Fluids in granulitic garnetites
high density CH_4 fluids versus H_2O-CO_2 bearing cordierites
Khabarny Massif (Ural, Russia)

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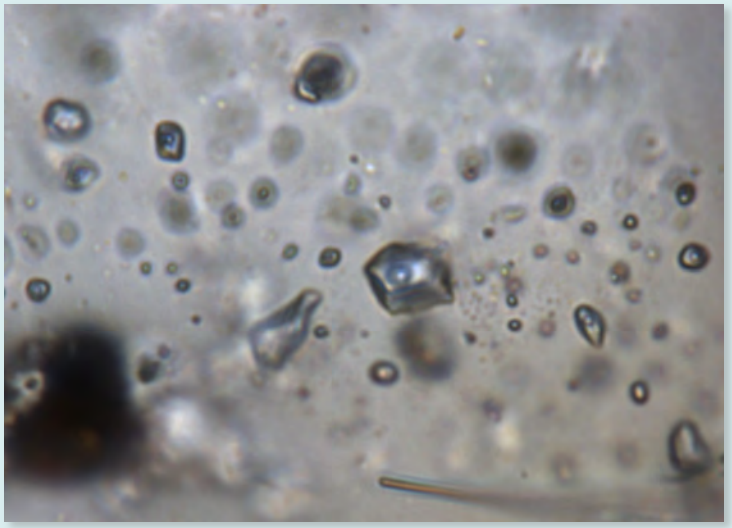
Fluids in high-metamorphic environments

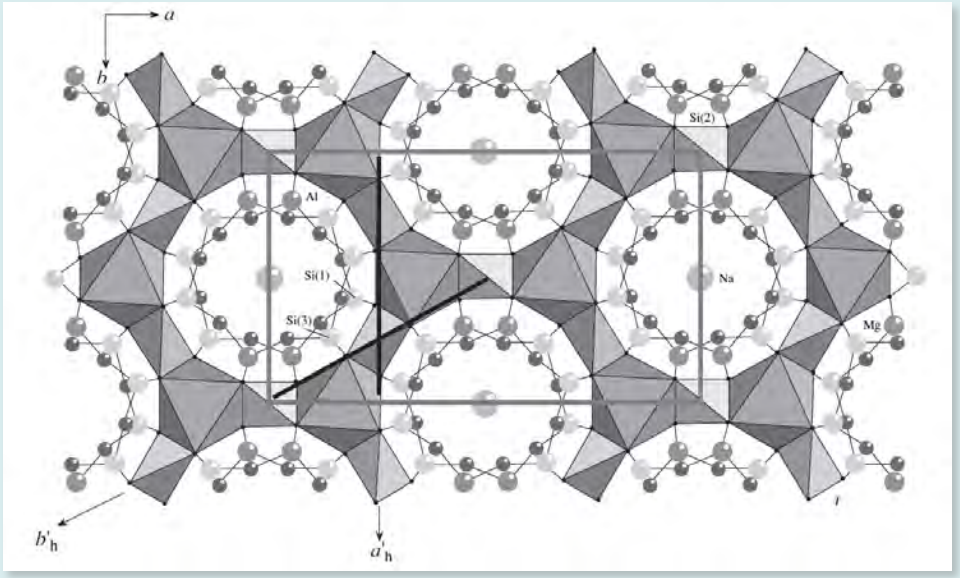
preserved in fluid inclusions?



preserved in cordierite?

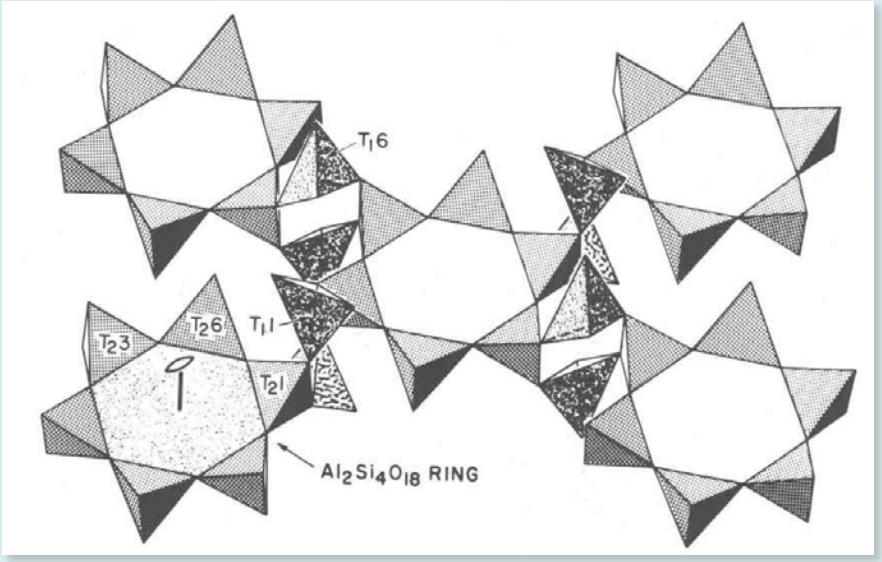
Fluid components in cordierite

analyses and interpretation



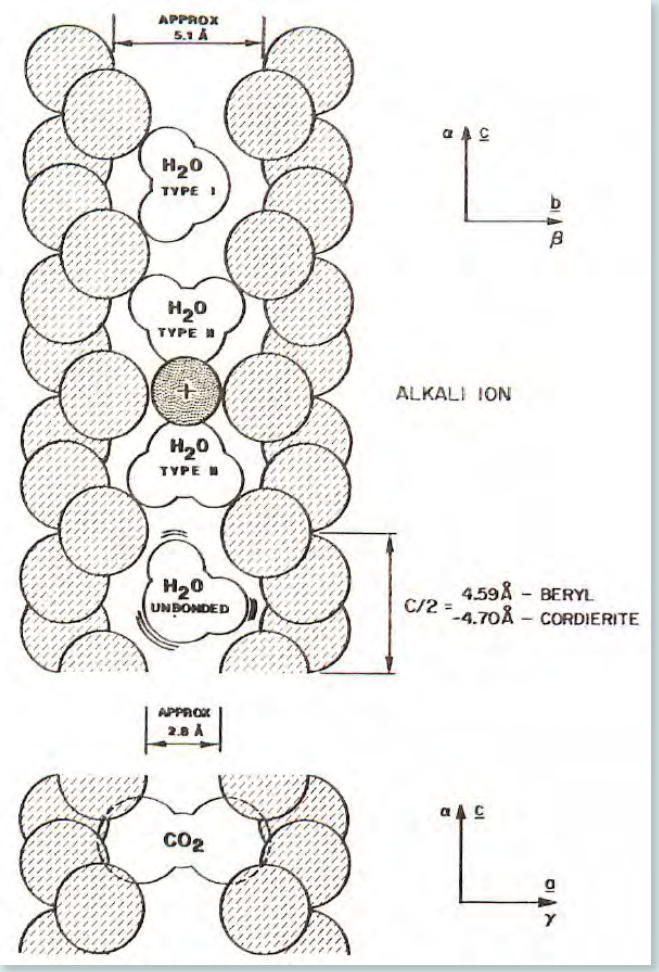
Yakubovich et al. (2004)

Cordierite crystal structure



Armbruster & Bloss (1982)

Fluid components in cordierite



Aines & Rossman (1984)

reported gas components in cordierite:

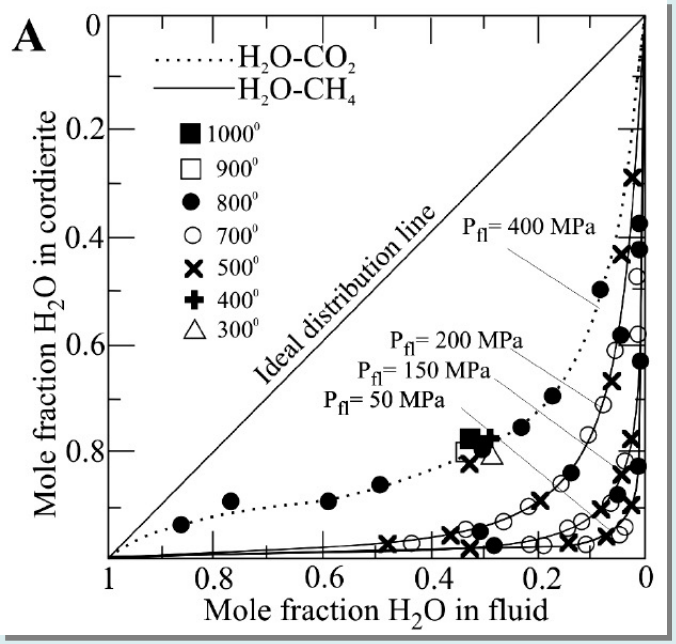
C-O-H-N, noble gases

methods of detection:

H-manometry
Coulometric titration
stepped-heating mass spectrometry
Secondary Ion Mass Spectrometry
Raman spectroscopy

to what extend does the content of cordierite channels reflects the composition of the pore fluid over the mineral at high pressure and temperature?

