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An erratic dropstone of granodiorite with a water-escape structure from a Weichselian terrace along the River Gauja (NE Latvia)

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ABSTRACT

A river terrace of the River Gauja (Latvia), built of Weichselian glaciolacustrine deposits, contains a large number of erratic boulders from the Fennoscandian Shield. These erratic boulders include several types of granites and granodiorites. Some of the granodiorites are so strongly weathered that they fall apart into mm-sized grains of individual minerals when it is attempted to take them out of the host sediment. This strongly weathered nature makes them physically comparable to unconsolidated sand. A consequence is that they may be subjected to soft-sediment deformation. The erratic granodiorite boulder under study here is the first described to show such a soft-sediment deformation structure inside: it has been intruded by a water/sediment mixture composed of the underlying silty/sandy material that must have been liquefied, possibly due to pressure exerted by the overburden, or – more likely – by the weight of the concentration of gravel of which the granodiorite boulder forms a part. The overpressurized water/sediment mixture tried to escape upwards through, among a few other places, the strongly weathered granodiorite, forming an escape structure.

1. Introduction

Unconsolidated sediments are commonly affected by a wide variety of processes during their accumulation and while still in an unconsolidated state. These processes may induce deformations of more or less complex shape and of different sizes. They may be restricted to one single layer or they may affect a set of layers (Van Loon, 2009). Wherever a solid particle is present within the unconsolidated sediment (e.g. a dropstone in a glaciomarine or glaciolacustrine succession), such an object tends to make the deformation of the adjacent sediment more complex, while remaining unaffected itself.

Obviously, also lithified sediments may show soft-sediment deformation structures (SSDS), but such structures must have originated at a stage when the sediment was still unlithified, and they were apparently preserved during lithification (Van Loon, 2003). It is also self-evident that lithified rocks may contain deformations that originated when the rock had already been lithified, but such deformations are almost exclusively due to tectonics. Only under exceptionally rare conditions may solid rocks show deformations that represent SSDS that were formed after lithification (Van Loon and Mazumder, 2011), but it might be a matter of debate whether such deformations should be considered as SSDS, even though the once lithified rock did react in a plastic way to the processes leading to the SSDS.

The feature that we deal with here is, as far as we are aware, the first of its kind described in literature. It concerns a strongly weathered granodiorite boulder that became deformed because a water-escape structure developed in it. This happened most probably after the erratic boulder had been transported in an already strongly weathered (and frozen) state by a land–ice mass during the Weichselian glaciation. It must also have happened after the erratic had been deposited in the glaciolacustrine succession that now forms a terrace of the River Gauja in NE Latvia. The physical and mechanical properties of the erratic obviously were completely different from the fresh granodiorite parent rock (cf. Chiu and Ng, 2014) when the water-escape structure developed.

2. Geological setting

The water-escape structure under study was found in the Dukuļi outcrop (25°23′17″E, 57°27′46″N), which is located in the north-eastern part of Latvia (Fig. 1A, B). The area is characterised by a thin (up to 10 m thick) succession of Quaternary sediments (Zelčs et al., 2011) consisting mainly of Late Weichselian till (Fig. 1C). During the Late Weichselian glaciation, the development of the area was controlled by the Burtnieks ice lobe of the Riga ice stream of the Fennoscandian ice sheet (Zelčs and Markots, 2004). The reconstruction of the ice flow by Boulton et al. (2001) suggests that the Riga ice stream started from the Bothnian Gulf as a part of the southern Baltic ice stream complex

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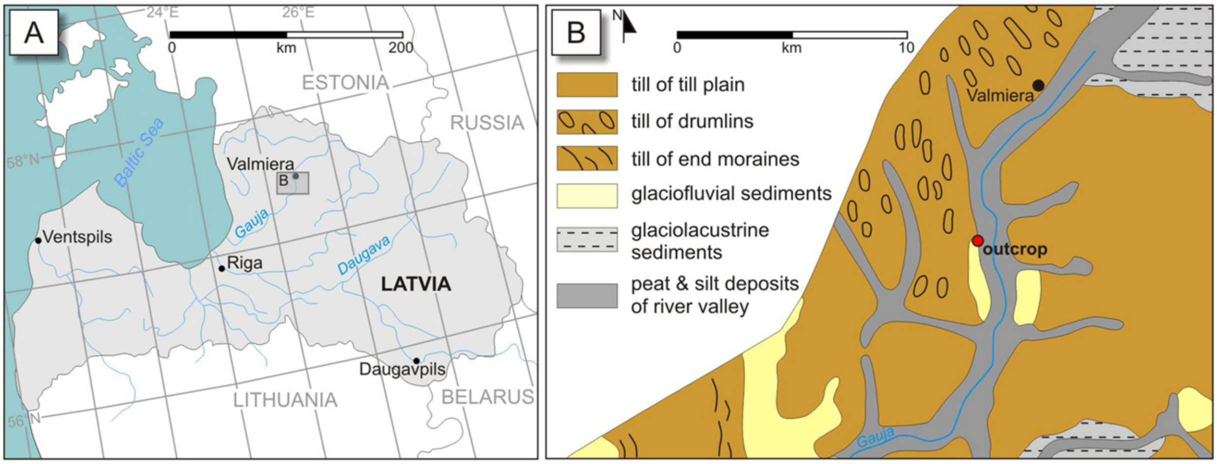

Fig. 1. Geological and geographical setting. A: location of the study area; B: geomorphology of the area. After Āboltiņš, 1971.

and then flowed over southern Finland and the Åland Islands, an area known for the extensive occurrence of granodiorites (Amantov, 1996).

