

"Gold" hydrogen in natural fluid inclusions

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Hydrogen "colours"

industry/artificial:



"grey" = fossil fuels, release of CO₂



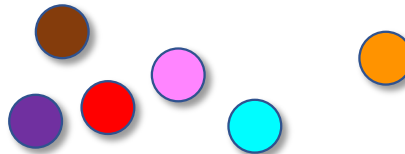
"blue" = fossil fuels, carbon is captured and sequestered *

** a little fairy tail*



"green" = split water, electrochemical processes, no emission of CO₂

some other "colours"



natural:



"gold" = natural subsurface accumulations

alternative:



"white"

source:

Science, vol. 379 (2023)
<https://www.h2bulletin.com/>



some important sources of Natural Hydrogen

1. serpentinization olivine, pyroxene + water \rightarrow H_2 + magnetite + silicates
2. oxidation state of mantle (Fe^{2+}/Fe^{3+}) e.g. QFM, WI buffer
3. radiolysis water in contact with an uranium oxide (e.g. uraninite)
4. degassing of core and mantle (premordial)

evidence of hydrogen in crust and mantle

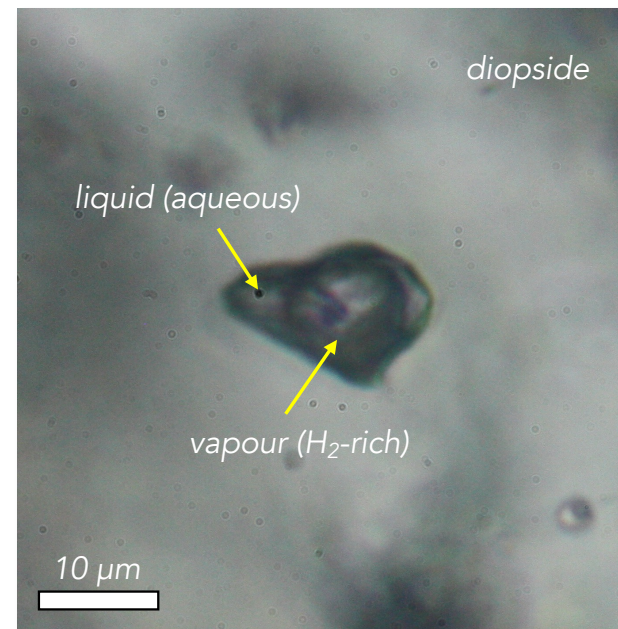
1. seeps



reservoirs (sinks), "unknown" origin

natural fires: flames, no smoke (Stoll, 1953)

2. fluid inclusions



natural samples of original pore fluids

Troodos (Cyprus)

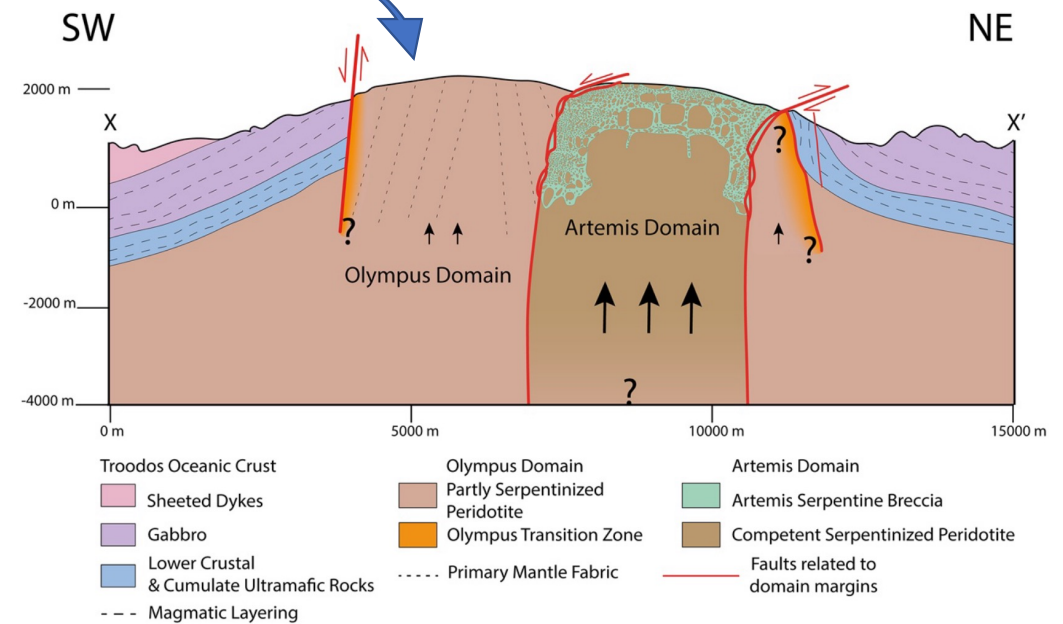
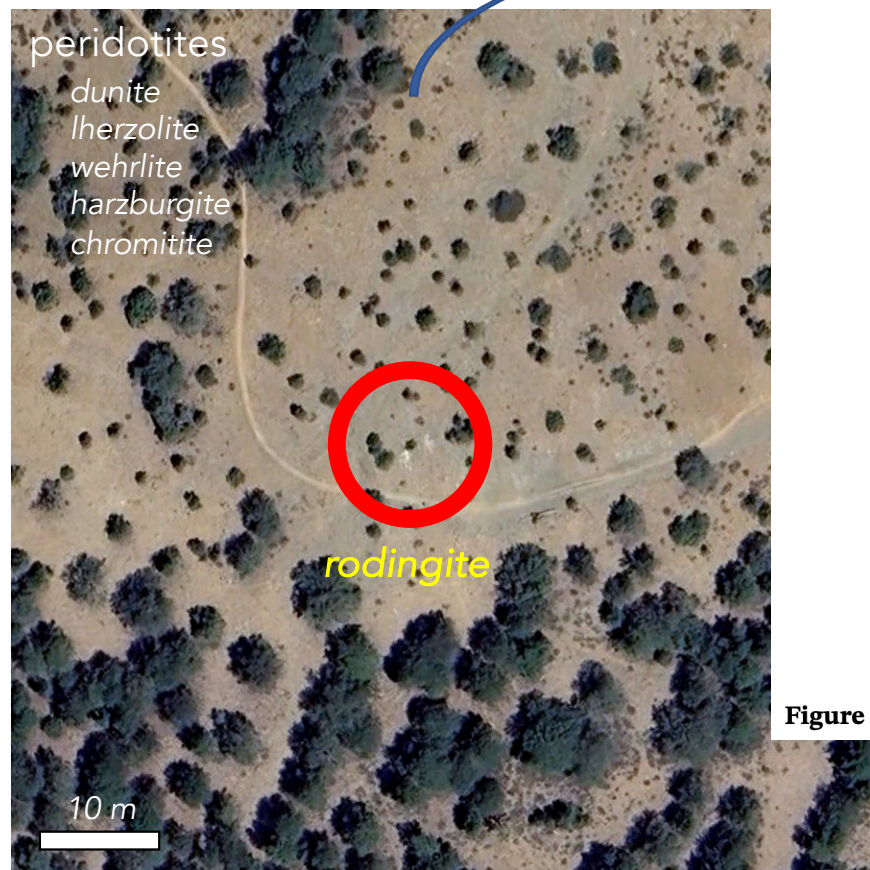


