Glacial geology

A re-interpretation of glaciovolcanic interaction at Mount Takahe and Mount Murphy, Marie Byrd Land, Antarctica

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Mount Takahe and Mount Murphy, two volcanoes in eastern Marie Byrd Land, were last visited during the 1967 – 1968 austral summer. On the basis of the brief reconnaissance field work, LeMasurier (1972) and LeMasurier and Rex (1983) suggested that both volcanoes formed subglacially, indicating that the level of the west antarctic ice sheet had fluctuated through a range 2,000 meters during Quaternary time. This interpretation rested on the sampling of hyaloclastite deposits (palagonitic sideromelane tuff-breccias) around the base of each volcano, some of which yielded potassium-argon dates of less than 1 million years ago. Hyaloclastite is produced by eruptions in subglacial or subaqueous environments as a consequence of water-magma interaction.

Mount Takahe and Mount Murphy were reexamined in greater detail during the 1984 – 1985 austral summer by a snowmobile-equipped team of four geologists and two mountaineers. Outcrops representing the basal and upper portions of each volcano were visited. New field observations suggest that the former interpretation of 2,000-meter fluctuations in ice-sheet level was too large. Instead, strong evidence was found that, during the eruptive histories of these volcanoes, ice-level fluctuations reached elevations only 350 to 400 meters above the present surface of the west antarctic ice sheet.

This paper addresses only ice-level changes that occurred during the eruptive histories of these volcanoes; larger ice-level fluctuations may have occurred before or after the volcanoes formed.

Mount Takahe. Mount Takahe (3,460 meters) is a broad, symmetrical-shield volcano 30 kilometers in diameter, capped by a 8-kilometer-wide snow-filled summit caldera (figure 1). It is located 100 kilometers south of its nearest neighbor, Mount Murphy, and is entirely surrounded by the west antarctic ice sheet, locally averaging 1,300 meters above sea level in elevation. Mount Takahe is almost completely undissected, showing only two small valley glaciers on the north and southwest flanks. The three available potassium-argon dates from Mount Takahe range from less than 250,000 years to 300,000 ± 300,000 years (LeMasurier and Rex 1983).

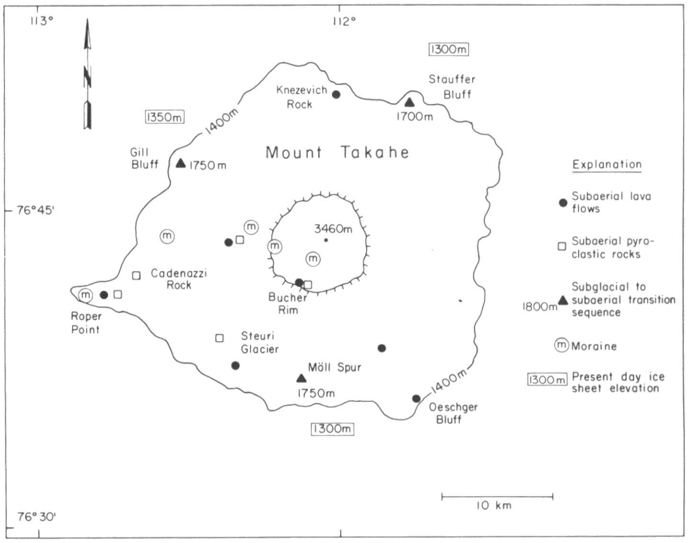

Figure 1. Map of Mount Takahe, showing localities visited and rock types observed. The 1,400-meter contour closely follows the base of the volcano and the hatched line denotes the snow-filled summit caldera. ("m" denotes "meter." "km" denotes "kilometer.") The symbol for subaerial pyroclastic rocks includes predominately hydroclastic and strombolian tuffs.

During our 3-week-long study of Mount Takahe we visited 12 outcrop and five moraine localities (figure 1), representing all of the exposures on the mountain not threatened by overhanging icefalls.

Three localities—Gill Bluff, Möll Spur, and Stauffer Bluff—were found to contain subaqueous-to-subaerial volcanic transition sequences. The lower portions of these three sequences consist of subaqueously deposited pillows, pillow breccias, and hyaloclastites, in places showing crude foreset beds dipping outward from the volcano. At Gill Bluff and Moll Spur, these units grade upward into subaerial lava flows; individual flows at Gill Bluff could be traced laterally from subaerial lavas into subaqueous pillows and breccias. At Stauffer Bluff, the basal pillows, breccias, and hyaloclastites are capped by subaerially accumulated tuff-cone deposits containing abundant accretionary lapilli. At all three localities the subaqueous-to-subaerial transitions are located 350 to 400 meters above the present level of the continental ice sheet. The sequences at these three localities are similar to Icelandic "flow-foot breccia" sequences described from the flanks of table mountains where subaerial lava flows entered glacial meltwater lakes (Sigvaldason 1968; Jones 1969) and from littoral areas where lavas entered the sea (Furnes and Fridleifsson 1974).

