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Glacial geomorphology of the Victoria Valley System, Ross Sea Region, Antarctica

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ABSTRACT

During the 2011–2012 austral summer, we had the opportunity to verify a surficial geology map prepared nearly 50 years ago for the Victoria Valley system (VVS), the largest of the McMurdo Dry Valleys. We used high-resolution landsat images and a digital elevation model to identify landforms and prepare detailed maps of each of the five valleys in the VVS, including lateral and end moraines, rock glaciers, gelifluction sheets, gravel ripples, and hummocky and ice-cored drifts. Our mapping suggests that the Bull drift is less extensive than previously thought, attains a maximum elevation of ~750 m in Balham and Barwick Valleys and the upper Bull Pass region, and does not occur in McKelvey Valley. We found Insel drift to 850 m elevation in eastern McKelvey Valley and upper Bull Pass and were able to trace Insel drift down Bull Pass where it becomes Peleus drift in Wright Valley. The Victoria Lower Glacier likely responded to grounding of ice in the Ross Embayment and was out-of-phase with alpine glaciers elsewhere in the VVS. We amplified and quantified Calkin's relative chronology and provide here our multiple-parameter relative chronology for the McMurdo Dry Valleys that is based on surface-boulder weathering, soil weathering, salt stage, degree of development of the desert pavement, and form of patterned ground. Except for Victoria Lower Valley, we correlate Packard drift with Taylor II drift (ca., 120 ka), Vida drift with Taylor III drift (ca., 300 ka), Bull drift with Taylor IVb drift (2.7–3.5 Ma, and Insel drift with Peleus drift (>3.7 Ma, <5.4 Ma). The lack of a strong correlation between soil salt stage and depth of visible salts with elevation leads us to question whether a high-level lake (ca., 200 m deep) existed in the VVS during the early Holocene.

1. Introduction

Since the seminal work of Bull et al. (1962) and Calkin (1964; 1971), there have been no comprehensive studies of glacial deposits and landforms in the Victoria Valley System (VVS) of Antarctica. However, there has been considerably more recent mapping and relative and numerical dating elsewhere in the McMurdo Dry Valleys (e.g., Brook et al. 1993; Hall et al. 1993; Marchant et al. 1993a; 1993b; Wilch et al. 1993).

Victoria Valley has been the subject of two scientific controversies that we only briefly address here. The first controversy pertains to whether or not there were high-level lakes in Victoria Valley. Whereas Calkin (1971) suggested that Lake Vida may have been 20 m higher during what he identified as the Vida glacial episode, Hall et al. (2002) and Kelly et al. (2002) suggested that a 200-m deep lake may have engulfed most of the VVS as late as the early Holocene. Bockheim et al. (2008b) argued against high-level lakes elsewhere in Taylor and Wright Valleys primarily on the basis of the lack of significant differences in soil properties, especially the depth-distribution and profile amounts of salts on equivalent-aged drifts above and below the conjectured upper lake levels.

A second controversy pertains to the behavior of the Victoria Lower Glacier. Calkin (1964; 1971) and Chinn (1987) treated the Victoria Lower Glacier as an alpine glacier and suggested that it fluctuated in-phase with other alpine glaciers in the valley, including the Victoria Upper and Webb Glaciers. In contrast, Borns (1978; 1982) identified cross-cutting of moraines and buried soils, suggesting that the Victoria Lower Glacier responded to grounding of ice in the Ross Embayment and was out-of-phase with the alpine glaciers.

During preparation of a geographic information system-based Environmental Domains Classification (EDC) of the Ross Sea region, we had occasion to validate and improve Calkin's map and provisionally address the two fore-mentioned issues.

2. Regional setting

The VictoriaValley system (VVS) is the largest of the McMurdo Dry Valleys (4800 km^2) with an ice-free area of 650 km^2. The VVS contains five valleys, the Victoria Upper, the Victoria Lower, Barwick, Balham, and McKelvey Valleys, and includes the upper Bull Pass area (Fig. 1). The valley floors range from 400 to 1000 m above sea level. Three large glacier tongues flow into the valleys, including the Victoria Upper into Victoria Upper Valley and the Webb Glacier into Barwick Valley from the northwest and the Victoria Lower Glacier from the Wilson Piedmont Glacier and local alpine glaciers from the

