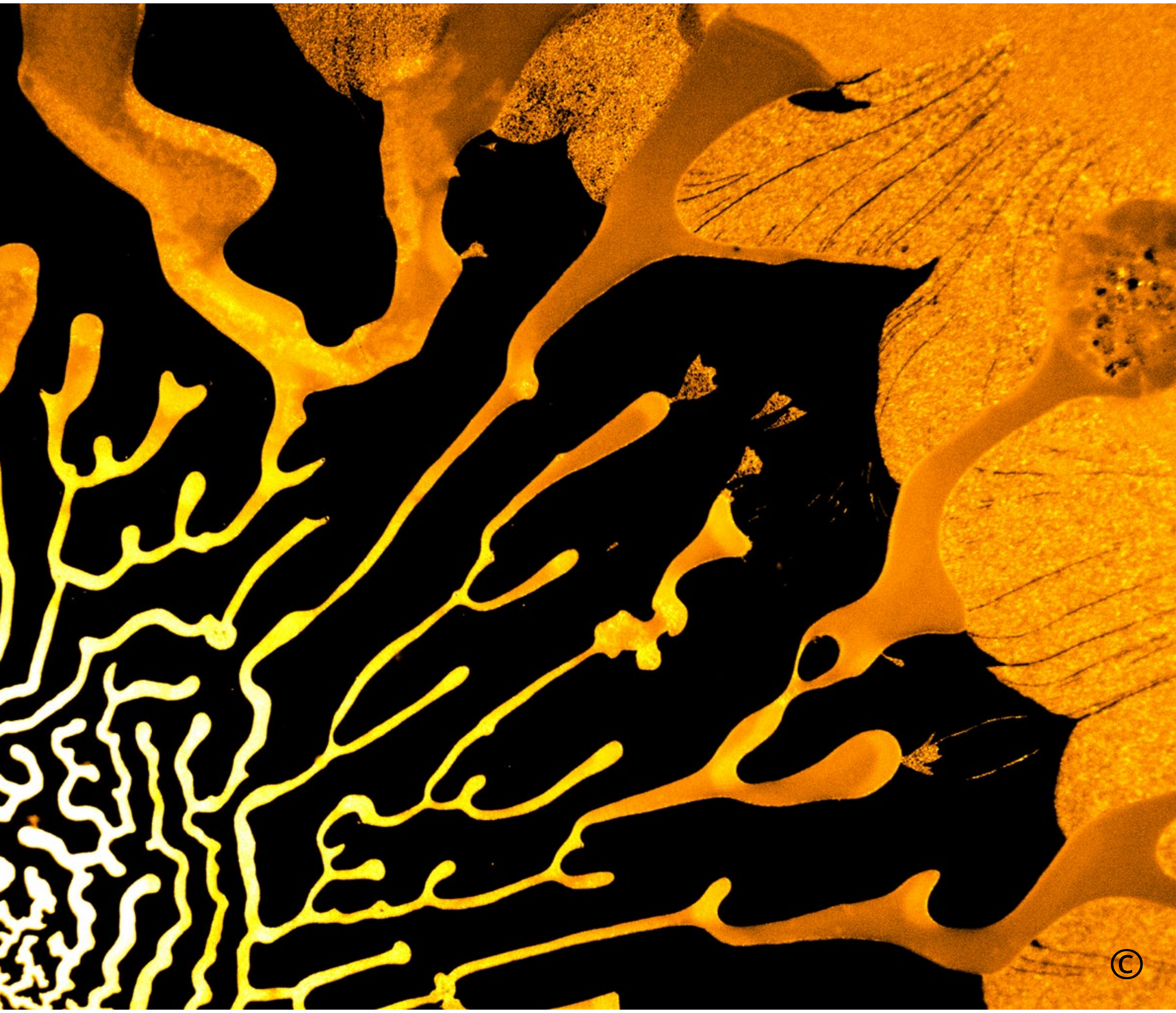
PoreLab
NTNU-UiO Porous Media Laboratory

Annual Report 2025



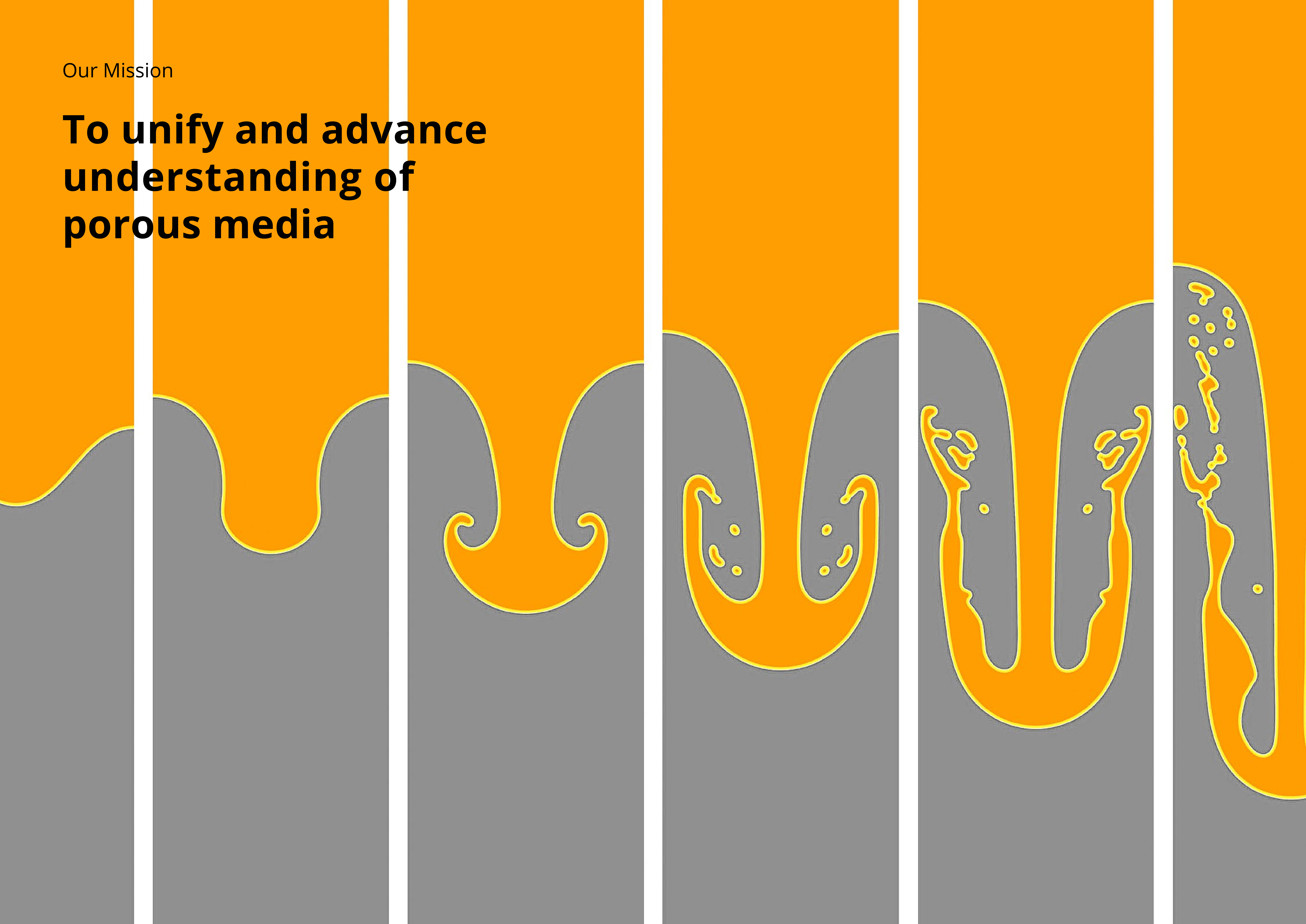
NTNU
Norwegian University of Science and Technology

UiO : University of Oslo

The Research Council of Norway

Our Mission

To unify and advance understanding of porous media



WHAT IS PORELAB?

The Research Council of Norway describes their Centre of Excellence (CoE) program as follows: *The CoE scheme gives Norway's best researchers the opportunity to organize their research activities in centres that seek to achieve ambitious scientific objectives through collaboration and with long-term basic funding.*

After an application process that started in 2015, we were awarded CoE status in August 2017 by the Research Council of Norway. PoreLab, acronym for Porous Media Laboratory, was born!

PoreLab has two nodes, at the Norwegian University of Science and Technology (NTNU) in Trondheim and at the University of Oslo (UiO). It is led by eight principal scientists from physics, chemistry, and reservoir engineering. At UiO, PoreLab is part of the Njord Center which is a cross-disciplinary geoscience-physics center.

The mission of PoreLab is to advance the understanding of flow in porous media, both at a fundamental level and in applications. Starting from a basis in physics we aim for a better description of flows that range from geological to biological and technological.

Our objective is to link together observations of how fluids behave at the pore scale with a proper description of flow in porous media at much larger scales – the scales that typically are relevant for applications. In other words, our aim is to construct a large-scale theory for flow in porous media based on the detailed physics at the pore level. To achieve this, we combine hydrodynamics, non-equilibrium thermodynamics and statistical physics using theoretical, computational, and experimental methods. But we also consider other problems such as the interactions between fluids and grains in unconsolidated porous media.

Our strength is to combine knowledge in physics, chemistry and geoscience using all three ways of approaching a problem: experimental, theoretical and computational.

PoreLab receives an annual funding from the Norwegian Research Council of about 15 MNOK. NTNU and UiO contribute with the same financial support. In December 2022, we received the information from the Research Council of Norway that the mid-term evaluation planned originally during the spring 2023 was cancelled. In December 2024, the Research Council of Norway approved a 1-year prolongation for PoreLab. Our new date of completion is September 2028.

TABLE OF CONTENTS

Picture: Core plugs from porous sedimentary rocks.

Picture pages 2/3: Lattice-Boltzmann simulation of a Rayleigh–Taylor instability when a denser fluid is placed on top of a less dense fluid. Reference: Haghani, Reza, Hamidreza Erfani, James E. McClure, Eirik Grude Flekkøy, and Carl Fredrik Berg. "Color-gradient-based phase-field equation for multiphase flow." Physical Review E 109, no. 3 (2024): 035301.

Cover page: Labyrinthian drying pattern of a colloidal suspension, driven by capillary forces (Photo: © Erika Eiser)

POROUS MEDIA RESEARCH: LEADERSHIP AND COMMUNITY

By Steffen Berg, Principal Science Expert at Shell Global Solutions, The Netherlands and Adjunct Professor at the Department of Physics, NTNU, Norway

Porous media are critically relevant for almost every aspect of human existence. Research is ongoing in fields from earth sciences to industrial and energy applications, renewable technologies and biomedical science. Setting an appropriate vision for the field, building a positive research culture and producing high-quality research are therefore essential for the future well-being and economic stability of society. To achieve this will require a research community that is defined and coherent, that acts boldly in the best interests of society and its members, and that can secure and allocate the resources required to achieve its vision. This cannot be done without appropriate and effective leadership. This article therefore sets out how we can recognize, and apply, effective leadership in porous media research.

POROUS MEDIA RESEARCH: A RETROSPECTIVE

To understand the requirements for effective leadership in porous media research, it is first necessary to understand the distinctive nature of this field of study – and how this influences the way in which porous media scientists understand the leadership concept. Porous media research has a history that goes back several centuries. Throughout that time, there were certain critical developments that shaped the evolution of the field.

In the 18th and 19th centuries, pioneers such as Woltman, Coulomb and Darcy developed new porous media concepts in earth science. The research spectrum at this time was dominated by analytical solutions in hydrology. Then, in the 20th century, the requirements of the emergent oil and gas industry extended the field's scope to petroleum engineering. The science of porous media developed, driven by analytical solutions. Generally a very effective form of reductionism, these provided a sustainable foundation for the next generation of scientists to drive advancements to the next level.

The 20th century introduced electronic computers, which yielded rapid advances as the emergence of data science and close collaboration with applied mathematicians produced effective numerical methods. As a result, numerical simulators matured and became mainstream – they are now routinely used in daily applications addressing specific societal needs in petroleum engineering, groundwater management, agriculture, and contaminant hydrology.

In the 1990s, increasing computational power was combined with newly available 3D-imaging techniques, such as X-ray computed micro-tomography. This opened up the field of pore-scale research, and the insight gained motivated researchers to revisit their approach to upscaling from pore scale to Darcy scale. Upscaling has become one of the dominant topics for porous media research because of the multiscale nature of many natural and engineered materials, and it remains a highly active research field [1].

Developments in the 21st century have notably been concerned with the energy transition. Examples include, from the mid-2000s, the topic of carbon dioxide sequestration; and, in the past five years or so, considerations for the underground storage of hydrogen, as well as for the exploitation of natural, or 'white', hydrogen.

FUTURE RESEARCH DIRECTIONS

What are the topics for porous media research, tomorrow and into the future? Predicting this is far from straightforward, and it is only possible to outline paths that research might take based on what is currently known.

The process by which new research trends are formed is neither predictive nor democratic. The future will combine entirely new (and therefore unpredictable) subjects with emergent technologies. For example, nanotubes and quantum computing are expected to have a significant impact but so will subjectively "old" and unresolved topics, such as upscaling –revisited and elevated to a higher level.

Upscaling is not only the incorporation of heterogeneity; it has deep fundamental consequences in the sense of the increasingly recognized principle that "more is different" [1]. Upscaling will inevitably shift into the domain of statistical physics, where researchers can adopt well-established frameworks and methodologies. Moreover, progressing through the scales (including heterogeneity scales) will inevitably require a more quantitative description of geological structures. Society will no longer accept statistical representation alone and will demand greater certainty about, for example, where carbon dioxide injected subsurface will go and stay.

In terms of un- (or under-) explored phenomena, there is a clear societal demand for clean energy solutions that could be addressed, in part, by understanding the water–energy nexus. This involves porous media at many critical points, from electrodes and membranes to adsorbants and more, and these are increasing in relevance compared to classical subsurface porous media. However, the importance of porous media as a subject in its own right has, so far, not been fully recognized or accepted by the communities driving these new topics forward.

Another emergent area is the investigation of porous media phenomena at ever smaller scales. Here, surface forces become increasingly relevant – but, more significantly, entirely new physics is encountered – for example, quantum mechanical effects that lead to superlubricity of water in hydrophobic nanochannels [2].

Nanotubes provide a fascinating research subject in their own right, but also offer potential new routes to harvesting abundant sources of energy [3]. New approaches, such as machine learning [4] and quantum computing [5], offer many new possibilities – and the porous media community is increasingly making use of them. That requires collaborating in an ever more interdisciplinary manner [6], but that, the author believes, is one of the strengths of the porous media community – and, with appropriate leadership, will remain so [2].

THE ROLE OF LEADERSHIP IN POROUS MEDIA RESEARCH

Trying to pin down the role of "leadership" in any scientific field, and porous media is no exception, can be problematic and controversial, and even provocative. In many communities, the term is often overused and conflated with the concept of a "leader" – an individual appointed to a specific senior management role. However, the reality is more complex, and it is perhaps no surprise that research communities generally, and porous media research scientists specifically, understand the leadership concept somewhat differently.

That difference is embraced by researchers in the social sciences. They typically recognize five main schools of leadership theories: trait and behavioral; contingency/situational; power and influence; and transformational/charismatic. These are in addition to concepts such as transactional, servant and authentic leadership. Researchers in porous media are therefore justified in looking beyond the concept of the individual leader. For them, leadership emerges in the form of the ability to guide and influence research activities and trends. It encompasses a range of skills and competencies essential for producing high-quality research, as well as building a positive research culture and vision that inspire others to follow.

What, then, is the current status of leadership in the domain of porous media research? Some indicators suggest a lack of effective leadership. Despite the critical relevance of this research field for so many aspects of human endeavor, it does not receive anywhere near the same level of attention as other, 'trendier' topics. Meanwhile, of the tens of thousands of scientists active in the wider spectrum of porous media research, only a very small fraction is organized in departments and learned societies that formally focus on porous media. But is that the relevant metric?

In contrast, there are prominent examples of the porous media community actively seeking collaboration. These include PoreLab, InterPore, and initiatives such as Structures of Strength [7]. There is also significant diversity in new research areas, from nano-porous media, where surface forces play a much more significant role [8], to transport processes in colloidal systems [9] and soil science, where biological activity is even more intrinsically coupled with transport phenomena [10]. Meanwhile, opportunities for open collaboration are increasing, and numerous open-source frameworks provide almost everyone with access to numerical simulators and code for many other applications, providing a very effective way of collaborating.

Overall, where the field stands in terms of leadership depends on the perspective taken. To help understand this, it may be helpful to consider an analogy with a porous media phenomenon: viscous fingering. That is what having only a few leaders in the research field would be like: a pattern of isolated 'fingers' in which the focus is on a few siloed specialties that the following research community will advance. However, porous media has many relevant applications, so it may need many leaders covering all relevant areas, some of which have yet to be defined. Then the 'viscous fluid' that is research progress will advance on a steady front covering all possible areas and leaving no gaps, but the overall pace of advance may be slower.

A LEADERSHIP PATH FOR THE FUTURE

The pattern from the history of porous media research is clear. In the past, each era had creative and visionary leadership, and research groups sprang up and began collaborating across the globe. The field was vigorous and spontaneous, and appropriate to the challenges of the time. But how can we carry that pattern of innovation forward into the future?

First, as a community, porous media researchers must always be careful to avoid just doing more of the same. Tomorrow's research community will look different, perhaps very different, from yesterday's. Second, researchers must avoid isolated ways of working and siloed thinking. This includes thinking about leadership – there is no one-size-fits-all model.

For example, "rediscovering" the concepts of capillarity in new research topics, such as underground storage of carbon dioxide and hydrogen, requires reference to what has been well established in vadose zone research and petroleum engineering. Ensuring this happens in a timely and effective manner, and without prejudice as to the perceived status or relevance of other research areas, requires leadership that can guide and influence, make introductions and manage conflict. Identifying novel aspects in which the behavior of carbon dioxide and hydrogen might be different, such as ripening [11, 12], may require a different kind of leadership, one that is intuitive, sees opportunities, and actively seeks resources to pursue unproven potential.

We are now at a point of inflection, experiencing a generational change that will open great opportunities for new, visionary leadership to define the research agenda of tomorrow. This is vitally important to the challenges facing porous media research. These include bringing new, breakthrough concepts onto the agenda; finally solving evolving topics (if any research topic is ever finally solved) or elevating them to a higher level; creating societal impact; and even satisfying scientific curiosity, which is how unknown and unanticipated challenges and solutions will emerge. How effective such leadership is will ultimately define the future of porous media research and its associated research community.

Perhaps, as a community, porous media researchers have been missing the opportunity to be more coherent, bolder and focused on outcomes. As 1972 Nobel Prize Recipient John Bardeen stated, *"the combined results of several people working together is often much more effective than could be that of an individual scientist working alone."* Perhaps the greatest challenge for future leaders in porous media research is to bring researchers together to work effectively on all the challenges that this research field, and society in general, is facing.

REFERENCES

[1] Hansen, A., Across the Scales Redux, PoreLab – Annual Report 2022.

[2] Falk, K. et al., Molecular origin of fast water transport in carbon nanotube membranes: superlubricity versus curvature dependent friction. Nano Lett. 10, 4067–4073, 2010.

[3] Siria, A. et al., Giant osmotic energy conversion measured in a single transmembrane boron nitride nanotube, Nature 494, 455–458, 2013.

[4] Tang, K. et al., Scaling deep learning for material imaging with a pseudo 3D model for domain transfer, Nature Communications, 2025.

[5] Succi, S., Sanavio, C., Love, P., The foundational value of quantum computing for classical fluids, arXiv:2510.09178, 2025.

[6] Flekkøy, E. G., Cross-Disciplinary Breakthroughs in PoreLab, PoreLab – Annual Report 2024.

[7] Structures of Strength, https://structuresofstrength.com/

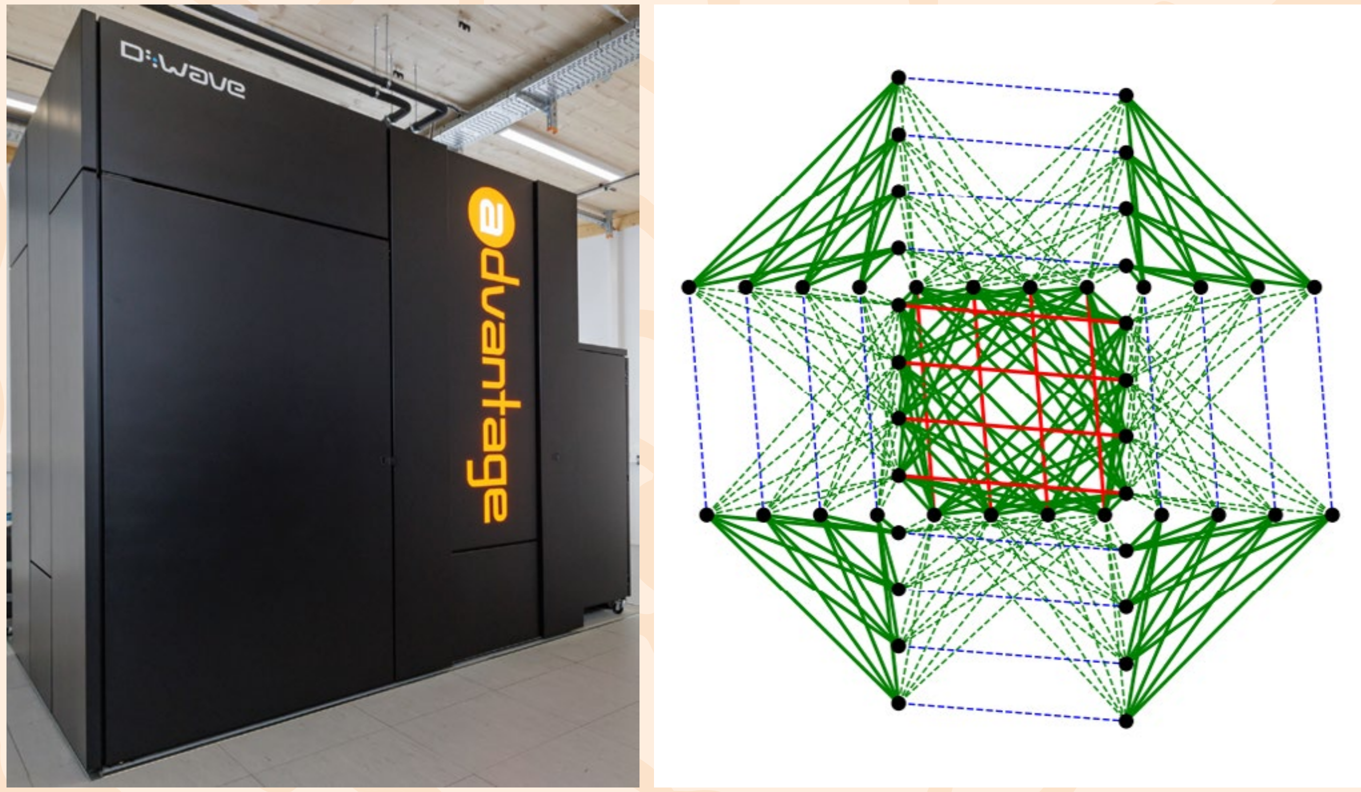
[8] Bedeaux, D., Kjelstrup, S., Schnell, S. K., Nanothermodynamics, World Scientific, 2023.

[9] Burelbach, J. et al., A unified description of colloidal thermophoresis, Eur. Phys. J. E. 41, 7, 2018.

[10] Bayeve, P. C. et al., Emergent Properties of Microbial Activity in Heterogeneous Soil Microenvironments: Different Research Approaches Are Slowly Converging, Yet Major Challenges Remain, Frontiers in Microbiology 9, 1929, 2018.

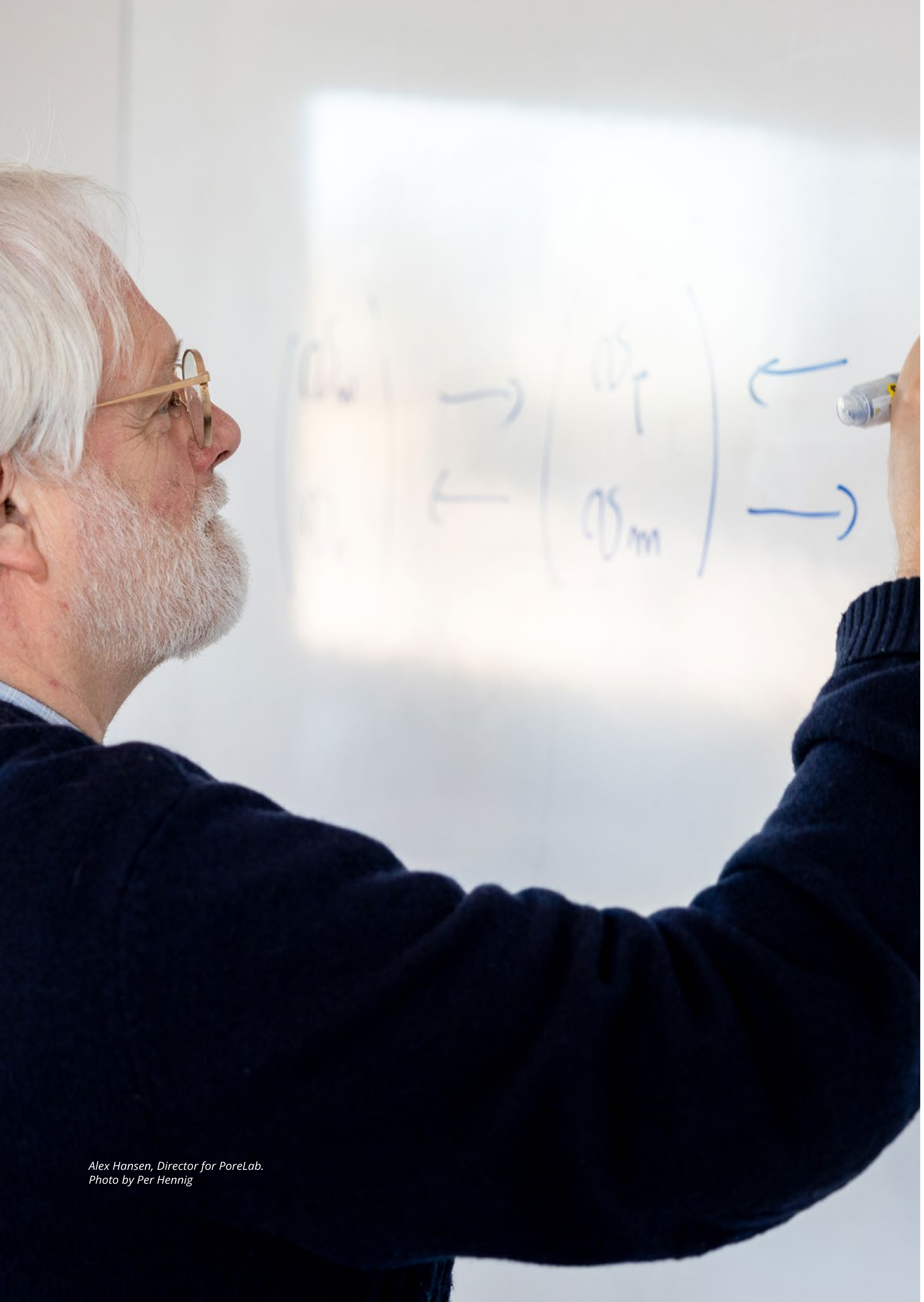
[11] de Chalendar, J. A., Garing, C., Benson, S. M., Pore-scale considerations on Ostwald ripening in rocks, Energy Procedia 114, 4857-4864, 2017.

[12] Xu, K., Mehmani, Y., Shang, L., Xiong, Q., Gravity-induced bubble ripening in porous media and its impact on capillary trapping stability, Geophysical Research Letters 46 (23), 13804-13813, 2019.



Quantum annealers, such as the D-Wave Advantage-2 device JUPSI (Left), located at the Jülich Supercomputing Centre, Research Centre Jülich, Germany, have yielded promising preliminary results for certain optimization tasks inherent in the study of porous media. The device, with nearly 5000 qubits arranged in the so called "Zephyr" topology (Right), leverages adiabatic quantum computing to solve a wide range of discrete optimisation problems across many scientific and engineering disciplines.

Further details on this will follow in the 2026 edition of the PoreLab annual report.
Photo (Right): © D-wave. Source: https://docs.dwavequantum.com/en/latest/quantum_research/topologies.html#topology-intro-zephyr



Alex Hansen, Director for PoreLab.
Photo by Per Hennig

DIRECTOR'S COMMENTS

It was a lot of work, a lot of discussions, but Erika Eiser submitted our proposal for a new Center of Excellence in November. People often complain that the time spent writing proposals is time lost. I disagree. In the same way writing papers clarifies details, writing proposals clarifies and structures the long-term aspects of research. Both aspects are necessary, not only for research that may get funded, but also for ongoing research. We know a lot more now and we have organized what we know much better due to this process. The proposal, named *Labyrint*, has its focus on capillary forces mainly in the context of porous media. Of the original PoreLab team of PIs that sent our proposal in 2015, only two carry over to *Labyrint*, Eirik Flekkøy and myself – and I will only be there for a year or so. If we succeed. Do read the essay by Eiser on page 75 in this annual report for more.

Scientifically, we made nice progress in 2025. Here are some short glimpses of our activities:

- **Research theme 1: Thermodynamics of flow in porous media.** Santanu Sinha and Alex Hansen with Brazilian collaborators have suggested and investigated that there is a new Darcy-scale phase in immiscible two-phase flow in porous media with the characteristics of a glass, thus providing a mechanism for hysteresis and slow dynamics.

- **Research theme 2: Steady state experiments and coarse-grained modeling.** Marcel Moura investigated together with colleagues at the University of Minnesota how filamentous fungi can be used to control flow distribution in porous media, finding that they can clog the widest channels of a network, forcing the flow towards previously inaccessible low-permeability areas.

- **Research theme 3: Experimental characterization of immiscible two-phase flow in porous media.** Knut Jørgen Måløy and colleagues at PoreLab conducted experimental, numerical, and theoretical studies of the effect of pore-scale disorder vs. gravity on slow drainage in two-dimensional and three-dimensional porous media, finding excellent agreement between theory, numerical and experimental results.

- **Research theme 4: Nanoporous materials and gels.** Erika Eiser and her group studied drying colloid suspensions in confined spaces, finding the formation of densely packed colloidal monolayers followed by a sudden transition to the fast formation of wet fingers containing the colloids. When completely dry, one is left with a labyrinth of fingers (as shown on the cover of this annual report).

- **Research theme 5: Thermodynamic driving forces.** Øivind Wilhelmsen and colleagues introduced non-nonocal solid-fluid interactions into the Navier-Stokes-Korteweg model, which is a methodology that can also be used to study wetting in porous media. Signe Kjelstrup, Marcel Moura and other colleagues in PoreLab and Australian National University studied experimentally saturation fluctuations in steady-state two-phase flow with the aim to determine the Onsager coefficients.

- **Research theme 6: Microfluidics and field studies.** Carl Fredrik Berg and Reza Haghani continued their work on wetting, resulting in a review paper on the subject, **TiPM**, 152, 93 (2025).

- **Research theme 7: Deformable porous media.** Eirik Flekkøy and colleagues at PoreLab demonstrate how the freezing point depression of water in small pores leads to the super-diffusive motion of melting fronts. Such melting fronts, which e.g. may be caused by heating of surface soil, may therefore penetrate faster and deeper into the ground than previously thought.

- **Research theme 8: Applications.** Øivind Wilhelmsen have with his colleagues at PoreLab mapped the limits of Feynman-Hibbs corrections in capturing contributions to thermodynamic properties of e.g. hydrogen, e.g. in connection with the handling of liquid hydrogen in porous media, resulting in an article followed up as Editors' Pick in the Journal of Chemical Physics.

- **Research theme 9: Mixing in porous media.** Gaute Linga and colleagues at PoreLab and Université de Rennes could present the first experimental evidence of enhanced chaotic mixing in two-phase porous media flow. Pore-scale images reveal that interfacial bursts in the individual pores produce transverse motions that are otherwise absent in steady flows, and these motions enhance the alternate stretching and folding of solute distributions to increase mixing rates.

More details on these highlights and other projects may be found on pages 26 to 61 in this annual report.

We got three adjunct professors under Research Topic 1, Thermodynamics of Porous Media in 2025, Saman Aryana, Steffen Berg and Sauro Succi.

Saman Aryana is Professor and Occidental Chair for Energy and Environmental Technologies at the Department of Chemical and Biochemical Engineering, University of Wyoming. His research interests are in sub-surface flow instabilities through experimentation and data analysis, development of general mathematical frameworks, and developing data-driven dynamical reservoir models along with robust solution schemes.

Steffen Berg is Principal Science Expert at Shell Global Solutions, Amsterdam. The upscaling problem, i.e., how to get to the Darcy scale from the pore scale in multiphase flow in porous media, is at the center of his current research.

Sauro Succi is researcher at the Italian Institute of Technology and a founder of the Lattice Boltzmann method – an approach that has revolutionized computational flow dynamics and central to porous media research, among other fields. His current research focuses among others on quantum computing in fluid dynamics.

They join PoreLab as have since long Adjunct Professor Renaud Toussaint and long-term visitors as Daan Frenkel and Per Arne Rikvold.

I must also mention that Lydéric Bocquet at l'Ecole Normale Supérieure in Paris holds the Onsager visiting professorship of 2025-2026, which he spends at PoreLab.

The main product of PoreLab is new science. But, as important, we also produce futures for young people, or MSc students, PhD students and postdocs. They stay with us for some years and then go on to positions in research or engineering. The importance of collaboration, not the least across boundaries between different fields, is one of the most important lessons we give. In PoreLab, rank and field are irrelevant. The social aspects are also very important, and it is great to see groups of people playing table tennis at any time.

AMBITIONS FOR 2025: DID WE DO WHAT WE SET OUT TO DO?

Here is what we wrote in the 2024 annual report (abridged):

"If we can keep up the pace we are now at, 2025 will be a productive year. We have managed to integrate our activities to a point where PoreLab is a unified group. We see shifting collaborations between the different PIs and their groups. Synergy is a well-worn but very appropriate term to use. Scientifically, we have no challenges as I see it. We need to deliver on our respective projects, but judging from the past, we will do so. We will send a proposal for a Center of Excellence to the RCN in November. What is a challenge is the message that the Trondheim part of PoreLab needs to move from its present location to the Science Building."

I believe we have fulfilled our scientific promises for 2025. Our activity is diverse, but we see how there are new collaboration constellations forming and old ones dissolving continuously within PoreLab. This signifies that we are a mature center.

We did send a Center of Excellence proposal as promised and as already described.

The Trondheim section of PoreLab has not yet moved to the Science Building. As a result of our continuous insisting that the premises where we will move will be as good as those we leave behind, this has taken more time to arrange than anticipated. The Physics Department leadership has been very helpful in this process. The resettlement is now scheduled for April/May 2026.

AMBITIONS FOR 2026

Our scientific ambitions are the same as for 2025. The plans for each Research theme are in place, and we will surely keep up the rate of scientific production. We see new collaborations on the horizon that are very promising – but more about that in the 2026 edition of our annual report.

We will find out whether we move to the second round with our Center of Excellence proposal. If we do, we will allocate considerable time to formulate the new proposal. Just to put things in perspective, a proposal over 15 pages will contain some 60000 characters. With a contribution from the Norwegian Research Council of €16 million, the value of the proposal will be around €30 per character. So, it is well worth putting considerable work into the proposal.

A big problem for PoreLab is the coming retirement of Professor Knut Jørgen Måløy at PoreLab/Oslo. This will be a big loss for PoreLab, but life is like that. But what is not ok is that his position in experimental physics is not planned to be continued. Yes, we know that the financial situation is difficult etc. But this rips the floor away from under the Oslo branch of PoreLab. The Aesop fable about the goose that laid golden eggs comes to mind.[1] We are witnessing the possible destruction of an activity that started with Jens Feder and Torstein Jøssang in the eighties, and which has been at the very forefront in the field ever since. It takes years to build an activity at this level. And it can be torn down in a moment.

[1] A Norwegian expression is more forceful in conveying the message: *"To piss in your pants to keep warm."* 161, 044113 (2024).

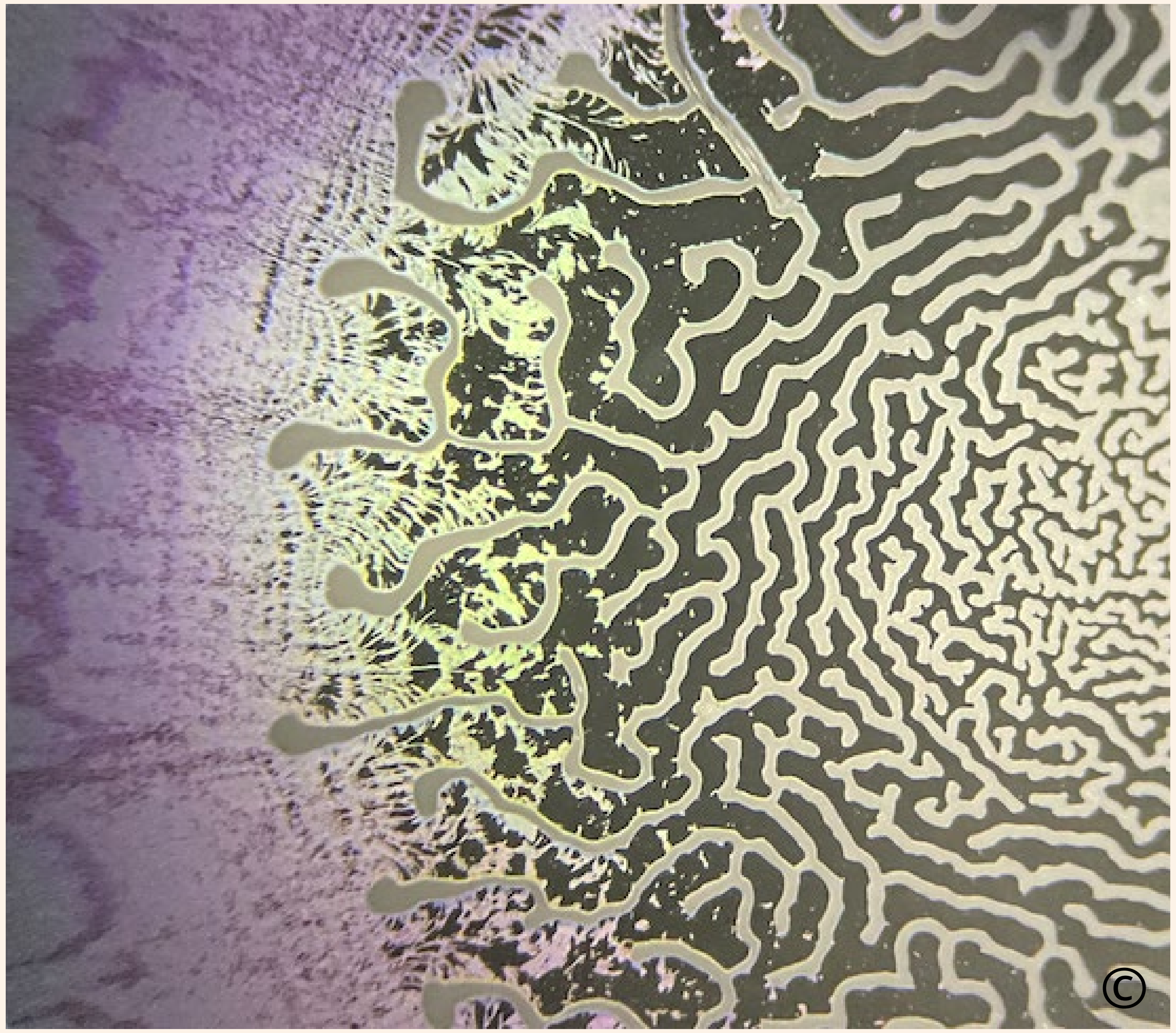


Figure: *Drying patterns of a confined colloidal suspension. Photo: © Erika Eiser*

PLAYING WITH THE VOIDS...

BY PROFESSOR LYDERIC BOCQUET, DIRECTOR OF RESEARCH AT THE CNRS AND PROFESSOR AT THE ÉCOLE NORMALE SUPÉRIEURE

Dr. Lydéric Bocquet is Director of Research at the CNRS and Professor at l'Ecole Normale Supérieure in Paris, France. He holds the Onsager visiting professorship at NTNU 2025-2026. PoreLab gratefully acknowledges Professor Bocquet for his insightful contribution to this year's annual report. Photo: © Frédérique PLAS / LPENS / CNRS Images

I discovered porous materials a bit by chance, a long time ago. My background is more on fluids, the way they flow and their statistical properties. Looking for alternative topics, I became interested, together with several colleagues, in granular systems and how humidity could drastically change their mechanical properties. Among other things, we observed logarithmic aging, increased stickiness at high humidity, and the emergence of simple mechanical laws. From the experiments, we understood that these phenomena were caused by the time-dependent condensation of capillary bridges between grains at the nanoscale, via the so-called capillary condensation. This phase transition involves high energy barriers and, combined with the disorder of the contact surfaces, leads to a humidity-dependent, extremely slow (logarithmic) increase of the adhesion forces between grains, which explained the experiments remarkably well. A bit later, we even realised that the same physical mechanism appeared in the mechanical properties of fabrics, where similar liquid condensation seemed to occur between fibres, giving some hints about the role of humidity in ironing.

Since then, my enthusiasm for porous materials has never faded. I became fascinated by the multitude of physical phenomena hidden behind these apparently trivial observations in granular, porous matter. Understanding their properties requires a remarkably broad spectrum of knowledge: from the collective elasto-plastic response of granular systems and nanoscale friction, to liquid phase transitions in the voids, interfaces and wetting, and the physics of disordered energy landscapes and their statistical properties.

For a scientist, this is a perfect topic: a wealth of scientific intrigue, strange behaviours to explain, burning questions to answer, new experiments to design, new theories to imagine, and new computational tools to invent. The playground is immense, ranging from geological phenomena and fluid transport in porous rocks to membranes and separation processes, energy harvesting and storage, and the chemistry of catalytic converters. The applications of this knowledge for industrial processes, for breakthrough technologies at the water–energy nexus, for the climate crisis, and for the common good are everywhere in our society. This is one of the rare domains where the distance between the frontier of knowledge and real-world applications is remarkably short.

This is what makes the very existence of the PoreLab initiative so vital. We urgently need new understanding in these areas. PoreLab is a unique, interdisciplinary centre that brings together a vast body of expertise, spanning physics, chemistry, geology, and engineering.

In many respects, the science of porous materials is still largely unwritten. One of my favourite topics is fluids at the nanoscale. In recent years there has been remarkable progress in our understanding of fluids at the smallest molecular scales. I like to say that this is the frontier where the continuum description of fluid mechanics meets the atomic, or even quantum, nature of matter. A whole cabinet of curiosities of exotic behaviours has been unveiled, and for most of them we still lack a full understanding. We are starting to see how these properties at the smallest scales have direct consequences at much larger scales, and how they can be harnessed for applications such as energy harvesting and advanced separation processes. Porous materials are precisely the place where nanoscale phenomena rise through the scales to generate new macroscopic properties. Bridging this divide is a demanding journey that requires us once again to push beyond current frontiers.

PoreLab is designed for such task, advancing the fundamental physics of porous media and use that understanding to improve applications ranging from geoscience to materials and energy technologies. Its people have the shoulders to carry the challenges ahead, and by doing so, they will also train new generations of junior scientists to tackle the most pressing challenges of our time. This is essential. This is an exciting time and I look forward to the progress that will be made in the years to come.

ORGANIZATION
OF PORELAB

PoreLab gathers scientists from 5 departments at NTNU and UiO. The NTNU Department of Physics is the host. Partners are the NTNU Departments of Chemistry, Geosciences, Civil and Environmental Engineering, and Department of Physics at UiO. SINTEF Industry is our external research partner.

The Center is managed by the Director, Alex Hansen (NTNU) jointly with the Deputy Center Director, Eirik Flekkøy (UiO) and the Center Administrative Leader, Marie-Laure Olivier (NTNU).

The organizational structure of the Center is flat. The team of the Principal Investigators (PIs) and the Administrative Leader forms the Leader Group and has bi-weekly meetings to discuss administrative and scientific issues and update each other on developments and progress. The system for immediate updates ensures interdisciplinary progress.

PoreLab's research is organized in nine Research Themes (RT) led by the Principal Investigators.

The PoreLab Executive Board includes representatives from the faculties involved at NTNU and UiO.

During the summer of 2025, several changes were made to the board's composition. Professor Jens Petter Andreassen succeeded Professor Øivind Gregersen as Dean of the Faculty of Natural Sciences at NTNU and therefore assumed the role of Chair of the PoreLab Executive Board. Professor Kathrine Røe Redalen replaced Professor Erik Wahlström as Head of the Department of Physics at NTNU and joined the board as a new member. In addition, Professor Terese Løvås from the Department of Energy and Process Engineering at NTNU succeeded Sveinung Løset as Vice Dean for Research and Innovation at the Faculty of Engineering at NTNU and has likewise become a new member of the board.

The two remaining board members, Professor Susanne Viefers, Head of the Department of Physics at the University of Oslo, and Professor Anders Malthe Sørenssen from the Center for Computing in Science Education at the University of Oslo, continue in their roles.

The Executive Board is responsible for ensuring that PoreLab's activities are carried out in accordance with the contract with the Research Council of Norway. A central part of its mandate is to strengthen collaboration among the participating departments at NTNU and UiO.

The Research Council of Norway that funds PoreLab demands there to be a Scientific Advisory Board, or SAB. The main role of the SAB is to evaluate and make recommendations on the scientific status and progress of PoreLab. It aids in the development of a strategy for the scientific development of the center, thereby helping the leadership group by giving advice on implementing appropriate means of actions to achieve the stated scientific aims and fulfil the strategy plan. The SAB is composed of international experts and leading scientists who act as external advisors to the management of PoreLab.

The SAB includes:
- Steffen Berg, senior research staff scientist at Shell Global Solutions International B.V. in The Netherlands.
- Douglas Durian, Professor of Physics at the Department of Physics and Astronomy at the University of Pennsylvania, USA
- Veerle Cnudde is Professor at Ghent University, Belgium and holds the Chair *"Porous media imaging techniques"* at Utrecht University, The Netherlands.
- Pål-Eric Øren, Chief Technology Officer at Digital Rock Services at Petricore in Trondheim, Norway

The SAB typically meets with the PI group once a year. The 2025 SAB meeting was held over two days in Oslo, on 1–2 April 2025.

