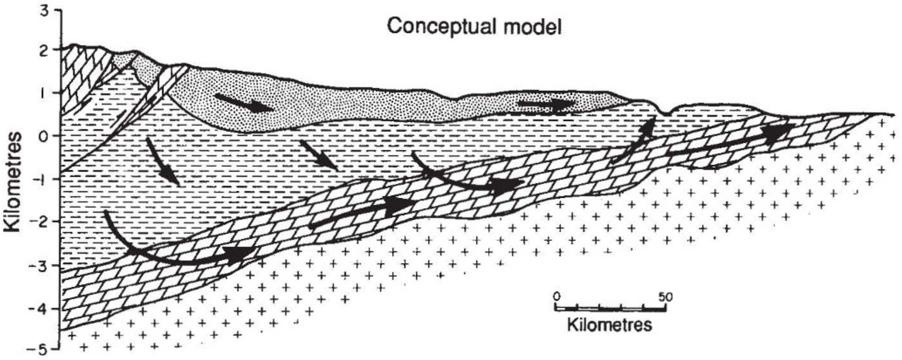
duplicated over continental-scales in the deep basement.

Another possible mechanism involves pumping of fluids along regional faults during seismic events[8]. Seismic pumping can generate flow volumes of the order of 5×10^6 m^3. But it is difficult to see how hot seismic pumping could explain the widespread and pervasive geochemical and thermal alteration observed throughout the midcontinent. Fracture networks are more likely to have affected regional and local permeability of the Palaeozoic section hosting the ores than to have provided a driving force for regional brine migration.



Schematic cross-section illustrating the style of gravity-driven, continental-scale fluid migration in uplifted foreland basins, which are formed in front of mountain belts created by compressional tectonics. The arrows indicate the focusing of deep groundwater and brine through a Cambrian–Ordovician carbonate aquifer (slanted brick pattern) which is underlain by nearly impervious Precambrian basement and overlain by low-permeability mudstones. Foreland sedimentary basins such as those in front of the ancient Appalachian and Ouachita Mountains provided the metal-bearing brines that were driven several hundreds of kilometres across the US midcontinent to form large ore deposits in discharge areas along the Mississippi Valley region. The hydraulic force responsible for brine migration is attributable to the newly elevated topography. This gravity-driven flow system decayed with erosion of the landscape, but flow rates of metres per year were capable of elevating heat flow at the basin margin for millions of years. The flow system portrayed here was apparently established after the Alleghenian–Ouachitan phases of mountain building (300–250 million years ago). Earlier periods of mountain building included the Taconic and Acadian orogenies (470–440 and 390–360 million years ago, respectively) and these too may have generated flow systems. But the fluid flow associated with these earlier phases represented only a small harbinger of the massive flow systems created by the subsequent uplift of the Appalachian and Ouachita Mountains and adjacent forelands. (From ref. 9.)

We prefer a picture involving groundwater circulation at the scale of entire basins, in which the deepest, saline pore water would be driven away from the newly formed mountain belt, updip towards the shallow edge of the foreland platform in its wake, by the raised topography alone[9] (see figure). A similar gravity-driven flow model may explain patterns of oil migration within the Alberta and Illinois Basins, and fluid flow in the Arkoma Basin.

Regional flow systems driven by topographic relief appear to place many of the pieces in the puzzle of MVT ore genesis in their correct positions. For example, deep flow rates of 1 – 10 m yr^{-1} can be sustained for millions of years, although the rates will wane after hundreds of thousands of years as erosion wears down the elevated landscape. Because of the elevated groundwater flow rates, regional heat flow becomes elevated near the edges of foreland platforms and along intracratonic arches, thereby explaining the typical deposition temperatures reflected by fluid inclusions. In addition, thermal and chemical transients would occur throughout the history of the ore deposition as the hydrological system adjusted to the landscapes generated by mountain building.

Large-scale patterns of petroleum accumulation, cementation and diagenesis associated with basin evolution also fit well. The application of such quantitative models are, nevertheless, limited by a lack of quantitative information on the timing and duration of the flows. It is here that isotopic dating studies help to constrain the models of fluid flow. If the isotopic studies could also constrain the durations of the flow systems, an even more fundamental understanding would be possible on the relationships between ore deposits, fluid flow and mountain building in continental terrains. □

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DAEDALUS

Exploding comets

LAST week Daedalus proposed the ultimate rocket fuel. He planned to irradiate solid hydrogen with ultraviolet light in an electric field, to dislodge and displace its constituent electrons and protons. The resulting intensely energetic matrix of monatomic hydrogen, ions and dislocations might easily store twenty times as much energy as TNT.

Daedalus now reckons that nature may have got there first. Far enough from the Sun, in fact at ten times the distance of Pluto's orbit, space becomes cold enough to freeze hydrogen. The tenuous interstellar gas is mainly hydrogen; in those cryogenic regions it must freeze onto any solid surface that offers itself. So, says Daedalus, a comet wandering through the depths of space must over the ages accumulate an outer frosting of solid hydrogen. At the same time it is feebly illuminated by the Sun and stars. By the photoelectric effect, their visible and ultraviolet light will slowly establish an electric field across the frozen, insulating material. Their far ultraviolet, unshielded by any atmosphere, will gradually scramble the protons and electrons of the solid hydrogen into ever more energetic positions. Ultimately, the reacted, radiation-damaged hydrogen surface will reach its maximum possible content of energy. By then it will be buried under new layers of accumulating hydrogen, which will store energy in their turn.

On its long interstellar sojourn, therefore, every comet slowly turns into a king-sized bomb. When it begins to fall towards the Sun, it starts to warm up. At ten times Pluto's orbital radius, sunlight becomes intense enough to melt hydrogen. The newly mobile atoms and ions will recombine in one enormous explosion. The comet will lose its hydrogen overcoat, and will receive a mighty kick in some unpredictable direction.

This, says Daedalus, explains the apparently endless supply of new comets. They are simply old comets blown off course, and appearing along unfamiliar and uncatalogued orbits. A cometary explosion will be sudden, brief, and unpredictable in space and time. Being largely the recombination of monatomic hydrogen, it should radiate mainly in the ultraviolet. Even with his telescope pointing the right way, an astronomer would probably dismiss it as a glitch in his detector electronics. But Daedalus advocates a serious search for such cometary blasts. If a comet later appears on an orbit emanating from that position, his theory will be confirmed. The emission spectrum of the explosion would sensitively reveal the comet's composition, and might serve as a fingerprint to classify it by.

David Jones