Developing a geologic hydrogen resources assessment approach using AI-assisted literature review and geo-data driven assessment tool

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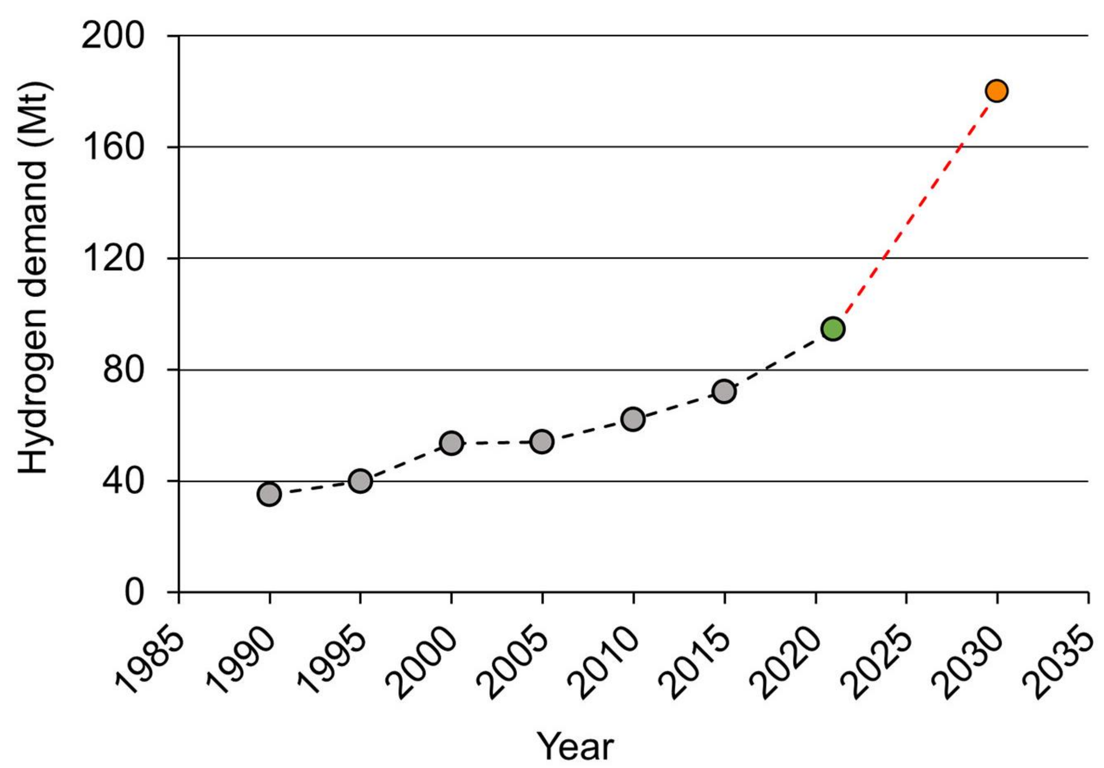
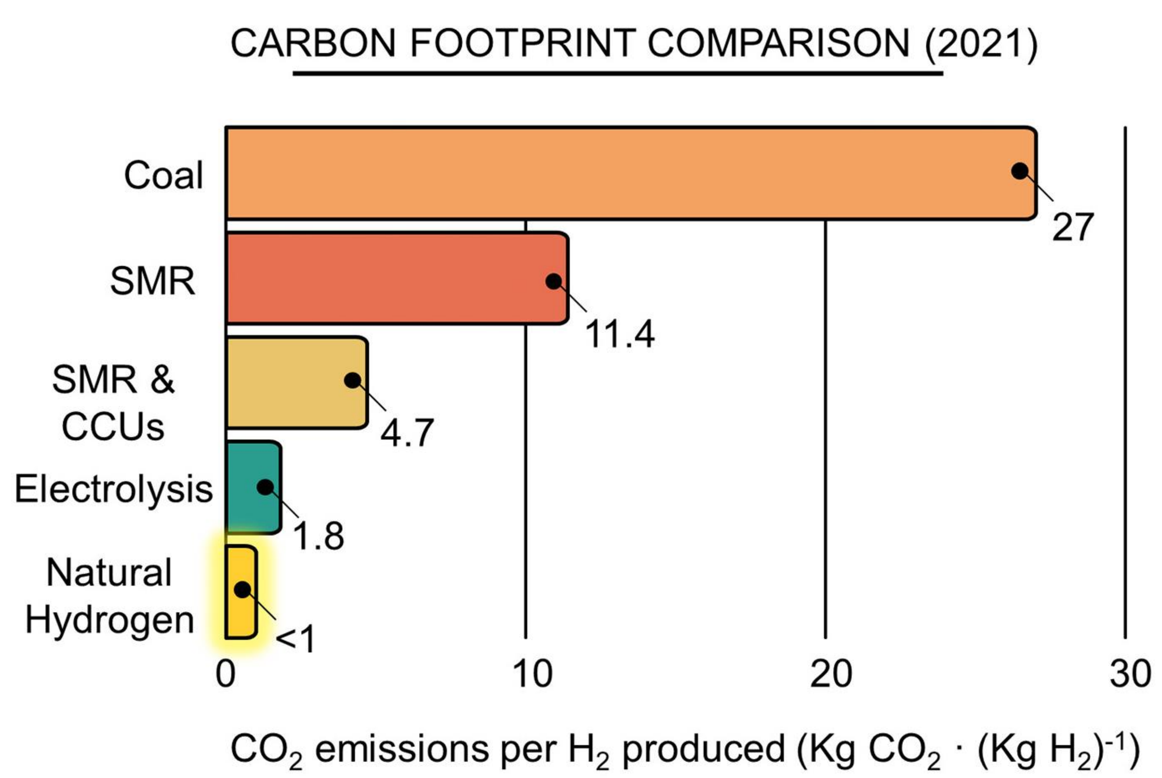
Introduction

