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Geomorphological aspects of glaciation in the Oldřichov Highland, Northern Bohemia, Czechia

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ABSTRACT

The Oldřichov Highland was glaciated during the Middle Pleistocene as evidenced by the proglacial sediments in the valley of the Jeřice River at Mníšek near Liberec. These sediments are a relic of a glaciofluvial terrace which accumulated in front of a small lobe of an ice sheet. Ice sheet mass advanced from north against northern face of the Oldřichov Highland. The southerly advancing ice lobe pushed through Oldřichov Col (478 m) and terminated ~ 400–500 m to the south of the col. The maximum thickness of the glacier to the north of the col was 50–60 m, in the col area it was < 10 m. Clast petrology varies up-section in the glaciofluvial sediments with the predominance of local and near rocks together with quartz clasts of mainly near origin. Lower amount of nordic material (below 8 %) was influenced by the local relief. Nordic erratic pebbles show the predominance of central and southern Swedish and east Baltic crystalline rocks and Cretaceous and Paleocene flints. The maximum extent of the glaciation was reconstructed by numerous sedimentological and geomorphological methods with sufficient accuracy.

Key words: continental glaciation, Middle Pleistocene, Oldřichov Highland

1. Introduction

Northern Bohemia area was repeatedly affected by the continental glaciation during the Middle Pleistocene. This part of the Czech territory represented during all glaciations only the marginal region and the ice sheet reached this area only during short periods in the course of glacial maxima. According to the present state of knowledge this occurred during both stadials of the Elsterian and those of the Saalian. For further detail overview see papers by Macoun and Králík (1995) and Nývlt (1998), for the maximum extent of the glaciation see also fig. 1. The extent of the glaciations has been greatly influenced by the local geomorphology.

The glaciated region incorporates the following geomorphological units: Frýdlant Hilly Land, Žitava Basin, and Šluknov Hilly Land within the Sudeten Mountains System in both geomorphological (Czudek ed. 1972, Demek ed. 1987) and morphostructural (Ivan 1999 a, b) division of Bohemian Massif. The other glaciated unit, Ralsko Hilly Land, lies within the Bohemian Tableland according to the geomorphological division (Czudek ed. 1972, Demek ed. 1987) and within the Bohemian Cretaceous Basin according to the morphostructural (Ivan 1999 a, b) and also geological (Mísař et al. 1983) division of Bohemian Massif. These units are separated by mountain ridges of the

Figure 1: Synoptical map of the Northern Bohemia area showing the maximum extent of glaciation, main geomorphological units and the study area (modified from Macoun and Králík 1995, Nývlt 1998 and Nývlt and Hoare 2000).

Lusatian Mountains, Jizera Mountains and by the Ještěd-Kozákov Ridge. Ice penetrated these mountain ridges via some transfluence passes: the Jítrava Saddle (424 m a.s.l.), the Upper Col (459 m a.s.l.) and the Oldřichov Col (478 m a.s.l.). The last one is the highest known place bearing traces of continental glaciation in Northern Bohemia.

The Oldřichov Highland is situated in the western part of the Jizera Mountains (fig. 1) with the highest hills over 700 m a.s.l. (Špičák 724 m, Ostrý hřeben 714 m and Stržový vrch 711 m), the lowest parts of the northern foothills lie at about 350 m a.s.l. The Highland is characterised by strongly broken denudation relief controlled in part by the properties of the underlying rocks (Nývlt 1999). The surface is covered by the mesoscale landforms produced by weathering and stripping the regolith so just hard cores of rocks in form of tors and castle-koppies remained. Other periglacial phenomena like cryoplanation terraces, frost cliffs, talus and block fields are also present. In the rocky bottoms of streams potholes occur.

The Oldřichov Col represents the lowest mountain pass on the watershed between the Lusatian Nisa and the Smědá rivers (which is made by the main ridge of the Jizera Mountains). The valley southward from the Oldřichov Col is an old preglacial valley modelled by the consequent stream of the Jeřice River and its subsequent, mainly left, tributaries. The northern valley of the Holubí Brook is trough-shaped with a well-developed backwall. These valleys set the Špičák-Stržový vrch Ridge off the Ostrý hřeben Ridge which both go at right angles to the main ridge of the Jizera Mountains.

The crossing of the Oldřichov Col by the glacier has already been mentioned by Králík (1988, 1989) suggested two or three ice sheet advances into the valley south of the col. The first of these (first Elsterian advance) was the strongest and the glacier could progressed about 5 km deep to the valley to the vicinity of Mníšek near Liberec (Králík 1989). As the glacier penetrated so far the valley, it must have filled a considerable part of the valley and produced erosional forms on the bedrock and changed the local geomorphology (Nývlt 1999).

By contrast, no geomorphological evidence of the glacier's presence (like striae, chattermarks, lunate and crescentic fractures, gouges, flutings, roches moutonnées, whale backs, drumlins, etc.) was identified on the micro- and mesoscale in the valley southward from the Oldřichov Col (Nývlt 1999). The only evidence is a small relic of the glaciofluvial terrace at Mníšek near Liberec left behind by the continental glacier receding from the Oldřichov Col (Nývlt 1999). The stratigraphic classification of this accumulation is still open to debate; Macoun and Králík (1995) link these proglacial sediments to the Early Saalian glaciation (Jítrava glaciation in local stratigraphical scale), however the exact age is still obscure.

