

KivSimEiBase vs. KivSimEi* (free beta version)

* The enhanced import/export functionalities of KivSimEi are developed in the framework of the GEOTREF research project (www.geotref.org). They are freely available through a beta version of KivSimEi, which is a temporary plugin. Eventually, they will be moved into a new plugin GefSim, which will provide a comprehensive link between SKUA-GOCAD and geothermal simulators.

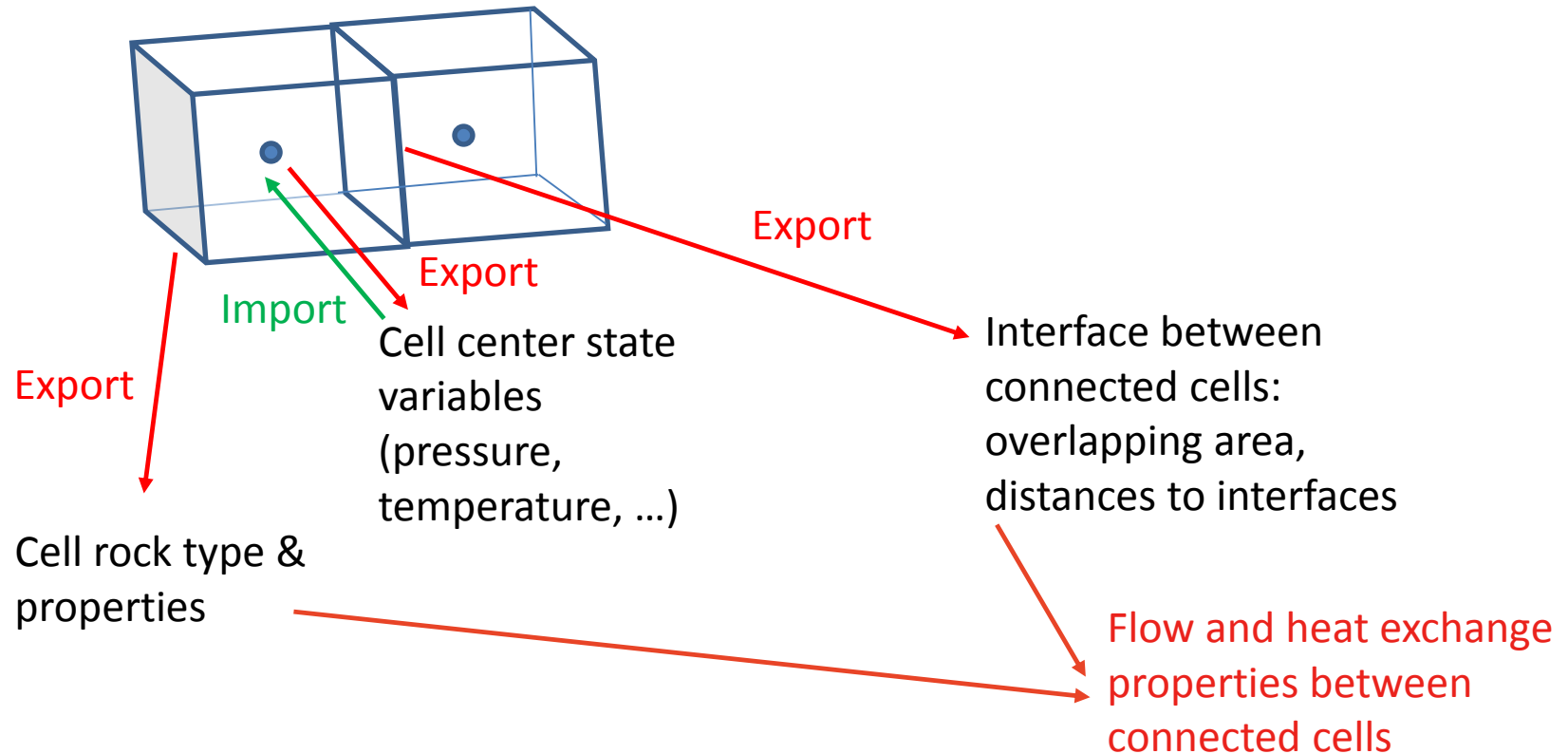
Export and import capabilities
for the TOUGH2 suite of simulators

TOUGH2 EXPORT CAPABILITIES

1. Possible import and export of grid data
2. Export of grid data (ROCKS & MESH files)
3. Conductive discontinuities modifiers
4. Non-conductive discontinuities modifiers
5. State variable data (INCON file)
6. Well data (GENER file)



Possible import and export of grid data



Export of grid data

Basic grid data to export

- Rocks model complexity
- Block data (volume, permeability factor)

New in KivSimEi: export of top and bottom boundary condition (BC) cells

- Possibility to add top and bottom cells (not present in the reservoir grid known by SKUA-GOCAD), and to specify their connections with top and bottom reservoir grid cells, in order to define top and bottom Dirichlet boundary conditions (BC) in TOUGH2 (prescribed state variable values)

1 Fill parameters to export files

Reservoir grid: SimGrid5km

Output directory:

Prefix to output file names: prefix_

2 Export grid or well data

Grid data | Non conductive discontinuity modifiers | Conductive discontinuity modifiers

☒ MESH and ROCKS files

Rock classification: Rocks [Edit] [Create...]

Check rock name consistency: [Check]

Rock type: ☒ From Gocad property ☐ Single

Gocad rock property: Rocks_3D [Create...]

