STOP 3: Late-glacial and early postglacial environmental processes and the history of the River Triečupīte valley and surroundings, in the foreland of the Vidzeme Upland

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The stop is located at the River Triečupīte valley (25°20'3.67"E, 57°19'58.46"N), in the Trikāta Rise, which forms a transitional zone between the Northern Vidzeme Lowland and the Vidzeme Upland (Fig. 3.1). It gives an insight into the geological structure, morphology and formation of the deep-cut glacial meltwater drainage valley system of the rivers Triečupīte, Vaive and Rauna, presenting a pattern of terraced valleys created as a result of late-glacial meltwater activity and postglacial fluvial erosion, along with an example of apron-like calcareous tufa deposition.

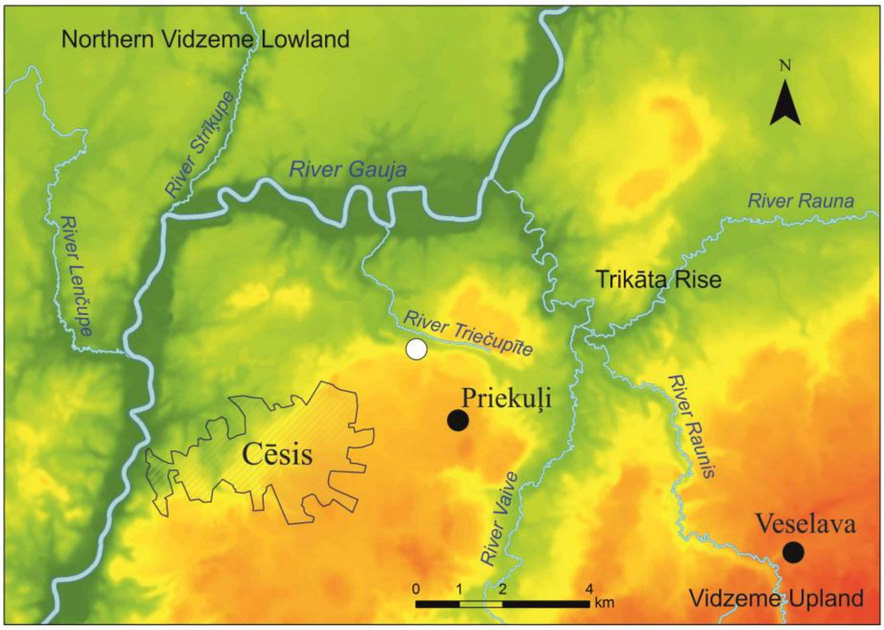

Fig. 3.1. Geographical location of the River Triečupīte (Kazu grava) valley. White circle – location of Stop 3, black circles – villages.

The thickness of the Pleistocene deposits along the River Triečupīte valley is less than 10 m. They rest on Upper Devonian dolomite, underlain by Upper Devonian sandstone and clay. In places rafted blocks and subglacial till, composed mainly of the local bedrock, can be encountered. The present-day surface topography has been shaped by the Burtnieks ice lobe and meltwater activity, particularly during the initial transgression of the Late Weichselian Fennoscandian Ice Sheet and its oscillatory retreat, beginning approximately 15.2 ka BP (Zelčs and Markots 2004; Zelčs et al. 2011).

River Triečupīte valley

The Triečupīte valley is about 3.6 km long and 0.3-0.8 km wide, and in the middle part its depth reaches 35-42 m. It crosses the watershed between the valleys of the rivers Vaive and Gauja. North-west of the Riga-Valka railway embankment the valley ramifies, forming a second, more elevated branch – Bušleja (Āboltiņš 1998). The River Triečupīte valley is confined to an ancient U-shaped buried valley which is incised into Middle Devonian silt, clay and sandstone, and Upper Devonian sandstone and dolomite (Bendrupe and Arharova 1981).

The bedrock surface alongside the valley is 110 m a.s.l., but at the bottom of the valley it varies from 70 m a.s.l. in the middle course up to 50 m a.s.l. in the direction of both ends. In the lowest part of the Triečupīte valley the bedrock is covered by Upper Pleistocene till. According to Juškevičs (2000) and Āboltiņš (1998), this indicates formation of the valley in proglacial conditions during at least part of the last Fennoscandian Ice Sheet transgression. The development of the present valley and transformation of the glacial relief in the adjoining area began with the retreat of the Burtnieks ice lobe from the marginal formations of the North Lithuanian (Linkuva) glacial phase. It can comparatively be correlated with the development of the valleys of the rivers Gauja, Rauna and Vaive as well as local meltwater basins during the Late Glacial. Alongside the slopes and within the Triečupīte valley Holocene peat and alluvial sediments have accumulated (Āboltiņš 1995).

