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Weathering Stages of a Tholeiitic Basalt (Dolerite), Queen Maud Mountains

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Dummett (east of Mount McCauley) and on Goodspeed Nunataks ("c" on figure 1), and by the distinctive sequence of quartzite and amphibolitic rocks exposed on Mounts Stinear, Rymill, McCauley, and Scherger. Rock types in this sequence (including subordinate mica schist) alternate in layers a few meters to over 100 meters in thickness. Cummingtonite is found in amphibolitic rocks. Tingey and England (1973) report a similar unit from Mount Menzies.

Metasedimentary rocks exposed on Mount Ruker are (1) banded iron formation (150 to 200 meters thick, bottom not exposed), (2) green slate, in places with carbonate (1,500 meters), (3) quartzite (in part conglomeratic or cross-bedded), slate, and calcareous or ankeritic phyllite alternating in layers 5 to 50 meters thick (300 to 400 meters), (4) conglomeratic mudstone (10 to 35 meters, "c" on map; figure 2), and (5) green phyllite (top not exposed). The conglomeratic mudstone is brown, unlayered, and has more matrix than clasts. This rock resembles conglomerates from Mount Rubin (Grikurov and Soloviev, 1974, page 27).

Dikes, sills, and tabular bodies of mafic rocks up to 100 meters or more across are abundant on Mounts Stinear, Rymill, and Ruker. These mafic rocks in places have discordant and chilled contacts and generally show evidence of recrystallization during regional metamorphism. Mafic intrusive rocks are widespread in the southern Prince Charles Mountains (Tingey and England, 1973; Tingey, 1975).

Kyanite, staurolite, sillimanite, and garnet are common aluminum-rich minerals (figure 1). Other aluminum-rich minerals are (1) chloritoid, associated with staurolite and chlorite in quartzite on Mount Rymill, (2) andalusite, on Mounts Rymill and Stinear, and (3) cordierite in schist with quartz, kyanite, sillimanite, staurolite, and biotite on Mount McCauley.

High-angle faults on Mount Stinear were active prior to regional metamorphism. Mafic rocks were subsequently emplaced along some of these faults, notably those striking north N. 25°W. to N. 45° W. Faults exposed on Mount Ruker (displacements of roughly 40 and 300 meters) and on Mount Maguire (including the gently south-dipping fault between the map units "ms" and "mv") are post-metamorphic.

A sequence of geologic events in the Prince Charles Mountains consistent with available field data is (a) deposition of sedimentary and volcanogenic rocks on a deeply eroded gneiss complex; (b) emplacement of mafic rocks and high-angle faulting; (c) regional metamorphism, folding, and emplacement of granite and pegmatite; and (d) faulting.

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Weathering stages of a tholeiitic basalt (dolerite), Queen Maud Mountains

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The sparsity of datable material and key horizons throughout most of the Transantarctic Mountains

