Environmental changes spanning the Early-Middle Pleistocene transition

Rudolf Musil und Karel Valoch

Abstract

In this paper all environmental and biological changes of sediments of the limestone hill Stránská Skála (Moravia, Czech Republic) are described from the Jaramillo subchron across the Brunhes-Matuyama boundary to the Cromerian interglacial complex[1].

Environmental results described in this paper arise from the study of the following disciplines: sedimentology, geochemistry, granulometry (Adamová 1982; Pelíšek 1972; Pelíšek 1995), palaeopedology (Smolíková 1995), phytopalaeontogy (Svobodová 1995), zoopalaeontology (Musil 1963; Musil 1965; Musil 1967; Musil 1968; Musil 1968a; Musil 1968b; Musil 1972; Musil 1972a; Musil 1972b; Musil 1995, Musil 1995a; Musil 1995b; Němec 1972; Thenius 1972; Tobien 1972; Fejfar 1971; Flerow/Reshetov 1972; Heller 1972; Kovanda 1972; Kovanda 1995; Kowalski 1972; Kurtén 1972; Kahlke 1995; Mlíkovský 1995; Ivanov 1997), human activity (Musil 1969; Valoch 1987; Valoch 1995; Odell 1975; Přichystal/Strnad 1995; Patou-Mathis 1995), palaeomagnetic data (Kočí 1982). Individual faunal groups are evaluated ecologically and chronologically. It appears that these evaluations differ within a single period depending on the size of the area inhabited by the individual faunal groups. The environment is described on the basis of the conclusions of the individual disciplines. Traces of human activity appear in the latest Cromerian layer. Plant species, molluscs, birds, amphibians, reptiles, bats, small and large mammals were separately determined for the individual layers.

A brief history of research

The site Stránská Skála Hill was selected as a model for the reconstruction of climatic change during the Early-Middle Pleistocene transition in Moravia (Czech Republic). The Stránská Skála Hill has a length of 1 500 m and a breadth of ca. 400 m; it is composed of Jurassic limestone, in which have been found numerous fossiliferous fissures and caves. Its vertical walls, inclined towards the northeast for a length of about 500 m, are covered with sediments preceding the Jaramillo subchron, by a complex of Cromerian interglacials and further, unfortunately already disturbed, sediments with rich palaeontological

1 All these chapters are written by R. Musil, the final chapters dealing with the settlement, microwear analysis, preservation and results are by K. Valoch.

material. In the Early and Middle Pleistocene Stránská Skála formed an outer bank (river bluff) of the river Svitava.

This site was one of the first localities from which very rich and therefore very significant palaeontological Middle Pleistocene finds were described. Stránská Skála has a highly stratified section. It shows a complex sequence of various fluvial, colluvial and aeolian deposits between which several layers of fossil soils and soil sediments are intercalated. Understanding the behaviour of the climate system requires knowledge of its individual components atmosphere, hydrosphere, cryosphere, lithosphere, biosphere and their interactions. Changes in these individual components have a significant impact on the climate. The site Stránská Skála fulfils a number of prerequisites that allow the identification not only of climatic changes and their intensity, but also whether these changes are of linear or non-linear character. Changes in vegetation and the dependent fauna reflect not only the climate of the time, but also have a significant impact on it (feedback).

There are relatively few palaeontological finds from the Brunhes-Matuyama reversal, these (zoopalaeontological, phytopalaeontological below archaeological) are concentrated predominately in Cromerian sediments. The exposure of Stránská Skála allowed the study of entire or essential parts of climatic oscillations of the Cromerian interglacial and also a larger part of the preceding glacial with a climatic oscillation of an interstadial character (based upon geology, sedimentology, geochemistry, granulometric composition, palaeopedology, palaeozoology, pollen analysis, human activity). Stránská Skála is thus one of the few sites which represent, through superposition, the transition of Early to Middle Pleistocene in numerous layers bearing a great number of finds and therefore enabling the interpretation of the evolution of the early environment (Musil 1965; Musil 1968; Musil 1968a; Musil 1968b; Musil 1971; Musil 1972; Musil 1972a; Musil 1972b; Musil 1982; Musil 1995; Musil 1995a; Musil 1995b).

The present paper and all interpretations included are based on earlier investigations of this site. These include investigations of both cave sediments (not covered in the present paper) and open-air sediments. Sediments of Middle Pleistocene date occurred in both cases whilst Early Pleistocene only occurred in open-air sediments. Earlier studies of Stránská Skála can be divided into two parts. The first includes field investigations and some processing, the second includes only studies of material obtained from this fieldwork. The first investigations were carried out as early as 1910–1911 (Woldřich's cave; J. N. Woldřich 1913), further work in 1921 and in the following years (open-air sediments; V. Čapek, J. Knies), in 1926–1933 (open-air sediments; K. Absolon, K. Krumpholz), in 1936 (open-air sediments; K. Schirmeisen), in 1949–1951 (Bear cave, cave No. 14; R. Musil), in 1957 (open-air sediments; V. Ložek, O. Fejfar), in 1964–1972 (open-air sediments; R. Musil), in 1966–1972 (cave No. 4; R. Musil), and in 1996–1998 (open-air sediments; K. Valoch). The site's history and its investigations have been summarized in former publications (Musil 1965; Musil 1971).

Location of Stránská Skála

Stránská Skála Hill is situated at the eastern margin of the town of Brno, roughly in the central part of Moravia (Czech Republic). The summit of the hill is 310 m above sea level,

Fig. 1 Position of Stránská Skála in Central Europe (location marked by asterisk).

geographical co-ordinates are approximately 49° 11′ N, 16° 36′ E. The exposure measured 11 m in length and 13 m in depth.

Stratigraphic description

The study of the environment during the transition from Early to Middle Pleistocene must begin with the description of the individual layers of the sediments (geochemistry, granulometry; Pelíšek 1972, Pelíšek 1995) and then proceed to the study of the changes that took place at that time. Along the entire western edge of the Stránská Skála hill runs a horizontal erosive rock-cut terrace covered mostly with talus cones of sediments. Some parts of these sediments have either come from an area higher above, or from the supposed cave entrance, and have been secondarily transported to talus cones either by gravity or by solifluction. The section (after Smolíková 1995) is distinctive for revealing soil formation of the Braunlehm type, which recur at least three times. All the soils are highly polygenetic.

The following paragraphs are devoted to the description of the talus cones. The exposure measured 11 m in length, 5 m in width and 13 m in depth.

Holocene

All the Holocene layers were almost free of debris and best developed only in the uppermost part of the exposure.
Layer 23: Recent fill (200 cm) resulting from limestone quarrying, most probably from the nearby platform where the cave entrance had been situated. The palaeontological content of the fill was studied by Woldřich (1916; 1917) in the early 20th century. Osteological finds, originally from the entrance of Woldřich's cave, were discovered in these displaced sediments and studied by Schirmeisen (1929).
Layer 22: Dark black soil, probably Sub-Atlantic to recent.
Layer 21: Light brown clay-loam soil, probably Sub-Boreal.
Layer 20: Dark black soil, in some areas completely free of stone debris, in some areas with coarse stone rubble, in others fine debris. Probably Atlantic.
Layer 19: Rust brown coloured soil, probably Pre-Boreal to Boreal. In its lowest bed also residues in the form of lenticles of dark soil.
The thickness of layers 22–19 amounted to 70 cm, all layers being parautochthonous.

Last Glacial

Layer 18 (Musil 1995b: layer 17): Loess of brownish to yellow colour, strongly calcareous, with a large number of calcareous pseudomycelia, occasionally containing larger limestone blocks with rounded edges. It is developed only in the uppermost part of the exposure. Slightly laminated due to solifluction.

End of the Last Glacial

Layer 17 (Musil 1995b: layer 16): Loess similar in colour to the loess in the overlying bed. It differs from the overlying bed however by a lower amount of $CaCO_3$. Apart from large limestone blocks, it also contains fine sharp-edged limestone debris. Occasionally small quartz pebbles may be present, originating from the cave situated above the exposure. The influence of solifluction is obvious, manifesting itself in smudges and lenses of browner soils in the loess. Brown soils evidently derive from a Würm interstadial.

Last Glacial (?)

A long sedimentary hiatus (probably Riss, Eemian and the beginning of the Last Glacial).

Middle Pleistocene[2]

Layer 16 (Musil 1995b: layers 15a, b, c, d): An enhanced quantity of $CaCO_3$ was found on the surface. Crumb structured brown soil with a large quantity of angular (frost shattered) debris. In some areas the debris predominates and is almost soil free. Apart from unweathered limestone debris, many weathered limestones and small quartz pebbles are present.

