B10 – Guided Interpretation #10

This session illustrates the workflow offered by Emeraude to match a temperature profile in single phase. The two Emeraude models are illustrated: segmented model and energy equation model.

The data was simulated with Rubis thermal - a coupled T-P numerical (non commercial) simulator, solving the complete energy and mass balance equations, in the reservoir and the wellbore, under transient conditions. The point is to match the Rubis output with the simpler Emeraude models.

In single phase, it is possible to get a rate profile using temperature but pressure is required for PVT calculations. In 2 or 3 phases, one can only discriminate between phases thanks to additional measurements functions of the phase split. A pressure gradient for instance might be a candidate; in 3-phase one more information is required.

B10.1 • Data Loading

- Create a new file; In Document, select Well Details and enter:
  - ID is 3.23 “; you can type one line with [1000 ft, 3.23 in]
  - Perfos: [3314 – 3346; 3379 – 3445; 3478 – 3510] all in ft
- In the Survey panel, click on Information to create a new Survey; Surface rate: Qg = 1000 Mscf/D.
- Load the file B10TP.LAS, Down 1 pass as suggested.
- Change the depth scale to 3280 ft to 3580 ft and set it as the default depth scale.

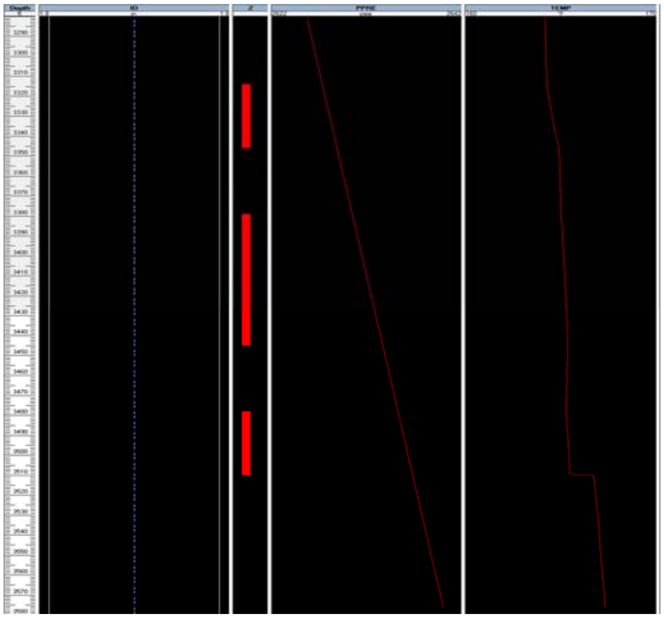
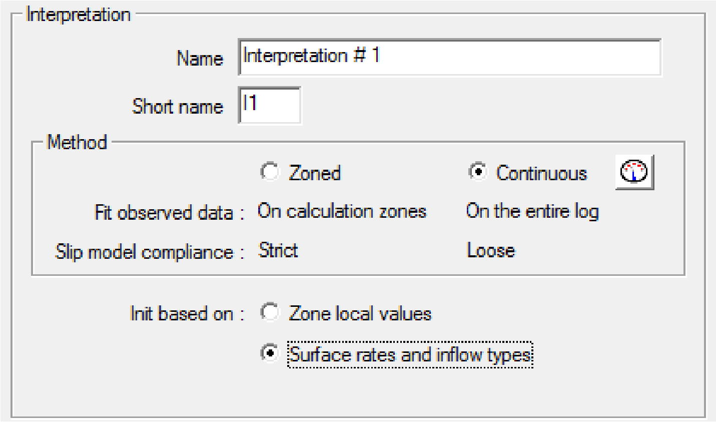


Fig. B10.1 • Screen after data loaded

B10.2 • First Interpretation: Using The Segmented Model

- ➢ In the PL Interpretation panel, click on Information to create a new interpretation. Keep default name and OK.
- ➢ In the second dialog, click on the tab 'Reference channels'; select the 'Continuous' method and choose to Init based on 'Surface rates and inflow types' (below left).