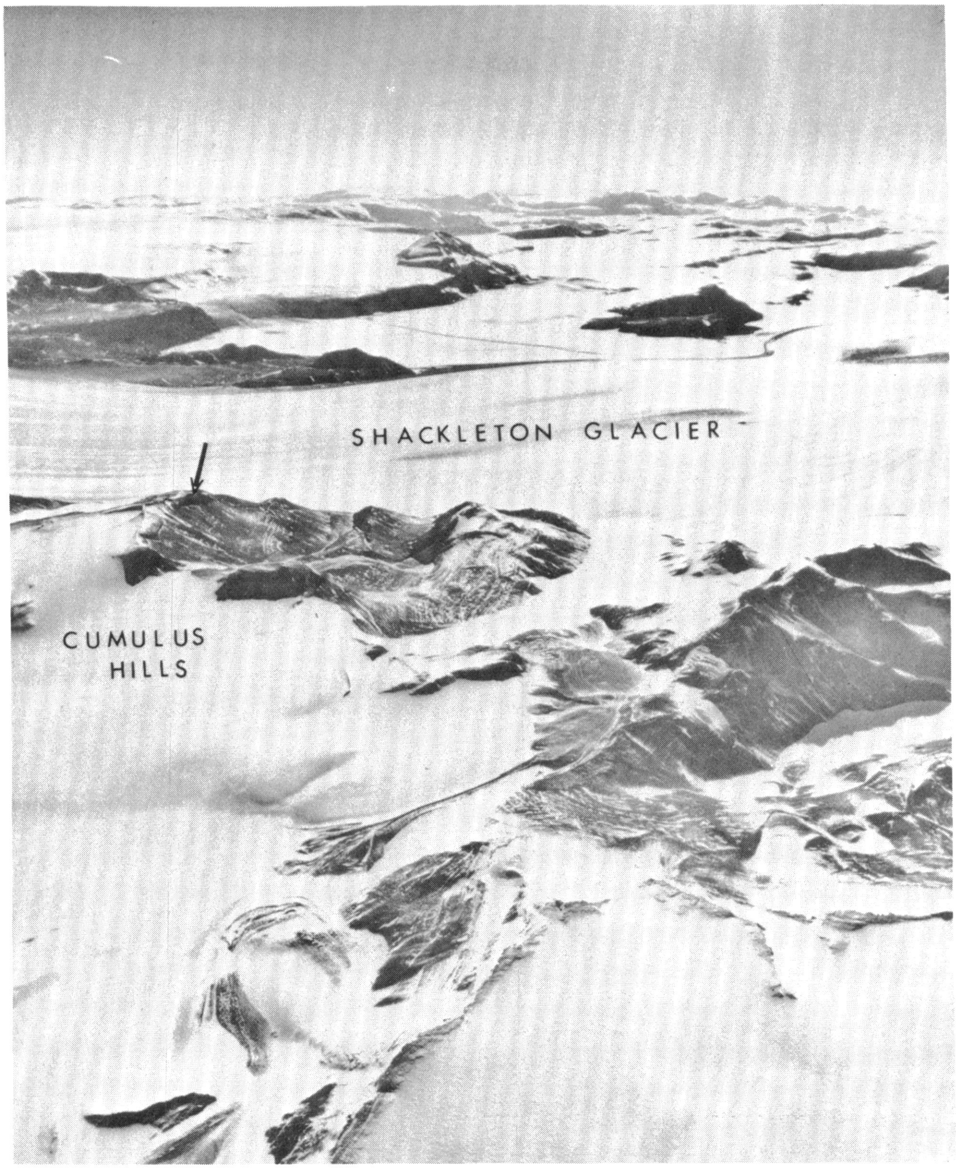

Figure 1. Location of the study site (marked by arrow). Air photo (U.S. Navy TMA 1006 4227 F31) looking west across the Shackleton Glacier.

requires that much of the mapping and correlation of glacial deposits, especially moraines, be based primarily on qualitative techniques. One qualitative method is to characterize the degree of weathering of clasts covering these deposits (Behling, 1971; Calkin, 1971; Nichols, 1971; and Mayewski, 1975). Lacking, however, is a detailed understanding of the role and method of weathering. To help solve this problem, soil studies have been made by Claridge and Campbell (1968) in the Shackleton Glacier region and Everett and Behling (1968), Linkletter (1972), Behling (1971), and Everett (1971) in the dry valleys of southern Victoria Land. Studies on individual lithologies (see, for example, Kelly and Zumberge, 1961) demonstrate the need for more sharply delimited studies, and we are examining a weathering suite of tholeiitic basalts (dolerites) from a site in the Queen Maud Mountains.

In the austral summer of 1970-1971, Dr. Mayewski collected a sequence of weathered tholeiitic basalts of the Ferrar Dolerite Formation for laboratory differentiation of internal and external weathering zones. The site is in the northern Cumulus Hills (figure 1) adjacent to the Shackleton Glacier, at approximately 85°10'S. 175°30'E. The site consists of a northeast facing slope at approximately 2,000 meters elevation. A columnar jointed, near vertically dipping basalt dike, several meters wide, forming a ridge crest, acted as a source area for the basalt clasts. A litter of these clasts had apparently spalled off the dike and onto an adjacent slope (average slope angle 18°) composed of cryoturbated mudstones and sandstones of the Fre-