Figure 2. Geological cross-section of the Troodos Mantle Sequence and associated ocean crustal rocks.

Evans et al. (2021)

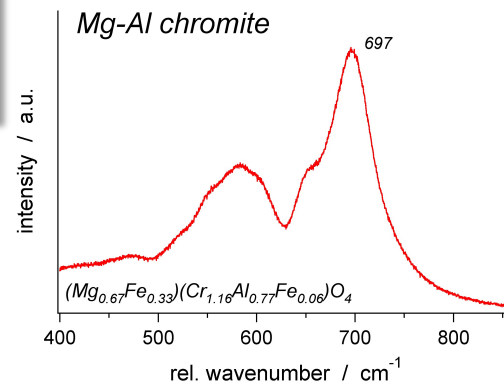
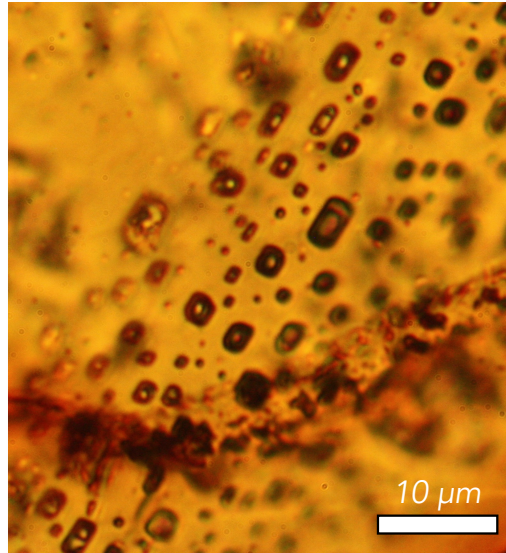
Troodos (Cyprus)

massive chromitite (podiform)

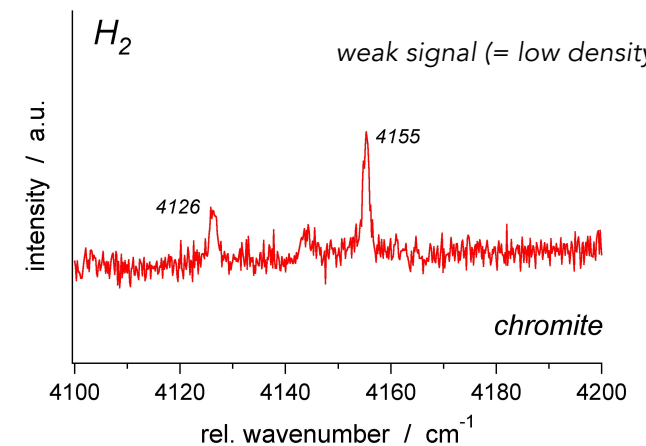


in harzburgite, dunite

fluid inclusions in chromite



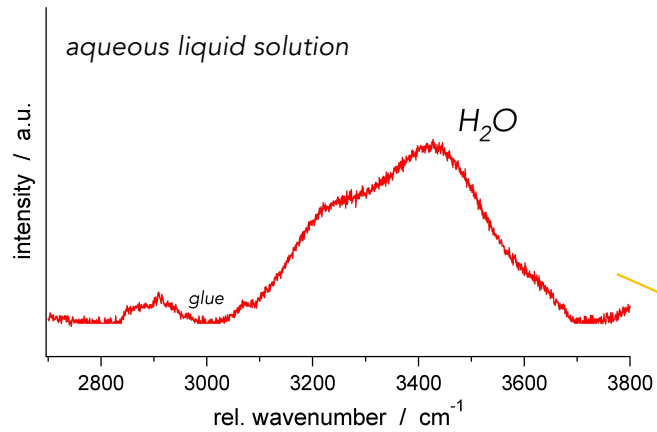
Raman Spectroscopy
composition gas phase fluid inclusions



locally traces of CH_4 , no CO_2

see also McElduff (1989) PhD Thesis

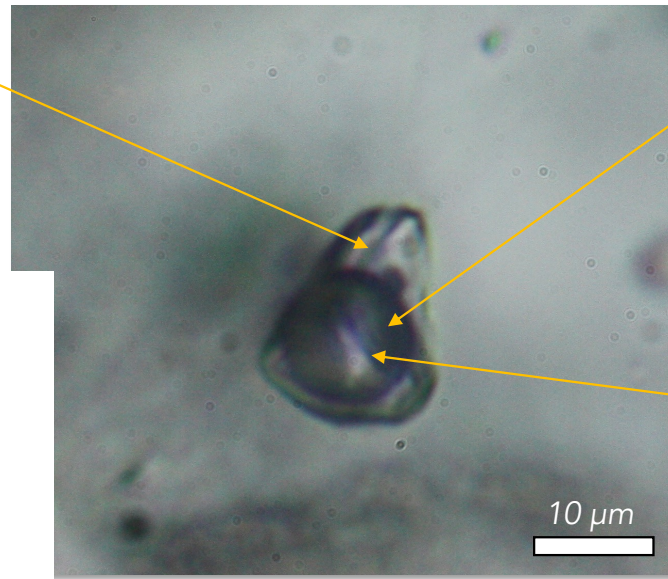
Troodos (Cyprus)