Single rock type: CdLim

Cell volume property: [Compute]

Min cell volume: 1e-3

☐ Export permeability factor

Gocad permeability factor property:

☐ Create mesh info file

☒ Add a top boundary condition cell

Specify the top grid cells to connect: everywhere

Cell volume: 1e+50

Permeability (m2): 1.e-10 Distance to interface (m): 1.e-09

☒ Add a bottom boundary condition cell

Specify the bottom grid cells to connect: everywhere

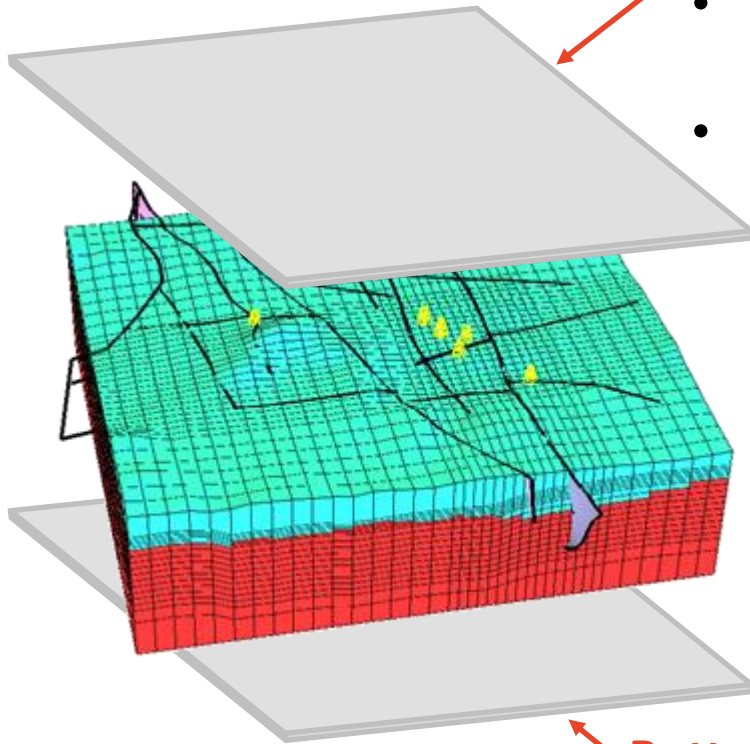
Cell volume: 1e+50

Permeability (m2): 1.e-50 Distance to interface (m): 1.e-09



Export of top and bottom BC cells

- **New in KivSimEi**



- **Top boundary condition cell known by TOUGH2**

- Usually thin (small distance from the reservoir grid) but with a high volume
 - Connected to all or part of top reservoir grid cells

Grid known by SKUA-GOCAD

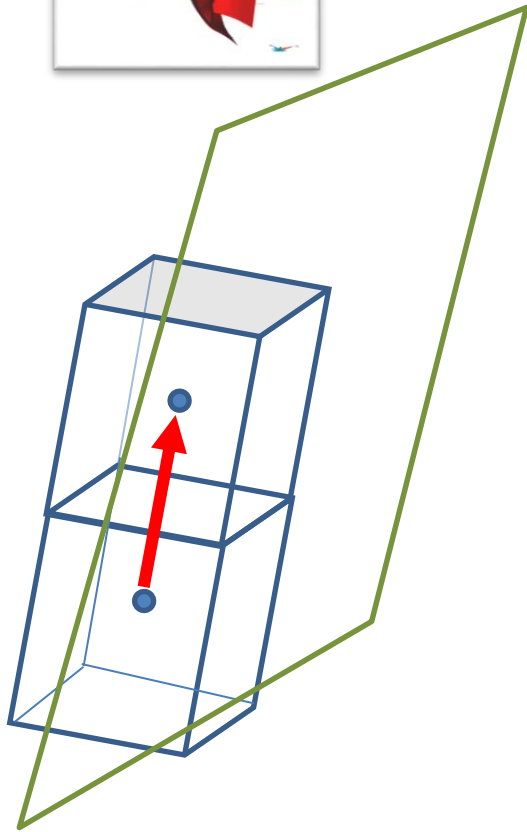
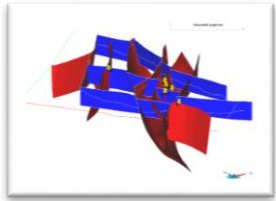
- **Bottom boundary condition cell known by TOUGH2**

- Usually thin (small distance from the reservoir grid) but with a high volume
 - Connected to all or part of bottom reservoir grid cells

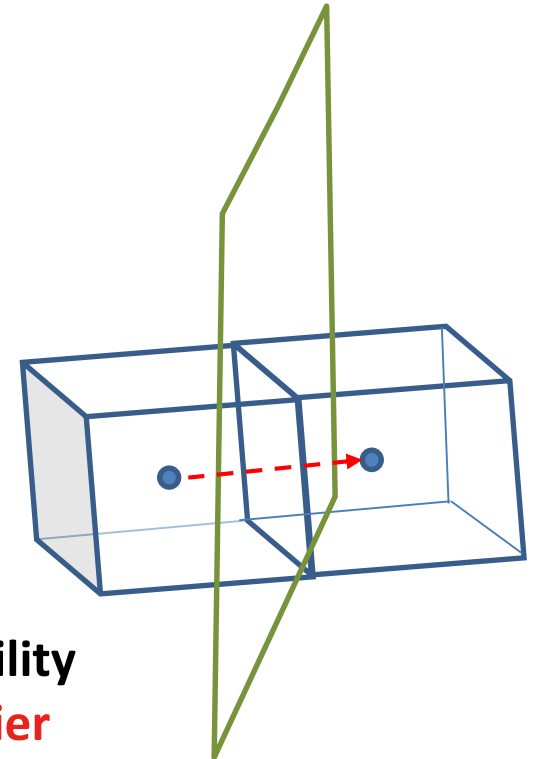


Taking into account discontinuities

- New in KivSimEi



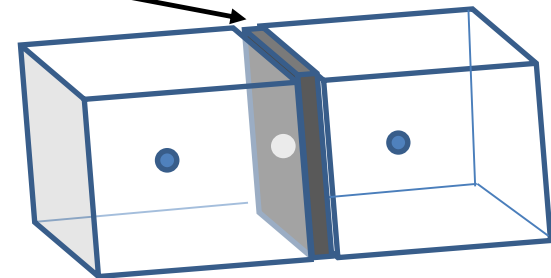
Conductive discontinuity
=> increased transmissibility
through increased area



