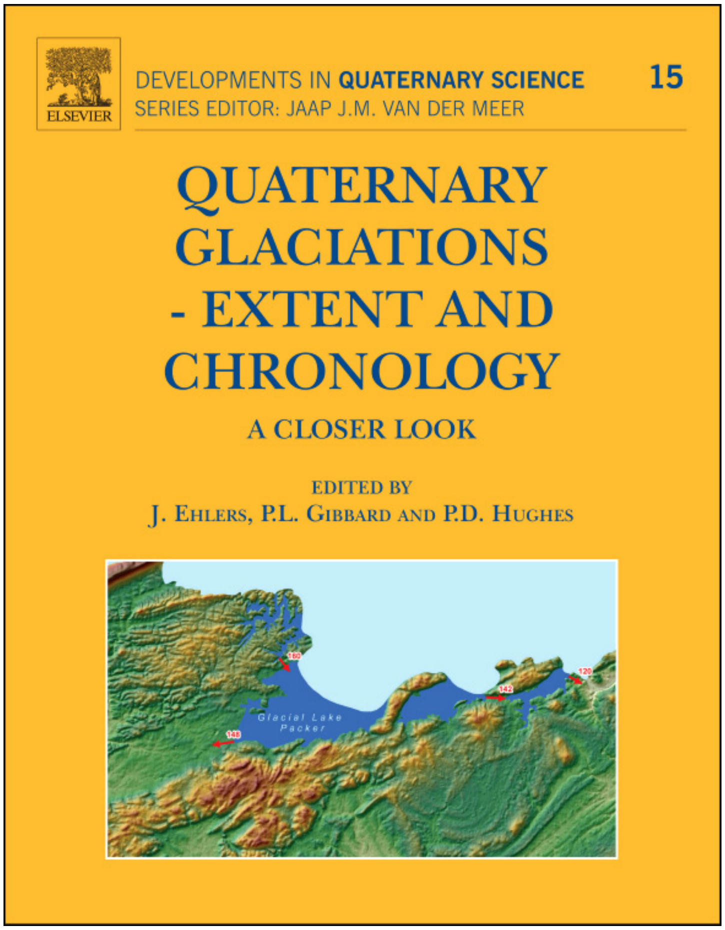

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Chapter 4

Pleistocene Glaciations of Czechia

Daniel Nývlt[1,*], Zbyněk Engel[2] and Jaroslav Tyráček[3,†]

[1]*Czech Geological Survey, Brno branch, Leitnerova 22, 658 69 Brno, Czech Republic*

[2]*Department of Physical Geography and Geoecology, Faculty of Science, Charles University in Prague, Albertov 6, 128 43 Praha 2, Czech Republic*

[3]*Czech Geological Survey, Klárov 3, 118 21 Praha, Czech Republic*

*Correspondence and requests for materials should be addressed to Daniel Nývlt. E-mail: daniel.nyvlt@geology.cz

†This study is dedicated to the memory of our colleague Jaroslav Tyráček (1931-2010) for his substantial contribution to the study of Pleistocene glaciations in our territory

4.1. INTRODUCTION

This is a review of current evidence of continental and mountain glaciation in Czechia and provides a closer look at the Pleistocene glacial limits and chronology for the region. It is based on numerous works published during more than a century of research in the Czech territory. The reference list, therefore, can include only the most important studies or those published in world languages. This chapter is divided into two main parts. The first part focuses on the products of the continental glaciations, whilst the second part deals with the local mountain glaciations in the Sudetes and the Šumava Mountains. Three Northern European ice sheets affected Czech territory during both the Elsterian (marine isotope stage (MIS) 16 and 12) and older Saalian (MIS 6) glaciations. They reached as far as northern Bohemia, northern Moravia and Czech Silesia. In contrast, mountain glaciation was limited to the Krkonoše (Giant), the Šumava (Bohemian Forest) and Hrubý Jeseník (*Altvatergebirge* in German) Mountains. The timing of mountain glaciation is still poorly known. Sedimentary and numerical evidence is available for both the Weichselian-age glaciations, but the chronostratigraphical framework of the pre-Weichselian glaciation remains questionable. Recent geomorphological, sedimentological and chronological studies have substantially improved the understanding of Pleistocene glaciations in Czechia, providing new information on their extent and chronology.

4.2. CONTINENTAL GLACIATION

The first evidence of continental glaciation in Czechia was already established by the end of the nineteenth century (e.g. Danzig, 1886; Tausch, 1889; Cammerlander, 1891). Czech territory was marginally overridden by northern European ice sheets during three separate events. They left behind considerable masses of glacial sediments, arranged mostly in a relatively narrow belt parallel to the general trend of the northern frontier mountain ridges. The maximum glacial extent is marked either by glacial deposits or by Nordic rocks spread on the land surface. This line has been called the ‘flint-line’ (*Feuersteinlinie*) because the most commonly represented lithology is flint derived from the Baltic region. More recent studies have focused not only exclusively on glacial sediments but also on glacial erosional morphological features. They have provided better control on the exact glacial limits, particularly in the granite landscapes of northern Bohemia. Numerous sedimentological and petrological studies of glacial deposits from Czechia (e.g. Růžička, 1980, 1995; Nývlt and Hoare, 2000, 2011; Sikorová et al., 2006; Víšek and Nývlt, 2006) are not discussed here, except for those which are directly connected to the topic of this contribution. Dating of individual ice-sheet advances has also been the subject of recent studies, but only a few results have been published to date (e.g. Nývlt, 2008; Nývlt et al., 2008). However, further studies are in progress and will be published in the near future.

