Application of carbon isotope for discriminating sources of soil CO_2 in karst area, Guizhou

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Abstract Using carbon isotope of soil CO_2 this paper discussed the sources of soil CO_2 in karst area, Guizhou Province, China. Oxidation-decomposition of organic matter, respiration of plant root and activity of microbe are thought to be the major sources of soil CO_2. However, in karst area, the contribution of dissolution of underlying carbonate rock to soil CO_2 should be considered as in acidic environment. Atmospheric CO_2 is the major composition of soil CO_2 in surface layer of soil profiles and its proportion in soil CO_2 decreases with increase of soil depth. CO_2 produced by dissolution of carbonate rock contributes 34%—46% to soil CO_2 below the depth of 10cm in the studied soil profiles covered by grass.

Keywords: carbon isotope, sources of soil CO_2, karst area.

In karst area, soil CO_2 is important in discussing the relationship between karstification and atmospheric CO_2 [1,2]. Soil CO_2 mostly comes from respiration of plant root, oxidation-decomposition of organic matter, activity of microbe, dissolution of underlying carbonate rock and interfusion of atmospheric CO_2. The $\delta^{13}C$ value of CO_2 generated by respiration of plant root and oxidation-decomposition of organic matter is related to the type of vegetation above soil and approximately equals that of corresponding plant. According to different routes of photosynthesis, plants can be divided into three types: C_3, C_4 and CAM [3]. They are composed of C_3 and C_4 plants in nature[4]. $\delta^{13}C$ value of C_3 plants is about –27‰(PDB), and that of C_4 plants is about −13‰(PDB)[5]. Meanwhile, $\delta^{13}C$ value of CO_2 produced by microbial activity ranges between –29.3‰— −18‰(PDB) [6] and that from dissolution of marine carbonate rock is about −1‰ (PDB)[7]. $\delta^{13}C$ value of atmospheric CO_2 is about −7‰(PDB). Based on the above different values of carbon stable isotope of CO_2 carbon isotope is used to discriminate sources of soil CO_2 in this paper.

1 Sampling and experiment

Considering different factors influencing the composition of soil CO_2 three groups of soil profiles in karst area, Guizhou province were selected: two soil profiles (Profile No. 1 and 2) covered by grass with limestone and dolostone basements respectively in Central Guizhou, two soil profiles (Profile No. 3 and 4) developed on dolostone basement with Grassland and woodland

ecosystems respectively in Central Guizhou, two soil profiles (Profile No. 5 and 6) with different soil moistures covered by wood and developed on the first terrace and second terrace of a brook in South of Guizhou. Sampling time is October 2 for the first group of soil profiles, October 3 for the second group and September 17 for the third group respectively. For the detailed soil gases sampling method see reference [8].

CO_2 from soil gas was purified through pre-processing system before measurement of carbon isotope on a Finnigan-MAT252 mass spectrometer. The analysis results are shown in Table 1.

Table 1 $\delta^{13}C$/‰ (PDB) value of soil CO_2 in karst area

Comparison item	Basement		Type of vegetation		Moisture	
Profile No.	1	2	3	4	5	6
Soil depth/cm	limestone	dolostone	grassland	woodland	first terrace	second terrace
0	–10.576	–13.653	–9.584	–14.661	–9.915	–10.037
5	–11.424	–15.734	–15.894	–	–20.617	–12.790
10	–12.480	–11.899	–12.717	-17.195	–21.273	–15.276
20	–12.811	–13.212	–13.853/15 cm	–19.039	–22.451	–19.871
30	–13.027	–13.656	–12.964/20 cm	–20.446	–23.107	–
40	–13.279	–14.271	–	–21.092	–	–24.703
50	–13.198	–	–	–	–	–
60	–13.492	–	–	–	–	–

2 Data analysis

2.1 Soil profiles developed on limestone and dolostone basements (Profile No. 1 and 2)

Compared with $\delta^{13}C$ value of soil CO_2 of Profile No.2: –11.899‰— –15.734‰(PDB), that of Profile No. 1 lightly tends to be positive and ranges between –10.576‰— –13.492‰(PDB). In two soil profiles, $\delta^{13}C$ value of soil CO_2 decreases with increase of soil depth, but the decrease amplitude is not remarkable (Fig. 1).

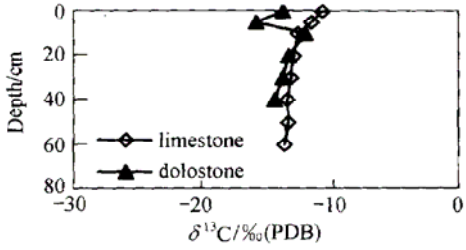

Fig. 1. The $\delta^{13}C$ value of CO_2 in soil profiles developed on different carbonate rocks.

2.2 Soil profiles coved by different types of plants (Profile No. 3 and 4)

The differences of $\delta^{13}C$ values of soil CO_2 between grassland and woodland soil profiles are notable. The former ranges between –9.584‰— –15.894‰ (PDB) and the latter between –14.611‰— –21.092‰ (PDB). Meanwhile, the decrease trend of $\delta^{13}C$ value of woodland soil CO_2 with increase of soil depth is remarkable, but that of grassland soil CO_2 has no obvious change trend (Fig. 2).

