Introduction and geochemical aspects of the GEMEX project

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GEMEX – Geochemical activity highlight

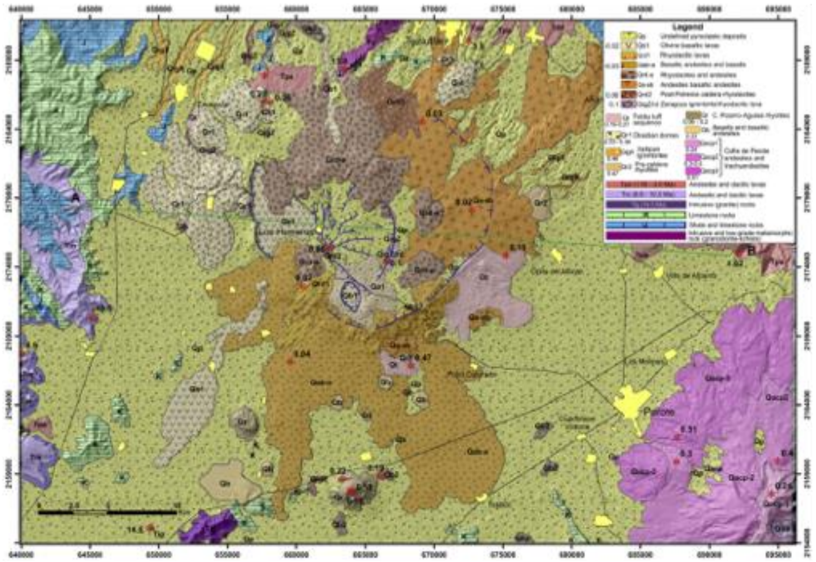
WP	Objective of activity	Status-quo
WP 3	• Integrative 3D modeling and characterization of the volcanic-geothermal system in 3 scales • Analogue modeling (tectonics - volcanic interaction)	• Preliminary LH and AC model • Ongoing well data requests • Draft report "Regional structural and tectonic synthesis for AC and LH"
WP 4	• Understand tectonic control on fluid flow in active and exhumed systems • Geochemical characterization and origin of fluids	• Structures: Collection of structural and kinematic data in all systems • Fluids: Preliminary assessment of geochemical data (LH) relative to waters discharged from 16 deep wells; First soil gas survey (LH); Fluid inclusion analyses (palaeo fluids); 3 HT tracer candidates (stable at 300°C) • Rocks: Samples for isotope and magnetostratigraphic studies (i.e., Radiometric dating, Geochronology)
WP 6	• Reservoir characterization (rocks, fluids, fractures) by experiments, analyses and conceptual models	• Sample treatment/Workflow defined (planned meas., meas. conditions, sample specifications and requirements) • PetroPhysicalProperties Database P^3 • 2 field trips for rock sampling: Key lithologies within the calderas, plus well/surface precipitates sampled; Comprehensive LH core catalogue + foto docu; First lab measurements on 01/17 rock samples; Shipment of rock samples 2nd field trip • Permission for drill plugs (LH) requested (3rd field trip) + sampl. of add. outcrop analogues of reservoir & basement planned • Multiple well data sets provided by CFE (LH, AC), not yet all necessary data accessible • Hydraulic fracturing workshop (AC)
WP 8	• Concepts for the development of superhot resources	• Workshop on "Corrosion, Erosion and Scaling in Los Humeros" • Agreement to test materials suitable for installations in a superhot well • Permission from CFE for a surface test of materials is already obtained • Current efforts to get permission for a downhole test • Currently the materials for installations in superhot wells are prepared • Data collection of soil trace elements in geothermal areas • Develop innovative chemical approach to test pollutant mobility