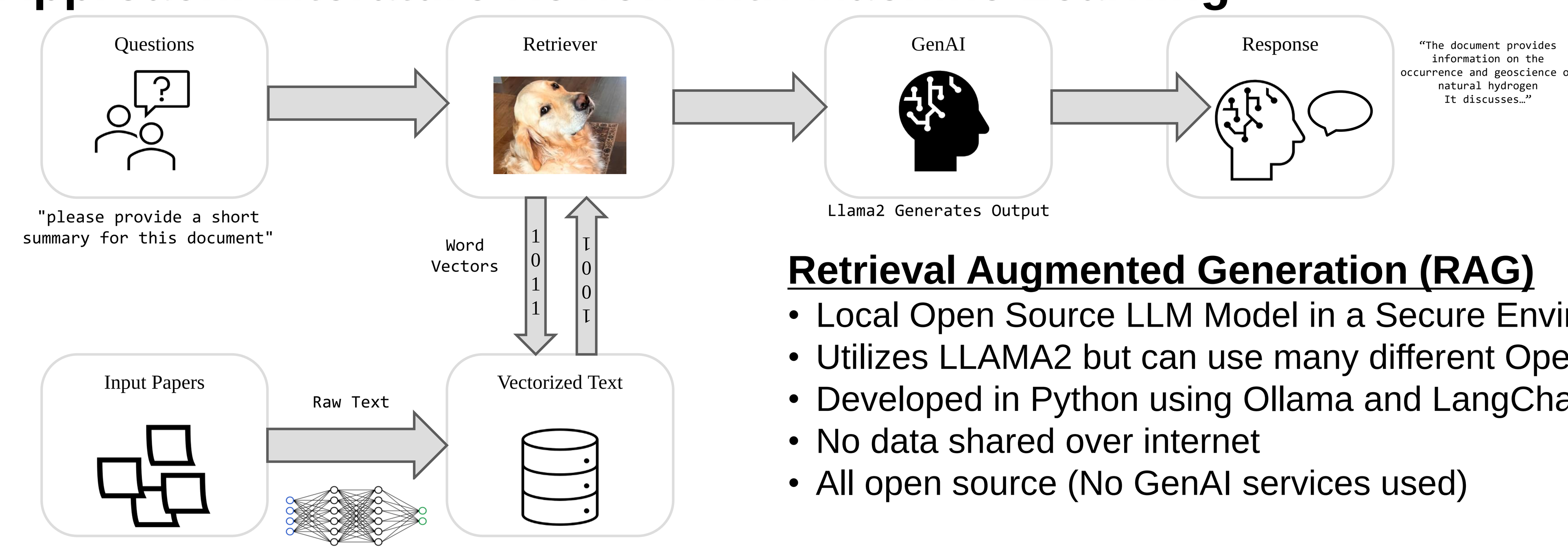




Goal

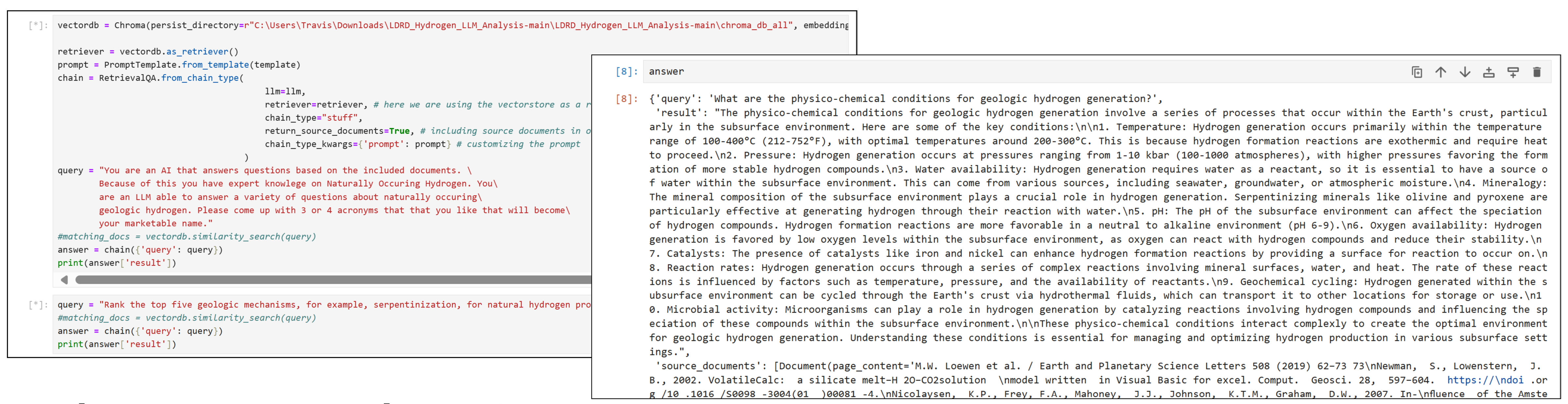
- Develop insights on potential natural hydrogen generation knowledge gaps
- Identification of potential hydrogen resources in US
- Domestic and regional assessment of potential hydrogen resources (preliminary development of workflow/tool and evaluation of technically recoverable resources)
- Evaluating hydrogen system as a natural analog for natural hydrogen storage
