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The influence of decreasing the temperature of geothermal water on precipitation and sedimentation of mineral compounds

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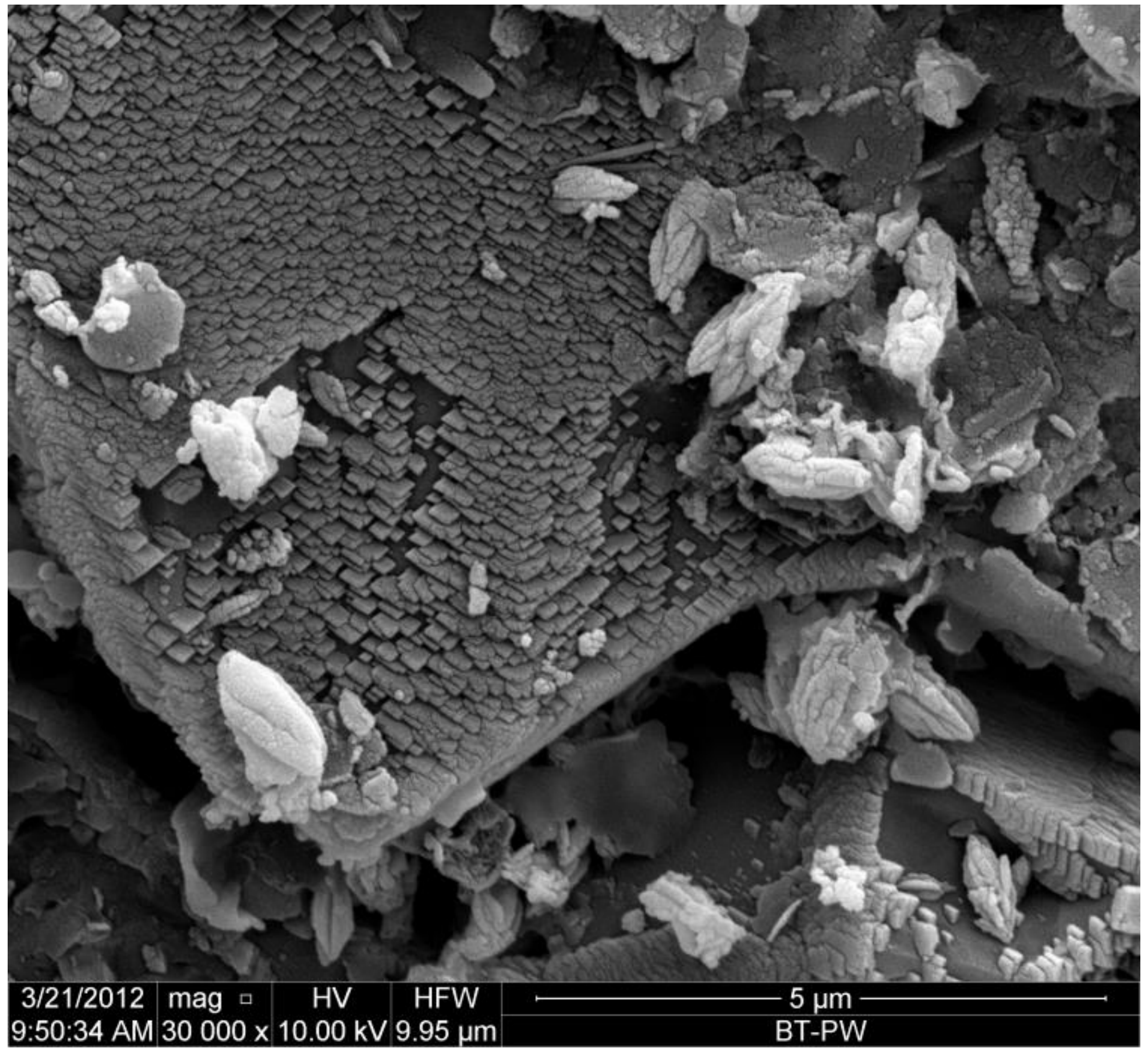
21.09.2023

DYNAMICS OF PROCESSES RELATED TO THE FORMATION, MIGRATION, AND DEPOSITION OF PARTICLES IN GEOTHERMAL SYSTEMS

In the mathematical modeling of effects related to scaling and clogging of the geothermal boreholes, the following should be taken into account:

- **mineral, petrographic, and structural analysis of geothermal system**
- construction of the injection well,
- flow, temperature, and geothermal water salinity injected into the reservoir,
- **content of dissolved substances, gases, suspension, bacteria, organic substances**
- thermal conductivity of geological materials,
- the density of the geological materials,
- specific heat of the geological materials,
- effective porosity and permeability of the aquifer….