HORIZON 2020

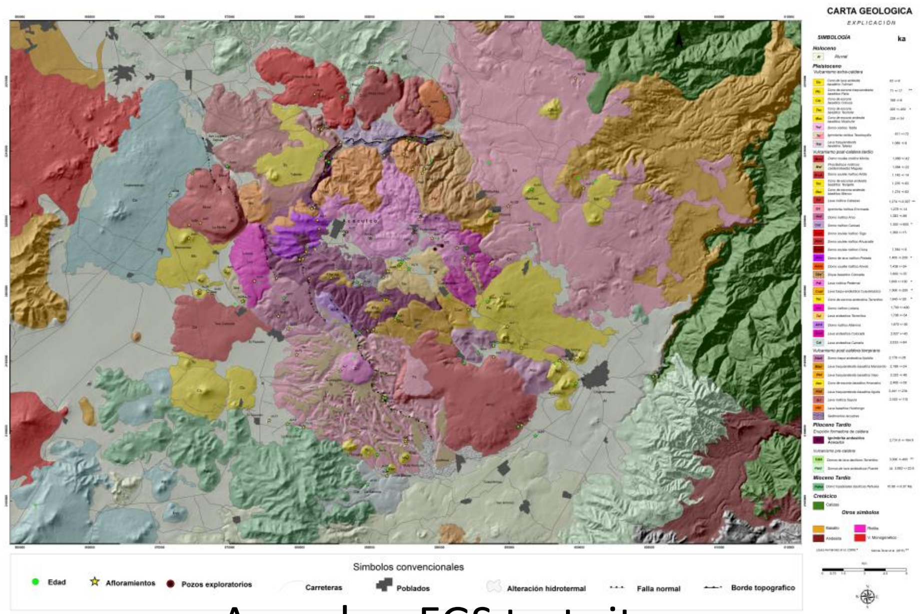
Los Humeros, Acoculco, Las Minas

HORIZON 2020

GEMex

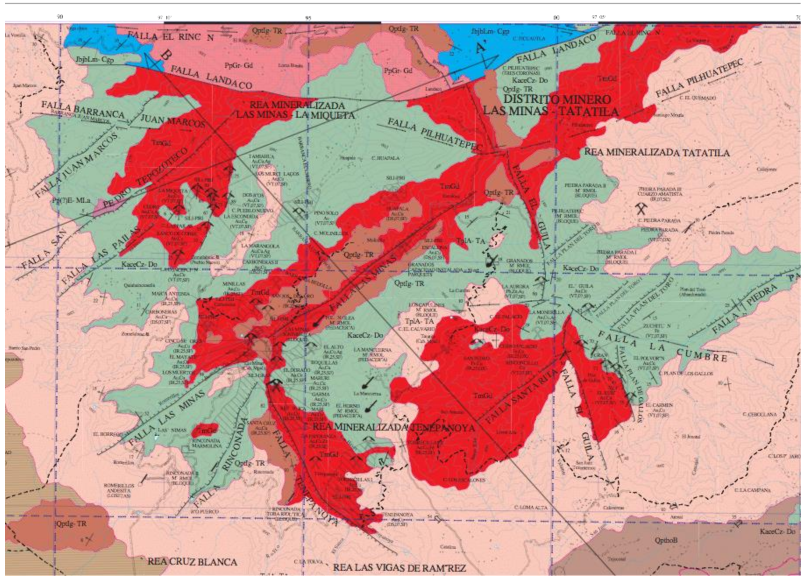


Los Humeros, Super-Hot geothermal system.



Acoculco, EGS test site.

Las Minas: Exumed system, analogue to Los Humeros with outcropping formations.

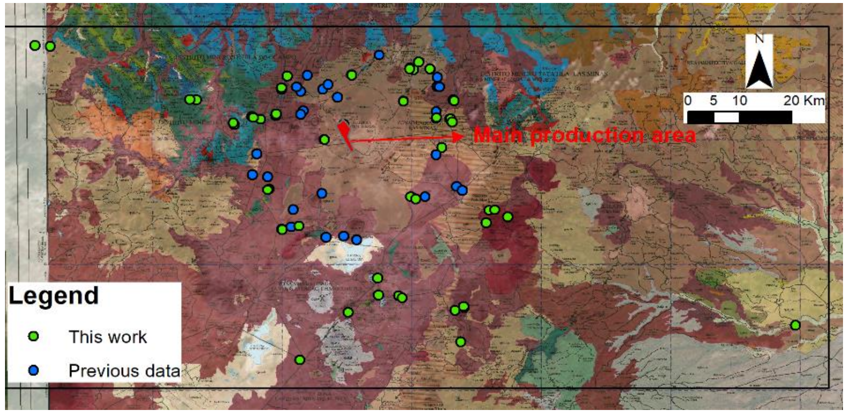


CNR - IGG Main goal (Task 4.3)

1) Define the origin of the geothermal fluid and identification of main recharge areas (stable isotopes of water);
2) Define physico-chemical characteristics of fluids and study its evolution (estimations of T and P at depth, secondary processes, …)
3) Identify the spatial distribution of CO_2 flux anomalies and its correlation with main faults/fracture.

⬇

Better definition of a *conceptual model* of the geothermal system



Field measurements: XY coordinates, altitude, T, pH, Electric Conductivity, Dissolved Oxygen, flow rate, depth (in case of wells) and total alkalinity.

