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Biotic and abiotic factors influencing soil properties across a latitudinal gradient in Victoria Land, Antarctica

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Abstract

Through the cooperative efforts of the Scientific Committee on Antarctic Research (SCAR) Evolution and Biodiversity in Antarctica (EBA) Project and the Latitudinal Gradient Project (LGP), a monitoring network was established in Victoria Land in 2002 to assess the impacts of climate change on vegetation, soils, active-layer dynamics, and permafrost across a latitudinal gradient. In this study, we report on the key factors influencing soil development across the gradient, including vegetation, parent material characteristics, and climate. Physical and chemical soil properties at depths of 2-8 and 10-20 cm were investigated at 7 sites and on 14 permanent plots from Apostrophe Island in Northern Victoria Land (73°30′S, 167°50′E) to Granite Harbour in Southern Victoria Land (77°00′S, 162°26′E) along the Ross Sea coast. The relationships among vegetation, parent material, and regional climate and soil properties were tested with Principal Component Analyses. There were no significant correlations or relationships in soil properties across the climate gradient. In fact, local microclimatic appears to be more effective than the regional gradient in influencing the properties. Microclimate was also important relative to active-layer depth and vegetation distribution. Lithology was strongly related to several chemical parameters, notably extractable Al, Fe, Ca, K, but was unrelated to grain-size distribution. Vegetation was related to the chemistry of the surface-soil layer, including nitrate, organic carbon, C/N ratio and water content, and also the active-layer depth. Penguins had the greatest influence on soil properties in initiating the development of ornithogenic soils. Further analyses on soil properties, including a greater number of sites, will be required to represent more extensively the lithological variability and to extend the latitudinal extremes of the gradient. The results presented here are an important reference for future monitoring activities in Victoria Land.

Keywords: Soil; Vegetation; Active layer; Parent material; Monitoring network; Climate change; Antarctica

1. Introduction

Polar regions are important for assessing and monitoring climate change impacts on biotic and abiotic components of Antarctic ecosystems (i.e. Convey, 2001; Doran et al., 2002; Geringhausen et al., 2003; Vaughan et al., 2003; Cook et al., 2005; Turner et al., 2005). Changes in climate may affect vegetation, soil properties, active-layer dynamics, and permafrost in different ways and these environmental components may interact through complex mechanisms, activating both positive and negative feedbacks. These topics have been studied only recently in Antarctica (Melick and Seppelt, 1997; Barrett et al., 2006a, 2006b; Beyer et al., 2000; Cannone et al., 2006; Guglielmin et al., 2005, 2008-this issue; Bockheim, 2008-this issue). Moreover, vegetation and active layer dynamics play an important role in the carbon cycle (cf., Oechel et al., 2000; Mack et al., 2004; Chapin et al., 2005), although the carbon content of Antarctic soils is much lower than in the Arctic.

In Antarctica, international panels are addressing the problem of how to detect the effects of climate change on ecosystems. In particular, within the framework of the Scientific Committee on Antarctic Research (SCAR) Evolution and Biodiversity in Antarctica (EBA) program, formerly the Regional Sensitivity to Climate Change in Antarctic terrestrial and limnetic ecosystems (RiSCC) project, specific research protocols have been developed for assessing and monitoring climate change impacts on vegetation, soils, and permafrost. Their main approach is to set

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up networks along latitudinal and environmental gradients (Cannone and Guglielmin, 2003; Cannone, 2004, 2006).

In the frame of the SCAR project EBA and, in cooperation with the Latitudinal Gradient Project (LGP), a monitoring network was established in 2002 and 2003 to assess the impacts of climate change on vegetation, soils, and permafrost in Victoria Land (Continental Antarctica) across a latitudinal gradient (Cannone, 2006). The network includes 7 sites and 14 permanent plots and is located along a latitudinal gradient from Apostrophe Island (73°30′S, 167°50′E) in Northern Victoria Land to Finger Point (Granite Harbour) (77°00′S, 162°26′E) in Southern Victoria Land. Plots are located at key sites along this gradient so as to include a coastal transect and a coast–inland sub-transect in the Terra Nova Bay area. The study sites were selected on the basis of the results of a latitudinal-transect study that investigated 25 sites from Cape Hallett (72°76′S, 169°56′E) to Lake Fryxell (77°35′S, 163°20′E) (Cannone, 2005).