Interpretation

Name: Interpretation # 1

Short name: I1

Method

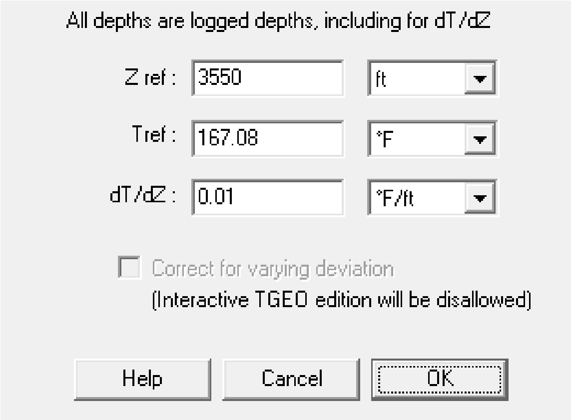
○ Zoned ● Continuous

Fit observed data : On calculation zones / On the entire log

Slip model compliance : Strict / Loose

Init based on : ○ Zone local values

● Surface rates and inflow types



All depths are logged depths, including for dT/dZ

Z ref : 3550 ft

Tref : 167.08 °F

dT/dZ : 0.01 °F/ft

☐ Correct for varying deviation

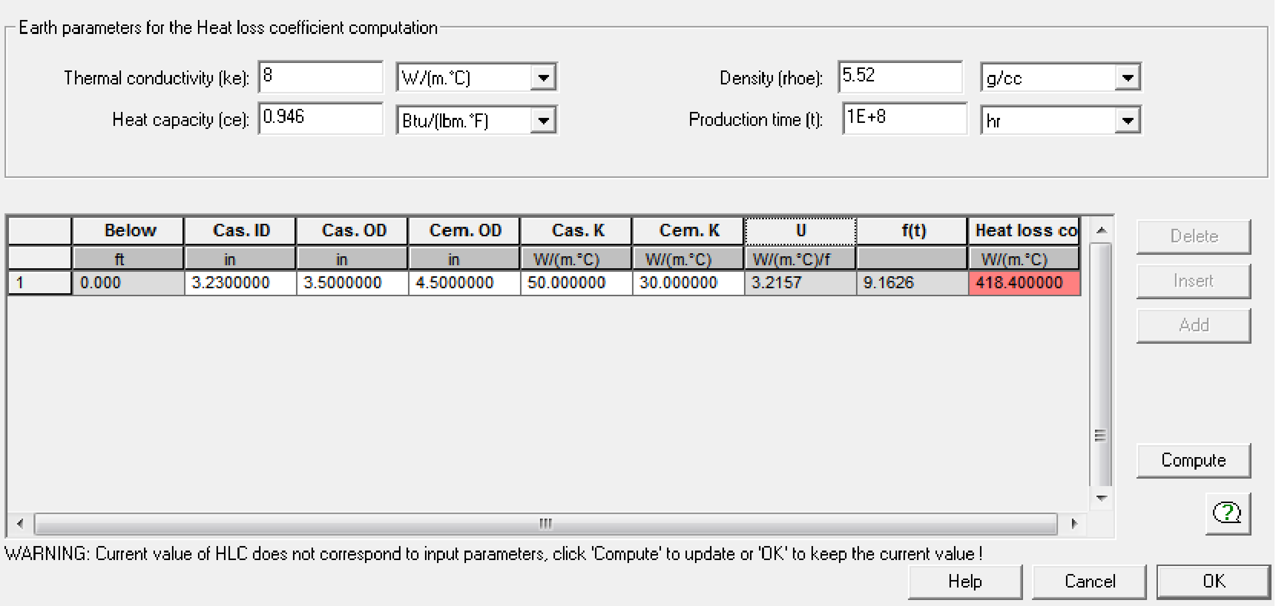
(Interactive TGEO edition will be disallowed)

Fig. B10.2 • Interpretation Information dialog

Fig. B10.3 • Geothermal profile

- ➢ Click on the Define buttons on the Temperature and Pressure lines, and pick the channels in Down 1.
- ➢ Move to the Temperature tab and click on the button to define the geothermal profile from a point and a slope (above right).
- ➢ Tick 'Simulate temperature' and 'Match temperature' and select the 'Segmented Model'. A dialog pop-ups, asking for conversion of the Heat Loss Coefficient (HLC): in this model, the HLC represents the heat loss from the wellbore to the outside, and it must be corrected for the transient effects when changing the thermal calculation method (more on this in B10.3). Answer No, as we will redefine the HLC.
- ➢ To define the HLC from the completion thermal properties, click on. Fill in the required information:
  - o Casing ID = 3.23 in, Casing OD = 3.5 in, Cement OD = 4.5 in
  - o Casing and cement thermal conductivities: 50 and 30 W/m/^{o}C respectively.
  - o Change the rock thermal conductivity to 8 W/m/^{o}C.
  - o Change the heat capacity to 0.946 Btu/(lbm.°F).
  - o Change the density (rhoe) to 5.52 g/cc.
  - o Change the production time to 1E+8 hrs.

The heat loss coefficient value appears in red, indicating that the current cell value is different from the value that will be obtained based on the completion geometry.



Earth parameters for the Heat loss coefficient computation

Thermal conductivity (ke): 8 W/(m.°C)

Heat capacity (ce): 0.946 Btu/(lbm.°F)

Density (rhoe): 5.52 g/cc

Production time (t): 1E+8 hr

	Below	Cas. ID	Cas. OD	Cem. OD	Cas. K	Cem. K	U	f(t)	Heat loss co
	ft	in	in	in	W/(m.°C)	W/(m.°C)	W/(m.°C)/f		W/(m.°C)
1	0.000	3.2300000	3.5000000	4.5000000	50.000000	30.000000	3.2157	9.1626	418.400000

WARNING: Current value of HLC does not correspond to input parameters, click 'Compute' to update or 'OK' to keep the current value !

Fig. B10.4 • Heat Loss Coefficient dialog

- Click on Compute and OK to validate.

Note that, by clicking on the icon, the HLC can also be estimated on the top zone from the knowledge of the surface rates and the recorded temperature.

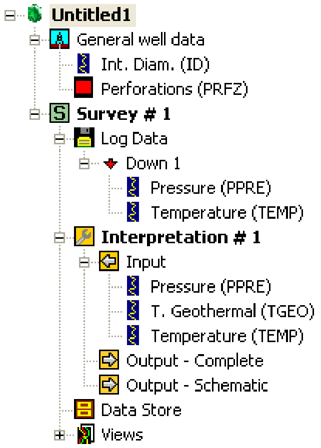
- Leave the dP Joule-Thomson to 0 for now.
- Press OK.

On the TEMP and PPRE views, the channels turned to white; the curves in Down 1 have been copied to the interpretation as reference channels; the latter are white (you can check the hierarchy by opening the data browser with).

An 'Interpretation#1' view is added with the reference channels (PPRE, TEMP), as well as a 'Temperature match' view with TEMP and TGEO.

- You can hide the ID, PPRE, and TEMP view.

- Define the PVT as dry gas with :
  - Specific gravity = 0.554
  - Choose Dranchuk for the Z correlation
  - Standard heat capacity = 0.43 Btu/lbm/F
  - Thermal conductivity = 0.1 W/m/^{o}C
  - Keep Lee et al. for the viscosity.



- **Untitled1**
  - General well data
    - Int. Diam. (ID)
    - Perforations (PRFZ)
  - **Survey # 1**
    - Log Data
      - Down 1
        - Pressure (PPRE)
        - Temperature (TEMP)
    - **Interpretation # 1**
      - Input
        - Pressure (PPRE)
        - T. Geothermal (TGEO)
        - Temperature (TEMP)
      - Output - Complete
      - Output - Schematic
    - Data Store
    - Views

Fig. B10.5 • PPRE and TEMP added to the interpretation

- ➢ Define rate calculation zones interactively with Qcalc above and between the perfs. The exact position is not so important (make sure that you do not overlap with perfs, and stay within the data range).