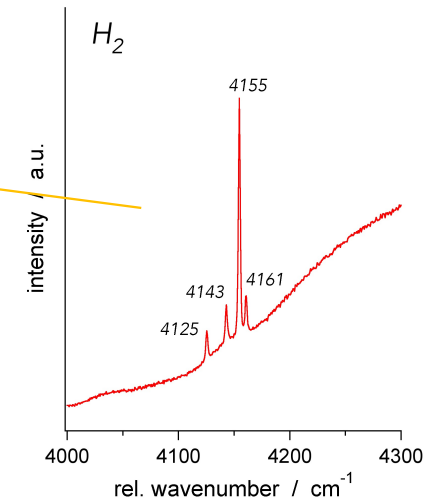
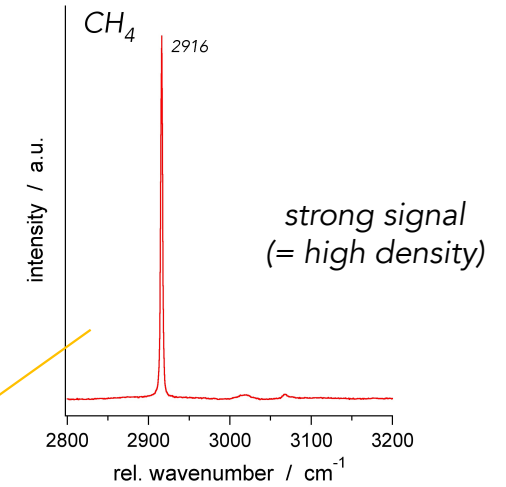
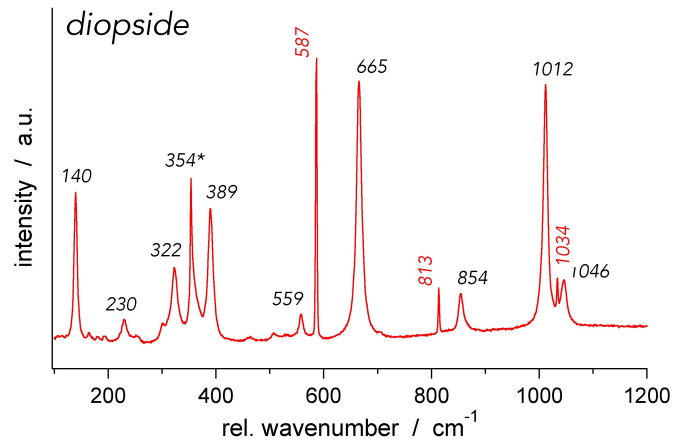
serpentinization and
rodingitization

rodingite

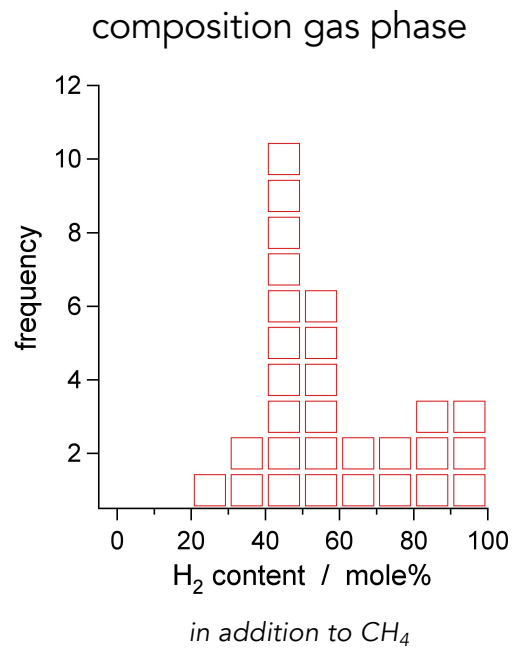
diopside, hibschite (hydro-grossular), calcite, clinocllore, graphite



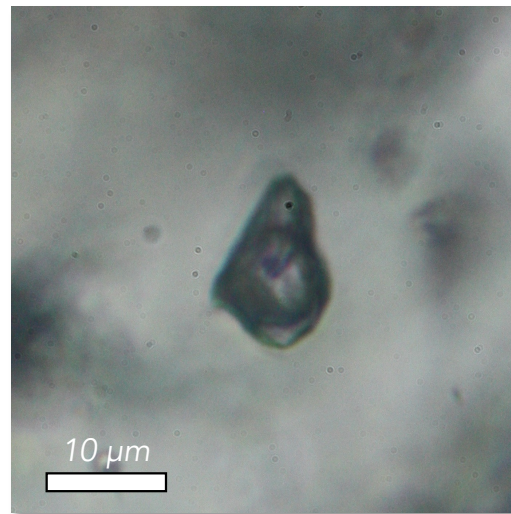
fluid inclusions in diopside



Troodos (Cyprus)



