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Soils of Fildes Peninsula, King George Island, the maritime Antarctic: Part •. Formation processes and pedogenetic particularities

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Abstract Based on the data obtained from tens of the investigated soil profiles scattered over the Fildes Peninsula, King George Island, the maritime Antarctic, the soil-forming processes were discussed. It was concluded that on the weathering crusts resulted from various physical courses, the strong freeze-thaw action within regolith, significant organic matter accumulation, evident leaching and illuviation, as well as initial argillification dominated the formation and development of the soils on the Fildes Peninsula. Furthermore, this study indicated that the juvenility of genesis, poor profile-expression, variation in column thickness, etc. characterized the pedogenetic features of the soils of the Fildes Peninsula.

Key words soil, soil genesis, pedological processes, the maritime Antarctic.

1 Introduction

In Antarctica, some 2% of the total area are actually ice or snow free, where the land surface is directly exposed to weathering action. It is only on these areas that soils can be formed and developed. The ice or snow-free areas generally exist around coast, along the Trans-Antarctic mountains and in the Antarctic Peninsula (Claridge and Campbell 1968), respectively belonging to three different climatic zones, namely Antarctic coast, Antarctic slope and the maritime Antarctic zones (Holdagte 1970, 1977; Campbell and Claridge 1987).

The maritime Antarctic zone includes the South Sandwich Islands, the South Shetlands and the west coast of the Antarctic Peninsula to about 70°S. Situated more northerly and surrounded by sea masses, the maritime Antarctic zone is the warmest and moistest region of Antarctica. As known, formation and development of the Antarctic soils are characterized by temperature condition and moisture availability. Some pedological investigations carried out in the Antarctic Peninsula and the associated islands have shown that soils of these regions are distinctly different from those of most other parts of Antarctica. (Allen and Heal 1970; Everett 1976; Tedrow 1977; O´Brien *et al*. 1979). According to Tedrow (1977), the soils of the maritime Antarctic region could be grouped into the polar desert zone and tundra soil zones. In contrast, the soils in other Antarctic climatic zones belong mainly to the cold desert soil zone. Similarly, Bockheim and Ugolini (1990) grouped the maritime Antarctic soils into the Subantarctic high tundra and the Antarctic sub-polar desert zones. It has been found that the genetic characteristics of main soil types in the maritime Antarctic zone are similar to those of some Arctic soils. Therefore, Everett (1976) suggested that some maritime Antarctic soils resembled the Arctic brown soils of Banks Island, while Tedrow (1977) likened them to shallow Arctic brown soils of the polar desert zone (Table 1).

Table 1. Climatic zonation of Antarctic regions where soils have been able to form*

Climatic zone	Antarctic slope	Antarctic coast	Maritime Antarctic
Localities	Inland Mountain: Inland edge of Trans-Antarctic Mountains; Central Mountain: Main portion of Trans-Antarctic Mountains; Coastal Mountain: Coastal fringe of Trans-Antarctic Mountains	Coastal regions of East and West Antarctic and east coast of the Antarctic Peninsula	West coast of the Antarctic Peninsula and Islands north of 55°S.
Temperature range	+ 5 ℃ to − 30 ℃	+ 10 ℃ to − 20 ℃	+ 12 ℃ to − 12 ℃
Precipitation	< 50 − 200 mm	200 − 500 mm	200 − 1000 mm
Pedologic zone	Cold desert zone	Cold desert zone, polar desert zone	Polar desert zone, tundra zone
Soil moisture availability	Soil moisture availability significantly varies from locality to locality. Soil moisture status varies from ultraxerous to subxerous. Liquid water is only rarely present in the Inland Mountain region, while it has marked influence on soil properties in the Coast Mountain region.	Oceanic subxerous soil moisture status. Liquid water present, soil moist for much of summer period.	Moist soil moisture status. Surface soils may moist and unfrozen for short periods at any time of the year.
Soil temperature regime	Ground temperatures rarely above freezing point in the Inland Mountain region, above freezing point for short periods in the Central Mountain and the Coastal Mountain regions. Furthermore, running water present for short periods in the coastal mountains.	Ground temperatures above freezing point for much of summer period.	Ground temperatures may rise above freezing point for short periods in any month of the year.

* Sources: Tedrow 1977; Campbell and Claridge 1987.

2 Studied area

The Fildes Peninsula (centered at 62°12′S, 58°58′W) of King George Island, South Shetland Islands, where the study was conducted, measures about 3.5 km from east to west, and 7.5 km from north to south. According to the records of the meteorological observatory in the Chinese Great Wall Station, from 1985 to 1990 the mean annual temperature was as low as − 2.1℃, while the mean annual precipitation reached as high as 635 mm (Xie *et al*. 1993). The relatively higher temperature and precipitation than the most Antarctic regions make Fildes Peninsula mostly ice-free in the midsummer and favorable to growth of the lower plant vegetation.

Like other parts of the South Shetland Islands, the rocks exposed in the Fildes Peninsula of the King George Island are dominated by various volcanic rocks formed from the Late Cretaceous to the Early Tertiary times (Campell and Claridge 1987). Within the sedimentary sequences of the Peninsula, there are intensely folded basaltic rocks, basaltic-andesitic metaporphyrites, volcanic clastic rocks and sedimentary rocks. The most widespread and structurally important rock units of the Fildes peninsula are the intrusives of volcanic rocks, namely secondary volcanic rocks. Their occurrence and distribution are considered to play a crucial role in the tectonic morphology of the Fildes Peninsula.

