Bridging the Gap Between Geotechnology and Geotechnics: A Comprehensive Clarification

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Abstract:
Many world languages contain two technical terms, "geotechnology" ("geotechnological") and "geotechnic" ("geotechnical"), which are equally used in modern scientific and industrial lexicons. At first glance, these terms seem interchangeable due to their phonetic similarity and related usage in geology, civil engineering, and industrial contexts. However, this similarity often leads to confusion and misuse. Geotechnology refers to the application of technological innovations in the exploration, extraction, and utilization of earth resources, such as mining and drilling, with a focus on efficiency and sustainability. In contrast, geotechnics, or geotechnical engineering, is a branch of civil engineering concerned with the behavior of earth materials like soil and rock, and focuses on foundation engineering and the stability of infrastructure. The lack of a universally accepted distinction between these terms has led to blurred definitions and frequent misuse in academic and industrial discussions. This article aims to clarify their specific applications, historical evolution, and importance in maintaining precise usage, ultimately helping to reduce confusion and improve communication in both scientific and industrial communities.

Keywords —Geotechnology, geotechnological, geotechnic, geotechnical, remote operated mining

INTRODUCTION

So, what do these two terms, geotechnical and geotechnology, really mean, and what is the key difference between them? Although these terms are often used interchangeably due to their similarity in sound, they refer to entirely different fields and industries, and understanding their distinction is crucial for their correct application. The term "geotechnical" has been in common usage since the mid-20th century, predominantly in association with words like "investigation" and "engineering." It has become central to the fields of civil engineering and construction, playing a vital role in designing and building infrastructure projects around the world. Geotechnical Engineering is the branch of engineering science that deals with the study and analysis of soil and rock mechanics. It encompasses the investigation of soil and rock behavior, as well as the design, construction, and maintenance of structures such as foundations, slopes, tunnels, retaining walls, roadways, and other systems that are built on or supported by soil or rock. The emphasis in geotechnical engineering is on ensuring the stability and safety of structures, particularly in construction, where the integrity of the ground materials is of paramount importance. In essence, geotechnical engineering is deeply rooted in the construction industry, where understanding the mechanical properties of the earth is critical for safe and efficient building practices.

On the other hand, the term "geotechnology" has a similarly long history but pertains to a completely different area of study. While geotechnics deals with construction, geotechnology focuses on resource extraction. The term is used to describe a set of engineering sciences and techniques, primarily in the mining industry, that are concerned with the exploration and extraction of Earth's natural resources. Specifically, geotechnology is heavily involved in the processes that convert these natural resources into usable forms, such as liquid or gas, while they are still located in their natural settings (in-situ conversion). This conversion process makes it easier and more efficient to extract these resources, which are often found deep within the Earth's crust. Geotechnology plays a significant role in industries such as mining, oil, and gas extraction, where its techniques and methods help access valuable resources in the most efficient and environmentally responsible way possible. Unlike geotechnics, which is primarily focused on construction, geotechnology's purpose is almost exclusively tied to the extraction of natural resources, making it indispensable to industries involved in resource management and mining operations.

Despite its importance in industries worldwide, the term "geotechnology" has not been as widely adopted or correctly used in the western hemisphere, where it is often overshadowed by its counterpart, geotechnical engineering. This lack of familiarity and misuse of the term in many Western contexts highlights the need for a closer examination of geotechnology and its proper usage. In many cases, geotechnology is mistaken for geotechnical engineering due to their similar-sounding names, even though they belong to entirely different industries. Understanding these differences not only prevents misuse but also ensures clear communication in scientific, industrial, and academic discussions. With geotechnology gaining prominence in industries focused on sustainability and responsible resource extraction, it becomes even more essential to distinguish it from geotechnical engineering, which continues to play a pivotal role in construction and civil engineering projects.