rodingite



preliminary results microthermometry
aqueous liquid rim

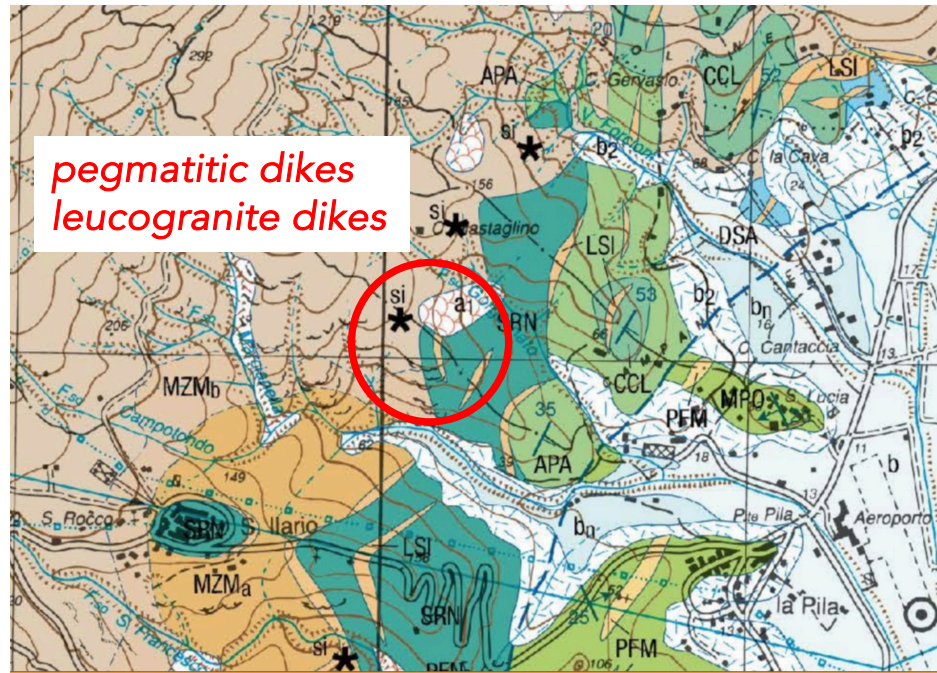
$$T_m = -5.2^\circ\text{C}$$

clathrate or ice ?
(optical difficulties)

further research:
combine with Raman spectroscopy

Elba (Italy)

ISPRA



SRN: serpentized mantle (Iherzolite) (middle-upper Jura)

MZM: granodiorite – monzogranite (Miocene)

LSI: leucogranite (Miocene)

* pegmatitic dikes

APA: metapelites (lower Cretaceous)

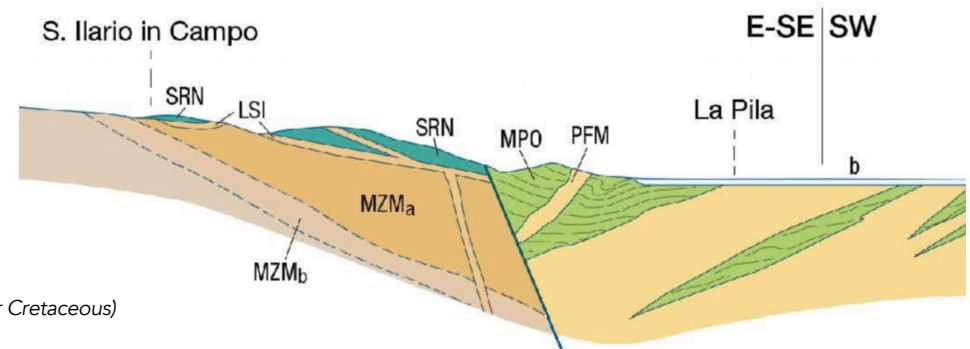
CCL: siliceous limestone (lower Cretaceous)

MPO: turbiditic limestones and sandstones (upper Cretaceous)

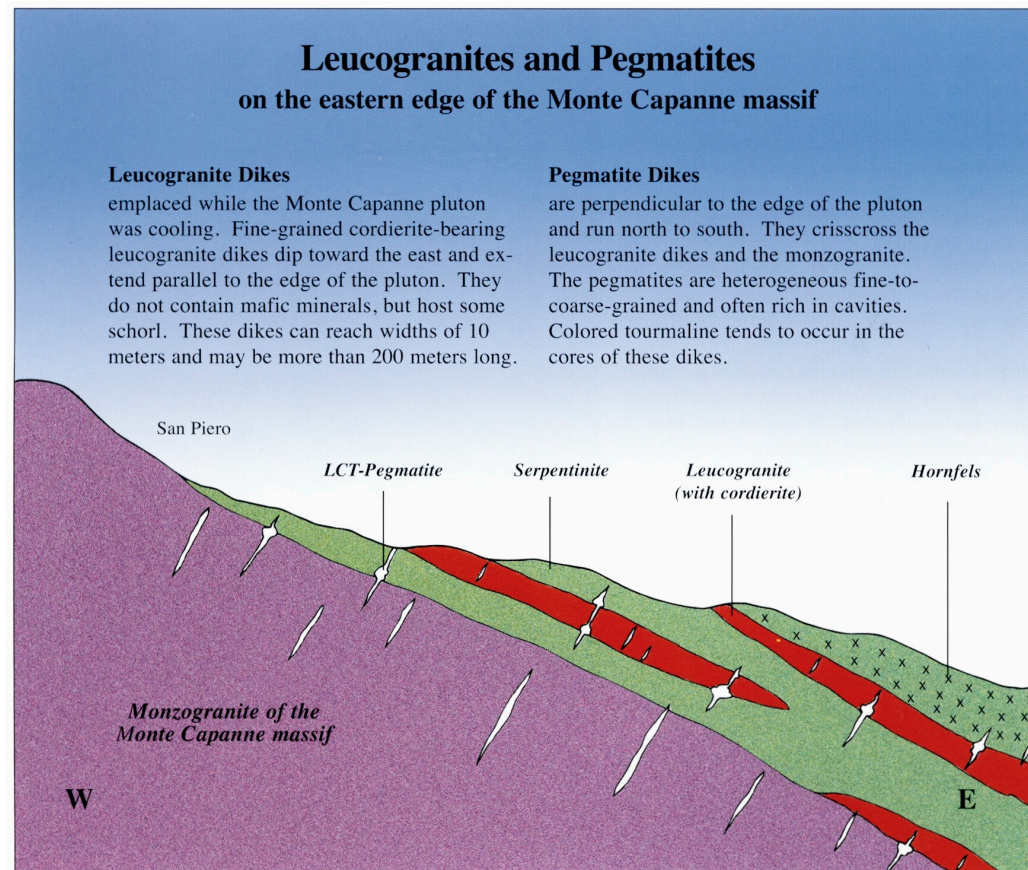
PFM: porphyric monzogranite (Miocene)



outcrop quality



Elba (Italy)