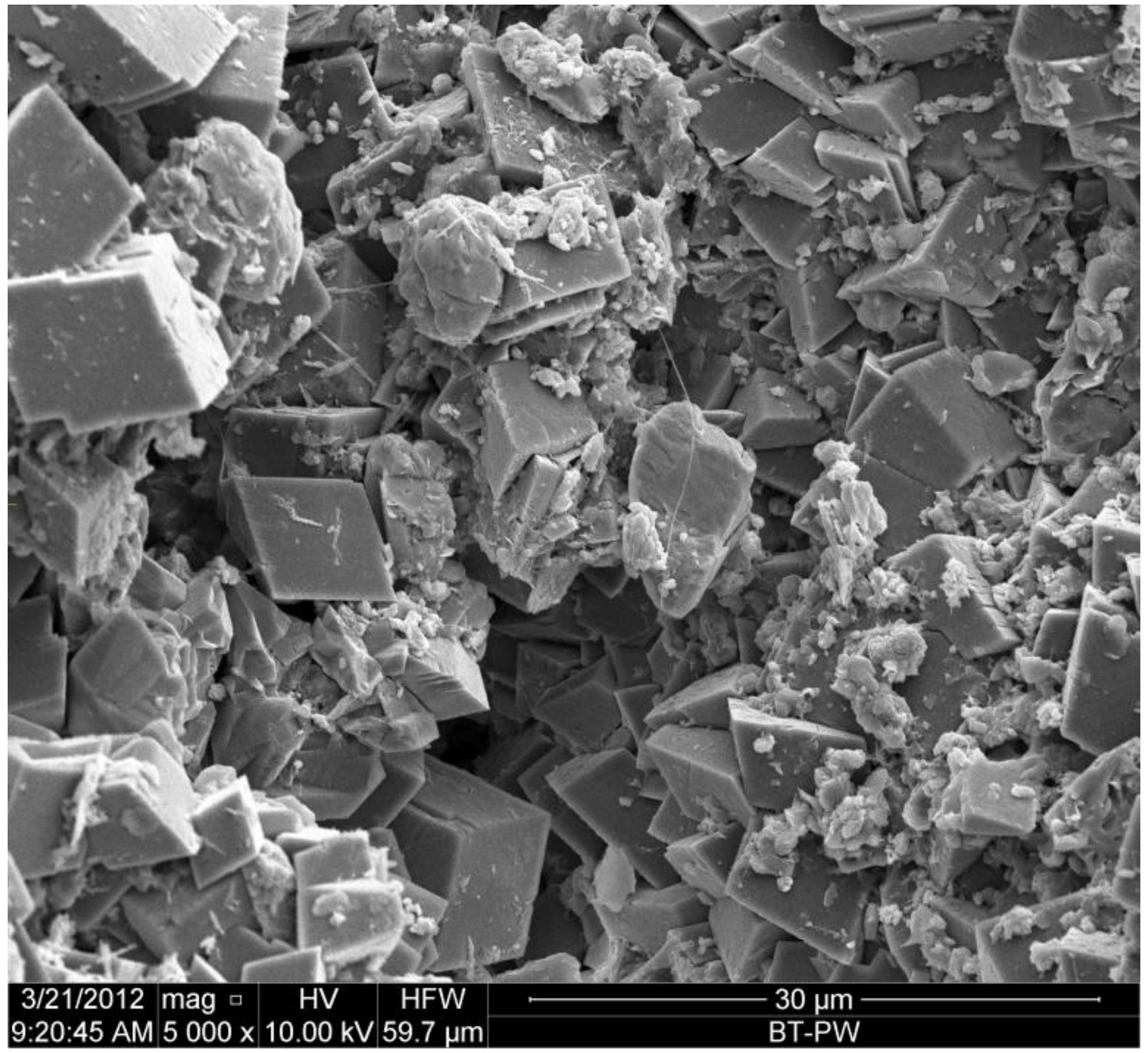


CALCITE

DYNAMICS OF PROCESSES RELATED TO THE FORMATION, MIGRATION, AND DEPOSITION OF PARTICLES IN GEOTHERMAL SYSTEMS

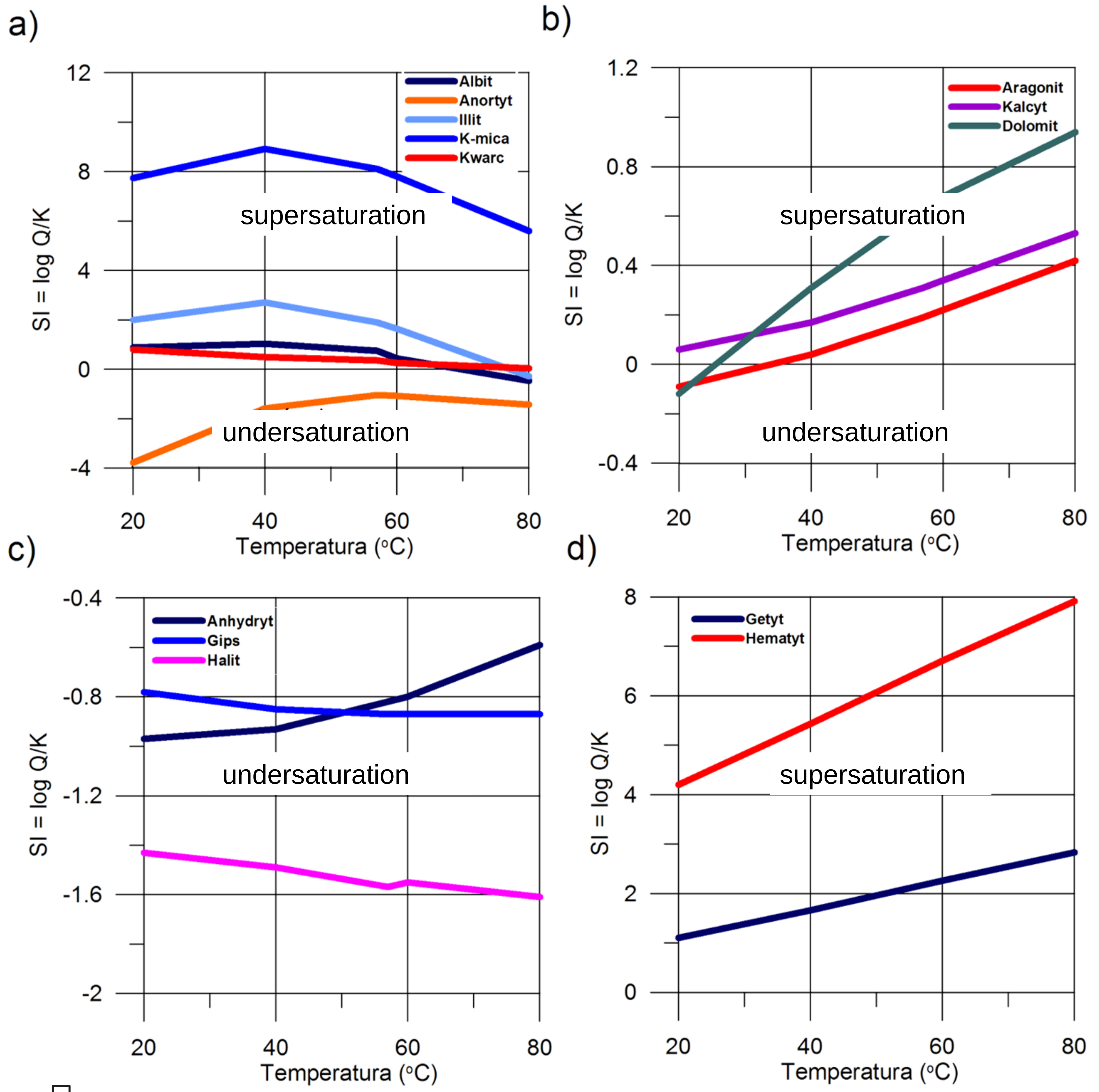
Scaling modeling should be based on computational algorithms including, especially:

