Glacial geology

Glacial history of the Ellsworth Mountains

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As part of the Ellsworth Mountains Project, we mapped glacial erosional and depositional features throughout the Ellsworth Mountains. Our primary objective was to relate the local glacial history to overall fluctuations of the west antarctic ice sheet, particularly during late Wisconsin and Holocene times.

The Ellsworth Mountains, which include the Sentinel and Heritage Ranges, stretch for 350 kilometers northwest-southeast (bounded by longitudes 80° and 87°W and latitudes 80°30′ and 77°15′S) near the present grounding line between the west antarctic ice sheet and the Ronne Ice Shelf. Because of their unique position as a barrier between the interior ice sheet and the coast, they have recorded levels of the former seaward expansion of grounded west antarctic ice. Although minor amounts of ice pass eastward through the Heritage Range, most present west antarctic ice flows around the Ellsworth Mountains into the Ronne Ice Shelf from an inland dome that forms an arc from the interior, northern Heritage Range through the Whitmore Mountains to the Thiel Mountains (Drewry 1980). A small dome also occurs inland of the central Sentinel Range (Drewry 1980). Moreover, the northern Ellsworth Mountains lie immediately downstream from a low divide, on ice that is grounded well below sea level near the base of the Antarctic Peninsula and separates the Ronne Ice Shelf from Pine Island Bay. The fast-moving Pine Island ice stream, which is unimpeded by a buttressing ice shelf, flows from this divide into Pine Island Bay. Stuiver, Denton, Hughes, and Fastook (1980) suggested that this is the portion of west antarctic ice most susceptible to future collapse.

Our study, which confirms the basic conclusions of Craddock, Anderson, and Webers (1964) and Rutford (1972), shows two phases of glacial history. First, both the Sentinel and Heritage Ranges exhibit classic features of alpine-glacier erosion. Although such erosion still occurs, several facts suggest that most alpine features antedate the current partial submergence of the mountains by the west antarctic ice sheet. The alpine topography commonly projects beneath the ice sheet, and on satellite images the shadow of classic alpine topography emerges through the thin ice sheet cover on the highland that projects southwest from the Ellsworth Mountains to the Whitmore Mountains. Many west-facing cirques in the Heritage Range are now innundated by the ice sheet; moreover, many east-facing cirques are now relict because the enveloping ice-sheet surface directs katabatic winds eastward through the range, leading to blue-ice ablation areas or ice-free areas in topographically favorable localities such as these cirques.

The second phase of glacial history involves partial submergence of the Ellsworth Mountains by a thicker-than-present west antarctic ice sheet, followed by a decline of the ice-sheet surface to the present level. The high ice-sheet surface left a well-defined trimline between two altitudinally defined landscape types that are best exhibited in widespread quartzite bedrock but also characterize other rock types. Bedrock crests and ridges above the trimline are highly serrated and show no signs of glacier overriding. On the other hand, bedrock crests and ridges below the trimline are never serrated and commonly show polish, striations, and grooves indicative of ice sheet overriding. Moreover, drift patches and erratics, as well as occasional moraines near blue-ice areas, occur below the trimline, particularly in the Heritage Range. We judge that the trimline is a recent feature—probably late Wisconsin in age by comparison with radiocarbon-dated features in the Transantarctic Mountains—because the striated and polished bedrock is well preserved, the erratics commonly are unweathered and show surface striations, quantitative studies of the drift show very little soil development (Bockheim this volume), and there are no sharp breaks in weathering of drift or glacially eroded bedrock below the trimline. We also think that the ice-sheet surface lowered to its present level quite recently, probably during late Wisconsin and Holocene time. We infer that evidence of any former, more extensive submergence of the mountains by the ice sheet would have been removed by the continuous frost-shattering of bedrock that produces the serrated crests on the steep ridges and crests above the trimline.

The areal pattern of the trimline allows reproduction of the former ice-sheet surface, which attained elevations of 3,000 to 2,000 meters on the interior flank and of 2,300 to 1,700 meters on the ice-shelf flank. Moreover, this areal pattern, as well as ice-flow indicators and erratic distribution, shows that former ice-flow directions and positions of domes are similar to those of today. Taken together with the presence of freshly polished and striated granite bedrock surfaces noted by B. G. Andersen on the summit of Mount Powell in the Thiel Mountains, these data strongly suggest that the interior "Whitmore" dome of the west antarctic ice sheet thickened 300 to 500 meters but remained in the same position during the last glaciation.

Evidence from the Ellsworth Mountains suggests to us that in late Wisconsin time a thicker-than-present west antarctic ice sheet poured seaward around and through the Ellsworth Mountains, while at least one interior dome attained a higher-than-present elevation. Glaciological reconstructions adjusted to fit elevations of the last Wisconsin ice-sheet surface near the Ellsworth Mountains suggest that grounded ice occupied much of the present area of the Ronne Ice shelf and southern Weddell Sea. The precise areal distribution of this grounded ice must await detailed examination of marine sediment cores from the floor of the southern Weddell Sea, although preliminary examination of available sediment cores suggests widespread surface or near-surface till.

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Glacial marine sedimentation in the Ross Sea, DSDP sites 270–273

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Over 24 percent of the ice surface area covering the Antarctic Continent drains into the Ross Sea. Thus, any major climatic changes affecting glaciation on Antarctica will likely be reflected in the glacial marine sedimentary record in the Ross Sea. The present research involves a stratigraphic study of Oligocene through Pliocene glacial marine sections in the eastern and western Ross Sea (figure 1). It also provides an opportunity to compare Ross Sea piston core data with the stratigraphic sections. The study entails initial textural and mineralogic identification of basal tills versus glacial marine sediments in piston cores from this region to distinguish grounded from floating ice deposits. This is accomplished using statistical criteria outlined by Anderson, Kurtz, Domack, and Balshaw (1980). The focus then shifts to identifying these deposits in the thick glacial marine sections recovered at Deep Sea Drilling Project (DSDP) sites 270, 271, and 272 in the western Ross Sea and site 273 in the eastern Ross Sea. In this case, "east" and "west" are defined in relation to the 180° meridian bisecting the Ross Sea.

Basal tills, glacial marine sediments, and sediments borderline between these two are recognized at the DSDP sites (figure 2) as well as eight texturally homogeneous till units, most averaging 20 meters in thickness (figure 3). The relative position of these units in the DSDP stratigraphic columns are used to model the advances and retreats of the Ross Ice Sheet grounding line during the Oligocene through Pliocene. These data also support depositon of a