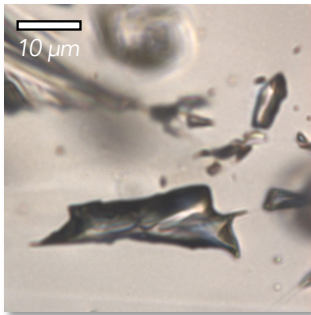


Pezzotta (2005)

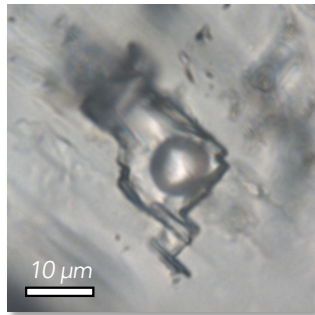
Elba (Italy)

H₂ in fluid inclusions

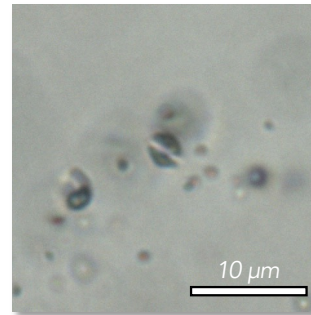
Leucogranite (67E)



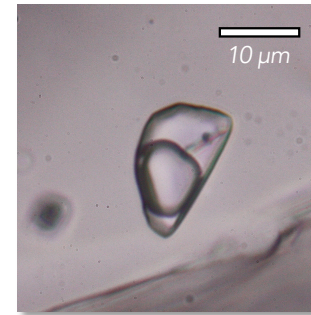
andalusite



plagioclase



quartz (type 1)

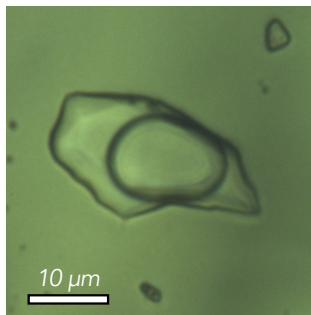


quartz (type 2)



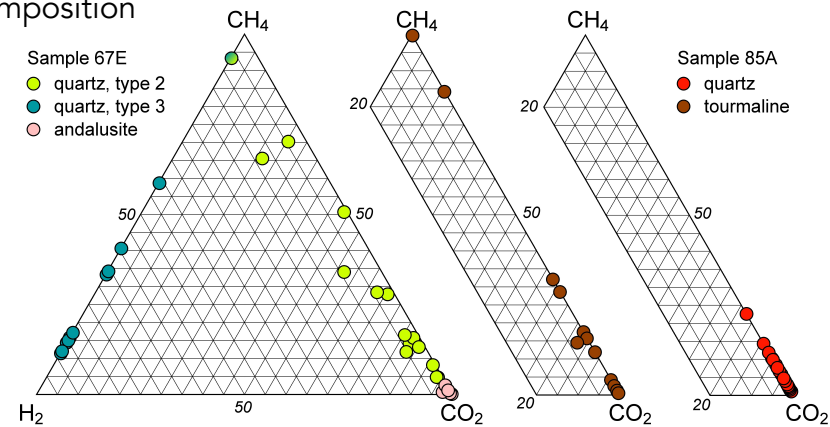
quartz (type 3)

Pegmatite (85A)



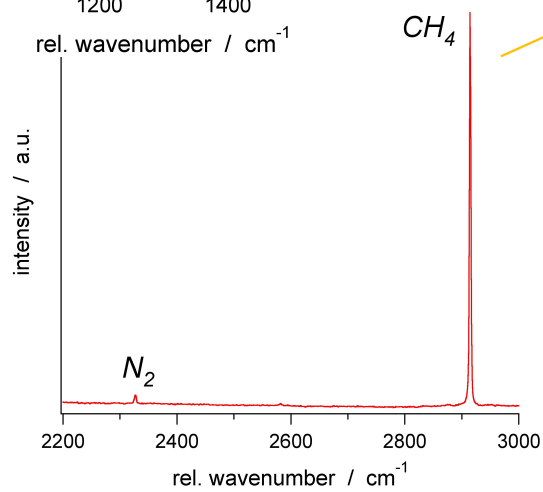
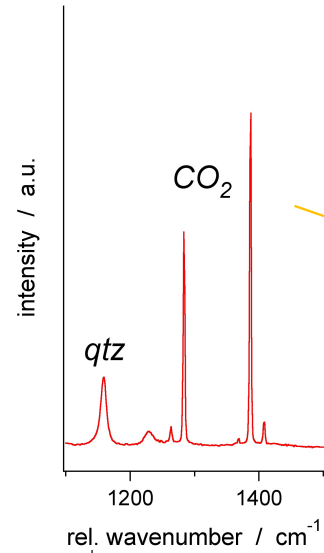
tourmaline

vapour phase composition

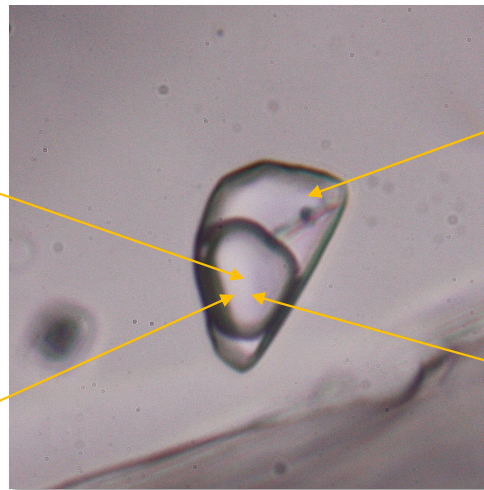


Bakker and Schilli (2015)