The outcrop under study is located on the right bank of the River Gauja, in a scarp of terrace III (Āboltiņš, 1971), formed by fluvial erosion in the outer bend of a meander. The surface of terrace III is situated 14 m above the present-day mean water level. The total depth of the present-day River Gauja valley near the Dukuļi outcrop is 35 m and the valley is some 2 km wide. The sediments in which the granodiorite boulder was found are fine-grained and show all characteristics of a (glacio)lacustrine deposit (Krievāns and Rečs, 2014). They are up to 4.5 m thick (Fig. 2) and build the largest part of the exposed succession.

3. The erratic boulder under study

The erratic boulder under study, which shows the water-escape structure, was located in the middle part of the glaciolacustrine succession, at a depth of 3.5 m from the top of the section (the position is marked with a star in Fig. 2). It is a granodiorite existing exclusively of quartz, feldspar

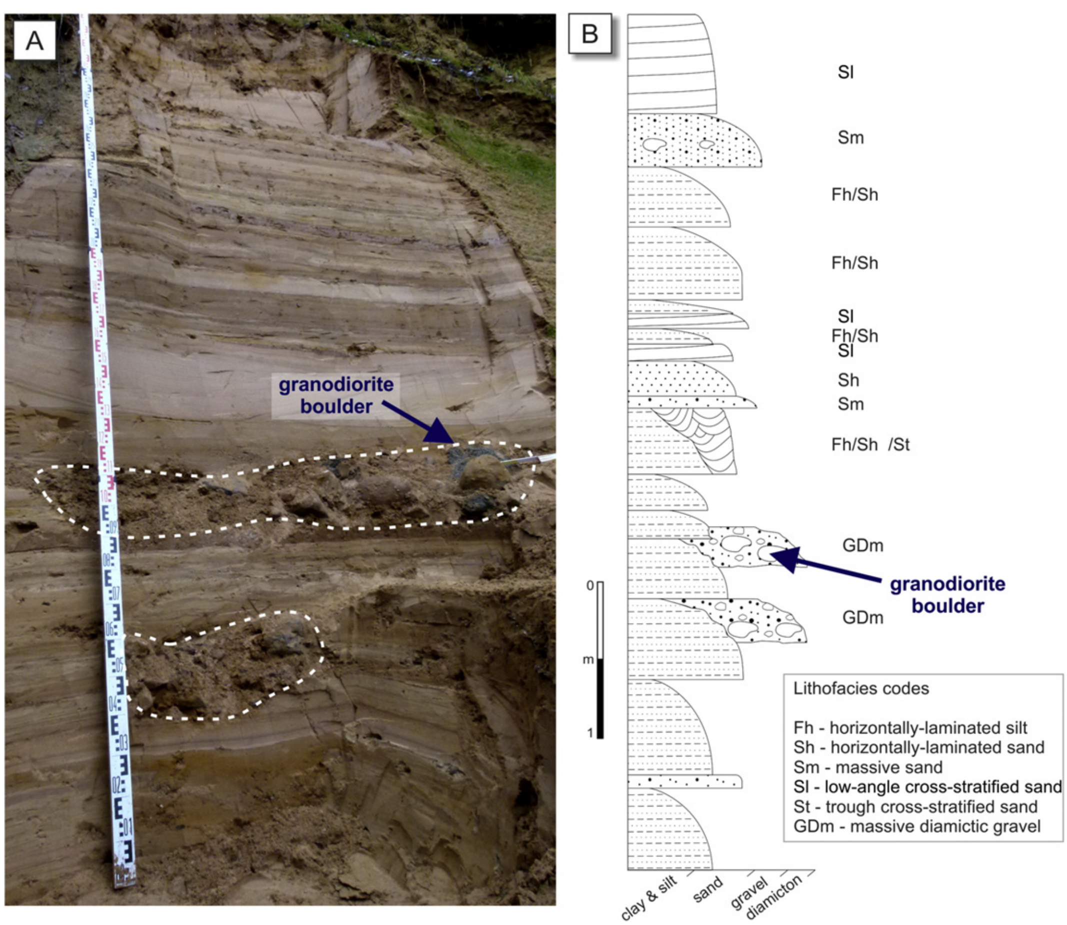

Fig. 2. The section under study (slightly modified after Krievāns and Rečs, 2014). A: As exposed in February 2014. The sediments between the dashed white lines are diamicton lenses within the glaciolacustrine sediments that build terrace III of the River Gauja. B: Grain sizes and sedimentary structures.