Comparative analysis of Geomechanics and General System Theory, Earth System Science and Geomechanics’ unique advantages in comprehensive survey of natural resources

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Abstract. Under the backgrounds of comprehensive investigation of natural resources, Earth System Science becomes popular. However, it still needs further development. Geomechanics possesses the merits of General System Theory and has endured more than half a century’s practical test. This article aims to analyse the advantage of Geomechanics through comparison of connotations and characteristics of Geomechanics, General System Theory and Earth System Science. By comparison and relationship analyses, the authors pointed out that Geomechanics possesses the theoretical foundation and scientific potential of solving the problems in Earth System Science. Moreover, it can support the “Trinity Comprehensive Investigation and Evaluation” of energy and mineral resources, technical conditions, engineering construction and environmental impact.

1. Introduction
Geomechanics is an interdisciplinary combining geology and mechanics[1-3], and has distinct characteristics of General System Theory[4, 5]. Earth System Science[6, 7] is now popular in comprehensive investigation of natural resources[8]. However, Earth System Science is still in development and needs further enhancement. It is essential to compare the connotations and characteristics of Geomechanics, General System Theory and Earth System Science and analyse what the advantages of Geomechanics are in comprehensive investigation of natural resources through analyses of their relationship.

2. Connotations and characteristics of Geomechanics, General System Theory and Earth System Science

2.1. Geomechanics’ connotation and characteristics
In 1941, Siguang Li (J. S. Lee) formally put forward “Geomechanics” in “Geomechanical Analysis of Nanling Geological Structure” [1]. And in 1945, he published “Foundation and Method of Geomechanics”, formally establishing the discipline of Geomechanics [2]. Geomechanics is an interdisciplinary combining geology and mechanics. It studies the processes and modes of lithospheric deformation and hydrosphere movement with principles of mechanics, and then discusses the crustal structure and the rules of crustal movement and their causes [3]. The mechanical principles involve not
only the nature, size and direction of the crustal stress, but also the mechanical property of the rock itself. It requires that tectonic phenomena can be explained by uniform crustal stress fields and verified by simulating experiments.

The main research contents of Geomechanics are the law and mechanical mechanism of the movement and deformation of the crust (lithosphere), as well as the migration and enrichment law of the crustal and mantle materials under the control of crustal stress [3]. Geomechanics has three distinct basic characteristics[9, 10]: (1) the view of connection: Geomechanics holds that any geological structure phenomena do not exist in isolation, and that the geological structural phenomena occurring by groups form a unified tectonic system as a whole; (2) the view of practice: Any correct hypothesis of crustal tectonic movement must be able to fully explain the objective geological phenomena, and must accept the strict test of the actual objective geological structure; (3) the view of essence: Almost each kind of geological structure is the direct result of crustal stress, and thus they all have certain mechanics attribute and mechanics essence.

2.2. General System Theory’s connotation and characteristics
General System Theory was first proposed by Austrian biologist Ludwig von Bertalanffy at a philosophical symposium at the university of Chicago in 1937. During 1947 and 1948, the thought of General System Theory was further clarified, pointing out that there are patterns, principles and laws applicable to general system regardless of the specific types, properties of components and their relations. General System Theory was then continuously developed and improved. And in 1968, Ludwig von Bertalanffy published “General System Theory: Foundation, Development and Application”[4], which summarized the concept, method and application of General System Theory[11] and laid the academic foundation of the discipline.

General System Theory belongs to the fields of Logic and Mathematics, and its key content is establishing general principles generally applicable to systems[4, 12]. General System Theory has the following important characteristics[4, 5]: (1) the view of integrity: The system always reveals its integrity based on the relationship between the whole and its elements, levels, structures and environments; (2) the view of generic relevance: A system is an generic collection of elements, whose nature is based on the nature of elements, but not the sum of the nature of elements. The nature of the system is absent from the nature of elements, and the significance of elements can only be reflected in the whole; (3) the view of dynamics: The internal structure of the system changes with time, and the system must exchange materials, energy and information with the external environment; (4) the view of orderliness: The structure, hierarchy and dynamic direction of the system together indicate that the system has orderliness, while the state of complete disorder indicates the disintegration of the system; (5) the view of predetermination: The development direction of a system depends not only on the accidental actual state, but also on its own inevitable direction.

