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The role of karst in engineering and environmental geosciences

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Abstract

Karst is a unique landform developed by soluble rock. It usually relates to groundwater drainage system, and provides important water resources. Current researches indicate that karst is closely related to the earth system and environmental protection, and it can also create potential natural hazard such as sinkhole flooding and land subsidence in urban area. Its relationship with hydrogeology has also been an important factor for studying water pollution, and nutrient cycles on engineering geosciences and agricultural geology.

1 Origin of "Karst"

Karst is a unique landform developed by soluble rock. By summarizing Ivan Gams and Andrej Kranjc's research on history of karst, Ford and Williams (2007) declared that "the origin of the word 'Karst' can traced back to pre-Indoeuropean origins" and its original word "karra/gara" means "stone" (Ford and Williams, 2007, p. 1). While "classic karst" usually provides a "stony" phenomena (such as the Dinaric Kras, which is the first karst landscape for scientific investigation), from late 18th century to 19th century, "Kras", which is the original German word of "karst", has been established as a technical term in Europe to describe this "stony" phenomena; and by extension, this term has been globally use after similar features have been found in other parts of the world (Ford and Williams, 2007; Palmer, 2007).

2 Definition of karst

After a half century of karst researches in late 20th century, karstology has been developed as a specific branch in geology and geography. The origins, phenomenon and classifications of karst terrains have also been widely studied by researchers. In modern geology, karst has been described as "the landscape created by dissolution

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and solution on the soluble rock, such as limestone, halite, and gypsum" (Ford and Williams, 2007, p. 1). Famous karstologists Derek Ford and Paul Williams defined karst as "comprising terrain with distinctive hydrology and landforms that arise from a combination of high rock solubility and well developed secondary (fracture) porosity" (Ford and Williams, 2007, p. 1). William B. White described karst as "a formation of chemical solution of the bed rock, with closed depressions of various size and arrangement, disrupted surface drainage, caves, and undergrounds drainage systems" (White, 1988, p. 3). Arthur N. Palmer explained definition of karst as the follow: "Karst is a land surface where it produces a variety of distinctive features such as fissures, rock pinnacles, closed depressions, and sinking streams" (Palmer, 2007, p. 21).

In conclusion, karst is a topography which includes the following characteristics:

- Created by dissolution or solution
- High secondary porosity
- With passages, caves, sinking streams, springs and etc.
- Usually related to groundwater drainage systems.
- Classical Exposed Karst (with no vegetation and plantation) are usually "rocky" and "stony"

3 Karst terrain in the world

During mid-1900s, public usually had a misinterpretation of "karst". They usually related karst with "show cave", or beautiful tourism spots such as Guilin, China (Mylroie, 1984). However, the extension of karst terrain is much more than that. White (1988) said, "Based on Gvozdetskii research in 1967, approximately 50 000 000 km^2 of land surface could qualify as karst" (White, 1988, p. 4). Palmer (2007) declared that "about 10–15% of Earth's land area consists of well developed, and this figure is much greater

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if it includes minor karst, buried paleokarst, and solution porosity formed by deep-seated processes" (Palmer, 2007, p. 36). By global distribution, karst landscape covers every continent, especially on North America, Europe, Middle East, and Southeast Asia (Gunn, 2004).

Therefore, karst terrain is global-distributed and can be varied by different locations and conditions. Researchers usually separate karst into two groups: "Continental Karst" and "Island Karst". Continental Karst is also known as "classical karst", which is mainly formed by stream erosion. "Island Karst" is the karst on carbonate islands (such as Bahamas, Bermuda, and Barbados), which usually relates to sea level change, and is formed by mixing zone between freshwater and saltwater (Mylroie and Carew, 1990). Based on hydrological condition, continental karst can also be separated into three sub-groups: Surficial, Interface, Subsurface (Mylroie, 1984). Each sub-group usually acts as different role in groundwater flowing system.

Famous examples of continental karst include "Stone Forest", China; Mammoth Cave, KY, USA; and Southeastern Coastal Plain, Florida, USA (Palmer, 2007, p. 40–41). Stone Forest is a well-developed surficial karst, which is not only famous for karst research, but also for geotourism. Mammoth Cave is the longest cavern system in the world, and a well-known interface and subsurface karst terrain (Palmer, 2007, p. 40). It has been well-studied for several decades. Southeastern Coastal Plain, Florida is one of the most complex karst systems in the world, because its karst processes involves stream erosion, chemical oceanography, as well as human-environmental interactions. Recently researches on Southeastern Coastal Plain include development of karst, karst hydrogeology, natural hazards, anthropogenic impacts, and pollution. It becomes one of the famous research centers for karst studies in North America nowadays.

