Basalt2017 Post-conference fieldtrip: A jJourney into the volcanic history of the Doupovské hory Volcanic Complex

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The Basalt2017 post-conference field trip focuses on the demonstration of ca. 14 million years of the volcanic evolution of the Doupovské hory Volcanic Complex. This excursion will follow the

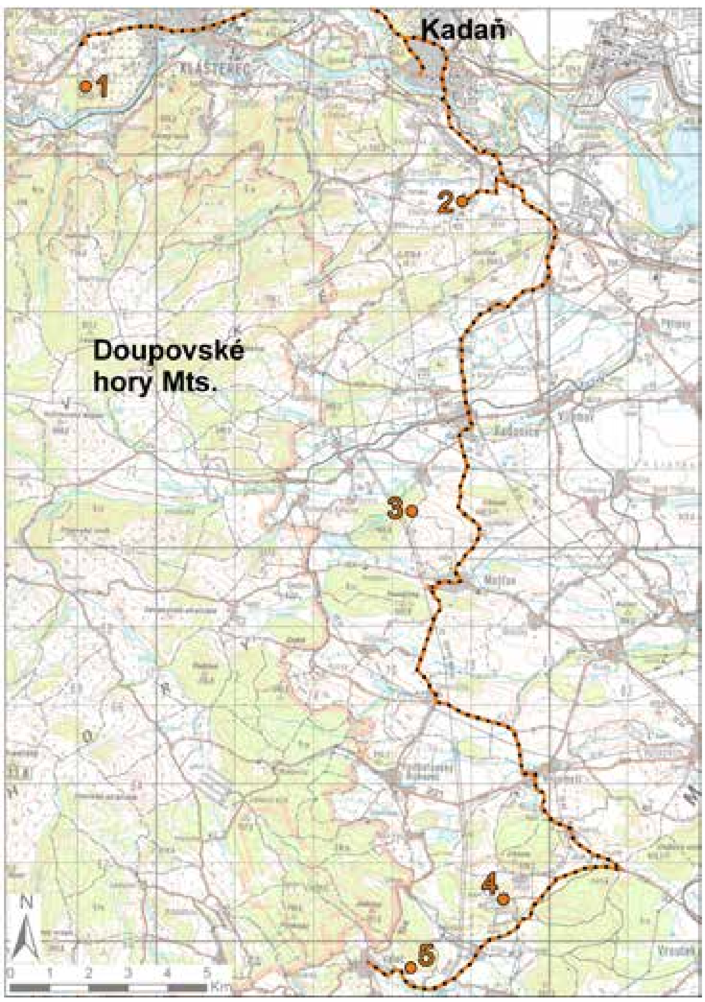


Fig. 1. Schematic sketch map of the post-conference field-trip drive.

eastern margin of the volcanic complex (Fig. 1), where distinct volcanic rocks and deposits represent individual phases of the complex evolution. We will sink into the history during the field trip, starting with the youngest manifestation of the volcanic activity and terminating with the oldest.

Locality 1
Šumná hill, remnant of Early Miocene scoria cone with trachybasaltic lava

The volcanic activity of the Doupovské hory Volcanic Complex (DHVC) ceased about 20 Myr ago. The latest activity is represented by a group of scoria cones in the northern part of the DHVC (Sakala et al., 2010) and some lava flows in the south (Ulrych et al., 2003). The first locality of our field trip represents the very youngest eruption within the DHVC. Šumná Hill (Fig. 2) penetrates Oligocene debris flows and debris avalanches deposits and rises above the Klášterec n. O. – Karlovy Vary road. The debris flows and debris avalanches deposits are exposed in the road cut. The debrites are mostly matrix-supported, containing frequent subangular to suboval fragments of various basaltic rocks. Some of the larger blocks (up to 3 m) display internal fragmentation with jig-saw fit of sub-clasts (Fig. 3) documenting the avalanche style of deposition.

The strategic position of the Šumná hill situated between an important historical road and the Eger / Ohře River was the main reason for construction of a medieval castle. In the trenches of the castle, pyroclastic deposits of this small volcano are well-exposed. The deposits consist of coarse-grained,

Fig. 2. View on the Šumná hill from northwest. Eger / Ohře River to the right of the Šumná hill and the city of Klášterec n. O. behind. Present shape of the hill almost corresponds to the original shape of the scoria cone.

clast-supported scoriae with empty voids between clasts. Two layers of scoria are separated by reddish fine ash (Fig. 4), probably representing fall deposit from some distant source. The scoriaceous deposits correspond to near-vent facies of a scoria cone erupting in Strombolian style eruptions. The scoria cone erupted a lava flow covering the plain north of the volcano. The K/Ar analyses determined the age of this volcano at 20 Ma (Sakala et al., 2010).

Fig. 3. Shattered block in the debris-avalanche deposit exposed in the road-cut on the foothills of the Šumná hill.

Fig. 4. Two layers of coarse-grained clast-supported scoria beds separated by fine reddish tuff of unknown origin.

Locality 2
Rokle bentonite pit, buried tuff cone

At the foothills of the Doupovské hory Volcanic Complex, bentonites and seladonites were traditionally exploited since 16th Century. The currently active bentonite pit at Rokle near Kadaň (Fig. 5) exposes a phreatomagmatic tuff-cone, which has been buried by subsequent effusive activity. The exploitation activity exposes the entire sequence deposited by phreatomagmatic eruptions of a tuff-cone located in a wet-land on the foothills of a large volcanic complex. The basal layer (Fig. 6) is ill-sorted with basaltic clasts of variable size. This unit contains frequent petrified tree-trunks (described below). The basal ill-sorted unit with petrified tree-trunks is overlain by well-sorted clast-supported lapilli-stone (Fig. 7). The lapilli-stone consists of subrounded clasts of non-vesicular basalt cemented by post-depositional calcite. Further upwards, the deposits are getting finer and represented by layers of fine tuff, locally bearing frequent biotite flakes. In the uppermost section of the profile, the tuff alternates with several thin intercalations of fossil peat (Fig. 8) and the entire sequence is overlain by basanite lava.

Many large tree trunks as well as smaller remnants of fossil wood have recently been found in an active bentonite pit in Rokle near Kadaň. One big trunk (Fig. 9, right) was identified as Taxodioxylon gypsaceum (Fig. 10). It is a fossil conifer species, very common in the Most Basin (Teodoridis & Sakala 2008), and described also from the Doupovské hory and České středohoří Mts. (Prakash et al. 1971, Koutecký & Sakala 2015). There are also angiosperms: Spiroplatanoxylon (Fig. 10) and Laurinoxylon (Fig. 11). Both types are known from the Doupovské hory Mts. (Sakala et al. 2010). Concerning Laurinoxylon, it can be attributed to Laurinoxylon Type 1 sensu Mantzouka et al. (2016) based on its oil/mucilage cells, which are present only in the extremities of rays (Fig. 12, arrow).

Fig. 5. View into the Rokle bentonite pit.