2.3. Earth System Science’s connotation and characteristics
In 1983, National Aeronautics and Space Administration requested Earth Science to be reviewed as an interactive system of different parts, and published “Earth System Science” in 1988[6]. Earth System Science was written as a guidance for global changes study, and therefore lacks a comprehensive elaboration of Earth System Science theory, also did not provide explicit definition of “Earth System Science”[7]. After continuously improvements, Earth System Science is currently defined as a discipline viewing the earth as a unified system composed of interacting core and mantle, lithosphere, hydrosphere, atmosphere, biosphere and planetary systems. Earth System Science focuses on the interaction between each part of the Earth. Earth System Science aims to understand the past, present and future behaviour of the entire Earth system by interpreting the dynamics and the evolution of the Earth, and the relationship between people and global changes[7, 13].

Earth System Science has the following important characteristics[13]: (1) the whole and evolutionary view: The earth system is composed of interacting parts of the whole, which is constantly changing and evolving; (2) the planet-global view: Understanding the structure and basic process of
the earth system from the perspective of celestial planets and global scale; (3) the interactive view: The various components interact, people and the Earth circle interact, regional and global processes interact; (4) the complexity view: The Earth System is an open and complex dynamic system with unbalanced, non-uniform, unstable and irreversible evolution; (5) the interdisciplinary and unified view: The interaction between disciplines is increasingly fierce, and develops towards unification.

3. Relationship between Geomechanics, General System Theory and Earth System Science

3.1. Geomechanics’ leading thought of integrity, generic relevance and orderliness

The core idea of Lee's Geomechanics, tectonic system[3], and the predecessor of Ludwig von Bertalanffy's General System Theory, living organism system[11], were both put forward in the early 20th century, and both embody the view of integrity, generic relevance, orderliness[10].

Geomechanics contains the view of integrity and generic relevance[5]: The Earth’s crust sections consist of various strata, rock mass. Each structural feature must have inseparable mates, and all structural feature are in groups. Each group of structural feature and other generic tectonic structural groups tend to form individual structural belt. And between the tectonic belts, there are sometimes blocks not very significantly deformed. These blocks and surrounding tectonic belts form a unified structural system.

Integrity and generic correlation also consist the core of Earth System Science half a century later. In the early 20th century, Geomechanics regarded the earth as a whole, studying the relationship between lithosphere, hydrosphere, atmosphere, biosphere and lower crust. Siguang Li (J. S. Lee) proposed that the Carboniferous-Permian strata in the north of China are mainly continental strata with a few marine strata. In the south, it is dominated by marine strata with a small portion of continental strata, and based on this, he proposed the relationship between the relative motion of hydrosphere and lithosphere and the changes of the Earth rotation rate [3].

Geomechanics stresses orderliness of geological phenomena and points out that, a complex structural system, especially the large tectonic system, is formed by structural composition of different times, different levels and is usually made up of many structural systems of smaller level. This smaller-level structural system, can be made up of even several smaller structural systems. The structural system extends in two directions. One direction is toward the high-level system, that is, the global structure is regarded as a large system. Furthermore, the global structure is compared with the surface structure of other planets, and regarded as a component of the Solar super-system. The other direction is toward the low-level system. Structural elements and structural traces in the tectonic system are the deformation of rocks. In fact, the crustal stress not only affects the internal particles of rocks, but also reaches the insides of particles [3].

In conclusion, the Geomechanics contains the core thoughts of General System Theory. However, Geomechanics do not evolve into General System Theory like Organism System Theory by Ludwig von Bertalanffy. Geomechanics mainly serves the construction of new China's national economy needs for energy, mineral, the location selection of the major projects. And the information technology, observation technology and other means at that time could not provide strong support. For example, at that time, there was a lack of effective means of investigation and research on the Earth’s crust under the ocean, which accounts for 71% of the Earth's surface area, and people did not pay enough attention to global environmental issues. Therefore, based on the above two points, Geomechanics failed to move forward to become General System Theory although it contains the same basic thoughts.

3.2. Earth System Science is the extension and application of General System Theory in Earth Science

As a complex giant system composed of multi- time- and space-scale processes, the Earth is a multi-layer system in space[7]. Each layer, each process and each element interact with each other and have chain response[13]. Currently, there are two development trends of Earth System Science. One is the Earth science and related disciplines promote their own development by thoughts of Earth System Science, giving the original subjects new vitality. The boundaries between disciplines may become
blurred, and different disciplines may penetrate into one another more deeply, promoting the formation of new disciplines. Another is to take Earth System Science as a new discipline to promote and develop, so as to reveal the nature and regularity of the Earth system.