- total uptake of fluid
- fractionation, absorption
- distribution coefficients
- diffusion, closure temperature



Bul'nak & Shvedenkov (2004)

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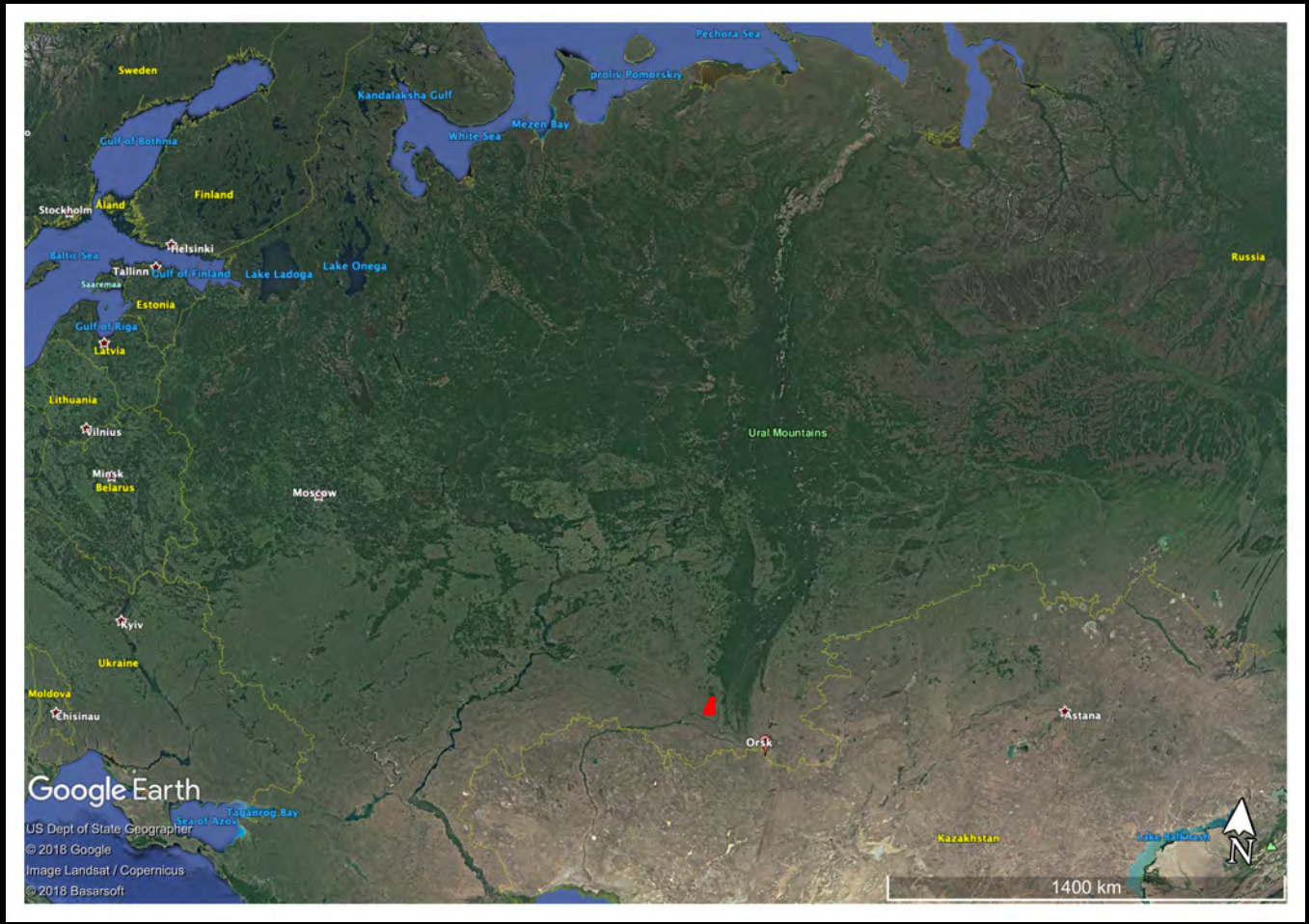
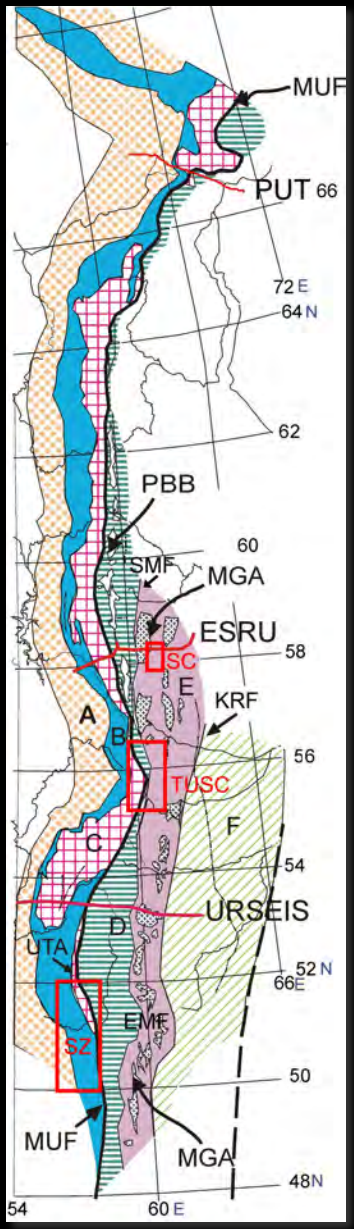
comparison with contemporary fluid inclusion assemblages

for example: Herms & Schenk (1992)

Case study: Khabarny Ultramafic Massif (Southern Ural)



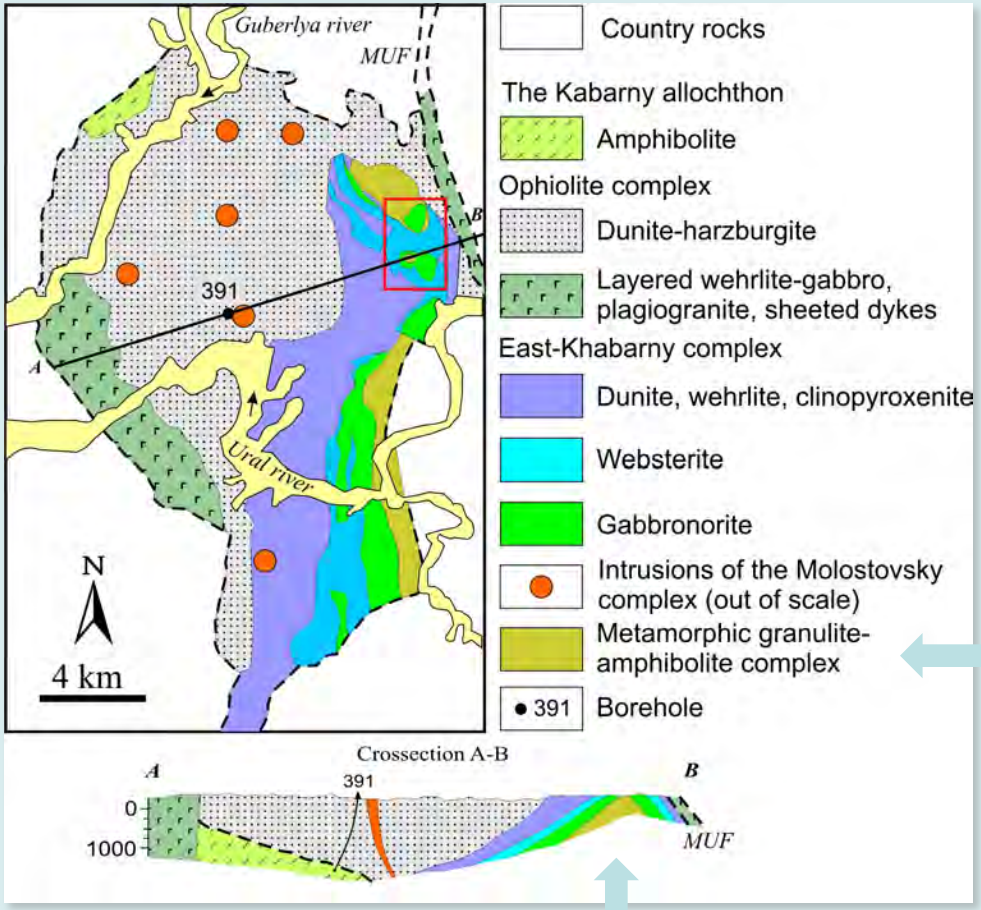


A– Preuralian foredeep
B– West Uralian zone
C– Central Uralian zone
D– Tagilo–Magnitogorskian zone
E– East Uralian zone
MUF – Main Uralian Fault