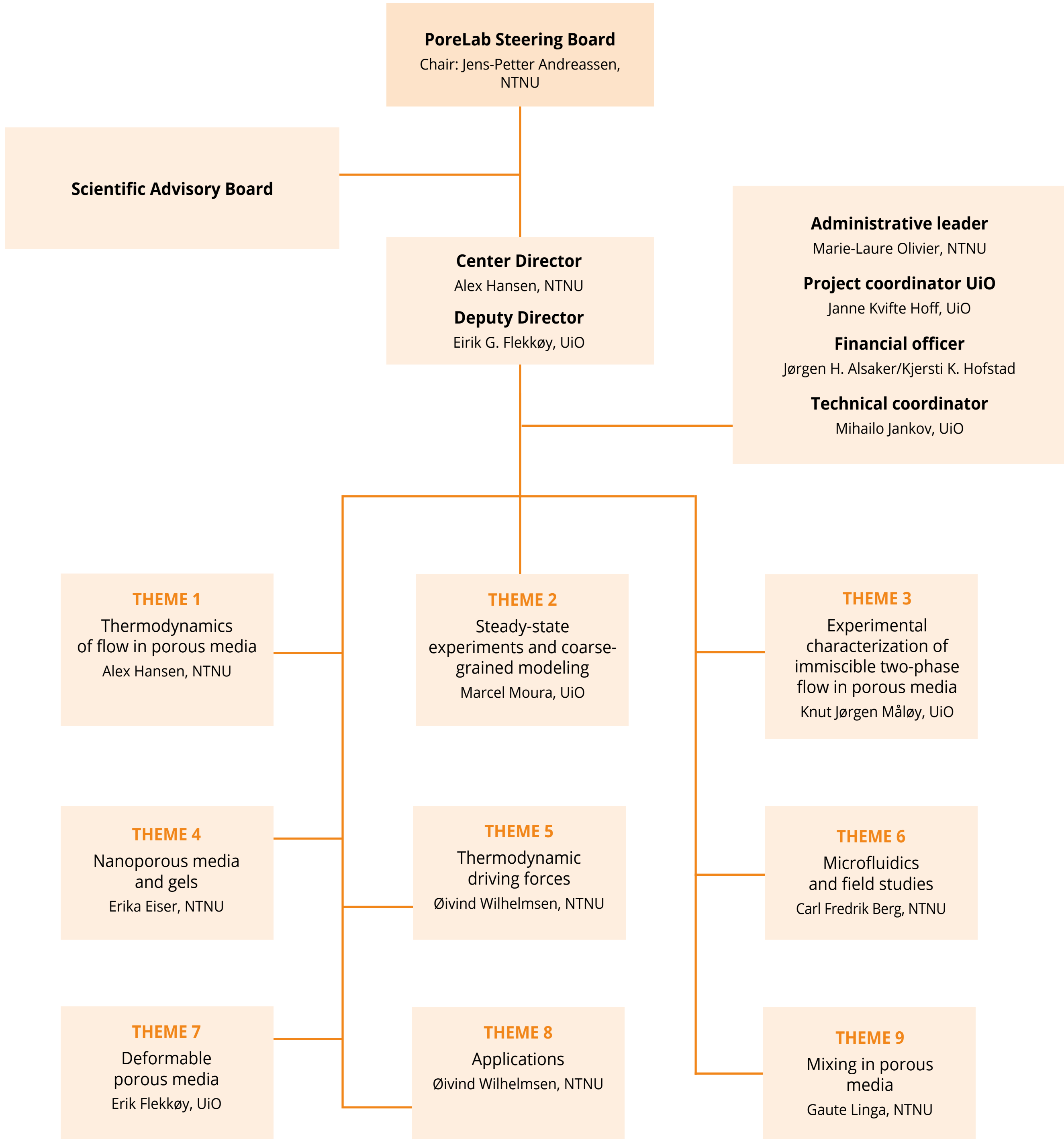
In the autumn of 2025, three adjunct professors joined PoreLab under Research Theme 1, *Thermodynamics of Porous Media:* Saman Aryana, Sauro Succi, and Steffen Berg

Saman Aryana is Professor and Occidental Chair for Energy and Environmental Technologies at the Department of Chemical and Biochemical Engineering at the University of Wyoming, USA. His research interests lie primarily in the fundamental physics of flow instabilities and dynamics of subsurface displacement processes.

Sauro Succi is a Senior Research Executive and Principal Investigator at the Center for Life Nano Science at the Italian Institute of Technology (IIT) in Rome. He is as well Research Affiliate to the Physics Department at Harvard University. Sauro Succi is one of the founders of the Lattice Boltzmann method for fluid dynamics and soft matter.

Steffen Berg has already been introduced above. With his new appointment as an adjunct professor at PoreLab starting in the autumn of 2025, he will step down from the SAB and be replaced by a new member in 2026

Structure of the organization



MANAGEMENT AND ADMINISTRATION

THE LEADER GROUP


Alex Hansen
Director
Professor, PI Theme 1


Marcel Moura
Researcher
PI Theme 2

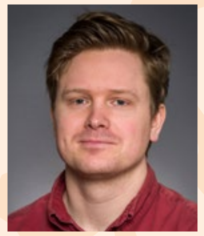

Knut Jørgen Måløy
Deputy Director
Professor,
PI Theme 3

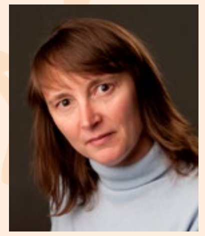

Erika Eiser
Professor
PI Theme 4


Øivind Wilhelmsen
Professor
PI Themes 5 and 8


Carl Fredrik Berg
Professor,
PI Theme 6


Eirik Flekkøy
Professor,
PI Theme 7


Gaute Linga
Associate Professor
PI Theme 9


Marie-Laure Olivier
Administrative leader

PORELAB EXECUTIVE BOARD


Øyvind Gregersen
Dean
NV faculty, NTNU
Until July 2025


Jens-Petter Andreassen
Dean
NV faculty, NTNU
From August 2025

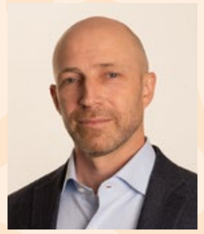

Erik Wahlström
Head of department
Department of Physics, NTNU
Until July 2025


Kathrine Røe Redalen
Head of department
Department of Physics, NTNU
From August 2025


Sveinung Løset
Professor, Department of Civil and Environmental Engineering, NTNU
Vice Dean Research and Innovation
Faculty of Engineering, NTNU
Until July 2025

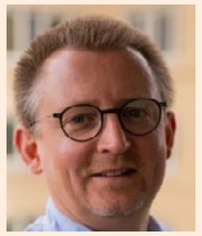

Terese Løvås
Professor, Department of Energy and Process Engineering
Vice Dean Research and Innovation
Faculty of Engineering, NTNU
From August 2025


Susanne Viefers
Head of department
Department of Physics
University of Oslo


Anders Malthe-Sørenssen
Professor,
Center for Computing in Science Education
University of Oslo

SCIENTIFIC ADVISORY BOARD


Veerle Cnudde
Professor
Ghent University, Belgium and Utrecht University
The Netherlands


Steffen Berg
Principal Science Expert at Shell Global Solutions International B.V. in the Netherlands


Douglas Durian
Professor of Physics and Astronomy, University of Pennsylvania, USA


Pål-Eric Øren
Chief Technology Officer
Digital Rock Services
Petricore, Trondheim, Norway

PARTNERS

NTNU

UiO : University of Oslo

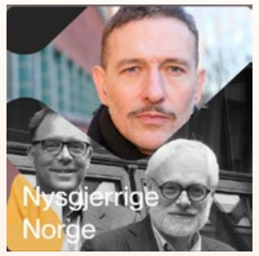
SINTEF

HIGHLIGHTS

2025
5 new projects granted to PoreLab members in 2025

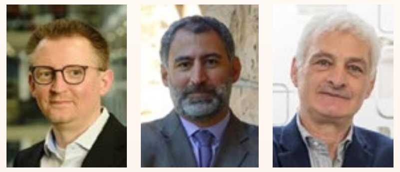
2025
ThermoPhys, a start-up created by PoreLab members, is taking off …

3–7 February 2025
IRP-DFFRACT Conference organized by PoreLab members in Courmayeur, Italy



13 April 2025
Podcast: Curious about porous media with Kristopher Schau

26–30 May 2025
PoreLab is among the organizers of a five-day school on machine learning techniques for physical sciences, at ENS in Lyon, France



Fall 2025
Steffen Berg, Saman Aryana and Sauro Succi join PoreLab at the department of Physics, NTNU, as Adjunct Professors

28–30 September 2025
INTPART project *"Non-Newtonian Flow in Porous Media"* Final Meeting on board the Norwegian Coastal Express NordNorge

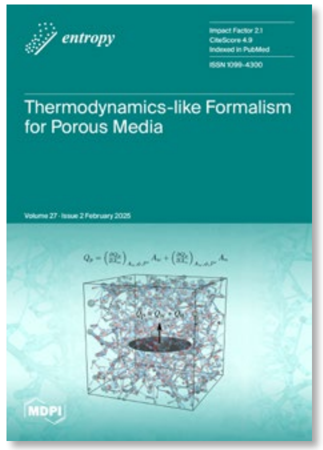
14 September – 14 November 2025
Gaute Linga, Young CAS Principal Investigator, is hosted at the Norwegian Centre of Advanced Study leading the Young CAS project *Mixing by Interfaces.*

21 November 2025
Dr. Lydéric Bocquet, Director of Research at the CNRS, Professor at l'Ecole Normale Supérieure in Paris has been awarded the 2025 Onsager Medal by NTNU

PUBLICATIONS IN THE SPOTLIGHT

Raffaela Cabriolu and her colleagues from the Swiss Federal Institute of Technology in Lausanne and the Free University of Amsterdam published their article titled *"Thermal Transport Mechanisms in ZIFs"* in ***Nature Communications*** on November 27, 2025.

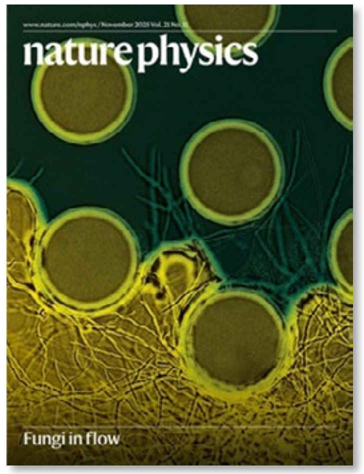
Fazel Mirzaei, Mukul Jaiswal, Daniyal Younas, Katharina Scheidl, Basab Chattopadhyay, Ragnvald H. Mathiesen, and Dag W. Breiby from the X-ray Physics group in the Porous Media section at NTNU, together with Anders Kaestner from the Laboratory for Neutron Scattering and Imaging in Switzerland, had their article entitled *"4D imaging of frost heave and ice lens growth in silt using neutron and x-ray computed tomography"* selected as a **Featured** article by the Journal Editor in *Applied Physics Letters* in May 2025.



The publication by Alex Hansen and Santanu Sinha, titled *"Thermodynamics-like Formalism for Immiscible and Incompressible Two-Phase Flow in Porous Media,"* was published in the *Journal of Entropy* in February 2025. It was featured as the **cover story**, accompanied by an illustration created by Dr. Santanu Sinha, researcher at PoreLab. The image depicts a porous medium stylized as a network of pores.

Ilaria Beechey-Newman, Andreas Andersen Hennig, Eirik G. Flekkøy and Erika Eiser, all members of PoreLab, together with Natalya Kizilova, Professor in the Department of Theoretical and Applied Mechanics at Kharkiv National University in Ukraine, had their article entitled *"Confined colloidal droplets dry to form circular mazes"* published in ***PNAS*** in August 2025.

The publication by Marcel Moura, Vanessa Kern, Knut Jørgen Måløy, Andreas Carlson, and Eirik G. Flekkøy, titled *"Droplet spreading in a wedge: a route to fluid rheology for power-law liquids,"* appears on the **cover** of *Soft Matter*. The paper was also **featured** as a "Soft Matter Open Access Spotlight" article and was published in July 2025.



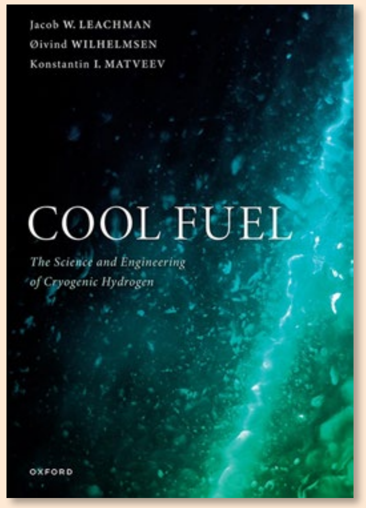
The November 2025 issue of ***Nature Physics*** features a publication co-authored by Marcel Moura. The work titled *"Filamentous fungi control multiphase flow and fluid distribution in porous media"* was led by Dr. Sang Lee at the laboratory of Prof. Peter Kang at the University of Minnesota.

Henrik Friis, Giacomo Luani, Basab Chattopadhyay and Dag Werner Breiby from the X-ray Physics group in the Porous Media section at NTNU, together with Håkon Nese and Ole Jakob Mengshoel from the Department of Computer Science at NTNU, and Colin Pryme, Lars Rennan and Anders Kristoffersen from Equinor, had their article entitled *"Implicit neural representation for fast 4D computed tomography of multiphase flow in porous media"* published in ***Communications Physics*** in August 2025

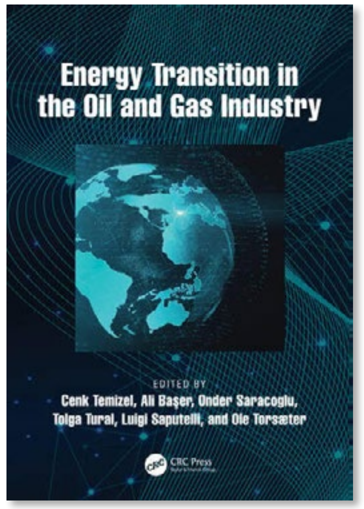
The article from Daniyal Younas, Ingvild U. Hageberg, Dag Werner Breiby and Basab Chattopadhyay from the X-ray Physics group in the Porous Media section at NTNU, together with Özgür Gülmez and Seniz Ucar from the Middle East Technical University in Turkey, Federico Zontone and Yuriy Chushkin from The European Synchrotron in Grenoble, Vladimir Roddatis and Anja Schreiber from GFZ Helmholtz Centre for Geosciences in Potsdam, entitled *"3D nanoscopy of calcite microparticles precipitated in the presence of fetuin-A"* was selected as **Editor's Pick** in the Journal APL Materials in August 2025

The article by Vegard Jervell and Øivind Wilhelmsen on how quantum effects should be represented in the thermophysical properties of substances such as hydrogen was selected as an **Editor's Pick** in *The Journal of Chemical Physics*. The article is titled *"The Limits of Feynman–Hibbs corrections in capturing quantum-nuclear contributions to thermophysical properties."*

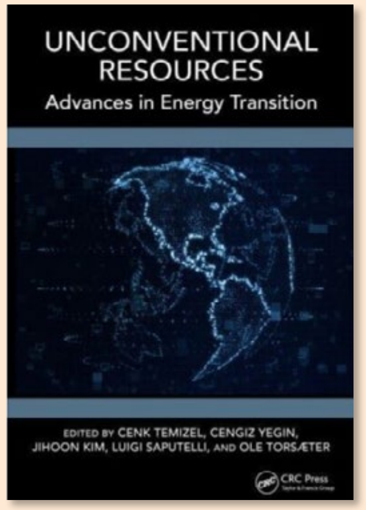
BOOKS AND SPECIAL ISSUES



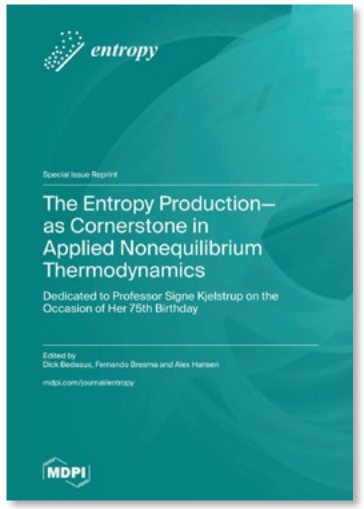
Jacob W. Leachman, Konstantin I. Matveev, and Øivind Wilhelmsen are co-authors of ***Cool Fuel: The Science and Engineering of Cryogenic Hydrogen,*** the first textbook in decades dedicated to cryogenic hydrogen. After years of dedicated work, the book was published in 2025 and is now available in bookstores. Øivind Wilhelmsen is PI at PoreLab.



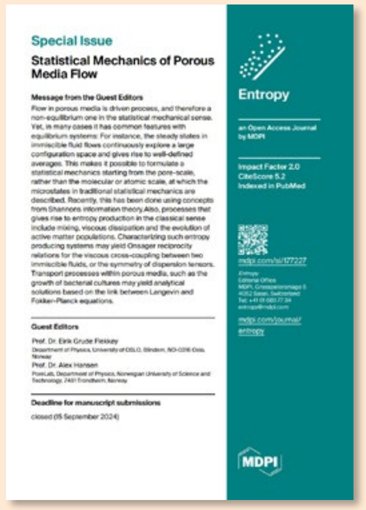
The first edition of ***"Energy Transition in the Oil and Gas Industry"*** was edited by Cenk Temizel, Ali Baser, Onder Saracoglu, Tolga Tural, Luigi Saputelli and Ole Torsæter in January 2025. Torsæter is Prof. Emeritus at PoreLab. Addressing energy holistically from a technology and engineering perspective, this book offers engineering professionals in the energy sector a wide-ranging view of current and near future changes taking place in this critical industry.



Unconventional Resources – Advances in Energy Transition is a book published in February 2025 by Cenk Temizel, Cengiz Yegin, Jihoon Kim, Luigi Saputelli and Ole Torsæter. Torsæter is Prof. Emeritus at PoreLab. The book provides surface and subsurface technical professionals in the oil and gas industry a thorough overview of unconventionals along with the integrated/hybrid applications that will enable them to stay current with the industry's transition.



"Entropy Production – as a Cornerstone in Applied Nonequilibrium Thermodynamics" is a **Special Issue** of the journal *Entropy* dedicated to Professor **Signe Kjelstrup** on the occasion of her 75th birthday. It was edited by Dick Bedeaux, Fernando Bresme, and Alex Hansen, and published in October 2025.



Eirik G. Flekkøy and Alex Hansen, both PI at PoreLab, are guest editors for a Special Issue entitled ***"Statistical Mechanics of Porous Media Flow"*** in the Journal *Entropy*. This special issue belongs to the section *"Statistical Physics"*.

The *Journal of non-Newtonian Fluid Mechanics* published a **Special Issue** after the **BIRS Workshop on Non-Newtonian Flows in Porous Media** in Banff, Canada (see PoreLab annual report 2024 page 68). The guest editors were Sujit Datta, Ian Frgaard, Arezoo Ardekani, Alex Hansen and Laurent Talon.

IMMISCIBLE TWO-PHASE FLOW IN POROUS MEDIA AS A GLASS

Santanu Sinha[1], Humberto Carmona[2], José Soares Andrade Jr.[2], Alex Hansen[1]

[1] PoreLab, Department of Physics, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[2] Departamento de Física, Universidade Federal do Ceará, Fortaleza, Brazil

In 1988, Lenormand et al. [1] presented a two-dimensional phase diagram for injection of a fluid into a porous medium saturated with another fluid, the two being immiscible. The control parameters were capillary number and viscosity ratio, thus identifying three generic types of injection patterns, viscous fingering, capillary fingering and stable displacement. Avraam and Payatakes [2] identified different pore-scale flow patterns under steady-state flow – i.e., when the two immiscible fluids are simultaneously flow through the porous medium. They found a "continuous pathway regime" at low flow rates, then a "large ganglion regime" at higher rates. At even higher rates, they identified a "small ganglion regime," which would turn into the "drop traffic regime" at sufficiently high flow rates. In 2025, Berg et al. [3] pointed out that a phase diagram for steady-state immiscible two-phase flow in porous media *on the Darcy scale* (i.e., on scales large enough for the porous medium to appear to be a continuum) is necessary. They did, however, identify several different regimes with increasing flow rate. A full phase diagram would have three axes: capillary number, viscosity ratio and either fractional flow rate or saturation as a third axis. Berg et al. identify four regimes: Ia, Ib, II, and III. The first one, Ia, is the frozen regime where flow appears through channels. Regime Ib is characterized by hysteresis, large fluctuations and a side range of time scales. For both regime Ia and Ib, we find a linear relationship between flow rate and pressure gradient. Regime II is the non-linear regime where the flow rate is a power law in the pressure gradient, whereas regime III reverts to linear dependency of the flow rate on the pressure gradient.

By using the Boltzmann machine learning technique [4], we map the flow patterns in our dynamic pore network model onto a spin lattice by matching spatial correlations in the saturation with spin-spin correlations [5]. Using Monte Carlo techniques, we may then investigate the spin model as a function of the pressure gradient applied to the pore network model. By running the mapping for several pressure gradients, we may plot the magnetic and spin Edwards-Anderson order parameters for the spin model. The magnetic order parameter measures order among the spins, whereas the Edwards-Anderson order parameter measures local frozen order among the spins. We show such a plot in Figure 1. We see that the magnetization remains essentially unchanged over the interval of pressure drops, whereas the Edwards-Anderson order parameter rises sharply. In Figure 2 we show the corresponding susceptibilities, seeing a peak for the spin glass susceptibility and not for the magnetic susceptibility. This indicates that we are seeing a transition between a paramagnetic phase in the spin model and a spin glass phase.

This signals that the dynamic pore network model experiences a transition to a *glassy* state. This would explain the hysteretic behavior, the large fluctuations and the wide range of timescales seen in regime Ib, as this is where we see the transition.

RECOMMENDED READING

[1] R. Lenormand, E. Touboul and C. Zarcone. Numerical models and experiments on immiscible displacements in porous media. *Journal of Fluid Mechanics,* **855**, 165 (1988).

[2] D. G. Avraam and A. C. Payatakes. Flow regimes and relative permeabilities during steady state two-phase flow in porous media. *Journal of Fluid Mechanics*, **293** 207 (1995).

[3] S. Berg, R. T. Armstrong, M. Rücker, A. Hansen, S. Kjelstrup, D. Bedeaux, From interface dynamics to Darcy scale description of multiphase flow in porous media. arXiv:2510.19582; *Journal of Colloid and Interface Science*, in press.

[4] L. Meshulam and W. Bialek. Statistical mechanics for networks of real neurons. *Rev. Mod. Phys.* 97, 045002 (2025).

[5] S. Sinha, H. Carmona, J. S. Andrade Jr. and A. Hansen, in preparation.

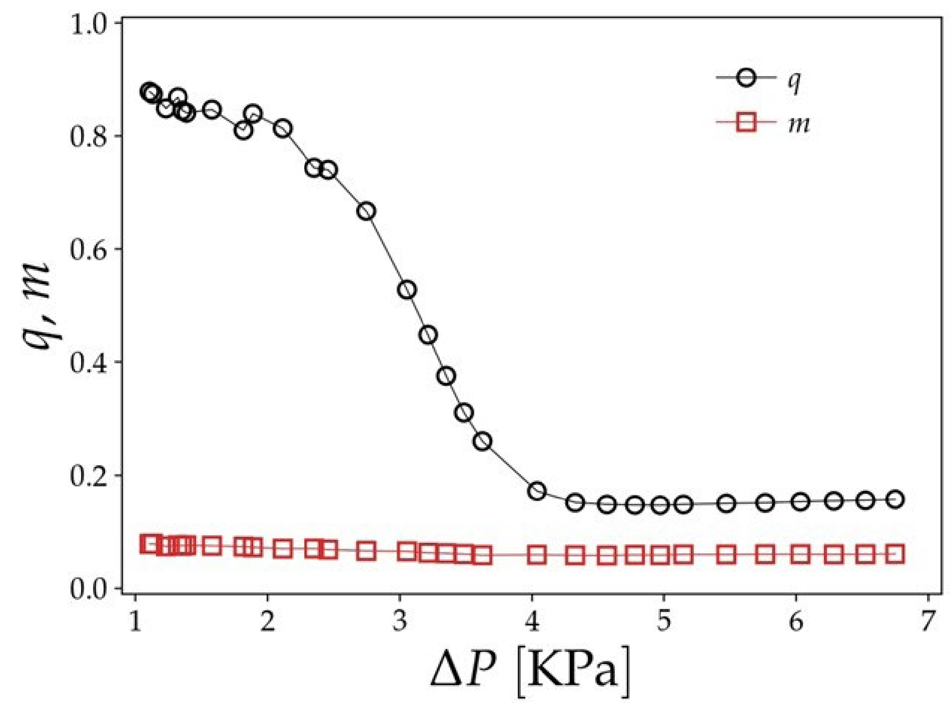


Figure 1: *Magnetization m and Edwards-Anderson order parameter q for the spin model as a function of the pressure drop across the dynamic pore network model.*

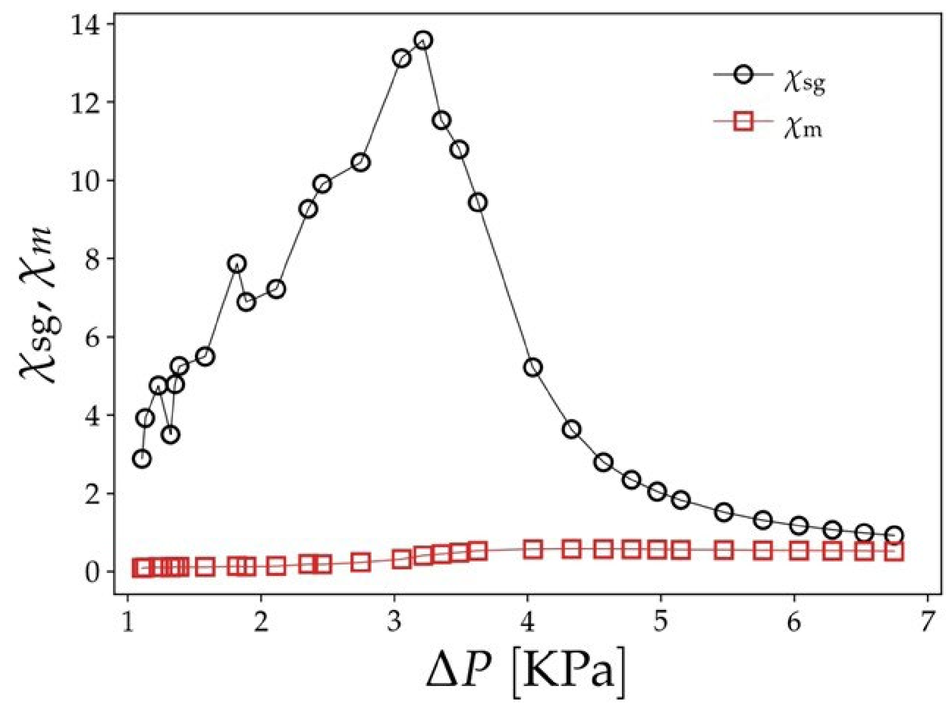


Figure 2: *Magnetic susceptibility χm and spin glass susceptibility χsg for the spin model as a function of the pressure drop across the dynamic pore network model.*

THERE'S A MUSHROOM IN THE NETWORK: FILAMENTOUS FUNGI CONTROL MULTIPHASE FLOW AND FLUID DISTRIBUTION IN POROUS MEDIA

Sang Hyun Lee[1,2], Marcel Moura[3], Shreya Srivastava[1], Cara Santelli[1,4] and Peter K. Kang[1,5]

[1] Department of Earth and Environmental Sciences, University of Minnesota – Twin Cities, Minneapolis, MN, USA
[2] Department of Microbiology, University of Massachusetts Amherst, Amherst, MA, USA
[3] PoreLab, The Njord Center, Department of Physics, University of Oslo, Oslo, Norway
[4] BioTechnology Institute, University of Minnesota – Twin Cities, St. Paul, MN, USA
[5] Saint Anthony Falls Laboratory, University of Minnesota – Twin Cities, Minneapolis, MN, USA

This project, led by our collaborator Sang Lee in the group of Prof. Peter Kang at the University of Minnesota, is quite different from most of the things we have been dealing with previously at PoreLab. While we have been mostly concerned with how liquids and gases move inside porous materials, such as rocks and soils, this motion is typically caused by the hydrodynamic forces at play. We are used to caring about pressure gradients, viscosity contrasts, surface tension, wettability etc. Things took a very sharp turn here where a key consideration for the fluid motion was the fact that something inside the porous medium was actually alive, growing and moving!

Fungi occur in many natural systems. They are found in your pizza and in forest soils, in decaying wood and agricultural fields, and even deep underground in rocks. Filamentous fungi grow in a very special way, forming networks of thread-like structures with a fuzzy, cotton-like appearance. When they develop inside a porous material, these structures can do something truly remarkable: they can clog pathways and divert fluid flow, much like a big cotton ball clogging a pipe in your kitchen can divert the water flow (possibly in a way you don't really want).

Consider a soil that has been contaminated by a pollutant, like an oil spill for example. One possible solution to the problem is to treat the soil by injecting a chemical (or even just rainwater) to restore its health. A common challenge, however, is that the invading fluid frequently fails to reach the tightest parts of the porous network (which can be most of it). While the pollutant may have penetrated these small pores, the injected fluid tends to follow the easiest paths (larger channels, fractures, or wider pores) bypassing the tighter regions entirely.

One way to overcome this issue is to intentionally clog the wider flow pathways, forcing the invading fluid into the smaller pores. This is easier said than done though, as these wide pathways might be hard to find and reach from the outside. This is precisely where fungi come into action. Microscopic fungal particles suspended in the injected fluid can preferentially adhere to the surfaces of wider channels where the fluid initially flows. Over time, on the scale of hours, they grow and expand, eventually clogging these channels and redirecting the flow into the tighter pore spaces where the pollutant resides. This idea was studied in detail in a microfluidics experiment in this project, see Fig. 1. We have demonstrated how filamentous fungi alter fluid flow and distribution in porous media, and how these effects could be harnessed for applications such as bioremediation and carbon sequestration.

ACKNOWLEDGEMENTS

This work was supported by MnDRIVE Advancing Industry, Conserving Our Environment, and a Seed Grant from the Biotechnology & Biomanufacturing Innovation Center at the University of Minnesota; the National Research Foundation of Korea (award 2018R1A6A3A03012913); the Research Council of Norway through projects 262644 (PoreLab SFF), 324555 (FlowConn YFF), and 309073 (COLOSSAL INTPART); and the National Science Foundation through the National Nano Coordinated Infrastructure Network (NNCI) (award ECCS-2025124).

RECOMMENDED READING

[1] Lee, S.H., Moura, M., Srivastava, S. *et al.* Filamentous fungi control multiphase flow and fluid distribution in porous media. *Nat. Phys.* **21**, 1719–1727 (2025). https://doi.org/10.1038/s41567-025-03020-6

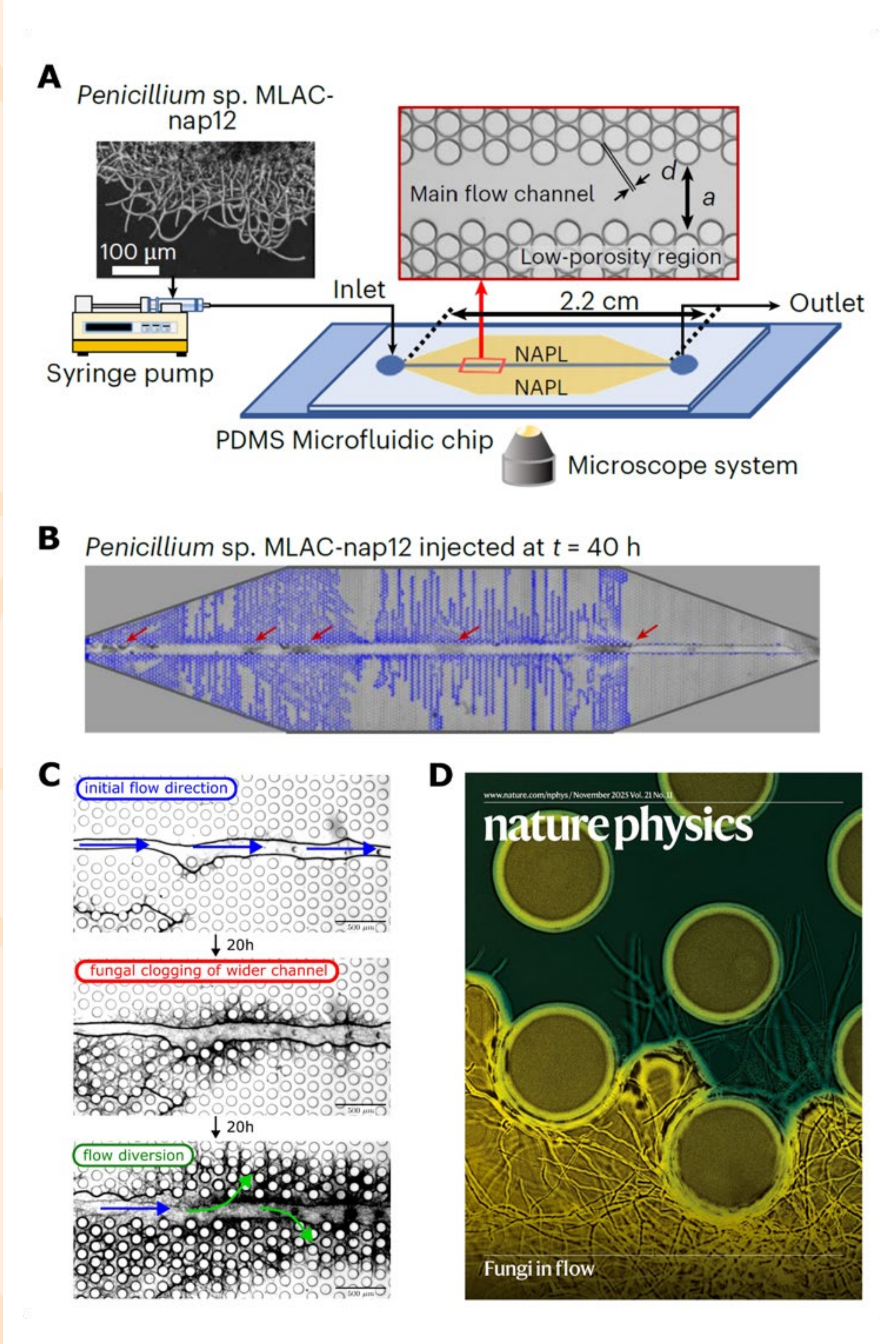


***Figure 1:** Fungi flow in porous media. Figure adapted from Ref. [1].*

***A:** Diagram of the experimental setup. A microfluidics chip with a dual-porosity system is shown. On the top left inset, we see the branching fungus employed, Penicillium sp. MLAC-nap12.*

***B:** The fungi colonies develop in the central channel, marked by the red arrows, thus causing a diversion of the flow and the invasion of the low- porosity region, shown in blue.*

***C:** Typical dynamics of the process. The incoming water initially flows through the central wider channel (top). As the fungi grows, this channel is clogged (middle) forcing the diversion of the flow to the low-porosity regions (bottom).*

***D:** cover of the journal Nature Physics featuring the work.*

STATISTICAL CHARACTERIZATION OF SATURATION FLUCTUATIONS IN POROUS MEDIA AND MEASUREMENT OF ONSAGER COEFFICIENTS

Marcel Moura[1], Dick Bedeaux[2], Ryan T. Armstrong[3] and Signe Kjelstrup[2]

[1] PoreLab, The Njord Center, Department of Physics, University of Oslo, Oslo, Norway
[2] PoreLab, Department of Chemistry, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[3] School of Civil and Environmental Engineering, The University of New South Wales, Sydney, Australia

In experimental physics, most of the time when we perform a measurement we are interested in the mean value of a given quantity. For example, if you ask the temperature in the room or the pressure of the air, or the speed of a car, you typically measure an average value of these quantities. If that average is taken over a short enough period (the time we look at the thermometer, barometer or speedometer), we think of that as an instantaneous measurement, but really it is still an average taken over a short-enough time. However, even though we frequently don't consider that, real-world quantities always present fluctuations over their average values. If we could measure something, say the pressure in the room, with enough precision, we would see that the value fluctuates around the average value. These fluctuations are typically discarded, in part because we might not need them and in part because they are harder to measure, requiring more precise instrumentation. However, under certain circumstances, the fluctuations might carry important information about the physics of the processes at play, and this is the overall idea that we explore here.

In this project we have considered a steady-state flow of two immiscible fluids (water and oil) that are co-injected in an artificial porous medium, created via 3D printing, see Fig. 1A, where the water is dyed dark blue and the oil is transparent. They enter the medium from the left and exit it from the right. As they move inside the porous network, they push each other around, generating an interesting dynamic of clusters that merge and break up. In the top row of Fig. 1B, we see two snapshots from a given experiment, separated by 10 seconds. The imaging window corresponds to the red square in Fig. 1A. On the rightmost panel in Fig. 1B, we show what has changed between the snapshots: in green we show points that were oil-filled and became water-filled and in magenta the opposite, i.e., points that were first oil-filled and 10 seconds later became water-filled. If we measure the amount of a given phase, say, water, inside the window, we will see that this amount (the water saturation) will fluctuate around a well-defined mean value, which is characteristic of the dynamics. In the present work, we have focused on the information content of those fluctuations by considering them under the light of the fluctuation-dissipation theorem (FDT).

The FDT links the correlation of equilibrium fluctuations to the linear response function of a given system. In the case of multiphase flows in porous media, this linear response function is the generalization of Darcy's law, where the proportionality constant linking a phase's volumetric flux and its pressure drop is essentially given by the relative permeability of that phase. Although this study is still an early step and there are many open questions that are not completely understood, it points out to a potential link between the systems fluctuations and its transport coefficients. In particular, we show how the analysis of the autocorrelation function of the derivative of the phase saturation (its fluctuations) can be used to obtain the Onsager coefficients associated with a given flow scenario. These coefficients are then postulated to be linked to the relative permeabilities. This is a new idea in the field that is currently under investigation by different research groups.

ACKNOWLEDGEMENTS

This work was supported by the Research Council of Norway through projects 262644 (PoreLab SFF), 324555 (FlowConn YFF) and the Australian Research Council through Future Fellowship project FT210100165.

RECOMMENDED READING

[1] Moura, M., Bedeaux, D., Armstrong, R. T., & Kjelstrup, S. (2026). Fluctuation-dissipation theorems in porous media two-phase flow: statistical characterisation of saturation fluctuations and measurement of Onsager coefficients. *Journal of Fluid Mechanics,* 1026, A2. doi:10.1017/jfm.2025.1098

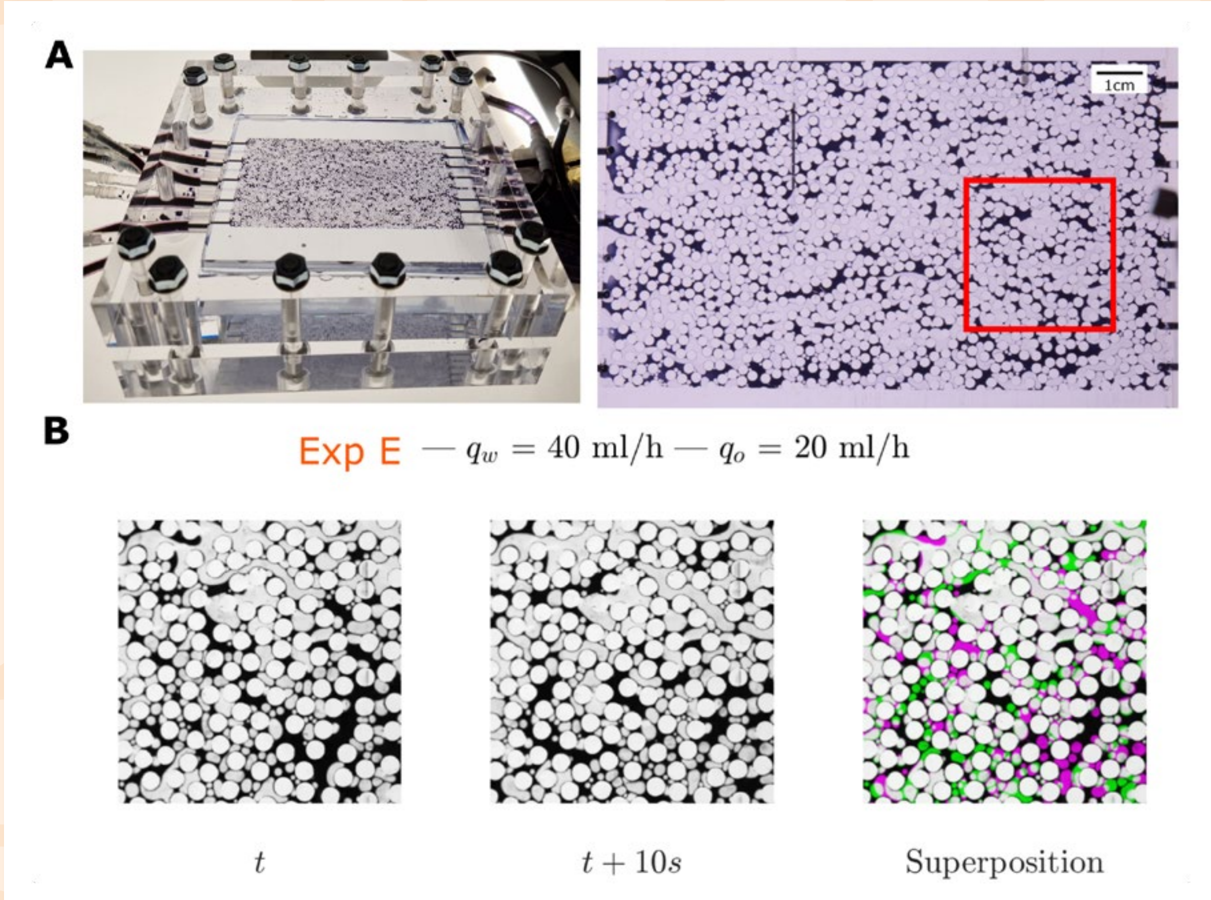


Figure 1: *Saturation fluctuations in steady-state porous media flows. Figure adapted from Ref. [1].*

A: *Experimental setup showing the co-injection of water (blue) and oil (transparent) in a 3D printed porous network.*
B: *Close-up on the region marked by the red square in A. As the dynamics progresses we see a continuous transformation of the pore space occupation. The two snapshots on the left are separated by 10 seconds. If a given pixel changes its occupation state from oil to water, it is marked in green on the rightmost panel and if it changes from water to oil, it is marked in magenta. The saturation of both phases fluctuates around a well-defined mean value. In this project we study the informational content of these fluctuations under the light of the fluctuation- dissipation theorem.*

DRAINAGE FRONT WIDTH IN A THREE-DIMENSIONAL RANDOM POROUS MEDIUM UNDER GRAVITATIONAL AND CAPILLARY EFFECTS

Paula Reis[1], Knut Jørgen Måløy[1,2]

[1] PoreLab, The Njord Center, Department of Physics, University of Oslo, Oslo, Norway
[2] PoreLab, Department of Geoscience, Norwegian University of Science and Technology, NTNU, Trondheim, Norway.

Understanding how fluids move through complex materials like soil, rock, or engineered filters isn't just academic, it matters in water management, oil recovery, carbon sequestration, and environmental cleanup. When one fluid pushes another out of a porous material, the interface between them doesn't always move smoothly. Sometimes it forms intricate, meandering fronts whose shape and thickness determine how efficiently the displacement happens. In this work we tackle the long-standing challenge of predicting the width of these drainage fronts when gravity and capillary forces act together in three-dimensional (3D) random porous media.

At the heart of the problem is the balance of two competing effects. Capillary forces — which arise from the surface tension between fluids in tiny pore channels — tend to create irregular, finger-like patterns as one fluid displaces another. Gravity, on the other hand, can stabilize the front by imposing a continuous pressure gradient that counteracts these instabilities.

One major difference from earlier two-dimensional studies is that in 3D porous structures both invading and defending fluids can percolate over a range of saturations. This leads to a more complex front made of multiple regions: a "critical tip" where the invading fluid first just reaches percolation, a transition zone, and another region where the defending fluid approaches its own percolation threshold. The overall width therefore doesn't follow a simple power law in the pressure gradient as it does in 2D; instead, its behavior depends on how these regions contribute across the full 3D front.

To test their theory, we used a bond invasion-percolation model, a computational approach that mimics slow drainage by allowing the easiest pore throats to be invaded first, while accounting for gravitational effects via a linear variation in capillary pressure with height. Across a wide range of parameters, the numerical results agreed well with the theoretical predictions, giving confidence that the new framework captures the essential physics of gravity-stabilized drainage in 3D disordered systems.

Beyond its theoretical contribution, this work helps bridge the gap between microscopic pore-scale phenomena and macroscopic predictions of fluid movement in real materials. It offers a pathway to more accurate modeling of drainage processes that are critical in both natural and engineered settings — from predicting how quickly aquifers drain to optimizing extraction strategies in porous rocks.

ACKNOWLEDGEMENTS

This work has been done with support from the Norwegian Research Council and its Center of Excellence Funding Scheme project no. 262644.

RECOMMENDED READING

P. Reis, and K.J. Måløy, Drainage front width in a three-dimensional random porous medium under gravitational and capillary effects. *Phys. Rev. Research 7*, 033244, (2025), DOI: https://doi.org/10.1103/5bbz-ksds

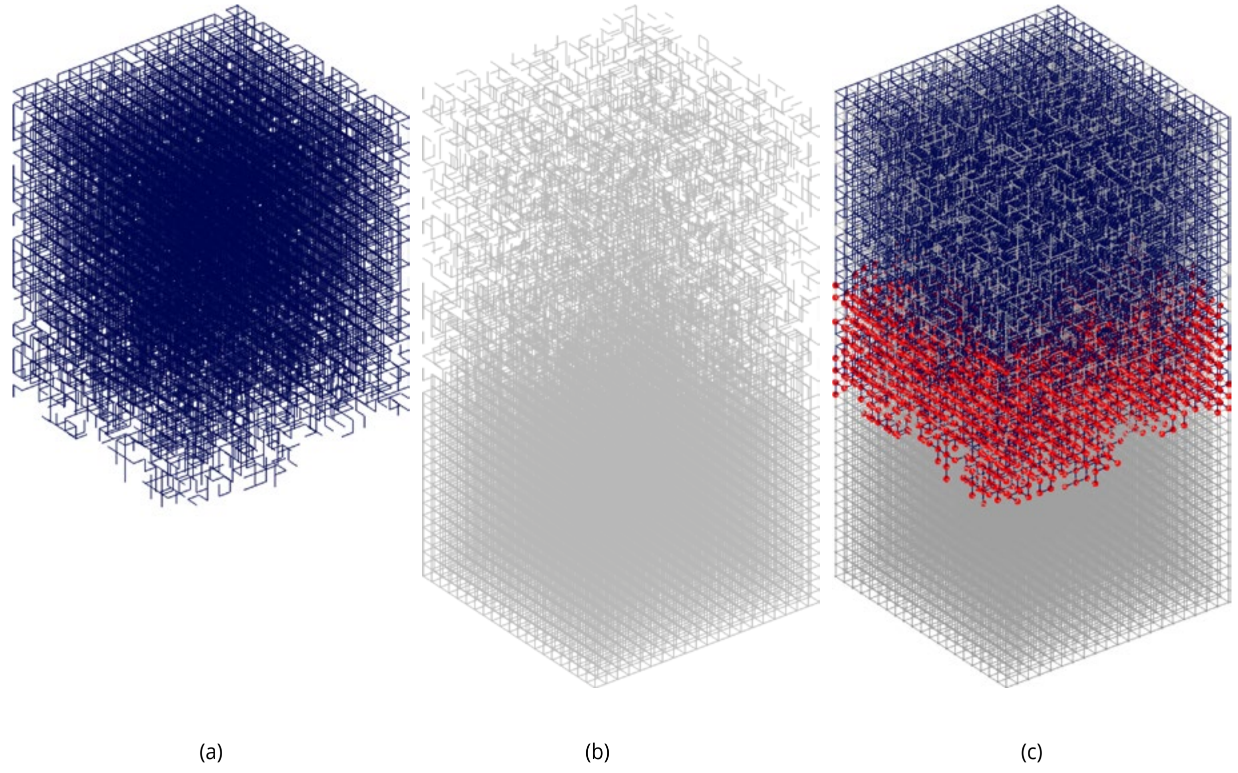


Figure 1: *Simple-cubic network midway through drainage, with invaded bonds in blue, noninvaded bonds in gray, and sites belonging to the invasion front in red. A low density fluid invading a high density fluid from above. (a) Bonds occupied by the invading phase, (b) bonds occupied by the defending phase, and (c) sites at the invasion front.*

INTERACTION BETWEEN CORNER AND BULK FLOWS DURING DRAINAGE IN GRANULAR POROUS MEDIA

Paula Reis[1], Gaute Linga[1,2], Marcel Moura[1], Per Arne Rikvold[1], Renaud Toussaint[1,4], Eirik Grude Flekkøy[1,3], Knut Jørgen Måløy[1,5]

[1] PoreLab, The Njord Center, Department of Physics, University of Oslo, Oslo, Norway
[2] PoreLab, Department of Physics, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[3] PoreLab, Department of Chemistry, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[4] ITES/Institut Terre et Environnement de Strasbourg, CNRS, Université de Strasbourg, Strasbourg, France
[5] PoreLab, Department of Geosciences, Norwegian University of Science and Technology, NTNU, Trondheim, Norway

Drainage in porous media takes place in a large range of natural and industrial processes of scientific interest. It occurs when a CO_2 plume migrates through an aquifer during subsurface carbon storage; when air infiltrates a wet soil after rain or a liquid contaminant spill; and in enhanced oil recovery when a gas is injected to push liquid hydrocarbons out of a reservoir. In these scenarios, it is normally important to estimate how much, and how fast, fluid can be introduced/removed from the porous medium. Such estimates rely on the characterization and understanding of drainage mechanisms at the length scale of pores, even though relevant drainage systems may span meters to kilometers.