Fig. 6. Close-up on basal deposits of the Rokle tuff-cone. Size of the sample is ca. 35 cm.

Fig. 7. Close up on lapilli-stone from the lower part of the Rokle tuff-cone sequence. Individual lapilli fragments are cemented by post-depositional calcite. The sample is ca. 30 cm large.

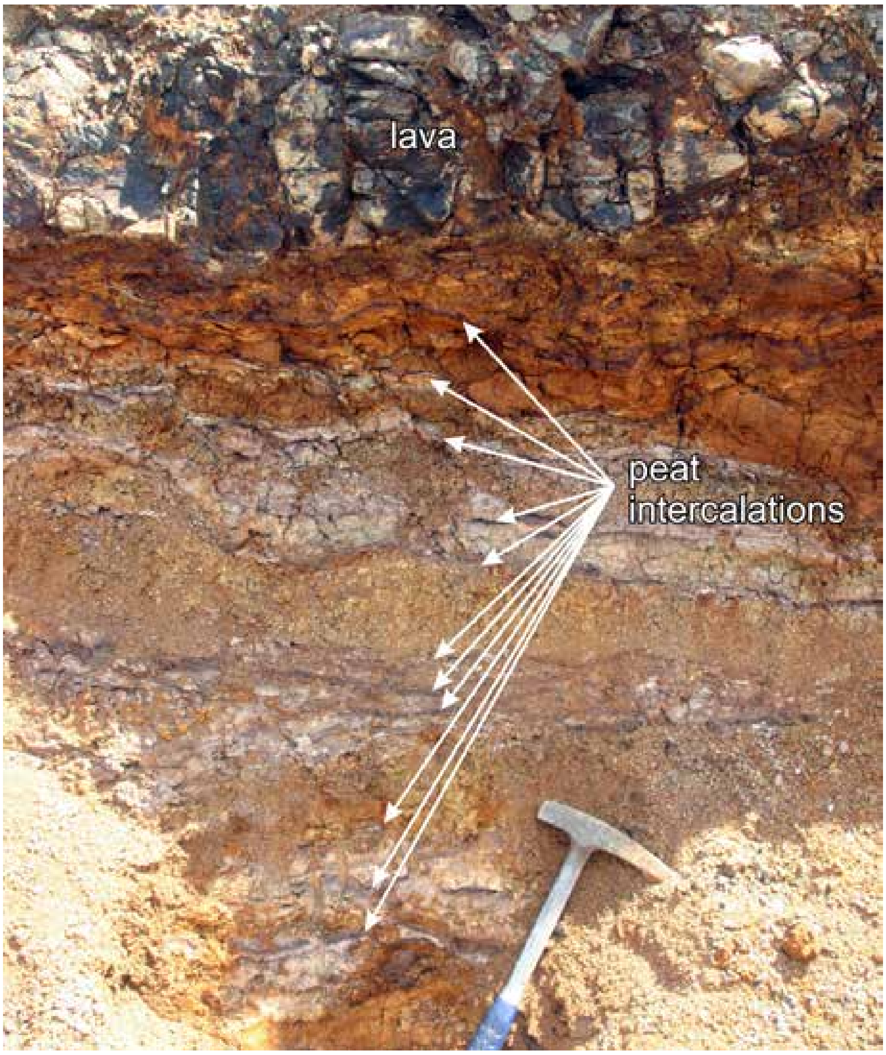


Fig. 8. Alternation of tuffs with fossil peat overlain by basanite lava in the uppermost part of the Rokle section.

Fig. 9. General view with huge trunks, Taxodioxylon (No. Rokle 01) on the right.

Fig. 10. Taxodioxylon gypsaceum (No. Rokle 01), tangential longitudinal section: arrow indicates a ray surrounded with axial parenchyma with dark resin substance and smooth to irregularly thickened transverse end walls

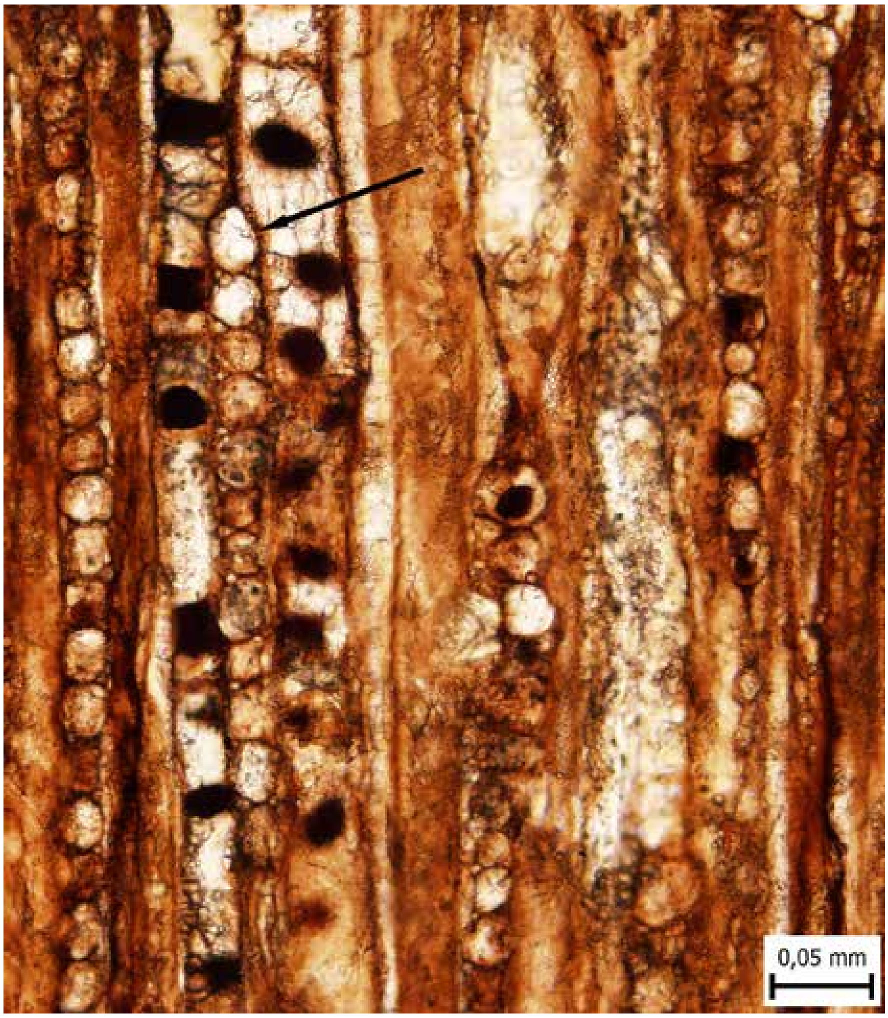
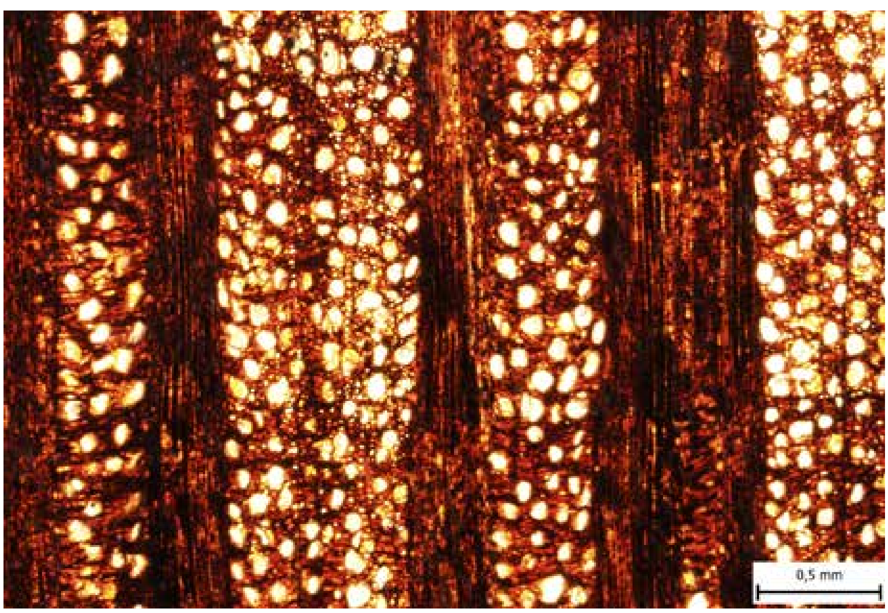


