

STOP 5: Veselava end moraine, north-western Vidzeme Upland

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The retreat of the Late Weichselian Fennoscandian ice sheet over the north-western part of the Vidzeme Upland is marked by three major ice-marginal zones (in order of decreasing age and hypsometric position: Kaldabruņa, Gulbene and Linkuva) (Meirons et al. 1976; Zelčs et al. 2011). Traditionally, these ice-marginal zones have tentatively been correlated with the South Lithuanian, Middle Lithuanian and North Lithuanian ice-marginal zones in Lithuania, respectively (Āboltiņš et al. 1972; Āboltiņš et al. 1975; Meirons et al. 1976; Zelčs and Markots 2004), but new OSL dates from the Middle Gauja Lowland (Nartišs and Zelčs 2011) shed doubt on the previous interregional correlation (ibid.) of the Linkuva ice-marginal formations with the Haanja zone in Estonia.

The Veselava end moraine is an almost 8 km long and 750–1200 m wide ridge in a chain of Linkuva ice-marginal features which extend discontinuously over the outer ice contact slope of the Vidzeme Upland (Fig. 5.1). On the highest part between the Silenieki and Lībieši gravel pits (see Fig. 5.2 for location) its maximum elevation varies from 160 to 170.6 m. The topmost part of the ridge has a slightly uneven recent surface topography complicated by superimposed small hillocks and elongated ridges, pitted in places. The end moraine rises above the upglacier-located till plain by up to 30 m, about 60 m above the Raunis palaeolake plain and 10–20 m above the bottom of the ice-marginal drainage valley (Fig. 5.2). The end moraine has an asymmetrical cross-profile, with a shorter and steeper downglacier slope.

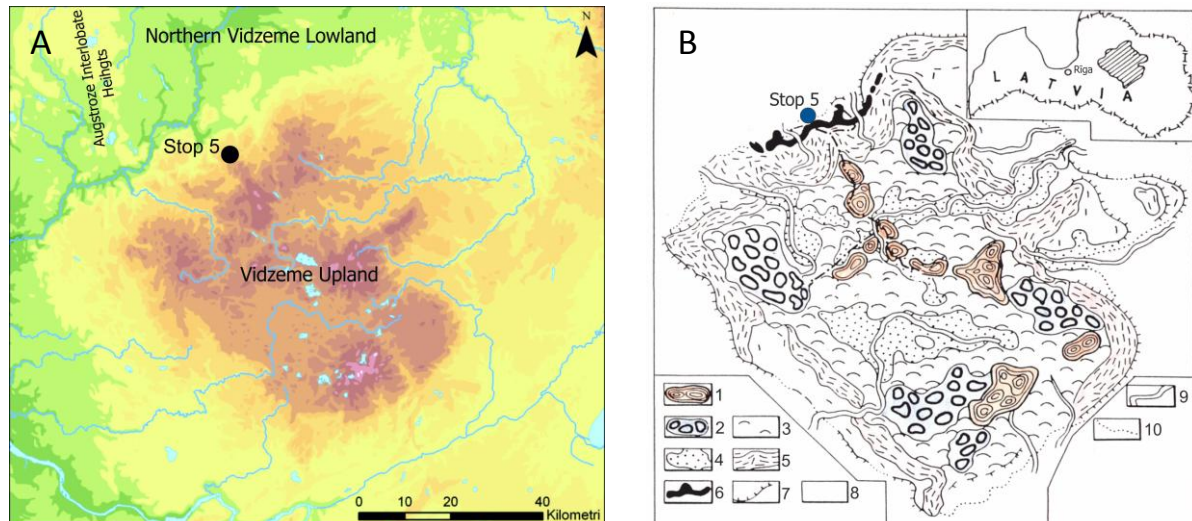


Fig. 5.1. Location of the Veselava end moraine and the stop site. A. Digital elevation model of the Vidzeme Upland and surrounding terrain. B. Geomorphological sketch of the Vidzeme Upland (modified after Āboltiņš 1995). Legend: 1 – composite interlobate hilly massifs; 2 – areas of plateau-like hills; 3 – various types of hummocks (with prevalence of morainic hummocks); 4 – largest glacial depressions; 5 – ice-marginal formations of the outer zone; 6 – end moraines and ramparts of ice-tongue lateral coalescence in the outer zone; 7 – marginal slopes; 8 – rolling plains in adjoining glacial lowlands; 9 – largest river valleys; 10 – boundary of the Vidzeme Upland.