According to the field and geospatial data, the River Triečupīte valley can be divided into three morphologically distinct parts – the north-western extension, the middle part and the south-eastern extension (Fig. 3.2.). In the SE extension two glaciolacustrine terraces were traceable at levels of 74 and 77 m a.s.l., and the highest glaciolacustrine terrace was detected at 87 m a.s.l. The terraces are composed of fine-grained and medium-grained sand.

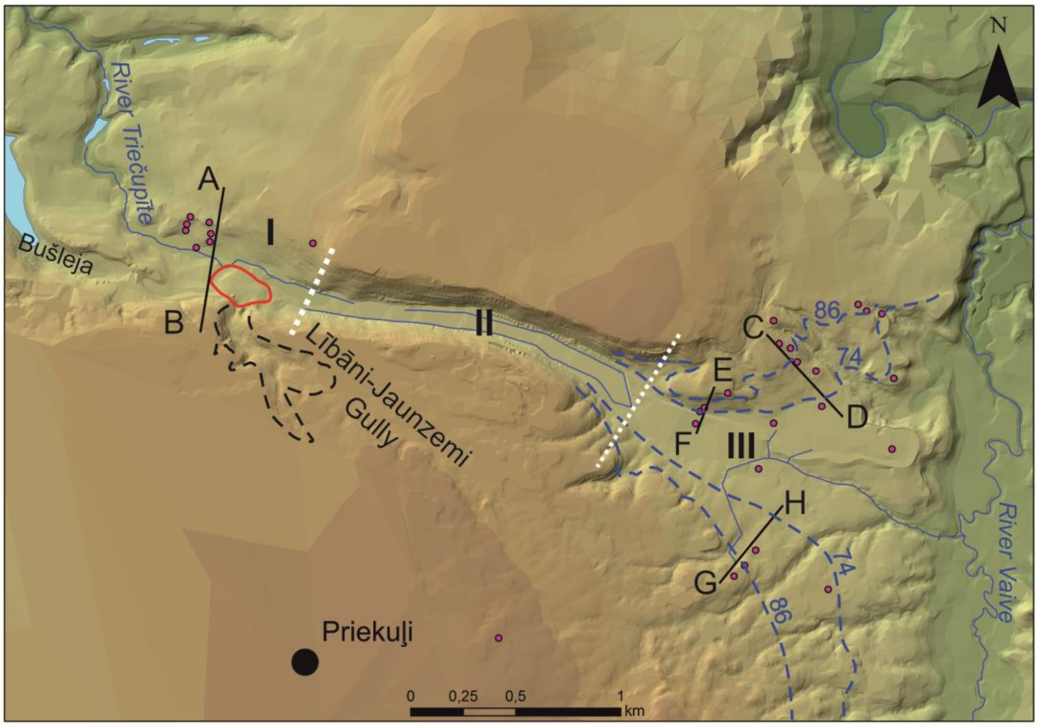

Fig. 3.2. Digital elevation model of the River Triečupīte valley and surrounding area. Solid black lines show location sites of profiles; red dots indicate the location of boreholes; blue dashed lines indicate the shorelines of the Kārkliņi palaeobasin; the contour marked by a red solid line denotes the location of the freshwater tufa apron; white lines separate geomorphologically distinct parts of the River Triečupīte valley: I – north-western extension; II – middle part; III – south-eastern extension.

The thickness of glaciolacustrine sediments varies from some tens of centimetres to a few metres. In the NW extension three terraces can be traced, at 72, 66 and 62 m a.s.l. (Fig. 3.3). The two highest are considered to be of erosional origin. In separate boreholes basin sediments have been detected at 65 m a.s.l. The middle part of the River Triečupīte valley is non-terraced, with a U-shaped cross-section. Its slopes are very steep, in some places reaching the critical angle of repose. In the upper part of the valley the Upper Devonian Pļaviņas Formation dolomite forms steep scarps. As result of suffosion of the underlying sandstone and subsequent subsidence and collapse of the cracked dolomite, a number of caves and sinkholes have formed. In total, eight caves occur on the right-bank slope of the river valley, as well as one cave on the left-bank slope. The best-known are Big Sikspārņi, Medium Sikspārņi and Small Sikspārņi ('Bat') Caves. These are among the largest caves in Latvia, and are often erroneously classified as karst caves in dolomite. It is likely that the base level of the caves reflects the historic groundwater level that served as the base of suffosion.