In this project, we focus on the stable drainage of a liquid by a gas from a quasi-2D granular porous medium. Previous studies (Hoogland et al., 2016; Moura, et al., 2019; Reis et al., 2023) indicated that, under slow flow conditions, liquid could be mobilized from a granular porous medium along the drainage front – through the bulk of pores – and behind the drainage front – within an active zone where liquid clusters are still connected to the front through capillary bridges and corners. These two mechanisms occur at significantly different time scales and their effectivities depend on the flow conditions.

In our latest work (Reis et al., 2025), we developed a dynamic pore-network model for the drainage of a liquid by an inviscid weightless gas, to investigate the effects of flow rate and buoyancy on both bulk and corner liquid flows. In line with the literature on the topic, our results indicated that liquid flow though the bulk of pores is enhanced by gravitational effects and hindered by high flow rates. As for the corner flow, as well the liquid connectivity behind the front (see Fig. 1), a complex non-monotonic dependency on Bond (ratio of gravitational and capillary forces) and Capillary (ratio of viscous and capillary forces) numbers was found.

As a potential application, the connectivity and flow of liquid in granular media during drainage can be linked, for instance, to water retention in soils. Characterizing the span and form of liquid-connected structures in unsaturated soil can also be instrumental to understanding how far and how fast nutrients or contaminants can travel within this type of porous medium.

ACKNOWLEDGEMENTS

This work has been done with support from the Norwegian Research Council and its Center of Excellence Funding Scheme project no. 262644, the Researcher Projects for Young Talents FlowConn (324555) and M4 (325819), and the CNRS/University of Oslo IRP D-FFRACT,

RECOMMENDED READING

[1] Hoogland, Frouke, Peter Lehmann, Rajmund Mokso, and Dani Or. Drainage mechanisms in porous media: From piston-like invasion to formation of corner flow networks. *Water Resources Research* 52, no. 11 (2016): 8413-8436.

[2] Moura, Marcel, Eirik Grude Flekkøy, Knut Jørgen Måløy, Gerhard Schafer, and Renaud Toussaint. Connectivity enhancement due to film flow in porous media. *Physical Review Fluids* 4, no. 9 (2019).

[3] Reis, Paula, Marcel Moura, Gaute Linga, Per Arne Rikvold, Renaud Toussaint, Eirik Grude Flekkøy, and Knut Jørgen Måløy. A simplified pore-scale model for slow drainage including film-flow effects. *Advances in Water Resources* 182 (2023): 104580.

[4] Reis, Paula, Gaute Linga, Marcel Moura, Per Arne Rikvold, Renaud Toussaint, Eirik Grude Flekkøy, and Knut Jørgen Måløy. Interaction between corner and bulk flows during drainage in granular porous media. *Advances in Water Resources* 198 (2025): 104914.

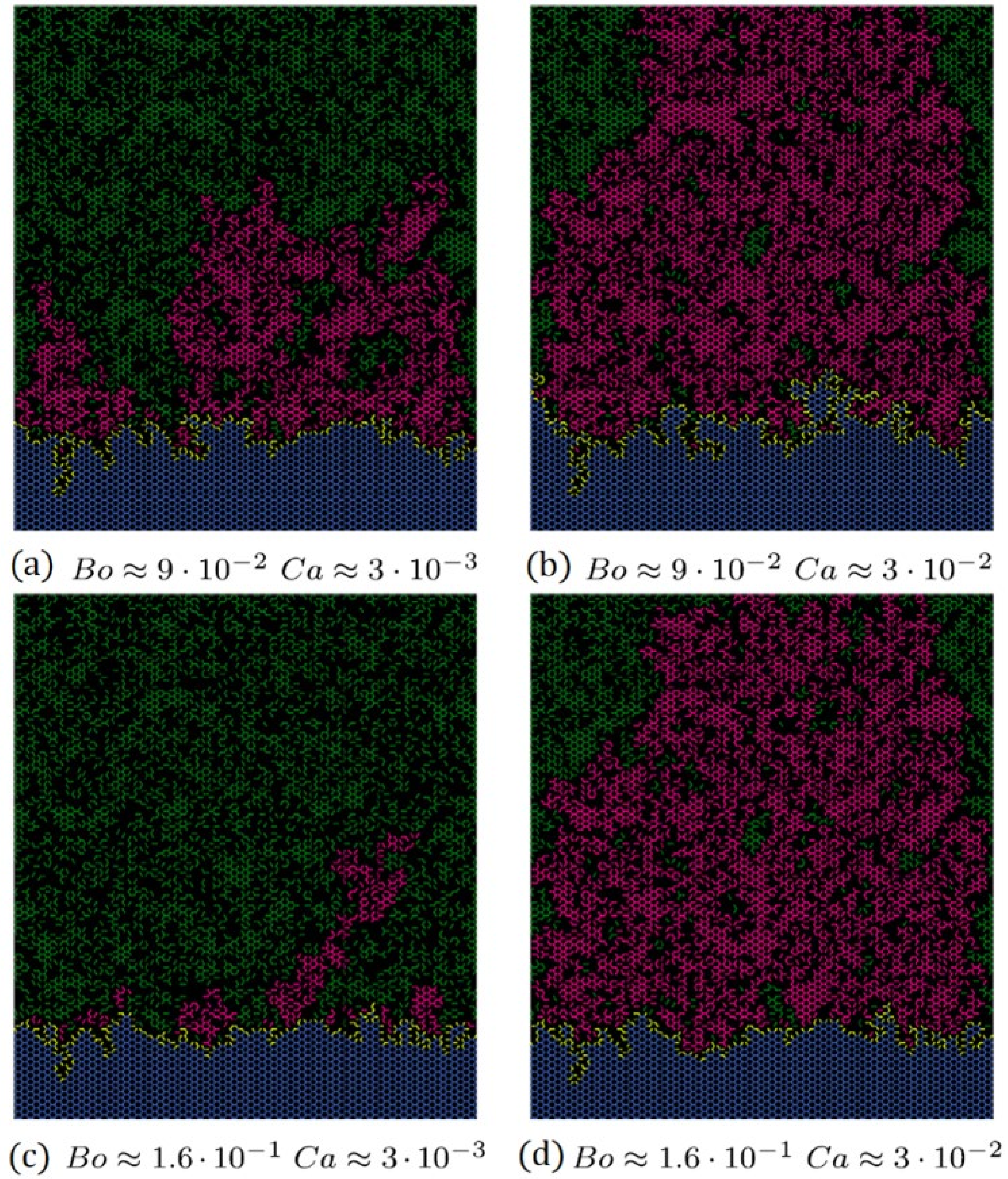


Figure 1: *Pore-network representation of stable drainage fronts in quasi-2D porous media, under different flow conditions, identified by Bo (Bond) and Ca (capillary) numbers. Blue represents the main defending liquid cluster, yellow represents the drainage front, pink represents liquid clusters connected to the front by capillary bridges and corners, and green represents trapped liquid clusters. Note that, while the drainage front does not vary significantly among the conditions represented from (a) to (d), the liquid connectivity behind the front does. (Reis et al., 2025),*

INTERFACE INSTABILITY OF TWO-PHASE FLOW IN A THREE-DIMENSIONAL POROUS MEDIUM

Joachim Falck Brodin[1], Kevin Pierce[1], Paula Reis[1], Per Arne Rikvold[1,3], Marcel Moura[1], Mihailo Jankov[1], and Knut Jørgen Måløy[1,2]

[1] PoreLab, The Njord Center, Department of Physics, University of Oslo, Oslo, Norway
[2] PoreLab, Department of Geoscience, Norwegian University of Science and Technology, NTNU, Trondheim, Norway.
[3] Department of Physics, Florida State University, Tallahassee, USA

We present an experimental investigation of immiscible two-phase flow through a three-dimensional porous medium composed of randomly packed, monodisperse glass spheres. By combining refractive-index matching with laser-induced fluorescence imaging, we obtained time-resolved, high resolution three-dimensional visualizations of the evolving fluid interface as a dense, viscous fluid (glycerol) was injected downward into a less dense, less viscous fluid (rapeseed oil). By systematically varying the injection rate, we explored how the interplay between gravitational and viscous forces governs interfacial dynamics, producing a transition from unstable, fingered invasion at low flow rates to stable, sheet-like displacement fronts at higher rates.

Simultaneously, we measured the temporal evolution of the pressure drop across the porous medium. Integrating the pressure measurements with quantitative analysis of the 3D image data, we derived a theoretical stability criterion for the fluid interface that incorporates phase-specific Darcy permeabilities and the time-dependent pressure gradient. Our results further reveal that the relative permeability of the invading phase depends on the injection rate, thereby influencing the displacement dynamics.

Finally, we show that local regions of crystalline ordering within the bead pack significantly affect the stability and morphology of the advancing front. These findings provide new insight into how structural disorder in porous media couples with viscous, capillary, and gravitational forces to control interfacial stability in multiphase flows.

ACKNOWLEDGEMENTS

This work is supported by the Research Council of Norway, through projects 262644 (PoreLab), 325819 (M4), and 324555 (FlowConn).

RECOMMENDED READING

[1] Brodin, Joachim Falck, Kevin Pierce, Paula Reis, Per Arne Rikvold, Marcel Moura, Mihailo Jankov, and Knut Jørgen Måløy. Interface instability of two-phase flow in a three-dimensional porous medium. *Phys. Rev Fluids* (2025). DOI: https://doi.org/10.1103/hm82-167x

[2] Brodin, Joachim Falck, Per Arne Rikvold, Marcel Moura, Renaud Toussaint, and Knut Jørgen Måløy. Competing gravitational and viscous effects in 3d two-phase flow investigated with a table-top optical scanner. *Frontiers in Physics* 10 (2022): 936915.

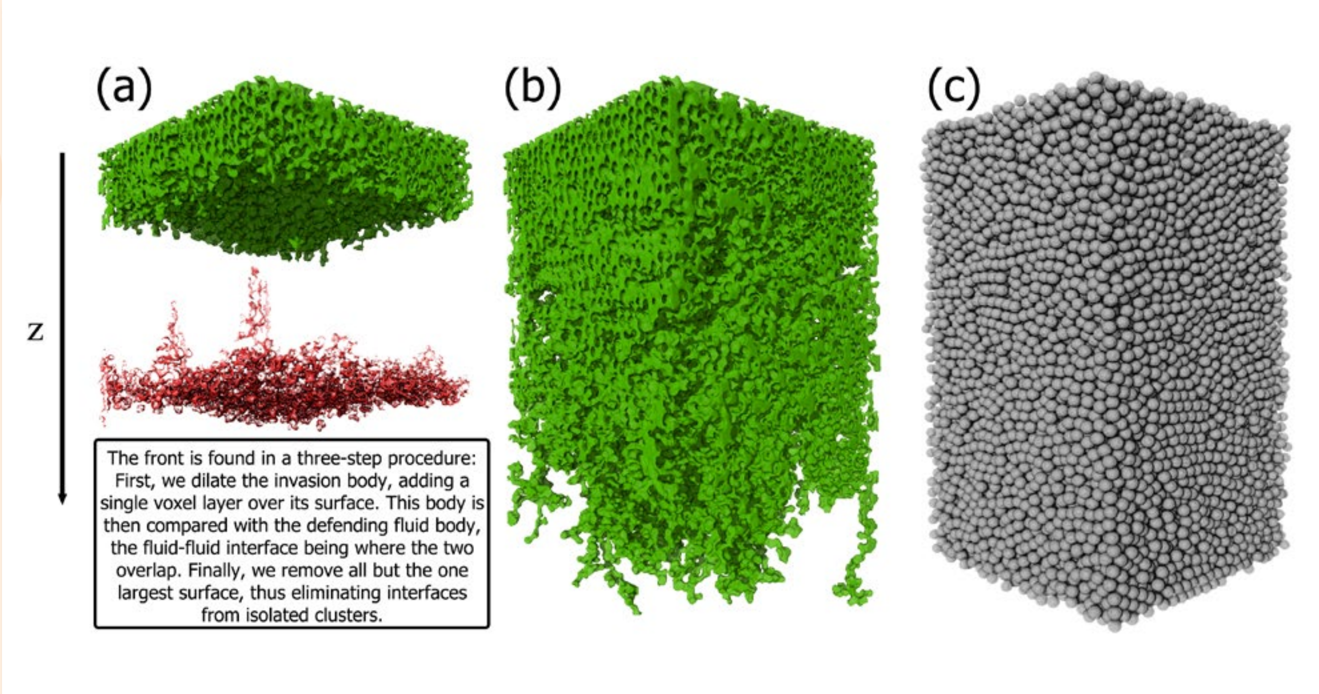


Figure 1: *Images show the segmentation bodies and the evolution from an initially planar front to an unstable, increasingly wide front. In (a), the front (in red) from an early image of the experiment is artificially shifted below the invasion body for visualization. Upward-trailing regions of pinned fluid are visible. In (b), the last image before the front leaves the imaging region is shown, with well-developed fingers extending from the main invasion body. In (c), we show a rendering of the porous medium.*

RESEARCH PROJECTS

MAPPING DISSOLVED CARBON IN SPACE AND TIME: AN EXPERIMENTAL TECHNIQUE FOR THE MEASUREMENT OF PH AND TOTAL CARBON CONCENTRATION IN DENSITY DRIVEN CONVECTION OF CO_2 DISSOLVED IN WATER

Hilmar Yngvi Birgisson[1], Yao Xu[1], Marcel Moura[1], Eirik Grude Flekkøy[1,2] and Knut Jørgen Måløy[1,3]

[1] PoreLab, The Njord Center, Department of Physics, University of Oslo, Oslo, Norway
[2] PoreLab, Department of Chemistry, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[3] PoreLab, Department of Geoscience, Norwegian University of Science and Technology, NTNU, Trondheim, Norway.

Reducing carbon dioxide (CO_2) emissions is one of the central challenges in addressing climate change. Among the strategies being explored, carbon capture and storage (CCS) aims to trap CO_2 before it reaches the atmosphere and store it safely underground. A key question for CCS is how securely CO_2 can be retained once injected into subsurface formations, particularly when it dissolves into groundwater and begins to move.

When CO_2 comes into contact with water, it dissolves and forms carbonic acid, slightly increasing the water's density. This small density change can trigger a process known as density-driven convection, in which carbon-rich water sinks while fresher water rises to the interface. This convective motion greatly enhances the amount of CO_2 that can dissolve, making it a crucial mechanism for long-term carbon storage. Despite its importance, accurately measuring how much carbon dissolves and how it spreads through water has remained a major experimental challenge.

Traditionally, laboratory studies of density-driven convection rely on pH color indicators to visualize flow patterns. These indicators change color when CO_2 lowers the pH, allowing researchers to observe plume-like structures as carbon-rich water sinks. While this approach provides striking images and qualitative insight, it has important limitations. Most studies use a single indicator, which effectively produces a binary picture: regions are either "affected" by CO_2 or not. This makes it difficult to quantify how much carbon is actually dissolved or to compare concentrations across space and time. Moreover, previous work has shown that the choice of indicator can strongly influence the observed plume shapes, raising questions about how much quantitative information can be reliably extracted.

In this study, we present a new experimental technique that moves beyond these limitations. By combining three different pH indicators with image analysis, we are able to measure pH continuously over a wide range (from about 4.0 to 9.5) rather than at a single threshold. This expanded range allows us to reconstruct detailed spatial maps of pH and, using established chemical relationships, infer the total dissolved carbon concentration in water.

We first calibrate the method using benchmark solutions with known properties, demonstrating that it can accurately recover both pH and carbon content. We then apply the technique to a laboratory experiment that mimics density-driven convection in a Hele-Shaw cell—a simplified model of a porous geological formation. This approach provides a direct, spatially resolved view of how dissolved carbon is distributed within convective plumes as they form and sink.

By turning color-based visualization into a quantitative measurement tool, this method opens new possibilities for studying CO_2 dissolution and transport in water.

ACKNOWLEDGEMENTS

This work has been done with support from the Norwegian Research Council and its Center of Excellence Funding Scheme project no. 262644.

RECOMMENDED READING

H.Y. Birggison, Y. Xu, M. Moura, E.G. Flekkøy, and Knut Jørgen Måløy. Mapping dissolved carbon in space and time: "An experimental technique for the measurement of pH and total carbon concentration in density driven convection of CO_2 dissolved in water." *Advances in Water Resources (2025)*, doi:https://doi.org/10.1016/j.advwatres.2025.104916.

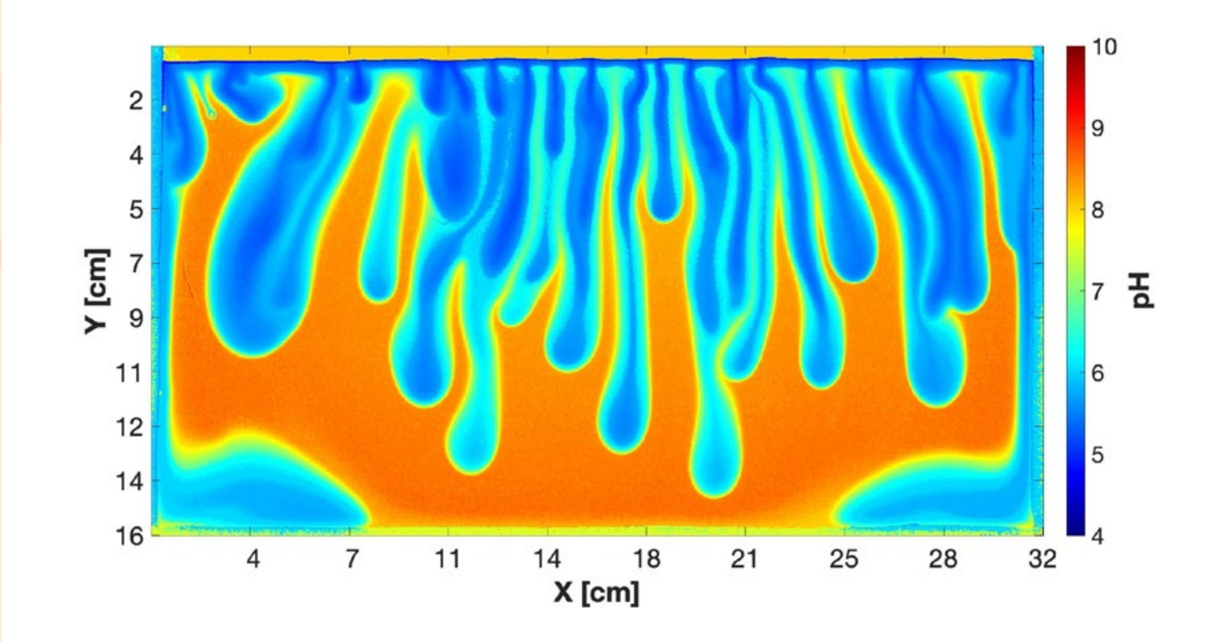


Figure 1: The pH field of an experiment with a tilt angle of 60° and Hele-Shaw dimensions of 32 cm × 16 cm × 2 mm, 46 min after CO_2 injection.

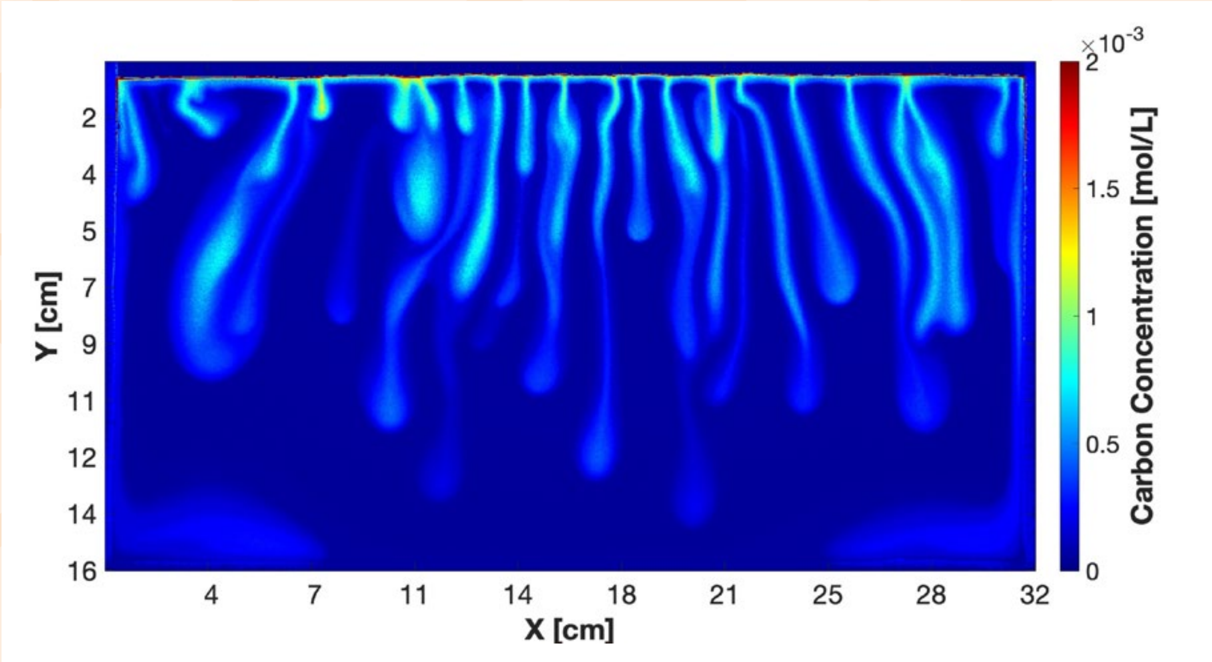


Figure 2: The carbon concentration field with a tilt angle of 60° and Hele-Shaw dimensions of 32 cm × 16 cm × 2 mm, 46 min after CO_2 injection.

GRAVITY STABILIZED DRAINAGE IN POROUS MEDIA WITH CONTROLLED DISORDER

Khobaib Khobaib[1], Paula Reis[1], Marcel Moura[1], Renaud Toussaint[1,2], Eirik Grude Flekkøy[1,3], and Knut Jørgen Måløy[1,4]

[1] PoreLab, The Njord Center, Department of Physics, University of Oslo, Oslo, Norway
[2] University of Strasbourg, Strasbourg, France
[3] PoreLab, Department of Chemistry, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[4] PoreLab, Department of Geoscience, Norwegian University of Science and Technology, NTNU, Trondheim, Norway.

Liquids flow through networks of microscopic pores found in materials such as rocks, soil, concrete, and sponges. Understanding fluid transport through these pore networks is essential for many natural and industrial processes, including groundwater filtration and oil recovery. The geometry of the pores, their size, shape, and spatial arrangement, plays a crucial role in determining fluid flow behavior, mechanical properties, and overall system performance. Key parameters such as capillary pressure, permeability, and flow efficiency are strongly influenced by pore-scale disorder.

In this study, we present a combined theoretical, experimental, and numerical investigation of the effects of pore disorder **ε** on invasion patterns during slow drainage in porous media. Experiments were conducted using 3D-printed porous models with systematically varied degrees of pore disorder, fabricated using a Formlabs 3D printer *(See Fig, 1)*

By controlling the level of disorder from minimally to highly disordered pore structures, we examined its impact on invasion front width, maximum trapped cluster length, and non-wetting phase saturation. Both experimental results and numerical simulations show that invasion behavior, including front morphology, trapped fluid clusters, and residual saturation, is primarily governed by the dimensionless fluctuation number, **F**, which is inversely related to the pore disorder parameter, **ε** *(see Fig. 2)*. Previous studies [2,3] have investigated the role of the fluctuation number in relation to viscous and gravitational forces, as well as systematic gradients in pore geometry.

Our findings provide new insight into fluid drainage mechanisms in porous media and help explain variations in fluid behavior across different materials. By establishing scaling laws and quantifying pore-scale disorder, this work offers a predictive framework for controlling multiphase flow. These results have practical implications for industries such as oil and gas, where they can inform strategies to enhance recovery and reduce pore-scale trapping, as well as for water filtration, where they can aid in the design of more efficient filter structures. Overall, this study advances the understanding of fluid flow in disordered porous media and supports the improved design and performance of systems that rely on porous materials.

ACKNOWLEDGEMENTS

This work is supported by the Research Council of Norway, through projects 262644 (PoreLab) and 324555 (FlowConn).

RECOMMENDED READING

[1] K. Khobaib, P. Reis, M. Moura, R. Toussaint, E. G. Flekkøy, and K. J. Måløy. Gravity Stabilized Drainage in Porous Media with Controlled Disorder. *Phys. Rev. Research* , 7, 023040 (2025). DOI: 10.1103/PhysRevResearch.7.023040

[2] K. J. Måløy, M. Moura, A. Hansen, E. G. Flekkoy, and R. Toussaint, Burst dynamics, upscaling and dissipation of slow drainage in porous media, *Frontiers in Physics* 9,10.3389/fphy.2021.796019 (2021).

[3] T. Vincent-Dospital, M. Moura, R. Toussaint, and K. J. Måløy, Stable and unstable capillary fingering in porous media with a gradient in grain size, *Communications physics* 10.1038/s42005-022-01072-1 (2022).

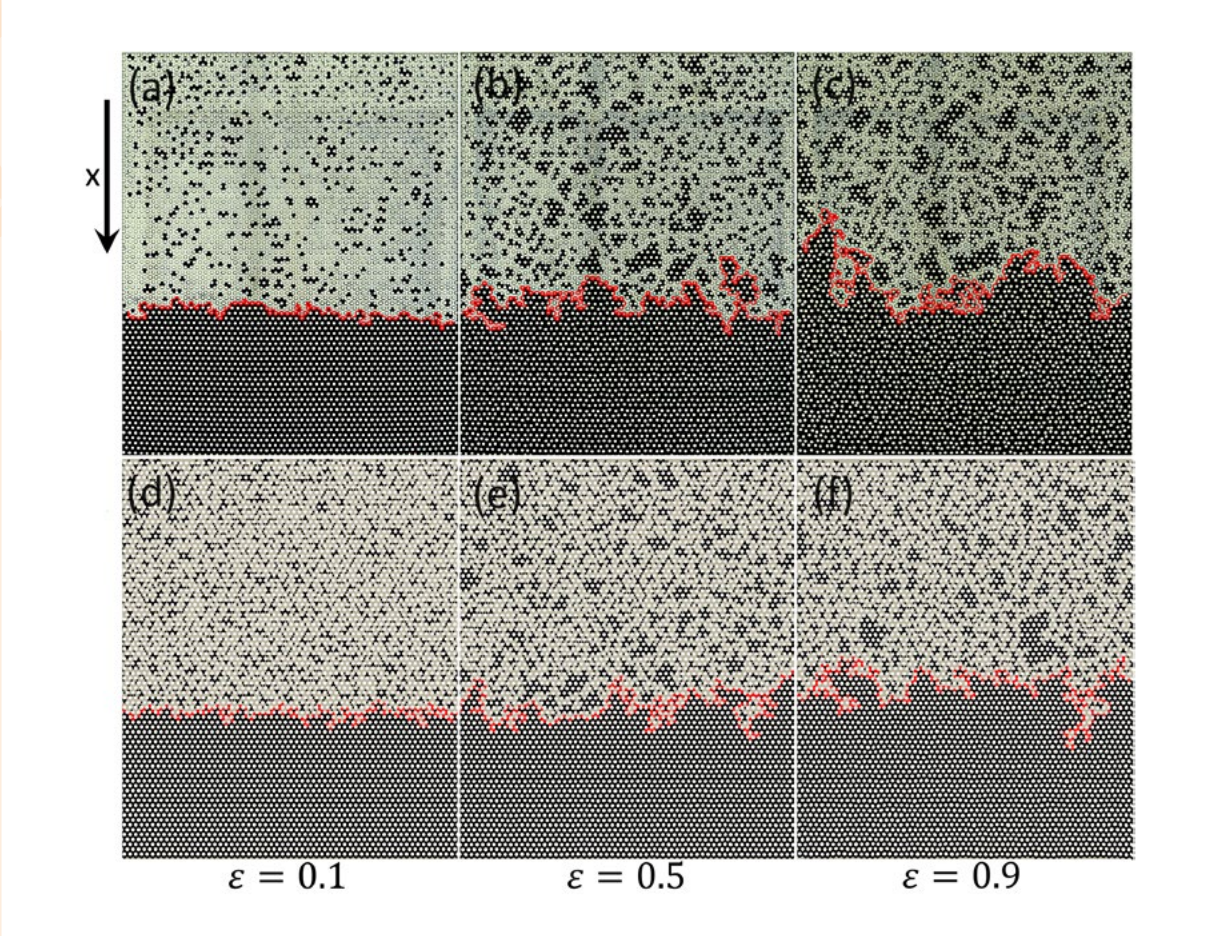


Figure 1: *(a-c) show experimental images for disorder levels ε = 0.1, 0.5, and 0.9, and (d-f) show simulated images. Black represents the wetting phase, light color the non-wetting phase, and the red line marks the drainage front*

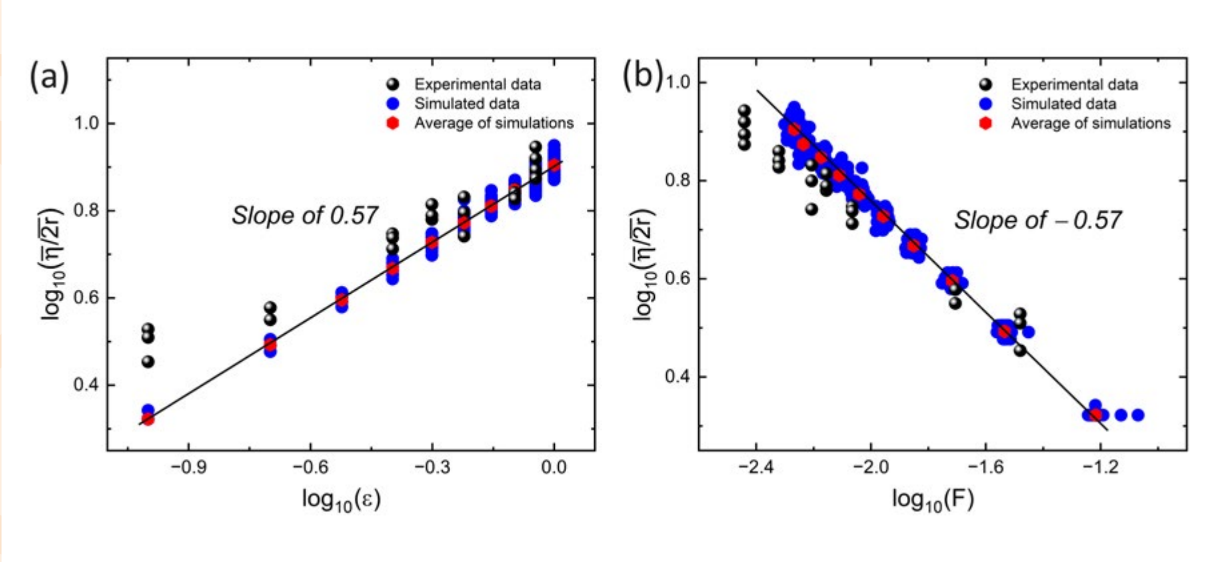


Figure 2: *The normalized mean invasion front width $\overline{\eta}/\overline{2r}$ as a function of ε in (a) and as a function of F number in (b). The value of front width denoted by $\overline{\eta}$, are normalized by mean pore-throat size $\overline{2r}$. The black solid line signifies the theoretically predicted slope of 0.57 and −0.57*

CONFINED COFFEE-RINGS ARE DIFFERENT

Ilaria Beechey-Newman[1], Natalya Kizilova[2,3], Andreas Andersen Hennig[1], Eirik Grude Flekkøy[4], Erika Eiser[1]

[1] PoreLab, Department of Physics, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[2] Department of Applied Mathematics, V. N. Karazin Kharkiv National University, Kharkiv, Ukraine
[3] Division of Aerodynamics, Institute of Aeronautics and Applied Mechanics, Warsaw University of Technology, Warsaw, Poland
[4] PoreLab, Department of Physics, University of Oslo, Oslo, Norway

Everybody has seen them: coffee rings. They form when sessile droplets of coffee dry out on a flat surface (see Figure A). The resulting dry coffee stains show a darker ring on the outer edge, while the inner area is lighter. This phenomenon has been first described by Deegan et al. [1] using a sessile droplet of an aqueous suspension of spherical colloids. For a surface to which the initial contact line (between solid, liquid and vapor) is pinned in position R, the droplet can only evaporate by losing height with time. The evaporation rate *J(r)* near the contact line will be larger than at the water air interface at the center, where the droplet has a lower curvature. This creates a velocity gradient in the water phase towards the edges, which in turn transports the colloids outwards, where they will be deposited. This capillary driven process is responsible for coffee stains.

The physics of drying droplets is complex and is important in various applications such as ink-jet printing or dying and washing of clothing. But it has also been developed to screen the drying patterns of droplets of blood for diseases.

The Eiser group (Theme 4) has discovered that when an aqueous droplet containing charge-stabilized, spherical colloids is confined in a cylindrical cell such that the evaporation rate is strongly reduced, a fingering pattern evolves [2] (Figure B).

Initially the cell is fully filled with the droplet. As evaporation can only take place between the narrow gap between the coverslip and the double-sticky tape that serves as a spacer, the evaporation rate is limited to the circumference of the coverslip itself. Consequently, it takes several days before air bubbles appear at the perimeter, which subsequently coalesce, to create a capillary bridge between the top and bottom surfaces. As the detached droplet becomes smaller, it starts depositing a monolayer of colloids (light gray circular band), which is driven by capillary forces. In transmission such a monolayer displays structural colors as the 1.8 micrometer large colloids act like a grating. However, once a critical radius of the capillary bridge is reached, we see a sudden rapture from the slow monolayer deposition to rapidly forming fingers. The width, length and orientation of these fingers typically show interesting sharp transitions themselves. Moreover, the fingers form an uninterrupted labyrinth.

RECOMMENDED READING

[1] R.D. Deegan et al., *Nature* **389**, 827–829 (1997).

[2] I. Beechy-Newman et al. 'Confined colloidal droplets dry to form circular mazes' *PNAS* **122**, e2508363122 (2025).

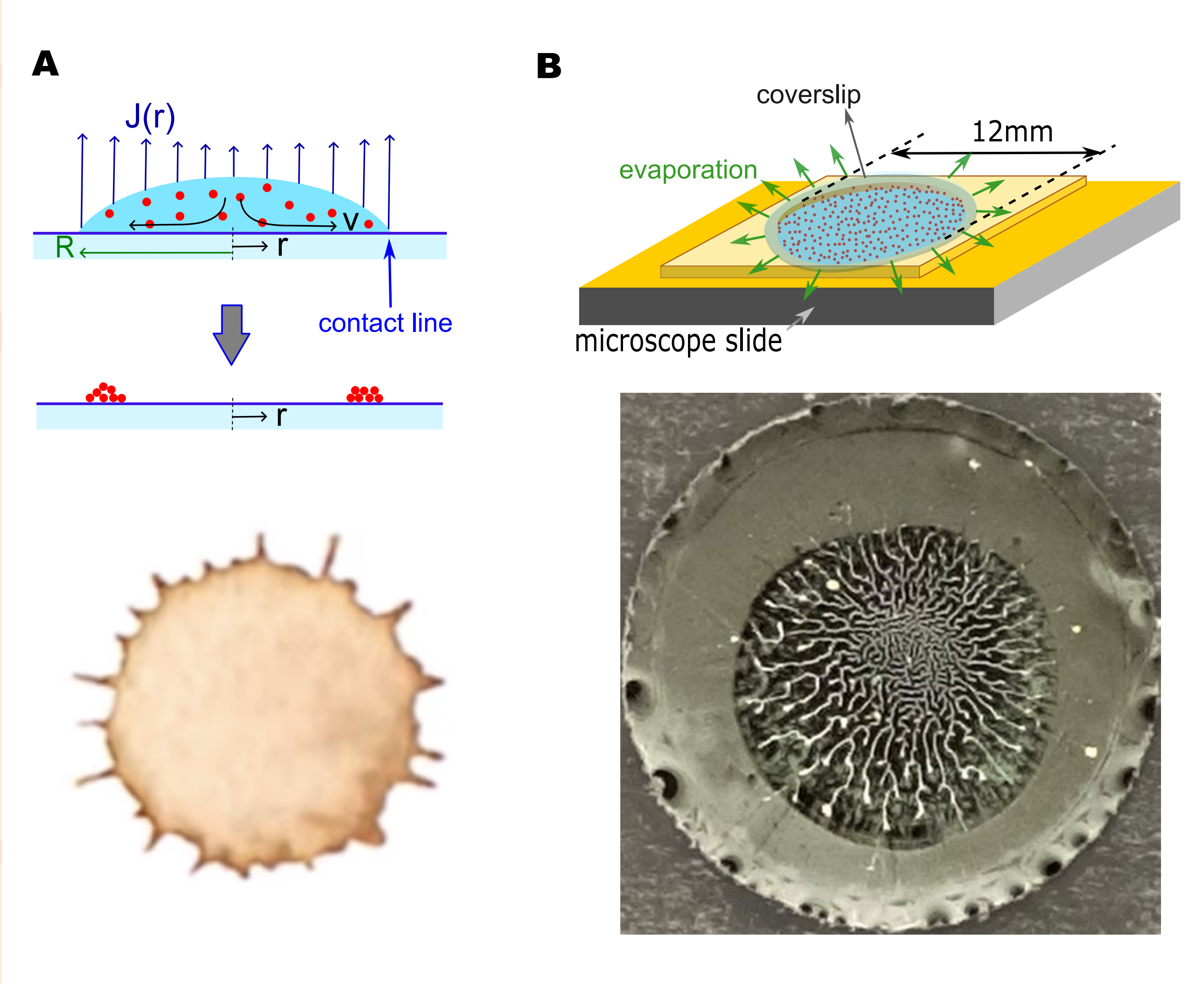


Figure: (A) Schematic of a sessile droplet with a pinned contact line. *The higher curvature at the contact line leads to faster evaporation than in the middle leading to a fluid transport outward. The suspended colloids are dragged along and deposited. Below the photograph shows the typical darker outer ring of a dried coffee drop that also contains tiny solid particles.* ***(B)*** *Schematic of the experimental preparation of the confining cell that is initially completely filled with a colloidal suspension. Below, a photograph of the finally dried droplet shows a wide band of a colloidal monolayer, while the center displays the labyrinthian pattern of fingers that contain the remaining colloids. See the reference by I. Beechy-Newman et al., PNAS* ***122****, e2508363122 (2025).*

MICRORHEOLOGICAL CHARACTERIZATION OF SHAKE-GELS

Iliya D. Stoev[1], Anasua Mukhopadhyay[2], Rene Tammen[3], Erika Eiser[3]

[1] Institute of Biological and Chemical Systems, Biological Information Processing, Karlsruhe Institute of Technology, Karlsruhe, Germany
[2] Adolphe Merkle Institute, University of Fribourg, Fribourg, Switzerland
[3] PoreLab, Department of Physics, Norwegian University of Science and Technology, NTNU, Trondheim, Norway

Natural clays are ubiquitous, abundant and play an important role in many industrial applications. For example, Montmorillonite, a natural 2:1 phylosilicate clay is used as gelling agent in many cosmetic applications, in drilling fluids, as clarifying agent in wine & oil production and in building materials such as mortar and cement. The synthetic clay Laponite is more often used as flow modifier in paints, as their aqueous solutions are transparent [1]. The reason why clays are so important is their shape and charging state in aqueous solutions. The cartoon in *Figure A* shows the typical structure of Laponite: The flat surfaces of their disk-like nanoparticles are negatively charged while their rims are positively charged in water and form a complex Diffuse Double-Layer (DDL) of counterions around them. Therefore, in quiescent solutions the rims can weakly bind to the negative surfaces, while equally charged surfaces repel each other. This leads to what we call aging or out-of-equilibrium behavior. Consequently, even at very low clay concentrations their initially fluid aqueous solutions eventually become a solid, gel.

However, when small amounts of high molecular weight polymer Polyethyleneoxide (PEO) are added to a Laponite solution the samples display the opposite behavior to what is expected. The initially fluid sample shear-harden upon vigorous shaking. When left at rest the gel reverts back to its initial fluid state. These systems are referred to as 'shake-gels' [2].

In collaboration with Dr. Iliya Stoev (KIT, Karlsruhe) and Dr. Anasua Mukhopadhyay (Merkel Institute, Fribourg, Switzerland), we studied the viscoelastic properties of solutions of Lapointe-PEO and Montmorillonite-PEO using bulk- and microrheology [3]. We used DLS-based microrheology to study the non-shaken samples, as they are fully transparent, and revert to Diffusing Wave Spectroscopy (DWS) for the shake gels that typically appear turbid.

To understand why both types of clays form shake-gels, we established first their phase-state diagram based on optical observations *(Figure B, showing only the Laponite-PEO behavior)*. The formation of a shake gel is believed to be due to the weak physisorption of the PEO chains to the tetrahedral silica surfaces of the clay disks. When sheared hard, long enough PEO chains will stretch and bind to several nanoplatelets. Clearly, only for appropriate concentrations of the clay particles and polymer chains percolating, solid-like gels will form. Interestingly, Montmorillonite-PEO solutions showed phase separation, which was attributed to the fact that their exfoliated sheets are much larger, promoting fast sedimentation. But we were able to identify a region (II.) that is similar to a homogenous weak shake-gel formation.

Finally, our experiments showed that the two different clay-polymer suspensions behave differently but give insights into designing fluids relevant in biological and pharmacological applications.

RECOMMENDED READING

[1] van Olphen H 'An introduction to clay colloid chemistry: for clay technologists, geologists, and soil scientists.' *Science* **143**, 1023 (1977).

[2] Zebrowski J, Prasad V, Zhang W, Walker LM, Weitz DA 'Shakegels: shear-induced gelation of Laponite–PEO mixtures.' *Colloids Surf A Physicochem Eng Asp* **213**, 189 (2003)

[3] I. D. Stoev, A. Mukhopadhyay, R. Tammen, E. Eiser 'Microrheological characterisation of clay-PEO nanocomposites' *Rheologica Acta* 1-13 (2025)

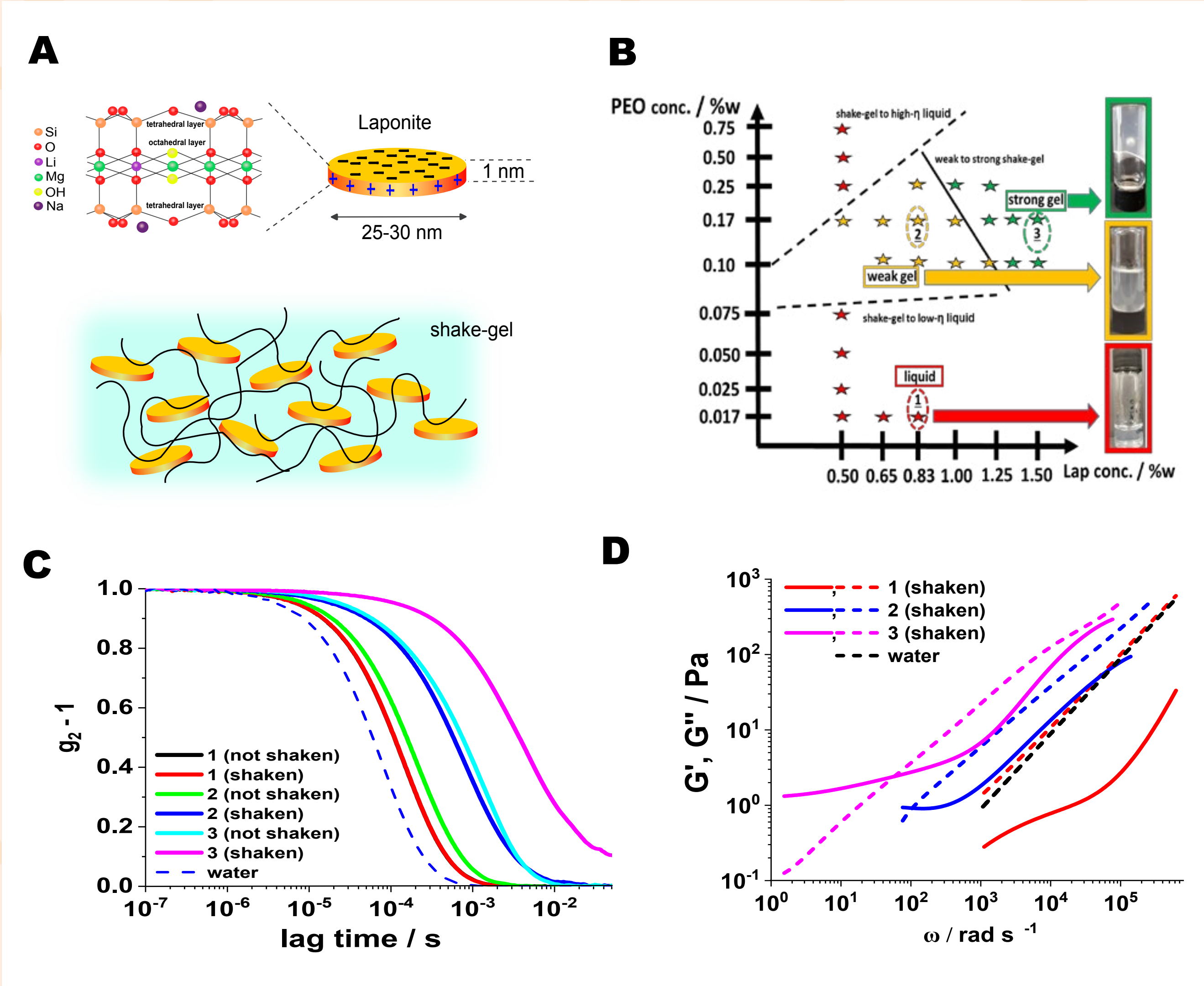


Figure: ***(A)*** *Schematic of the structure of Laponite. The cartoon below illustrates how the long PEO chains connect the particles in aqueous solutions after rapid shaking.* ***(B)*** *State diagram of the Laponite-PEO system. We identify three regions: (i) samples remain predominantly liquid; (ii) at these concentrations the samples show a weak gel; and (iii) the strong shake-gel regions.* ***(C)*** *Intensity autocorrelation functions (ACF) of DWS measurements before shaking the samples and after vigorous shaking. The curves were taken in all three regions. The dashed line is obtained for a pure water sample for comparison.* ***(D)*** *From the ACF-curves we then extract the elastic (G'(w), solid lines) and loss (G"(w), dashed lines) modulus of the samples. In region (i) the loss modulus clearly dominates at all frequencies, while in the weak gel region loss and elastic modulus are closer together. Only in the strong gel region the elasticity dominates at long times (small frequencies), showing that on average the samples are solid-like. Images are in part taken from Stoev et al.[3]*

PHASE TRANSITIONS IN POROUS MEDIA STUDIED WITH TIME-RESOLVED NEUTRON AND X-RAY COMPUTED TOMOGRAPHY

Mukul Jaiswal[1*], Giacomo Luani[1*], Jessica A. Zeman[1*], Chayene G. Anchieta[1], Elvia A. Chavez[2], Ragnvald H. Mathiesen[1], Basab Chattopadhyay[1], and Dag W. Breiby[1]

[1] Department of Physics, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[2] Department of Materials Science, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[*] These authors contributed equally

The physics of fluids in porous media is a rich playground for multiscale phenomena which have profound implications for environmental, industrial and biological processes. The huge societal impact combined with the deep science are key reasons for the success of CoE PoreLab. During recent years, X-ray micro-CT has transformed this scientific field as it has become possible to non-destructively image with sub-micron resolution the inner 3D structure of porous media. A current trend is to extend these imaging experiments towards monitoring dynamics, typically related to monitoring liquid displacements or phase transitions, sometimes referred to as "4D CT".

