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Glacial geomorphology, soil development and permafrost features in central-upper Wright Valley, Antarctica

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Abstract

We mapped surficial deposits, soils and permafrost features in the central-western Wright Valley, Antarctica, from Lake Vanda in the east to near the mid-part of the South Fork in the west. Outstanding features of the landscape include two large rock glaciers covering approximately 323 ha with a volume of 0.14 km^3, and the sinuous Upper Wright III moraine in the South Fork with typifying yellowish brown (10YR 5/6) subsoil colours. Soil morphology and weathering stage indicate the features are early Quaternary age and younger than Alpine III deposits. Soils are dominated by sodium and chloride ions, and the total salt content increases with age except where profile soil water is recharged either by subsurface flow from streams, melt water production at high elevation or sporadic surface flow. Ice-cemented permafrost at less than 70 cm depth is common, being associated with relatively young alluvial soils of the Onyx River, and with soils on the steep slopes of the south valley wall near the Dais where melt water from high elevation recharges soil water.

Keywords: Rock glaciers; Soil weathering salts; Soil chronosequence

1. Introduction

Although the surficial geology and soil development of the Wright Valley has been studied extensively since the late 1950s (Péwé, 1960; Ugolini 1963; Nichols, 1971; Calkin and Bull, 1972; Bockheim, 1979a; Denton et al., 1991; Hall et al., 1993; Prentice et al., 1993; Hall and Denton, 2005; Prentice and Krusic, 2005; Bockheim and McLeod, 2006), most of the research has been concentrated in the region east of the eastern end of Lake Vanda and especially east of Bull Pass where advances of ice from grounding in the Ross Embayment and alpine glaciers on the south wall have been mapped (Hall et al., 1993; Prentice et al., 1993) thereby providing an excellent field laboratory to determine the glacial chronology of Wright Valley (Hall et al., 1993; Prentice et al., 1993). In conjunction with the glacial chronology, Bockheim (1979a) developed relationships between soil morphology and age, later showing how this sequence would be arrested if soil water was recharged thus preventing depth to ice-cemented permafrost (ICP) increasing with age (Bockheim 1979b).

An early exception to study in the eastern Wright Valley was by Calkin and Bull (1972) who described deposits left by eastward advances of the Upper Wright Glacier–Upper Wright I, II, III, IV. Upper Wright IV is now generally referred to as Peleus till (Prentice et al., 1993), which was deposited during the Miocene (Hall et al., 1993). Prentice et al. (1993) later presented a comprehensive surficial geology map from the Dais in the west to Meserve Glacier in the east. However, in this study as a result of more detailed work we were able to re-interpret some of his colluvial deposits south east of the Dais as rock glaciers. A regional-scale geology map (Isaac et al., 1996) also identifies the features as rock glaciers.

Although soil descriptions have been made in the central Wright Valley, they have primarily been used to aid interpretation of surficial geologic deposits and assign ages/names to develop correct chronology. Renewed interest in environmental classification in a spatial framework (Waterhouse 2001) has led to the demand for soil and permafrost maps.

The objectives of this paper are to map the surficial geology, soils and permafrost in central-upper Wright Valley (Fig. 1) and

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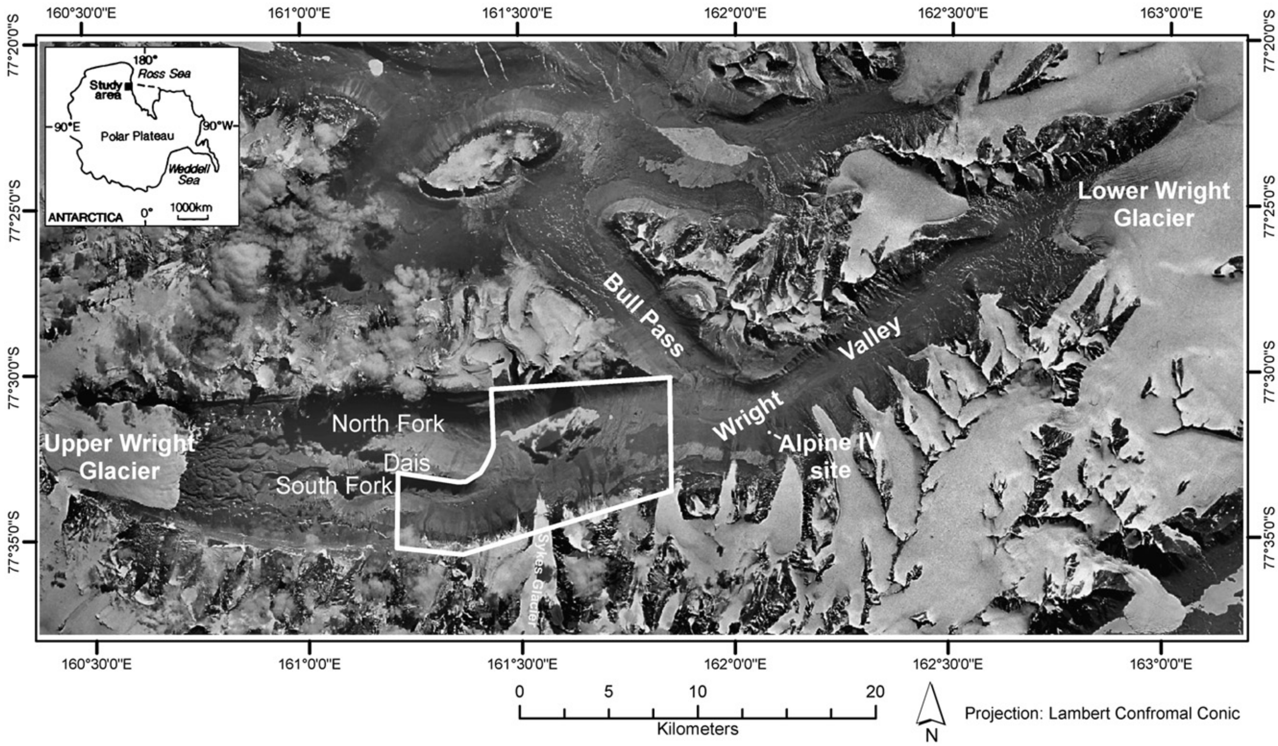

