Global progress in natural hydrogen exploration and development and prospects of natural hydrogen resources in China

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Speech outline

1. Hydrogen energy, artificial hydrogen production and natural hydrogen
2. Natural hydrogen formation, accumulation and distribution
3. Progress in natural hydrogen exploration and development abroad
4. Exploration prospects of natural hydrogen resources in China

Hydrogen energy is an important choice to achieve the strategic goal of green low-carbon energy transformation and carbon neutrality

- Hydrogen is a kind of zero-carbon, efficient, renewable and clean energy with wide sources, high calorific value, no pollution, wide use and various forms.
- Hydrogen energy is an important component of the clean energy development strategy, is an important carrier to achieve green low-carbon transformation with energy terminals, and hydrogen energy industry is also a strategic emerging industry.

Global Hydrogen National Strategy

Nation	Development strategy	Year
Japan	《Hydrogen Basic Strategy》	2017
Australia	《National Hydrogen energy Strategy》	2019
Germany	《National Hydrogen energy Strategy》	2020
Korea	《Basic plan for hydrogen economy development》	2021
China	《Medium and Long-Term Plan for the Development of Hydrogen Energy Industry (2021-2035)》	2022
America	《U.S. National Clean Hydrogen Strategy and Roadmap》	2023
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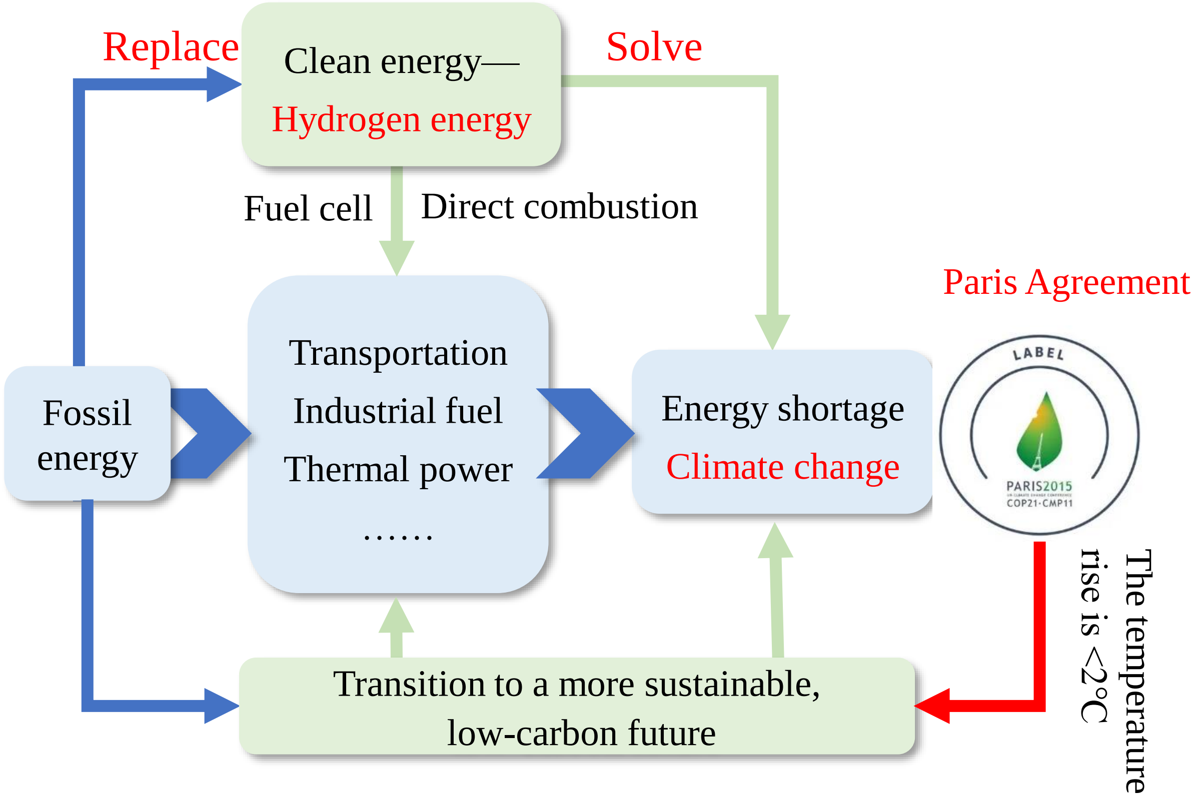
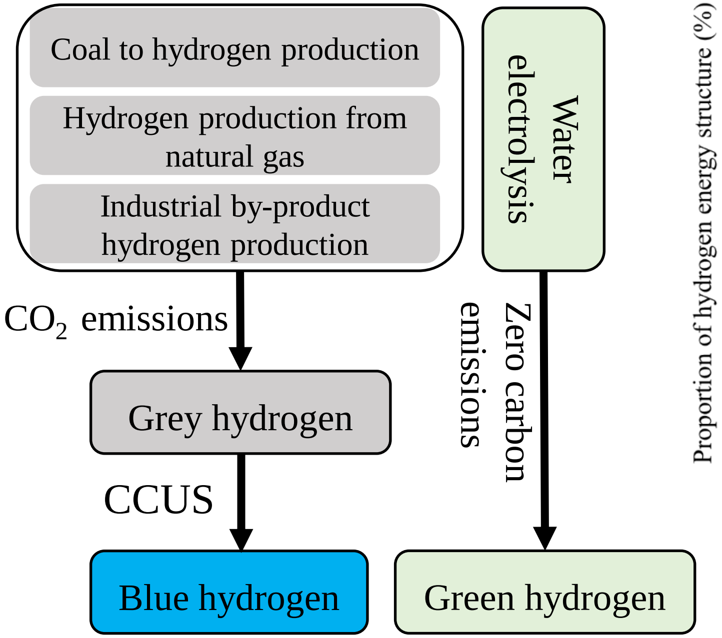


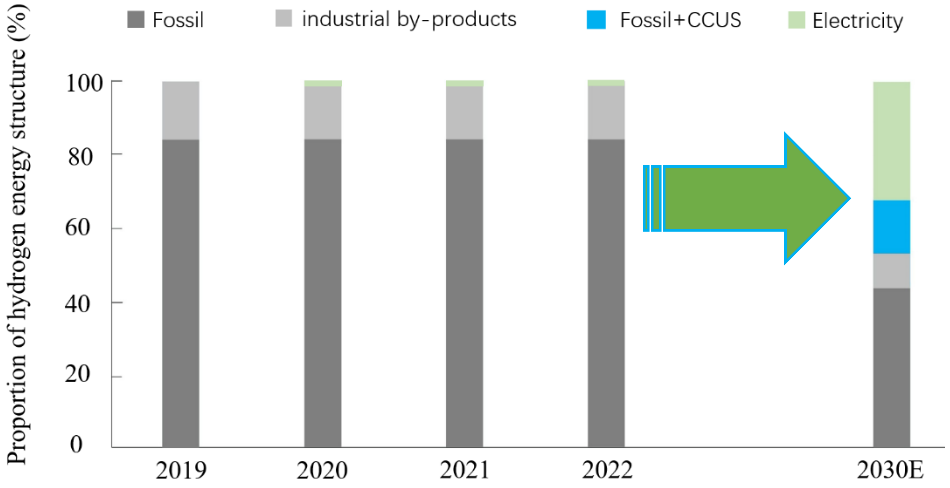
The strategic positioning of hydrogen energy in clean energy development strategy

At present, hydrogen energy mainly comes from artificial hydrogen production, facing the "three high" challenge

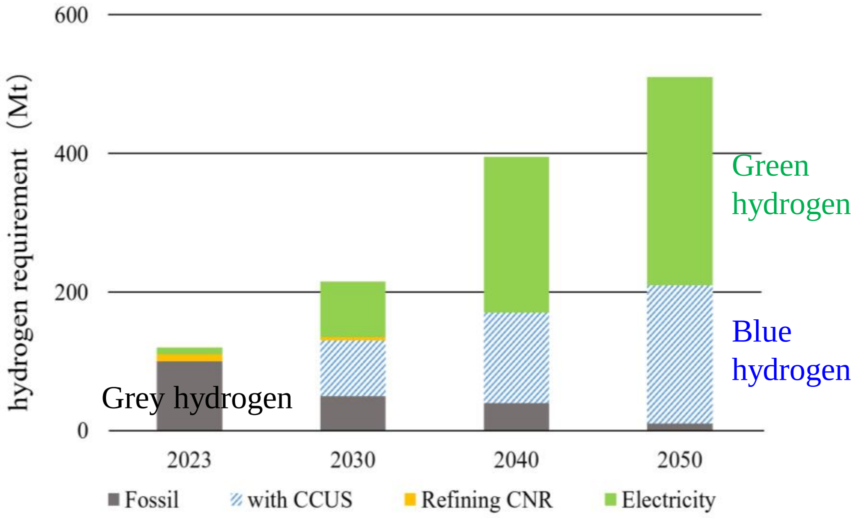
- Global hydrogen production mainly comes from fossil fuel hydrogen production, accounting for more than 80%, and low-carbon emissions such as electrolytic water hydrogen production account for only 0.7% (IEA, 2021).
- The transformation of gray hydrogen to blue hydrogen and green hydrogen faces the triple challenge of "high technology, high cost and high pollution", and it is a long way to go to ensure the market demand for hydrogen energy multiple applications.

Main paths and environmental effects of hydrogen production





Changes in Global Hydrogen Supply Modes



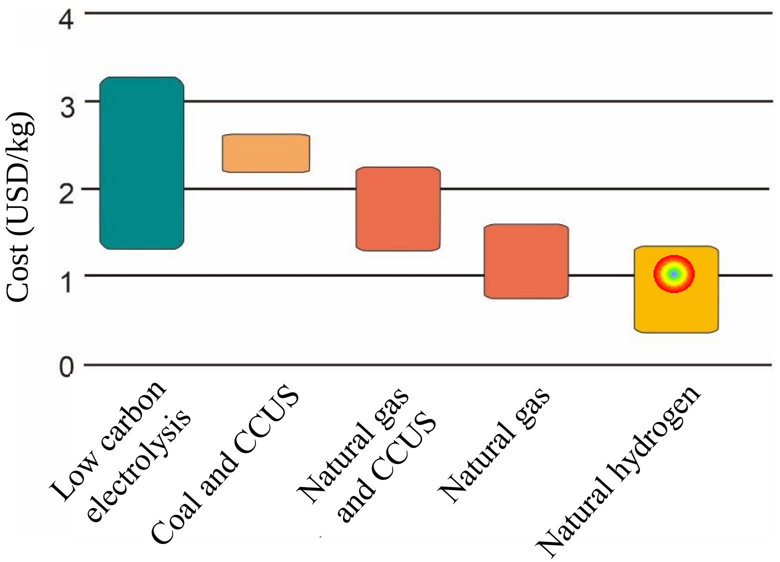
Estimated global hydrogen energy demand

(Source: International Energy Agency IEA, Global Hydrogen Review (2024))

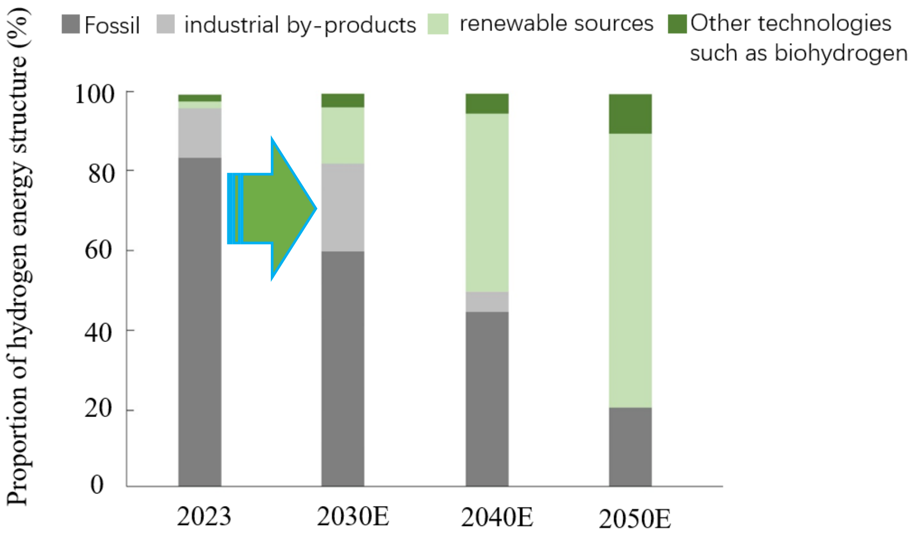
In the future, hydrogen energy may mainly come from natural hydrogen, and the strategic substitution advantage is becoming more prominent

- Natural hydrogen (geological hydrogen, white hydrogen, gold hydrogen) is a molecular hydrogen generated in nature through geological processes.
- Natural hydrogen is an emerging strategic resource with zero carbon, renewable and lower production cost advantages.
- Underground search for natural hydrogen is an important path to achieve large-scale and low-cost hydrogen energy development and clean energy transformation.