Fig. 11. Spiroplatanoxylon (No. Rokle 02), transverse section: general aspect with numerous solitary vessels and broad rays up to 20 cells wide.



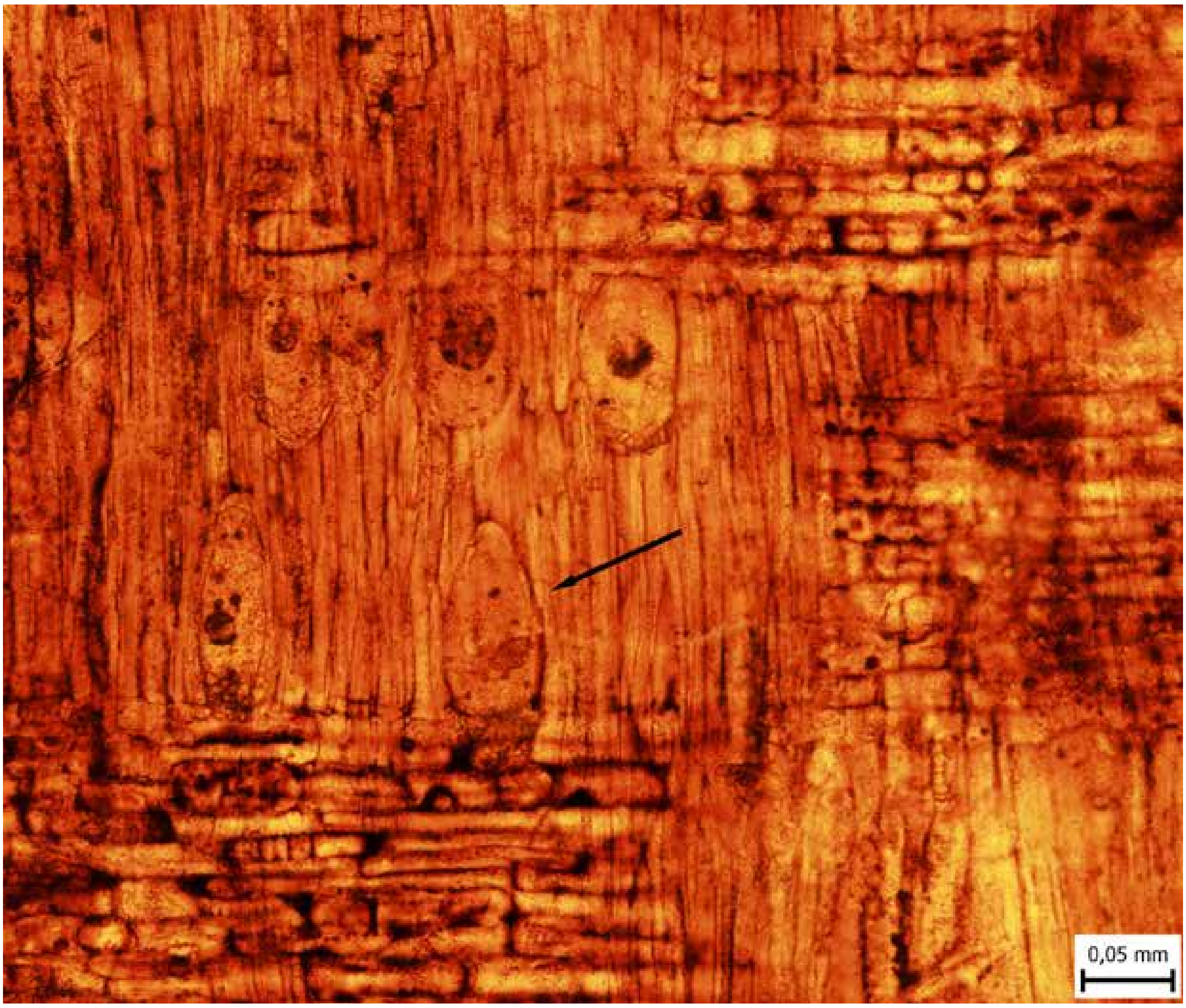


Fig. 12. Laurinoxylon Type 1 (No. Rokle 06), radial longitudinal section: arrow indicates enlarged oil / mucilage cell in the ray margin.

