# Source, Seal, Trap: Lessons from Helium Exploration in De-risking Subsurface Uncertainty

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Helium's ultra-small atomic size and low molecular weight give it a unique ability to diffuse through virtually all materials over geologic time—even unfractured granite, albeit slowly. With the easy accumulations largely found, what exploration principles can ensure North America avoids dependence on foreign helium—and can these same principles apply to oil and gas?

This is no trivial matter. Semiconductor chips are 100% dependent on helium—affecting automobiles, smartphones, space propulsion, satellite systems, computers, and solar cells. Helium is also vital to national defense, MRIs, welding, fiber optics, and leak detection.

Helium accumulations fundamentally occur when the **rate of expulsion from source** exceeds the **rate of leakage through seal**. Not all sources and seals are created equal, but common traits of successful helium systems include:

- Proximal mafic lithospheric basement rocks rich in uranium/thorium
- Moderate to deep, well-timed four-way and faulted three-way paleo-structures capped by evaporites
- Shallow to deep reservoirs sealed by minimally fractured tight limestones and/or hard shales

Then comes the fun part: assigning a **Probability of Success (Ps)** by quantifying parameters such as:

- Helium concentration
- Porosity and permeability
- Diagenetic history
- Migration effectiveness
- Timing and tectonics
- Trap size, integrity and preservation
- Seal capacity

How *quantifiable* are these risk components? Regardless of whether the target is helium, oil, or gas, this question often hinges on the availability of meaningful analogs and appropriate seismic data. With a proximal analog and seismic resolution suitable to the play style, an explorationist can often build a respectable Ps for each parameter—except one:

**Seal.**

Statistically, inadequate seal analysis has led to more economic failures—across oil, gas, and helium—than any other single factor.

Helium's diffusivity is significantly higher than that of methane, whose molecular mass is approximately four times greater (4 vs. 16 g/mol). Besides requiring elevated seal integrity, a single short-lived tectonic

event can negate 100’s of millions of years of helium accumulation (radioactive decay is a drip drip drip process).

What inductive reasoning applies when attempting to assess late-stage tectonic effects like micro-fracturing and fault reactivation? And how do we evaluate the ‘healing’ behavior of elastic evaporites like anhydrite and salt?

This presentation will examine how pore pressure plots, isochrons/isopachs, bore-hole image logs, and palinspastic maps can assist in de-risking these seals:

1. Upper Mississippian tight limestones on the US Four Corners Platform
2. Southern Rockies Pennsylvanian evaporites of the Paradox Basin
3. Upper Devonian Prairie Evaporite, Western Canada

All of this occurs under the backdrop of helium geopolitics. Following a recent price war in China, Russia has rapidly overtaken ~50% of the Chinese helium market (AKAP)—with significant spare capacity. Gazprom and its affiliates are watching U.S. helium exploration closely. For domestic producers, it’s high stakes—and risky business.