Czech territory contains evidence of three Middle Pleistocene glaciations during which glaciers advanced into two regions, northern Bohemia and northern Moravia, and to a larger extent into Czech Silesia. The area was especially invaded by ice of the Polish Odra lobe (e.g. Hesemann, 1932; Piotrowski, 1998). Only the eastern glaciated part of northern Moravia and Czech Silesia was glaciated by ice sheets that combined both the Vistula and Odra lobes (e.g. Marks, 2005). The local morphology at the glacier margin affected the extent of the ice sheets, such that the glaciers penetrated further to the south in the low-lying Zittau and Ostrava Basins or in the Moravian Gate. The fronts of the advancing ice-sheet lobes crossed the local or regional watersheds in some places. The main European watershed was crossed by the ice at the Poruba Gate, and the associated proglacial outwash drained into the Danube River catchment (e.g. Tyráček, 1961, 1963, 2011). The Sudetes mountain belt

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was crossed by an outlet of the ice sheet in the Jítrava Saddle, thereby penetrating into the inner part of the Bohemian Highlands, that is, to the Labe (Elbe) River catchment (e.g. Danzig, 1886; Šibrava, 1967; Macoun and Králík, 1995). These key areas are important for direct correlation of glacial sequences with fluvial terrace-deposit systems of the rivers in the Labe and Danube catchments (e.g. Šibrava, 1967; Macoun and Králík, 1995; Tyráček and Havlíček, 2009; Tyráček, 2011). Morphostratigraphical correlation was formerly the only available approach for dating of individual glacial deposits and landforms. Individual stratigraphical systems, based on these correlations, were developed for the continental glaciation in northern Bohemia and northern Moravia and Czech Silesia (the most recent are given by Macoun and Králík, 1995 or Růžička, 2004).

4.3. ELSTERIAN GLACIATIONS

Traditionally two separate advances of Northern European ice sheets reaching the northern parts of Czechia were linked to the Elsterian Stage (e.g. Šibrava, 1967; Macoun, 1985). They are correlated with MIS 16 and 12 (e.g. Šibrava et al., 1986; Lindner et al., 2004) and locally to Elsterian 1 and 2 in Germany (Eissmann, 1997, 2002) or the Sanian 1 and 2 in Poland (Lindner et al., 2004; Marks, 2004, 2005). Individual glaciations are described separately for both glaciated areas of Czechia, they could be correlated via the area of Poland.

4.3.1. Northern Bohemia

During the Elsterian 1 (MIS 16 = Donian glaciation of Russia; Chapter 26), the Northern European ice sheet covered Šluknov Hilly land, Frýdlant Hilly land and Zittau Basin, the frontal lobe crossed the Jítrava Saddle in the Ještěd Range and entered the Ralsko Hilly land, that is, the catchments of Ploučnice and Jizera Rivers (Šibrava, 1967; Králík, 1989; Macoun and Králík, 1995; Nývlt, 2008).

The Elsterian 1 glaciation was the most extensive continental glaciation in northern Bohemia. The glacial limit has been mapped in detail in the Šluknov Hilly land (Nývlt, 2001, 2008) district. In contrast to the adjoining parts, this area was only affected by the older Elsterian 1 glacier. This glaciation originated by the confluence of two individual ice-sheet lobes that advanced from the North and East to join along the watershed between the Labe and Oder River catchments (Fig. 4.1). The maximum advance of this ice sheet has been dated on the depth profile of proglacial glaciofluvial deposits using ^{10}Be cosmogenic nuclide to 606 ± 53 ka BP (Nývlt, 2008). This should correspond to MIS 16, which culminated ~620–635 ka BP (EPICA Community Members, 2004; Jouzel et al., 2007).

The best-preserved glacial sequence for study of glacial stratigraphy of these Middle Pleitocene deposits is in the Zittau Basin, where both Elsterian tills are preserved in superposition at different sites (Šibrava, 1967). Here the Elsterian 1 glaciation was the most extensive, the ice-sheet front crossed the Jítrava and Horní Saddle and penetrated further to the Ralsko Hilly land (Šibrava, 1967; Králík, 1989). The Elsterian 2 ice front crossed also the Jítrava Saddle and deposited a terminal moraine at Jítrava (Šibrava, 1967; Králík, 1989). Proglacial glaciofluvial accumulations deposited in the Ploučnice river catchment have been correlated with the terrace deposits sequence of the Labe River (Grahmann, 1933; Šibrava, 1967; Tyráček and Havlíček, 2009).

Remnants of both Elsterian glaciations are also found in the Frýdlant Hilly land (Králík, 1989; Macoun and Králík, 1995). Here it seems that the Elsterian 1 glaciation was less extensive than that during the subsequent Elsterian 2 (Králík, 1989; Nývlt, 2003). The ice sheet crossing of the Jizerské hory mountain belt, through the Oldřichov col at 478 m a.s.l. (Králík, 1989), took place during the Elsterian 2 Stage (Nývlt, 2003; Nývlt and Hoare, 2011). The glaciation limit in the northern slope of the Jizerské hory, which is connected with the Elsterian 2 ice sheet, was recently mapped by Černá 2011. Here the glaciation limit was delimited using a combination of different geomorphological methods to the altitude of 470–490 m a.s.l. (Traczyk and Engel, 2006; Černá 2011; Černá and Engel, 2011; Fig. 4.2). The highest site with glacial sediments in northern Bohemia lies in the Anděl Saddle at 522 m (Janásková and Engel, 2009), in the northern part of the Jizerské hory. Here the glaciation is represented by proglacial glaciofluvial sediments deposited in front of the ice-sheet advancing to the saddle from the east. The precise position of the glacier has not been determined, but the glacier's surface must have been higher than that of the saddle, because its melt waters were draining to the west (Janásková and Engel, 2009).

