginia field gases are dominantly CH_4 (73-99%), with modest N concentrations (up to 11%) and sub-percent levels of H, CO_2 and C2-4. Helium concentrations range from 0.5 to 12% at an average of 3.5%. In contrast to the unconventional helium deposits in North America, He/N ratios are extremely high (0.1 to 1.2). This implies that the gas production process is very different. C, H and clumped isotope ($^{13}CH_3D$ and $^{12}CH_2D_2$) composition of the methane suggests that it is a mixture of a microbially-produced gas present in palaeo-meteoric waters and abiotic methane derived from ancient saline fluids in the deep mines. Anaerobic oxidation of CH_4 by methanotrophic microbes known to exist in mine fluids explains the absence of H compared to He-poor gases from the northern Witwatersrand Basin. The absence of CO_2 in the He-bearing gases, and the extremely low $^3He/^4He$, rules out a significant contribution from the Karoo magmatism. The dewatering of deep gold/uranium mines in late 20th century may in part be responsible for the presence of the He-rich gases beneath the Karoo.

The generation of the Virginia helium deposit has required the coincidence of a number of key geological factors. Over one hundred U-rich palaeo-placer quartz pebble conglomerates are documented globally, many have been mined for uranium (e.g. Pele Mountain, Elliot Lake, Canada). Consequently it is possible that more Witwatersrand-type helium deposits may be waiting to be discovered.