2.3 Soil profiles with different soil moisture (Profile No. 5 and 6)

The first terrace soil profile (Profile No. 5) is closer to the brook than the second terrace soil profile (Profile No. 6), and humidity of the former is larger than the latter. The δ^{13}C value of soil CO_2 of two soil profiles vary in the same ranges. They range between –9.915‰— –23.107‰ (PDB) for Profile No. 5 and –10.037‰— –24.703‰ (PDB) for Profile No. 6 respectively. Both of

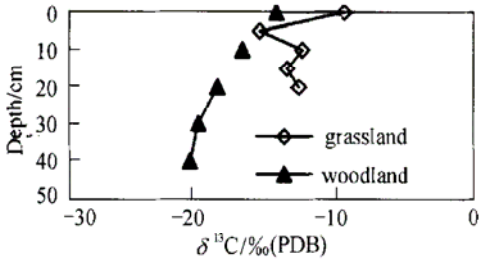

Fig.2 The δ^{13}C value of CO_2 in grassland and woodland soil profiles.

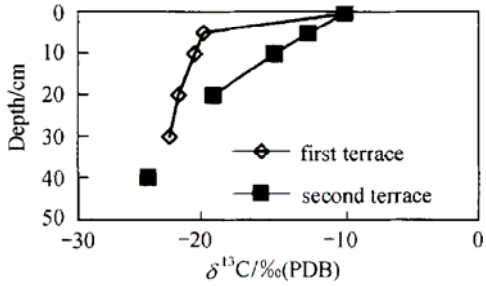

Fig. 3. The δ^{13}C value of CO_2 in soil profiles of different soil moistures.

them decrease with increase of soil depth (Fig. 3). The slight difference is that δ^{13}C value of soil CO_2 in Profile No.5 decreases rapidly to –20.617‰(PDB) at 5cm below soil surface.

3 Discussion

In general, the soil depth of infiltration of atmospheric CO_2 is influenced by soil physical properties, such as soil compactness and moisture. If soil is compact, no matter how the humidity of soil is, atmospheric CO_2 only can reach to 0 and 5cm below soil surface. Profile No.1, No.2, No.3 and No.5 are such soil profiles. Otherwise, atmospheric CO_2 can influence the δ^{13}C value of soil CO_2 in deeper soil layer, such as in Profile No.4 and No.6.

The δ^{13}C value of soil organic carbon in the studied karst area, Guizhou is about –21‰ (PDB)[9]. If the δ^{13}C value of soil CO_2 at soil depth is larger than –21‰ (PDB), it is reasonable to postulate that there exists the addition of atmospheric CO_2 and CO_2 produced by dissolution of underlying carbonate rock with positive δ^{13}C values. Meanwhile, If the δ^{13}C value of soil CO_2 at deepest depth of soil profiles is less than –21‰ (PDB), the addition of CO_2 produced by dissolution of underlying carbonate rock can be excluded. The percentage of different sources of CO_2 in soil can be calculated by carbon isotopic composition[10]. Taking –21‰ (PDB) as δ^{13}C value of CO_2 coming from respiration of plant root and oxidation of soil organic matter, –1‰ (PDB) as δ^{13}C value of CO_2 produced by dissolution of underlying carbonate rock, –7‰ (PDB) as δ^{13}C value of atmospheric CO_2, the percentage of different sources of CO_2 in soil has been calculated (Table 2).

4 Conclusion

The following conclusion can be obtained from the above calculation of percentage of dif-

ferent sources of soil CO_2:

Table 2 The percentage (%) of different sources of CO_2 in soil profiles[a)]

No.	1			2			3			4			5			6		
D	O	A	C	O	A	C	O	A	C	O	A	C	O	A	C	O	A	C
0	26	74	0	48	52	0	18	72	0	55	45	0	21	79	0	22	78	0
5	32	68	0	62	38	0	64	36	0	-	-	-	97	3	0	41	59	0
10	57	0	43	54	0	46	59	0	41	73	27	0	100	0	0	59	41	0
20	59	0	41	61	0	39	60	0	40	86	14	0	100	0	0	92	8	0
30	60	0	40	63	0	37	Depth: 15cm			96	4	0	100	0	0	-	-	-
40	61	0	39	66	0	34	*64*	*0*	*36*	100	0	0	-	-	-	100	0	0-
50	61	0	39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60	62	0	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

a) No. for number of soil profile, D for soil depth/cm, O for CO_2 coming from organic matter, A for atmospheric CO_2, C for CO_2 produced by dissolution of underlying carbonate rock.

(1) CO_2 coming from oxidation and decomposition of organic matter, respiration of plant root and microbe activity is major source of soil CO_2 in kart area, at some soil profiles, soil CO_2 is completely made up of it below certain soil depth.

(2) The proportion of atmospheric CO_2 in soil profile decreases with soil depth. It is influenced by physical properties of soil, such as soil compactness, soil moisture and so on.

(3) CO_2 produced by dissolution of underlying carbonate rock contributes 34%—46% to soil CO_2 of those profiles covered by grass. A little more CO_2 is generated in limestone soil profile than in dolostone soil profile.

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