Sealed discontinuity
=> decreased transmissibility
Not a heat transport barrier

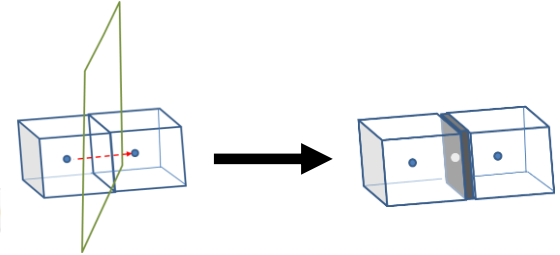


**Adding intermediate cells
known only by TOUGH2**



Taking into account discontinuities

- Nonconductive discontinuities



Non conductive discontinuity modifiers

Conductive discontinuity modifiers

State variable

☒ Non conductive discontinuities for mesh file

Target region

ReservoirRegion

	Discontinuity	Permeability factor
1	Conductor_fracture...	1.e-3
2	F1_2km	1.e-3
3	F2_2km	1.e-3
4	F3_2km	1.e-3
5	F4_2km	1.e-3
6	F5_2km	1.e-3
7	F8_2km	1.e-3
8	F9_2km	1.e-3

Apply same permeability factor
to selected rows

Volume factor 1e-1

Remove

Apply

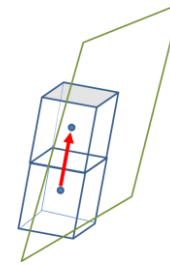
New in KivSimEi: non-conductive discontinuities

- Accounting for nonconductive discontinuities by adding intermediate cells, known only by TOUGH2, in between GOCAD-SKUA grid cells.
- New cell properties are calculated from GOCAD-SKUA grid cell properties, based on a permeability (reduction) factor and a volume (reduction) factor.



Taking into account discontinuities

- Conductive discontinuities



Grid data Non conductive discontinuity modifiers **Conductive discontinuity modifiers** State variable

☒ Conductive discontinuities for mesh file

Permeability model
☒ Single (CONNE) ☐ Dual

Target region ReservoirRegion

	Discontinuity	Transmissivit
1	Corredor_fract...	9.9e-13
2	Corredor_fract...	9.9e-13
3	Corredor_fract...	9.9e-13
4	Corredor_fract...	9.9e-13
5	Corredor_fract...	9.9e-13
6	Corredor_fract...	9.9e-13

Remove

Apply same transmissivity to selected rows 9.9e-13 Apply

New in KivSimEi: conductive discontinuity modifiers

- Accounting for conductive discontinuities by correcting the transmissibility of connected cells for which the interface is intersected by one or several discontinuity surfaces.
- The correction applies to the interface area (only interface parameter available as input to TOUGH2) and is based on the intersection length and the transmissivity assigned to each discontinuity.
- Exporting conductive discontinuities into a dual permeability model is an option which is not yet available (interest to be confirmed).



State variable data (INCON file)

Grid data Non conductive discontinuity modifiers Conductive discontinuity modifiers **State variable data** Well data

☒ INCON file

☐ Export porosity

Gocad porosity property

Import state variables from existing INCON file

	Sorted TOUGH2 state variables	Top cell values	Bottom cell values	
1	Sim_Grid_09062016!Project/P_0	1.0e5	4.0e7	P_0 T_0 Sg_0 <input type="button" value="Add"/>
2	Sim_Grid_09062016!Project/T_0	10	360	<input type="button" value="Remove"/>
3	Sim_Grid_09062016!Project/Sg_0	0.99	0.0	<input type="button" value="Up"/>
				<input type="button" value="Down"/>

New in KivSimEi: boundary conditions

- Specifying the state variable values in the top and bottom boundary condition cells




Well data (GENER file)

Grid data | Non conductive discontinuity modifiers | Conductive discontinuity modifiers | State variable data | **Well data**

☒ GENER file

Well name	Perforation	MD Top (m)	MD Bottom (m)
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Add
Remove

 **Add Well Perforation**


1 Select well(s)

☐ Add all perforations from selected wells

☒ Add selected perforations from one well

Well   

2 Select perforations

Perforations 

Create

OK Cancel Help

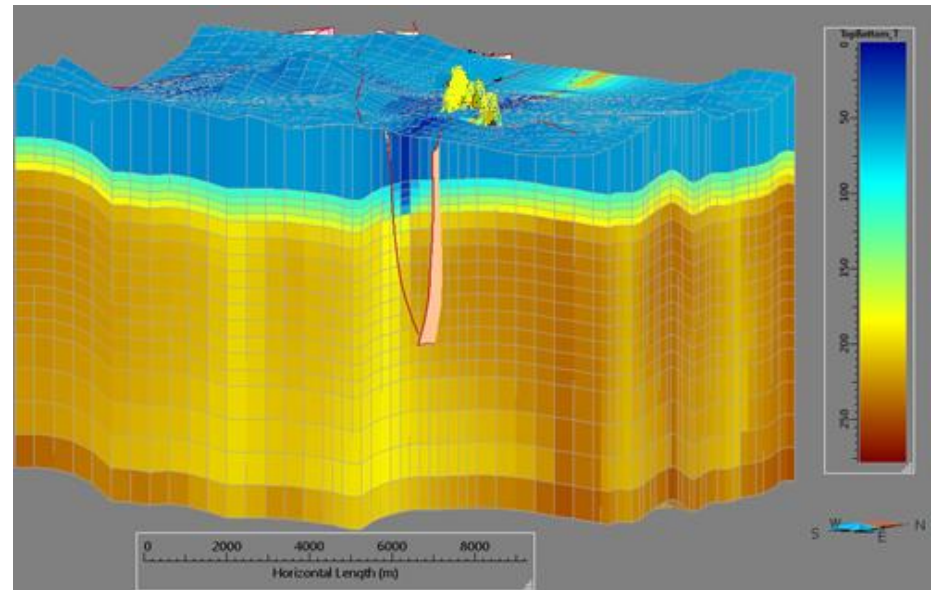
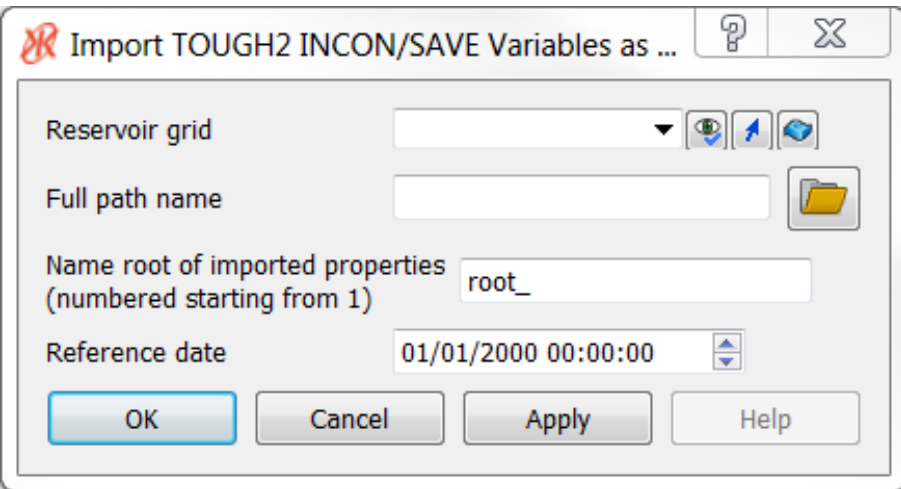


