An analysis of the origin of $CaCO_3$ in soils on Fildes Peninsula of King George Island, Antarctica

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It has been vague whether the soil-forming processes include calcification or decalcification in Antarctic Peninsula and its adjacent islands. Everett (1976) reported that carbonate in soils derived from limestone in the South Shetland Islands; but Bockheim (1990) considered that carbonation is maximized in the region[1]. There are no published data reporting $CaCO_3$ content of soils in Fildes Peninsula. Based on the results of soil survey and test in the area, this note shows the $CaCO_3$ origin of the present soils, and discusses the relationship between the transference of $CaCO_3$ and soil-forming environment.

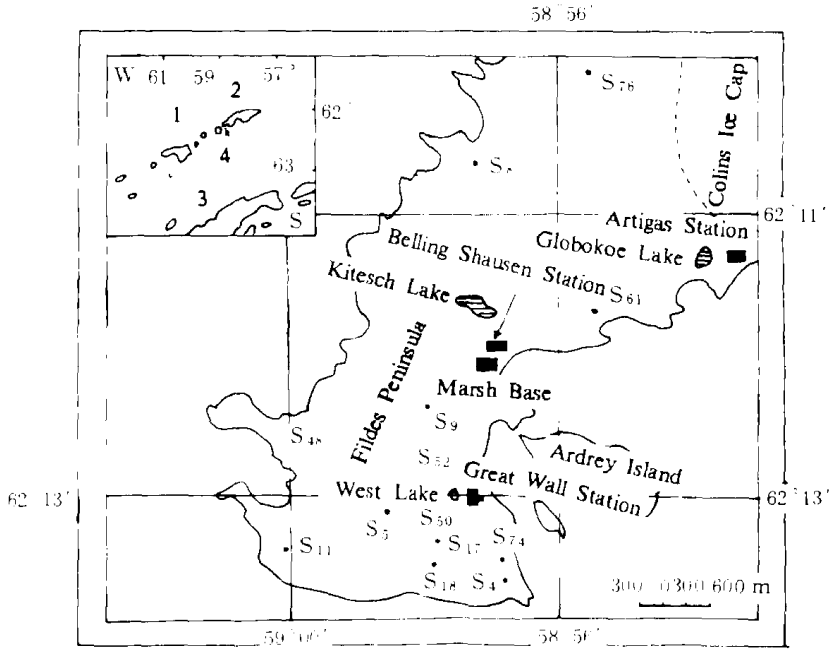

Fig. 1. Map of Fildes Peninsula showing location of soil profiles (black dots and numbers). 1, South Shetland Island; 2, King George Island; 3, Antarctic Peninsula; 4, Fildes Peninsula.

1 Sampling and methods

The soil sampling locations are shown in fig. 1. The mean annual air temperature and mean annual precipitation are about −2.1℃ and 630 mm in the study area. The climate is of the sub-antarctic oceanic type. The permafrost occurs at depths of 40—70 cm in most soils.

From December, 1992 to February, 1993, the field investigation of soils was undertaken, and the samples of soils were collected. The points of the soil profiles were selected according to the rules of *Soil Survey Manual*. The profiles were dug down to the frost layer. The soil color, texture, structure morphology and the distribution of stones in the profiles were observed, and the soil moisture content was determined. The soil horizons of the profiles were laminated according to the differences of these characteristics in the profiles. The soils were sampled in all horizons, then the samples were kept in a cloth-bag for drying in the laboratory of the Great Wall Station, and all samples were sieved and weighed. The soil acidity was determined using a pH meter. The content of organic carbon was determined with $K_2Cr_2O_7$-H_2SO_4 combustion method (Turin method). The $CaCO_3$ content was determined with gas-volumetric method and the laboratory conditions remained stable (the temperature is 18—20℃, and the pressure is 1 013—1 016 hPa). At the same time, the stones (1—10 mm) of the horizons were ground using a quartz-grinder, and the $CaCO_3$ content of the stones was determined[2].

2 Results and discussion

The results of soil survey and test are shown in table 1 for the 46 samples of the 13 profiles collected from Fildes Peninsula. The results show that there is no $CaCO_3$ in most soils of the study area, but there are some $CaCO_3$ in the soils of S_5, S_{11}, S_{18}, S_{48} and S_{50} profiles. These profiles develop on the weathering products of the basalt and subvolcanic rocks in the southern peninsula, and there are few of lichen and mosses on these products. Zheng Xiangshen *et al.* reported that the hydrothermalism causes the development of amygdaloidal structure in the basalt on the southern peninsula, and the main composition of the amygdali is calcite[3]. The new-growth of $CaCO_3$ in the soils during the field survey is not found. The scanning electron microscope (SEM) of the soil-particles in the S_{11} profile shows that the particles of $CaCO_3$ are grain-shaped crystals of calcite. The X-ray diffraction data of the clay ($\leqslant 2$ μm) of S_{48} profile also show that there is some calcite in the clay[4]. These results show that $CaCO_3$ in the present soils is primary mineral. Wellman reported that the carbonate in soils of Ross Island is derived from the loesslike dusk blown from Victoria Land[5]. Thus generally the soils inherit some primary $CaCO_3$ from parent material in subantarctic islands.

