Radio carbon isotopic analysis of calcic horizons in Mongolian Steppe soils

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Introduction

Soil horizon enriched with calcium carbonate (CaCO3) is prominent feature in Mongolian steppe soils. Such a horizon is called as calcic horizon (Bk or Ck horizon). The carbonate is accumulated in soils by calcification which is one of major soil forming processes in arid and semiarid regions. In general, depth of calcic horizon is related to the annual precipitation (Arkly 1963). It is important to clarify the forming process of pedogenic CaCO3 accumulation from the viewpoint of the carbon cycle in terrestrial ecosystem. However, that was reported only in the limited areas, such as the southern and northern parts of the United States. Recently, it came to be able to measure the small amount of 14C by the Accelerator Mass Spectrometry (AMS), and radiocarbon isotope ratio (?14C) of Bk horizons can be considered as an indicator of carbonate movement in soils. The purpose of this study was to clarify the forming process of Bk horizons by using radiocarbon isotopic analysis.

Materials and methods

Study area and Soil survey

Soil samples were taken from six sites at forest steppe, steppe and govi steppe in Mongolia. The six soil profiles were surveyed and described according to Hand book of Soil Survey (Japanese Society of Pedology, 1997) and each soil was classified by WRB (FAO, ISRIC, ISSS 1998) soil classification system. Baganuur (BGN) was in Forest steppe (Fig.1 a), Jagalthaan (JGH), KherlenBayan-Ulaan (KBU), Und- erhan (UDH) and Darhan (DH) (Fig.1 b) were in steppe, Blugan (BG) (Fig1. c) was in Govi steppe.

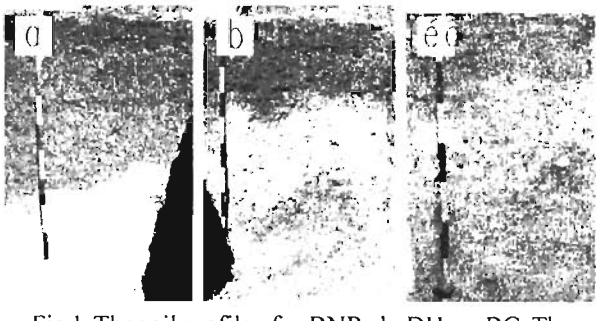

Fig 1 The soil profile of a: BNR , b: DH , c: BG. The white colored horizons are the calcic horizons (Bk horizon).

Samples

Soil samples for physical measurement, chemical and isotopic analyses were taken from each horizon of the six soil profiles. Soil samples for chemical and isotopic analyses were air-dried, and sieved through 2 mm. The sub samples of finery ground samples were reground to pass through 0.5 mm and 0.2 mm mesh sieves. Undisturbed soil core samples for physical measure- ments were sampled by sylindrial core sampler (100 ml).

Chemical analyses

pH(H_2O), Soil inorganic carbon contents (measured by wet combustion method (Kosaka, et al., 1959, Clark and Ogg, 1942)), Water soluble cation of Ca^{2+}, Na^{+}, Mg^{2+}, K^{+} (determined by Atomic Absorption Spectrophotometry using AA-6200, SHIMADZU Co., Kyoto) . The calcium carbonate content was calculated from the inorganic carbon content.

Physical measurements

Three phase ratio and saturated hydraulic conductivity were determined by the core method.

Isotopic analysis

The soil samples taken from Bk horizons were reacted with 85% phosphoric acid under a high

vacuum to release CO_2 and they were reduced to graphite with the hydrogen over the high purity iron. The ¿"^{14}C0values were measured by the MALT-AMS system at the University of Tokyo (Matsuzaki et. al., 2004).

$$\delta\,^{13}C\,(‰) = \{ (^{13}C/^{12}C)_{sample} / (^{13}C/^{12}C)_{PDB} - 1 \} \times 10^3$$

$$\Delta^{14}C\,(‰) = \{ (^{14}C/^{12}C)_{sample\,(-25)} / (^{14}C/^{12}C)_{STD} \times 2^{((t-1950)/5730)} - 1 \} \times 10^3$$

$\delta\,^{13}C$ STD: the PDB standard, $\Delta^{14}C$ STD:NIST HOX II (1950)

^{14}C age

$$= -8033 \ln \left[(^{14}C/^{12}C)_{sample(-25)} / (^{14}C/^{12}C)_{STD(-25)} \right]$$

Results

There were remarkable differences on the distribution of the carbonate contents and ¿"^{14}C ratio between forest steppe soils and govi steppe soils.