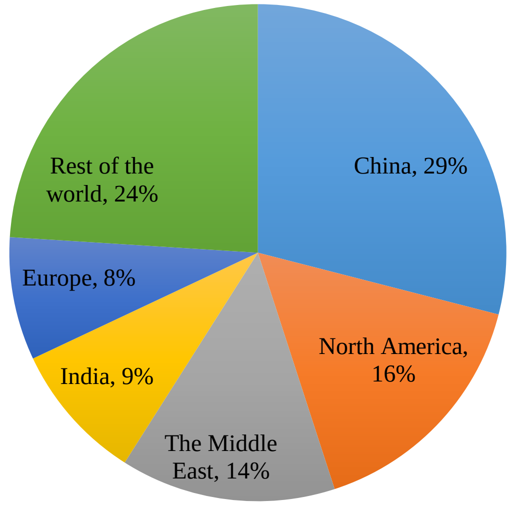
✓China's energy endowment: rich in coal, poor in oil and less gas, difficult to change in the short term



Estimated global hydrogen production costs



China's hydrogen supply structure changes



Global hydrogen energy use in 2023

Source: International Energy Agency IEA, Global Hydrogen Review (2024), China Hydrogen Development Report, 2023

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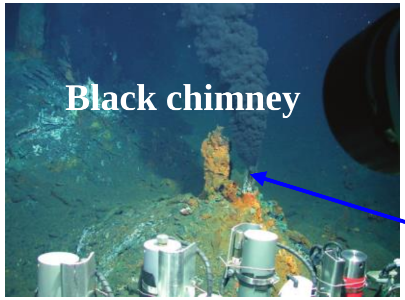
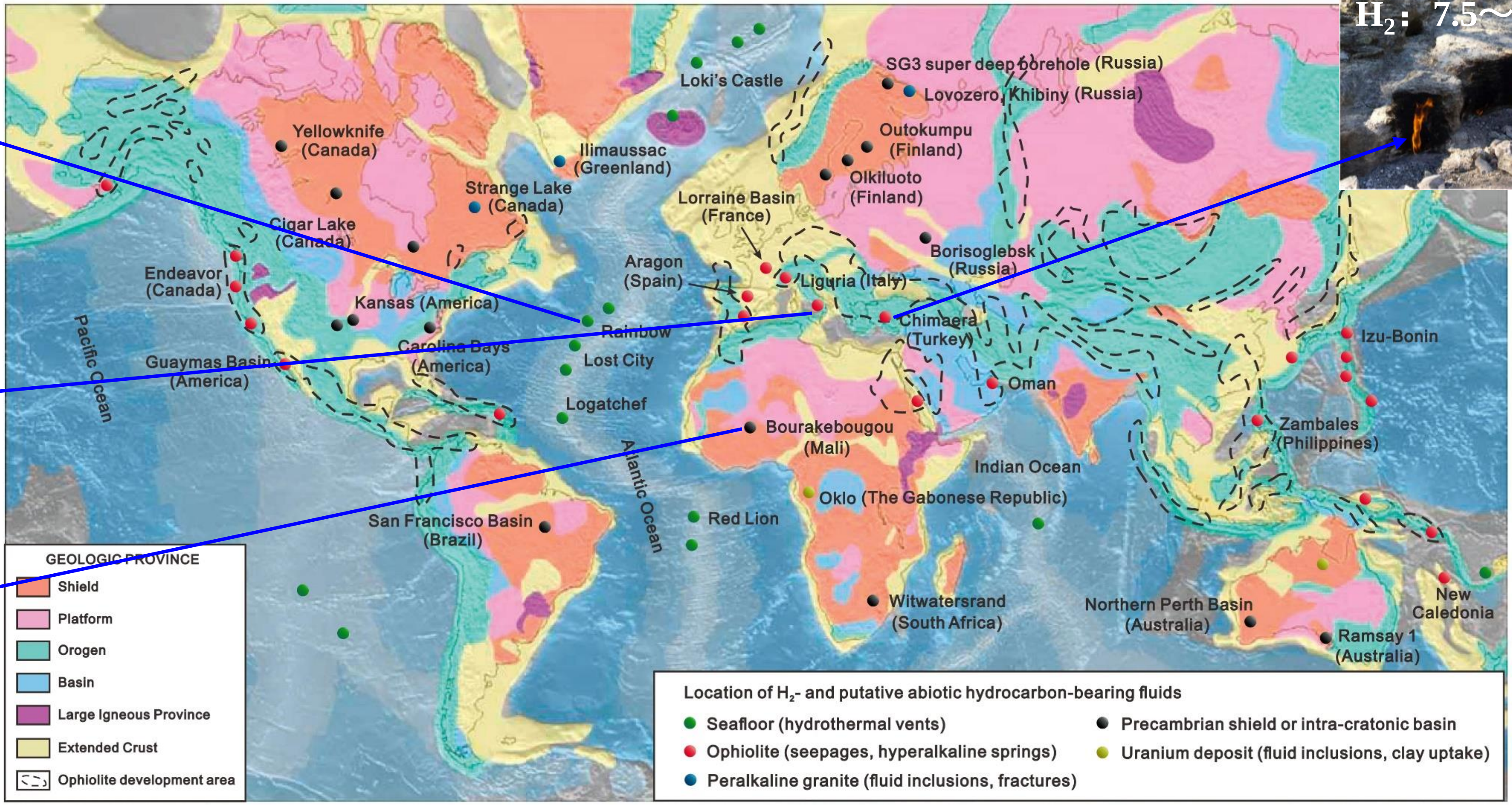
Natural hydrogen is widely distributed in many geological environments





Distribution map of natural hydrogen anomalies in different geological tectonic environments around the world

（Briere et al., 2017；Blay et al., 2024；Laurent et al., 2020；Dou et al., 2024；Xiong et al., 2024）

Natural hydrogen has a variety of sources: biological origin, non-biological origin

- Hydrogen (H_2) is a single substance formed by hydrogen element, molecular weight is 2.01588, density is 0.089g/L, colorless and odorless at room temperature and pressure, easy to burn, difficult to dissolve in water, is the lightest gas in nature.

Hydrogenase: H_2 （$\leftrightarrows H^+ + H^-$） $\leftrightarrows 2H^+ + 2e^-$

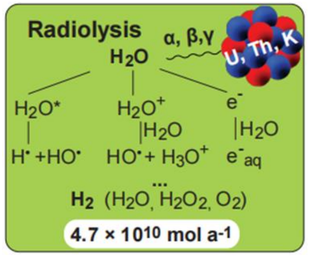
Azotase: $N_2 + 8H^+ + 8e^- \longrightarrow 2NH_3 + H_2$

$RCH_2CH_2CH_3 + 4H_2O + \longrightarrow R + 2CO_2 + CH_4 + 5H_2$

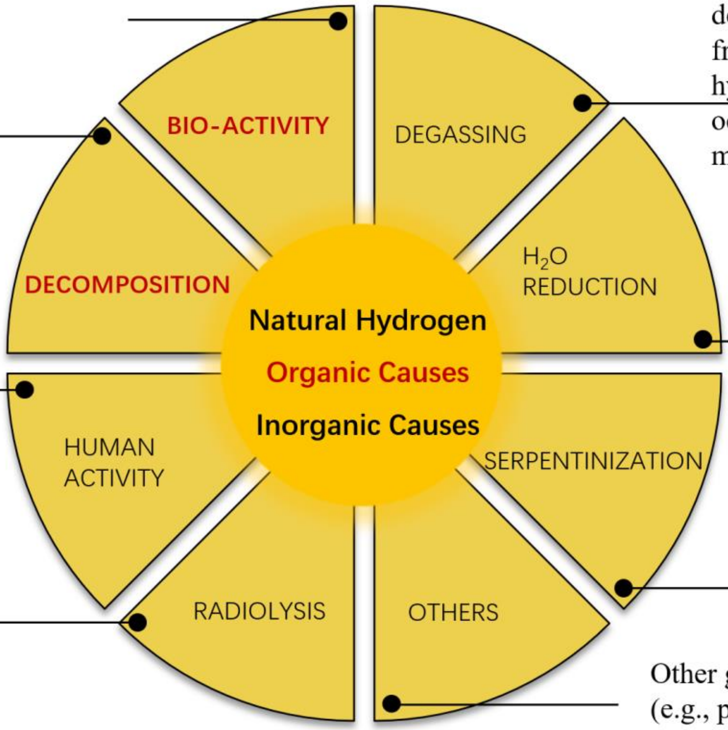
Cerain microorganisms may produce or utilize H_2 (e.g., fermentative and redox processes)

The decomposition of organic matter can give rise to the production of H_2, (e.g., hydrogen associated with oil and gas generation)

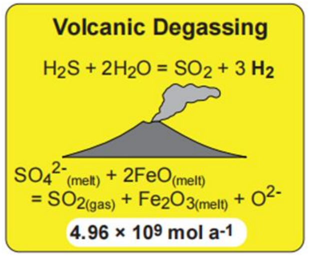
Human activities impact in H_2 production and Earth naturalcycles(e.g., Fe corrosion)



Radioactive decay of heavy metals. (e.g ^{235}U,^{232}Th) can ionize water generating H_2 through highly reactive species such as H· and OH·(e.g., hydrogen production by radiolysis of uranium-rich Craton bedrock)

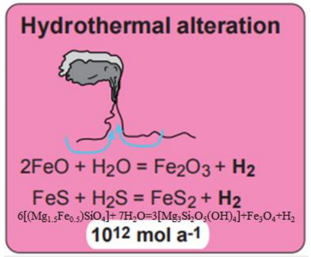


Earth activity may provoke the degassification of deep-seated hydrogen from the core and mantle (e.g., hydrothermal hydrogen injection at mid-ocean ridges, degassing of continental magmas)

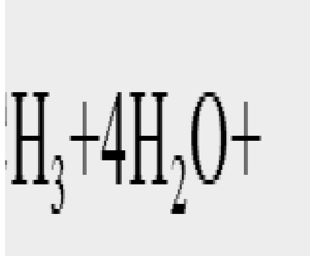


The number of reducing agents capable of reduce water increses with depth(e.g., Mn and Co)

Fe^{2+} rich rocks (e.g., olivine) turn into serpentine and magnetite coupled with eparticularly large production(e.g., hydrogen production from iron-rich ultramafic rocks by aqueous rock reactions)



Other geochemical processes can produce H_2 (e.g., pyritization, hydration of siderite, and PH_3, hydrolysis)



Different hypotheses for the formation of natural hydrogen in nature

（Klein et al., 2020; Zgonnik, 2020; Rubén Blay-Roger, 2024）

The water-rock reaction of iron-rich rock mass is the main source of natural hydrogen

- **Water-rock reaction:** The chemical (hydration) reaction between aqueous solution and rock under geological action is the main process of forming hydrothermal deposits.

- **Basic-ultrabasic serpentinization reaction:** Hydrothermal alteration (hydration) reaction occurs in magnesium-rich ferric olivine and pyroxene, which transforms into serpentine and produces hydrogen:

$$\underbrace{Fe_2SiO_4 + 5Mg_2SiO_4}_{\text{OLIVINE}} + 9H_2O \xrightarrow{\text{HYDRATION}} \underbrace{3Mg_3Si_2O_5(OH)_4}_{\text{SERPENTINE}} + \underbrace{Mg(OH)_2}_{\text{BRUCITE}} + 2Fe(OH)_2$$

$$6Fe(OH)_2 \xrightarrow{\text{OXIDATION}} \underbrace{2Fe_3O_4}_{\text{MAGNETITE}} + 4H_2O + \mathbf{2H_2}$$

Global ophiolite belt: The annual flux of natural hydrogen is (0.18～0.36) $\times 10^{12}$g (Zgonnik, 2020; Hand, 2023)

- **Water-rock reaction of alkaline granite:** Minerals rich in Fe^{2+} undergo hydration reactions, such as hornblende containing Fe^{2+}.

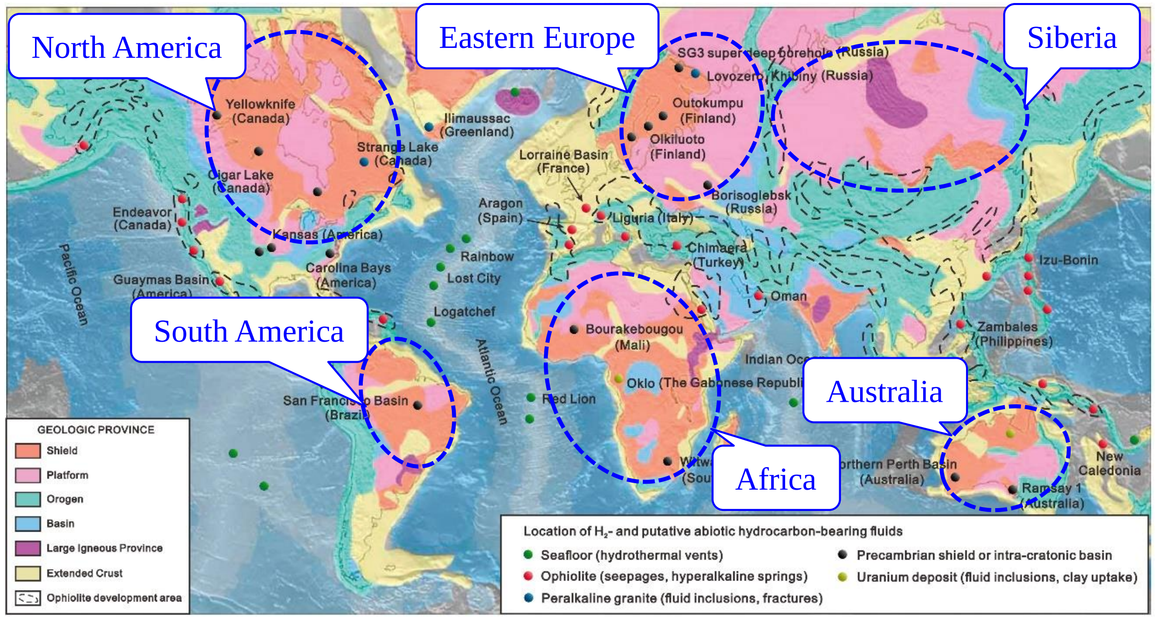
$$Fe^{2+}O+H_2O \rightarrow Fe(OH)_2 \rightarrow Fe^{3+}O_3+\mathbf{H_2}\uparrow$$

(Klein et al. ,2020; Zgonnik, 2020; Laurent et al., 2020; Rubén Blay-Roger, 2024; Dou et al., 2024; Xiong et al., 2024)

- **Cratonic basement:** It is mainly composed of Precambrian granites and greenstone belts (basic-ultrabasic rocks).

$$2Fe^{2+}+H_2O \rightarrow Fe^{3+}+\mathbf{H_2}\uparrow$$

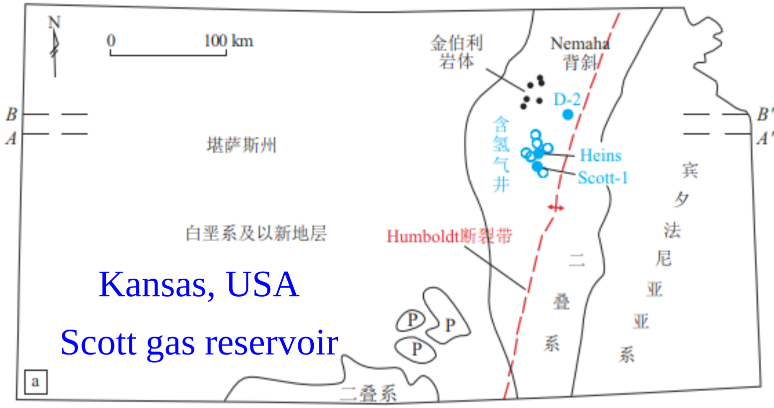
Precambrian craton: 5.54×10^{14}g of hydrogen is formed every year (Sherwood et al., 2014)