The Fildes Peninsula belongs to mount and hilly area, with the topmost elevation of less than 200 m. Resulting from the volcanisms, the ancient glaciations and the periglacial activities, the following four main morphological forms have been developed: 1) The small volcanic islands and relic volcanic structures formed by the ancient volcanisms; 2) The glaciated surfaces and moraines by multiple glaciations; 3) The eroded coastal terraces and marine sediments by the shifting of the Peninsula or the drop of the sea level; 4) And the ancient and modern periglacial morphologic units by frost action. The modern morphology characterized by the landforms mentioned above exerts significant influences on the genesis and development of soils in the Fields Peninsula.

3 Samples and methods

Totally 61 soil profiles scattered over the Fidles Peninsula were investigated and more than 200 soil horizon samples were collected (Fig. 1). Besides, the parent materials and rocks were sampled at more than 30 sites. Furthermore, for a better understanding of the soil moisture availability and temperature regime on the Peninsula. The observations on the dynamic changes of the soil moisture status and soil temperature were carried out.

The analysis issues of the soil and rock samples in this study were conducted according to The Standard Laboratory Methods of Soil Analysis for Chinese Soil Taxonomy (CSTRG 1991). Some special analysis issues can be found in the related sources for more details (Chen and Gong 1995, 1996). The Data on the dynamic of soil moisture status were collected and recorded with a freeze-tolerant instrument specially developed for this study by the Soil Physical Department and Scientific and Technological Developing Company of the Institute of Soil Science, the Chinese Academy of Sciences.

4 Soil formation

As mentioned in the foregoing, in contrast with the soils in the regions of the coastal and continental Antarctica, the soils of the Fildes Peninsula are more influenced by available water due to the higher temperature and precipitation. It seems to be incontestable that, besides the strong rock weathering caused by various physical causes, freeze-thaw action, organic matter accumulation, leaching and illuviation, argillifucation are the most important pedogenic processes characterizing the formation and development of the soils in the Fildes Peninsula (Chen 1994).

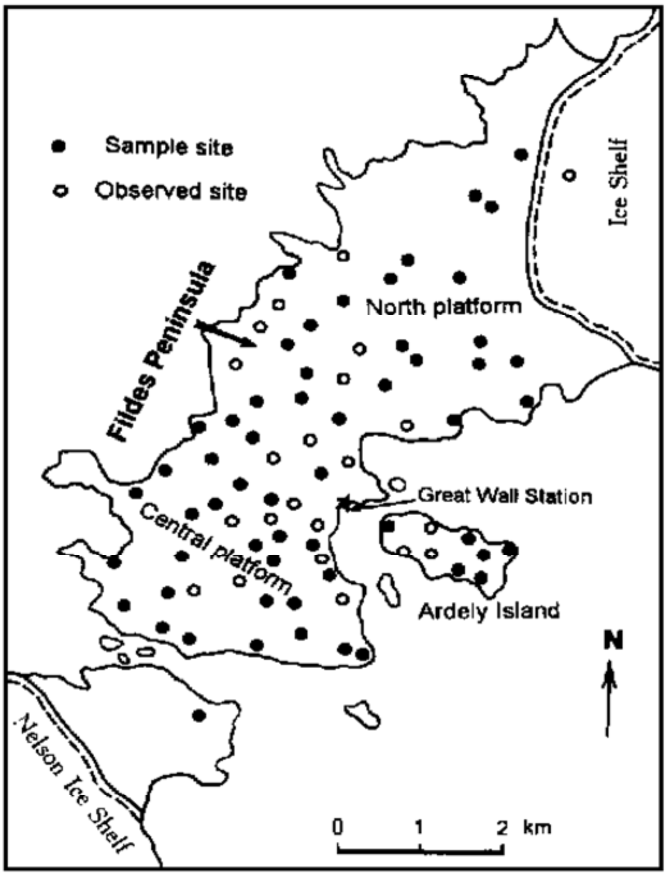

Fig. 1. Sketch map showing the main investigated soil profile scattered on the Fildes Peninsula.

4. 1 *Rock weathering processes*

The weathering processes on the Fildes Peninsula are mainly attributed to various physical causes which dominate the disintegration of rocks, the formation of regolith, the frost action and stirring process within the regolith. Rock disintegration, the first step of weathering, is caused by different modes such as glacial action, water action in forms of liquid and ice, salt weathering, insolation and wind action etc.. On the Fildes Peninsula, however, salt weathering and insolation action play very little role in rock disintegration, while water-based processes are very effectively in contrast with the most other Antarctic regions.

After rock disintegration, the regolith derived from debris of the broken rocks is ultimately formed in situ or on the deposits transported and re-sorted by the exterior forces such as water flow, glacier movement, blocky movement, creep and solifluction. On the Fildes Peninsula, generally it is only on various deposited regolith that soils have been well formed and developed because these regoliths normally have a much bigger thickness and a much higher content of fine particles such as sand and silt than in situ regoliths.