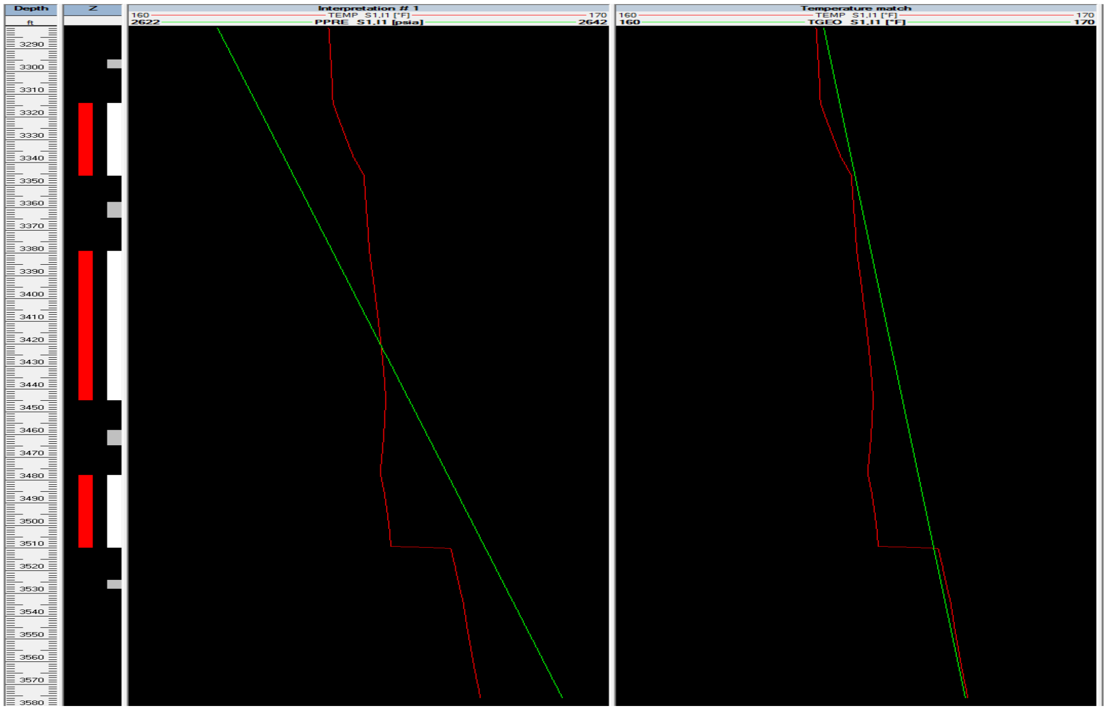


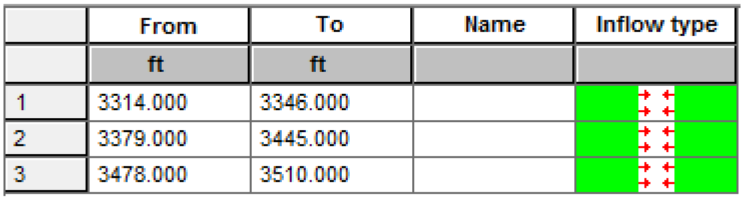
Fig. B10.6 • TEMP, PPRE and TGEO display

3 inflow zones are identified, corresponding to the perforations. We see on the temperature log that they are all producing. We can use this information now in the following manner:

- ➢ Double click on an inflow zone (white).

A grid pops up with the zones and a question mark in the 'Inflow type' column.

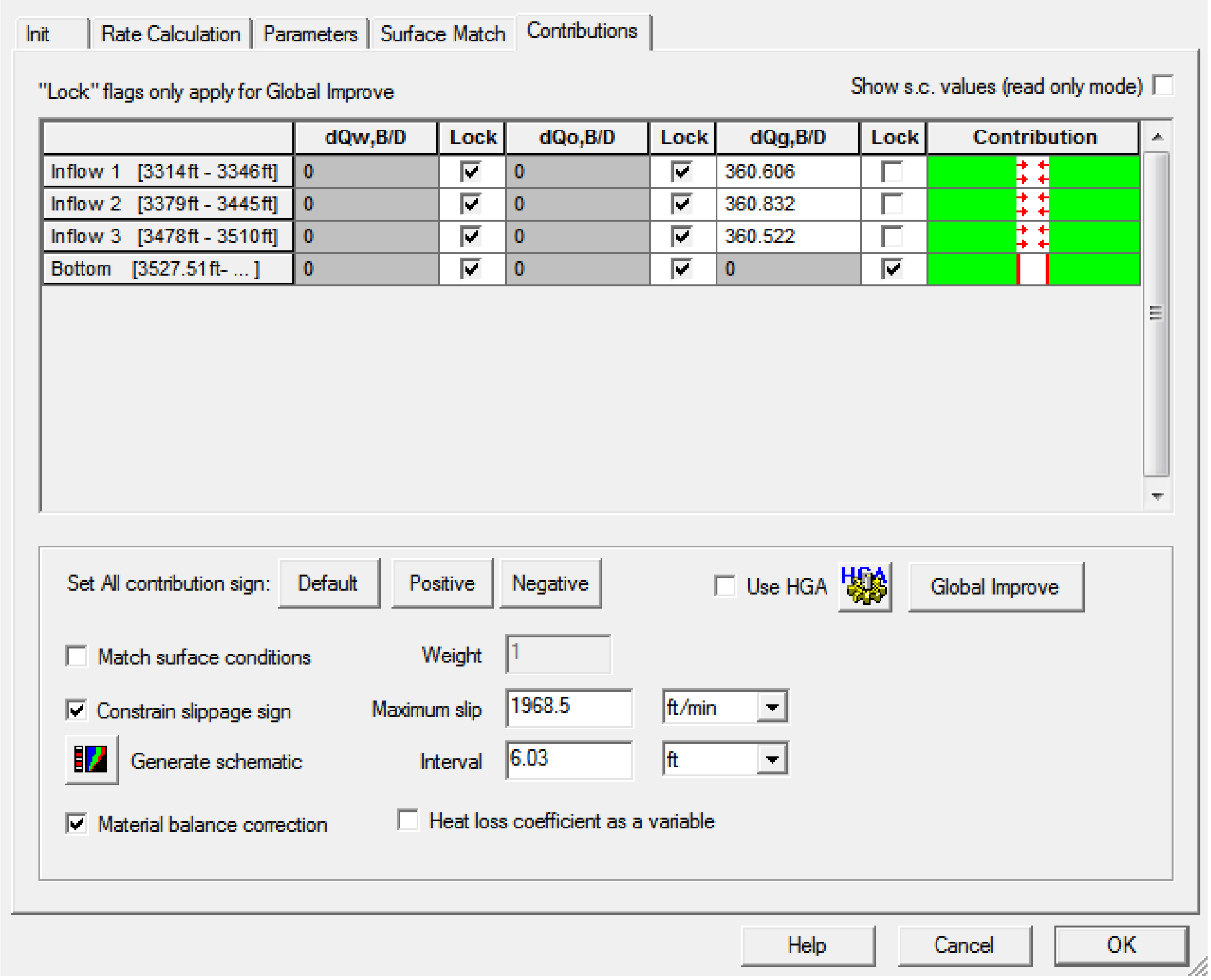
- ➢ Click on the question marks to set each zone to a producing zone and OK.