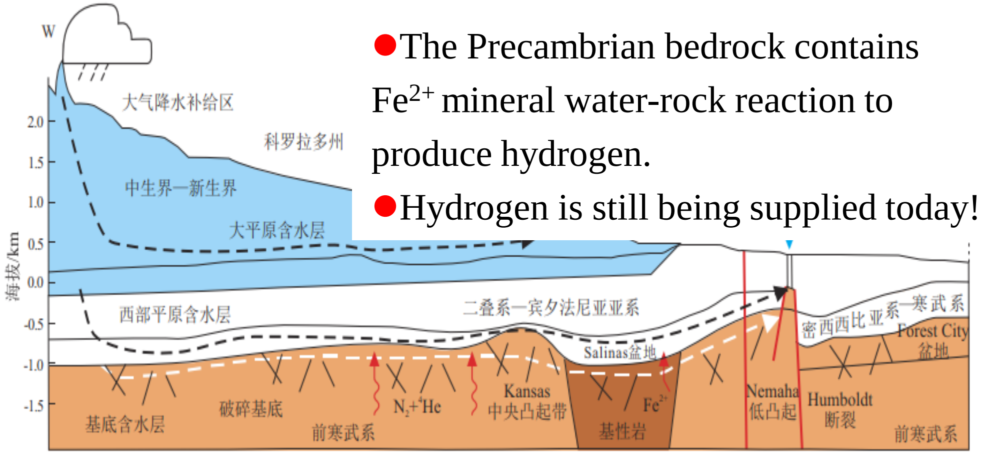


Global craton, ophiolite zone and natural hydrogen anomaly distribution map

Serpentinization mechanism is the main way of sustainable and large-scale development and utilization of natural hydrogen

- **Serpentinization process:** Under medium and low temperature conditions, the iron-rich rock and its infiltrated water are undergoing water-rock reaction, and continue to produce hydrogen.
- **Influencing factor:** Temperature, pressure, rock composition（SiO_2、Ni^{2+}）

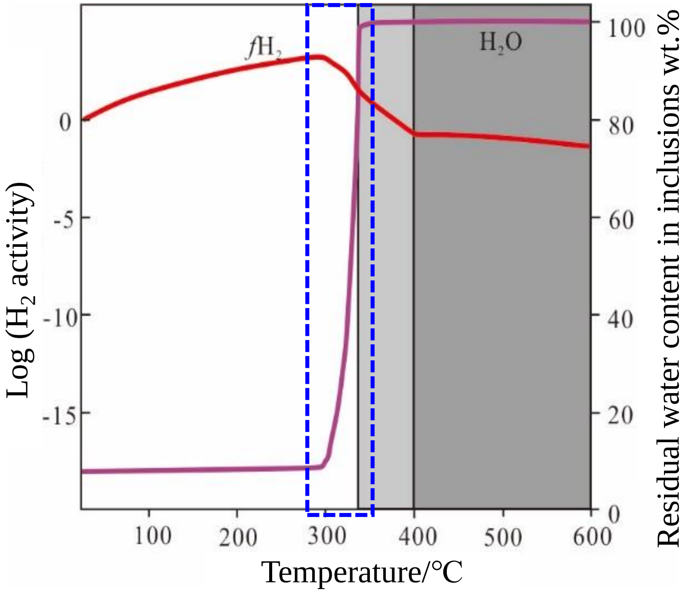




●The Precambrian bedrock contains Fe^{2+} mineral water-rock reaction to produce hydrogen.

●Hydrogen is still being supplied today!

Hydrogen rich reservoir formation process（Guelard et al., 2017）



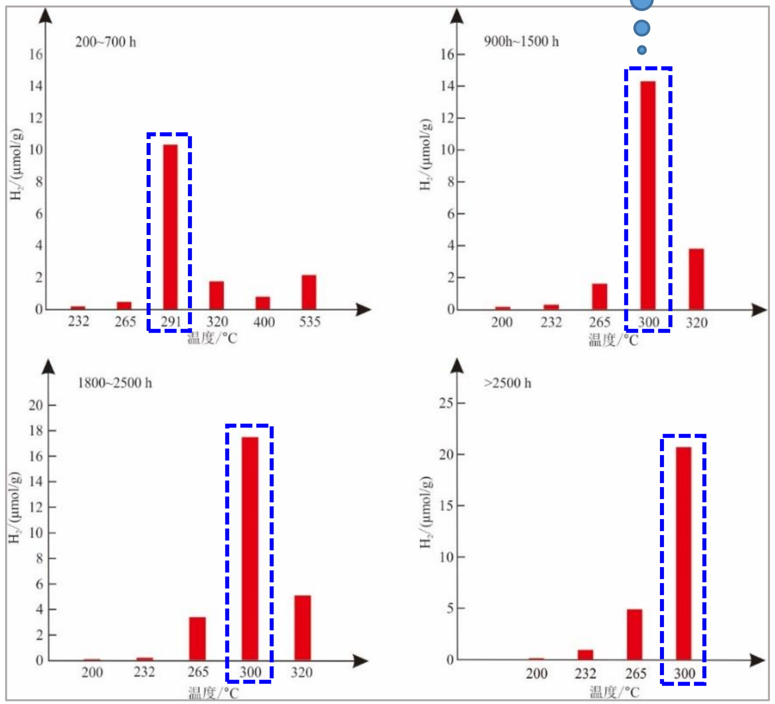
H_2 production per gram of olivine at different temperatures

(McCollom et al., 2016; Huang et al., 2015)

Effect of temperature on serpentinization reaction and H_2 generation

(Klein et al., 2019)

300°C±

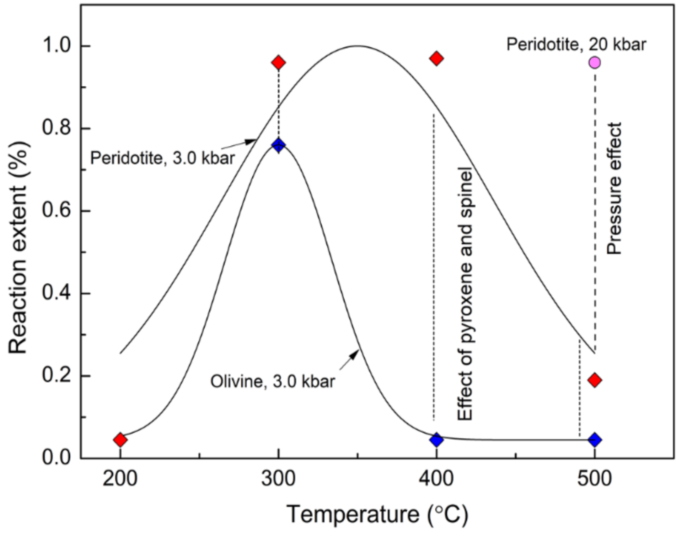


Serpentinization is the main way of natural hydrogen renewable and sustainable development and utilization

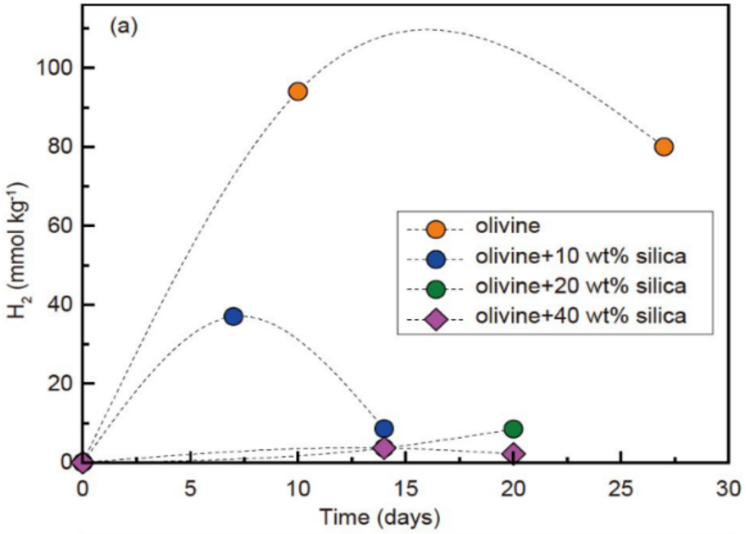
- **Influencing factor:** Temperature, pressure, rock composition （SiO_2、Ni^{2+}）

- Increasing pressure promotes serpentinization of peridotite

- Ultramafic rocks can produce large amounts of H_2 in a key property: low SiO_2 content

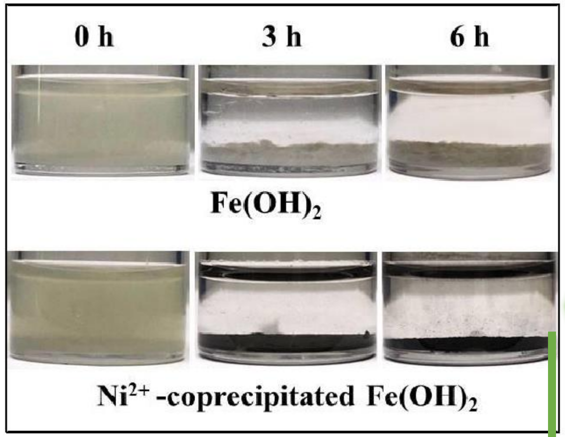


Effect of pressure on serpentinization rate of olivine/peridotite(Huang et al., 2020)

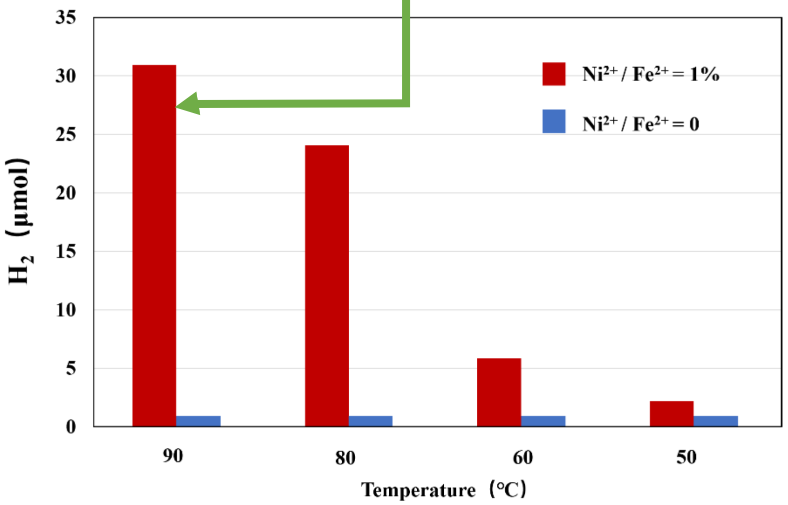


Effect of SiO_2 on H_2 formation from serpentine (Frost &Beard，2007; Huang et al., 2024)

Photos of $Fe(OH)_2$ suspension co-precipitated by $Fe(OH)_2$ and Ni^{2+} at 90℃ for different reaction times



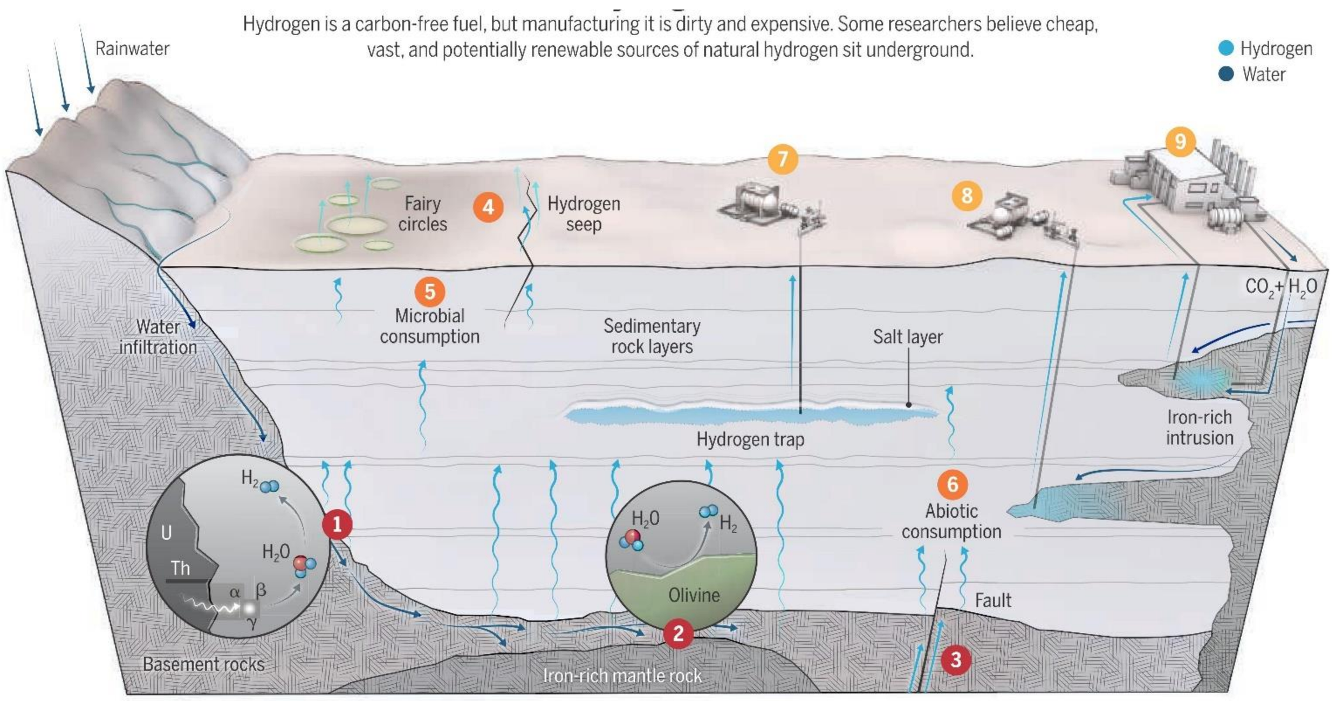
Artificial underground water injection + low temperature + catalytic stimulation "continuous hydrogen production" provides new hope



Influence of Ni on H_2 formation from serpentine (Song et al., 2022)