Chen and Gong (1995) described the main processes of physical weathering on the Fildes Peninsula and elsewhere Antarctica in detail. Here a sketch map of rock disintegration and regolith formation is presented for a better understanding (Fig. 2).

4. 2 *Freeze-thaw action within regolith*

Freeze and thaw is one of the most important water-based agencies of physical process within regolith, contributing significantly to formation and development of soils. According to Campbell and Claridge (1987), frost action resulting from freeze and thaw cycle occurs mainly within the top few centimeters of the regoliths and soils of Antarctica, only where is enough moisture available after periodic wetting by snow meltwater. On the Fildes Peninsula, however, it is believed that freeze and thaw is markedly more effective.

An in-situ observation carried out in the ice-free area of the Fildes Peninsula makes it possible to easily figure out the freeze-thaw cycle of the investigated soil profiles, as

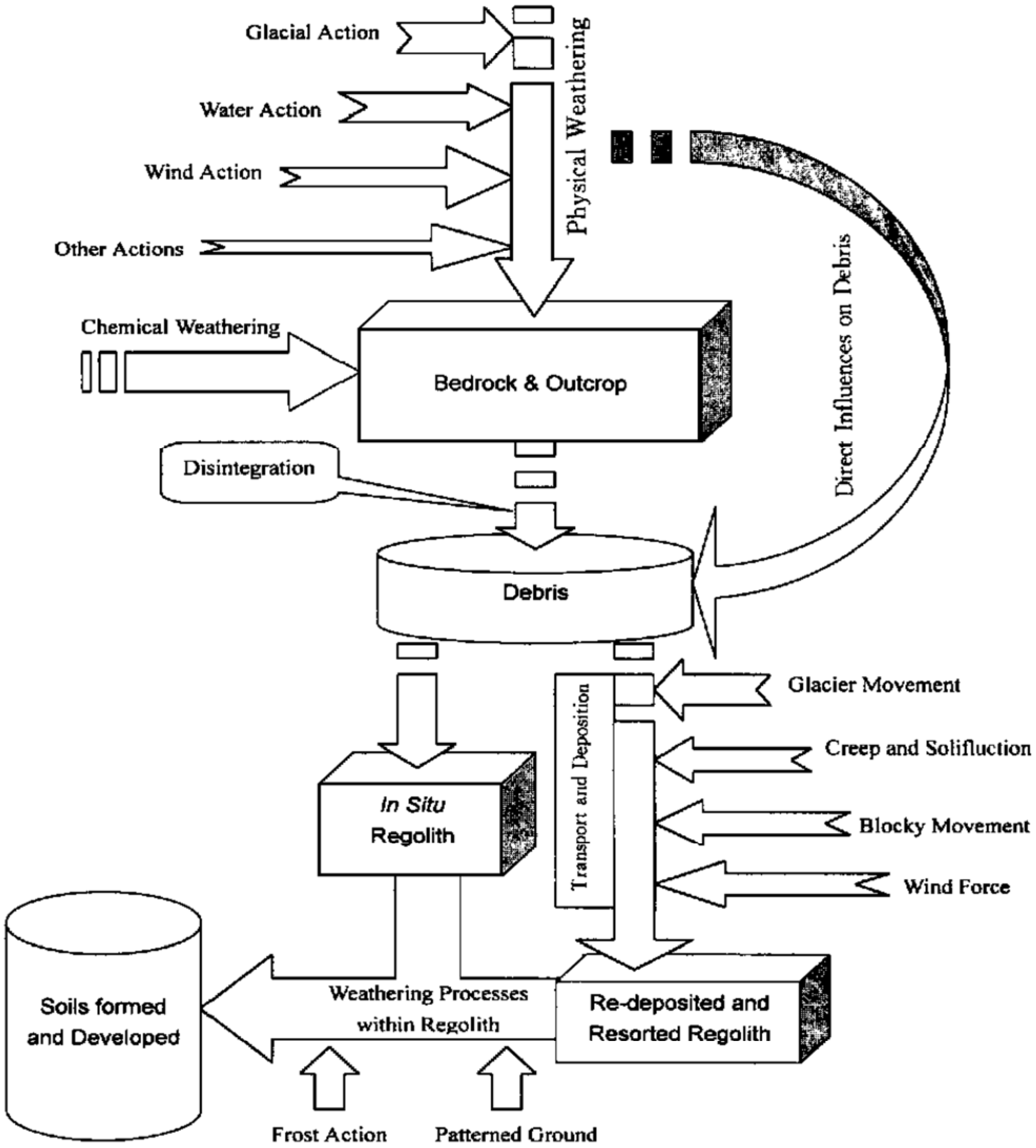

Fig. 2. Chart showing physical weathering processes of rocks within regolith.

shown in Fig. 3. It can be clearly seen that thawing action takes 5 ~ 6 months or more, and free water is available through the whole soil profiles in the midsummer, indicating frost action of freeze-thaw can reach much deeper than usually expected. In most instances, freeze-thaw cycle causes particle-size reduction, so-called granular disintegration, formation of patterned ground, and shifting of permafrost table.

