Geochemical modelling within the GeoWell project

GeoWell

Innovative materials and designs for long-life high-temperature geothermal wells

Miskolc, 26/10/2017

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BRGM

The GeoWell project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654497

GeoWell project

H2020 three-year collaborative research project
8 partners and 3 third parties

Developing reliable, cost effective and environmentally safe technologies for design, completion and monitoring of high-temperature (>400°C) geothermal wells:

- Cement and sealing technologies
- Materials and coupling of casings
- Temperature and strain measurements in wells using fibre optic technologies to monitor well integrity
- Development of risk assessment methods

The technology developed will be tested in laboratories and partly in real geothermal environment

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GeoWell project - Geochemistry

Geochemical work within GeoWell is mostly about cements and carried out by BRGM and TNO

How will the cement behave at temperatures exceeding 400°C:

- Curing
- Hydration/dehydration – excess water pressure can damage the cement
- Mineral phases evolution with temperature – effect on the mechanical properties
- Long term duration

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GeoWell project - Geochemistry

TNO is working on cement analysis and laboratory experiments and also on geochemical modelling

- IDDP-1 well (Iceland Deep Drilling Project)
- Located at Krafla geothermal field NE-Iceland which is operated by Landsvirkjun the national power company of Iceland
- Approximately 6 m of the well were dug up and sent to a workshop in Reykjavík to be examined
- Cement samples were taken from all cement layers (1-4)at the top and bottom locations from the 6m section

Source: TNO

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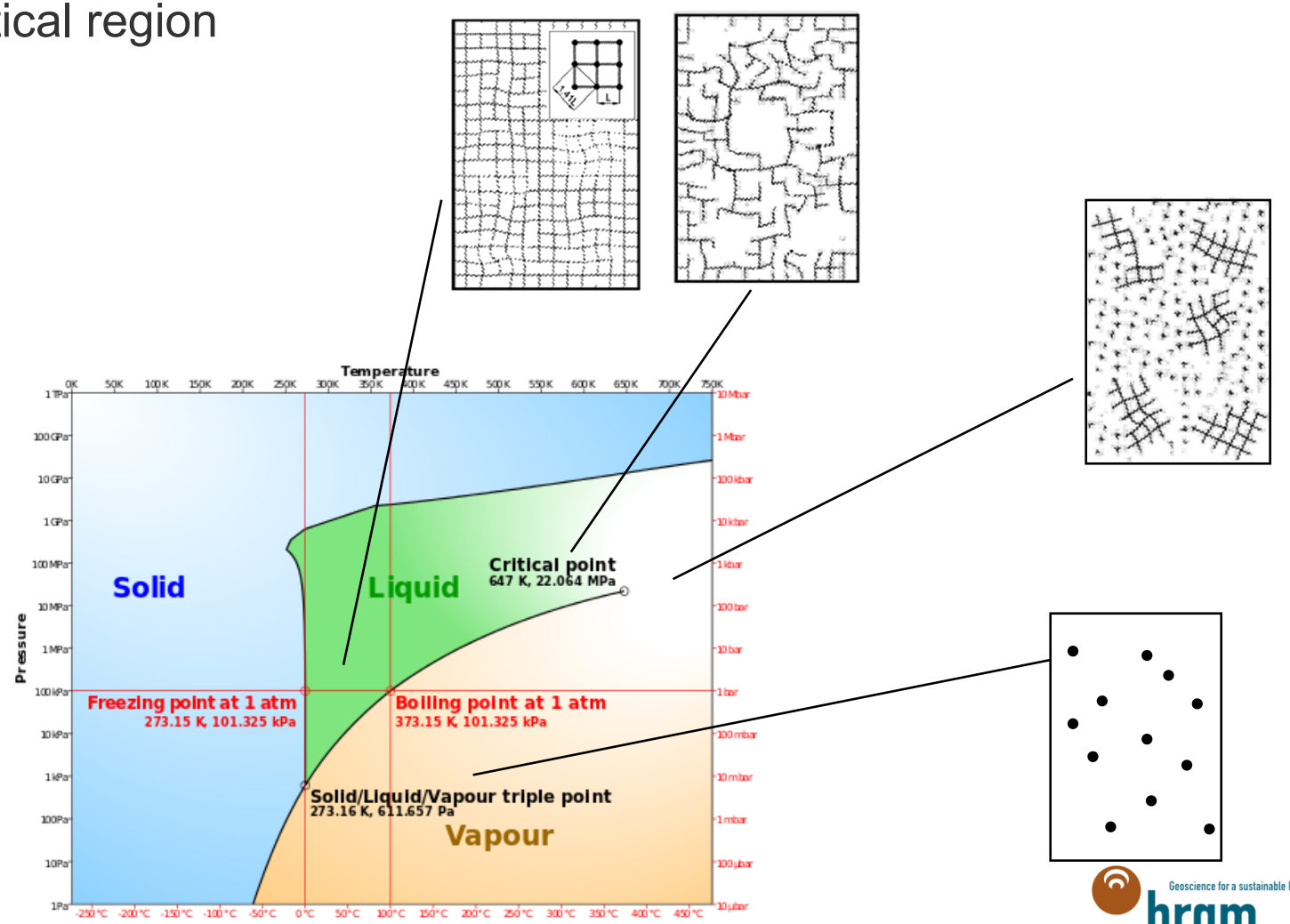
GeoWell project - Geochemistry