So far, erratics in Czechia have been studied in detail only in Northern Moravia and Silesia. For the general summary and for further details of results in that region see Gába and Pek (1999). The erratics in glacial sediments in Northern Bohemia has not been studied at all so far.

2. Bedrock geology

The study area is underlain by the Krkonoše-Jizera granite pluton, which is one of the typical representatives of the Variscan granitoids of the Bohemian Massif (Chaloupský et al. 1989). These rocks were intruded towards the end of the Variscan magmatic and tectonometamorphic processes during the Upper Carboniferous, some 313–314 Ma ago (Mazur 1998, Marheine et al. 1999). The northern boundary of the Krkonoše-Jizera granite pluton follows the Jizera (locally Libverda) Fault Zone (Chaloupský et al. 1989). This is also true for the northern slope of the Oldřichov Highland.

The Oldřichov Highland is created by porphyritic medium-grained biotite granite to granodiorite (Klomínský 1969, Chaloupský et al. 1989). The rock comprises almost always porphyritic and all-directionally granular texture with unequigranular groundmass. A fresh sample is a light grey to pink rock. The groundmass (3–5 mm) consists of plagioclase, K-feldspar, biotite, chlorite and hornblende. Feldspar phenocrysts (30–50 mm, exceptionally 70 mm) show a weak planar and linear preferred orientation and correspond mainly to whitish or pink K-feldspar and minor plagioclase (Klomínský 1969). Plagioclase typically prevails over K-feldspars, muscovite is absent (Chaloupský et al. 1989).

The primary pink colour of phenocrysts of K-feldspar has usually been bleached to white due to chemical weathering. The granite massif has been weathered by the function of physical weathering. The bedrock is in some places loosened to the depth of about 3 m, creating thick regolith cover with very common isolated feldspar crystals (Nývlt 1999).

3. Sedimentology

The sand and gravel accumulation at Mníšek near Liberec, 3.5 km to the south of the col, represents a small relic of a valley sandur associated with an outlet glacier which crossed the Oldřichov Col (Nývlt 1999). Typical sedimentation of proglacial braided rivers led to the formation of a glaciofluvial terrace. There was only one input event of continental ice into this basin, so the incision and subsequent accumulation of a new terrace influenced by the next glacier impact did not occur. The glaciofluvial terrace has subsequently been eroded by the Jeřice River and now survives as a relatively thin relic (usually 3-5 m) on the left side of the valley (Nývlt 1999).

Lithofacies and sedimentary structures have been classified according to the codes for glaciofluvial sequences (Miall 1977). Typical lithofacies of intermediate to distal braided rivers prevail. The sequence in the section UEA (fig. 2) consists mainly of massive cross-

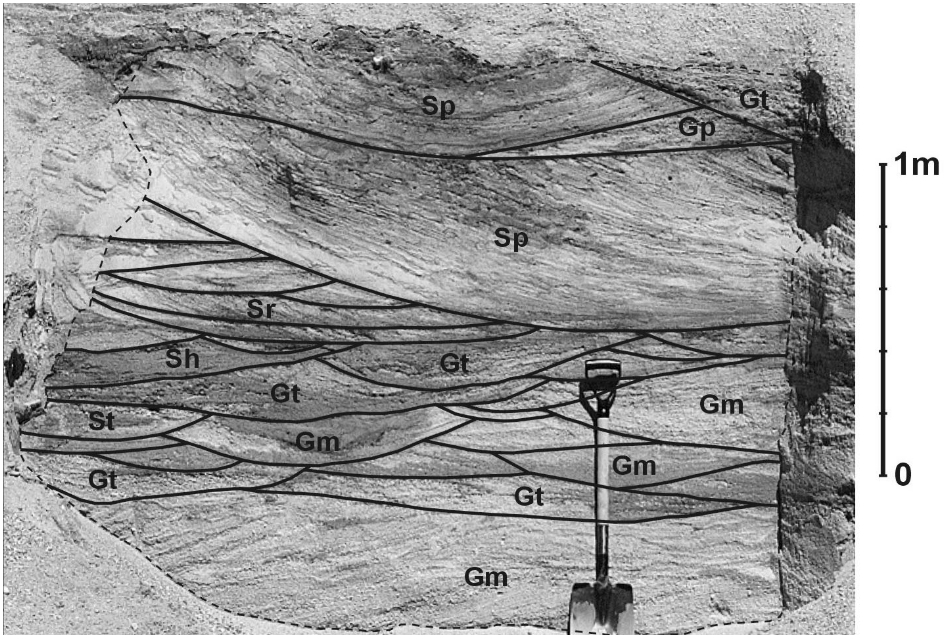

Figure 2: Section UEA in the upper exposure in the sand pit at Mníšek near Liberec with the main lithofacies. The lithofacies codes adopted from Miall (1977); see text for description.

bedded gravels (Gm), planar (Sp, Gp) and trough (St, Gt) cross-bedded sands and gravels, subhorizontally to horizontally bedded sands (Sh), and ripple cross-laminated sands (Sr). No tills were found at the whole locality (Nývlt and Hoare 2000). The sequence represents a small relic of a typical intermediate to distal zone of a sandur with relatively wide and shallow channels. The sequence documents the aggradation and then abandonment of channels, reflecting frequent channel and longitudinal and transverse bar migration (Nývlt 1999).