The whole layer consists of a large number of lenticles of variable thickness. The lower part of one lens butts a large boulder which must have hindered further downhill movement. The layer represents lenticular deposits produced by solifluction and related to several chronological phases.

Here two materials, from different periods and climate, seem to be mixed. Brown soil and palaeontological finds derive from a warm period (soil of the Rotlehm type or rubification, originally from the cave entrance, pending layer 12? in section), whereas the formation of fine debris (congelifraction) and solifluction took place in a markedly cold period. The soil and the palaeontological finds contained within it belong to the Cromerian interglacial, the formation of angular debris and indicative of solifluction are later in date (Mindel?).

Sedimentary and chronological hiatus[3]

Layers 15, 14, and 13 (Musil 1995b: layers 14c, 14b, 14a): only in the lower part of the exposure. Yellow brown loess loam (layer 13) with relics of a fossil soil (Braunlehm, autochthonous soil, layer 14). These relics are preserved in the form of sharp-edged pieces of various sizes as a result of cryoturbation and being moved whilst frozen into the underlying loess bed. Brown mottling represents the remains of a fossil soil, which has been subjected to the processes of cryoturbation. Large yellow and brown areas are clearly recognisable in the section. In some places foliaceous parting in loess is detectable; otherwise, completely without debris. Following Smolíková (1995) the soil is most similar to layer 12 (Cromerian interglacial) which corresponds to the parautochthonous soil. It provides evidence of intensive pedogenesis (soil of the Rotlehm type or rubification).

The brown fossil soil may be related to a warm period of interglacial character following the loess sedimentation. This warm period is again followed by the formation of loess (layer 15) and a markedly cold climate.

Palaeopedologic results of layer 14 (Smolíková 1995): the deep brownish orange matrix is marked by the presence of two different constituent forms, namely segregate and aggregate, which are mutually mixed. Orange tinted segregates consist of Braunlehm building plasma; brown tinted aggregates are constituted by flocculated plasma.

Upper layers were affected by solifluction and cryoturbation. The manner of their sedimentation was, however, different. Whereas in layers 13, 14 and 15 cryoturbation prevailed and the sediments remained in situ, layer 16 is an allochthonous sediment that reached its present position from the platform and from the cave entrance above the exposure.

Interglacial Cromerian II[4]

Layer 12 (Musil 1995b: layer 13): End of sedimentation of talus cone IV and last parautochthonous layer (Braunlehm). In the underlying bed of layer 12 parautochthonous and

2 Cold Period (Mindel?), older layers transported by solifluction.

3 Cold, warm (interglacial Cromerian III?) and cold period.

4 Talus cone IV and fossil soil sediments.

autochthonous sediments appear which lack a long chronological or sedimentary hiatus. It is most probable that layer 12 has not been preserved in its original thickness and that the upper layers were eroded so that this complex is represented here only by a basal torso. In some places on the surface of the layer minor depressions are visible (erosion furrows?).

Brown gritty soil, on its surface flat limestone blocks with rounded edges. Apart from unweathered limestone debris, there was also debris that disintegrated into sand. In the underlying bed brown soil with fine stony debris occurs. At its base boulders of larger dimensions appear, to about the size of limestone blocks. The boundary with the underlying layer was abrupt. Moreover, this layer was the only one to contain many Jurassic fossils weathered from the limestone.

Layer 12 is the find layer of man-made artifacts and pieces of charcoal from fireplaces. Palaeopedological results (Smolíková 1995): The matrix is formed by both flocculated and peptized building plasma. The portions composed of flocculated plasma are slightly humic. Pseudogleyization is manifested here both by abundant pseudogley concretions and by almost black »manganolimonite« borders on the walls of some aggregates.

Layer 11 (Musil 1995b: layer 12): rusty-yellow loess loam.

Layer 10 (Musil 1995b: layer 11): the beginning of sedimentation of talus cone IV. On the surface are large boulders. Near the base fine sharp-edged debris and on the base a deposition of larger limestone boulders of about 1–2 m^3. Limestones weathered to sand are present. The soil is a dark or rusty-brown colour.

Sinter Deposit C: lime content increased towards the base of the layer until a compact sinter deposit developed near the bedrock. Its termination towards the overlying bed (layer 10) is therefore not sharp, but it gradually blends into the sediment which is strongly saturated with $CaCO_3$. Waters saturated with calcium carbonate are likely to have come from a vertical fissure in the rock. The sinter deposit slants down the slope in the same way as layer 10, thus it is syngenetic. In some places the sinter contains natural hornstone splinters. A fragment of a straw stalactite was found within it, which must have come from a cave situated higher above.

Layer 9, loess intercalation (Musil 1995: layer 10): aeolian loess up to loess loam, yellow ochre or yellow brown in colour. Developed as a typical yellow loess at its base. Towards its upper surface it gradually becomes browner and changes into a loess loam. A large number of pseudomycelia are present, occasionally small quartz pebbles; limestone debris varies in density from sporadic to abundant.

Interglacial Cromerian I[5]

Layer 8 (Musil 1995b: layer 9): Light yellow brown soil with lots of large debris. In the lower part it contained areas with large boulders, but also areas with fine but sub-angular debris. The layer gradually blends in colour into the underlying bed. A large number of fillings are formed by deep red Braunlehm plasma. They provide evidence of intensive pedogenesis leading either to the formation of Rotlehm type soils or to rubification (Smolíková 1995).

Layer 7 (Musil 1995b: layer 8): brown loess loam, abundant in fine flat limestone debris and sporadically also larger rounded debris, the quantity of which decreases away

5 Talus cone III and fossil soil sediments.

from the rock down the slope. There are many weathered limestones. Traces of earthworm activity are common.

Palaeopedological results (Smolíková 1995): Braunlehm building plasma is concentrated into rounded lumps with spherical outlines, which may also occasionally appear as parts constituted of humic flocculated plasma and fragments of highly weathered reddish brown soils.

Layer 6 (Musil 1995b: layer 7): brown soil, darker than the overlying layer, abundant in fine flat limestone debris similar to that in the overlying bed. Many weathered limestones. At the bottom large debris. After its sedimentation near the rock, layer 6 is formed as a sinter deposit. Where there is no sinter deposition, it is possible to observe a gradual transition towards the underlying bed.

Palaeopedological results (Smolíková 1995): The matrix consists of two different components. One is composed of deep brown-orange coloured Braunlehm building plasma, the other is formed of slightly humid flocculated building plasma. Humic parts are concentrated in lumps. The skeleton structure is analogous to layer 7.

Sinter Deposit B: Following the deposition of coarse debris the lower part of the layer near the rock was saturated so much with $CaCO_3$ that it developed into a sinter layer which penetrated into the underlying bed.

Layer 5 (Musil 1995b: layer 6): Genetically it belongs to the underlying bed, from which it differs in many respects and is sharply delimited. The mineral composition of samples from this layer and from the upper part of layer 4 are however quite similar. Besides the prevailing quartz, feldspars are common, mica minerals and calcite are moderately represented, whilst the mineral group of montmorillonite, kaolinite and dolomite are scarce (Adamová 1982). Loess loam to loess, of yellow to yellow-brown colour with calcareous pseudomycelia and with fine debris similar to that in the overlying bed. In the upper part are larger boulders. During sedimentation of this layer, block collapse of the rock wall occurred.

Brunhes-Matuyama boundary (0.78 Ma; close to the base of layer 5).

Talus cone IV and talus cone III are separated by a loess layer. The talus cones are markedly different with respect to their composition.

Menapian Glacial

Layer 4 (Musil 1995b: layer 5): Layer 4 is clearly separated from its overlying beds. Typical aeolian loess deposit of substantial thickness (380 cm!), almost debris free, except rare smaller rounded fragments of limestone which are mostly heavily weathered. Large limestone blocks have been pressed into its surface. The yellow brown loess is lighter in colour than the overlying layer; pseudomycelia are scarcer. Sharp division to the overlying bed.