	From	To	Name	Inflow type
	ft	ft		
1	3314.000	3346.000		🟩
2	3379.000	3445.000		🟩
3	3478.000	3510.000		🟩

Fig. B10.7 • Inflow zones

- ➢ Click on 'Inflow Rates'; the default is on 'Single phase' which is fine; click OK.



"Lock" flags only apply for Global Improve

Show s.c. values (read only mode) ☐

	dQw,B/D	Lock	dQo,B/D	Lock	dQg,B/D	Lock	Contribution
Inflow 1 [3314ft - 3346ft]	0	☑	0	☑	360.606	☐	🟩
Inflow 2 [3379ft - 3445ft]	0	☑	0	☑	360.832	☐	🟩
Inflow 3 [3478ft - 3510ft]	0	☑	0	☑	360.522	☐	🟩
Bottom [3527.51ft- ...]	0	☑	0	☑	0	☑	🟩

☐ Use HGA

☐ Match surface conditions Weight 1

☑ Constrain slippage sign Maximum slip 1968.5 ft/min

Interval 6.03 ft

☑ Material balance correction

☐ Heat loss coefficient as a variable

Fig. B10.8 • Contributions

In the present solution, the surface rates were split (to the Bg local variation) between the 3 inflows equally.

- ➢ Press to see this first solution, in terms of logs (Temperature and rate).

The simulated temperature (blue with dots) is not matching the measurement. But this is just our starting point.