The measurement of palaeocurrents has been conducted in through cross-bedded sands, at the same part of the exposure as the lithofacies analysis (section UEA). Twenty-five measurements of the declination of cross-beds are shown in fig. 3. A bimodal distribution is clearly visible: 200° (corresponding to the present valley orientation) and transverse 275°. The transverse component has probably been created by the aggradation of a transverse bar, which was almost at right angles to the main gradient of the valley

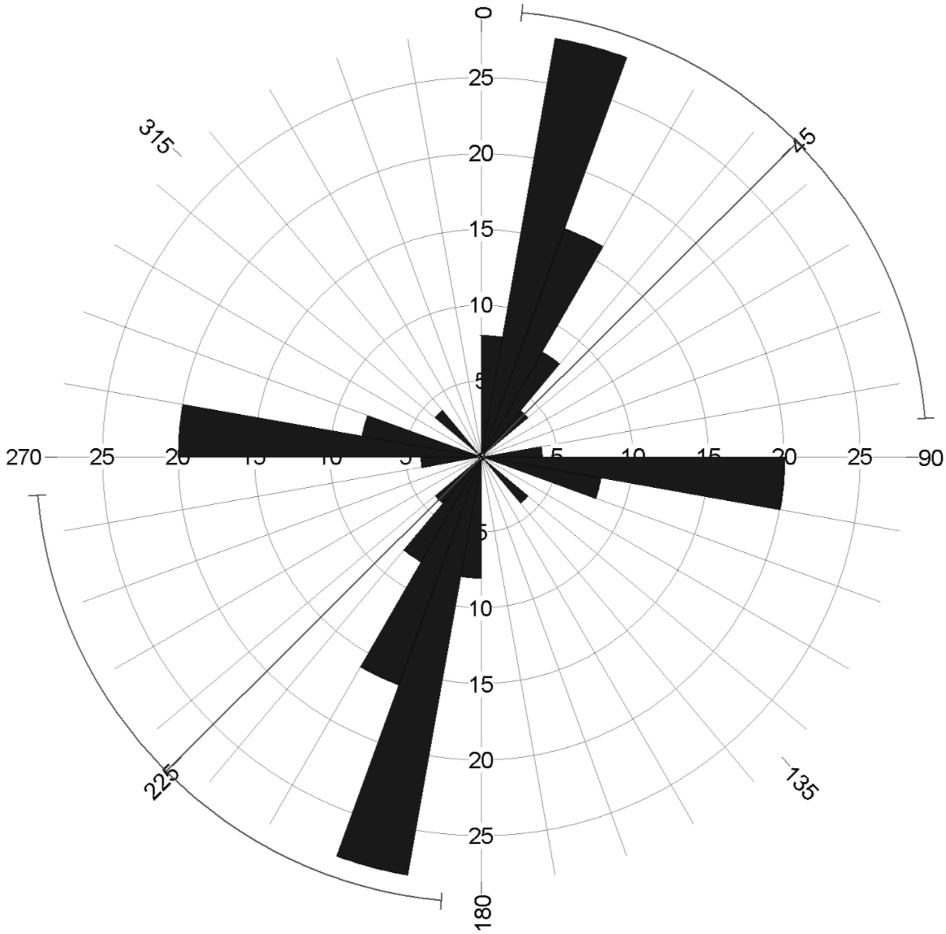

Figure 3: Rose diagram indicating palaeocurrents with the mean vector in the UEA section of the upper exposure in the sand pit at Mníšek near Liberec (adopted from Nývlt 1999).

(Nývlt 1999). The mean declination (225°) agrees well with the direction Oldřichov Col – relic of the glaciofluvial terrace (222°). The mean inclination (15.2°) fits more to the intermediate or distal part of the glacial outwash rather than to the proximal part of a sandur (Nývlt 1999).

There were found no glacial (tills or glaciofluvial) sediments in the upper part of the valley north of the Oldřichov Col, and the cover of slope deposits in the lower part is also very limited. This is in discrepancy with the prevailing conservation of thick mantles of slope and aeolian deposits on northern and northeastern slopes within the whole Czech Massif (Prosová and Sekyra 1961).