In this context, the X-ray Physics Group at NTNU has several on-going projects aiming at better understanding dynamic processes in porous media, using a range of optical, neutron and X-ray imaging methods, applied to both natural geomaterials and to manmade devices like Li-ion batteries. A central theme of the X-ray Physics Group is to develop and apply computational imaging methodologies where computer algorithms can enhance the imaging process and facilitate multimodal and dynamic imaging.

The simplest conceivable model for a porous material is a single narrow capillary. With two fluid phases present in a capillary, one phase will be denoted the wetting phase (viz., water) and the other the non-wetting phase (viz.: air). Water in a capillary is known to follow Jurin's law and to form a meniscus separating the air from the water. The curvature of the meniscus is described by the Young-Laplace equation, relating the curvature of the meniscus to the pressure difference across the meniscus. This simple model fails, however, to capture many important characteristics of multiphase fluid flow, in particular cooperative phenomena like air pockets, ganglia and corner flow commonly seen in realistic systems.

Salt is often present in natural soils and adds further complication to the system. When the brine is sufficiently over-saturated (in fact, often near 160% for NaCl) inside a homogeneous solution, salt crystals will precipitate. Precipitation of solid particles from a liquid is an important phenomenon in many fields, including physics, material science, chemistry, biology and engineering. The phase transformation from liquid to solid can often be understood in terms of classical nucleation theory where the transition occurs via a single step. Two-step or multistep processes have also been proposed and experimentally observed. Despite the simplicity of NaCl forming isotropic cubic crystals, the fundamental mechanism of NaCl precipitation is still debated and presents open scientific problems. In the *SaltyPore* project, we study salt precipitation under conditions relevant for subsea storage of CO_2, which entail high temperatures and pressure. Experimental CT studies of the thermodynamical processes involving salt in porous media, see Fig. 1, are important for many environmental and industrial processes.

Starting with *compressed sensing* techniques [1], we have developed advanced CT methods for studying water dynamics in porous media. A recent highlight was the study of Haines jumps, which are fast liquid reorganization events seen mainly during drainage experiments, when a pore body suddenly (during milliseconds) gets filled with a wetting liquid [2]. Building on these efforts, we have in collaboration with Equinor ASA developed machine learning algorithms that give unprecedented spatial and temporal resolution to CT measurements [3]. In particular, the use of Internal Neural Representation (INR) allows a continuous 4D model of the sample to be derived from the CT measurements. The continuous model is a conceptual leap forward from the (discrete) experimental data, while also being highly efficient in terms of computer memory.

Frost heave is a well-known phenomenon in regions with clay-rich soil and cold temperatures. Contrary to common belief, the elevation of the soil is not driven by the expansion of water during freezing. Rather, the porous soil acts with a wicking mechanism, effectively sucking up liquid water from deeper-lying aquifers. With the freezing in the air and the top-most region of the soil, an effectively 1D temperature gradient arises, which keeps driving water upwards. Below a certain depth, the water is in its liquid state and near the transition zone, so called *ice lenses* form. We have monitored the formation of such ice lenses in situ, using combined X-ray and neutron CT [4], cf. Fig. 3. Neutron CT outperforms X-ray CT in observing liquids, as neutrons have a higher cross section for light elements. Recently, we have been reevaluating our dynamic data using the abovementioned INR methods, with promising results.

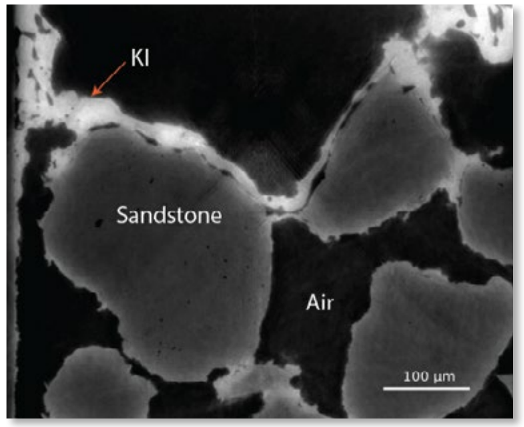


Figure 1: *High-resolution X-ray CT image of precipitated salt (potassium iodide, KI) inside a sandstone, measured using nano-holography at ESRF. The salt is seen to bridge gaps between sandstone (quartz) grains, still without coating the grains. These studies are important both for environmental protection of rock buildings, CO_2 storage, and industrial process optimization. [Zeman et al, to be published].*

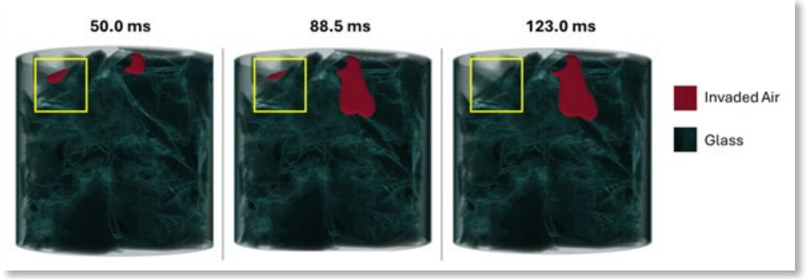


Figure 2: *Temporal development of a Haines jump. Differences in liquid configuration are shown in red, superposed on the porous medium. Note how the main pore filling event is accompanied by a correlated retracting liquid front (inside the yellow frame). [Jaiswal et al, to be published].*

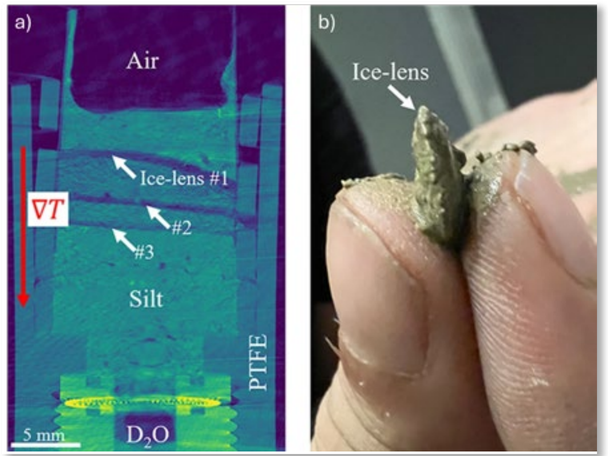


Figure 3: *CT image of ice lens formation within a silt column in contact with a water (D2O) reservoir and exposed to a temperature gradient. The photograph shows one of the ice lenses recovered after the experiment. Figure reproduced from Ref. [5].*

ACKNOWLEDGEMENTS

We thank our previous group members Henrik Friis, Håkon Nese, Fazel Mirzaei and Kim Robert Tekseth for important contributions to this work. We further thank Anders Kaestner at Paul Scherrer Institute, and Bratislav Lukic and Julie Villanova at the European Synchrotron ESRF. Our collaboration partners Anders Kristoffersen, Colin Pryme, Lars Rennan and Haili Long-Sanouiller in Equinor are thanked for valuable discussions. Paul Scherrer Institute and The European Synchrotron ESRF are acknowledged for beamtimes. This research was financed by the Research Council of Norway through its FRINATEK programme (projects #335519 *SaltyPore* and #275182 *4D-CT*) and Infrastructure #245942/F50 *NcNeutron*. We also thank Equinor ASA for direct funding.

RECOMMENDED READING

[1] 4D imaging of two-phase flow in porous media using laboratory-based micro-computed tomography. KR Tekseth and DW Breiby. *Water Resources Research*, 60, e2023WR036514 (2024)

[2] Multiscale drainage dynamics with Haines jumps monitored by stroboscopic 4D X-ray microscopy. KR Tekseth, F Mirzaei, B Lukic, B Chattopadhyay, DW Breiby. *Proceedings of the National Academy of Sciences (PNAS)*, Vol. 121 e2305890120 (2024)

[3] Implicit neural representation for fast 4D computed tomography of multiphase flow in porous media. H Friis, H Nese, G Luani, C Pryme, L Rennan, B Chattopadhyay, A Kristoffersen, OJ Mengshoel, DW Breiby. *Communications Physics*, 8, 339 (2025)

[4] 4D imaging of frost heave and ice lens growth in silt using neutron and x-ray computed tomography. F Mirzaei, M Jaiswal, D Younas, A Kaestner, K Scheidl, B Chattopadhyay, R H Mathiesen, DW Breiby. *Applied Physics Letters* 126, 17 (2025)

[5] Imaging of frost heave formations no longer frozen in time, thanks to 4D method. A Lim. *Scilight* 181106 (2025)

DIRECTIONAL- AND SCALE-DEPENDENCE OF PERMEABILITY

Azadeh Aghajanpour[1] and Carl Fredrik Berg[1]

[1] PoreLab, Department of Geosciences, Norwegian University of Science and Technology, NTNU, Trondheim, Norway

Permeability is a critical porous media property but notoriously difficult to measure directly. CT imaging offers high resolution structural information that captures lamina scale heterogeneities, which strongly influence permeability magnitude and anisotropy. In a recent study we have employed CT images of core samples to investigate the interplay between scale, direction and permeability.

The workflow begins by establishing an initial correlation between CT grayscale values—proxies for density and, indirectly, porosity—and measured core plug permeabilities. Because permeability often exhibits a log linear relationship with porosity, the study assumes a log linear form between CT values and permeability. Regression on average CT values at plug depths provides initial slope and intercept parameters.

Once each voxel in the CT cross section is assigned a permeability value, the study applies two families of upscaling methods. Analytical upscaling uses combinations of harmonic, arithmetic, and geometric averages to approximate effective permeability for horizontal and vertical flow directions, reflecting idealized layered systems. Numerical upscaling solves the steady state Darcy flow equation using finite difference discretization and boundary condition controlled pressure fields, yielding more physically rigorous effective permeabilities.

Figure 1 shows the result for 3 meters out of the more than 80 meters of core considered. The results show that a simple linear relationship between CT values and voxel scale permeability is sufficient to reproduce plug scale permeability with reasonable accuracy. Moreover, computationally inexpensive analytical averaging methods perform comparably to more demanding numerical simulations for this dataset. The study finds that average CT value is the dominant control on permeability at centimeter scale, while fine scale heterogeneities primarily influence how permeability changes with scale. These heterogeneities also contribute to directional anisotropy, which becomes more pronounced at coarser scales.

Overall, the work demonstrates that whole core CT images can serve as a practical foundation for deriving scale aware, directionally dependent permeability estimates. This approach bridges the gap between high resolution imaging and reservoir scale modeling, offering a pathway to more consistent permeability characterization across scales.

RECOMMENDED READING

Azadeh Aghajanpour and Carl Fredrik Berg. Directional-and scale-dependent permeability estimations from CT images. *Geoenergy Science and Engineering* 247 (2025): 213593.

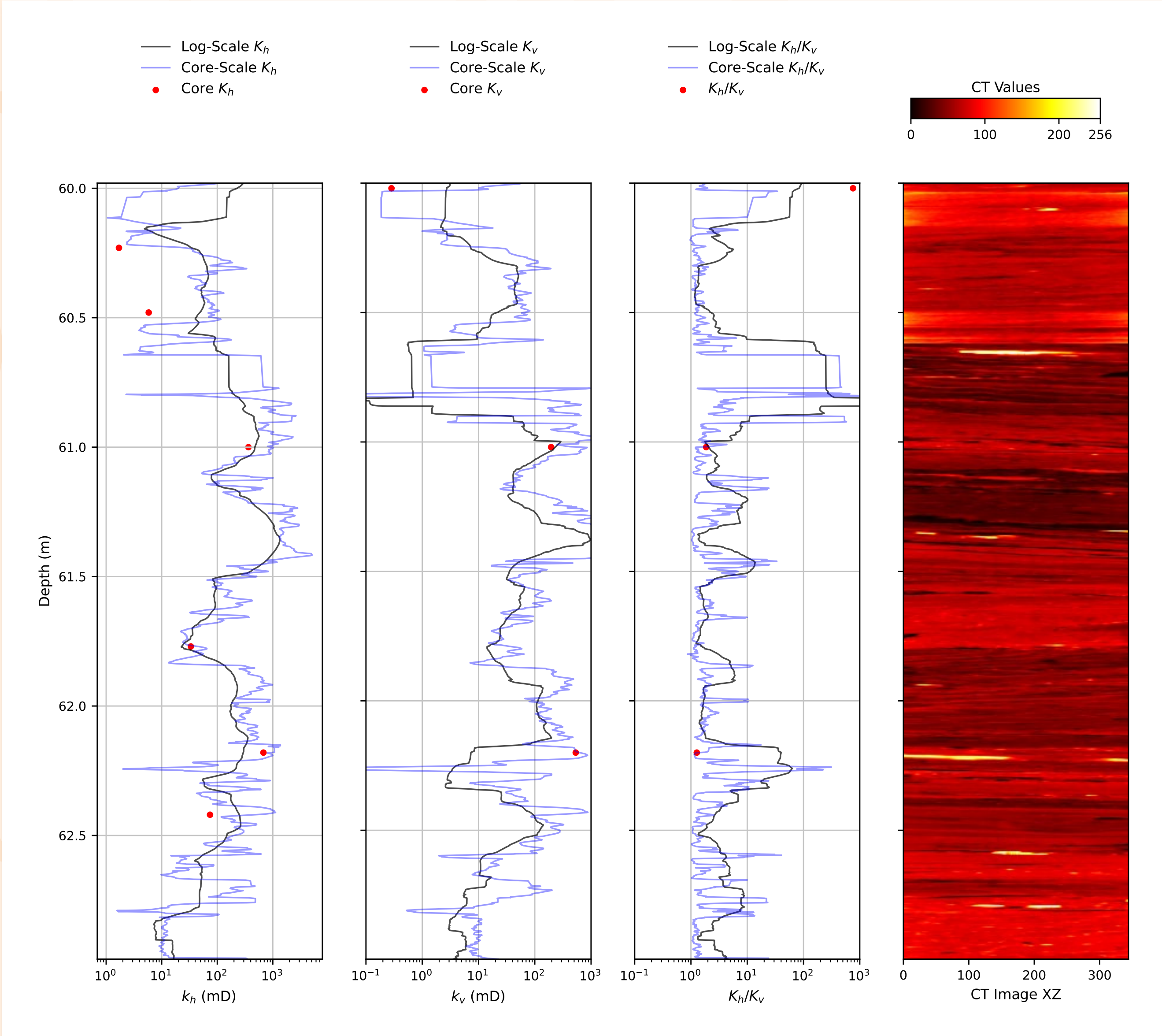


Figure 1: *Permeability estimated from the CT images, for different scales and directions, compared to experimentally obtained permeability. These permeability values are calculated based on the analytical upscaling.*

A REVIEW ON WETTABILITY CHARACTERIZATION FROM 3D PORE-SCALE IMAGES

Reza Haghani[1] and Carl Fredrik Berg[1]

[1] PoreLab, Department of Geosciences, Norwegian University of Science and Technology, NTNU, Trondheim, Norway

Wettability, characterized by contact angles at three-phase contact points, is a fundamental property that governs multiphase flow behavior in porous media. Its accurate determination is crucial for applications ranging from CO_2 storage and hydrocarbon recovery to fuel cell design. Traditional experimental methods provide only aggregate wettability values for entire samples, masking the spatial heterogeneity that significantly impacts macroscopic flow properties like relative permeability and capillary pressure. Recent advances in micro-CT imaging have enabled visualization of fluid distributions at the pore scale, opening new possibilities for detailed wettability characterization.

We have examined numerical methods for determining wettability distributions from three-dimensional pore-scale images. We categorized existing approaches into six distinct methodologies: geometry-based, topology-based, multiphase-based, machine learning-based, thermodynamic-based, and event-based methods. Each category employs fundamentally different principles for extracting contact angle information from segmented micro-CT images.

Geometry-based methods directly analyze the angles formed at three-phase contact lines by fitting planes and measuring interfacial tangents. These methods range from manual approaches requiring user selection of measurement points to fully automated algorithms that process entire contact loop networks. Topology-based methods characterize wetting through contact loop curvature and shape descriptors rather than traditional angle measurements. Multiphase-based methods leverage pore-scale simulations to reproduce observed fluid configurations and extract wettability from the matching process. Machine learning-based approaches train neural networks to predict contact angles from image features, offering rapid analysis once trained. Thermodynamic-based methods determine contact angles by analyzing energy conservation during displacement events, while event-based methods track individual pore-filling events in time-resolved image sequences to measure dynamic contact angles.

Figure 1 illustrates the key elements common to various workflow approaches for contact angle determination. These elements include identification of three-phase contact lines where solid, wetting, and non-wetting phases meet; segmentation of fluid-fluid and solid-fluid interfaces; extraction of normal vectors at contact points; and calculation of angles. The figure demonstrates how different methods share fundamental building blocks while implementing distinct computational strategies.

Our review reveals that no single method excels across all criteria. Geometry-based approaches tend to be most versatile and robust, directly measuring the physical angle but showing high sensitivity to image noise and resolution. Time-resolved methods provide contact angle classifications (advancing, receding, equilibrium) unavailable to static approaches, though they demand sophisticated interface tracking algorithms and high temporal resolution imaging. Machine learning methods offer computational efficiency but require extensive training datasets. The choice of method depends on available imaging capabilities, required accuracy, computational resources, and whether contact angle hysteresis characterization is needed.

RECOMMENDED READING

Reza Haghani and Carl Fredrik Berg. "A Review on Wettability Characterization from 3D Pore-Scale Images", *Transport in Porous Media* 152, no. 11 (2025): 93.

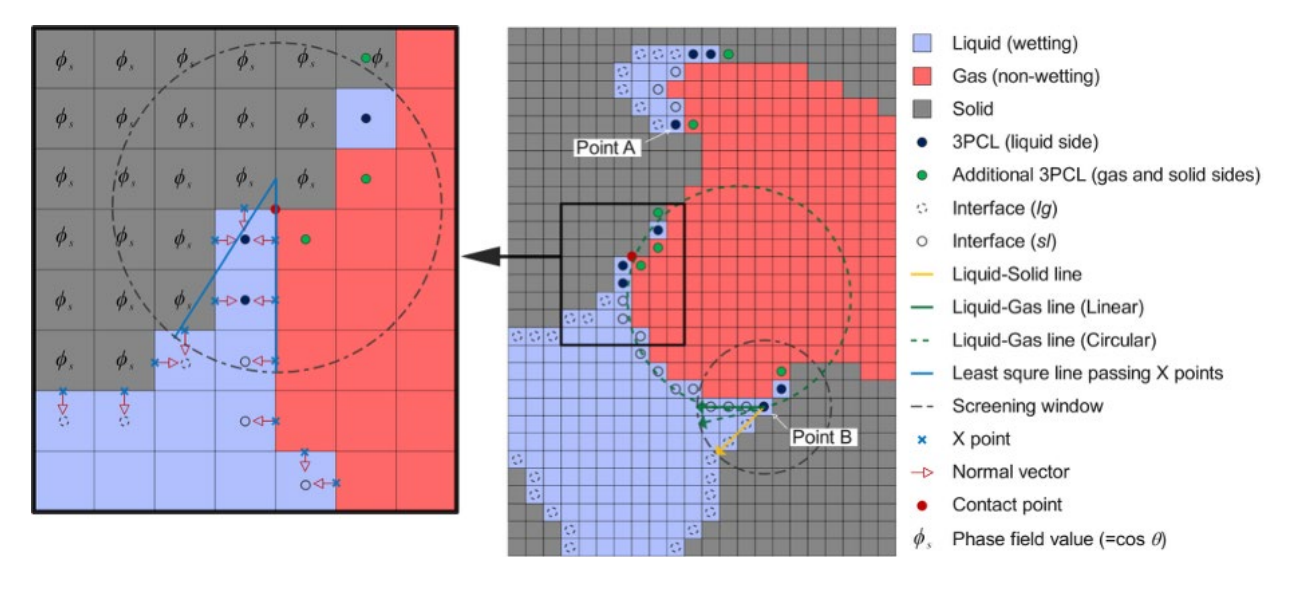


Figure 1: *Different elements used in workflows for determining contact angles from pore-scale images. The workflow components include three-phase contact line extraction, interface segmentation, normal vector determination, and angle calculation through various computational approaches. These fundamental elements are shared across different characterization methods, though their specific implementations differ.*

SYSTEMATIC STUDY OF ZETA POTENTIAL MEASUREMENTS AS METHOD TO QUANTIFY WETTABILITY

Antje van der Net[1] and Tomislav Vukovic[1]

[1] PoreLab, Department of Geosciences, Norwegian University of Science and Technology, NTNU, Trondheim, Norway

For multiphase flow description in porous media, which is subject of studies in PoreLab, the surface affinity of the phases flowing through the pores is very important. This fluids-rock surface interaction is characterized by the wettability, but its quantification is however challenging. For solid, non-porous materials, wettability is quantified by measuring the contact angles according to the Young Laplace equation. In porous media, consisting of curved irregular solid surfaces, these contact angle measurements can be performed using 3D images from the microCT scan where at pore level the contact lines are analyzed in 3D, see ***Figure 1***. Interfaces are often pinned and a wide spread of contact angles is found, which questions the applicability of the method.

For characterization of wettability in natural hydrocarbon reservoirs, wettability is measured on rock samples drilled from the field, which might be affected by the drilling process. Restoration of the wettability is attempted by restoring the oil coating of the rock surface, but this might not represent the original reservoir wettability. It would be ideal if wettability could be measured in the reservoir directly. There are standard qualitative methods performed in the laboratory to obtain information on wettability for natural rock materials like Amott-Harvey or the USMB method [3], but they cannot be used insitu. In the literature, zeta potential measurements are opted as possible method to derive wettability [4,5] with a potential to be extended to field measurement and existing flooding set-ups in the lab could rather easily be extended to incorporate the measurement.

Zeta potential represents the surface charge of a material. Materials in contact with water can form a charged surface, which charge is counterbalanced by ions in the liquid. The ions form an electrical double layer (EDL), which is partially movable with the fluid. The electrical potential at the slip plane of EDL is known as zeta potential (ZP), a measure of the macroscopic charge state of solid surfaces or colloidal particles in contact with a solvent [6]. The zeta potential plays a significant role in various fields, including colloidal dispersion stability, flocculation and coagulation, drug delivery system design, cosmetics, the food industry, and material surface characterization. In this project zeta potential is explored to be used to quantify wettability.

The initial work centered around developing a trustful flooding set-up to measure zeta potential based on measuring the voltage difference that builds up when charge during flow is moved, named streaming potential, which can be converted in zeta potential by the modified Helmholtz–Smoluchowski equation [7,8]. Most zeta potential data for consolidated porous samples are obtained using an in-house-built flooding apparatus, without an established benchmarking procedure, resulting for comparable systems in a large spread in zeta potential values [3]. With the objective of establishing a benchmark, zeta potential measurements were conducted on soda lime glass bead packs, comparing two experimental setups: an in-house system and a commercial electrokinetic analyzer, by evaluating the bead size on electrokinetic responses in sodium chloride solutions.

Results show that identical solid–liquid systems can yield distinct zeta potential values depending on the experimental setup, highlighting the importance of measurement configuration and system size in comparative studies. Measurements across bead packs with different bead sizes revealed an increase in zeta potential magnitude with decreasing bead radius, see ***Figure 2***, contradicting predictions from the modified Helmholtz–Smoluchowski equation for porous media [9]. Additional comparisons with glass plates of similar composition indicate that smaller beads exhibit apparent zeta potential overestimation, likely due to surface reactivity and pH variation. The initially assumed inert glass beads show not to be inert, increasing the pH of the brine from 6 to ~10. The effect of pore size dependent surface reactivity provides for the first time a plausible explanation for a size dependent zeta potential, also observed by others [5,10]. However, the intended benchmarking failed and is to be obtained using non-reactive material.

As next step zeta potential was measured for bead packs having different wetting states, to systematically test whether zeta potential can be used for determination of the wetting state. The different wettability states of the beads were established by silanization, exposing the bead samples to different coating solutions [11]. The sample wettability was characterized by an average contact angle. The bead size was kept constant, assuming reactivity is comparable. Results seen in ***Figure 3*** show that the correlation between the zeta potential of the single-sized bead pack with a homogenous wetting state and the corresponding contact angle is non-unique. The contact angles become constant at a higher degrees of silanization (surfasil-heptane volume ratio), while the zeta potential values still change. Before the plateau, a correlation between contact angle and zeta potential is present, where with zeta potential decreases with increasing contact angle.

The non-unique correlation between zeta potential and contact angle, combined with a bead size-dependent zeta potential, will limit the use of zeta potential for contact angle derivation at least for the system of soda lime glass beads with various silanization coatings used here. Monitoring relative changes of wetting conditions might still be possible.

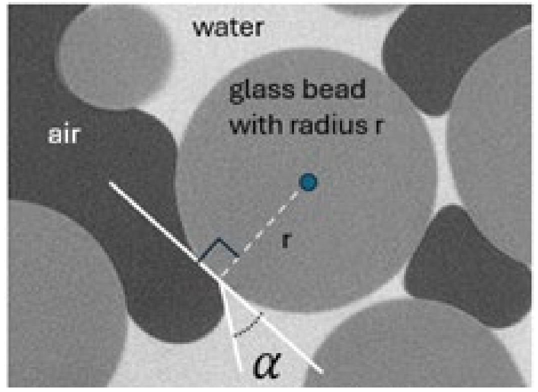


Figure 1: *Cross section through a bead pack, by mCT scan imaging, showing a contact angle measurement at a 3-phase contact point, where water-air and the glass bead meet, using the plane perpendicular to the normal through the bead center. This sample is water wet.*

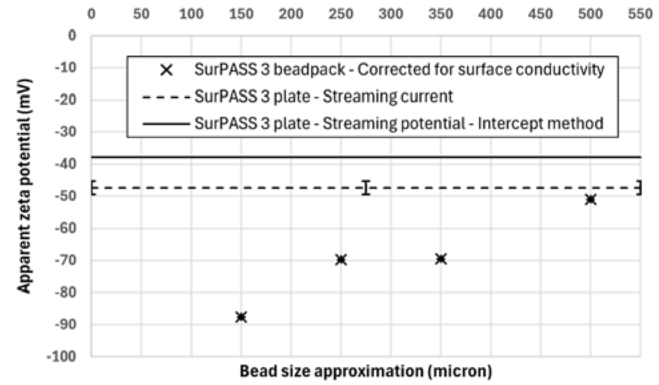


Figure 2: *The measured zeta potential for glass bead packs of different sizes using a 1mM NaCl solution at 21°C and a pH of 5.9, showing a size dependent zeta potential using the commercial electrokinetic analyzer (x), with the plate data depicted as lines calculated in 2 different ways.*

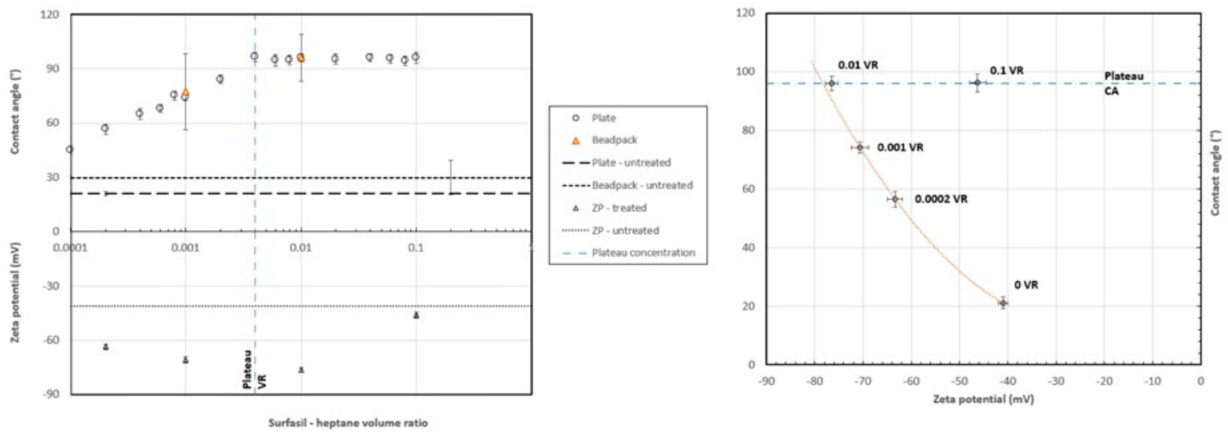


Figure 3: *The graph on the left shows the independent measured Contact angle(top) and Zeta potential (bottom) dependent on the concentration reactant Surfacil in the coating solution (180sec. exposure), the graph on the right shows the non-unique correlation between the zetapotential and contact angle.*

A data-set extension and further studies on non-reactive materials will need to be performed to explore the correlation of zeta potential and wettability.

This summary is based on the following two articles and for further details:

[1] T. Vukovic, J. Røstad, T. Luxbacher, J. Vinogradov, U. Farooq, O. Torsæter, A. van der Net. Zeta potential of glass bead packs — Streaming potential apparatus bench-marking and search for a reference value. Colloids and Surfaces A: Physicochemical and Engineering Aspects, Volume 732, 2026, 139150, https://doi.org/10.1016/j.colsurfa.2025.139150.

[2] T. Vukovic, T. Luxbacher, J. Røstad, U. Farooq, O. Torsæter, A. van der Net, Correlation Between Interfacial Parameters in Bead Packs: Contact Angle and Zeta Potential. Colloids and Interfaces 2026,10,19.

ADDITIONAL BIBLIOGRAPHY

[3] H. Karimaie, A. van der Net, O. Torsæter, Core Analysis of Reservoir Rock systems, 2025, CRC Press

[4] Jackson, M.D.; Vinogradov, J. Colloids Surfaces A Physicochem. Eng. Asp. 2012, 393, 86–95.

[5] Sadeqi-Moqadam, M.; Riahi, S.; Bahramian, A. Colloids Surfaces A Physicochem. Eng. Asp. 2016, 497, 182–193.

[6] M. Predota, M. L. Machesky, D. J. Wesolowski, Langmuir 32 (40) (2016) 10189–10198.

[7] A. Revil, P. A. Pezard, P. W. J. Glover, J. of Geophysical Res: Solid Earth 104 (B9) (1999) 20021–20031.

[8] A. Revil, H. Schwaeger, L. Cathles III, P. Manhardt, J.of Geophysical Res: Solid Earth 104 (B9) (1999) 20033–20048.

[9] P. W. Glover, N. Déry, Geophysics 75 (6) (2010) F225–F241. doi:10.1190/1.3509465.

[10] A. Boleve, A. Crespy, A. Revil, F. Janod, J.-L. Mattiuzzo, J. of Geophysical Research: Solid Earth 112 (B8) (2007).

[11] T. Vukovic, J. Røstad, U. Farooq, O. Torsæter, and A. van der Net, ACS Omega 2023, 8, 36662−36676

HOW SEALS FORM LABYRINTHS IN THEIR NOSES

Hyejeong L. Cheon[1], Natalya Kizolova[2], Eirik G. Flekkøy[3], Matthew J. Mason[4], Lars P. Folkow[5], Signe Kjelstrup[2], Jonathan E. Kings[3], Øyvind Hammer[6] and Fengzhu Xiong[4,7]

[1] PoreLab, Department of Physics, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[2] PoreLab, Department of Chemistry, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[3] PoreLab, Department of Physics, University of Oslo, Oslo, Norway
[4] Department of Physiology, Development & Neuroscience, University of Cambridge, Cambridge
[5] Department of Arctic and Marine Biology, UiT, the Arctic University of Norway, Tromsø, Norway
[6] Natural History Museum, University of Oslo, Norway
[7] Gurdon Institute, University of Cambridge, Cambridge, UK

Labyrinthine structures that are formed in the lab using granular, non-living materials are seen in the PoreLab logo. However, similar labyrinthine structures are found in heat exchange organs (called maxilloturbinates) that some animals, like seals, reindeer and dogs have in their noses, see figure 2, which shows a cross section of such an organ. The intriguing questions, that seemed to beg an answer, was if there could be a common origin or description of these visually similar patterns. In order to address this question, we performed simulations using a model where the boundary line that separates the organ and the air in a cross section had evolved according to simple mechanical rules. An image of such a cross section is shown in figure 2 while the corresponding modelling of the evolution during the growth of the animal is shown in figure 3. The model simply describes a boundary line that grows within a confining circle, and while it grows it folds into a convoluted structure that that is constrained only by the condition that it does not overlap with itself or the confining outer circle.

Indeed, the granular labyrinths and the biological ones are quite similar, also in terms of quantitative measures (such as fractal path dimension and branching ratios) that describe their geometry. This demonstrates that the detailed architecture of the resulting patterns does not have to be genetically encoded but may result from an algorithm or recipe that in itself contains much less information than what is needed to describe the end result.

RECOMMENDED READING

[1] Hyejeong L. Cheon, Nataliya Kizolova, E.G. Flekkøy, Matthew J. Mason, Lars P. Folkow and Signe Kjelstrup, 2024. The nasal cavity of the bearded seal: An effective and robust organ for retaining body heat and water, *Journal of Theoretical Biology* Volume 595

[2] Jonathan E. Kings, Lars P. Folkow, Øyvind Hammer, Signe Kjelstrup, Matthew J. Mason, Fengzhu Xiong, and Eirik G. Flekkøy, 2025. A model for maxilloturbinate morphogenesis in seals. *PLOS ONE*, published 3 March 2025. doi.org/10.1371/journal.pone.0316669

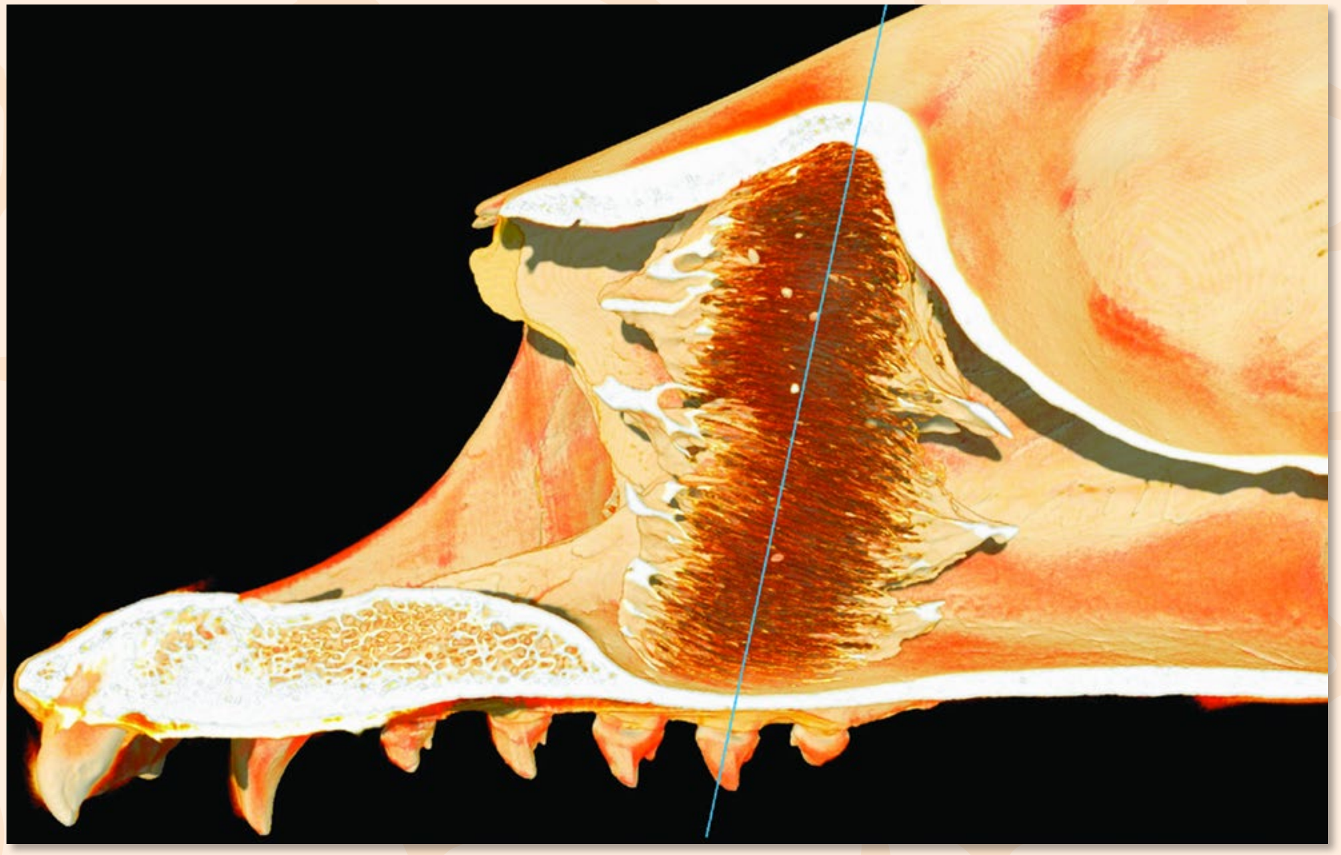


Figure 1: *CT reconstruction of the maxilloturbinate region of the adult harp seal (specimen 7495), sectioned parasagittally [2]*

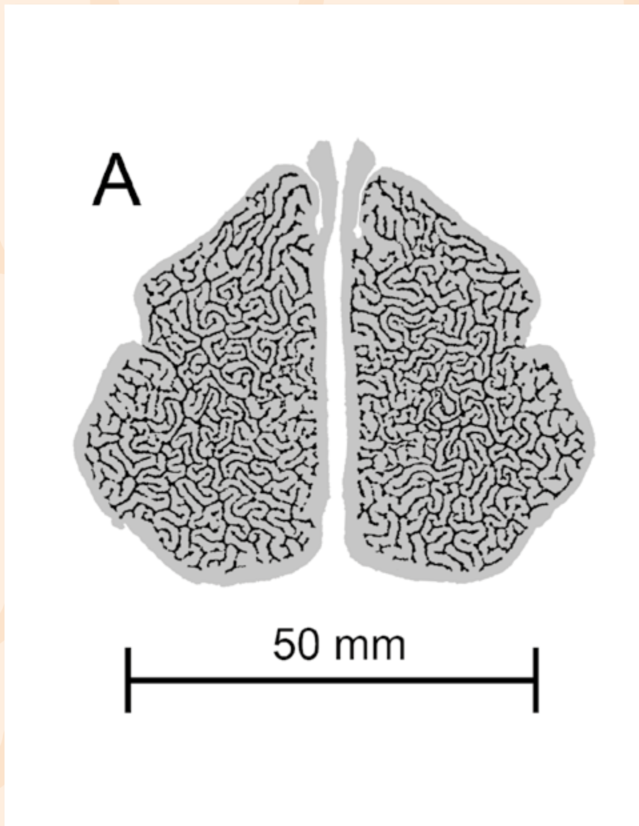


Figure 2: *A cross-section through the heat exchange organ, a maxilloturbinate, of a subtropical seal (Monachus monachus). The air flow is transverse to the plane of the image.*

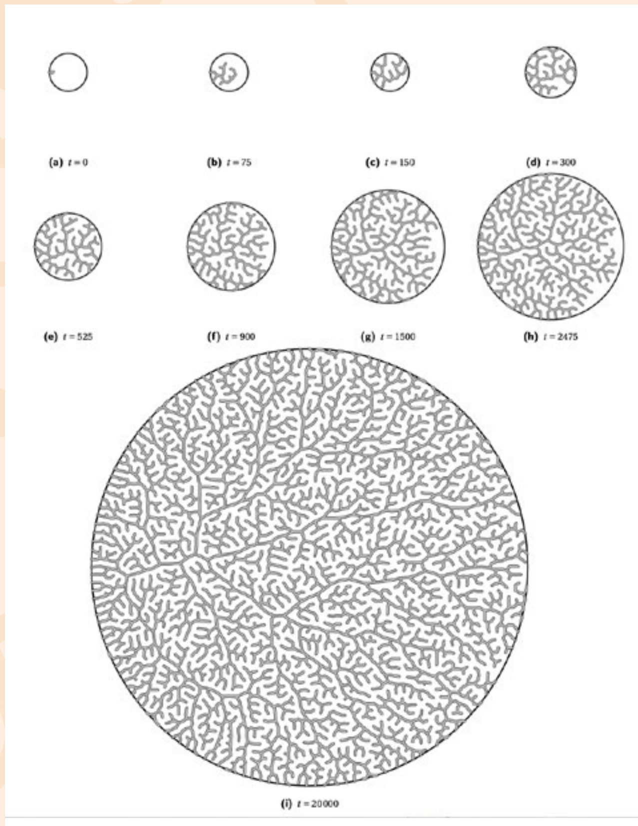


Figure 3: *Evolution of a model that simulates the growth of a maxilloturbinate only on the basis of local elastic interactions.*

RESEARCH PROJECTS

LONG RANGE HEAT PROPAGATION IN POROUS MEDIA

Eirik G. Flekkøy[1,2], Alex Hansen[3] and Erika Eiser[3]

[1] PoreLab, Department of Physics, University of Oslo, Oslo, Norway
[2] PoreLab, Department of Chemistry, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[3] PoreLab, Department of Physics, Norwegian University of Science and Technology, NTNU, Trondheim, Norway

Water in small (nanometer sized) pores freezes below 0°C. Such freezing point depression is well known as the 'Gibbs-Thomson effect' which may cause ice to form only at temperatures as low as -40°C. The actual freezing point depends mostly on the size of the pores, but also on such factors as salinity and pore geometry. When a heat front causes the temperature to rise, smaller pores will melt before the larger pores, *see figure 1*. A major part of the heat goes into the melting process rather than the temperature increase of the porous medium itself, and so, as pores of different sizes melt at different temperatures many of the pores will not absorb much heat. In other words, the heat bypasses a main fraction of the pores that do not melt, or have already been melted. An interesting result of this effect is that melting fronts in nano-porous materials will spread out much more when the freezing point depression is an active effect, than when it is not.

Figure 2 illustrates this: Here the time- and length scales are chosen to represent the melting of ice in the ground of a tundra, assuming that sufficiently small pores are present there. During the summer a heat front propagates downwards, causing water to melt at depths of some meters. Without the freezing point depression, however melting only extends to depths of 2-3 meters, while the presence of the freezing point depression may cause melting down to 10-20 meters.

Our theoretical work on this effect maps out how various parameters affect the flow of heat in porous media of different geometrical compositions and suggests a practical route to carry out experimental validations of our predictions.

