Mineralogical and geochemical characteristics of alteration minerals related to fossil geothermal activities in the Kızıldere geothermal field, Western Turkey

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Presenter: CHIEH-HSIN WANG
Advisor: Prof. YI-CHIA LU
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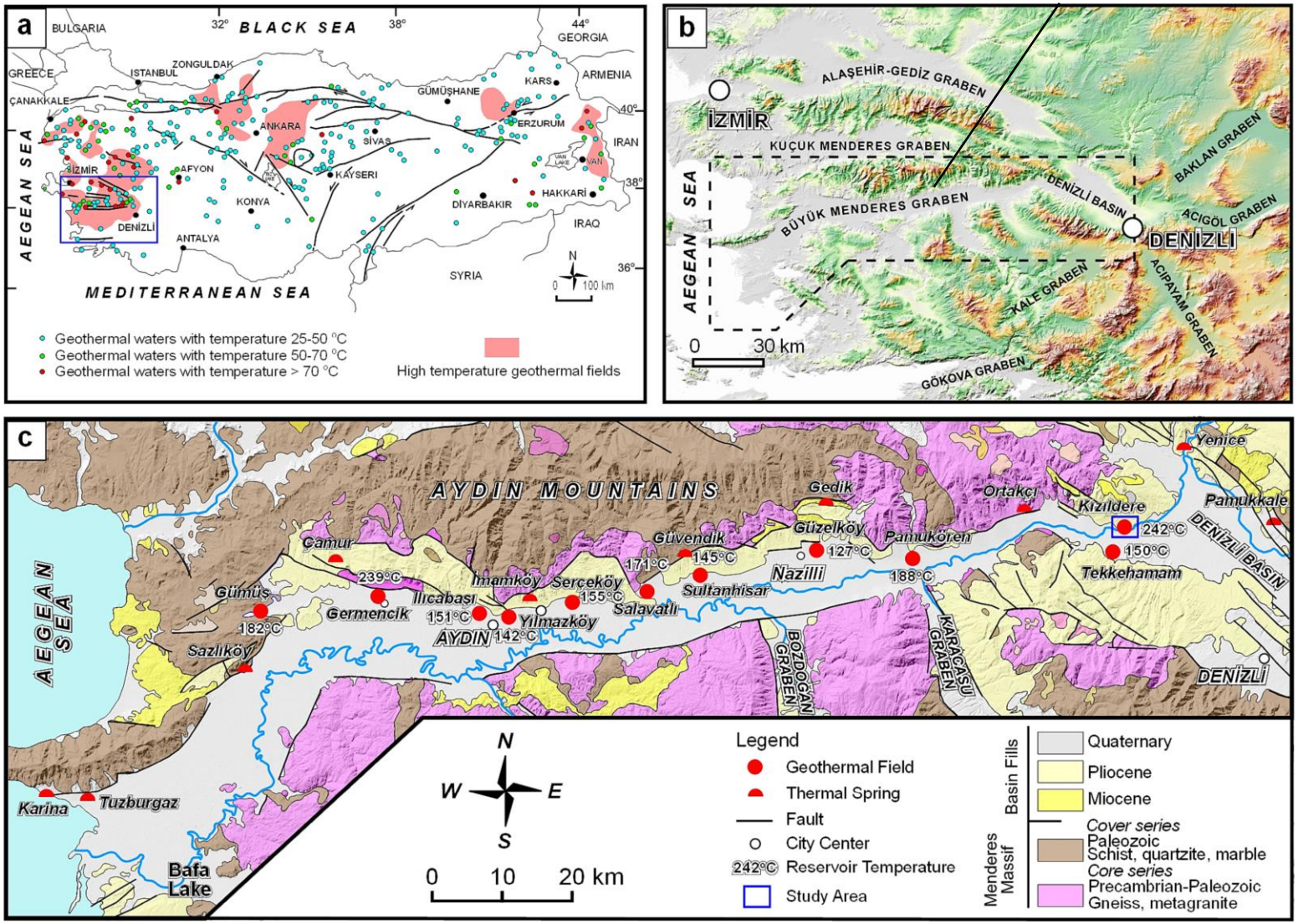
- In geothermal fields, mineralogical and geochemical characteristics of hydrothermal alteration in carbonate, sulfate, and clay provide important data on the origin of geothermal water, temperature conditions, age, and duration of the geothermal systems

- Hot fluids in geothermal fields provide hydrothermal alteration products as a result of physical and chemical interactions with the host rock

Study area : Kızıldere geothermal field

Tectonically active extension zone

N-S expansion ➞hosts many geothermal fields



Objectives

1. Determination of the mineralogical-petrographic and geochemical properties of the geothermal mineral formations determined in the alteration zones observed on the surface related to the geothermal system and the samples at different depths of the drillings made in the field, and determining their lateral and vertical distributions.

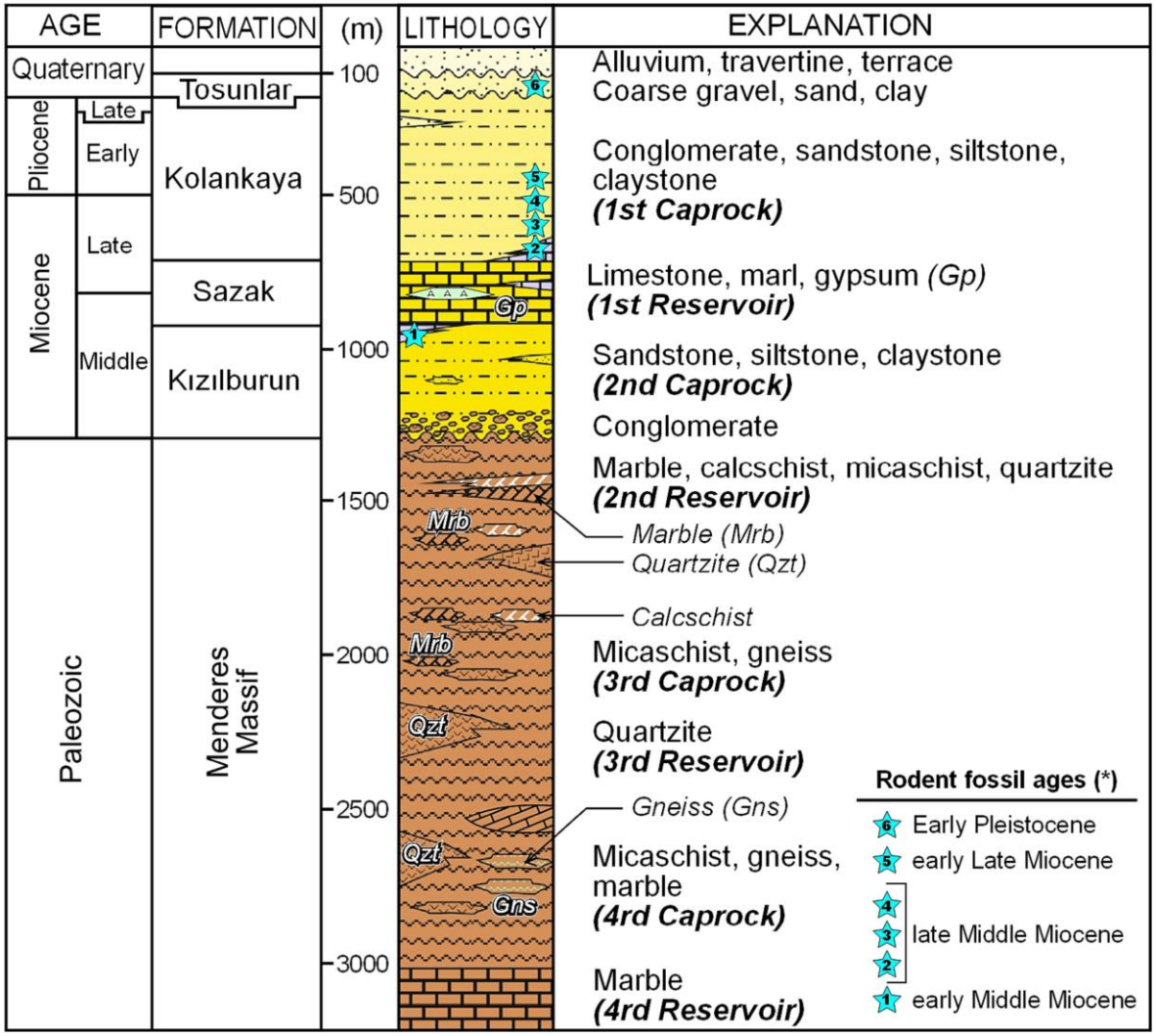
2. Determination the cation and anion compositions of carbonate (calcite, dolomite) and sulfate (gypsum, anhydrite) minerals, which are extracted from the surface and drilling specimens associated with the geothermal system, and their comparison with current geothermal water compositions.