4. Sedimentary petrology

Clast petrology of the 8–16 mm fraction were undertaken throughout the sections LE and UEB (Nývlt and Hoare 2000), for the position of samples and for the provenance substitution see fig. 4. Glacial erratics transported only below ~10 km from the bedrock source were described as local rocks. Near rocks derived from bedrock sources 10–100 km

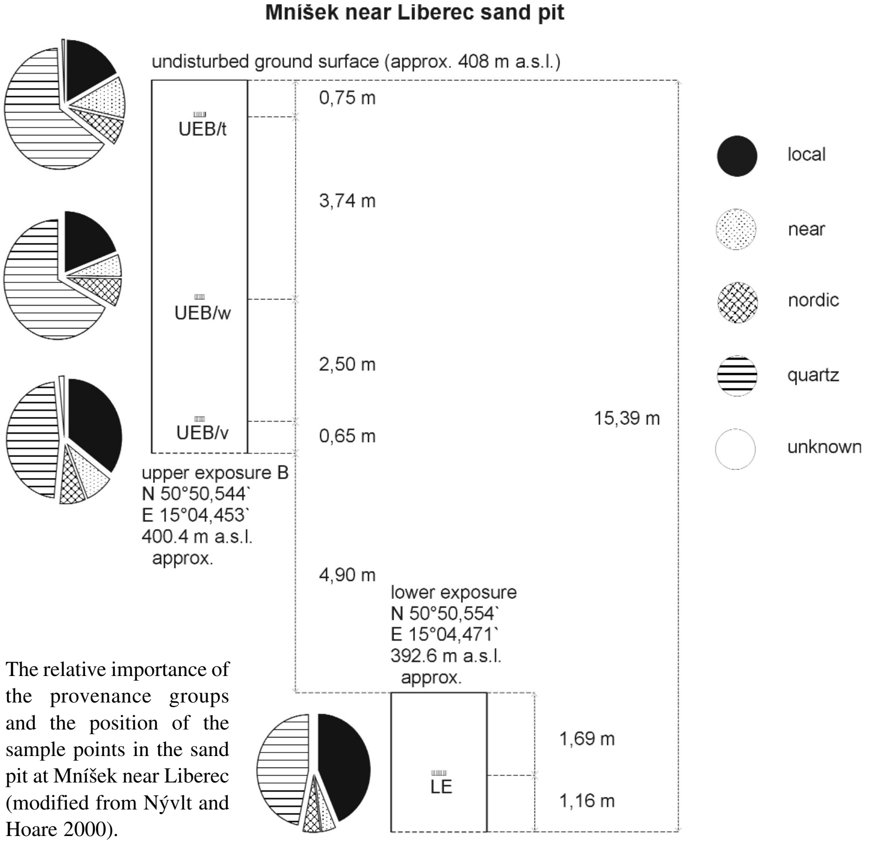

Figure 4: The relative importance of the provenance groups and the position of the sample points in the sand pit at Mníšek near Liberec (modified from Nývlt and Hoare 2000).

away, the more distal material lies within the nordic rocks. Whilst crystalline rocks and its minerals (mainly K-feldspar and quartz) of local and near origin prevail, there is an up-section reduction in granitoids and feldspars and corresponding enrichment in quartz. As the granitoids and feldspars are predominantly of local origin, 80–90 % of the quartz clasts were probably derived from the nearby Lusatian Granodiorite Complex, mainly from Rumburk granite, Zawidow and Václavice granodiorite and are of near origin. The grey-blue colour and size of the quartz clasts are strongly suggestive of a near origin. The amount of nordic material never exceeds 8 % (Nývlt and Hoare 2000).

Nordic erratic pebbles and cobbles (20–100 mm) were taken from the upper exposure B close to the sample UE/v (fig. 4). Some of these erratics were identified petrologically and their provenance could therefore been established beyond reasonable doubt (Nývlt 1999). The most common erratics are those from groups 1, 2, 6 and 7 according to the classification of Zandstra (1988) and Gába and Pek (1999), see also fig. 5.

Only rocks from Åland Islands (like Åland Rapakivi, Åland Granite Porphyry and Åland Quartz Porphyry) have been determined from the first group. In the second group occur solely Red Baltic Sea Quartz Porphyry from the sea floor southeast of the Åland Islands (Nývlt 1999). The rocks from Dalarna (the Group 6 of Zandstra) prevail slightly and are represented by a variety of porphyries, which are often summarized as Dala Porphyries (Gába and Pek 1999).

Nevertheless Bredvad, Glöte and Red Särna Porphyry, together with Grönklitt Porphyrite and Siljan Granite have been determined within the group of Dala Porphyries

