Difference of carbon dynamics of soil carbonate under vegetation sequence, Mongolia

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Introduction
The accumulation of carbonate in soils is one of the most prominent soil forming processes in arid and semiarid regions. This carbonate is termed pedogenic or secondary carbonate to distinguish it from lithogenic calcite. It is estimated that soil organic carbon is about 1550 Gt to 1 m depth, while inorganic carbon accounts for 950 Gt to the same depth (Lal, 2004). So, the existence of pedogenic carbonate not only reveals the nature of the soil forming processes of the soil in a particular area but also serves as an important reservoir of carbon in the terrestrial ecosystem. However, there is very little study about dynamics of pedogenic carbonate.

Dissolution of carbonate and its subsequent accumulation in a Bk horizon are governed by two factors: the CO2 pressure of the soil air and the concentration of dissolved ions in the soil water (Driessen et al., 2001). Therefore, it is important to study the Dynamics of pedogenic carbonate in different vegetations and climates from the viewpoint of its role in the carbon cycle in terrestrial ecosystems.

Mongolia is located in a transition zone between the Siberian taiga and the Central Asian desert region. The soils of the semi arid grasslands that occupy most of the plains have carbonate accumulation horizons. The morphology and characteristics of the soils distributed over the plains area correspond with the vegetation coverage (Dordschgotov, 2003). Therefore, this region was suitable for studying the vegetation-soil sequence.

The objective of this study is to provide information on the dynamics of pedogenic carbonate by using carbon isotope analyses.

Study site
Soil samples were taken from five study sites in a forest steppe, steppe, and govi steppe in Mongolia; Baganuur (BGN) on the forest steppe, Jargalthaan (JGH), Kherlen Bayan-Ulaan (KBU) and Underhaan (UDH) on the steppe, respectively where AWS sites of RAISE project (Sugita et al., 2006), and Bulgan (BG) on the desert steppe. Each study site was located on a flatland. Vegetation at forest steppe and steppe site were described in Asano et al. (2006), and desert steppe site was studied Sasaki et al. (2005). The in KBU, JGH, BGN, and UDH as Calcic Kastanozems (Asano et al., 2006 ) and that in BG as Haplic Calcisol (FAO/ ISRIC/ ISSS, 1998).

The lacustrine record of Lake Baikal during the past 23,000 years shows the last deglacial was at 18,000 yr BP and that the taiga was developed at 12,000yr BP; after that there was an increase of thick vegetation with extensive development of soil layers (Horiuchi et al., 2000). We can define the soil age as the time when soil genesis started. Carbonate accumulation would start when the climate and vegetation had become amenable to pedogenesis. Thus, it is presumed that the soil ages in the study sites are almost same period at least older than 12,000 yr BP.

Materials and methods
The soil samples taken from each horizon were air dried and passed through a 2-mm mesh sieved.

Stable carbon isotope ratio (δ13C) of soil organic matter and pedogenic carbonate were measured by using mass spectrometer (Finigan, MAT 252). Radiocarbon isotope ratio (Δ14C) was determined by the Tandem-Accelerator Mass Spectrometry (MALT-AMS) system at The University of Tokyo (Matsuzaki et al., 2004). Inorganic carbon content was determined by the wet combustion methods described by Kosaka et al. (1959). The soil organic carbon and total nitrogen contents in the A horizons were determined by the dry combustion method using a NC analyzer.

Results and discussions
δ13C value of soil organic matter
The δ13C values of soil organic matter vary from -23.2 ‰ to -20.2 ‰. Bulk C3 and C4 plants tissue distinctive δ13C ranges of -25.0 ‰ to -27.3 ‰ (with a average of -26.2 ‰) and -12.5 ‰ to -14.3 ‰ (with a average of -13.4 ‰), respectively (Li 2006, personal communication). The range of δ13C values of soil organic matter falls between reported C3 and C4 plants. These result suggested the soil organic matter of study sites were derived from mixture grassland of C3 and C4 grass in agreement with vegetation survey.

δ13C value of pedogenic carbonate
The δ13C values of pedogenic carbonate vary from -1.3 ‰ to -10.4‰. Two types of vertical distributions
were observed: (1) The $\delta^{13}C$ values of pedogenic carbonate increase with soil depth at BGN, JGH, KBU, and UDH site; and (2) no relation was observed with soil depth at BG site. The resulting fractionation $\alpha = 1.004$, which means that the average $^{13}C$ content of the soil CO$_2$ between root zone and soil surface is 4.4 $\%$ higher than the produced CO$_2$ in theory (Salomons and Mook, 1986).

The $\delta^{13}C$ value of soil carbonate is in equilibrium with atmospheric CO$_2$ of -8.0 $\%$ near the soil surface and decrease with depth due to an increasing proportion of plant-respired CO$_2$ depleted in $^{13}C$ (Cerling, 1984; Cerling et al., 1989). So, the vertical distributions of $\delta^{13}C$ value at BGN, JGH, KBU and UDH sites trend suggested that the soil carbonate was equilibrium with soil CO$_2$. While, pedogenic carbonate in BG has affected or record CO$_2$ other than modern vegetation.

$\Delta^{14}C$ value of pedogenic carbonate

$\Delta^{14}C$ values for pedogenic carbonate at all sites were from -392 to -776 $\%$. Figure 2 shows that the vertical distribution of the inorganic carbon content and the $\Delta^{14}C$ values in the forest steppe soils significantly differed from those in the desert steppe soils. The $^{14}C$ contents slightly decreased with depth, presumably due to the decrease in wetting events in the lower part of the profile (Pendal et al., 1994), and this suggested that contamination by more recent $^{14}C$ derived from plant root respiration, organic mater decomposition, and atmospheric CO$_2$ was rare.

Figure 2 a) Vertical distribution of inorganic carbon content (g kg$^{-1}$) and b) $\Delta^{14}C$ value of the pedogenic carbonate. (O, BGN; ■, JGH; □, KBU; ▲, UDH; ●, BG)

Exchange of carbonate carbon under vegetation sequence

The results from carbon isotopic analyses showed that exchange of carbonate carbon difference among the study site under vegetation sequence.

Forest steppe: It became clear that exchange of carbonate carbon with soil CO$_2$ occurs more frequently than steppe and desert steppe site. The abundance ratio of carbon from soil organic matter in pedogenic carbonate reached to 91 $\%$.

Steppe: Exchange of carbonate carbon was not frequent than that in forest steppe, and the record of past plant composition was still remained.

Desert steppe: The abundance ratio of carbon from soil organic matter in pedogenic carbonate was the lowest among all study sites. It was clarified that the exchange of carbonate carbon was relatively rare.

Reference