Stratigraphy and lithology

Quaternary debris and alluviums

Basin-fill sedimentary rocks

Metamorphic rocks

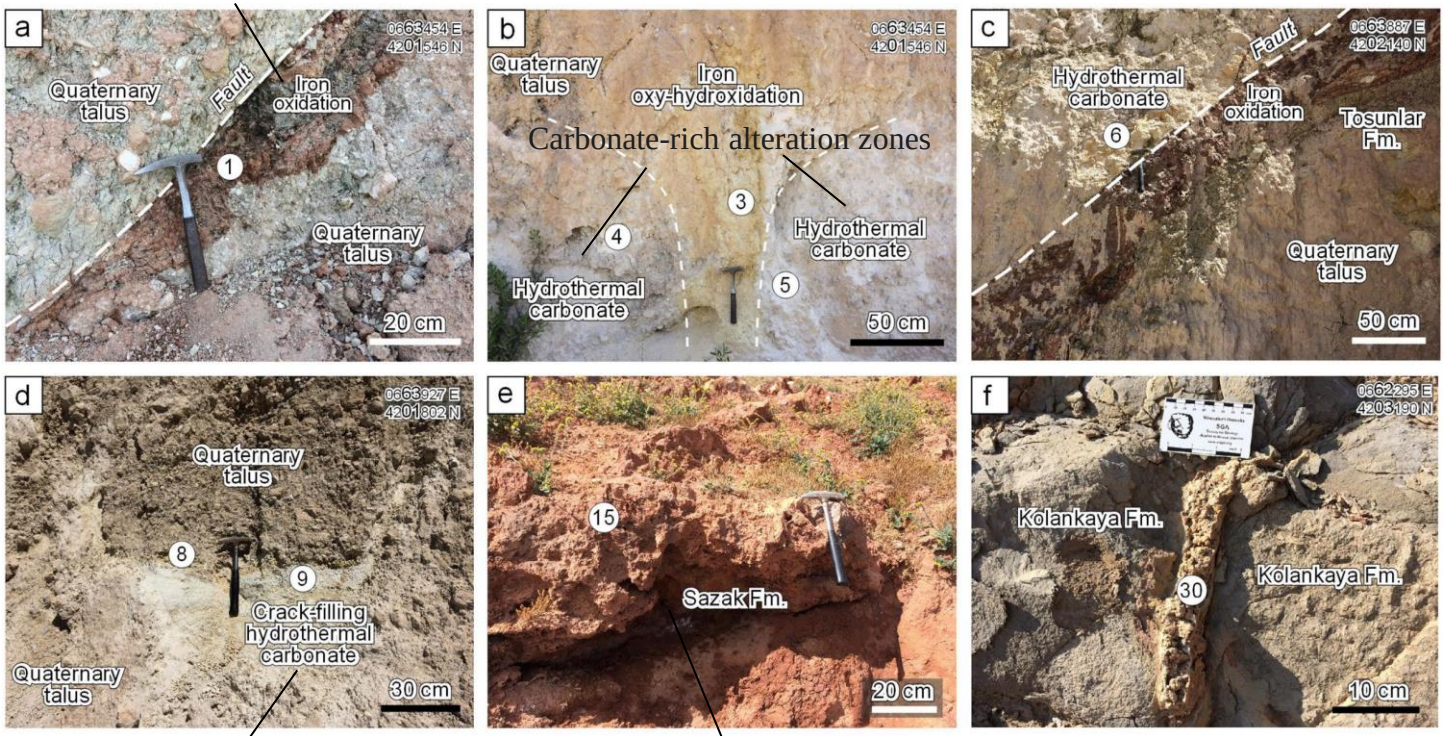


Surface sample characteristics of alteration zones

- The silica, carbonate and sulfate formations developed along the tectonic zones within the Miocene to Quaternary clastic and carbonate rocks are entirely related to geothermal waters.

The geothermal fluids caused the development of iron oxidation zone

Fossil hot water-steam outlet



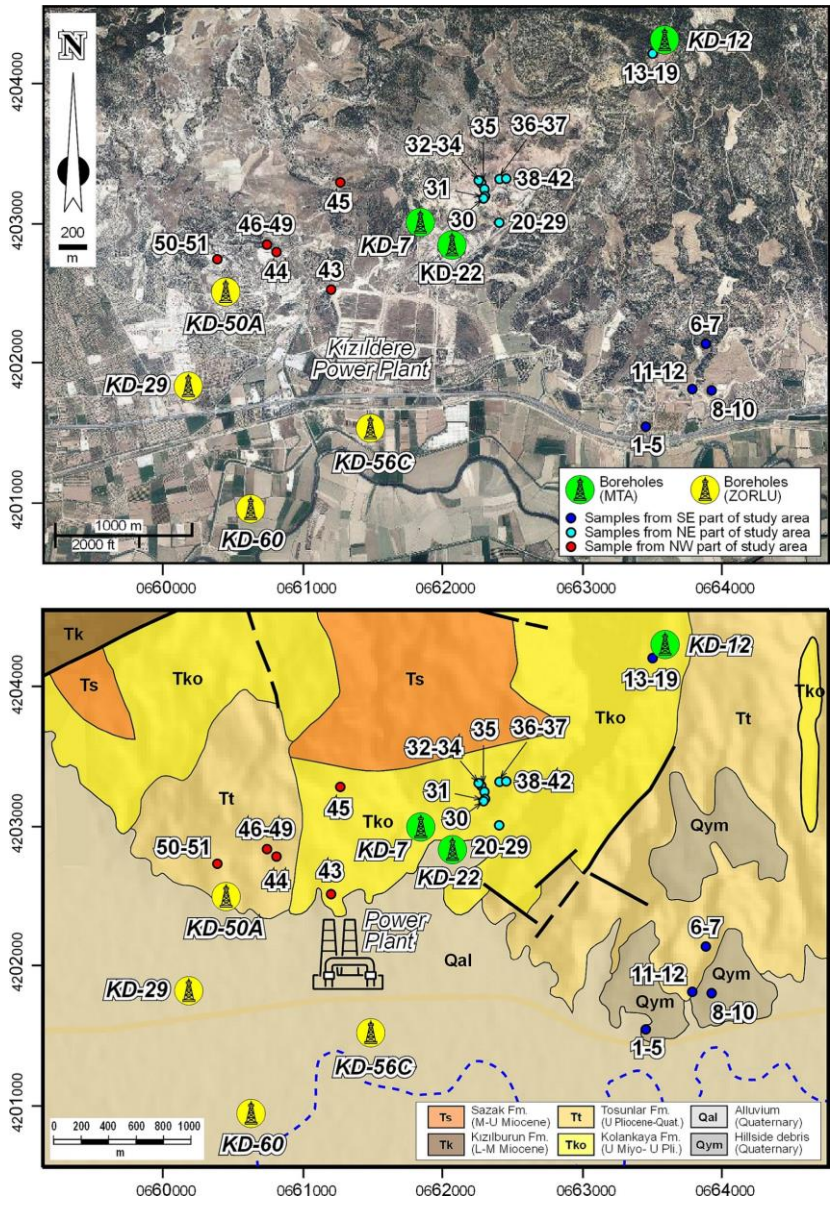
Crack-filling type geothermal carbonate

Carbonates, iron oxides/hydroxides and clay formations with dissolution spaces as a result of hot water-steam alteration

Materials

- A total of 51 samples were taken to determine the alteration formations associated with the host rock and geothermal waters in and around the geothermal field

- Sampling of alteration zones from different geological units aimed to study their lateral and vertical distribution in the field.



Methods

- Scanning electron microscope (SEM) :

  Take three-dimensional images

- Energy dispersive spectrometry (EDS) :

  Semi-quantitative chemical compositions of the minerals

- X-ray diffraction (XRD) and geochemical analysis :

  The purity of the carbonate (calcite, dolomite) and sulfate (gypsum, anhydrite) mineral samples separated under the microscope was tested

- Optical microscope :

  Investigations on the samples taken from surface alteration zones rock-forming components were performed for host rock determination and textural properties of the alteration related minerals

- ICP-MS and IC :

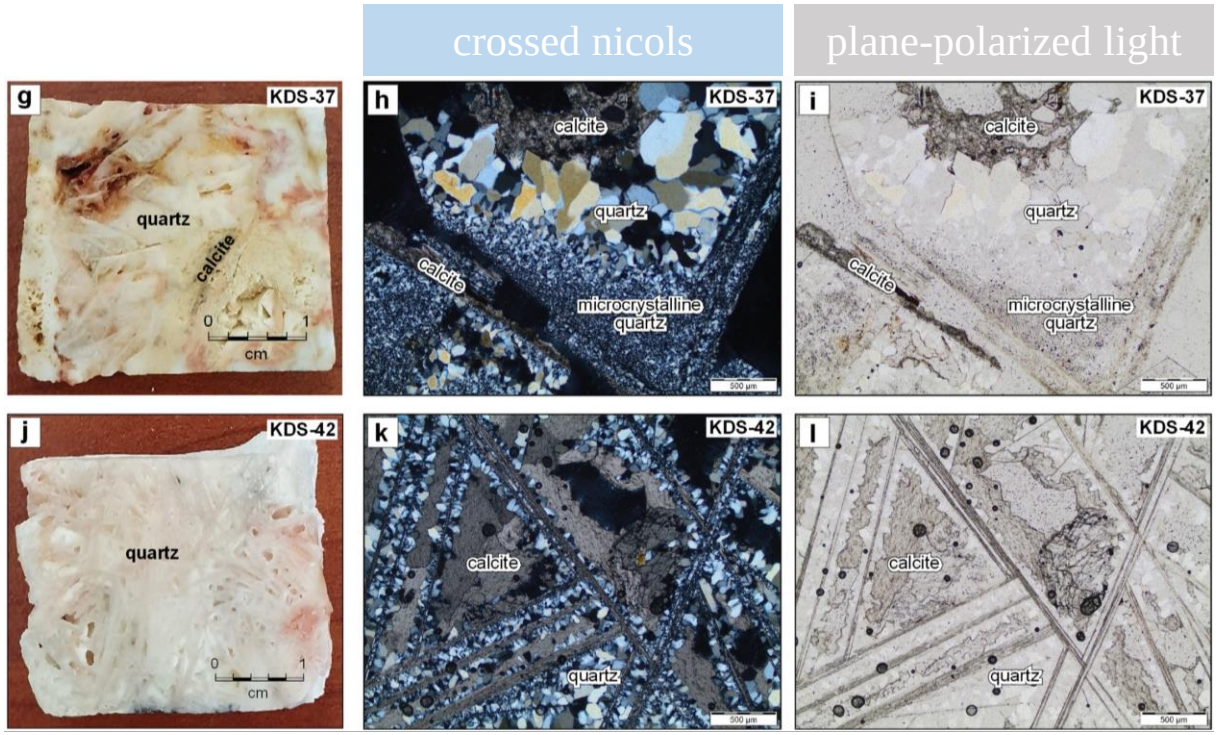
  The determination of element (Ex:The cation and anion contents of pure or nearly pure calcite, dolomite, and anhydrite mineral samples precipitated by geothermal solutions)