The remaining nine outcrop localities all exhibit distinctive subaerially formed rock types. Around the base of the volcano, lava flows are exposed at Roper Point, Oeschger Bluff and a nearby nunatak, Knezevich Rocks, and along the Steuri Glacier (figure 1). Some of these lava flow outcrops extend down nearly to the present level of the continental ice sheet. Subordinate amounts of distinctive subaerial pyroclastic rocks, including accretionary lapilli tuffs and/or welded airfall units, were observed at Cadenazzi Rock, Steuri Glacier, and near Roper Point. Both lavas and airfall tuffs are present at an unnamed nunatak located at 2,900 meters elevation on Takahe's western flank. At Bucher Rim, on the southern edge of the caldera, we observed a 60-meter thick sequence of lavas, welded airfall tuffs, accretionary lapilli tuffs, and obsidian bomb-and-block units.

In addition to the above outcrops, all exposures of glacial till and moraines were observed to contain primarily clasts of lava and subaerial pyroclastic rocks; hyaloclastite erratics are rare.

The predominance of subaerial rock types at Mount Takahe strongly suggests that most of the exposed portions of the mountain formed subaerially. The presence of both subaerial and subaquatic/subglacial rock types near the base of the volcano indicates that the level of the continental ice sheet fluctuated during Mount Takahe's eruptive history, reaching levels 350 to 400 meters above the present ice-sheet surface. Because Mount Takahe is so undissected, only its outer carapace was observable. The nature and eruptive environment of the older rocks forming its interior are unknown.

Mount Murphy. Mount Murphy (2,703 meters) shows a general, broad, gentle shield morphology (figure 2), probably originally similar to Mount Takahe but now deeply dissected. The elevation of the present day continental ice sheet is 750 meters above sea level on the south side of Mount Murphy, stepping down to 200 meters above sea level on the north side. Two previous dated samples, one from the flanks of Mount Murphy and a second from Turtle Peak, an adjacent nunatak, yielded potassium-argon ages of 0.9 ± 0.3 million years and 14.0 ± 2.0 million years respectively (LeMasurier and Rex 1983).

This season's 5 days of field work on Mount Murphy were concentrated on the southwestern portion of the mountain, including the ridge between Bucher Peak and Sechrist Peak, cliffs along the base of the west-facing cirque below this ridge, and adjacent Turtle Peak and Hedin Nunatak (figure 2).

As at Mount Takahe, subaquatic/subglacial rock types are confined to lower outcrops. Hyaloclastites and palagonitic breccias, interbedded with subordinate subaerial lavas, were observed in the lower portions of cliffs along the western edge of Mount Murphy and along the eastern margins of nearby Turtle Peak and Hedin Nunatak. The upper portions of these three exposures consist predominantly of subaerial lava flows and subordinate strombolian tuffs. The elevation of the transition from partially subaqueous to wholly subaerial rock types at these three exposures ranges from 100 to 250 meters above the present ice level.

With the exception of Sechrist Peak, the entire observed upper portion of Mount Murphy consists of subaerial lava flows, welded spatter, and strombolian tuffs, extending at least as high as Bucher Peak (2,446 meters).

Palagonitic tuffs and breccias, intruded by basalts and showing considerable soft-sediment deformation, comprise the bulk of Sechrist Peak (1,350 meters, figure 2), which stands above the exposures described above, and extends to 600 meters above the present level of the continental ice sheet to the south. The origin of these units is uncertain. Water-magma interactions were certainly involved in their formation, but because no subaqueous-to-subaerial transition was observed, the level of the continental ice sheet cannot be confidently inferred.

A prominent striated glacial unconformity was observed on the top of a subaerial lava flow near the base of Mount Murphy's west-facing cirque. This unconformity is overlain by 2 to 3 meters of black tillite containing striated basaltic cobbles. The tillite is in turn overlain by palagonitic breccia and lava flows.

Like Mount Takahe, Mount Murphy was apparently erupted under predominantly subaerial conditions. Deep dissection has exposed older interior portions of the volcano. The presence of intercalated subaqueous/subglacial and subaerial lavas in the lowermost exposures, as well as at least one glacial unconformity, suggest that small (less than 250 meters) ice-level fluctuations occurred early in Mount Murphy's eruptive history.