Khabarny Ultramafic Massif

Russia

Kazakhstan



two-pyroxene granulite
garnetite
graphite-bearing quartzites

Kirilovka anticline area

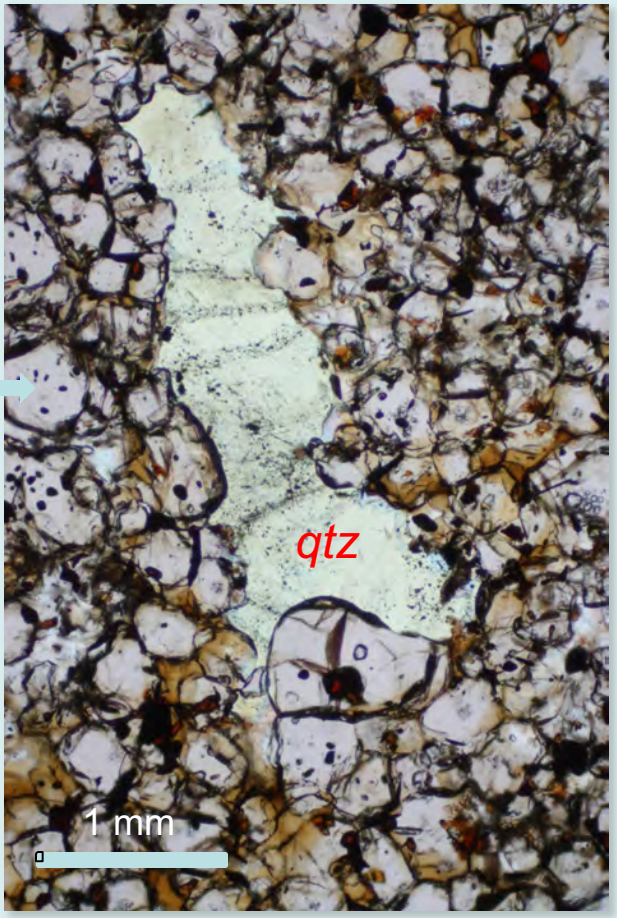
Khabarny Ultramafic Massif

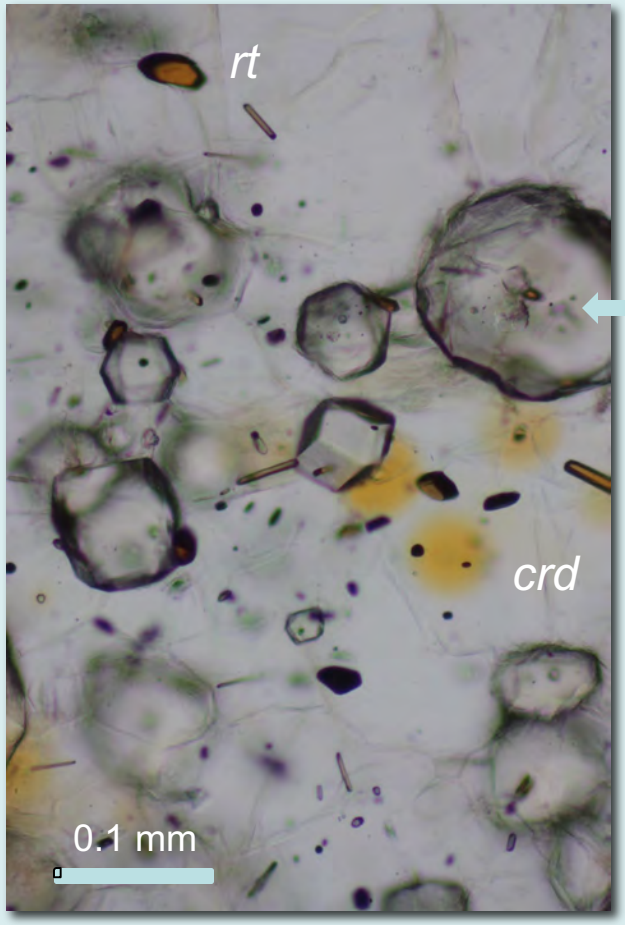
Petrography and mineralogy of garnetite

Petrography and mineralogy of garnetite

main phases
- fine-grained almandine-pyrope-spessartine-rich garnets (75%)
- magnesian-rich cordierite (10%)
- quartz (12%) nodules and inclusions

accessoric phases
- rutile
- ilmenite
- graphite
- magnetite
- plagioclase
- phlogopite
- zircon





grt

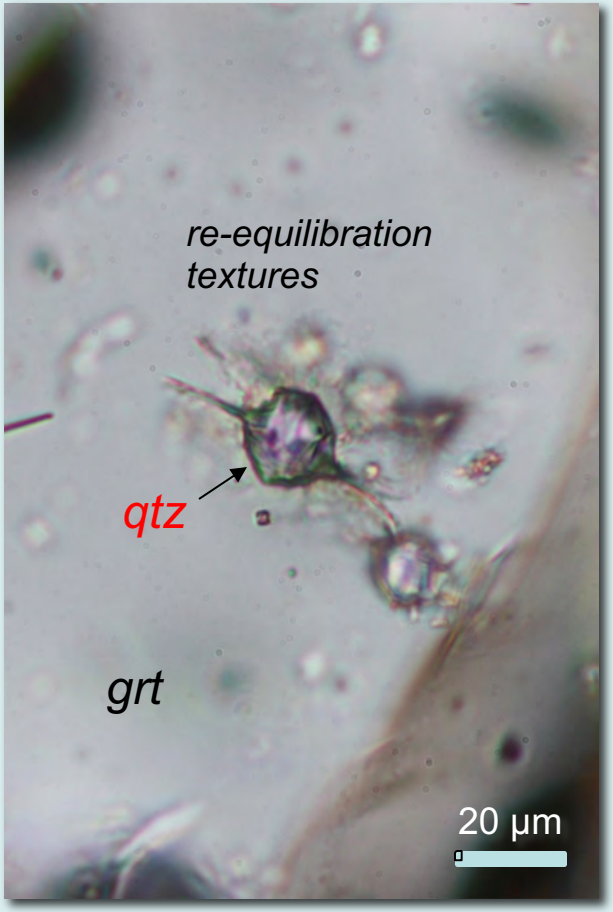
48.5% almandine (±3.9)
34,7% pyrope (±3.3)
10.3% spessartine (±1.1)
1.8% grossular (±1.5)
1.5% andradite (±1.5)