The hypsometric position of the bedrock surface ranges from 50–80 m to 100–110 m a.s.l. The end moraine is located next to the area of the lithological boundary between Devonian terrigenous and carbonate sedimentary rocks. This boundary is morphologically expressed as a dolomite escarpment up to 40 m high covered by less than 12 m thickness of Quaternary

sediments. Weakly cemented sandstone or soft silt and clay is found underlying small, low bedrock depressions, whose strike coincides with the ice flow direction or buried valleys which tend follow the edge of the dolomite escarpment. These small bedrock depressions have a tongue-like shape and are quite well reflected in the modern topography (Fig. 5.2, note River Raunis depression). Presumably, due to the faster ice flow in the centre of the bedrock depression in comparison to ice flow alongside the lateral slopes, the Veselava end moraine is slightly curved downglacier. Dolomite forms the most elevated compartments of the sub-Quaternary surface. In addition, the dolomite plates gently dip against the ice movement direction with a gradient of about 9 m per 1000 m. Evidently, this has stimulated glacier rafting and assimilation of local dolomitic bedrock material. The Veselava end moraine rests on dolomite, at a minimum distance of only 2–3 km downglacier from the escarpment.

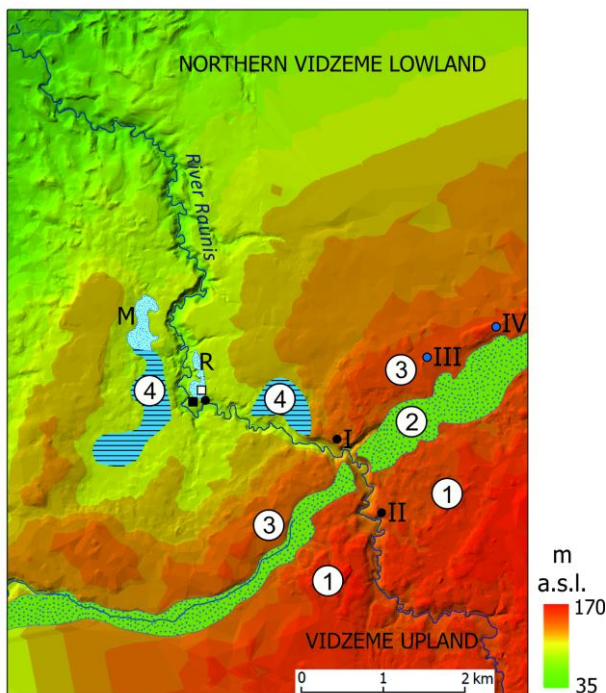


Fig. 5.2. Digital elevation model of the Veselava end moraine and adjoining area. Legend:

1 – Gulbene ice-marginal zone; 2 – ice-marginal drainage channel; 3 – Veselava end moraine of Linkuva phase ice-marginal zone; 4 – occurrence of glaciolacustrine deposition at levels of 125–140 m a.s.l. Late-glacial and Early Holocene palaeolakes with the highest level 110 m a.s.l.: R – Raunis; M – Mīlīši. Figures I and II denote location of sections studied by Āboltiņš (1972, 1975), III and IV – location of Silenieki and Lībieši gravel pits, respectively.

The thickness of Pleistocene deposits in the Veselava end moraine is 40 m on average. In general they thin out in the proximal direction. The buried bedrock valley, which coincides with an ice-marginal drainage channel (Fig. 5.2), is filled with an almost 100-m-thick sequence mainly

composed of till (tentatively assigned by Meirons and Straume (1979) to Middle and Upper Pleistocene glacials), with interlayered thin glacioaquatic sediments. Between the two upper till units warmer period sediments were found in a coring section placed distally from the end moraine. Similar silty sand sediments with silt and clay intercalations containing disseminated organics and macroscopic plant remains were encountered by Āboltiņš (pers. comm.) in the lower part of both sections (see Fig. 5.2: I and II for location), studied at the beginning of the 1970s (Āboltiņš 1972, 1975).