Concerning particle-size reduction within the regoliths and soils, Xie *et al*. (1993) concluded that there were several mechanisms as follows: 1) Ice wedging action by the freezing of moisture in the rocks cracks; 2) Hydration-dehydration action among granular particles; 3) Expansion and contraction from temperature variation. On the Fildes peninsula, evidence of particle-size reduction in the regolith can be seen everywhere. Because particle-size reduction is a strongly water-based process, the particle composition of

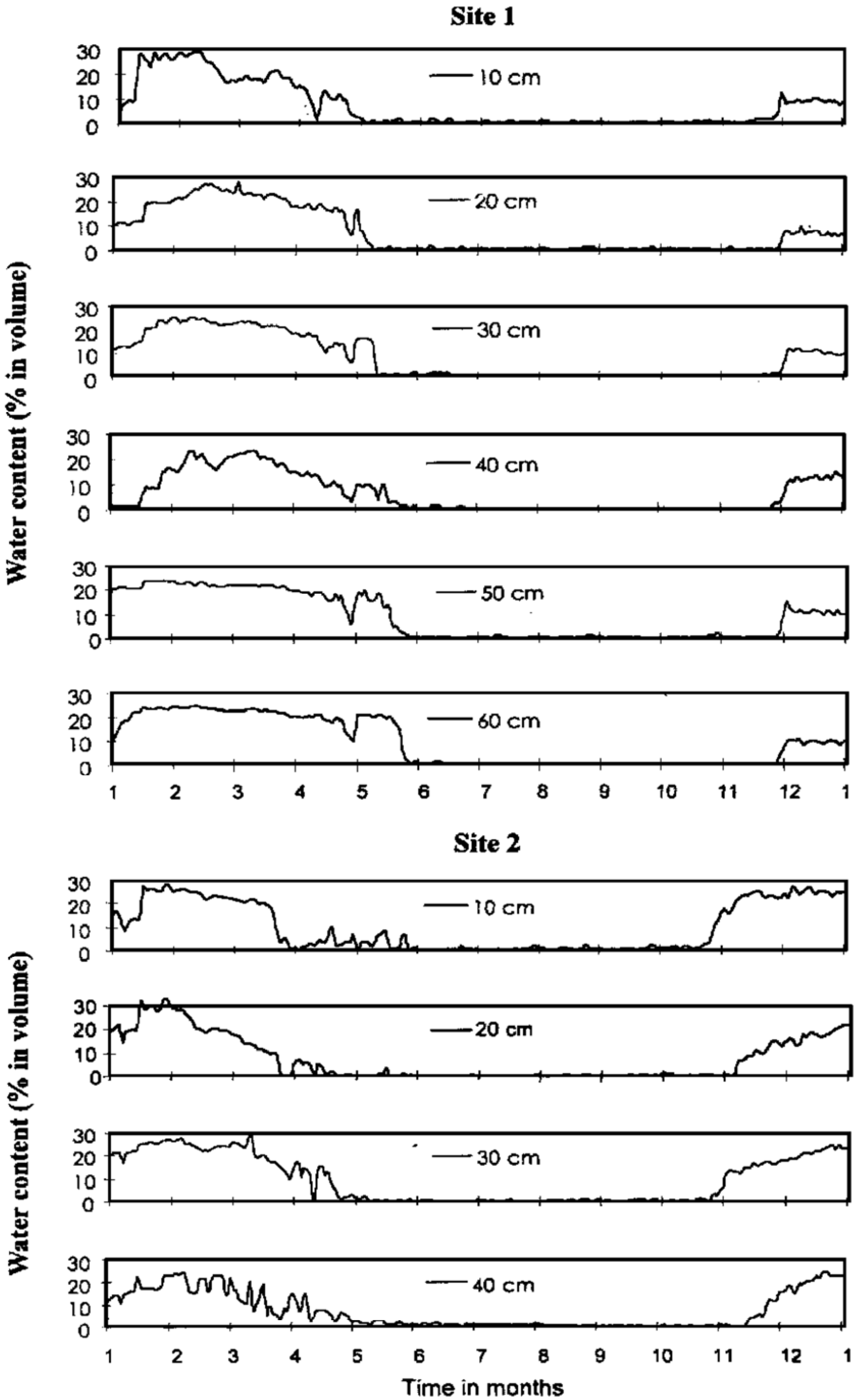

Fig. 3. Yearly dynamic changes of soil free (unfrozen)-water content (in volume %) at the investigated depths within the soil profiles at two sites.

the soils even formed on the same type of regoliths may vary greatly due to the variation of moisture availability.

Patterned ground resulted from freeze-thaw cycle is a very important feature of the landscape of the Fildes Peninsula, and is considered to reflect various features of the terrains in which they occur (Black and Berg 1966; Campbell and Claridge 1987). The processes of formation and development of patterned ground have been intensively investigated in Antarctica and elsewhere in the world (Pewe 1962; Berg and Black 1966; Campbell and Claridge, 1975a, b). Generally, patterned-ground processes exert both positive and negative effects on soil formation. Development of patterned ground causes further breakdown of the regolith, meanwhile, it brings about disturbance to expression of the soil profile. Compared with soils on stable sites, the soils where patterned ground is developing have a weaker profile expression and a lower degree of horizon differentiation.