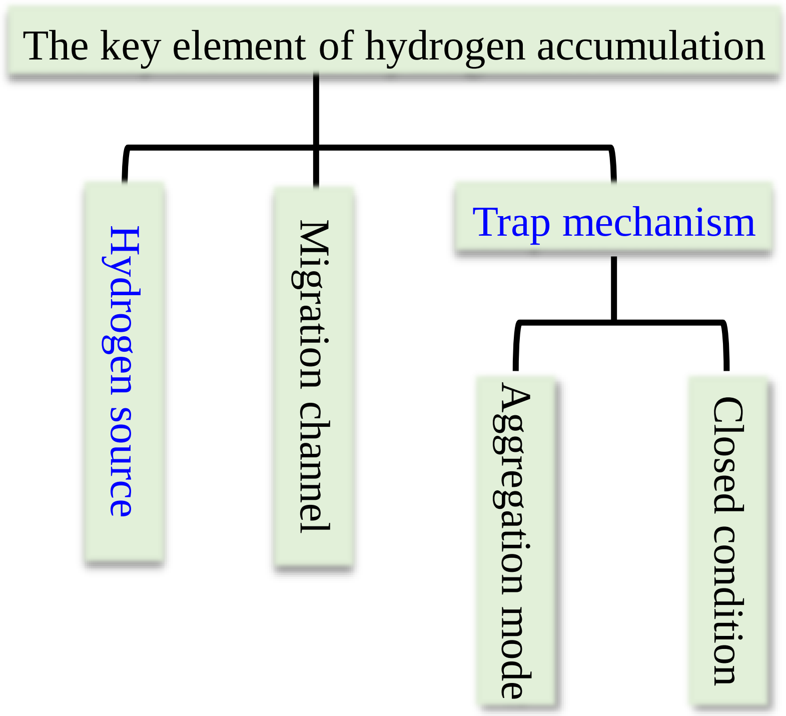
Natural hydrogen accumulates on a large scale in a special geological environment and can be exploited and utilized

- Accumulation characteristics: ongoing generation → continuous supply → instantaneous, dynamic gathering and dispersing
- Scale aggregation key: Quantity supplied > quantity lost
- Migration path: The hydrogen source body is connected to the fracture (fracture) system, and the water source + hydrogen source is continuously supplied
- Preservation conditions: Reductive environment + strong closure (aquifers - dense lithology (e.g. salt rock, argillaceous rock, diabase)



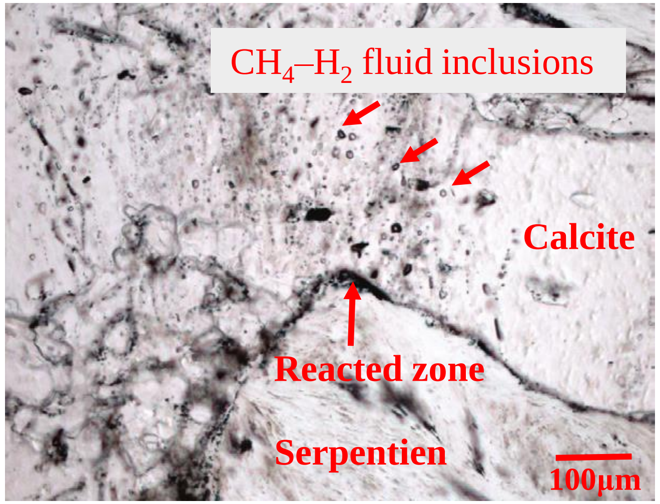
Model diagram of underground hydrogen plant (Hand Erick, 2023)

Hydrogen system ≠ oil-gas system

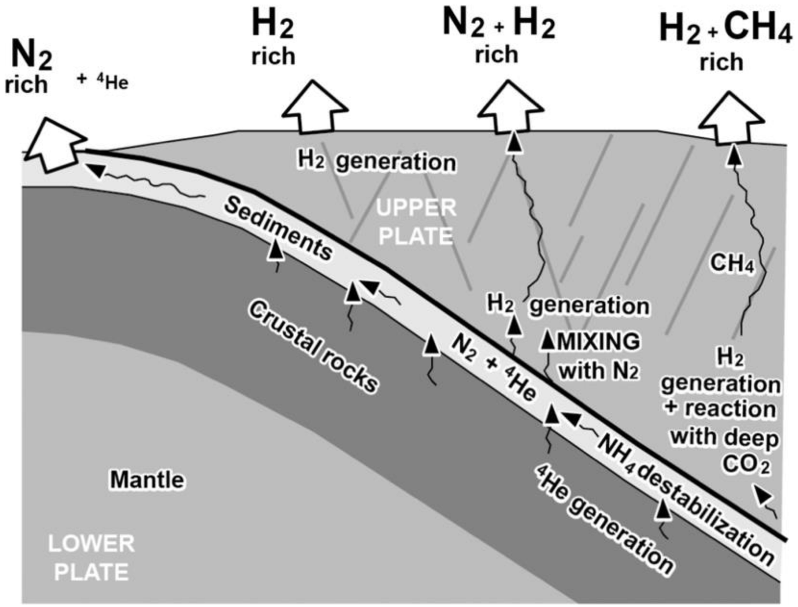


Natural hydrogen accumulates on a large scale in a special geological environment and can be exploited and utilized

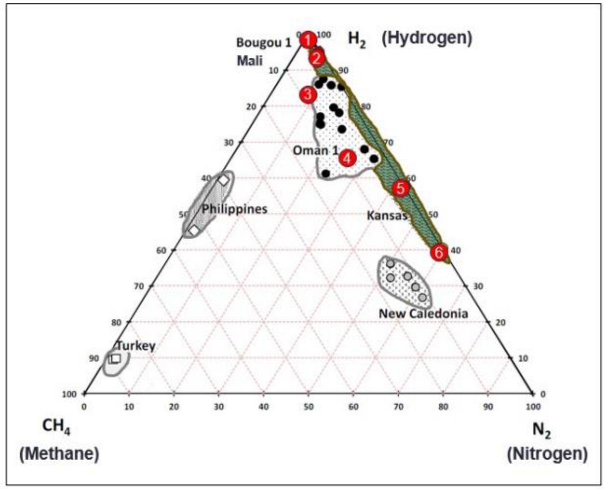
- **Occurrence state:** free state, adsorption state, dissolved state, inclusion
- **Associated components:** CH_4、N_2、He、oil-gas associated gas



Micrograph of CH_4-H_2 fluid inclusions encased in serpentinized calcite crystals in the Lanzo peridotite (Italian Alps). Thin section, plane polarized light.(Laurent et al., 2020)



H_2-CH_4-N_2gas mixtures from various sources (Vacquand et al., 2018)



#	Well Name	Location	Permit Holder
1	Bougou-1	Mali, Africa	Hydroma
2	Sue Duroche-2	Kansas, USA	Hyterra
3	Minlaton Bore (Ramsay-1),	South Australia	Gold Hydrogen
4	American Beach Bore	South Australia	Gold Hydrogen
5	Scott-1	Kansas, USA	HyTerra
6	Heins-1	Kansas, USA	*unheld*

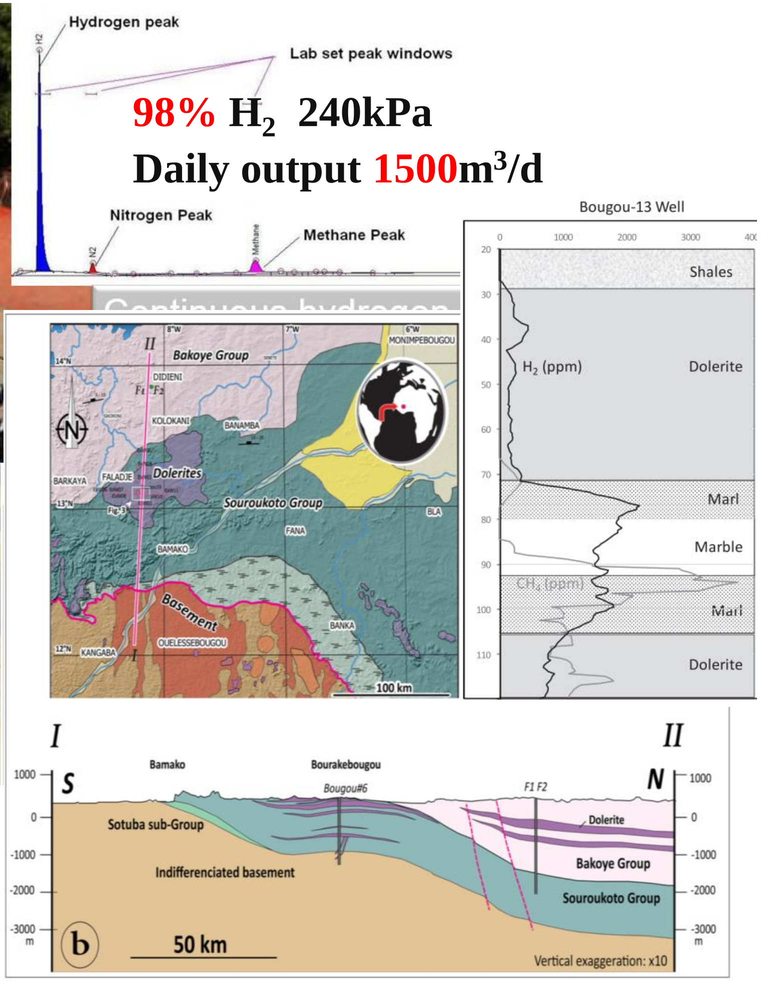
Ternary diagram of the relative ratios of H_2, CH_2, and N_2 for various gas samples containing natural hydrogen (Vacquand et al., 2018; Newell et al., 2007； Guélard et al., 2017; Rubén Blay-Roger, 2024)

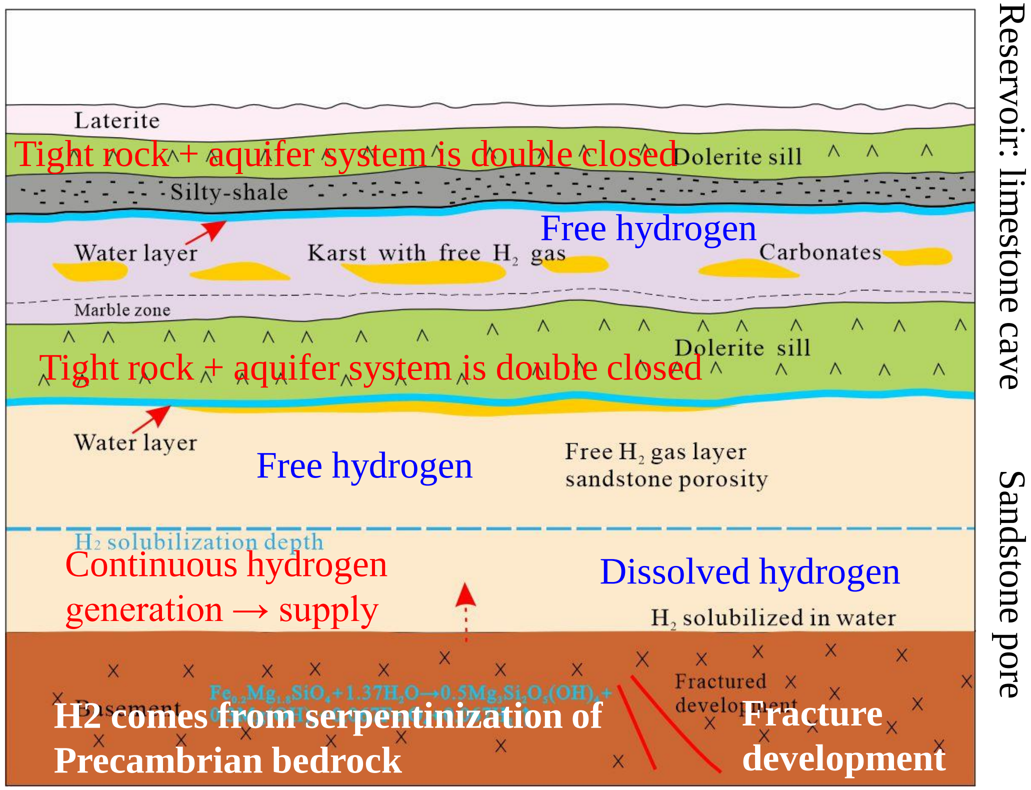
Bourakébougou natural hydrogen reservoir in Taoudenni Basin, African Craton

- In 2011, PETROMA of Canada deployed the Gazbongou-1 well in Mali's Taoudenni Basin, where diabase bedrock and sedimentary rocks produced H_2 with up to 98% H_2 content, along with trace amounts of CH_4 and N_2 (about 1%), the world's only natural hydrogen gas reservoir in production.

H_2 production from Gazbongou-1 well

(Briere et al., 2017)



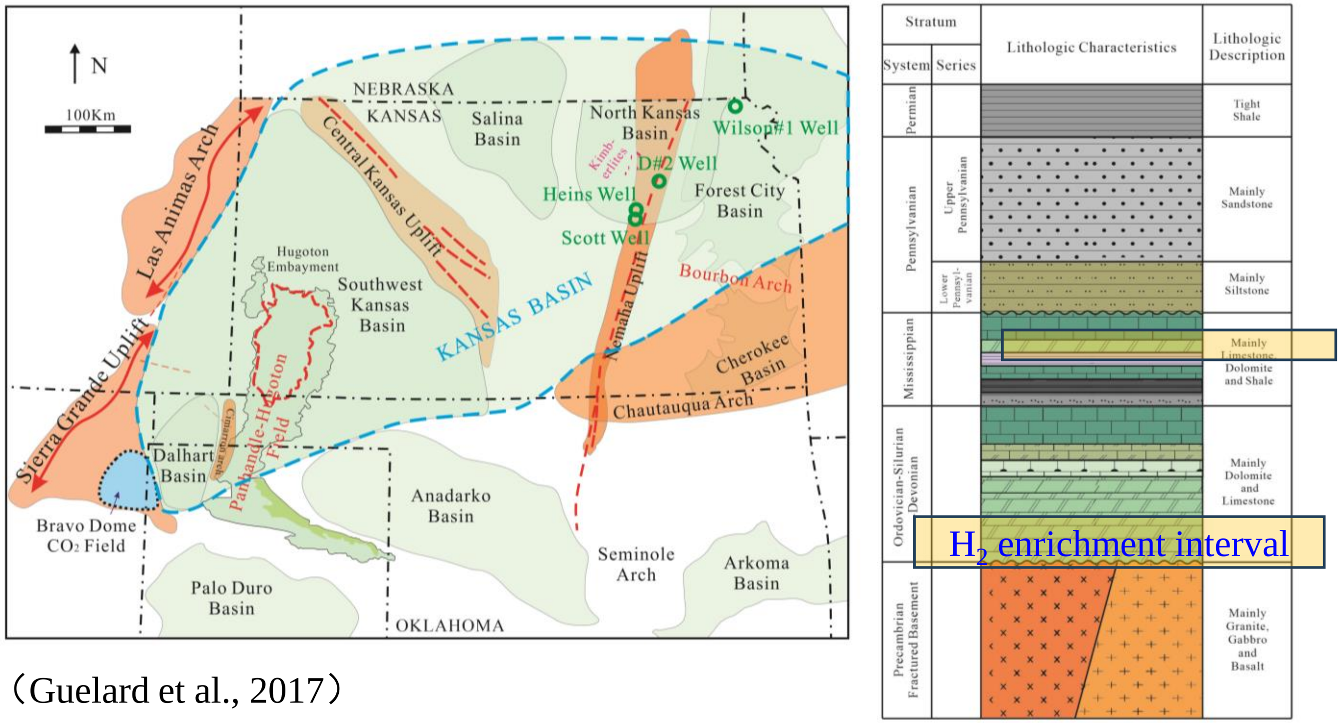


Geological model map of H_2 gas reservoir drilled in Mali

Scott hydrogen reservoir, Kansas Basin, Rift Valley, Central continental United States

