Geomechanics: historical contributions, current challenges and considerations on development for the new era

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Abstract. Geomechanics is a marginal subject combining mechanics and geology and thus can be regarded as a branch of mechanics. Geomechanics is a discipline invented by China, and has made outstanding contributions in both theoretical and practical fields fulfilling national key demands. However, under the new situation, it is also faced with both challenges of theoretical and practical demands in fulfilling national needs. In this article, the authors analysed the challenges, and pointed out strategies for developing Geomechanics in the new era: rebuilding confidence in the advantage of Geomechanics, refining and enhancing already existing progresses and deploying future research concentrated on providing Geomechanics solutions to key national needs.

1. Introduction

“Geomechanics” was formally proposed by Li Siguang (J. S. Lee) in his speech “Geomechanical Analysis of Nanling Geological Structure” in 1941[1]. Geomechanics is a marginal subject combining mechanics and geology. It is a discipline that studies crustal structure, crustal movement and its causes with the principle of mechanics[2, 3]. Geomechanics can be regarded as a branch of mechanics[3]. What is crucial and characteristic is that it involves both the nature, magnitude and direction of the crustal stress and the mechanical properties of the rock itself. According to Geomechanics, the structural trace can be explained by unified stress field and verified by simulation experiments. Therefore, Geomechanics is a rigorous discipline based on the geological reality of China and Eastern Asia, and also an original subject of geoscience by China, rather than imported ones, which is one of most distinctive features of geomechanics and a major theoretical contribution. Its distinctive features also lie in answering the urgent national needs of China, and it has made outstanding contributions to the economic and social development of P. R. China[4]. However, the economic and social requirements for Geomechanics have undergone fundamental changes. And Geomechanics faces the challenges of theoretical, technical and methodological innovation under the new situation. Therefore, in this article the authors reviewed the past contributions and advantages of Geomechanics, and then analysed the challenges confronted, and at last pointed out strategies for developing Geomechanics for the new era.

2. Historical contributions of Geomechanics

Geomechanics introduces mechanics into geoscience and is a self-invented discipline by China[1]. This makes the Chinese geologists achieve our own geological discipline for the first time. Furthermore, Geomechanics put forwards the system theory almost at the same time as Batterunffy L.
V. proposed the general system theory[5], which is now considered as a new methodology of science[6]. Therefore, Geomechanics can also be considered as the combination of structural geology and Earth System Science[5], which is regarded as the next major theoretical breakthrough direction[7].

Geomechanics proposes that, the distribution of endogenous minerals and exogenous minerals is controlled by tectonic system[8, 9]. Guided by Geomechanics, in the huge subsidence zone in the eastern part of China, Daqing, Dagang and Shengli oil fields were successively found[8, 10]. And in the west of China, Tahe oilfield was found[11]. These discoveries fundamentally changed the oil industry in our country. Geomechanics also guided the prospecting work of P. R. China’s Uranium, Iron ore, Gold and other minerals, especially guided the discovery of Uranium ores in Northern Guangdong[12, 13, 9], and thus made great contributions to China’s atomic industries.

The second is site selection. According to the Geomechanics, in some active tectonic belts, there are relatively stable areas (also known as “safe islands”). The key lies in finding out the distribution and characteristics of active structures and carrying out regional crustal stability evaluation[14, 15]. The “safe islands” theory has pointed out the direction for the site selection of Western China’s “Major Third-line Construction Project”, and also guided the site selection planning of Qinghai-Tibet railway, Dayawan Nuclear Power Station, the Yangtze River Three Gorges Dam and other major projects.

3. Current challenges confronted by Geomechanics

Geomechanics has made outstanding contributions, but now the situation has changed: (1) The oil and gas fields, during whose discoveries Geomechanics has played an important guiding role, has become high-water-content oil and gas fields, and the exploration targets have evolved from conventional oil and gas reservoirs to unconventional ones[16]. (2) The already discovered mines under the guidance ore-field structure are becoming crisis mines, and the deep mining in second prospecting space has become main developing trend[17]. (3) Modern construction techniques and methods have greatly expanded construction areas, such as, tundra super long tunnels, great bridges, and river tunnel engineering construction in the Tibet plateau. This will inevitably enter the complex and dangerous mountainous areas from former “Safe Islands”[18]. (4) The 19th National Congress of the Communist Party of China clearly put forward the need to build a beautiful China and strengthen the comprehensive investigation and evaluation of natural resources and geological environment. And the bell has alarmed for “march towards the deep earth”. All these have fully demonstrated that the economic and social requirements for Geomechanics have undergone fundamental changes. Therefore, Geomechanics is facing the challenge of continuing to support and serve the major needs of the country under the new situation in the new era.