GEOTECHNOLOGY

Geotechnology (GT) encompasses a wide range of innovative mining methods that are primarily focused on the extraction of valuable resources from the Earth without the need for large-scale surface mining operations. These methods are advanced and specialized, relying on engineering techniques to access minerals, metals, oil, and other resources while minimizing the environmental footprint and eliminating the necessity of having personnel physically present in the mine. Here, we will explore several key examples of geotechnological mining methods, each showcasing how GT has revolutionized the way we extract resources from the Earth.

One of the oldest and most well-known GT mining techniques is Solution Mining (SM), which is applied for the recovery of soluble minerals, particularly salt. This method involves drilling a single or multiple boreholes into a salt dome, then pumping fresh water into the formation. As the water flows through the salt layers, it dissolves the salt, creating a saturated brine solution, which is then pumped back to the surface. SM has been widely used for centuries and remains a prominent method for salt extraction. Its efficiency and relatively minimal environmental impact have made it a staple in the geotechnology toolbox, and it serves as an excellent example of how resources can be extracted using boreholes without the need for large-scale surface mines.

Another notable GT method is In-Situ Leaching (ISL), which is used for the extraction of metals like uranium, copper, and gold. This method requires the drilling of both injection and extraction holes into the metal-bearing ore body. A chemical reagent is pumped into the formation through the injection holes, which dissolves the metal as it travels through the ore. The resulting "pregnant" solution, now carrying the dissolved metal, is pumped back to the surface through the extraction holes. This method eliminates the need for traditional mining, where large quantities of earth are moved to access the metal. Instead, ISL allows metals to be extracted directly from the ore in place, offering a more efficient and environmentally friendly alternative to conventional mining practices.

Sulfur Melting Mining, also known as the Frasch Process, is another innovative GT technique. It involves pumping super-hot water or steam into sulfur-bearing formations, causing the sulfur to melt. The molten sulfur is then pumped back to the surface through a borehole. This method is highly effective for extracting sulfur in its pure form, and like other geotechnological methods, it eliminates the need for personnel to work underground. The Frasch Process highlights how heat can be applied in GT to transform solid minerals into a liquid state for easier extraction, further advancing the efficiency and safety of mining operations.

Underground Coal Gasification (UCG) is yet another advanced GT method that showcases the ingenuity of geotechnological mining. UCG involves drilling boreholes into coal seams, through which oxygen or air is pumped. The coal is then ignited in a controlled manner, and the heat generated from the combustion process is used for various purposes such as heating buildings or powering agricultural operations. The key feature of UCG is that it allows coal to be utilized without ever needing to physically mine it. The energy from the coal is harnessed directly at the source, providing a cleaner and less invasive way to extract energy from underground coal deposits.

Borehole Mining (BHM) is a GT method applied to extract friable, unconsolidated ores like phosphate, iron, coal, gold, uranium, and rare earth elements. This method is based on the principle of using in-situ water jetting to dislodge the ores, creating a slurry that is simultaneously pumped back to the surface. BHM is particularly advantageous for ores that are difficult or dangerous to mine using traditional methods, offering a safer, more cost-effective solution to resource extraction. The ability to perform BHM through narrow boreholes further demonstrates how GT can reduce the need for disruptive surface mining operations.

A similar technique is Heavy Oil Stimulation, which is comparable to the Frasch Process but focuses on the extraction of oil. In this method, hot steam is injected into the oil-bearing formation via boreholes, heating the surrounding strata and effectively liquefying the heavy oil. The "liquefied" oil is then pumped to the surface through the same or adjacent boreholes. This method is highly effective for accessing thick, heavy oil deposits that would be difficult or inefficient to extract through conventional means. By injecting heat into the formation, heavy oil stimulation increases the flow of oil, making it easier to extract and more economical.