CO₂-CH₄-H₂ mixtures in vapour phase

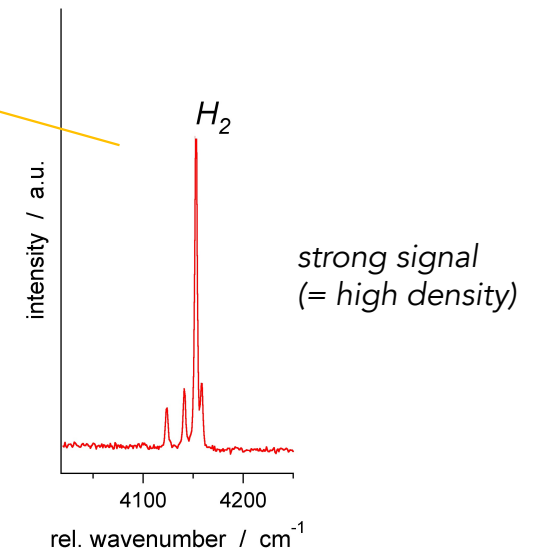
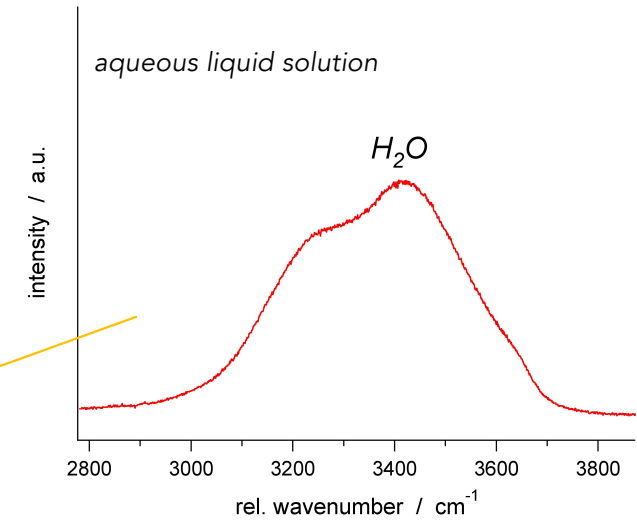


Leucogranite



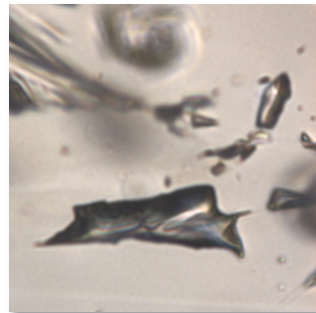
quartz (type 2)

Raman spectroscopic analyses fluid phases

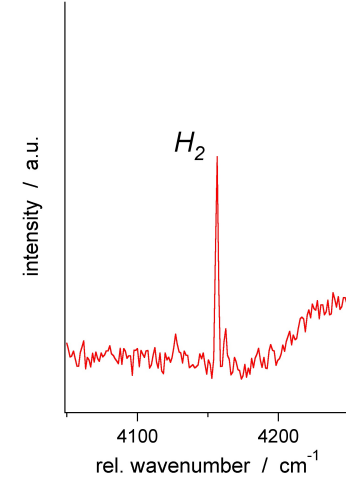
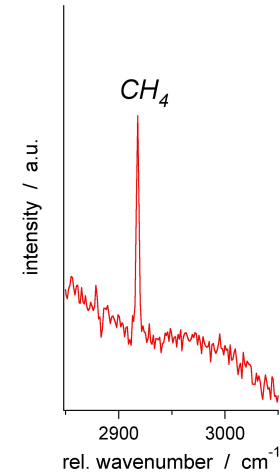
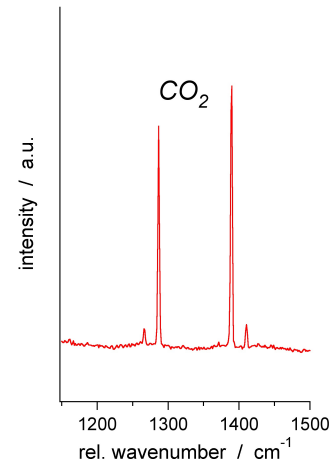


CO₂-CH₄-H₂ mixtures in vapour phase

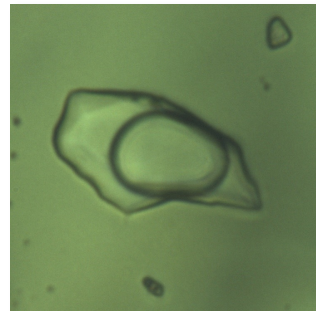
Leucogranite



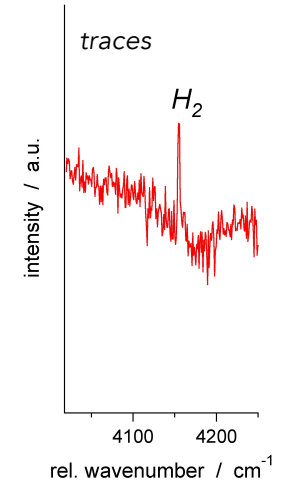
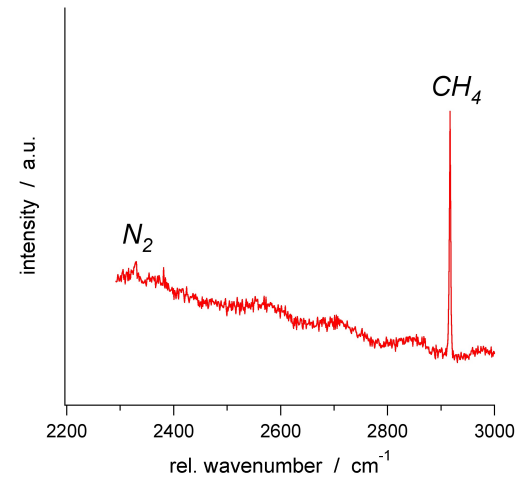
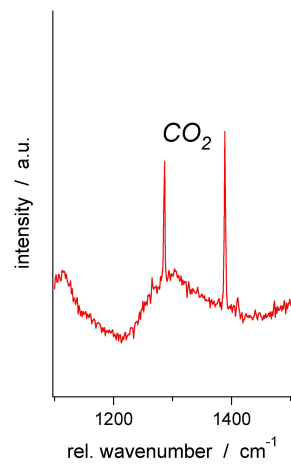
andalusite