1. **mineral precipitation prognosis in changes in the thermodynamic status of water**
2. flow resistance in the borehole,
3. resistances related to pumping the fluid into the reservoir,
4. resistance caused by the aquifer in the zone adjacent to the filter (so-called skin effect),
5. the influence of changes in the properties of the injected fluids on the repression pressure (viscosity and density)
6. the influence of heat exchange between saline water and the geological medium.



SIDERITE AND CLAY MINERALS

Thermodynamic equilibrium distributions of the water analysed within the temperature range 20°C to 80 °C – results of geochemical modelling



At temperature of 68°C (well-head temperature), water is mainly saturated with: silicates, aluminosillicates as well as clay and carbonate minerals.

Analyses also demonstrated super-saturation of the water with iron-based minerals: goethite and hematite. Sulphate-based minerals (anhydrite and gypsum) can dissolve in the water.

The water is super-saturated with carbonate mineral phases at a temperature of 50°C - temperature of the water injected in the rock formations during the absorbance tests.

a) silicates, aluminosillicates and clay minerals,

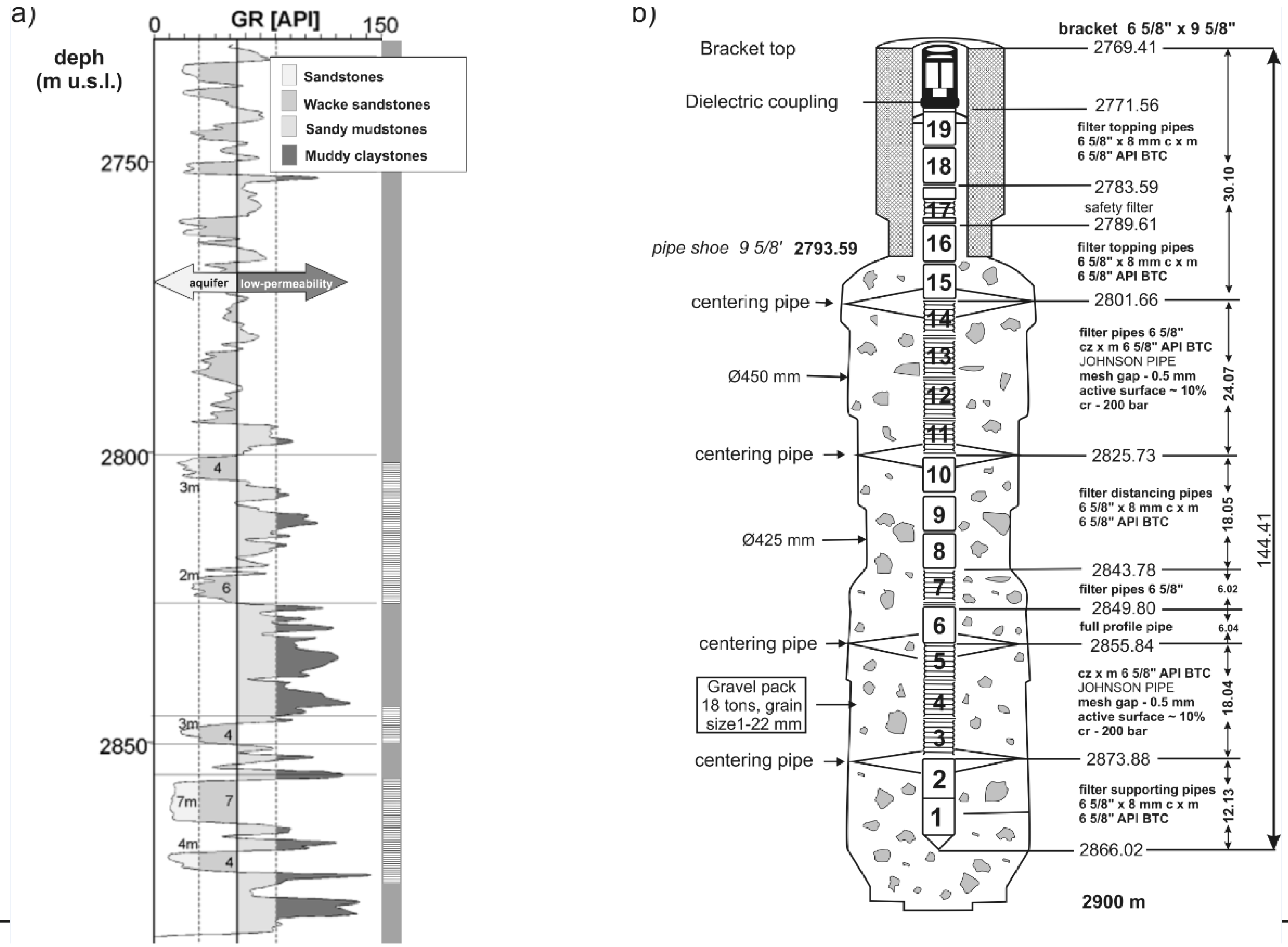
b) carbonates,

c) sulphates and halites,

d) iron-based minerals.

Precipitation of secondary sediments from the geothermal water

Taking into account the thermodynamic parameters of the water under the conditions described, it has been estimated that **the amount of sedimentation in the immersed filter zone can reach 0.063 mg/dm^3 of solids**, mainly in the form of **aragonite and calcite**. At a flow intensity of **25 m^3/h** this corresponds to approximately **1.5 kg of calcium carbonate**, and at **50 m^3/h**, twice that amount, i.e. approximately **3 kg per hour** (the length of the active section of the filter is 48.13 m).



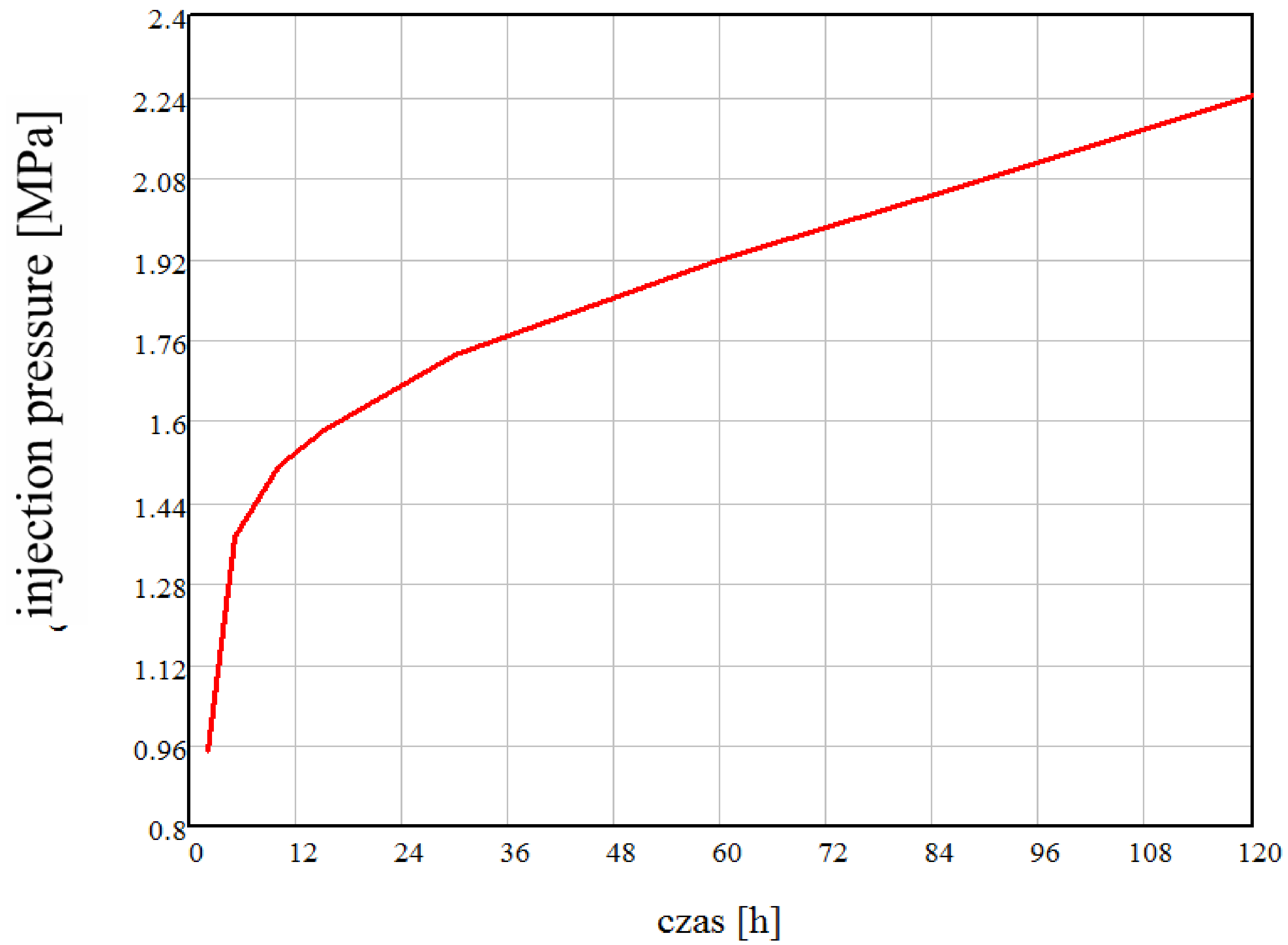
Active zone in an injection well:

a) share of sandstone formation in the lithological profile opened to exploitation

