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the ice
age

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Figure 4.31 Ice-pushed chalk on Møn, Denmark. Photograph by Jürgen Ehlers.

Figure 4.32 Geological profile of Ristinge Klint, Langeland, Denmark

Figure 4.33 The western part of Ristinge Klint (top) and the raft of reddish till (below). Photographs by Jürgen Ehlers.

Figure 4.34 (a) Parallel valleys of the East Frisian-Oldenburg Geest made visible in the SRTM elevation model (b) location map.

Figure 4.35 Glacier dynamics of the Scandinavian Ice Sheet during the Weichselian. (a) An early ice

advance, the Ristinge Ice Stream, reached Denmark. (b) In the subsequent Main Weichselian Ice Advance, the Baltic Sea Basin played no role in controlling the ice movement. (c) During the Young Baltic Advance, ice movement was again controlled by the Baltic Sea Basin. (d) The last ice advance, the Bælthav Advance, brought rock material from more easterly source areas to Denmark.

Chapter 5

Giant pothole in the forefield of Briksdalsbreen glacier, Norway. Photograph by Jürgen Ehlers.

Figure 5.1 Fjords in Alaska in the satellite image. In the low-lying parts, former cirques can be seen which became 'drowned' in the postglacial sea-level rise. The narrow ridges between those cirques are called arêtes.

Figure 5.2 The Sognefjord is 204 km long and, at the lowest point, the bedrock lies about 1500 m below the water table. Photograph by Jürgen Ehlers.

Figure 5.3 Lake Schmalsee, a subglacial meltwater erosion channel north of the Weichselian ice margin near Mölln, Schleswig-Holstein. Photograph by Jürgen Ehlers.

Figure 5.4 Fifteen generations of Pleistocene subglacial channels at the bottom of the North Sea. The channels are completely filled with sediment and only visible in the 3D seismic data. In the section shown there are two underground salt domes (SD), and the channels run around the salt domes.

Figure 5.5 Detailed view of two glacial meltwater channels on the North Sea floor as depicted in 3D seismic data. The irregular base typical for subglacial channels is clearly visible in both channels.

Figure 5.6 Resistance measurements can be used to explore the subsurface geology and to detect buried channels. Here the EM-31 device of the Canadian Geonics company is seen in operation. Photograph by Steve Mathers.

Figure 5.7 Small Elsterian channels in East Anglia, UK, discovered by resistance measurements. Above: the course of the channels; bottom: resistivity profile and cross-section based on boreholes at Snape Hall, Suffolk.

Figure 5.8 Traces of meltwater erosion at Hillington, Norfolk, UK. The upper part of the chalk has been incorporated in the glacier movement, and plucking has resulted in the formation of steps. Meltwater sand has been washed into the clefts of the highly fractured chalk. Ice movement was from left to right.

Figure 5.9 Sand grains under the electron microscope. (1-6) Till from the Oslo Fjord area, Norway and (7-13) till from Hamburg. The sand grains from Norway show fresh fractures; the grains from Hamburg traces of strong weathering. Photographs by Jürgen Ehlers.

Figure 5.10 (a) Eskers at Folldal, Norway. (b) Exposure in an esker at Folldal, Norway. The coarse, well-rounded pebbles of these eskers, the 'Rolling Stones', provided the starting point for the discussion of the great stone flood. Photographs by Jürgen Ehlers.

Figure 5.11 Skeiðará-Sandur, outwash plain at the southern edge of Vatnajökull in Iceland, with the typical braided drainage system. Photograph by Jürgen Ehlers.

Figure 5.12 Sandur sediments at the edge of Kverkjökull glacier in Iceland. Photograph by Jürgen Ehlers.

Figure 5.13 Flow directions (a) on the Skeiðará-Sandur, Iceland, and (b-d) in the Harburger Berge hills near Hamburg. The wide range of drainage directions is typical of a braided river system.

Figure 5.14 Drainage directions of the Saalian meltwater streams in the Hamburg area. (a) Middle Saalian Glaciation (older phase): The ice is coming from the NE and drainage to the NW is still open. (b) Middle Saalian Glaciation (younger phase): the ice margin has advanced and the runoff is now directed to the SW towards the Weser. (c) Younger Saalian Glaciation: the ice is coming from the east and the drainage through the Elbe Valley is free.

Figure 5.15 Deposits of Lake Agassiz, an ice-dammed lake in North America. (a) False-colour satellite image; the stripes are giant striae produced by icebergs.

Figure 5.16 Seasonally layered lake sediments from Lake Sacrow near Potsdam, Germany. Centre: photograph of the carbonate-organic varves of a frozen core. The light layers represent summer calcite precipitate. Right: radiograph of the same frozen core. The calcite precipitates are the clearly visible dark layers. Left: micrograph of varves from Lake Sacrow under polarized light, revealing the internal structure of the annual layers. In most cases three sublayers are recognizable: most notably is the white summer calcite layer. It is overlain by the grey detritus layer of autumn/winter. Below the calcite layer (and not always well developed) is a relatively

dark spring layer of diatoms. Photographs by Bernd Zolitschka.