Eissmann (1997, 2002) proposed the concept of a huge ice-dammed lake in the Labe River valley upstream of the present Bad Schandau, where, according to him, the Elsterian ice sheet terminated. Some rhythmically bedded clays occur at the Foksche Höhe in Děčín (Šibrava, 1967) or in Ctiněves near the Říp Hill (Žebera, 1961), but their glacial meltwater origin has never been proved (e.g. Žebera, 1974; Růžička, 2004). Other clay beds have been identified in several river terrace sequences of the Vltava and Labe (Elbe) rivers at various altitudes in the Říp area. However, they do not match any contingent ice-dammed lake. Indeed, no traces of such a huge ice-dammed lake have been found in the Czech part of the Labe River valley, so far. Therefore, Eissmann's (1997, 2002) interpretation of the occurrence of a huge ice-dammed lake in the inner Bohemian Massif during the Elsterian cannot be accepted. If some temporary glacial lake existed around Bad Schandau, then it must have drained beneath the glacier, through the fissures within the ice body or along the glacier front on German territory (Ehlers et al., 2004).

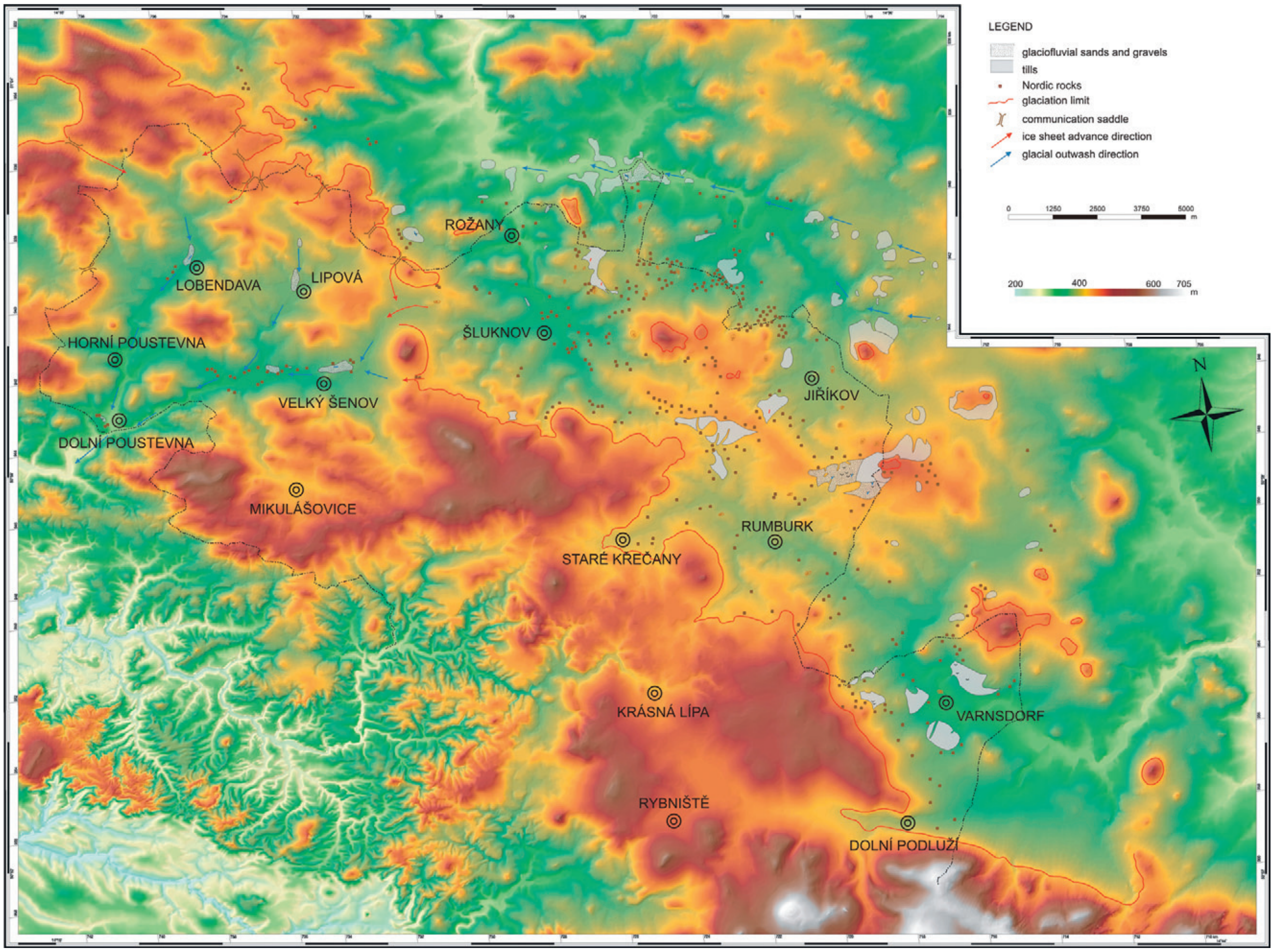

FIGURE 4.1 Palaeogeographical reconstruction of the Elsterian glaciation in the Šluknov Hilly land (modified from Nývlt, 2008).

