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Bluebonnet: Scaling solutions for production analysis from unconventional oil and gas wells

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Summary

Unconventional oil and gas wells are only productive due to extensive hydraulic fracturing treatments. Therefore, the character of their production over time is greatly influenced by engineering decisions. However, it can be difficult to separate the engineering decisions from the effects due to fluid properties. Also, during production these wells might be producing oil, gas, and water simultaneously, with each phase interacting with the others. Numerical tools are necessary to fully capture the effects of fluid properties on production.

`Bluebonnet` is a Python package that uses dimensionally scaled solutions of a pressure diffusivity equation to analyze, history-match, and forecast production of tight-oil and shale gas wells. `Bluebonnet` has been developed to help researchers and petroleum engineers analyzing production data from unconventional (shale gas and tight oil) wells. It provides the user with a set of tools to evaluate production performance of tight-oil and shale gas wells. These tools provide the following functionality:

1. `bluebonnet.fluids`: pressure-volume-temperature properties for oil, water, and gas phases.
2. `bluebonnet.flow`: physics-based production curves and hydrocarbon recovery factors.
3. `bluebonnet.forecast`: fits and forecasts for unconventional production.

The `fluids` submodule estimates the formation volume factors, solubility ratios, and viscosity for the oil, water and gas phases given the reservoir temperature, oil API gravity, gas specific gravity, and initial gas/oil ratio.

The `flow` submodule solves the pressure diffusivity equation to provide estimates of the hydrocarbon production over time and the hydrocarbon recovery factors. This module allows the user to estimate production for shale gas wells using scaled solutions of the single-phase real gas diffusivity equation (Male, 2015; Patzek et al., 2013). In addition, this module simulates production for tight-oil and gas condensate wells using a two-phase scaled solution of the pressure diffusivity equation (Ruiz Maraggi et al., 2022a). The `flow` submodule also allows users to capture production variations due to changes in bottomhole pressure.

The `forecast` submodule performs history matches and forecasts the production of unconventional wells using the scaling solutions present in the `flow` module. The `forecast` submodule also allows users to history-match and forecast production of wells subject to variable bottomhole pressure conditions using a modification of the approach developed by Ruiz Maraggi et al. (2022b).

Statement of need

`Bluebonnet` is a Python package using petroleum engineering methods to perform production analysis of hydrofractured wells. Parts of this code were first developed to assist in determining U.S. shale gas reserves (Male, 2019; Patzek et al., 2013).

There are no free open-source tools that use physics-based scaled flow solutions of the diffusivity equation to perform decline-curve and rate-transient analysis for unconventional reservoirs like `bluebonnet`. The goal for producing this software package is to provide researchers and reservoir engineers with a free and open source tool suitable to analyze production from unconventional (tight oil and shale gas) reservoirs.

The present library can be used for the following tasks:

1. Estimate fluid properties of reservoir fluids.
2. Build type curves and recovery factors for shale gas and tight-oil reservoirs.
3. History-match and forecast the production of shale gas and tight-oil wells.
4. Perform Rate-transient analysis (rate-time-pressure) of unconventional reservoirs.

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This project relies on the following open-source Python packages: NumPy (Harris et al., 2020; Walt et al., 2011), SciPy (Virtanen et al., 2020), matplotlib (Hunter, 2007), and pandas (McKinney, 2010).

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References

Harris, C. R., Millman, K. J., Walt, S. J. van der, Gommers, R., Virtanen, P., Cournapeau, D., Wieser, E., Taylor, J., Berg, S., Smith, N. J., Kern, R., Picus, M., Hoyer, S., Kerkwijk, M. H. van, Brett, M., Haldane, A., Río, J. F. del, Wiebe, M., Peterson, P., … Oliphant, T. E. (2020). Array programming with NumPy. *Nature*, *585*(7825), 357–362. https://doi.org/10.1038/s41586-020-2649-2

Hunter, J. D. (2007). Matplotlib: A 2D graphics environment. *Computing in Science & Engineering*, *9*(3), 90–95. https://doi.org/10.1109/MCSE.2007.55

Male, F. (2015). *Application of a one dimensional nonlinear model to flow in hydrofractured shale gas wells using scaling solutions* [PhD thesis, University of Texas at Austin]. https://repositories.lib.utexas.edu/handle/2152/46706

Male, F. (2019). Assessing impact of uncertainties in decline curve analysis through hindcasting. *Journal of Petroleum Science and Engineering*, *172*, 340–348. https://doi.org/10.1016/j.petrol.2018.09.072

McKinney, Wes. (2010). Data Structures for Statistical Computing in Python. In Stéfan van der Walt & Jarrod Millman (Eds.), *Proceedings of the 9th Python in Science Conference* (pp. 56–61). https://doi.org/10.25080/Majora-92bf1922-00a

Patzek, T. W., Male, F., & Marder, M. (2013). Gas production in the Barnett Shale obeys a simple scaling theory. *Proceedings of the National Academy of Sciences*, *110*(49), 19731–19736. https://doi.org/10.1073/pnas.1313380110

Petroleum Engineers, S. of. (2021). *SPE Data Repository, Dataset # 1*. https://www.spe.org/en/industry/data-repository

Ruiz Maraggi, L. M., Lake, L. W., & Walsh, M. P. (2022a). A Two-Phase Flow Model for Reserves Estimation in Tight-Oil and Gas-Condensate Reservoirs Using Scaling Principles. *SPE Reservoir Evaluation & Engineering*, *25*(01), 81–98. https://doi.org/10.2118/199032-PA

Ruiz Maraggi, L. M., Lake, L. W., & Walsh, M. P. (2022b). Rate-Pseudopressure Deconvolution Enhances Rate-Time Models Production History-Matches and Forecasts of Shale Gas Wells. *SPE Reservoir Evaluation & Engineering*, 1–20. https://doi.org/10.2118/208967-PA

Virtanen, P., Gommers, R., Oliphant, T. E., Haberland, M., Reddy, T., Cournapeau, D., Burovski, E., Peterson, P., Weckesser, W., Bright, J., van der Walt, S. J., Brett, M., Wilson, J., Millman, K. J., Mayorov, N., Nelson, A. R. J., Jones, E., Kern, R., Larson, E., … SciPy 1.0 Contributors. (2020). SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python. *Nature Methods*, *17*, 261–272. https://doi.org/10.1038/s41592-019-0686-2

Walt, S. van der, Colbert, S. C., & Varoquaux, G. (2011). The NumPy array: A structure for efficient numerical computation. *Computing in Science & Engineering*, *13*(2), 22–30. https://doi.org/10.1109/MCSE.2011.37