Geo-Energy and subsurface processes

Exam 28.01.2022

Exam Hall 4 G12 – I, 8.30-10.30 am

Name: Student ID:

Q1 Geothermal energy (30P)

In Figure 1 you see a dipping reservoir layer of approx. 180m thick. A geothermal doublet has been drilled into it with an injector updip and a producer downdip. The perforated zones in the wells are indicated in red.

The power of the doublet is described by:

$$P = \rho_w c_w (T_1 - T_0) Q$$

Where T_0: cold water temperature at inlet, T_1: initial aquifer temperature, ρ_w: water-density (1000 kg/m^3), c_w: specific heat of water (4000 Jkg^{-1}°C^{-1}), Q: volume flow-rate.

a) assuming the production rate equals the injection rate, what is then the power output in MW of the doublet, measured 3 years after start of injection? (7P)
b) As in a) but after 43 years after start of injection? (7P)
c) Why is the “cold zone” below the injector well wider than above it? (2P)
d) The “breakthrough time” is defined as the time after start of injection when the temperature at the producer has dropped below a certain level, in this case 25°C. If we would swap the locations of the injector and producer wells, would the breakthrough time then become shorter, longer or stay equal? Motivate your answer. (4P)

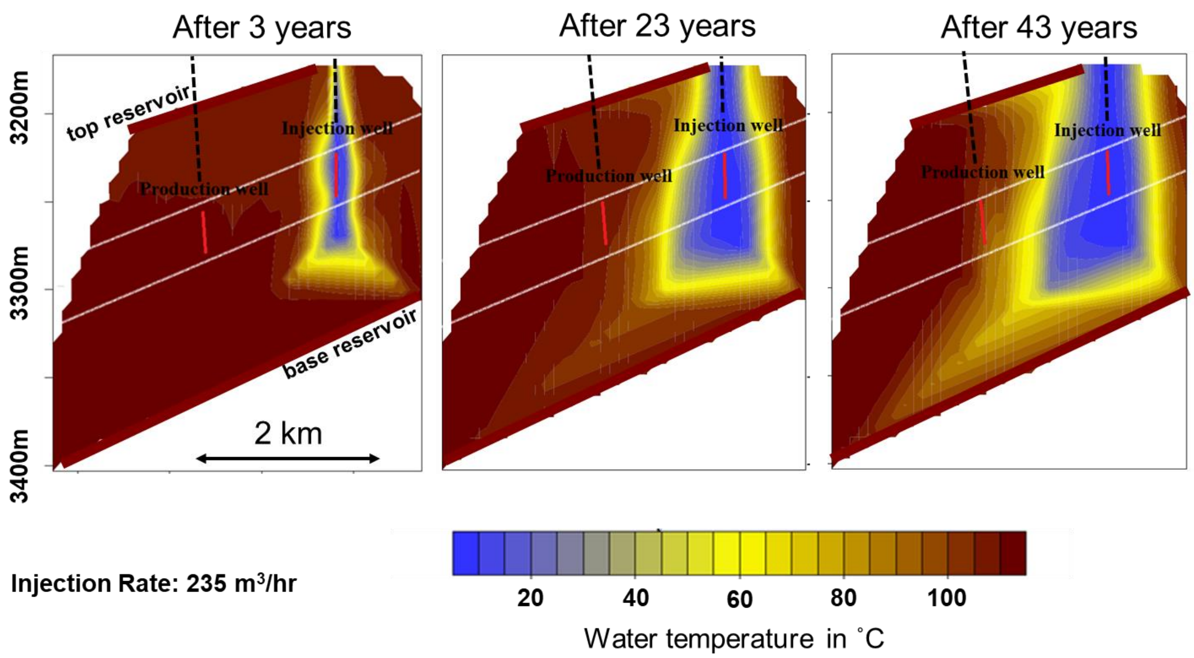

Figure 1. Geothermal doublet cross section.

a)

P= 1000*4000(115-5)* (235/3600)

= 28.722.222 W

=28,72 MW

7 P

b)

P= 1000*4000*(95-5)*(235/3600)

=23.500.000 W

= 23.5 MW

7P

c)

Cold water is denser and sinks to the bottom of the reservoir.