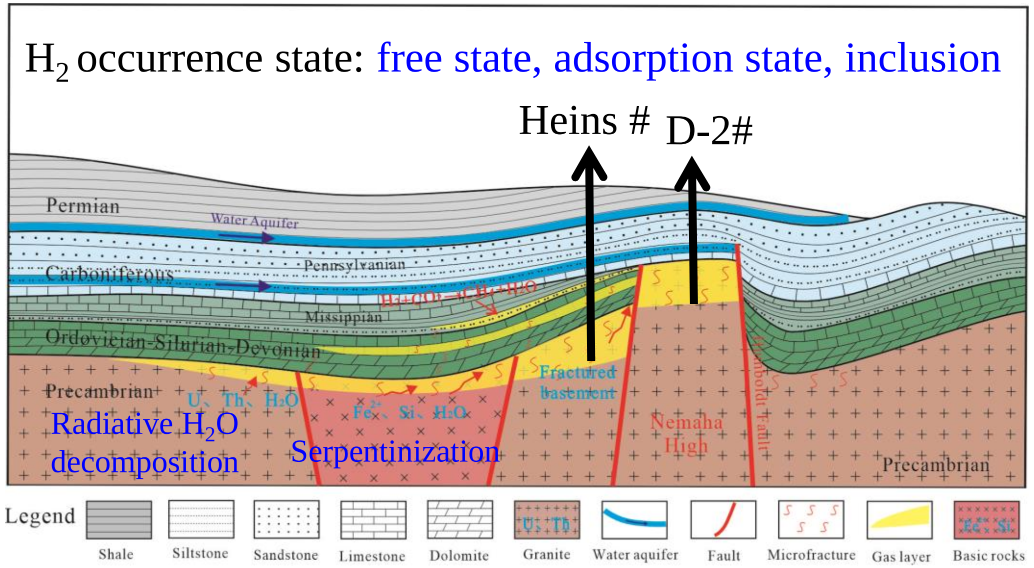
- In the 1980s, it was found that the H_2 gas reservoir rich in H_2 drilling, H_2 content of more than 50%, has been continuously exploited for nearly 40 years, H_2 content of 24-43%, cratonic basement igneous rock H_2, containing N_2, CH_4, daily production of 30~80m^3/d.
- In 2008, the H_2 content of D2# Precambrian basement was 91.8%.

- H_2 enrichment is continuously supplied by near source
- The quantity supplied is significantly greater than the quantity lost
- Tight rock and aquifer are sealed



(Guelard et al., 2017)

Regional location and comprehensive lithology column map of the Kansas Basin



The formation process of hydrogen rich reservoir, which coexists with N_2

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The global search for natural hydrogen sources is hot, and it has been rated as the top ten scientific breakthroughs in 2023 by Science magazine

Before 2011

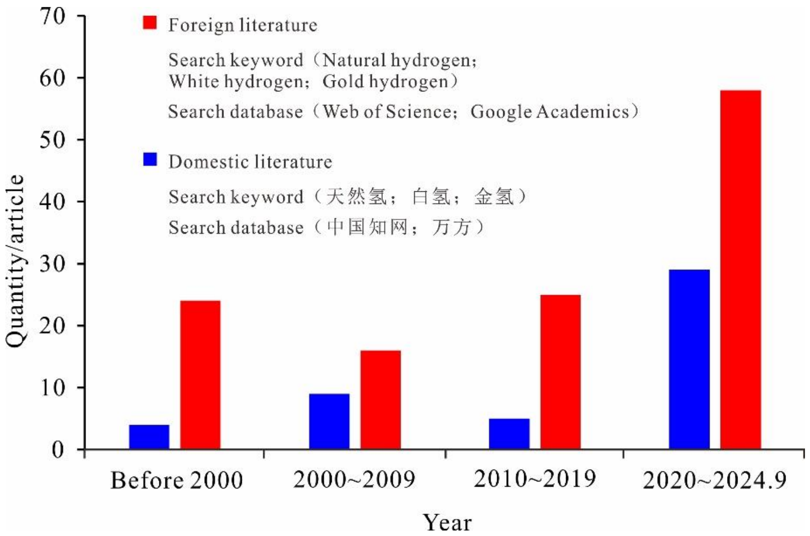
- **In 1888, Mendeleev first discovered hydrogen in a Ukrainian coal mine**
- **In the 1960s and 1970s, Marine surveys found that black chimneys were rich in hydrogen**
- **In the 1980s, Wells with high hydrogen content were found in the Kansas Basin of the United States**
- **At the beginning of the 21st century, hydrologic survey in the Malibu gas field found leakage of high purity hydrogen**

2012～2018

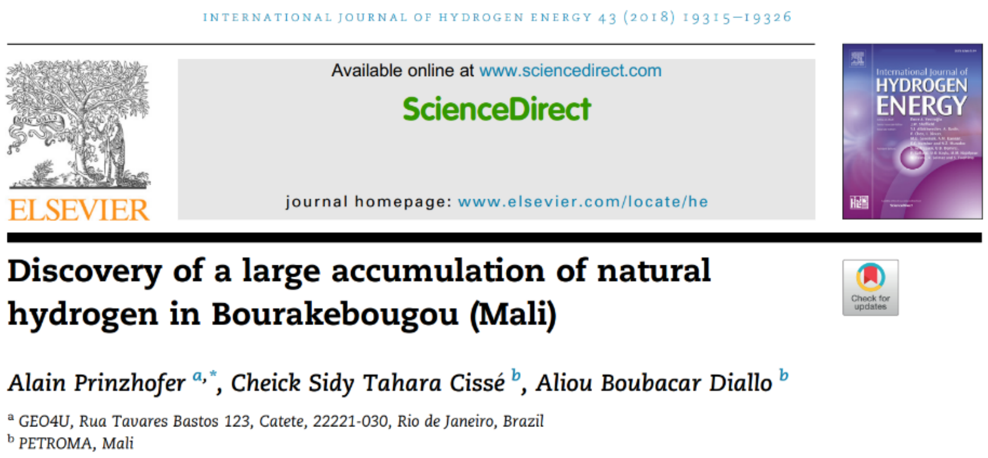
- **Natural hydrogen exploration in Malibukbugu gas field**
- **Russia and Brazil investigate hydrogen anomalies on the surface of the "fairy Circle"**

2018 to date

- **Commercial extraction of natural hydrogen in Mali**
- **Natural hydrogen deposits were found in the Lorraine Basin of France**
- **Natural hydrogen reservoirs found in the Spanish Pyrenees**
- **America is exploring for natural hydrogen in the Kansas Basin**
- **High purity H_2 was found in the Ramsey 1 exploration well in Australia**



Status of published natural hydrogen papers



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Discovery of a large accumulation of natural hydrogen in Bourakebougou (Mali)

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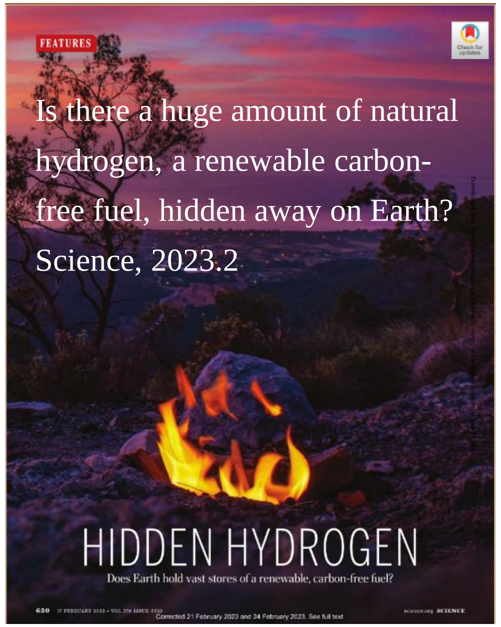
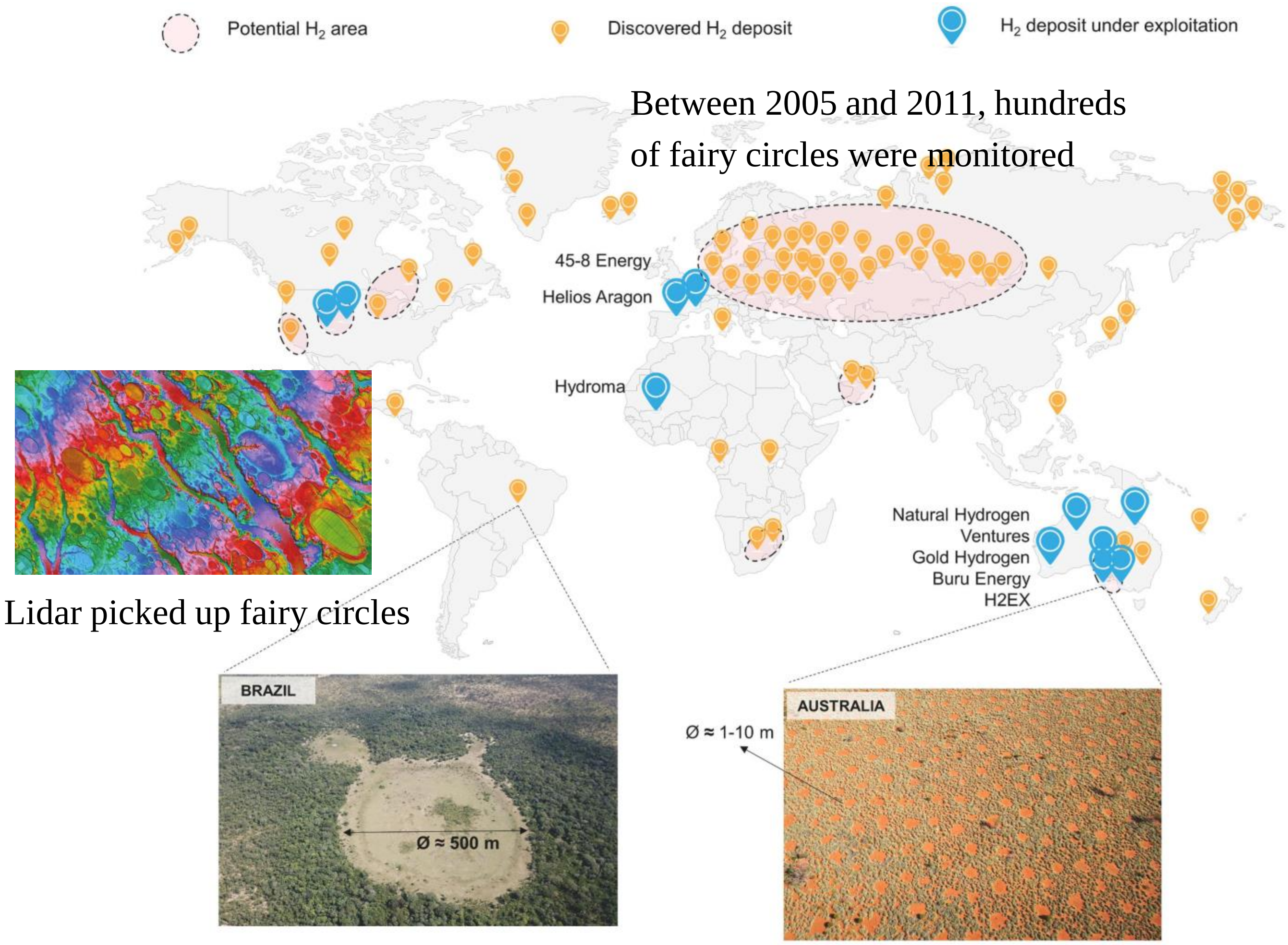
[b] PETROMA, Mali



Countries around the world are accelerating the layout of natural hydrogen exploration and development, and substantial progress has been made



Between 2005 and 2011, hundreds of fairy circles were monitored

Lidar picked up fairy circles

Natural hydrogen deposits and fairy circles are known worldwide

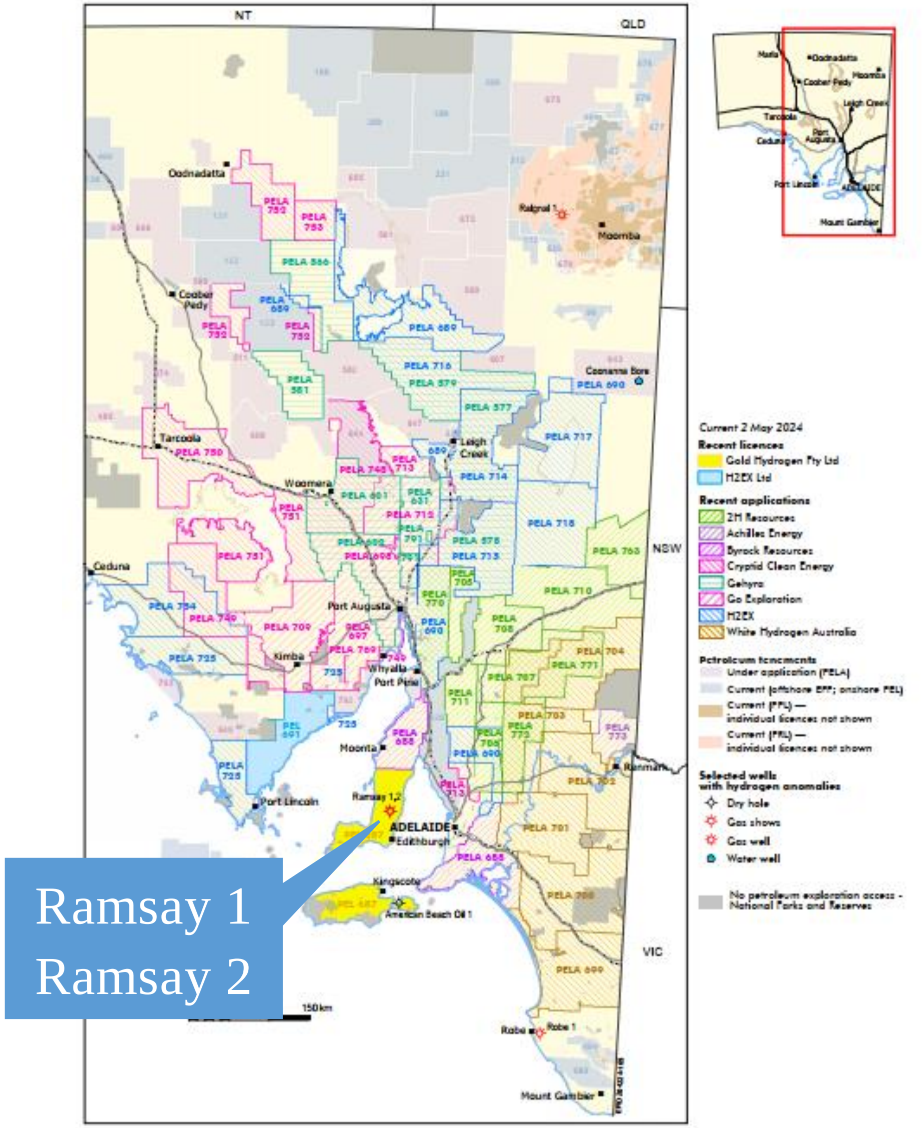
(Prinzhofer et al. ,2019; Getzin et al., 2021; Rubén Blay-Roger, 2024)