Relatively abundant are root tubes formed of $CaCO_3$, 0,5–3 cm in diameter (Rhizosolenia). They are root sheaths of shrubs and trees. Their orientation is very variable. Fossil earthworm faeces occurred abundantly at a depth of 290–300 cm from the layer surface. In the upper part, fine foliaceous structures can be seen. These can be identified as a thin lamination which subsequently flakes off. At a depth of 350 cm thin lenses of aeolian sand (up to 2 cm thick) begin to appear. They have different gradients and mark the former surface. A few light coloured lenses alternate with darker ones and occasionally with lenses containing coarser material. The gradient of the aeolian sand of solifluction laminae is, at around 60^0, considerably high. They indicate not only the slope gradient of that time but also the fluctuating wind intensity. This gradient is even followed by almost flat boulders. Small fragments of local chert occur sporadically in aeolian sands. Large lime nodules (ca. 10 cm x 4 cm) are also found here although they do not represent a marked deposit.

In the middle and lower parts of the layer there are horizons of a rusty and distinctive grey colour, sometimes in the form of spots – these are gleyey layers. Their inclination is the same as that of wind-blown sands. They were formed during the sedimentation of the layer and not in a later period. The whole layer was deposited under periglacial conditions.

Palaeopedological results (Smolíková 1995): In the soil matrix there are sparsely distributed irregular, radially confined pseudogley concretions, minute Braunlehm concretions of smooth outlines, and coprogenic elements of earthworms. The matrix shows slight traces of stratification.

Talus cone II and fossil sediments[6]

Layer 3 (Musil 1995: layer 4): This layer begins with a deposit of coarse debris that upwardly gradually decreases. Limestone is heavily weathered to sand in some areas. The weathering differs substantially in intensity between talus cone III and IV, where heavily weathered limestone was scarce. A yellow to yellow-brown loess loam is found within the debris. Towards the bottom it becomes more clayey.

Sinter Deposit A (Musil 1995: layer 4a): Sinter consolidates principally at the rock wall, forming the lower part of the debris from layer 3. The base of this layer is horizontal.

Fluvial sediments

Layer 2 (Musil 1995: layers 3b, 3a): The surface of this layer is almost level and the debris from the overlying bed is pressed into it. It is a typical fluvial sediment which reflects gradually receding fluvial accumulation of a flood loam analogous to present-day flood loams in river valleys. It consists of grey loess loam sediments with horizontally deposited fine sand, occasionally with fine debris, containing rust coloured spots and smudges of precipitated limonite due to oxidation processes. The boundary to the overlying bed of the layer is sharply defined. The fluvial horizontally deposited sands become coarser towards the bottom. However, terrestrial sediments begin to predominate in this layer. On the base of the layer were found several heavily weathered rock fragments of the Brno massif (the largest being 18 cm x 8 cm x 8 cm). The layer represents the final accumulation of flood loams of the Stránská terrace.

Jaramillo subchron (0.99–1.07 Ma). This is situated at the beginning of layer 2.

---

6 Warm climatic oscillation of interstadial character.

Talus cone I and fossil sediments

Layer 1 (Musil 1995: layer 2): Lies directly on the erosion terrace level. Layer 1 is a river sediment that contains scattered, well-rounded gravels and is composed of heavily weathered limestone debris ranging down to sand sized grains. In the talus cone, sometimes lenses of fluvial sand occur; in places also grey clayey loam similar to the overlying layer. It is not a real talus cone, but results from the intermittent collapse of limestone debris on to the former riverbed. During the formation of this layer the talus cone was only submerged at times of raised water levels. The upper part of the talus cone was made up of small limestone debris, the lower part of coarser debris.

Horizontal erosion terrace level

This is an almost horizontal limestone stratum on which fluvial sediments of the Stránská terrace are deposited.

Reconstruction of the palaeoclimate of individual layers

In conclusion, the reconstruction of sedimentary conditions of the studied section were carried out and classified into individual cycles. The mode of sedimentation of these cycles (talus cones) strongly resembles the Holocene (e.g. beginning always with large limestone blocks and a sinter horizon).

From the previous description it follows that according to their macroscopic appearance, the sediments may be grouped into several separate complexes. Of importance is the repeated formation of sinter, which solidifies the individual talus cones. All the preserved soils are highly polygenetic. From the base to the surface it is possible to reconstruct the following sedimentary complexes.

Concise reconstruction of individual layers based on sedimentological research

1. Eroded rock ledge. Probably pre-Quaternary.
2. Formation of talus cone I (layers 1 and 2, Menapian) with imbedded fluvial sediments of the Stránská terrace. It is not a real talus cone, but accumulates from intermittent collapse of limestone debris on to the former riverbed. However, terrestrial sediments begin to predominate in Layer 2. Flood loams in the overlying bed represent only fluvial sedimentation of the Stránská terrace. A period of increasing water precipitation is recorded here which resulted in the erosion of sediments in the surroundings and during floods in increased accumulation of flood loams. For all these reasons it is necessary to assume a cold climate and a mostly unforested landscape covered with only steppe vegetation and thus vulnerable to sediment erosion. At that time the accumulation of flood loams ceases and it appears that the valley gradually begins to deepen.

   Environment: Cold humid climate, spate water precipitation, increased sediment erosion, steppe vegetation. At the beginning of the sedimentation of layer 2, Jaramillo subchron (0.99–1.07 Ma).

3. Formation of talus cone II (layer 3, Menapian). On the base of layer 3 the Sinter Deposit A forms with large limestone blocks. High proportions of $CaCO_3$ in sinter horizons as well as cementing substances in debris are indicative of climatic periods with abundant atmospheric precipitation. The former cold weather still continues (humid oscillation). Judging from the vegetation the landscape remained unchanged. Perhaps it is possible to postulate only a weak climatic oscillation of interstadial character.
   Environment: Cold humid climate, increased precipitation at the beginning of the sedimentation of layer 3 (Sinter Deposit A), steppe vegetation, climatic oscillation of interstadial character (Menapian interstadial?).
4. Cold climate persists, but gradually becomes drier. Only now does this result in the formation of a typical aeolian loess deposit of substantial thickness (380 cm!).
   Environment: Gley horizons in the lower half of the loess represent cyclically repeating major and extended precipitation which must have interrupted aeolian activity. Laminar development of a part of the loess indicates the presence of permafrost. Horizons of wind-blown sand indicate oscillations in wind intensity during the beginning of its accumulation phase. We must assume that higher locations in the vicinity lacked vegetation cover. Highly unstable cold and arid climate with oscillations (Menapian Glacial).
5. Layer of loess loam (layer 5), differs in a number of respects from the underlying bed, from which it is sharply separated. The Brunhes-Matuyama boundary (0.78 Ma) is found in its lower part.
6. Talus cone III (Sinter Deposit B, layers 6, 7, 8, Cromerian I) represents the onset of a warm interglacial climate. A number of differently developed layers indicate more intense climatic oscillations during this period. Intensive pedogenesis leads to the formation of soils of the Rotlehm type or to rubification. Layers of sediments of this complex represent a slow and uninterrupted sedimentation after the preceding glacial. Following the cessation of loess sedimentation large limestone blocks and debris were released and a great and persistent precipitation occurred (Sinter Deposit B). The greatest amount of small debris is contained in layer 6. This layer consists of soil sediments, which are composed of transported material of disturbed, slightly humic Braunlehm. The degree of soil weathering is high. Biogenic activity increases (abundant coprogenic elements, tubes left by roots and worms, carbonized wood remains). Layer 7 is a brown loess loam with abundant fine flat weathered limestone debris. It differs from layer 6 in its lower huminification. There are many characteristics of earthworm activity.
   The sinter horizon again documents a major precipitation (humid oscillation). This group of layers represents the onset of a warm interglacial climate. A complete analogy can be found for example in sediments of the early Holocene (Cromerian I).
   Environment: The glacial period had come to an end and a marked warming set in. From the onset and development of the Cromerian I interglacial to its climax.
7. Loess intercalation (layer 9) that was highly probably sedimented during a warm period. This indicates a highly arid climate which evidently resulted at certain exposed locations in the removal of plant cover and thus the possible formation of aeolian sediments.

