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Distribution of soil taxa in Antarctica: A preliminary analysis

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ABSTRACT

Only 0.35% (49,500 km^2) of Antarctica is ice-free. These areas are scattered around the periphery of the continent and in interior mountain ranges, making soil mapping difficult. Here we compile the results of mapping in five of the nine ice-free areas that account for 79% of the ice-free area on a reconnaissance scale and interpret the distribution of soil subgroups in *Soil Taxonomy*. Soils of Antarctica are contained in four orders, dominantly Gelisols (84%), 13 suborders, 27 great groups, and 76 subgroups. Forty-five percent of the soils of Antarctica are Orthels, Gelisols that show minimal cryoturbation and occur in dry landscape positions; 38% of the soils are Turbels showing cryoturbation and occurring in more moist landscape positions. Only 16% of the soils of Antarctica lack permafrost in the control section and are classified as Entisols (Gel-great groups), Inceptisols (Gelepts suborder or Gelaquepts), or Histosols (Gel-great groups). These soils occur almost exclusively along the western Antarctic Peninsula and at elevations below 30 m in the South Shetland Islands (SSI) and South Orkney Islands (SOI). Typic Anhyorthels are the dominant soil subgroup comprising nearly 15,340 km^2, or 31% of the soils in Antarctica. These soils occur primarily in central and southern Victoria Land, but also occur in the Thiel and Pensacola Mountains and Shackleton Range, the Prince Charles Mountains, and the mountains of Queen Maud Land. Typic Haploturbels and Typic Anhyturbels occupy 14 and 13% of the soils of ice-free regions of Antarctica, respectively. Most abundant in central Victoria Land, they are common in most mountainous regions of Antarctica. The dominant soil processes of maritime Antarctica are cryoturbation, gleization, melanization, podzolization, paludization, and phosphatization. In coastal East Antarctica, the major soil processes are rubification, salinization, calcification, pervection, and gleization. The predominant soil-forming processes in the Transantarctic Mountains include rubification, salinization, desert pavement formation, and permafrost development. Measures of pedodiversity will be valuable in the selection of protected areas in Antarctica.

1. Introduction

Antarctica occupies an area of 14 million km^2 and according to the Antarctic Treaty (http://www.ats.aq/e/ats.htm) is comprised of the entire area south of 60°S. Only 0.35% of Antarctica is ice-free (Fig. 1), with the Transantarctic Mountains and mountains along the Antarctic Peninsula comprising 50% and 20% of the total ice-free area, respectively. During 1964 to 1975, a series of 19 Antarctic Map Folios were prepared by the American Geographical Society showing the distribution of vegetation, mammals, glaciers, and other natural resources of Antarctica (Bushnell, 1974); however, this series did not include maps of soil resources.

Soil mapping is important in Antarctica for several reasons, including (i) an inventory of key natural resources of Antarctica; (ii) the provision of benchmark data for detecting global change impacts; and (iii) the protection of unique resources and sites of scientific interest.

McCraw (1967) prepared the first soil map of Antarctica, a third-order (1:63,500) map of Taylor Valley based primarily on topography and parent materials. Since the early map of McCraw (1967), several soil maps using units from *Soil Taxonomy* (Soil Survey Staff, 2014) have been published for portions of five of the nine ice-free areas at scales ranging from 1:1000 to 1:2 million (Table 1). A recent book, *Soils of Antarctica* (Bockheim, in press), documents soils of each of the ice-free regions. The purpose of this study is to use the published maps and regional analyses to elucidate the distribution of soils in Antarctica.

2. Study area

Much of the following information is taken from a summary by Bockheim (in press). Antarctica is often subdivided based on two large ice sheets separated by the Transantarctic Mountains into East

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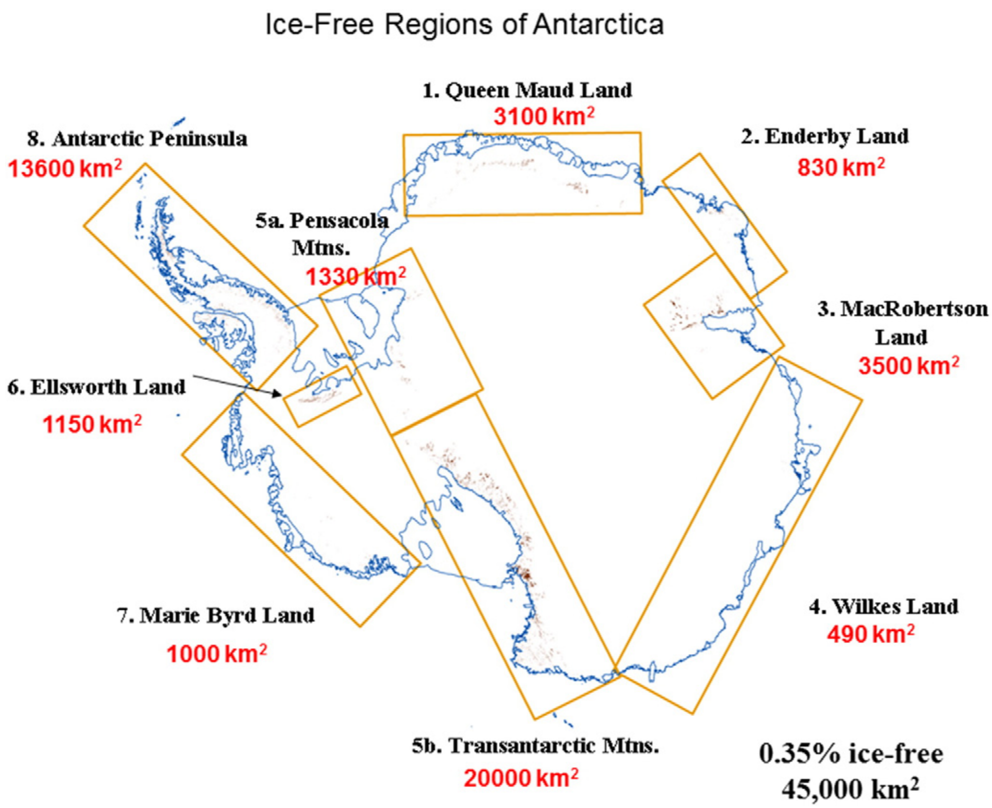