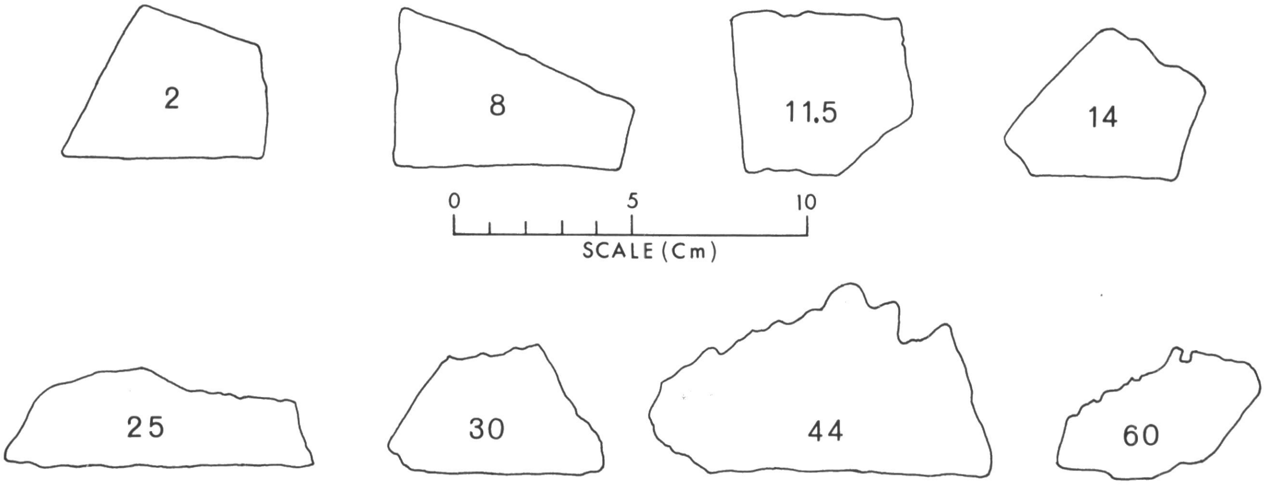

Figure 2. Cross-sectional views of samples with field orientations maintained. Distance from ridge crest in meters in noted on the samples. Note that the sample at 11.5 meters, based on its shape and surface features, may have been rotated recently.

mouw Formation. Solifluction induced downslope transport of the basalt clasts. A sampling traverse was taken from the ridge crest to 60 meters downslope. As nearly representative clasts as could be discerned by eye were collected 2, 8, 11.5, 14, 25, 30, 44, and 60 meters downslope from the ridge crest.

The site has several advantages. It is representative of ice-free areas in the Queen Maud Mountains, and it is small, thus minimizing microclimatic effects. Also, the basalt clasts and the underlying Fremouw Formation have widely divergent weathering rates, the former being far more resistant, thus minimizing their interrelation. The dike is an unweathered source for comparison, and downslope transport has produced a weathering continuum with increasing distance from the dike source. Lastly, the weathering suite has been above the level of active outlet glacier inundation for approximately the last 4.2 million years based on correlation with the elevation of nearby lateral moraines studied by Mayewski (1975).

Following are results of our preliminary weathering analysis.

Megascopic examination of characteristically angular basalt fragments from the dike demonstrates the variability of external morphology versus distance from the dike source (figure 2). Samples closest to the source (most recently spalled) display angular edges, nonpitted but slightly roughened surfaces, and a deep-brown color. Farther downslope, the samples, with increasing subaerial exposure, show decreasing angularity, smoother surfaces, darker brown colors, and cavernous weathering in the form of hollows (maximum 1.0 centimeter in depth). Development of hollows is accompanied by an increase in textural roughening within the hollows similar to the overall surfaces of the recently exposed samples.

In microscopic analysis, the basalt dike represents a typical tholeiite. Principal minerals are basic labradorite and subcalcic augite set in a reddish-brown devitrified glass and quartzo-feldspathic matrix. The texture is diabasic. Average grain size for the plagioclase and subcalcic augite is 0.2 millimeter. Microscopic measurement of the depth of penetration of various weathering zones on the top, side, and bottom surfaces reveals a systematic trend with distance from the source. To distinguish the various zones, a general reference scheme was developed, based on the color of the stain, the concentration of the staining, and mineral phases (including glass) affected by the staining, all of which are related to increasing exposure to weathering and, therefore, increasing distance from source.