8. Talus cone IV (Sinter Deposit C, layers 10, 11, 12, Cromerian II). The complex of layers 10–12 again forms a unit. Sedimentation starts again with large debris. Climatically it represents another interglacial stage (Cromerian II). Layer 12 represents a basal torso of Braunlehm in parautochthonous position. Now larger debris is formed against talus cone III. The beginning of this period is again characterised by increased precipitation which resulted in the formation of sinter (humid oscillation, Sinter Deposit C). It concerns the last sediments which were not impaired. It is probable that the upper layer(s?) of this complex layers was/were removed by erosion and they continued in the original position.
   Layer 12 contains man-made artifacts, burnt bones and pieces of charcoal from fireplaces. In respect of the composition of talus cones III and IV, their content and the debris particle size, they seem to have been deposited under different climatic conditions.
9. Yellow brown loess loam (layer 13). The layer was affected by solifluction and cryoturbation during a cold climatic phase.
10. Layer 14. The formation of Braunlehm took place during the deflation and sedimentation in a warm and humid climate (soil analysis indicates a climatic optimum). The layer represents an autochthonous soil which is, however, only preserved in traces. It probably belongs to the Cromerian interglacial (Cromerian III?).
11. Layer 15 (Musil 1995: layer 14a): Loess. An extremely cold climate prevailed, with a period of solifluction and sediment denudation.
12. Sedimentary and chronological hiatus.
13. Layer 16 is a source of fine angular gravels during a markedly cold climate. These were transported via solifluction with soil and palaeontological finds of the (Cromerian) interglacial. In the soil there are palaeontological finds identical to those in talus cone III and IV, deriving from layers lying on the platform or in the cave entrance above the exposure. The formation of angular debris and solifluction are of later date (Mindel?). A very cold period with glacial climate.
14. A longer sedimentary hiatus (Probably Riss, Eemian and the beginning of the Last Glacial).
15. Two layers of loess from the Last Glacial (layers 17 and 18) of brown to yellow colour. A weak solifluction occurred in the lower part of layer 17.
16. Holocene soils (Layers 19–23). Holocene layers are generally free of debris.

Results of the phytopalaeontological analysis of the Cromerian sediments[7]

Samples taken for the analysis of sporomorphae come from sediments belonging to the Cromerian interglacials. Sample A was taken from the base of the Cromerian Interglacial I (layers 4 and 5), further samples came from interglacial layers B (layer 6), C (layer 8) and D (layer 12). The samples thus represent the two interglacial complexes (Cromerian I and II). Svobodová (1995) mentions the following sporomorphs:

Pollen analysis of Sample A which comes from the Brunhes-Matuyama boundary (transition of layers 4 and 5; Cromerian I): AP 40 %: pine (13 %), alder (10 %), birch (8 %), hornbeam (2 %), spruce, willow, elm, *Dryopteris* sp. (fern), *Carya* sp. NAP: Cyperaceae

7 Conclusion based upon 51 taxa (Svobodová 1995).

(11 %), Poaceae (22 %, Asteraceae Tubiflorae, *Helianthemum* sp., *Phragmites* sp. (reed), *Artemisia* sp. (southernwood), Pteridophyta: *Dryopteris* sp. (fern), Bryophyta: Bryales, Algae: (Desmidiaceae). Both thermophilic wood species and those requiring a humid climate were found.

Sample B comes from layer 6, i. e. from the base of talus cone III (Cromerian I): AP 25 %. Pine prevails (6 %), additionally spruce, fir, birch, alder, *Carya* sp., hazel, beech, oak, yew and *Sciadopithys* sp. are present. Alder is already absent. NAP> Asteraceae Liguliflorae, Asteraceae Tubiflorae (both 19 %), *Achillea* sp., *Gentianella* sp. (40 %), *Artemisia* sp. (southernwood), *Helianthemum* sp., Daucaceae, Brassicaceae (*Barbarea* sp., Cyperaceae, Poaceae, Pteridophyta: *Equisetum* sp. (horsetail), *Dryopteris* sp. (fern), Pteridium aquilinum, Bryophyta: *Sphagnum* sp., Algae: Desmidiaceae.

In the field investigation of layer 10 a large quantity of fruits of *Celtis* sp. (stones) were found. It was the richest layer of this genus.

Sample D (layer 12) comes from talus cone IV (Cromerian II). An increased amount of pollen of wood species (AP 20 %) is characterised by prevailing deciduous thermophilic trees, such as oak, ash and hornbeam, also represented are fir, birch, heather, ivy, pine, yew, lime-tree and stones of *Celtis* sp. Alder and willow reappear. Amongst the herbs, Cyperacea (23 %) and Poaceae (10 %) dominate, accompanied by genera *Artemisia* sp. (southernwood, 7 %), *Barbarea* sp. (15 %), *Achillea* sp., *Cirsium* sp. (card-thistle), *Potentilla* sp. (cinquefoil), *Sanquisorba officinalis*, *Equisetum* sp. (horsetail), *Dryopteris* sp. (fern) and further representatives of the family Viciaceae (9 %), Rosaceae (7 %), Chenopodiaceae (1 %), Asteraceae Liguliflorae, Daucaceae, Silenaceae. The assemblage indicates, according to Svobodová (1995) improved climatic conditions with an open unforested landscape.

Sample C derives from layers 13, 14 and 15 (Cromerian III?): the pollen spectrum is quantitatively relatively poor, AP 12 %, alder, beech, ivy, spruce, pine, oak, willow. NAP: *Cardus* sp. prevails (thistle, 42,6 %), *Artemisia* sp. (southernwood) and *Cardamine* sp. (both 3 %), *Achillea* sp., *Centaurea jacea* (cornflower), *Filipendula* sp., *Galium* sp. (catchweed), *Nuphar* sp., Poaceae, Rosaceae, Viciaceae, Chenopodiaceae, Cyperaceae, Asteraceae Liguliflorae. According to Svobodová (1995) the vegetation corresponds to a dry steppe and a slight climatic deterioration. Sporomorphs of water plants evidently come from the nearby stream. As the samples derive from climatically different periods, it is difficult to use them. They will probably mainly derive from layer 14.

Reconstruction of palaeoclimate based on pollen analysis

Samples taken for the analysis of sporomorphae come from sediments belonging to the Cromerian interglacial. On the basis of further knowledge of the site, its immediate and distant environment it must be assumed that their composition does not simply represent the plant cover of the site, but also that of the nearest surroundings. In all talus cones plant assemblages are thermophilic. Here are found both plants growing on the river-bank and on moist or waterlogged meadows, and such requiring dry conditions. The first groups come from the valley below the site, where at that time a river flowed and the valley was relatively moist, the second from Stránská Skála, which is limestone and both in the past and at present has grass cover. The last group are tree species growing in the immediate surroundings and constituting major forest units. The assemblages of all samples taken thus express the representation of all these quite different habitats, in no case just the site of Stránská Skála Hill.

Layer 12: An increased amount of pollen of tree species (AP 20 %) is characterised by prevailing deciduous thermophilic trees. The assemblage indicates improved climatic conditions with an open unforested landscape.

Layers 13, 14, 15: The vegetation corresponds to a dry steppe and a slight deterioration of climate. Sporomorphs of water plants evidently come from the nearby stream. As the samples derive from climatically different periods, it is difficult to use them. They will probably be mainly from layer 14.

Already at the beginning of the Brunhes-Matuyama boundary the vegetation indicates an interglacial climate. This culminates in talus cone IV (Cromerian II), characterised by optimum climatic conditions, the best in the given group of layers. The plant assemblage of the layer complex 13, 14 and 15 shows again that the position of the brown loams (layer 14) will most likely still belong to the Cromerian interglacial (Cromerian III?).

Spatially abrupt environmental changes of faunal communities

Such rich and varied faunal communities at one single site over an extended period are only known from very few sites. In our case there are aquatic communities living in the stream at the foot of Stránská Skála (mainly ostracods, lamellibranches and snails; the ostracods and lamellibranches have so far not been studied.) and terrestrial communities found in varying numbers of species in almost all layers. Terrestrial communities come on the one hand from Stránská Skála proper, the summit of which was evidently always grassed, and on the other from the immediate and distant surroundings. Our present knowledge indicates that it is not possible, not even for one layer, to correlate these ecologically varied communities (various biotopes) and thus to try to reconstruct the environment of Stránská Skála. The environments of various biotopes are quite different within the individual animal groups. The picture one would gain would in any case not correspond to reality. This shows that attempts of environmental and climatic reconstruction on the basis of only a single group of organisms are not objective.

Results of the molluscan analysis[8]

From this locality come the largest collection of mollusc shells. Significantly, climax interglacial species rank the Stránská Skála hill among the classic evidence of abundantly developed assemblages of the interglacial climax of Central Europe. All mollusc finds were identified by Kovanda (1972; 1995; 1995a; 1995b).