Āboltiņš (1972, 1975, 1989) emphasized the complicated internal structure of the exposed deposits, noting the abundance of glaciotectonic deformation in bedded and laminated gravel, sand, silt, clay and basal till. He (ibid.) divided the Veselava end moraine cross-section into two different parts: the lower portion, with intensive glaciotectonic folding, and the topmost part, where these folded strata are overlain by up to four imbricate thrust scales of till with assimilation contacts at the base of some till sheets. In addition, the till overthrust scales are capped by thin (2–3 m) sandy gravel with sandwiched silt and silty sand interlayers. Glaciokarst phenomena are also common in the covering strata, giving rise to some topographic undulations.

The Silenieki and Lībieši gravel pits are located on the highest part of the end moraine ridge and have a more lateral position in comparison to the sections studied by Āboltiņš (Fig. 5.2).

Silenieki gravel pit section

The section is located in the topmost part of the end moraine (25°29'35"E, 57°17'58"N). The surface of the end moraine abounds in erratic boulders. The exposed sequence is up to 4 m thick. In its upper part this section, transverse to the moraine ridge crest, consists of pebbles with cobbles interlayered by massive diamicton (Fig. 5.3). The diamicton macrofabric is relatively strong, but dispersed. The macrofabric maximum strikes at an acute angle to the moraine ridge crest. Strong fabric is common in the direction of shear (Bennett and Glasser 2009). Both shear zones in the section can be interpreted as proglacial thrusting. The material is poorly sorted, coarsening upward, and contains a lot of local dolomite clasts. The dolomite clasts are angular, in places striated and faceted. The coarse clastic part of the section is underlain by silt of varying thickness. The lower contact of the silt apparently originates from erosion of the underlying fine-grained sand interlayered with silt. On the right hand side of the section both lithological units are folded concordantly with one another, probably because of mass flow.

The OSL age of burial of the sand deposited in the lower part of the Silenieki section is 59 ± 10 ka. An OSL date of 33.6 ± 6.4 ka has been obtained in the northern part of the Burtnieks drumlin field, in the vicinity of Rūjiena town. This seems to indicate sand deposition during the Middle Weichselian interstadial.

