Reservoir Properties of Lacustrine Carbonate Buildups from Pleistocene Lake Lahontan: Analogues for South Atlantic Reservoirs*

Laura M. DeMott¹, James D. Muirhead¹, and Christopher A. Scholz¹

Search and Discovery Article #30585 (2018)**
Posted October 22, 2018

*Adapted from poster presentation given at 2018 AAPG Annual Convention & Exhibition, Salt Lake City, Utah, May 20-23, 2018
**Datapages © 2018 Serial rights given by author. For all other rights contact author directly. DOI:10.1306/30585DeMott2018

¹Earth Sciences, Syracuse University, Syracuse, New York  (lmdemott@syr.edu)

Abstract

The lacustrine carbonate reservoirs of the South Atlantic margin contain vast quantities of hydrocarbons, but predicting reservoir properties remains a significant challenge. Seismic-scale Late Pleistocene analogues for these reservoirs are found in carbonate buildups from paleo-Lake Lahontan, a large pluvial lake in the Basin and Range, western USA. These buildups are up to 100 m high, and consist of stacked successions of domes, pillars, and branches (<5 m high) which exhibit meso- and microscale textural trends. Reservoir properties were examined by combining field observations, porosity and permeability measurements, and outcrop modeling. Porosity data were obtained from thin section optical porosity, and permeability measurements were made on hand samples and outcrops to create a large reservoir property dataset.

We present conceptual models of depositional “building blocks”, based on observed trends in morphologies and textures, using a combination of ArcGIS, Matlab, and DecisionSpace software to model simplified reservoir properties and examine heterogeneity. We present 3D morphological models based initially on simple forms, and extended into larger stratal units. Porosity and permeability properties are stochastically incorporated into the models based on observed texture. Fluid flow through the reservoirs is modeled to examine how shape and texture affect property distribution and flow patterns. Small-scale conceptual models are applied to larger-scale, digital outcrop models constructed from imagery collected from sUAS (small unmanned aerial vehicles or drones). Reservoir property and flow simulations are applied to the larger model. We observe complex vertical and horizontal heterogeneity dependent on growth direction, texture, internal structure, overall morphology, and gross stacking patterns. The models indicate that unlike siliciclastic reservoirs, the lacustrine carbonate reservoir potential is strongly dependent upon environmental factors including water chemistry, depth, clarity, and temperature. The outcrop-based models demonstrate that stacking patterns indeed have a measure of predictability, and are useful analogues for predicting the distribution of reservoir properties and fluid pathways at the basin scale.
Reservoir Properties of Lacustrine Carbonate Buildups from Pleistocene Lake Lahontan: Analogues for South Atlantic Reservoirs

Laura M. DeMott, James D. Muirhead, and Christopher A. Scholz

Department of Earth Sciences, Syracuse University, Syracuse, NY, USA

Abstract

The lacustrine carbonate reservoirs of the South Atlantic margin contain vast quantities of hydrocarbons, but predicting reservoir properties remains a significant challenge. Seismic-scale late-Pleistocene analogues for these reservoirs are found in carbonate buildups from Pleistocene Lake Lahontan, a large pluvial lake in the Basin and Range, western USA. These buildups are up to 100 m high, and consist of stacked successions of domes, pillars, and branches (5 m high) which exhibit meso- and microscale textural trends. Reservoir properties were examined by combining field observations, porosity and permeability measurements, and outcrop modeling. Porosity data were obtained from thin section optical porosity, and permeability measurements were made on hand samples and outcrops to create a large reservoir property dataset. We present conceptual models of depositional "building blocks", based on observed trends in morphologies and textures, using a combination of ArcGIS, Matlab, and DecisionSpace software to model simplified reservoir properties and examine heterogeneity. We present 10 morphological models based initially on simple forms, and extended into larger stratigraphic units. Porosity and permeability properties are stochastically incorporated into the models based on observed texture. Fluid flow through the reservoir is modeled to examine how shape and texture affect property distribution and flow patterns. Small-scale conceptual models are applied to larger-scale, digital outcrop models constructed from imagery collected from UAVs (small unmanned aerial vehicles or drones). Reservoir property and flow simulations are applied to the larger model. We observe complex vertical and horizontal heterogeneity dependent on growth direction, texture, internal structure, overall morphology, and gross stacking patterns. The models indicate that unlike siliciclastic reservoirs, the lacustrine carbonate reservoir potential is strongly dependent upon environmental factors including water chemistry, depth, clarity, and temperature. The outcrop-based models demonstrate that stacking patterns indeed have a measure of predictability, and are useful analogues for predicting the distribution of reservoir properties and fluid pathways at the basin scale.