Lab. analysis: Na, K, Mg, Ca, Cl, SO_4, NO_3, SiO_2, F, Li, B, Sr, As, δ^2H and δ^{18}O

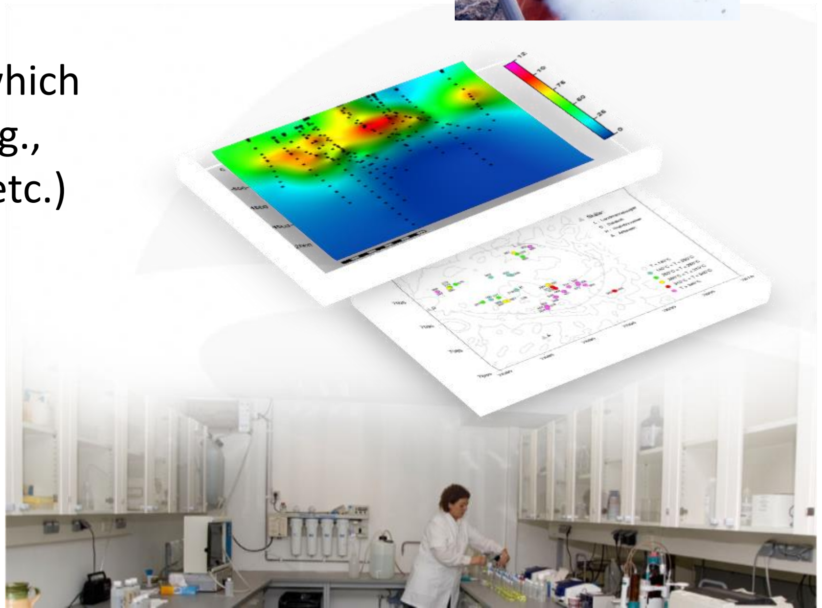
Iceland GeoSurvey - ISOR

Geochemical studies performed at ÍSOR include:

- Sampling of high and low temperature wells
- Chemical analysis of the samples
- Calculations of the deep fluid composition using geochemical computer codes e.g. WATCH
- Monitoring of the CO_2 soil degassing
- Interpretation of the data
- Consulting at all stages of geothermal development: exploration, development and production stage

Main task within GEMex:

- Development of a new computer code RockJuice which will extend features already included in WATCH (e.g., mineral dissolution, precipitation, boiling, mixing, etc.)



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Soil gas measurements at Los Humeros Volcanic Complex

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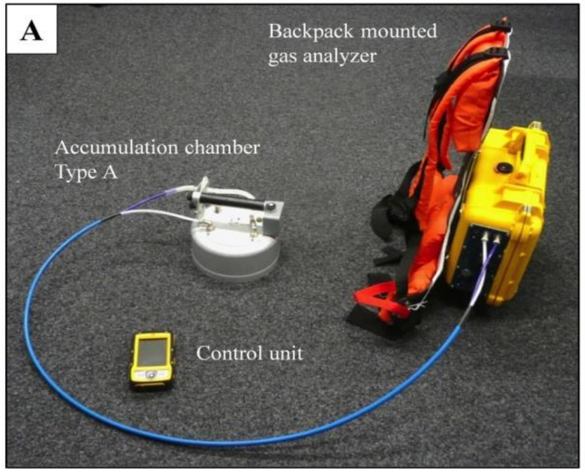


Accumulation chamber technique

Use of soil gas measurements:

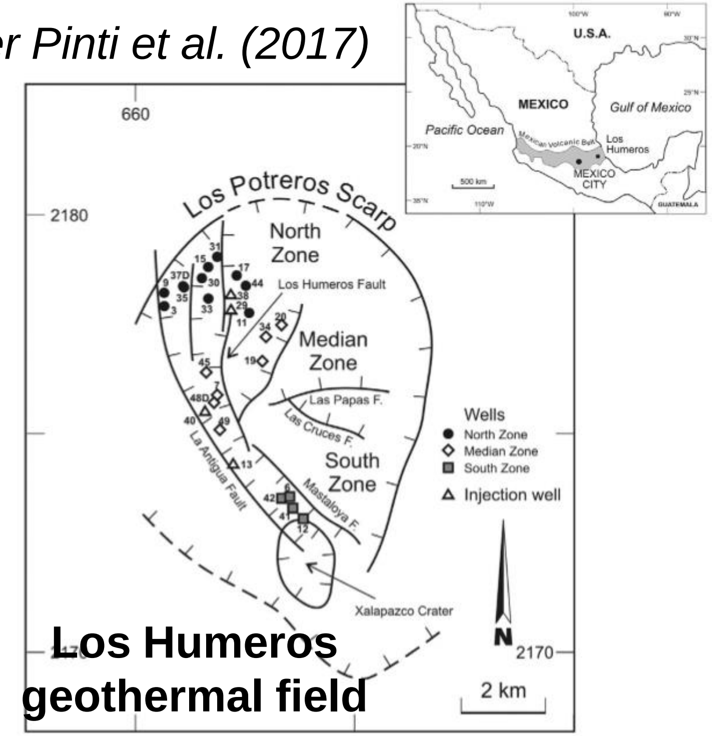
- Fault zone analysis
- Understanding the pathways of fluid migration within the system
- Assessment of relative structural permeability
- Monitoring of spatial and temporal changes
- Information on the origin of gases