- Coupled processes related with hydrogen production (CO2 storage/critical mineral exploration)
- Develop a new research portfolio for future in-house and collaborative research.

Approach: Literature Review with Machine Learning



Retrieval Augmented Generation (RAG)

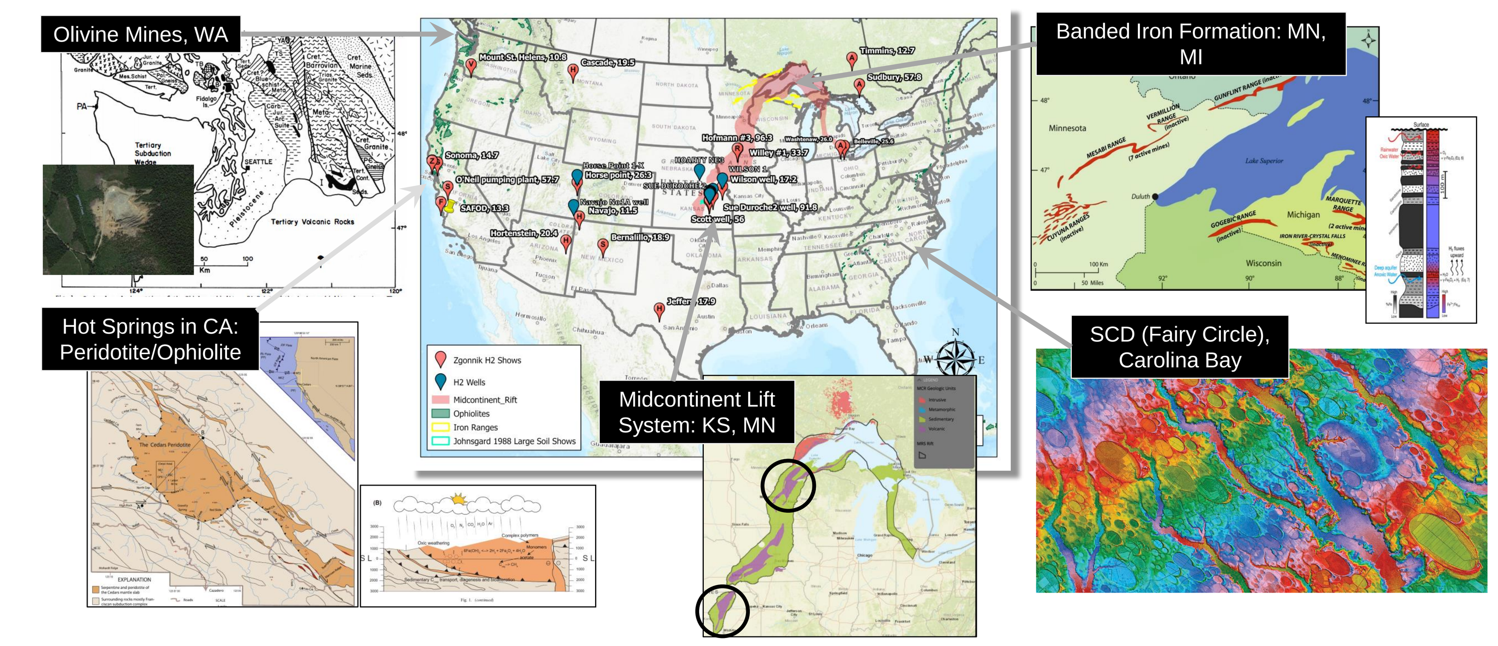
- Local Open Source LLM Model in a Secure Environment
- Utilizes LLAMA2 but can use many different Open LLM
- Developed in Python using Ollama and LangChain libraries
- No data shared over internet
- All open source (No GenAI services used)