TOUGH2 IMPORT CAPABILITIES


1. Final simulated state variables (INCON/SAVE files)
2. Simulated state and derived variables at intermediate time-steps (*.out files)
 - Cell centered variables
 - Cell exchange variables
 - Flux vectors






INCON/SAVE files




*.out files

 Import TOUGH2 Output Variables as SGrid Property...


1 Select grid and properties

Reservoir grid   


Full path name 

Prefix to property names

2 Define date


Reference date 

☒ Import as initial condition simulation
☐ Import results from output time steps




3 Import simulation results

☐ Read cell variables


Select cell variables 

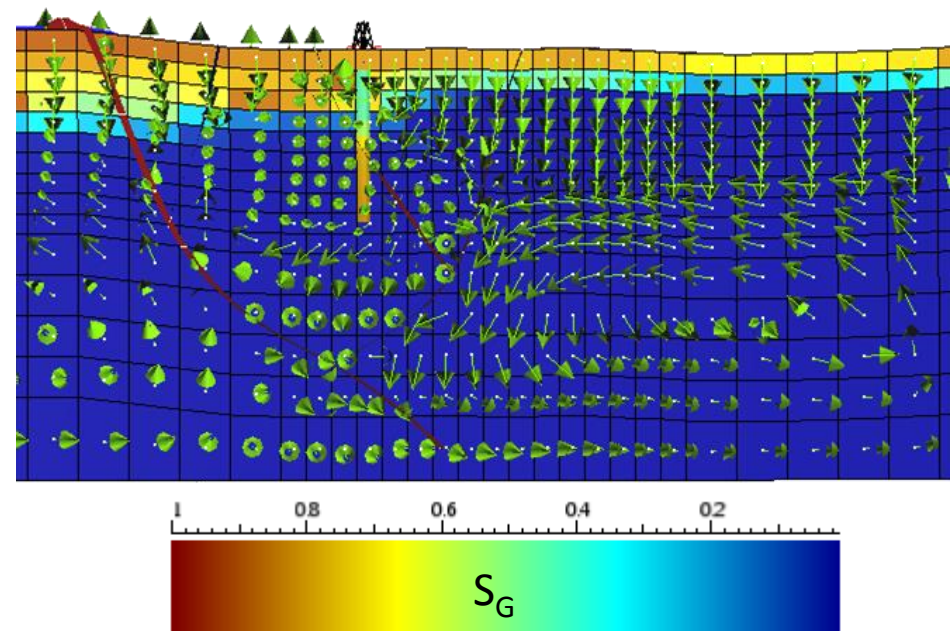
☐ Read cell exchange variables

Select exchange variables 

Exchange direction
☒ Cell input ☐ Cell output

☐ Compute flux vectors

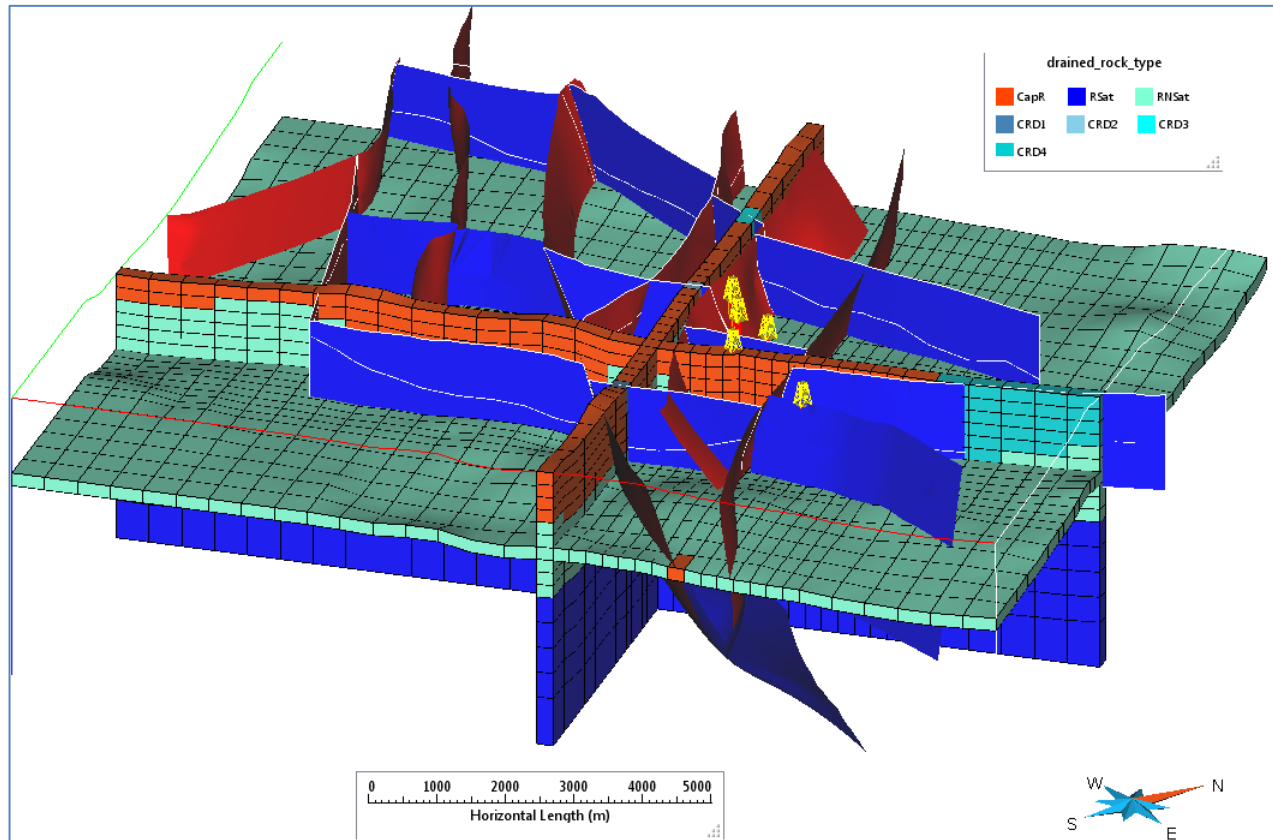
Select rate variable 



ILLUSTRATION



Structural model

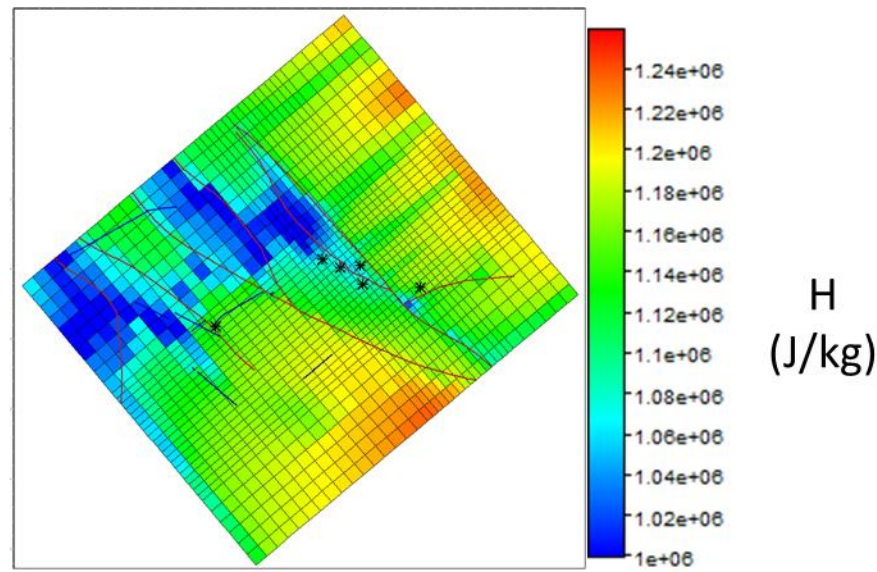
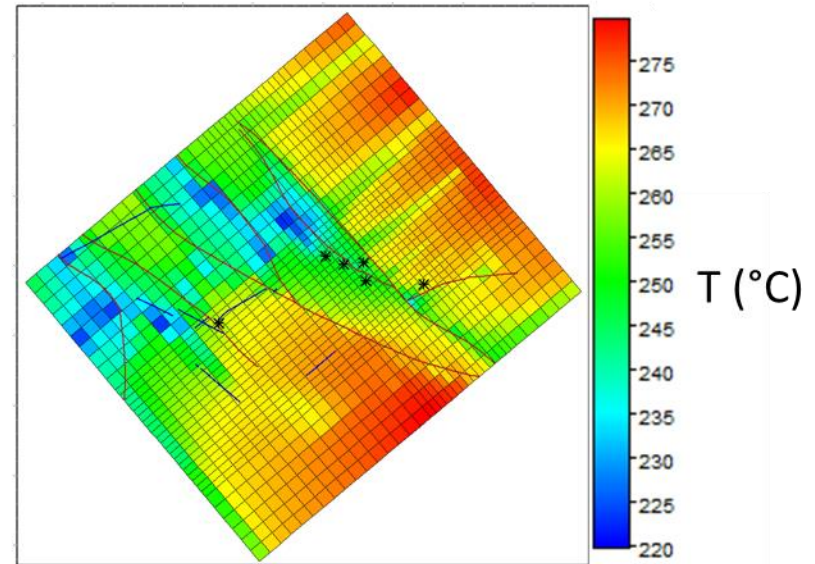
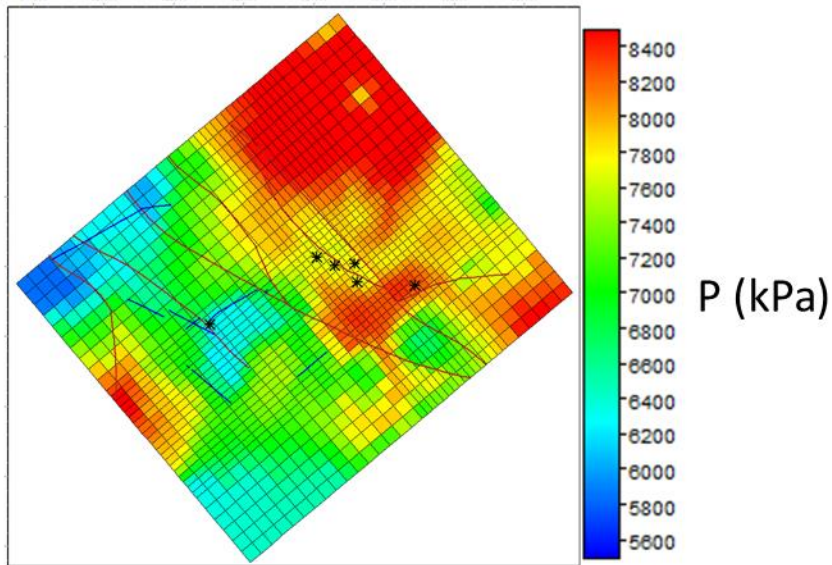


