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Perspective

Reflections on the water cycle and ecological protection and restoration

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Editor's Note: To fulfill the new requirements of geological work in the modern era and explore the latest advancements, the cutting-edge directions and trends of hydrogeology science, as well as the key scientific issues and major demands in hydrogeology, those contribute to the development of an ecological civilization and effective natural resource management, the national hydrogeological academic symposium took place from October 25th to 27th, 2024. Organized by the China Geological Society and collaboratively hosted by the Hydrogeology Professional Committee, the event featured an insightful speech by Mr. Wang Min, former Deputy Minister of the Ministry of Natural Resources. His perspectives offer valuable insights for current geological endeavours, and we have compiled the content of this speech into this article.

Honorable experts, colleagues, and comrades,

Good morning to you all!

This academic symposium, titled "Water Cycle and Ecological Protection and Restoration", holds great practical significance. Water is not only a precious resource but also a vital natural agent, playing an active and sensitive role in our environment. It is water that connects mountains, forests, farmlands, lakes, grasslands, and deserts into a unified community of life. Among all natural elements, water uniquely exhibits permeability, fluidity, and the ability to acts as a universal solvent, making life possible. Through processes like evaporation, precipitation, infiltration, and surface and subsurface flow, water intricately links natural elements, fostering their interactions and sustaining life on Earth. As the saying goes, "Mountains become miraculous only when combined with water". This concept encompasses atmospheric water, surface water, groundwater, condensate water, soil water, vadose zone water, perched water, bound water, and structural water.

Water sustains humanity, which, in turn, flourishes near it. Water levels rise and fall, and various forms of water undergo continuous transformation. These dynamics shape the framework and evolution of ecosystems in river basins and beyond, involving a host of geological issues. To better serve the construction of ecological civilization, geological work must prioritize water as a key element.

Nearly 30 years have passed since China shifted the focus of geological work from mineral prospecting to balancing resources and the environment. This balance requires a comprehensive, systematic, and dialectical approach to addressing both resource and environmental challenges. Transforming traditional geological prospecting into a modern geological perspective is essential. This entails comprehensive evaluations of resources and environment, aiming to gain a more comprehensive, systematic, and objective understanding of nature, enhance cognition, and promote the harmonious coexistence.

Regarding the geochemical surveys of soils, extensive surveys revealed significant findings. These include soil contamination in numerous areas, though this issue received limited attention. Furthermore, we identified the enrichment of multiple beneficial elements in various regions. However, public recognition has largely focused on selenium-rich soils have been widely known, which gives the expression that the geochemical surveys of soils are only about developing selenium-rich agricultural products. While these achievements are valuable, more in-depth analyses and summaries are needed to fully understand the

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scope of geochemical survey of soils.

In nature, elements of the same type can exist in different forms under varying redox conditions and acidic or alkaline environments. This variability influences their involvement in biogeochemical reactions and their absorption by plant roots. Consequently, the presence of heavy metals above permissible limits does not necessarily imply agricultural contamination, nor does the enrichment of beneficial elements guarantee distinctive agricultural products. These outcomes depend heavily on the hydrogeochemical conditions of the elements involved. While the presence of elements provides a foundation, regulating their occurrence forms is crucial. These considerations necessitate a shift in perspective and an adjustment in work practices, transitioning from traditional geological prospecting to a more balanced focus on both resources and the environment.

A second example can be found with groundwater. Previous studies on water quality and quantity have largely focused on water as a resource, with much less attention paid to the ecological issues arising from changes in water levels and hydraulic heads. For instance, the extraction of phreatic water can lead to a drop in groundwater levels, and if extraction methods are not poorly managed, they may degrade groundwater-dependent ecosystems, potentially causing further deterioration. When pore-confined water is extracted and the hydraulic head pressure drops, this can induce the compaction and release of water from clay soils, which may lead to ground subsidence. This can be prevented unless there are cyclic fluctuations in hydraulic head pressure, which could transform the elastic-plastic deformations of clay soils into completely elastic deformations. Extracting deep pore-confined water accelerates the natural compaction and diagenesis of sedimentary basins. Since land subsidence typically result in an irreversible loss of ground elevation, simply restoring hydraulic head pressure does not restore water resources. From an ecological protection perspective, deep groundwater resources in water-bearing systems should be reserved, except for localized, small-scale drinking water supplies. Groundwater resource assessments must take into account the adverse impacts of large-scale recovery, distribution, and intensity of groundwater extraction on ecosystems.