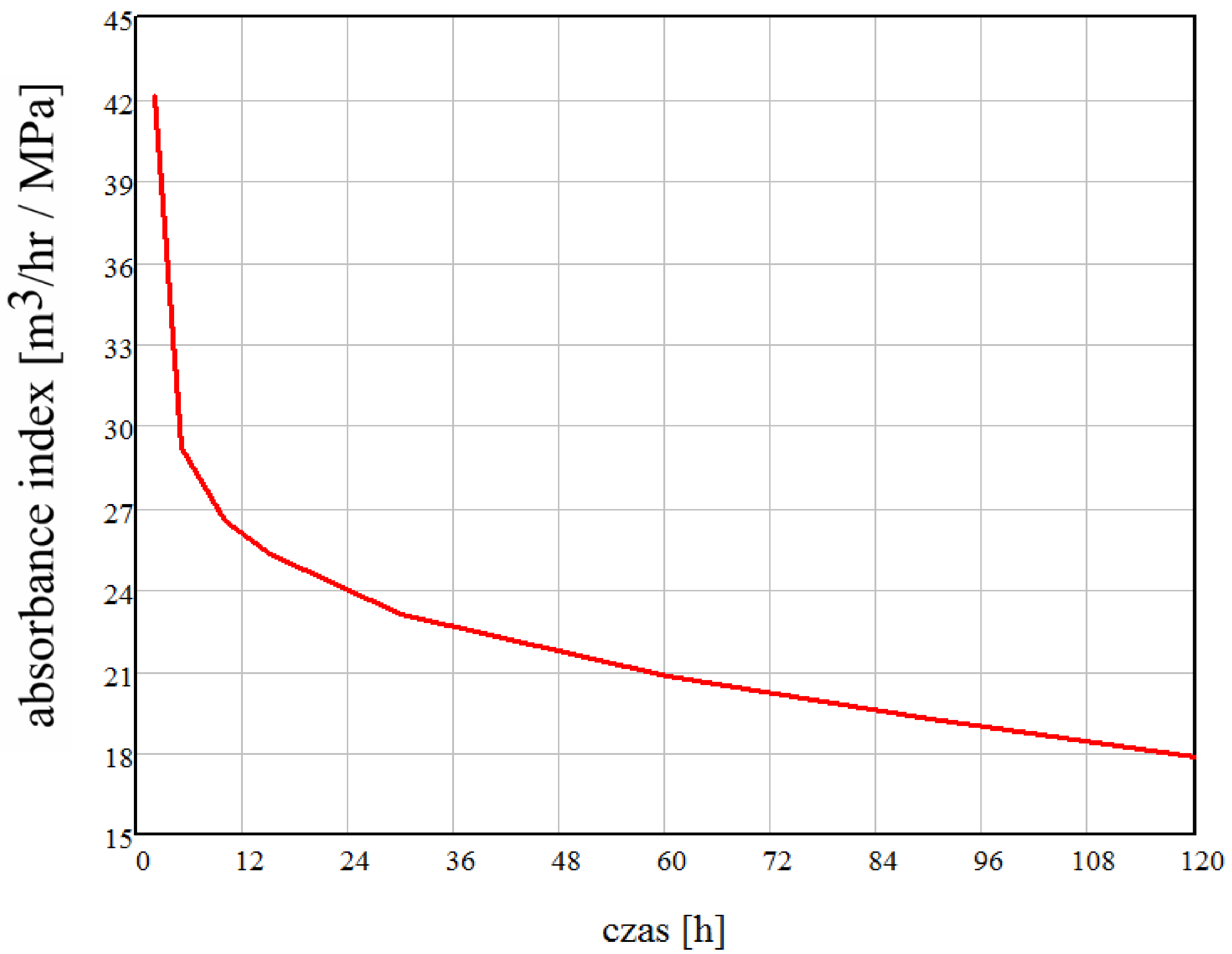
b) construction diagram of the Johnson's filter in the injection well

Dynamics of the clogging process in the active area

The forecast shows the **injection pressure increasing** particularly rapidly in the **first 24 hours of pumping**. In the subsequent hours of the period analysed the increase in pressure is close to linear and continual, **reaching a value of ~2.2 MPa at 120 hours**. The value of the **absorbance index declines**, more particularly in **the first six hours**. In the period investigated, the value decreases from more than **42 to approximately 18 m³/h/MPa at 120 hours after** initiation.