crd

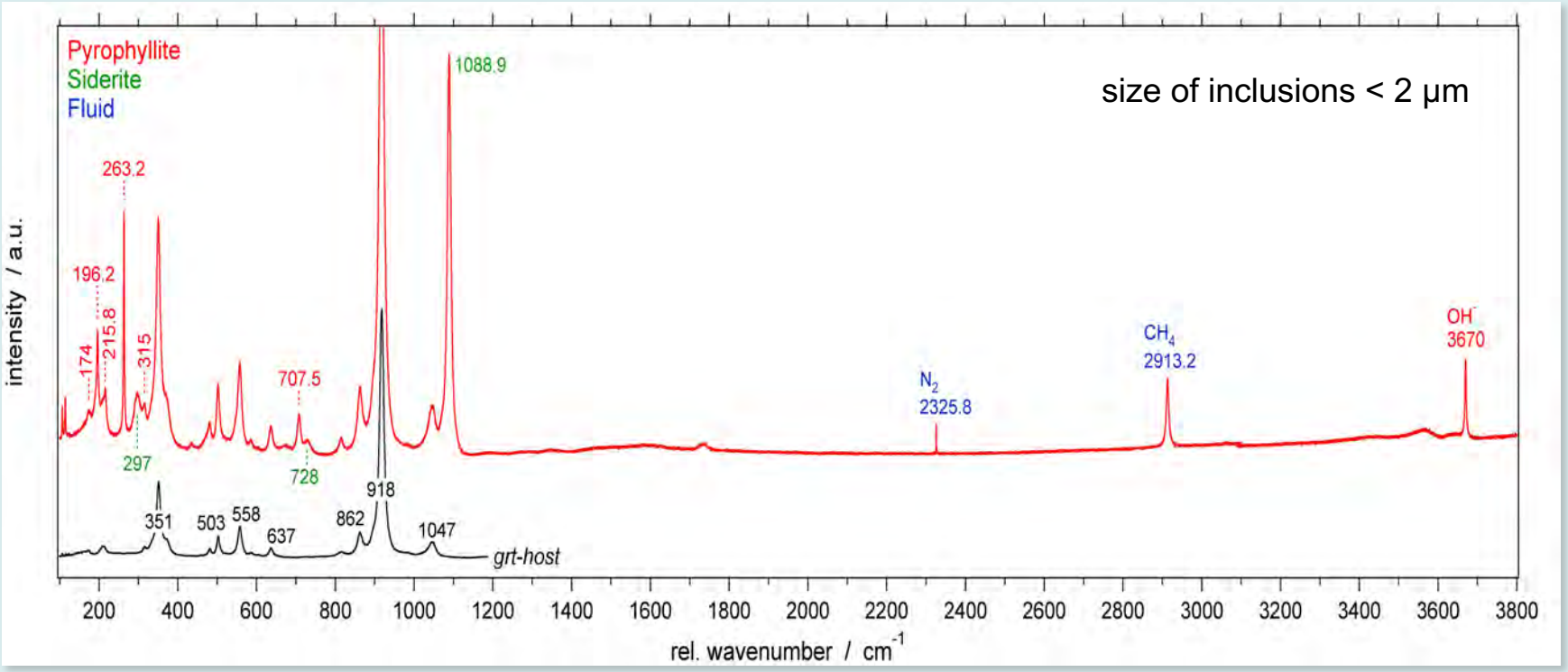
#Mg = 0.787

Solid inclusions in garnet

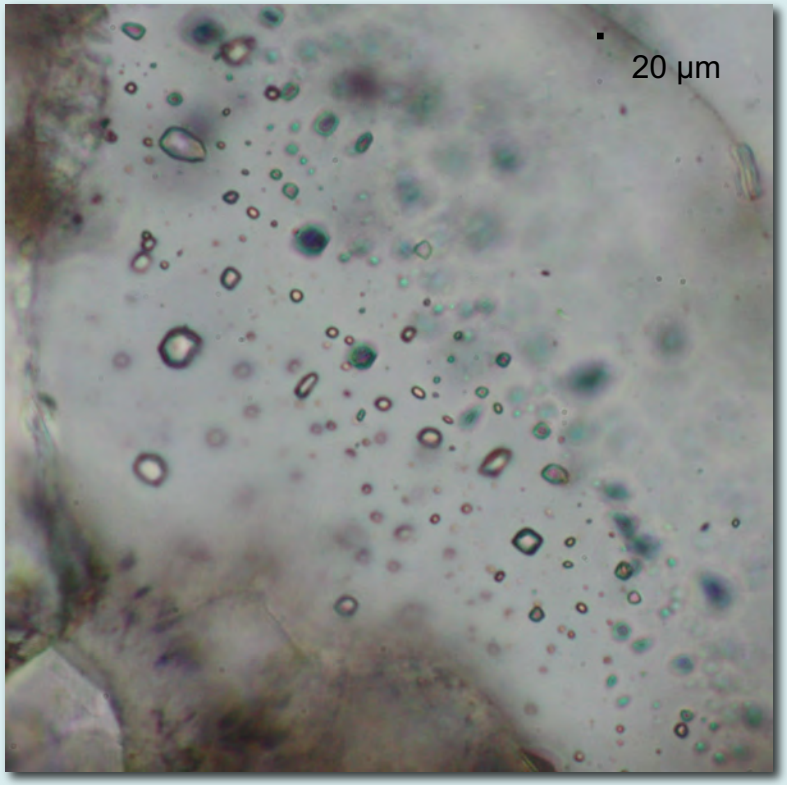
- quartz (90%)
- cristobalite
- ilmenite
- rutile
- graphite
- plagioclase (variable Na-Ca content, albite to labradorite)
- magnetite,
- cordierite
- phlogopite
- zircon

