



# Simultaneous oil recovery and residual gas storage: A pore-level analysis using in situ X-ray micro-tomography

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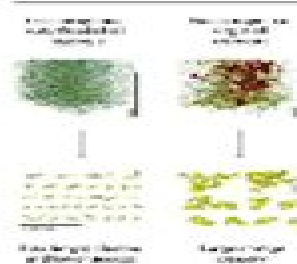
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## HIGHLIGHTS

- Waterflooding a reservoir prior to gas injection leads to significantly lower oil recovery.
- More oil can be produced by directly injecting gas into a virgin oil reservoir.
- Waterflooding a reservoir prior to gas injection leads to significantly lower gas storage capacities.
- More residual gas can be stored by directly injecting gas into an oil reservoir.
- Residual oil and gas clusters have a large cluster size distribution and surface area.

## GRAPHICAL ABSTRACT



## ARTICLE INFO

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## ABSTRACT

We imaged sandstone cores at residual gas saturation ( $S_{gr}$ ) with synchrotron radiation at a nominal resolution of  $(19 \mu\text{m})^3$ . We studied two three-phase flooding sequences: (1) gas injection into a core containing oil and initial water followed by a waterflood (gw process); (2) gas injection into a waterflooded core followed by another waterflood (wgw process). In the gw flood we measured a significantly higher  $S_{gr}$  ( $\approx 20.4\%$ ;  $S_{gr}$  in the wgw flood was  $5.3\%$ ) and a significantly lower residual oil saturation ( $S_{or}$ ;  $S_{or}$  in the gw flood was  $21.4\%$  and  $S_{or}$  in the wgw flood was  $29.3\%$ ). We also studied the size distribution of individual trapped clusters in the pore space. We found an approximately power-law distribution  $N \propto r^{-\tau}$  with an exponent  $\tau = 2.02$ – $2.03$  for the residual oil clusters and  $\tau = 2.04$  for the gas clusters in the gw flood.  $\tau$  ( $\approx 2.32$ ) estimated for the gas clusters in the wgw process was significantly different. Furthermore, we calculated the surface area  $A$ –volume  $V$  relationships for the clusters. Again an approximate power-law relationship was observed,  $A \propto V^p$  with  $p = 0.75$ . Moreover, in the gw flood sequence we identified oil layers sandwiched between the gas and water phases; we did not identify such oil layers in the wgw flood. These results have several important implications for oil recovery, carbon geo-sequestration and contaminant transport: (a) significantly more oil can be produced and much more gas can be stored using a gw flood; (b) cluster size distributions for residual oil or gas clusters in three-phase flow are similar to those observed in analogue two-phase flow; (c) there is a large cluster surface area available for dissolution of the residual phase into an aqueous phase; however, this surface area is significantly smaller than predicted by percolation theory ( $p = 1$ ) which implies that  $\text{CO}_2$  dissolution trapping and contamination of aquifers by hazardous organic solvents is slower than expected because of reduced interfacial contact areas.

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# Simultaneous Oil Recovery And Residual Gas Storage A Pore

**Laura Romero-Zerón**



## **Simultaneous Oil Recovery And Residual Gas Storage A Pore:**

Imperial College Lectures In Petroleum Engineering, The - Volume 2: Reservoir Engineering Martin Blunt, 2017-03-24

This book covers the fundamentals of reservoir engineering in the recovery of hydrocarbons from underground reservoirs. It provides a comprehensive introduction to the topic including discussion of recovery processes, material balance, fluid properties, and fluid flow. It also contains details of multiphase flow including pore scale displacement processes and their impact on relative permeability, with a presentation of analytical solutions to multiphase flow equations. Created specifically to aid students through undergraduate and graduate courses, this book also includes exercises with worked solutions and examples of previous exam papers for further guidance and practice. As part of the Imperial College Lectures in Petroleum Engineering and based on a lecture series on the same topic, Reservoir Engineering provides the introductory information needed for students of the earth sciences, petroleum engineering, and geoscience.

Chemical Enhanced Oil Recovery (cEOR) Laura Romero-Zerón, 2016-10-19

Commercial application of chemical enhanced oil recovery (cEOR) processes is expected to grow significantly over the next decade. Thus, Chemical Enhanced Oil Recovery (cEOR) A Practical Overview offers key knowledge and understanding of cEOR processes using an evidence-based approach intended for a broad audience ranging from field operators and researchers to reservoir engineers dealing with the development and planning of cEOR field applications. This book is structured into three sections: the first section surveys overall EOR processes; the second section focuses on cEOR processes; while the final section describes the electrorheology technology. These sections are presented using a practical and realistic approach tailored for readers looking to improve their knowledge and understanding of cEOR processes in a nutshell.

**Development of Unconventional Reservoirs** Reza Rezaee, 2020-04-16

The need for energy is increasing, but the production from conventional reservoirs is declining quickly. This requires an economically and technically feasible source of energy for the coming years. Among some alternative future energy solutions, the most reasonable source is from unconventional reservoirs. As the name unconventional implies, different and challenging approaches are required to characterize and develop these resources. This Special Issue covers some of the technical challenges for developing unconventional energy sources from shale gas, oil, tight gas, sand, and coalbed methane.

**Multiphase Flow in Permeable Media** Martin J. Blunt, 2017-02-16

This book provides a fundamental description of multiphase fluid flow through porous rock based on understanding movement at the pore or microscopic scale.

