STOP 7: Madona-Trepe ice-marginal ridge at Smeceres sils, East-Latvian Lowland

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The Madona-Trepe ice-marginal ridge (Fig. 7.1) is the most prominent ice-marginal formation in Latvia. This spectacular moraine ridge, generally oblique to streamlined landforms (megaflutes to mega-lineations), marks the maximum extent of the Lubāns ice lobe during the Gulbene deglacilation phase in the East-Latvian Lowland (Meirons et al. 1976; Zelčs and Markots 2004; Zelčs et al. 2011).

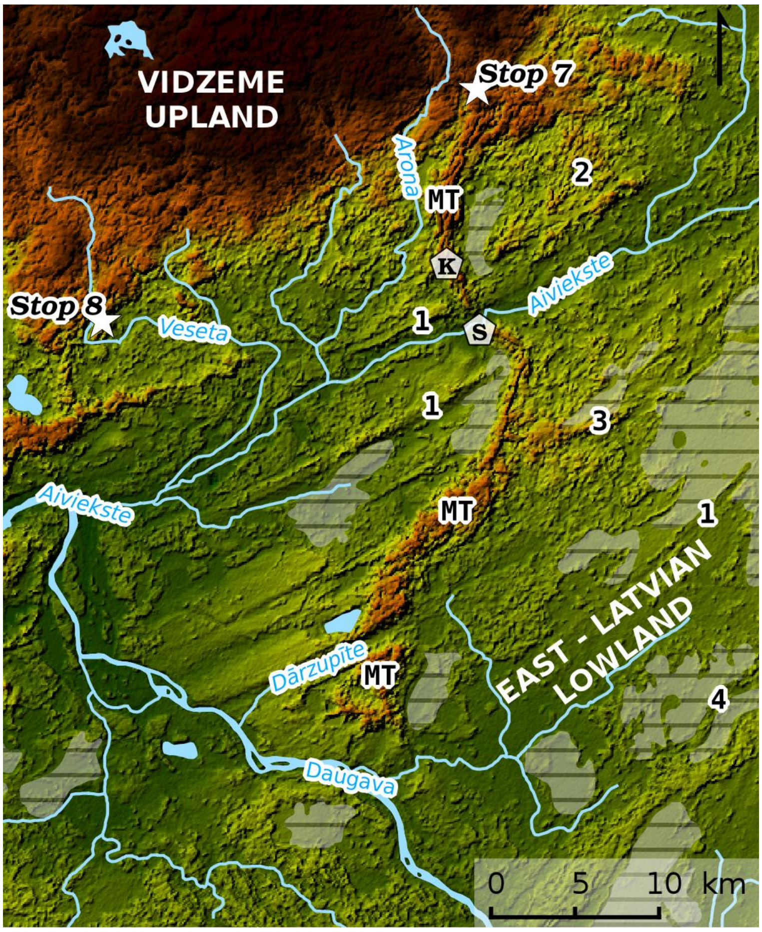

Fig. 7.1. SRTM DEM of the glacial terrain along the Madona-Trepe ice-marginal ridge. Note that megaflutes and megascale lineations are superimposed by small recessional moraine ridges. Legend: MT – Madona-Trepe ridge; K – Krustkalni gravel pit; S – Sāviena gravel pit; 1 – megaflutes and megascale lineations; 2 – hummocky topography; 3 – lateral shear marginal moraine; 4 – esker.