The occurrence of permafrost at the bottom of some soil profiles of the Fildes Peninsula is likely to contribute to soil moisture condition, because frozen-ground table can acts as a barrier to stop the downward flow of free water from the surface and the upper layers. It is reasonable, therefore, that permafrost plays a significant role in water-based weathering processes. Besides, the range of annually rising and falling of frozen-ground table, so-called active layer, actually is under conditions of repeated freeze and thaw. An increase in the fine-particle fraction of the active layer might be expected. The information available on particle composition suggests, in many instances, that the frozen ground and its active layer contain materials that have been weathered to a degree comparable with the soils of the uppermost few centimeters.

Resulted from freeze and thaw discussed above, soils of the Fildes Peninsula are characterized by the following macro- and micro-morphological features: 1) Strong frost heaving and cracking, sorted and non-sorted circles on the surface of soils shose have a deep column and high fine-particle fraction; 2) Spongeous structure, gell and stoma in the upper part, and squamose structure in the lower of soils; 3) Lower differentiation of genetic horizon and poor profile expression.

4.3 Organic matter accumulation

As pointed, the climate of the Fildes Peninsula is maritime Antarctic in which temperatures rarely exceed 0℃ in summer and rarely fall bellow − 15℃ in winter, and considerably more moisture is available than elsewhere in continental Antarctica. As a result, the soils are more highly productive and have a much more diverse flora dominated by mosses and lichens, which, in some favorable situations, form an almost complete plant cover. Besides, large numbers of seabirds, especially penguins nest during the summer period on rookeries in the ice-free area of coastal strips. Obviously, the biological factors can be expected to play a comparatively active role in the weathering and soil-forming processes (Chen and Gong 1995).

The accumulation of organic matter in soils of the Fildes Peninsula resulted from both surface vegetation and the inhabiting of seabirds(Table 2 − 4). Accordingly, protoanker soils under the vegetation cover dominated by lichen and moss and ornithogenic soils from guano deposited at seabird rookeries have been formed. Generally, within the profile of protoanker soils no true A horizon is developed, although in some soils formed at the favorable sites, for example, under moss mat, there is considerable accumulation of organic matter. The occurrence of organic matter in the surficial layer is mainly in the forms of root hairs and incorporated plant fragments rather than that of humified material, since temperatures are still too cold for complete decomposition of the organic matter or for humus formation even on the Fildes Peninsula. The accumulation of organic matter in soils by plant vegetation has little detectable effect on chemical weathering. In the ornithogenic soils mainly formed on the penguin rookeries, extremely high quantity of organic matter derived from marine sources is largely contributed in the form of droppings, feathers and the remains of the birds and characterized by presence of phosphorus (Tedrow and Ugolini 1966). It was estimated that penguins alone could carry to the land 1.5×10^4– 2.0×10^4 t of phosphorus annually, during the nestling period, in the maritime Antarctic (Tatur and Myrcha 1984). It was reported that more than 10 secondary phosphates including struvite ($Mg[NH_4]PO_4\ 6H_2O$), fluorapatite ($Ca_5[PO_4]_3F$), and brushite ($CaHPO_4\ 2H_2O$) were identified from the ornithogenic soils (Myrcha and Tatur 1991). These secondary phosphates, resulting from reactions between guano leachates and surrounding stony fragments, play a very important role in the genesis of the ornithogenic soils.

Table 2. Comparison of organic matter contents between soils of the Fildes Peninsula and the soils in the high latitude and alpine regions of China

Regions	Soil types	Samples	OM/%
The maritime Antarctic			
Fildes Peninsula (62°09′– 62°15′S)	Ornithogenic soils	4	18.09
	Soils with dense vegetation cover	7	2.42
	Soils with thin vegetation cover	9	0.84
	Soils without vegetation cover	7	0.57
High latitude regions			
Tahe County, Heilongjiang Province (52°20′N)	Podzolized dark brown soil	1	5.62
Huzhong County, Heilongjiang Province (51°50′N)	Podzolized dark brown soil	1	2.70
Gulian County, Heilongjiang Province (52°10′N)	Cryogenic gleysol	1	4.64
Xiguitu, Inner Mongolia (48°05′N)	Cryogenic podzol	1	2.15
Alpine regions			
Tibet Plateau (elevation 4490 – 5250 m)	Meadow soils	6	13.35
Tibet Plateau (elevation 4490 – 5250 m)	Mountain tundra soils	6	1.71
Tibet Plateau (elevation 4490 – 5250 m)	Cryosols	4	0.83
Tibet Plateau (elevation 4490 – 5250 m)	Cryogenic yyermosols	2	0.49

Organic matter accumulation in soils strongly varies from site to site, although there is no climatic difference at all within such a small area as the Fildes Peninsula. The site differences of organic matter accumulation in soils mainly result from variation of biological activities, which may be attributed to moisture availability, surface stability and distance to coastal lines of localities. Because of low temperature and absence of active soil microorganisms, the organic matter accumulated in protoanker soils of the peninsula is characterized by low decomposition and humufication, therefore, in most instances, it exerts little influence on soil weathering processes and chemical properties. For ornithogenic soils, in contrast, the accumulated organic matter dominates most of soil genetic features.