Fig. 1. Location diagram of study site and Alpine IV soil sample location to the east of the study site.

to interpret the results in the context of the glacial and climatic history and of Wright Valley.

2. Study site

Wright Valley (Fig. 1), lying east–west, forms part of the ice-free McMurdo Dry Valleys where precipitation is relatively low as a result of the effects of adiabatically warmed winds (relative humidity 2–5%; Bromley, 1986) that flow down-valley off the Polar Plateau (Keys, 1980). However, at low elevation (<100 m) east along the valley floor to the western end of Lake Vanda, the site lies at the limit of coastal Zone 1 (Marchant and Denton, 1996) where the climate is relatively mild with precipitation at Vanda station of approximately 80 mm yr^{-1} (Thompson et al., 1971).

However, in Zone 2, above 100 m, Marchant and Denton (1996) indicate cold, very dry conditions, with snowfall less than in Zone 1, and rare melt water except on snow banks and glaciers. During the 2006 summer field season (January) we observed many melt water surface flows and seepages along foot slopes of the south wall of the valley, i.e. north facing slopes, as anticipated by Marchant and Denton (1996).

Unconsolidated deposits in central-upper Wright Valley (Fig. 2) are dominated by: 1) two large rock glaciers, covering about 325 ha, that extend northwards from the southern wall (Isaac et al., 1996): 2) Peleus till (Prentice et al., 1993); 3) colluvium from north and south valley walls, and 4) alluvium from the Onyx River. For ease of discussion the two large rock glaciers have been termed Sykes West Rock Glacier (SWRG) for the larger and eastern-most rock glacier, and Plane Table Rock Glacier (PTRG) for the smaller western rock glacier. Deposits from alpine glaciers cover only a small area within the study site where Alpine II and III drifts (Calkin and Bull, 1972) are associated with Sykes Glacier. These drifts are likely of Quaternary and Pliocene age respectively (Hall et al., 1993). South east of Lake Vanda, where the valley floor is not covered in drift, mafic monzonite and felsic porphyry dikes (Turnbull et al., 1994) crop out, while at lower elevation on valley walls Jurassic Ferrar dolerite dykes intrude early Paleozoic orthogneiss (Isaac et al., 1996). Analyses from a profile of soil developed in Alpine IV drift, taken from outside the study area, about 1 km NNW of Conrow Glacier, is included in the dataset for comparison.

3. Methods

Stereo pair aerial photographs of Wright Valley were examined with preliminary soil boundaries plotted onto a GIS-based geo-referenced satellite image (http://usarc.usgs.gov/ant-ogc-viewer/declasdownload.htm) and a hill shade image built from a 2-m post-processed resolution LIDAR file (http://usarc.usgs.gov/ant-ogc-viewer/lidardownload.htm) at a 1:50 000 scale. LIDAR data were used in conjunction with Spatial Analyst® (ESRI, ArcGis V9.1) to determine rock glacier volume.

During the 2005/06 austral summer, fieldwork was undertaken to validate the preliminary boundaries and determine the nature of surface geology, soils and permafrost. Eighty-five small test pits were excavated, described and classified following USDA *Soil Taxonomy* (Soil Survey Staff, 2003) and located by GPS. The soil