**Jupyter-Notebooks\_for-Characterization-of-a-New-Open-Source-Carbonate-Reservoir-Benchmarking-Case-Study**

We have used the new hierarchical carbonate reservoir benchmarking case study created by Costa Gomes J, Geiger S, Arnold D to be used for reservoir characterization, uncertainty quantification and history matching.

**According to Costa (1):**

*“This work presents a new open-source carbonate reservoir case study, the COSTA model, that uniquely considers significant uncertainties inherent to carbonate reservoirs, providing a far more challenging and realistic benchmarking test for a range of geo-energy applications. The COSTA field is large, with many wells and large associated volumes... “*

In our GitHub repository we have used a new, comprehensive reservoir characterization database from Costa, Geiger and Arnold(1) located at this link:

<https://github.com/Philliec459/Jupyter-Notebooks_for-Characterization-of-a-New-Open-Source-Carbonate-Reservoir-Benchmarking-Case-St>

We employed all the available well logs, Routine Core Analysis (RCA) and Special Core Analysis (SCAL and implemented our normal carbonate reservoir characterization workflow as discussed by Phillips (2). For this repository we did not use the 3D static or dynamic models, but we did use the time-series dynamic production and formation pressure data by well in Spotfire to better understand the dynamic aspects of the reservoir too. This is a rich dataset that needs to be explored further, more than what is presented in the scope of this project.

The RCA and SCAL core data as well as the 17 well logs provided as las files were used extensively in our Petrophysical evaluation. These data are all in a Geolog project that is included in this repository.

RESOURCES:

https://researchportal.hw.ac.uk/en/datasets/costa-model-hierarchical-carbonate-reservoir-benchmarking-case-st

https://github.com/Philliec459/Geolog-Used-to-Model-Thomeer-Parameters-from-High-Pressure-Mercury-Injection-Data

<https://github.com/Philliec459/Geolog-Used-to-Automate-the-Characterization-Workflow-using-Clerkes-Rosetta-Stone-calibration-data>

REFERENCES:

1. Costa Gomes J, Geiger S, Arnold D. The Design of an Open-Source Carbonate Reservoir Model. Petroleum Geoscience,

https://doi.org/10.1144/petgeo2021-067

2. Phillips, E. C., Buiting, J. M., Clerke, E. A, “Full Pore System Petrophysical Characterization Technology for Complex Carbonate Reservoirs – Results from Saudi Arabia”, AAPG, 2009 Extended Abstract.

3. Clerke, E. A., Mueller III, H. W., Phillips, E. C., Eyvazzadeh, R. Y., Jones, D. H., Ramamoorthy, R., Srivastava, A., (2008) “Application of Thomeer Hyperbolas to decode the pore systems, facies and reservoir properties of the Upper Jurassic Arab D Limestone, Ghawar field, Saudi Arabia: A Rosetta Stone approach”, GeoArabia, Vol. 13, No. 4, p. 113-160, October 2008.

New add

We have a new set of python Jupyter Notebooks for Carbonate Reservoir Characterization at the following link on GitHub:

https://github.com/Philliec459/Jupyter-Notebooks\_for-Characterization-of-a-New-Open-Source-Carbonate-Reservoir-Benchmarking-Case-St

There are two notebooks that cover the characterization mentioned in this post, and this one is of particular interest:

3test\_Chartbook\_Porosity\_Optimized-Lithology\_Perm\_Thomeer\_Saturations\_ver3-Lasio\_with\_FWL\_search-implement\_Optimization-Illite\_another\_Scipy\_optimization\_method-newperm.ipynb

We are experimenting with python Panel widgets in the selection of the well and petrophysical log analysis parameters in the notebook above.

Each notebook contains most of the python steps required for a typical petrophysical log analysis and field characterization study:

1. Read in any las file using Lasio for each well/
   1. We are using Andy McDonald’s methods to use Lasio to read in the las files and generate a basic plot to show the depth extent of the various logs in the las file.
2. Calculate a Neutron-Density Chartbook solution to Total Porosity (PHIT) and Matrix Density (Rho Mat) using chartbook data from the Schlumberber’s CNL and TNPH Neutron tools using python’s kNN to make the estimations with a depth-plot at the end of the section to display the results.
3. We have written a basic optimization process using SciPy to solve for lithology using either the ‘Calcite\_Dolomite’ or ‘Quartz\_Calcite\_Dolomite’ options with an option for the Volume of Illite clay too; again, with depth plots at the end of the section to display the results.
4. Using core calibration, we use kNN to estimate Permeability for each well.
5. Using core calibration, we use kNN to estimate the Thomeer Capillary Pressure parameters and Petrophysical Rock Types (PRT) over the study interval for each well.
6. We use the Thomeer Capillary Pressure parameters to calculate Capillary Pressure Curves for Capillary Pressure based saturations at each well:
   1. For the first run, we vary the Free Water Level (FWL) from an upper possible limit to a lower possible limit to estimate the FWL at each well.
   2. We use the final FWL estimate to calculate the Capillary Pressure based saturations for each well with a depth plot comparing the results between our log analysis-based saturations and the Capillary Pressure-based saturations.
   3. The FWL estimates from each well are used to create a plane in the 3D model to calculate water saturations in the model too.
   4. We export all the data and well results to an Excel file for each well.