Table 3. Various accumulation of organic matter in the soils with vegetation cover and its influence on soils of the Fildes Peninsula

Vegetation types	Soils covered by the lichen-dominated vegetation		Soils covered by the moss-dominated vegetation	
Distribution	Leveled mountain-tops	Slopes and plats	Slopes and foothills	Beaches and river-sides
Vegetation coverage	50% - 95%	< 50%	> 90% (only in patches of moss)	> 90% (only in strips of moss)
Features of litter layer	Evident litter layer formed from plant fragments, with a thickness < 5 cm.	No evident litter layer formed.	Evident litter layer in form of moss-mat, with various thickness from site to site, relatively higher decomposition degree.	No evident litter layer.
Surficial OM-enriched layer	Surficial organic-rich layer has been evidently developed; weak decomposition of organic matter within the layer; soil color is obviously darker than underlying horizons.	Organic layer is not formed, and differentiation between layers can be observed.	Evident organic-enrich layer with a thickness around 5 cm is formed, within which relatively higher decomposition of organic matter is observed; besides, root-hair of moss can reaches a considerable depth, however, no clear color differentiation can be seen amongst different horizons.	Root-hair of moss reaches a considerable depth, however, no evident organic-enriched layer is formed.
Organic matter content	Organic matter content of top layer ranges from 3% to 20%.	Organic matter content is much lower than that of soils on leveled mountaintop, mostly < 1%, rarely beyond 2% even in the top layer.	Organic matter content normally ranges from 3% to 5% in organic-enriched layer.	Organic matter in the top layer ranges from 1% to 2%.

Table 4. Features of organic matters accumulated in different ornithogenic soils

	Seabird rookeries	
	Penguins	Black-back gulls
Habitats	Rookeries are concentrated on hilltops along coastal lines, most of the rookeries are perennial; ground surface in the habitats is normally avoided of any vegetation.	Rookeries are distributed in form of scattered pieces, situated much far from coast than that of penguins; generally there is a rather dense vegetation cover on ground surface around the rookies.
Sources of organic matter	Marine sources	Marine source and plant fragments
Organic-enriched layer	Surficial organic-enriched normally is thinner less than 5 cm (including fresh guano), with a gray crust on the top; the column of this layer is impacted by penguin activities. The content of organic matter is mostly higher than 10%; soil particles are well cemented by organic matter; soil color from dark brown in the upper part tends to dark pink in the lower.	There is a much thicker surficial organic-enriched layer than that on the penguin rookeries, but a lower organic matter content less than 10%; soil is much softer than that on penguin rookeries and yellow-brown in color through the whole layer.
Decomposition degree of organic matter	Higher decomposition degree of organic matter; except a small portion of feathers and fresh guano there is no other un-decomposed organic matter observed.	In comparison with that of the soils on rookeries, decomposition degree of organic matter in the top layer is lower; in soil column there is mount of fresh and half-decomposed shell pieces and plant fragments.

4.4 *Leaching and illuviation*

On the Files Peninsula, moisture available in soils from precipitation and snow-melt water is much higher than evaporation loss for at least three months a year, as a result, a distinct leaching process occurs in the most of soils, thus making the soils of the Peninsula significantly different from that of the continental Antarctica.

In Fig. 3, it can be easily seen that the soil at every investigated depth contains more than 20% free water in volume in the thawing period. Such a content of free water is sufficient to cause significant leaching in soils of the Fildes Peninsula due to their relative low moisture-holding capacity. A careful examination of the curves in Fig. 3 indicates that soil free-water content in surface layers (with maximum depth of 10 cm) of the profiles rapidly decreases when an obvious increase of the free-water content occurs in the underlying layer. This fact suggests that snow-melting water on the surface and soil free-water from the thawing action form a downward flow when the surface soil becomes saturated, which penetrates the surface layer and contributes to the available moisture of the underlying layer. Step by step, the downward flow may penetrate the whole column. Besides downward flow, slope runoff and lateral seepage, occurring in many cases, also are expected to accelerate leaching process in soils.

The observed soil features resulted form leaching process include demolishment of soil morphological structures, downward translocation of materials such as soluble salts, organic matter and fine materials. The structure demolishment caused by leaching process is mainly observed in the upper part of soil profiles and results in the enlargement of the cracks and disappearance of the spongeous structures and stoma. In some cases, soils become hardened and impervious due to disaggregation of organic-inorganic aggregates. The material translocation in soils of the Fildes Peninsula will be discussed as a special issue somewhere else in detail. In general, calcium carbonate suffers the biggest leaching loss. As a result, soils of the Fildes Peninsula normally have a very low content of calcium carbonate (< 1%) and, in a fewer extreme cases, calcium carbonate almost disappeared through the whole profiles. Other salts, for example, some soluble salts of Na, K, Mg, are translocated more or less although they have not been entirely leached out of soil profiles.

The downward translocation of materials in the soil could be indicated by detectable illuviation. In a profile avoiding of leaching influence, normally cation exchange capacity of soil (CEC) in the upper part is higher than in the lower of a profile avoided of leaching process, because these upper soil usually has relatively higher clay fraction and organic matter content. From Table 5 and Fig. 4, however, it can be clearly seen the CECs at the lower position of some soil profiles are higher than that at the upper. Such an increase of CEC along with depth is believed to demonstrate that salts and clays are more or less leached out of the upper part of soil profiles and illuviated in the lower part, although no obvious illuvial horizon has been developed in many soils of the Fildes Peninsula. Besides, clay coating, found on the surfaces of soil particles and rock fragments in the lower part of soils, further presents observational evidence of leaching and illuviation, since the materials contained in the clay coating are mostly optically oriented.

