



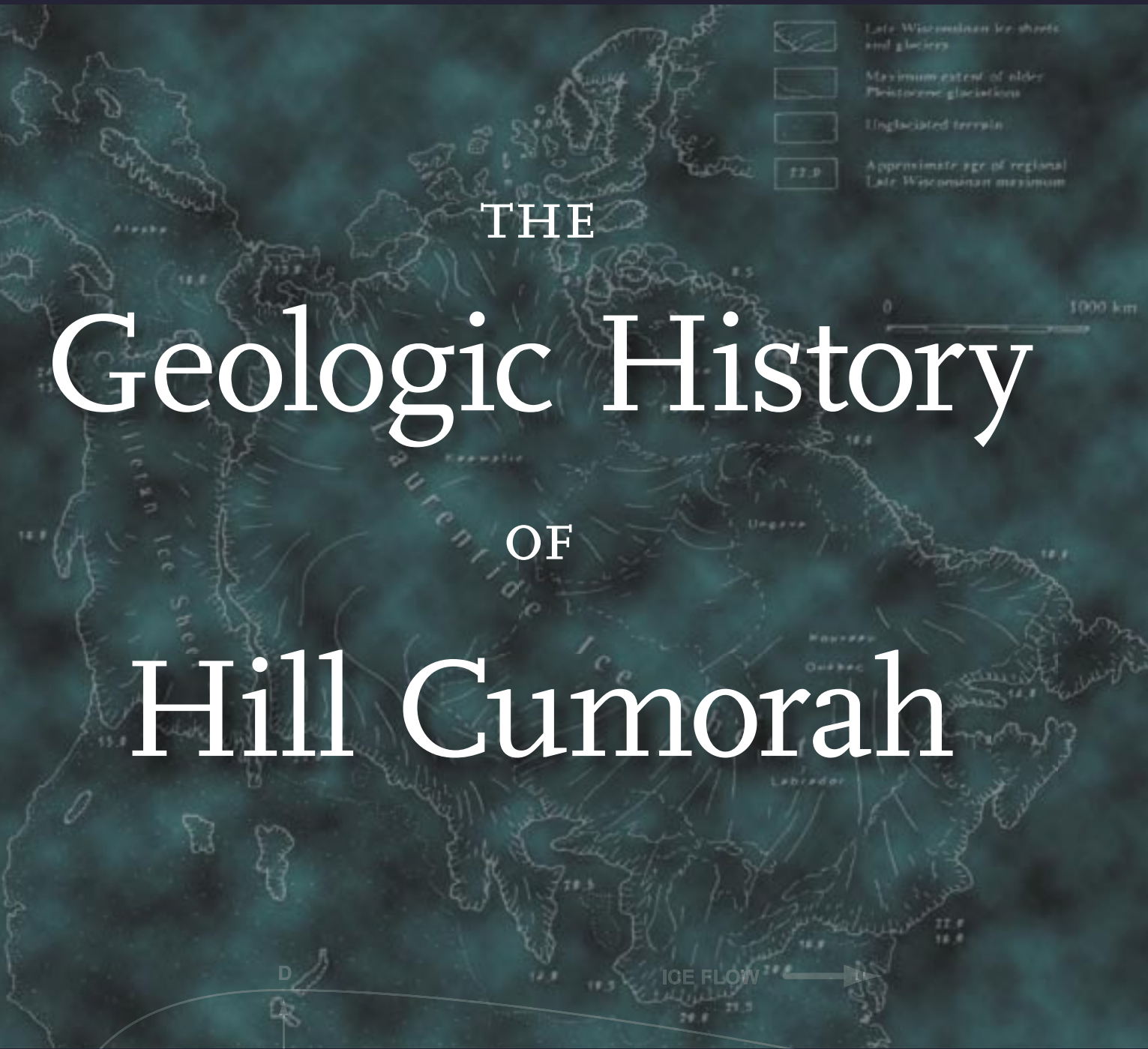




-  Late Wisconsinan ice sheets and glaciers
-  Maximum extent of older Pleistocene glaciations
-  Unglaciated terrain
-  Approximate age of regional Late Wisconsinan maximum