On the basis of the spatial distribution of the fine-grained sediments, a model of the Kārkliņi palaeolake terraces has been developed (Fig. 3.2). According to this model, the palaeolake sediments and associated fluvial sedimentation occur in a much wider area than is displayed in a map by previous researchers (Zīverts and Arharova 1981), where the distribution of glacioaquatic sediments is restricted to a small area within the valley, at 75 m a.s.l. Between Vieķi Hill and near the Rauna-Mūrmuiža road within the valley of the River Rauna three shorelines of the Middle Rauna glacial lake can be identified, at 102, 80 and 76 m a.s.l.

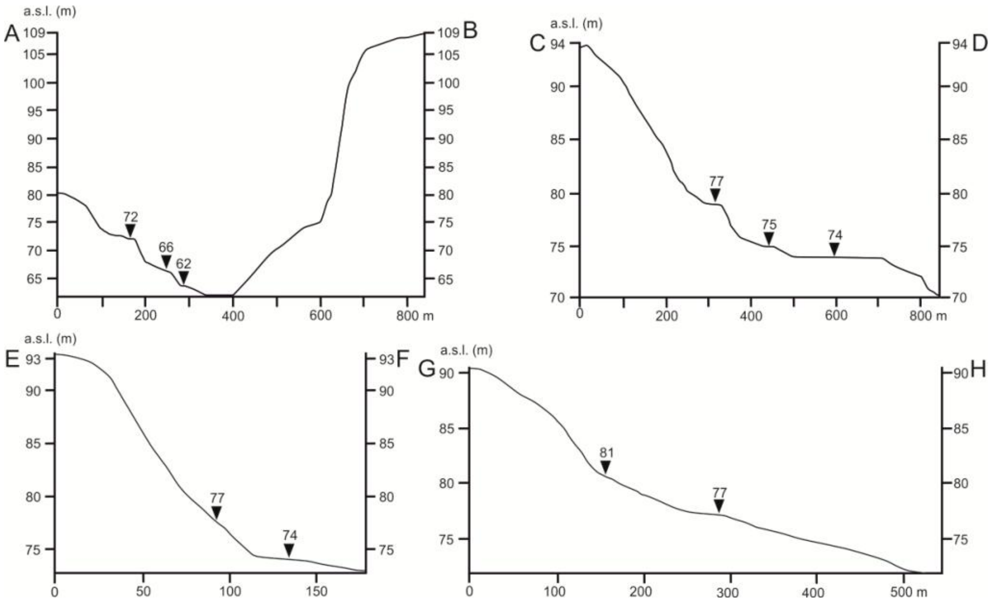

Fig. 3.3. Cross profiles of the Triečupīte valley. Triangles indicate detected terrace and shoreline levels.

Taking into account the hypsometric position of the shorelines of the Middle Rauna and Kārkliņi lakes, the layout of terrace-shaped forms, the surface topography and the distribution of the glacioaquatic sediments, it can be concluded that the Kārkliņi palaeobasin initially drained towards the west along the Bušleja into the Triečupīte valley, forming a lateral meltwater drainage valley. Later on, after melting of the dead ice blocks in the depression located north of Bušleja, runoff occurred via the River Triečupīte branch. The water level of the Kārkliņi palaeobasin dropped discontinuously. Short-term stabilization phases are indicated by shorelines traceable along the southeastern extension.

Palynological characteristics of the Lībāni-Jaunzemi freshwater tufa deposit

The apron-like freshwater tufa deposit is located on the southern side of the Triečupīte valley, where the Lībāni-Jaunzemi valley-like gully (Fig. 3.4), which is deeply incised into the Upper Devonian dolomite and sandstone, joins with the Triečupīte valley (Āboltiņš 1998). A freshwater tufa sequence up to 3.5-6 m high and 50 m wide is exposed in a quarry located at the mouth of the Lībāni-Jaunzemi valley-like gully. The total thickness of the freshwater tufa deposit (freshwater limestone, according to Āboltiņš 1998) reaches up to 12.2 m (Fig. 3.5).

