

地殻環境・エネルギー技術の新展開

Toward Advanced Environmental Geomechanics and Energy Technology



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2020年に当研究室で行った主な研究は以下の通りである。なお、詳細説明は3つの研究に絞る。

- 1) 岩石のマクロ破壊靱性とマイクロ破壊靱性の共依存関係 (Fig.1, 2, 3)
- 2) 軟岩体における高精度地圧測定法の開発
- 3) 巨大地震後の鉛直地圧の倍増現象の解明
- 4) 超臨界地熱環境下における水圧破砕き裂生成に及ぼす制御法の影響 (Fig.4, 5, 6)
- 5) Super Critical 環境下における水圧破砕のメカニズム
- 6) 高温環境下における岩石き裂の間隙水圧誘起すべり特性

In 2020, our research activities are as follows.

- 1) Codependency between the macro fracture toughness and the micro fracture toughness of rock (Figs.1, 2, and 3)
- 2) Development of high-precision rock stress measurement method in soft rock mass
- 3) Elucidation of the doubling phenomenon of vertical crustal stress after a huge earthquake
- 4) Effect of loading control system on hydro-fracturing crack formation in the ductile rock (Figs.4, 5, and 6)
- 5) The mechanism of the hydraulic fracturing under the supercritical conditions
- 6) Injection-induced slip characteristics of a rock fracture under high temperatures

岩石のマクロ破壊靱性とマイクロ破壊靱性の共依存関係

本研究は、不均質体である岩石の破壊進展機構を従来のマクロな視点での評価のみならず、ミクロな視点においても詳細に評価し、岩石のマクロ破壊靱性とマイクロ破壊靱性の共依存の観点から解明することを目的とする。本年度は、最高倍率 2,500 倍の CCD カメラを搭載したマイクロ破壊靱性試験装置 (Fig.1, 2) を導入した。使用する供試体は、直方体岩石ブロック (3mm × 5mm × 7mm) の角面上に FIB (Focused Ion Beam) によって加工した 10μm × 10μm × 50μm のサイズのカンチレバータイプである (Fig.3)。本年度は、稲田花崗岩の構成鉱物の黒雲母、石英、斜長石、カリ長石について供試体を作製して破壊靱性試験を行なった。

Codependency between the macro fracture toughness and the micro fracture toughness of rock

The purpose of this study is to elucidate the fracture propagation mechanism of rocks from the viewpoint of codependence between the macro fracture toughness and the micro fracture toughness of rocks. We introduced a micro fracture toughness test system (Fig.1 and Fig.2) equipped with a CCD camera with a maximum magnification of 2,500 times. The specimen used is a cantilever type with a size of 10 μm × 10 μm × 50 μm processed by FIB (Focused Ion Beam) on the square surface of a rectangular parallelepiped rock block with a size of 3 mm × 5 mm × 7 mm (Fig.3). This year, specimens of biotite, quartz, plagioclase, and alkali feldspar, which are constituent minerals of Inada granite, were prepared, and fracture toughness tests were conducted.

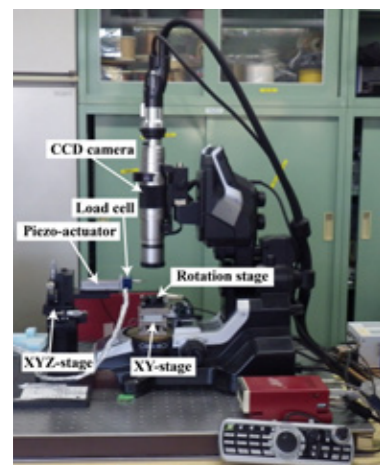


Fig.1 The testing system for the micro fracture toughness using the micro-sized specimen.

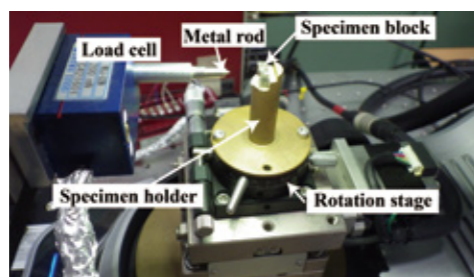


Fig.2 View of the specimen placed at the testing system.

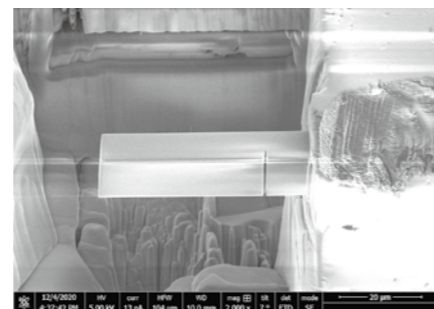


Fig.3 SEM images of the micro-sized specimen of alkali feldspar.