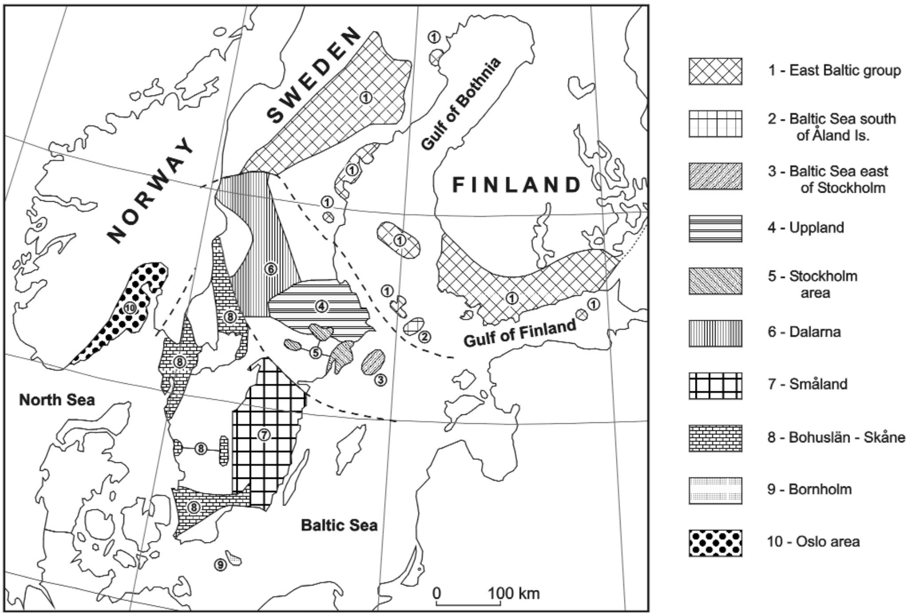

Figure 5: Source areas of the nordic crystalline rocks. Group numbers adopted from Zandstra (1988) and Gába and Pek (1999), see text for description.

(Nývlt 1999). Southern Swedish rocks (the Group 7 of Zandstra) are represented exclusively by granites (Växjö and Uthammar Granite). Besides these crystalline rocks, sedimentary rocks of nordic origin such as Cretaceous and Paleocene flints, Dala and Nexö Sandstones have also been recognised at Mníšek near Liberec. According to the crystalline erratic association, the standard Hesemann's number (Hesemann 1975) was estimated at 3430 (Nývlt 1999).

5. Geomorphology and morphometry

On the basis of the 1:10 000 scale topographic map, longitudinal (fig. 6) and cross profiles (fig. 7) of both main valleys were constructed. The position of the glaciofluvial terrace and of all cross profiles is also indicated on the longitudinal profile. The reconstructed glacier surface, immediate postglacial surface and morphological trimlines have also been added to the cross profiles and to the longitudinal profile.

The re-modelling of slopes caused by intensive weathering of bedrock on the contact of the glacier body with the rock has been used to reconstruct the maximum extent of the glaciation by Prosová (1981) in Northern Moravia mountains. The ordinary trimline describes the upper limit of the glacier erosion in weathered bedrock on valley sides (Benn and Evans 1998). The morphological trimline, indicated by the change in the slope shape, shows on the other hand only stagnation of the glacier, not the maximum reach of the glacier in the valley. The accuracy of the use of the trimlines (ordinary and morphological) to reconstruct the ice sheet is therefore limited, especially as the process of abrasion and plucking at the glacier bed requires a minimum ice-thickness that could have amounted to a few tens of metres.

Other specific limits of use of the trimline method arise in the study area. The glacial impact on the Oldřichov Highland is quite old (Middle Pleistocene), so overprinting by younger geomorphological processes (mainly periglacial and fluvial) is quite extensive. As a next limit the lithological properties of the local bedrock must be mentioned, which

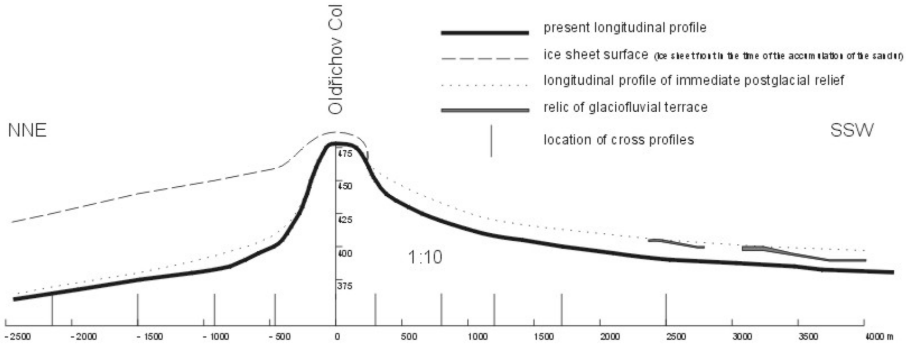

Figure 6: Longitudinal profile through the Oldřichov Highland with the position of the glaciofluvial terrace, ice sheet surface, longitudinal profile of the immediate postglacial relief and with the locations of cross profiles in fig. 7.

is susceptible to both types of weathering, especially to the frost action documented by periglacial phenomena such as cryoplanation terraces, frost cliffs, and block fields in the upper part of valleys and on hill summits.

The asymmetry of the valleys northward and southward from the Oldřichov Col is clearly visible in the longitudinal profile (fig. 6). These valleys originated on a fault at right angles to the main Jizera Fault Zone (see above). Both were preglacially modelled by fluvial action during the Pliocene and the Lower and early Middle Pleistocene. The