In addition to these resource extraction methods, Geothermal Energy production is another key application of geotechnology. Geothermal energy involves the use of natural heat from the Earth's crust to generate electricity or heat buildings. Cold water is pumped into the hot portions of the Earth's crust through injection wells, where it is heated as it migrates towards extraction wells. The heated water is then pumped back to the surface, where it can be used for electricity generation, greenhouse heating, or similar applications. Geothermal energy is a prime example of how GT can be used not only for resource extraction but also for harnessing the Earth's natural energy to create sustainable power sources.

One of the most striking aspects of all these GT methods is that they are remotely operated through boreholes, eliminating the need for personnel to be present in potentially hazardous environments such as mines. This has led to the concept of "mineless technology," as these methods no longer require traditional mines where workers are exposed to physical dangers. Instead, the entire process is controlled and monitored from above ground, often from great distances using computerized systems. The boreholes themselves, typically measuring less than 20 inches in diameter, represent a stark contrast to the massive, invasive footprints left by conventional mines. This smaller scale has led some researchers to refer to GT as a "non-intrusive" form of resource extraction, a synonym for "mineless" technology. By minimizing the environmental and social impacts of mining, geotechnology offers a promising path forward for the future of sustainable resource extraction.

Fig 1. A gold mining GT-rig deployed on the edge of the open pit. Courtesy of Borehole Mining International, Inc. 2019

Mineless Geotechnology is an innovative approach not only used in resource extraction but also in various other applications, including oil and gas stimulation, the underground construction of storage facilities within salt domes, the building of underground walls and curtains, groundwater collection systems, and numerous other specialized construction projects. What makes geotechnology so radically different from other methods is that it is based on mineless, remotely operated mining techniques. This fact sets it apart as a distinct and unique branch of both science and business, operating independently of traditional mining processes. The key to its innovation lies in the fact that geotechnology doesn't require massive surface disruption or personnel to be present at the extraction site, making it an efficient and safer alternative.

In addition to the methods previously discussed, there are several other approaches classified under Geotechnology, such as Heap Leaching and Solvent Extraction-Electrowinning (SX-EW), along with the reprocessing of old mining tailings. However, it is important to note that in order to obtain the ore needed for leaching, a conventional form of mining—either surface or underground—is still necessary. This reliance on traditional methods for the initial extraction disqualifies these particular GT methods from being categorized as truly "mineless." Thus, while these techniques do incorporate aspects of geotechnology, they still fall short of the fundamental principles of mineless extraction that define the true nature of geotechnology.

One of the primary advantages of mineless GT methods is that they eliminate the need for any large-scale earth-moving operations. This makes these methods the most rapid, safe, cost-effective, and environmentally friendly technologies available for extracting resources that were previously considered uneconomic or difficult to access. By removing the necessity of earthmoving equipment and personnel working directly at the extraction site, mineless geotechnology enables operations in hazardous conditions, such as radioactive environments, and unstable strata that would be too dangerous for traditional mining methods. It also broadens the scope of where mining can occur, allowing for resource extraction in remote areas that were once deemed inaccessible, including offshore regions, desert landscapes, and the challenging polar zones.

Moreover, in many cases, geotechnical investigations are required to determine the most effective parameters for GT operations. These investigations include a comprehensive set of studies, such as rock and ore sampling, laboratory testing, hydrogeological assessments, and rock mechanics studies. Advanced computer simulations are also often utilized to model the behavior of the Earth's subsurface and the resources being extracted. While this might make the two terms—geotechnical and geotechnological—sound similar, they carry vastly different meanings. Geotechnical engineering serves a crucial role in optimizing geotechnological methods, ensuring that the extraction process is both efficient and safe. Therefore, in the context of mining, geotechnical engineering supports and enhances geotechnology by providing the necessary data to fine-tune operating parameters and achieve the best possible results.