Given the description of generic relevance in General System Theory, that is, the nature of the system is not the sum of the properties of the elements’, but the nature of the system is absent from the elements’. The rules followed by the system are not the same as the rules followed by the elements, nor is it the sum of the rules followed by the elements[14]. It can be concluded that the Earth System Science in the real sense needs to reflect the first trend, but more importantly to reflect the second trend to reveal the nature and regularity of the Earth system. Now, the Earth System Science reflects the first trend more, namely, the related branches of the Earth science study one or several subsystems under the global system background by the idea of general system theory. Revealing Earth System Science in a strict sense still needs further efforts, and stands for an important development direction in Earth science.

If Earth System Science represents the development direction and trend of the Earth science, Geomechanics can be regarded as the current realistic stage. Geomechanics not only contains the basic thoughts of General System Theory, but also has extensive practicability and operability in application, which has been proved in the application of petroleum, natural gas, coal, various kinds of metal ore exploration and development, and disaster geological investigation and prevention and other aspects.

4. Advantages of Geomechanics in comprehensive investigation of natural resources
China is advancing the unified management and systemic repairing of “Mountain, Water, Forest, Field, Lake” and plans: (1) to set up observation monitoring system covering multi-factor of natural resources of minerals, water, sea, forest, grass, wetland, so as to acquire the characteristics data of natural resources elements, such as quantity, occurrence and distribution, and master the their changes using integrated survey methods from both the heaven and land and water; (2) to comprehensively evaluate the quality, ecological value or benefits of resources based on the attribute characteristics of each category of resources using modern information technologies such as big data and cloud computing; (3) to simulate the hydrological, biogeochemical, and the ecological processes during development and utilization of natural resources, to predict and warn the possible changes of natural resources system from the national, regional and local levels, to provide scientific support to managers and decision makers for making preparedness, response mechanism, reducing or eliminating risks[8].

For a long time in the future, China’s national economy will maintain a medium-high growth rate, and the demand for energy resources will continue to grow. The increasingly severe situation of energy supply has become a bottleneck restricting the sustainable development of China’s economy and society. Compared with the developed countries, China’s energy structure is not very reasonable, the proportion of coal is still more than 60%. The proportion of cleaner energy sources such as oil, natural gas, nuclear energy and geothermal energy is far lower than the world average. The national goal of “Build Beautiful China” requests that the future exploration of energy resources and other natural resources must be comprehensive investigation including environmental influence of subsequent exploitation and other risks.

To carry out such works, obtaining comprehensive and accurate data is critical, but what’s even more crucial is putting forward a new scientific theory based on the data, providing corresponding solutions based on the Earth System Science.

Geomechanics is created with the thoughts of General System Theory. Moreover, it is proposed based on the actual geological and social economic conditions of China, and endures practical tests for more than half a century. Geomechanics is ahead of the currently popular Earth System Science for nearly half a century which is still in the development. Geomechanics representing the real stage of the Earth System Science should play a more important role. Geomechanics has the theoretical foundation and scientific potential of solving the problems in Earth System Science, and enriching the Earth System Science through combining modern information technology, observation and monitoring technology, and simulation method.
And in practice, Geomechanics has unique advantages in the construction of large-scale energy and mineral resources bases. (1) Geomechanics has outstanding successful experiences in oil and mineral exploration for many years. (2) Geomechanics has made long-term significant contributions in fields including site selection of major projects, regional crustal stability evaluation, and survey of internal dynamic geological disasters, which can provide scientific basis for the construction of major facilities and avoiding possible geological disasters in the development and utilization of energy and mineral resources. (3) Geomechanics can solve the geological problems in the development and utilization of energy and mineral resources, such as roadway deformation, well tube distortion and so on. Therefore, Geomechanics proves able to carry out the “Trinity Comprehensive Investigation and Evaluation” of energy and mineral resources, technical conditions, engineering construction and environmental impact.

5. Conclusions
Geomechanics representing the real stage of the Earth System Science. And it has the theoretical foundation and scientific potential of solving the problems in Earth System Science and carrying out the “Trinity Comprehensive Investigation and Evaluation” of energy and mineral resources, technical conditions, engineering construction and environmental impact.

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