Remains of fossil trees (branches, leaves and trunks) occur together with freshwater molluscs. Pollen analysis indicates that freshwater tufa precipitation started in the Boreal and lasted up to the Subatlantic (Danilāns 1957, 1973). The freshwater tufa deposit has an apron-like shape. According to Pedley (1990), freshwater tufa can be classified as a fluvial deposit precipitated by a spring. Spring water in this area has a high calcium carbonate content. Calcareous sediments were gradually deposited on the lower part of the slope. The small folds that occur in the tufa were created by sediment flows of the unconsolidated calcareous deposits (Āboltiņš 1998). However, these small-scale deformation structures are most likely responsible for the settling of the calcium carbonate on the roughened fluvial or mass-wasting erosional surface. The springs have formed a multi-level waterfall about 7 m high.

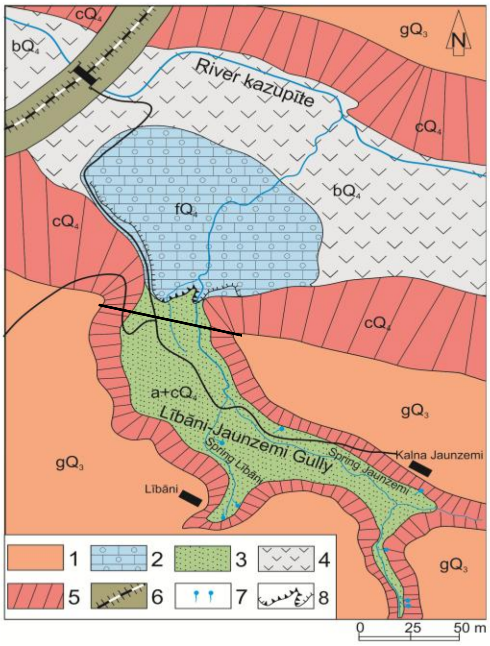

Fig. 3.4. Quaternary superficial sediments in the area of the Lībāni-Jaunzemi tufa deposit. 1 – Late Weichselian till (gQ_3); 2 – freshwater tufa (fQ_4); 3 – alluvial-colluvial sediments ($a+cQ_4$); 4 – peat (bQ_4); 5 – colluvium (cQ_4); 6 – railway embankment; 7 – springs; 8 – outcrop; black straight line indicates location of cross section shown in Fig. 3.5.

A 7.60-m-long section of the Lībāni-Jaunzemji tufa outcrop has been sampled for pollen analysis. These data have been used for approximate estimation of the time and environmental conditions of tufa deposition. A new pollen diagram constructed according to these data allows four local pollen assemblage zones (PAZ) to be distinguished (Fig. 3.6; Table 3.1). Zoning was done using correlations with pollen diagrams in the region and pollen data obtained from previous investigation on a 10.5-m-long sequence by A. Timšs (published in Danilāns 1957). Even though the current section is 2.9 m shorter, the pollen data show approximately the same characteristics of pollen spectra.

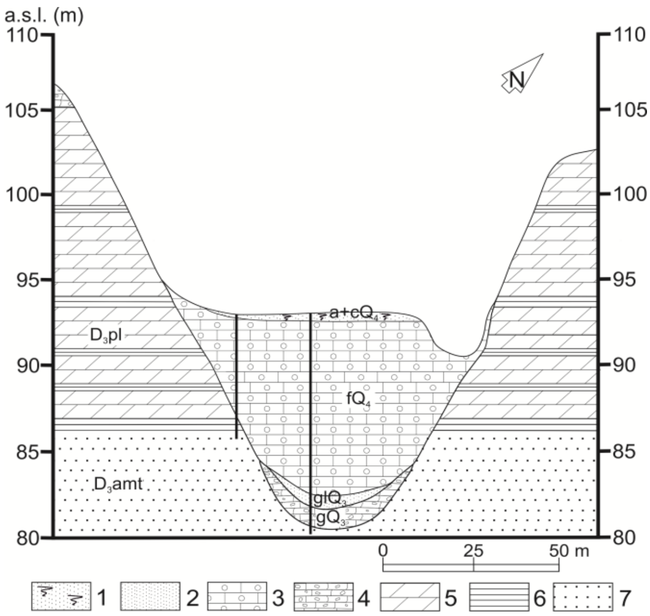

Fig. 3.5. Geological section across the Lībāni-Jaunzemi valley-like gully (modified from Danilāns 1957).
Legend: 1 – alluvial-colluvial sediments ($a+cQ_4$); 2 – glaciolacustrine sand (glQ_3); 3 – freshwater tufa (fQ_4); 4 – Late Weichselian till (gQ_3); 5 – Upper Devonian dolomite of Pļaviņas formation (D_3pl); 6 – Upper Devonian clay interlayers; 7 – Upper Devonian sandstone of Amata formation (D_3amt). See Fig. 3.4 for location of section.