- Global ophiolite belt：
  - In Oman, the surface of the ophiolite belt shows hydrogen anomalies in many places, and most of the H_2 content is more than 60%, the highest is 97.0 ~ 99.0%（Neal & Stanger, 1983; Vacquand et al., 2018）
- Precambrian craton：
  - In Australia, Ramsay 1 and Ramsay 1 Wells both achieved high levels of H_2, with 73.3% in the first test and 95.8% in the second (Gold Hydrogen, 2024)
  - In the United States, the natural gas in the Kansas Basin generally contains H_2, up to 91.8%（Newell et al., 2007；Guélard et al., 2017）
  - In South Africa, the content of H_2 in Witwa-tersrand Basin ranges from 0.40 to 13%, with a maximum of 30.4%（Sherwood et al., 2007， 2014）
- Old coal, iron, uranium deposits
  - In May 2023, France, while examining the biogas risk in abandoned mines in the Lorraine Basin, FDE discovered a large deposit of natural hydrogen with an estimated reserves of 46 million tons (Hand, 2023)

Countries around the world are accelerating the layout of natural hydrogen exploration and development, and substantial progress has been made

Some startup exploration around the world

Nation	Company name	Exploration area
America	Cemvita	Permian Basin, West Texas
	Desert Mountain Energy	Arizona
	Eden Geopower	Oman Samail ophiolite
	Koloma	Nebraska
Australia	Mosman Oil and Gas	The Amadeus Basin
	Gold Hydrogen	Yorke Peninsula
	H2EX	Eyre Peninsula, South Australia
	2H Resources	Adelaide, South Australia
France	45-8 Energy and Storengy	Pyrenees-atlantic Province
	FDE	Lorraine region
	TBH2 Aquitaine	Bearn district, Pyrenees-Atlantic Province
Spain	Helios Aragon	Ebro basin, south Pyrenees
Colombia	Ecopetrol	The Llanos Basin
Brazil	Petrobra、ENGIE and Geo4U	Marica、São Francisco Basin



Map of hydrogen licensing areas and potential mining areas in Australia

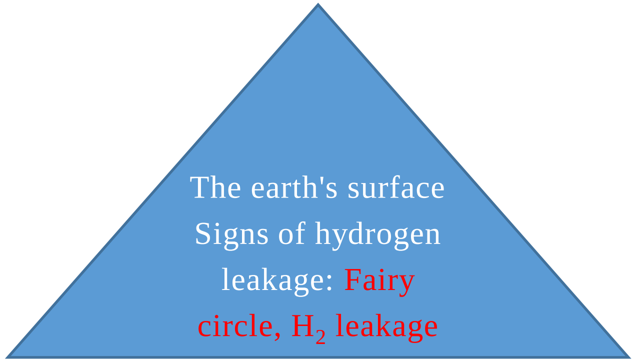
Summary of selected examples of natural hydrogen content exceeding 40% worldwide

Reference	H_2（%）	Region/Country	Geological environment and formation mechanism
Guélard et al. (2017)	91.8	Kansas，America	Precambrian rocks (deep source hydrogen; Water reduction reactions related to Fe oxidation; Reactions in tubes associated with high levels of reduced iron)
Ward (1933) 、Boreham et al., (2021)	68.6、73.3	Penneshaw，Australia	Precambrian iron-rich strata (serpentinized, hydroradiolysis)
Smith et al. (2005), Lollar et al. (2014)	57.8	Sudbury，Canada	Precambrian iron-rich strata (radiolysis and water-rock reaction)
Prinzhofer et al. (2018)	98.0	Bourakebougou，Mali	Precambrian iron-rich strata(serpentinization)
Wood (1972)	75.8	Poison Bay，New Zealand	Sedimentary rock (serpentinization)
Li et al.，2002	43.8	Chuxiong Basin, China	Serpentinization, deep source degassing?
Morrill et al. (2013)	50.9	Camp Spring，America	Ophiolite (Serpentinization of shallow and deep water)
Vacquand (2011)	97	Bahla，Oman	Ophiolite (serpentinization)
Etiope et al. (2017)	48.3	Vaiceva Voda，Bosnia and Herzegovina	Ophiolite (serpentinization)
Coveney et al. (1987)	96.3	Hoffman，America	Rift region (inorganic reaction of Fe^{2+})
Zgonnik (2020)	80.4	Iriklinskoe，Russia	Magmatic rock (water-rock reaction/serpentinization reaction)
Angino et al. (1984)	80.5	Nizhny Tagil，Russia	Magmatic rock (water-rock reaction/serpentinization reaction)
Sano et al. (1985)	57.3	Namafjall，Iceland	Rift region (Reductive carbon and water reaction in magma)
Symonds et al. (2003)	51.5	Augustine，America	Volcanic gas (shallow crustal sedimentary rock)
Nakamura and Maeda (1961)	51.4	Arima，Japan	Fountains and hot springs (Deep source degassing/serpentinization reaction)
Truche et al. (2024)	84.0	Bulqizë，Albania	Ultramafic rock mass(serpentinization)

The formation of natural hydrogen exploration technology and method system requires diversified exploration strategies

- Most surface indications of natural hydrogen are slight circular or oval depressions (fairy circles), and surface hydrogen leakage indicates the scale and sustainability of underground hydrogen resources（Cathles et al., 2020； Maiga et al., 2023； Hand, 2023）
- There are many sources of natural hydrogen, and it is necessary to adopt diversified exploration strategies to consider different migration channels and trapping mechanisms（Christopher et al., 2021； Hand, 2023）
- Continuous monitoring of multiple dense monitoring sites for at least 24 hours and understanding the characteristics of pulse changes (changes in leakage rate and intensity over time) are critical for exploration and production（Boreham et al., 2021）

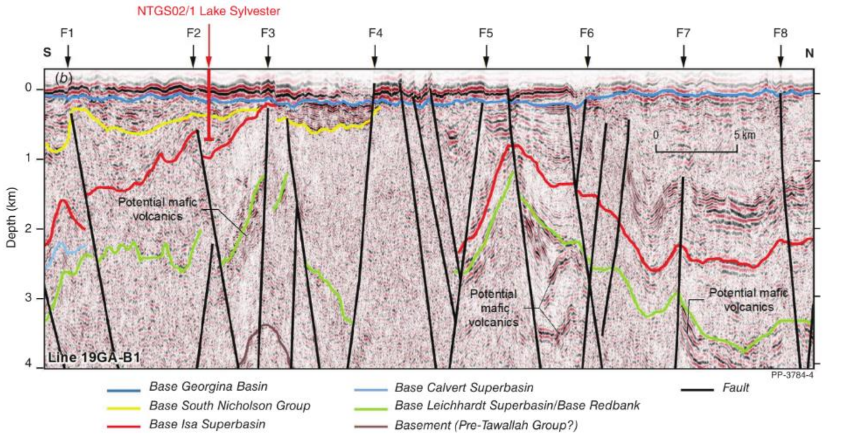
Aerial remote sensing technology



Sample collection: Soil, springs, gases, inclusions

Field gas detection
Dynamic long-term monitoring

Gironde Ring Depression, South of France - Chivalrine Circle: Aerial remote sensing images, "three measurements" of the surface（Halas et al.2021）



Integrated interpretation of hydrogen source and fault locations from seismic, gravity and magnetic data, South Nicholson Basin, Australia（Christopher et al.2021）

Speech outline

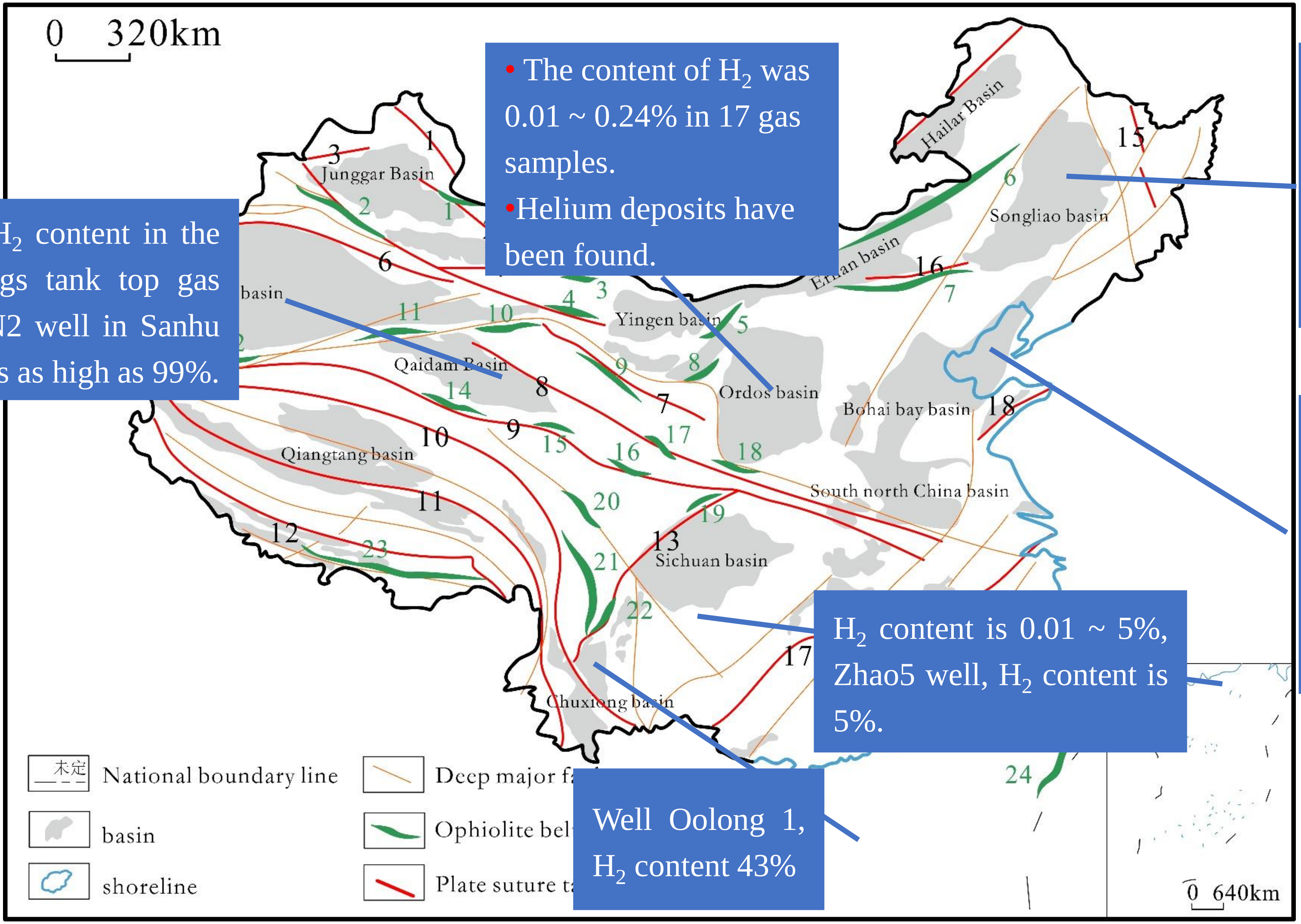
1. Hydrogen energy, artificial hydrogen production and natural hydrogen

2. Natural hydrogen formation, accumulation and distribution

3. Progress in natural hydrogen exploration and development abroad

4. Exploration prospects of natural hydrogen resources in China

China's land has a number of natural hydrogen content abnormal display



The H_2 content in the cuttings tank top gas of SN2 well in Sanhu area is as high as 99%.

- The content of H_2 was 0.01 ~ 0.24% in 17 gas samples.
- Helium deposits have been found.

- In the central depression, H_2 content ranges from 1.0% to 85.54%, with an average of 9.88%.
- H_2 content was > 10% in 22 Wells and >50% in 2 Wells.

- More than 30 gas samples showed H_2 content ranging from 0.01 to 13%.
- The highest H_2 content is 13% at the outer edge of the basin.

H_2 content is 0.01 ~ 5%, Zhao5 well, H_2 content is 5%.