8 Conclusions based on 76 taxa (Kovanda 1995).

Aquatic communities

Layer 1 (Menapian): Freshwater species predominate (over 62 %, more than 96 % of specimens). Most frequent species: *Valvata piscinalis* (freshwater biotopes, abundant), *Lymnaea ovata* (freshwater biotopes, abundant), *Pisidium amnicum* (freshwater biotopes). Occasionally occurring species: *Lymnaea truncatula* (freshwater biotopes), *Pisidum* sp. (rare). Terrestrial species (less than 4 %) are represented by: *Succinea* cf. *putris* (rare, living on the waterside, marshes and swamps), *Succinea oblonga* (hygrophilous species, humid sites), *Clausilia* cf. *dubia*, *Vallonia tenuilabris* (cold loess species, open areas).
Layer 2 (Menapian): Freshwater molluscs form around 37 %. The most abundant species: *Lymnaea ovata* (freshwater biotopes), occasionally *Pisidium amnicum* (freshwater biotopes), *Planorbis planorbis* (freshwater biotopes), *Valvata piscinalis* (freshwater biotopes), *Anisus leucostomus* (freshwater biotopes), *Lymnaea* cf. *palustris* (freshwater biotopes). Rarely: *Semilimax cotulae* (small groves and forest steppe), *Pupilla sterri* (a steppe species), *Vallonia costata* (open areas), *Vallonia pulchella* (open areas), *Columella columella* (open areas, loess species), *Succinea oblonga* (humid sites), *Lymnaea truncatula* (freshwater biotopes), *Pisidium* sp. (freshwater biotopes). Further species: *Helicopsis striata*, *Pupilla triplicata* (a steppe species, locally present in loess), *Vallonia tenuilabris* (open areas, loess species), *Pupilla muscorum* (open areas), *Pupilla loessica* (open areas, loess species), *Cochlicopa lubrica*, *Trichia* sp., *Clausilia dubia*, *Bradybaena* sp. or *Arianta* sp. (small groves and forest steppe), *Vitrea crystallina* (small groves and forest steppe).

Palaeoecology of layers 1 and 2

Fossil molluscs from fluvial layers 1 and 2 indicate running water and cold climate. In layer 2 besides water species there also begin to appear terrestrial species. Steppe species and those of open grassed landscape dominate, the occurrence of a forest-steppe landscape cannot therefore be excluded. As for terrestrial species, some are hygrophilic and some are riparian. *Vallonia tenuilabris* is currently found in loess. Generally they are a cold glacial climate species, but appear already from the onset of a milder phase of a warmer stage (Kovanda 1995). The community of layer 2 is similar to the earlier one, with the exception that the number of water species decreases in favour of terrestrial species. These are mainly species living in steppe or in the open grassed landscape; some of them indicate the possibility of a forested steppe landscape.

Terrestrial communities

Layer 3, Sinter Deposit A (talus cone II, Cromerian I)
With the exception of one single species (*Lymnaea ovata*, freshwater biotope) there appear only terrestrial mollusc species. The most abundant species: *Helicopsis striata*, *Pupilla muscorum* (open areas), *Vallonia tenuilabris* (open areas, loess species), *Succinea oblonga* (humid sites), *Bradybaena fruticum* (small groves and forest steppe), *Similimax kotulae*, *Granaria frumentum* (steppe species, locally present in loess), *Chondrula tridens* (steppe species, locally present in loess), *Cochlicopa lubrica*, *Pupilla sterri* (steppe species), *Pupilla triplicata* (steppe species, locally present in loess), *Trichia* sp.
Layer 3, upper part of talus cone II (Cromerian I)
Three species are aquatic: *Planorbis planorbis* (freshwater biotopes), *Lymnaea ovata* (freshwater biotopes), *Lymnaea truncatula* (freshwater biotopes). Terrestrial species:

Helicopsis striata (steppe species), *Vallonia tenuilabris* (open areas, loess species), *Clausilia dubia*. Further species are the same as were found in the underlying Sinter Deposit A.

Palaeoecology of layer 3

A quite different pattern of association occurs in the underlying beds. In Sinter Deposit A elements of steppe and open areas play a dominant role with meagre areas of forest steppe. 85 % of the specimens belong to species inhabiting unforested sites. In the upper part of layer 3 more than 88 % of the individuals are typical of steppe and open areas. This shows a continuation of Sinter Deposit A, there were no substantial changes. The climate leading to the formation of sinter horizons in the lower part of the layer was not reflected in any way in the molluscan fauna. According to Kovanda (1995) it is a typical example of quite developed associations of »transition faunas« occurring in intervals between cold and warm periods, i.e. between glacials and interglacials. Summing up, it is possible to state that at that time the climate was hardly cold, instead rather mildly warm. In the near vicinity there were steppes, in some places perhaps small groves.

Palaeoecology of layers 4 and 5

Representatives of open grassed areas ranging up to species of steppe character predominate. A common loess assemblage of moderately cold character is involved (Kovanda 1995b).
Layers 4 (upper part) and 5 (= Complex I, Kovanda 1995a)
A thick layer of loess (Layer 4), in overlying layers loess loam (Layer 5). Typical loess fauna: *Vallonia tenuilabris* (open areas, loess species), *Helicopsis striata* (steppe species), *Clausilia dubia*, sporadically *Pupilla sterri* (steppe species), *Pupilla muscorum densegyrata* (open areas), *Succinea oblonga* (humid sites), *Pupilla triplicata* (steppe species, locally present in loess), *Helicopsis striata* (steppe species), *Pupilla muscorum* (open areas), *Cochlicopa lubrica*, *Trichia* cf. *plebeia*, *Trichia hispida*, *Nesovitrea hammoni*, *Vallonia tenuilabris* (open areas, loess species).

Palaeoecology of Sinter Deposit B and of the upper part of layer 6

Species of molluscs in the lower layer reflect the onset of a warm period. In the layer forest-steppe species are found in negligible quantities, most, however, are steppe species, with a few xerothermic species. According to Kovanda (1995, 1995a) this association of species is characteristic of the beginning of a warm period.

Sinter Deposit B and upper part of layer 6 (talus cone III, Cromerian I) (= Complex II, Kovanda 1995b). This marks the beginning of the sedimentation of talus cone III. The assemblage of molluscs was very abundant: *Discus ruderatus*, *Discus perspectivus*, *Arianta* sp. or *Bradybaena* sp. (small groves and forest-steppe), *Truncatellina australis*, *Pupilla triplicata* (steppe species, locally present in loess), *Granaria frumentum* (steppes, locally present in loess), *Chondrula tridens* (steppe species, locally present in loess), *Helicopsis striata* (steppe species), *Vertigo pusilla*, *Vertigo pygmea*, *Truncatellina cylindrica*, *Vallonia pulchella* (open areas), *Vallonia costata* (open areas), *Cochlicopa lubricella*, *Cochlicopa lubrica*, *Punctum pygmeum*, *Nesovitrea* sp., *Clausilia dubia*, *Sphaerium* or *Corbicula*, *Limacidae*.

Layers 7–8 (talus cone III, Cromerian I; = Complex III, Kovanda 1995a).
End of sedimentation of talus cone III. Faunal association of the interglacial climax period. Forest species represent up to 50% of all the groups (Kovanda 1995): *Discus perspectivus, Macrogastra densestriata,* cf. *Aegopis verticillus* (closed forest, leading interglacial species), *Zonitoides sepultus, Soosia diodonta* (closed forest, leading interglacial species), *Drobacia banatica, Helicigona capeki* (closed forest, leading interglacial species), *Acicula polita, Acicula diluviana, Orcula doliolum, Cochlodina laminata, Ruthenia filograna, Isognostoma isognostoma, Ena* sp., *Vertigo pusilla, Discus ruderatus, Clausilia cruciatta triplicata,* cf. *Vitrinobrachium breve, Cepaea* cf. *nemoralis, Helix pomatia* (small groves and forest-steppe, significant species of warm and humid periods), *Bradybaena fruticum* (small groves and forest-steppe), cf. *Arianta arbustorum* (small groves and forest-steppe), *Macrogastra ventricosa, Perforatella* cf. *vicina, Perforatella bidentata.* The steppe species and species of open grassed areas: *Truncatellina claustralis, Pyramidula rupestris, Pupilla triplicata* (steppe species, locally present in loess), *Granaria frumentum* (abundant, steppe, locally present in loess), *Chondrula tridens* (steppe species, locally present in loess), *Helicopsis striata* (steppe species), *Vertigo pygmaea,* T*runcatellina cylindrica, Vallonia costata* (open areas), *Vallonia pulchella* (open areas). Xerothermic species: *Cochlicopa lubricella, Euomphalia strigella, Cochlicopa lubrica, Punctum pygmaeum, Clausilia dubia, Euconulus fulvus.* Euryecnic species: *Nesovitrea* sp. Paludinal species: cf. *Zonitoides nitidus.* Inhabitants of freshwater biotopes: *Lymnaea peregra,* Unionidae, *Sphaerium* sp. or *Corbicula* sp., *Pisidium* sp. (freshwater biotopes). Not closer classifiable individuals of the family Limacidae, fragments of *Aegopinella* sp., *Perforatella* sp., *Trichia* sp.