Locality 3
Radechov natural outcrop, sequence of lahars and lavas

The third stop focuses on an amazing outcrop in >200 m thick sequence of lahar deposits interbedded with several lava flows. The outcrops known as "V Jámách" near Radechov are not accessible by bus that must be left in Vojtěchov. From Vojtěchov, the site of interest requires a 2 km walk. The landscape in this area is characterized by E–W elongated ridges resembling hummocky relief (Fig. 13). As we walk over the lahar fan on the volcano foothills, we recognize that this relief does not reflect the original hummocks of debris avalanches. Rather, the elongated ridges are the result of erosion of a thick lahar deposit, where erosion follows individual channels and tongues of the lahars. An interesting view of the morphology of the DHVC will be seen approximately after 1 km of walking. Gently dipping slopes of the volcanic edifice can be seen well from this view-point. These slopes reflect surfaces of basaltic lava flows of a low viscosity. Morphology is one of the arguments against the hypothesis that the DHVC represent an erosional remnant of a single stratovolcano. The gentle slopes of a volcano dominated by basaltic lavas correspond to a shield volcano and the observed morphology can be well compared with Hawaiian volcanoes like Mauna Loa or Mauna Kea. Once we reach the outcrop, a total of 50 m high rock-walls expose deposits of the lahars interbedded with lava flows. According to available borehole data, this outcrop exposes only one fourth of the entire sequence. The sequence consists of numerous flow units with variable texture (Fig. 14). Each flow unit reaches 1–1.5 m in thickness. Some units are clast-supported while the others are matrix-supported reflecting water-saturation in the mass-flow. Occasionally, up to 2 m large boulders can be found floating in the lahar deposit which had high cohesion. Most of the flow units have preserved fine-grained layer atop (Fig. 15), representing reworking of fine-grained material during the latest stage of lahar deposition. These fine-grained layers highlight morphological boundaries between individual layers. The lahars are also interbedded with three lava flows. The composition of these lavas shows a differentiation trend from olivine-bearing trachybasalt, basaltic trachyandesite to trachyandesite. Such compositions are not common in the DHVC, and the source vent of these lavas can be therefore traced to the Nad Hájenkou hill (495 m), 1 km to the SW from the locality. The final stage of the differentiation is represented by a phonolite, which was not able to expand out of Nad Hájenkou Hill due to its high viscosity. The trachybasaltic to trachyandesitic lava flows are coated with a carapace facies of autoclastic breccia. The autoclastic breccias are clast-supported with empty voids and consist of angular fragments of the lava. The autoclastic breccias are formed due to mechanical fragmentation of solidified crust of continuously moving lava. Geochronological analyses of the lavas (25.5, 24.6 and 26.9 Ma, Fig. 14) constrain the age of this lahar sequence. The main triggering process producing this lahar succession was the instability of the south-eastern sector of the DHVC due to heterogeneous basement. Most of the DHVC basement consists of Variscan metamorphic and plutonic rocks (granites, amphibolites, gneisses, phylites, etc.), but the tectonically limited Žatec Basin with up to 800 m of Permo–Carboniferous sedimentary infill plunges underneath the DHVC to the SE (Mlčoch and Konopásek, 2010). The heterogeneous plastic sediments were incapable to carry the load of the thick sequence of basaltic lavas with high specific weight. This resulted in sector spreading of the volcanic complex producing frequent debris flows (Fig. 16).

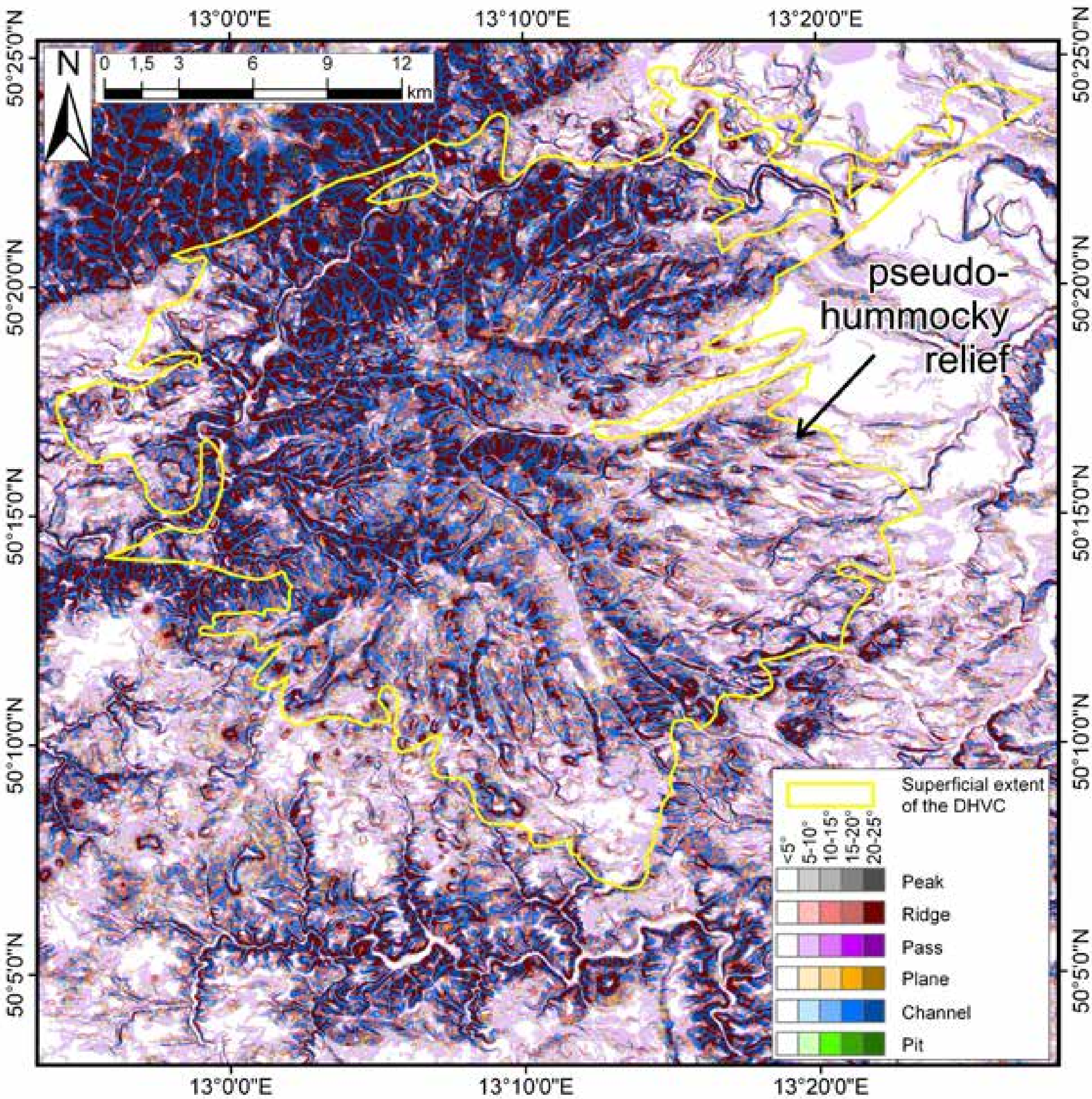


Fig. 13. Morphometric analysis image of the Doupovské hory Volcanic Complex showing the pseudo-hummocky relief on the eastern periphery.

Fig. 14. Sequence exposed on the Radechov outcrop.

