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Dissolution rate of limestone at a doline in the Akiyoshidai karst plateau

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The spatial variation of limestone dissolution rates is significant for landform evolution of karst terrain including doline. Although many laboratory experiments and field observations have elucidated dissolution rate of limestone under specific conditions, but few studies estimated dissolution rates in situ around doline. This study aims to estimate the current rate of dissolution at a doline in the Akiyoshidai karst plateau in Yamaguchi Prefecture, combining the following two methods. One is electric resistivity survey and measurement of soil property, which reveal subsurface structure of the doline including the depth of the soil-rock interface and the spatial variations of soil moisture contents. The other is weathering experiments and hydrological observations, which reveal the relationship between limestone dissolution rates and the environmental factors including moisture contents, water chemistry, temperature, and CO_2 concentration.

Electrical resistivity imaging (ERI) survey reveals spatial variations of resistivity in soil or bedrock below slope and bottom of the doline. Comparing the result of the resistivity imaging with manual sounding using a cone penetrometer, resistivity value of 300 ohm m approximately corresponded to the soil-rock interface ranging from 1 m deep at upper doline slope to 10 m deep at bottom of doline. Low resistivity (50-100 ohm m) zones, which are equivalent to saturation zones, existed above the soil-rock interface even in drier seasons, indicating that soil is hydrologically saturated through the year immediately above the soil-rock interface.

In the field weathering experiment, limestone tablets (rock fragment of 3.5 cm in diameter and 1 cm thick) were buried in soil at 4 sites of the doline: S1 located at the upper slope; S3 located at the middle of slope; S5 located at the lower slope; S6 located at bottom of the doline. In these sites, soil moisture contents and ground temperature were monitored 10-min intervals, and manual measurement of concentration of CO_2 in the soil air and soil water sampling were carried out about every two months. The experiments and observation were conducted for total 768 days from 2009 to 2011.

The dissolution rates of tablet were 1.6-3.3%/y at S1 and S3, where soil moisture saturation sustained for a long time after precipitation. The smallest dissolution rate was 0.11-0.55%/y at S5, where the period of high soil moisture was short after precipitation. The result of regression analysis revealed that dissolution rate of tablets were strongly controlled by W_{97} (R^2=0.65), which is defined as the proportion of the duration of saturation (degree of saturation $>$97%) to whole time of the experiment . Furthermore, combination of two variables, W_{97} and mean value of estimated CO_2 concentration show a stronger correlation with dissolution rate of tablets (R^2=0.74), although W_{97} primary controls dissolution rate of limestone tablets.

For the case that the soil immediately above the soil-rock interface is saturated (W_{97} of 100%) throughout year, dissolution rate of limestone would be 3.90%/y, which corresponds to denudation rate of 137 mm/kyr. This rate is slightly faster than the long-term denudation rates inferred from cosmogenic ^{36}Cl concentrations at the same site. Low resistivity zones with high soil moisture also exist beneath some parts of the slope as well as the bottom of the doline, implying that such slopes have a fast dissolution rate equivalent to the bottom of doline.

Keywords: limestone, karst, doline, electric resistivity survey, dissolution rate