Investigating the porosity of sedimentary rock with neutrons

April 22 2024

Dr. Vitaliy Pipich at the KWS-3 instrument of Forschungszentrum Jülich at the FRM II in Garching. Credit: Bernhard Ludewig

Whether sedimentary rocks store fossil hydrocarbons or act as impermeable layers to prevent the rise of oil, natural gas or stored carbon dioxide—all depends on their porosity. The size, shape, organization, and connectivity of the pore spaces are decisive.

At the Heinz Maier-Leibnitz Research Neutron Source (FRM II) at the Technical University of Munich (TUM), the networks of micropores were characterized using small and very small angle neutron scattering.

Dense, dark, compact—at first glance, the sedimentary rock samples that Dr. Amirsaman Rezaeyan has on his lab desk are only slightly different. Pores are not visible to the naked eye.

Nevertheless, it is precisely the pores that give the mudrocks their special properties: The pores, ranging from a few micrometers to sub-nanometers in size, are formed during sedimentation and compacted over time, determining the permeability. These pores are the decisive factor for the rock's ability to reside oil and natural gas or form impermeable layers under which the fossil fuels collect.

"Depending on the distribution, size and structure of the pores, the fine-grained sedimentary rocks are also suitable for disposing of radioactive waste or sealing carbon dioxide storage," explains Dr. Amirsaman Rezaeyan, a researcher at the University of Calgary in Canada. "The pore structure of mudrocks and its influence on the permeability for fluid flow have hardly been studied to date but are enormously important if you want to assess the potential of mudrocks as oil reservoirs or impermeable layers."

But how do you measure pores that are not bigger than bacteria? There are actually various methods that can be used to quantify the pore volume, but most of them can only detect larger structures or limited pore sizes.

"Only small and very small angle neutron scattering is suitable for fully quantifying pores between a few nanometers and micrometers," says Rezaeyan, who, together with an international team at the Heinz Maier-Leibnitz Research Neutron Source (FRM II) at TUM, has analyzed the porosity of a dozen sedimentary rocks from Europe and America.

Measuring pores with nanometer precision

There are only a few measuring facilities for Small Angle Neutron Scattering (SANS) and Very Small Angle Neutron Scattering (VSANS) around the world. Two of them, KWS-1 and KWS-3, are operated by Forschungszentrum Jülich at the Heinz Maier-Leibnitz Zentrum (MLZ).

The MLZ is the scientific cooperation between TUM, Forschungszentrum Jülich and Helmholtz-Zentrum Hereon, which makes the neutrons of the FRM II available to guest researchers in the form of scientific instruments.

And so Rezaeyan from the Lyell Center at Heriot-Watt University in Edinburgh, Scotland, where he was working at the time, traveled to Garching with his rock samples—all thinly polished and without gas or liquid inclusions—to detect micropores.

The samples were irradiated with neutrons from the reactor in the small-angle scattering instruments at the FRM II. As neutrons only interact with the nuclei of atoms, the diffraction pattern recorded by the detector can be used to deduce the arrangement of the atoms and thus—indirectly—that of the atom-free pores.

Back in Scotland, the researchers correlated the measurements with the microscopic properties of the rock samples. The result has now been published two articles, one in the journal *Energy* and the other in *Energy & Fuels*.

The researchers found that the porosity of the fine-grained mudrocks is dependent on the proportion of clay minerals contained in the sediments: The more clay, the greater the probability of smaller pores, which have a diameter of less than 50 nanometers. Rocks with a high clay content are therefore potentially well suited for sealing a disposal or storage place underground as an impermeable layer.

"However, clay content is only one piece of the puzzle: there are a whole range of factors that need to be taken into account when selecting suitable mudrock layers for production of oil and gas or CO_2 storage," emphasizes Rezaeyan. "We therefore included other factors in the data analysis, such as rock compaction and organic matter. Doing this, we were able to establish correlations of high statistical significance."

With the help of these correlations, it should be possible in the future to estimate the physical properties of fine-grained sedimentary rocks based on the sedimentation conditions and to find out whether they are suitable as impermeable layers for nuclear waste repositories and CO_2 storage sites.

More information: Amirsaman Rezaeyan et al, Compaction and clay content control mudrock porosity, *Energy* (2023). DOI: 10.1016/j.energy.2023.129966

Amirsaman Rezaeyan et al, Evolution of Pore Structure in Organic-Lean and Organic-Rich Mudrocks, *Energy & Fuels* (2023). DOI: 10.1021/acs.energyfuels.3c02180

Provided by Technical University Munich

Citation: Investigating the porosity of sedimentary rock with neutrons (2024, April 22) retrieved 8 May 2024 from https://phys.org/news/2024-04-porosity-sedimentary-neutrons.html

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.