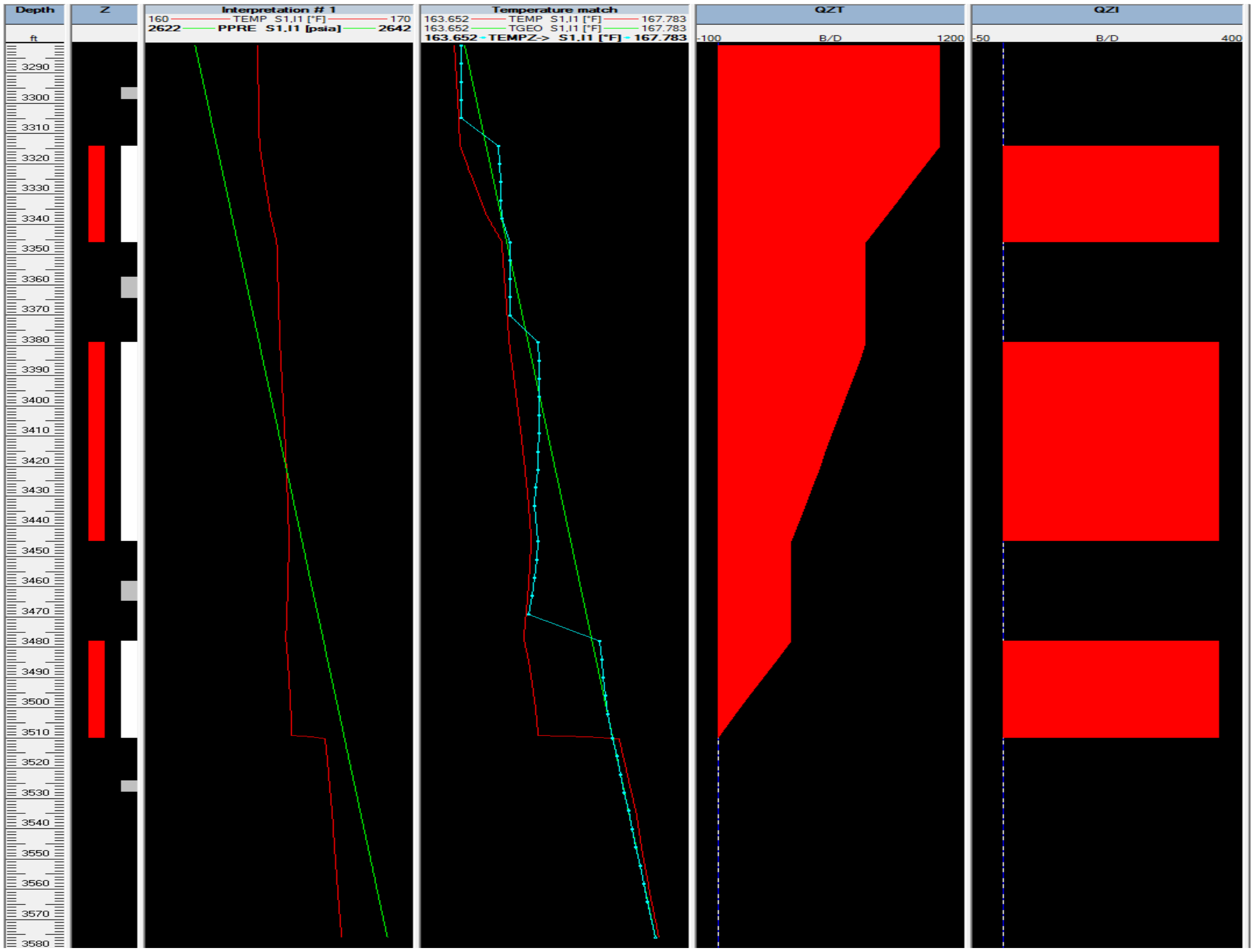


Fig. B10.9 • First temperature match solution (segmented model)

The model we are using here is the segmented model. This model divides the well into segments in front and between inflows, and applies a specific equation to them. Each segment is solved in isolation, starting from a point of the actual temperature curve. We see in this particular case that on the bottom inflow, the data exhibit cooling usually referred to as 'Joule-Thomson' (JT) cooling, and the model does not replicate this trend as the entering fluid is considered to arrive at geothermal. The temperature change within the layer is in part affected by the JT effect and in part by other effects such as convection and conduction. In the Emeraude segmented model – as in other models used in the industry – we take a shortcut saying that any temperature difference between the fluid entry temperature and the geothermal corresponds to a JT effect linked to 'some' pressure drop: dT = KJT x dP where KJT is the JT coefficient.

- Select Information, move to the Temperature tab; the current 'dP (Joule-Thomson)' value is 0.
- Experiment by changing this value starting with 10 psia, then 30, 50, etc. Click 'Apply' to see the temperature updated.
- Go for 55 psia and you should have a reasonable match on the bottom zone. Click OK.
- Go back to 'Inflow Rates'.
- Tick 'Match surface conditions'.
- Select 'Global Improve'; the final match is obtained.

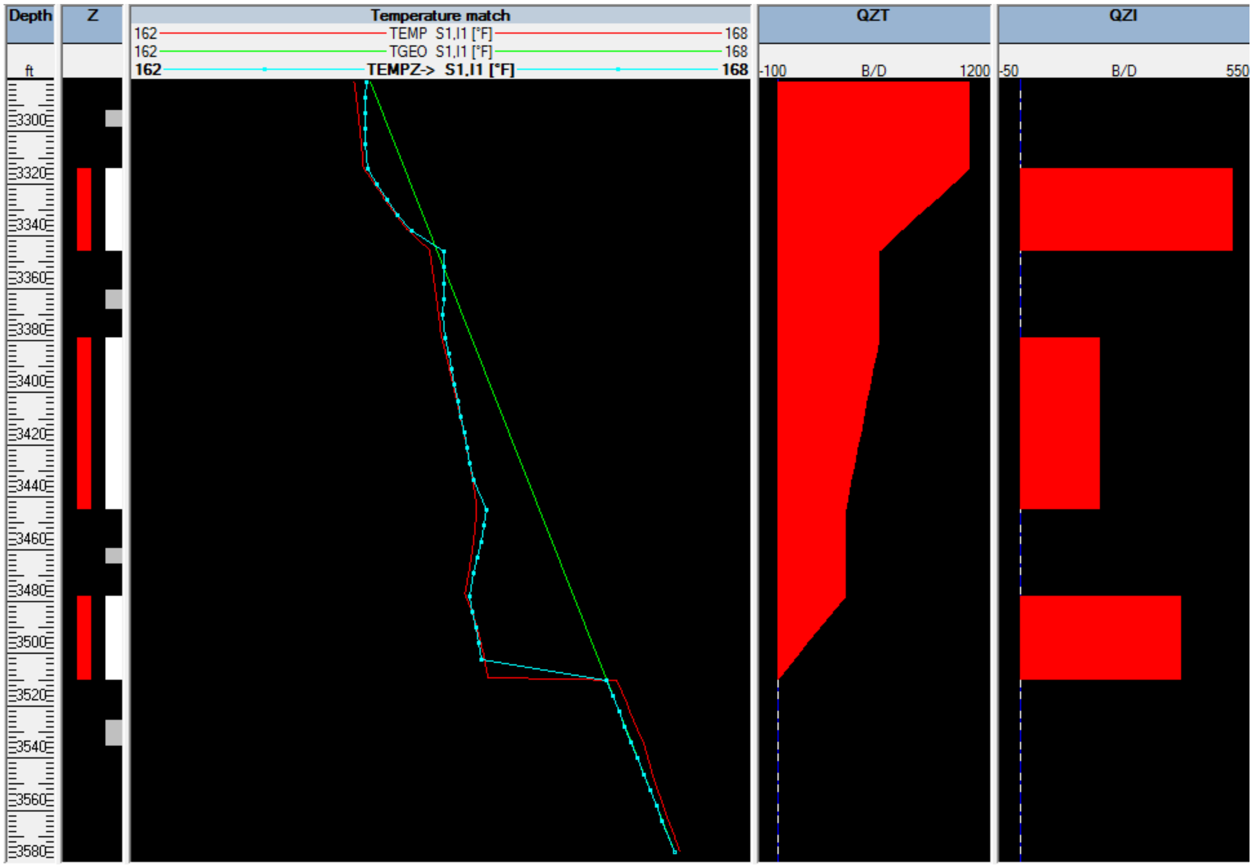
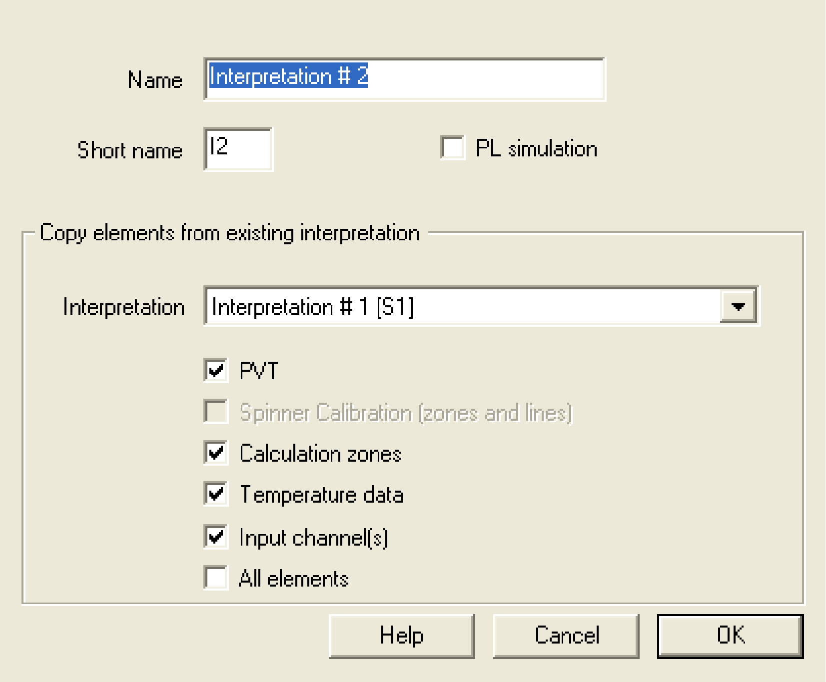