We have used this new hierarchical carbonate reservoir benchmarking case study created by Costa Gomes J, Geiger S, Arnold D to be used for reservoir characterization, uncertainty quantification and history matching. These data include log data in las format, Routine Core Analysis, SCAL, production and even 3D models. This is a rich dataset that needs to be explored further.

**ChatGPT Version for GitHub:**

We have created a Jupyter Notebook on GitHub to demonstrate a comprehensive Petrophysical Characterization Workflow for a carbonate field where we have used chatGPT3 to refine our python coding. Our Petrophysical workflow includes:

1. Read in any las file for each well using Lasio.
2. We use kNN to calculate a Neutron-Density chartbook solution for Total Porosity (PHIT) and Matrix Density (RHO\_MAT) using chartbook data from the Schlumberber’s CNL and TNPH Neutron tools.
3. We use ipywidgets to create an interactive Pickett Plot to refine the electrical properties (m&n) and formation water resistivity (Rw).
4. We have a new process using SciPy optimization to solve for lithology using either the ‘Calcite\_Dolomite’ or ‘Quartz\_Calcite\_Dolomite’ options with an option for the Volume of Illite clay.
5. We employ core calibration data to estimate Permeability using kNN.
6. We use Thomeer Capillary Pressure parameter calibration data with kNN to estimate the Capillary Pressure parameters.
7. Using Thomeer Capillary Pressure parameters we calculate Capillary Pressure based saturations at each well:
   1. We employ a Free Water Level (FWL) search from an upper possible limit to a lower possible limit to estimate the FWL at each well.
   2. We use the final FWL estimates at each well to calculate the Capillary Pressure based saturations.
   3. The FWL estimates from each well are used to create a plane in the 3D model to calculate water saturations in the model too.
   4. We export all the data and well results to an Excel file for each well.

We have included the las files for all wells in a field from a new hierarchical carbonate reservoir benchmarking case study created by Costa Gomes J, Geiger S, Arnold D that was intended to be used for reservoir characterization, uncertainty quantification and history matching.

The python coding for this entire process can be found on GitHub at the following link:

**From chatGPT**

We have developed a comprehensive Petrophysical Characterization Workflow for a carbonate field, and to demonstrate it, we have created a Jupyter Notebook on GitHub. Our workflow comprises several steps, and we have used chatGPT3 to refine our python coding. The various steps involved in our Petrophysical workflow are as follows:

Firstly, we use Lasio to read in any las file for each well. Next, we employ kNN to calculate a Neutron-Density chartbook solution for Total Porosity (PHIT) and Matrix Density (RHO\_MAT) using chartbook data from the Schlumberger’s CNL and TNPH Neutron tools.

We then use an interactive SciPy optimization to solve for lithology using either the ‘Calcite\_Dolomite’ or ‘Quartz\_Calcite\_Dolomite’ options with an option for the Volume of Illite clay. To refine the electrical properties (m&n) and formation water resistivity (Rw), we use ipywidgets to create an interactive Pickett Plot.

We also use core calibration data to estimate Permeability using kNN and Thomeer Capillary Pressure parameter calibration data with kNN to estimate the Capillary Pressure parameters. Using these parameters, we calculate Capillary Pressure based saturations at each well.

To estimate the Free Water Level (FWL) at each well, we perform a FWL search from an upper possible limit to a lower possible limit. We then use the final FWL estimates at each well to calculate the Capillary Pressure based saturations. The FWL estimates from each well are used to create a plane in the 3D model to calculate water saturations in the model too.

Finally, we export all the data and well results to an Excel file for each well. We have included the las files for all wells in a field from a new hierarchical carbonate reservoir benchmarking case study created by Costa Gomes J, Geiger S, Arnold D, which was intended to be used for reservoir characterization, uncertainty quantification, and history matching.

You can find the python coding for this entire process on GitHub at the following link: [insert link].

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