Part II

Soils, Soil Development and Soil Properties

Preface

A first summary of descriptions of soil formation theories was developed by Jenny (1941). The last edition of his book, published in Volume 37 of Ecological Studies (Jenny 1986), contains the 'CLORPT equation' (soil formation=f (cl, ø, r, p, t), where cl is climate, ø is biotic factor, r is topography, p is parent materials and t is time). This general figure is still valid for our current understanding of soil development, and only the human factor needs to be added (Amundsen et al. 1994). For Antarctica, it has been suggested for a long time that climate and climatic effects (cl-factor) are basic constraints for soil formation. This is most evident for the polar desert regions with high aridity (Priscu 1998) where chemical and biological factors are widely hampered by low temperature. Here, soil formation is primarily driven by physical processes, a fact to which Campbell and Claridge (1987) focus much attention when reviewing studies on Antarctic soils. The Antarctic has only a very limited extent of soils, which are at a low level of development, and they are only poorly described, hence, their taxonomy is also fairly vague. Tedrow (1977) was the first who tried to put them into a soil classification system, and this approach is still under discussion.

This chapter is mainly a monograph on the available soil information on three typical Antarctic oases. It excludes the Dry Valley region, which is not regarded as an oasis due to its aridity and therefore has a desert ecosystem character (see definitions in Chap. 1). This opinion contradicts the current literature (e.g. Tedrow 1977; Campbell and Claridge 1987; Priscu 1998). The chapter focuses on soil ecological properties within the framework of interactions between plants–soil organisms–soils–microclimate and attempts to show that the terrestrial environments in Antarctica are not fully characterised by the current knowledge on the Dry Valley ecosystems. Both the biological (ø factor) and chemical processes are much more comparable to lower latitudes as suggested earlier. The intensity of chemical weathering depends on the parent materials (p-factor), the topography (r) as well as the time (t). In this chapter we would like to show that the whole CLORPT equation in its full breadth is valid for soils of Antarctic oases.

Recently, several attempts have been made to combine traditional and newly elaborated concepts for Antarctic soils. The papers of Bockheim and

Ugolini (1990), Bockheim (1997) and Beyer et al. (1999) provide such information. The summary provides, for the first time, detailed information on soil formation for the soils in the Antarctic oases.

The locations in our presentation need special attention because of their coastal positions. During the glacier retreat after the last glaciation, they were lifted to considerable heights. Our own observations of spicules from marine sponges at our sites close to Casey Station underline this with biological evidence (Chap. 8). Wide areas of coastal regions are Pleistocene sediments, e.g. the areas of the Vestfold Hills (Pickard 1986). Uncertainty remains about the extent of the former glacial ice sheet which is not well dated, e.g. whether it just reached the present coastline. For two regions described in this part, the Windmill Islands as well as Admiralty Bay region at King George Island, terraces and moraines can be seen, but precise dates are still pending. Hence, important data for judging soil development must be obtained.

In contrast to old soils of the Dry Valley regions, which can be dated back to 10–15 million years (Claridge and Campbell 1985), the story of the sites mentioned here is much shorter and much more variable due to biological influences. Chapter 6 focuses on the most recent glacial retreat and its consequences. The actual diversity of soils, their extension and patchiness are presented by the examples of the Windmill Islands and King George Island (Chap. 7). Connections with harsh weather conditions, mainly with freeze-thaw cycles, energy balances and the impacts of chemical soil weathering are given in Chapters 8 and 9.

The tundra-like soils as well as regions with considerable peat in the maritime Antarctic have led to areas with high stocks of below-ground organic matter. Although there are areas in the continental regions also showing such patterns, they are much more restricted to small local phenomena. Nevertheless, soil-forming processes even at high levels, e.g., podzolisation, have been observed. This serves the hypothesis that the general processes of soil formation in Antarctica are similar to those of other areas of the world, but just at (smaller) local scales and need longer time scales to form visible structures. Chapter 10 focuses on the organic matter as structural matter of soils and as an indicator for biological processes. With Chapter 11, this part of the book focuses on the biological factor (ø) of the CLORPT equation, knowing full well that the effect of penguins is quite uncommon for soil systems out of Antarctica.

A prominent factor for structuring effects in coastal areas are seals and birds, i.e. their resting or breeding places. The special type of ornithogenic soils, first noted by Syreochkovsky (1969) and then generally outlined by Tedrow and Ugolini (1966), is a special feature not only of this region, and can be compared best with the South American guano fields, or even to dump fields in former agricultural regions. The unstable nature of penguin rookeries has influenced wide regions as it can be seen from typical soil layers, e.g. at King George Island (Chap. 11). Influences are mirrored by soil and vegetation patterns to different extents and these document a history of landscape development.

It is often a competition between fox and hare when discussing the point of interaction between soils and plants and which of these two preconditions the other. In the Antarctic region we can learn that both plant colonisation and soil formation act in close relationship – when the input of microbes, i.e. bacteria, cyanobacteria and algae (ø factor), is considered. Indicators for this are changing pH values with distance from glacier fronts, the coastline, or rookeries. Factors like relief (r-factor) and parent materials (p-factor), which basically means the effective heat input, water supply from snow melt or occasional paddy areas, show important constraints on the processes leading to local soil patterns rather than the general environmental condition of permafrost. Thus, the availability of water and its local action become a prominent feature of soil pattern structure and the main reason for wide ranges in parameters used to describe its condition in physical, chemical or biological terms.

References

Amundsen R, Harden J, Singer (1994): Factors of soil formation: a fiftieth anniversary retrospective. SSSA Special Publication No 33. Soil Science Society of America, Madison, Wisconsin

Beyer L, Bockheim JG, Campbell IG, Claridge GGC (1999) Genesis, properties and sensitivity of Antarctic Gelisols. Antarct Sci 11:387–398

Bockheim JG (1997) Properties and classification of cold desert soils from Antarctica. Soil Sci Soc Am J 61:224–231

Bockheim JG, Ugolini FC (1990) A review of pedogenic zonation in well-drained soils of the southern circumpolar region. Quart Res 34:47–66

Campbell IB, Claridge GGC (1987) Antarctica: soils, weathering processes and environment. Elsevier, Amsterdam

Claridge GGC, Campbell IB (1985) Physical geography – soils. In: Bonner WN, Walton DWH (eds) Key environments: Antarctica. Pergamon Press, Oxford, pp 62–72

Jenny H (1941) Factors of soil formation. McGraw-Hill, New York

Jenny H (1986) The soil resource. Ecological studies 37. Springer, Berlin Heidelberg New York

Priscu JC (1998) Ecosystem dynamics in a polar desert. The McMurdo Dry Valleys, Antarctica. Antarctic Research Series 72, American Geophysical Union, Washington, pp 1–369

Syroechkovsky EE (1959) The role of animals in the formation of primary soils under the condition of circumpolar regions of the earth (Antarctica). Zool Zhurn 38:1770–1775

Tedrow JCF (1977) Soils of the polar landscapes. Rutgers Univ Press, New Brunswick

Tedrow JCF, Ugolini FC (1966) Antarctic soils. In: Tedrow JCF (ed) Antarctic soils and soil forming processes. American Geophysical Union. Antarct Res Ser 8:161–177

Pickard J (1986) The Vestfold Hills: a window on Antarctica. In: Pickard J (ed) Antarctic oasis. Terrestrial environments and history of the Vestfold Hills. Academic Press, Sidney, pp 333–351