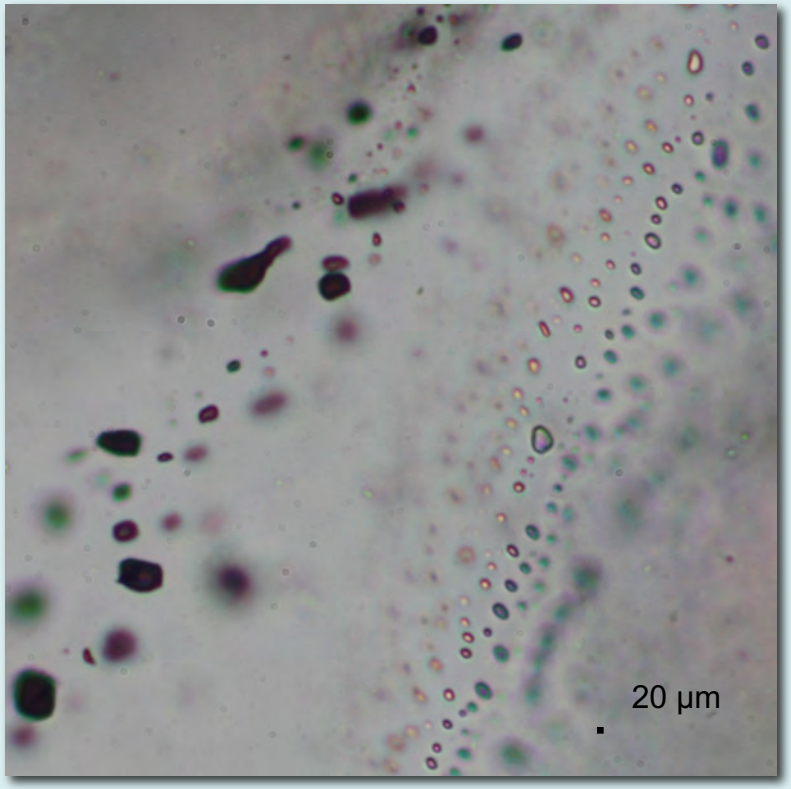


Multi-phase fluid inclusions in garnet

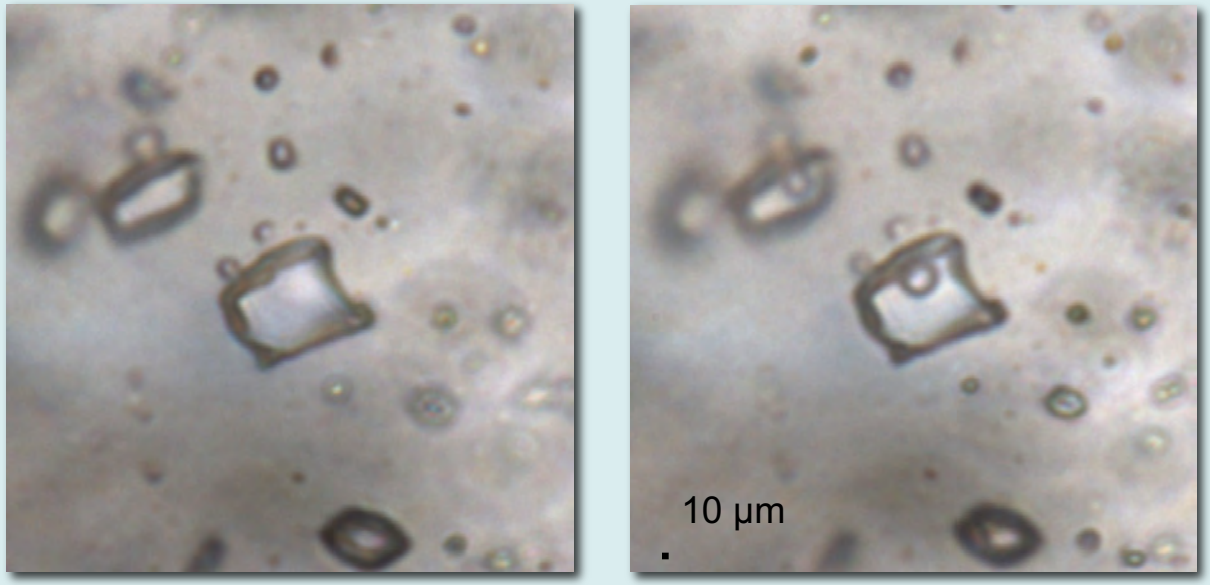


Fluid inclusions in quartz nodules





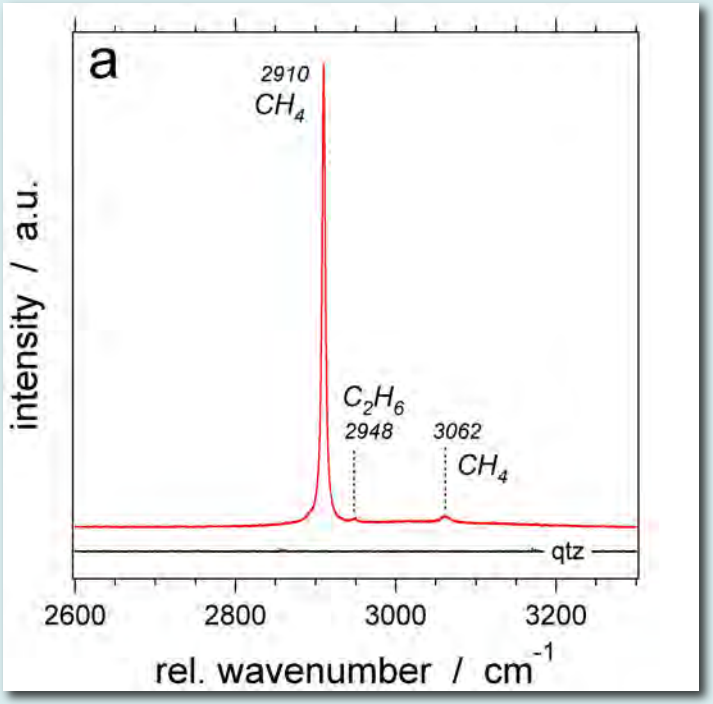
high density CH_4 fluid inclusions in quartz

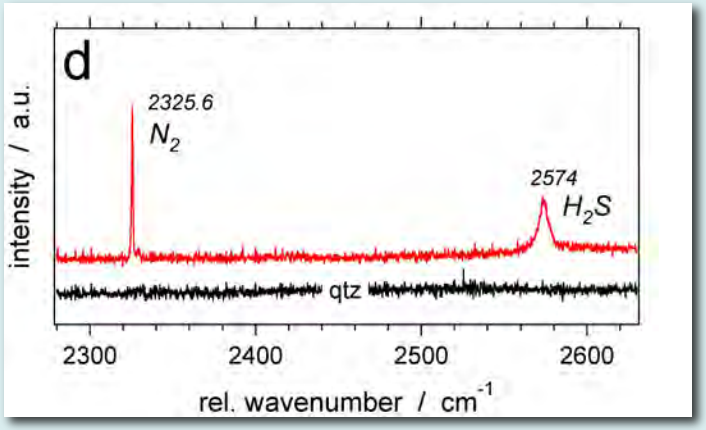


20 ˚C

-150 ˚C

high density CH_4-rich fluid inclusions in quartz



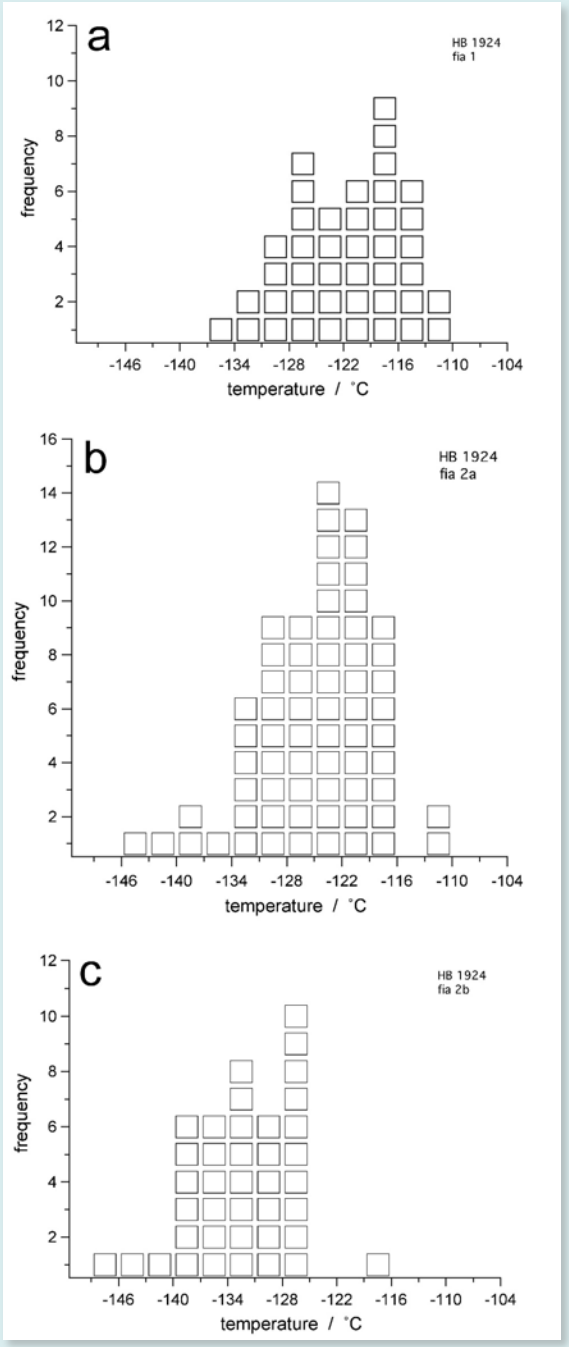


density:

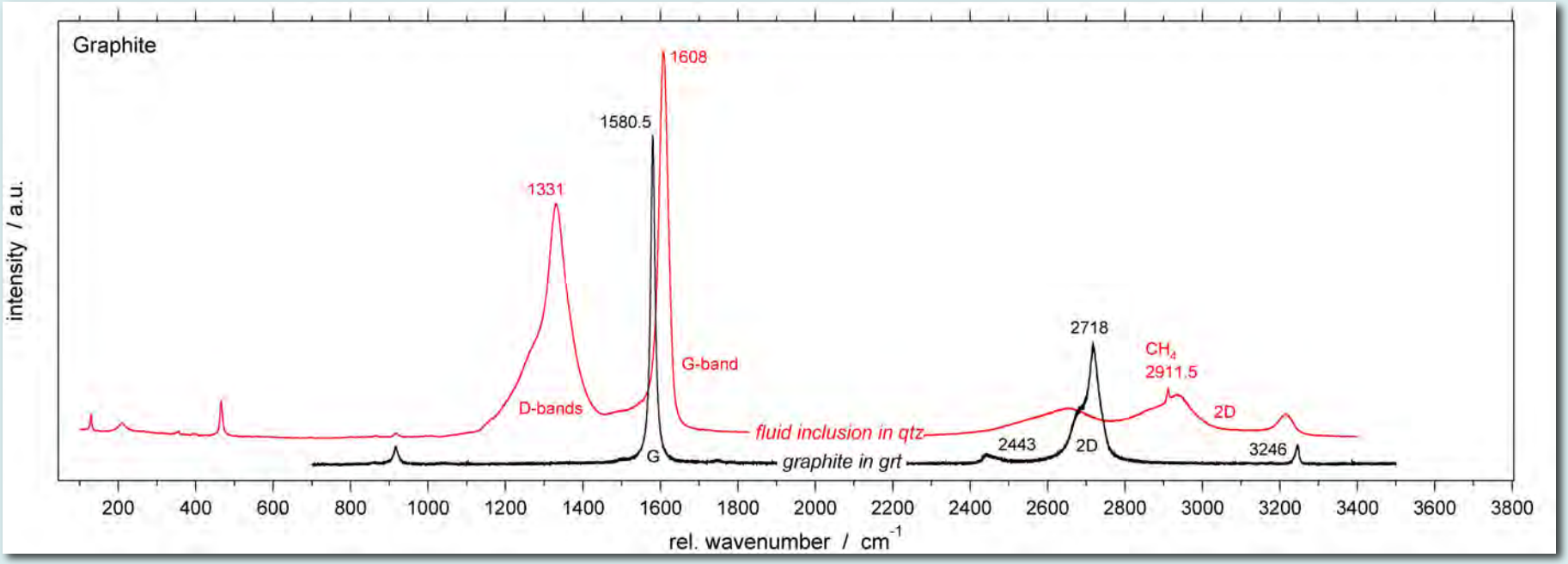
0.349 to 0.367 g/cm^3

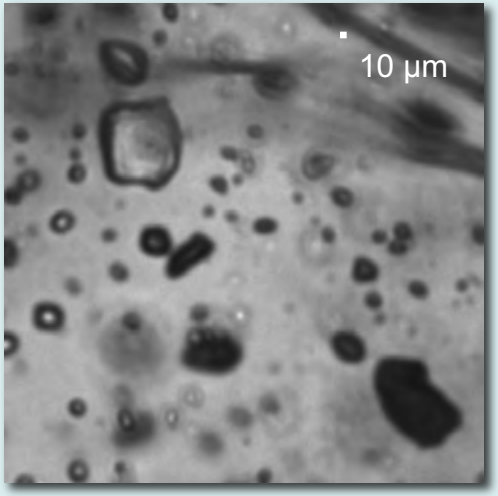
molar volume:

43.7 to 45.9 cm^3/mol



Graphite

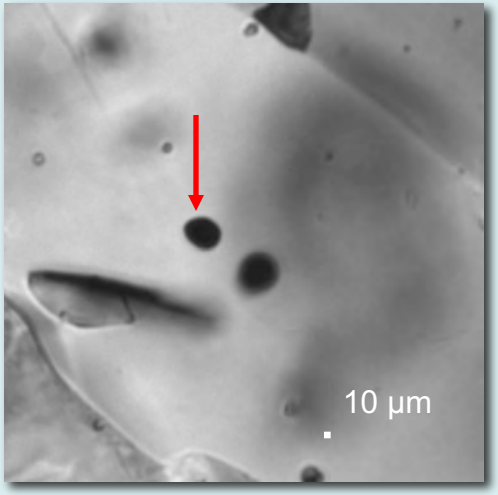




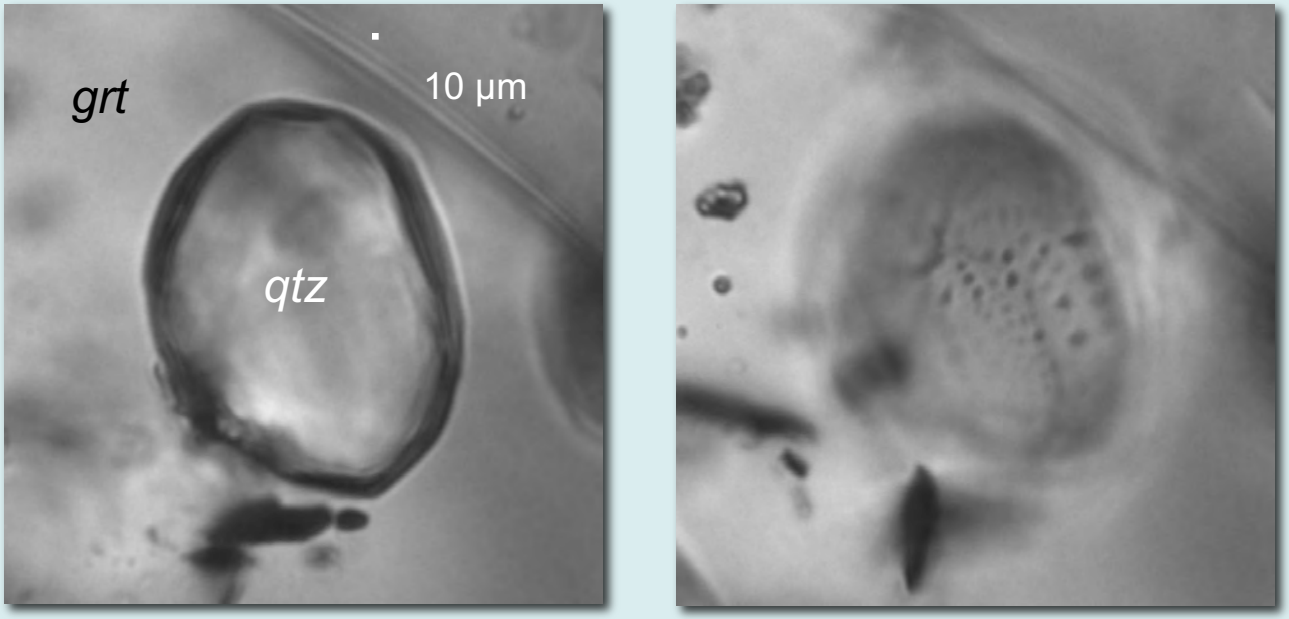
graphite in
fluid inclusions in qtz

crystallisation temperatures of
graphite in fluid inclusions are
calculated at 300 to 310 ± 27 ° C
(IFORS, Lünsdorf and Lünsdorf, 2016)

