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The Role of Mechanical Erosion in the Process of Karst Denudation: An Initial Report.

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The rate of limestone dissolution in water with pH > 6 was reported to be in the range of 1 mm/ka to 10 mm/ka (Morse and Arvidson, 2002; Ford and Williams, 2007). The variables considered in the process include the amount of dissolved CO_2 in water and the dolomitic composition of the limestone. The rate of karst denudation was also measured, mostly in the field, to be in the range of 10 mm/ka to 1000 mm/ka (Ford and Williams 2007, Gabrovsek 2009). Among these studies, most of the considerations were focused on the mechanism of chemical dissolution. The role of mechanism of erosion in the denudation process was usually not considered or was not clearly identified. However, it is generally recognized that mechanical erosion should play a role in the process.

Parameters involved in the mechanical erosion of limestone are considered and evaluated in this study. Similar study is commonly carried out in engineering research but the tested material is usually metals rather than rocks, and the conditions and environments of test, such as speed, temperature, concentration etc., are more intense when compared with normal geological conditions. (e.g. Chiu et al 2005; Ashrafizadeh and Ashrafizadeh, 2012). Devonian platform micritic wackestone/packstone from Ohio, USA is used for the test in this study. The rocks are nearly all made of carbonate with approximately 30% Mg content. All samples are porous with various pore geometry and various micritic structure (Periere et al 2011). It turned out that the texture of these limestone serves as a critical factor in determine the rate of mechanical erosion.

Polished limestone slabs of approximately 4 cm by 7 cm are subjected to mechanical erosion through the impact of water current in a 1.5 meter long circulation tank. The pH of the tap water used is 7.4; The speed of flow is 0.45 m/s; the angle of impact is 90° and the duration of impact is about 24 hours. In such a setting, the effect of chemical dissolution imposed to the limestone is taken as negligible. All the weight loss inflicted upon the samples is attributed to the effect of mechanical erosion. There are three set-ups on the erosional environments: 1) sediments free, clear current only; 2) current carried suspended SiC particle at about 1 gram/liter. The size of SiC is 15 microns (US grit #600); And 3) clear water, but the water pH is maintained at 6 by adding HCl. In the last case, the time of erosion is limited to 30 minutes. Petrographic features are examined before and after every erosion test.

Petrographic observation suggested that the mechanical erosion of limestone may take place in three forms on a microscopic scale: 1. Pitting: The direct solid particle impact made a pit on the surface of the rock; 2. Dislodging: The impact caused a wider area of disintegration rather than just making a single pit. The area may include the coalesce of many pits, but it is more likely a dislodging or a failure of inter-grain structure, such as sheets split along mineral cleavage. 3. Cavitation: The dislodging is focused on a particular locality and caused a collapse of the rock structure surrounding a pit or an original pore space. The mechanism of both dislodging and cavitation involved significant large amount of mass loss in a very short period of time. The rate of mechanical erosion is calculated by the weight loss of the sample over the time period of erosion. The overall resistance of a limestone to mechanical erosion is independently tested by the weight loss during a 30 minutes ultrasonic vibration in a ultrasonic cleaner.

Since the speed of flow, the size of solid particles, the angle of impact are set constant in this study, the remaining major factor which will affect the rate of mechanical erosion is the lithology of the rock. The test results show two general orders on the rate of erosion in the pH neutral water current: 100 mm/ka to 500 mm/ka, and 1000 mm/ka to 2000 mm/ka. The former group includes limestones with interlocked micritic or spar crystals; The latter group includes limestones that have large pore space or have relatively loose micritic aggregates. A significant discovery is that the limestone

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will still be mechanically eroded even there is no solid particle suspended in the current. In comparison, the erosion rate caused by the clear current of pH 6 is significantly higher. It ranges from 30,000 mm/ka on the structurally tightest samples to 190,000 mm/ka on a structurally loose sample. This is approximately 100 times higher than that found in neutral water with or without suspended particles.

As a result of this study, we suggest that mechanical erosion is at least equally, or more effective than the chemical dissolution in the karst process. With all conditions considered, the mechanical erosion would be responsible for at least half of the amount of karst denudation. Since the pH of meteoric water is more acidic in high mountain area, it could dramatically enhance the rate of erosion to the limestone in the Himalayan region. In turn, the higher rate of limestone denudation would significantly increase the overall denudation rate of the whole mountain.

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