軟岩体における高精度地圧測定法の開発

軟岩体 (泥岩等) に施工される地下構造物の設計・施工のために、鉛直ボーリングでの高精度地圧測定の開発を行った。高精度で信頼性の高い方法とされる応力解放法をベースに開発を行った。具体的には、ボアホールの孔底を円錐状に加工し、その先端にカッティングス溜め用の小口径ボアホールを持つ孔底ひずみ法を提案した。高精度を維持し、かつ測定歩留まりの高い方法とすることを目的に、孔底形状 (円錐の頂角、小口径ボアホールの直径、長さ) を変化させて、回転体境界要素法による数値シミュレーションを行い、最適な孔底形状を提案した。

超臨界地熱環境下における水圧破砕き裂生成に及ぼす制御法の影響

これまで延性地殻を対象とした水圧破砕実験を行ってきた。その中で、供試体への軸載荷を荷重制御で行なったためと思われる過剰な破壊現象が見られた。破壊や透水性の過大評価が否かを明らかにするために、現有の実験装置を変位制御型に改良 (Fig.4) して実験を行なった。実験後の供試体の状態は、明らかに異なり (Fig.5, 6)、変位制御の場合は、一見健全に見えた。しかし、透水性は確実に 2 オーダー上昇しており、延性地殻の水圧破砕の有効性を適切な方法で明らかにした。

受賞

- 1) 坂口清敏：岩の力学連合会論文賞

研究費

- 1) JSPS 科研費 17H03504 (基盤研究 (B)・分担)
- 2) JSPS 科研費 K18K190390 (挑戦的研究 (萌芽)・分担)
- 3) JSPS 国際共同研究事業 (ドイツとの国際共同研究・分担)
- 4) 軟岩対象用地圧測定法の開発 (企業との共同研究・代表)

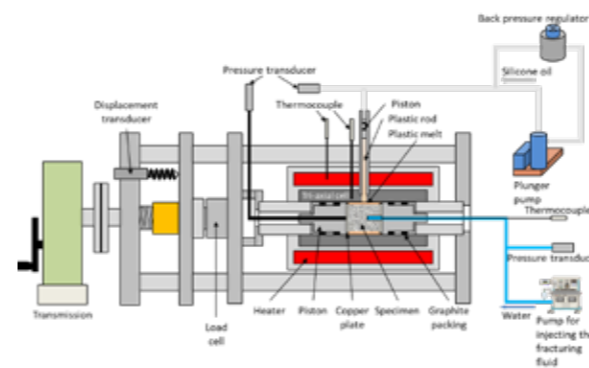


Fig.4 Experimental system of displacement control type.

Development of high-accuracy rock stress measurement method in soft rock

We have proposed a high-accuracy rock-stress measurement method by vertical boreholes in soft rock bodies. This new method was based on the overcoring method, which is considered a highly accurate and reliable method. We proposed an overcoring method in which the bottom of the borehole is processed into a conical shape and a small-diameter borehole for storing cuttings is provided at the tip. Numerical simulation by the boundary element method by changing the borehole bottom shape to maintain high accuracy and high measurement yield was conducted. The optimum borehole bottom shape was proposed.

Effect of loading control method on hydraulic fracture formation in the ductile rock

We conducted hydraulic fracturing experiments on the ductile crust. An excessive fracture phenomenon was observed, which was thought to be due to the load control. To clarify whether or not the fracture or permeability was overestimated, the experimental equipment was improved to a displacement control type (Fig.4), and the experiment was conducted. The state of the specimen after the experiment was clearly different (Fig.5 and Fig.6), and in the case of displacement control, it seemed to be no-fracture. However, the permeability definitely increased by two orders of magnitude. Therefore, the effectiveness of hydraulic fracturing of the ductile crust was clarified.

Awards

- 1) Kiyotoshi Sakaguchi received the Best Paper Award from the Japanese Society for Rock Mechanics.

Grants

- 1) JSPS KAKENHI 17H03504 (Co-investigator)
- 2) JSPS KAKENHI K18K190390 (Co-investigator)
- 3) JSPS-LEAD with DFG (Co-investigator)
- 4) Development of the rock stress measurement technique for soft rock (Collaborative research/Investigator)

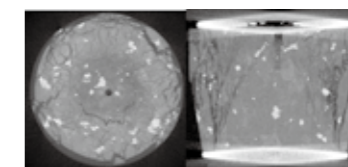


Fig.5 X-ray CT image of the specimen after the experiment by load control system.

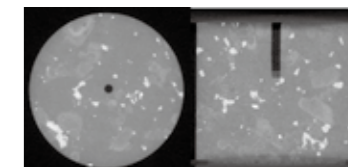


Fig.6 X-ray CT image of the specimen after the experiment by displacement control system. There appear to be no cracks, but the permeability has increased by two orders.