# THE Geologic History OF Hill Cumorah



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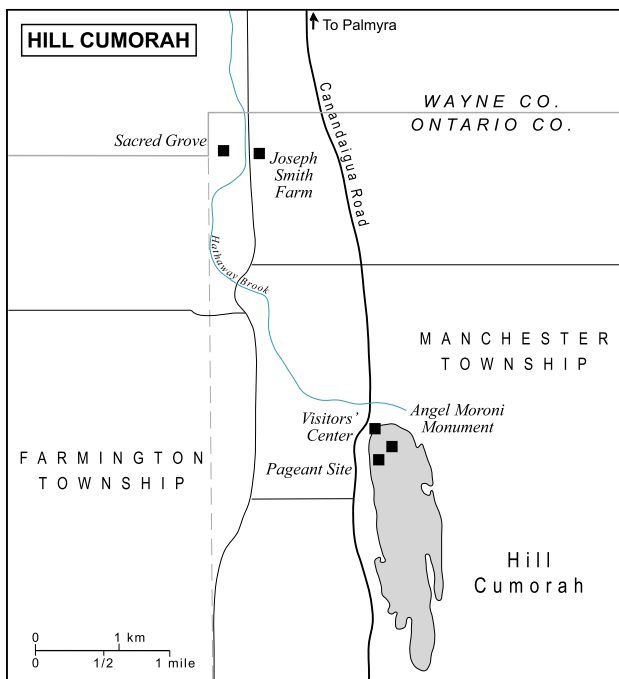
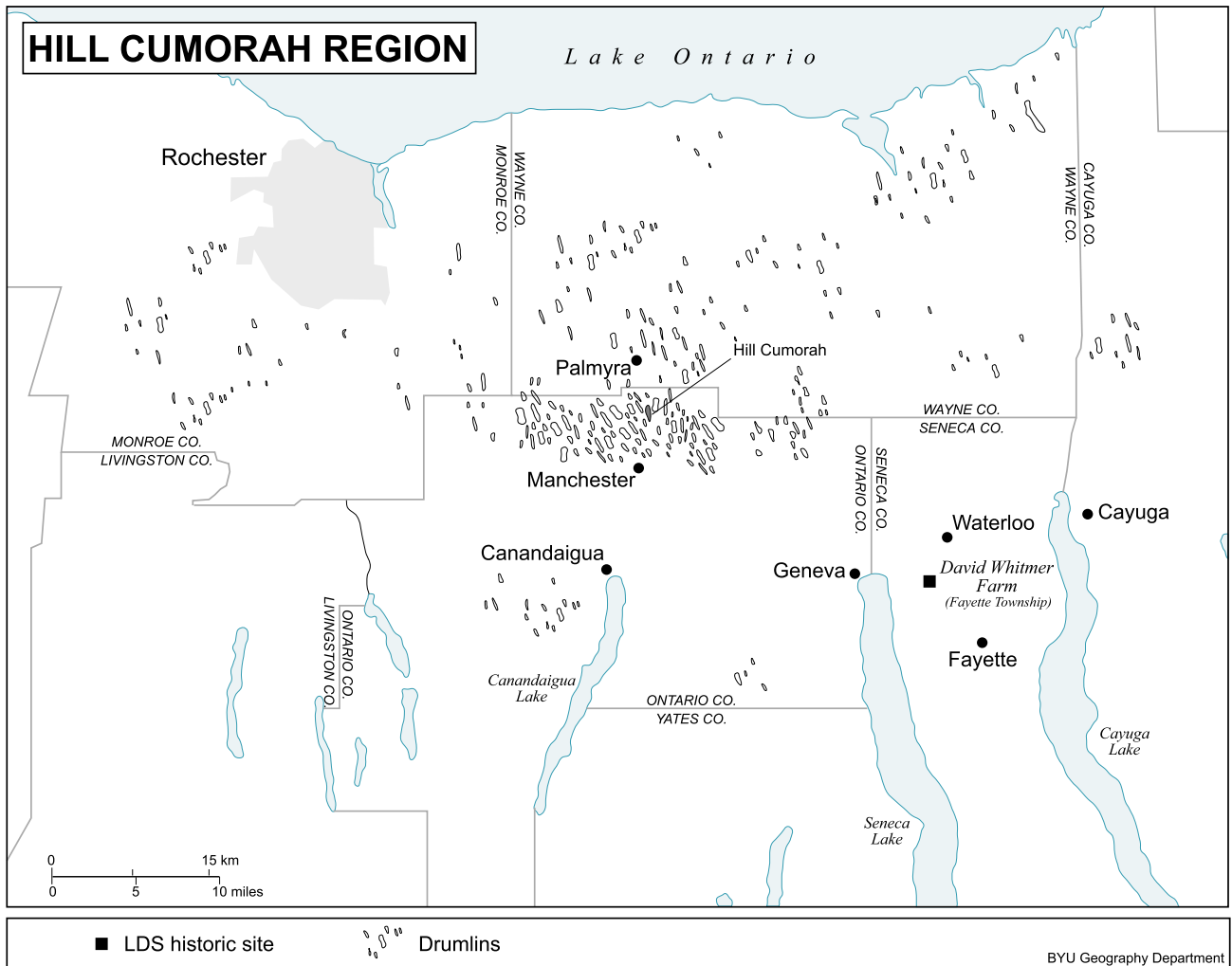
**C**UMORAH! THE VERY MENTION of the name brings multiple images to the minds of Latter-day Saints. We commonly think of the coming forth of the golden plates under the direction of the angel Moroni and of the faithfulness of the Prophet Joseph Smith in fulfilling his mission. We may also think of the preparation of the plates themselves, from Nephi's making a second set of plates, whose ultimate purposes he knew not, to Moroni's final words engraved on that sacred record before he placed it in the Hill Cumorah. The preparation of the Smith family may come to mind as well, such as the fact that Joseph was born of righteous parents and thus was spiritually prepared to become the prophet of the restoration. Perhaps less thought goes to the climatic<sup>1</sup> and financial difficulties that the Smith family experienced while living in New England, prompting them to move to New York in proximity to Cumorah, where a new dispensation would dawn.