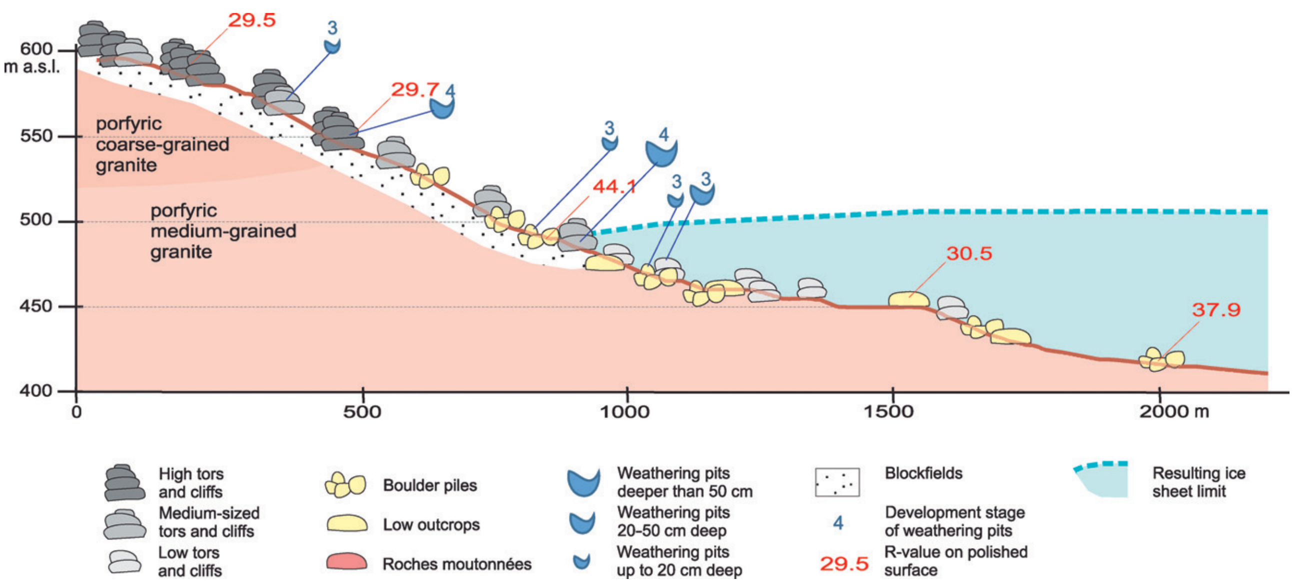

FIGURE 4.2 Profile line through the northern slope of the Jizerské hory reconstructing glaciation limit using Schmidt hammer measurements and geomorphological analyses of glacial and periglacial landforms (from Černá, 2011).

4.3.2. Northern Moravia and Czech Silesia

The Elsterian glaciation also extended into northern Moravia and Czech Silesia, where from the west to east the foothills of the Rychlebské, the Hrubý Jeseník and the Zlatohorská Highlands were glaciated (e.g. Macoun et al., 1965; Prosová, 1981; Macoun and Králík, 1995; Sikorová et al., 2006). The ice sheet advanced into the Ostrava Basin, the Opava Hilly land and the Moravian Gate (Macoun et al., 1965; Macoun, 1980; Macoun and Králík, 1995; Tyráček, 2011) penetrating up to 40 km towards the south of the prevalent maximum glacial limit making an outlet ice-sheet lobe (Fig. 4.3). Because most of the glaciated areas in northern Bohemia and Czech Silesia were overridden by the Saalian ice sheet, most of the Elsterian glacial deposits are buried by younger sediments. In the Ostrava Basin, their greatest thicknesses (over 100 m) are preserved in tunnel valleys or isolated enclosed depressions, which are thought to typify the Elsterian glaciation (Van der Wateren, 2003) and also occur in other European regions.

Morphologically, the most important are two polycyclic push moraines (the northern one at Chuchelná and the southern one at Kravaře) in the Opava Hilly land. They are composed of tills and terminoglacial deposits of both the Elsterian and older Saalian glaciations (Macoun, 1980; Macoun and Králík, 1995). Tills of Elsterian 1-age are known from the Opava Hilly land and the Ostrava Basin. The advance of Elsterian ice sheet into the Moravian Gate was the object of fruitful discussions for decades (e.g. Tyráček, 1963, 2011; Macoun, 1989; Czudek, 2005). On the basis of the recent studies by Tyráček (2011), it seems that the Elsterian ice sheet did not advance closer to the main European watershed and proglacial glaciofluvial outwash was not drained via the Moravian Gate to the Danube River catchment. However, the U-shaped northern termination of the Poruba Gate has not been satisfactorily explained so far (Tyráček, 2011). However, it seems very probable that this morphological feature is of pre-glacial origin. The frontal part of the Elsterian ice sheet was drained towards the North below the glacier. This is supported by numerous north-sloping overdeepened tunnel valleys, sometimes up to