Palaeoecology of layers 7 and 8

The ecological diversity is typical of faunal associations of peaks of warm climate. Forest species represent roughly half of all species, some evince closed forest units, and others belong to steppe species and/or those belonging to an open grassed landscape. A minor number of species are found that evidently derive from areas below Stránská Skála which were humid and near the river.

Palaeoecology of layers 9 and 10

Species typical of steppe, open landscape and forest are present. The period is climatically quite dissimilar to the preceding one, indicating climate deterioration and evidently some cooling. The layer is similar to layer 6 and represents the onset of another warm period (Kovanda 1995a).
Layers 9–10 (loess intercalation and talus cone IV, Cromerian II; = Complex IV, Kovanda 1995a). Steppe species and species on open grassed areas: *Pupilla triplicata* (steppe species, locally present in loess), *Granaria frumentum* (steppes, locally present in loess), *Helicopsis striata, Vallonia costata* (open areas), *Vallonia tenuilabris* (open areas, loess species). Euryecnic species: *Punctum pygmaeum, Clausilia dubia.* Forest species: *Vitra subrimata, Vertigo pusilla, Vitra cystallina.*

Detailed palaeoecological and palaeoclimatological reconstruction based on molluscs

Fossil molluscan analysis provided excellent information on the development of palaeoecological and palaeoclimatic conditions existing at Stránská Skála. Molluscs from fluvial layers 1 and 2 (Menapian) indicate flowing water and cold climate, later perhaps also the beginning of warming. In layer 2, besides water species, there begin to appear also terrestrial species. Steppe species and those of open grassed landscape dominate; the occurrence of a forest-steppe landscape cannot be excluded.

In the overlying layer 3 (talus cone II, Menapian) are found steppe species and those typical of open grassed landscape, as well as forest-steppe species. However, species typical of unforested terrain predominate overall. The lower part of this layer is sintered, whereas the upper half is unsintered. This marked climatic change is not reflected in the molluscan faunas in any way. During the sedimentation of the whole layer the climate was hardly cold, instead rather moderately warm (Kovanda 1995a).

The following thick layer 4 (Menapian) of aeolic loess contains a typical loess fauna. On the basis of its species pattern Kovanda (1995a) believes that it does not express an extremely cold period, as is for example known from loess of the Last Glacial.

Overlying layers 5 and 6 (beginning of talus cone III, Cromerian I)

The sinter deposition in the lower part of layer 6 can be defined as the beginning of a warm interglacial climate. The molluscan analysis shows that while the limestone summit of Stránská Skála was still covered with grass and habitated by typical mollusc species, its slopes and surrounding sites were already wooded. Only rarely do xerothermic species occur, which, after all, also corresponds with a relatively thick sinter deposition denoting a period of increased precipitation.

The species of overlying layers 7 and 8 (end of talus cone III, Cromerian I) belong to the period of interglacial climatic climax. In the faunal association forest species are represented by roughly half of all finds, but steppe species or those of an open grassed landscape are also present. Thus, two different assemblages of molluscs are found, an assemblage of a moist mixed deciduous forest, according to Ložek and Fejfar (1957) of sub-Mediterranean character, and a steppe assemblage corresponding to the limestone rock platform. Also this analysis indicates the fact that the Stránská Skála platform has always been, irrespective of cold or warm climate, covered with grass and that it was thus a place where steppe species have always lived, whereas the slopes and surroundings of Stránská Skála could at the same time have supported a quite different plant cover. There is a negligible amount of xerothermic species, paludinal species and species typical of water biotopes which derive from areas below Stránská Skála, where at that time a river flowed.

The beginning of the sedimentation of talus cone IV (layers 9 and 10, Cromerian II) is quite similar, in terms of the molluscan assemblage, to what we saw at the beginning of talus cone III (layer 6). There are again steppe species and those of an open grassed landscape which, taken as a unit, again indicate the beginning of another interglacial.

Vertebrate communities

Vertebrate communities are most important for our purpose. Here, they are divided into three independent groups:

- Organisms living exclusively at one location: frogs, insectivores, bats, reptiles, small mammals. Their occurrence in sediments corresponds principally to the biotope where they lived. On the basis of these organisms we are able to reconstruct the environment of the site relatively well.
- Organisms living in the nearby surroundings: birds. Their remains were introduced into the sediments secondarily, mostly as victims of birds of prey residing on the vertical cliffs such as owls and similar birds. These finds characterise the environment of the immediate surroundings of the site.
- Animals whose area of seasonal movement is relatively extensive: large mammals. It is possible to reconstruct the landscape remote from the site proper based on these animals. This group also includes those animals which were hunted by man. They occurred in layer 12.

Organisms living exclusively at one location

Frogs

Identified osteological material derives from earlier collections and was not classified to individual layers. It was found in a complex of sediments of Cromerian age. J. Němec (1972) identified the following species:
Family Bufonidae:
Bufo viridis (part of cranium, os parasphenoideum, vertebra sacralis, urostyl, scapula, humerus, os ilium). Most abundant species.
Bufo bufo (humeri and some ilia have been found in large numbers, also one scapula and one vertebra sacralis).This species appeared in the near surroundings much less frequently than *Bufo viridis*.
Bufo calamita (several humeri and ossa ilium). This species lived in smaller numbers than *Bufo viridis*.
Family Ranidae:
Rana temporaria (remains are very rare, only one humerus and two ossa ilium).
Rana esculenta (only several humeri).
Family: Pelobatidae:
Pelobates fuscus (only two ossa ilium).

Insectivora

The finds come from earlier investigations, they are not ranked into individual layers and derive from the entire Cromerian complex. They were processed by B. Rzebik-Kowalska (1971).
Family Erinaceidae:
Erinaceus europaeus (eleven mandible fragments, collections of Absolon and Čapek).

Chiroptera

The finds come from earlier excavations and they are unstratified. They were processed by K. Kowalski (1972).
Family Rhinolophidae:
Rhinolophus ferrumequinum (one mandible fragment).
Family Vespertilionidae:
Plecotus auritus (six mandible fragments and one skull fragment).
Myotis bechsteini (two mandible fragments and three skull fragments).
Myotis daubentoni (two mandible fragments and five skull fragments).
Myotis nattereri (sixteen mandible fragments and two skull fragments).
Eptesicus serotinus (one mandible fragment).

Reptiles

The study of the reptilian fauna indicates relatively high diversification. The finds were restricted to layers of the Cromerian interglacial, they were found solely in layers 5, 7, 8 (Cromerian I), 10, 12 (Cromerian II) and 14 (Cromerian III?). M. Ivanov (1995, 1997) identified the following species (native in the recent past): *Natrix natrix* (grass snake, 11 %), *Natrix tesselata* (7 %), *Natrix* sp. (12 %), *Elaphe longissima* (grass snake, 24 %), *Coronella* sp. (3 %), *Vipera berus* (2 %), *Coluber* sp. (few), *Lacerta* sp. (lizard, 31 %). Exotic taxa: *Coluber* cf. *viridiflavus* (7 %), *Vipera* cf. *ursinii* (few).
The above species were found in the following layers:
Layer 5 (Brunhes-Matuyama boundary): *Elaphe longissima*
Layer 7: *Natrix natrix, Natrix tesselata, Natrix* sp., *Elaphe longissima, Coluber* cf. *viridiflavus, Coronella* aff. *austriaca, Vipera berus, Lacerta* sp.
Layer 8: *Natrix natrix, Natrix tesselata, Elaphe longissima, Coluber* cf. *viridiflavus, Coluber* sp., *Vipera berus, Lacerta* sp.
The above layers belong to talus cone III.
Sinter Deposit C: *Natrix natrix, Natrix tesselata, Elaphe longissima, Coluber viridiflavus, Lacerta* sp.
Layer 9: *Natrix natrix, Natrix tesselata, Natrix* sp., *Elaphe longissima, Coluber* cf. *viridiflavus, Vipera berus, Lacerta* sp.
Layer 10: *Natrix natrix, Natrix tesselata, Natrix* sp., *Elaphe logissima, Coluber* cf. *viridiflavus, Coronella* sp., *Lacerta* sp.
Layer 12: *Natrix natrix, Natrix tesselata, Natrix* sp., *Elaphe longissima, Coluber* cf. *viridiflavus, Coronella* sp., *Vipera* cf. *ursinii, Vipera berus, Lacerta* sp.
The above layers belong to talus cone IV.
Layer 14: *Vipera ammodytes, Lacerta* sp.