Gamma spectroscopy

Planned activities:

Methods	Parameter
Alpha particle spectroscopy	^{222}Rn, ^{220}Rn
Micro gas chromatography (µ-GC)	CO_2, CH_4, H_2, N_2, O_2, SO_2, H_2S, Ne, He, Ar
Isotopic ratio mass spectrometry (IRMS)	$\delta^{13}C_{CO2}$ isotopes
Quadrupole mass spectrometry (QMS)	He, ^{40}Ar, ^{38}Ar, ^{36}Ar
High- resolution mass spectrometry (SMS-Sector field mass spectrometer)	$^{3}He/^{4}He$ ratio

After Pinti et al. (2017)



Los Humeros geothermal field

> Develop auxiliary chemical and isotope geothermometers like Na-Li, Na-Rb, Na-Cs, K-Sr, K-Mn, K-Fe, K-F, K-W and $\delta^{18}O_{H2O-SO4}$ and compare the temperatures estimated from them with:

- those using classical water geothermometers (Na-K, Na-K-Ca, K-Mg, SiO_2…)
- gas geothermometers (CO_2-CH_4-H_2S-H_2, CO_2-CH_4-H_2, CO_2-CH_4, H_2-Ar, CO_2-Ar…)
- numerical multicomponent geochemical modelling

in order to better know the deep reservoir temperature in HT volcanic environments such as Los Humeros and Acoculco

Team : B. Sanjuan, F. Gal, R. Millot and P. Durst

> Campaign of water samples collected from selected geothermal wells in Los Humeros area and from thermal springs in Acoculco area, envisaged at the end of 2017

> Isotope and chemical analyses

WP4 Field data collection

BGS geochemistry activities within the GEMex project

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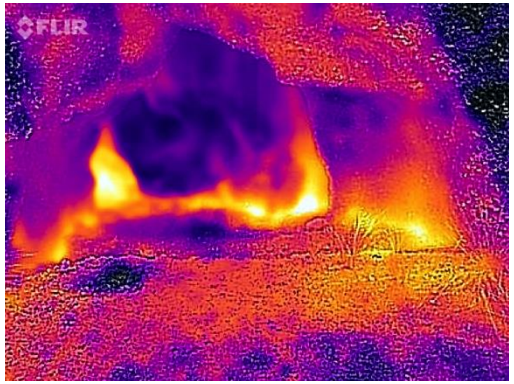
- Objective: Use field data to identify ongoing processes in the reservoir.
- Aim 1: Study of exhumed systems, (ancient) equivalents of what is ongoing in the deep subsurface (mineral assemblages reflect previous geochemical processes).
- Aim 2: Geochemical surveying of soil gases (identification of surface faults with high permeability to fit into 3D site-wide models, identification of gas source via isotopes etc).

Contact zone between igneous and sedimentary rocks

Sampling waters and gases from geothermal springs

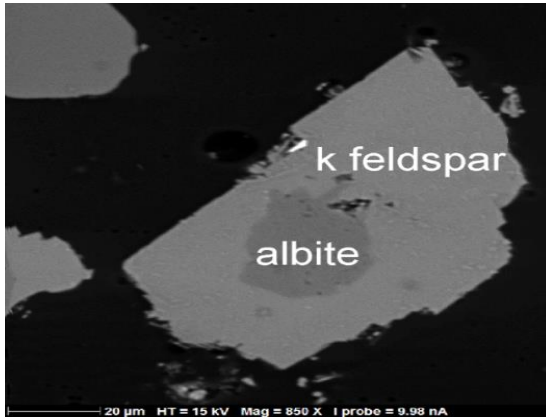
Thermal imaging of gas vents show coincidence of mass and heat flow



Fluid rock interaction experiments at supercritical conditions

They are performed in order to:

- ascertain mineralogical reactions occurring in geothermal systems and track fluid chemistry evolution (Photo 1);
- develop synthetic fluid inclusions which can be utilized as valuable thermometers in geothermal wells (Photo 2).