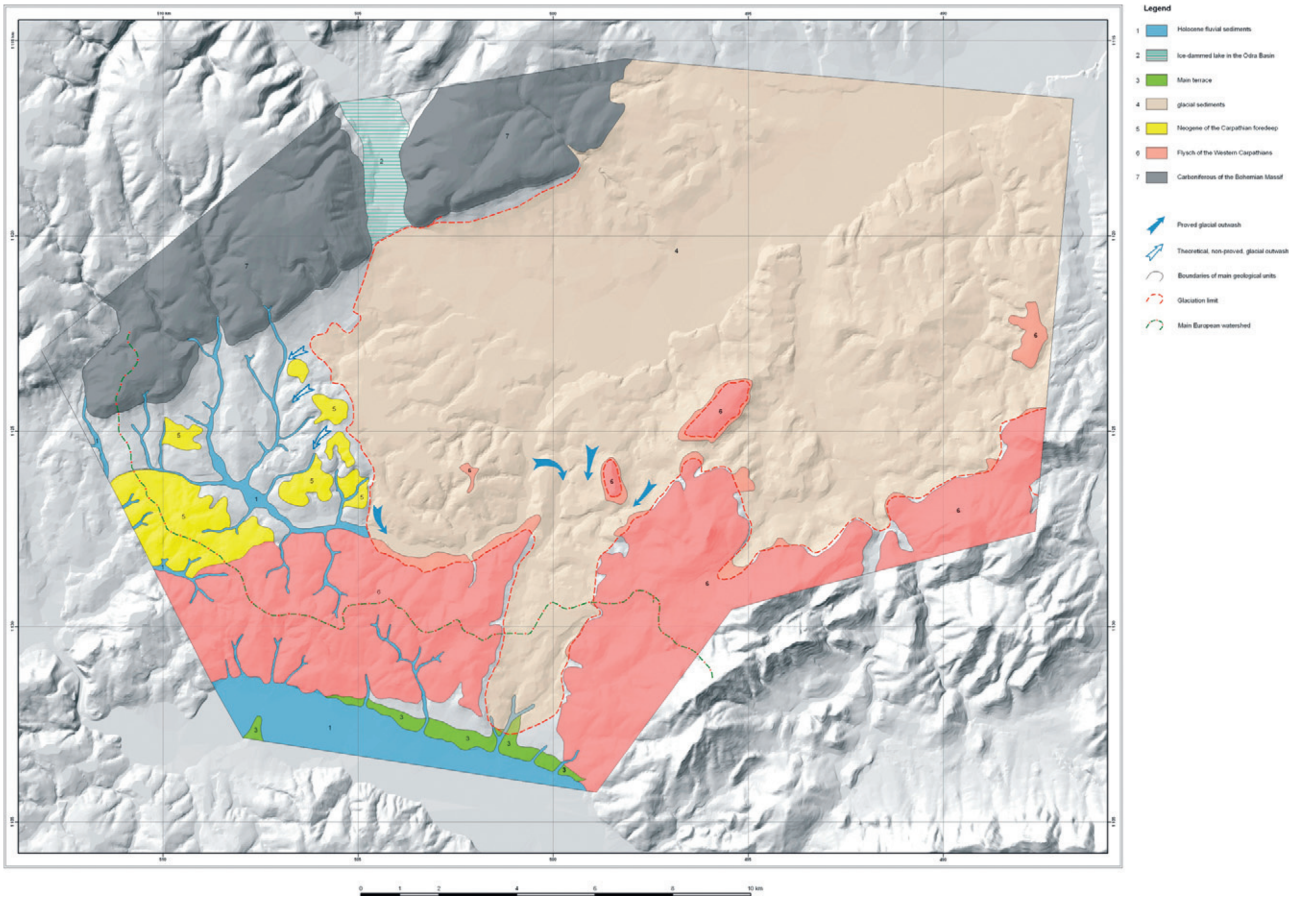

FIGURE 4.3 Palaeogeographical reconstruction of the maximum Saalian glaciation in the Moravian and Poruba Gates (modified from Tyráček, 2011).

100 m deep (Macoun et al., 1965; Czudek, 2005), which developed due to soft bedrock and dynamic advancing ice-sheet front. Local short-lived ice-dammed lakes developed randomly in front of Elsterian ice sheet in the Ostrava Basin and Opava Hilly land (Macoun, 1980).

Shallow lakes formed in the Ostrava Basin during the subsequent Holsteinian Stage interglacial (Stonava Lake, e.g. Menčík et al., 1983). These lacustrine sediments, with abundant organic remains, have been studied in detail (e.g. Kneblová-Vodičková, 1961; Břízová, 1994) and represent the only genuine interglacial separating the Elsterian and Saalian glacial sequences in northern Moravia and Czech Silesia.

4.4. SAALIAN GLACIATION

The northern European ice sheet also advanced into the marginal northern parts of Czechia during the Saalian. This happened during the first Saalian glacial (Drenthe: Woldstedt, 1954, Ehlers, et al., 2004; Odranian: Lindner, et al., 2004, Marks, 2004, 2005), which is dated to the first glacial maximum during MIS 6. The former correlation of the Saalian 1 advance of Northern European ice sheet with MIS 8 (e.g. Šibrava et al., 1986) is no longer valid.

4.4.1. Northern Bohemia

The advance of Saalian ice sheet into the Northern Bohemia has been discussed in the literature for decades (e.g. Šibrava, 1967; Králík, 1989; Macoun and Králík, 1995; Czudek, 2005). Recent studies from neighbouring Poland (e.g. Badura and Przybylski, 1998; Berger et al., 2002; Marks, 2005) show that the Saalian ice-sheet extent was significantly smaller in the Western Sudetes. The Odra ice lobe advanced only into the northernmost part of the Frýdlant Hilly land and deposited a vast accumulation of proglacial glaciofluvial sediments in the surroundings of Horní Řasnice and Háj villages in the Frýdlant Hilly land.

4.4.2. Northern Moravia and Czech Silesia

The main terrace of individual fluvial sequences in the Bohemian and Moravian rivers provides an important stratigraphical marker in the Czechia. This allows reliable correlation of the terrace sequences of individual rivers and glacial sequences throughout northern Moravia and Czech Silesia (Tyráček and Havlíček, 2009). In spite of ‘double terrace’ origin of most of the main terraces of Czech rivers (e.g. Šibrava, 1964; Tyráček, 2001), the upper accumulation developed during the long pre-glacial period of Saalian glaciation (Tyráček, 2001; Tyráček and Havlíček, 2009), possibly during MIS 8. Because it is developed along most of the larger streams in northern Moravia, this unit may be used (from a stratigraphical point of view) as an important marker for classification of Elsterian and Saalian glacial deposits.

