geoconvention
Calgary • Canada • May 11-13 2026

Basement and stratigraphic controls on the generation and migration of helium and hydrogen in the Paleozoic strata, southwestern Manitoba

Michelle P.B. Nicolas
Manitoba Geological Survey

Summary

Helium and geologic hydrogen occurrences have been mapped in southwestern Manitoba (Nicolas 2018; 2024). Many of the locations of these occurrences occur in the vicinity of deep basement structures and are related to mineralogical composition of the source rocks. Precambrian domain boundaries and within the large crustal suture of the Superior boundary zone (SBZ) are commonly associated with structural and stratigraphic anomalies in the overlying sedimentary strata, providing opportunities for migration pathways and trapping mechanisms. The variable composition of the Precambrian crust provides ample source rocks for the generation of helium and hydrogen. Putting these elements together can help predict or model helium and hydrogen generation “hot spots”.

Previous Work

Previous foundational work in Manitoba includes Nicolas (2018) which compiled the helium occurrences in Manitoba and Nicolas (2024) compiled the natural hydrogen occurrences (Figure 1). Follow up studies for helium included work by (Nicolas et al., 2023, 2024, 2025b) to use an innovative method to studied the distribution of helium in pore spaces through most of the Paleozoic strata. Additional work on hydrogen in partnership with the Geological Survey of Canada (Nicolas et al., 2025a) is a preliminary review of the effect on chemical composition and hydrogen generation potential.

Helium and Hydrogen Sources

In Manitoba, helium and geologic hydrogen is primarily sourced from the Precambrian basement which underlies the Williston Basin Paleozoic strata (Nicolas, 2018; Nicolas, 2024). Helium is formed primarily by the radioactive decay of uranium and thorium bearing minerals in crystalline Precambrian basement rocks, but also from detrital sedimentary rocks such as shales. In the geological environment, hydrogen is formed as a byproduct of several reactions, including rock-water interactions (e.g., the oxidation of Fe^{2+}-bearing minerals and serpentinization of ultramafic rocks), weathering, radioactive decay casualties, decomposition of organic matter, and natural water hydrolysis ((Lin et al., 2005; Warr et al., 2019). Helium and