Detailed reconstruction of palaeoclimate based on reptiles[9]

Snakes are only found in interglacial sediments. They are entirely absent in sediments of cold periods. Palaeoclimatic reconstruction based on snakes was made by Ivanov (1995). Talus cones III (Cromerian I) and IV (Cromerian II) differ rather in their composition.

9 Conclusions based on 13 taxa (Ivanov 1997).

Whilst in talus cone III the reptilian fauna is relatively abundant and with comparatively high diversity, in talus cone IV remains of reptiles are also abundant, but the diversity of the assemblages decreases. The fauna of talus cone III corresponds to a warmer period than the fauna of talus cone IV, which is proved by the presence of a relatively large number of para-Mediterranean remains of the species *Elaphe longissima*. This species is the most abundant taxon occurring in the rich layer 7 and it outnumbers not only all other snakes but also the representatives of the genus *Lacerta* sp. In layers of talus cone IV the number of thermophilous taxa falls and the number of psychrophylous taxa rises. *Elaphe longissima* is no longer the dominating snake taxon.

Small mammals

The small mammals mostly include voles which were found in almost all layers in high numbers. If a count is not given, then it concerns only a small number of finds. Numbers after the taxon indicate the percentage present in the layer. Only a very small fraction of them have been studied, most of them are still waiting for processing. Some of the layers were processed by several authors (Knies 1925; Ložek/Fejfar 1957; Musil 1965; Musil 1968b; Fejfar 1972; Heller 1972; Tobien 1972).

Layer 1 (talus cone I, Menapian): *Microtus* sp., *Pitimys* sp.

Layer 2 (talus cone I, on the base of the Jaramillo subchron layer, 0.99–1.07 Ma, Menapian): *Sorex* sp., *Ochotona pusilla, Citellus* sp., (19 %), *Clethrionomys glareolus, Microtus* sp., (15 %), *Pitimys* sp. (6 %), *Mimomys* sp. (6 %).

Sinter Deposit A and upper part of layer 3 (talus cone II, Menapian): *Ochotona pusilla, Lepus* sp., *Citellus* sp. (19 %), *Apodemus* sp., *Cricetus cricetus, Dicrostonyx torquatus* (1 %), *Clethrionomys glareolus, Microtus* sp. (12 %), *Pitimys* sp. (66 %), *Mimomys* sp.

Layer 4 (loess layer, Menapian): Anura, *Talpa europaea, Sorex* sp. *Chiroptera, Ochotona pusilla* (2 %), *Lepus* sp., *Citellus* sp. (22 %), *Cricetus cricetus, Dicrostonyx torquatus* (3 %), *Lagurus* sp., *Clethrionomys glareolus* (2 %), *Microtus* sp. (13 %), *Pitimys* sp. (55 %), *Mimomys* sp. (2 %).

Layer 5 (on the base of layer Brunhes-Matuyama reversal, Cromerian I): Anura, *Sorex* sp. (1 %), Chiroptera, *Ochotona pusilla* (2 %), *Lepus* sp., *Citellus* sp.(19 %), *Apodemus* sp. (1 %), *Cricetus cricetus, Clethrionomys glareolus, Microtus* sp. (18 %), *Pitimys* sp. (44 %), *Mimomys* sp. (2 %).

Sinter Deposit B, upper part of layer 6 and layers 7, 8 (talus cone III, Cromerian I): Anura (9 %), *Lacerta* sp. (6 %), *Erinaceus europaeus, Talpa europaea* (3 %), *Sorex* sp. (2 %), Chiroptera (4 %), *Ochotona pusilla, Citellus* sp. (6 %), *Apodemus* sp. (3 %), *Cricetus cricetus* (5 %), *Lagurus* sp. (1 %), *Clethrionomys glareolus* (6 %), *Microtus* sp. (9 %), *Pitimys* sp. (35 %), *Mimomys* sp. (10 %).

From those layers finds of malacofauna and small fauna are described in the paper Ložek and Fejfar (1957). In the paper the following species are mentioned: *Pitimys arvaloides, Pitimys hintoni, Microtus arvalinus, Mimomys intermedius, Pliomys episcopalis, Clethrionomys glareolus, Talpa minor, Sorex* cf. *runtonensis*.

Sinter Deposit C and layers 10, 11, 12, (talus cone IV, Cromerian II): Anura (8 %), *Lacerta* sp. (2 %), *Erinaceus europaeus* (2 %), *Talpa europaea* (1 %), *Desmana moschata* (1 %), *Sorex* sp., Chiroptera (1 %), *Ochotona pusilla, Citellus* sp. (1 %), *Glis* sp., *Apodemus* sp. (1 %), *Cricetus cricetus* (4 %), *Clethrionomys* glareolus (4 %), *Lagurus* sp. (4 %), *Microtus* sp. (15 %), *Pitimys* sp. (47 %), *Mimomys* sp. (8 %).

Palaeontological evaluation of small fauna

The small fauna is representive of Stránská Skála proper, and indicates that the area was continuously grassed. This is confirmed by some animal species which occur in all layers, although in varying numbers. These include for example *Ochotona pusilla*, a typical steppe species, which was always present in small numbers. Another such animal is *Citellus* which was always relatively numerous, mostly in layer 3 (Menapian) through to the beginning of layer 6, i.e. during the sedimentation of talus cone I (Menapian, 19 %), talus cone II (Menapian, 19 %), further in the overlying thick loess layer (layer 4, Menapian, 22 %), and in layer 5 and in the beginning of layer 6 (Cromerian I, together 19 %). Its highest count is recorded in the loess layer, layer 4. Thereafter it decreases markedly into the background in sediments of talus III (Cromerian I, 6 %) and even more in talus IV (Cromerian II, 1 %). This means that the highly arid continental climate persisted until the onset of interglacial Cromerian I and then it changed relatively quickly. It evidently became increasingly humid, which is reflected in the retreat of the grass cover at Stránská Skála.

Composition of small fauna in Sinter Deposit B, upper part of layer 6 and layers 7 and 8 (talus cone III, Cromerian I): Anura (9 %), *Lacerta* sp. (6 %), *Erinaceus europaeus, Talpa europaea* (3 %), *Sorex* sp. (2 %), Chiroptera (4 %), *Ochotona pusilla, Citellus* sp. (6 %), *Apodemus* sp. (3 %), *Cricetus cricetus* (5 %), *Lagurus* sp. (1 %), *Clethrionomys glareolus* (6 %), *Microtus* sp. (9 %), *Pitimys* sp. (35 %), *Mimomys* sp. (10 %).

The finds of malacofauna and small fauna from layers of Sinter Deposit B, upper part of layer 6 and layers 7 and 8 (talus cone III, Cromerian I) have also been studied by Ložek and Fejfar (1957). In the paper the following species are described: *Pitimys* arvaloides, *Pitomys hintoni, Microtus arvalinus, Mimomys intermedius, Pliomys episcopalis, Clethrionomys glareolus, Talpa minor, Sorex* cf. *runtonensis.*

Finds of lemmings in layers 3 and 4 indicate a colder climate than that of the overlying layers.

Also finds of the genera *Microtus* and *Pitimys* (the most abundant genus) are found in great numbers in almost all layers.

From this it is clear that the most important species for our conclusions is the genus *Ochotona* and above all *Citellus*. A marked boundary at the base of layer 6 divides the period into two parts: a highly arid and at the beginning even colder continental climate is reflected by the increase in grassed areas at Stránská Skála and persisted until the beginning of the sedimentation of layer 6. It reached the highest intensity during the sedimentation of the thick layer of loess (Layer 4). From the base of layer 6 there was a change, the climate became increasingly humid, and consequently the grass cover retreated, even though it was still preserved in small areas. This climatic change is thus reflected in the reduction of the number of finds of steppe species. This climate continues until at least the end of the sedimentation of talus cone IV (Cromerian II), which shows even more intense precipitation than the preceding period.