Pegmatite

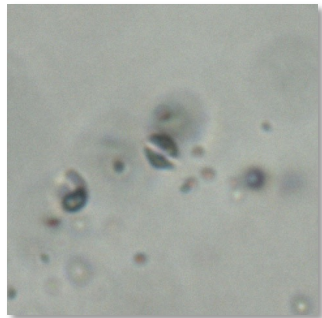


tourmaline

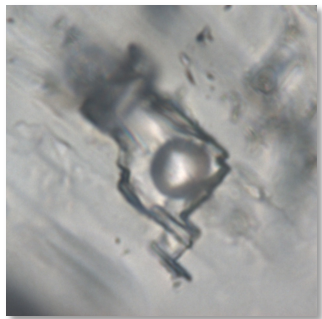
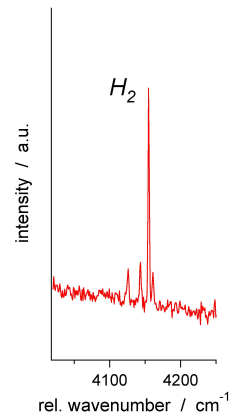
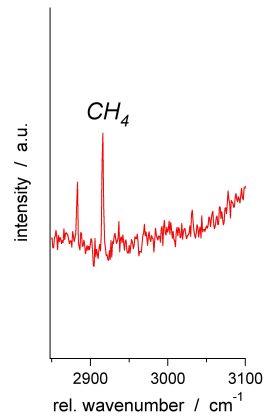


CH₄-H₂ mixtures in vapour phase (no CO₂)

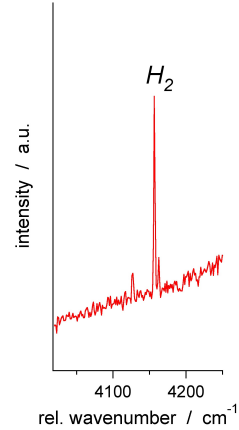
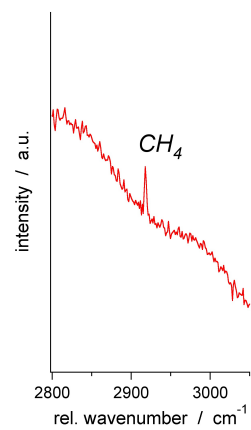
Leucogranite



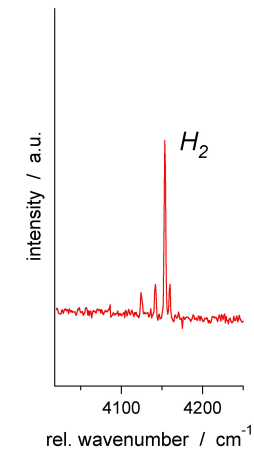
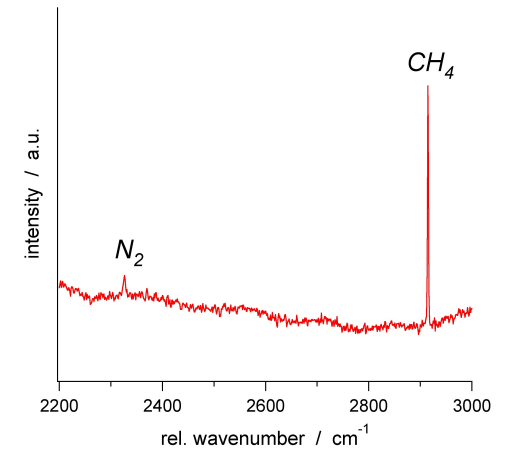
quartz (type 1)



plagioclase



quartz (type 3)



Arkaroola (Australia)

Uranium mining at Radium Hill and Mt. Painter - Mt. Gee

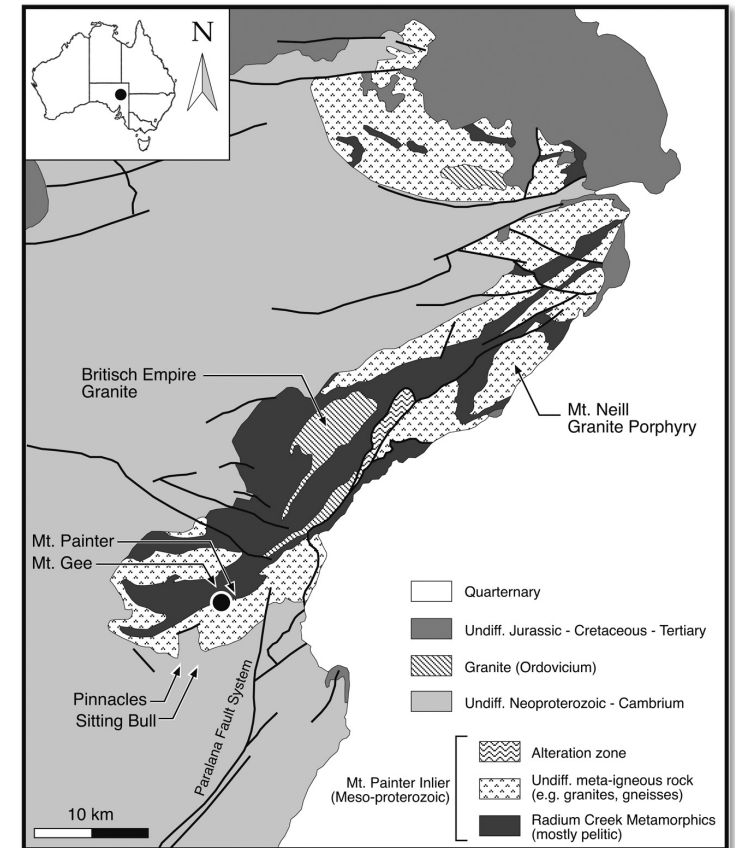


remobilisation younger than 3.5 Ma

Basement
Meso-proterozoic
pelitic metamorphics

thermal pulse (440 Ma):

