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Mechanism of overpressure development in the Kazusa Group

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Abnormally high pore pressure zone may affect many properties and processes in underground, and thus it is important to study the mechanism of developing the high pore pressure zone. In mudstone formations of the Kazusa Group at the Boso peninsula, high porosity anomaly of approximately 5 to 20 % is observed, and this anomaly is suggested to have been generated by an abnormally excess pore pressure. However, the development process of the high pore pressure is still unknown. In general, pore pressure anomalies can develop through normal sedimentation-compaction process under some conditions of permeability and storage capacity, and/or sedimentation rate. In this study, we investigated how much pore pressure and porosity anomalies can develop just only by normal sedimentation-compaction process in the case of the Kazusa Group mudstone formation. Firstly we obtained effective pressure dependencies of permeability and porosity for siltstone specimens from the Kazusa Group by using laboratory experiments, and then carried out 1-D numerical simulation of pore pressure development during sedimentation-compaction processes using the parameters from the experiments.

The rock samples used in the experiments were collected from outcrops at Umegase Formation (Fm.), Otadai Fm., Kiwada Fm., Ohara Fm. and Katsuura Fm. of the Kazusa group. The collected samples were shaped into a cylindrical shape about 40 mm in diameter and about 30 mm in height. The measurements were performed using an intra-vessel deformation fluid-flow apparatus at Toho University. Distilled water was used for pore fluid and confining pressure was applied by using oil. Permeability and porosity of siltstones were measured at room temperature and under effective pressures from 2 to 35 MPa. To obtain porosity under effective pressure, we measured a volume of water discharged from the specimen when confining pressure was applied. We measured permeability by monitoring flow rate through the specimen under the condition of constant pore pressure differences at the both side of the specimen. Measured porosity ranged from approximately 34 to 42 %, except for the specimens of Ohara Fm., porosity of which was up to 55 %, higher than others. Permeability ranged from 10^{-20} to 10^{-16} m^2. We obtained the effective pressure dependencies of porosity and permeability for each specimen by fitting normal consolidation domains of the experimental results with some functions. We then simulated developments of pore pressure and porosity anomalies during sedimentation of silt(stone) layer up to the thickness of 3000 m. By using finite difference method, we discretized a differential equation modeling pore pressure developments by sedimentation-and-compaction, and diffusion in the vertical direction of pore pressure. The conditions for the simulation are as follows: the lower boundary of the calculation domain is impermeable, and pore pressure is constant at the upper boundary of the sediments. The sediment layer is initially 54 m in the thickness, and the initial pore pressure is hydrostatic (no pore pressure anomaly). Skempton's constant is 0.9. The sedimentation rate is constant, and we used three values, 4.0, 9.49, 40.0×10^{-4} m/year, estimated from the previous studies at the Kazusa Group. The results of the numerical simulations suggested that, pore pressure anomaly was increased as the depth was increased, and when the sedimentation rate was 9.49×10^{-4} m/year, developed maximum pore pressure and porosity anomaly ranged from 3 to 12 MPa and 0.5 to 6 %, respectively. As the sedimentation rate was increased, the anomalies were increased, and pore pressure and porosity anomalies were increased up to 18 MPa and 8 % when the sedimentation rate was 40.0×10^{-4} m/year. These results indicate that, when considering conditions for the Kazusa Group, pore pressure anomaly of more than 10 MPa and porosity anomaly of several percentages can develop.

Keywords: the Kazusa Group, overpressurization, permeability, laboratory permeability measurement, numerical simulation