BRGM is working on extending geochemical modelling possibilities to water supercritical region



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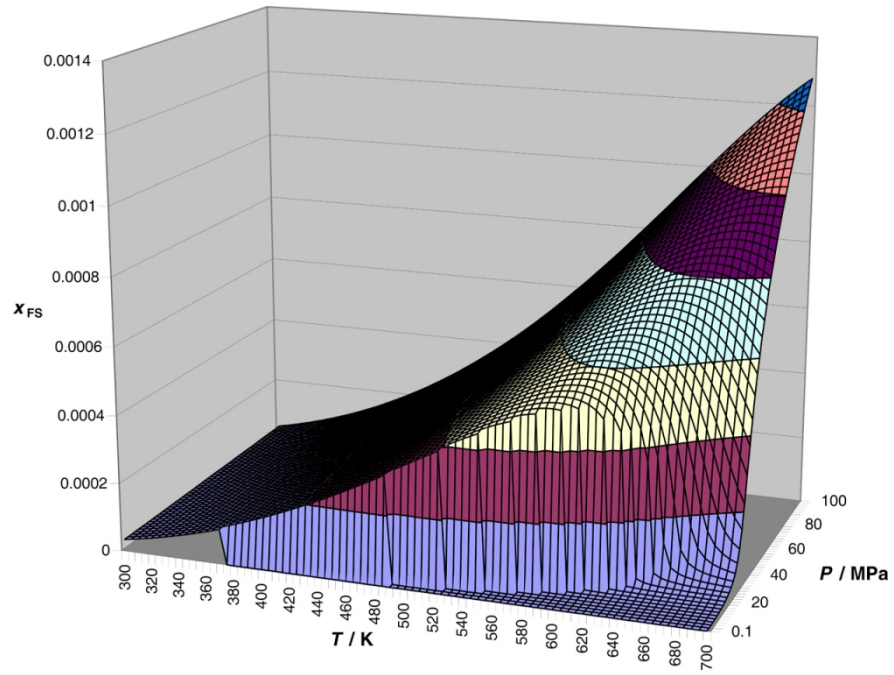
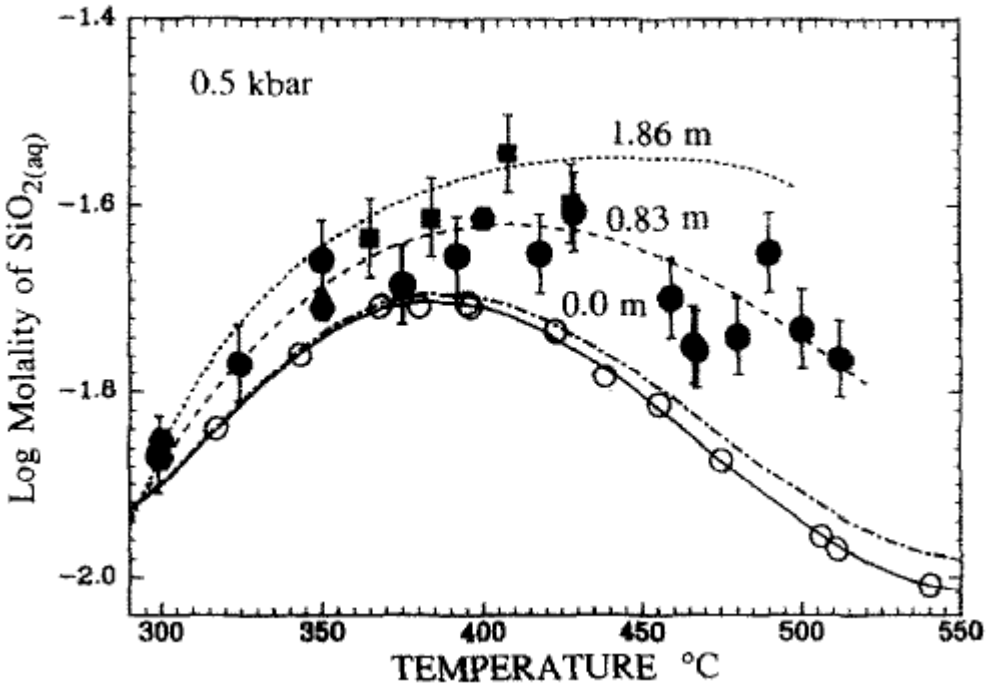
Geochemical modelling in supercritical conditions