This preliminary discussion deals with the outer two zones (4 and 5). Zone 5, the outermost or most weathered zone, is typified by a dark, red-brown coloration of the glass matrix and the pyroxene core plus an extensive red-brown coating on the plagioclase. Zone 4, the second zone from the sample edge, shows light red-brown (burnt-orange) coloration of the glass matrix and pyroxene core, along with a slight alteration of the plagioclase core. Zone 4 thicknesses were measured from the inner edge of zone 5 inward toward the center of the sample until weathering zone 3 was detected. The thicknesses of zones 4 and 5 are plotted on figure 3. The data suggest:

(1) Zone 5 thicknesses (top, bottom, and side) increase in a generally linear fashion with respect to distance from source (greater duration of exposure). Minor breaks occur between samples at

sites 8 and 14 meters (top, bottom, and side), 25 and 30 meters (side), and 44 and 60 meters (top). Zone 5 thicknesses appear to reach a critical value at roughly 0.5 millimeter. This phenomenon is believed related to the relative degree of weathering of the glass phase prior to total disintegration and production of soils.

(2) Zone 4 thicknesses (top, middle, and side) reflect a less regular relationship to distances from source than zone 5. Samples with less duration to exposure from locations at 8 and 11.5 meters reflect irregular zone 4 thicknesses versus distance from source, which changes to a more linear relationship at 14 meters for top and bottom thicknesses, but remains irregular for side thicknesses. The random relationships are believed suggestive of a stage of pre-equilibrium thickness attainment that is prevented from being achieved for sample sides due to differences in microclimate. These microclimatic effects are less effective on insulated sample bottoms and totally exposed sample tops, and therefore, top and bottom thicknesses eventually demonstrate more regular characteristics.

(3) Bottom thicknesses are generally not as great as top or side thicknesses. This suggests that atmospheric exposure is one of the decisive factors controlling the thickness of weathering rinds.

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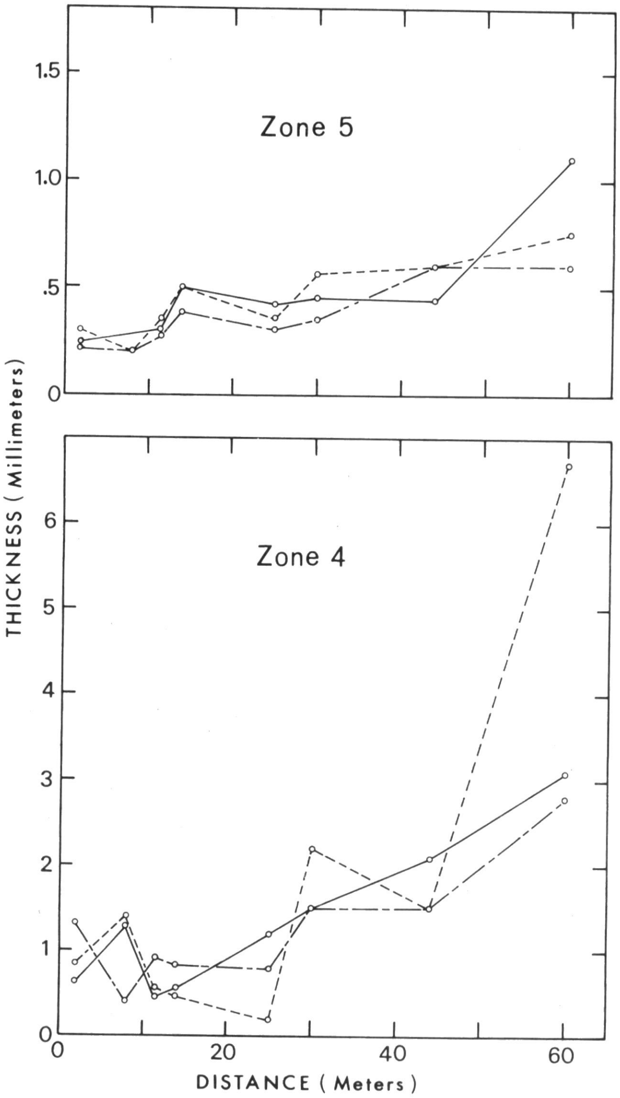

Figure 3. Zone 4 and 5 top, bottom, and side thicknesses plotted as a function of distance from ridge crest. Top—solid line; bottom—long dash, short dash; side—short dash.

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