Fig. B10.10 • Final temperature match solution (segmented model)

It must be noted that the dP calculated for the bottom zone has been applied everywhere else. On all zones but the lowest, dP and dQ actually provide 2 degrees of freedom, i.e different dP will give different dQ. Since the segmented model allows zoning dP, you can easily convince yourself that another dP for the high zones will impact the dQ found. Since there is no rationale to finding this dP, the segmented model can be quite dangerous when the fluid experiences temperature change within the layers. In this case the more rigorous energy equation model should be preferred.

B10.3 • Second Interpretation: Using The Energy Equation Model

- Create a new interpretation and copy elements from the Interpretation#1 as shown below:



Name: Interpretation # 2

Short name: I2

☐ PL simulation

Copy elements from existing interpretation

Interpretation: Interpretation # 1 [S1]

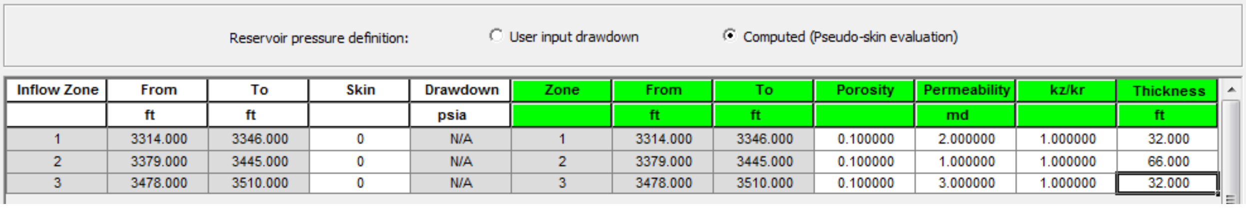
☑ PVT
☐ Spinner Calibration (zones and lines)
☑ Calculation zones
☑ Temperature data
☑ Input channel(s)
☐ All elements

Fig. B10.11 • Interpretation initialization dialog

- On the next dialog, 'Temperature' tab, change the 'Calculation method' to 'Energy equation'. Click Yes when asked if the HLC conversion should be made.

  As you accept the conversion, the heat loss coefficient is modified together with the production time if needed (defined in the transient part of the HLC dialog). This is because in the segmented model this term represents all the surrounding material, whereas in the energy equation model it represents only the completion. Transient effects weight as well the HLC in different manners. If you click on the icon, you can see that values of the first interpretation have been properly carried on.

- Select the 'Layer and inflow parameters' option and change the permeability to 2 md for the top zone, to 1 md for the middle zone and to 3 md to the bottom zone. Keep all other parameters and validate with OK.



Reservoir pressure definition: ○ User input drawdown ● Computed (Pseudo-skin evaluation)

Inflow Zone	From	To	Skin	Drawdown	Zone	From	To	Porosity	Permeability	kz/kr	Thickness
	ft	ft		psia		ft	ft		md		ft
1	3314.000	3346.000	0	N/A	1	3314.000	3346.000	0.100000	2.000000	1.000000	32.000
2	3379.000	3445.000	0	N/A	2	3379.000	3445.000	0.100000	1.000000	1.000000	66.000
3	3478.000	3510.000	0	N/A	3	3478.000	3510.000	0.100000	3.000000	1.000000	32.000

Fig. B10.12 • layer and inflow parameters dialog

An important difference between the segmented model and the energy equation model is that the latter accounts for the pressure and temperature change within the layers. In other words we do not rely on the definition of some pressure drop but instead, we need to enter the layer properties.

The calculation needs the overall pressure drop in the layer. This can either be input directly or else, computed using a steady state pseudo-skin equation. This computation is influenced by the layer thickness, the position of the perforations within the layers, and the well deviation within the layers. When entering the model without reservoir zones, a default creation is made with reservoir zones corresponding exactly to the perfos. In a standard situation, you should define the reservoir zones beforehand. We will correct this afterwards.

- Exit the Information dialog with OK.
- Go to Inflow Rates; an initial solution will be calculated from an even split of the surface rates.
- Press OK on the Init tab to view the Contributions tab.
- Generate the schematics with and close the window with OK.

