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Microbes on Carbonate Rocks and Pedogenesis in Karst Regions

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INTRODUCTION

Guizhou is located in the centre of East Asian karst area, one of the karst development areas in the world, and has a karst area of 130 000 km^2. The chemical weathering and pedogenesis are very active in the karst regions in which the ecosystems are believed to be fragile (Yuan and Liu, 2003; Wang et al., 1999; Lu, 1986). Multidisciplinary investigations were conducted on the erosion and dissolution of carbonate rocks and their environmental effects. Important achievements were made, including the interaction between karst environment and life activities, as well as the role of karst ecosystem structure, function, mechanism in improving the environment and in the mitigation of rocky desertification (Zhang and Yuan, 2005; Yuan and Liu, 2003). However, the origins of the karst soil are still in highly debate; the mechanisms proposed include the karst weathering metasomatism (Li et al., 1991), sedimentary soil-formation (Wan, 1996), weathering residue (Wang et al., 1999), filled soil (Zhu et al., 1996), and so on. It is notable that the pedogenesis in carbonate regions is more than a simple destruction and decomposition of the parent rocks and a secondary mineral formation and evolution because the carbonate rock itself contains very little soil-forming materials. The existing parlance is difficult to explain satisfactorily the major source of soil materials in karst regions. Interactions among rocks, soil, water, air and organisms are the main soil-forming processes in karst areas. Knowledge on the biological weathering of carbonate rocks, especially the microbial weathering, is still less. We present here some evidence and propose the role of microbes in the pedogenesis processes in karst regions.

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MICROBIAL DIVERSITY ON CARBONATE ROCKS

Exposed rocks could be a special habitat, such as the surface in contact with air, and are featured by enormous fluctuant environmental conditions, including solar radiation, drought, nutrient deficiency and temperature, but still many types of microorganisms are present in the cracks and on the surface of the rocks (Gorbushina, 2007). The rock microorganisms described earlier are some photosynthetic and nitrogen-fixating autotrophic microorganisms, such as algae, cyanobacteria and lichens. Later, some kinds of heterotrophic bacteria and fungi were found on bare rock surfaces, which are proposed to be pioneers of rock weathering species too in some areas (Burford et al., 2006, 2003; Gorbushina et al., 2003; Staley et al., 1982). Globular bacteria and filamentous fungi, such as *Calothrix* sp., *Gloeocapsa* sp., *Nostoc* sp., *Stigonema* sp., *Phormidium* sp. and *Scytonema* sp., were isolated from the surface of dolomite (Gorbushina, 2007). Some bacteria, fungi, lichens and algae were identified or isolated from the surface of Triassic limestone and dolomite in Guizhou, Southwest China too (Fig. 1) (Lian et al., 2008).

Although the rock surface is not suitable for the survival of microorganisms, autotrophic microorganisms may be able to survive through photosynthesis and N fixation, and heterotrophic microbes adopt survival strategy in symbiosis with autotrophic microorganisms (e.g. lichen type fungi) or intercepting small soil particles in which nutrients were occasionally brought in from air flow and rainwater (Viles and Gorbushina, 2003). The rock microorganisms are thus of collaboration or symbiosis, and different from soil microorganisms commonly found in the relationship of competition or predation. The main purpose of different microbial taxa is to retain water and gain limited trace nutrients to sustain life activities and population continuity (Gorbushina, 2007; Sterflinger, 2000). These micro-organisms growing on the surface of rocks in the acute shortage of nutrients can bore into the rock to form a small cave or tunnel (Fig. 2), strengthening the colonization on the rock surface, and to form the rapidly expanding biofilm or biological crust under appropriate conditions (such as suitable temperature and humidity) (Lian et al., 2008; Jongmans et al., 1997). Prokaryotic microorganisms found on the rock surface usually have the spores and extracellular polysaccharides to protect cells against adverse environment and to maintain water.