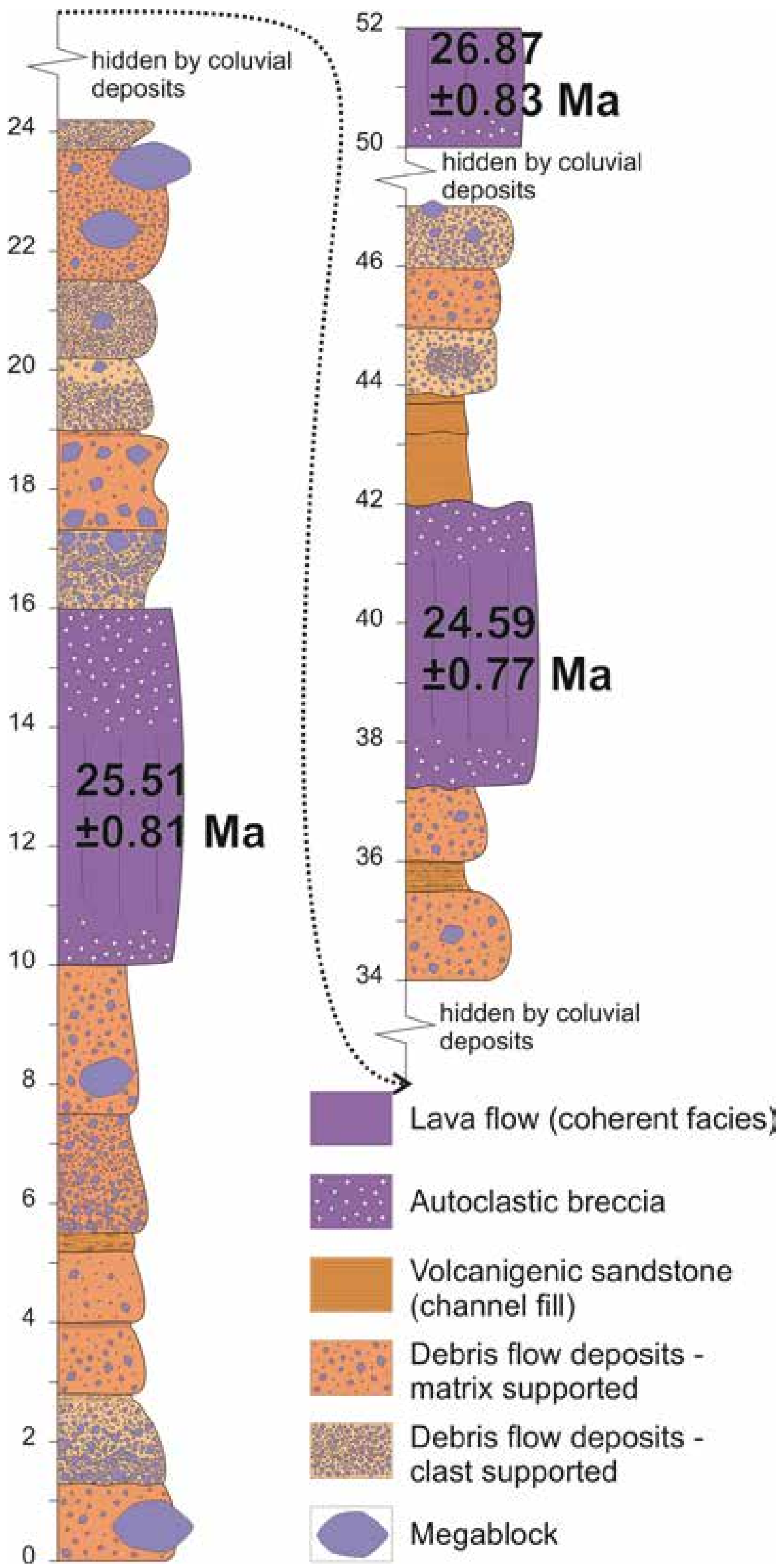


Fig. 15. Two lahar units exposed on the Radechov outcrop with chaotic accumulation of the main body and fine-grained top.

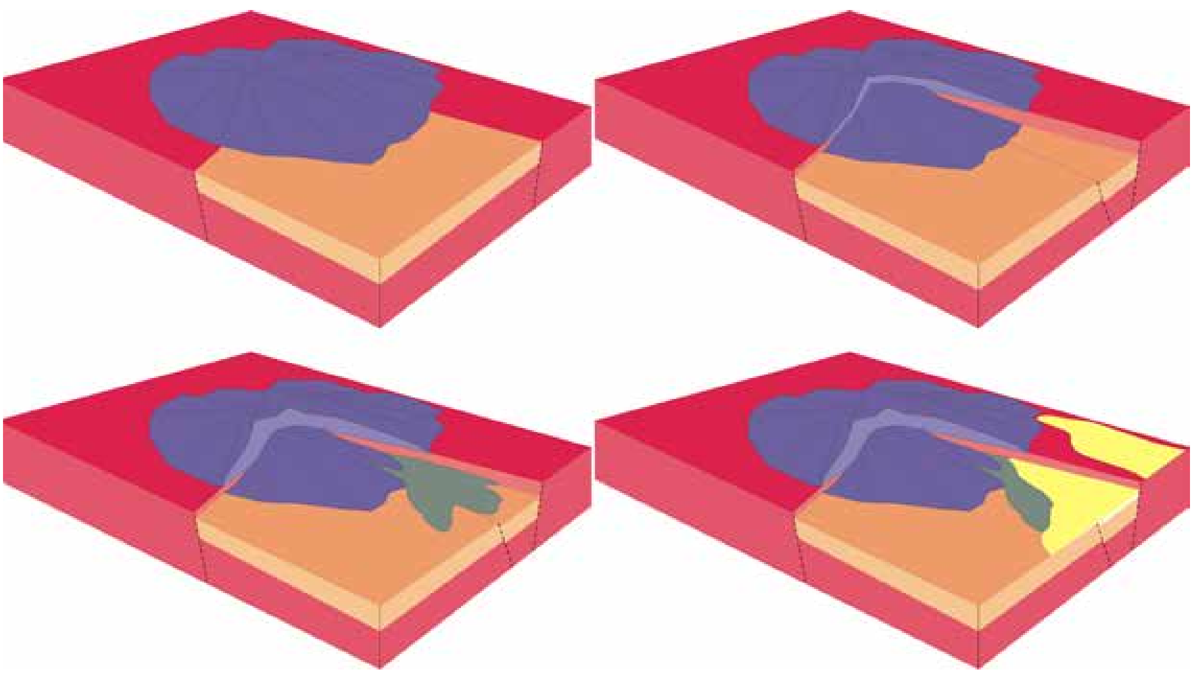


Fig. 16. Scheme summarizing the evolution of the eastern part of the Doupovské hory Volcanic Complex.