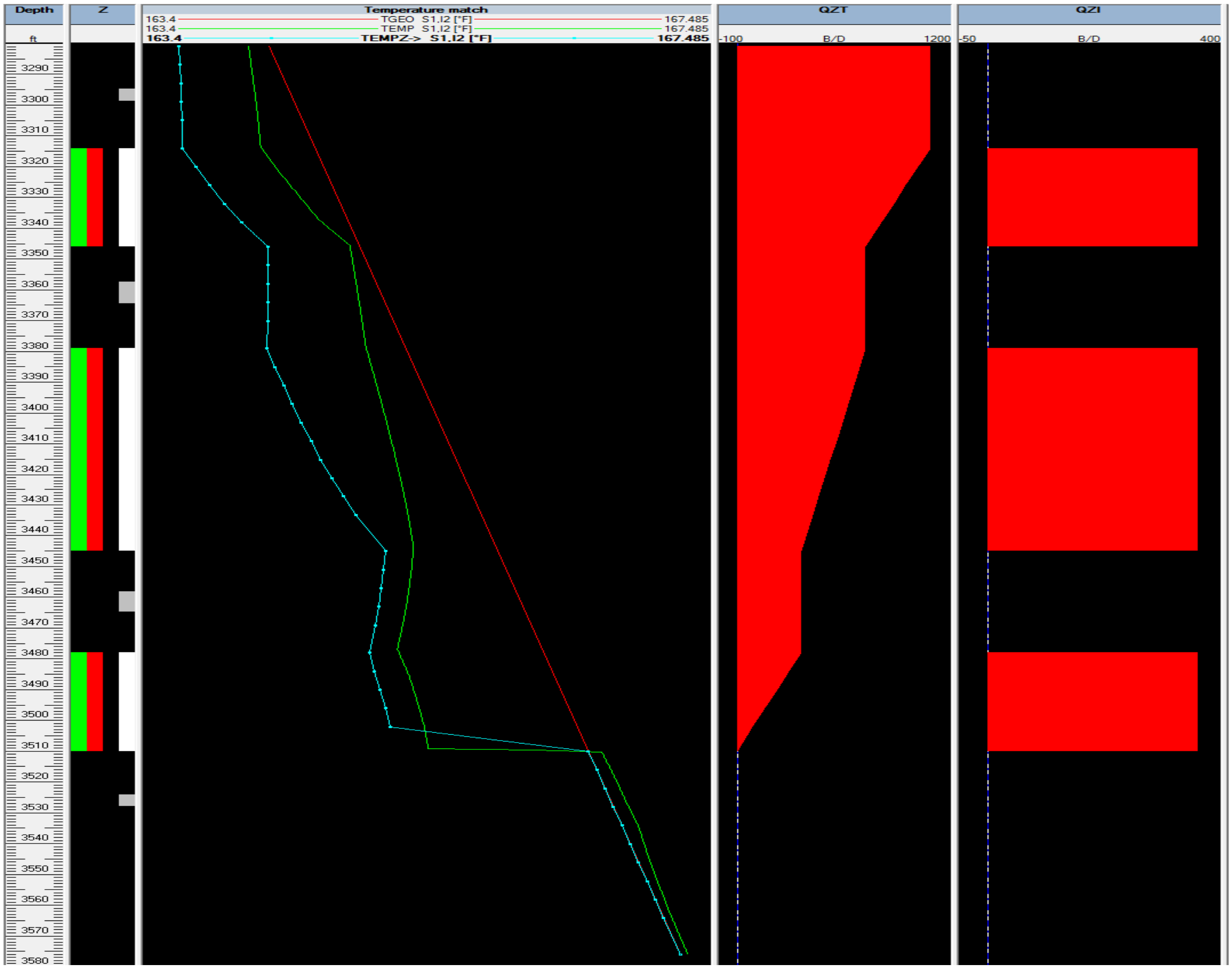
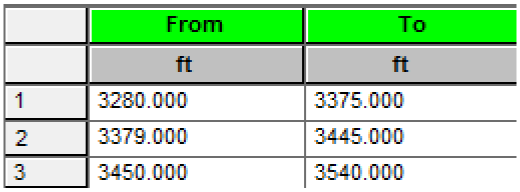


Fig. B10.13 • Initial temperature match solution (energy equation model)

Before improving we will enter the proper reservoir zones.

- Double-click on a (green) reservoir zone; enter the depths shown below:



	From	To
	ft	ft
1	3280.000	3375.000
2	3379.000	3445.000
3	3450.000	3540.000

Fig. B10.14 • Reservoir zones

- Go back to the PL Interpretation 'Information', 'Temperature' tab.
- Click the 'Layer and inflow parameters' button and in the corresponding dialog click the bottom left icon Reset layer thicknesses based on current reservoir zones. .

The thickness column in the dialog should now indicate: 95, 66, 90 ft.

- Validate with OK.
- Exit the Information dialog with OK.

The temperature profile is corrected.

We may now launch the final regression.

- Go to 'Inflow Rates'.
- On the 'Contributions' tab tick 'Match surface conditions'.
- Select 'Global Improve'; the final match below is obtained. Close the window with OK.