Optical microscopy

Limestone cracks

- Blade-like calcite crystals replaced by quartz indicate that the hydrothermal fluids associated with the geothermal system are rich in silica as well as carbonate
- Carbonate minerals develop early and are later replaced by silica minerals

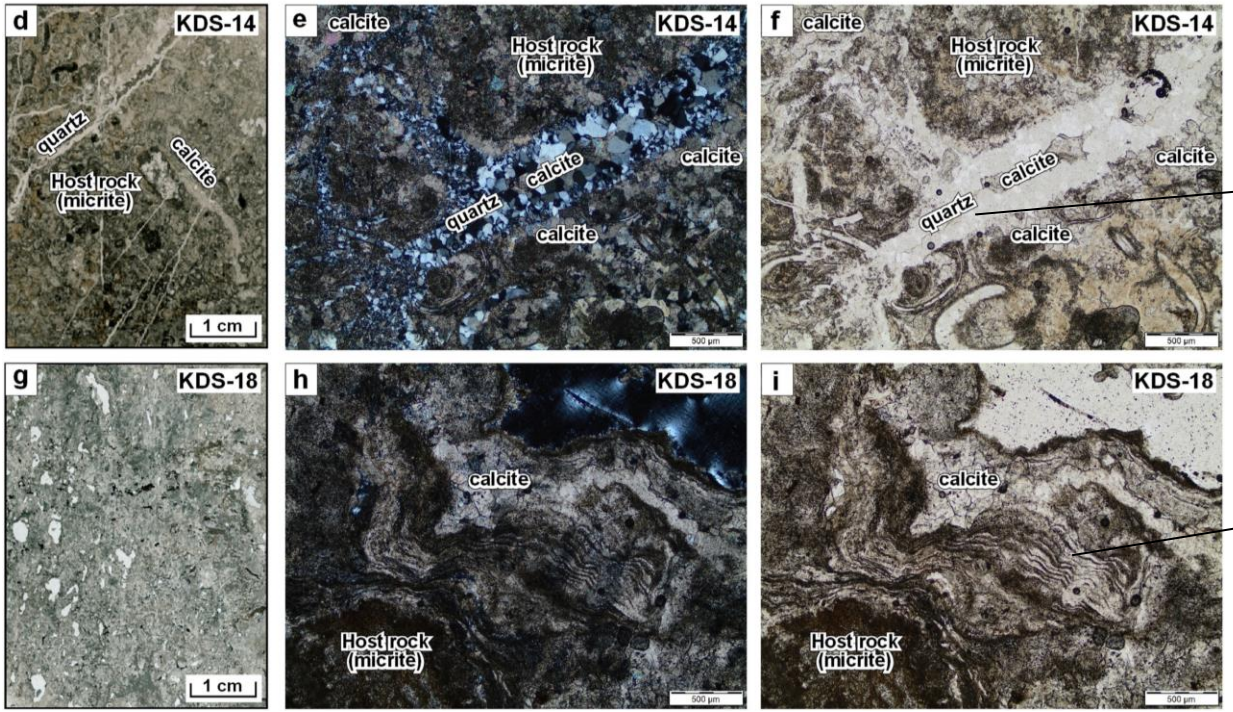
Rhombohedral calcites with lattice structure replaced by anhedral quartz



Optical microscopy

Fumarole area

- Hydrothermal carbonate precipitations developed as gel texture which indicates direct chemical precipitation from the solution
- Calcite formations are crystallized within the limestones as a product of dissolution-recrystallization or direct precipitation from geothermal fluids

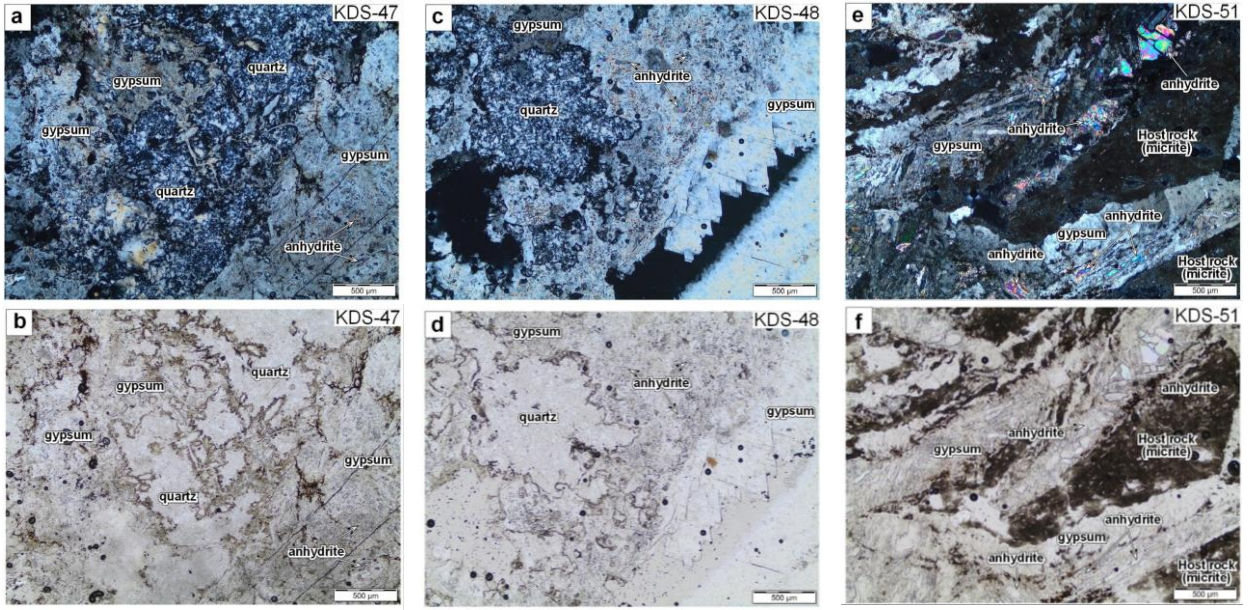


Optical microscopy

Western part of the Kızıldere geothermal field

- Coarse-crystalline calcites, which are observed as vein fillings with gel texture
- Hydrothermal silica minerals observed to corrode the host rock (micritic limestone) are represented by quartz
- Gypsum crystals are observed as vein fillings within the host rocks

Quartz gnawing gypsum and anhydrite



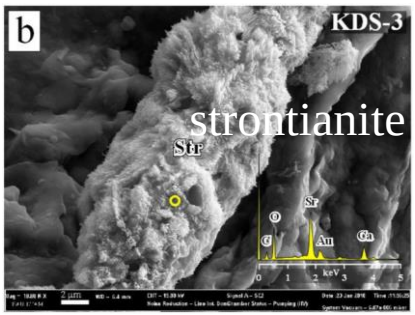
Chalcedonic quartz was developed after gypsum and anhydrite

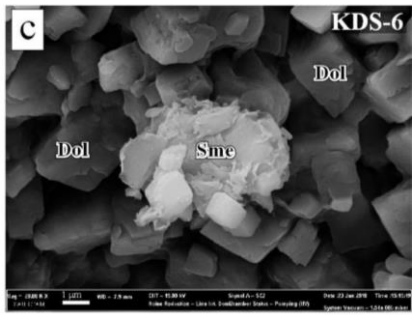
➢ Indicating precipitation from the hot aqueous solutions caused by geothermal fluids

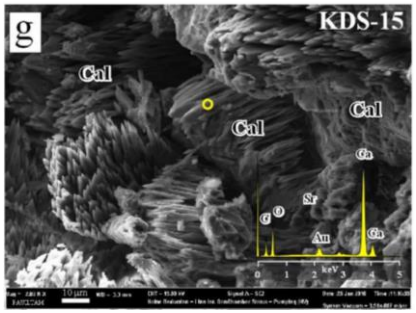
Scanning electron microscopy (SEM)

SEM investigations of hydrothermal carbonate minerals are mainly represented by euhedral dolomites and flaky smectites that were occurred directly from geothermal solutions