Ex: Silica solubility





Xie and Walther, 1993

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Geochemical modelling in supercritical conditions

Goals :

- Extending modelling code capacities
  - Higher temperature
  - Dependance on pressure

- Extending/creating a thermodynamic database suited for those conditions

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GEOCHEMICAL DEVELOPMENTS

Temperature extension

Current

Thermoddem.dat:
limited temperature at 300°C and 85 bars

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(Brgm contribution)

Technical challenges

Aqueous species:
- To implement T°C up to 600°C, 5 kbars

Minerals/gases:
- To complete the database for the T > 300°C conditions

Aqueous species

HKF estimates

Aqueous/mineral/gases

Test at T > 300°C (10 species thermodynamic + solubility data)

Extending to the whole database

Verification (geothermal/ hydrothermal field cases)

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HKF MODEL

Useful to compute the equilibrium constant of aqueous complexes

Methodology

$$-\mathrm{RT}\ln K = \Delta G_r^0 = \sum_{produits} \Delta G_f^0(produits) - \sum_{reactif} \Delta G_f^0(reactif)$$

- **The Gibbs free energy of formation is computed following HKF model using several parameters**
  - The standard Gibbs free energy of formation at (T_r,P_r): obtained from equilibrium constant determined on experimental data
  - The standard entropy at (T_r,P_r):
    - For ionic species: found in the literature
    - For complex species: found in the literature, optimized on experimental data or computed using Sverjensky et al (1997) correlation
  - The HKF parameters:
    - For ionic species: found in the literature
    - For complex species: found in the literature, optimized on experimental data or computed using Sverjensky et al (1997) correlation

Objective:
Using Sverjensky et al (1997) correlation to determine equilibrium constant of aqueous species over a wide temperature range.

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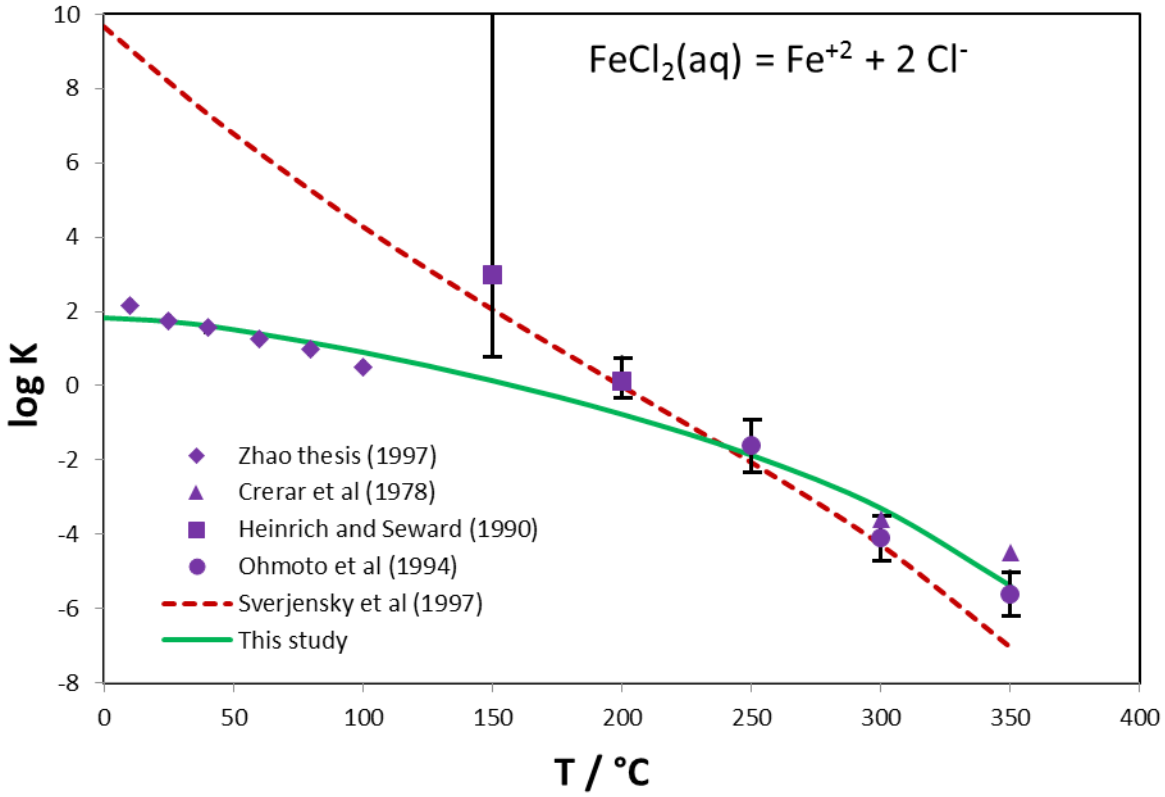
EXAMPLE