RECOMMENDED READING

Eirik G. Flekkøy, Alex Hansen and Erika Eiser, Heat and super-diffusive melting fronts in unsaturated porous media, *Frontiers in Physics* **13**, 1610082 (2025)

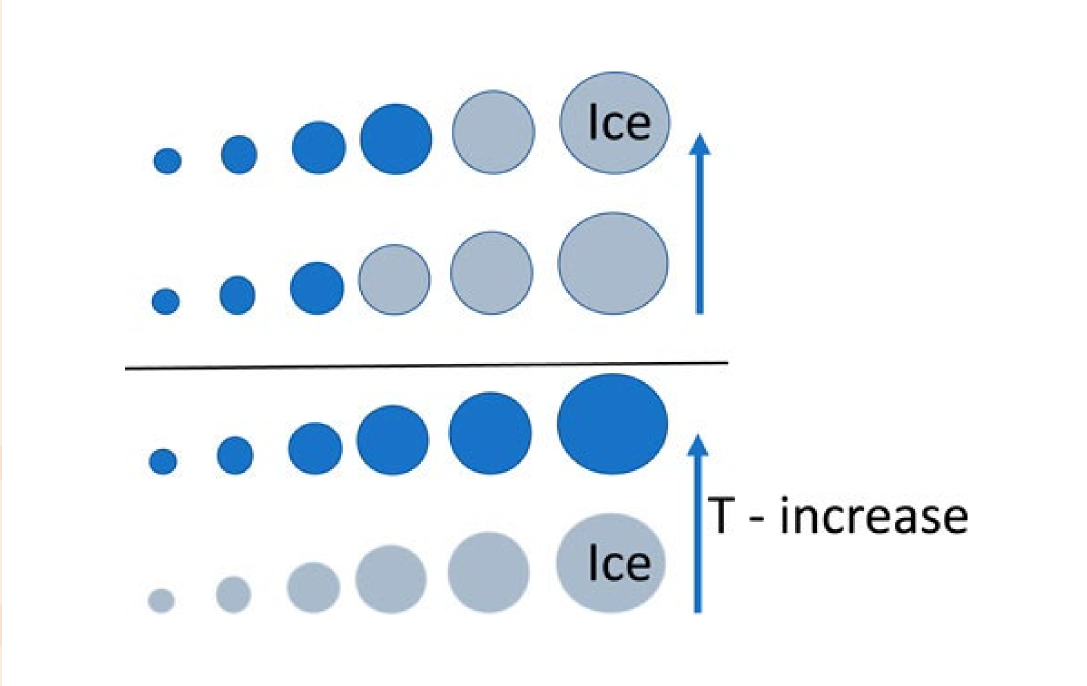


Figure 1: *Nano-scale pores containing water. The upper figure shows ice melting when the freezing point depression is present, while the lower figure shows the melting process without this effect. Ice is shown in gray, and liquid water is shown in blue.*

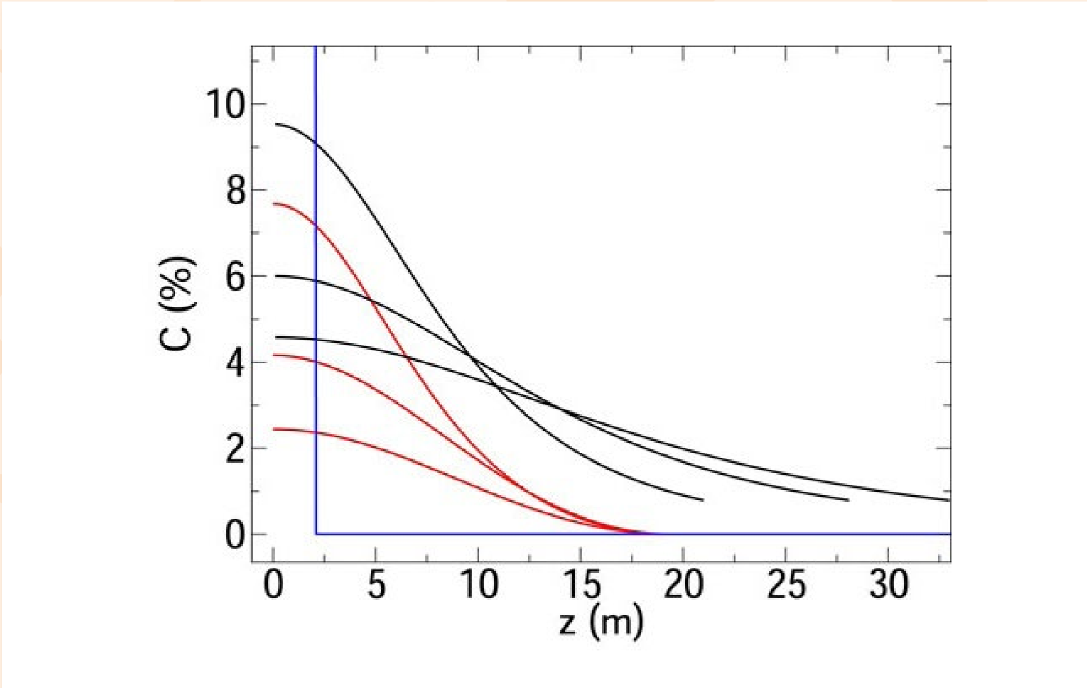


Figure 2: *The melted water fraction as a function of depth at the different times t=4 months, 8 months, and 12 months. The black curves show predictions that ignore the heat capacity of the porous media, only including the latent heat of melting, while the red curves show the more realistic case where the heat capacity is included. By comparison, the blue curve shows the case where there is a no effect of the freezing point depression, and the melting front is much shallower.*

RESEARCH PROJECTS

MAKING BUBBLES AT THE MICROSCALE

Yuequn Fu[1] and Eirik G. Flekkøy[1,2]

[1] PoreLab, Department of Physics, University of Oslo, Oslo, Norway
[2] PoreLab, Department of Chemistry, Norwegian University of Science and Technology, NTNU, Trondheim, Norway

When a porous medium containing a liquid, like water, expands so fast that the liquid does not have time to fill the extra space, it will boil, forming a bubble of its own vapor. This process, which is known as cavitation, is perhaps most commonly observed behind boats where the propellor causes these bubbles by a local pressure reduction. At very small scales, in an expanding confinement cavitation, bubbles are even more likely to form as the relative importance of viscous forces is larger and so may cause larger local pressure drops.

This is the case in the simulations illustrated in *figure 1*, where a bubble forms as a solid sphere in water is pulled away from a plane. When this happens, the hydrodynamic force on the sphere changes rapidly. In a sense, the water that is responsible for the viscous forces, ruptures as the liquid is suddenly replaced by the much less viscous vapor. Therefore, this small scale, short lived process may by important during such geological processes as landslides or earthquakes where deformation happens in a water-filled granular media.

The simulations were carried out using molecular dynamics with realistic inter-molecular forces between water molecules and silica molecules. Such simulations are limited to small time and length scales, but they resolve the bubble dynamics at the nanometer/nanosecond scales of interest. *Figure 2* shows quantifications of the process: Most notably, the behavior at different pulling speeds gives rise to a data-collapse where all the simulation results are represented by one single curve *(figure 2b)*. A surprising property of cavitation bubbles at small scales is that they live shorter the larger they are: More precisely, the maximum volume of the bubbles decreases with their lifetimes with an exponent of -2/3, see *figure 2d*, which shows this behavior.

RECOMMENDED READING

Yuequn Fu and Eirik G. Flekkøy: Molecular simulations of cavitation bubble dynamics, *Frontiers in Physics* **13**, 1614785 (2025)

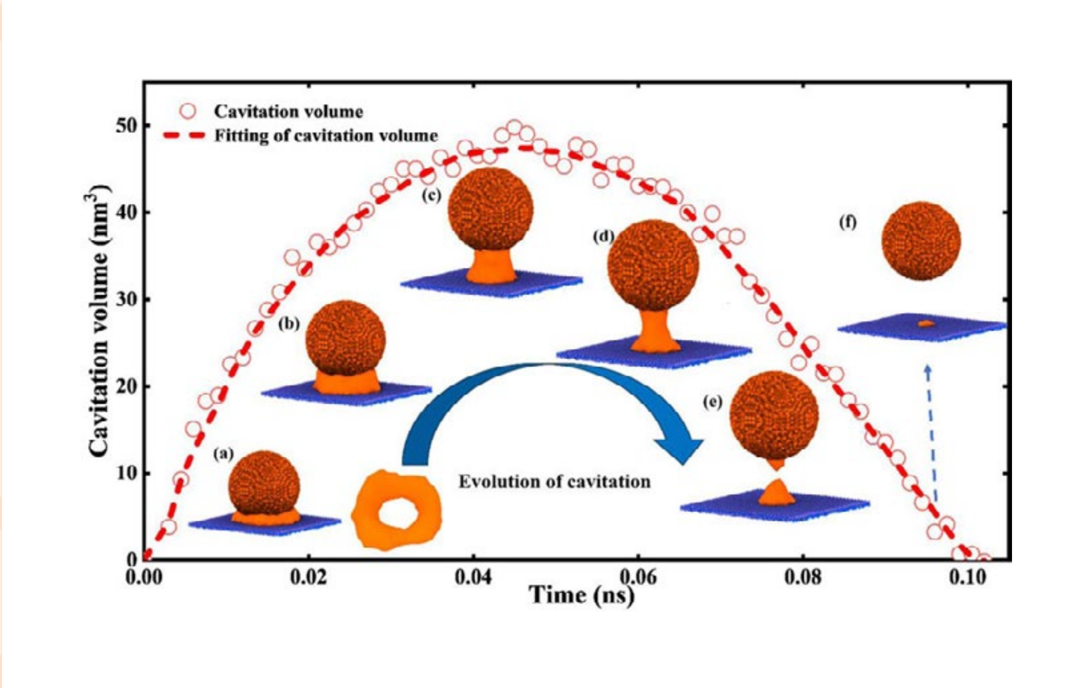


Figure 1: *Molecular dynamics simulations of a cavitation bubble forming in water under a solid silica sphere that is pulled suddenly upwards*

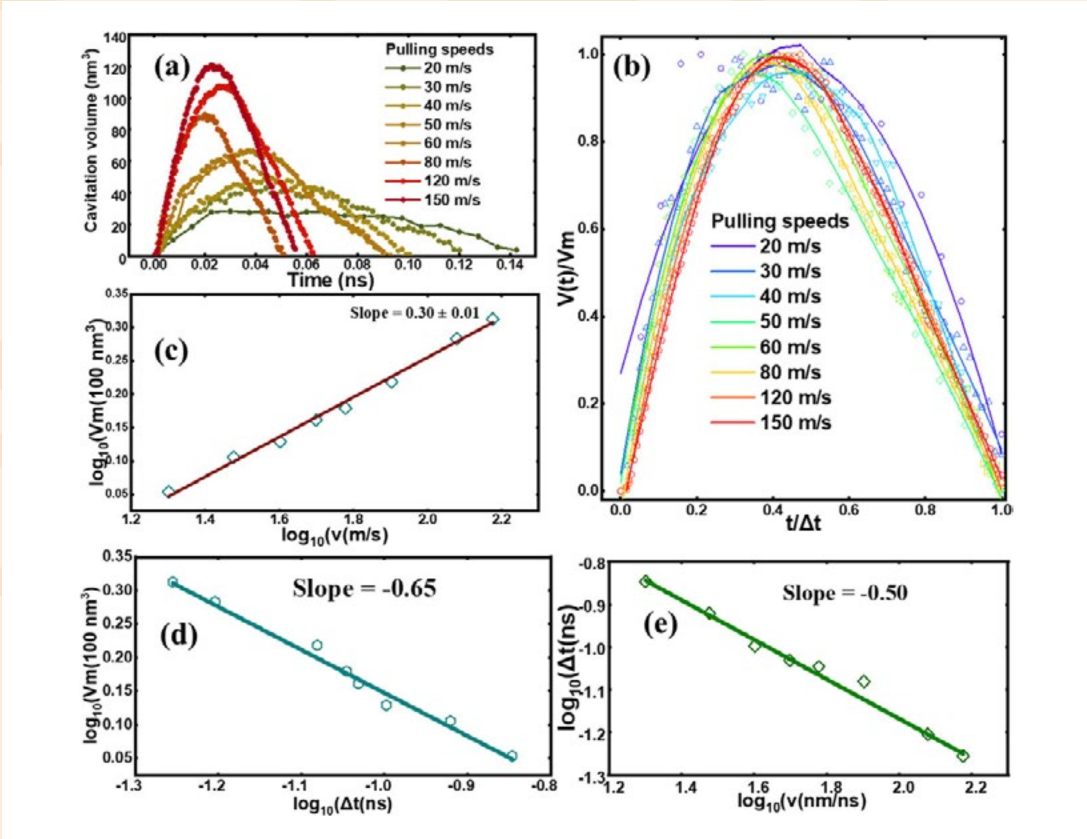


Figure 2: *(a) Bubble volume versus time, (b) collapse of the data (dots) and their fitting curves (lines) showing the bubble volume normalized by its maximum value versus time normalized by the lifetime of the bubble, (c) the maximum volume as a function of the pulling speed, (d) the maximum volume as a function of lifetime, and (e) the lifetime as a function of pulling speed.*

HOW WALLS SHAPE PHASE CHANGE

Vitor H. C. Cunha[1], Øivind Wilhelmsen[1], Carlos A. Dorao[2], Maria Fernandino[2]

[1] PoreLab, Department of Chemistry, Norwegian University of Science and Technology, NTNU, Trondheim, Norway
[2] Department of Energy and Process Engineering, Norwegian University of Science and Technology, NTNU, Trondheim, Norway

Ultrathin fluid films, often thinner than 100 nanometers, appear in many settings where fluids touch solids. At these scales, gravity and inertia are usually weak. Intermolecular forces, such as van der Waals and electrostatic interactions, become dominant. These forces can control adsorption, wetting, evaporation, condensation, and film stability. To understand nanoscale fluid morphologies, we therefore need models that can represent both the dynamics and the underlying thermodynamics.

Capturing these phenomena in predictive continuum models is challenging because the standard formulations often require assumptions about the behavior of the liquid vapor interface. In many continuum models, the role of the solid is introduced mainly through boundary conditions. Typical examples are imposed contact angles, wall energies, or disjoining pressure type terms. These tools are useful and often accurate at larger scales. However, at nanometric scales the interface is diffuse, density varies strongly, and the effect of the wall can extend a finite distance into the fluid. In that case, it becomes restrictive to treat solid fluid interactions as something that acts only at the boundary.

In this work, we take a complementary approach. We use a phase field description, where the liquid vapor interface is represented as a smooth transition in density. This type of model relies on an energetic description of the system. We build that description using density gradient theory, which provides a thermodynamically consistent free energy that includes bulk fluid energetics and interfacial gradient energy. We then couple this energetic formulation to the Navier Stokes Korteweg equations, which describe the dynamics of a compressible fluid with capillary stresses and diffuse interfaces. The key step is to add a Lennard Jones like solid fluid interaction potential directly into the free energy. This makes the wall influence part of the same thermodynamic structure that drives the flow. It also produces a body force in the momentum balance, instead of encoding everything through boundary conditions.

Using this formulation, we then examine how the interaction potential reorganizes the fluid near the wall in both vapor and thin film settings. In vapor systems, attractive interactions compress the fluid close to the wall and form an adsorption layer. The layer remains vapor like, but becomes denser than the far field, and it is accompanied by a local pressure increase near the wall. As the repulsive component becomes stronger, this near wall densification is reduced and can even turn into a slight depletion, depending on the balance between attraction and repulsion. We then consider ultrathin liquid films in coexistence with their vapor. In the purely attractive case, the film is first compressed near the wall during an early transient. After that, the film thickens as vapor condenses into the liquid, driven by the energetic preference created by the interaction potential. When we impose heating or cooling at the wall, the interaction potential mainly modifies the late time evolution: during evaporation, near wall compression inhibits late time evaporation and stabilizes the film at a finite thickness, while during condensation the film grows at first and then gradually approaches a stabilized state as the near wall region relaxes toward equilibrium.

Overall, the message is simple. Solid fluid interactions can control adsorption, pressure, and interfacial mass transfer at nanometric scales. A main contribution of this paper is to treat these interactions as a nonlocal contribution inside the free energy, not only as a boundary condition. This preserves thermodynamic consistency while allowing the wall to influence the fluid over a finite distance into the domain. The approach complements molecular simulations by enabling longer time and larger length scale studies, while keeping a physics based link to intermolecular forces. This perspective is also relevant when thinking about porous media, where flow is dominated by confinement, surface forces, and transience. Many current porous media applications involve large scale engineering, such as CO_2 storage and carbon capture, geothermal and heating technologies, and subsurface water and energy storage, where improved predictive models can directly improve design and risk assessment. Phase change in pores is often transient. It evolves in time and can be strongly influenced by adsorption layers, thin films, and near-wall confinement effects. A continuum framework that can describe these transient nanoscale processes, while accounting for solid fluid interactions beyond boundary conditions, is a useful step toward studying phase change dynamics in confined geometries.

This work was carried out through a collaboration between the Thermal Two Phase Flow Lab at the Department of Energy and Process Engineering and the Thermodynamics group at PoreLab, based at the Department of Chemistry. The study grew out of an ongoing research collaboration between these environments at NTNU, combining expertise in two phase flow, wetting and phase change with thermodynamic modeling. The collaboration also supported researcher mobility across departments, linking the PhD work carried out in the Thermal Two Phase Flow Lab with the continued development of the project within PoreLab.

RECOMMENDED READING

Vitor H. C. Cunha, Øivind Wilhelmsen, Carlos A. Dorao and Maria Fernandino. Introducing nonlocal solid-fluid interactions into the Navier-Stokes-Korteweg model. *Phys. Rev. Fluids*, **10**, 124001, 2025. DOI: https://doi.org/10.1103/qknz-k9cs .

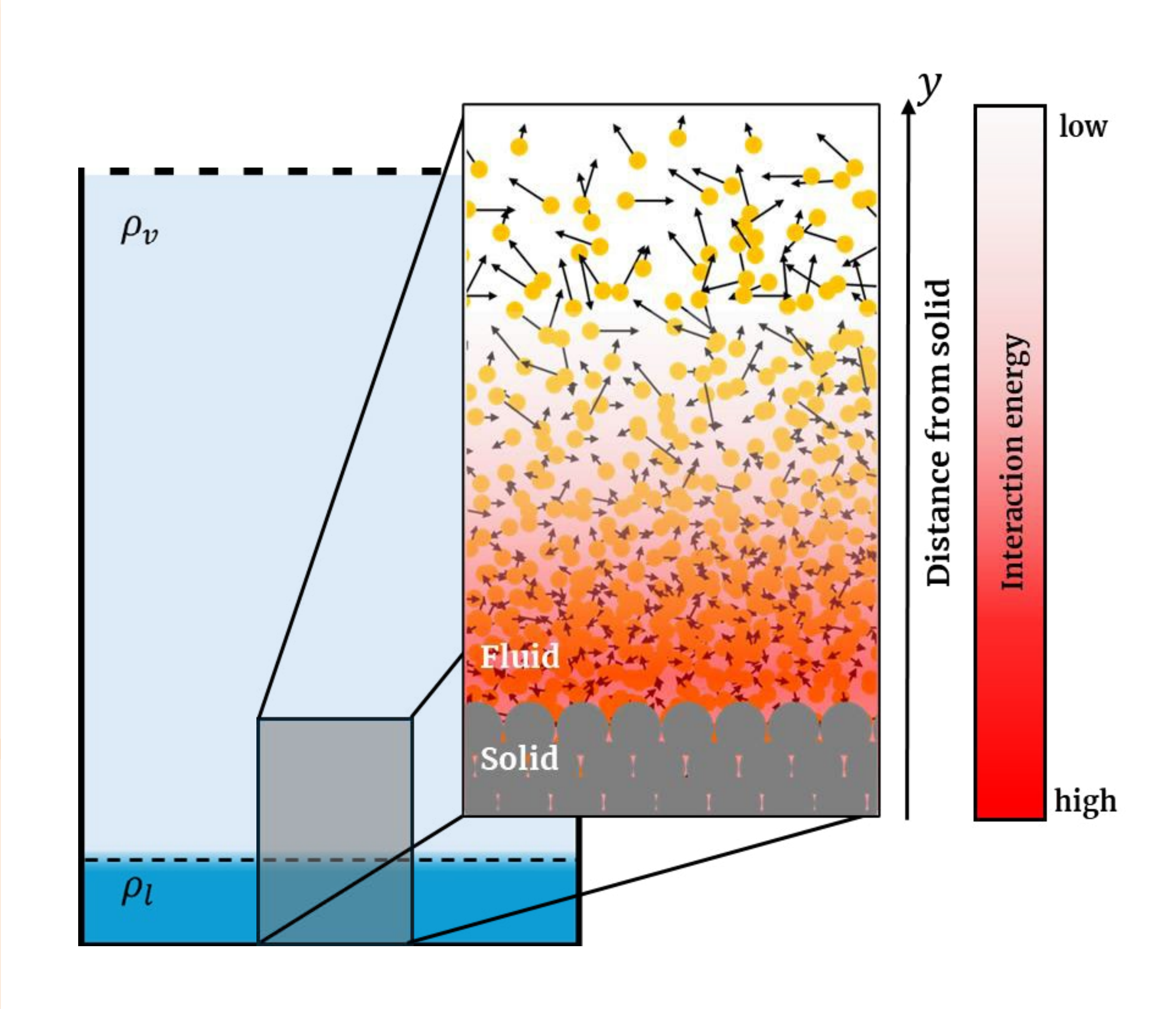


Illustration by Vitor H. C. Cunha

RESEARCH PROJECTS

POSTDOC

QUIRINE KROL

Department of Physics, NTNU

Who are you? What is your background?

I am a snow physicist driven by a curiosity for emerging phenomena and their underlying physics, especially how microstructure shapes the behavior of the snowpack at larger scales. My work combines modeling, simulations, and experiments such as micro-computed tomography and magnetic resonance methods. I focus on understanding vapor transport, coarsening processes, and melt–refreeze dynamics.

I studied Theoretical Physics in the Netherlands, and when a PhD position in Snow Physics in Davos was advertised, I immediately felt it was a perfect match. My PhD (at the University of Lausanne) focused on microstructural changes in snow throughout the winter season. Thereafter, I worked as a postdoc at ETH Zurich on computational microfluid dynamics in porous media and wrote two research proposals to study snowmelt with magnetic resonance methods in the USA and Norway.

Photo: Flash evaporation experiment with boiling water spray at -25°C.
***Disclaimer:** No animals were hurt during the experiment.*

Can you elaborate on your current project?

My current project is funded through a Marie Skłodowska-Curie Action (MSCA), which has allowed me to develop an independent research line at the interface between snow physics and advanced imaging. The core objective is to better understand phase-change and mass transport processes in snow by using magnetic resonance methods in a way that has not traditionally been applied in cryospheric research.

In the final stage of the project in Trondheim, I focus on the analysis of rapid one-dimensional MRI profiling to monitor melt processes in snow and other porous media. Instead of relying solely on classical imaging, we use frequency-encoded profiles to capture changes in signal intensity associated with water redistribution and flow events at 10–100 ms temporal resolution. This approach makes it possible to resolve the dynamics of meltwater distribution within a snow sample, as well as single flow events such as the onset of percolation.

The results demonstrate that we can record short-lived flow events, such as Haines jumps, and structural transitions that are difficult to capture with conventional methods. This opens a pathway toward linking pore-scale dynamics directly to macroscopic snow hydrology, which is one of the central challenges in current snow modeling.

Why did you decide on coming to Norway and PoreLab specifically?

PoreLab was especially compelling to me because of its focus on porous media physics. Snow is, fundamentally, a highly dynamic porous material, and many of its processes involve phase changes that are ultimately governed by pore-scale interactions. Being embedded in an environment where pore-scale theory, experiments, and upscaling methods are central themes allows me to connect my snow physics background to a broader physical framework. It felt like the right place to deepen the fundamental understanding of snow while contributing my expertise in cryospheric applications.

Besides science, what are your hobbies?

I love nothing more than experiencing snow in its natural environment, whether through skiing, climbing, or riding my horse through the winter landscape. Ice crystals and the way they grow continue to fascinate me both scientifically and aesthetically.

PHD

ILARIA BEECHEY-NEWMAN

Department of Physics, NTNU

Who are you? What is your background?

I am Ilaria, a final year PhD candidate in the department of physics at NTNU, as part of PoreLab and under the supervision of Erika Eiser. Before moving to Norway to do a PhD, I completed an integrated master's degree in chemistry at the University of Oxford in the United Kingdom, where I grew up. In my master's thesis, as part of the Physical and Theoretical Chemistry Laboratory, I explored the physical properties of water-in-salt electrolytes and ionic liquid mixtures, for their potential use in lithium-ion batteries.

What area of physics is your PhD about?

Broadly speaking, my PhD topic fits under the area of Soft Matter physics, as it aims to explore processes of self-assembly in colloidal systems. More specifically, my primary PhD project has been to investigate the physical processes behind the formation of self-assembled patterns produced as a result of the drying of droplets of colloidal suspensions.

What are the most important results so far?

The most important result is that we have been able to produce beautiful, self-assembled, fractal-like, fingering patterns reproducibly. We have developed an experimental set up that allows for the evaporation rate of the droplet of colloidal suspension to be extremely slow, on the order of a week or so, which is key to achieving just the right balance of forces that allow for the colloids to assemble themselves in this way. This work is detailed in full in our paper published in PNAS in August 2025.

What is your favourite activity in your research?

My favourite activity in my research has to be synthesising colloids. Given my background as a chemist, it might be unsurprising that I like being in the lab and doing chemistry. I find it to be quite therapeutic, in the same way that baking a cake can be. At the end of the day, chemistry and baking are both about measuring accurately, mixing meticulously, and 'cooking' for just the right amount of time!

What made you decide to come to Trondheim, Norway?

Having only ever lived and studied in the UK, I was keen to have a novel study and research experience. Apart from the specific research project, I was drawn to Trondheim because I wanted to live somewhere relatively quiet and peaceful, to contrast with the high-paced and chaotic nature of research and graduate studies. Trondheim's medium size and proximity to untouched nature is a great asset in this respect. I was also drawn by Norway's strong culture around work-life balance, which in the academic world can be lacking. I felt that these two aspects would enable me to do a PhD in a happier and healthier way.

How is the working environment at PoreLab?

PoreLab has a highly social working environment, where interaction between PhDs, post docs, and professors is encouraged and facilitated. This allows for greater collaboration across each topic or group within PoreLab, leading not only to better research, but to a happier and more relaxed cohort of researchers.

PHD

RENÉ TAMMEN

Department of Physics, NTNU

Who are you? What is your background?

Moin, my name is René Tammen, and I am from Bremen, Germany. Currently, I am in the final year of my PhD at Porelab in the Department of Physics at NTNU. My academic background is in geology. I received my bachelor's degree in Geoscience, with a focus on marine geology, from my hometown university in Bremen. I obtained my master's degree in Hannover, Germany, where I focused on geochemistry and mineralogy.

After my studies, I honestly did not see myself pursuing a PhD and started working as a geologist in a mineral testing lab in Sodankylä, Finland. However, when I saw the PhD position I am currently in, I just had to apply because it sounded so interesting.

Tell us more about your project

My PhD work is part of the Sustainable Stable Ground (Bærekraftig Grunn) project. This is an interdisciplinary collaboration involving the Departments of Physics, Structural Engineering, Mechanical and Industrial Engineering, Chemistry, and Civil and Environmental Engineering at NTNU. Together, we are working toward a deeper understanding of quick clay and improving the stabilization of these marine clay formations in order to reduce the carbon footprint.

Our work spans multiple length scales, starting at the atomic level and scaling up to the macro scale. My own work focuses on the nano- to microscale. In this part of the project, I study the physical and chemical interactions between clay particles using a range of experimental setups and techniques. This proved important information for finding new additives in the stabilization technology. This provides important information for identifying new additives for stabilization technologies.

Why is your research important?

Quick clay is a metastable marine clay formation. When it is disturbed, it can liquefy and lead to deadly landslides. Although modern stabilization technology using lime cement is effective and relatively low-cost, it produces a large carbon footprint. My work contributes to improving these methods by reducing the amount of lime cement needed, thereby lowering the carbon footprint while still ensuring that quick-clay areas remain stable. In this way, we are helping to protect the environment, lives, and infrastructure.

What is your favorite activity in your research?

Being in the lab! Testing different things and ideas to see how the clay behaves is simply fascinating. Not everything works, but figuring out why some experiments succeed while others don't is real fun and often leads to more ideas.

How is the working environment at PoreLab?

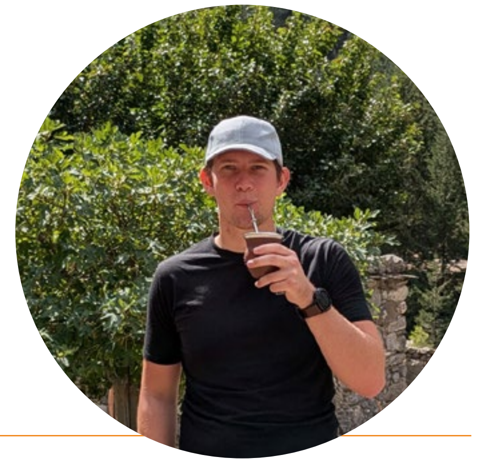
PoreLab is an amazing place to work and grow as a scientist! We are people from different backgrounds and departments, which leads to many interesting discussions. Especially on Mondays, when we all meet at the Onsager table and enjoy a delicious cake from Marie-Laure.

Also, having the opportunity to do puzzles or play table tennis as a short break from work is excellent for refreshing your mind and chatting with colleagues. I have really enjoyed my time at PoreLab.

PHD

ANDREAS ANDERSEN HENNIG

Department of Physics, NTNU



Who are you? What is your background?

My name is Andreas, and I grew up in a town called Halden – known for our famously humane prison (which appears on a Netflix documentary), tall concrete towers (some call Halden the New York of Norway), prize winning architecture (ugliest building 2024) and important fortress (making us the only mentioned city in our national anthem). There, I had some fantastic teachers who showed me the wonders of physics and mathematics, which is what I went on to study. I particularly enjoyed fluid mechanics and statistical physics, and was lucky to find the MSc project in PoreLab with Alex Hansen and Laurent Talon, which sent me on an adventure to Paris. Now I am halfway into a PhD in PoreLab, working both on experiments and simulations while I enjoy my yerba mate and daily ping-pong. Other than physics, I spend my time biking all over Norway, skiing with my wife, and trying to read a bit of non-physics books too.

What area of physics is your PhD about?

I am working on evaporating liquid interfaces with dispersed colloidal particles. This is an area within Soft Matter Physics, which is concerned with all materials that are not exactly solid and not exactly fluid – something in between. My project aims to better understand the mechanisms at play when confined colloidal droplets dries to form mazes, in which particle interactions, surface tension, Brownian motion and hydrodynamic interactions play each their roles, acting at vastly different time-scales, which makes these systems notoriously hard to understand.

How are you performing your research?

I am mainly trained to perform numerical simulations on fluids. However, as I am mainly supervised by an experimentalist, I have grown more and more fond of experimental work too. I am working on a microscopy technique to study the dynamics of colloidal particles (DDM), and I perform simulations on similar systems. The simulations can give us a lot of extra information, like the local pressures and particle velocities, which is easier to compare with existing theory.

What is your motivation to be a part of PoreLab?

PoreLab is the binding agent between what the Norwegian industry is able to solve (reservoir flows) and what the world needs (secure and efficient CO_2-storage, predictable water supply, better batteries), with a very clear task for physicists: finding the right equations to describe these systems. On this mission, you quickly discover the elegance of thermodynamics, the beauty of flowing fluids and all the unexpected quirks of nature. PoreLab covers the two fundamental motivations for physics – utility and curiosity – in a way very few other research groups do.

How is the working environment at PoreLab?

The working environment at PoreLab is unique because we mix chemists, physicists and geoscientists even within each professor's group. We are spoiled with great research talks a few times a month with our PoreLab lecture series and learn to criticize papers in our journal club. In addition, the social environment is in full bloom, with daily ping-pong, bi-weekly board game nights and occasional dinner invitations.

PHD

TAGE WINTHER MALTBY

Department of Chemistry, NTNU

Tell us about yourself, how did you get here?

I'm a Norwegian from the town of Arendal which is in the south of Norway. I first came to NTNU as an integrated master student back in 2016 where I started as a teacher student in math and chemistry. I found out that I mainly enjoyed the science aspect and quickly changed my study to Industrial chemistry. This again led me to take the Irreversible Thermodynamics course where I got to have a project with Prof. Øivind Wilhelmsen. He's been my supervisor since, as I have written my master thesis and subsequently done my PhD work at PoreLab with the Thermodynamics group.

What does your project entail?

My project is funded through the FME known as HYDROGENi where my research is connected to risks associated with process of hydrogen liquefaction. In order to make hydrogen a liquid, we have to cool it down to very low temperatures. If the liquid contains impurities, like air components (argon, nitrogen, CO_2), these will crystallize and clog equipment. Our goal is to predict when this is going to happen using thermodynamics. This has led me to learn a lot of interesting things pertaining to solid-state physics, low temperature thermodynamics and loads more.

Who is involved in your research?

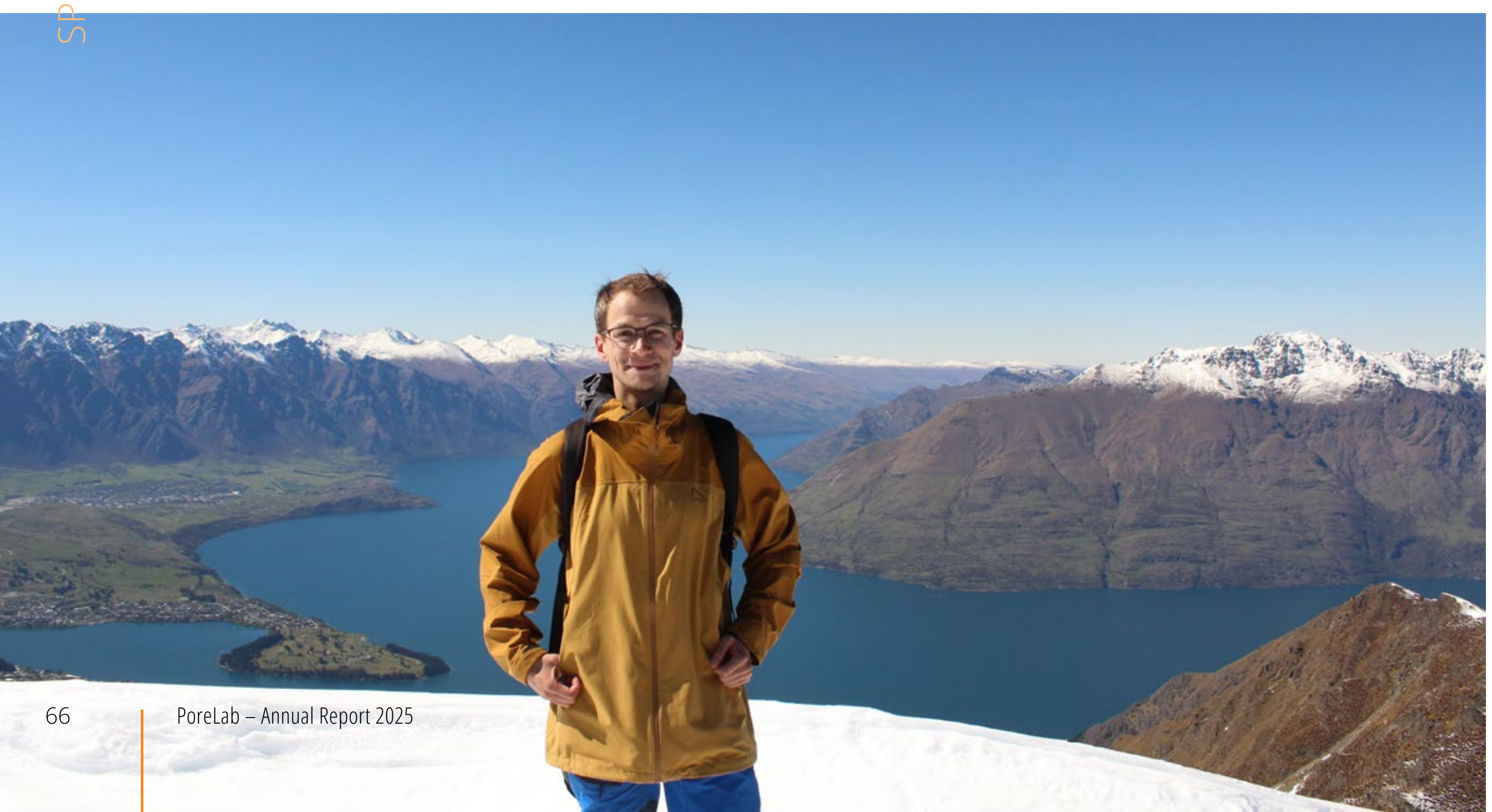
Most of my collaborators are from within the thermodynamics group. However, I have gotten to visit collaborators in New Zealand, at Massey University. I recommend everyone to do a research visit. It widens both your perspectives when it comes to collaborating, understanding problems, and more.

What do you find most fulfilling in working at PoreLab?

A cornerstone of how we work is built upon understanding underlying theories. So there is something very satisfying about acquiring accurate predictions within experimental uncertainty using said theories. It is also nice to have the trust where one can pursue new methodologies to assess a problem.

How is it to be a (PhD, post-doc, researcher) at PoreLab?

Just wonderful! In my years here we've been blessed with being a large group of PhDs, so the social cohesion has been second to none. Lunch chats are always interesting and activities like the Junior Forum have helped to get insight into various fields.



PHD

VEGARD GJELDVIK JERVELL

Department of Chemistry, NTNU

Tell us about yourself

I was born in Oslo but spent a lot of my youth living abroad. My family travelled from Norway to the US, and then to Bangladesh, before returning to Norway in 2008. Since then, I've taken a master's degree in chemical engineering at NTNU before starting my PhD with PoreLab. Here, I study interfacial thermodynamics and kinetic transport theory, which at first may seem very disconnected, but turn out to have some very interesting connections.

How did you become interested in kinetic theory?

It's a bit of a funny story really: In the fourth year of my master's, I was working on a project where I needed to reproduce some results from an article. I remember a sentence in the article stating that "Ref. 12 provides a practical guide to the calculation of the thermal diffusion factor". Following up that reference brought me to the university library and an absolute brick of a book from the 1960's. The book was anything but a "simple, practical guide" for a fourth-year student, but there was something awe-inspiring about reading about what these people had accomplished, that made me want to dig deeper in the field.

If anything, I've learned something about how seemingly inconsequential things, like a single sentence in an article I read during my studies, can have a big impact: I got to know my current supervisor during that project, and the topic of my PhD is a result of reading that single sentence and being ensnared by it.

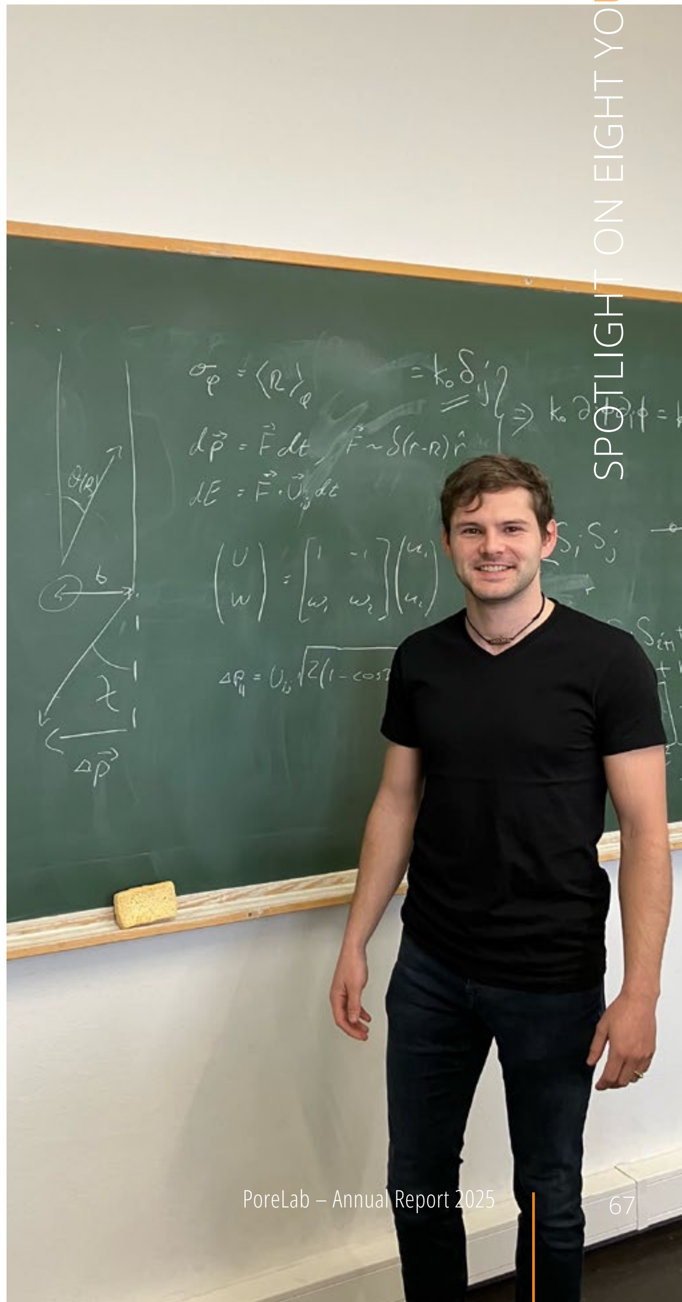
What are you hoping to find?

To be frank, it would be incredible if we were able to develop a fully predictive model for the transport properties of liquid mixtures. The only issue is that people have been trying to do that since the time of Boltzmann and Maxwell, so it's a bit of a high bar to hope that we'll be the ones to finally pull it off. On the other hand, I think it's fun to have ambitious goals. Even if we don't reach them, we'll hopefully make some progress that others can build on.

Why is your research important?

One side of things is the fact that experiments are expensive, and the industry needs accurate predictive models in order to design and run anything from a hydrogen liquefaction facility to a battery factory. Besides that, the research I'm doing is based on developing a broader understanding of how the properties of species on a molecular scale influence the macroscopic properties of gases and liquids.

Basically, we're trying to contribute some progress to the age-old question in statistical mechanics of how we can link our understanding of the everyday macroscopic world to the microscopic description of atoms and molecules. This is a problem some of the world's brightest researchers have wrestled with for over a century, but I sincerely hope that we can make at least a small contribution to the field.



PHD

MUKUL JAISWAL

Department of Physics, NTNU

Who are you? What is your background?

My name is Mukul Jaiswal. I am a Ph.D. student in physics, based at NTNU in Trondheim. My academic background is rooted in experimental physics, with education and training in laser physics and spectroscopy during my bachelor's and master's studies at University of Allahabad in India. Over time, my interests have shifted toward imaging and measurement techniques that allow us to observe physical processes as they happen, rather than only before-and-after states. This curiosity led me toward X-ray based methods, where physics, instrumentation, and data analysis intersect. Moving to Norway to pursue a Ph.D. at Norwegian University of Science and Technology offered a strong and supportive research environment, and access to advanced experimental infrastructure, making it a natural place to develop this line of work further.

What area of science is your PhD about?

My PhD focuses on the use of X-ray computed tomography to study multiphase flow in porous media. In simple terms, I work on methods that allow us to image the interior of porous materials in three dimensions while capturing their spatiotemporal evolution, often at millisecond or sub-millisecond scales. These systems are governed by capillarity, fluid dynamics, and interfacial physics, and they are notoriously difficult to describe using theory or simulations alone. Imaging provides a way to directly observe the relevant physics at the pore scale, where many macroscopic behaviours originate.

Importantly, the same imaging tools and analysis frameworks developed in my Ph.D. are not limited to multiphase flow. They can be applied to a wide range of dynamic processes in porous and heterogeneous materials, such as fracture formation, phase transitions, reactive transport, and structural evolution under mechanical or thermal conditions. This makes time-resolved X-ray tomography a broadly useful experimental approach for studying complex processes across physics, geosciences, medical science and materials science.

Who is involved in your research?

My research is inherently collaborative. It is primarily supervised by Prof. Dag W. Breiby with close scientific guidance from Dr. Basab Chattopadhyay. Other Co-supervisors of my Ph.D. project are Prof. Ragnvald H. Mathiesen at NTNU and Prof. M. Nadeem Akram at University of South-Eastern Norway. The work is carried out in continuous interaction with my supervisors, colleagues and collaborators working on porous media physics, X-ray physics, and quantitative data analysis.

Beyond NTNU, I collaborate with scientists at international large-scale research facilities such as ESRF-The European Synchrotron in France and Paul Scherrer Institute (PSI/ETH) in Switzerland, where synchrotron X-ray and neutron experiments are performed. Imaging experiments require tightly coordinated efforts across instrumentation, theory, and computation. The resulting exchange of perspectives often shapes both the experimental strategy and the scientific questions we pursue.

Why is your research important?

By developing and applying time-resolved imaging methods, my research helps reveal these hidden dynamics and provides quantitative data that can be used to test and improve physical models. In the longer term, this improved understanding can support more reliable predictions of fluid behaviour in complex subsurface and engineered systems. Such insight is essential for designing safer, more efficient, and more sustainable technologies, particularly in the context of the energy transition and medical sciences. Beyond specific applications, the work also contributes to advancing experimental methods in physics, enabling us to observe and quantify fast, complex processes that were previously inaccessible, and opening new possibilities for studying dynamic phenomena in porous and heterogeneous materials in different arenas of sciences such as medical science, material sciences, environmental sciences, geoscience and many more.

PHD

YAO XU

Department of Physics, UiO

Tell us about yourself

I am from Chengdu, a vibrant city in southwest China, renowned for its spicy cuisine and as the home of the giant panda. Two and a half years ago, I began my Ph.D. at PoreLab Oslo. Since moving here, I have embraced the local lifestyle. When I'm not in the lab, you'll likely find me hiking, skiing, or working out. I am also dedicated to learning the Norwegian language to better connect with the culture and community.

Tell us about your project

I am also a member of the CO_2Basalt project at Njord, University of Oslo. This interdisciplinary Carbon Capture and Storage (CCS) initiative brings together geologists and geophysicists to test a vital hypothesis: can the multiscale flow pathways in basaltic rocks host the massive volumes of CO_2 charged water required for permanent mineral storage?

My research specifically focuses on density-driven convection at the millimeter to centimeter scale. When CO_2 is injected into a reservoir, it dissolves into the ambient fluids at the interface. This process increases the liquid's density, triggering a 'sinking' motion or convection current within the porous rock.

Why is your research important?

This phenomenon is a critical driver of carbon sequestration. It dictates how CO_2 and pH are distributed throughout the medium, which, in turn, governs the efficiency of mineralization—the ultimate chemical reaction in which carbon transforms into solid rock. However, this convection is highly 'elusive' and influenced by complex pore structures and competing physical forces. My work aims to illuminate these hidden dynamics through experimental techniques.

How is the working environment at PoreLab?

Pursuing my Ph.D. at PoreLab has been a deeply rewarding journey. While the nature of doctoral research brings inherent challenges and stress, the supportive environment here makes every hurdle manageable. I am particularly grateful for my supervisors: their willingness to provide immediate, detailed feedback ensures my work remains efficient. What I value most is the intellectual balance: I receive expert guidance while my own ideas are consistently heard and respected.

Beyond the lab and the manuscript, life at PoreLab is vibrant and pleasant. The center provides incredible opportunities for growth, from presenting my research at international conferences to building connections with the wonderful colleagues from Trondheim during the PoreLab annual Junior Forum. Additionally, the PoreLab bi-weekly lecture series offers a front-row seat to cutting-edge porous media research from world-leading scholars, keeping my work connected to the global scientific stage.

HEADING FOR THE FUTURE:

OUR NEW EXTERNALLY FUNDED PROJECTS

In 2025, PoreLab researchers and associated members secured five new externally funded projects, either as project leaders or in collaboration with partners. These include two prestigious Marie Skłodowska-Curie postdoctoral fellowships and an Erasmus+ Capacity Building project funded by the European Commission. In addition, two projects were funded by the Research Council of Norway: a Researcher Project for Early Career Scientists awarded to Dr. Paula Reis, and a FRIPRO project. Results from previously awarded projects are presented separately under the Research Projects section of PoreLab annual reports.

INTERCORR

Full title: Unravelling the Role of Interfacial Effects on Corrosion Thermodynamics in CCS
Call: HORIZON-Marie Skłodowska-Curie Actions (MSCA) Postdoctoral Fellowships 2024
Project leader: Fufang Yang
Duration: 01.09.2025 – 31.08.2027

Dr. Fufang Yang was awarded a prestigious Marie Skłodowska-Curie grant and joined the thermodynamics group at PoreLab NTNU on September 2025 as a postdoctoral researcher for two years. Dr. Yang earned his PhD from the Department of Energy and Power Engineering at Tsinghua University in China, where he also completed his Bachelor's degree. His thesis was titled *"Practical Equation of State from the Perspective of Molecular Thermodynamics"*. Over the past five years, Dr. Yang has held several research positions at the École Normale Supérieure de Lyon (France), IFP Energies Nouvelles (France), and Tsinghua University (Beijing, China).

What is Fufang's INTERCORR project about? Corrosion poses significant economic, safety and environmental challenges, especially in CO_2 capture and storage systems, where acidic impurities and water accelerate the process. Even when water is below its solubility limit, it can form ultrathin films on metal surfaces, creating a complex environment for chemical reactions. This phenomenon, known as dry corrosion, is largely influenced by interfacial effects. With the support of the MSCA programme, the InterCorr project will combine thermodynamics with interfacial modelling to predict dry corrosion under varying conditions of temperature, pressure and composition. By offering new insights into interfacial behaviour, InterCorr could lead to new, more affordable corrosion-resistant materials and better strategies for corrosion prevention.