The Madona-Trepe ridge stretches for a distance of 45 km between the east-Latvian stretch of the River Daugava valley and the outer slope of the Vidzeme Upland, associated with a belt of lateral moraine ridges (so-called oriented marginal relief of the peripheral zone after Āboltiņš et al. 1975; Āboltiņš 1995) modified by meltwater discharge. Deeply incised transverse meltwater drainage channels, probably tunnel valleys, maintained nowadays by the Rivers Aiviekste and Dārzupīte, and the dry valley next to Stop 7 at Smeceres sils (26°09'54"E, 56°49'39"N), split the Madona-Trepe ridge into four parts. On both sides of the dry valley the highest points of the surface topography slightly exceed 170 m a.s.l. and rise almost 70 m above proximal ice-scooped basins occupied by lakes and mires, a distally located ice-marginal drainage channel and large glaciokarst kettles. The elevation and local relief fall away in the direction of the River Daugava valley, i.e. the centre line of the ice lobe terminus. The width of the Madona-Trepe ridge varies from 0.7 km to 5 km. South of the dry valley its surface is undulated by 2–50 m high, subparallel or parallel elongated ramparts. Their roughly NNE-SSW strike corresponds to the general orientation of the ice-marginal ridge.

The Madona-Trepe ice-marginal ridge is situated on an elongated bedrock rise. It lies about 80 m a.s.l. in its more elevated part, and gradually lowers to 50 m a.s.l. in the direction of the centre line of the Lubāns lobe terminus. The bedrock consists of Upper Devonian terrigenous deposits, but S of the dry valley these are replaced by carbonate rocks. The complex of Weichselian sediments, mainly waterlain, that overlies the bedrock, is 80–90 m thick in the morphologically more expressed part, thinning towards the SSW to 40–50 m. Here it is at least twice or up to four times thicker than in the adjoining proximally located ice-scooped basins and glacially megalineated terrain.

The internal structure has been examined in several gravel quarries located in different parts of the ice-marginal ridge. There is no substantial difference in lithological composition between these parts of the ridge, but they differ greatly in their internal architecture, as explained below.

The coarse material (gravel, gravel and pebbles with sand), which forms most of the exposed sequence, is underlain by thinly laminated sandy sediments, which make up the lowermost part of the exposed sections. In places the coarse sediments are interlayered with sand up to 2–3 m thick, with intercalations of finer material (Fig. 7.2: I) and containing occasional gravel and dispersed small pebbles in the lower part of the interlayer. The laminated sandy sediments also occur in an enormous area along both sides of the Madona-Trepe ridge, also beneath kame terrace sediments. OSL dates of 19.6±1.0, LV 05/42 and 26.8±1.1 LV 05/43, obtained from the interlayer of sand (Fig. 7.2: II) in the Smeceres sils quarry, suggest that they were most probably deposited slightly before and/or during the maximum transgression of the Late Weichselian glaciation in this area (Raukas et al. 2010). However, the burial OSL age of the thinly laminated sand deposited in the lower part of two other sections (46.0±8.6; 41.4±8.6; 49±22; due to very wide paleodose distributions, the results should be considered only as age estimates), located in a small ice-pushed ridge and lateral shear moraine moraine, yield evidence of deposition during the Middle-Weichselian interstadial.

Four recently studied sections (Fig. 7.2), situated at levels from 169 m a.s.l. to 153 m a.s.l. in the gravel quarry at the Smeceres sils, reveal the internal structure of the northern stretch of the Madona-Trepe ice-marginal ridge. In general, the internal structure of the ridge has been altered only by limited glaciotectonic deformation and by mass sliding and flowage, which is encountered on the ENE slope (Fig. 7.2: IV). Coarsening upwards of the coarse sequence (Fig. 7.2: I) can be explained by the acceleration of ice melt, resulting in boulder concentration, in some cases also in the formation of a boulder pavement on the topmost part, and in the appearance of scattered boulders on the distal slope of the ice-marginal ridge. Besides this, cobbles and boulders have been altered to some extent by frost weathering and covered by coversand. The upper coarse sequence rests on up to 2–3 m thick, predominantly medium- to fine-grained sand with intercalations of silt and clay strings (Fig. 7.2: II). The sand has been OSL dated (Raukas et al. 2010). The underlying gravel bed is interlayered with sand, which contains occasional gravel strings and dispersed small pebbles (Fig. 7.2: III). According to bedding plane measurement data, it is more likely that the exposed sediments represent ice-marginal fan deposition. The ridge slope consists of supraglacial melt-out and gravity flow till in places with lenses of meltwater sediments underlain by laminated sand (Fig. 7.2: IV).