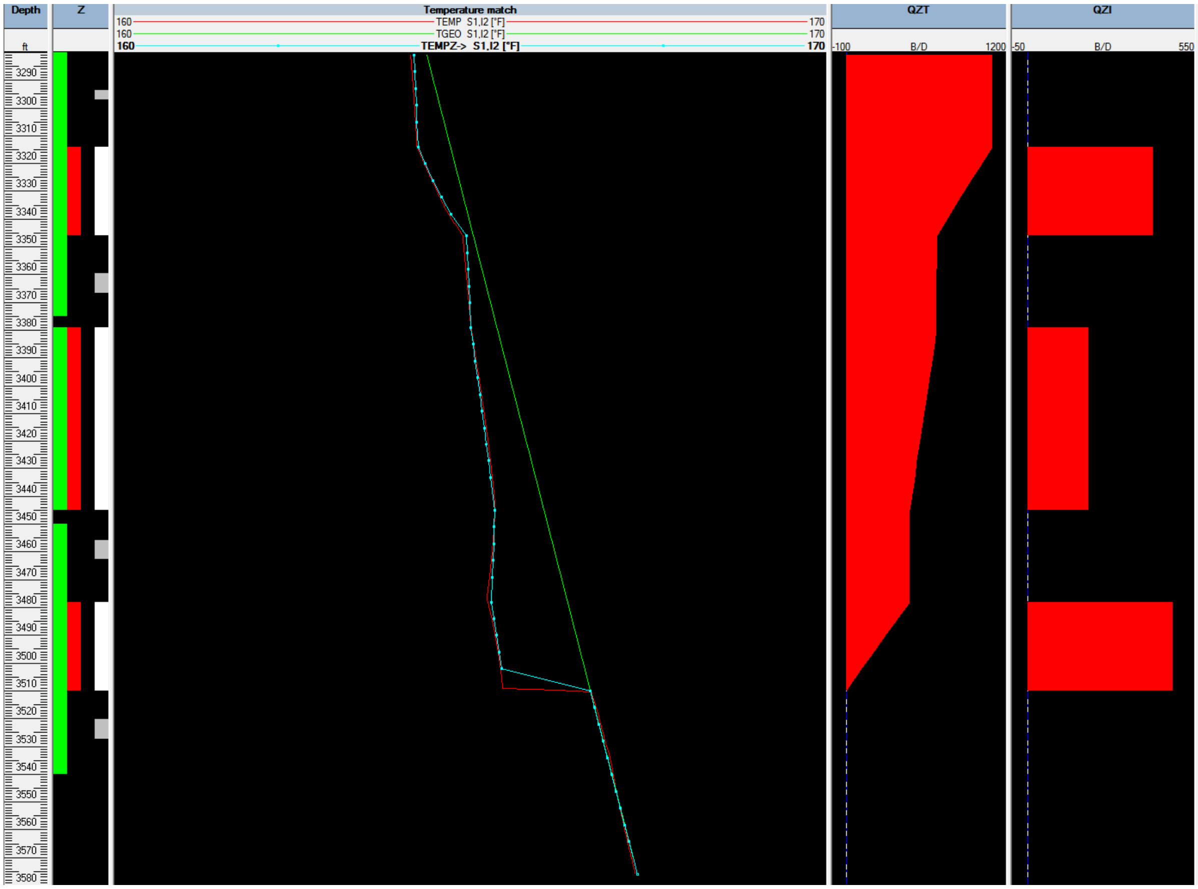


Fig. B10.15 • Final temperature match solution (energy equation model)

You can build a user view to compare the rates obtained with both interpretations (QGZT under ‘Schematic output’) and you will see that they are fairly close. The energy equation model should nevertheless be preferred as it represents physically what is happening in the reservoir. The segmented model is by comparison lumping all reservoir effects into a Joule-Thomson process, itself a function of a pressure drop that is non-physical. If this pressure drop can be estimated from the data for the lowest zone, this is not the case elsewhere where it *de facto* behaves as an additional degree of freedom.

The next plot illustrates the QGZT for the two interpretations (segmented model in green, energy model in blue) compared to the reference solution obtained from Rubis (numerical simulation, in red).

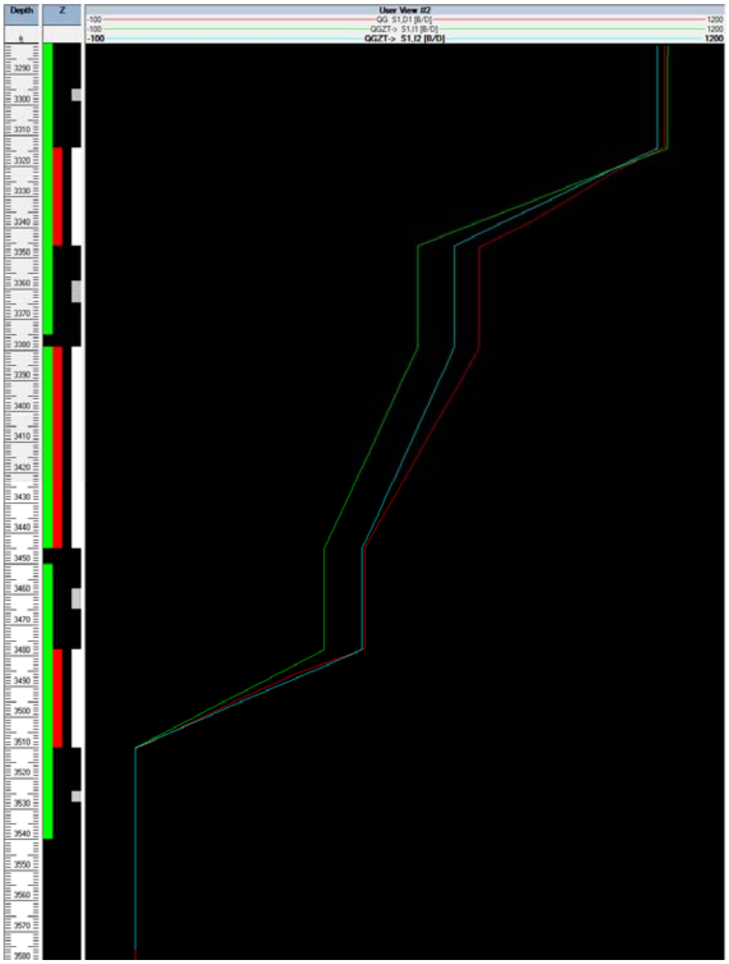


Fig. B10.16 • Emeraude temperatures vs Rubis temperature

This concludes Guided Interpretation #10.