Locality 4
Dětaň, sequence of Early Oligocene pyroclastic deposits

The earliest volcanic deposits of the DHVC are exposed on its SE margins, around Dětaň, Dvérce and Valeč. These earliest volcanic rocks are represented by up to 80 m thick sequence of layered pyroclastic deposits (Fig. 17). The tuffs, lapilli-tuffs and lapilli-stones are exposed in an abandoned quarry, which was exploiting kaolin underneath the pyroclastic rocks. The exposures of pyroclastic deposits around Dětaň, Valeč and Dvérce are important and extensively studied paleontological localities (e.g., Fejfar and Kaiser, 2005). The assemblage of mammal bones and teeth (rodents, hyenodonts, entelodonts, rhinos, etc.) found in these sequences correspond to mammal zone MP-21 giving the exact age of the initial phase of DHVC activity to the very early Oligocene. In the Dětaň quarry, we can see sequences of tuff and lapilli layers differing slightly in colour and grain size. The lowermost layer with signs of diagonal cross bedding is the main fossiliferous bed, and most-likely represents pyroclastic surge deposits from a maar eruption. Good sorting and massive texture of the overlying layers suggest fall deposition. These pyroclastic deposits exposed at Dětaň were formerly interpreted as products of explosive eruptions from a central volcano in the middle of the DHVC, some 16 km to the NW from Dětaň. However, in the other parts of the DHVC, comparable pyroclastic sequences were not found. Following the Dětaň pyroclastic sequence in outcrops available in near surroundings, a rapid change in individual bed thickness as well as in the grain size (up to coarse scoria beds) can be observed over a few meters distance. Such dramatic changes are inconsistent with the proposed origin of these deposits as distal deposits of large eruptions from a single central volcano. The observed distribution of pyroclastic rocks is more likely related to the field of small monogenetic volcanoes located in different directions from Dětaň. Additional data on early DHVC volcanic activity were obtained from N-1 drillcore (Fig. 18) some 3 km SW from Dětaň. This drilling penetrated pyroclastic deposits identical to the Dětaň sequence. Clast-supported and well-sorted deposits exposed in this drilling were dominated by angular clasts of non-vesicular basaltoid suggesting phreatomagmatic eruption. The bedding of these deposits are dipping some 30° suggesting slope facies of a phreatomagmatic tuff-cone were recorded by this drilling underneath younger lahar deposits. Collectively, the pyroclastic sequence at Dětaň represents a group of monogenetic volcanoes including scoria cones, tuff cones and maars supplying the studied locality with pyroclastic fall deposits of variable grain size and structure.

The layer of white sandy kaoline clay at the base of the pyroclastic deposits (actually flooded by the pond) contains the assemblage of fossils. Leaf imprints are rare. Parts of calcified woody roots, some of them in situ, are common in some parts of the outcrop. Small pieces of wood charcoal are present very rarely. Skeletal remains of vertebrates (predominantly mammalian) are highly fragmented and widely scattered through the basal ash beds. This assemblage (e.g., Insectivora, Rodentia, Artiodactyla: *Gelocus laubei* Schlosser; *Bachitherium* cf. *curtum* Filhol; *Lophiomeryx mouchelini* Brunet & Sudre; *Paroxacron* sp.; *Propalaeochoerus* cf. *paronae* Piaz; *Entelodon antiquum* Repelin; *Antracotherium* cf. *monsvialense* Zigno; *Elomeryx crispus* Gervais. Perissodactyla: *Ronzotherium* cf. *filholi* Osborn. Carnivora: *Cephalogale* sp.; *Pseudocyonopsis* cf. *antiquus* Ginsburg. Deltatheridia: *Hyaenodon* sp.) excludes the age before the Grande Coupure and proves the mammalian Paleogene zones MP-21 or MP-22. A more precise dating to the older zone MP-21 is given by the index form

Entelodon antiquum Repelin and by the general evolutionary level of some rodent species as well. The whitish bones are often covered with fine traces of gnawing by small carnivores and termites. The tuff beds of Dětaň contain frequent insect trace fossils (ichnogenera *Celliforma* div. isp., *Coprinisphaera* isp., and *Palmiraichnus* isp.) and rare burrows of small mammals. Root traces vary in density and diversity. The insect traces indicate purely subaerial environment of the respective beds (Fejfar, 1987; Mikuláš et al., 2003; Fejfar & Kaiser, 2005).

Fig. 17. Southern wall of the Dětaň quarry exposes beds of pyroclastic fall deposits differing in grain size and degree of sorting.

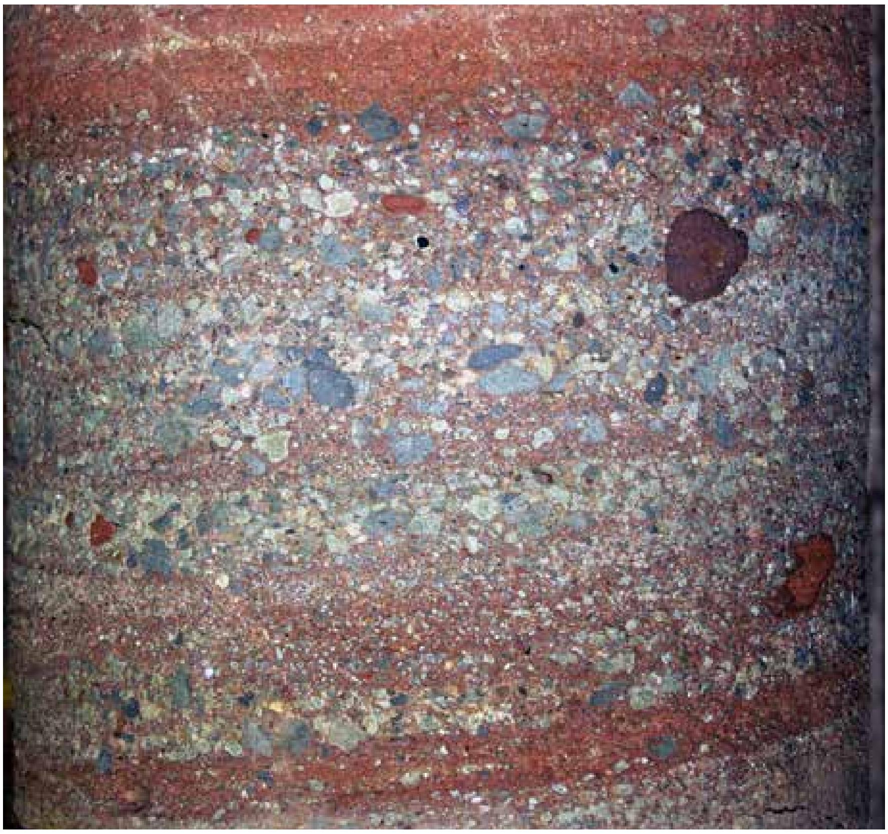


Fig. 18. A piece of N-1 (Valeč) drillcore displaying coarse-grained, ill-sorted, clast-supported (near-vent fall facies) pyroclastic deposits.

Fig. 19. Assemblage of gastropoda collected from possible termite-house within the pyroclastic deposits.

Fig. 20. Reconstruction of the situation in Dětaň area in very early Oligocene (author Petr Modlitba).