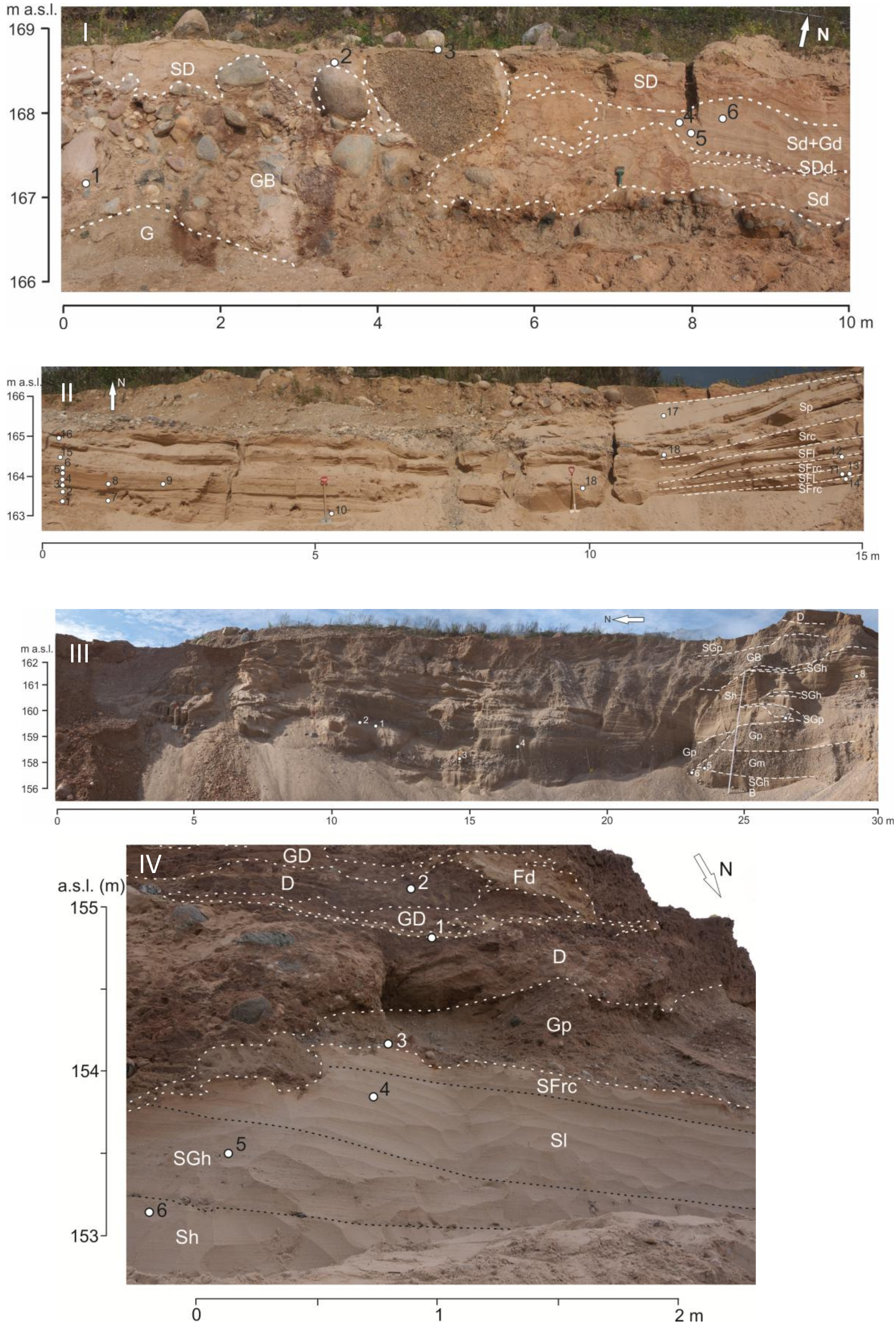

Fig. 7.2. Internal structure of the Madona-Trepe ice-marginal ridge at Smeceres sils in the exposures of the gravel pit located next to the dry meltwater discharge valley. Note that the sections are located at different elevation. White dots and numbers denote measurement sites of the bedding planes and glacial striation; D – diamicton; B – boulders; G – gravel; Gd – deformed gravel; Gm – massive gravel; Gp – planar cross-stratified gravel; GD – diamictic gravel; GB – bouldery gravel; Sd – deformed sand; Sh – horizontally bedded sand; Sl –

low-angle cross-bedded sand; Sp – planar cross-bedded sand; Src – subcritically climbing-ripple cross-laminated sand; SD – diamictic sand; SDd – deformed diamictic sand; SGh – horizontally bedded gravelly sand; SGp – planar cross-stratified gravelly sand; SFl – low-angle cross-bedded sand with fines; SFrc – climbing ripple cross-laminated sand with fines; Fd – deformed silt. I. Gravel with cobbles and boulders altered to some extent by frost weathering, underlain by gravel with dispersed pebbles and covered by coversand; II. Up to 2–3 m thick, predominantly medium- to fine-grained sand with intercalations of silt and clay strings, OSL dated (Raukas et al. 2010); III. Gravel interlayered with sand, containing occasional gravel strings in some interlayers; IV. Supraglacial melt-out and gravity flow till in places with lenses of meltwater sediments underlain by the laminated sand.

The internal structure reveals that between the dry valley at Smeceres sils and the River Aiviekste valley recessional megablock and thrusted scale sheets are dominant. These glaciotectonic deformation structures mainly consist of gravel with an admixture of pebbles, gravel with sand, and occasional interlayers of gravelly sand. Common south of the River Aiviekste valley up to the Dārzupīte are large inclined and overturned folds, fold-faults and overthrusts with plastering of till on the upglacier side. These differences in internal structure, their spatial succession and the