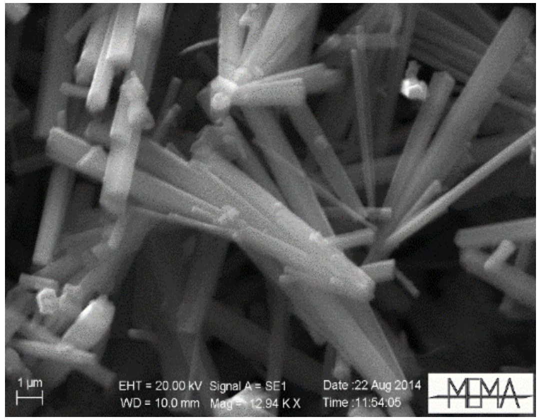


Photo 1: BSE images showing a micaschist reacting with a B-bearing aqueous fluid at 500°C, 100 MPa developing neo formed K-feldspar on an albite relict (left); acicular tourmaline crystals grow, as well (rigth).

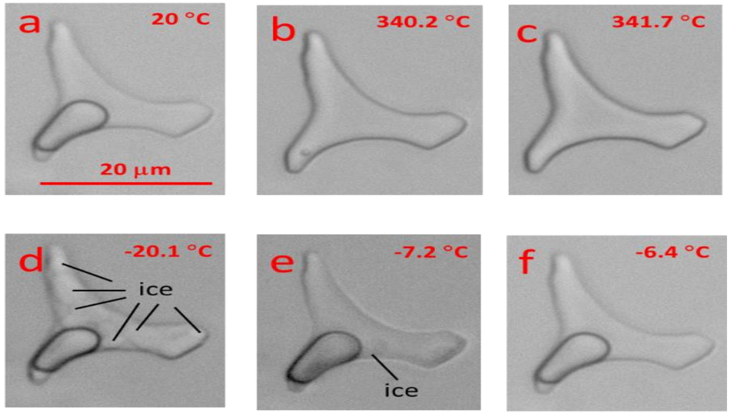


Photo 2: Sequence of micro-photographs taken during microthermometric analyses of a synthetic fluid inclusions produced in a geothermal well in Krafla (Iceland). Homogenization temperature can give accurate estimate of temperature in geothermal wells.