Blue: conductive discontinuities (fracture corridors, deep faults)
Red: nonconductive discontinuities (flow barriers)



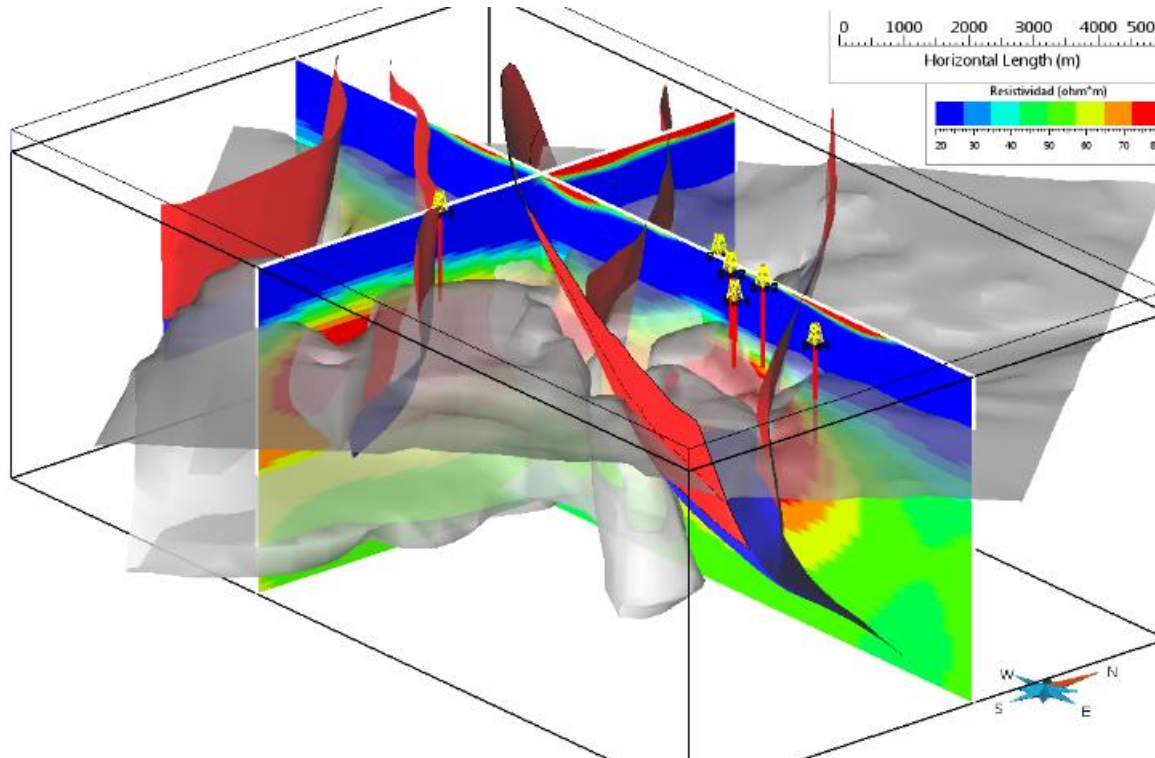
Simulation of initial conditions

- Pressure, temperature and enthalpy @ 1500 m



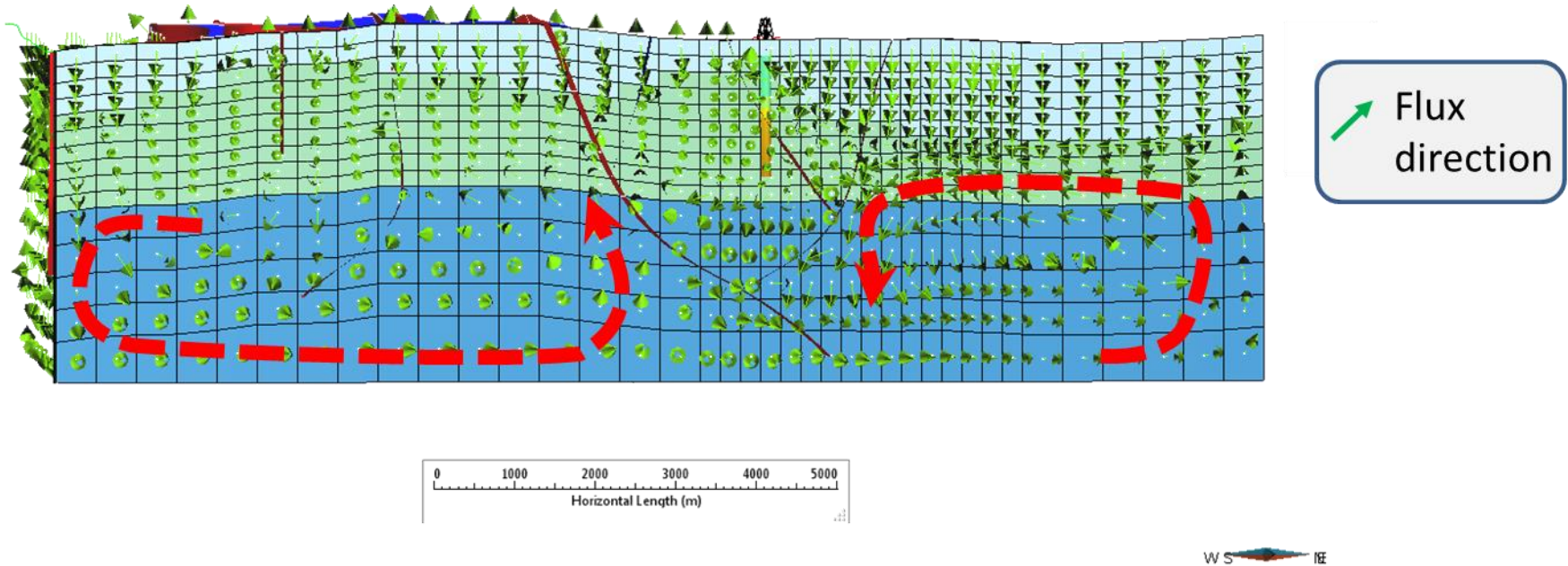
Simulation of initial conditions

