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# Soil and landform interplay in the dry valley of Edson Hills, Ellsworth Mountains, continental Antarctica

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ABSTRACT

The main relief units from the dry valley of Edson Hills, Ellsworth Mountains, Antarctica (79°49′12.4″/83°40′16.1″), were assessed, emphasizing the analysis of soil and landform interplay. Soil morphological, physical, and chemical properties; salinity; surface boulder weathering (frequency and feature); classification; and weathering stages were analyzed. Three distinct landforms summarize the geomorphology of the dry valley of Edson Hills, Ellsworth Mountains: (i) periglacial features like slightly creeping debris-mantled slopes, steep debris-mantled slopes, patterned grounds, and thermokarst; (ii) glacial features like hummocky moraines, lateral moraines (supraglacial), lakes, kettle hole (proglacial), cirques infill (subglacial), horn, and arête (erosional glacial); and (iii) nonglacial features like scree slopes and talus deposits. All these glacial and periglacial features are related to the West Antarctica ice sheet variations. Soils in the dry valley of Edson Hills are pedologically poorly developed. However, the degree of development in soils associated with patterned ground and moraine systems is remarkable. All soils present desert pavement owing to the action of severe aeolian erosion. In addition, soils accumulate salts depending on the local drainage conditions. The most expressive soil classes among the studied soils were Typic Haploturbel and Typic Anhyorthel, especially because of: (i) a general trend of ice-cemented permafrost occurrence in lower portions of the landscape, particularly in the patterned ground area and in the hummocky moraine; and (ii) the presence of dry permafrost in higher positions of the landscape, in relief units such as in debris-mantled slopes and talus deposits. Thus, a close relationship among soil characteristics and landforms were observed in the dry valley of Edson Hills.

## 1. Introduction

In Antarctica, a close relationship exists between the parental material, its spatial distribution, mantle alteration, and pedogenesis as the climate does not cause drastic changes that completely differentiate the material coverage from which they originated. Landscape studies focusing on landforms and soils development interplay in Antarctic areas, represent important sources of glacial landscape evolution interpretation. Glacial history may be elucidated by the interface among geology, geomorphology, and pedology (Denton et al., 1992).

The Ellsworth Mountains have 2095 $km^2$ of ice-free areas, which corresponds to 4.2% of the total Antarctica (49,500 $km^2$). This region is a key area for the study of Antarctic glacial history as it is very close to the current limit of West Antarctica and the Ronne-Filchner ice shelves (Denton et al., 1992).

Pedological and geomorphological studies of the Antarctic landscape are still scarce, being restricted to ice-free areas in the Dry Valleys located between the Transantarctic Mountains and Antarctic Peninsula coast areas. Only a few studies of landform assembly in continental polar areas are available in the literature (Ó Cofaigh et al., 1999). In the Ellsworth Mountains context, Denton et al. (1992) and Bockheim and Schaefer (2015) analyzed the theme under a regional perspective and Vieira and Simões (2011) and Vieira et al. (2012) investigated the glacial geomorphology of the Independence and Patriot Hills in the southernmost part of the Ellsworth Mountains. However, detailed work related to the soil and landform interplay in the region of Union Glacier is lacking.

Therefore, the aim of this work is to analyze soil and landform

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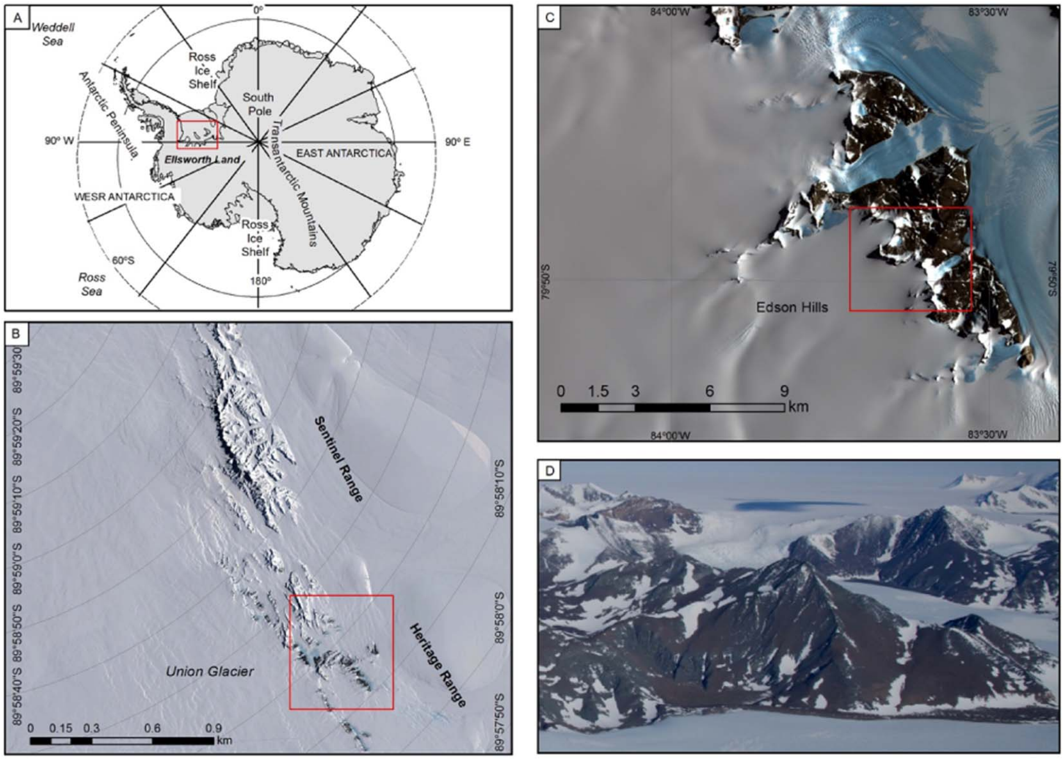