Another example is the evolving understanding of the functions of channels. In the past, the focus was primarily on their utility. Channels were primarily used for flood control and drainage through desilting and dredging. They also served purposes such as water supply, transportation, and hydroelectric power generation. However, from a modern ecological perspective, channels should be viewed as tools for regulating water resources and the water environment. For both banks of channels, riverside wetlands should be prioritized over embankments. This approach allows channels to store water, reduce flood peaks during floods, and release water to maintain streamflow during dry seasons. The close interconnection between channels and wetlands, as along with the constructive interactions between surface water and groundwater, enables the reasonable regulation of water resources. It also helps to create natural ecosystems and garden-like landscapes that facilitate water purification and biodiversity. In traditional practice, floods were viewed as fierce adversaries, with embankments acting as protective barriers and channels being dredged to carry floodwaters to the sea as quickly as possible. While this traditional approach was shaped by historical circumstances and made significant contributions in the past, it has led to issues such as droughts, waterlogging and ecological imbalances. As a result, it has become less suitable for the challenges we face today. The changes in how we view and manage surface ecological construction will inevitably impact the subsurface environment. Therefore, environmental geological efforts must adapt to these changes, explore new challenges, and address emerging issues. In previous studies on the transformations between atmospheric water, surface water, phreatic water, and soil water, extensive field observations and analyses of the characteristic curves of vadose zone water were conducted, often from the perspective of water as a resource. These studies are equally important for ecological construction, and should be revisited to support the shift from resource hydrogeology to ecological hydrogeology.

The final example involves ecological geology, a concept introduced many years ago. Over the years, researchers have conducted specialized surveys and published numerous papers and books, making significant contributions to the advancement of ecological civilization. However, despite these efforts, the field has yet to achieve the level of vibrancy and impact it deserves. Notably, there is a pressing need for major theoretical innovations and methodological breakthroughs that can profoundly enhance our understanding of natural ecological processes and shed new light on the intricate relationship between humans and nature.

As the old saying goes, "The environment shapes the people it sustains", reflecting a deep understanding of the relationship between humans and nature. Soils are created through the weathering of rocks, which serve as the parent materials and ultimately determine the composition of the soil. When atmospheric water infiltrates the ground, it interacts with rocks and soils through various physical, chemical, and biological processes, resulting in the formation of different rock and soil solutions. Consequently, components from parent rocks migrate and enter biological chains after being absorbed by plants. This, along with the exchange between groundwater and surface water and the release of gases from the ground, forms the foundation of the living environment for all life, including humans.

In regions where sandstones serve as parent rocks, soils are typically deficient in copper. Soils derived from purple mudstones generally lack zinc. Carbonate soils formed from limestones tend to be highly fertile, while karst phreatic water typically has Total Dissolved Solids (TDS) of less than 0.5 g/L and is rich in bicarbonate and calcium ions. In areas with abundant dolomite, the water predominantly exhibits a hydrochemical profile of heavy magnesium carbonate. In contrast, fissure water from granites is enriched with multiple elements, including potassium, sodium, calcium, and magnesium. The concept of "different water and soils" essentially refers to these distinct underlying environmental conditions.

A traditional Chinese medicine doctor often inquires about a patient's place of origin and recent dietary habits. This helps to gain insight into their living environment and the evolving relationship between humans and nature within that context. Modern medicine has confirmed that the human intestines are home to up to 100 trillion bacteria, encompassing more than 40 bacterial genera and 400 to 500 species. The intestinal flora plays a vital role in synthesizing essential vitamins and amino acids, metabolizing sugars and proteins, and aiding in the absorption of key minerals such as iron, magnesium, and zinc. In this way, the intestinal microbiome is crucial for maintaining overall human health.