Locality 5
Valeč historical adit, pyroclastic deposits alternating with lacustrine limestones

The Šibeniční vrch hill (Galgenberg) is situated about one kilometre east of Valeč (Waltsch) on the south-east margin of the Doupovské hory Mts. Between the layers of pyroclastics a 2-metres thick body of lacustrine limestone can be found. The limestone used to be extracted for construction purposes (Fejfar 2016) and the mining remains are still visible on the southern slope of the hill. Even though the mining took place mostly on the surface, there is at least one underground gallery. The limestone was a source for many significant paleontological discoveries. The most famous one is the so-called "rodent from Waltsch" (Fig. 21) which was probably found around 1690 (Fejfar and Kvaček 1993). First described by G.F. Mylius in 1718, it was immediately made famous as the „witness of the flood", mentioned in Genesis as well as other Mesopotamian and Greek myths. The fossil rodent was supposed to be a proof of this mythical flood, because it was one of the first terrestrial fossils found in water-redeposited sediment. The fossil was later mentioned by scientists like Carl Linné, Georges Cuvier, Alexander von Humboldt and Johann Wolfgang von Goethe. The fossil was re-examined in 1993 by prof. Fejfar and determined as dormouse Bransatoglis micio. In addition to the „rodent from Waltsch", several types of fish and insects as well as many plant remains were described from the locality (Fejfar and Kvaček 1993). Palaeoclimatic estimates based on Coexistence Approach (CA) were made from the plant remains and the results shows humid and sub-tropical climate – the average year temperature around 9.5–21.7°C and the mean annual precipitation 979–1741 mm (Teodoridis and Kvaček 2015). The assemblage of fauna and flora probably belongs to the after post-Grande Coupure age (ca. mammalian Paleogene zone MP-21).

Sedimentary processes recorded in a measured section in the underground gallery at locality Valeč in 2016 (Fig. 22) reveal that most of the pyroclastics (lapilli-stone VA1 and tuff VA9 and all lapilli-stones above) were deposited by a pyroclastic fall. These deposits do not show any sedimentary structures pointing to water transport (Fig. 23). The only exception is lapilli-stone VA2 which shows cross bedding and coal debris and mm to 1 cm-sized coal seam. It can be interpreted as water redeposition of pyroclastic fall and terrestrial plants and peat or pyroclastic surge deposit. Lacustrine deposits are represented mostly by fine laminated carbonates 10–40 cm thick with 5 mm to 3 cm thick tuff interbeds; lacustrine succession is ending with 7–9 cm thick carbonate with pyroclastic admixture. Lamination often is disturbed, wavy or obliterated by water escape structures (convolute bedding). These structures point to rapid deposition and the deformation may be also triggered by seismic events. Rapid deposition of the last lacustrine pyroclastic carbonate bed (VA8) is also evidenced by load casts at its base. Laminae in carbonates typically form bundles of dark and light lamina, bundles are 1–3 mm thick. If the laminae reflect seasonality, 2 m thick carbonate succession can represent ca. 1,000 years of lacustrine history. Relatively short period of lacustrine deposition was repeatedly (at least 5 times) interrupted by thin fine-grained tuff interbeds which might originate in more distant eruptions.

Despite its fame the locality has never been exactly dated. Data from the surrounding localities are diverse. Furthermore, the localities are not easy to correlate. The age of the biotite crystals from the nearby quarry near the village Dětaň was determined at 37.5 Ma by K/Ar dating method (Fejfar 1987). However, this value is in agreement neither with the mammalian remains gathered from the same layer nor with the paleontological findings from other localities (Fejfar and Kvaček 1993). The inaccuracy could be caused by alteration of the biotite. The age of the basaltic lava overlying the pyroclastics was determined at 32.6 ± 1.7 Ma (Mikuláš et al. 2003). The relative paleontological dating reckons the findings to the mammalian Paleogene zone MP-21 (Fejfar and Kvaček 1993) which indicates the early Oligocene age. The association of the mammalian species belongs to the age after the „Grande Coupure“ (Mikuláš et al. 2003). A new biotite sample has been obtained from the upper part of the sequence studied, but the results must be correctly discussed and interpreted before publishing.

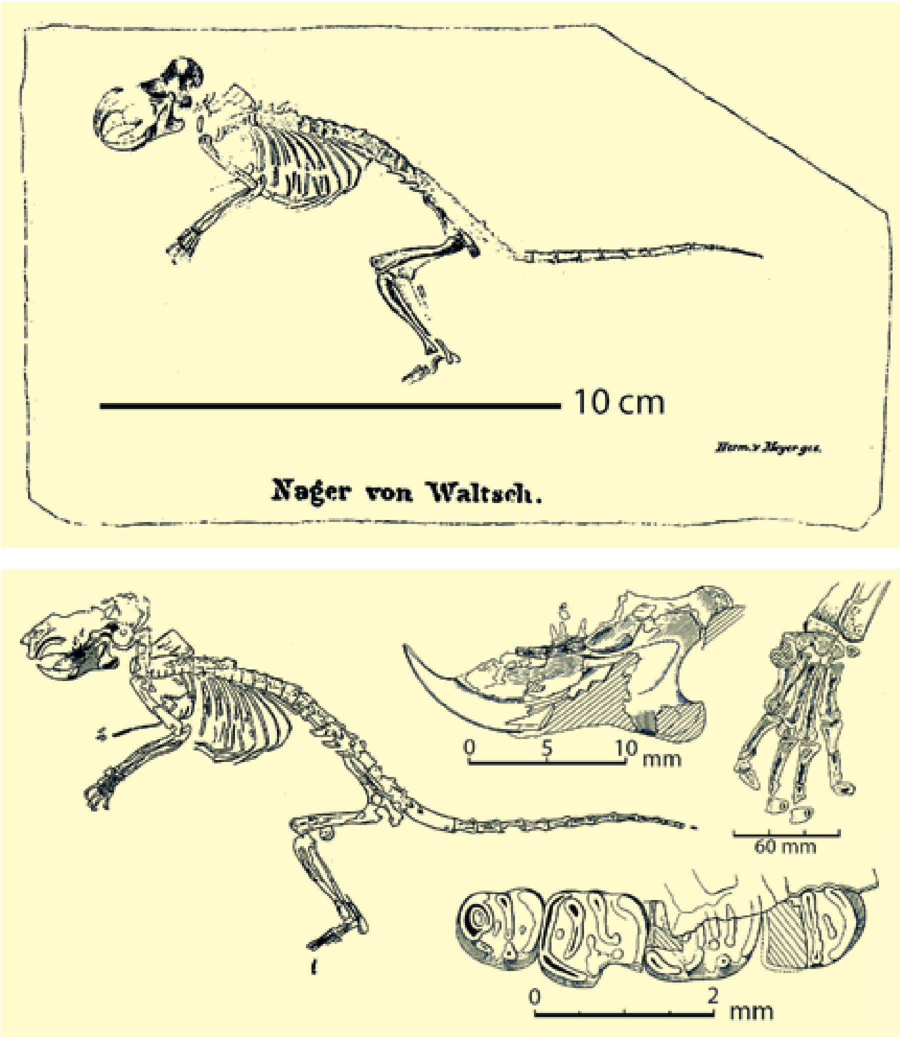


Fig. 21. Rodent from Waltsch
(adopted from Fejfar 2016 with authors kind permition).