Fufang describes his research activities as follow:
My research focuses on thermodynamic property models for complex fluid mixtures in energy applications. My project, InterCorr (MSCA postdoctoral fellowship), investigates interfacial effects on the electrolyte systems related to corrosion in CCS systems. The project is highly relevant for corrosion under highly porous insulation materials.

EnergyLeap

Full title: Leveraging wettability in computational design tools for porous materials
Call: HORIZON-Marie Skłodowska-Curie Actions (MSCA) Postdoctoral Fellowships 2024
Project leader: Pranay Shrestha
Duration: 01.09.2026 – 31.08. 2029

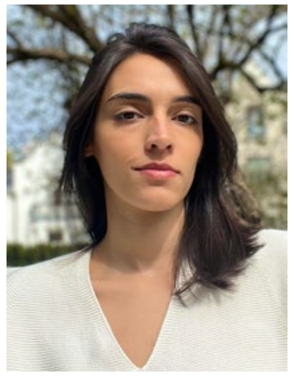
Dr. Pranay Shrestha earned his PhD from the University of Toronto, Canada, where he conducted experimental and theoretical research on transport phenomena in electrochemical energy conversion and storage devices for the development of novel materials. In July 2023, he joined the University of Oxford, UK, as a postdoctoral researcher in clean energy.

Following his InterPore–PoreLab Award in 2023 (see Annual Report 2023, p. 70), Pranay visited PoreLab at the University of Oslo in spring 2023. This collaboration led to the development of the EnergyLeap project proposal, through which Pranay was awarded a prestigious Marie Skłodowska-Curie Postdoctoral Fellowship. He will join PoreLab at the University of Oslo in September 2026 for a three-year research stay.

Pranay describes his project EnergyLeap as follow: Many clean energy devices like fuel cells contain porous materials in contact with fluids. These pores affect the surface's wettability – its ability to maintain contact with the liquid. Wettability depends on both the intermolecular interactions between the liquid and the surface (adhesive forces) and those within the liquid itself (cohesive forces). Wettability is a vital design parameter yet still poorly defined, particularly for two-phase flow. With the support of the Marie Skłodowska-Curie Actions programme, the EnergyLeap project aims to develop design tools for porous materials in next-generation energy devices. Leveraging microfluidics and computational methods, outcomes could have far-reaching impact on clean energy technologies, disease diagnosis and other engineered-flow-system applications.

SCAL3D

Full title: Exploring Scaling Laws for Drainage in 3D Porous Media
Call: The Research Council of Norway – Radical Research Ideas for Early Career Scientists
Project leader: Paula Kozlowski Pitombeira Reis
Duration: 2026 – 2027



Flow and transport in porous media play a central role in a range of environmental, geological, and engineering applications. Yet, the current understanding of these processes is, to a great extent, shaped by studies using two-dimensional models. Recent advances in experimental and computational capabilities have allowed the discovery of new behaviors in three-dimensional porous-media flows that challenge previously established knowledge. With SCAL3D, Paula Reis (picture on the left), Researcher at PoreLab UiO, and her team intend to substantiate their new theoretical model for drainage fronts in 3D porous media, which radically contrasts with conventional scaling laws derived for flow in two dimensions. This represents a first and necessary step toward a more ambitious project involving a joint theoretical, numerical, and experimental approach to develop predictive models for drainage in 3D porous media.

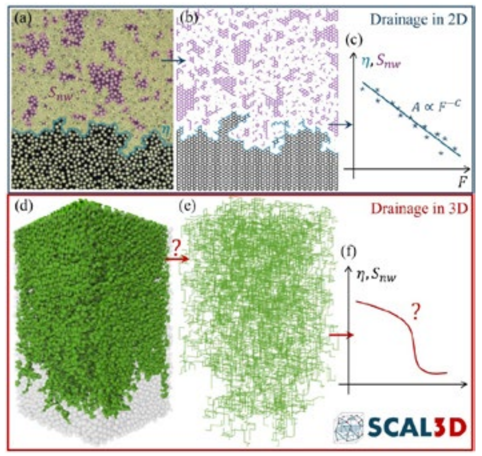


Figure: *Project goal illustration. In 2D porous media, drainage can be adequately represented by percolation models, which leads to the formulation of simple scaling laws for the front width η and phase saturation Snw according to the flow conditions. Images (a), (b), and (c) represent, respectively, 2D drainage experiments in Hele-Shaw cells, IP simulation results, and the theoretical numerical-experimental agreement. In 3D, Paula Reis and her team will test the ability of simple percolation models to represent drainage in naturally occurring/engineered porous media. With this, they will corroborate their theoretical model for η and propose a model for Snw. Image (d) represents 3D drainage visualization experiments, (e) IP simulations on 3D ideal lattices, and (f) the theoretical models proposed and tested with SCAL3D.*

GREENSEA

Full title: Advancing Green Education Partnerships between European and Southeast Asia Higher Education Institutes
Call: EU – ERASMUS+ Capacity Building
Project leader: Dong Trong Nguyen, Department of Marine Technology at NTNU and Thuat Trinh for PoreLab
Duration: 2026 – 2028

GREENSEA project is a collaborative effort bringing together ten Higher Education Institutes (HEIs) from Europe (Norway and Poland) and Southeast Asia (Vietnam, Indonesia and Thailand) to foster collaboration in green education, and research.

GREENSEA is centered around modernization curricula and building capacity in green technologies, renewable energy, and sustainable practices, aligning with the principles of the European Green Deal and regional sustainability goals. A major focus of GREENSEA is the development and integration of new courses and modules into existing Master's programs, emphasizing areas like marine technology, renewable energy, smart grids, and environmental management systems.

Dr. Thuat Trinh, a researcher at PoreLab, will join the NTNU team for the project, contributing to WP4 (Mobility and Research Collaboration) and WP6 (Dissemination, Communication, and Impact Tracking). Dr. Trinh's expertise is in renewable energy, with a particular focus on hydrogen production, bioenergy, and biomass conversion technologies.

GREENSEA

DYNCAT

Full title: Multiscale dynamics of the semi-catalytic Rochow-Müller process
Call: FRIPRO from the Research Council of Norway
Project leader: Senior Scientist Dr. Francesca L. Bleken at SINTEF Industry and Raffaela Cabriolu for PoreLab/NTNU
Duration: 2025 – 2028

DYNCAT aims to provide a highly predictive physics-based model of the Rochow-Müller process at the atom-scale that can be used together with other models in a digital twin for minimizing the overall energy consumption and environmental footprint of the global production. DYNCAT offers an in-depth understanding of this highly dynamic process starting at the electronic scale.

The project will allow modeling catalytic reactions on or inside porous supports, providing atomistic insights to calibrate porous flow and transport models, and enabling multiscale simulation from quantum chemistry to pores and finally full reactor. The project team combines complementary expertise from SINTEF and NTNU.

Dr. Raffaela Cabriolu is an associate professor at the Department of Physics at NTNU and associated member at PoreLab. She is the leader for the Work Package: *atomistic modelling*. Her expertise spans statistical mechanics and the simulation of rare events, with a focus on modelling the kinetics and thermodynamics of physico-chemical processes.

DYNCAT is financing a position for a PhD candidate at NTNU. In September 2025, Srinivasa Ranganadha Raghavendra Nomula (picture on the left) joined the Materials Theory group at the department of Physics, NTNU, with associate professor Raffaela Cabriolu as supervisor and Dr. Francesca L. Bleken at SINTEF Industry as co-supervisor..

THERMOPHYS
ABOUT BRIDGING SCIENCE AND INDUSTRY AT PORELAB

ThermoPhys *(https://thermophys.com/)* is a Norwegian technology start-up specializing in advanced computational tools and software for thermophysical property calculations, process modeling, and flow assurance. The company focuses particularly on applications relevant to the green energy transition, such as carbon capture and storage (CCS), hydrogen, and ammonia systems. ThermoPhys is firmly rooted in academic excellence and represents a direct transfer of long-standing research activities into industrially relevant software solutions, with strong scientific foundations originating from PoreLab.

ThermoPhys was founded in 2024, but the company began its main activities and growth phase in 2025. It emerged from more than a decade of research in thermodynamics, transport phenomena, and energy systems modeling, with strong ties to NTNU and PoreLab, where several of the founders and key developers have been actively involved. The premises of ThermoPhys are currently located at PoreLab in Trondheim.

The motivation behind ThermoPhys was to address a well-known gap between modern thermodynamic research and the tools available to industry. While academic models for multiphase thermodynamics, transport properties, and phase behavior have advanced significantly, many industrial software packages still rely on legacy models developed decades ago. ThermoPhys was created to make state-of-the-art scientific models accessible, robust, and easy to integrate into engineering workflows.

ThermoPhys' mission is to enable safer, more efficient, and more sustainable energy systems by providing high-accuracy thermodynamic and transport property models. The company believes that reliable predictions of phase behavior, fluid properties, and flow phenomena are essential for the successful deployment of technologies such as CCS, hydrogen infrastructure, and ammonia-based energy solutions.

By building directly on research performed at PoreLab, ThermoPhys aims to shorten the time from scientific discovery to industrial application, ensuring that the latest advances in thermodynamics are rapidly made available to engineers and decision-makers.

A defining characteristic of ThermoPhys is the strong academic background of its team and its close connection to PoreLab.

Dr. Morten Hammer, Chief Technology Officer and founder of ThermoPhys, is an Adjunct Professor affiliated with PoreLab and a former postdoctoral researcher at the center. He has been the lead developer of the Thermopack Github repository since 2011. He brings decades of experience in thermodynamics, flow assurance, and process modeling, with extensive experience developing industrial-grade engineering software.

Dr. Øivind Wilhelmsen, Chief Executive Officer of ThermoPhys, is a Professor of Thermodynamics at NTNU and a Principal Investigator (PI) at PoreLab. He has published more than 100 peer-reviewed scientific articles and authored textbooks on thermodynamics and hydrogen technology. His research at PoreLab forms a major scientific foundation for ThermoPhys' models and vision.

Dr. Ailo Aasen, Chief Developer at ThermoPhys, is a former PhD graduate from PoreLab. He placed top five in the Norwegian Mathematics and Physics Olympiads (2009), received the Stubban prize for *"promising young mathematicians"* at NTNU (2014), and earned the EFCE Excellence Award in Thermodynamics and Transport Properties (2021) for his PhD. Ailo has a decade of experience as a research scientist in SINTEF Energy, solving challenges in CCS, ammonia and hydrogen technologies.

Vegard Jervell is Developer at ThermoPhys, specializing in the implementation of complex numerical algorithms and the modeling of transport properties, including viscosity, thermal conductivity, and diffusion coefficients. His expertise focuses particularly on hydrogen and carbon dioxide–rich systems. In addition, Vegard is the lead developer of the Kinetic Gas repository on GitHub. He is also a PhD candidate at PoreLab working on transport properties at interfaces.

Dr. Karl Yngve Lervåg joined ThermoPhys as a Senior Full-Stack Developer in November 2025. He has a strong background as an experienced researcher and as the person responsible for IT infrastructure at SINTEF, as well as experience as a backend developer and technical lead at the Norwegian Agency for Shared Services in Education and Research.

Through these individuals, ThermoPhys maintains a continuous knowledge flow between cutting-edge research at PoreLab and industrially oriented software development.

ThermoPhys develops cloud-based software tools and APIs for advanced thermophysical calculations.

THERMOPHYS CLOUD (TPCLOUD)

TPCloud is a cloud-based platform (currently under development) that provides access to high-fidelity thermodynamic models. Core capabilities include:

- Accurate PVT properties and phase equilibria for complex mixtures
- Prediction of hydrate formation conditions, critical for flow assurance
- Identification of dry ice (solid CO_2) formation, essential for CCS safety
- Steady-state process simulations for designing infrastructure

The cloud-based architecture allows continuous model updates, reflecting the latest scientific developments emerging from research environments such as PoreLab.

THERMOPHYS API

The ThermoPhys API enables integration of advanced thermophysical models into existing simulation environments, including CFD tools, reservoir simulators, and process modeling software. This allows industry users to benefit directly from research-grade models without abandoning established workflows.

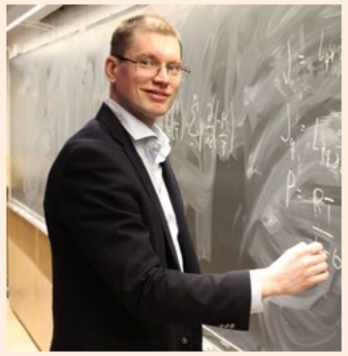
ThermoPhys' technology is particularly relevant for:

- Carbon Capture and Storage (CCS): Accurate modeling of CO_2-rich mixtures, phase transitions, hydrates, and dry ice is essential for safe transport and storage.
- Hydrogen Systems: Thermophysical accuracy is critical for hydrogen production, compression, transport, and storage.
- Ammonia Applications: As an energy carrier and industrial chemical, ammonia requires precise property modeling under varying conditions.

Key advantages of ThermoPhys' solutions include high accuracy, rapid model updates, and strong grounding in peer-reviewed research.

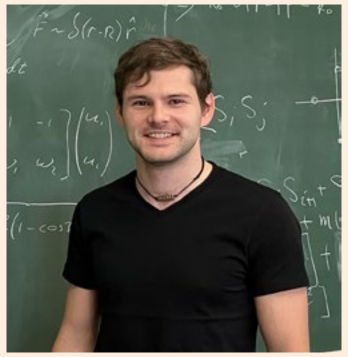
ThermoPhys maintains close ties to academia through ongoing interaction with PoreLab, NTNU, and international research networks. This ensures that the company remains at the forefront of thermodynamic research while delivering practical tools to industry. The ThermoPhys team is also actively involved in the research and supervision of PhDs and Postdocs at PoreLab.

Morten Hammer



Øivind Wilhelmsen

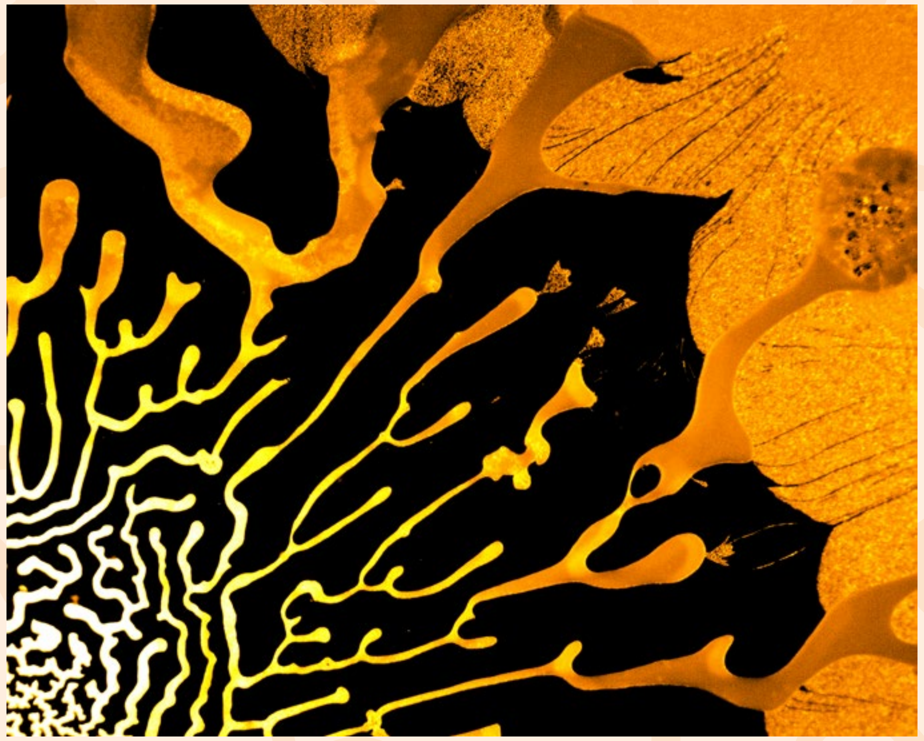
Ailo Aasen

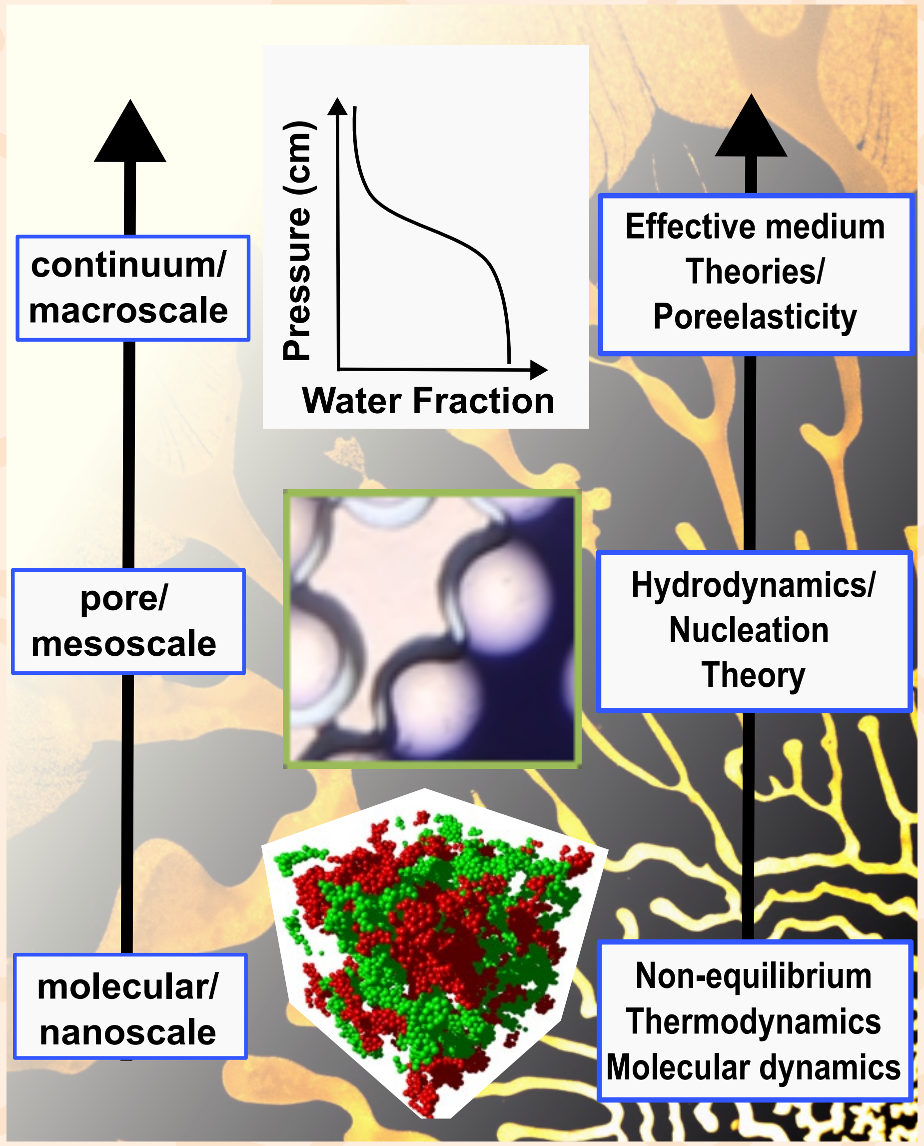


Vegard Jervell

Karl Yngve Lervåg

Contact information:
contact@thermophys.com





THE LABYRINT PROPOSAL:

NAVIGATING TOWARD A NEW ERA OF EXCELLENCE

PoreLab will run until 2028, but it has already provided many new insights on the properties of fluids in porous materials. In parallel, new, relevant experimental, theoretical and numerical tools ranging from quantum annealing simulations to high-resolution time-resolved X-ray tomography have become available. Together, these developments mean that we are now in a position to address a central problem of modelling two-phase flow in porous materials, namely the "upscaling problem", which aims to link our knowledge of the "microscopic" underlying physical processes to the two-phase flow behavior on the macroscopic scale.

The central feature that makes this upscaling problem complex is the dynamics of interfaces in porous materials, in particular the role of capillary forces in the motion of such interfaces. One immediate consequence of capillarity is that two-phase flow in porous materials is intrinsically irreversible, even at low flow rates, under conditions where one-phase flow can simply be described by the Stokes equation. Even though the challenge of formulating an upscaled theory of hysteretic two-phase flow has been identified for well over a century, our tools to describe, let alone predict this process have not developed much since the 1930s. Yet the problem is of considerable practical importance for sustainability such as in the description of replenishment of sub-surface fresh-water aquifers or large-scale CO_2 storage. All these issues have become more urgent due to the rapidly evolving climate crisis, as capillarity plays a critical role in groundwater dynamics, permafrost degradation, and glacier melting. All these processes are particularly relevant in Norway, where climate induced thawing of permafrost poses growing environmental and infrastructural challenges, and this is why Norwegian science should take a lead in this field. But, of course, capillarity is also fundamental to process industries and modern energy technologies, such as heat exchangers and batteries, and it also plays a vital role in numerous biological and medical processes, including transport in tissues and cellular systems.

Despite its profound societal and technological importance, pore scale transport governed by capillary forces remains poorly understood. Existing theoretical and computational models are largely phenomenological and often fail to establish a consistent connection between microscopic interfacial processes and macroscopic flow behavior. This lack of predictive capability limits progress in fields ranging from mitigating the effects of climate change, to geophysics, energy systems and biomedical engineering.

Recent advances in experimental techniques and computational power have created a timely opportunity to address these challenges. State of the art imaging, microfluidics, and molecular scale simulations now enable fluid flow and interface dynamics to be explored with unprecedented spatial and temporal resolution. These developments call for new, physics based theories and computational frameworks capable of fully exploiting the richness of modern data.

In 2025, a group of professors and researchers from both NTNU and the University of Oslo prepared a proposal to the Norwegian Centers of Excellence scheme (CoE), sixth generation, administered by the Research Council of Norway, aimed at addressing this fundamental and applied challenge, The group includes seven Principal Investigators from PoreLab – Erika Eiser, Eirik G. Flekkøy, Carl Fredrik Berg, Alex Hansen, Øivind Wilhelmsen, Marcel Moura, and Gaute Linga – together with Dag Werner Breiby, Section Leader for the Porous Media Physics group at NTNU, and Andreas Carlson, Professor in the Department of Mathematics at UiO.

Together, they propose the establishment of the Centre of Excellence LABYRINT, an acronym for *Laboratory for Capillarity and Interface Driven Flow*. The proposed center aims to develop fundamentally new predictive theories rooted in novel experiments and integrated with advanced computational methods, including Machine Learning, data driven modeling and optimization based on quantum annealing. By explicitly linking experiments, theory, and computation across scales, LABYRINT seeks to overcome long standing limitations in porous media science.

A central ambition of LABYRINT will be to mitigate disciplinary fragmentation by establishing a truly multidisciplinary research environment. The center aims to unify physicists, geoscientists, mathematicians, engineers, and researchers from related disciplines around a shared scientific framework, strengthening the foundations of porous media science. In doing so, LABYRINT aspires to strengthen its position as a global knowledge hub and a unique arena for training, collaboration, and scientific discussion.

Through excellence in basic research, LABYRINT should generate broad scientific impact across physics, geology, biology, and energy research, while simultaneously enabling innovation in sustainable engineering and technology. By advancing the understanding of capillarity and interface driven flow, the centre aims to contribute meaningful solutions to pressing societal challenges related to climate adaptation, energy transition, and environmental stewardship.

PORELAB GRADUATE SCHOOL

TRAINING THE NEXT GENERATION OF RESEARCH LEADERS

Training Master- and PhD students, as well as postdoctoral researchers, is a core activity at PoreLab. Student and researchers' education is a central part of the mission of both NTNU and UiO as universities, and PoreLab is an important contributor in this regard. Our ambition is to provide each junior researcher with a scientifically stimulating and inclusive working environment that goes beyond the standard PhD or postdoctoral program. To achieve this, our training program is organized across institutions and in collaboration with international partners, creating an interdisciplinary and global platform for developing our junior researchers.

Training for our students and young researchers

Each student and research fellow follows their regular institutional training program, which includes specific requirements for scientific work, supported by coursework and other academic activities.

What distinguishes PoreLab is its cluster-based approach to scientific work, organized around each PhD candidate. Each cluster typically includes two supervisors, along with master's students, postdocs, or visiting researchers who are working on, or interested in, the same research problem. This structure enhances collaboration, promotes interdisciplinary exchange, and strengthens professional networks, while providing valuable mentoring opportunities.

National and international collaborations are strongly encouraged and actively supported among students and young researchers. The Center provides funding both to host international students and researchers and to enable our own master students, PhD candidates, postdocs, and young researchers to gain experience abroad. A few examples are presented below.

PhD candidate Andreas Hennig spent several weeks in March and again in September 2025 at the Department of Fundamental Physics at the University of Barcelona in Spain, working with our long-term partner, Professor Ignacio Pagonabarraga. During his research stay, Andreas learned to use a simulation code for performing Lattice–Boltzmann simulations on colloidal systems, benefiting from the expertise of PhD students who work on very different research questions but use the same code. During his September stay, he also attended the CECAM conference *Dynamics of Non-Equilibrium Variables: Multiscale-multiphysics applications of fluctuating hydrodynamics*, held in Zaragoza from 15 to 19 September 2025, where he presented a poster entitled *"Confined Colloidal Droplets Dry to Form Circular Mazes."*

In autumn 2025, PhD candidate Tage Maltby spent seven weeks in Auckland, New Zealand, at Massey University. During his stay, he visited the New Zealand Institute for Advanced Study (NZIAS), where he collaborated with Distinguished Professor Peter Schwerdtfeger and his research group. Their work focussed on phase transitions in the solid state.

Everyone at PoreLab—including master's students, PhD candidates, and postdocs—is invited to attend, organize, and contribute to all PoreLab events, such as the PoreLab Lecture Series and the Journal Club. Junior members are encouraged to submit abstracts and present posters or talks at national and international conferences, with expenses covered by the Center.

Each year, the Center hosts numerous visitors, including renowned national and international researchers. These visits provide junior researchers with valuable opportunities to meet and engage with leading scientists. A list of visitors can be found on page 90.

PoreLab Lecture series, Porous Media Tea Time Talk and Journal Club

The use of video conferencing grew significantly during the pandemic, enabling us to expand our pool of lecturers and leading to increased attendance. The PoreLab Lecture Series is now primarily delivered by external speakers and is consistently held online to ensure accessibility for everyone.

The PoreLab Lecture Series is scheduled alongside the Porous Media Tea Time Talks (#PorousMediaTTT), a webinar series streamed on YouTube and organized by a group of young porous media researchers, including PoreLab members. In 2025, eleven sessions of the Porous Media TTT, each featuring at least two talks, were organized.

PoreLab @ NTNU restarted the Journal Club in Spring 2024 to foster discussion and critical analysis of recent or significant research papers. Our junior researchers are given a short preparation time to quickly read, grasp the key content, and effectively present the paper. A key concept of the Journal Club is that all PhD candidates are required to present a paper at least once a year.

PoreLab Master Students 2025

As in previous years, a dedicated catalog showcases our outstanding master's students. With backgrounds in physics, chemistry, computer science, and geosciences, they embody PoreLab's interdisciplinary nature. The catalog offers an overview of the master's projects completed in 2025 and includes suggestions for new project opportunities. We hope it will inspire future students to join our team.

Two PoreLab courses and beyond...

Two courses are offered by PoreLab scientists, open to both PhD and master students, at our host institutions. The courses have a special focus on porous media physics.

The PoreLab course *"Experimental Techniques in Porous and Complex Systems"* (FYS4420/FYS9420) is organized every year during the fall semester by UiO. The course gives students an introduction to important experimental techniques in the field of condensed matter physics. The teaching is based on four projects in which the students apply techniques on realistic problems in condensed matter physics. Students from NTNU travel to UiO to attend the laboratory courses with financial support from PoreLab. The course lecturer is Professor Knut Jørgen Måløy, PI at PoreLab.

The PoreLab course on theory and simulation of flows in complex media is offered in a digital format in order to welcome students at both UiO and NTNU. The course has a double title and code: *"Dynamics of complex media"* (FYS4465/FYS9465) at UiO and *"Flows in porous media"* (KJ8210) at NTNU. It covers hydrodynamics where capillary and viscous forces play a role. The course lecturer is Professor Eirik G. Flekkøy, PI at PoreLab.

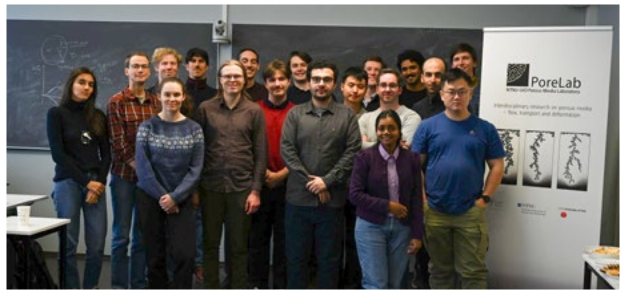
Courses on ethics, rhetorics, dissemination, and communication are for instance available at both NTNU and UiO. The course on *"Doing science: Methods, Ethics and Dissemination"* (MN 8000) is mandatory for all PhD candidates at PoreLab NTNU. Postdocs are also offered a variety of courses and workshops suitable for their career plan at the host institutions, NTNU and UiO. Examples are courses on PhD supervision, or workshops on publishing practice in international journals. Pedagogical topics' courses, offered by UNIPED (NTNUs Educational Development Unit) are also relevant.

External courses and workshops can be funded for our students and young researchers when needed. The following CECAM school is an example.

In May 2025, Raffaela Cabriolu, an associated member of PoreLab, and Alex Hansen joined the organizing team for a CECAM School titled *"Machine Learning in Physical Sciences: Theory and Applications"* at the ENS (École Normale Supérieure) in Lyon, France. The event was supported by the Norwegian–Icelandic Consortium (NIC CECAM) and additionally sponsored by the Gemini Centre COSY. This five-day school on machine learning (ML) techniques for physical sciences, focused on modeling and direct applications in various fields. The aim of this school was to provide comprehensive ML training within physical science topics that extend beyond well-established applications—such as data processing and developing accurate potentials—and highlight emerging trends in ML applications that are significantly advancing several fields.

PoreLab Junior forum

The PoreLab Junior Forum was founded by and is led by the junior members themselves. Its primary goal is to bring together PhD students, postdocs, and early-career researchers at PoreLab, fostering greater interaction and allowing them to share their work and scientific interests. The forum plays a crucial role in connecting the two PoreLab hubs in Oslo and Trondheim. Held annually, the forum enhances opportunities for scientific collaboration and networking.



The 2025 Junior Forum was postponed several times due to various events, but it finally took place in Oslo on January 23rd, 2026. Yao Xu and Federico Lanza, respectively PhD candidate and postdoctoral fellow at PoreLab UiO were the organizers of the 2025 edition. They summarized the event as follows: *The forum kicked off with a series of insightful presentations, where senior members shared updates on their research and new members introduced their backgrounds. These talks sparked many inspiring discussions. During the lunch break at the Frederikke canteen, attendees took the opportunity to connect and network in a more relaxed setting.*

In the afternoon, the focus shifted towards a peer round-table discussion on work-life balance and lab stress. This session fostered an open and supportive dialogue, allowing attendees to share experiences and effective strategies for managing the pressures of lab life as junior researchers. The formal program concluded with a highly engaging Njord seminar by Nicholas Rathmann on "Crystal fabric evolution in glacier ice and rock-forming minerals". The day culminated in a wonderful dinner at an Italian restaurant, followed by a friendly minigolf competition at Oslo Camping.

MEETINGS AND CONFERENCES

Researchers at PoreLab have numerous opportunities to present their scientific activities and research results to both internal and external events. We list in the following pages the meetings and specialized workshops organized by PoreLab members alongside other experts in their field in 2025, as well as important events for PoreLab.

IRP-DFFRACT CONFERENCE, 3-7 FEBRUARY 2025, COURMAYEUR, ITALY

The IRP–DFFRACT Conference 2025 was organized by Professor Knut Jørgen Måløy, Principal Investigator at PoreLab; Stéphane Santucci, CNRS Researcher at the École Normale Supérieure de Lyon, France; and Renaud Toussaint, Professor at the University of Strasbourg and adjunct professor at PoreLab Oslo. This popular and unmissable conference is held each year at the Hotel Pilier d'Angle in Courmayeur, Italy.

DFFRACT stands for Deformation, Flow and Fracture of Disordered Materials.

Researchers from PoreLab played a major role in the event, contributing a series of presentations by Federico Lanza, Paula Reis, Maud Viallet, Mihailo Jankov, Antoine Dop, Kevin Pierce, François Renard, Knut Jørgen Måløy, and Eirik G. Flekkøy. They were joined by collaborators and colleagues from the University of Swansea, the University of Strasbourg, and the École Normale Supérieure de Lyon.

PHYSICISTS' MEETING 2025, 16-18 JUNE 2025, TRONDHEIM, NORWAY

On behalf of the Norwegian Physical Society (NFS), the Department of Physics at NTNU organized the Physicists' meeting 2025, held in Trondheim from June 16 to 18. The event welcomed physicists from academia, research institutes, secondary education, and industry.

The program featured plenary talks highlighting the latest development in physics in Norway, along with parallel sessions organized by the eight topical subgroups at NFS: 1) Acoustics, 2) Biophysics and Medical Technology, 3) Condensed Matter Physics and Atomic Physics, 4) Industrial and Energy Physics, 5) Optics, 6) Norwegian Teacher's Society, 7) Space-, Plasma- and Climate Physics and 8) Subatomic Physics and Astrophysics.

The program also included the traditional biannual meeting and award ceremonies.

PoreLab was well represented at the event with Ilaria Beechey-Newman, Yann Dumay, Erika Eiser and Andreas Hennig. Professor Alex Hansen delivered an invited talk.

ANNUAL MEETING OF THE NORWEGIAN CHAPTER OF INTERPORE & BERGEN CONFERENCE

PoreLab has played an active role in the Norwegian chapter of InterPore since its establishment in 2017. Its mission is to create a platform for scientists and engineers involved in porous media studies in Norway or with connection to Norway. The Norwegian Chapter of InterPore focuses on interdisciplinary and/or fundamental studies of porous media in connection with applications and national and international technological demands. It aims to advance and disseminate knowledge for the understanding, description, and modeling of natural and engineered porous media systems.

Three PoreLab members serve on the steering committee: Santanu Sinha, Seyed Ali Ghoreishian Amiri and Paula Reis.

In 2025, a two-day event, organized in collaboration with the VISTA-funded Center for Modeling of Coupled Subsurface Dynamics at the University of Bergen, served both as the center's final conference and as the annual meeting of the InterPore Norway chapter.

The event, titled *Bergen Conference on Modeling and Simulation of Coupled Subsurface Dynamics*, brought together researchers and practitioners from a wide range of fields.

The conference highlighted key research areas including coupled deformation, reactive transport, multiphase flow, and seismic wave propagation, and featured distinguished speakers from Norway, abroad, and industry. A major highlight was the Kimberly-Clarke lecture delivered by Rainer Helmig. The program also included poster sessions on both days, the annual business meeting of InterPore Norway, and presentations showcasing the research achievements of the VISTA Center for Modeling of Coupled Subsurface Dynamics (CSD).

FINAL MEETING FOR THE INTPART PROJECT, NON-NEWTONIAN FLOW IN POROUS MEDIA, 28-30 SEPTEMBER 2025

The main goal of the INTPART program from the Research Council of Norway RCN) is to develop world class research and education environments in Norway through long term international collaboration with leading institutions worldwide.

In 2020, with this objective in mind, PoreLab, together with the Laboratoire FAST at the University Paris-Saclay in France and the Complexity group at the Universidade Federal do Ceará (UFC) in Brazil, developed a project on *Non-Newtonian Flow in Porous Media* funded by the RCN's INTPART program. The project aimed to upscale the description of flow of non-Newtonian fluids in porous media from pore scale to the continuum scale.

Saying that our INTPART project was a major success for PoreLab would be a clear understatement. It enabled us to organise a wide range of activities, including:

- a kick-off workshop in December 2021 at the University Paris-Saclay, bringing together all three partners,
- a comprehensive international workshop on non-Newtonian flow in porous media, in Fortaleza, Brazil, on 28-30 June 2022 (see PoreLab annual report 2022 page 69)
- a second, significantly larger workshop at the Banff International Research Station in Canada from 14-19 July 2024 (see PoreLab annual report 2024, page 68)
- short- and long research stays for students and researchers across the three laboratories
- Visits from external experts for both short and extended periods.

The INTPART project also enabled us to establish a joint PhD degree for Federico Lanza between the University Paris-Saclay and NTNU. Federico spent 18 months at FAST, and 18 months at PoreLab. He successfully obtained his joint PhD degree on 3 November 2023.

The collaboration fostered with both long-standing and newly established partners through the INTPART project was extensive and highly productive.

The project concluded in November 2025. From 28 to 30 September 2025, we held the project's final meeting onboard the *Hurtigruten* (the Norwegian Coastal Express) together with our main partners, Laurent Talon and Alberto Rosso from CNRS/University Paris-Saclay and José Soares Andrade Junior from UFC, along with a group of researchers who had played key roles throughout the project. Each presentation was allocated one hour, allowing for an unhurried program with ample opportunity for discussion following every talk.

Building on the success of the first two international workshops in Fortaleza and Banff, we plan to continue organizing workshops on non-Netonian flow in porous media every second year. The next workshop is scheduled to take place in May 2026 in Cargèse, Corsica, France, as a collaboration between PoreLab, FAST and LPTMS at the University Paris-Saclay, and the University of British Columbia

COSY PROPOSALS DAY, 2 DECEMBER 2025, TRONDHEIM, NORWAY

The Computational multi-Scale materials society (COSY) Gemini senter Proposal Day took place on December 2 at the Natural Science Building at NTNU in Trondheim, Norway. The event was organized, among others, by Associate Professor Raffaela Cabriolu from the Department of Physics and Professor Astrid de Wijn from the Department of Mechanical and Industrial Engineering, both associated members of PoreLab.

The program featured a series of short presentations introducing various funding opportunities and sharing insights from previous application processes. Its main goal was to foster collaboration and build partnerships for future grant proposals in a relaxed and informal setting. After each presentation, participants engaged in brief discussions, and the event concluded with a one-hour brainstorming session. It was open to PhD candidates, early-career researchers, and scientists from a wide range of disciplines to encourage interdisciplinary exchange and collaboration.

Among the speakers was Dr. Quirine Krol, postdoctoral research fellow at PoreLab. She presented on the MSCA grants (Marie Skłodowska-Curie Actions), the European Union's flagship program for doctoral education and postdoctoral training (see PoreLab Annual Report 2022, page 62).

PROMOTING PORELAB'S SCIENCE TO THE PUBLIC

A key objective of PoreLab is to communicate its research and discoveries, while also fostering a greater appreciation and understanding of science overall. Bringing scientific culture and research closer to pre-university educational levels and promoting research vocation is of great importance to PoreLab. These next pages highlight some of the activities PoreLab scientists were involved in throughout 2025.

"Nysgjerrige Norge" (Curious Norway) is a podcast series produced by the Research Council of Norway, in which Kristopher Schau meets some of the country's leading scientists to discuss their career paths and the research they conduct. Schau is a well-known Norwegian musician, comedian, novelist, and television host.

In Season 1, Episode 11, titled *'Is Everything Porous?'* and released on 13 April 2025, Kristopher Schau visits PoreLab, where he meets **Alex Hansen, Eirik Grude Flekkøy,** and **Marcel Moura.** Together, they discuss why porous media—ranging from soil, skin, and coffee to traffic and pandemic masks—are found all around us. Why is this so important, yet so little known? And what actually happens in a laboratory that is trying to develop a unified theory for the entire porous universe?

The event was recorded on 30 January 2025 at PoreLab UiO. Picture below, from left to right: Marcel Moura, Alex Hansen, Kristopher Schau and Eirik Grude Flekkøy

Physics students from **Thora Storm High School** in Trondheim visited the Department of Physics at NTNU on March 28, 2025.

During the visit, the students toured three laboratories to gain insight into different areas of physics. One of these was the PoreLab laboratory led by Professor **Erika Eiser**. Professor Eiser and her team introduced the students to the concept of polymers and explained why they are of great scientific interest. Many materials used in everyday life are made of polymers. The team also demonstrated that polymers are not only important for technological applications, but are essential to the human body itself, which would not function without biopolymers such as proteins, DNA, and the extracellular matrix that holds our tissues together.

*(AI-generated illustration by PhD candidate **Yann Dumay**)*

Researchers' Night was launched at the European level as part of the initiative *"Researchers in Europe 2005."* The initiative consists of a one-evening event aimed at the general public, featuring activities that increase public awareness and understanding of researchers and research, while also providing an enjoyable experience. The event is held annually on the last Friday of September.

The Porous Media Physics section participated in **Researchers Night 2025** with two groups.

The Eiser's group for Complex Fluids at PoreLab consisted of **Professor Erika Eiser** and her PhD students: **Yann Dumay, Andreas Hennig, Ilaria Beechey-Newman** and **René Tammen**. They presented a series of interactive demonstrations designed to share the ideas and curiosity driving their research. A live experiment on the Marangoni effect invited visitors to observe the rapid spreading and bursting of a water– isopropanol droplet on an oil surface, a striking example of how subtle surface-tension differences can set fluids in motion. Alongside this, visual displays and hands-on discussions introduced ongoing studies on drying-induced colloidal patterns, quick-clay stability, and two-phase flow through porous media. Together, these presentations offered an accessible glimpse into the group's exploration of complex fluid behaviour and its environmental relevance.

The X-Ray Physics group, consisting of staff and PhD candidates, **Arshitha Mathew, Chayene G. Anchieta, Giacomo Luani, Mukul Jaiswal, Soumya Pallitpotta**, and **Shibi Tharayanmaru Palliyalil**, presented the ongoing research activities on the application of advanced X-ray methodologies viz. X-ray Computed Tomography (CT) to investigate complex processes in porous media including the use of artificial intelligence (AI) based tools for smarter data acquisition and analyses.

The activity targeted towards students at secondary and high schools, aimed to enhance public knowledge of the research conducted within the X-ray Physics Group and to inspire interest in scientific disciplines among younger audiences. The presentation demonstrated representative examples of application of CT within carbon capture and storage (CCS) and battery research.

The engagement with students and other visitors was extremely satisfying as they showed strong curiosity and enthusiasm, emphasizing the importance of effective science communication. For the X-ray Physics group interacting with young minds is both inspiring and rewarding, serving as a valuable reminder of the significance and joy of spreading scientific knowledge beyond the laboratory.

(Photos: Per Hennig)

The Young Academy of Norway (AYF), in collaboration with the Centre for Advanced Study (CAS), hosted the **Young Researchers Night** (YRN) in Oslo on 26 September 2025. The event took place at Litteraturhuset.

Centre for Advanced Study
at The Norwegian Academy of Science and Letters

YRN is an annual event and part of *Forskningsdagene*. This year's theme for *Forskningsdagene* was Safety and Security. The evening program featured engaging talks, presentations, panel discussions, and an excellent opportunity to network with other young researchers. The event was co-hosted and sponsored by CAS.

As a new member of the Young Academy of Norway, Associate Professor **Gaute Linga**, Principal Investigator at PoreLab, gave a talk on *"Security in physics"*.

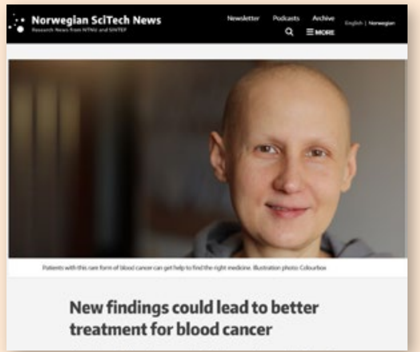
SOCIAL MEDIA

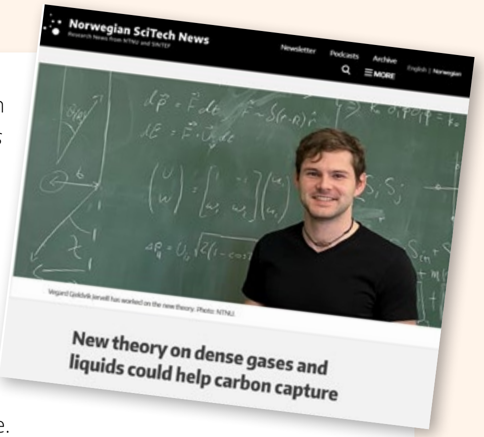
Visit our website **www.porelab.no** where you find daily updated information on our researchers, scientific findings, happenings, studies and many more.

Follow us on Bluesky as well, and YouTube

In an article published in *Norwegian SciTech News* (*Gemini* in Norwegian) on 9 January 2025, new research led by PhD candidate Jennifer Sheehan at NTNU presents an important advance in personalized treatment for chronic myeloid leukemia (CML). Sheehan, the study's first author, contributed to the development of a computational model that can predict which of the available CML drugs will be most effective for individual patients, helping them receive the right medication more quickly. Professor **Astrid S. de Wijn**, Sheehan's supervisor and associated member at PoreLab, underscores that CML often develops without symptoms for many years, making early and precise treatment decisions especially critical. Together, their work aims to reduce ineffective treatments and improve long-term outcomes for patients through more targeted drug selection.

Read also the interview with Jennifer Sheehan in our PoreLab Annual Report 2024, page 57.





In an article published in *Norwegian SciTech News* (*Gemini* in Norwegian) on 14 February 2025, researchers at PoreLab present a new theoretical framework that improves understanding of transport properties in dense gases and liquids, with clear relevance for carbon capture and storage.
PhD candidate **Vegard Gjeldvik Jervell** at PoreLab, has developed the theory under the supervision of Professors **Øivind Wilhelmsen,** Principal Investigator at PoreLab, and **Morten Hammer**, adjunct professor at PoreLab. The work provides a fundamental, molecule-based description of viscosity, thermal conductivity, and diffusion in dense gas mixtures, reducing reliance on costly experiments. This strong theoretical foundation positions PoreLab as a key contributor to more efficient and reliable large-scale gas transport solutions.

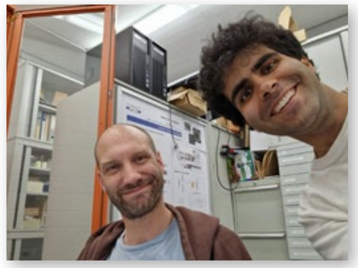
Read also the interview with Vegard Gjeldvik Jervell page 67.

New research shows that earthquakes do not begin as large, uniform events, but instead start from a highly localized point deep within the Earth's crust. **Fabian Barras**, a researcher at the NJORD Centre for Earth Physics, and associated member at PoreLab, plays a central role in developing advanced models that link small-scale geological observations with large-scale seismic data. His work demonstrates that the initial deformation occurs at a single weak point and then rapidly spreads like a crack through a fault, similar to breaking glass or triggering an avalanche. By applying principles from fracture mechanics, Barras aims to better understand how earthquakes start and propagate. The research was featured in *Titan* on 28 March 2025.