During the Saalian 1 event, the Northern European ice sheet advanced into the Ostrava Basin, the Opava Hilly land and the Moravian Gate (Macoun et al., 1965; Macoun, 1980; Macoun and Králík, 1995). Two oscillations of the Saalian 1 ice sheet are recorded in the Opava Hilly land and the Moravian Gate (Macoun, 1985, 1989; Růžička, 2004). The northern push moraine (at Chuchelná), in the Opava Hilly land, was finally morphologically sculptured (Macoun, 1980) and represents the best-preserved glacial depositional landform connected with continental glaciation in Czechia (Růžička, 2004). The formerly presumed huge ice-dammed lake that was thought to have occupied the whole Ostrava Basin (Žebera, 1964) has not been confirmed. However, local short-lived small lakes developed irregularly during the early Saalian within the basin instead (Růžička, 2004; Czudek, 2005; Tyráček, 2011).

The deposits representing the maximum Pleistocene glaciation in the Moravian Gate are of Saalian 1 age (Tyráček, 2011). Glaciofluvial and glaciolacustrine deposits overlying sediments of the main terrace in the Poruba Gate provide supporting evidence that the Saalian meltwaters crossed the main European watershed. The Moravian Gate was drained during the maximum Saalian 1 ice-sheet extent through the Poruba Gate at the level of the 15 m terrace (Tyráček, 2011); nordic rocks are found in the equivalent terrace deposits of the Bečva River (Tyráček and Havlíček, 2009). Retreating proglacial glaciofluvial sands overlain by glaciofluvial silts and silty muds were dated at Kunín in the Odra part of the Moravian Gate. They directly overlie the fluvial sediments of the main Odra fluvial terrace and have been dated by optically stimulated luminescence (OSL) to 162.0 ± 9.4 ka BP (Nývlt et al., 2008). This corresponds to the end of the first cool period during MIS 6, when the Saalian 1 (Odranian) glaciation occurred (e.g. Lindner et al., 2004; Marks, 2004).

4.5. MOUNTAIN GLACIATIONS

The mountainous regions in the Czech Republic comprise two different geological units. The Hercynian ranges in the western part border an ancient crystalline massif, whereas the mountains on the eastern boundary belong to the West Carpathians, formed by the Alpine orogeny. The geological conditions and tectonic activity controlled the mountain development, resulting in a diverse relief pattern of the two mountain regions. The Hercynian Mountains comprise a series of dissected plateau surfaces forming large areas above 1000 m a.s.l. Ridges and summit plateaux rise up to 1600 m a.s.l. and have a generally low relief with broad valleys. The relief of the Carpathians is more dissected by deep valleys and only individual summits rise above 1200 m a.s.l. During the Quaternary, a periglacial environment prevailed in these mountain areas. However, small mountain glaciers developed in the Krkonoše Mountains, the Šumava Mountains and the Hrubý Jeseník Mountains (Partsch, 1882; Prosová, 1973). The existence of local mountain glaciers in the Krušné hory, the Jizerské hory, the Králický Sněžník and the Beskydy Mountains remains controversial (Pelíšek, 1953; Král, 1968; Demek and Kopecký, 1998; Pilous, 2006; Pánek et al., 2009).

4.6. PRE-WEICHSELIAN GLACIATION

4.6.1. Krkonoše Mountains

At present there is no numerical age evidence for glaciation prior to Weichselian. Understanding the timing and extent of glaciations has historically been limited to the identification of two generations of moraines, originally associated with Riss and Würm glaciations (Partsch, 1894). Results of numerical and relative-age dating reject the idea of pre-Weichselian origin of well-preserved moraines within the Krkonoše Mountains (Braucher et al., 2006; Engel et al., 2011). A pre-Weichselian glacial episode is indicated by the Weischselian moraines embedded in the pre-existing troughs of the upper Labe and the upper Úpa valleys (Engel, 2007). There is some field evidence to suggest that the large high altitude plateau areas may have been glaciated by small plateau ice-fields prior to the last glaciation (Sekyra and Sekyra, 2002). Additionally, recent sedimentological investigations in the Úpa Valley revealed till deposit that probably represents pre-Weichselian glaciation (Carr et al., 2002). If the interpretation is valid, then the Quaternary glaciations were probably more extensive than previously considered.

4.6.2. Šumava Mountains

The chronology and extent of pre-Weichselian glaciations remains unknown. Field evidence appears to conflict with the hypothetical ice-sheet and ice-cap glaciation proposed by Bayberg (1886) and Preihäusser (1934) for the Middle Pleistocene. However, a spatial relationship of glacial landforms in the Bavarian part of the mountains together with glacial transformation of the valleys suggests that the Šumava Mountains had been glaciated prior to Weichselian (Hauner, 1980). Glacial deposits preserved downvalley from the Weichselian moraines in the Kleiner Arbersee region indicate older glaciation preceding the deposition of moraines (Raab, 1999).

