8–9 Subsurface Soils Participate in Global Carbon Cycle

— Carbon Dynamics Revealed by Tracing "Bomb" Radiocarbon over Past Half-Century —

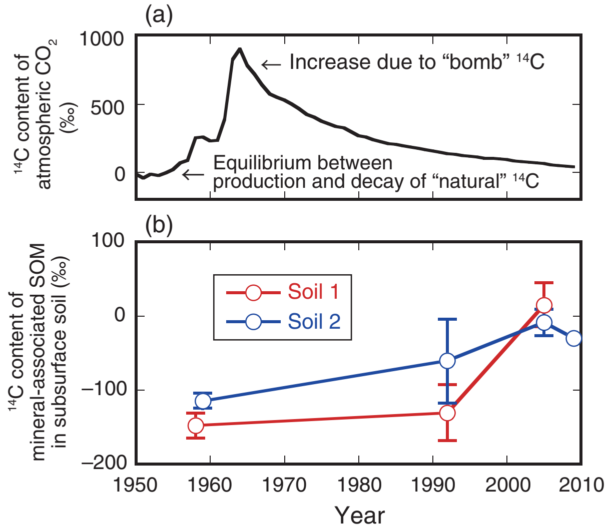

Fig.8-23 Carbon-14 content of atmosphere and subsurface soils
Carbon-14 content is expressed as per mil deviation of $^{14}C/^{12}C$ ratio of sample from that of atmospheric CO_2 in 1950. (a) Carbon-14 content of atmospheric CO_2 rapidly increased due to nuclear weapons testing in the early 1960s. (b) Carbon-14 content of mineral-associated SOM in subsurface soils remained low; however, it increased markedly from 1992 to 2005 owing to incorporation of "bomb" ^{14}C.

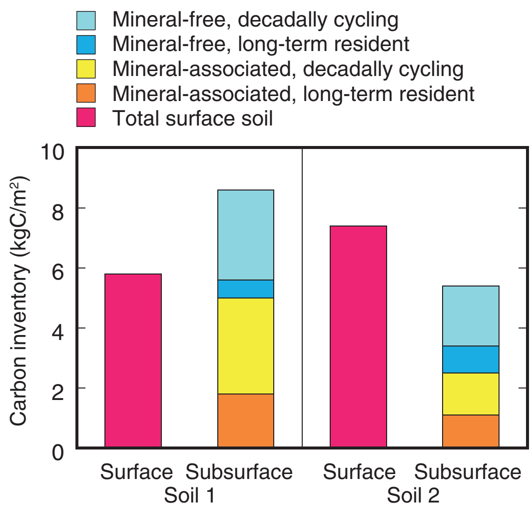

Fig.8-24 Stock and turnover of C in subsurface soils
Subsurface soils store as much C as surface soils (the upper 20 cm). About half of the subsurface soil C was not associated with soil minerals, >70% of which was estimated to be decadally cycling C. Decadally cycling C was also found in mineral-associated SOM. Overall, the amount of C that turns over on decadal timescales in subsurface soils reached 3–6 kg/m^2.

Soil plays an important role in the global carbon (C) cycle through soil–atmosphere C exchange. Recent studies have shown that soils store more C in the subsurface horizons (20–60 cm depth) than in the surface horizons (the upper 20 cm). However, subsurface soil C has received little attention in terms of its contribution to C exchange because it has been thought to be very stable on the basis of its average age of centuries to millennia.

We used radiocarbon (^{14}C) to identify the dynamic nature of C in subsurface soils. There are two main sources of ^{14}C: "natural" ^{14}C that is produced in the upper atmosphere by cosmic rays, and "bomb" ^{14}C that was produced by atmospheric nuclear weapons testing during the early 1960s (Fig.8-23(a)). Similar to stable ^{12}C, ^{14}C in the atmosphere is fixed as organic matter by plants via photosynthesis and then enters soils. Carbon-14 decays with a half-life of 5730 years in soils; thus, a lower ^{14}C content in soil organic matter (SOM) reflects a longer residence time of C in the soils. On the other hand, the incorporation of bomb ^{14}C into the soils increases the ^{14}C content in SOM. Therefore, we hypothesized that C exchange that occurs on timescales of decades through subsurface soils can be identified by tracing bomb ^{14}C incorporation over the past half-century, if it really exists.

The ^{14}C content was determined for subsurface soil samples taken several times from 1958 to 2009 at two forest sites in California. We found an increase in the ^{14}C content in mineral-associated SOM with a time lag of >20 years after the increase in the atmosphere (Fig.8-23(b)). A model analysis showed that ~40%–70% of the SOM turns over on decadal timescales. We also found bomb ^{14}C incorporation in mineral-free SOM and CO_2 released from subsurface soils collected in 2009.

The results demonstrate that subsurface soils store a large amount of C that is exchanged with the atmosphere (Fig.8-24) and that a lagging response of the C to climate change is possible. The findings will improve our understanding of the global C cycle.

Reference

Koarashi, J. et al., Dynamics of Decadally Cycling Carbon in Subsurface Soils, Journal of Geophysical Research, vol.117, issue G3, 2012, p.G03033-1–G03033-13.