Despite its numerous advantages and broad applications, geotechnology is not a one-size-fits-all solution and cannot entirely replace conventional mining methods. There are many situations in which traditional mining methods are still preferable or more effective. For example, in environments where the geological conditions are well-suited for conventional mining, or where the costs and logistics of implementing GT would be impractical, conventional methods remain the go-to choice. However, there are also instances where geotechnology is the only feasible option. One such scenario is below-the-ocean-floor mining, where few, if any, alternatives to geotechnology exist. In this case, the challenges of extracting resources from beneath the ocean floor require a level of precision, control, and remote operation that only geotechnological methods can provide.

Ultimately, geotechnology, when used in conjunction with conventional mining, forms a comprehensive and flexible technological arsenal that allows for more versatility in modern resource extraction. By offering a range of techniques suited to various geological, environmental, and economic conditions, the combined use of geotechnological and traditional methods allows for greater efficiency and flexibility in mining operations. This flexibility ensures that resources are extracted in the most effective way possible, whether through the innovative mineless techniques of geotechnology or the well-established methods of conventional mining. Together, these approaches are shaping the future of resource extraction, making it more sustainable, efficient, and capable of meeting the needs of an ever-evolving world.

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Over the course of many decades, and even spanning centuries, numerous generations of scientists, researchers, and engineers from all corners of the world have contributed their immense talent, vast knowledge, and hands-on experience to the development and evolution of geotechnology. These individuals have played an instrumental role in shaping geotechnology into what we recognize today as a modern, sophisticated scientific discipline and a highly specialized industrial branch. Without their countless hours of hard work, dedication, and determination, geotechnology would not have reached the level of commercial success it enjoys in today's global market. The author would like to take this opportunity to gratefully acknowledge the tremendous and invaluable input of these brilliant minds throughout history. Their relentless pursuit of innovation and excellence has paved the way for many of the cutting-edge technologies and techniques we see today in the field of geotechnology. The complex systems and methods now utilized in resource extraction, infrastructure building, and various other industrial applications are direct results of their meticulous research, detailed experimentation, and practical implementation. Furthermore, the success of geotechnology as both a commercial industry and a scientific domain owes a great deal to the collaborative efforts of these professionals from various disciplines, who have come together over the years to refine and enhance this important field. It is truly a testament to their enduring legacy that geotechnology continues to thrive and grow in both scope and application across the world.

CONCLUSION

Geotechnology, as a discipline, does not suffer from a shortage of scientific literature, technical publications, or informational resources. On the contrary, it boasts a wealth of academic and professional materials, including but not limited to scientific publications, detailed engineering reports, comprehensive case studies, insightful white papers, innovative patents, and numerous internet blogs that discuss its ever-expanding capabilities and applications. Since the mid- to late-20th century, a number of Geotechnology Departments have been established in various prestigious institutes and universities around the globe. These departments can now be found in countries as diverse as Canada, Estonia, Japan, Indonesia, Norway, Russia, Slovakia, Vietnam, the United States, and many more. The primary objectives of these academic departments are twofold: first, to provide thorough education and training to students in the field of modern mining technologies, and second, to conduct cutting-edge research and development (R&D) to further advance the capabilities and methodologies of geotechnology.

As the field continues to grow and evolve, it is becoming increasingly important for both seasoned professionals and newcomers to the discipline to familiarize themselves with the terminology that has been established and widely accepted within the industry. Proper use of this terminology ensures clear communication, avoids potential confusion, and maintains a level of professionalism across all forms of discourse related to geotechnology. This is especially vital for the newer generations of researchers and engineers who are stepping into this dynamic field. Understanding and adhering to the established terminology will not only help them align with the rest of the scientific and industrial community but will also allow them to build upon the work of their predecessors in a coherent and structured way. In doing so, they will be able to make meaningful contributions to the field, pushing the boundaries of modern geotechnology and ultimately moving the world forward. Geotechnology has become a cornerstone of modern industrial practices, and with the collective effort of past, present, and future experts, it will continue to play a pivotal role in the future development of sustainable and efficient mining technologies, resource extraction, and construction methods.

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