Dissociation constant of $FeCl_2(aq)$

- Parameters for ionic species are provided by Shock et al (1997)
- HKF parameters are determined using the correlation of Sverjensky et al (1997)
- Equilibrium constant obtained are compare with data provided by literature



Outlook:

i)Using this methodology on a restricted system to determine equilibrium constant of complex species at high temperature (between 0-600°C)

ii)Compare the results with literature data

iii)Realize calculation on a test case using this new model

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DATABASE

Temperature extension

Objective

- **A database allowing geochemical calculations up to 600°C with PHREEQC-V2**

Starting point

PHREEQC-V3:
limited temperature at 350°C
(due to of water properties)

Thermoddem.dat:
limited temperature at 300°C

Evolution

HKF estimates

Thermoddem

ThermoZNS

Provides equilibrium constants along a T-P profile

Adaptation of the current code for T > 300°C

Geochemical database for a specific T-P profile

Calculations with Phreeqc-V2

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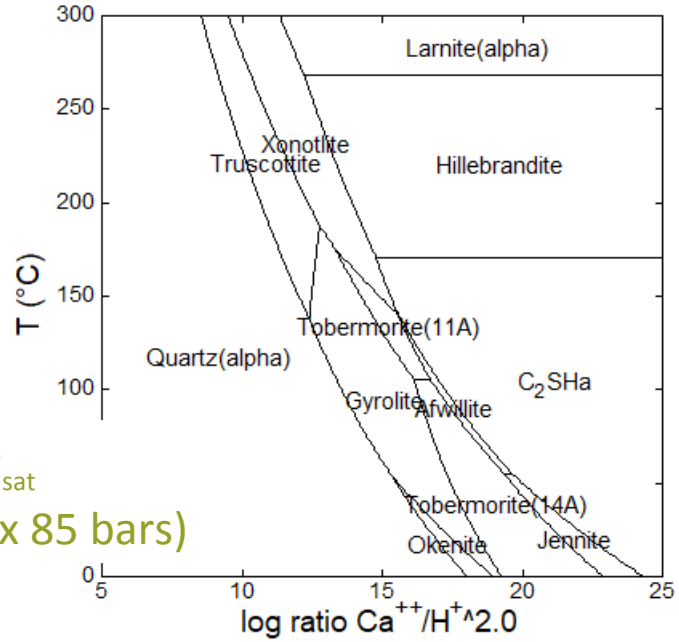
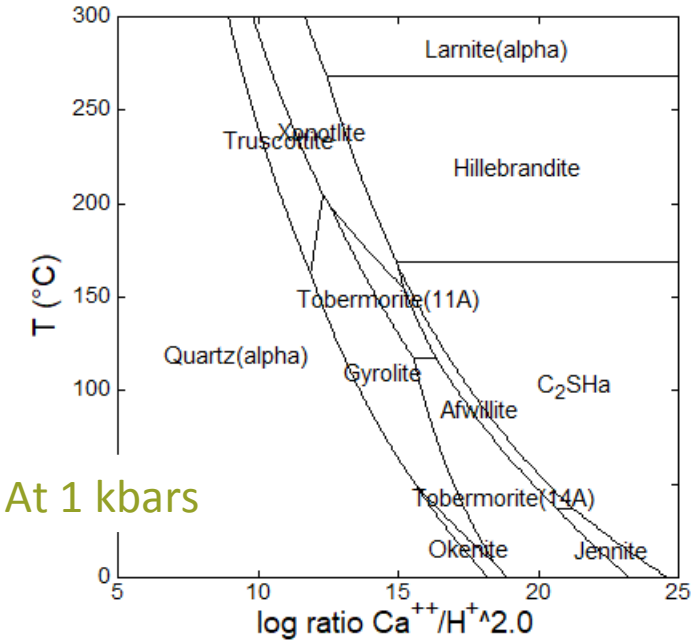
EXAMPLE: implementing pressure effects

Stability diagram in the $CaO-SiO_2-H_2O$ system



At P_{sat} (max 85 bars)



At 1 kbars

- Few modifications for the stability domains of the minerals
- More consequences expected for gases and hydrates

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GeoWell project – Geochemistry – Next steps

Having a version of Phreeqc/database able to perform at supercritical temperature

Compare to lab results from TNO

Predictive modelling

Thank you for your attention

www.geowell-h2020.eu

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