- Iso-surface of $T = 220^{\circ}\text{C}$



Simulation of initial conditions

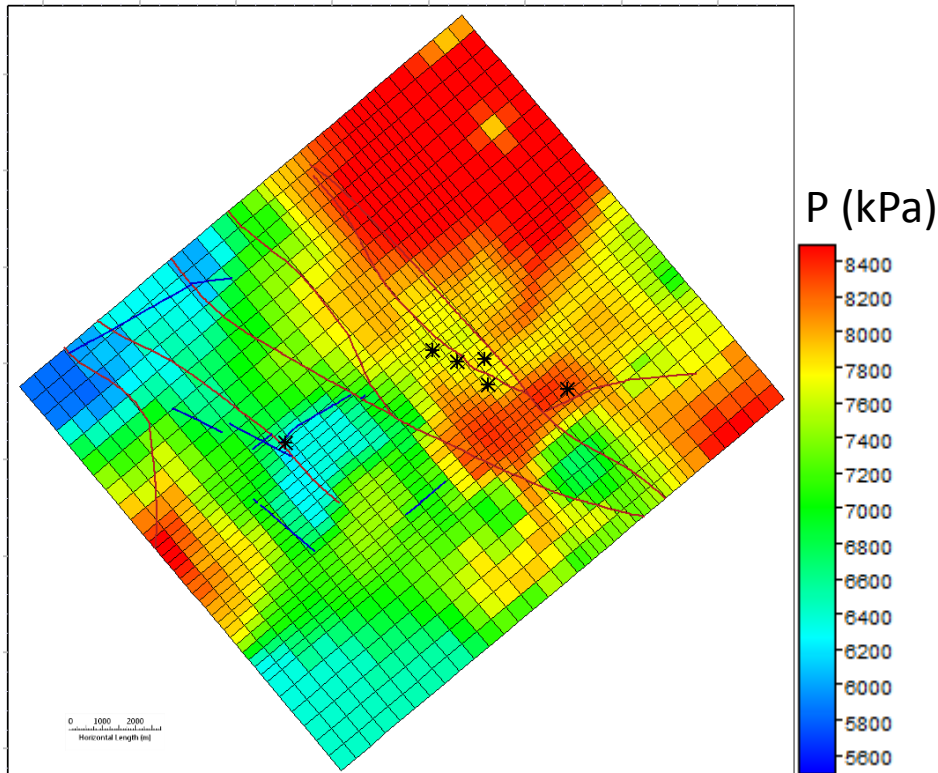
- Flux vectors



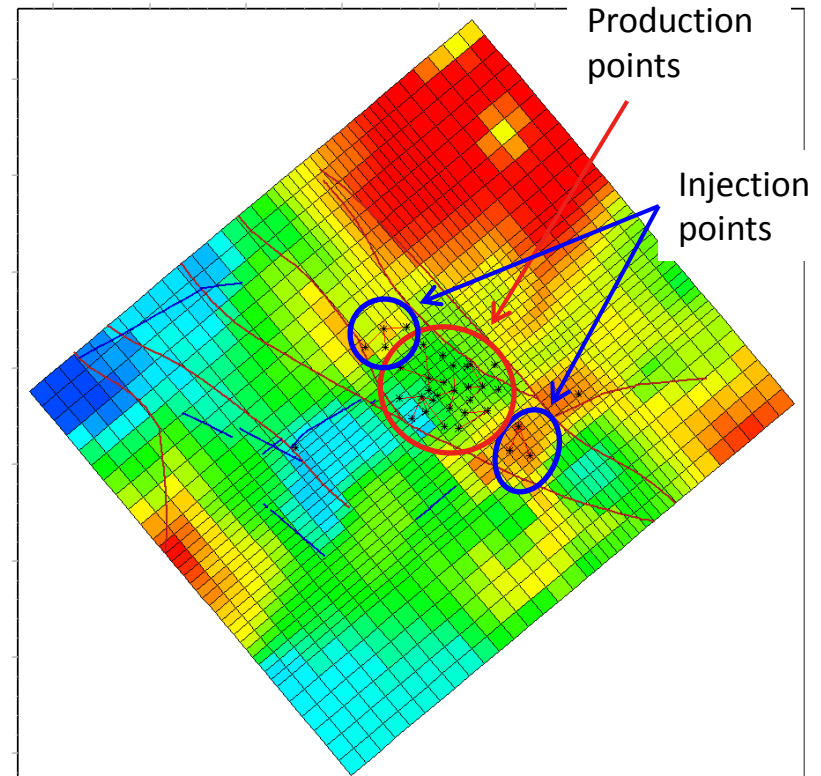
Simulation of a development plan

- Pressure map @ 1500 m

Initial conditions



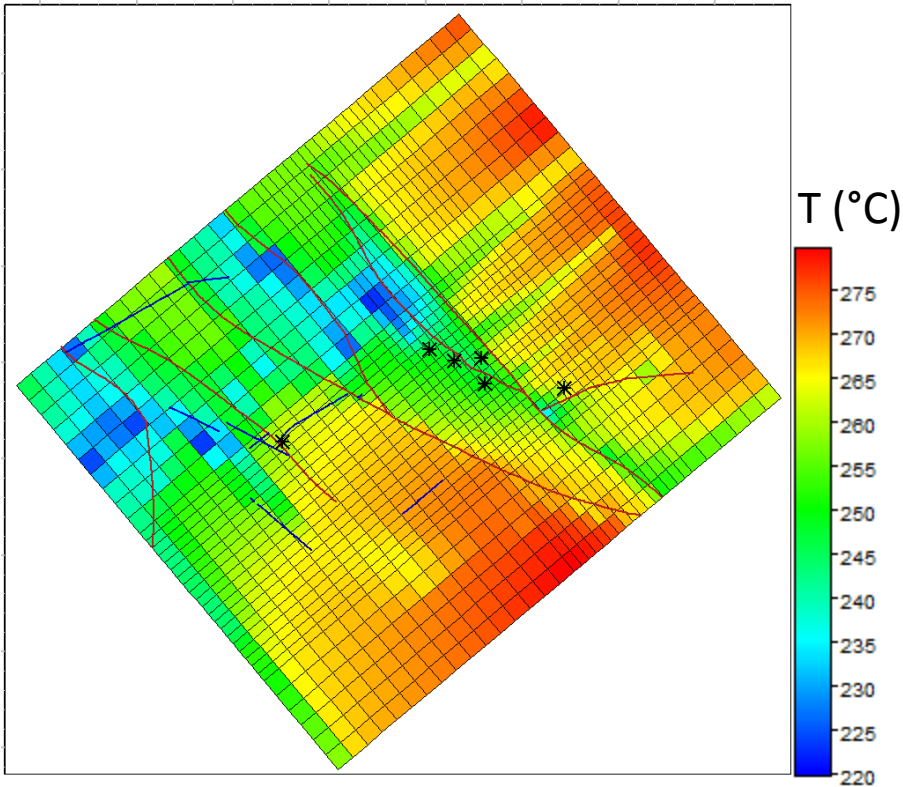
Conditions after 50 years of production