Intestinal flora has developed since early childhood, continuously adapting to our living environment. When significant changes occur in the surrounding water and soil conditions, our bodies may respond with discomfort. A common example of this is the intestinal stress response following alcohol consumption. Many individuals experience diarrhea after drinking excessive amount of wine because alcohol disrupts the balance of microorganisms, leading to intestinal flora imbalance. Similarly, while coffee is a favored drink among many Westerners, tea is the preferred choice in Chinese culture. When a Westerner drinks tea or a Chinese person drinks coffee, they may experience what is known as "non-acclimatization". In a sense, being kind to ourselves also means being kind to the tiny, ravenous microorganisms within our intestines, highlighting the importance of the relationship between humans and nature.

Therefore, in the study of ecological geology, we must prioritize aligning with and adapting to nature. We should examine environmental changes through the lens of geological processes, assess the impact of natural environments on life processes, and analyze geological structures, minerals, rocks, topography, and landforms, along with their historical changes and geological evolution, from the perspective of human-nature relationships. In particular, conducting in-depth studies of local hydrogeological environments is essential.

Groundwater can be compared to an expansive natural chemistry laboratory. From recharge to runoff and discharge, it continuously interacts with surrounding rocks under varying conditions such as temperature, pressure, acidity, alkalinity, and redox reactions. These interactions, including leaching, dissolution, sedimentation, and precipitation, result in energy and material exchanges, involving diverse physicochemical and biochemical processes. These processes profoundly impact the quality of ecosystems.

In the past, the dynamic field conditions of groundwater were significantly altered by human activities. Groundwater depression formed by artificial groundwater exploitation, spanning from natural recharge areas to runoff and drainage zones, have become widespread, disrupting natural dissolution and precipitation processes. Efforts today have significantly mitigated the excessive decline in groundwater levels. However, further attention is needed in two key areas: (1) emerging challenges due to rising groundwater levels, such as salinization and the immersion and erosion of underground structures; and (2) The need to shift focus from merely recovering water levels and hydraulic heads to restoring geological environments, while strengthening studies on the chemical characteristics of groundwater.

With increasing infrastructure development and urbanization, ground hardening has severely hindered the exchange of gas components (e.g. oxygen, carbon dioxide, and nitrogen) between groundwater and the atmosphere. This disruption negatively impacts the acidic or alkaline conditions and redox environment of groundwater, interfering with natural physical, chemical, and biological processes, and thereby altering the relationship between humans and nature. In urban area, it has been noticed that green spaces should be strategically placed between buildings at certain intervals to maintain gas exchanges between the surface and underground — what we term "connecting to ground gases". To foster a more harmonious relationship between humans and nature, innovative hydrogeological methods should be developed to calculate and assess the optimal spacing between green spaces and the broader regional land layout.

From the perspective of ecological geology, we should systematically study production and living practices that align with nature, adjust and optimize the layout of buildings, and minimize the use of reinforced concrete and cement. By preserving as much of the natural landscape as possible and facilitating the free exchange of materials and energy above and below the surface, we can foster a healthier relationship between humans and nature.

Notably, the relationship between humans and nature also encompasses aboveground factors such as the surface, atmosphere, sunlight, precipitation, plants, and organisms, as well as human-nature interactions. People inhabit various regions on Earth, each shaped by different celestial relationships, geological structures, lithologies, climates, topography, landforms, mountains, rivers, and biodiversity. All these factors must be considered holistically and investigated systematically. Nevertheless, the relationship between humans and nature is predominantly shaped by geological conditions. Ultimately, ecological geology, a field that integrates geology and ecology, seeks to guide people toward a scientific and healthy life by studying this relationship.

Groundwater differs greatly from surface water, particularly in the context of water-rock interactions, where many aspects require further in-depth research. I believe this conference will play a crucial role in accelerating innovations in the theories and technical methods of hydrogeology.

Thank you.