emplacement of diopside-titanite veins,
pegmatites, and uranium mineralisation



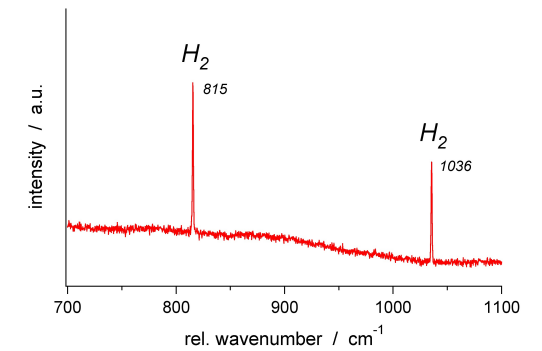
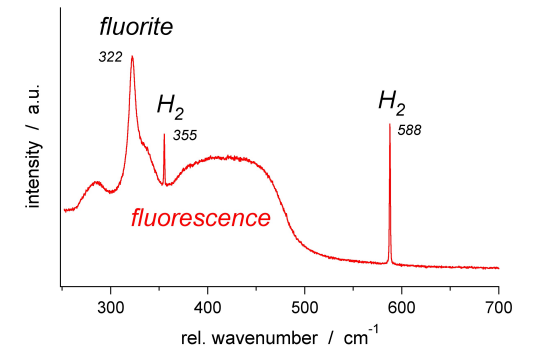
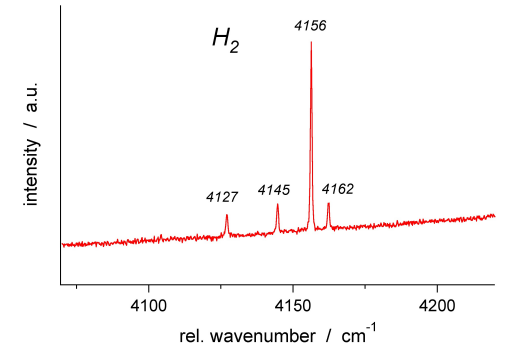
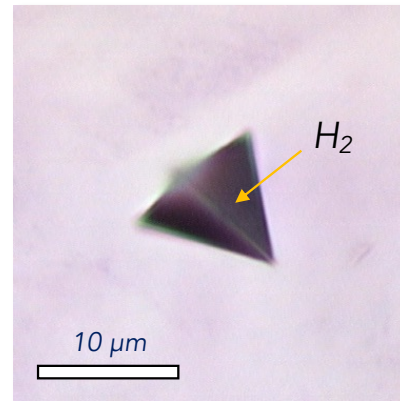
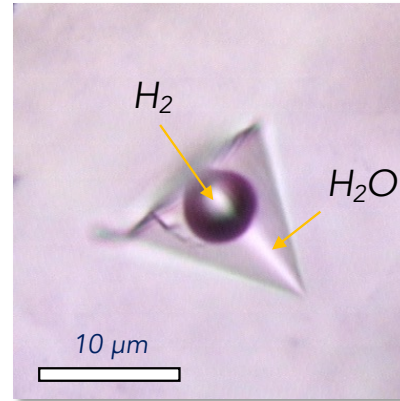
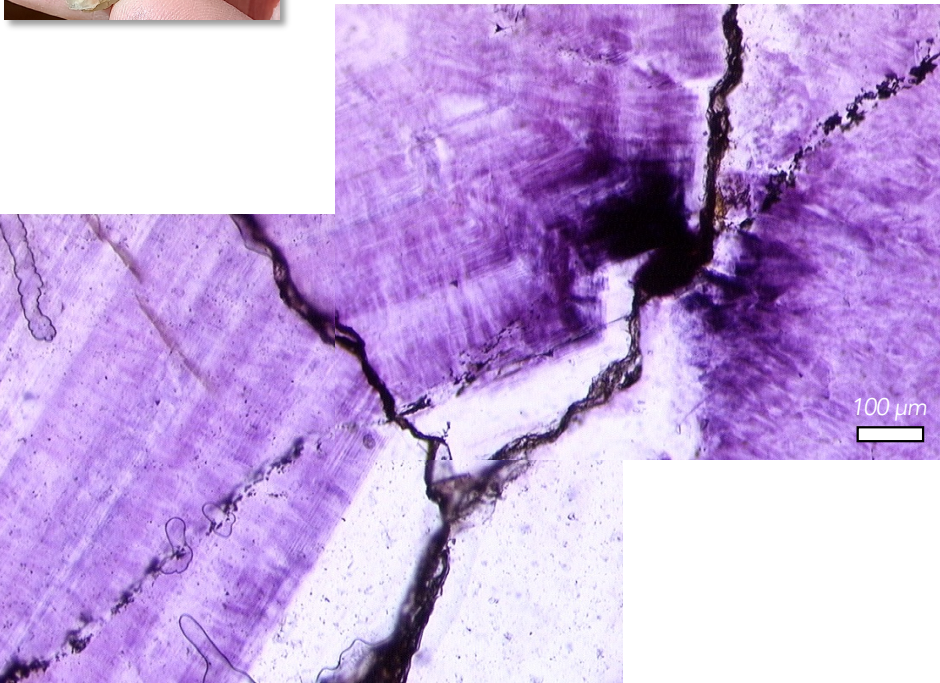
Elburg et al. (2003)
Bakker and Elburg (2006)

Arkaroola (Australia)



Fluorite
associated with uranium mineralisations

radiolysis



the application of fluid inclusions:

fluid inclusions are isolated micro-vessels ("closed system")

constant volume, no transfer of mass

fluid inclusions are able to preserve their H₂ content

remember Roedder (1984):

"fluid inclusion represent actual samples of fluids existing at some time in the geological past"

"fluid inclusions provide a unique record of valuable clues for unravelling past geological events"

"understanding the temperature, pressure, density and composition of fluids that traversed the rock"

summary of illustrated examples:

1. serpentinization produces large amounts of H_2 (e.g. Klein et al., 2013)

but serpentine crystals are not suitable to entrap fluid inclusions

this H_2 is trapped in:

- diopside produced in associated rodingitization processes
- small intrusive granitic dikes in serpentinite (or original peridotites)

2. mantle H_2 : chromite in peridotites entraps H_2 from a mantle source (highly reduced conditions)
3. radiolysis: fluorite associated with uranium mineralisation contain abundant H_2

"Gold" hydrogen in natural fluid inclusions

thank you for your attention

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