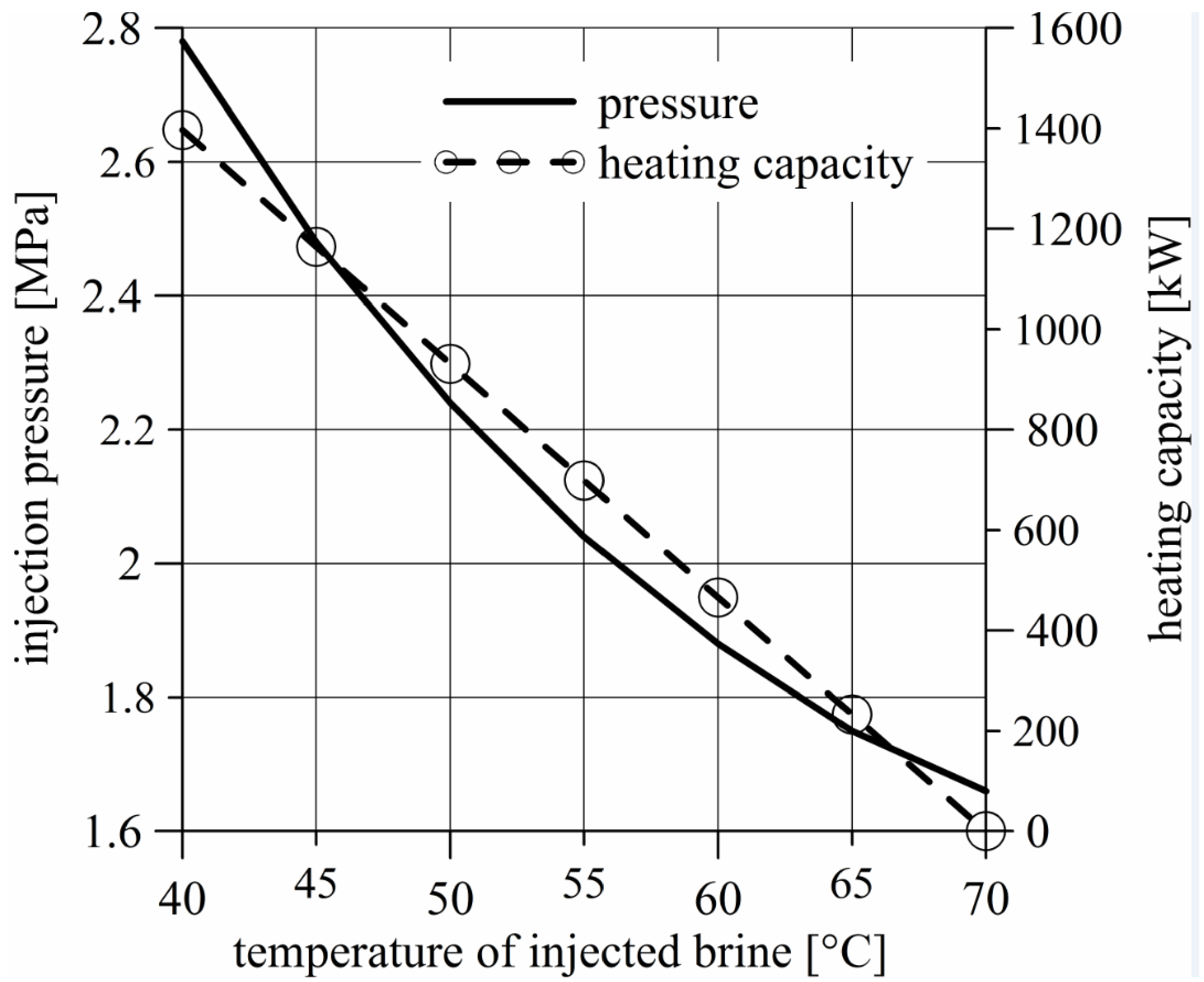
Forecast changes in the injection pressure required with time, assuming a 40 m^3/h constant flow of brine injection.



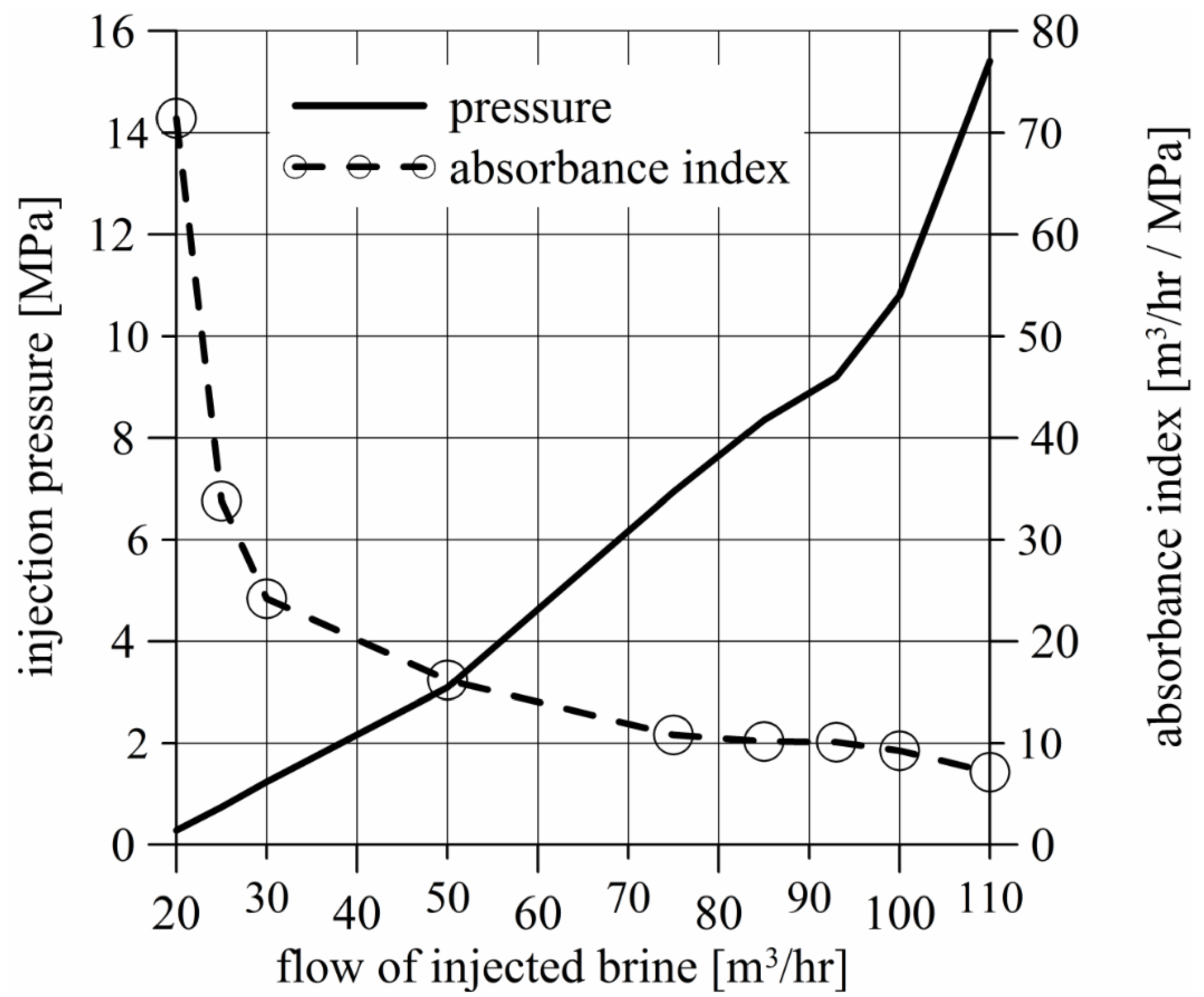
Forecast changes in the absorbance index with time, assuming a 40 m^3/h flow of brine injection.