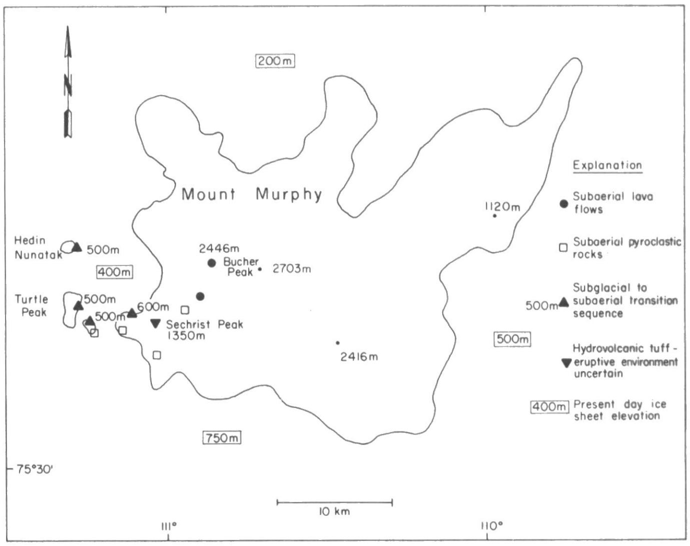

Figure 2. Map of Mount Murphy, showing localities visited and rock types observed. The line denoting the base of the volcano does not represent an elevation contour. ("m" denotes "meter." "km" denotes "kilometer.")

The age of Mount Murphy is uncertain. However, the advanced degree of dissection of the thick section of lavas suggests that Mount Murphy may be considerably older than the 0.9 ± 0.3 million year age suggested by LeMasurier and Rex (1983). (See Andrews and LeMasurier 1973.)

Conclusions. Petrologic and petrographic laboratory work and potassium-argon and fission-track dating of samples collected at Mount Takahe and Mount Murphy are presently in progress. Field observations, however, indicate that both volcanoes were erupted under predominantly subaerial conditions. There is good evidence for fluctuations in the level of the continental ice sheet during their eruptive histories. However, these fluctuations reached maximum levels of 350 to 400 meters above the present surface of the west antarctic ice sheet, rather than 2,000 meters as previously believed.

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Radiocarbon chronology of the last glaciation in McMurdo Sound, Antarctica

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Ross Sea drift forms a nearly continuous sheet on the west coast of McMurdo Sound, on volcanic islands and peninsulas in the sound, and in eastern ends of ice-free valleys in the adjacent Transantarctic Mountains (Stuiver et al. 1981). This drift records the youngest grounded ice sheet to occupy McMurdo Sound and the western Ross Sea (Denton, Armstrong, and Stuiver 1971). Because an accurate chronology of the Ross Sea glaciation is essential to deducing the antarctic ice sheet's role in the last global ice age, we have undertaken during the last several austral summer seasons a program of radiocarbon dating and geologic field mapping in Taylor Valley. We now report only preliminary results, because many dating samples await.

Glacial Lake Washburn occupied the coastal Fryxell and the inland Bonney basins of Taylor Valley during the Ross Sea glaciation. Radiocarbon dates of fossil blue-green algae in perched deltas on the valley walls afford a chronology of former lake levels in both basins. Two models relate these lake levels to the areal extent of the Ross Sea ice lobe in eastern Taylor Valley. The first model postulates a substantial source of subglacial water from beneath Ross Sea ice to augment minor surface meltwater flow from side-wall valley glaciers (Stuiver et al. 1981, pp. 345 – 355). According to this model, changes in the areal extent of the Ross Sea ice lobe in lower Taylor Valley caused lake-level variations in both basins. Ross Sea ice expansion into the Fryxell basin displaced lake water and diminished the lake-surface ablation area, hence causing lake-level rise and water spillage over the mid-valley threshold into the Bonney basin. By the same line of reasoning, Ross Sea ice recession caused lake-level drop. Hence, the highest radiocarbon-dated lake levels between 17,000 and 21,200 years ago were assumed to be coeval with maximum Ross Sea ice advance. Likewise, lake levels in the Bonney basin below the mid-valley threshold were related to Ross Sea ice extent, which controlled overflow from the Fryxell basin.

Recent field work and numerous new radiocarbon dates, particularly of perched deltas in the Bonney basin, permit a second model of lake-level fluctuations. On the basis of new geologic data, this model precludes a subglacial water source in eastern Taylor Valley, as well as water overflow from the Fryxell to the Bonney basin. Rather, input into Glacial Lake Washburn in both basins was strictly from surface meltwater streams draining all glaciers that flowed into the valley. Variations of the Ross Sea ice lobe did not exert a primary control on lake-level fluctuations in either basin. Instead, summer temperature and corresponding surface glacial melt were the primary influence on lake-level variations. These variations, in turn, drove fluctuations of the Ross Sea ice lobe in lower Taylor Valley, rather than the reverse situation as postulated by the first model. By the new model, thick blocking ice in McMurdo Sound still reflected an extensive grounded ice sheet due to lowered global sea level. However, summer temperatures and corresponding lake levels drove fluctuations of the thin ice lobe that projected into lower Taylor Valley from this grounded ice sheet. Warm summers and rising lake levels forced Ross Sea ice back to the high valley-mouth threshold; conversely, cold summers and falling lake levels permitted Ross Sea ice advance westward into the valley.