Well Oolong 1, H_2 content 43%

Hydrogen rich structure types and natural hydrogen display in China

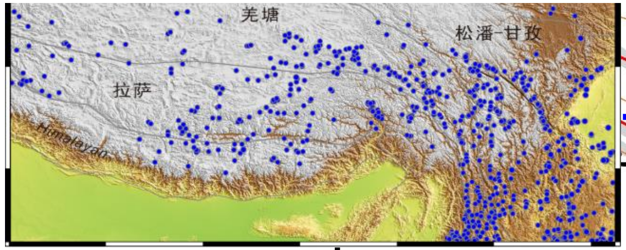
（Tian et al., 2022；Jin et al., 2024；Dou et al., 2024；Liu et al., 2024）

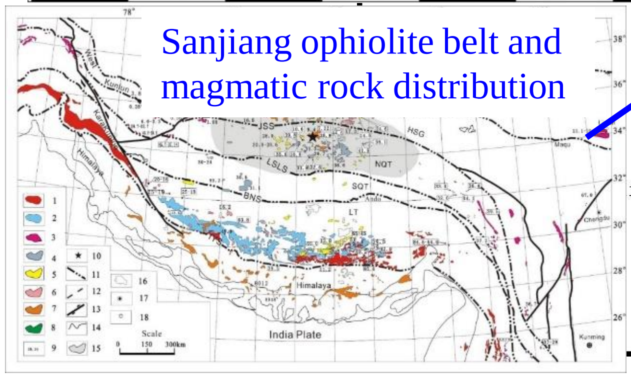
China's land has a number of natural hydrogen content abnormal display

Qilian Mountains, southern margin of Xining ophiolite

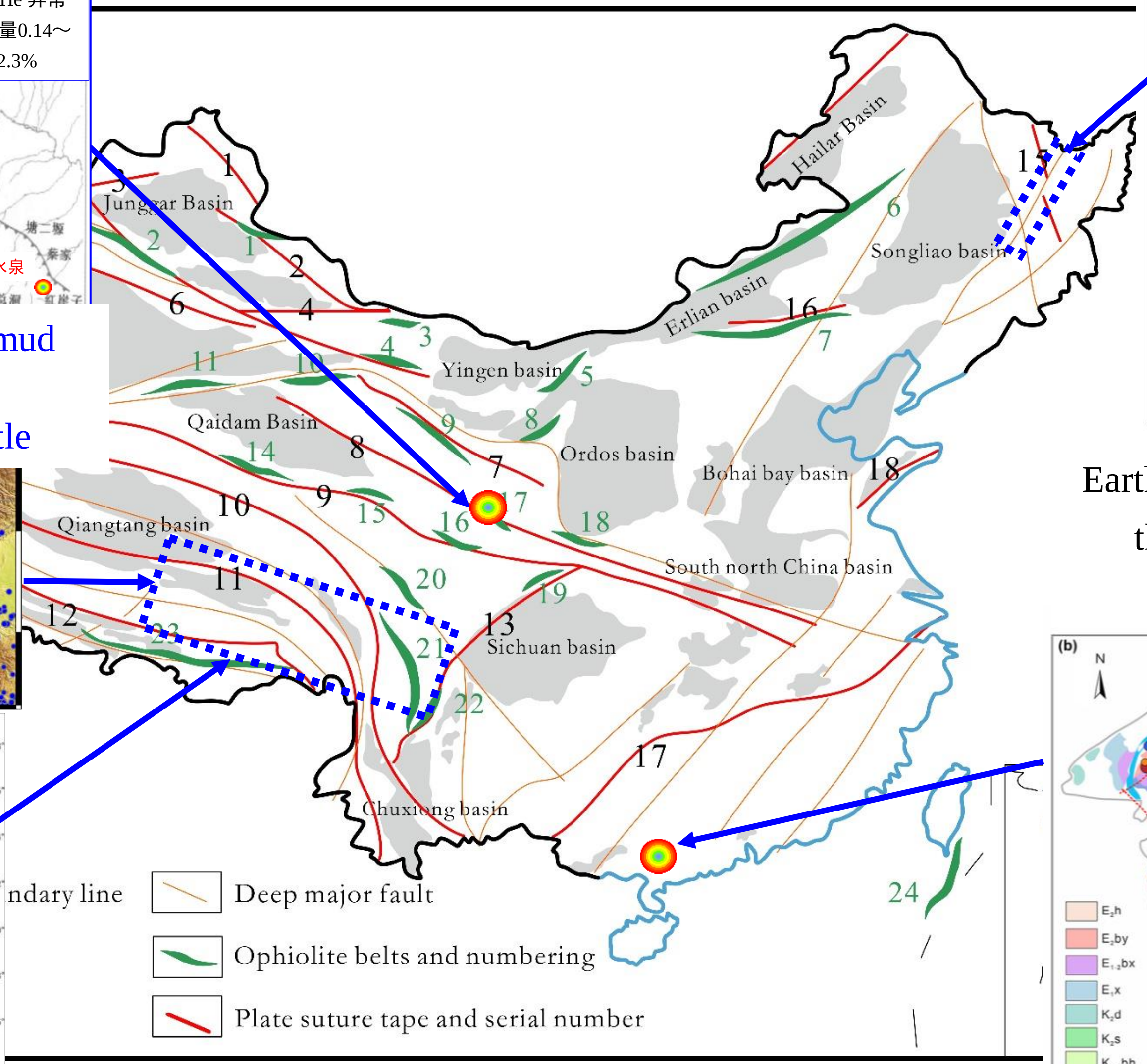
Distribution of geothermal, hot spring and mud volcano in Sanjiang area

The main distribution area of He from mantle

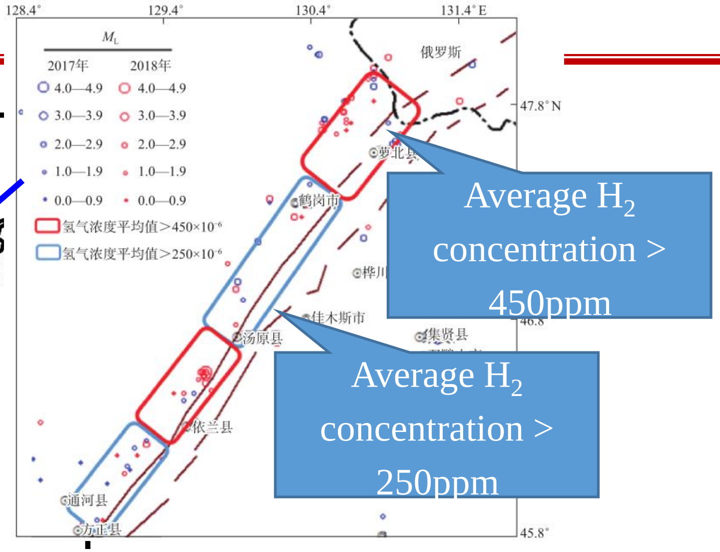




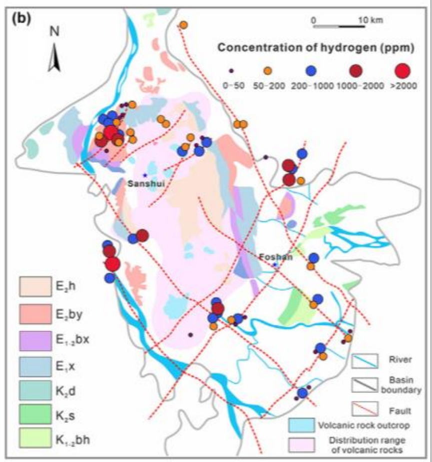
（Tang、He et al., 2024）



Hydrogen rich structure types and natural hydrogen display in China



Earthquake and hydrogen content distribution in the northern section of Yilan-Yitong fault （Kang et al., 2020）

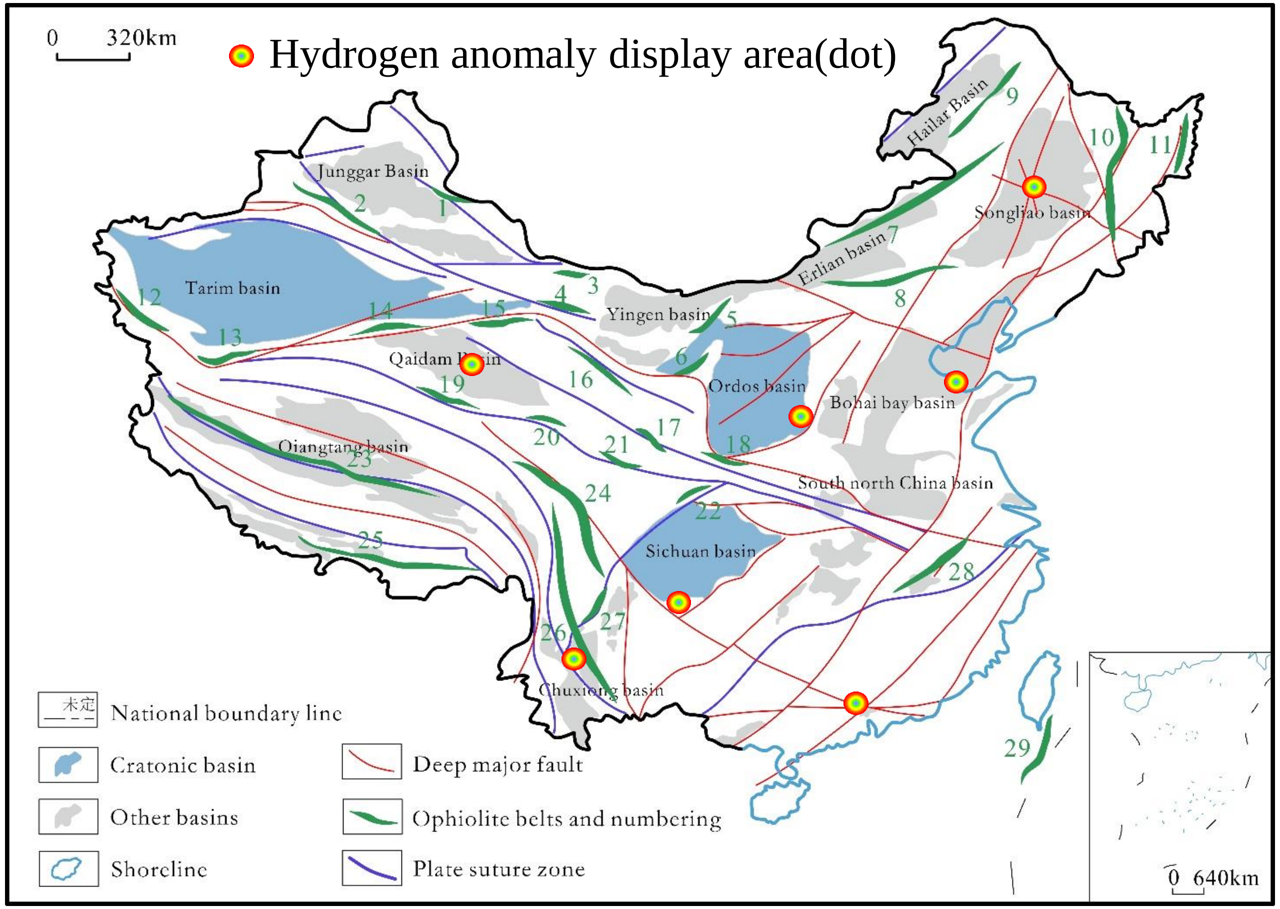


The hydrogen in Sanshui Basin is abnormal, with the highest H_2 content reaching 6948ppm (Jin et al., 2024)

China has the basic geological conditions and exploration potential to search for natural hydrogen

Favorable zones and directions for natural hydrogen accumulation:

- ✓ The middle ophiolite zone of suture zone (orogenic belt)
  - Ophiolite in Sanjiang suture zone, Qinghai-Tibet
  - Ophiolite in the Aljin-Qilian-Qinling suture zone
  - Ophiolite in the Tianshan-Greater Khinganling tectonic belt
- ✓ Precambrian basal-Craton basin
  - Precambrian basement of Ordos Basin
  - Precambrian basement of Sichuan Basin
  - Precambrian basement of Tarim Basin
- ✓ The active belt of the deep rift in eastern China
  - The rift basin around the Tan-Lu fault zone
  - Deep magmatic activity zone (basic-ultrabasic rock development area)
  - Seismicity zone
- ✓ A solid deposit coupled with iron-rich strata and deep faults(mine)



Distribution map of deep fault zone, ophiolite zone, craton and natural hydrogen anomaly in China

（Dou et al., 2024；Xiong et al., 2024；Liu et al., 2019）

The main problems in China's natural hydrogen field

In the early stage, research on hydrogen mainly focused on seismic activity monitoring and geochemical index research for oil and gas exploration.

So far, natural hydrogen as a resource, has not carried out systematic investigation and research and exploration and development work, the past two years only began to do some scattered basic research and follow-up research work.

Is there natural hydrogen? What kind of natural hydrogen is there?

The genetic type and accumulation mechanism of natural hydrogen are still unclear

Where is the rich area and what is the potential?

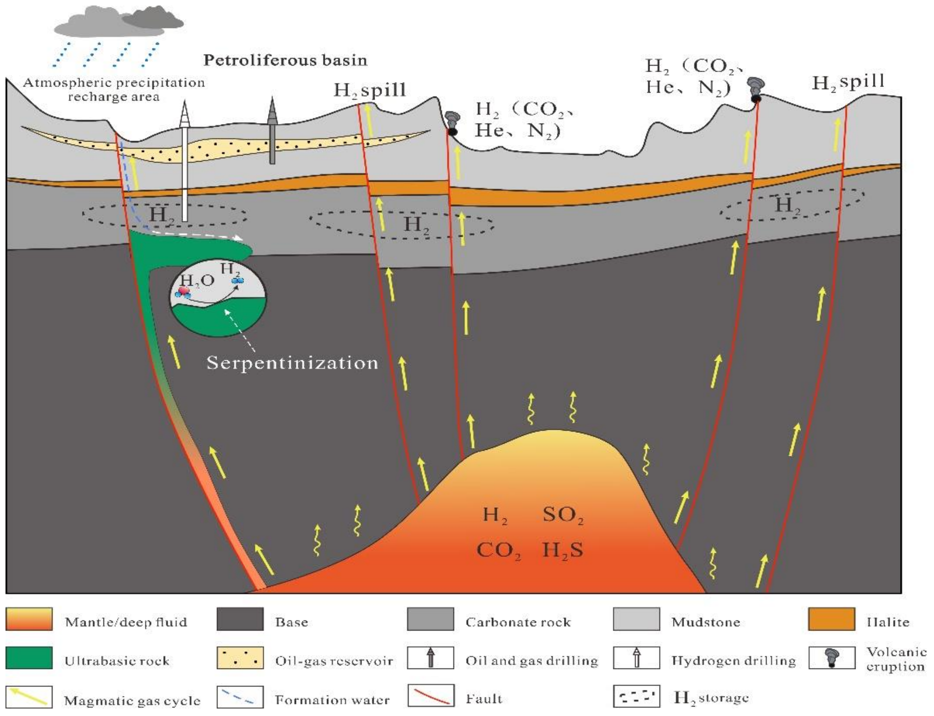
The distribution, enrichment and resource potential of natural hydrogen are still unclear

What technology do we use? How do we find it?

