Thirty years of measurements of sand wedge growth in lower Wright Valley, Antarctica

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Troy Pewe first reported the existence of nonsorted polygons with active sand wedges in the McMurdo Sound region and ice-free valleys, Antarctica (Pewe 1959). Bob Black, one of the acknowledged U.S. authorities on cold-region periglacial processes (along with Pewe and Lincoln Washburn), first visited the area the year following Pewe's reconnaissance. During the 1960–1961, 1961–1962, and 1962–1963 seasons, Black and his field assistants Tom Berg, Jim Sullivan, and Peter Vogt established 14 sites on Ross Island, in the Taylor, Beacon, and Wright Valleys, and at several miscellaneous sites (including Marble Point). The purpose of these sites was to monitor the growth of the sand wedges. In his previous studies in arctic environments, Black had shown that wedge growth was relatively monotonic; indeed, he had successfully used wedge growth rate and transverse dimension to estimate the age of glacial deposits and periglacial activity affecting them. During the 1963–1964 season, Black and Berg returned to Victoria Land and made measurements after 1–2 years. Their published results (Berg and Black 1966, pp. 61–108) indicate preliminary growth rates of 0.5 to 3.8 millimeters per year, measured over a year's time.

Black returned several times between 1967 and 1982 to measure the sites. The tone of his last *Antarctic Journal* article (Black 1982), suggested disappointment with the results of the study, which by 1982 suggested that the growth rate was highly variable and that, in fact, some wedges were shrinking. He concluded that only about half the sites had sufficiently "uniform" growth rates to be of any use in age dating and that "...many decades of measurement [would be] required to determine reasonably precise growth rates and ages over the lives of antarctic polygons" (p. 54).

If a project is truly long-term, death may overtake the investigator before it is completed. In the case of studies of nonsorted polygons in Antarctica, the most reasonable successor to Black—his co-investigator Tom Berg—died in Antarctica at a young age: the Berg Field Center is named for him. Black died in the mid-1980s without making provisions for the work to continue.

This past field season (1993–1994), during visits to test sites established 10 years ago to study chemical and physical weathering in the ice-free valleys and Transantarctic Mountains, we had the opportunity to examine a small number of Black's sites to see if the wedge growth behavior had changed over the past 12 years. On 21 January 1994, we spent a day in the lower Wright Valley looking for, and eventually recovering, three of Black's sites. The sites, designated in Berg and Black (1966, pp. 61–108) as Wright Valleys sites B, C, and D, are located immediately north (site C), and south (B, D) of the Onyx River at the locations shown in table 1.

Site D was 150 meters (m) south-southwest of the cairn at site B. Latitude and longitude were measured using a Magellan global positioning system receiver; elevation was measured using a Casio wristwatch altimeter/barometer calibrated against the deploying helicopter's altimeters.

Distances between all stakes were remeasured at sites B and C. Owing to time constraints, only about one-half the stake pairs were remeasured at site D. The same person read all measurements. At least three measurements were made, with a standard error on the order of less than 0.01 centimeter (cm). Our measurements are probably somewhat worse than this, and marginally worse than Black's, because we used a Lufkin 3-m steel tape measure rather than a low coefficient of thermal expansion (CTE) metal rule. If the tape measure we used was imprinted when the tape was at 27°C (about 80°F), and our measurements were made while the tape was –3°C (close to the actual air temperature measured throughout the period of wedge measurement), then for a CTE of 12×10^{-6} per degree C, the systematic offset of our measurements would be $12\times10^{-6}\times30\times$ approximately 100 cm or 0.036 cm. Thus, the results for 1982–1994 shown below are most reasonably accurate only to, say, 0.05 cm.

Using the data presented in Black (1982) and Berg and Black (1966, pp. 61–108), we computed the average growth rates for wedges at the sites over the period 1982 to 1994 (table 2). For comparison, we also give the rates from Black.

Given the precision of the measurements, it is unlikely that these decadal long averages are much in error. The non-monotonic variations seen by Black appear to have continued.