Pollen spectra in both diagrams suggest that the most intensive freshwater tufa precipitation occurred in the Early Holocene. Sandy tufa started to be deposited at the base of both analysed sections. The proportions of tree and shrub, or arboreal (AP) and herb or non-arboreal (NAP) pollen point to a partly open mosaic landscape during the time of deposition of the freshwater tufa. No relationship has been identified between the pollen composition and variation in tufa types.

Table 3.1. Local pollen assemblage zones of the Lībāni-Jaunzemji tufa outcrop section.

LPAZ and chronology	Description of zone
LJ4 *Betula-Alnus-Pinus* (beginning of the Holocene Thermal Maximum, i.e. beginning of the Atlantic – AT1)	This zone is characterized by stable records of *Pinus* (50-55%) and *Betula* (15-20%) pollen, an increase of alder (*Alnus*) to 10% and hazel (*Corylus*) pollen up to 6%, as well as the empirical maxima of pollen values of broadleaved trees, varying from 0.5 to 3%. *Picea* percentages increase, reaching 2.8%. Some increase is also characteristic for herb pollen, mainly represented by Poaceae, Cyperaceae, Ranunculaceae and *Aster* type.
LJ3 *Betula-Alnus-Pinus* (end of the Early Holocene, i.e. 2nd part of the Boreal – BO2)	The lower part of the laminated tufa and dense tufa in the depth interval 1.8-3.35 m contains pollen with a composition indicating a decrease of pine forest in the area, some increase in *Betula*, *Alnus* and *Corylus*, and the appearance of *Ulmus*. The occurrence of *Picea* and increase in ruderal plants suggest some changes in vegetation and climate. Particularly the increase in *Plantago*, Chenopodiaceae, *Rumex* and Rubiaceae indicates the possibility of human activity in the area. Spores are mainly represented by green algae Bryales and ferns Polypodiaceae.
LJ2 *Pinus* (2nd part of the Early Holocene, i.e. 1st part of the Boreal – BO1)	Represented by clayey freshwater tufa in the lower part of the zone interval (6.4-6.9 m) and dense freshwater tufa in the upper part. *Betula* pollen significantly decreases and *Pinus* reaches its maximum (80%) in the pollen diagram above the previous zone. The dominance of *Pinus* is characteristic for the first half of the Boreal in the pollen spectra of pollen diagrams for Latvia. There is still a significant presence of various herbs, suggesting that the surrounding area was not covered by dense forest. Pollen of pasture/meadow plants and also *Plantago* and *Urtica* indicates some presence of man in the area during the first half of the Boreal.
LJ1 *Betula-Pinus* (1st part of the Early Holocene – Preboreal)	Pollen spectra indicate the dominance of *Betula* sect. *Albae* and a comparatively high amount of *Pinus* and herbs in the lower part of sediment sequence of the section represented by clayey and silty freshwater tufa overlying the sandy tufa at the base of the section. The herb pollen is mainly represented by Poaceae, Cyperaceae and ruderal herbs, such *Artemisia* and Chenopodiaceae. Total pollen composition points to a partly open landscape, covered by sparse pine-birch forest accompanied by a rich grass community. Comparison with regional pollen spectra indicates that the zone described may be correlated with the Preboreal (PB).

Many studies of freshwater tufa in Central Europe using radiocarbon datings and pollen analysis show that a peak of tufa precipitation occurred during the Atlantic and Subboreal climatic periods (5000–2500 BP) of the Holocene, when climatic conditions were warmer and wetter (Goudie et al. 1993; Banks et al. 2012). Freshwater tufa deposits in Latvia have not been dated by radiometric dating methods. The age of the freshwater tufa has been estimated approximately using pollen data. The pollen data from the new section of the Lībāni–Jaunzemi deposit allow us to conclude that the largest volume of tufa was formed before the cold event of 8200 cal yr. BP, which is clearly expressed by a sharp peak of birch (*Betula*) pollen and a brief decrease in alder, hazel and broadleaved pollen (Seppä et al. 2007). This is in good agreement with studies in the Pudost massif (Nikitin et al. 2011), where accumulation of freshwater tufa (paratravertine) was determined as having occurred from 7.5±0.4 to 6.8±0.4 ka BP.