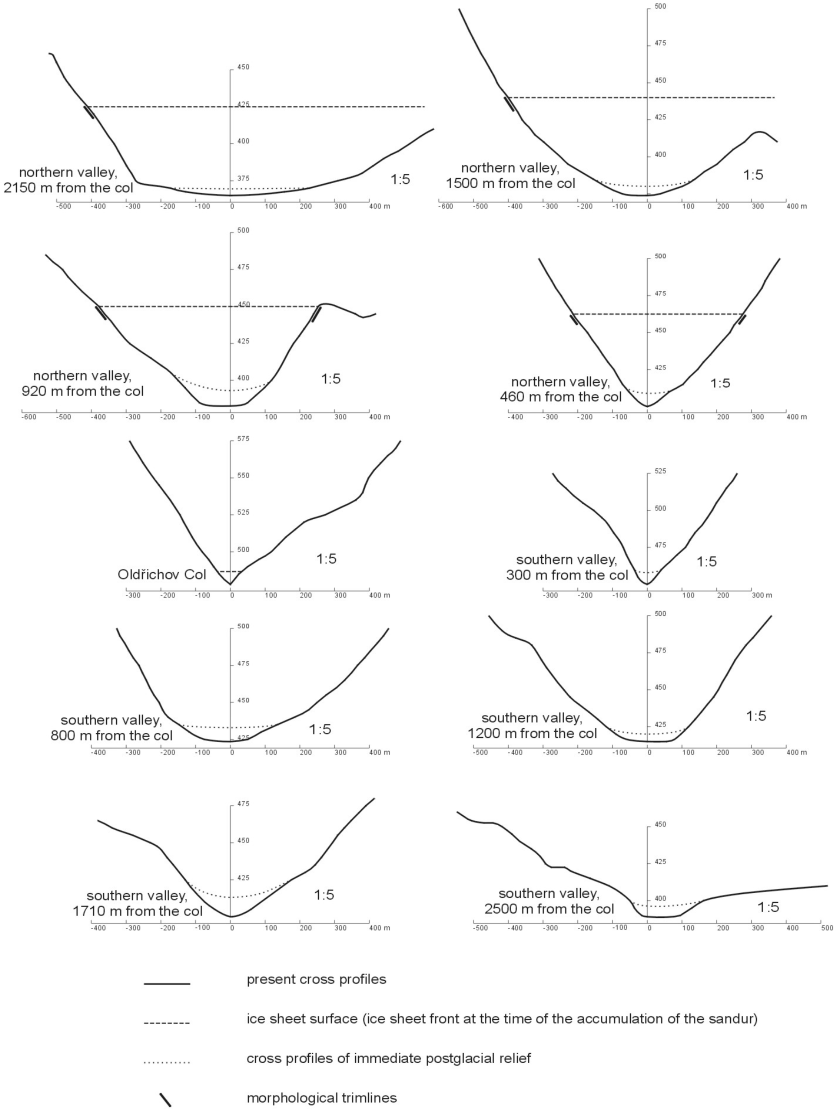

Figure 7: Cross profiles through both main valleys of the Oldřichov Highland with the ice sheet surface, cross profiles of the immediate postglacial relief and with the morphological trimlines.

analysis of aerial photographs together with the cross-profiles shows a flat and wide bottom with steep slopes on the sides of the northern valley in comparison with the valley south of Oldřichov Col. (fig. 7). Flat and wide bottom is also not present in other valleys in the northern foothills of the Jizera Mountains. This flattening and widening of the valley could have been created by glacier erosion. The steep slope of the northern valley must also have been influenced by glacial abrasion and removal of debris fragments, as the highest inclination in the upper part of the valley north of the col is about 16°, on the other hand the steepest slope in the valley southward from the Oldřichov Col remains below 10°.

6. Discussion and Conclusions

Sedimentological, sedimentary petrological and geomorphological analyses carried out in the Oldřichov Highland could be summarized with regard to the glaciation of this area as follows. The continental glacier was checked in the course of its southern advance through the Frýdland Hilly Land by the barrier of the Jizera Mountains. The ice sheet reached up to ~420–430 m a.s.l. in the northern foothills of the Jizera Mountains. The only possibility for the continuing of the glacial penetrating to the south was the upward movement through narrow valleys against the flow of recent rivers. Indeed, only in the Oldřichov Highland was the transfluence pass on the watershed low enough to enable the crossing of the ice sheet lobe over it.

The northern valley was first filled to the altitude 430–460 m a.s.l. (in dependence to the distance from the col) by the ice, but due to the subsequent pushing of the advancing ice mass stood the ice sheet front up to the Oldřichov Col (478 m). The ice penetrated ~400–500 m beyond the col to the southern valley during its maximum advance (see fig. 8). The extent of the outlet glacier in the valley south of the col is considerably smaller than was supposed by Králík (1988, 1989). The maximum thickness of the ice in the valley north of the col did not exceed ~50–60 m. Near the Oldřichov Col the ice thickness remained <10 m, which is considerably less than the figure suggested by Králík (1989). The accuracy of the maximum extent of the glacier (especially in the northern valley) is limited by the trimline method to ±10–20 m.

The study of the outwash sediments indicates the definite material input from the col. The lithofacies and the mean inclination of palaeocurrents show the sedimentation in the intermediate to distal zone of a valley sandur accumulation. The ice lobe front was located ~200–300 m SSW from the col during the accumulation of the upper part of the glaciofluvial succession (fig. 6).