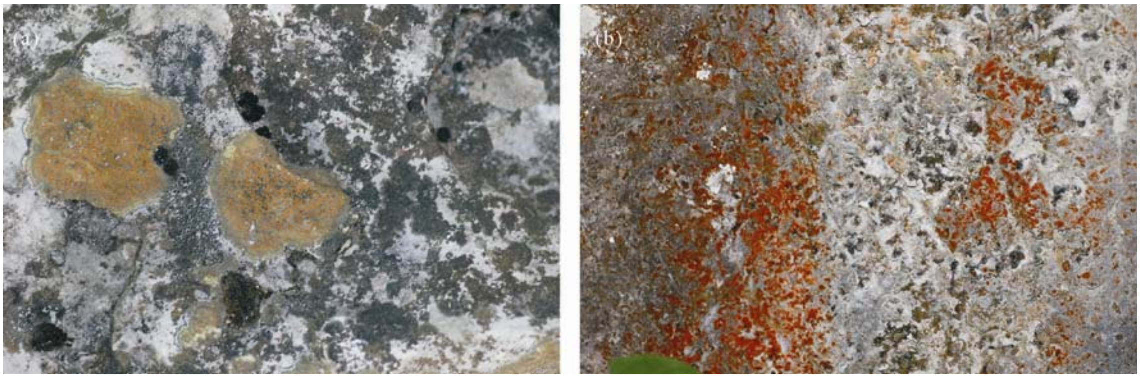

Figure 1. Microbes including lichens on the surface of Triassic carbonate rocks in Guizhou.

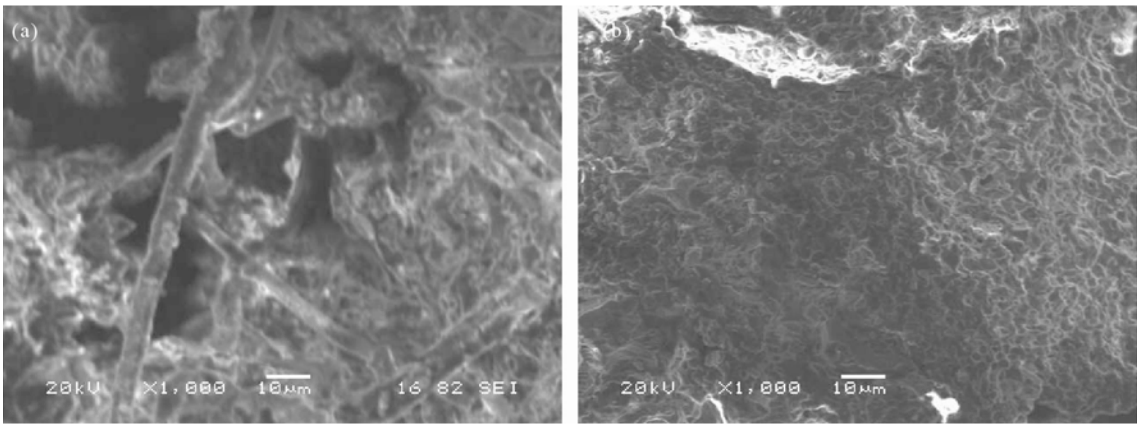

Figure 2. Scanning electron microscope images showing mycelium and bio-boring (a) and possibly prokaryotic cell backbone (b).

SOIL-FORMING AND MICROBIAL ACTIVITY

Normally, the carbonate rocks are enriched in Ca, Mg and lack of Si, Al, and Fe, but soil inorganic substances are mainly Si, Al, Ca, Mg, Fe, etc.. Pure carbonate rocks alone can thus not be weathered to supply a large number of soil materials. Although carbonate rocks in nature are not pure enough, and more or less contain some clay to form muddy carbonate or mixed rock types, the carbonate rocks in the karst regions are dominant, and the role of microorganisms can not be ignored on the rock erosion and the contribution to the soil material in karst areas.