New theoretical advances from PoreLab researchers are shedding light on the solid-phase behavior of argon, with important implications for gas transport and energy technologies. Led by Professor **Øivind Wilhelmsen**, Principal Investigator at PoreLab, and carried out largely by PhD candidate **Tage Maltby** at PoreLab with contributions from **Morten Hammer**, adjunct Professor at PoreLab, the team has developed the most accurate equation of state to date for solid argon. Built from fundamental molecular interactions, the theory enables precise prediction of when solids form during cooling and transport of gases such as CO_2 and hydrogen. The work was featured in *Gemini* on 10 March 2025 and highlights PoreLab's leading role in advancing thermodynamic theory with strong industrial relevance.

Read also the interview with Tage Maltby page 66.

New research explores how carbon dioxide can be permanently stored by turning it into solid minerals within basalt rock. PhD candidate at the Njord center, **Paiman Shafabakhsh**, plays a key role in investigating what happens at the smallest scales, studying how CO_2 and fluids move and react inside the tiny pores of basalt using advanced X-ray and neutron imaging. His work helps reveal processes that large-scale models often miss. Complementing this, PhD candidate at PoreLab, **Yao Xu**, conducts controlled laboratory experiments using 3D-printed rock models to visualize CO_2 flow and convection in detail. Together, their work strengthens understanding across scales, from pores to reservoirs. The research was featured in *Titan* on 27 May 2025, with a Norwegian version dated 19 May 2025



Paiman Shafabakhsh has used X-rays and neutrons to observe what happens in lava rocks when CO_2 gas is pumped in. Here he is in the control room at PSI in Switzerland with collaborator Benoit Cordonnier from ESRF in France. Photo: Private

CO_2 is invisible, so Yao Xu uses a glass of water to check that there is gas in the system. Photo: Hilde Lynne-bakken/UiO

Researchers at PoreLab have uncovered unexpected labyrinth-like patterns in slowly drying droplets containing microscopic particles. The work was led by Professor **Erika Eiser**, Principal Investigator at PoreLab. By confining particle-laden droplets between glass plates and carefully controlling evaporation, Erika and her team identified new mechanisms that extend beyond the classic coffee-ring effect. Their experiments show that when particles are sufficiently small, they modify surface tension and drive the formation of intricate finger-like and folded structures. This fundamental research enhances understanding of drying processes relevant to both natural pattern formation and particle-based technologies. The study was featured in *Titan* on 14 November 2025, as well as in *Teknisk Ukeblad* on 24 December 2025.

Part of the project team at PoreLab. PhD candidate at PoreLab René Tammen (partly hidden), Principal Investigator at PoreLab Professor Erika Eiser, associated member at PoreLab Professor Astrid Silvia de Wijn, associated member at PoreLab Researcher Ge Li, PhD candidate Kamila Zablocka, Professor Klaartje de Weerdt, and associated member at PoreLab Researcher Ali Amiri.
Photo: PoreLab, NTNU.

In an article published by *Gemini* on 14 November 2025, researchers at PoreLab present new insights into why quick clay is so unstable and prone to catastrophic landslides. Researcher **Ge Li**, together with Professor **Astrid Silvia de Wijn**, both associated members at PoreLab, has carried out highly detailed simulations that reveal what happens at the nanoscale when salt is washed out of marine clay. Their work shows how ions from saltwater attach to clay particle surfaces, increasing friction and preventing particles from sliding past each other. When fresh water replaces salt water, this stabilizing effect is lost, making the clay dangerously weak. By uncovering these fundamental mechanisms, PoreLab researchers aim to enable safer and more environmentally friendly alternatives to today's cement- and lime-based stabilization methods.

This work is part of a large interdisciplinary project called *Sustainable Stable Ground (SSG)*, funded by the Research Council of Norway (see PoreLab annual report 2021, page 57).

AWARDS and prestigious nominations in 2025

The 2025 InterPore-PoreLab award: **Dr. Chiara Recalcati**

The close cooperation between Interpore and PoreLab has led to the creation of the InterPore-PoreLab award for young researchers. First introduced in 2018, the award recognizes outstanding contributions to fundamental research in the field of porous media. Award winners receive a grant of 1000 euros and are invited to spend up to 60 days at PoreLab, supported by a daily stipend.

The 2025 winner of the InterPore-PoreLab Award for Young Researchers is Dr. Chiara Recalcati, a postdoctoral researcher in the Department of Water Resources and Drinking Water at the Swiss Federal Institute of Aquatic Science and Technology (Eawag) in Dübendorf, Switzerland. Before joining Eawag in September 2025, Chiara was a postdoctoral researcher in the MIPORE Group (Porous media Across Scales) at Politecnico Di Milano, Italy. She earned a double PhD degree in Environmental and Infrastructure Engineering (Politecnico di Milano) and Earth Sciences (Université de Lausanne) in 2024. Her doctoral work was recognized with the Prix de la Faculté des Géosciences et de l'Environnement (Université de Lausanne) for an outstanding PhD thesis, selected from among 70 dissertations, and with the 32nd Gustavo Sclocchi Award (Society of Petroleum Engineers – SPE – Italian Section, Italian Sustainable Energy Resources Industry Association – Assorisorse – and European Association of Geoscientists and Engineers – EAGE).

The InterPore PoreLab Award ceremony was held during the 17th International InterPore Conference, which took place in Albuquerque, New Mexico, USA, from May 19 to 22, 2025.

The award citation reads:

"Dr. Chiara Recalcati's diverse research portfolio on fundamental porous media science, her publications, and her successful and already broad international experience, serve as an inspiration to young scientists everywhere. She is rapidly emerging as a reference scientist in the experimental and theoretical characterization of the heterogeneous nature of reactive processes taking place across the surface of minerals in contact with a fluid and driving chemical weathering of natural porous media."

I am truly honored and grateful to accept the InterPore-PoreLab award for Young Researchers

– Chiara Recalcati, 2025 winner of the InterPore-PoreLab Award for Young Researchers

The 2025 Lars Onsager Professorship: **Dr. Lydéric Bocquet**

Dr. Lydéric Bocquet, Director of Research at CNRS and Professor at the Ecole Normale Supérieure in Paris, France, was awarded the Onsager Medal by NTNU on November 21st, 2025.

His nomination was submitted by Professor Erika Eiser, PI at PoreLab. The Lars Onsager Lecture and the Lars Onsager Professorship are awarded annually by the Onsager Committee at NTNU.

The Onsager Professorship is granted each year to an outstanding researcher in honor of Lars Onsager. Lars Onsager, a Norwegian-American chemist and physicist, began his studies at NTH (the Norwegian Institute of Technology, now NTNU, Norwegian University of Science and Technology), and later received the Nobel Prize in Chemistry in 1968 for his work done in 1931 on irreversible thermodynamics.

Professor Bocquet spent one month at PoreLab in August 2025, followed by a one-week stay in November 2025. He plans to return in spring 2026.

Professor Bocquet held on November 21st, 2025, a Lars Onsager Lecture titled *"The molecular mechanics of fluids – from ionic memory to quantum plumbing"*.

During his lecture, he discussed experimental and theoretical results that his group obtained recently on the transport of water and ions in nanopores, both in 1D nanotubes and 2D channels obtained by van der Waals assembly. He focused on two phenomena: first the emergence of memory in quasi–two-dimensional water channels rooted in the 2D Wien-Onsager effect, enabling the development of ion-based neuromorphic computing; then the emergence of hydro-electronic couplings, explaining the strange flows of water in carbon nanotubes. This opens new perspectives for nanoscale fluid transport, which he illustrated on the phenomena of flow tunneling across walls, and (ion-free) hydro-electronic energy conversion.

Dr. Marcel Moura: chair of the InterPore Student Awards and Grants Sub-Committee

On June 20th, 2025, the InterPore Executive Committee nominated Dr. Marcel Moura, PI at PoreLab, as Chair of the InterPore Student Awards and Grants Sub-Committee. The Committee noted that the role requires the level of experience and seniority that Dr. Moura brings and commended him for his willingness to take on this responsibility.

The InterPore Student Awards and Grants Sub-Committee is responsible for evaluating conference poster presentations as well as grant applications. It acts based on the InterPore vision to gather outstanding researchers from across the world who study and research in the field of porous media. On behalf of the InterPore Foundation, the Committee offers conference grants to students and scientists from academic institutions in countries with lower- or middle-income economies. It also identifies outstanding posters which are presented in the InterPore annual conferences.

Dr. Marcel Moura has served InterPore in many capacities over the years. In 2018, he received the InterPore Rosette Award, an honor reserved for individuals who have made significant contributions to InterPore activities. Dr. Moura chaired the InterPore Student Affairs Committee (SAC) from 2017 to 2021. He has been one of the creators and organizers of the YouTube webinar series *Porous Media Tea Time Talks (#PorousMediaTTT)*, a platform created in June 2020 and meant to provide the worldwide porous media community with a practical outlet for the early career scientists to communicate and advertise their recent work and interact with the broader scientific community. Dr. Moura serves on the Scientific Advisory Board of the InterPore Academy and is a founding member of the Norwegian Chapter of InterPore. He is also currently co-chairing the InterPore Young Academy, a division dedicated to promoting educational activities for early-career researchers from academia and industry working in the broad field of porous media science.

Award for Outstanding Research at the Faculty for Natural Sciences: **Professor Erika Eiser**

Each year, the Faculty of Natural Sciences at NTNU recognizes outstanding contributions by its staff through the NV Awards, which are presented in seven categories. One of these is the Award for Outstanding Research. The purpose of this award is to acknowledge individuals or research groups whose work has achieved a high international standard.

The 2025 recipient of the Award for Outstanding Research is Professor Erika Eiser, Principal Investigator at PoreLab. She received the award on January 8, 2026, during NVDAY26, the Faculty Day of the Faculty of Natural Sciences.

The evaluation committee stated the following: *Prof. Erica Eiser has made exceptional contributions to the field of soft matter and colloidal science, combining theoretical insight with experimental innovation. Her research has significantly advanced our understanding of self-assembly processes and complex materials, with broad implications for nanotechnology and biomimetic systems.*

This year, Erica's work was featured in Proceedings of the National Academy of Sciences (PNAS), underscoring the international impact and originality of her research. The study exemplifies her ability to address fundamental scientific questions while opening pathways for practical applications. Beyond this recent achievement, Erica has a long-standing record of excellence, including pioneering work on DNA-mediated colloidal interactions and the development of novel approaches to control material properties at the nanoscale.

Her collaborations across institutions, including NTNU and the University of Cambridge, have fostered interdisciplinary research and strengthened NTNU's global scientific profile.

For these reasons, we strongly support Erica's nomination for this award, recognizing her outstanding research achievements and her role in advancing the mission of the NV Faculty at NTNU.

COMPLETED PHDs IN 2025

NAME	DEPARTMENT	DATE	THESIS	SUPERVISORS
Mohammad Hossein Golestan	Department of Geosciences, NTNU	07.02.2025	*Pore-scale investigations of fluid flow and interfacial mass transfer*	Carl Fredrik Berg, Ole Torsæter
Caroline Einen	Department of Physics, NTNU	28.02.2025	*Ultrasound-mediated delivery and transport of nanomedicines through the tumor extracellular matrix – effects and possible mechanisms*	Catharina Davies, Signe Kjelstrup, Einar Sulheim and Rune Hansen
Paiman Shafabakhsh	Department of Geosciences, UiO	05.03.2025	*Imaging and Numerical Modeling of Fluid Mixing in Rocks with Evolving Porosity*	François Renard, Gaute Linga, Tanguy Le Borgne, Joachim Mathiesen
Håkon Pedersen	Department of Physics, NTNU	25.04.2025	*Geometry of the Co-Moving Velocity in Immiscible and Incompressible Two-Phase Porous Media Flow*	Alex Hansen, Knut Jørgen Måløy
Jennifer Ruth Sheehan	Department of Mechanical and Industrial Engineering, NTNU	22 and 23.05.2025	*Decay Behaviour, State Transitions and Escape Rates in Simple Models for Complex Systems*	Astrid de Wijn, Nuria Espallargas, Alex Hansen
Fazel Mirzaei	Department of Physics, NTNU	10.06.2025	*Neutron and X-ray microscopy of water dynamics, liquefaction and ice formation in porous media*	Dag Werner Breiby, François Renard, Knut Eilif Aasmundtveit
Joachim Brodin	Department of Physics, UiO	17.10.2025	*Stable and unstable invasion in two-phase flow in three-dimensional porous media*	Knut Jørgen Måløy, Eirik G. Flekkøy, Marcel Moura
Reza Haghani	Department of Geosciences, NTNU	28.11.2025	*Wettability characterization of porous media – Multiphase Lattice-Boltzmann simulation*	Carl Fredrik Berg, Eirik G. Flekkøy

Defense of thesis for ***Mohammad Hossein Golestan***

From left to right:
Senior Researcher Johan Olav Helland, Professor Lesley Anne James, Professor Emeritus Ole Torsæter, Dr. Mohammad Hossein Golestan, Professor Carl Fredrik Berg, Associate Professor Antje van der Net

Defense of thesis for ***Caroline Einen***

From left to right:
Professor Twan Lammers, Associate Professor Rita Dias, Dr. Caroline Einen, Researcher Einar Sulheim, Professor Catharina Davies, Senior Lecturer James Choi and Professor Emerita Signe Kjelstrup

Defense of thesis for ***Paiman Shafabakhsh***

From left to right:
Associate Professor Gaute Linga, Dr. Paiman Shafabakhsh, Professor François Renard, Professor Samuel Krevor, Scientific Researcher Linda Luquot

Defense of thesis for ***Håkon Pedersen***

From left to right:
Dr. Santanu Sinha, Professor Bjarne Andresen, Dr. Håkon Pedersen, Dr. Thomas Ramstad, Professor Alex Hansen, Dr. Marie-Laure Olivier

Defense of thesis for ***Jennifer Ruth Sheehan***

From left to right:
Professor Roy Johnsen, Professor Merja Heinäniemi, Professor Supriya Krishnamurthy, Dr. Jennifer Ruth Sheehan, Professor Astrid de Wijn

Defense of thesis for ***Fazel Mirzaei***

From left to right:
Dr. Fazel Mirzaei, Professor Dag Werner Breiby, Professor Luise Theil Kuhn, Dr. David Wragg, Professor Turid Reenaas

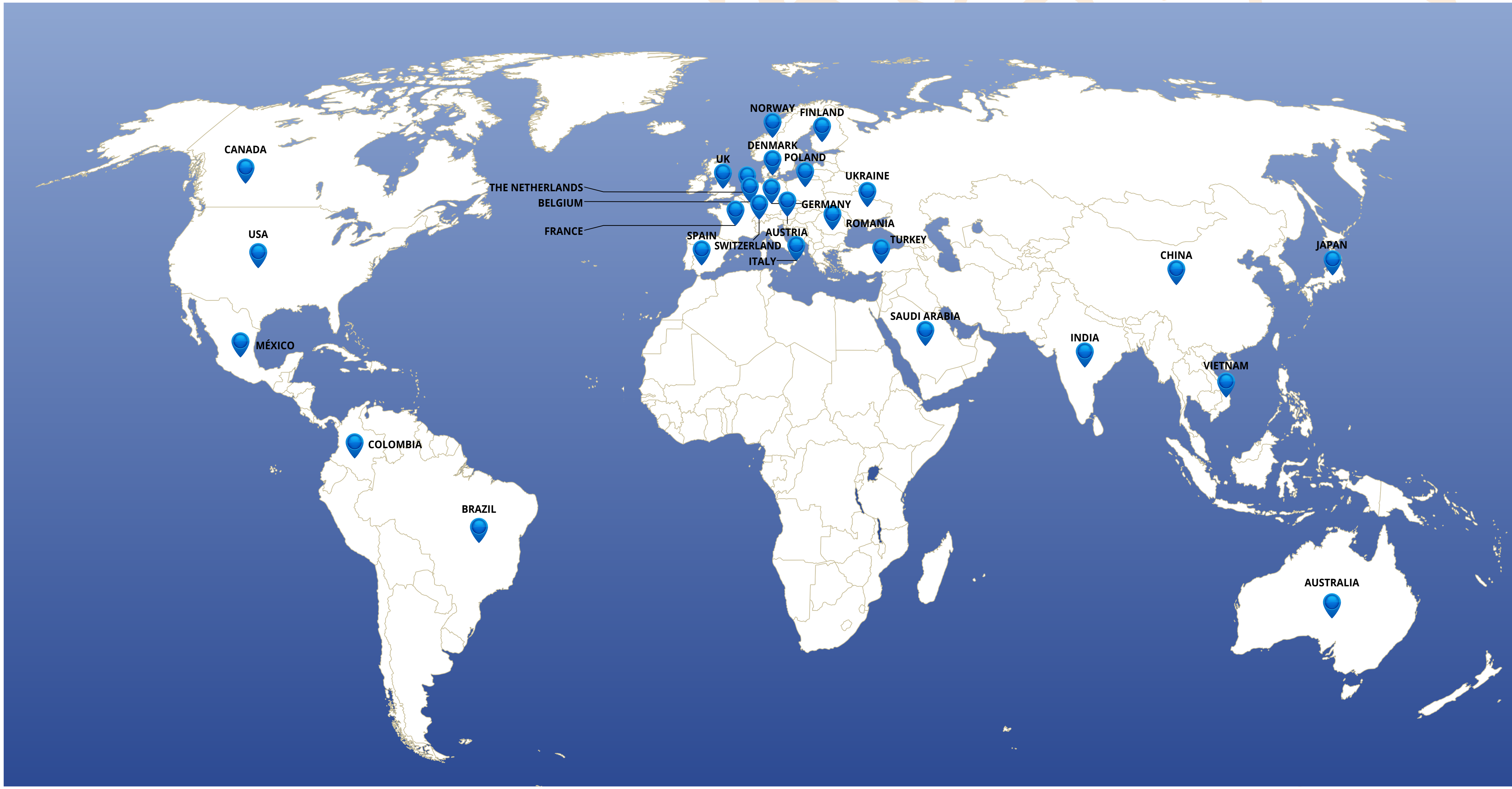
Defense of thesis for ***Joachim Brodin***

From left to right: Professor Eirik G. Flekkøy, Professor Knut Jørgen Måløy, Professor Emeritus Per Arne Rikvold, Dr. Marcel Moura, Dr Joachim Brodin

Defense of thesis for ***Reza Haghani***

From left to right:
Professor Carl Fredrik Berg, Professor Sauro Succi, Dr. Reza Haghani, Dr. Marie-Laure Olivier, Dr. Mohammad Masoudi

NATIONAL AND INTERNATIONAL COLLABORATION



USA
Sarah L. Codd, Joseph Seymour: *College of Engineering, Montana State University, Bozeman*
James E. McClure: *Virginia Tech*
Peter Kang: *University of Minnesota*
Saman Aryana: *University of Wyoming*
Douglas Durian: *University of Pennsylvania*
Catherine Spurin: *Stanford University*
Muhammad Sahimi: *University of Southern California*
Bauyrzhan Primkulov: *MIT*
Sanjana Kamath: *Princeton University*
Sang Hyun Lee: *University of Massachusetts Amherst*

CANADA
Apostolos Kantzas: *University of Calgary*
Ian Frigaard: *University of British Columbia*

MÉXICO
Filiberto Herrera Castro: *Universidad Nacional Autónoma de México*

COLOMBIA
Daniel Barragán, Andrés Arango-Restrepo: *School of Chemistry, Faculty of Sciences, National University of Colombia*

BRAZIL
José Soares Andrade Jr., Hans J. Herrmann: *Universidade Federal do Ceara*
Fernando A. Oliveira: *University of Brasilia*
Vinicius Martins: *UNICAMP, Campinasl*
Rodrigo Surmas, Rodrigo Skinner, Fatima Brazil: *Petrobras*
Cirilo Seppi Bresolin, Guilherme Henrique Fiorot, Lorenzo Olivo Filippini: *ReoSul*

NORWAY
Magnus Aa. Gjennestad, Rune Hansen, Asbjørn Solheim, Vegard Brøtan, Pierre Cerasi: *SINTEF*
Ailo Aasen, Karl Yngve Lervåg, Morten Hammer: *ThermoPhys*
Preben Vie, Geir Helgesen, Kenneth Knudsen: *Institute for Energy Technology, IFE*
Lars Folkow: *The Arctic University of Norway*
Bernt O. Hilmo: *Asplan Viak AS*
Marianne Øksnes Dalheim, Kristin Syverud: *RISE PFI AS*
Harald Berland, Olav Aursjø: *NORCE Norwegian Research center AS*
Thomas Ramstad, Lars Rennan, Colin Pryme, Anders Kristoffersen, Haili Long-Sanouiller: *Equinor*
Kim Roger Kristiansen: *Ocean GeoLoop AS, Steinkjer*

DENMARK
Joachim Mathiesen, Mogens Høgh Jensen, Bjarne Andresen: *Niels Bohr Institute, University of Copenhagen*

FINLAND
L. Laurson, Mikko Alava: *Department of Applied Physics, Aalto University, Espoo*

GERMANY
Rainer Helmig, Joachim Gross and Luca Schmid: *University of Stuttgart*
Andrzej Gorak: *TU Dort*
Steffen Schlüter: *Helmholtz Center for Environmental Research, Leipzig*
Clemens Bechinger: *Konstanz University*
Iliya D. Stoev: *Karlsruhe Institute of Technology (KIT)*

SWITZERLAND
Berend Smit: *Ecole Polytechnique Fédérale de Lausanne (EPFL)*
Anasua Mukhopadhyay , Frank Scheffold: *Merkel Institute, Fribourg*
Prescelli Annan: *ETH, Zurich*
Anders Kaestner, Andreas Menzel: *PSI*

THE NETHERLANDS
Thijs J.H. Vlugt, Claire Chassagne, Othon Moultos: *Delft University of Technology*
Majid Hassanizadeh: *Multiscale Porous Media Laboratory, Utrecht University*
Edgar M. Blokhuis: *University of Leiden*
Steffen Berg: *Shell Research, Amsterdam*
Maja Rücker: *Eindhoven University of Technology*
Michel Versluis: *University of Twente*

BELGIUM
Tom Bultreys, Veerle Cnudde: *Gent University*

AUSTRIA
Sofia Kantorovich: *University of Vienna*

UK
Bjørnar Sandnes: *Energy Safety Research Institute, College of Engineering, Swansea University*
Fernando Bresme, Erich A. Müller: *Imperial College London*
Daan Frenkel, Matthew Mason, Mike Cates: *University of Cambridge*
Robin Cleveland: *Oxford University*
Ran Holtzman: *Coventry University*
Alin Marin Elena: *Daresbury Laboratory*
Richard Barker: *University of Sheffield*

FRANCE
Lydéric Bocquet, Marie-Laure Bocquet: *CNRS/Ecole Normale Supérieure, Paris*
Sunniva Indrehus: *Pierre and Marie Curie University, Paris VI*
Alberto Rosso: *Laboratoire Physique Théorique et Modèles Statistiques (LPTMS), Université Paris-Saclay, Orsay*
Laurent Talon, Nathan Abitbol: *Laboratoire FAST, Université de Paris-Saclay, Orsay*
Renaud Toussaint, Monem Ayaz: *Institut de Physique du Globe de Strasbourg, CNRS, Université de Strasbourg*
Tanguy Le Borgne, Yves Méheust : *University of Rennes*
Jean-Marc Simon: *University of Bourgogne, CNRS*
Stéphane Santucci, Michael Bourgoin: *Ecole Normale Supérieure de Lyon, UMR CNRS, Lyon*
Wei Dong: *CNRS, Lyon*
Osvanny Ramos: *Department of Physics, Claude Bernard University, Lyon*
Jean-Noël Jaubert, Silvia Lasala: *Université de Lorraine*
Francesco Puosi: *University Gustave Eiffel*
Yuriy Chushkin, Bratislav Lukic: *ESRF – The European Synchrotron Radiation Facility*

SPAIN
Miguel Rubi, David Reguera, Jordi Ortín, Ramon Planet, Ignacio Pagonabarraga: *University of Barcelona*
Juan José Hidalgo González, Marco Dentz: *Institute of Environmental Assessment and Water Research (IDAEA)*

ITALY
Sauro Succi: *Instituto Italiano di Tecnologia*
Luciano Colombo: *University of Cagliari*
Davide Picchi, Paolo Botticini: *University of Brescia*

POLAND
Wojciech Debski: *Department of Theoretical Geophysics, Institute of Geophysics Polish Academy of Sciences, Warszawa*

ROMANIA
Mirela-Nicoleta Stoeac-Vladuti: *Art space director, META Spatiu, Timisoara*
Cosmin Haias, automation engineer and artist, *Timisoara*

UKRAINE
Natalya Kizilova: *Department of Theoretical and Applied Mechanics, Kharkov National University*

TURKEY
Talha Erdem: *Abdullah Gul University, Kayseri*
Levent Akyalçin: *Eskişehir Technical University, Eskişehir*
Seniz Ucar: *Middle Eastern Technical University*

INDIA
Purusattam Ray: *Institute of Mathematical Sciences, Chennai*
Subhadeep Roy: *BITS Pilani, Hyderabad*
Sitangshu B. Santra, Jnana Das: *Indian Institute of Technology, Guwahati*

SAUDI ARABIA
Cenk Temizel, *ARAMCO*

VIETNAM
Thi H. Ho: *Van Lang University, Ho Chi Minh City*
Hien Duy Tong: *Vietnamese-German University (VGU), Ho Chi Minh City*

CHINA
Ye Xu: *School of Mechanical Engineering and Automation, Beihang University, Beijing*
Xin Wang: *Institute of Oceanography Instrumentation, Shandong Academy of Sciences, Qingdao*

JAPAN
Pieter Krüger: *Graduate School of Science and Engineering, Molecular Chirality* Research Center, Chiba University, Chiba
Taiki Yanagishima: *Kyoto University*

AUSTRALIA
Benjy Marks: *University of Sydney*
Ryan Armstrong: *University of New South Wales*
Mark Knackstedt: *Australian National University, Department of Applied Mathematics, Canberra*
Christoph Arns: *UNSW, Sidney*

GUEST RESEARCHERS AT PORELAB

At PoreLab, we have fostered an open, inclusive, and collaborative culture since the very beginning. Guests are always welcomed, whether visiting for a short stay or an extended collaboration. They come from diverse disciplines and communities. They bring with them a wealth of knowledge, experience and fresh perspectives that enrich our research activities. Hosting guest researchers not only broadens our academic horizons but also fosters collaboration and interdisciplinary exchange. Most of them gave lectures and workshops were organized when international delegations visited us.

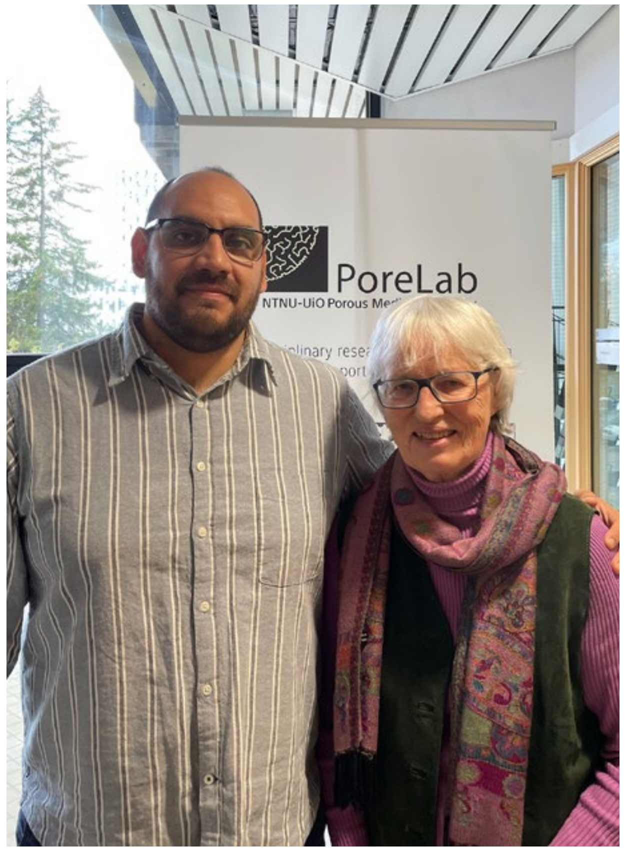
NAME	POSITION	AFFILIATION	PERIOD
Paolo Botticini	PhD candidate	Department of Mechanical and Industrial Engineering, University of Brescia, Italy	15.01.25 – 15.07.25
Daan Frenkel	Professor Emeritus	University of Cambridge, UK	18.01.25 – 07.02.25
Lesley Anne James	Professor	Faculty of Engineering and Applied Science, Memorial University, Newfoundland and Labrador's University, Canada	05.02.25 – 07.02.25
Mogens Høgh Jensen	Professor	Niels Bohr Institute, University of Copenhagen, Denmark	12.02.25 – 14.02.25
Daan Frenkel	Professor Emeritus	University of Cambridge, UK	17.02.25 – 01.03.25
Daan Frenkel	Professor Emeritus	University of Cambridge, UK	23.03.25 – 31.03.25
Nathan Abitbol	PhD candidate	FAST (Fluides, Automatique et Systèmes Thermiques), University Paris-Saclay, Orsay, France	24.03.25 – 24.04.25
Daan Frenkel	Professor Emeritus	University of Cambridge, UK	07.04.25 – 24.04.25
Bjarne Andresen	Professor	Niels Bohr Institute, University of Copenhagen, Denmark	24.04.25 – 26.04.25
Julie Delhaie	Master student	École Normale Supérieure de Lyon, France	25.04.25 – 25.07.25
Natalya Kizilova	Professor	Department of Theoretical and Applied Mechanics, Kharkov National university, Ukraine	06.05.25 – 10.05.25
Daan Frenkel	Professor Emeritus	University of Cambridge, UK	07.05.25 – 16.05.25
Konstantin Matveev	Professor	Hydrogen Properties for Energy Research (HYPER) Center at Washington State University	08.05.25
Anasua Mukhopadhyay	Postdoctoral researcher	Merkel Institute in Fribourg, Switzerland	13.05.25 – 18.05.25
Daan Frenkel	Professor Emeritus	University of Cambridge, UK	26.05.25 – 06.06.25
David Reguera López	Professor	Department of Condensed Matter Physics of the University of Barcelona, Spain	26.05.25 – 16.06.25
Daan Frenkel	Professor Emeritus	University of Cambridge, UK	19.06.25 – 24.06.25
Emma Le Du	Master student	Ecole Centrale Nantes, France	23.06.25 – 20.07.25
Davide Picchi	Associate Professor	Department of Mechanical and Industrial Engineering, University of Brescia, Italy	23.06.25 – 28.06.25
Daan Frenkel	Professor Emeritus	University of Cambridge, UK	20.07.25 – 23.07.25
Daan Frenkel	Professor Emeritus	University of Cambridge, UK	30.07.25 – 27.08.25
Lydéric Bocquet	Director of Research at the CNRS	NTNU Lars Onsager Professorship 2025. Director of Research at the CNRS, Professor at the École Normale Supérieure, ENS, University PSL, France	03.08.25 – 06.09.25
Marie-Laure Bocquet	Director of Research at the CNRS	Director of Research at the CNRS, École Normale Supérieure, ENS, University PSL, France	03.08.25 – 06.09.25
Ahmad Arabkoohsar	Professor	Department of Civil and Mechanical Engineering, Thermal Energy, Technical University of Denmark (DTU)	11.08.25 – 13.08.25
Meisam Sadi	Tenure track researcher	Department of Civil and Mechanical Engineering, Thermal Energy, Technical University of Denmark (DTU)	11.08.25 – 13.08.25
Amirmohammad Behzadi	Postdoctoral researcher	Division of Building Technology and Design, KTH Royal Institute of Technology, Sweden	11.08.25 – 13.08.25

NAME	POSITION	AFFILIATION	PERIOD
Valentino Sanguinetti	PhD candidate	Laboratoire de Physiques de l'Ecole Normale Supérieure, ENS, Paris, France	11.08.25 – 15.08.25
Prescelli Annan	PhD candidate	Swiss Seismological Service (SED), ETH Zurich, Switzerland	11.08.25 – 29.08.25
Steffen Berg	Professor	Principal Science Expert at Shell Global Solutions International B.V. in the Netherlands – Adjunct Professor at NTNU, Trondheim, Norway	01.09.25 – 05.09.25
Daan Frenkel	Professor Emeritus	University of Cambridge, UK	27.09.25 – 22.10.25
Luca Schmid	Master student	Mechanical Engineering, University of Stuttgart, Germany	22.09.25 – 25.01.26
Marcel Filoche	Professor	Ecole Polytechnique, CNRS Research Director at the Langevin Institute of ESPCI, Paris, France	27.09.25 – 01.10.25
Laurent Talon	Researcher	FAST (Fluides, Automatique et Systèmes Thermiques), University Paris-Saclay, Orsay, France	27.09.25 – 01.10.25
Alberto Rosso	Research Director	CNRS, LPTMS (Laboratoire Physique Théorique et Modèles Statistiques), University Paris-Saclay, Orsay, France	27.09.25 – 01.10.25
José Soares de Andrade junior	Professor	Universidade Federal do Ceará, Fortaleza, Brazil	27.09.25 – 01.10.25
Paolo Botticini	PhD candidate	UNIBS, University of Brescia, Brescia, Italy	27.09.25 – 01.10.25
Nathan Abitbol	PhD candidate	FAST (Fluides, Automatique et Systèmes Thermiques), University Paris-Saclay, Orsay, France	27.09.25 – 01.10.25
Sanjana Kamath	PhD candidate	University of Princeton, Princeton, NZ, USA	27.09.25 – 01.10.25
Filiberto Herrera Castro	Postdoctoral researcher	Universidad Nacional Autónoma de México	07.10.25 – 18.10.25
Cirilo Seppi Bresolin	Professor	ReoSul (Federal University of Rio Grande do Sul), Brazil	19.10.25 – 29.10.25
Guilherme Henrique Fiorot	Assistant Professor	ReoSul (Federal University of Rio Grande do Sul), Brazil	19.10.25 – 21.11.25
Lorenzo Olivo Filippini	Master student	ReoSul (Federal University of Rio Grande do Sul), Brazil	17.10.25 – 21.11.25
Daan Frenkel	Professor Emeritus	University of Cambridge, UK	29.10.25 – 05.12.25
Lyderic Bocquet	Professor	NTNU Lars Onsager Professorship 2025. Director of Research at the CNRS, Professor at the École Normale Supérieure, ENS, University PSL, France	20.11.25 – 25.11.25
Marie-Laure Bocquet	Director of Research at the CNRS	CNRS, École Normale Supérieure (ENS), Paris, France	20.11.25 – 25.11.25
Sauro Succi	Senior Research Executive	Center for Life Nano Science at la Sapienza, Roma, Instituto Italiano di Tecnologia, Italia. Adjunct Professor at NTNU, Trondheim, Norway	24.11.25 – 29.11.25
Iliya D. Stoev	Research Fellow	Karlsruhe Institute of Technology (KIT), Germany	26.11.25 – 30.11.25
Steffen Berg	Professor	Principal Science Expert at Shell Global Solutions, The Netherlands. Adjunct Professor at the department of Physics, NTNU, Norway	24.11.25 – 05.12.25

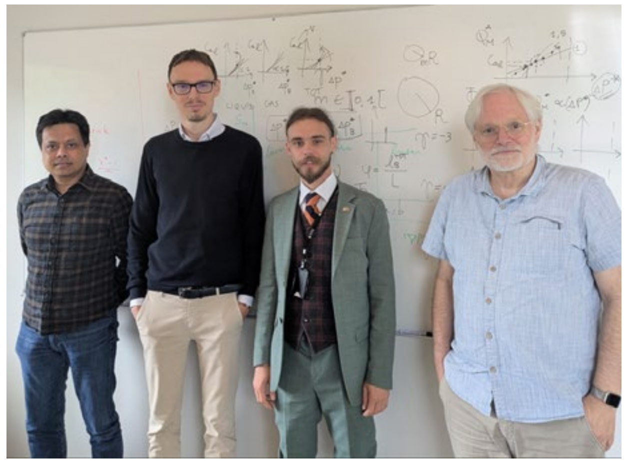
From left to right: PhD candidate Yann Dumay (PoreLab, Department of Physics), PhD candidate Ilaria Beechey-Newman (PoreLab, Department of Physics), Master student Gabriel Paaske (PoreLab, Department of Physics), Professor Erika Eiser (PoreLab, Department of Physics), Julie Delhaie (Ecole Normale Supérieure de Lyon, France) and Dr. Anasua Mukhopadhyay (Merkel Institute in Fribourg, Switzerland).

From left to right: Professor David Reguera (University of Barcelona, Spain), Ailo Aasen (ThermoPhys, Norway), Professor Morten Hammer (ThermoPhys and Adjunct Professor at NTNU, Norway).

Dr. Filiberto Herrera Castro (Universidad Nacional Autónoma de México) and Professor Emerita Signe Kjelstrup



From left to right: Researcher Santanu Sinha (PoreLab, Department of Physics), Associate Professor Davide Picchi (University of Brescia), PhD candidate Paolo Botticini (University of Brescia), Professor Alex Hansen (PoreLab, Department of Physics).

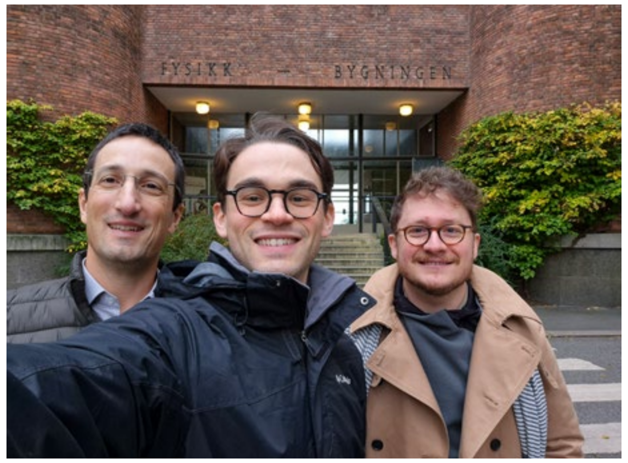


Visit from DTU – Thermal Energy Group at PoreLab/NTNU. From left to right: Professor Emeritus Bjørn Hafskjold, Professor Øivind Wilhelmsen, Professor Emeritus Dick Bedeaux, Professor Emerita Signe Kjelstrup, Dr. Meisam Sadi (DTU), Professor Ahmad Arabkoohsar (DTU), Postdoctoral researcher Amirmohammad Behzadi (KTH)

From left to right: Emeritus Professor Daan Frenke (Cambridge University), Research Director Marie-Laure Bocquet (ENS, Paris), PhD candidate Yann Dumay (PoreLab, NTNU), Professor Lydéric Bocquet (ENS, Paris) and Professor Erika Eiser (PoreLab, NTNU)

Master students Emma Le Du (Ecole Centrale de Nantes, France) and Julie Delhaie (Ecole Normale Supérieure de Lyon, France)

From left to right: Professor Cirilo Seppi Bresolin, Master student Lorenzo Olivo Filippini and Assistant Professor Guilherme Henrique Fiorot – Delegation from ReoSul (Federal University of Rio Grande do Sul), Brazil to PoreLab Oslo



FUNDING IN 2025

PoreLab's funding varies annually based on its activities. The combined contributions from the Research Council of Norway (RCN), NTNU, and UiO will total 283,1 MNOK over the center's entire duration.

In January 2025, the Research Council of Norway approved our request to extend PoreLab's duration until the end of September 2028. This extension, resulting from delayed recruitments, does not impact the total budget, which remains unchanged

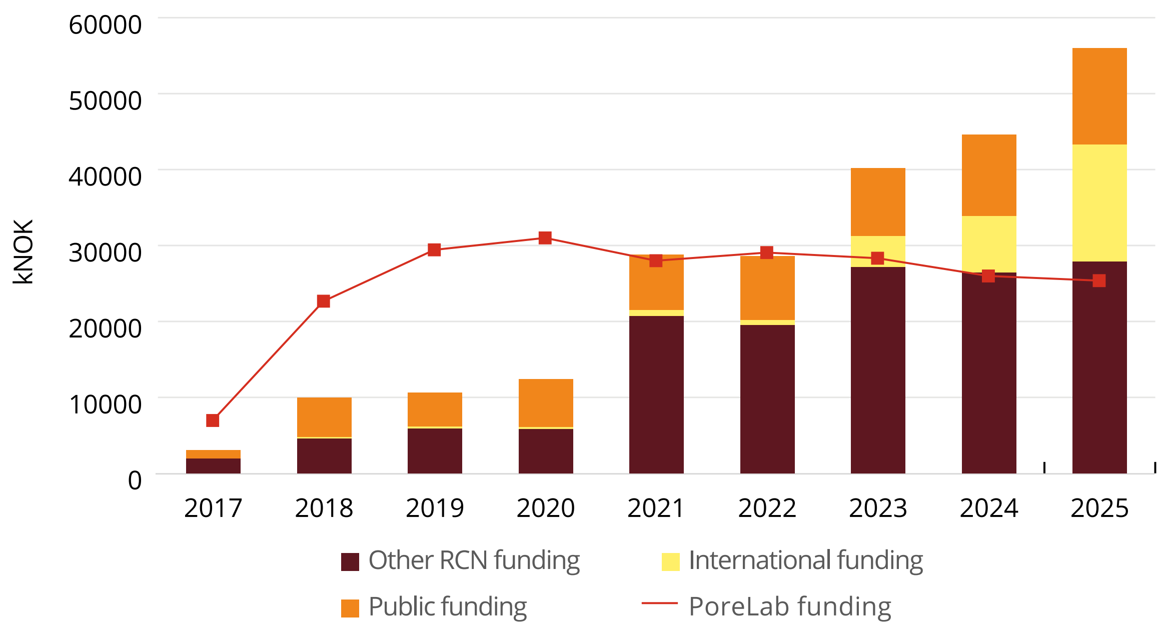
PoreLab's funding consists of the resources allocated to establish and sustain the Center, covering its operational costs. Over 11 years (2017–2028), the Research Council of Norway (RCN) will provide a total of 148,1 MNOK. During the same period, NTNU and UiO will contribute a combined 135 MNOK, with NTNU providing 72 MNOK (53%) and UiO contributing 63 MNOK (47%).

FUNDING (kNOK)	AMOUNT	PERCENTAGE
The Research Council	13 247	52 %
NTNU	6 672	26 %
University of Oslo	5 454	21 %
TOTAL	25 373	100 %

As part of the Center of Excellence (CoE) agreement with the Research Council of Norway (RCN), PoreLab researchers are encouraged to develop additional externally funded projects (see *"Heading for the Future: Our New Projects"* in PoreLab's annual reports). These projects, carried out under PoreLab's umbrella, can receive funding from the RCN, the EU, industry partners, university internal funds, and other sources. The graph on the right illustrates annual funding (in kNOK) by source. *"Other RCN funding"* denotes financial support from additional projects funded by the Research Council of Norway. *"International funding"* primarily refers to support from the European Commission, while *"Public funding"* mainly represents internal contributions from NTNU and UiO.

Two important results are worth noting:

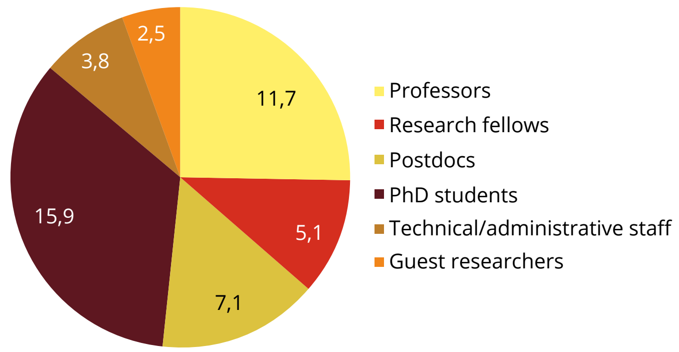
1. Funding from additional externally funded projects has continued to grow, reaching an impressive 56 MNOK in 2025.
2. 2023 marked a pivotal year when funding from these additional projects significantly surpassed PoreLab's core funding.