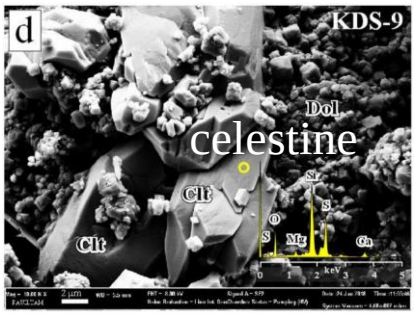
- The presence of celestine and strontianite minerals as fossil hydrothermal minerals in the Kızıldere geothermal field was determined for the first time in this study
- Calcite crystals as well as iron oxide-hydroxides (goethite, limonite) indicate boiling or hot water activities along the fault zones

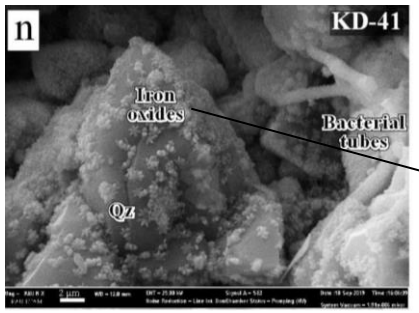




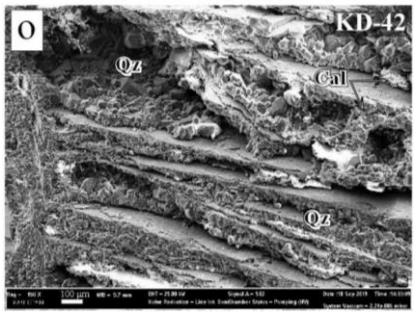


Hydrothermal blade calcites within porous limestone





Iron oxide in pores

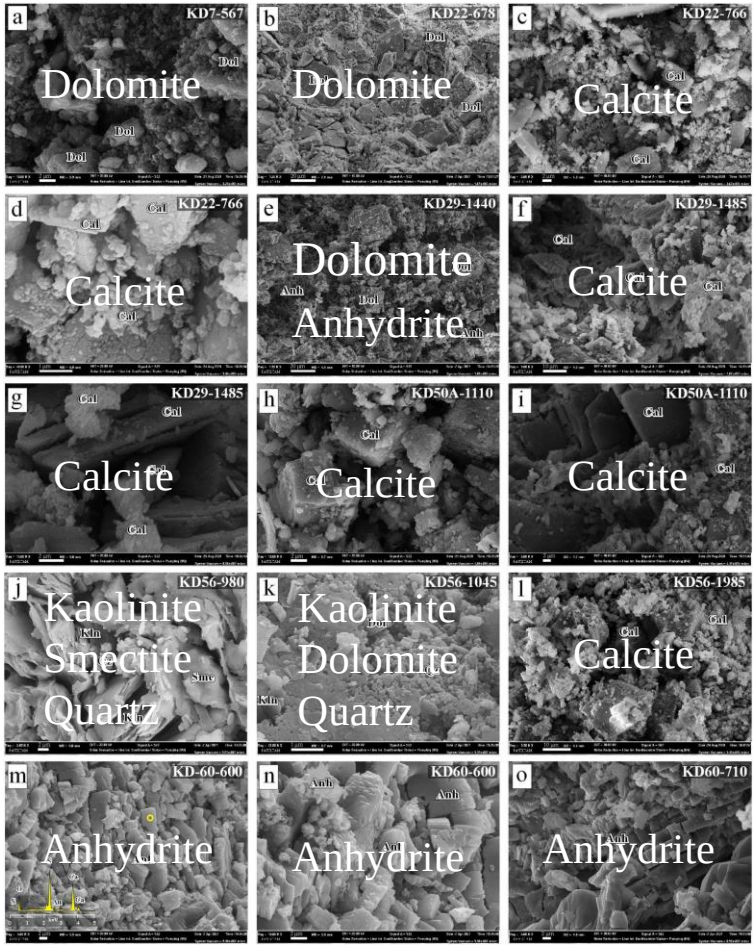


Quartz replacing blade calcites and calcite residues

➢ Indicating the samples are related to the geothermal system

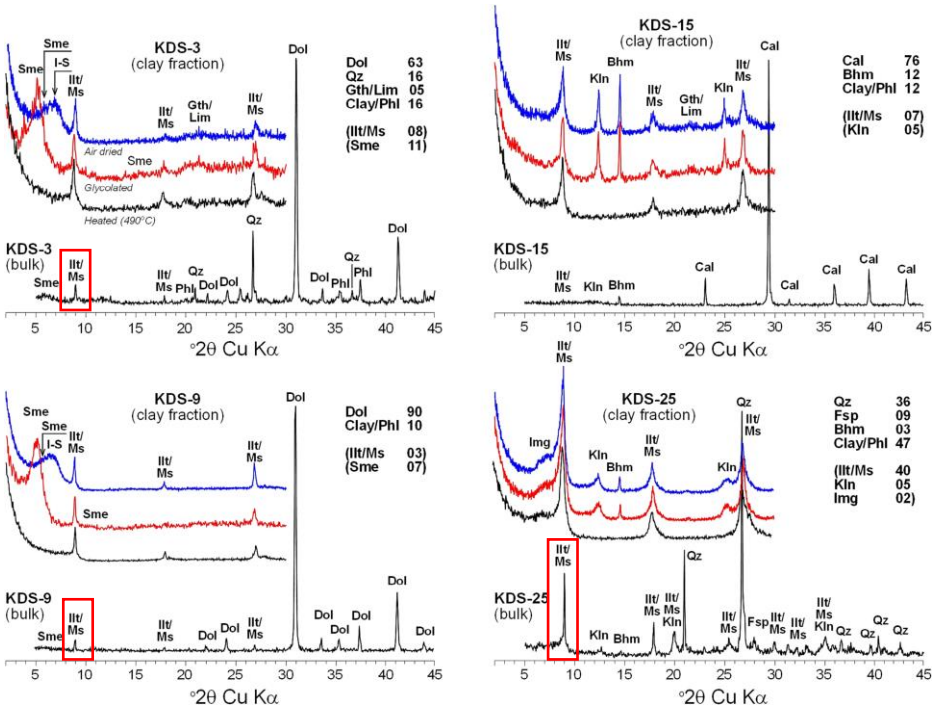
Scanning electron microscopy (SEM)

- Alteration minerals represented by mainly calcite, dolomite and anhydrite, and rare kaolinite, smectite and quartz

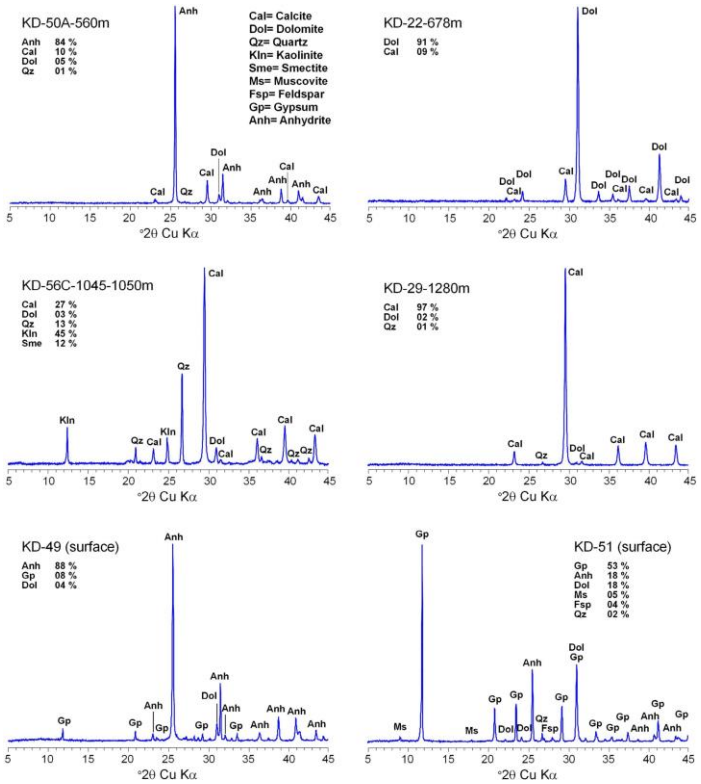


Mineralogy---XRD

Cal=Calcite
Dol=Dolomite
Qz=Quartz
Kln=Kaolinite
Sme=Smectite
Ms=Muscovite
Fsp=Feldspar
Gp=Gypsum
Anh=Anhydrite