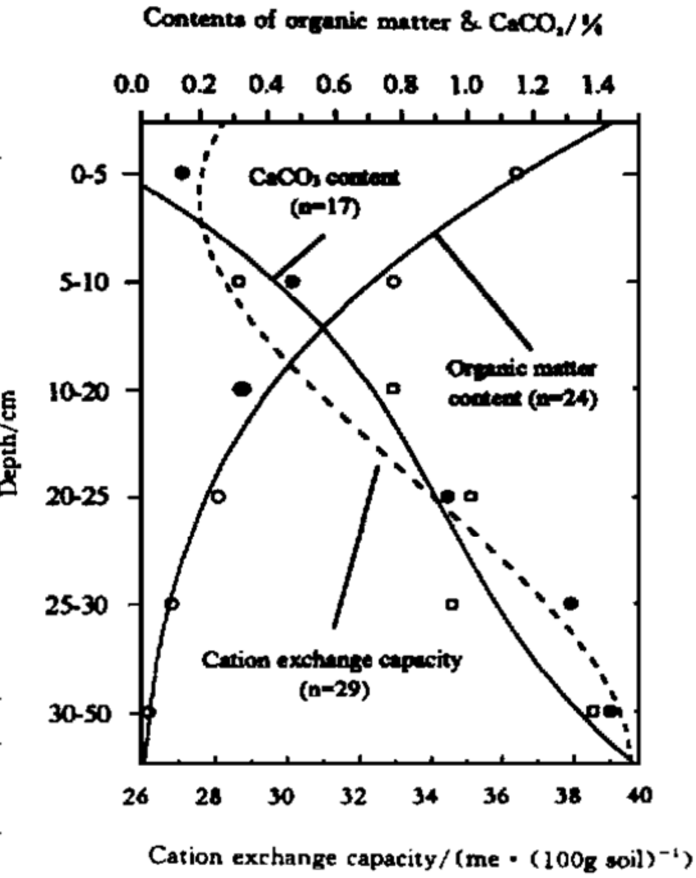

Fig. 4. Variations of organic matter and $CaCO_3$ contents, cation exhange capacity within soil profile of the Fildes Peninsula.

Table 5. Variations of cation exchange capacity within soil profiles

Position	Samples	Mean ECE/ me (100g soil)$^{-1}$	Varying range
Surficial layer	15	28.11	12.41 - 50.03
Middle parts	15	32.95	16.95 - 51.74
Bottoms	7	37.31	19.67 - 51.33

The downward translocation of organic matter is also illustrated in Fig. 4. Despite a rapid decrease of organic matter content with depth of profile, it is still present at a detectable degree through almost whole profile. Observational evidence of organic matter immigration was also obtained in the field. For instance, dark brown organic channel cutans were found in water passages of many soil profiles and lingulate transition between top layer rich in organic matter and the underlying horizon was present in many soil profiles.

Conclusively, leaching process on the Fildes Peninsula is mainly dominated by the downward flow of free water, which concentratively occurs in a short period in the year. Since the downward flow usually rapidly penetrate through the intensive cracks and stoma formed by freeze-thaw action, it is impossible for the leached soils to develop a true B horizon of illuviation, although evident material translocation occurs within the soil profiles.

4.5 Clay formation

In general, the clay content of soils in the Fildes Peninsula is relatively low. According to the author's statistical results, the soils formed on the residual weathered, deposited and residual-deposited crusts have a average content of clay material of 9.25%, 4.48% and 10.35%, respectively. The clay materials of soils in the Fildes Peninsula are likely to originate from two different mechanisms of clay formation. The clays that are formed by modern weathering process and soil development are so-called residual clays, while those clays formed under paleaoclimatic conditions and remaining in transported deposits are named as relic clays. X-ray diffraction data indicated that the clay fractions of soils on the Fildes Peninsula were characterized by the followings (Fig. 5):

First of all, the clays almost are complex minerals dominated by smectite and chlorite, which are accompanied by vermiculite, kaolinite, smectite-chlorite mixed-layer minerals, and a small amount of primary minerals such as quartz, feldspar as well. The fact that smectite is dominant clay mineral in the most of soils suggests that clay-forming process of the most soils on the Peninsula is developing only at its initial stage.

Second, the composition of clay minerals is closed related to the lithological characteristics of the parent rocks. For instance, the clays of the soils developed on tuff and tuffaceous sedimentary rocks are dominated by semectite, while those of the soils on volcanic agglomerates by the mixed-layer minerals of smectite-chlorite. Furthermore, the mixed-layer clay minerals commonly occur at various degrees in all types of the soils of the Peninsula. This is also supported by study of xie *et al*. (1993) who named the mixed-layer minerals of smectite-chlorite as I/S minerals.

At last, kaolinite detected in many soils of the Fildes Peninsula is believed to has been formed under the palaeoclimatic conditions, since it was found that kaolinite in the older deposited crusts had a higher content and a better crystallization. Some authors suggested that these kaolinite minerals were formed during the weathering process of the marine abrasion period when the higher temperature and precipitation made the alkali and alkaline-earth metals were subjected to loss from the parent materials, therefore resulted in the formation of kaolinite minerals.