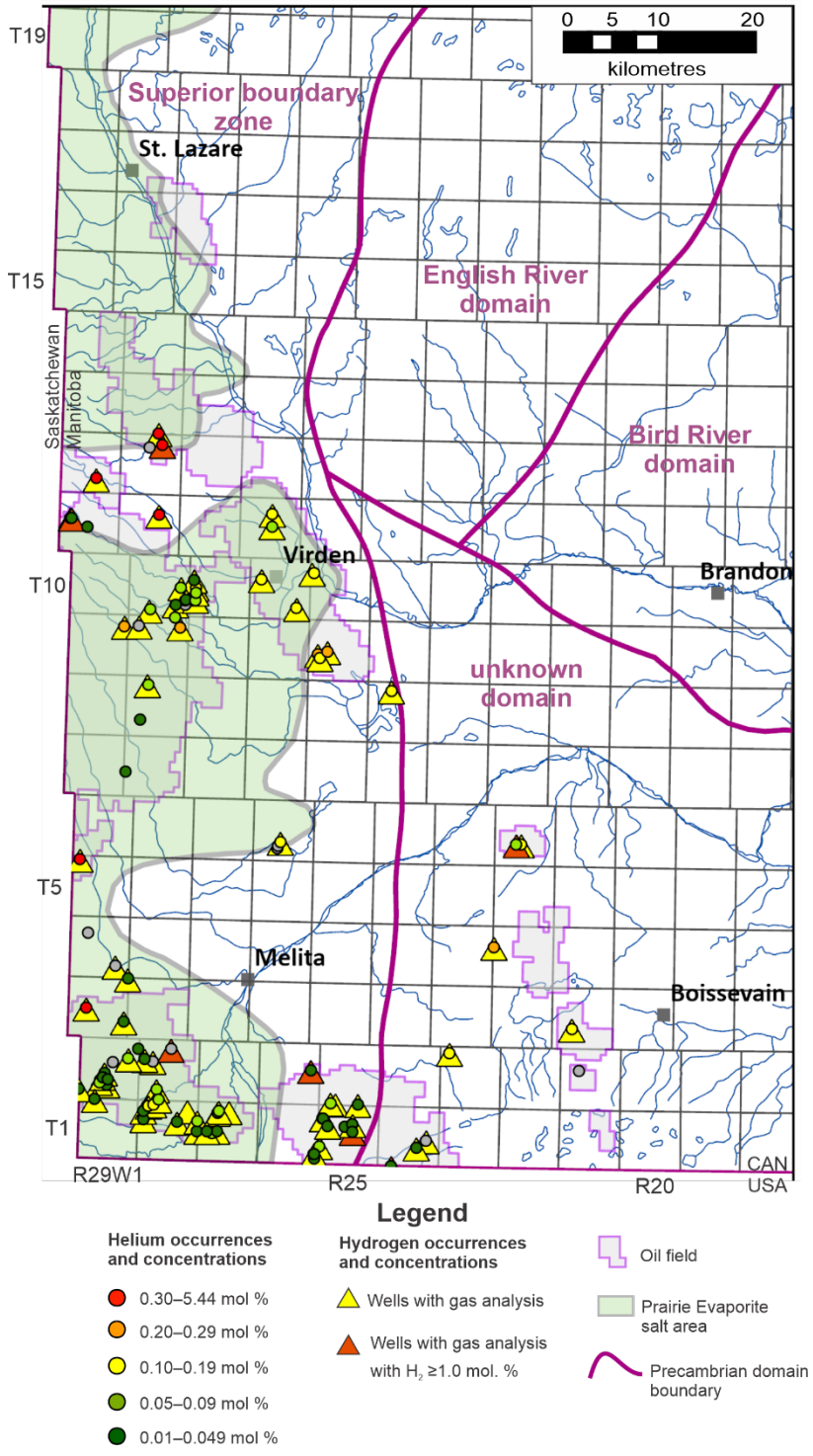


Figure 1: *Helium and hydrogen occurrence map of southwestern Manitoba showing oil fields, the location of Precambrian domain boundaries and Superior boundary zone and area with preserved salt in the Prairie Evaporite.*

hydrogen share a common genesis through radioactive decay of uranium and thorium. Helium is a direct by-product of this nuclear reaction, while the formation of hydrogen is a side effect of the reaction formed by water molecules bombarded by radiation (radiolysis). This commonality allows for the two elements to be found in the same reservoirs under the right circumstances. However, hydrogen is highly reactive while helium is inert, but in the subsurface, these elements can diffuse through solid rock into pore waters where its transmissivity is strongly controlled by the chemistry of the migrating fluids in which it resides. Unless trapped underground these small and light elements will reach Earths surface, where it easily escapes the atmosphere into space. The reactivity and diffusibility of hydrogen has led to the belief that economic accumulations are not possible, however natural accumulations do occur.

Precambrian Basement Features

The Precambrian basement that underlies the Williston Basin is a mosaic of ancient crustal blocks (domains) stitched together over eons of movement and collisions but also affected by billions of years of erosion and sediment and ice loading cycles. Each blocks has a unique mineralogical and chemical composition, physical characteristics and structural fabric making the boundaries between the domains potential areas of localized crustal weakness due to the differing crustal competencies of each domain. These crustal domain junctions are known to cause faulting and fracturing in the strata above and enhance fluid flow. It is through multiple observations, such are outcrop, core, seismic, magnetic and gravity geophysical maps that these features can be observed.

The large crustal suture of the SBZ — the most significant sub-Phanerozoic Precambrian feature in the Williston Basin in Manitoba — is responsible for the development of the oil fields in the south, and has numerous documented faults and fractures and stratal disturbances (McCabe, 1959; Bezys et al., 1996; Bezys et al., 1997; Dietrich and Bezys, 1998; Nicolas, 2012). This includes preferential and accelerated dissolution of the thick Devonian Prairie Evaporite salt beds. In addition, post-basin–formation hydrothermal systems and large networks of saline water fractures have also been documented; these create the much-needed deep migration pathways required to tap into ancient networks and deep fluids (Nicolas, 2024).

Target Mapping

The SBZ and areas around crustal domain boundaries would serve as the best potential for helium and natural hydrogen sources and pathways. The migration through a network of pores, fractures and faults into the sedimentary strata above, with its porous reservoirs and multiple sealing units, provide for the rest of the hydrogen system requirements. Understanding the fabric of the basement rocks and the location of domain boundaries can help to predict possible areas of enhanced fluid flow and migration pathways, while knowing the composition of those

domains and likelihood of them generating helium and hydrogen can help predict or model helium and hydrogen generation “hot spots”.