In addition, as to the Geomechanics theory itself, the formation and development of Geomechanics benefited from J. S. Lee’s advanced academic thinking[5], and also benefited from the combination of experimental science, basic science and technology science. The foundation of Geomechanics absorbed the latest technology, including crustal stress, simulating experiment, and paleo-geomagnetic and isotopic element dating technology, high-pressure and high-temperature experiment and so on. However, in recent years, Earth science, Earth observation, the deep-Earth exploration and experiment testing technology and information technology, such as big data has experienced tremendous innovation and development. Absorb these results in a timely and effective manner has become the key to the development of Geomechanics theory. Therefore, Geomechanics faces the challenge of theoretical, technical and methodological innovation under the new situation.

In short, whether from the theory of Geomechanics itself or from serving the major needs of the country, Geomechanics has entered a new era to meet challenges.
4. Strategies for facing challenges and developing Geomechanics

4.1 Rebuild the confidence in Geomechanics

In conquering all challenges, the human factor is the most important, and thus the real challenge comes from the people working on Geomechanics themselves. Through the horizontal comparison, it can be found that the Geomechanics theory is systematic at the beginning of the founding. Its core theory, “structural system”, defined as a “integral whole consisting of various structural elements of certain structural belts and the clamp blocks or blocks between structural belts, the elements and blocks are of different forms, different nature, different grades and different time, but genetically related”, embodies the entirety, relevance, orderliness, dynamics, and is consistent with general system theory[5]. For example, the structural system includes the uplifting belts that produces metallic minerals and the subsiding belts that produces coal and oil and natural gas. The fault tectonic belt controlling the migration of mineral fluid, oil and gas may be the active belt to be avoided in the location selection of “Safe Islands” theory. Therefore, Geomechanics possesses the advantage that one discipline fullfills the needs of comprehensive survey of natural resources and geological environment which other disciplines do not have. Therefore, the first aspect to meet the challenge lies in the people working on Geomechanics, who should adhere to theoretical confidence in thinking, have confidence in the science created by our country, have confidence in the science that has made outstanding contributions to the country’s economic and social construction, and have confidence in making new contributions in combination with the new needs of the new era.

4.2 Three-step strategy for action

The first step is to concentrate on refining and integrating the existing achievements. Geomechanics, in fulfilling major national demands, has formed many subdivisions, including oil and gas Geomechanics, the regional crustal stability evaluation, ore-field structure, etc.. However, with long-term development separetely, Geolmechanics appears more and more incompact, and its influence as a whole is becoming more and more weaker. Therefore, it is time to “put the outstretched fingers clenched into a fist” again. It is time to refine the theoretical progresses of all Geomechanics’ branches, and improve Geomechanics theory, strengthening Geomechanics’ theoretical kernel. Moreover, the dispersed progresses of scientific research in Geomechanics should be integrated together, forming remarkable and influencial achievements. This is the first step, concentrating on enhancing the existing achievements, to answer “what is Geomechanics? What have Geomechanics done?”

The second step is deploying the future geological survey and research work consciously around the Geomechanics’ core business in solving practical problems. There are four aspects to do: (1) strengthening two existing key geological surveying projects, “Investigation of important active tectonic zones with geological disasters and regional crustal stability” and “Special regional geological mapping” to be sure to output macroscopic achievements in Geomechanics; (2) strengthening innovative team centring key projects of science and technology like “Tianshan orogenic belt and sandstone-type uranium mineralization” and “Northern margin of North China” which have obvious advantages. Through doing this, influential academic groups who can build large-scale, influencial scientific research will be formed; (3) combining the structural system with the oil and gas survey and research of shale gas in Qaidam and Tarim basins in the south, and the structural system with the ore-prospecting and prediction research of Tianshan and Aljinshan, etc., so as to maintain the theoretical characteristics and make innovations; (4) grasping the chance of “National Deep Earth Plan”. As we have a considerable early accumulation, there is a lot we can do in seeing through the earth, exploring deep resources, expanding space and making green use of it.

The third step is to give full play to the advantages of Geomechanics systemic characteristics and that the Institute of Geomechanics possesses complete business departments suitable for large-scale three-dimensional combat. Aiming at countries’ significant new demand to the research of forecast, through double leaping in both theory and the economic and social benefits, Geomechanics will sure bloom again.
It must be kept in mind that the projects is a platform but never a destination. It is providing Geomechanics solution to the major demands of resources and environment that really matters. For doing this, the relationship between basic geological survey and original innovation must be optimized. Although the size of various original innovative funding projects is small, their originality should not be ignored. Trickle-down streams become rivers. The key is that they can flow into the Geomechanics, enter the main battlefield of geological survey, and play a leading role in scientific and technological innovation. Furthermore, if the projects is the platform, the organization is the guarantee. The business offices will be transformed into distinct research centres so as to straighten out the mechanism and to integrate resources, and to provide to effective organizational guarantee for fighting hard battles.

5. Conclusions
Geomechanics has made outstanding contributions in both theoretical and practical fields fulfilling national key demands. But it is also facing challenges in both theoretical and practical fields under the new situation. Rebuilding confidence, refining and enhancing already existing progresses and deploying future research concentration on providing Geomechanics solutions to key national needs are the main strategies for conquering these challenges.

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