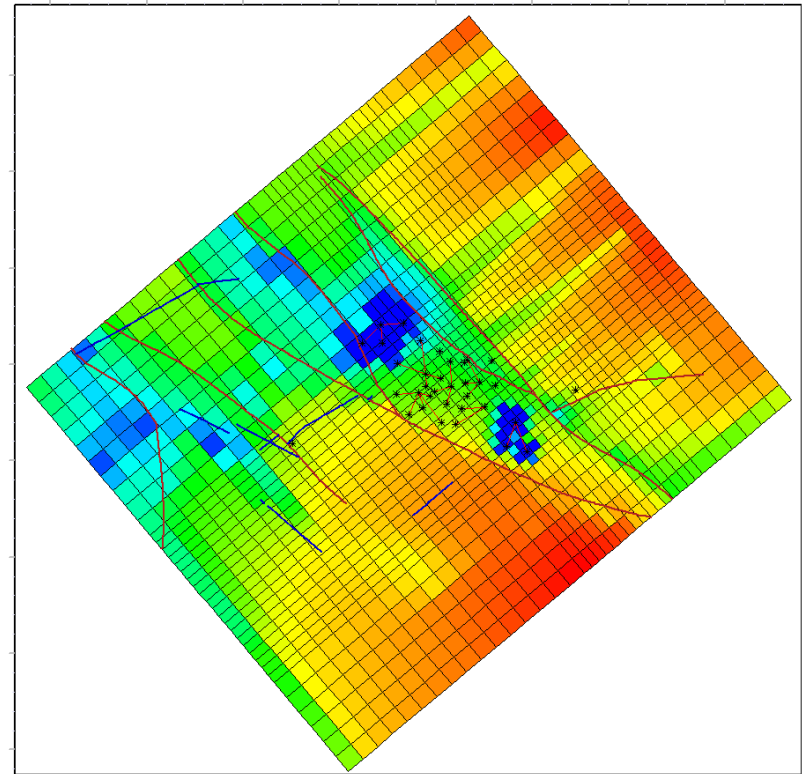
Simulation of a development plan

- Temperature map @ 1500 m

Initial conditions



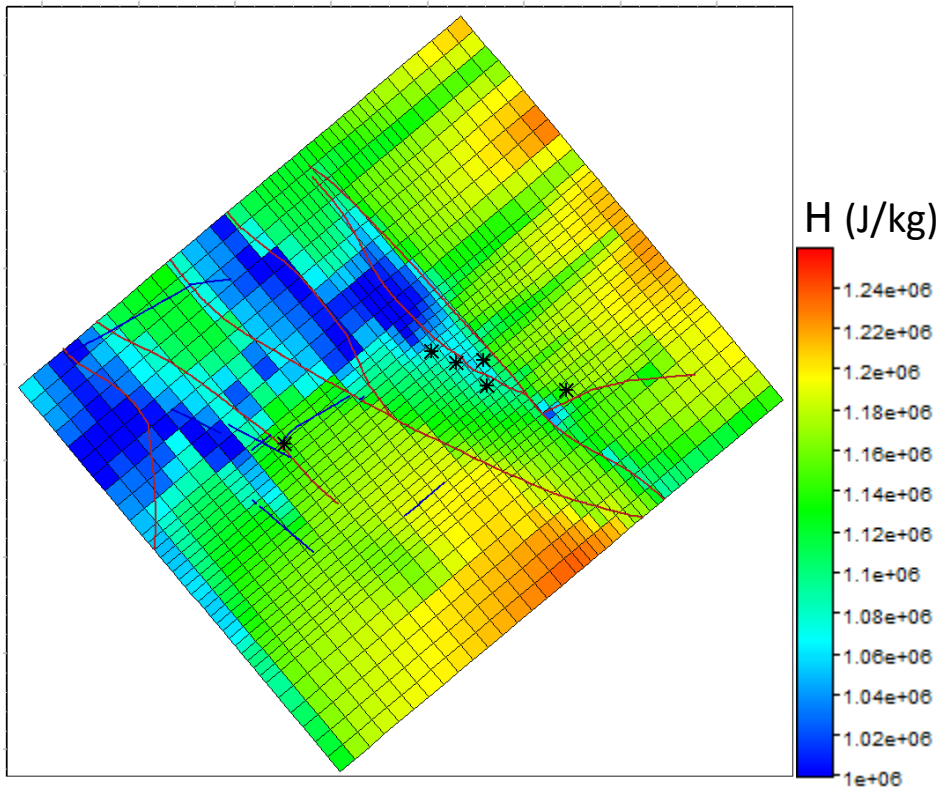
Conditions after 50 years of production



Simulation of a development plan

- Enthalpy map @ 1500 m

Initial conditions



Conditions after 50 years of production