Acknowledgements

The author would like to acknowledge C. Smith and M. Smith from Advance Hydrocarbon Stratigraphic Ltd. for the collaboration on mapping helium diffusion through the sedimentary strata, and O. Ardakani and D. Coutts from the Geological Survey of Canada for their insights and collaborative work on hydrogen generation modelling of Precambrian rocks.

References

Bezys, R. K., Fedikow, M. A. F., Bamburak, J. D. and Abercrombie, H. J. 1997: Geological setting of Prairie-type Au mineralization, Mafeking Quarry, west central Manitoba 1996 work (NTS 63C); Manitoba Energy and Mines, Preliminary Map 1997P-1, 1 map, scale 1:5_000.

Bezys, R. K., Fedikow, M. A. F. and Kjarsgaard, B. A. 1996: Evidence of Cretaceous(?) volcanism along the Churchill-Superior boundary zone, Manitoba (NTS 63G/4); in Report of Activities 1996, Manitoba Energy and Mines, Geological Services, p. 122-126.

Dietrich, J. R. and Bezys, R. K. 1998: Basement-sedimentary cover relationships along the Churchill-Superior Boundary Zone, southwestern Manitoba; in Eighth International Williston Basin Symposium, J. E. Christopher, D. F. Gilboy, D. F. Paterson and S. L. Bend (eds.), Saskatchewan Geological Survey, p. 175.

Lin, L. H., Slater, G. F., Sherwood Lollar, B., Lacrampe-Couloume, G. and Onstott, T. C. 2005: The yield and isotopic composition of radiolytic H2, a potential energy source for the deep subsurface biosphere; Geochemica et Cosmochemica Acta, v. 69, p. 893-903.

McCabe, H. R. 1959: Mississippian Stratigraphy of Manitoba; Manitoba Department of Mines and Natural Resources, Mines Branch, Winnipeg, 99 p.

Nicolas, M. P. B. 2012: Stratigraphy and regional geology of the Late Devonian-Early Mississippian Three Forks Group, southwestern Manitoba (NTS 62F, part of 62G, K); Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, Geoscientific Report GR2012-3, 92 p.

Nicolas, M. P. B. 2018: Summary of helium occurrences in southwestern Manitoba; in Report of Activities 2018, Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, p. 110-118.

Nicolas, M. P. B. 2024: Geologic hydrogen in the Williston and Hudson Bay basins, southwestern and northeastern Manitoba (parts of NTS 53, 54, 62, 63); Manitoba Economic Development, Investment, Trade and Natural Resources, Manitoba Geological Survey, p. 164-171 p.

Nicolas, M. P. B., Coutts, D. and Ardakani, O. H. 2025a: Preliminary investigation into the natural hydrogen generation potential of Precambrian rocks below the Williston Basin, southwestern Manitoba (parts of NTS 62G, J, K, O and 63B, C, G, K); in Report of Activities 2025, Manitoba Business, Mining, Trade and Job Creation, p. 104-109.

Nicolas, M. P. B., Smith, C. M. and Smith, M. P. 2023: Volatiles analysis of drill cuttings to evaluate the helium prospectivity of southwestern Manitoba (parts of NTS 62F2, K3); in Report of Activities 2024, Manitoba Economic Development, Investment, Trade and Natural Resources, Manitoba Geological Survey, p. 93-104.

Nicolas, M. P. B., Smith, C. M. and Smith, M. P. 2024: Rock volatiles analysis of drill cuttings to evaluate the helium and hydrocarbon prospectivity of southwestern Manitoba (parts of NTS 62F2, K3); Manitoba Economic Development, Investment, Trade and Natural Resources, Manitoba Geological Survey, 153-163 p.

Nicolas, M. P. B., Smith, C. M. and Smith, M. P. 2025b: Effects of drill-cutting size and age on the reliability of measuring helium and other volatiles in samples, southwestern Manitoba (parts of NTS 62K6, 7, 11), Report of Activities 2025, Manitoba Business, Mining, Trade and Job Creation, Manitoba Geological Survey, p. 110-119.

Warr, O., Giunta, T., Ballentine, C. J. and Sherwood Lollar, B. 2019: Mechanics and rates of 4He, 40Ar, and H2 production and accumulation in fracture fluids in Precambrian Shield environments; Chemical Geology v. 530, p. 13.