

Contact Deformation and Induced Ground Potential of Granular Geo-Materials as Porous Elastoplastic Media

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論文内容要旨

(NO. 1)

氏名	金子尚人	提出年	令和 2 年
学位論文の 題目	Contact Deformation and Induced Ground Potential of Granular Geo-Materials as Porous Elastoplastic Media (多孔質弾塑性体としての地質粒状体の接触変形と誘起地電位)		

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論 文 內 容 要 旨

Granular geo-materials show various mechanical behavior under loading. However, the theoretical foundations of porous elastoplastic media have not established for the soil mechanics, geotechnology, civil engineering, seismology, mineralogy, geomorphology and geology.

The present thesis has been applied to the formulation of constitutive relations in elastoplastic mechanics, thermodynamics, and electromagnetics and been confirmed through these discussions directly or indirectly. From the results, the conclusions in the present thesis are written below.

In chapter 2, we showed that plasticity index theoretically determines deformation patterns of soils by Cam-clay model, and we prove that the index closely affects the bifurcation formulas and mention that plasticity index can reflect a mechanical bifurcation of variety of folds.

In chapter 3, we mentioned that the earthquake precursor time based on the Terzaghi's consolidation equation which is equivalent to diffusion-like equation on precursory phenomena for earthquakes. This precursor time could be reflected the crustal movement, electric resistivity, radon emission, and seismic velocity that we discussed another each chapter.

In chapter 4, we revealed volcanoes could be classified as a typical form by some unified parameters with respect to length and angle regarded as an aggregation of granular bodies for the landform. Moreover, we concluded that the longitudinal profile of volcanoes can be explained by the Rowe's equation derived from the variation inequality in non-equilibrium thermodynamics and principle of maximum entropy.

In chapter 5, focused on the difference of permeability from the point of view of porous medium, we proposed the torsionic tubular flow model considering the change in radon concentration. The upward migration path of fluid including radon depends on not only crack width but also porosity and void ratio. Based on Kozeny-Carman equation, the model of variation of radon concentration in groundwater with earthquakes can be explained by the relationship between specific surface area and pressure.

In chapter 6, we showed that geological evidences for the change in ground potential associated with fluid movement by earthquakes. Also, the relationship between acceleration and shear stress could directly affect the mechanical behavior of porous media such as landslides caused by change in water head.

In chapter 7, we elucidated that the current-voltage characteristics of semiconductor minerals can be changed by the variation of the capacitance and the parallel resistance of the equivalent circuit of semiconductor minerals associated with contact pressure changes. With respect to the dielectric characteristics of ore deposits, the resistivity presents the diameter of circular arc on the complex-plane impedance diagram. Therefore, the continuous monitoring of complex resistivity, such as induced-polarization (IP) method, would detect electromagnetic phenomena associated with earthquakes in dry ore deposits.

In summary, we stress the importance of close attention to the contact deformation and induced ground potential of granular geo-materials as porous elastoplastic media. Granular geo-material is a continuum of discontinuous particles. This system has complex characteristics such as pores, fluids (i.e., water and gases), and porous elastoplastic media. Based on this point of view, it seems likely that it is important to consider the thermodynamic and statistical discussions as an aggregation rather than as individual particles. The characteristics of system were be proposed to explain by its internal mechanism and could affect the seismogenic processes. Since the process is related to the (precursory) deformation/fracture and electromagnetic phenomena, the modeling of granular geo-material should be recognized as a fundamental task for the geophysical characterisation.

金子尚人提出論文は、多孔質弾塑性体としての地質粒状体の特性を理論的に明らかにすることによって、接触変形と誘起地電位変化についてのメカニズムを議論したものである。本論文は8つの章からなる。第一章では、熱・連続体力学の知見に基づいて熱力学第一法則から塑性ポテンシャルを導出し、現象論方程式と流動電位、散逸過程を伴う電場を紹介した。また、第二章から第五章では接触変形について、第六章から第七章では主に誘起地電位について焦点を当てて論じ、第八章で総括した。議論の詳細は以下のようにまとめられる。

第二章では、塑性指数が土壌の変形パターンを理論的に決定することを示し、塑性指数が分岐的に密接に影響することを証明するとともに、塑性指数が多様な褶曲の力学的分岐パラメータと見なせることに言及した。

第三章は、地震前駆現象の先行時間は、Terzaghi の圧密方程式に支配されている。これは地震の前兆現象に関する拡散的な方程式に相当している。この先行時間は、別の章で述べた地殻変動、電気抵抗率、ラドン放出、地震速度変化などと関係している。

第四章においては、火山がその地形を構成する粒状体の集合体と見なす長さや角度の統一的なパラメータによって、火山が典型的な形態に分類できることを明らかにした。さらに、火山の縦断面形状は、非平衡熱力学の変分不等式と最大エントロピーの原理から導かれる Rowe 式で説明できると結論づけた。

第五章では、多孔質媒体の観点から開口亀裂の透水性との違いに着目し、地下水中ラドン濃度の変化を考慮した屈曲管状流モデルを提案した。ラドンを含む流体の上方への移行経路は、亀裂幅だけでなく、間隙率や間隙比にも依存する。また、Kozeny-Carman 方程式に基づき、地震に伴う地下水中のラドン濃度の変動を比表面積と圧力の関係で説明できるモデルを提案した。

第六章は、地震による流体の移動に伴う地電位の変化について、地質学的な証拠を示した。また、地震の加速度と剪断応力の関係は、水頭の変化による地盤の多孔質媒体の力学的挙動に直接影響を与えることを示した。

第七章においては、接触圧力の変化に伴う半導体鉱物の等価回路中の静電容量と並列抵抗の変化によって、半導体鉱物の電流-電圧特性が変化することを明らかにした。鉱床の誘電特性については、抵抗率は複素平面インピーダンス図上で円弧の直径に相当する。そのため、強制分極法(IP法)のような複素比抵抗の連続的なモニタリングにより、鉱床の地震に伴う電磁気学的変動現象を検出することができることを指摘した。

これらの研究成果は、粒状体の集合体と見なされる地盤材料の複雑な力学的挙動の理解を大きく前進させるものであり、様々な理論の拡張と構築を通して、学会や発表論文によって支持を得た。

以上のように、金子尚人は自立して研究活動を行うに必要な高度の研究能力と学識を有することを示した。したがって、金子尚人提出の博士論文は、博士(理学)の学位論文として合格と認める。