5 Pedogenetic particularities

Characterized by the soil-forming processes discussed above, the pedogenetic particularities could be generalized as the followings.

(1) Simplistic genetic types: all the soils developed on the Fildes Peninsula can be accommodated into only 7 soil groups of three classification orders, i. e. Histosol, Cambisol and Entisol, according to Chinese Soil Taxonomy.

(2) Juvenility: Cambisols and Entisols occupy more than 80% of soil areas, indicating that the soils of the Peninsula is comparatively young.

(3) Poor profile-expression: strongly influenced by freeze-thaw action and periglacial activities, the most of soils have very poorly-developed profile morphology and weak differentiation of genetic horizons.

(4) Variation in column thickness: as a result of variation of the parent materials on which soils are formed, the thickness of soils vary from 2 cm to more than 1 m.

(5) Close relationship to parent materials: many chemical and mineral attributes of soils have obvious similarity to those of the bedrock and parent materials of the soils.

(6) Avoidance from human impact: due to the geographic remoteness of Antarctica, the soils suffer nearly nothing from human activities during their formation and development.

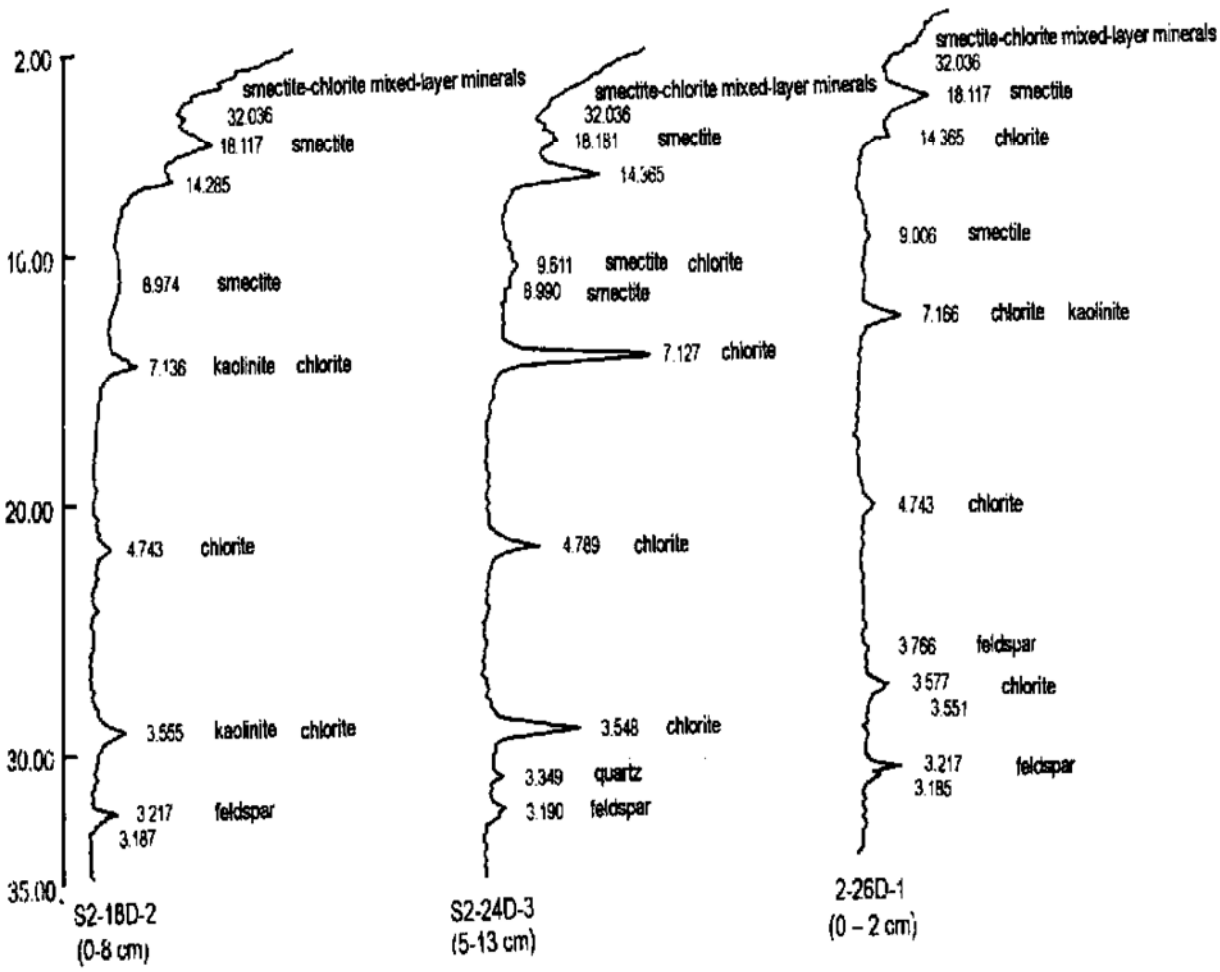

Fig. 5. X-ray diffraction diagram of the clay fractions in representative soils of the Fildes Peninsula.

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