**Fundamentals and Practical Aspects of Gas Injection** Reza Azin, Amin Izadpanahi, 2021-07-28

This book covers different aspects of gas injection from the classic pressure maintenance operation to enhanced oil recovery (EOR), underground gas storage (UGS), and carbon capture and storage (CCS). The authors detail the unique characteristics and specific criteria of each application, including material balance equations, phase behaviour, reservoir engineering, well design, operating aspects, surface facilities, environmental issues. Examples, data, and simulation codes are provided to enable the

reader to gain an in depth understanding of these applications Fundamentals and Practical Aspects of Gas Injection will be of use to practising engineers in the fields of reservoir engineering and enhanced oil recovery It will also be of interest to researchers academics and graduate students working in the field of petroleum engineering Progress and Challenge of Porous Media: Proceedings of the 16th Annual Meeting Conference on Porous Media Jun Yao,Yongfei Yang,Wendong Wang,Hai Sun,Lei Zhang,Kai Zhang,2025-04-08 This book is a compilation of selected papers from the 16th Annual Meeting Conference on Porous Media InterPore 2024 The work focuses on novel techniques for porous media materials transport mechanisms in porous media multiscale multiphysics pore scale modeling and porous media mechanics The contents make valuable contributions to academic researchers engineers in the industry and regulators of aviation authorities As well readers will encounter new ideas for problems in porous media science and engineering Proceedings of the Sixteenth World Petroleum Congress Institute of Petroleum,World Petroleum Congress,2001-03 **Fossil Energy Update** ,1986 Quantitative Characterization and Engineering Application of Pores and Fractures of Different Scales in Unconventional Reservoirs - Volume II Wenlong Ding,Hu Li,Shuai Yin,2023-04-05 **Journal of the Institute of Petroleum** ,1963 *Petroleum Engineering Handbook* Larry W. Lake,2007 **Journal of the Institute of Petroleum** Institute of Petroleum (Great Britain),1963 **Journal** Institute of Petroleum (Great Britain),1962 Vols 7 include Abstracts which beginning with v 9 form a separately paged section and from v 17 on have separate title pages Abstracts of the Journal Institute of Petroleum (Great Britain),1962 Petroleum Abstracts ,1993-04 Proceedings Society of Core Analysts. International Symposium,2006 **Shale Shaker** ,1975 Society of Petroleum Engineers Journal Society of Petroleum Engineers of AIME.,1972 **Journal of Petroleum Technology** ,1988-06 Transactions of the Society of Petroleum Engineers American Institute of Mining, Metallurgical, and Petroleum Engineers,1983

The Enigmatic Realm of **Simultaneous Oil Recovery And Residual Gas Storage A Pore**: Unleashing the Language is Inner Magic

In a fast-paced digital era where connections and knowledge intertwine, the enigmatic realm of language reveals its inherent magic. Its capacity to stir emotions, ignite contemplation, and catalyze profound transformations is nothing in short supply of extraordinary. Within the captivating pages of **Simultaneous Oil Recovery And Residual Gas Storage A Pore** a literary masterpiece penned by a renowned author, readers embark on a transformative journey, unlocking the secrets and untapped potential embedded within each word. In this evaluation, we shall explore the book's core themes, assess its distinct writing style, and delve into its lasting effect on the hearts and minds of people who partake in its reading experience.

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web amygdalin is a plant substance found in raw nuts bitter almonds as well as apricot and cherry seeds plants like lima beans clover and sorghum also contain amygdalin some people call laetrile vitamin b17 although it isn't a vitamin why people with cancer use it laetrile has been used as an anti cancer agent since the 1800s

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web nov 21 2019 writer bio there are two types of almonds sweet and bitter sweet almonds are frequently used in cooking or can be eaten as a snack bitter almonds are frequently used for food flavorings or in oils sweet almonds grow on trees in australia south africa the mediterranean and the united states

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web aug 21 2023 bitter almonds are a variety of regular sweet almonds bitter almonds contain traces of prussic acid also known as hydrocyanic acid in its raw state hydrocyanic acid is a solution of hydrogen cyanide and water the byproduct is an organic version of the well known poison cyanide

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web jun 13 2019 today many people have never even heard of poisonous almonds much less come across one in the wild though some folks still eat bitter almonds in small doses in tunisia for instance people

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web feb 28 2020 bitter almonds are the seeds of certain trees belonging to prunus dulcis namely those that grow in the middle east and asia these seeds are often classified as nuts but they aren't true nuts and are actually a form of a drupe where the seed is enclosed in an outer hull and a hard shell

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web bitter almond overview almonds are a familiar type of nut they can be sweet or bitter depending on the type of tree that produces uses effectiveness insufficient evidence to rate effectiveness for other conditions more evidence is needed to side effects do not use bitter almond

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web cyanide is sometimes described as having a bitter almond smell but does not always give off an odor and not everyone can detect this odor how people can be exposed to cyanide after a release of cyanide into the air people can be exposed through skin contact or eye contact or inhaling breathing in the cyanide gas

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web bitter almond prunus amygdalus var amara is a type of almond it contains a toxic chemical called amygdalin which is poisonous when consumed the amygdalin in bitter almond turns into

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web bitter almonds contain 42 times higher amounts of cyanide than the trace levels found in sweet almonds extract of bitter almond was once used medicinally but even in small doses effects are severe or lethal especially in children the cyanide must be removed before consumption

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web jul 3 2020 bitter almonds were the most common species grown until a few thousand years ago when a genetic mutation inhibited the almond tree s ability to make amygdalin the compound that gives bitter