Because Black's study was initiated to examine age relationships by using monotonic growth of wedges as an age-dating technique, he may have found the variations in growth rate to be annoying at best. His 1982 paper was more than a little pessimistic about the chances of doing anything useful with the wedge measurements.

On the other hand, the cause of the variations in growth rate seems interesting. There are many possible factors contributing to the different rates—variations in moisture reach-

Table 1. Location of polygon sites in lower Wright Valley

Site	Latitude	Longitude	Elevation
B	77°26.82'S	162°31.78'E	940'
C	77°26.69'S	162°31.68'E	920'

Table 2. Average growth rates for wedges (cm/year)

	62–69	69–82	82–94	62–94
WV-B	1.39	0.78	0.71	0.89
WV-C	0.90	0.33	0.49	0.52
WV-D[a]	0.49	0.52	1.28	0.81

[a] Remeasurement incomplete at this site.

ing the wedge-growth zone, variations in slope response to near-by geomorphic action (for example, undercutting of the banks of the Onyx River), and variations in the contraction/expansion cycle of the perennially frozen ground in which the wedges are growing. The overriding factors causing all of these other contributing factors, however, are environmental: variations in temperature of the surface and subsurface owing to insolation variations, air temperature variations and the like. These changes in the rate of wedge growth represent a 30+ year record of their response to environmental change.

Consider, for example, temperature control of the wedging process. Owing to the 15–50 cm of relatively dry (certainly unsaturated) regolith overlying the permafrost in southern Victoria Land, the annual temperature wave attenuates quickly: measured 50°C annual surface temperature excursions are less than 15° at the top of the permafrost and less than 7° at 5 m depth. These values suggest a thermal skin depth for annual variations of roughly 15 cm in the regolith and 3 m in the permafrost. Calculations of the thermal skin depth that use textbook values for average thermophysical properties give comparable numbers. Using such calculations, we can show that decadal-long temperature excursions of a few degrees are less affected by the regolith: a 5°C surface excursion is still nearly 4° at the top of the regolith and over 2° at 5 m depth. Taken as an integral, the cumulative effects of variations on timescales of decades to centuries are likely to contribute as much as one-third or more to the temperature variation seen at the depth where wedges are formed. The magnitudes of the variations seen by Black (and in our measurements) are of this order.

It has been suggested that Black's sites be removed as part of the general cleanup of the ice-free valleys. It is our opinion that this should not occur, because they may prove useful in monitoring long-term environmental change in the ice-free valleys.

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Late Wisconsin/Holocene history of the Wilson Piedmont Glacier

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The extent—and even the existence—of a grounded ice sheet in the Ross Sea during the last glacial maximum remains an unresolved question. Based on the distribution and generally low elevations (32 meters or less) of Holocene raised beaches along the Scott Coast (figure 1), Colhoun et al. (1992) and Kirk (1991, pp. 85–105) suggested not only that grounded ice in the Ross Sea was areally limited but also that the thickest grounded ice emanated from Victoria Land near Mackay Glacier. This view is at odds with the hypothesis of an extensive, grounded Ross Sea ice sheet that flowed into McMurdo Sound and projected into ice-free valleys of the Transantarctic Mountains (Denton et al. 1989; Stuiver et al. 1981, pp. 319–436).

We present here new evidence pertaining to the late Wisconsin/Holocene history of the Wilson Piedmont Glacier, which is situated in southern Victoria Land beside the critical raised beaches of the Scott Coast (figure 1). The Wilson Piedmont Glacier covers over 800 square kilometers and extends from Hjorth Hill to Mackay Glacier. An ice divide trends north-south along the central axis of the glacier, with flow from the divide both east toward the Scott Coast and west into Wright Valley. Much of the eastern flank of the Wilson Piedmont Glacier calves into the Ross Sea and McMurdo Sound along the Scott Coast, but Cape Bernacchi, Marble Point, Gneiss Point, Spike Cape, Dunlop Island, and Cape Roberts remain free of ice and reveal the raised beaches that constitute a key piece of evidence used by Colhoun et al. (1992) to suggest restricted grounded ice in the Ross Sea. Here, we discuss the significance of local glacial geology to the interpretation of raised beaches on the Scott Coast.