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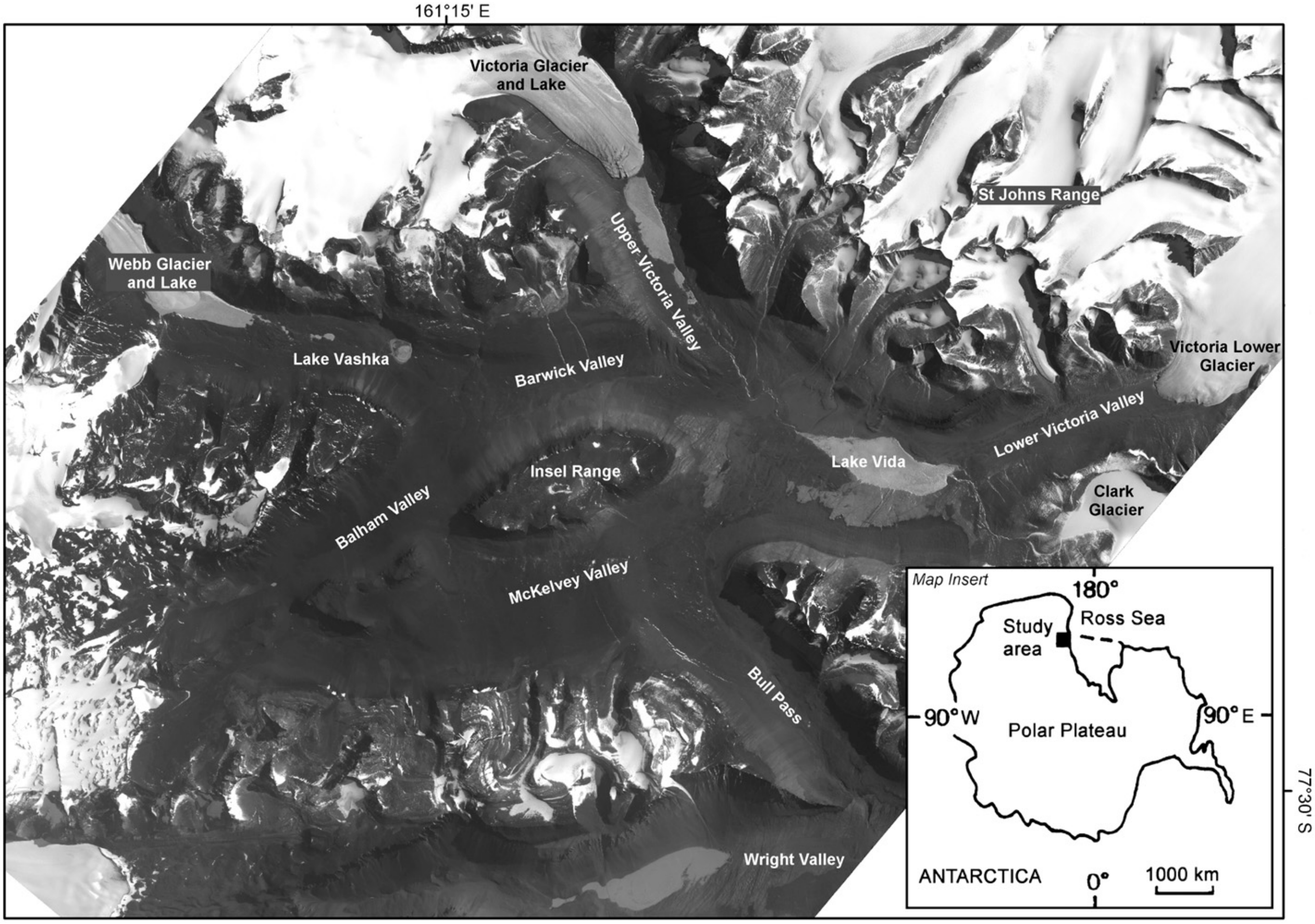

Fig. 1. Land satellite image of the Victoria Valley System.

northeast. A smaller alpine glacier, the Packard Glacier, flows into Victoria Lower Valley.

The VVS is underlain by igneous, metamorphic, and sedimentary rocks that range from Cambrian to Mesozoic in age. The eastern half of the VVS contains granites, schists, gneisses, and marbles; the western half of the VVS features Beacon sandstones intruded by Ferrar dolerites (Gunn and Warren 1962).

Bull et al. (1962) and Calkin (1964; 1971) studied the surficial geology of the VVS. Bull et al. (1962) recognized four major glaciations. The earliest two glaciations were the most extensive; glaciers flowed eastwards from the ice plateau through the coastal ranges and cut broad valleys extending to McMurdo Sound and the Ross Sea. Moraines from these glaciations are thin and highly weathered. The third glaciation was less extensive and consisted of advances of smaller glaciers from the inland ice plateau, the Wilson Piedmont Glacier, and névés in the dividing ranges. The fourth and youngest glaciation was comprised of small advances by remnants of the plateau-fed valley glaciers. Thick boulder-belt moraines from this glaciation overlie earlier deposits.

Calkin (1971) identified two major glaciations, including the Insel and the Victoria. He subdivided the Victoria glaciation into three major glacial episodes, including from oldest to youngest, the Bull, Vida, and Packard. The Insel glaciation was an eastward flow of ice from the inland plateau through the valleys to the coast. The Insel glaciation contains silty till and erratic gravels and cobbles on mesas 300 to 600 m above the valley floors. The till lacks moraine topography, and upstanding boulders are of limited extent. During the recessional phase of the Insel glaciation, deep melt-water channels were cut in all of the valleys. In contrast, the Victoria glaciation featured strong invasions from local ice-fields and from the coast.

Based on unpublished data (C.A. Seybold, Natural Resources Conservation Service, personal communication), the mean annual air temperature over the period 1995–2010 along the eastern shore of Lake Victoria (elev. 410 m) is −23.2°. The relative humidity is 49%, and the mean and maximum wind velocitiesare 2.2 m/s and 18 m/s, respectively. The active-layer depth averages 21 cm. We were unable to find any published information on soils of the VVS.

3. Methods

Mapping was conducted using standard geologic field techniques. We used a geographic information system (GIS) and the following data: (1) an ALOS PRISM satellite image (5 m resolution) from JAXA, (2) a DEM from airborne LIDAR data collected by NASA (2.5 m resolution), (3) high-resolution aerial photographs from the U.S. Navy digitized and archived by the U.S. Geological Survey, (4) 1:50,000 topographic maps from the U.S. Geological Survey, and (5) a surficial-geology map at a scale of 1:250,000 originally prepared by Calkin (1971). In addition to mapping individual moraines within a sequence, we mapped other features not reported by Calkin (1971), including gelifluction terraces, rock glaciers, gravel ripples, and hummocky and ice-cored drifts.

During a five week period (23 December, 2011–28 January, 2012), we collected data from 71 sites throughout the VVS. These data included surface boulder frequency and weathering features (Calkin 1971), soil salt stage (Bockheim 2002), rock and soil weathering stages (Bockheim and McLeod 2006), and characteristics of high-center polygons. For