Hydrogen vs. Petroleum System

"Typical"…		Petroleum Systems			(Potential for commercial-scale production) Geologic Hydrogen Systems				
		Natural	Anthropogenic		Natural			Anthropogenic	
Analog	System Subtype Name	"Primary Production"	"Enhanced Production"	"Reservoir Emplaced into Source"	"Migration Pathway Target"	"Mantle-Source"	"Natural Serpentinization"	"Generation-Stimulated Source"	"Generation and Reservoir Emplaced into Source"
	Example Field/Play	Prudhoe Bay, AK, USA	SACROC, TX, USA	Marcellus Shale, Appalachian basin, USA	*Mid-Continental rift, KA, USA (Coveney et al., 198)7*		Bourakebougou, Mali	*"Orange Hydrogen" concepts (Osselin, et al., 2022)*	
Source	Lithology	Organic mudstone			Mantle rock; Greenstones; BIFs	Mantle rock	Greenstones (e.g., Ophioloites; Basalts; Ultra-mafics; Peridotites); Banded Iron Formations (BIFs)		
	Component	Organic material			Fe-hydrides; Fe-rich minerals	Fe-hydrides	Fe-rich minerals (olivine; Fe-hydrides)		
	Anthropogenic Input	-			-			Thermal (steam) or chemical (water)	
	Generation Mechanism(s)	Thermal maturation			Active/ongoing degassing or serpentinization	Active/ongoing degassing	Active/ongoing serpentinization	Induced serpentinization	
	Generation Timeframe	Geologic-scale				Project-scale			
Migration	Pathway(s)	Open discontinuities; dipping porous permeable rock		-	Project-scale-effective fractures; faults; discrete boundaries	Deep-seated paths (faults; kimberlite boundaries) to shallower discreet boundaries	Fractures; faults; discrete boundaries	Project-scale-effective fractures; faults; discrete boundaries	-
	Mechanism(s)/Drive	Advection: buoyancy		-	Advection: gas phase - buoyancy; in solution - pressure gradients				-
Reservoir	Lithology	Porous permeable siliciclastics and carbonates		fractured/propped (otherwise impermeable) source rock	Migration Pathway rock	Porous siliciclastics and carbonates			*Possibly fractured/propped* source rock
	Production Drive	Primary (overpressure)	Secondary (anthropogenic)	Primary (overpressure) after physical stimulation	Primary (overpressure)			Primary (overpressure) after thermo-chemical stimulation of source	
	Anthropogenic Input	-	Chemical (CO_2); Thermal (steam); Physical (waterflood)	Physical (hydraulic fractures and proppant)	-				*Possibly physical (hydraulic fractures and proppant)*; Thermal (steam) or chemical (water)
	Project-scale timeframe Loss Mechanism(s)	(Biotic) biogenic consumption		Physical (containment-breaking hydraulic fractures)	Physical (advection along migration pathway)	Physical (advection or diffusion through seals); Biotic (biogenic consumption); Chemical (oxidation)			
Containment	Seal Lithology	Low-permeability lithologies (e.g., mudstones and evaporites)		-	-	Low-permeability lithologies (e.g., mudstones; evaporites; igneous intrusions; volcaniclastics)			
	Trap Geometry	Structural closure of seal and/or trapping elements (domes; anticlines; faults); stratigraphic pinchouts; permeability pinchouts (e.g., secondary diagenetic cements)		-	-	Structural closure of seal and/or trapping elements (domes; anticlines; faults); stratigraphic pinchouts; permeability pinchouts (e.g., secondary diagenetic cements)			-
	Containment timeframe	Geologic-scale			-	Project-scale (containment rate must exceed combined rates of production and loss)			
Extraction Project	Project-Scale Renewability	Non-renewable hydrocarbons; non-renewable inputs			Renewable hydrogen			Renewable hydrogen; non-renewable anthropogenic inputs	
	Infrastructural Needs	Production well	Injection well; Production well; Ongoing supply of reservoir input	Production well; One-time hydraulic fracture stimulation	Production Well			Injection well; Production well; Ongoing supply of source input	Injection well; Production well; Ongoing supply of reservoir input; *Possibly one-time hydraulic fracture stimulation*