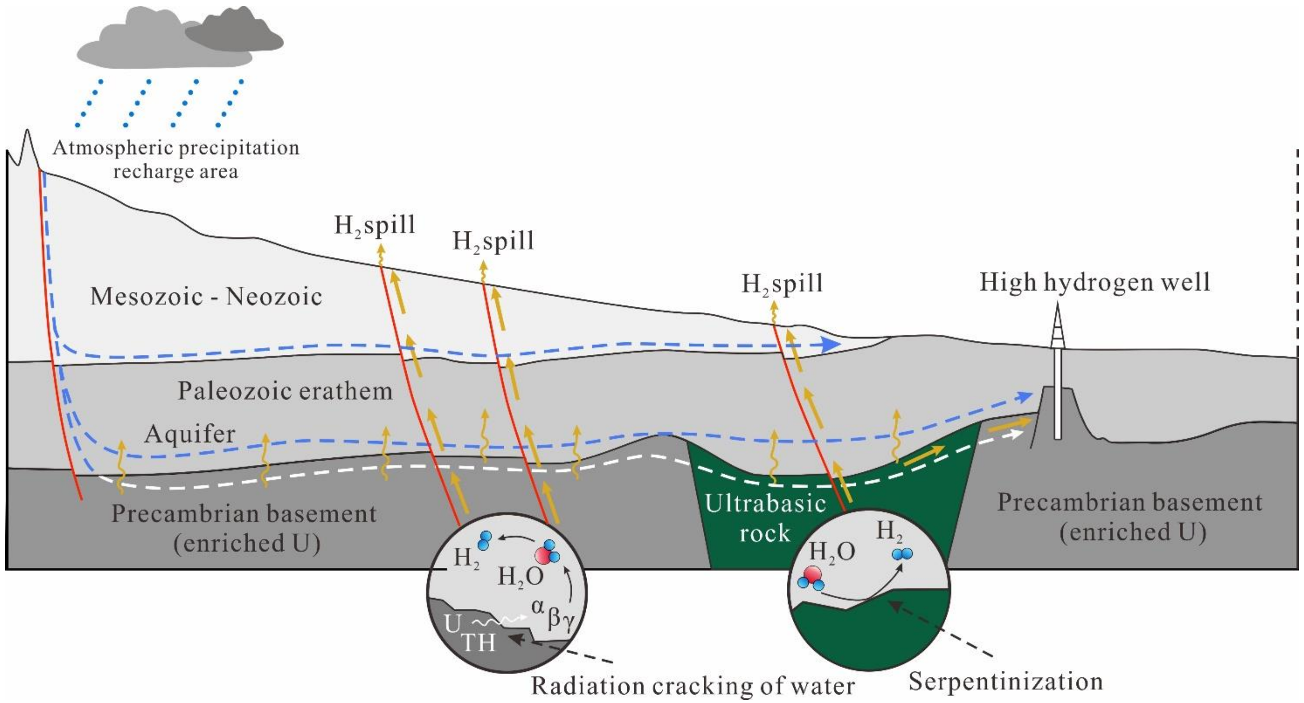
Lack of systematic and mature exploration technology for natural hydrogen resources

Prospect and suggestion of natural hydrogen investigation in China

- Changing the prospecting idea, it expands from oil-bearing basin to marginal orogenic belt (ophiolite) and advances to the deep craton basement of the basin.
- Diversified exploration strategy, combined with oil and gas, solid mineral and geothermal resources exploration, strong combination, complementary advantages; Different genetic types of natural hydrogen take different exploration and development strategies.



Deep and large fault zone model



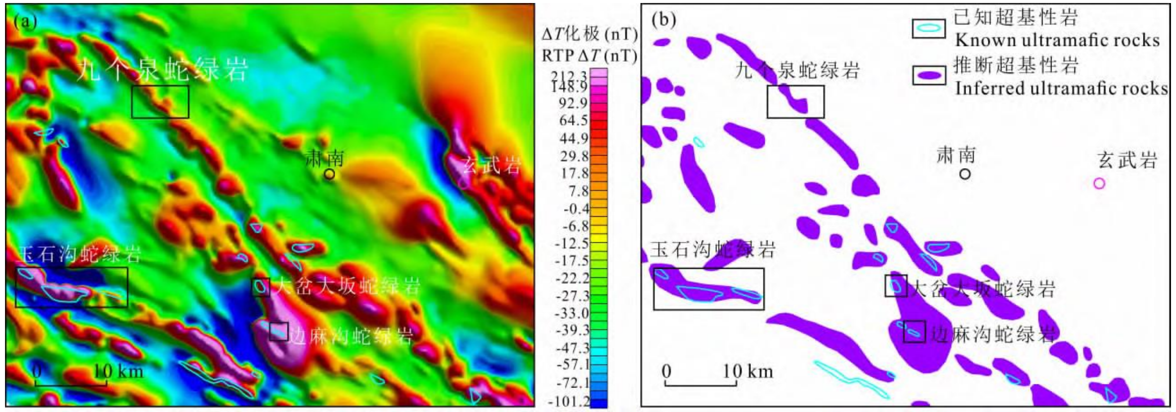
Iron - and uranium-rich craton basement (pluton) model

Prospect and suggestion of natural hydrogen investigation in China

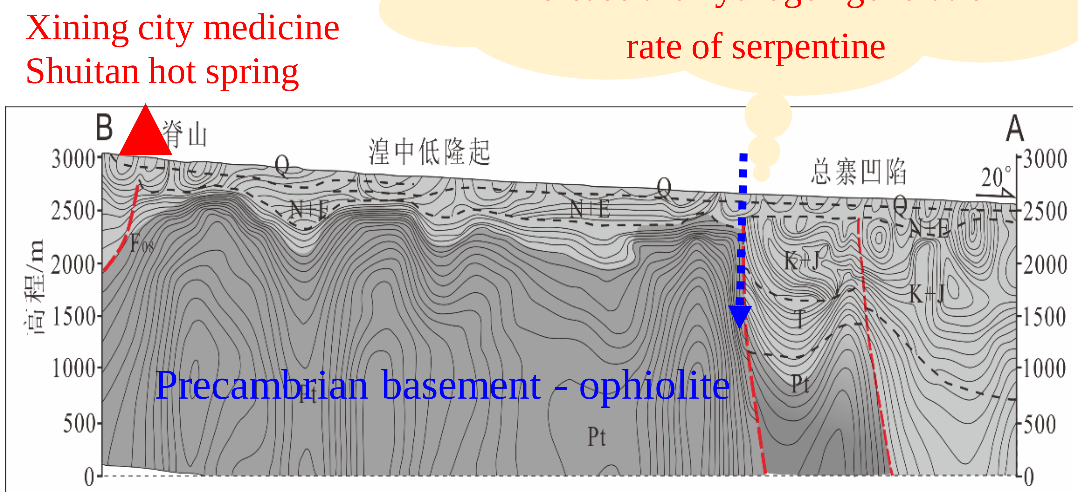
- Build applicable technologies, give full play to technological advantages in the exploration and development of oil and gas and solid minerals, and carry out key core technology research in the exploration and development of natural hydrogen resources.
  - Technical methods of resource evaluation (reserve calculation), selection evaluation and experimental testing
  - Deep detection technology of hydrogen source body (ophiolite, deep fracture) (aerial remote sensing + seismic + non-seismic coupling technology)
  - Exploration + mining + transportation + storage + security integration technology system
  - Artificially stimulated (cryoserpentinized, microbially mediated) underground hydrogen plants

Artificial water injection - low temperature stimulation

Increase the hydrogen generation rate of serpentine



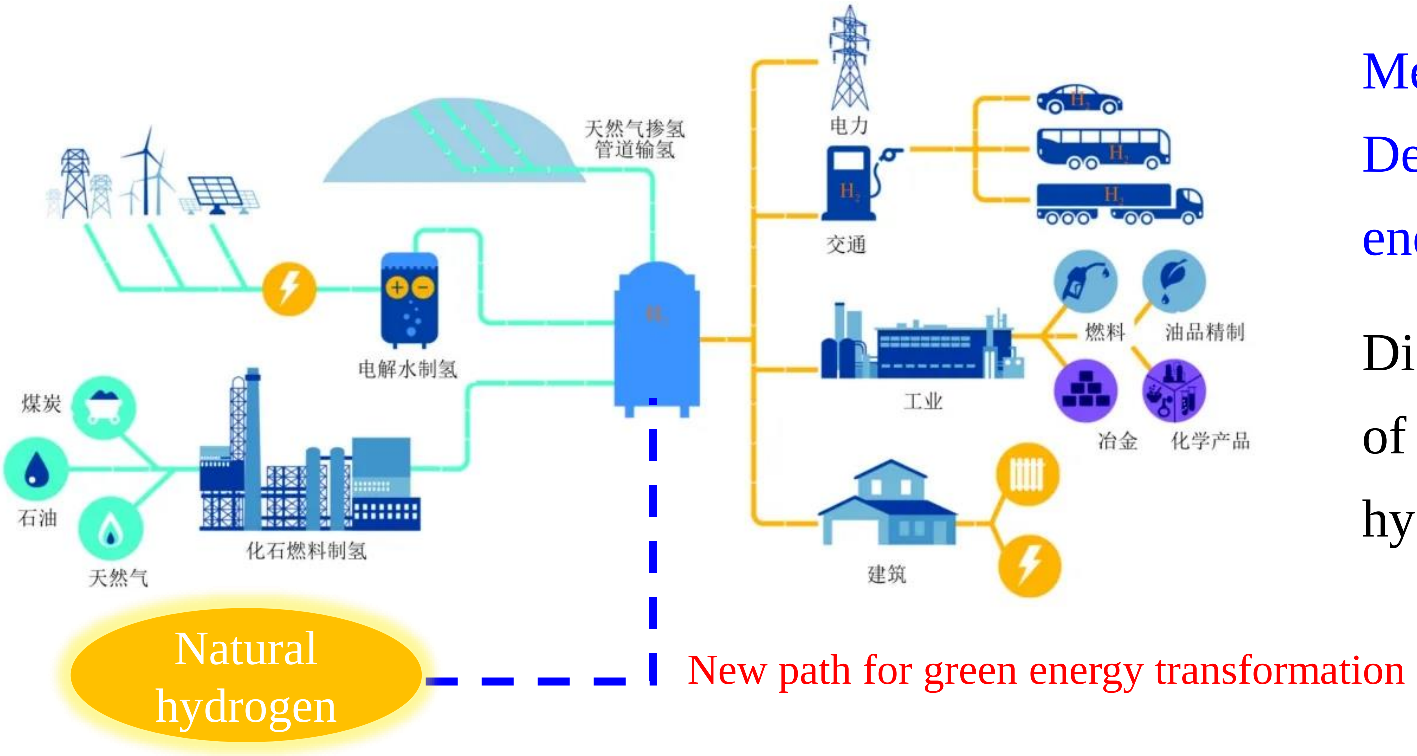
Distribution characteristics of aeromagnetism and ophiolite in the middle part of North Qilian（Xiong et al., 2024）



Ophiolitic pluton in southern margin of Xining Basin, Qinghai province（Wang et al., 2011）

Prospect and suggestion of natural hydrogen investigation in China

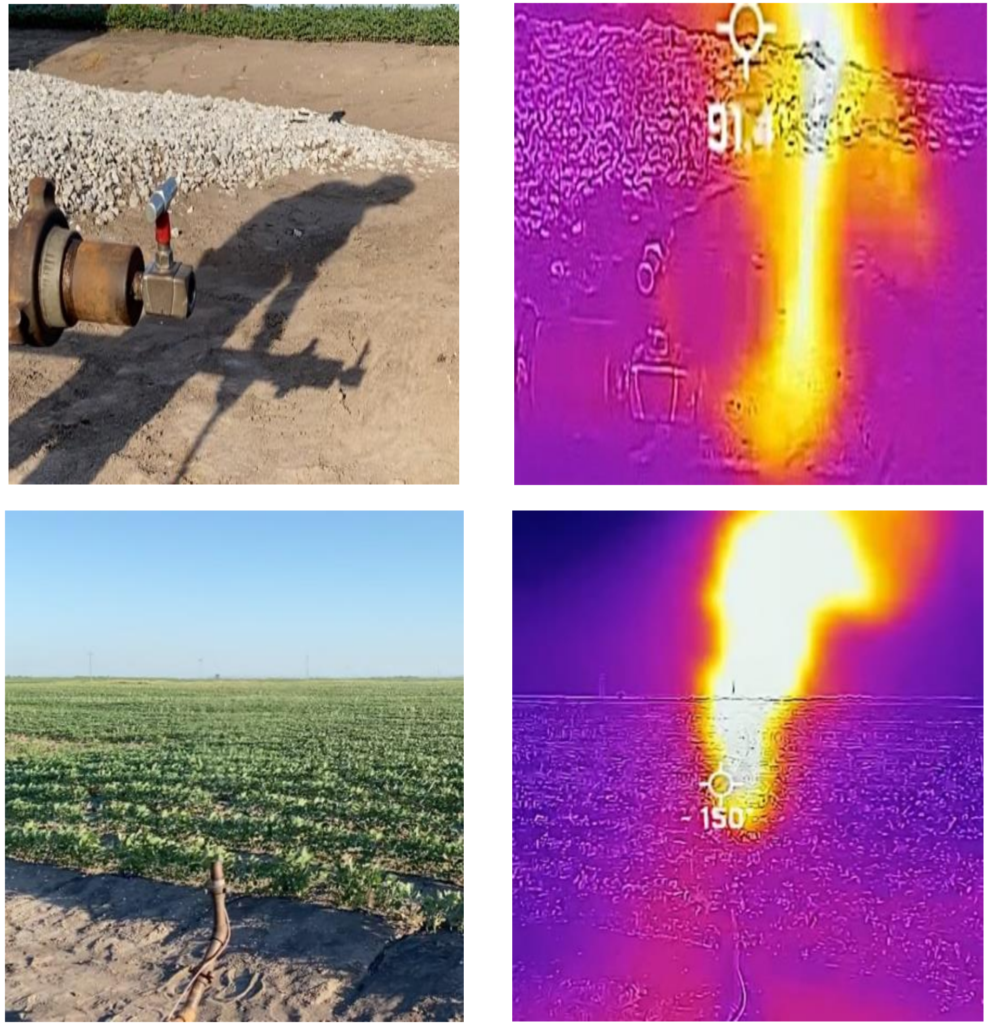
- Hydrogen energy industry development, strategic layout of natural hydrogen exploration and development, basic research and technical research work
  - Natural hydrogen urgently needs to enter the national new energy system and hydrogen energy industry development strategic planning
  - Fully launch the investigation and evaluation of natural hydrogen resources to understand the "bottom line" of natural hydrogen resources
  - Various scientific and technological innovation approaches such as major projects and fund research will be adopted to accelerate research on natural hydrogen science and technology



Medium and Long-Term Plan for the Development of China's hydrogen energy Industry (2021-2035) :

Diagram of the whole industrial chain of hydrogen energy with green hydrogen as the core

Natural hydrogen = geological hydrogen = white hydrogen = gold hydrogen



The flame is colorless and transparent under natural light

The flame is pale yellow in infrared light

Hoarty NE3 hydrogen reservoir in the Kansas Basin margin zone of the North American Rift Valley

The world's first hydrogen exploration Well (Hoarty NE3)

H_2： 24%， N_2： 68.95%， CH_4:11%， He： 0.05%

（ https://hyterra.com/wp-content/uploads/2024/03/HyTerra-Corporate-Presentation.pdf ）

Thank you!