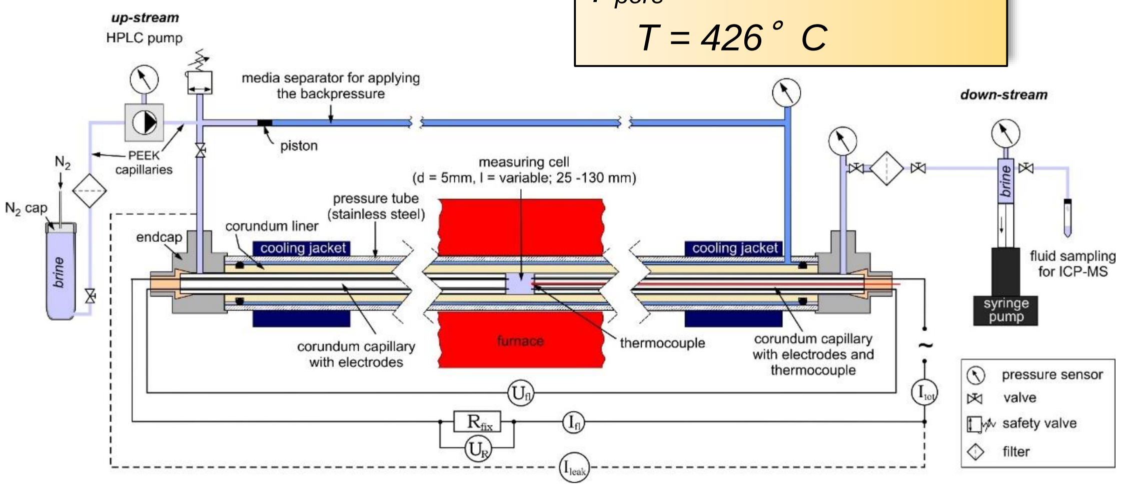
National Research Council of Italy

Monitoring fluid-rock interactions via electrical measurements

successfully tested up to

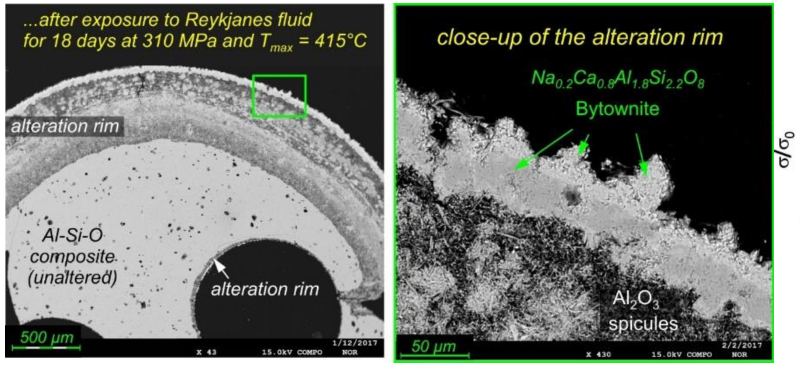
p_{pore} = 310 bar

T = 426 ° C

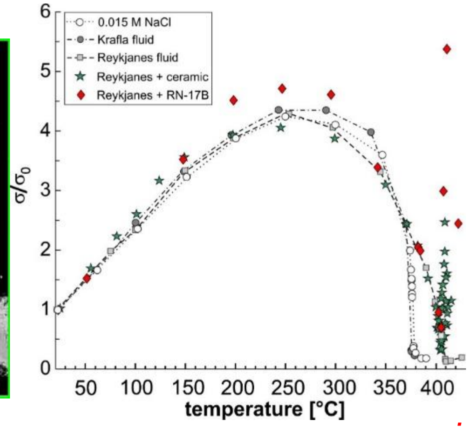


➡ **study of brines with the composition of natural geothermal fluids**

➡ **study of the effect of chemical fluid-rock interactions on the electrical properties of geothermal fluids**

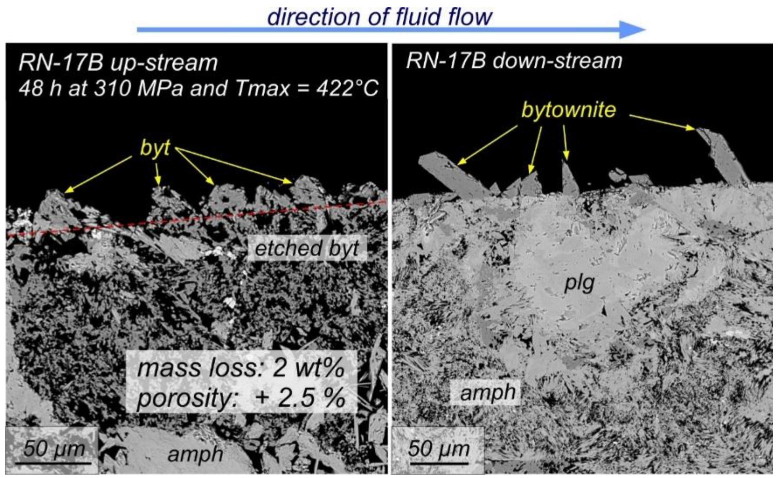


dissolution



precipitation

Kummerow et al.,
(submitted to JVGR)



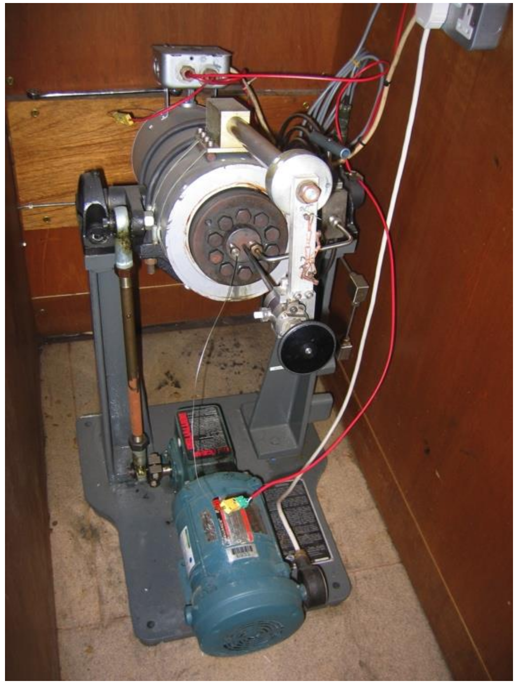
Understanding reaction kinetics

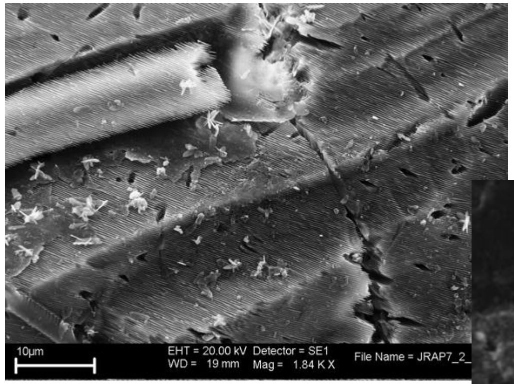
- mineral separates
- bulk samples
- at various flow rates