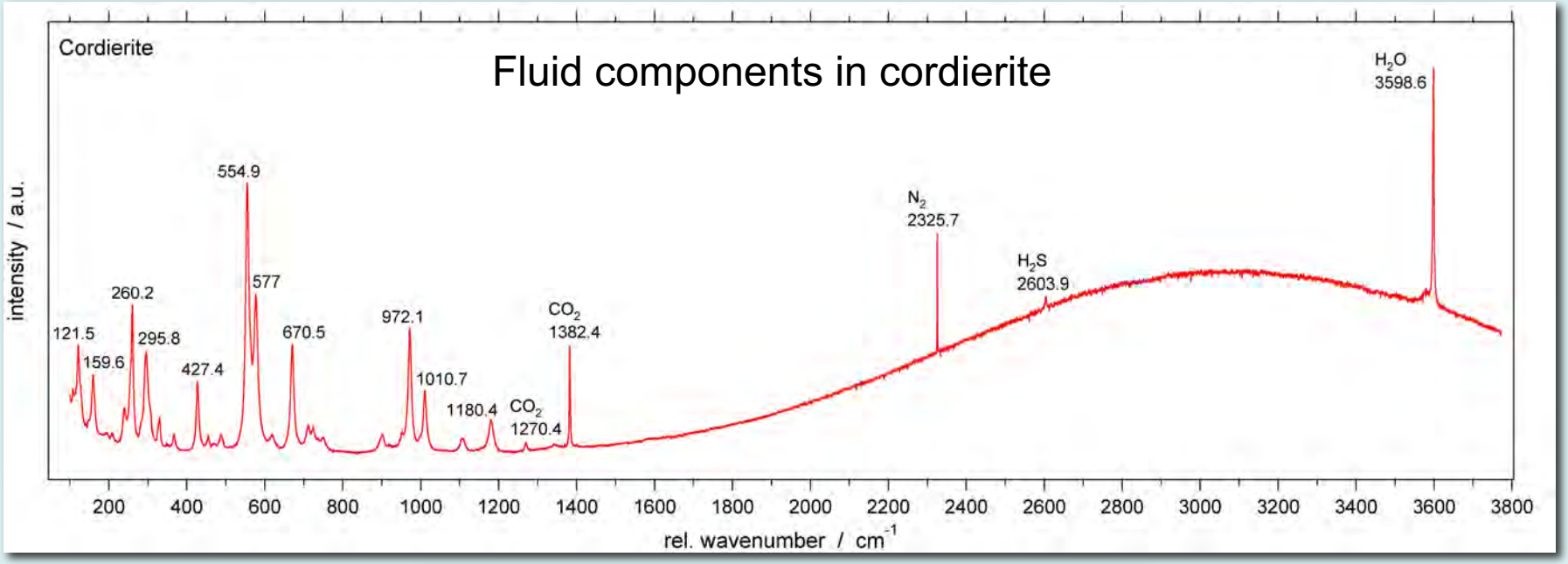
graphite
in garnet
> 600 °C



CH_4 fluid inclusions at quartz surface in garnet

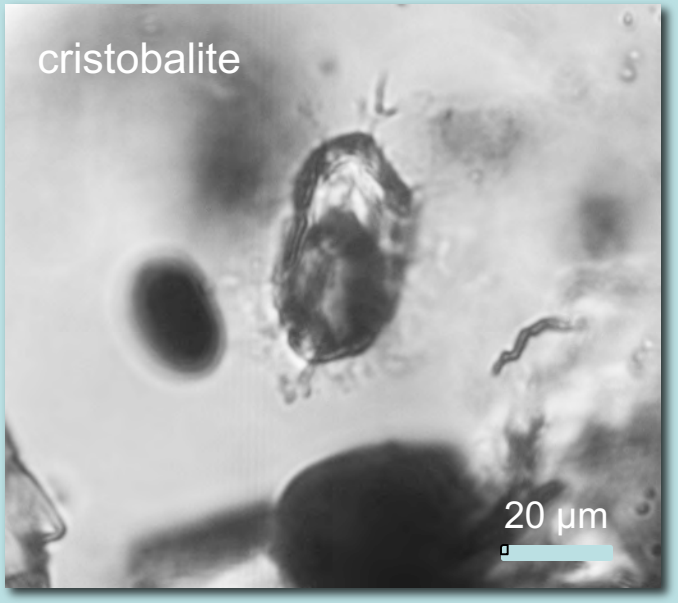


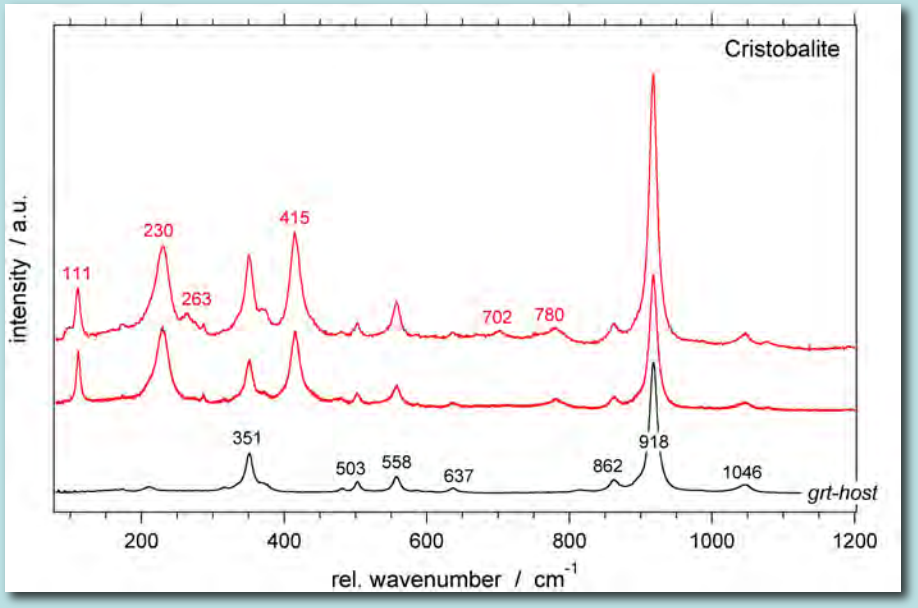
Fluid components in cordierite



Raman band (cm^{-1})	*classification*	*area (a.u.)*	*amplitude (a.u.)*	*width (cm^{-1})*	*Gauss factor*
971.8 (960.2)*	SiO_4 (ν_1)	14673.8 (1940.2)	1162.5 (70.9)	8.4 (25.7)	0.0883 (1.0)
1011	SiO_4 (ν_2)	1052.7	94.4	10.3	0.9373
1179.9 (1167.9)*	SiO_4 (ν_3)	15483.8 (1954.3)	846.1 (55.4)	12.8 (33.2)	0.2034 (1.0)
1269.6	CO_2 (ν_1)	2645.2	261.8	7.3	0.0345
1369.8	$^{13}CO_2$ (ν_1)	50.2	23.0	2.1	1.0
1382.2	CO_2 ($2\nu_2$)	9165.9	2191.0	2.8	0.1304
1394.9	CO_2 (base)	1627.3	38.6	27.9	0.0811
2325.5	N_2 (ν_1)	1362.8	1004.3	1.0	0.2646
2603.2	H_2S (ν_1)				
3598.2 (3585.4)*	H_2O (ν_1) Class I and II	6853.3 (2144.8)	1226.4 (55.0)	3.8 (25.8)	1.0 (1.0)