FACTS AND FIGURES

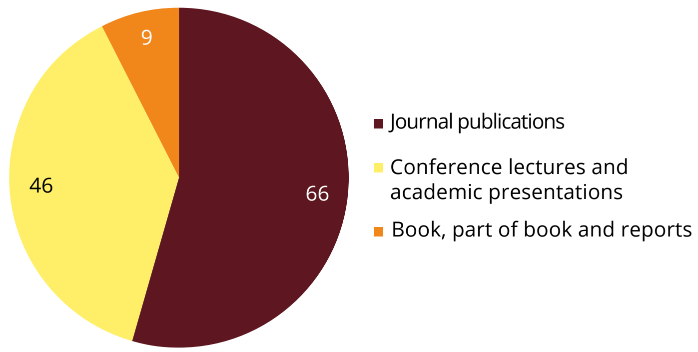
PORELAB STAFF categorized by position

PoreLab equals 46 man-years in 2025
The pie chart on the right shows the categorization of our staff by position



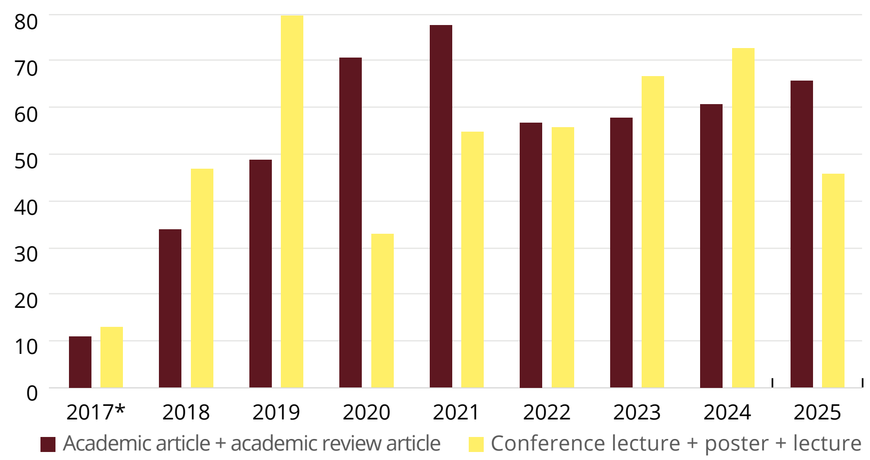
PUBLICATIONS in 2025

66 Journal Publications
46 Conference lectures and academic presentations
9 books, part of book and reports



PUBLICATIONS since 2017

H-index in 2025 = 39
The H-index has been calculated based only on the number of peer-reviewed journal publications



*Publications over 4,5 months since PoreLab started on 15.08.2017

PORELAB MEMBERS

PoreLab Executive Board

Øyvind Gregersen
Dean
NV faculty, NTNU
Until July 2025

Jens-Petter Andreassen
Dean
NV faculty, NTNU
From August 2025

Erik Wahlström
Head of department
Department of Physics, NTNU
Until July 2025

Kathrine Røe Redalen
Head of department
Department of Physics
NTNU
From August 2025

Sveinung Løset
Professor, Department of Civil and Environmental Engineering, NTNU
Vice Dean Research and Innovation
Faculty of Engineering, NTNU
Until July 2025

Terese Løvås
Professor, Department of Energy and Process Engineering
Vice Dean Research and Innovation
Faculty of Engineering, NTNU
From August 2025

Susanne Viefers
Head of department
Department of Physics
University of Oslo

Anders Malthe-Sørenssen
Professor, Center for Computing in Science Education
University of Oslo

The Leader Group

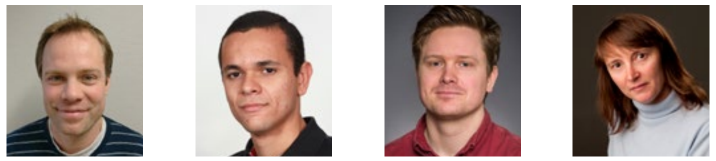
Alex Hansen
Director, Professor,
Department of Physics,
NTNU

Eirik Flekkøy
Deputy Director, Professor,
Department of Physics,
UiO

Knut Jørgen Måløy
Professor
Department of Physics,
UiO

Erika Eiser
Department of Physics,
NTNU

Øivind Wilhelmsen
Professor,
Department of Chemistry,
NTNU



Carl Fredrik Berg
Professor,
Department of Geosciences,
NTNU

Marcel Moura
Researcher,
Department of Physics,
UiO

Gaute Linga
Associate Professor,
Department of Physics,
NTNU

Marie-Laure Olivier
Administrative leader,
Department of Physics,
NTNU

Scientific Advisory Board

Veerle Cnudde
Professor
Ghent University, Belgium and Utrecht University
The Netherlands

Steffen Berg
Principal Science Expert at Shell Global Solutions International B.V.,
The Netherlands

Douglas Durian
Mary Amanda Wood Professor of Physics and Astronomy,
University of Pennsylvania,
USA

Pål-Eric Øren
Chief Technology Officer
Digital Rock Services
Petricore, Trondheim, Norway

PhD Students

Ilaria Beechey-Newman
PhD,
Department of Physics,
NTNU

Fazel Mirzael
PhD,
Department of Physics,
NTNU

Håkon Pedersen
PhD,
Department of Physics,
NTNU

Mukul Jaiswal
PhD,
Department of Physics,
NTNU

Reza Haghanihasanabadi
PhD,
Department of Geosciences,
NTNU

Vegard Jervell
PhD,
Department of Chemistry,
NTNU

Tage Maltby
PhD,
Department of Chemistry,
NTNU

Rene Tammen
PhD,
Department of Physics,
NTNU

Kamila Zablocka
PhD,
Department of Structural Engineering,
NTNU

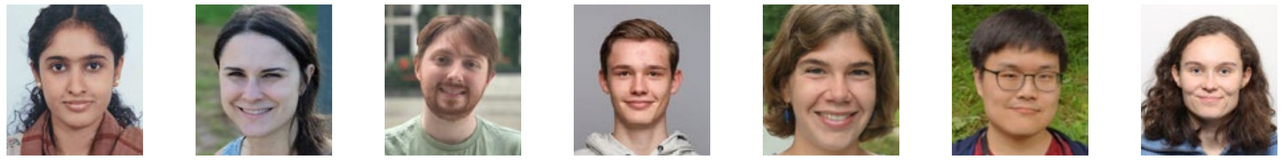
Andreas Henning
PhD,
Department of Physics,
NTNU

Mohammad Hemayati
PhD,
Department of Civil and Environmental Engineering,
NTNU

Jonas Bueie
PhD,
Department of Chemistry,
NTNU

Arshitha Mathew
PhD,
Department of Physics,
NTNU

Shibi Palliyalil
PhD,
Department of Physics,
NTNU



Soumya Pallipotta
PhD,
Department of Physics,
NTNU

Jessica Zeman
PhD,
Department of Physics,
NTNU

Joe Stickland
PhD,
Department of Physics,
NTNU

Bjarte Matre
PhD,
Department of Physics,
NTNU

Mateja Macut
PhD,
Department of Geosciences,
NTNU

Tae Kwon Yun
PhD,
Department of Geosciences,
NTNU

Sigrid Aunsmo
PhD,
Department of Chemistry,
NTNU

Yann Dumay
PhD,
Department of Physics,
NTNU

Johannes Løken
PhD,
Department of Chemistry,
NTNU

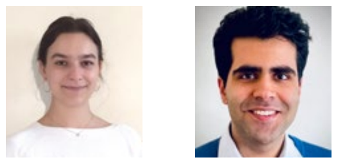
Mohammad Hassan Taleghani
PhD,
Department of Geosciences,
NTNU

Anders Daltveit Melve
PhD,
Department of Physics,
NTNU

Giacomo Luani
PhD,
Department of Physics,
NTNU

Srinivasa R. R. Nomula
Department of Physics,
NTNU

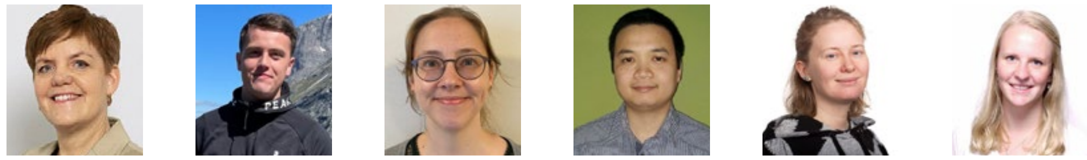
Yao Xu
PhD,
Department of Physics,
UiO



Maud Viallet
PhD,
Department of Physics,
UiO

Paiman Shafabakhsh
PhD,
Department of Geosciences,
UiO

Administrative and Technical Staff



Janne Hoff
Administrative coordinator for Njord Center and PoreLab UiO

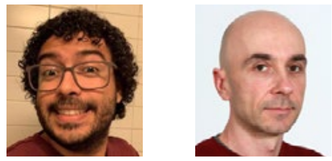
Jørgen Haukø Alsaker
Senior executive officer, Faculty of Natural Sciences, NTNU
Until September 2025

Kjersti Karlsen Hofstad
Financial officer, Department of Physics, NTNU
From October 2025

Thuat Trinh
Senior engineer, Department of Chemistry, NTNU

Augusta Hlin Aspar Sundbø
Senior engineer, Department of Physics, NTNU

Corinna Dannert
Head Engineer, Department of Physics, NTNU



Osvaldo T. Neto
Head Engineer, Department of Physics, NTNU

Mihailo Jankov
Senior Engineer, Department of Physics, UiO

PostDocs

Quirine Krol
PostDoc, Department of Physics, NTNU

Farid Aligolzadeh
PostDoc, Department of Chemistry, NTNU

Vitor Heitor Cardoso Cunha
PostDoc, Department of Chemistry, NTNU

Fufang Yang
PostDoc, Department of Chemistry, NTNU

Pooja Singh
PostDoc, Department of Physics, NTNU

Øystein Gullbrekken
PostDoc, Department of Materials Science and Engineering, NTNU

Ge Li
PostDoc, Department of Mechanical and Industrial Engineering, NTNU

Khobaib Khobaib
PostDoc, Department of Physics, UiO

Federico Lanza
PostDoc, Department of Physics, UiO

Antoine Dop
PostDoc, Department of Physics, UiO

Kevin Pierce
Postdoc, Njord center, UiO

Researchers and Associates

Signe Kjelstrup
Professor Emerita, Department of Chemistry, NTNU

Bjørn Hafskjold
Professor Emeritus, Department of Chemistry, NTNU

Dick Bedeaux
Professor Emeritus, Department of Chemistry, NTNU

Santanu Sinha
Researcher, Department of Physics, NTNU

Basab Chattopadhyay
Associate professor, department of Physics, NTNU

Morten Hammer
Adjunct Professor, department of Chemistry, NTNU

Renaud Toussaint
Adjunct Professor, Department of Physics, UiO

Ole Torsæter
Professor Emeritus, Department of Geosciences, NTNU

Dag Werner Breiby
Professor, Department of Physics, NTNU

Catharina de Lange Davies
Professor, Department of Physics, NTNU

Seyed Ali Amiri
Researcher, Department of Civil and Environmental Engineering, NTNU

Raffaela Cabriolu
Associate Professor, Department of Physics, NTNU

Luiza Angheluta-Bauer
Associate Professor, Department of Physics, UiO

Chayene Anchieta
Researcher, Department of Physics, NTNU

Steffen Berg
Adjunct professor, Department of Physics, NTNU

Saman Aryana
Adjunct professor, Department of Physics, NTNU

Astrid de Wijn
Professor, Department of Mechanical and Industrial Engineering, NTNU

Anders Lervik
Associate Professor, Department of Chemistry, NTNU

Antje van der Net
Associate Professor, Department of Geosciences, NTNU

Thomas Combriat
Researcher, Njord center, UiO

Fabian Barras
Researcher, Njord center, UiO

Paula K. P. Reis
Researcher, Department of Physics, UiO

Sauro Succi
Adjunct professor, Department of Physics, NTNU

Lydéric Bocquet
Onsager Professor, Department of Physics, NTNU

Per Arne Rikvold
Professor Emeritus, Department of Physics, UiO

PUBLICATIONS 2025

The following lists journal publications; books; reports; doctoral theses, conference lectures and academic presentations generated in 2025

JOURNAL PUBLICATIONS

Aghajanpour, Azadeh; Berg, Carl Fredrik
Directional- and scale-dependent permeability estimations from CT images. 2025. *Geoenergy Science and Engineering.* Volume: 247 NTNU

Alfazazi, Umar; Moura, Marcel; Wang, Ying Da; Bedeaux, Dick; Kjelstrup, Signe; Mostaghimi, Peyman; Armstrong, Ryan
Using the fluctuation-dissipation theorem to measure total phase mobility during fractional flow experiments. 2025. *Zenodo* UiO

Amiri, Seyed Ali Ghoreishian; Grimstad, Gustav; Dadrasajirlou, Davood
Integration of hyperplastic models in strain space. 2025. *Géotechnique* NTNU

Beechey-Newman, Ilaria; Kizilova, Natalya; Hennig, Andreas Andersen; Flekkøy, Eirik Grude; Eiser, Erika
Confined colloidal droplets dry to form circular mazes. 04.08.2025. *Proceedings of the National Academy of Sciences of the United States of America (PNAS).* Volume: 122(32) NTNU UiO

Birgisson, Hilmar Yngvi; Xu, Yao; Moura, Marcel; Flekkøy, Eirik Grude; Måløy, Knut Jørgen
Mapping dissolved carbon in space and time: An experimental technique for the measurement of pH and total carbon concentration in density driven convection of CO_2 dissolved in water. 2025. *Advances in Water Resources.* Volume: 198 UiO NTNU

Brodin, Joachim Falck; Pierce, James Kevin; Reis, Paula Kozlowski Pitombeira; Rikvold, Per Arne; Moura, Marcel; Jankov, Mihailo; Måløy, Knut Jørgen
Interface instability of two-phase flow in a three-dimensional porous medium. 11.06.2025. *Physical Review Fluids.* Volume: 10(6) UiO NTNU

Buendía, Gloria M.; Mendes, Celeste; Rikvold, Per Arne.
A comparative review of recent results on supercritical anomalies in two-dimensional kinetic Ising and Blume–Capel ferromagnets. *European Physical Journal B : Condensed Matter Physics.* 23.08.2025. Volume: 98.(8) UiO

Cunha, Vitor Heitor Cardoso; Wilhelmsen, Øivind; Dorao, Carlos Alberto; Fernandino, Maria
Introducing nonlocal solid-fluid interactions into the Navier-Stokes-Korteweg model. 08.12.2025. *Physical Review Fluids.* Volume: 10(12) s. 1–28 NTNU

Darraj, Nihal; Manoorkar, Sojwal; Spurin, Catherine; Foroughi, Sajjad; Saleh, M.; Berg, Steffen; Blunt, Martin J.; Krevor, Samuel
Heterogeneity Driven Trapping at the Pore-Network Scale in Edwards Brown Dolomite. 16.12.2025. *Energy & Fuels*

Das, Jnana Ranjan; Sinha, Santanu; Hansen, Alex; Santra, Sitangshu B.
Mixed-wet percolation on a dual square lattice. 18.09.2025. *Physica A: Statistical Mechanics and its Applications.* Volume: 679 s. 130957 NTNU

Diaa-Eldeen, Tarek; Berg, Carl Fredrik; Hovd, Morten
Data-Driven Spectral Methods for Stochastic Surrogate Modeling and Efficient Data Assimilation in Subsurface Flows. 2025. *Mathematical Geosciences.* NTNU

Do, Tuong Ha; Trinh, Dao; Truong, Thi Be Ta; Trinh, Thuat
Molecular insights into supercritical water gasification process of polyoxymethylene plastics. 2025. *Scientific Reports.* Volume: 15(1) NTNU

Einen, Caroline; Snipstad, Sofie; Wesche, Håkon Fossland; Nordlund, Veronica; Devold, Ella Johanne; Amini, Naseh; Hansen, Rune; Sulheim, Einar; Davies, Ruth Catharina de Lange
Impact of the tumor microenvironment on delivery of nanomedicine in tumors treated with ultrasound and microbubbles. *Journal of Controlled Release.* Volume: 378 s. 656–670 NTNU SINTEF

Flekkøy, Eirik Grude; Hansen, Alex; Eiser, Erika
Heat and super-diffusive melting fronts in unsaturated porous media. 07.07.2025. *http://arxiv.org/abs/cond-mat*

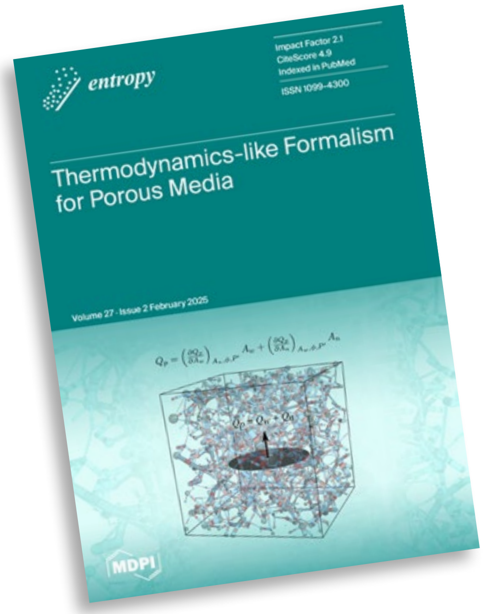
Flekkøy, Eirik Grude; Hansen, Alex; Eiser, Erika
Heat and superdiffusive melting fronts in unsaturated porous media. 29.09.2025. *Frontiers in Physics.* Volume: 13

Fu, Yuequn; Flekkøy, Eirik Grude
Molecular simulations of cavitation bubble dynamics. 2025. *Frontiers in Physics.* Volume: 13.

Hafermaas, Daniel; Köhler, Saskia; Koehn, Daniel; Toussaint, Renaud
Dynamic System Roughening from Mineral to Tectonic Plate Scale: Similarities Between Stylolites and Mid-Ocean Ridges. 16.07.2025. *Minerals.* Volume 15(7) s. 743 UiO

Haghani, Reza; Berg, Carl Fredrik
A Review on Wettability Characterization from 3D Pore-Scale Images. 27.09.2025. *Transport in Porous Media.* Volume 152.(11) NTNU

Hammer, Morten; Log, Alexandra Metallinou; Deng, Han; Austegard, Anders; Munkejord, Svend Tollak
Decompression-induced condensation of carbon dioxide: Experiments, and prediction of the supercooling limit using classical nucleation theory. 2025. *Chemical Engineering Science (CES).* Volume: 309 NTNU SINTEF



The publication by Alex Hansen and Santanu Sinha, published in the Journal Entropy in February 2025, was featured as the ***cover story.*** *The image depicts a porous medium stylized as a network of pores.*

Hansen, Alex; Sinha, Santanu
Thermodynamics-like Formalism for Immiscible and Incompressible Two-Phase Flow in Porous Media. 2025. *Entropy.* Volume: 27(2) NTNU

Hernandez-Perez, Kevin; Schäfer, Gerhard; Lehmann, François; Piri, Mohammad; Toussaint, Renaud
An innovative experimental device to quantify the water relative permeability and in situ water retention curves of unconsolidated porous media. 05.11.2025. *Comptes rendus Geoscience.* Volume 357. s 475–488 UiO

Ho, Thi H.; Tong, Hien Duy; Trinh, Thuat
Molecular mechanisms of Congo Red adsorption on hydrochar: The critical role of hydroxyl groups in dye removal. 25.12.2025. *Chemical Engineering Journal Advances.* Volume: 25 NTNU

Jervell, Vegard Gjeldvik; Gjennestad, Magnus Aashammer; Trinh, Thuat; Wilhelmsen, Øivind
Corrigendum to "The influence of thermal diffusion on water migration through a porous insulation material" [International Journal of Heat and Mass Transfer (2024) 125576](International Journal of Heat and Mass Transfer (2024) 227, (S0017931024004071), (10.1016/j.ijheatmasstransfer.2024.125576)). 2025. *International Journal of Heat and Mass Transfer.* NTNU SINTEF

Jervell, Vegard Gjeldvik; Hammer, Morten; Wilhelmsen, Øivind; Trinh, Thuat
Thermodynamic Properties of Hydrogen Adsorbed on Graphite Surfaces at Temperatures Above 100 K: A Molecular Dynamics and Classical Density Functional Theory Study. 2025. *Entropy.* Volume: 27(2) NTNU

Jervell, Vegard Gjeldvik; Wilhelmsen, Øivind
The limits of Feynman–Hibbs corrections in capturing quantum-nuclear contributions to thermophysical properties. 08.10.2025. *Journal of Chemical Physics.* Volume: 163(14) NTNU

Khobaib, Khobaib; Reis, Paula Kozlowski Pitombeira; Moura, Marcel; Toussaint, Renaud; Flekkøy, Eirik Grude; Måløy, Knut Jørgen
Gravity stabilized drainage in porous media with controlled disorder. 2025. *Physical Review Research (PRResearch).* Volume: 7(2) UiO NTNU

Khoeini, Mohammad Hossein; Wensink, Gijs; Vukovic, Tomislav; Kraft, Ilja; van der Net, Antje; Ruecker, Maja; Luna-Troguero, Azahara
Nanoscale Analysis of Surface Modifications on Silanized Glass: Wettability Alteration and Long-Term Stability. 2025. *ResearchGate* NTNU

Kings, Jonathan; Folkow, Lars; Hammer, Øyvind; Kjelstrup, Signe; Mason, Matthew J.; Xiong, Fengzhu; Flekkøy, Eirik Grude
A model for maxilloturbinate morphogenesis in seals. 2025. *PLOS ONE.* Volume 20.(3) UiO NTNU

Kristiansen, Kim Roger; Hafskjold, Bjørn
Local equilibrium approximation in non-equilibrium thermodynamics of diffusion. 08.04.2025. *Entropy.* Volume: 27(4) NTNU

Krol, Quirine Eibhilin; Skuntz, Matthew E.; Codd, Sarah L.; Seymour, Joseph D.
Rapid MRI profiling of two-phase flow in porous media. 01.12.2025. *Journal of magnetic resonance* (San Diego, Calif. 1997 : Print). Volume: 381 NTNU

Lee, Sang Hyun; Moura, Marcel; Srivastava, Shreya; Santelli, Cara; Kang, Peter K.
Filamentous fungi control multiphase flow and fluid distribution in porous media. 01.09.2025. *Nature Physics.* UiO

The November 2025 issue of Nature Physics ***features*** *a publication by Marcel Moura and his collaborators from the University of Minnesota.*

Li, Ge; de Wijn, Astrid S.
Molecular dynamics simulations of nanoscale friction on illite clay: Effects of solvent salt ions and electric double layer. 2025. *Journal of Colloid and Interface Science.* Volume: 703(part 1) NTNU

Liu, Xintong; Zhang, Yu; Shi, Qiao; Qu, Yongxiao; Hao, Yongchao; Fu, Yuequn; Zhang, Zhisen; Wu, Jianyang
Machine-learning insights into the mechanical strength of methane hydrate-silica interfaces. 2025. *Journal of Physics D: Applied Physics.* Volume: 58(13) UiO NTNU

Lyu, Chuangxin; Amiri, Seyed Ali Ghoreishian; Grimstad, Gustav; Aalberg, Arne; Shen, Yuanjie; Ingeman-Nielsen, Thomas
Modeling the degradation of Saline marine permafrost: the influence of soil freezing characteristics. 2025. *Canadian geotechnical journal* (Print). Volume: 62 s. 1–16 NTNU

Løken, Johannes Salomonsen; Jervell, Vegard Gjeldvik; Hammer, Morten; Hafskjold, Bjørn; Trinh, Thuat; Wilhelmsen, Øivind
Viscosity, thermal conductivity and self-diffusion coefficient of the Lennard-Jones spline fluid: Evaluation of theories for a short-ranged potential. 10.09.2025. *Fluid Phase Equilibria.* Volume: 601 s. 114584 NTNU

Maltby, Tage Winther; Aasen, Ailo; Hammer, Morten; Wilhelmsen, Øivind
Review of Experimental Data and Evaluation of Equations of State for Modeling Formation of Solid CO_2 in CCS and Natural Gas Applications. 04.12.2025. *Industrial & Engineering Chemistry Research* NTNU

McClure, James E.; Fan, Ming; Berg, Steffen; Armstrong, Ryan T.; Berg, Carl Fredrik; Li, Zhe; Ramstad, Thomas
Derivation of A Representative Elementary Volume (REV) for Upscaled Two-Phase Flow in Porous Media. 03.02.2025. *Petrophysics.* Volume: 66(1) NTNU

Meghraoui, Mustapha; Cakir, Ziyadin; Kariche, Jugurtha; Toussaint, Renaud; Provost, Floriane; Karabacak, Volkan; Sbeinati, Reda; Altunel, Erhan; Nemer, Tony
The 2023 Mw 7.8 Kahramanmaraş earthquake rupture increases potential failure along the northern Dead Sea Fault. 01.08.2025. *Tectonophysics.* Volume: 910 s. 230799 UiO

Mendoza, Diego F.; Quintero-Díaz, Juan Carlos; Kjelstrup, Signe
Entropy production minimization in a tubular ammonia synthesis reactor: a mathematical optimization approach with variable geometry and heat flux control. 20.08.2025. *Frontiers in Energy Research.* Volume 13 NTNU

Mohammadi, Saber; Berg, Carl Fredrik; Schümann, Heiner
Low-emission offshore oil and gas production: A review of achievements and challenges. 2025. *Journal of Cleaner Production.* Volume: 525 s. 146504 NTNU SINTEF

Mohammadi, Saber; Berg, Carl Fredrik; Schümann, Heiner
The Potential of Subsea Water Separation and Treatment for Efficient Offshore Operations. 2025. *Energy & Fuels.* Volume: 39(42) s. 20104-20128 NTNU SINTEF

Moura, Marcel; Bedeaux, Dick; Armstrong, Ryan T.; Kjelstrup, Signe
Fluctuation–dissipation theorems in porous media two-phase flow: statistical characterisation of saturation fluctuations and measurement of Onsager coefficients. 26.12.2025. *Journal of Fluid Mechanics.* Volume: 1026 UiO NTNU

Moura, Marcel; Kern, Vanessa; Måløy, Knut Jørgen; Carlson, Andreas; Flekkøy, Eirik Grude
Droplet spreading in a wedge: a route to fluid rheology for power-law liquids. 07.07.2025. *Soft Matter.* Volume: 21(36) s. 7014–7020 UiO NTNU

*The publication by Marcel Moura et al. appears on the **cover** of Soft Matter. The paper was also **featured** as a "Soft Matter Open Access Spotlight" article.*

Nandar, Phoo Pwint; Bergmo, Per Eirik Strand; Berg, Carl Fredrik
A Field Case Study of Subsurface Storage for Intermittent Energy. *SPE Europe Energy Conference and Exhibition.* 10.06.2025. SPE-225577-MS. NTNU

Nandar, Phoo Pwint; Bergmo, Per Eirik Strand; Berg, Carl Fredrik
Subsurface storage for integration of intermittent energy supply during subsurface production. 2025. *Geoenergy Science and Engineering.* Volume: 255 s. 214068 NTNU SINTEF

Ni, Hailun; Li, Boxiao; Darraj, Nihal; Ren, Bo; Harris, Catrin; Krishnamurthy, Prasanna G.; Bukar, Idris; Berg, Steffen; Snippe, Jeroen; Ringrose, Philip; Meckel, T.A.; Krevor, Samuel; Benson, Sally
The impact of capillary heterogeneity on CO_2 flow and trapping across scales. 01.11.2025. *Earth-Science Reviews.* Volume: 270 s. 105257 NTNU

Olsen, Kristian Polanco; Hafskjold, Bjørn; Lervik, Anders; Hansen, Alex
A new thermodynamic function for binary mixtures: The co-molar volume. 13.11.2025. *Journal of Chemical Physics.* Volume 163.(18) NTNU

Pedersen, Håkon; Hansen, Alex
Geometric structure of parameter space in immiscible two-phase flow in porous media. 2025. *Frontiers in Physics.* Volume: 13 NTNU

Price, Sebastian Everard Nordby; Gjennestad, Magnus Aashammer; Kjelstrup, Signe Helene; Hansen, Rune
The effect of temperature constraints on the treatment of tumors using focused ultrasound-induced acoustic streaming. 2025. *Scientific Reports.* Volume: 15 (1) NTNU SINTEF

Raizada, Aman; Berg, Steffen; Benson, Sally M.; Tchelepi, Hamdi A.; Spurin, Catherine
Dynamic Mode Decomposition of 4D imaging data to explore intermittent fluid connectivity in subsurface flows. 01.09.2025. *Advances in Water Resources.* Volume: 203 s. 105013

Reis, Paula Kozlowski Pitombeira; Linga, Gaute; Moura, Marcel; Rikvold, Per Arne; Toussaint, Renaud; Flekkøy, Eirik Grude; Måløy, Knut Jørgen
Interaction between corner and bulk flows during drainage in granular porous media. 2025. *Advances in Water Resources.* Volume: 198 UiO NTNU

Reis, Paula Kozlowski Pitombeira; Måløy, Knut Jørgen
Drainage front width in a three-dimensional random porous medium under gravitational and capillary effects. 07.05.2025. http://arxiv.org/abs/cond-mat UiO

Reis, Paula Kozlowski Pitombeira; Måløy, Knut Jørgen
Drainage front width in a three-dimensional random porous medium under gravitational and capillary effects. 12.09.2025. *Physical Review Research (PRResearch).* Volume: 7(3) UiO

Sarma, Pritom; Aharonov, Einat; Toussaint, Renaud; Parez, Stanislav
Fault Gouge Failure Induced by Fluid Injection: Hysteresis, Delay and Shear-Strengthening. 01.06.2025. *Journal of Geophysical Research (JGR): Solid Earth.*
Volume: 130(6) UiO

Schloms, Felix; Gullbrekken, Øystein; Kjelstrup, Signe
Lithium-Ion Battery Modeling for Nonisothermal Conditions. 23.05.2025. *International journal of thermophysics.* Volume: 46(7) NTNU

Shafabakhsh, Paiman; Cordonnier, Benoit; Le Borgne, Tanguy; Mathiesen, Joachim; Linga, Gaute; Pluymakers, Anne; Kaestner, Anders; Tengattini, Alessandro; Renard, Francois
Coupling Neutron and X-Ray Imaging of Fluid Mixing and Precipitation in Rocks: Challenges and Opportunities. 29.11.2025. *Water Resources Research.* Volume: 61(12) UiO

Solberg, Simon Birger Byremo; Holmqvist, Peder Langsholt; Kristiansen, Kim Roger; Kjelstrup, Signe
Apparent transport numbers from Seebeck coefficients for ion-exchange membranes. 2025. *Electrochimica Acta.* Volume: 527 NTNU

Sousa, Carlos G. L.; Andrade, José S.; Moreira, André A.; Filho, Cesar I. N. Sampaio; Eiser, Erika; Hansen, Alex; Herrmann, Hans J.
Unlimited number of spanning clusters in three-dimensional percolation above the critical point. 2025. *Physical Review Research (PRResearch).* Volume: 7(2) NTNU

Stoev, Iliya D.; Mukhopadhyay, Anasua; Tammen, Rene; Eiser, Erika
Microrheological characterisation of clay-PEO nanocomposites. 2025. *Rheologica Acta.* Volume: 64(4) s. 241–253 NTNU

Sutoyo, Handita Reksi Dwitantra; Schümann, Heiner; Berg, Carl Fredrik
Autonomous Inflow Control Technology and Its Impact on Energy Efficiency. 10.12.2025. *SPE Journal.* Volume: 30(12) s 7778 NTNU SINTEF

Truong, Thi Be Ta; Ha, Do Tuong; Tong, Hien Duy; Trinh, Thuat
Molecular investigation of pyrolysis and thermal gasification pathways in polyethylene microplastics degradation. 2025. *Chemical Engineering and Processing.* Volume: 213 NTNU

Truong, Thi Be Ta; Ha, Do Tuong; Tong, Hien Duy; Trinh, Thuat
ReaxFF molecular dynamics studies on the impact of reaction conditions in polystyrene conversion through hydrothermal gasification. 2025. *Chemical Engineering Journal Advances.* Volume: 22 NTNU

Vu, Tuan V.; Hieu, Nguyen N.; Hiep, Nguyen T.; Trinh, Thuat; Kartamyshev, A.I.; Phuc, Huynh V.
Two-dimensional piezoelectric AlSiX2 (X = N, P, As) semiconductors with Raman activity, favorable band-gap, and high carrier mobility based on first-principles calculations. 2025. *Physical Chemistry, Chemical Physics – PCCP.* Volume: 27 s.5131–5140 NTNU

Vukovic, Tomislav; Røstad, Jostein; Luxbacher, Thomas; Vinogradov, Jan; Farooq, Umer; Torsæter, Ole; van der Net, Antje
Zeta potential of glass bead packs — Streaming potential apparatus bench-marking and search for a reference value. 2025. *Colloids and Surfaces A: Physicochemical and Engineering Aspects.* Volume: 732 s. 1–17 NTNU SINTEF

Zhang, Xiaoqi; Barthel, Senja; Li, Yutao; Smit, Berend; Cabriolu, Raffaela
Thermal transport mechanisms in ZIFs. 27.11.2025. *Nature Communications.* Volume: 16 NTNU

CONFERENCE LECTURES AND ACADEMIC PRESENTATIONS

Abitbol, Nathan; Hansen, Alex; Rosso, Alberto; Talon, Laurent
Single- and Two-Phase Flow of Bingham Fluids in Pore-Networks: Scaling and Flow Regimes. RCN – INTPART Scheme Non-Newtonian Flow in Porous Media. 28.09.2025–30.09.2025 NTNU

Beechey-Newman, Ilaria; Eiser, Erika; Kizilova, Natalya; Hennig, Andreas Andersen; Flekkøy, Eirik Grude
Confined Colloidal Droplets Dry to Form Circular Mazes. Norwegian Physical Society (NFS) Annual Meeting. Trondheim, Norway. 16.06.2025–18.06.2025 NTNU

Beechey-Newman, Ilaria; Eiser, Erika; Hennig, Andreas Andersen; Kizilova, Natalya; Flekkøy, Eirik Grude
Confined Colloidal Droplets Dry to Form Circular Mazes. StatPhys29 2025, The 29th International Conference on Statistical Physics. Florence, Italy. 13.07.2025–19.09.2025 NTNU

Berg, Carl Fredrik
Using machine learning to classify and characterize geological material. Machine Learning in Physical Sciences: Theory and Applications. Lyon, France. 26.05.2025–30.05.2025 NTNU

Botticini, Paolo; Picchi, Davide; Sinha, Santanu ; Hansen, Alex
The origin of pressure-flow non-linearity in two-phase intermittent flow in porous media. RCN – INTPART Scheme Non-Newtonian Flow in Porous Media. 28.09.2025–30.09.2025 NTNU

Brodin, Joachim Falck; Moura, Marcel; Pierce, James Kevin; Reis, Paula Kozlowski Pitombeira; Rikvold, Per Arne; Jankov, Mihailo; Måløy, Knut Jørgen
Experimental Investigation of Two-Phase Flow with a Table-Top Optical Scanner: Interface Instability in a Three-Dimensional Porous Medium. 8th Brazil Chapter InterPore Conference on Porous Media. Florianópolis, Brazil. 11.08.2025–13.08.2025 UiO

Dumay, Yann; Hennig, Andreas Andersen; Beechey-Newman, Ilaria; Tammen, Rene; Eiser, Erika
Fra Kaffeflekker til Kvikksand. Ungdommens forskernatt. Trondheim, Norway. 26.09.2025 NTNU

Dumay, Yann; Eiser, Erika
What are Polymers? School Visit. Trondheim, Norway. 28.03.2025 NTNU

Physics students from ***Thora Storm High School*** *in Trondheim visited the Department of Physics at NTNU on March 28, 2025, including the PoreLab laboratory led by Professor* ***Erika Eiser.***
(AI-generated illustration by PhD candidate ***Yann Dumay****)*

Eiser, Erika
Capillary driven pattern formation of viscoelastic colloidal droplets in confinement. RCN – INTPART Scheme Non-Newtonian Flow in Porous Media. 28.09.2025–30.09.2025 NTNU

Eiser, Erika
Confined Coffee-Rings Are Different. Soft and Liquid Matter Physics: Past, Present and Future. Tokyo, Japan. 10.03.2025–13.03.2025 NTNU

Eiser, Erika; Stokke, Bjørn Torger; Vanin, A. P.
Hydrogels – characterization and applications. Nordic Polymer days 2025. Trondheim, Norway. 11.06.2025–13.06.2025 NTNU

Eiser, Erika
Multivalent Colloidal Particles enabling Superselective Bacterial Genome Detection. 8th International Conference on Multifunctional, Hybrid and Nanomaterials 2025. Montpellier, France. 03.03.2025–06.03.2025 NTNU

Eiser, Erika; Beechey-Newman, Ilaria; Hennig, Andreas Andersen; Flekkøy, Eirik Grude; Kizilova, Natalya
Pattern Formation in Confined Coffee-Rings. Understanding Surfaces and Interfaces: A Symposium Celebrating 7 Decades of Service. Kyoto, Japan. 13.03.2025–15.03.2025 NTNU

Flekkøy, Eirik Grude; Eiser, Erika; Hansen, Alex
Freezing, melting and metastable states in porous media. RCN-INTPART scheme Non-Newtonian flow in porous media. 28.09.2025–30.09.2025 NTNU

Hafskjold, Bjørn; Kjelstrup, Signe
Thermodiffusion and thermo-osmosis in membranes. International Meeting on Thermodiffusion (IMT16). Milano, Italy. 09.06.2025–13.06.2025 NTNU

Hansen, Alex
Porous media: A rapidly advancing basic research field with immediate applications. Fysikermøtet. Trondheim, Norway. 16.06.2025–18.06.2025 NTNU

Hansen, Alex
Statistical mechanics of immiscible two-phase flow in porous media. Flowing matter in porous media. CECAM. Berlin, Germany. 24.02.2025–27.02.2025 NTNU

Hansen, Alex
Statistical Mechanics of Immiscible Two- Phase Flow in Porous Media. Statphys29. IUPAP. Florence, Italy. 13.07.2025–18.07.2025 NTNU

Hennig, Andreas Andersen; Beechey-Newman, Ilaria; Kizilova, Natalya; Eiser, Erika
Circular finger pattern from a slowly drying colloidal droplet. 9th International Soft Matter Conference. ISMC. Greece. 28.09.2025–03.10.2025 NTNU

Hennig, Andreas Andersen; Beechey-Newman, Ilaria; Kizilova, Natalya; Flekkøy, Eirik Grude; Eiser, Erika
Confined Colloidal Droplets Make Circular Mazes. Dynamics of Non-Equilibrium Variables: Multiscale-multiphysics applications of fluctuating hydrodynamics. CECAM. Zaragoza, Spain. 15.09.2025–19.09.2025 NTNU

Hermundstad, Amalie Eveline; Sinha, Santanu; Hansen, Alex
Configurational entropy in immiscible two-phase flow in porous media. RCN – INTPART Scheme Non-Newtonian Flow in Porous Media. 28.09.2025–30.09.2025 NTNU

Kjelstrup, Signe
Modelling electrochemical systems using nonequilibrium thermodynamics. Lecture on WEB / YouTube. National University of Mexico, UNAM, Mexico. 26.03.2025 NTNU

Kjelstrup, Signe
Naturen som inspirasjon for prosess design. Eksempel fra nesen til en sel. Gløshaugen Akademiske Klubb. Trondheim, Norway. 10.04.2025 NTNU

Lanza, Federico; Linga, Gaute; Barras, Fabian; Khobaib, Khobaib; Flekkøy, Eirik Grude; Måløy, Knut Jørgen
From Carbopol to magma: challenges in complex flows through porous and confined media. RCN – INTPART Scheme Non-Newtonian Flow in Porous Media. 28.09.2025–30.09.2025 NTNU

Lee, Sang Hyun; Moura, Marcel; Srivastava, Shreya; Santelli, Cara; Kang, Peter K.
There's a mushroom in the network: Filamentous fungi control multiphase flow and fluid distribution in porous media. 2nd Brittany Workshop on Flow and Transport in Porous Media. Rennes, France. 15.09.2025–19.09.2025 UiO

Linga, Gaute
Mixing by interfaces. Flow and Transport in Porous and Fractured Media. Géosciences Rennes, CNRS, Université de Rennes. Île Grande, France. 15.09.2025–19.09.2025 UiO

Linga, Gaute
Security in Physics. Young Researchers Night. Oslo, Norway. 19.09.2025 UiO

Mohsenifesgandis, Alireza; Berg, Carl Fredrik; Ghaderi, Amir; Eliasson, Peder
Exploring the Transferability of Optimization Methods from Production to Storage: A Case Study of CO_2 Injection at Smeaheia. The 13th Trondheim CCS Conference (TCCS-13). Trondheim, Norway. 16.06.2025–20.06.2025 NTNU

Moura, Marcel; Kern, Vanessa Ruth; Olsen, Pål Eivind; Carlson, Andreas; Måløy, Knut Jørgen; Flekkøy, Eirik Grude
Complex fluids in confinement: spreading in a wedge and instabilities in textured lifted Hele-Shaw cells. Non-Newtonian Flow in Porous Media. Norway. 27.09.2025–01.10.2025 UiO

Moura, Marcel; Kern, Vanessa Ruth; Olsen, Pål Eivind; Carlson, Andreas; Måløy, Knut Jørgen; Flekkøy, Eirik Grude
Fluidos complexos em confinamento: espalhamento em cunha e instabilidades em células de Hele-Shaw texturizadas. Colóquio Aberto de Professores e Alunos das Engenharias. Porto Alegre, Brazil. 15.08.2025 UiO

Moura, Marcel; Reis, Paula Kozlowski Pitombeira; Rikvold, Per Arne; Linga, Gaute; Flekkøy, Eirik Grude; Schäfer, Gerhard; Toussaint, Renaud; Måløy, Knut Jørgen
Thin Film Flow: Fluid Transport via Thin Liquid Films in Slow Porous Media Flows. French InterPore Chapter 2025 Conference. Orléans, France. 04.11.2025–06.11.2025

Pierce, James Kevin ; Le Borgne, Tanguy; Linga, Gaute
Burst-enhanced mixing in multiphase flows through porous media. Geosciences Rennes Monthly Seminar. 08.05.2025 UiO

Pierce, James Kevin; Lamblin, Marc; Le Borgne, Tanguy; Heyman, Joris; Linga, Gaute
Enhanced mixing in dynamic multiphase flow through 3D porous media. 2nd Brittany Workshop on Flow and Transport in Porous Media. L'Ile Grande, Pors Gelin, France. 15.09.2025–19.09.2025 UiO

Pierce, James Kevin; Le Borgne, Tanguy; Linga, Gaute
Impact of structural disorder on mixing in porous media. IstoPore Group Seminar. Orléans, France. 27.03.2025 UiO

Reis, Paula Kozlowski Pitombeira; Måløy, Knut Jørgen
Drainage fronts in two and three-dimensional random porous media under gravitational and capillary effects. The 8th Njord-NBI writing workshop. NJORD. Bresle, France. 23.06.2025–28.06.2025 UiO

Reis, Paula Kozlowski Pitombeira; Moura, Marcel; Linga, Gaute; Toussaint, Renaud; Rikvold, Per Arne; Flekkøy, Eirik Grude; Måløy, Knut Jørgen
Modeling Gas-Liquid Drainage in Porous Media with Network Models. IstoPore Group Seminar. Orléans, France. 02.07.2025 UiO

Reis, Paula Kozlowski Pitombeira; Måløy, Knut Jørgen
Numerical investigation of invasion-front characteristics during stable drainage in a three-dimensional porous medium. IRP-DFFRACT Conference. Courmayeur, Italy. 03.02.2025–07.02.2025 UiO

Santi, Andrea Callioli; Delbet, Chloe; Berg, Carl Fredrik; Macut, Mateja; Ringrose, Philip Stefan; Yun, Tae Kwon
Quantifying Long-Term CO_2 Storage Containment via Sequential Multi-Physics Trapping Models. World CCUS Conference. Bergen, Norway. 01.09.2025–04.09.2025 NTNU

Sinha, Santanu; Carmona, Humberto; Andrade Jr, José S..; Hansen, Alex
The glassy dynamics of multiphase flow: Disorder, frustration and flow regimes. XXXVI IUPAP Conference on Computational Physics (CCP2025). Oak Ridge National Laboratory, USA. 03.11.2025 NTNU

Sinha, Santanu; Carmona, Humberto; Andrade Jr, José S..; Hansen, Alex
The glassy dynamics of multiphase flow: Disorder, frustration and flow regimes. RCN-INTPART scheme Non-Newtonian flow in porous media. Norway. 28.09.2025–30.09.2025 NTNU

Sutoyo, Handita Reksi Dwitantra; Schümann, Heiner; Berg, Carl Fredrik
Energy Efficiency Comparison of Different Well Path Designs. SPE Europe Energy Conference and Exhibition. Vienna, Austria. 10.06.2025–12.06.2025 NTNU

Tammen, Rene; Eiser, Erika; Zabłocka, Kamila; de Weerdt, Klaartje
Characterization of Illite Clay Mineral in Norwegian Quick Clay. International Clay Conferences AIPEA, XVIII ICC. Dublin. 13.07.2025–18.07.2025 NTNU

Tammen, Rene; Eiser, Erika; Li, Ge; de Wijn, Astrid S.; Zabłocka, Kamila; de Weerdt, Klaartje
Experimental Investigation on Illite Clay for Sustainable Ground Stabilization. InterPore 2025 17th Annual Meeting. Albuquerque, USA. 19.05.2025–22.05.2025 NTNU

Xu, Yao; Moura, Marcel; Flekkøy, Eirik Grude; Måløy, Knut Jørgen
Quantification for density-driven convection of CO_2 in water. 17th Annual meeting InterPore 2025. Albuquerque, USA. 19.05.2025–22.05.2025 UiO

Yun, Tae Kwon; Macut, Mateja; Dyngeland, Tobias; Ringrose, Philip Stefan
Reservoir simulations of the main trapping mechanisms for CO_2. Modeling strategies for CO_2 injection. Stavanger, Norway. 14.10.2025 NTNU

Zabłocka, Kamila; de Weerdt, Klaartje; Lothenbach, Barbara; Eiser, Erika; Justnes, Harald; Lopez, Ana Priscilla Paniagua
Towards sustainable cementitious binders for quick clay stabilization. 25th Nordic Concrete Federation Symposium 2025. Sandefjord, Norway. 19.08.2025–22.08.2025 NTNU

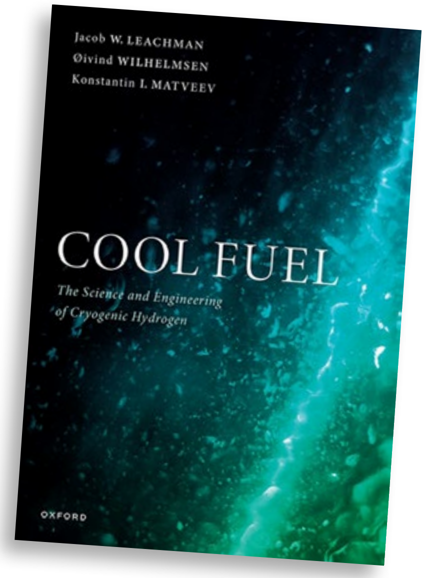
BOOKS, PART OF BOOKS, REPORTS

Brodin, Joachim Falck; Måløy, Knut Jørgen; Flekkøy, Eirik Grude; Moura, Marcel
Stable and unstable invasion in two-phase flow in three-dimensional porous media. *Doctoral theses at UiO 2025*

Einen, Caroline; Davies, Catharina; Kjelstrup, Signe; Hansen, Rune
Ultrasound-mediated delivery and transport of nanomedicines through the tumor extracellular matrix – effects and possible mechanisms. *Doctoral theses at NTNU 2025*

Golestan, Mohammad Hossein; Berg, Carl Fredrik; Torsæter, Ole
Pore-scale Investigations of Fluid Flow and Interfacial Mass Transfer. *Doctoral theses at NTNU 2025*

Leachman, Jacob W; Wilhelmsen, Øivind; Matveev, Konstantin I
Cool Fuel. *Oxford University Press.* ISBN: 978-0-19-893666-4, 978-0-19-893668-8



Jacob W. Leachman, Konstantin I. Matveev, and Øivind Wilhelmsen are co-authors of ***Cool Fuel: The Science and Engineering of Cryogenic Hydrogen****, the first textbook in decades dedicated to cryogenic hydrogen.*

Pedersen, Håkon; Hansen, Alex; Måløy, Knut Jørgen
Geometry of the Co-Moving Velocity in Immiscible and Incompressible Two-Phase Porous Media Flow. *Doctoral theses at NTNU 2025*

Sheehan, Jennifer Ruth; de Wijn, Astrid S.; Alvarez, Nuria Espallargas; Hansen, Alex
Decay Behaviour, State Transitions and Escape Rates in Simple Models for Complex Systems. *Doctoral theses at NTNU 2025*

Temizel, Cenk; Yegin, Cengis; Kim, Jihoon; Saputelli, Luigi A.; Torsæter, Ole
Introduction. Unconventional resources. Advances in energy transition. *CRC Press.*. Page: 1-39. ISBN 978-1-032-32293-3

Temizel, Cenk; Yegin, Cengis; Kim, Jihoon; Saputelli, Luigi A.; Torsæter, Ole
Reservoir engineering, reservoir management, and surveillance in unconventional resources. Unconventional resources. Advances in energy transition. *CRC Press.*. Page: 239-283. ISBN 978-1-032-32293-3

Temizel, Cenk; Baser, Ali; Saracoglu, Onder; Tural, Tolga; Saputelli, Luigi A.; Torsæter, Ole
Energy transition in the oil and gas industry. *CRC Press.* Pages: 728. ISBN: 978-1-032-25249-0

Porous Media Laboratory
NTNU, UiO

VISITING ADRESSES:

Trondheim:
S.P. Andersens vei 15B
PTS2
7031 Trondheim

Oslo:
The Physics building
Sem Sælands vei 24
0316 Oslo

POSTAL ADDRESSES:

Trondheim:
Department of Physics, NTNU
PoreLab
7491 Trondheim

Oslo:
P. O. Box 1048
Blindern
0316 Oslo

CONTACT:
Professor Alex Hansen, Center Director
Phone: +47 73 59 36 49
E-mail: alex.hansen@ntnu.no

Professor Eirik Grude Flekkøy, Vice Director
Phone: +47 22 85 50 34
E-mail: e.g.flekkoy@fys.uio.no

Dr. Marie-Laure Olivier, Administrative Leader
Phone: +47 73 41 30 98
E-mail : marie-laure.olivier@ntnu.no

Visit our website

www.porelab.no

for more information and research results

Skipnes.no Nordic swan ecolabel - printed matter, 2041 0731