Dynamics of the clogging process in the active area

The relationship between the **absorbance index and the flow of injected brine**, suggesting a dramatic and sudden drop of the index in the flow range up to 50 m³/h. After exceeding 50 m³/h, the value of the absorbance index decreases at a slower rate – of course increase in the injection pressure required is still observed.

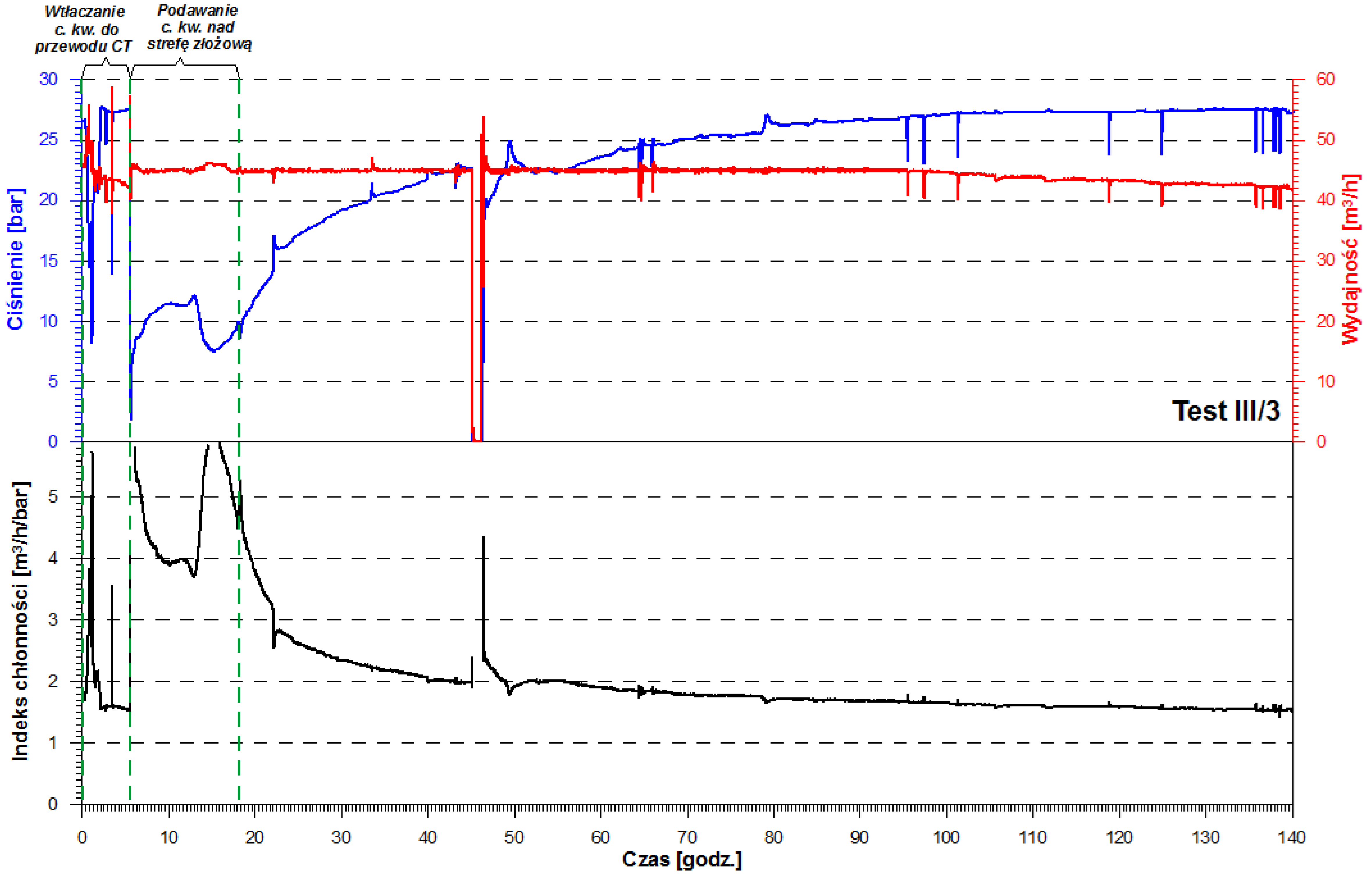


Forecast changes in injection pressure and thermal capacity of the doublet 120 hours from start-up of a cleaned injection well, at a constant flow of exploited and injected water 40 m³/h