morphological peculiarities of the distinct parts of the Madona-Trepe ice-marginal ridge, in the light of the recent studies done by Evans et al. (2008, 2014) and Krüger et al. (2010), suggest quite different circumstances along the terminus of the Lubāns lobe during the Gulbene oscillation phase. In the segments of glacial recession glaciotectonic shortening prevailed due to compressive ice basal motion, while along the centre line of the ice lobe terminus the glacier has overridden smoothed and, possibly, buried push moraines.

The topography of the Madona-Trepe ridge and the terrain beyond and behind it resembles to a great extent the Wolf Lake vicinity, Alberta, described by Andriashek and Fenton (1989). Besides, as seen in Fig. 7.1, the Madona-Trepe ridge is curved, forming arcuate clusters. This morphololological feature indicates differentiation of the ice basal marginward motion in the transverse section of the Lubāns lobe in a similar manner to that suggested by Stephan (1985: Fig. 3) in a block movement model for glacier pushing. Lowering and widening of the ridge, and thinning of the landforming sediments in the direction of the centre line of the Lubāns lobe terminus can be explained by the mechanism noted by Krüger et al. (2010). They report (ibid.), that "the most prominent ice-marginal ridges under formation were seen where the advancing glacier pushed against a rather thick body of hochsander fan deposits or a frontal ramp of mass-movement deposits. Where the glacier overrode ground moraine, the ice-marginal ridge was commonly small, probably because the glacier toe, when overriding ground moraine, was almost at the same level as the till surface beyond." Taking into account that in the case under consideration stratified gravelly sediments form a thick body and occur in a vast area on the upglacier and downglacier sides of the Madona-Trepe ice marginal ridge, they have been interpreted as most probably constituting outwash (excluding the part N of the dry valley).

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