The carbonate was not included in the A horizons under forest steppe and steppe sites. On the other hand, the soils at govi steppe site containd carbonate over the entire soil profile (Fig. 2).

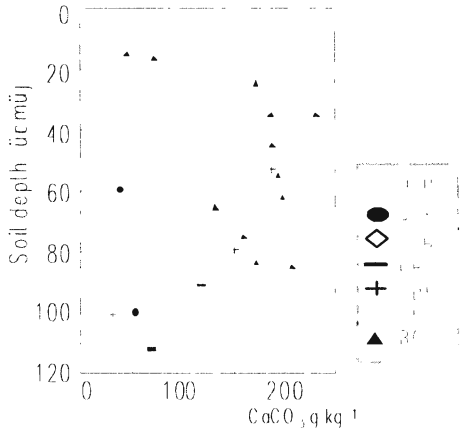

Fig. 2 Vertical distribution of the $CaCO_3$ in the Bk horizons.

The Fig. 3 shows the vertical distributions of the ¿"^{14}C value of the $CaCO_3$ in the soil profiles. At the forest steppe site, the ¿"^{14}C ratio show the large value as compared with other site at every depth. The vertical distribution of the ¿"^{14}C ratio at the steppe sites showed various tendency and vary widely. In the govi steppe site, the ¿"^{14}C value0decreased with depth linearly. The ¿"^{14}C value at forest steppe and steppe sites were considered to be influenced by environmental factors other than time progress. It is necessary to consider the factors to change the ¿"^{14}C value such as the respiration of vegetation and soil microorganisms, infiltration of soil water, soil erosion which the soils of every site have received.

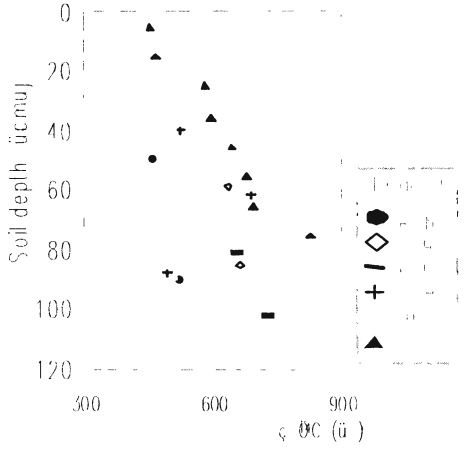

Fig. 3 Vertical distribution of the ¿"^{14}C ratio of $CaCO_3$ in the Bk horizons

The accumulation rate of the $CaCO_3$ in the soils was calculated 0.8 g m^{-2} yr^{-1} from the relationship between the radiocarbon age and the contents of $CaCO_3$ in the Bk horizons (Fig.4 and Fig.5). This value was considered to the average rate of carbonate accumulation (Machette, 1985). This average rate was available to compare the climatic factors, vegetation and influx of Ca^{2+} in the soils at the each region.

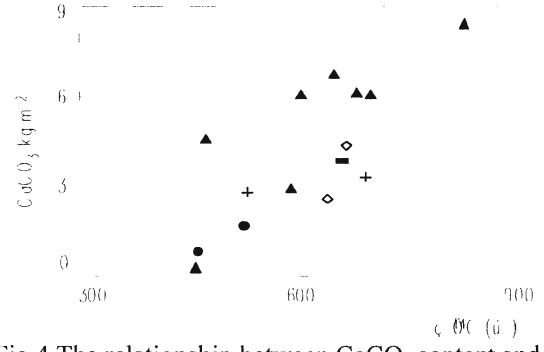

Fig.4 The relationship between $CaCO_3$ content and ¿"^{14}C ratio of carbonate in the Bk horizons. (Legend is same as Fig.1 and 2.)

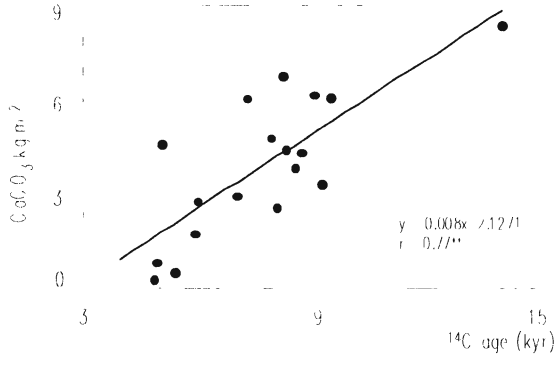

Fig.5 The relationship between the content of $CaCO_3$ and the ^{14}C age of carbonate in Bk horizon.

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