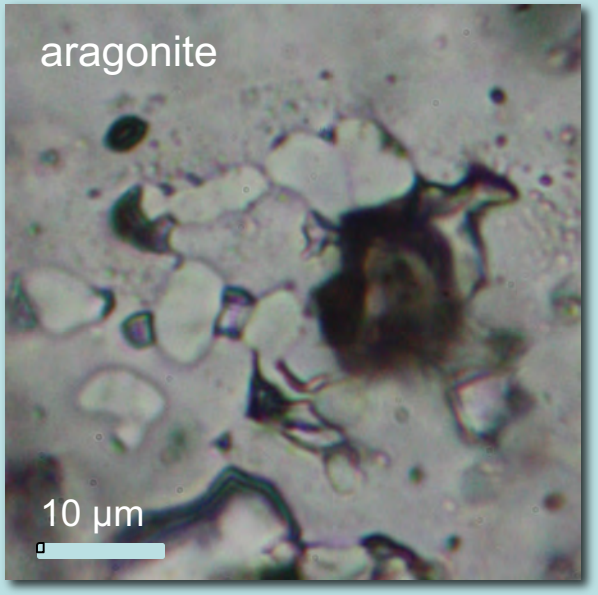
Specific mineralogical observations

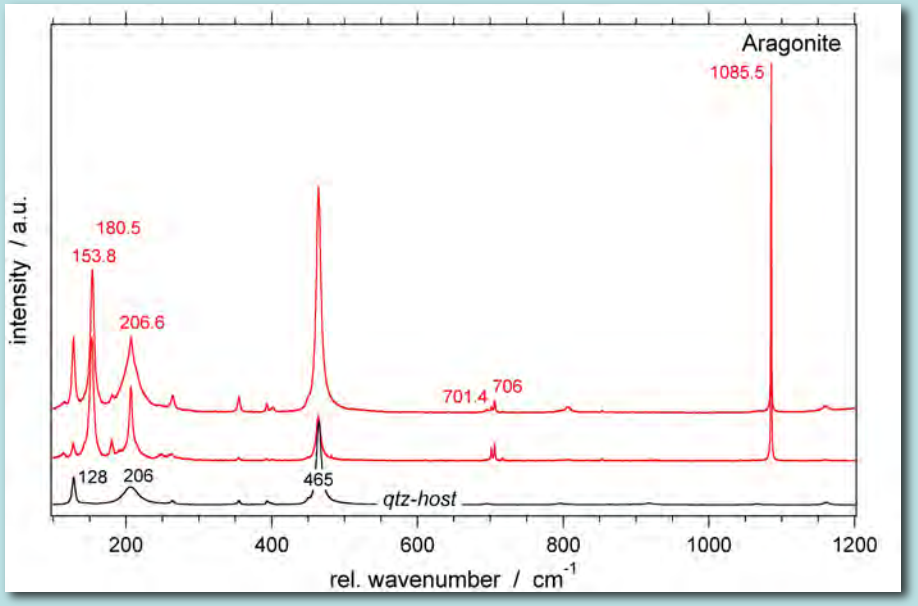




high-temperature metamorphism

Specific mineralogical observations

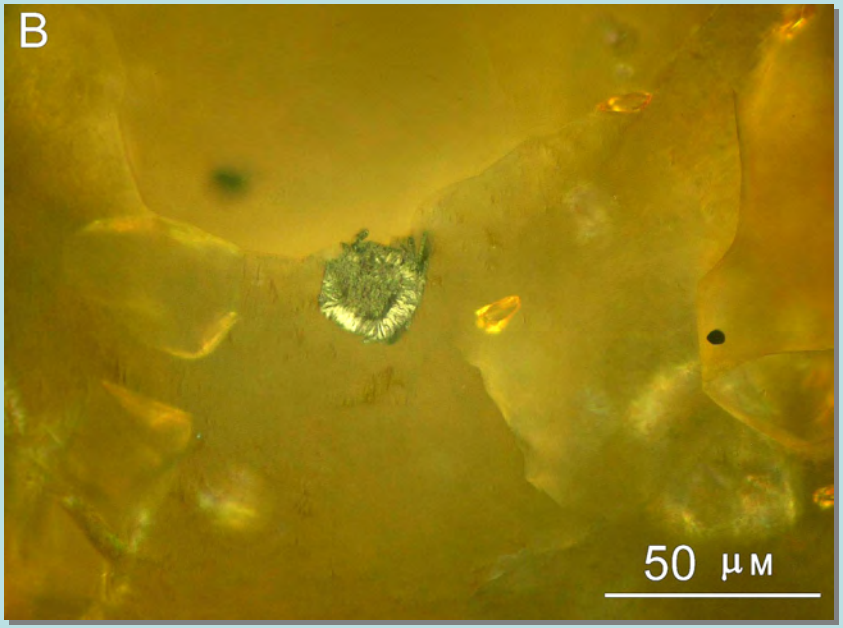




high-pressure metamorphism

Specific mineralogical observations

„cubic“ graphite



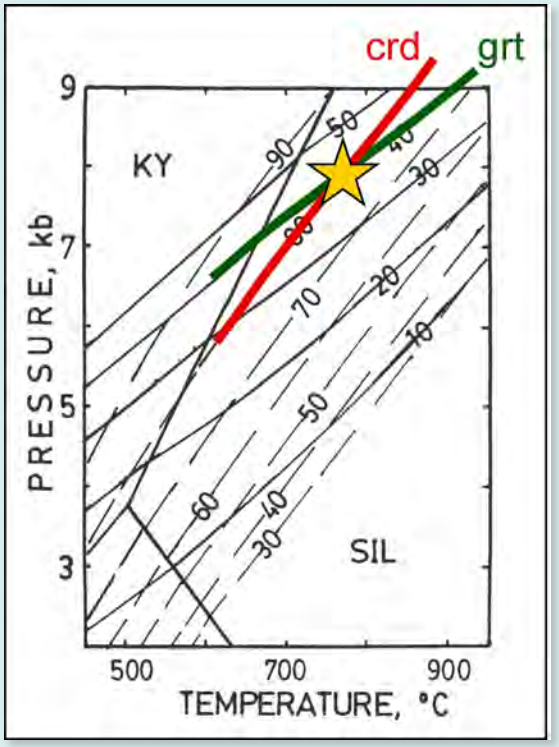
pseudomorph diamond?

Geothermobarometry

Aranovich & Podlesskii (1983)	cordierite-garnet-sillimanite-quartz	
Perchuk & Lavrent'eva (1983)	cordierite-garnet-biotite	
Bhattacharya et al. (1988)	cordierite-garnet thermometer	± 65 ˚C

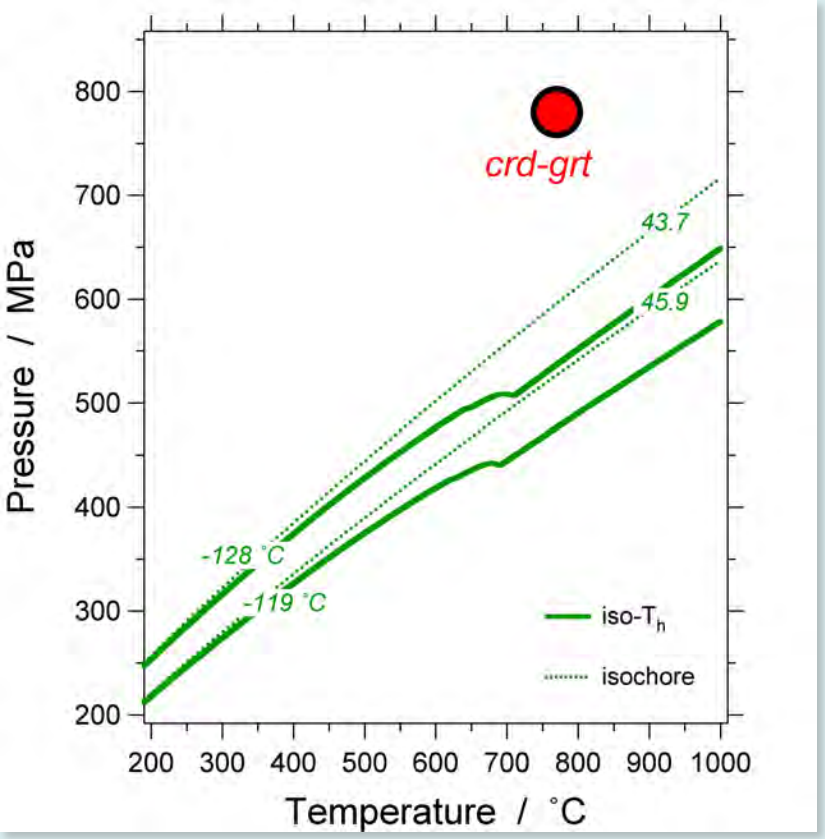
Mg-numbers

cordierite: 0.80 ± 0.01
garnet: 0.41 ± 0.03



Geothermobarometry

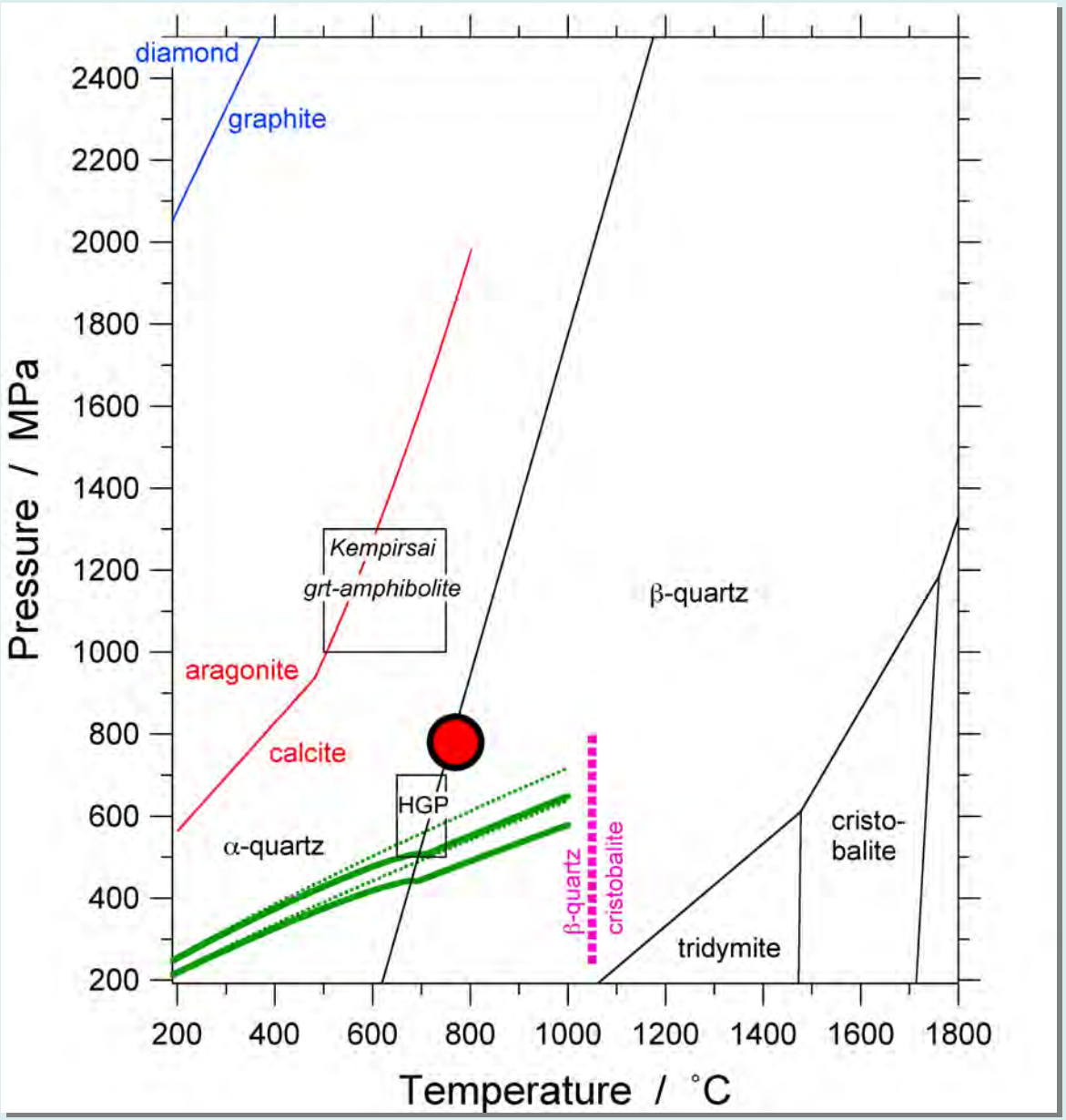
CH_4 isochore/iso-T_h curves



Controversies?

CH_4 and graphite

H_2O and CO_2



garnet-amphibolite (Khabarny)
HGP = hastingsite-garnet-plagioclase