Potential H_2 sites in US for future production



Conclusions

- H_2 demand + C footprint ➔ natural H_2..!!
- Global in-place H_2 reserves: from thousands to billions of megatons. Over 100 field discoveries with H2 detected in concentration over 10% in volume.
- AI-assisted + Geo-data driven tools ➔ identify potential H_2 sites..
  - Hydrogen vs. Petroleum system ➔ similar, opportunities to applying the existing knowledge for future H_2 production.
- In North America, favorable geological settings for potential natural H_2 production includes midcontinent rift system underlying parts of the Upper Midwest and Great Plains, Precambrian rocks underlying Atlantic coastal plain, west coastal ophiolite complex and geothermal system, and Alaskan subduction zones.

References

· Blay-Roger et al., 2024, "Natural hydrogen in the energy transition: Fundamentals, promise, and enigmas", Renewable and Sustainable Energy Reviews, Elsevier, Vol 189(PA)

· Djerlev, 2008, "The Iron Ranges of Minnesota", Mining History Association 19th Annual Conference, June 12-15, 2008, Chisholm, Minnesota.

· Enverus, 2024, "H2 wells", https://prism.enverus.com/prism/new

· Geulard et al., 2017, "Natural H2 in Kansas: Deep or shallow origin?", Geochemistry, Geophysics, Geosystems 2017, Vol. 18 Issue 5, Pages 1841-1865

· Geymond et al., 2022, "Can Weathering of Banded Iron Formations Generate Natural Hydrogen? Evidence from Australia, Brazil and South Africa", Minerals 2022, Vol. 12 Issue 2 Geymond et al., 2023, "Reassessing the role of magnetite during natural hydrogen generation", Front. Earth Sci., April 2023, Sec. Geochemistry, Vol. 11-2023

· Hand, 2023, "Hidden Hydrogen", Science 2023, Vol. 379, Pages 630-636

· Johnsgard, 1983: "The fracture pattern of north-central Kansas and its relation to hydrogen soil gas anomalies over the Midcontinent Rift System", KGS Open File Report 8-25

· Mann, P. and A. Taira, 2004, Global tectonic significance of the Solomon Islands and Ontong Java Plateau collision zone, Tectonophysics, vol. 389, pp. 137-190, doi:10.1016/j.tecto.2003.10.024. Figure 1.

· Morille et al., 2013, "Geochemistry and geobiology of a present-day serpentinization site in California: The Cedars", Geochimica et Cosmochimica Acta 2013, Vol. 109, Pages 222-240

· NETL, "Basement Faults_NETL PRELIMINARY", 2024

· Truche et al., 2024, "A deep reservoir for hydrogen drives intense degassing in the Bulqize ophiolite", Science 2024, Vol. 383, Issue 6683, Pages 618-621

· USGS, "Map of the iron ranges of the Lake Superior region", ca. 2015 by W.F. Cannon for the USGS, [online]: https://www.mnopedia.org/multimedia/map-iron-ranges-lake-superior-region

· USGS, "Understanding the Mineral Resources of the Midcontinental Rift", January 25, 2018, [online]: https://www.usgs.gov/news/science-snippet/understanding-mineral-resources-midcontinent-rift

· Zgonnik, et al., 2015, "Evidence for natural molecular hydrogen seepage associated with Carolina bays (surficial, ovoid depressions on the Atlantic Coastal Plain, Province of the USA), Prog. Earth Planet. Sci. 2015, Vol. 2 Issue 1

· Zgonnik, 2020, "The Occurrence and geoscience of natural H2: A comprehensive review", Earth-Science Reviews, Vol. 203, April 2020, 103140

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