But what of Hill Cumorah itself? The Lord in his foreknowledge knew that this hill would be the depository of the plates. What geologic processes occurred to form the hill and surrounding lands that would be attractive to the Smiths and other settlers in the early 19th century? Why was it a suitable

location for storing the golden plates for hundreds of years until the stone box that contained them was first opened by the boy prophet? A look at the geologic history of the Hill Cumorah affords answers to these questions.

### Setting of Hill Cumorah

Cumorah is perhaps the most famous drumlin in the world, other than Breed's Hill, where the Battle of Bunker Hill took place during the American Revolutionary War. A drumlin, after the Gaelic word *druim* for hill, is an elongated hill formed by glacial processes. Cumorah is one of 10,000 similar hills of west-central New York that compose one of the largest drumlin fields in the world (see fig. 1). The field defines an east-west trending belt about 35 miles wide bordering the south side of Lake Ontario and extends for about 140 miles from Syracuse to the Niagara River.<sup>2</sup> In order to understand the processes that formed Hill Cumorah, a brief explanation of the causes of continental glaciation, the extent of Pleistocene glaciation, and the geomorphological evidence of glaciation in the Palmyra region of New York is in order.



**Figure 1.** Numerous drumlins are scattered throughout the Hill Cumorah region (above), including the one named Hill Cumorah (left). Maps from *Historical Atlas of Mormonism*. © 1994 by The Gale Group. Reprinted by permission of The Gale Group.

### CAUSES OF GLACIATION

The geologic record preserves evidence of many glacial advances and retreats during the last billion years of the earth's history. However, these glaciation events are somewhat unusual in that conditions conducive to widespread glaciation occurred only during specific times: the late Proterozoic (ca. 800 to 600 million years ago), the Pennsylvanian and Permian (ca. 350 to 250 million years ago), and the late Neogene to Quaternary (the last 4 million years).<sup>3</sup> Within each of these major periods, many short-term fluctuations occurred in which ice sheets and glaciers repeatedly advanced and retreated. The causes, while not completely understood, are com-



nents (such as the current position of Antarctica) or by restricted, landlocked oceanic basins (such as the present configuration of the Arctic Ocean), conditions were favorable and, coupled with the astronomical factors, contributed to icehouse conditions and widespread glaciation.

During periods when all of the above factors, or at least the necessary combination of the essential factors, caused global cooling, snow began to accumulate in the northern latitudes to the extent that vast glaciers covering huge land areas formed and began to flow across the northern regions of North America (glaciers formed in Europe and elsewhere as well).