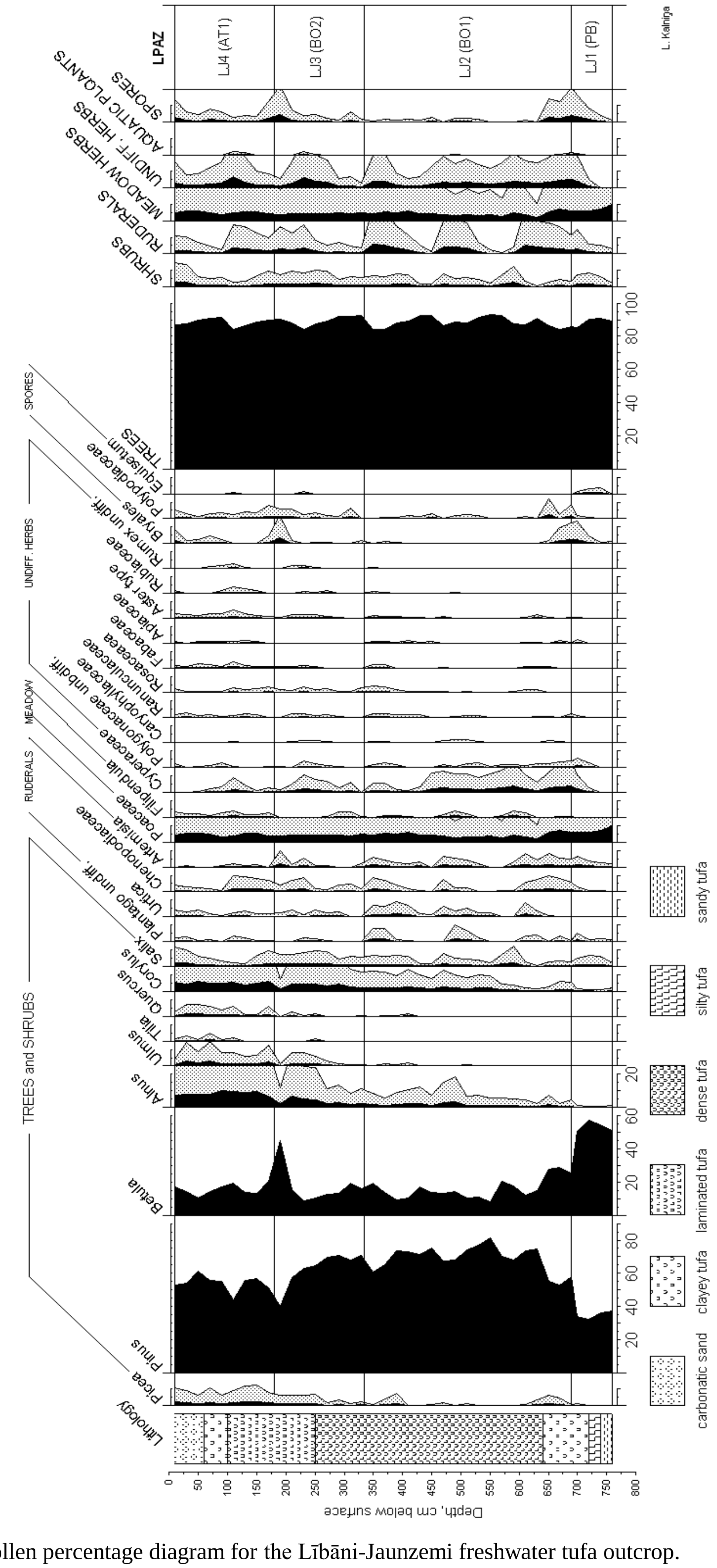

Fig. 3.6. Pollen percentage diagram for the Lībāni-Jaunzemi freshwater tufa outcrop.

Most of the largest freshwater tufa deposits (Lake Vilgale, Pikste, Seriestade, Lībāni-Jaunzemji) in different regions of Latvia have been studied palynologically. According to palynological data it can be concluded that freshwater tufa started to precipitate at least in the Early Holocene. In many cases the accumulation of freshwater tufa ended during the first half of the Holocene Thermal Maximum, but this also depended on the local geological conditions.

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