The microorganisms in karst areas erode the rocks by micro-colonies, biofilms, and biological crust on the rock surface or in micro-cracks through the chemical degradation (organic acids secreted by the microbial metabolism to promote calcium carbonate dissolution and weathering), the biological effect (the mineral particles are broken due to microbial growth by such as fungal hyphae interspersed to the mineral particles, which generates more easily eroded surface) and the enhanced erosion by metabolites or enzymes (microorganisms secrete enzymes such as carbonic anhydrase enzymes etc.) to speed up the weathering of calcium carbonate (Dou and Lian, 2009; Chen et al., 2008; Ding and Lian, 2008; Lian et al., 2008; Yu et al., 2004). Microbial weathering of carbonate rocks produces a large number of residual minerals, secondary minerals and organic components in a long time duration, providing a source of soil material in the karst areas. In addition, autotrophic microorganisms in the microbial community (micro-colonies, biofilms, and biological crust) on the rocks can fix N and C elements from the air, and become the main producers of primary products on the rocks (Gorbushina, 2007; Cao and Yuan, 1999). Furthermore, microorganisms, biofilms and biological crust can also capture, intercept or absorb dust and soil particles brought in by air flow and rain, and use these particles to maintain limited life activities, producing more soil materials. Figure 3 shows possible pathways in which microorganisms are involved to form karst rocky soil.

To sum up, soil material is composed of not only the residual minerals after weathering, but also the organic materials photosynthesized or N-fixed by microorganisms as well as the microbially captured particles from water, eolian dust and atmospheric aerosols. A long time accumulation of these materials from diverse processes shown above would lead to the progressive rock fragmentation and the formation of thicker soil particles, which in turn develops a diversity of microbial populations, and the emergence of biological succession.

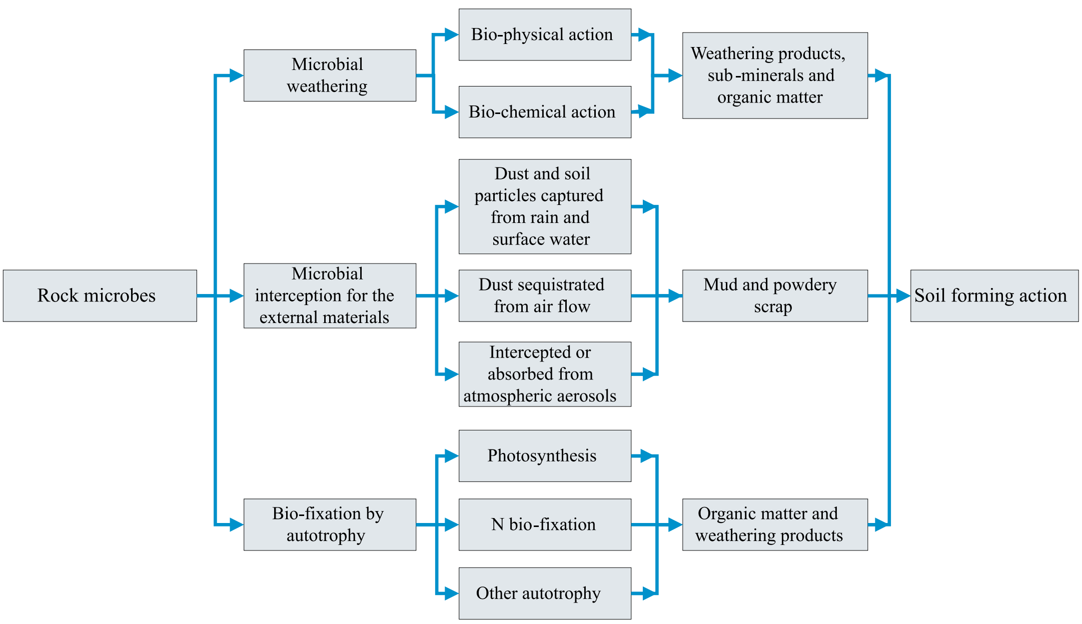

Figure 3. Geomicrobiological processes to form soil materials in karst regions.

CONCLUSIONS

Not all the soil materials in karst areas come from the local rock weathering processes. Geomicrobiological processes within the long time duration will also contribute these materials; they include the aggregation of biological reproduction (from micro-colonies to the larger biofilms), microbial photosynthesis and biological nitrogen fixation, micro-colonies or biofilms sequestration to foreign substances. Microbes on the rocks play an irreplaceably important role in providing soil materials, associated with non-biological processes of chemical weathering and geological processes.