Forecasted variation of the absorbance index and injection pressure with flow of the injected liquid, 120 hours from initiation of injection into the rock formation

Dynamics of the clogging process in the active area



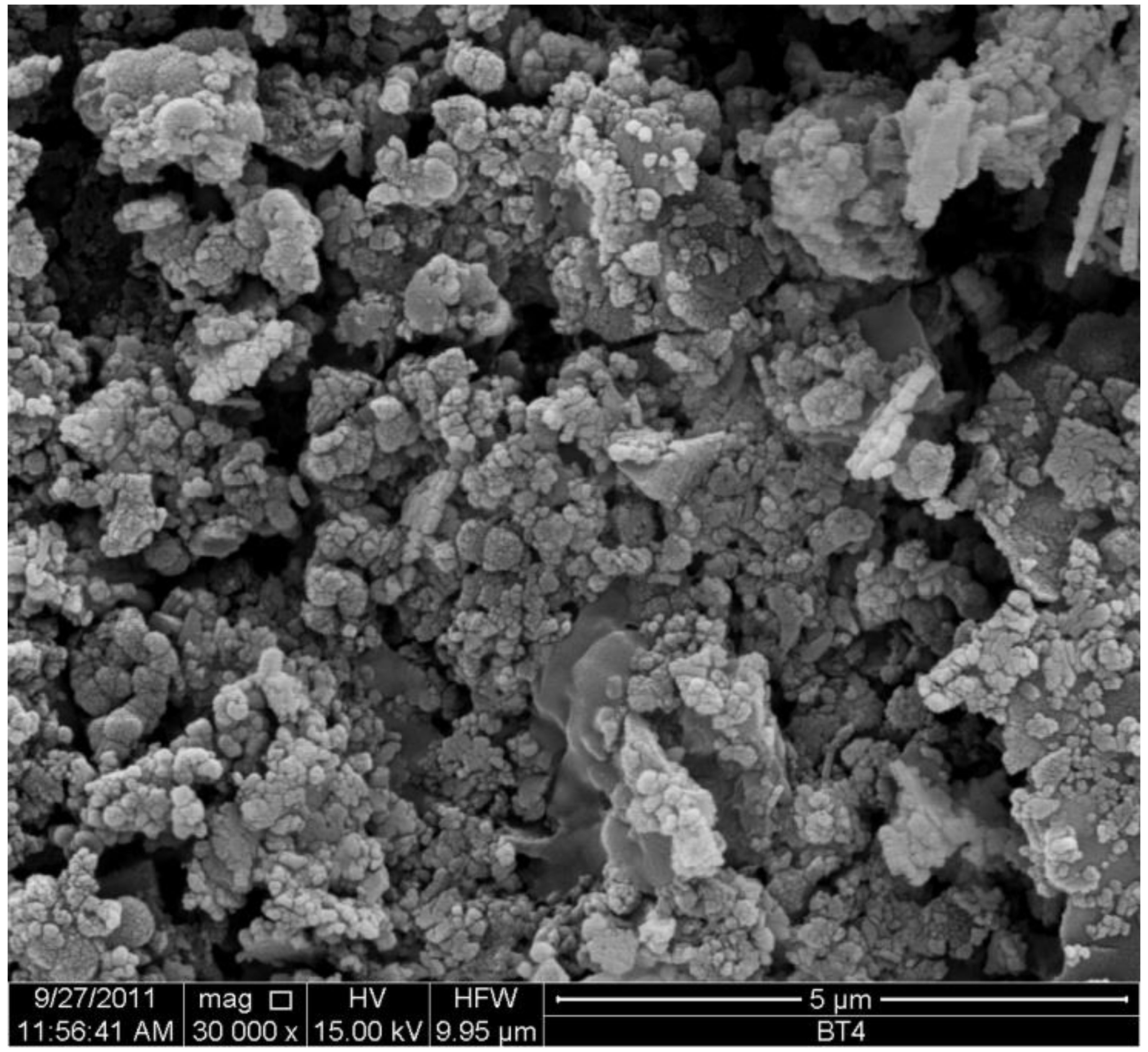
The results of analyses based on the model were verified with absorbance tests in the injection borehole, using the same flow intensity and temperature of the water injected into the source rock formation.

The results of the forecasts and real measurements taken at the borehole are comparable. The absorbance index measured during hydrodynamic tests dropped down to approximately 20 m³/h / MPa after 120 hours.

In the hydrogeothermal conditions analyzed, a sudden drop in absorbance index is being observed when the injection capacity is 50 m³/h. Above the value of 50 m³/h, the value of the absorbance index decreases at a much slower pace.

Conclusion

- Due to the number of variables involved, the mathematical description of the process is both complicated and ambiguous.
- The mathematical description of the physical properties of mineralized brines, as a function of their pressure, temperature, physical properties and chemical composition requires, by itself, the application of empirical equations developed for very specific (and not general) situations.
- The mathematical description of the injection process has been derived using a significant number of assumptions made to simplify the process.
- To that, one must add the changes in permeability of the filter zone and the reservoir formation itself caused by the precipitation of various types of substances and products of corrosion processes. Because of all these factors, calculation of the pressure to overcome in injecting brine to the rock formation can only be estimated and approximated.
- Having a well-prepared mathematical or numerical model, we can only describe reality with some approximation. Carrying this kind of calculation, has a value and purpose such as, for instance, **shedding light on the scale of the problem and identifying the issues that need to be overcome**.



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Thank you!

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