Here we report on work carried out at seven coastal transect sites in Victoria Land to analyze changes in physical and chemical properties of soils in relation to parent material and vegetation conditions along the climatic gradient. The main aims of the paper are to:

1) describe the main physical and chemical parameters of the soils within the monitoring network as a reference for future monitoring activities;
2) assess the relationships between the soil characteristics and a) the latitudinal gradient, b) the lithology, c) the vegetation.

2. Study Sites

The study area is located in Victoria Land, East Antarctica where, within the main latitudinal network, seven sites and 14 permanent plots were investigated from Apostrophe Island (73°30′S, 167°50′E) to Finger Point (Granite Harbour) (77°00′S, 162°26′E) (Fig. 1). The climate of Victoria Land is a frigid Antarctic one, with a gradient of increasing mean annual air temperature (MAAT) from (a) Southern Victoria Land, with MAAT of −19.9 °C at Scott Base (77° 51′ S; 167°46′E) over the period 1957-2005 (Harper, unpublished), to (b) Boulderclay (74°43′ S, 164°05′E), in the vicinity of Mario Zucchelli Station (Terra Nova Bay area), with MAT of -16.4 °C to −15.1 °C in the period 1997-2003 (Guglielmin, 2006), to (c) Cape Hallett, where the MAT is c. −15.3 °C (Duphorn, 1981). Precipitation, always in the form of snow, is very low and ranges between 100 and 200 mm (Grigioni et al., 1992).

All sites are located along the coast, with the exception of Tarn Flat, which is inland on the slope area before the plateau. They have a similar altitudinal range (10 - 250 m a.s.l.) so that comparable data, not influenced by elevation, are obtained for assessing relationships along the latitudinal gradient. The sites represent the most common environmental conditions, and almost all the rock substrates were sampled (i.e. granite, basalts,

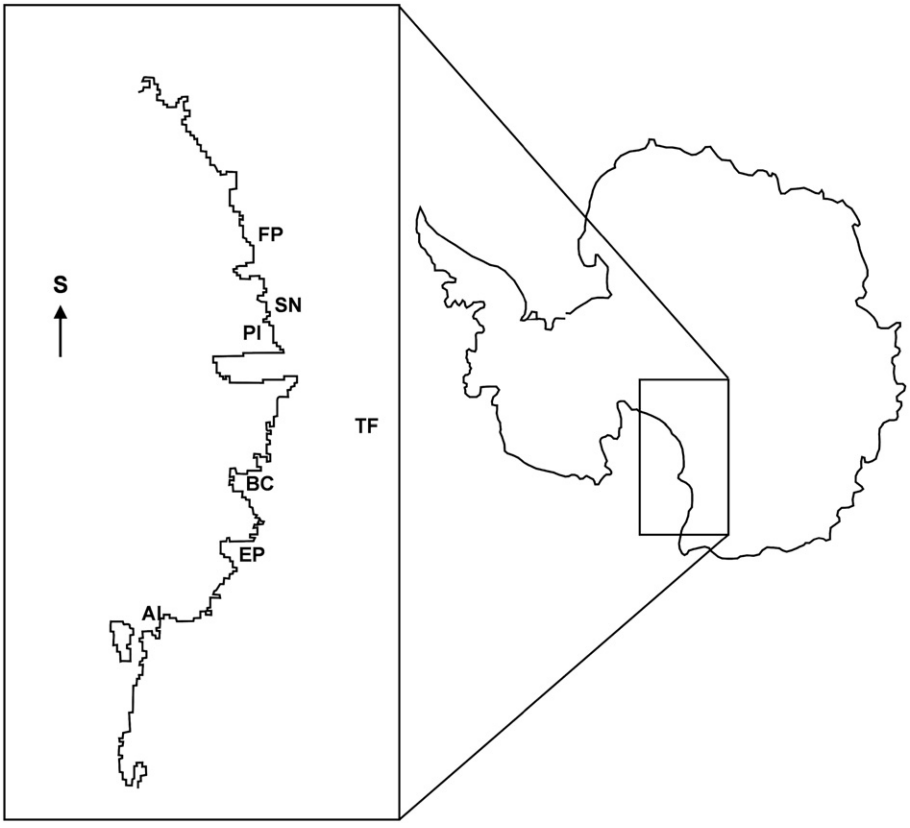

Fig. 1. Location map of the investigated sites in Victoria Land. Legend: AI = Apostrophe Island, BC = Boulder Clay, ED = Edmonson Point, FP = Finger Point, PI = Prior Island, SN = Starr Nunatak, TF = Tarn Flat.