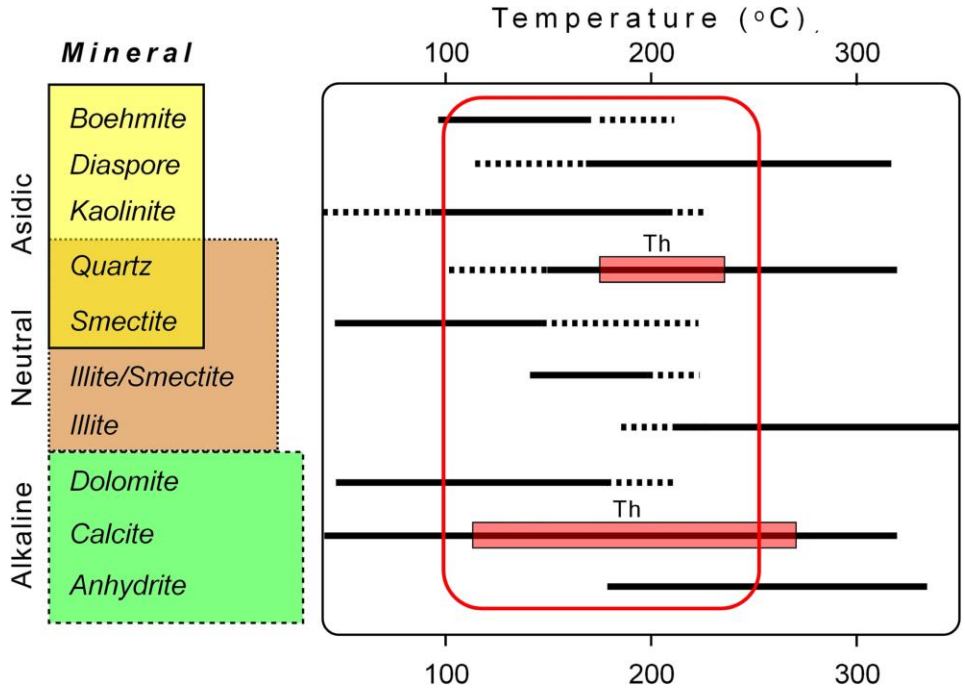


Representative carbonate-clay
from surface alteration zones



Carbonate and sulfate
from surface and drill core alteration zones

- The red areas in quartz and calcites represent the range of fluid inclusion homogenization temperatures (Th ˚C) measured from these minerals
- Indicate the temperature conditions between 100 and 250 ˚C



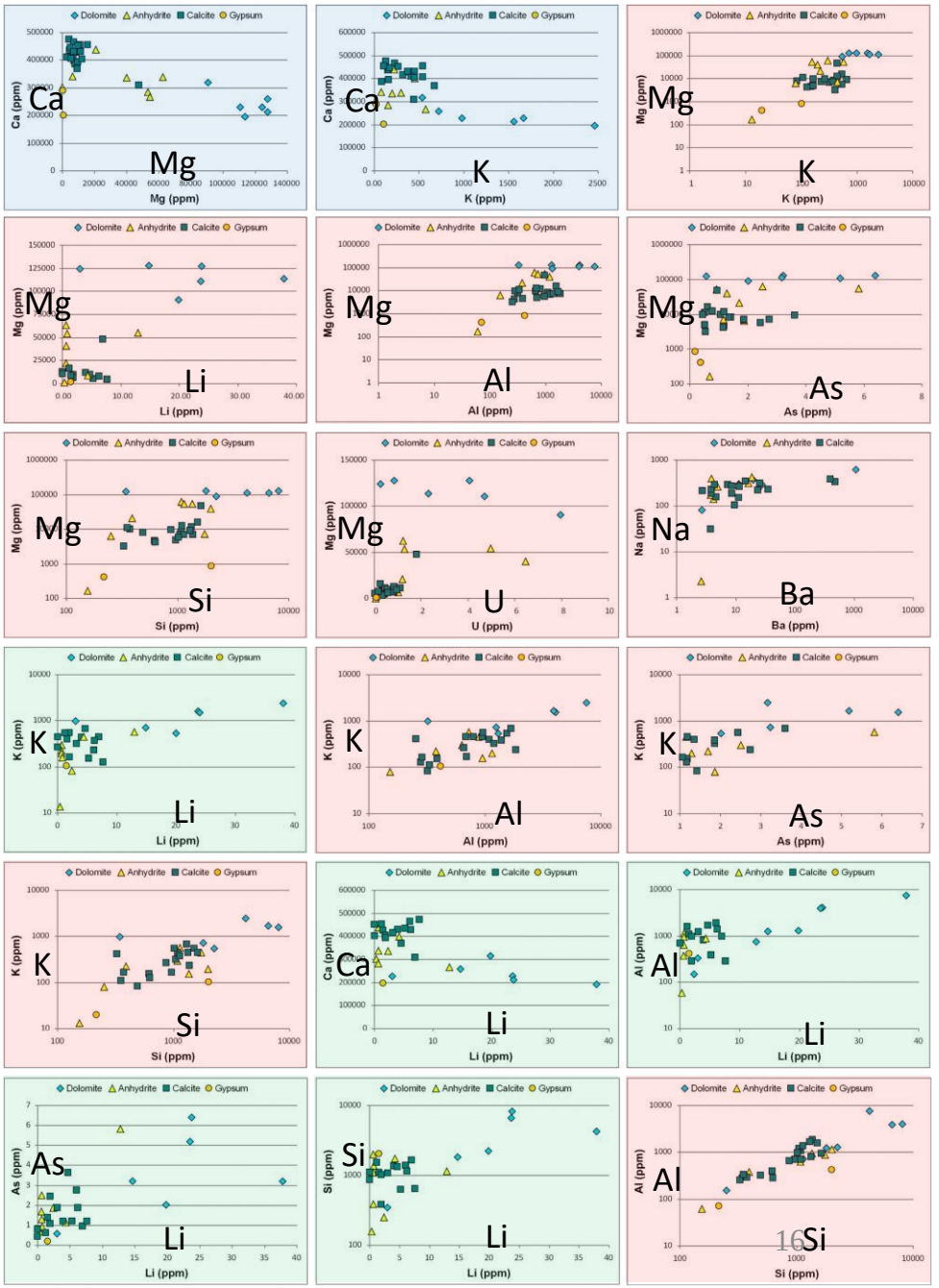
Temperature conditions of minerals determined in the Kizildere geothermal field surface alteration zones

Different element pairs were distributed from extracted hydrothermal calcite, dolomite, and anhydrite minerals

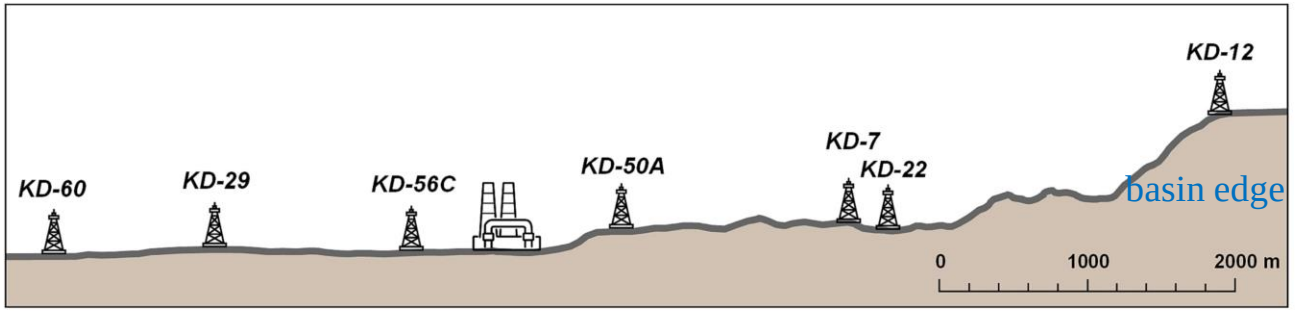
- Positive correlation
  Si, Al, Mg, K, and Na
  from silicate minerals in schist
  or gneiss type metapelitic rocks

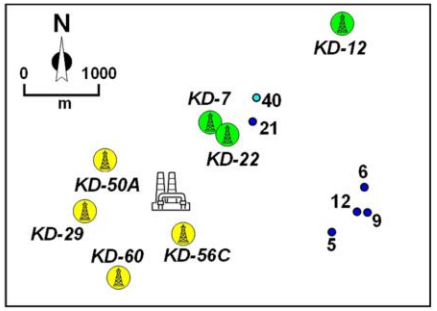
- Negative correlation
  Ca-Mg and Ca-K element pairs
  seem to be associated with
  metacarbonate rocks (marble,
  calcschist)