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4 The role of karst in earth sciences

While geoscientist and geographers have just started to rise up the concern on karst from late 20th century, karst actually takes an important role in earth sciences. One of the biggest contributions of karst is how it acts as carbon sink and historical climate records on the earth. Cave researchers discovered that stalagmites can be an indicator of paleoclimate (Cosford et al., 2008; Mylroie, 2008; Yuan et al., 2008). John E. Mylroie suggested that flank margin caves in carbonate island is actually a result of sea level highstand, and its elevation can be acted as a paleo-sea level indicator (Mylroie and Carew, 1990; Mylroie and Mylroie, 2009; Walker et al., 2008). However, more importantly, karst is usually related to water resources; especially on carbonate island, which location of karst is acted as the locator of freshwater lens. Because of its closed relationship with hydrogeology, engineering geologist and environmental civil engineer usually pay a serious attention on this issue. Traditional concerns on engineering geology are how to detect the aquifer and groundwater discharge of karst system (Smart and Worthington, 2003; Worthington and Smart, 2003), and how karst integrates with water pollution and land subsidence; while the characteristic of second porosity in karst system usually increases the infiltration rate and discharge of pollutants, and karst development by dissolution can create unpredictable land surface collapse (Mylroie and Carew, 1997; Waltham and Fookes, 2003; Wilson et al., 1995; Zhou and Beck, 2008).

5 The role of karst in engineering and environmental geosciences

Therefore, the role of karst in engineering and environmental geosciences is how it acts as an agent between human and the environment. When karst usually provides a first image to people with a beautiful topography for geotourism such as Guilin, China; actually, the human-environmental interaction between karst and people is more necessary to be studied. Current karst researches for human-environmental interaction are

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focusing on two issues: (1) Result of urbanization on karst terrain, and (2) Feedback of agricultural development on karst region.

For urbanization on karst terrain, the main concern of engineer geologists is the hazard on urban environment by karst processes. In the US, most serious hazards on urban karst area are sinkhole flooding and sinkhole collapse, which they can create properties damage, and human losses (Waltham and Fookes, 2003; Zhou and Beck, 2008). Rapid urban development on karst regions also increases surface runoff rate, complexity of groundwater flows and instability of karst terrain and it directly increases the chances of sinkhole flooding and sinkhole collapse (Blansett and Hamlett, 2010; Campbell, 2005; Hart, 2006; Mills et al., 1991; Li et al., 2010a; Waltham and Fookes, 2003; Zhou, 2006; Zhou and Beck, 2008).

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By definition of "sinkhole", it is a dissolution or collapsed feature from the enlargement of second porosity in groundwater drainage system. Its location is difficult to predict. Previous studies indicated sinkhole can be buried by thick soil layer, and can also be enlarged by continuing dissolution from infiltration (Waltham and Fookes, 2003; Zhou and Beck, 2008). Furthermore, similar features with different geologic histories in karst such as banana holes, blue holes and pit caves can have the same or more extensive geologic hazard potential (Mylroie and Carew, 1997; Wilson et al., 1995). Even it is no sinkhole in the karst regions, continuing karstic development under urban area can also affect the stability of building foundation (Chan and Lai, 2005; Darigo, 1989). Rapid urban development on karst usually increases the mass on land surface, which rises up the chance of surface collapse; at the same time, impervious surface of urban area usually blocks soil infiltration, which messes up the original groundwater systems, and the further karstic development is becoming more uncertain.

In addition, urban development on karst area without well planning can cause water pollution and aquifer contamination. It usually spreads disease and can break down the chain of biological cycle (Boulton et al., 2003; Li et al., 2010b).

For agricultural development on karst region, most concerns from engineering and environmental geologists are how the carbon cycle, nitrogen and phosphorus cycle integrates with karst and plantation (Chen and Lian, 2010; Li et al., 2006; Zhang et al., 2007). Location, storage, usage, and pollution of water resources are also the important issues of agricultural engineering and agricultural geology (Wang et al., 2001; Li et al., 2001b).

6 Summary

Karst terrain is a complex system with close relationships to earth system science, engineering geology, hydrogeology, environmental geology and agricultural geology. It takes an important role on the earth, but the complete image of karst processes for environmental engineering is still being explored. Recent researches indicate that

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geotechnical engineers usually faced a technical problem when they were building roads, highways and tunnels. The constructions usually enlarge the surface area of karst and increase the rate of karst development. Methods to mitigate this problem are still being investigated.

Current techniques for investigating karst processes include dye tracing, geophysical survey, mapping and modeling. Using GIS as an analyzing tool has also been a global trend for studying karst. However, the fundamental problem of engineering geology for karst processes is lack of background about karst classification. Similar karst features with different geologic histories (such as glacied karst landscape and sinkhole) are usually misclassified by engineer, especially in landform analysis (Mylroie and Mylroie, 2004). For perspective of environmental engineering application of karst analysis, it is necessary to build up a high quality karst geodatabase, with data of karst features, relationship between karst features, and relationship of karst features with current hydrologic situation.

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