

# Lithium Resource Estimates for Petro and Geothermal Brine Projects: What Porosity Value to Use?

Alex Haluszka, M.Sc., P. Geo., Daron Abbey, M.Sc., P. Geo.  
Matrix Solutions Inc.

## Introduction

Interest in Lithium Brine resources has accelerated in the last decade as global demand for lithium has increased. Because the first lithium brine aquifers to be developed are relatively shallow, near surface brines in mountain basins in South America (“salars”), much of the initial work and technical guidance has been written by hydrogeologists focused on this depositional environment and groundwater flow regime. As discussed in the National Instrument 43-101 framework for mineral resource and reserve estimation, to be considered as a resource, mineral deposits must have a “reasonable prospect for eventual economic extraction” (CIM 2014). Specifically, in the current guidance written for Canadian and Australian securities regulations for brine resources it is mentioned that ‘specific yield’ should be used to estimate the amount of resource in place, and that resource estimates based on total or effective porosity could lead to “unrealistic production expectations” (Hains 2012). Specific yield is a hydrogeological term related to the accessible pore volume assuming the aquifer is dewatered. However, due to the confined nature of deeper lithium brine deposits hosted in petrolithium and geothermal brine reservoirs, the dewatering of aquifers is impractical and by taking advantage of the pressure support provided by reinjection as part of typical reservoir management, more of the porosity can be accessed through typical extraction techniques. The following describes the concepts of specific yield, effective porosity, and reservoir pressure management with respect to lithium brine resources in these deep confidence aquifers. Some specific examples from the Leduc Formation Aquifer in Alberta will be illustrate these concepts along with other deep aquifers.

## Theory

In the field of hydrogeology, *specific yield* ( $S_y$ ) is defined as the amount of water that drains from the connected pores under gravitational forces (Woessner and Poeter 2020). The inverse of  $S_y$ , the water that is retained in the pore space bound due to molecular attraction and capillary forces is *specific retention* ( $S_r$ ). The authors are not aware of an exact equivalent term to  $S_y$  in petroleum reservoir engineering, but  $S_r$  is generally equivalent to *irreducible water saturation* assuming the displacing fluid is air as opposed to oil or methane. Petrolithium and geothermal brines are typically deep confined pressure systems of a single fluid phase (water) and therefore, the concept of irreducible water should not apply provided that a minimum confining pressure is maintained in the reservoir during production (von Rosenberg 1956).

In the field of hydrogeology, *effective porosity* ( $n_e$ ) is defined as the volume of interconnected void space whereas *total porosity* ( $n$ ) is defined as the total void space in a given rock volume (Woessner and Poeter 2020). These definitions are generally the same in the oil and gas industry. It is intuitive that based on this definition,  $n_e$  is the appropriate parameter to consider in a brine resources when confining pressures maintain saturation, making dissolved lithium in all connected porosity accessible to the water flowing through the system.

The most common methods to measure porosity in deep reservoirs is through geophysical logging. Most common conventional geophysical logging measurements (neutron, density, sonic) record total porosity. Some petrophysical methods exist to estimate  $n_e$  from geophysical logs but these assume that the relationship between  $n_e$  and  $n$  is a function of clay content (i.e.  $v_{shale}$ ). Carbonate rocks can have very low clay content but due to diagenesis have variable proportions of connected pores such that we cannot effectively assess effective porosity from log response alone. Similarly, fractured hard rock systems can have low clay content but a difference between effective and total porosity due to the nature of the fracture network. Therefore, other techniques are needed to evaluate  $n_e$  and complete a resource estimate. Gas injection in core plugs can quantify connected pore space ( $n_e$ ), which can be completed on intact core samples (American Petroleum Institute 1998). This technique may not be suitable for fractured reservoirs due to scale of those pore systems.

## Results, Observations, Conclusions

The key findings from this work that will be presented include:

- Effective porosity is a suitable parameter to estimate resource volumes for brine resources contained in deep confined aquifers
- Effective porosity is not necessarily a function of clay content
- Effective porosity should be quantified through core analysis (specifically gas injection) for porous media
- Alternative methods may be required to characterize effective porosity in fractured rock

## Novel/Additive Information

Petroleum geologists and engineers obviously have relevant knowledge on fluid production at depth than can be effectively applied to develop lithium brine resources. Because the initial guidance for brine resources has been developed by hydrogeologists, we need to ensure alignment in terminology and approaches as these resources continue to be developed. We have presented a framework that provides alignment in terminology and theory that allows for consistency when working across disciplines and a review of methodology that can be used to support resource estimates that leverage existing technologies and data in the oil and gas industry and is consistent with the current relevant securities regulations (NI 43-101).

## Acknowledgements

The authors would like to thank our clients at E3 Lithium for their patience and support in delving into first principles of hydrogeology and reservoir engineering in order to address these concepts for their resource estimates.

## References

American Petroleum Institute. 1998. *Recommended Practices for Core Analysis*. Recommended Practice 40, Second Edition. API Publishing Services, Washington, DC, 20005. February 1998.  
<http://w3.energistics.org/RP40/rp40.pdf>

Canadian Institute of Mining, Metallurgy and Petroleum (CIM). 2014. *CIM Definition Standards for Mineral Resources & Mineral Reserves*. Prepared by the CIM Standing Committee on Reserve Definitions. Westmount, Quebec. May 19, 2014.

Hains D. H. 2012. *CIM Best Practice Guidelines for Resource and Reserve Estimation for Lithium Brines*. Published by CIM Estimation Best Practice Committee. November 1, 2012.

von Rosenberg, D. U., "Mechanics of Steady State Single-Phase Fluid Displacement from Porous Media," A. I. Ch. E. Journal, 2, No. 1 (1956), 55-58.

Woessner W.W. and E.P. Poeter. 2020. *Hydrogeologic Properties of Earth Materials and Principles of Groundwater Flow*. Published by the Groundwater Project. ISBN: 978-1-77705-412-0. Guelph, Ontario. 2020. 205 pp.  
<https://books.gw-project.org/hydrogeologic-properties-of-earth-materials-and-principles-of-groundwater-flow/>