2P

d)

Breakthrough time would be longer as the cold water would sink to the bottom of the reservoir (to the left) and the cold plume would take longer to reach the production well.

4P

Q2 CO2 storage (30P)

A gasfield has been identified for possible CO_2 storage. At the moment the field is however still in production, but CO_2 injection will start as soon as the field is completely depleted. The expected cumulative production can be predicted using Figure 2. In line with storage regulations in the Mining Law, a maximum storage pressure needs to be adhered to, which has a safety margin of 60 bar below the initial gas pressure.

The field is situated at a depth of 3850m and is 175 bar overpressured. The local temperature gradient is 15˚ + 0.035˚C/m. Based on the reservoir conditions the gas expansion factor E = 288.

a) How much natural gas will be produced from the gas field during its lifetime at standard and at subsurface conditions?
b) What is the CO2 density at reservoir conditions (taking maximum allowed pressure for storage into account)?
c) Assuming that the pore space previously occupied by the natural gas, how much CO2 could be stored in the reservoir (in million tonnes)?

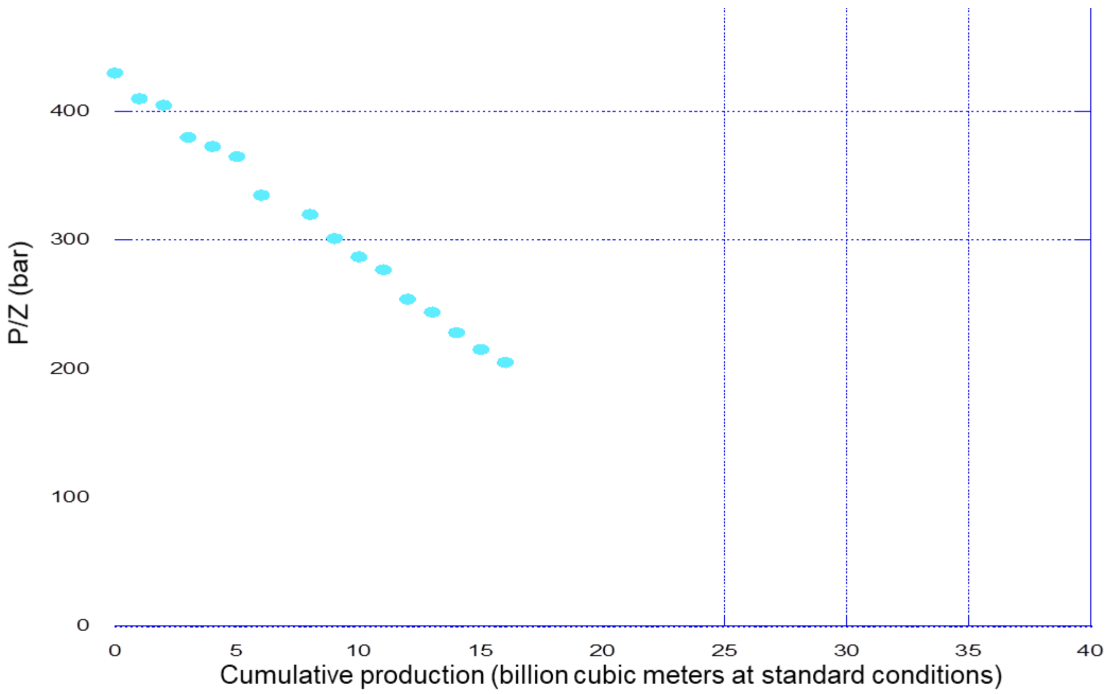

Figure 2: Commulative Production vs P/Z plot of the gas field. Production ends at P/Z = 0.