#### DEFINITION AND TYPES OF GLACIERS

Glaciers are bodies of ice that are massive enough to flow under their own weight. They occur in regions where the input from winter snowfall exceeds what melts during the summer. Present-day sites of glacial formation occur only at high lati-

tudes or high elevations, but such was not the situation during the relatively recent geologic past.

Freshly fallen snow contains about 80 percent air among 20 percent ice crystals. The snow compacts as it is compressed by additional snowfall and partial melting. Over time, the snow becomes denser and contains an ever-decreasing amount of pore space for air as the grains become rounded and compacted. By the end of winter, old snow may have a porosity of about 50 percent. *Firn*, from a German word meaning “anything related to last year,” or in this usage “last year’s snow,” is even more granular and rounded, with a porosity of 20–30 percent. Deeply buried firn is further compacted and is transformed to glacial ice with less than 20 percent pore space. When accumulated snow and ice reach a thickness of about 130 feet, the ice is able to flow under its own weight even though it remains in the solid state.

Glaciers that form in mountains are called *alpine* or *valley glaciers*. These are rivers of moving ice that flow downhill. Once melted, they leave



**Figure 3.** This Greenland ice sheet resembles the ice sheet that once lay across the northeastern corridor of the United States and created an extensive drumlin field. Photo courtesy of Peter G. Knight.

behind eroded U-shaped valleys such as those of Yosemite Valley (in California's Sierra Nevada) and those of Little Cottonwood Canyon (in Utah's Wasatch Range). Other glaciers form ice sheets that are not confined to mountain valleys but cover large areas of thousands of square miles. The immense size of these glaciers is indicated by the name *continental glaciers*. There are currently two continental glaciers remaining on Earth, covering much of Greenland and Antarctica. These glaciers approach 10,000 feet in thickness and continually flow away from the main accumulation areas, much like pancake batter flows across a pan as additional batter is poured in the center of the pancake. A glacier of immense size, named the Laurentide Ice Sheet, was centered on Hudson Bay in Canada and flowed over large portions of North America. It was most extensive around 21,000 years ago, when glaciers covered most of Canada and much of the northern United States (see fig. 2).

When the input of snow to a glacier matches the output by melting and sublimation, the glacier's margin, or edge, remains stationary. In spite of the stationary margin, however, the ice is constantly flowing toward the margins, with the rate of melting being matched by the flow. When the rate of input is greater than that of melting, the mass of the glacier increases and the glacier advances over larger areas. Conversely, when the rate of input is less than that of melting, the mass of the glacier shrinks in size, even though the ice still continually flows toward the margins.

This constant movement of ice hundreds to thousands of feet thick gives a glacier an enormous capacity to erode the bedrock over which it flows. Erosion is mainly accomplished by *plucking*, as blocks of bedrock are removed along joints and fractures by the flowing ice, and by *abrasion*, which results in a tremendous amount of material being transported by continental glaciers, mainly in the lower portions of the continental ice sheet. Some of