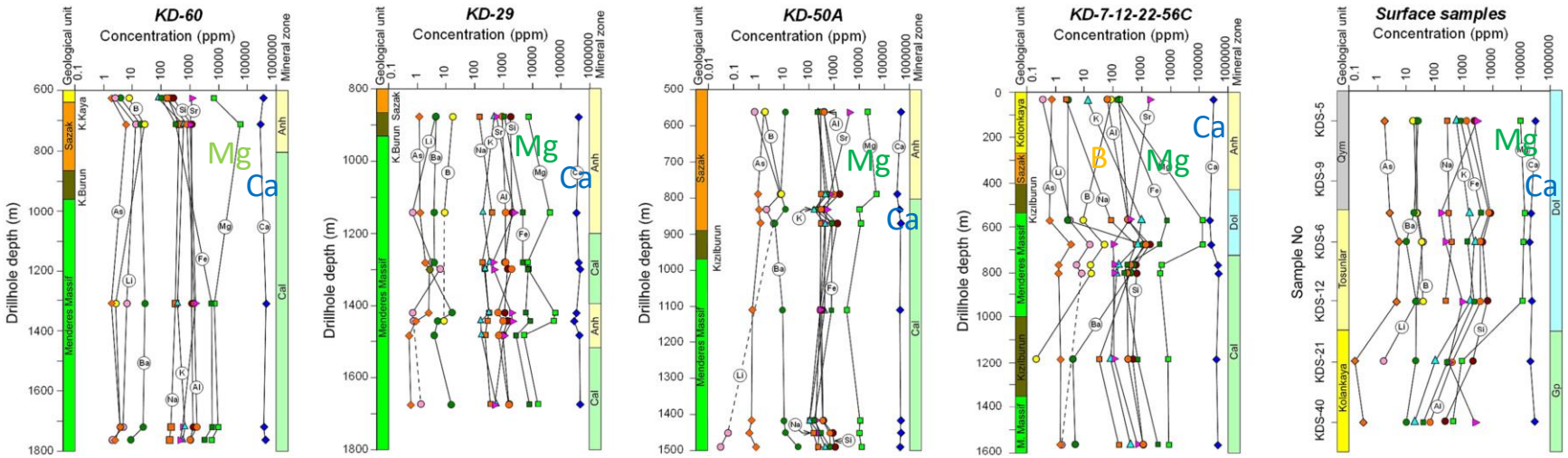
- Random
  Li



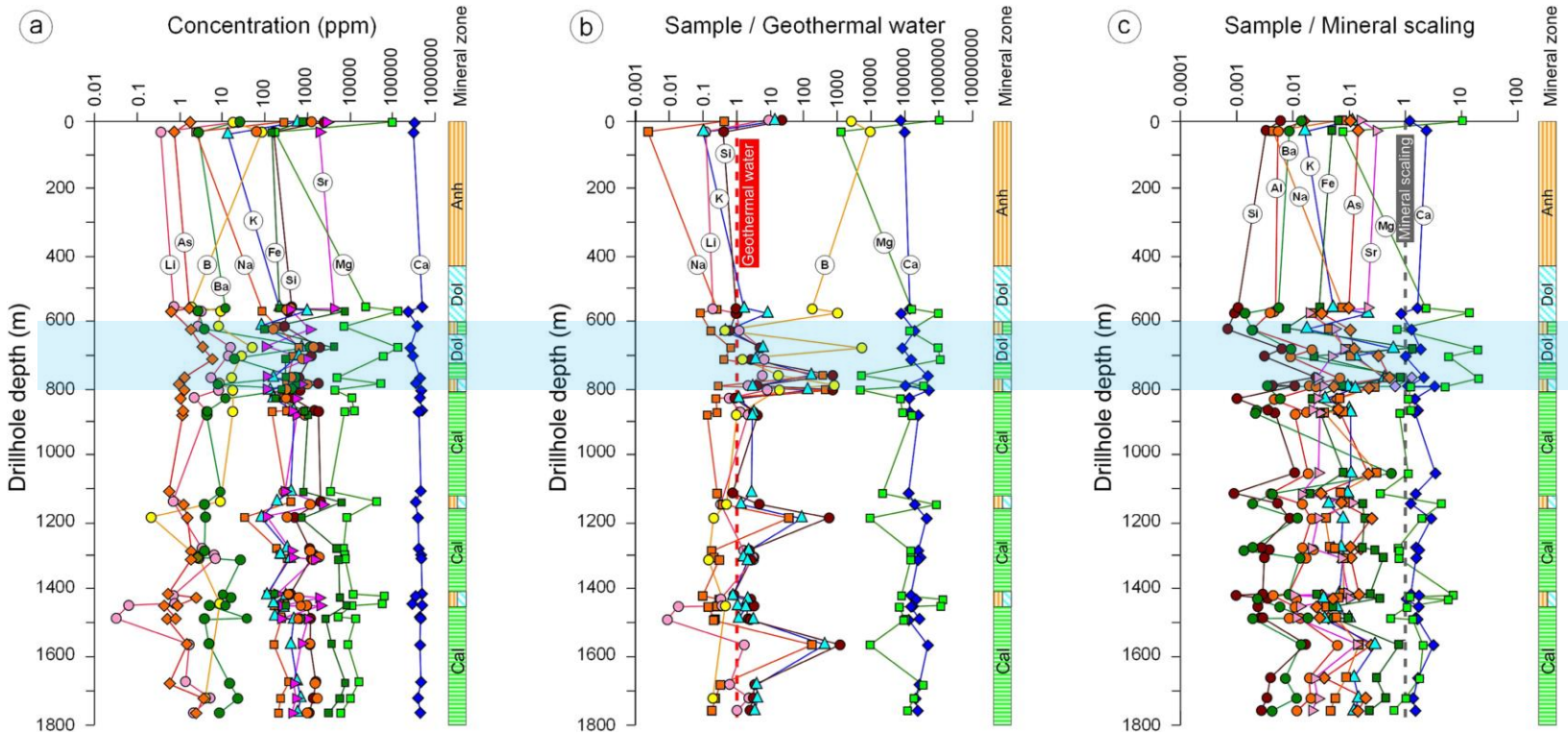
- In the drillings in the deep parts of the basin, enrichment in Ca and Mg, which reaches 100,000 times according to the geothermal water composition
- In shallow depth drilling and surface samples close to the basin edge,1000,000 times Mg, 100,000 times Ca, and 1000 times B enrichment were determined



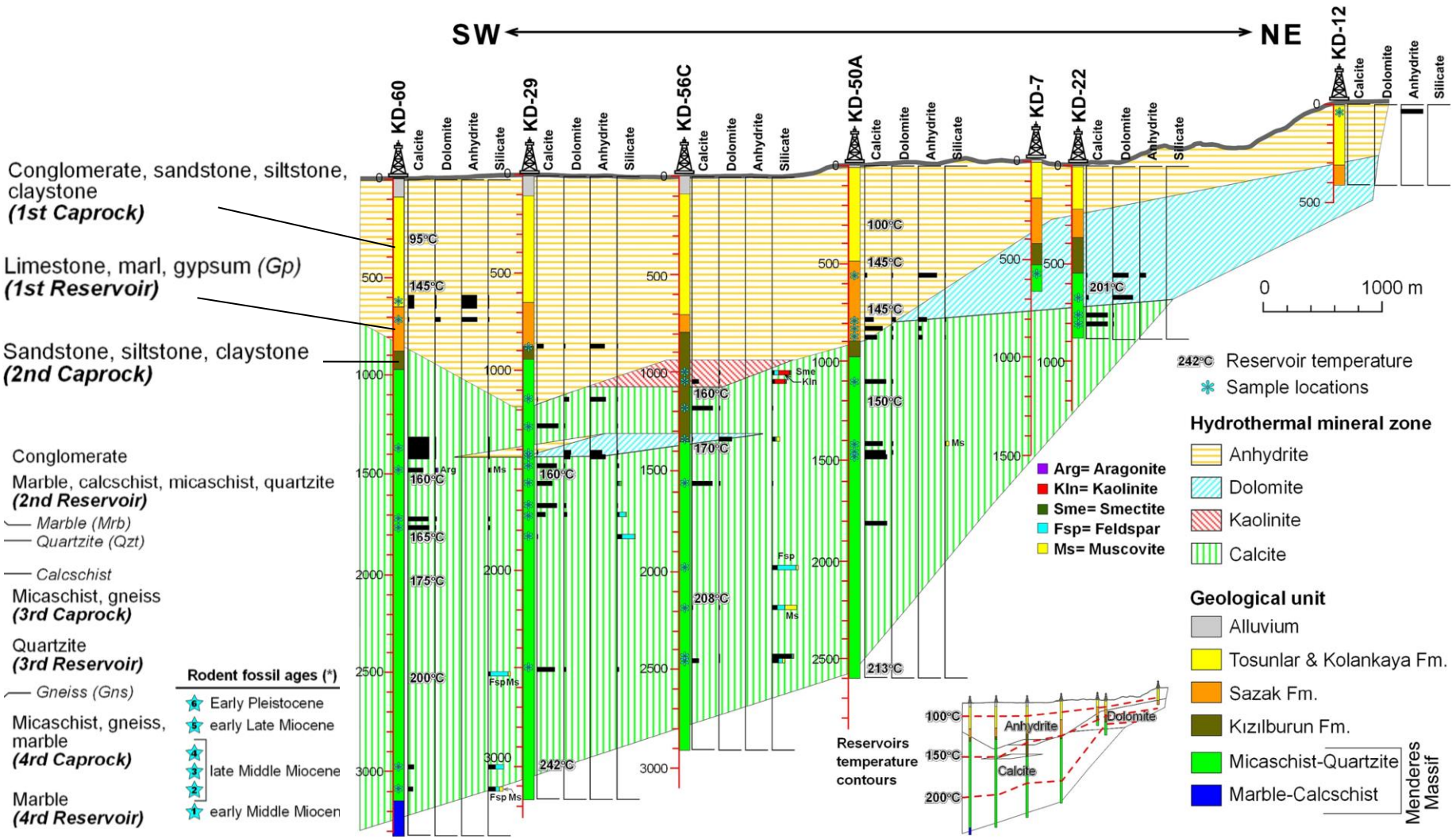




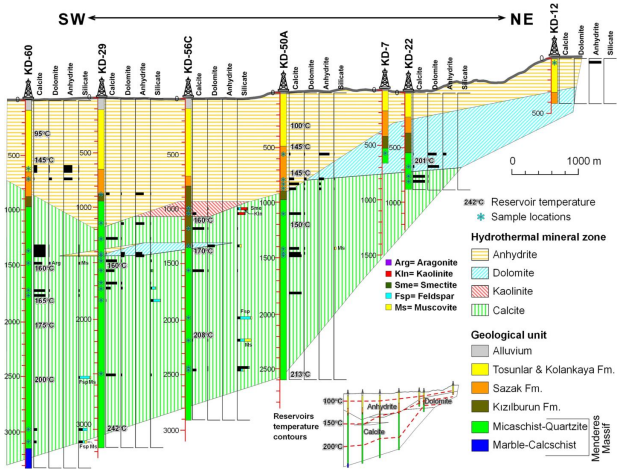
- Mg enrichments in some levels between 600 and 800 m, corresponding to dolomite zones