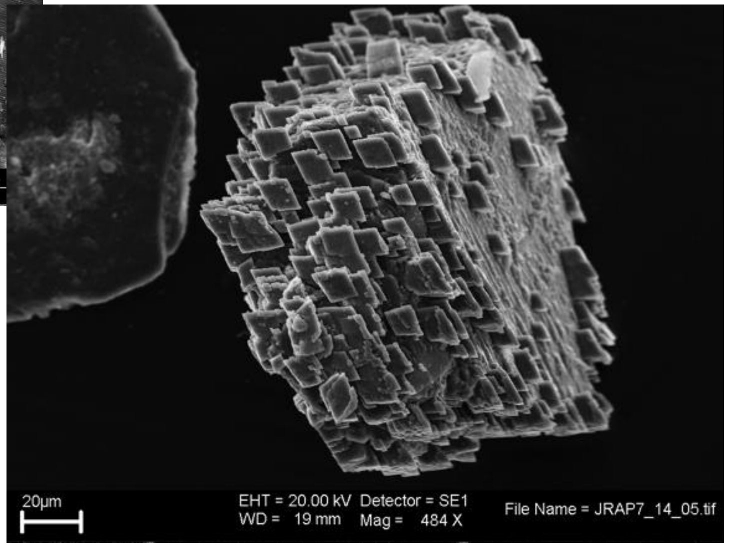
Task 6.1: Fluid-rock reaction experiments (BGS)

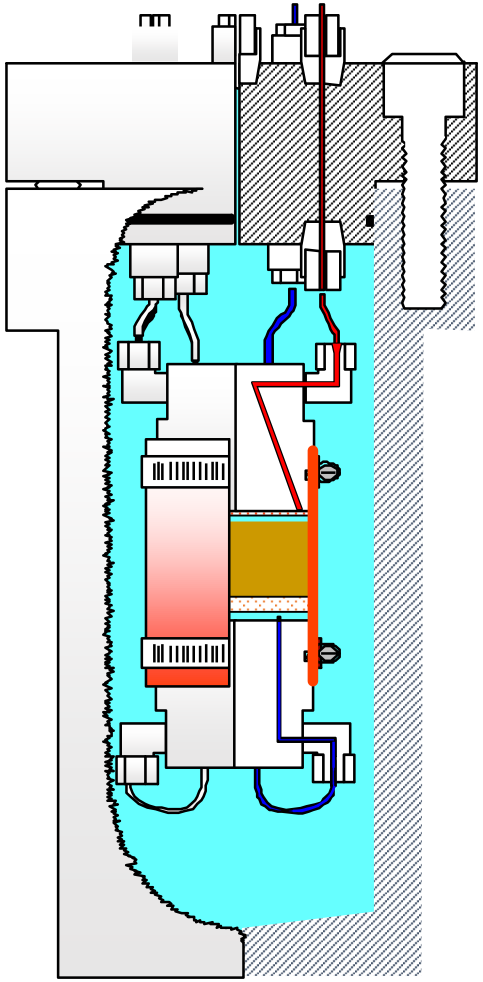
- Utilise the BGS Hydrothermal Laboratory, and associated downstream analytical labs, to quantify directions, rates and magnitudes of fluid-rock reactions:
  a) When water is added to hot dry rock
  b) Under supercritical conditions
- The BGS Hydrothermal Laboratory contains several high pressure / temperature autoclaves. Can simulate subsurface conditions up to 600°C and 500 bar.
- Can quantify dissolution/precipitation reactions and their potential to impact on fluid flow.