Table 1 shows that some $CaCO_3$ of the upper-layers of S_5, S_{11}, S_{18}, S_{48} and S_{50} profiles has been leaching out. The leaching ratios of total-earth are 53%—70%. The general reaction involved in the carbonate leaching-illuviation is as follows:

$$CaCO_3(\text{solid}) + H_2O + CO_2 \rightleftharpoons Ca^{2+} + 2\,HCO_3^-.$$

Table 1 $CaCO_3$ content, organic-carbon content, pH value and parent material of soils from Fildes Peninsula

Soil	Depth /cm	Organic carbon (%)	pH(H_2O) (1:5)	$CaCO_3$ (%) fine-earth <1 mm	$CaCO_3$ (%) stone 1—10 mm	$CaCO_3$ (%) total-earth <10 mm	Parent material
S_4	0—6	0.554	7.56	0	0	0	P.[b] of
	6—14	0.294	7.42	0	0	0	basaltic
	14—29	0.205	7.68	0	0	0	andesite
S_5	0—2	0.122	7.94	7.33	8.95	8.74	P. of
	2—14	-	8.07	18.96	21.47	20.74	basalt
	14—22	—	8.13	19.76	21.86	21.46	
	22—30	—	—	—	22.30	22.30	
S_8	0—6	2.640	6.04	0	0	0	Till & P. of
	6—12	1.021	6.72	0	0	0	basaltic
	12—21		6.81	0	0	0	andesite
S_9	0—4	5.678	6.46	0	0	0	P. of
	4—12	2.620	6.80	0	0	0	basaltic
	12—26	1.745	7.14	0	0	0	andesite
	26—40	1.364	7.28	0	0	0	
S_{11}	0—6	0.312	7.68	1.56	6.64	3.23	P. of
	6—14	0.250	8.24	3.03	6.72	4.72	basalt
	14—37	—	8.27	6.09	6.72	6.43	
	37—46	-		7.53	6.75	6.93	
S_{17}	0—10	0.401	7.26	0	0	0	P. of
	10—29	0.200	7.22	0	0	0	basaltic
	29—38	0.145	7.16	0	0	0	andesite
S_{18}	0—6	0.310	7.73	1.34	7.20	4.11	P. of lava
	6—27	0.224	7.87	9.19	15.82	12.03	& subvolcanic
	27—33	—	7.85	11.12	15.08	13.69	rocks
S_{48}[a]	0—8	0.195	7.71	1.09	—	—	P. of basalt
	8—32	0.216	7.98	4.23	—	—	
	32—40	0.212	8.12	6.15	—	—	
S_{50}	0—5	0.321	8.07	1.73	3.88	2.76	P. of basalt
	5—12	—	8.36	7.98	9.02	8.42	
	12—18	—	8.40	9.06	9.41	9.23	
S_{52}	0—10	1.323	6.94	0	0	0	P. of basaltic
	10—23	0.786	7.50	0	0	0	andesite
	23—40	0.307	7.82	0	0	0	
	40—52	—	—	0	0	0	
S_{61}	0—6	1.333	6.87	0	0	0	P. of
	6—14	0.532	6.94	0	0	0	sedimantary
	14—27	0.279	7.02	0	0	0	clastic rocks
	27—45	—	7.00	0	0	0	
S_{74}	0—10	9.716	5.28	0	0	0	P. of lava
	10—22	2.734	5.43	0	0	0	
	22—34	0.708	5.90	0	0	0	
	34—48	0.463	6.80	0	0	0	
S_{76}	0—10	0.603	7.40	0	0	0	Till
	10—24	0.615	6.94	0	0	0	
	24—38	0.184	7.04	0	0	0	
	38—45	—	—	0	0	0	

a) The composition of stone in the profile is agate-stone; b) P., products.

According to the principle of chemical equilibrium and the solubility isotherm of $CaCO_3$ and CO_2 in water, when H_2O and CO_2 are present in soils, the reaction moves to the right and decalcification occurs; in the cold-wet soils (or Cryaquents) of Fildes Peninsula, the decalcification occurs easily. Zhao also reported that the mobility of calcium is at its maximum in polar environment[6]. In winter, the soils are frozen and the chemical reaction in the soils is stagnant. In summer, the thawing water and rain is so much that the substratum of the soils is saturated, and there is no illuviation of $CaCO_3$. According to the standard of *Keys to Soil Taxonomy*, the soils have no calcic-horizon and there is no calcification in the present soil-forming processes.

$CaCO_3$ content of the total-earth in the substrata of the profiles is similar to that of stones in the same layer. The causes are as follows: (i) the leaching ratio of $CaCO_3$ in the substrata is small; (ii) $Ca(HCO_3)_2$ in the soil solution is concentrated during the sample-drying (the content of the soil moisture is 20%—35%). The permafrost occurs at the depths of 40—70 cm in soils, which decreases the downward water and reduces the leaching of $CaCO_3$ in the substrata. In the area, the thawing period of the substrata is short and the leaching-period is also short. So the leaching ratio of $CaCO_3$ in the substrata is lower than that in the upper horizons.

In the center area of the southern peninsula, the ice cap shrank back early and there are the longer soil-forming processes[7], but the biochemical process is weak, the content of organic carbon of surface-soils $\leqslant 0.35\%$, pH $\geqslant 7.5$, and the soils contain primary $CaCO_3$. In the coast area and the northern peninsula where many lichen and mosses grow, the content of organic carbon of the surface-soils $>1.0\%$, pH $=5.3$—7.5, and these soils contain no $CaCO_3$. Table 1 shows that there is a significant negative correlation between the $CaCO_3$ content of the total-earth and the content of organic carbon in soils (the correlative coefficient $r=-0.5535$, $n=17$), and there is a very significant negative correlation between the pH value and the content of organic carbon in soils (the correlative coefficient $r=-0.6907$, $n=34$). Thus it can be seen that the biochemical processes may accelerate the dissolution and leaching of $CaCO_3$ in the soils.

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