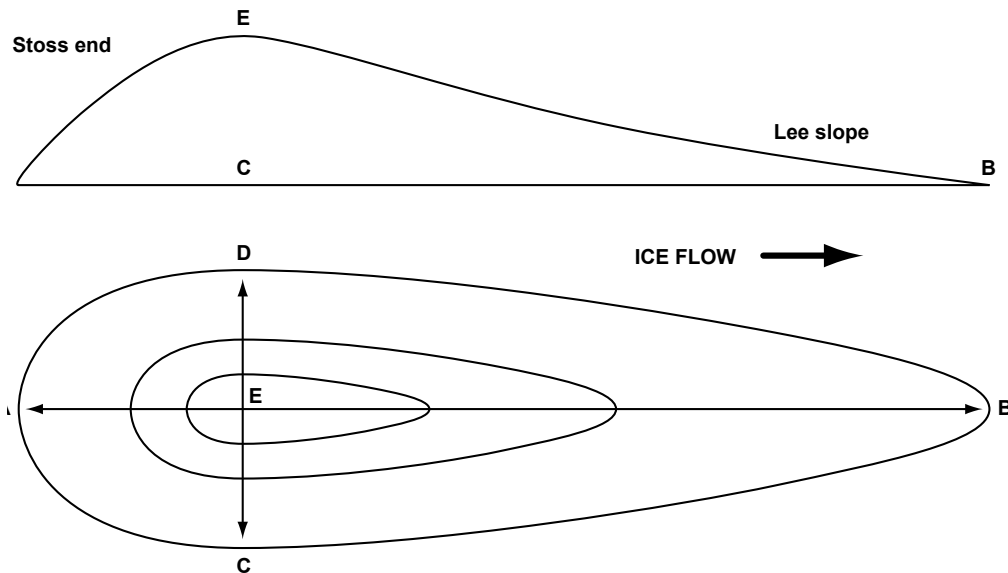


Figure 4. Profile and cross section of a drumlin with typical elongated and inverted-spoon shape.

this eroded material, called *drift*, is smeared below the glacial ice, but most is transported within or on the ice sheet to be dumped at the margin of the glacier in a similar manner to material being dropped at the edge of a conveyor belt. Accumulations of this marginal material, or *end moraines*, mark the extent of glaciation. Moraines occur south of the Hill Cumorah region, indicating that western New York was once completely covered by the Laurentide glacial sheet.

#### ORIGIN AND CHARACTERISTICS OF DRUMLINS AND HILL CUMORAH

A type of drift deposited by continental glaciers, drumlins are not uniformly distributed under continental glaciers but form in distinct areas called *drumlin swarms* or *fields* (see fig. 1). Although their dimensions vary, drumlins are elongated, tapered hills that range from one-half to three-quarters of a mile in length, are about a quarter of a mile wide, and rise approximately 100 to 150 feet above the surrounding lowlands.<sup>7</sup> In profile, they resemble inverted spoons with the shallow lee slope pointing in the direction of ice flow (see fig. 4). The aspect ratios of drumlins are thought to reflect the speed of the glacier that produced them. That is, narrower and longer drumlins may indicate faster glacial movements than wider, shorter ones.<sup>8</sup>

Because the formation of drumlins is a process that occurs under glaciers and is unobservable, the origin of drumlins has been a controversial topic. One theory is that because some drumlins contain stratified sands and gravels similar to those deposited by streams, the drumlins are water deposits.<sup>9</sup> Subglacial flooding is thought to carry immense volumes of floodwater and sediment in cavities between the glacier and its underlying rock and sediment bed. Another theory is that because other drumlins are not stratified but consist of *till*, a poorly sorted sediment deposited by glaciers, drumlins are the result of a deformable layer of sediment between the glacier and bedrock.<sup>10</sup> The sediment layer that forms drumlins is shaped by pressure exerted by the mass of the overlying glacier, with the sediment migrating to lower pressure regions under the ice sheet.

Beginning about 19,000 years ago, when the Laurentide Ice Sheet began to melt at a faster rate than snow accumulated at its source, the margin of the glacier retreated, disappearing entirely from the Palmyra area around 12,000 years ago.<sup>11</sup> As the ice retreated, glacial features that had formed below the ice sheet were exposed, including the large drumlin fields of west-central New York.

Hill Cumorah is typical of the drumlins of this region, being 1.7 miles long and 0.4 miles wide and attaining a height of 140 feet above the lowland topography. The hill is also typical because its elongated profile is shaped like an inverted spoon with one end of the hill being steeper (the location of the Angel Moroni Monument and the pageant) and the other tapering off at a shallower angle (see fig. 6). Perpendicular to its length, the hill has a cross-