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REFERENCES CITED

Burford, E. P., Fomina, M., Gadd, G. M., 2003. Fungal Involvement in Bioweathering and Biotransformation of Rocks and Minerals. *Mineralog. Mag.*, 67(6): 1127–1155

Burford, E. P., Hillier, S., Gadd, G. M., 2006. Biomineralization of Fungal Hyphae with Calcite ($CaCO_3$) and Calcium Oxalate Mono- and Dihydrate in Carboniferous Limestone Microcosms. *Geomicrobiology Journal*, 23(8): 599–611

Cao, J. H., Yuan, D. X., 1999. Relationship between Water-Holding of Carbonate Rock and Saxicolous Algae, Lichen and Moss and Its Ecological Significance. *Geochimica*, 28(3): 248–256 (in Chinese with English Abstract)

Chen, S., Lian, B., Liu, C. Q., 2008. Effect of *Bacillus mucilaginosus* on Weathering of Phosphorite and a Preliminary Analysis of Bacterial Proteins. *Chinese Journal of Geochemistry*, 27(2): 209–216

Ding, L. J., Lian, B., 2008. Experimentation of Microbial Weathering to $CaCO_3$. *Carsologica Sinica*, 27(3): 197–200 (in Chinese with English Abstract)

Dou, C. W., Lian, B., 2009. Microbial Weathering of Calcite by Rock Fungi. *Acta Mineralogical Sinica*, 29(3): 387–391 (in Chinese with English Abstract)

Gorbushina, A. A., 2007. Life on the Rocks. *Environmental Microbiology*, 9(7): 1613–1631

Gorbushina, A. A., Whitehead, K., Dornieden, T., et al., 2003. Black Fungal Colonies as Units of Survival: Hyphal Mycosporines Synthesized by Rock Dwelling Microcolonial Fungi. *Can. J. Bot.*, 81(2): 131–138

Jongmans, A. G., van Breemen, N., Lundström, U., et al., 1997. Rock-Eating Fungi. *Nature*, 389(6652): 682–683

Li, J. Y., Wang, C. F., Fan, Y. Z., 1991. Weathering Crust of Carbonate Rocks and Process of Karst Earth Formation. *Carsologica Sinica*, 10(1): 29–38 (in Chinese with English Abstract)

Lian, B., Chen, Y., Zhu, L. J., et al., 2008. Progress in the Study of the Weathering of Carbonate Rock by Microbes. *Earth Science Frontiers*, 15(6): 90–99

Lu, Y. R., 1986. Models of Karst Geomorphological Evolutions in China. *Geographical Research*, 5(4): 25–34 (in Chinese with English Abstract)

Staley, J. T., Palmer, F., Adams, J. B., 1982. Microcolonial Fungi: Common Inhabitants of Desert Rocks? *Science*, 215(4536): 1093–1095

Sterflinger, K., 2000. Fungi as Geologic Agents. *Geomicrobiology Journal*, 17(2): 97–124

Viles, H. A., Gorbushina, A. A., 2003. Soiling and Microbial Colonisation on Urban Roadside Limestone: A Three Year Study in Oxford England. *Build Environ.*, 38(9–10): 1217–1224

Wan, G. J., 1996. Carbonate Rocks and the Environment (Volume 1). Seismic Press, Beijing. 16–56 (in Chinese)

Wang, S. J., Ji, H. B., Ouyang, Z. Y., et al., 1999. Preliminary Study on Carbonate Rock Weathering. *Science in China* (*Series D*), 29(5): 441–449 (in Chinese with English Abstract)

Yu, L. J., Wu, Y., Li, W., et al., 2004. Study on the Stability of the Extrocellular Carbonic Anhydrase from Soil Bactera in Karst Aeras of Southwest China. *Life Science Research*, 8(4): 365–370 (in Chinese with English Abstract)

Yuan, D. X., Liu Z. H., 2003. Carbon Cycle and Karst Geological Environment. Science Press, Beijing. 10–45 (in Chinese)

Zhang, C., Yuan, D. X., 2005. IGCP448: Progresses of World Correlation of Karst Ecosystem. *Carsologica Sinica*, 24(1): 83–88 (in Chinese with English Abstract)

Zhu, L. J., Fu, P. Q., Li, J. Y., 1996. Clay Minerals in the Laterite Developed from Carbonate Rocks in Guizhou Province and Their Forming Mechanism. *Acta Mineralogica Sinica*, 16(3): 290–297 (in Chinese with English Abstract)