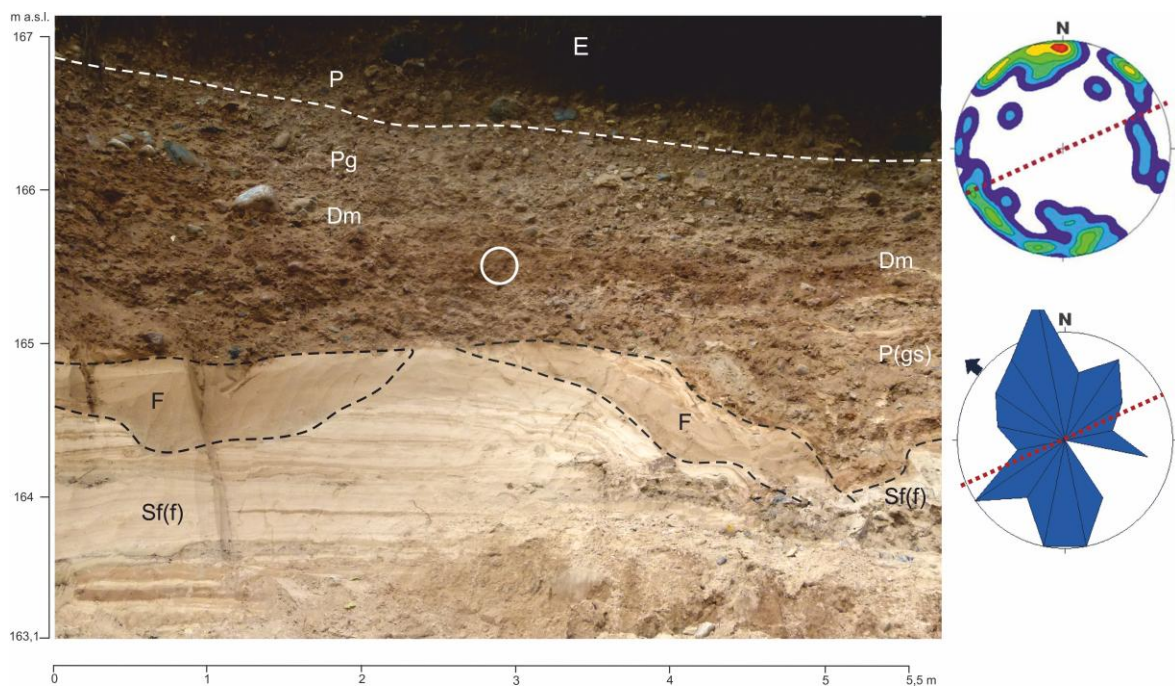


Fig. 5.3. Internal structure of the topmost part of the Veselava end moraine in the Silenieki gravel pit and clast fabric contour and rose diagrams in the lower diamicton interlayer.

Legend: F – silt, Dm – diamicton massive, P – pebbles with occasional cobbles, Pg – pebbles and gravel; P(gs) – pebbles and gravel mixture with sand matrix, Sf(f) – fine grained sand interlayered by silt, F – fines. Large circle denotes macrofabric measurement site, red dotted line shows strike of the end moraine ridge crest.

Three-dimensional diagram of macrofabric orientation is on the lower hemisphere and in equal area projection. Based on 50 macrofabric measurements. Contoured at 0-1-2...7 percent areas.

Lībieši gravel pit section

This section is located about 1.5 km ENE of the Silenieki site (25°30'53,938"E 57°18'12,365"N). It displays supra-glacial meltout till, probably altered by gravity flow (Fig. 5.4). The supraglacial till consist of rare pebbles in an abundant matrix rich in sandy silt and clay. Till macrofabric is variable and poorly developed (Fig. 5.4). Nevertheless, some

packages probably show different flow directions. In places bent lenses or chunks of silty sand can be encountered. The supraglacial till is underlain by pebbles with occasional cobbles and gravel admixture. This part of the section is similar to the composition of the uppermost part of the Silenieki section.