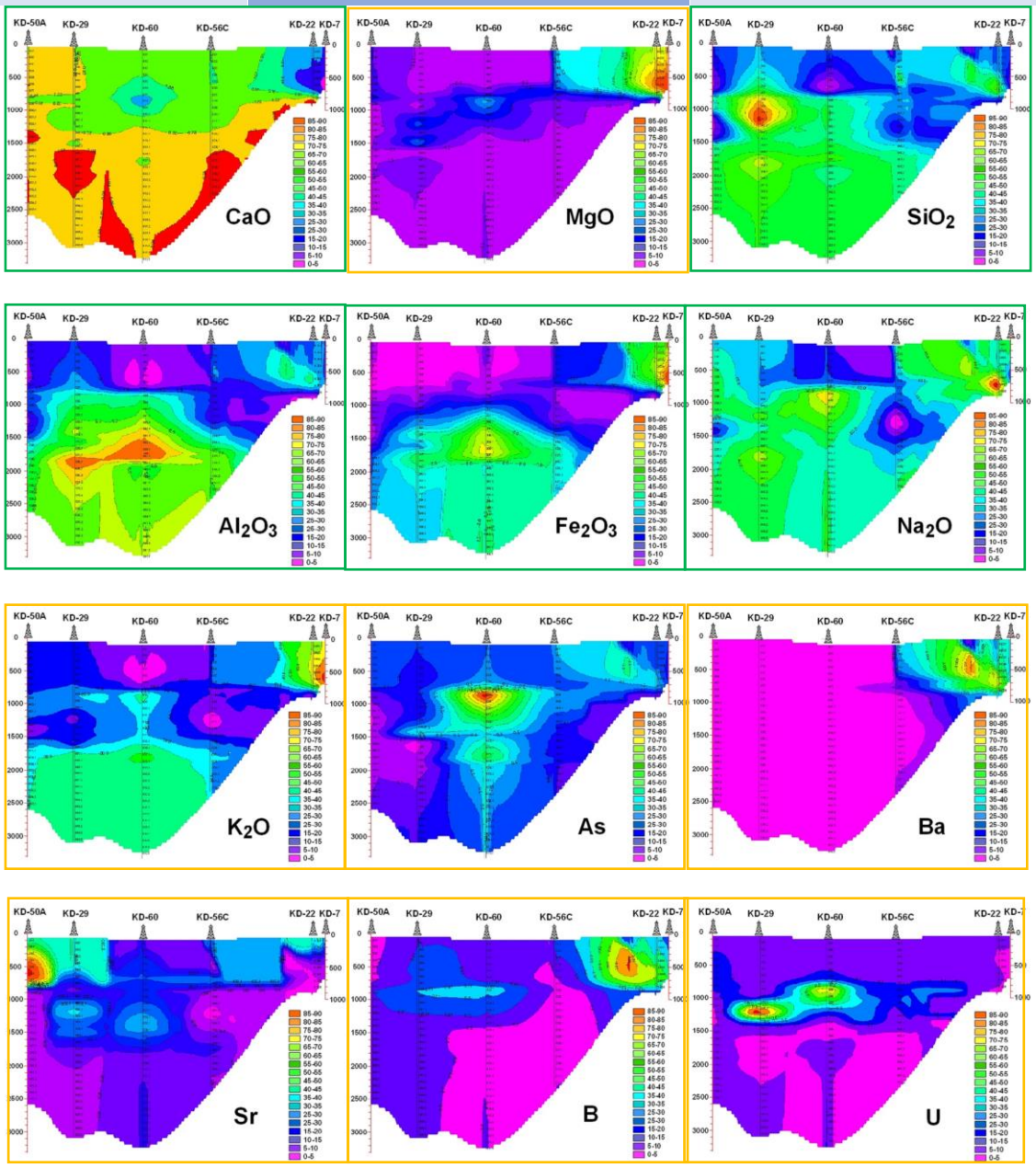


Mineralogical compositions and lateral and vertical distribution of hydrothermal minerals extracted from drill core chips corresponding to different depths.



- There are similarities between the obtained oxides or element contour data and the distribution of minerals



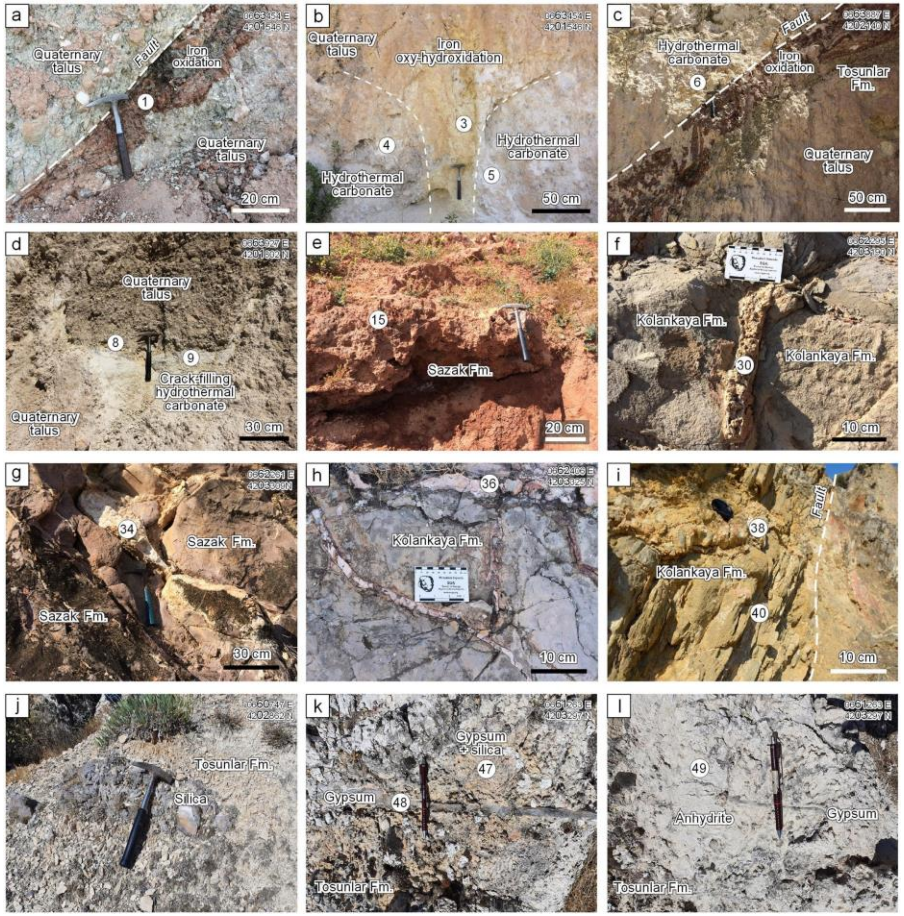


Lateral and vertical distributions of major oxides (%) and elements (ppm) in samples taken from drillings

Conclusions

- Current and fossil fumaroles and alteration zones associated with the geothermal system are directly related to tectonic lines.
- According to optical and electron microscope observations, carbonate, silica, and clay were deposited directly from the geothermal fluids in the form of pore or crack fill in the host rocks.
- Strontianite, celestine, anhydrite and boehmite occurrences in hydrothermal alteration zones were determined for the first time.
- Mineral associations in the alteration zones indicate the temperature conditions between 100 and 250 ˚C.
- The carbonate and sulfate minerals were formed in situ and in a formation order in the direction of calcite → gypsum → anhydrite → quartz.
- Calcite and replacement quartz formations in siliceous-carbonate veins associated with faults indicate boiling in hydrothermal fluids.
- Mineralogical data obtained from the drillings reflected anhydrite, dolomite and calcite zoning in the vertical direction.
- The positive correlation of Si, Al, Mg, K and Na elements with each other shows that they are derived from silicate minerals in metapelitic rocks, and Ca, which has a negative relationship with these elements, is derived from metacarbonates.