Figure 5.17 Varve thickness measurements of four parallel sedimentary sequences from Holzmaar lake, Westeifel volcanic field. Counts and thickness measurements by B. Zolitschka (HTM-B/C) and B. Rein (HTM-1, HTM 2, HTM-3) were performed on thin sections of the early Holocene varve sequence. The average of the four determinations is shown in the upper graph (red) together with a moving average over seven points (blue). These curves show the Holzmaar system's response to the early Holocene Preboreal (11,400-11,000 cal BP) and Boreal (10,500-10,200 cal BP) climatic oscillations. Both climate fluctuations resulted in thicker varves, caused by increased minerogenic sediment entry.

Figure 5.18 Grimsmoen, a delta of a Weichselian ice-dammed lake in Folldal, Norway. Photograph by Jürgen Ehlers.

Figure 5.19 Deposits of ice-dammed lakes: varves overlying Saalian till in Neumark-Nord opencast mine (left); varved silt in Sweden (right). Photographs by Jürgen Ehlers.

Figure 5.20 Moulin kame on Langeland, Denmark. The gravel hill was accumulated in a glacier mill during the Weichselian Glaciation. Photograph by Jürgen Ehlers.

Figure 5.21 Two examples of *hatbakker*, the so-called 'hat-shaped hills' on Langeland. These are kames which were created in the decay phase of the Weichselian ice age. Photograph by Jürgen Ehlers.

Figure 5.22 (a) Cliff sections through *hatbakker* on the Danish island of Langeland; (b) cross-sections

through the Dovns Klint and Bagenkopsbjerg hatbakker; and (c) photograph from Bagenkopsbjerg. (a, c) Photographs by Jürgen Ehlers.

Figure 5.23 Kame terrace at Loch Etive, Scotland: (a) kame terrace surface with dead-ice hollow; and (b) the kame terrace deposits. Photographs by Jürgen Ehlers.

Figure 5.24 Kame at Groß Zecher, Schaalsee Lake, Schleswig-Holstein. Photograph by Jürgen Ehlers.

Figure 5.25 Kryžių kalnas (Hill of the Crosses) at Šiauliai in Lithuania is also a kame. Photograph by Jürgen Ehlers.

Figure 5.26 The traces of the Missoula Flood are clearly evident in the Channeled Scablands in Washington State.

Figure 5.27 Erratic block beyond the limits of glaciation in Idaho, the result of a meltwater flood from the outbreak of an ice-dammed lake. Photograph by Jürgen Ehlers.

Figure 5.28 Gravel dunes in the Todza Basin, Altai, which are traces of a catastrophic outflow of an ice-dammed lake. Note the car for scale. Photograph by Keenan Lee.

Figure 5.29 Development of the *urstromtal* drainage in the Weichselian Glaciation. (a) Glogau-Baruth *urstromtal*; (b) Warsaw-Berlin *urstromtal*; (c) drainage shifting to the north. (d) Thorn-Eberswalde *urstromtal*; and (e) relocation of the drainage to the edge of the present Baltic Sea.

Figure 5.30 Thorn-Eberswalde *urstromtal* (white arrows) branching off from the Vistula (Weichsel) river valley near Bydgoszcz in Poland. The ragged

relief on the edge of the glacial valley is caused by dunes.

Chapter 6

The geoid, the actual shape of the Earth, height exaggerated 15,000 times. The Earth is round, but it is not a ball. With the help of satellite measurements we have a very clear idea of what the shape of its surface actually looks like. (a-i) Globes modelled by GFZ Potsdam illustrate the deviations from the ideal shape.

Figure 6.1 Whitehorse Sheet of the International Map of the World printed in 1960, depicting the border region of Alaska-Canada. White spots at the southwestern edge of the map still bear the inscription: UNSURVEYED.

Figure 6.2 Limits of the Weichselian Glaciation in the Caucasus, presented on the DCW base map.

Figure 6.3 Comparison of the DCW (top) with the VMAP1 + GTOPO30 (bottom). The extent of the Early Weichselian Ice Sheet (MIS5b) in the northern Urals is shown in blue.

Figure 6.4 Top: Errors in the GTOPO terrain model, an example from Siberia. The altitudes were chosen so that the diagonal stripes and blocks appear most clearly. Bottom: The same area shown in VMAP1.

Figure 6.5 Comparison of the ASTER terrain model (top) with the SRTM terrain model (below) for the Elbe river valley near Lauenburg, Germany.

Figure 6.6 Russian topographic map 1:50,000, sheet Gmunden.

Figure 6.7 Image acquired by an American KH-9 Hexagon spy satellite from the Eckernförde area in