Flow reactors for permeability tests

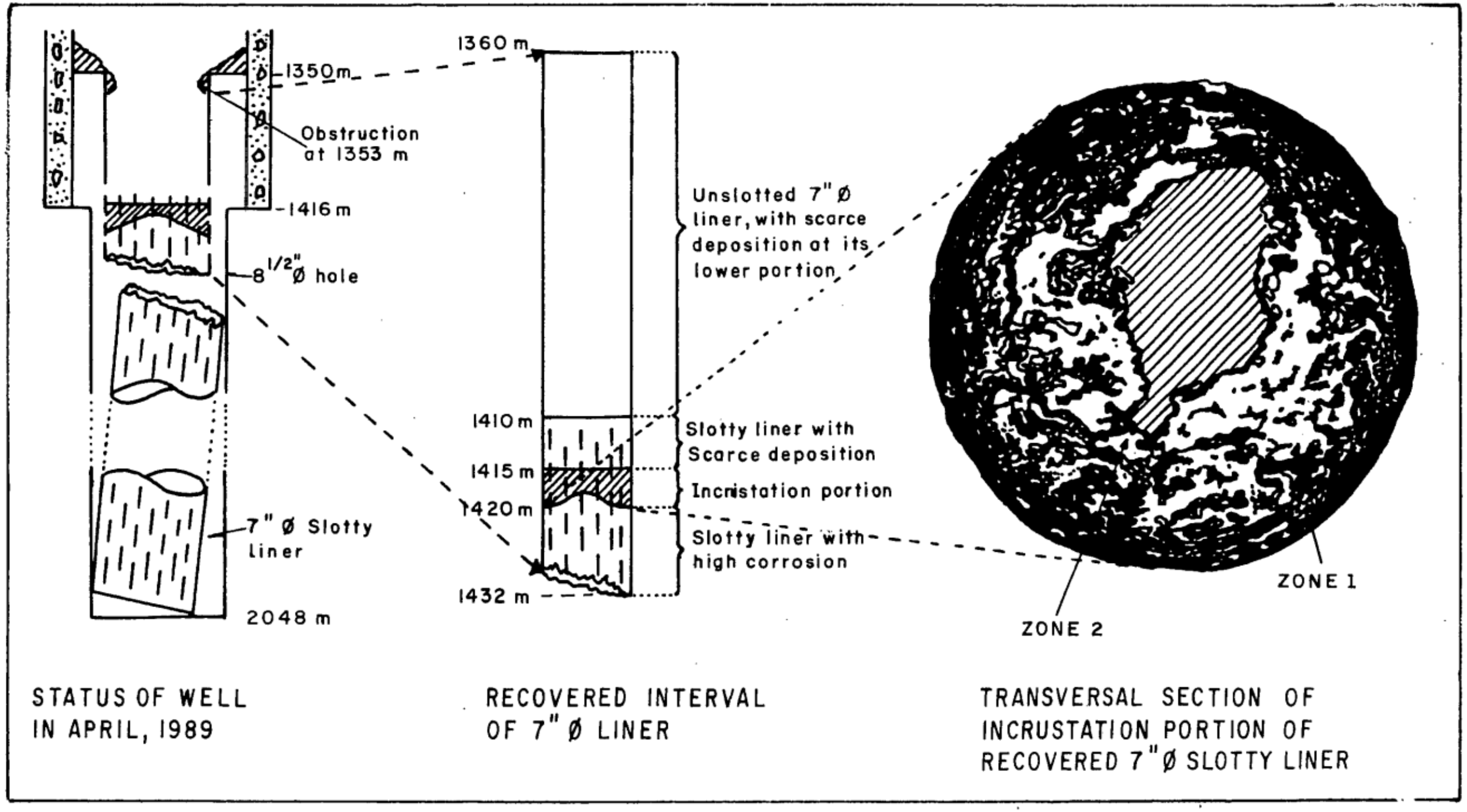








Los Humeros wells and problems (e.g. well H-16)



- Liner was removed from the well
- Only 72.3 m of the liner were recovered
- Total length of liner ~690 m
- The corrosion rates of the liner was determinet in a rank from 0.623 to 0.872 mm/year
- Remarkable higher than normal 0.03 to 0.3 mm/year
- Severe scaling was found at 1415-1420 m depth

Los Humeros geothermal system

Scaling and corrosion

Scaling challenges, data requirement and measurements. Work with CFE.

Types of scales and corrosion:

- 1. Calcite
- 2. Consequences of superheated fluid -> corrosion, erosion, deposits, orifice plate

Case studies:

- Well H16 scaling and corrosion example (paper from 1990)
- Well H59 drilled in same path as H16 -> key parameters
- Well H43 drilled 2007-2008, superheated well with deposit problems, maybe erosion problems,

abandoned and concreated

- Well H63 (twin well to 43)
- Key to improve and increase the production from Los Humeros
- H16 was good producer in the beginning, production zone cemented off, later more problems occurred and the well was closed with cement (pipe with soda pumping got severed and dropped downhole).
- Well H59 same well path as H16, different casing (low chrome material), original plan was to have it barefoot but chrome liner was selected instead, treatment for acidic conditions with better material pipe.
- With the flowing of H59, the well has problem of two production zones, possibility of calcite scaling. 30 t/s now 10 t/s possibly due to scaling, the well is in production.


Thank you…