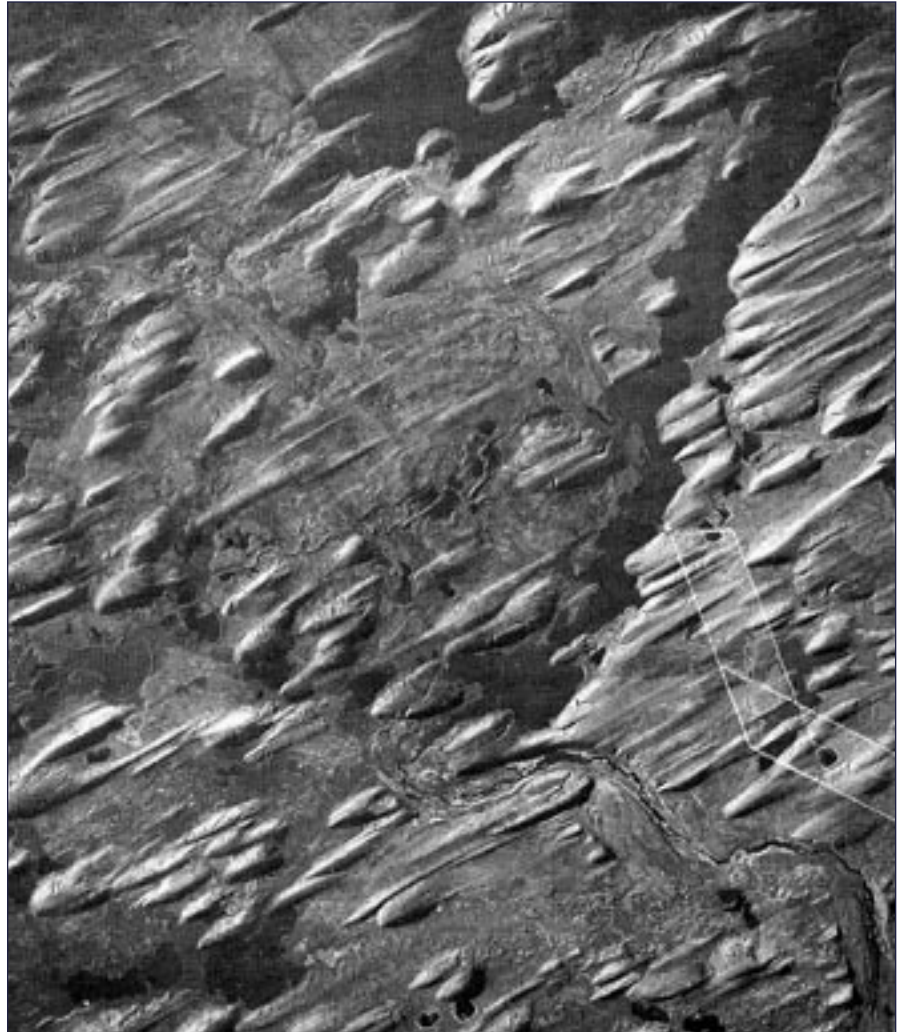


Figure 5. Aerial photo of drumlin field in northern Saskatchewan caused by an ice flow from the bottom left. Photo from Douglas I. Benn and David J. A. Evans, *Glaciers and Glaciation* (1998). Reprinted by permission.

tional profile common to drumlins, namely, a wide base of several hundred feet and a narrow summit, especially at the northern end where it narrows to less than 20 feet.

Drumlins are composed of a variety of materials including mixtures of till, sand, and gravel.<sup>12</sup> Most of these materials have high porosity and permeability, which, combined with the slope of the hill, would have allowed efficient water drainage that could have been important in the preservation of the plates, Urim and Thummim, Laban's sword, and the Liahona over the centuries after their deposition in the stone box by Moroni.

The tills and outwash deposits from the ice sheet at Palmyra are excellent sources of sand and



Figure 6. Aerial view of Hill Cumorah looking northeast. Photo by Paul Gilbert © 2004.

gravel and are well suited for agriculture. It was these fertile soils that attracted the Smiths and other early agriculturally minded settlers. Indeed, had glaciation and till deposition not produced good farmlands in western New York, the Smiths might not have migrated there, and the restoration of the gospel might have commenced elsewhere. We readily recognize that the religious freedoms provided by the Constitution of the United States, coupled with the religious fervor that swept western New York in the early 1800s, were essential to providing the political and cultural conditions necessary for the restoration of the gospel. But it was the development of the appropriate climate and agricul-

tural conditions of western New York by glaciation and till deposition that brought the Smiths to Palmyra. Once the family was there, the unique political and cultural conditions provided the appropriate setting for the boy prophet to begin his divinely appointed mission. While it is faith promoting to see the Lord's foresight in the preparation and preservation of the plates, it is also faith promoting to see an even greater foreknowledge of the Lord throughout the thousands of years of geologic history that led to the formation of Hill Cumorah and the surrounding lands. For he who has seen "the least of these hath seen God moving in his majesty and power" (Doctrine and Covenants 88:47). ❏