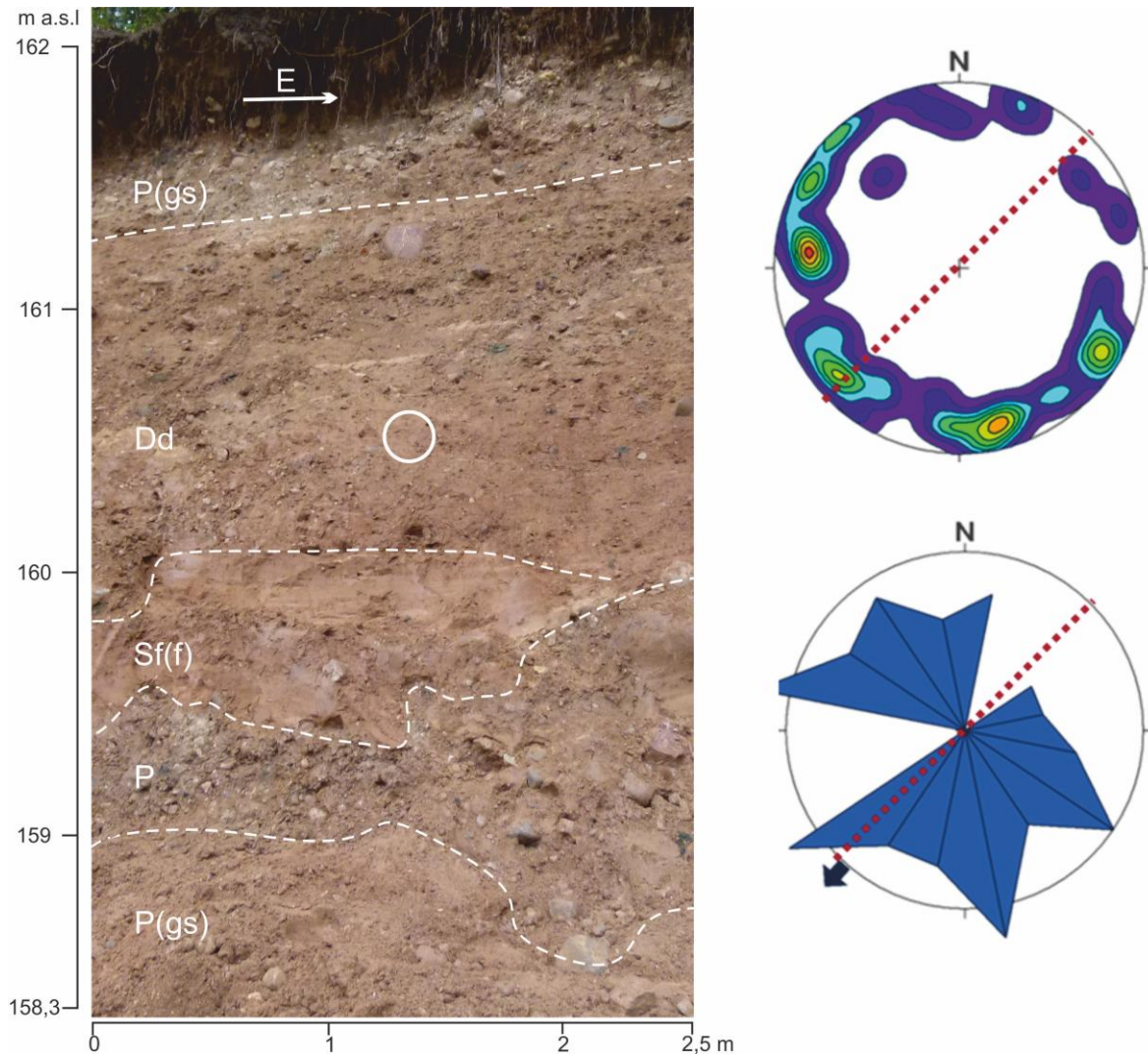


Fig. 5.4. Internal structure of the uppermost part of the Veselava end moraine in the Lībieši gravel pit and clast fabric diagram of the stratified diamicton.

Legend: Dd – diamicton with minor deformation structures, P – pebbles with occasional cobbles, P(gs) – pebbles with gravel admixture, Sf(f) – fine grained sand interlayered with silt. Large circle denotes macrofabric measurement site, red dotted line shows strike of ridge crest.

Three-dimensional diagram of macrofabric orientation is on the lower hemisphere and in equal area projection. Based on 50 macrofabric measurements. Contoured at 1-2...8 percent areas.

To sum up, the Veselava end moraine contains both mass-flow and waterlain sediments, and evidence of proglacial thrusting during small oscillations of the glacier terminus. Formation of ice-marginal moraines by a combination of proglacial thrusting and gravity processes (high sediment mobility) during the melting out of buried ice blocks is also suggested by Knight (2006). The morphometric parameters of the Veslava moraine most probably indicate that the glacier transported a large amount of drift with a high content of local bedrock fragments, and that glacier flow was relatively fast. In places, after glacier retreat, the end moraine ridge has been fragmented by subsequent fluvial erosion.

According a model of end moraine sedimentation based on data from Pleistocene ice

sheet margins proposed by Krzyszkowski and Zieliński (2002), it can be classified as a B type end moraine, which represents “the most typical sequence in the end moraine zones” (Krzyszkowski and Zieliński *ibid*, p. 73). It is also possible that in some stretches of the Veselava end moraine where ice-marginal drainage has been hindered or promoted by proglacial topography, other types of end moraines may have developed.

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RĪGA 2014

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Latvian Association for Quaternary Research
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Editors: Vitālijs Zelčs and Māris Nartišs

The English texts of the field guide were revised by Valdis Bērziņš

Recommended reference for this publication:

Zelčs, V. and Nartišs, M. (eds.) 2014. Late Quaternary terrestrial processes, sediments and history: from glacial to postglacial environments. Excursion guide and abstracts of the INQUA Peribaltic Working Group Meeting and field excursion in Eastern and Central Latvia, August 17-22, 2014. University of Latvia, Rīga, 2014, 150 pages.

Sponsored by:

University of Latvia

Layout: Vitālijs Zelčs, Māris Nartišs and Māris Krievāns

ISBN 078-9934-517-60-0

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