1. Introduction

Extensive carbonate "tufas" found in the North American Great Basin rift lakes are valuable analogues for the extensive lacustrine carbonate reservoirs of ancient rift lake basins, such as those found in the Santos and Campos basins of offshore Brazil. These porous limestones are commonly associated with rift basin lake settings, and are well-known in the rift lake basins of the western United States, as well as other lake settings. However, the tufa deposits associated with Pleistocene pluvial Lake Lahontan, particularly in the Pyramid and Winnemucca subbasins, are among the few such deposits that approach the scale of Cretaceous hydrocarbon reservoirs. These tufa deposits can be up to 100 m in height, and cover thousands of square meters in area. The extensive deposits of tufa in the Great Basin, particularly those in the Pyramid and Winnemucca subbasins, are primarily thought to form where hydrothermal springs emerge into alkaline lake waters. Many of the extremely large tufa deposits in Pyramid Lake are associated with rift structures, as strike-slip and normal faults in the basin serve as the primary fluid pathways for these springs (Frary et al., 2011). To fully capture the intricacies of lacustrine carbonate stratigraphic architecture and to address the complexity of such deposits, new spatial models of lacustrine carbonate deposits are required, which are both detailed and quantitative. This poster presents ongoing research developing three-dimensional digital outcrop models to address variability in tufa type and morphology across the Winnemucca Dry Lake area.

A generalized fault map of the area indicates the major faults in the Pyramid and Winnemucca basins. The geothermal systems indicated are known to be associated with large tufa deposits.

A generalized fault map of the area indicates the major faults in the Pyramid and Winnemucca basins. The geothermal systems indicated are known to be associated with large tufa deposits.

Hydrothermal geyser at the Needles Rocks, Pyramid Lake.

Schematic Deposition Model of Pyramid Lake Tufas
Laura M. DeMott, James D. Muirhead, and Christopher A. Scholz
Department of Earth Sciences, Syracuse University, Syracuse, NY, USA

Reservoir Properties of Lacustrine Carbonate Buildups from Pleistocene Lake Lahontan: Analogues for South Atlantic Reservoirs

2. Geologic Background

3. Tufa Textural Classification

3A. Thrombolite Tufa

3B. Thinolite Tufa

3C. Laminated Tufa

3D. Grainstones/Packstones/Wackestones

4. Methods

4A. Optical Porosity

4B. Permeability

4C. UAV-Sourced Photogrammetry

5. Porosity and Permeability of Tufa Outcrops

5A. Porosity

5B. Permeability

6. Outcrop Models

6A. Thinolite Tufa

6B. Laminated Tufa

6C. Grainstones/Packstones/Wackestones

6D. Model Application
Reservoir Properties of Lacustrine Carbonate Buildups from Pleistocene Lake Lahontan: Analogues for South Atlantic Reservoirs

Laura M. DeMott, James D. Muirhead, and Christopher A. Scholz
Department of Earth Sciences, Syracuse University, Syracuse, NY, USA

7. Implications and Future Work

The current results demonstrate that:
- Tufa textural and morphological patterns are present across both basins.
- While the mean porosity is similar across tufa textures, the range of values is distinct to each textural type.
- Permeability is highly variable with respect to tufa texture, and indicates that some tufa types may be significant barriers to flow (laminated/stromatolitic tufas).
- 3D models have provided insight into the depositional trends across the basin and the relationship to subsurface geology.

Future work on tufa reservoir architecture includes:
- Increasing the sample size for porosity and permeability measurements.
- Transfer of 3D digital outcrop models into geomodeling software such as Petrel, Move, or Skua-GOCAD.
- Development of 3D flow models
  - Conceptual models using generalized tufa morphologies and textures.
  - True earth models using inputs derived from the digital outcrop models.

References


Acknowledgements

The authors would like to thank Jacqueline Corbett for field assistance and drone piloting, Peter Cattaneo for computing assistance, Lachlan Wright and Nick Zaremba for valuable discussion, and the EMPOWER program at Syracuse University for support throughout this research.

This material is based upon work supported by the National Science Foundation under Grant No. DGE-1449617. Additional funding for this work was provided by Syracuse University through the John J. Prucha Field Research Fund, the College of Arts and Sciences Graduate Student Summer Fellowship, alumnus James Thomson, and the Central New York Association of Professional Geologists Grant for Earth Science Student Research.