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論文 / 著書情報
Article / Book Information

題目(和文)	多孔質内における混和性流体の重力不安定対流の三次元フィンガー構造
Title(English)	Three-dimensional fingering structure of gravitationally unstable convection between miscible fluids in a porous medium
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	創造エネルギー　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（工学　）
学生氏名： Student's Name	WANG LEI	指導教員（主）： Academic Supervisor(main)	末包　哲也　教授
		指導教員（副）： Academic Supervisor(sub)	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

In this work, the three-dimensional fingering structure of gravitationally unstable convective flows in a porous medium was investigated using a micro-focused X-ray computer tomography (CT). A miscible fluid pair with nonlinear density properties (a sodium chloride solution and a mixture of methanol and ethylene glycol doped with sodium iodide) was used to model the density increase from mixing upon carbon dioxide (CO_2) injection into the reservoir. A series of laboratory experiments with different combinations of Rayleigh number and Péclet number have been carried out in a porous medium. The focus was to study the characteristics of density-driven mixing and fingering patterns relevant to CO_2 dissolution in aquifer and CO_2 enhanced oil recovery, and to quantify the effect of Rayleigh number and Péclet number on the fingering behaviors.

Chapter 1: Introduction

This chapter introduced the background Carbon dioxide of Capture and Storage (CCS). CO_2 Geological storage is a key part in the whole CCS process because of the large capacity of CO_2 storage, which make a significant contribution to reduction in CO_2 emissions. The modes of CO_2 storage formation, CO_2 trapping mechanisms, and some previous studies about CO_2 dissolution in deep saline formation and CO_2 in enhanced oil recovery were presented. It is necessary to figure out the mixing mechanism and the fingering characteristics during convective mixing process. The objectives and the outline of this dissertation was presented as well.

Chapter 2: Miscible fluids with nonlinear density property modelling density-driven convection

In this chapter, the design of the laboratory experiments was presented. A mixture of miscible fluids, methanol and ethylene-glycol (MEG) doped with sodium iodide (MEG-NaI) and a sodium chloride (NaCl) solution, exhibits a nonlinear density profile, such that the density of intermediate mixtures of these fluids is higher than either pure fluid. Herein, these fluid pairs were used to model the process of the density increase when CO_2 dissolve into the aquifer or oil reservoir. Four different plastic particles with the average diameter in a range of 647 μm to 1410 μm were packed in a cylinder with a diameter of 70 mm as a porous medium for varying the permeability and porosity related to Rayleigh number and Péclet number.

Chapter 3: Three-dimensional fingering structure of density-driven natural convection

In this chapter, the process of CO_2 dissolution in deep saline formation had been modelled using the mixtures of MEG-NaI and NaCl solutions. The three-dimensional structure of extending fingers associated with density-driven natural convection was observed. Three-dimensional CT images provided the local concentration in fingers, which was critical for discussing the effect of Taylor dispersion on the structure of the fingers. The

key questions of the finger-extension velocity, the mass transfer rate, and, the effect of transverse dispersion on the finger structure, give insight into understanding the mixing mechanism and evaluating the long-term fate of the injected CO_2 in deep saline aquifers.

Chapter 4: Effect of layered heterogeneity on fingering structure

The homogeneous pore structure has been assumed to simplify the model. However, in reservoir, stratigraphic structure has a heterogeneity, which is composed of alternating layers, such as sandstone and shale, reflecting an isotropic property in the horizontal direction and different permeability in the vertical direction. In this chapter, density-driven natural convection also was conducted in a porous medium with layered structure. The influence of heterogeneity on the fingering structure and finger velocity during the convection process was discussed.

Chapter 5: Gravitational fingering due to density increase by mixing at a vertical displacing

The miscible fluid pair with nonlinear density property (MEG-NaI) was used to model the density increase due to CO_2 dissolution in oil. The development of three-dimensional gravitational fingering in a packed bed during the injection process was observed. The characteristics of fingering associated with an increase in density by mixing in gravitationally stablilized displacements were presented quantitatively. The local concentration distribution in fingers for each unit of time during the injection process was estimated based on CT images, which is critical to discuss the mixing mechanism and the effect of Péclet number on fingering behavior. The key measures of gravitation fingering during the injection process — the finger extension velocity, finger number density, mixing length of fingers, and relative volume of fingers — were compared at different Péclet numbers by changing the permeability of the porous media and the injection speed. The investigation of the effect of the injection process on the fingering structure provides insights into the mixing mechanism and recovery performance of CO_2 injection into oil reservoirs.

Chapter 6: Conclusions and outlook

A summary of this dissertation and the outlook were given. The new findings of this work and the impacts on CO_2 geological storage were stated.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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