The absence of glacial and other types of Quaternary sediments in the upper part of the valley northward from the Oldřichov Col, which is not common within the Czech Massif for that exposure of the valley (Prosová and Sekyra 1961), was affected by the glacier excavating its soft bed during the ice sheet retreat from the area and by the subsequent fluvial and periglacial erosion of unconsolidated material. The fluvial and periglacial activity was also responsible, together with the lithological properties of local bedrock, for the absence of micro- and meso-scale glacial landforms within the area. The glacier

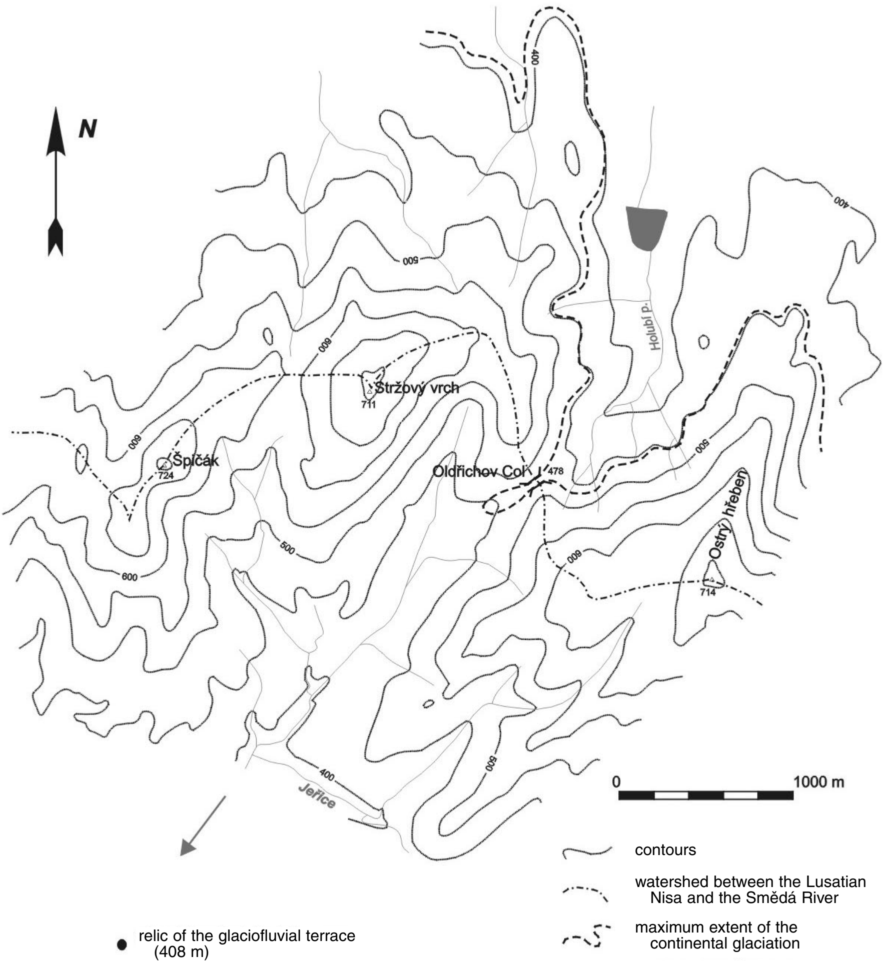

Figure 8: Hypsographic map of the Oldřichov Highland, with the position of the glaciofluvial terrace and the maximum extent of the continental glacier.

re-modelling of the upper part of the northern valley is seen in the longitudinal profile (fig. 6) and in the flattening of its floor in the cross-profiles (fig. 7).

The material which was transported for a distance of first tens of kilometres (local and near) prevails in the pebble fraction. The reduction of local material up-section and the enrichment of near rocks in the same direction are well shown in the section, this can be interpreted as follows. After the ice front had reached the col, the meltwaters flowed to the southern valley and an erosion of local rocks occurred. The front and basal layers of the glacier were prevalently loaded by the local rocks. The more distal material (particularly the near rocks), transported mainly in the middle and upper layers of the glacier, was deposited later during the continuing glacier pushing through the Oldřichov Col. The amount of nordic material is consistently between 5 and 8 %. This relatively small content was particularly influenced by the position of the accumulation beyond the Oldřichov Col, as nordic rocks are usually transported further from the ice sheet front (Benn and Evans 1998, Nývlt and Hoare 2000). The release of near and nordic rocks from the middle and upper glacier layers and its enrichment, documented in the upper part of the section, occurred during the ice sheet retreat (Nývlt and Hoare 2000).

Considerable predominance of central and southern Swedish and east Baltic crystalline rocks shows well, whereas no western Scandinavian (Norwegian and western Swedish) rocks were found. The transport path of the nordic erratics is almost from the north with the significant eastern component. The statistics of the erratic association were not used for the stratigraphical classification, as there has been a very limited amount of erratic statistic results in Northern Bohemia so far, and the correlation with other areas (Northern Germany, Northern Moravia) is not possible due to the different geographic position of the areas in relation to the advancing European ice sheet. Therefore, the stratigraphic position of the glaciation proposed by Macoun and Králík (1995) cannot be confirmed or challenged.

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References

BENN D. I., EVANS D. J. A. (1998): Glaciers & Glaciation. 734 pp., London.