4.7. WEICHSELIAN GLACIATION

4.7.1. Krkonoše Mountains

Chronological studies and numerical evidence concerning the Weichselian glaciation are still scarce. Geomorphological and sedimentary evidence, as well as few numerical data, imply glacial advances in the Krkonoše Mountains during the early Weichselian. Thermoluminescence (TL) dating of sediments in a glacial environment below the Sněžné jámy Cirques has provided the first chronological indication of pre-late Weichselian glaciation. The data from two cores suggest that the maximum glacial advance occurred well before 90 ka (Chmal and Traczyk, 1999). The idea of an early Weichselian glaciation was supported by tentative correlation of glacial sediments in the Úpa Valley (Sekyra, 1964; Carr et al., 2002) and by restricting the extent of Late Weichselian moraines in the Łomnica valley (Traczyk, 1989; Engel et al., 2011). The lowermost preserved terminal moraines below Sněžné jámy Cirques, together with indistinct relics of glacial deposits in the Łomnica and Úpa valleys, indicate a more extensive glaciation preceding the Late Weichselian glacier advance. The glaciation on the northern flank of the mountains took the form of broad wall-side glaciers, whereas alpine valley glaciers extended down the valleys on the southern flank.

The Late Weichselian glaciation was reconstructed using numerical and relative-age dating techniques in the Labe, Úpa and Łomnica valleys. The sedimentary record from the Labe valley indicates that the cirque was ice-free around 30 ka BP, suggesting the limited timing of the last glaciation to MIS 2 (Engel et al., 2010). ^{10}Be exposure ages from moraine boulders deposited by the Labe and Łomnica valley glaciers imply a deposition of preserved moraines between 17.0 ± 0.4 ka and 12.1 ± 0.8 ka (Braucher et al., 2006; Engel et al., 2011). The lowermost moraines in the Łomnica valley have been tentatively associated with the Last Glacial Maximum (LGM). The exposure ages show that the glacial recession began around 14 ka and glaciers persisted in suitably orientated parts of cirques until the beginning of the Holocene (Braucher et al., 2006). The retreat of the Labe glacier into the cirque during the Late Glacial period was followed by a re-advance and subsequent recession of the glacier (Engel et al., 2010). A radiocarbon date of around 10 ka BP provides a maximum age for the presence of local cirque glacier in the Łomnica Valley (Chmal and Traczyk, 1999). The extent of the late Weichselian glaciation is indicated by moraines deposited during the LGM by valley glaciers and later by cirque-type glaciation. The extent of glaciers and locations of the dating sites is indicated in Fig. 4.4.

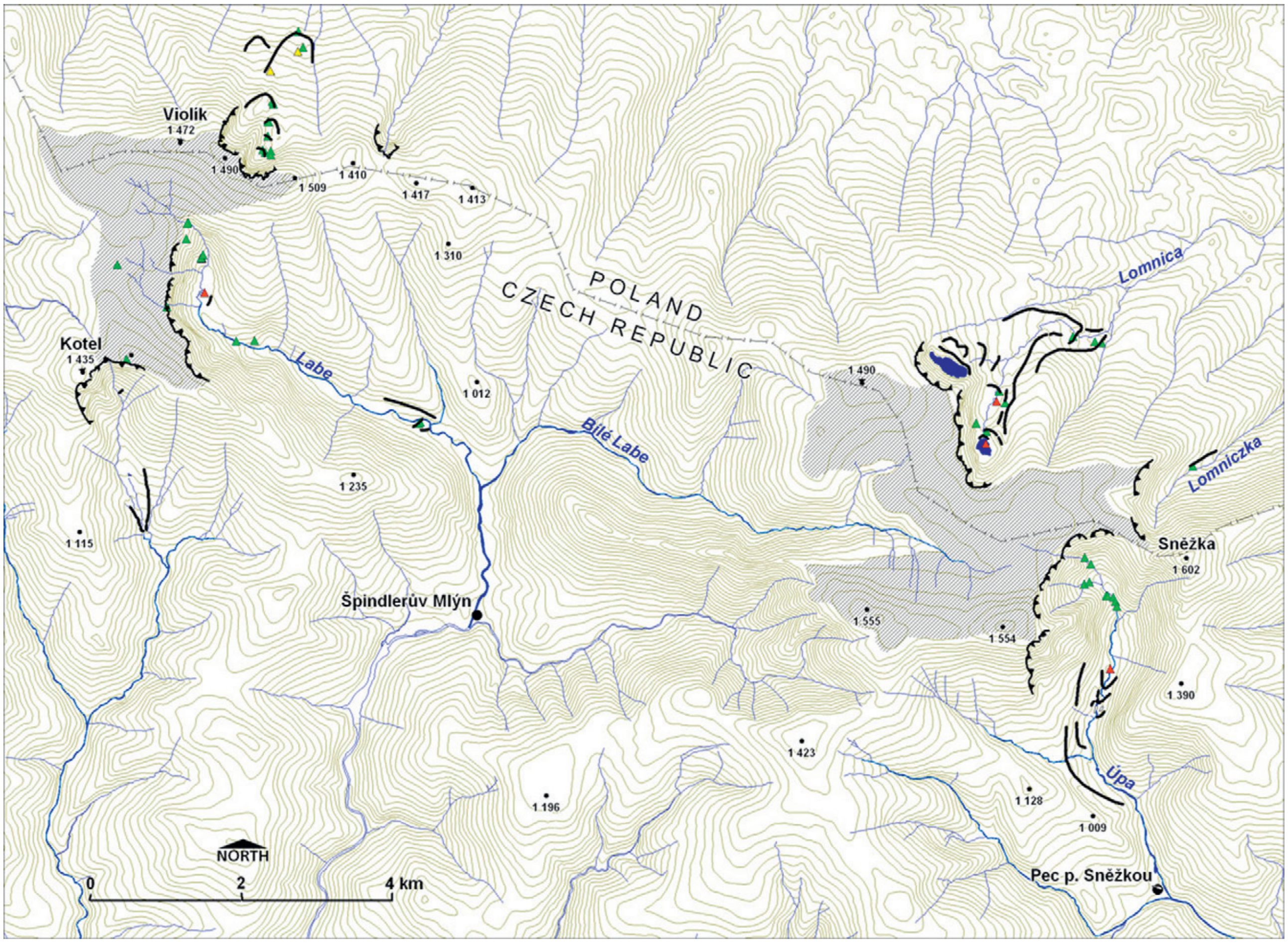

FIGURE 4.4 Late Weichselian moraines in the Krkonoše Mountains. Green, red and yellow triangles represent sites of ^{10}Be, ^{14}C and TL dating.