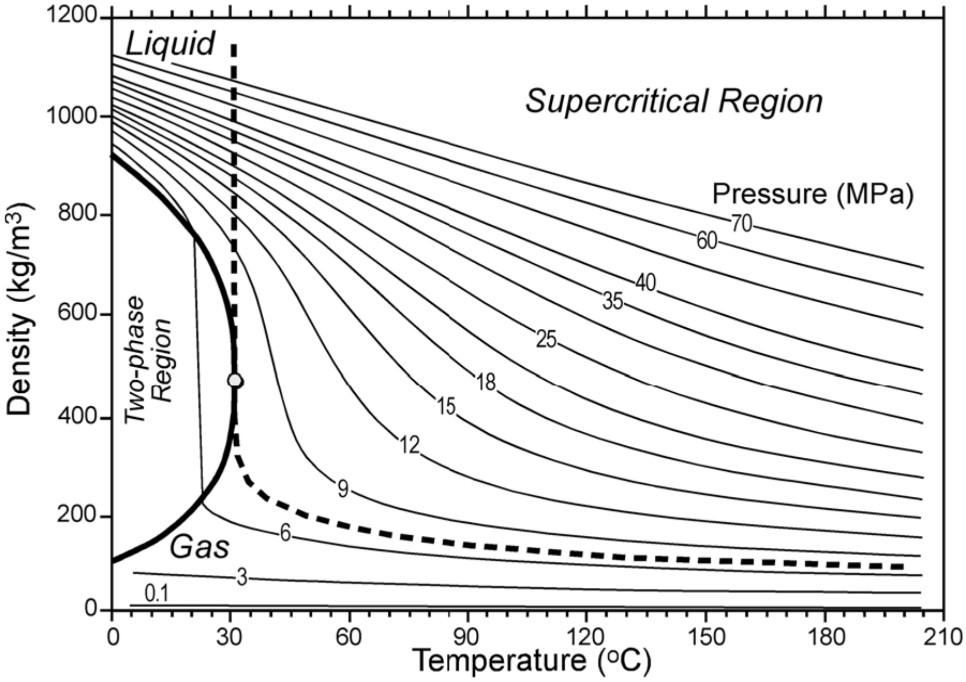

Figure 3: CO2 density as function of Temperature and Pressure.

a)

30 BCM (P/Z =0) at standard conditions

30/288 BCM at reservoir conditions = 104.166.666 m³

b)

T = 149, 75 -> ~ 150°C

P = hydrostatic + overpressure – 60 bar safety margin

= 38,5 + 17,5 -6 MPa = 50 MPa

CO2 Density (150 °C/50MPa) = 687 ~ 700 kg/m³

c)

104.166.666 m³ * 700 kg/m³ = 72.916.666.200 kg -> 72.92 Mt

Q3 True or False (15P)

True or False? Two points per correct answer.

1. The inclination of the paleo-magnetic field is related to the paleo-longitude.
2. The velocity of elastic waves, caused by an induced earthquake at reservoir level, decreases significantly when they reach the shallow soil interval at around 50m below the surface.
3. Salt structures are better determined on gravity profiles than on magnetic profiles.
4. The seismic response of a series of lithological contrasts in the subsurface is determined by the convolution of the source wavelet with the acoustic impedance time-series.
5. The so-called “lower bound” pressure is determined by the fracture initiation pressure derived from leak off tests in wells.
6. The density logging tool contains a radio-active source.
7. Under isothermal conditions is the viscosity of CO_2 decreasing with increasing pressure.
8. The thermal conductivity in limestones is lower than in salt.
9. The heatflow of geothermal energy is predominantly caused by the cooling of the planet earth
10. The velocity of compressional (longitudinal) elastic waves is higher than the velocity of shear (transversal) elastic waves.

Q4 (10P)

Oder the clastic reservoirs based on likely reservoir quality (good to poor reservoir quality). To each type, add a typical geometry (fans, channels, dunes, flats, sheets, stacked sands).

Coastal

Fluvial

Basin floor

Shelf

Deltaic

Alluvial

Slope

Aeolian

1. Coastal	Sheets
2 Deltaic	Stacked sands
2 Aeolian	Dunes /flats
2 Slope	Channels
3 Fluvial	Channels
4 Shelf	thin sheets
4 Basin floor	fans
5 Alluvial	fans /channels

Q5 (15P)

What are at least five risks associated with subsurface utilization? What can be done to minimize these risks? Please elaborate.

Reservoir compaction

Induced seismicity

Surface subsidence

Environmental impact from polluted waters

Leakage of fluid though faults /overburden

Leakage along wells

Bacteria growing

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Site characterization (how?)

Guidelines

Monitoring (how?)

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