**Fig. 1.** Ellsworth Mountains in the Antarctic context (A); Union Glacier area (B); dry valley of Edson Hills (C); and panoramic photography of the dry valley of Edson Hills (D).

interplay in the dry valley of Edson Hills, southern part of Ellsworth Mountains, continental Antarctica, contributing to the understanding of glacial history in the area, aiming at understanding the formation of terrestrial ecosystems in the polar desert context.

## 2. Regional setting

Ellsworth Mountains form a group of mountains located in the central region of West Antarctica (Fig. 1A), comprising 350 and 80 km of length and width, respectively (Fig. 1A). It is composed by the Sentinel Range (north) and the Heritage Range (south), being divided by the Minnesota Glacier in the center (Webers et al., 1992b). Orientation is NNW-SSE, limited by 78° and 87°W longitudes and 80°30′ and 77°15′S latitudes (Denton et al., 1992). Union Glacier, an important regulator of the local hydrologic system, is located in the central part of the Heritage Range (Fig. 1B). This study is focused in the Edson Hills (Fig. 1C) glacial valley (Fig. 1D) ice-free area of the Union Glacier region.

The dry valley of Edson Hills is one of the areas with the most diverse lithology in Ellsworth Mountains. It is orthogonally cut by three geological formations: (i) Drake Icefall Formation composed of black schist and marbles; (ii) Hyde Glacier Formation composed of greywacke, argillite, and conglomerates; and (iii) Union Glacier Formation composed of tuffaceous diamictite (Webers et al., 1992a). The dry valley of Edson Hills constitutes a rocky glacial valley with a patterned ground behind and the entrance blocked by the Union Glacier morainic system.

The landscape of Ellsworth Mountains has not always been glacial. Campbell and Claridge (1987) reported that today's geomorphological features are, in fact, a result of several active glacial and nonglacial processes during its geologic history. As in the entire Antarctic continent, Ellsworth Mountains also experienced fluvial processes that were responsible for the formation of the local valley drainage system. Nevertheless, these features built by fluvial action were mainly either destroyed or buried by water.

The first glacial manifestation in the Ellsworth Mountains consisted of alpine glaciers and subsequently became continental (Campbell and Claridge, 1987). These authors believed that the current topography originated from the alpine glaciation phase as milder temperatures in this period contributed to the elevated erosive power of warm-based glaciers. Rutford et al. (1980) reported that alpine glaciation possibly started in the upper Mesozoic and lower Cenozoic when the Ellsworth Mountains formed an archipelago or island. In the subsequent phase (continental glaciation), cold-based glaciers had little influence on the modification of the features sculpted before. Continental glaciation practically covered the entire area, with only the most elevated peaks exposed as nunataks. This phase is called the Last Glacial Maximum (20,000–18,000 years before the present time; Bentley et al., 2010). Later, the region experienced deglaciation owing to the West Antarctica ice sheet oscillations (Rutford et al., 1980). Several of these features and glacial deposits are preserved in the current landscape.

Denton et al. (1992) reported two main features of glacial erosion in the Ellsworth Mountains region. The first is that exposed mountains present classical features of alpine glacial erosion, such as horns, arêtes, and sharp spurs. These features are especially evident in the northern part of the Ellsworth Mountains, called the Sentinel Range, as well as present in the Heritage Range southern part. The second feature of glacial erosion is called trimline, characterized by mountains and hills along the entire length of the Ellsworth Mountains. The ridges above the trimline are sharp and pointed, whereas below this pattern is substituted by surfaces of polishing and glacial striation. Glacial deposits and several erratic blocks commonly occur below the trimline. Based on the interpretation of glacial Ellsworth landscape associated with characteristics of the superficial alteration model as well as the pedological features model, Denton et al. (1992) reported that the last ice expansion occurred during the Late Wisconsin and Holocene.

Ellsworth Mountains climate data are scarce and highly variable (Vennum and Nishi, 1992). According to the Chilean meteorological station Teniente Parodi in Patriot Hills, south of the Heritage Range, average summer air temperatures are around − 15 °C, although − 30 and − 5 °C in October and December were reported, respectively. On the other hand, average air temperatures may reach to − 40 °C during