4.7.2. Šumava Mountains

A reliable glacial stratigraphy and chronology of Weichselian glaciation has yet to be established. Thus, it is difficult to describe the stratigraphy, timing and nature of pre-Late Weichselian glaciation in the region. A pre-Weichselian glacial episode is indicated by the presence of moraine ridges downvalley from the LGM moraines and by exposure data from the Bavarian part of the mountains. An exposure age of 61.5 ± 3.1 ka from a bedrock surface in the Grosser Arber summit region has been interpreted as a result of a more extensive glaciation during the early Würmian (Reuther, 2007). However, these data provide little evidence that may be used to determine the ages of the moraines located in the valleys beyond the Late Weichselian moraines. The location of glacial landforms suggests that the early Weichselian glaciation was the most extensive during the late Quaternary. Valley glaciers up to 7 km long have been reported from the Bavarian side of the mountains (Hauner, 1980; Pfaffl, 1998).

Consistent chronological data for Late Weichselian glaciation have only been derived from the Bavarian side of the mountains. Here the maximum age of the last glaciation was determined to 32.4 ± 9.4 ka using infrared stimulated luminescence dating (Raab and Völkel, 2003). ^{10}Be exposure ages show that the initial advance of the Kleiner Arbersee glacier at 20.7 ± 2.0 ka was followed by several readvances until 15.5 ± 1.7 ka and then by the recession of the glacier into the cirque after 14.5 ± 1.8 ka (Reuther, 2007). The only numerical age, which can constrain the Late Weichselian timing of local glaciation on the Czech side of the mountains, was reported from the closure of the Černý potok River (Vočadlová et al., 2009). The beginning of the deglaciation period is supported by a radiocarbon age of ~14 ka cal. BP from cirques in the Plechý and Poledník Mountains. This was interpreted as indicating the termination of the last glaciation on the Czech side of the mountains (Pražáková et al., 2006; Mentlík et al., 2010). On the basis of the position and volume of moraines, the extent of Late Weischselian glaciation was limited only to valleys and cirques.

4.8. CONCLUSIONS

The study of individual glacial limits in the Czech Republic is still under debate. This is because the glacial deposits are mostly correlated using a morphostratigraphical approach with fluvial sequences of inner Czechia. The cross-border correlation with Poland is still not established. However, it seems well established that the maximum continental glaciation in the Sudetes (from northern Bohemia in the west, to the foothills of the Rychlebské hory and Hrubý Jeseník Mountains in the east) was of Elsterian age (e.g. Šibrava, 1967; Králík, 1989; Nývlt, 2003, 2008). On the other hand, the maximum advance in the Ostrava Basin and the Moravian Gate, where the ice sheet and its melt waters, respectively, crossed the main European watershed between the Odra and Danube Rivers, took place during the first Saalian glaciation (e.g. Tyráček, 1963, 2011; Nývlt et al., 2008). The ice-sheet advance into the Moravian Gate represents the southernmost glaciation limit in Central Europe. A rather complex stratigraphy of continental glaciations (Macoun and Králík, 1995) with five 'glaciations' (of the formation rank and 10 oscillations of the member rank), copying partly the German and Polish schemes, is based upon breaks in deposition indicated by palaeosols. None of these divisions have been tested by any modern method (e.g. soil micromorphology, dating techniques, etc.). Therefore, the character and duration of the 'temperate periods' identified are insufficiently defined. So the Stonava interglacial (Holsteinian) is the only genuine interglacial event known to separate the Elsterian and Saalian glaciations in Czechia. Exposure and luminescence dating of individual ice-sheet advances currently in progress (e.g. Nývlt, 2008; Nývlt et al., 2008) will substantially improve our knowledge of the timing of continental glaciations at their southern Central European limits.

Mountain glaciations have been studied in detail in the Krkonoše and Šumava Mountains. Glacial landforms have been identified, the extent of glaciations outlined and preconditions of the glaciation described (Partsch, 1882; Migoń, 1999). However, consistent and precise chronology of the Quaternary glaciations within these ranges and their correlation with chronostratigraphical systems of other glaciated areas in continental Europe are not yet established. Attempts to solve the question of chronology of the local glaciations were usually based on morphological evaluation of the glacial landforms, and this has proven to be insufficient. Some progress has been made with the presentation of the first geochronological data (Chmal and Traczyk, 1999; Mercier et al., 2000). A further step towards the determination of local glaciation chronology has been made recently in the Krkonoše Mountains, although only in these mountains (Carr et al., 2007; Engel et al., 2011). Therefore, it is not possible to include the local mountain glaciations into the chronostratigraphical framework of the Quaternary glaciation of continental Europe. In addition, it is not yet possible to utilise the local knowledge from the mountains for solving problems of environmental changes in the Late Quaternary.

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