Fig. 1. Ice-free regions of Antarctica (Bockheim, in press).

Antarctica and West Antarctica. The East Antarctic ice sheet is underlain at depths up to 4.1 km by a land mass with a network of sub-glacial lakes and streams and is believed to have been relatively stable throughout the Pleistocene. In contrast, the West Antarctic ice sheet is marine-based, unstable, and has responded synchronously with Northern Hemisphere glaciations. These two ice sheets contain 70% of Earth's freshwater.

Widespread glaciation began in Antarctica after the continent separated from South America approximately 35 to 40 million years ago during the Eocene or Oligocene. During the mid-Miocene the ice sheet had built up sufficiently to enable katabatic winds to pass from the polar plateau to mountain valleys causing a shift in climate from polar to polar-hyperarid.

Antarctica currently features three contrasting climates: (i) a humid-maritime climate along the West Antarctic Peninsula (WAP) with a mean annual temperature (MAAT) of −1.7 to −3.4 °C and mean annual precipitation (MAP) ranging from 400 to 1000 mm; (ii) a dry-maritime climate along the coast of East Antarctica with a MAAT of −9 to −11 °C and a MAP of 200 to 250 mm; and (iii) a hyper-cold, hyper-arid inland, mountain climate with a MAAT of −17 to −35 °C and a MAP of 100 mm or less. Antarctic currently is experiencing considerable warming, especially along the WAP where the MAAT has increased 3.4 °C since 1950 (Vaughan et al., 2003).

Permafrost is continuous in continental Antarctica and discontinuous in the South Shetland Islands. Active-layer (seasonal thaw layer) depths commonly range from 1 to 2.5 m or more along Antarctic Peninsula, from 0.3 to 1.1 m along the coast of East Antarctica, and from 0.1 to 0.4 m in the inland mountains.

Plant life is restricted to mosses, lichens and algae in continental Antarctica, with vascular plants limited to two species (*Deschampsia antarctica* and *Colobanthus quitensis*) in the Antarctic islands north of 67°S, particularly in the South Orkney and South Shetland Islands. There are more than 400 species of lichens in Antarctica, 40% of which are endemic, and more than 130 species of bryophytes, mostly mosses. Seabirds and nesting birds constitute the dominant factor influencing soil organic carbon and nutrient levels in Antarctic soils.

Despite the small ice-free area, geologists have been able to map a large portion of the bedrock of the continent from nunataks, mountains that project above the ice. Ice-free regions 1 through 4 in East Antarctica (Fig. 1) feature primarily Precambrian gneisses and schists. The Transantarctic Mountains (region 5b) contain the Jurassic to Devonian age Beacon Group (sandstones intruded by dolerite) fronted by the Cambrian-Ordivician Granite Harbour Intrusives. The northern Transantarctic Mountains contain Upper and Older Precambian metasedimentary rocks. The Pensacola Mountains (region 5a) are derived from Jurassic basaltic rocks, Upper Precambrian metasediments, and Paleozoic strata. The Ellsworth Mountains (region 6) contain Paleozoic strata. Ice-free areas in Marie Byrd Land are composed of Cenozoic volcanic rocks and Cretaceous intrusive rocks (granitic rocks). The Antarctic Peninsula is made up of a wide variety of rocks that are dominated by volcanic and granitic types.

The soil parent materials of Antarctica are primarily of glacial origin and include till, outwash, and limited areas of glaciofluvial and glaciolacustrine deposits. Colluvium, talus and other deposits from mass-movement occur throughout Antarctica. Debris flows and gelifluction deposits are common along the Antarctic Peninsula and throughout coastal Antarctica. Aeolian deposits include sand dunes and mega-ripples, but not loess. Volcanic ash and lapilli are common in the SSI and SOI; and scoria and other tephra occur in the MDV. Residuum is common in the high mountains and nunataks of interior Antarctica. Patterned ground is ubiquitous in ice-free areas of Antarctica, including sorted and non-sorted circles, polygons, and stripes, mudboils.

3. Methods and materials

This study is based on data and maps identified in Table 1, particularly from summaries of each ice-free region contained in *Soils of Antarctica*. All