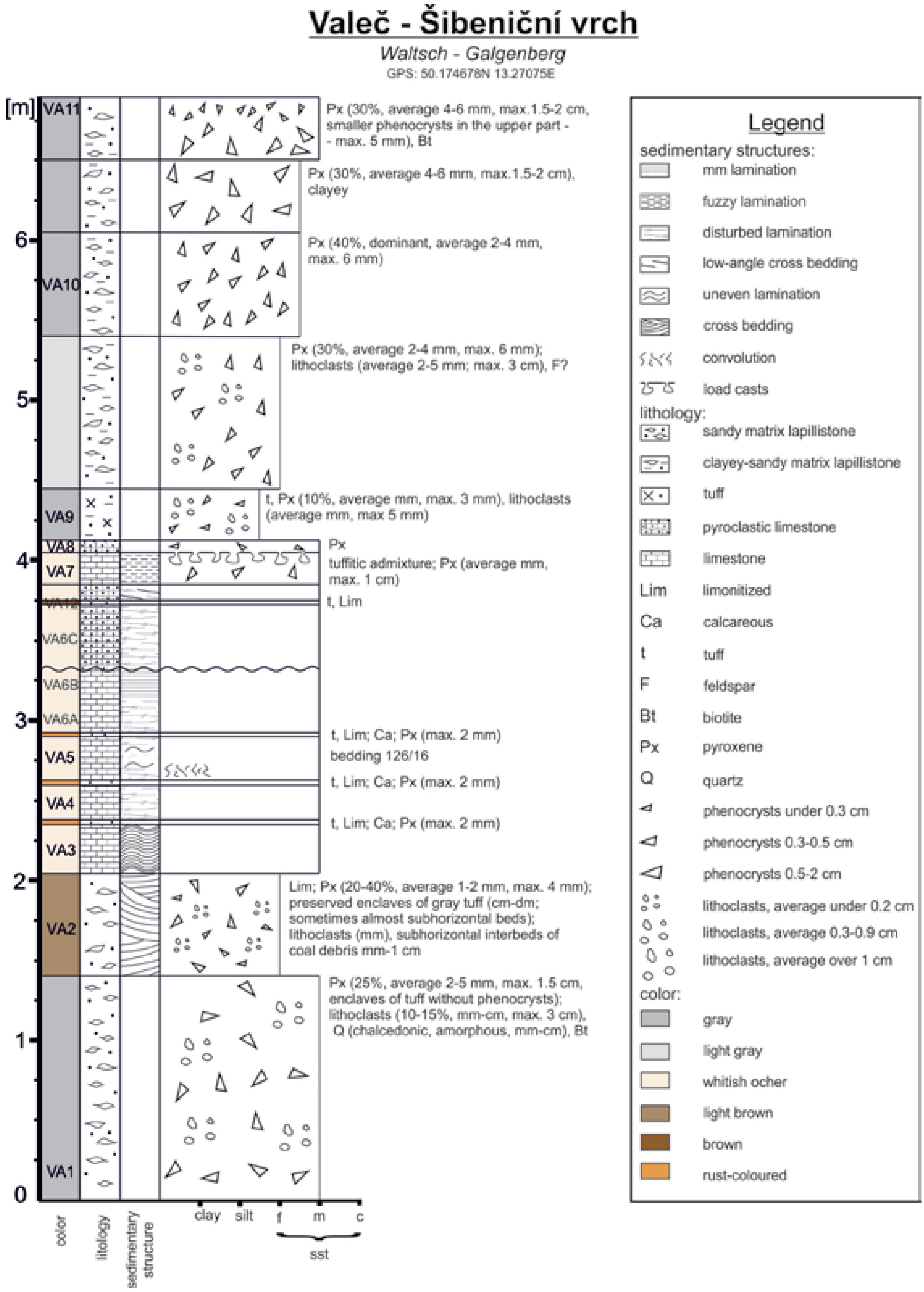


Fig. 22. Schematic profile of the Valeč sequence with pyroclastic deposits alternating with lacustrine limestones.

Fig. 23. Close up on pyroclastic deposits in the Valeč adit.

References

Fejfar O. (1987) A Lower Oligocenemammalian fauna from Dětáň and Dvérce (NW Bohemia, Czechoslovakia). *Münchner Geowiss. Abh. Reihe A* **10**, 253–264.

Fejfar O. (2016) Fosilní fauna, 63–76. In: Matějů J., Hradecký P., Melichar V. (Eds.) Doupovské hory. Česká geologická služba & Muzeum Karlovy Vary, Praha. (in Czech)

Fejfar O., Kvaček Z. (1993) Excursion Nr. 3 Tertiary basins in Northwest Bohemia. Paläontologische Gesellschaft 63. Jahrestagung 21.–26. September 1993 in Prag. Universita Karlova, Česká geologická společnost, 1–35.

Mikuláš R., Fejfar O., Ulrych J., Žigová A., Kadlecová E., Cajz V. (2003) A Study of the Dětaň Locality (Oligocene, Doupovské hory Mts. Volcanic Complex, Czech Republic): Collection of Field Data and Starting Points for Interpretation. *Geolines* **15**, 91–97.

Mlčoch B., Konopásek J. (2010) Pre-Late Carboniferous geology along the contact of the Saxothuringian and Teplá-Barrandian zones in the area covered by younger sediments and volcanics (western Bohemian Massif, Czech Republic). *J. Geosci.* **55**, 81–94.

Teodoridis V., Kvaček Z. (2015) Palaeoenvironmental evaluation of Cainozoic plant assemblages from the Bohemian Massif (Czech Republic) and adjacent Germany. *Bull. Geosci.* **90**, 695–720.

Koutecký V., Sakala J. (2015) New fossil woods from the Paleogene of Doupovské hory and České středohoří Mts. (Bohemian Massif, Czech Republic). *Acta Mus. Nat.s Pragae, Series B Historia Natur.* **71**, 377–398.

Mantzouka D., Karakitsios V., Sakala J., Wheeler E.A. (2016) Using idioblasts to group *Laurinoxylon* species: case study from the Oligo-Miocene of Europe. *IAWA Journal* **37**, 459–488.

Prakash U., Březinová D., Bůžek Č. (1971) Fossil woods from the Doupovské hory and České středohoří Mountains in Northern Bohemia. *Palaeontograph. Abt. B* **133**, 103–128.

Sakala J., Rapprich V., Pécskay Z. (2010) Fossil angiosperm wood and its host deposits from the periphery of a dominantly effusive ancient volcano (Doupovské hory Volcanic Complex, Oligocene-Lower Miocene, Czech Republic): systematics, volcanology, geochronology and taphonomy. *Bull. Geosci.* **85**, 617–629.

Teodoridis V., Sakala J. (2008) Early Miocene conifer macrofossils from the Most Basin (Czech Republic). *N. Jb. Geol. Paläontol. – Abh.* **250**, 287–312.

Ulrych J., Lloyd F.E., Balogh K. (2003) Age relations and geochemical constraints of Cenozoic alkaline volcanic series in W Bohemia: a review. *Geolines* **15**, 168–180.