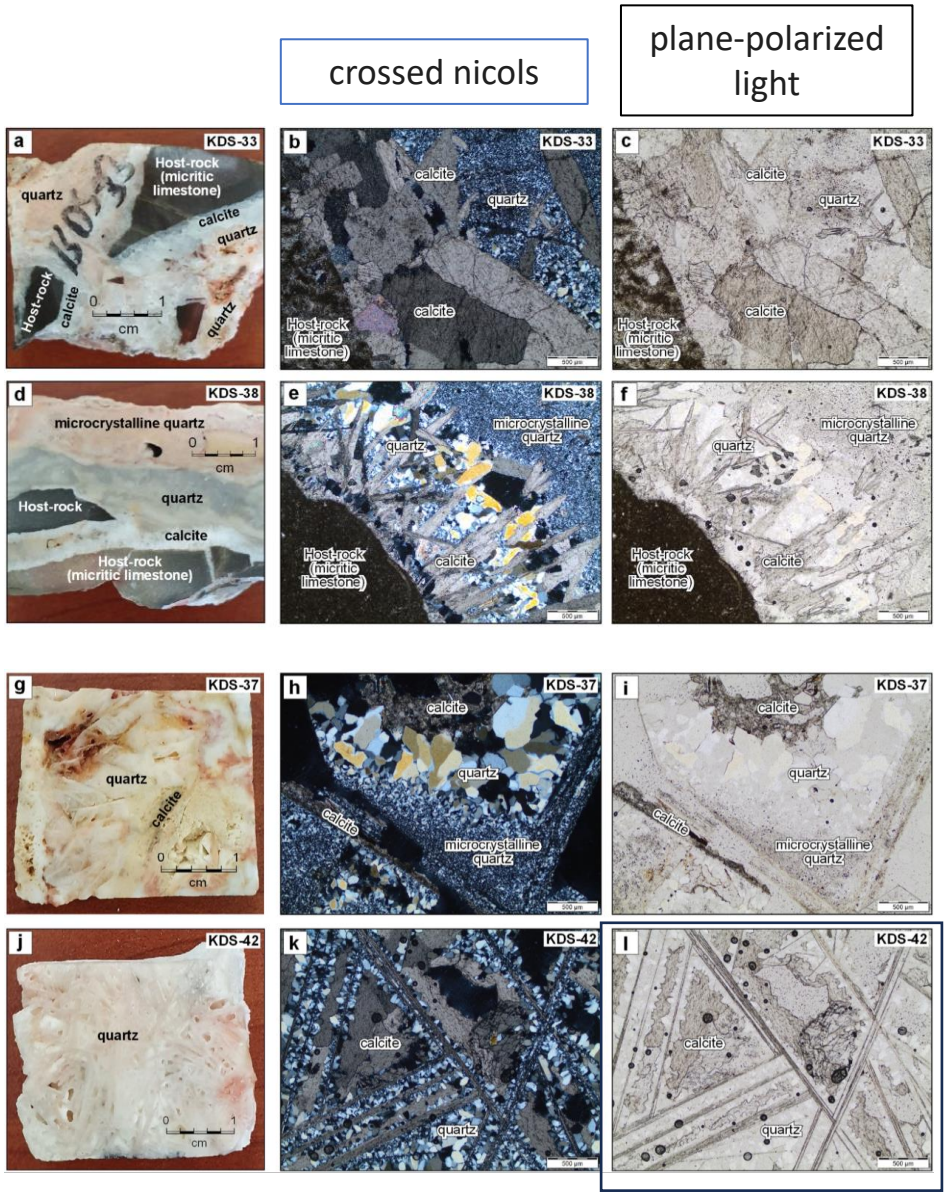
Thank you for listening

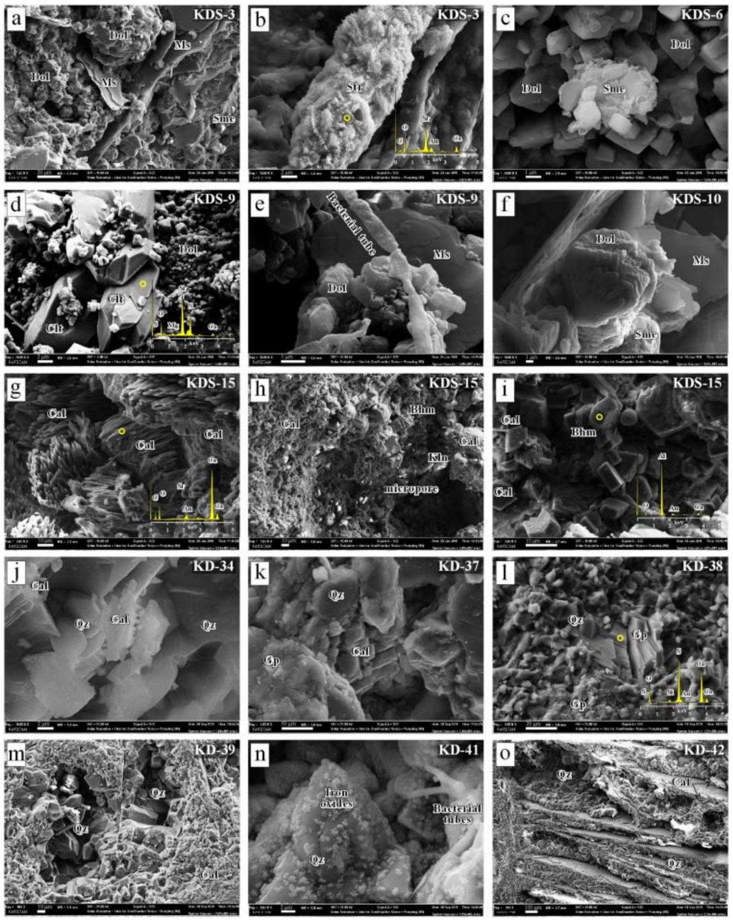

a
Quaternary talus
Fault
Iron oxidation
1
Quaternary talus
20 cm
b
Quaternary talus
Iron oxy-hydroxidation
3
4
Hydrothermal carbonate
5
Hydrothermal carbonate
50 cm
c
Fault
Hydrothermal carbonate
Iron oxidation
6
Tosunlar Fm.
Quaternary talus
50 cm
d
Quaternary talus
8
9
Crack-filling hydrothermal carbonate
Quaternary talus
30 cm
e
15
Sazak Fm.
20 cm
f
Kolankaya Fm.
30
Kolankaya Fm.
10 cm
g
34
Sazak Fm.
Sazak Fm.
30 cm
h
36
Kolankaya Fm.
10 cm
i
Fault
38
Kolankaya Fm.
40
10 cm
j
Tosunlar Fm.
Silica
k
Gypsum + silica
47
Gypsum
48
Tosunlar Fm.
l
49
Anhydrite
Gypsum
Tosunlar Fm.

Optical microscopy

Limestone cracks

- Calcite crystals replaced by quartz indicate that the hydrothermal fluids associated with the geothermal system are rich in silica as well as carbonate
- Carbonate minerals develop early and are later replaced by silica minerals

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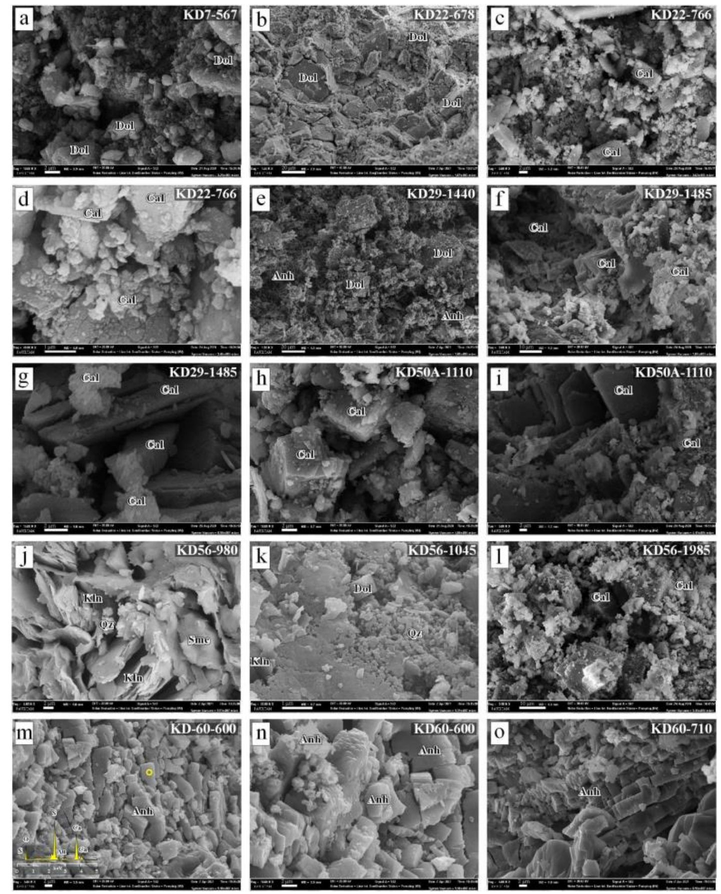
b KDS-3 Str
c KDS-6 Dol Dol Sme
d KDS-9 Dol Chl Chl
e KDS-9 Bacterial tube Ms Dol
f KDS-10 Dol Ms Sme
g KDS-15 Cal Cal Cal
h KDS-15 Bhm Cal Cal Kln micropore
i KDS-15 Cal Bhm Cal
j KD-34 Cal Qz Cal Qz
k KD-37 Qz Gp Cal
l KD-38 Qz Gp Gp
m KD-39 Qz Qz Cal
n KD-41 Iron oxides Bacterial tubes Qz
o KD-42 Qz Cal Qz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b KD22-678 Dol Dol Dol
c KD22-766 Cal Cal
d KD22-766 Cal Cal Cal
e KD29-1440 Anh Dol Dol Anh
f KD29-1485 Cal Cal Cal
g KD29-1485 Cal Cal Cal Cal
h KD50A-1110 Cal Cal
i KD50A-1110 Cal Cal
j KD56-980 Kln Qz Sme Kln
k KD56-1045 Dol Qz Kln
l KD56-1985 Cal Cal
m KD-60-600 Anh
n KD60-600 Anh Anh Anh
o KD60-710 Anh

Lateral and vertical distributions of major oxides (%) and elements (ppm) in samples taken from drillings

- Due to interactions with host rocks, Deep geothermal calcites in metamorphic rock areas have higher SiO2, Al2O3, Fe2O3, CaO, Na2O, and K2O.
- Shallow geothermal dolomites and anhydrites show higher MgO, K2O, As, Ba, Sr, Li, B, and U contents.
- This mineralogical zonation is related to geothermal waters are affected by metacarbonate rocks at deep levels and by evaporitic rocks near the surface.