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sediments left behind after a glacier retreats.When glaciers retreat, they often deposit large mounds of gravel, small rocks, sand, and mud, called kames. Eskers are meandering ridges of gravel that were likely deposited by rivers flowing on top of glaciers, through glacial cracks, and/or in tunnels under glaciers. Because glacier ice comprised the banks of these rivers, and that ice eventually melted away, the gravel deposited by the old rivers is now elevated above the surrounding land surfaces.Kettle lakes form when a piece of glacier ice breaks off and becomes buried by glacial till or moraine deposits. Over time, the ice melts, leaving a small depression in the land, filled with water. Kettle lakes are usually very small, more like ponds than lakes.Photo gallery of landformsGlacial grooves and striations — Credit: Micah Maziar/Flickr Glacial grooves and striations are gouged or scratched into bedrock as the glacier moves downstream. Boulders and coarse gravel get trapped under the glacial ice, and abrade the land as the glacier pushes and pulls them along.Chatter marks are a series of often crescent-shaped gauges chipped out of the bedrock as a glacier drags rock fragments underneath it. — Credit: wildnerdpix/stock.adobe.com Glacial troughs, or glaciated valleys, are long, U-shaped valleys that were carved out by glaciers that have since receded or disappeared. Troughs tend to have flat valley floors and steep, straight sides. — Credit: Julien Seguinot/Flickr Fjords — Credit: Tobias Van Der Elst/Flickr Fjords, such as those in Norway, are coastal troughs carved out by glaciers. Once the glaciers receded, seawater covered the floor of the trough-shaped valleys to create fjords.Moraines — Credit: Romain Schläppy/Imaggeo Moraines are accumulations of dirt and rocks that have fallen onto the glacier surface or have been pushed along by the glacier as it moves. The dirt and rocks composing moraines can range in size from powdery silt to large rocks and boulders. A receding glacier can leave behind moraines that are visible long after the glacier retreats. As a glacier retreats, the ice literally melts away from underneath the moraines, so they leave long, narrow ridges that show where the glacier used to be. Glaciers do not always leave moraines behind, however, because sometimes the glacier's own meltwater washes the material away. Medial moraines run down the middle of a glacier, lateral moraines along the sides, and terminal moraines are found at the terminus, or snout, of a glacier. Sometimes one glacier flows into another, creating combined wider moraines. Often these linear deposits of rocks are left behind, almost intact, after the ice in a glacier has melted away. Studying these rocky debris remnants, and the sediments that were once beneath the glacier, is the subject of glacial geology and geomorphology.Glaciers leave behind anything they pick up along the way, and sometimes this includes huge rocks. Called glacial erratics or erratic boulders, these rocks might seem a little out of place, which is true because glaciers have literally moved them far away from their source before melting out from underneath them. Erratics can be carried for hundreds of kilometers and can range in size from pebbles to large boulders. Scientists sometimes use erratics to help determine ancient glacier movement. — Credit: Wally Gobetz/Flickr Drumlins are elongated, teardrop-shaped hills of rock, sand, and gravel that formed under moving glacier ice. What caused drumlins to form is poorly understood, but scientists believe that they were created subglacially as the ice sheets moved across the landscape during the various ice ages. Theories suggest that drumlins might have been formed as glaciers scraped up sediment from the underlying ground surface, or from erosion or deposition of sediment by glacial meltwater, or some combination of these processes. Because the till, sand, and gravel that form drumlins are deposited and shaped by glacier movement, all drumlins created by a particular glacier face the same direction, running parallel to the glacier's flow. Often, hundreds to thousands of drumlins are found in one place, looking very much like whale backs when seen from above. They can be up to 2 kilometers (1.25 miles) long. — Credit: Tobi Gaulke/Flickr Impacts of climate change on glaciersGlaciers are useful indicators of climate change. The relationship between temperature and glacial fluctuations was the basis for scientific activity beginning in the eighteenth and nineteenth centuries and led directly to the formation of the International Commission of Snow and Ice in 1894. The study of glacier fluctuations is relevant to an understanding of climate and climate change over temporal scales from decades to thousands of years, and at regional to global spatial scales. One of the most prominent signs of ongoing climatic change is that, with few exceptions, the vast majority of glaciers are shrinking worldwide. The 1991 discovery of the 5,000-year-old iceman preserved in a glacier in the European Alps fascinated the world, yet the discovery meant that this glacier was the thinnest it had been in the last 5,000 years. Glaciers around the world have retreated at unusually high rates over the last century. Some have disappeared altogether. Many more are retreating so rapidly that they may vanish within decades. Since the Industrial Revolution, which began about 1760, human activity, such as burning fossil fuels, industrial processes, agriculture, and land-use change have increased the amount of carbon dioxide and methane (natural gas) in the atmosphere. In fact, these gases have reached higher concentrations in the atmosphere than at any time in the past 1,000,000 years. How do scientists know this? Because bubbles in glacial ice trap samples of Earth's atmosphere, they record the composition of the atmosphere at the time ice is formed.Heat-trapping gases, sometimes called greenhouse gases, are the cause of most of the climate warming and glacier retreat since the early twentieth century. Greenhouse gases include carbon dioxide (CO2) and methane (CH4). During the ice ages, CO2 levels were around 200 parts per million (ppm), and during the warmer interglacial periods, they hovered around 280 ppm. In 2013, CO2 levels surpassed 400 ppm for the first time in recorded history, and levels continue to rise. In March 2023, NOAA's Global Monitoring Laboratory reported a CO2 level of 421 ppm.Greenhouse gases absorb heat being radiated from Earth's surface, and by absorbing this heat the atmosphere and oceans slowly warm up. Warming ocean and air temperatures increase glacier ice melt. Thus, scientists have confirmed that glacial retreat is an unintended effect of the Industrial Revolution and modern energy use.Increasing temperatures are not the only cause, however. Increased dust and soot from grazing, farming, and burning of fossil fuels and forests also increase glacier retreat. Dust and soot settle on glaciers to form a dark layer that absorbs more solar energy and increases their melt.Glaciers move by internal deformation of ice (creep) and basal sliding under their own weight. The movement transfers ice, snow, and firn from locations with net accumulation to locations with net loss. For valley and mountain glaciers this movement is from the head of the glacier towards its terminus. If a glacier as a whole has a positive mass balance, the glacier terminus advances and the glacier expands in area. If a glacier has a negative mass balance, the amount of ice transferred to the terminus is not enough to offset ice melt and the position of the glacier terminus retreats and the glacier shrinks in area. Even though the terminus position is retreating, glacier ice is still moving towards the terminus. With a few exceptions, glaciers in all regions of the Earth have negative mass balances. Their termini are retreating and they are shrinking in area. Glacier growth occurs when the amount of snow that accumulates on the glacier is greater than the amount of ice and snow that is lost from the glacier. Shrinkage occurs when the amount of snow and ice lost from is greater than the amount of snow that accumulates on a glacier. The difference between this accumulation and loss is called the mass balance. Growth occurs when the mass balance is positive. Shrinkage occurs when the mass balance is negative. Accumulation can occur by snowfall directly on the glacier surface but also from avalanches that deposit snow from slopes adjacent to the glacier and from snow being blown onto the glacier from surrounding areas. In some regions of the Earth, condensation of water vapor on glacier surfaces adds to accumulation. Ice and snow can be lost from the glacier by melting and runoff, evaporation of melt water, sublimation (the direct change from solid ice to water vapor), and through calving of ice is an increase in a glacier volume.