CZUDEK T. (ed.) (1972): Geomorfologické členění ČSR. Studia Geographica, 23, 140 pp., Brno.

DEMEK J. (ed.) (1987): Zeměpisný lexikon ČSR – Hory a nížiny. 584 pp., Praha.

GÁBA Z., PEK I. (1999): Ledovcové souvky moravskoslezské oblasti. 126 pp., Šumperk.

CHALOUPSKÝ J. et al. (1989): Geologie Krkonoš a Jizerských hor. 288 pp., Praha.

IVAN A. (1999 a): Geomorphological aspects of the late Saxonian epiplatform orogeny of the Bohemian Massif (Part 1). Moravian Geographical Reports, 7, 1, 18–33, Brno.

IVAN A. (1999 b): Geomorphological aspects of the late Saxonian epiplatform orogeny of the Bohemian Massif (Part 2). Moravian Geographical Reports, 7, 2, 12–31, Brno.

KLOMÍNSKÝ J. (1969): Krkonošsko-jizerský granitoidní masív. Sborník geologických věd, Geologie, 15, 7–133.

KRÁLÍK F. (1988): Kontinentální zalednění severních Čech. Zprávy o geologických výzkumech v roce 1985, 110–111.

KRÁLÍK F. (1989): Nové poznatky o kontinentálních zaledněních severních Čech. Sbor. geol. Věd, Antropozoikum, 19, 9–74.

LÜTTIG G. (1991): Erratic boulder statistics as a stratigraphic aid – Examples from Schleswig-Holstein. Newsletters on Stratigraphy, 25, 2, 61–74.

MACOUN J., KRÁLÍK F. (1995): Glacial history of the Czech Republic. In: Ehlers, J., Kozarski, S., Gibbard, P. L. (eds.): Glacial deposits in North – East Europe. 389–405, Rotterdam.

MARHEINE D., KACHLÍK V., PATOČKA F., MALUSKI H. (1999): The Palaeozoic Polyphase Tectonothermal Record in the Krkonoše-Jizera Crystalline Unit (West Sudetes, Czech Republic). Geolines, 9, 133–135.

MAZUR S. (1998): Variscan thrusting and extensional collapse in the Karkonosze – Izera Massif, West Sudetes: tectonics, sedimentary and magmatic record. Geolines, 6, 43–44.

MIALL A. D. (1977): A review of the braided river depositional environment. Earth-Science Reviews, 13, 1–62.

MÍSAŘ Z., DUDEK A., HAVLENA V., WEISS J. (1983): Regionální geologie ČSSR I, Český masív. 380 pp., Praha.

NÝVLT D. (1998): Kontinentální zalednění severních Čech. Geografie – Sborník ČGS, 103, 4, 445–457.

NÝVLT D. (1999): Pevninské zalednění Oldřichovské vrchoviny. Unpublished Mgr. Thesis, Faculty of Science, Charles University, 82 pp., Praha.

NÝVLT D., HOARE P. G. (2000): Valounové analýzy glacifluviálních sedimentů severních Čech. Věstník ČGÚ, 75, 2, 121–126

PROSOVÁ M. (1981): Oscilační zóna kontinentálního ledovce. Jesenická oblast. Acta Universitatis Carolinae – Geologica, 25, 3, 265–294.

PROSOVÁ M., SEKYRA J. (1961): Vliv severovýchodní exposice na vývoj reliéfu v pleistocénu. Časopis pro mineralogii a geologii, 6, 4, 448–463.

ZANDSTRA J. G. (1988): Nordelikje kristallijne gidsgesteenten. 469 pp., Leiden.

GEOMORFOLOGICKÁ HLEDISKA ZALEDNĚNÍ OLDŘICHOVSKÉ VRCHOVINY V SEVERNÍCH ČECHÁCH, ČESKO

Résumé

Oldřichovská vrchovina ležící v západní části Jizerských hor byla ve středním pleistocénu postižena zásahem kontinentálního ledovce. Zachovaný relikt glacifluviální terasy u Mníšku u Liberce byl akumulován od čela ledovce nacházejícího se nedaleko Oldřichovského sedla (478 m). Během svého maximálního postupu zasáhl ledovcový splaz asi 400–500 m od sedla do jižního údolí, což je výrazně menší zásah, než jaký byl uvažován dříve. Maximální mocnost ledovce se v severním údolí zřejmě pohybovala okolo 50–60 m, v oblasti sedla mocnost ledovce jistě nepřekračovala 10 m. Studium petrologie valounů glacifluviálních sedimentů ukazuje na převahu místního a blízkého materiálu společně s křemennými valouny. Patrné je postupné nabohacování blízkých hornin do nadloží. Množství nordického materiálu bylo výrazně ovlivněno geomorfologickou překážkou v podobě Oldřichovského sedla a je tedy poměrně nízké (pod 8 %). Nordické souvky vykazují převahu středošvédských porfyrů, jihošvédských a východobaltských granitoidů, spolu s významným obsahem křídových a paleocenních pazourků. Podle různých sedimentologických a geomorfologických metod výzkumu byl stanoven maximální rozsah zalednění ve studovaném území (obr. 8) s přesností cca ±10–20 m.