Organisms living in the nearby surroundings

Birds

The only group of vertebrates found which belong in this class are birds (Jánossy 1972; Mlíkovský 1995). A large proportion of avian species from this site occur in the western palaearctic. The birds' range of activity is relatively large and they are a source of environmental information from the local surroundings of the site. Numbers of autopodial, stylopodial and zeugopodial bones are distributed rather evenly, which according to Mlíkovský (1995), suggests that owls were not accumulators of the taphocenosis. Wing bones are present in much higher numbers than leg bones. This indicates that a significant proportion of the bones were accumulated by some rather large raptor (probably *Falco peregrinus*). A small proportion could have been accumulated by smaller carnivores, such as wolf. In a few cases they represent probably remains of birds nesting in the perpendicular rocks (*Falco peregrinus, Falco tinnunculus, Apus apus, Corvus monedula, Hirundo rustica, Delichon urbica*), according to Mlíkovský (1995) approximately 2% of MNI.

The finds of bird bones differ of course, in terms of quantity, in the individual layers. Generally, they are very numerous, with about 1600 pieces, belonging to 23 families, 51 genera and 68 species. One extinct genus and seven extinct species were identified (*Mergus connectens, Plioperdix ponticus, Plioperdix capeki, Plioperdix subfrancolinus, Gallinula gigantea, Corvus pliocaenicus, Corvus moravicus*). With regard to the avian finds, this is quantitatively the richest site from the studied period in Central Europe, not only in terms of the number of pieces found, but also in the number of climatically different periods of finds in superposition at any one site. All finds were identified by Mlíkovský (1995).

The list of birds in the individual layers and the reconstruction of the environment

Finds of birds begin in the lowest layers and the number of species progressively increases. The reconstruction of the environment was not made by analysing the environmental requirements of the various species, but only the requirements they have for building their nests. In my opinion this method better explains the given environment.

Layer 1 (Menapian, fluvial sediments): No avian finds.

Layer 2 (Menapian, fluvial sediments, on the base of Jaramillo subchron, (0.99–1.07 Ma): *Pluvialis squatarola, Limosa* sp., *Apus apus, Motacilla* sp., *Corvus monedula*. Analysis of nesting habits: swamps, grassed areas, rock recesses.

Layer 3 (talus cone II, Menapian): *Anas querquedula, Anas strepera, Anas clypeata, Falco tinnunculus, Falco peregrinus, Tetrao tetrix, Coturnix coturnix, Fulica atra, Vanellus vanellus, Philomachus pugnax, Gallinago gallinago, Scolopax rusticola, Tringa* sp., *Apus apus, Corvus moravicus, Corvus monedula.*

Analysis of nesting habits: rock recesses, swamps and swampy meadows, open steppe landscape, deciduous forests. Most species seek swampy meadows or swamps for nest building, others nest in rock niches, only sporadically.

Layer 4 (Menapian, except for thick loess layer): *Anas strepera, Anas querquedula, Anas clypeata, Falco tinnunculus, Falco subbuteo, Tetrao tetrix, Perdix perdix, Fulica atra,* *Himantopus himantopus, Pluvialis squatarola, Vanellus vanellus, Philomachus pugnax, Gallinago gallinago, Gallinago media, Scolopax rusticola, Limosa* sp., *Numenius phaeopus, Tringa* sp., *Larus canus, Athene noctua, Garrulus glandarius, Corvus* cf. *corone.*

Analysis of nesting habits: It might be assumed, that aeolian loess would mostly affect birds building their nests in an open steppe landscape. However, this is not the case. Most species still looked for swampy meadows and swamps, which means that the valley below Stránská Skála changed little from the preceding period. Some species built their nests in trees or in their cavities, others in rock recesses and there was even one which requires a deciduous forest. The picture of the flood plain is thus somewhat different than might be judged simply from the wind-blown loess.

Layer 5 (Cromerian I, at the base of the Brunhes-Matuyama reversal): *Anas strepera, Anas querquedula, Anas clypeata, Falco tinnunculus, Falco subbuteo, Tetrao tetrix, Perdix perdix, Coturnix coturnix, Plioperdix ponticus, Charadrius* sp., *Vanellus vanellus, Philomachus pugnax, Gallinago gallinago, Gallinago media, Scolopax rusticola, Limosa* sp., *Numenius phaeopus, Tringa* sp., *Cuculus canorus, Apus apus, Dolichon urbica, Anthus* sp.

Analysis of nesting habits: There was a change. Although species nesting in swampy meadows are relatively abundant, roughly the same number of birds appear to be nesting in either open or park landscape or in rock recesses.

Sinter Deposit B (layer 6, talus cone III, Cromerian I): *Anas clypeata, Tetrao tetrix, Vanellus vanellus, Calidris* sp., *Lymnocryptes minimus.*

Analysis of nesting habits: Moist and swampy meadow habitats are typical, the find of *Tetrao tetrix,* which requires a steppe landscape and if possible also deciduous woodland, is rather an exception.

Layer 6 (upper part, talus cone III, Cromerian I): *Anas strepera, Anas querquedula, Anas clypeata, Falco peregrinus, Bonasa bonasia, Tetrao tetrix, Coturnix coturnix, Plioperdix ponticus, Ralus aquaticus, Crex crex, Pluvialis squatarola, Vanellus vanellus, Philomachus pugnax, Scolopax rusticola, Limosa* sp., *Numenius phaeopus, Tringa* sp., *Riparia riparia, Delichon urbica, Nucifraga caryocatactes, Corvus monedula, Pica pica.*

Analysis of nesting habits: Species restricted to nest building in swampy meadows to swamps persist. Further, there appear a number of birds building their nests in trees, in coniferous or deciduous forests, in meadows, in the open landscape and in rock recesses. One specie occurred which builds its nests on sands or gravels on riverbanks.

Layer 7 (talus cone III, Cromerian I): *Anas querquedula, Anas clypeata, Bonasa bonasia, Coturnix coturnix, Tringa* sp., *Anthus* sp., *Hirundo rustica, Delichon urbica, Corvus monedula, Coccothraustes coccothraustes.*

Analysis of nesting habits: Mainly species building their nests in an open landscape and in rock recesses. For the first time there was a large drop in birds building their nests in humid meadows or swamps.

Layer 8 (end of talus cone III, end of the Cromerian I): *Anas querquedula, Anas clypeata, Tetrao tetrix, Coturnix coturnix, Plioperdix subfrancolinus, Gallinula gigantea, Fulica atra, Vanellus vanellus, Scolopax rusticola, Limosa* sp.

Analysis of nesting habits: All biotopes mentioned above are represented in roughly equal numbers. None dominates.

Layer 9 (loess layer): *Anas querquedula, Anas clypeata, Bucephala clangula, Falco peregrinus, Tetrao urogallus, Tetrao tetrix, Coturnix coturnix, Plioperdix ponticus, Crex crex,* *Gallinula gigantea, Vanellus vanellus, Philomachus pugnax, Scolopax rusticola, Limosa* sp., *Numenius phaeopus, Pica pica.*

Analysis of nesting habits: There was no essential change. In the flood plain there are still swampy meadows, in the surroundings there are meadows, coniferous and deciduous trees and open grassed areas.

Layer 10 and 11: (beginning of talus cones IV, beginning of the Cromerian II): *Anas querquedula, Anas clypeata.*

Layer 12 (end of the talus cones IV, end of the Cromerian II): *Podiceps griseigena, Anser* sp., *Anser strepera, Anas querquedula, Anas clypeata, Bucephala clangula, Mergus serrator, Mergus connectens, Accipiter nisus, Falco tinnunculus, Falco subbuteo, Falco peregrinus, Bonasa bonasia, Tetrao urogallus, Tetrao tetrix, Coturnix coturnix, Plioperdix ponticus, Plioperdix capeki, Plioperdix subfrancolinus, Crex crex, Gallinula gigantea, Fulica atra, Tetrax tetrax, Charadrius* sp, *Pluvialis squatarola, Vanellus vanellus, Gallinago gallinago, Gallinago media, Scolopax rusticola, Limosa* sp., *Numenius phaeopus, Tringa* sp., *Athene noctua, Apus apus, Picus canus, Dendrocopus major, Hirundo rustica, Dolichon urbica, Anthus* sp., *Turdus* sp., *Garrulus glandarius, Pica pica, Nucifraga caryocatactes, Corvus pliocaenus, Corvus* cf. *corone, Corvus moravicus, Corvus monedula.*

Analysis of nesting habits: The layer richest in bird bones, here were evidently optimal living conditions. For the first time species prevail that require deciduous or coniferous trees, and/or open landscape with bushes and isolated trees for their nests. Also rock recesses are abundantly populated. In the valley there are still swampy meadows or swamps, and/or moist meadows. Some species occurred that require stagnant water with dense vegetation cover near the bank, others sandy to gravelly sediments. This all suggests a landscape rich in water.

Layers 13, 14, 15 (layers of loess; 13, 15) and interglacial soil (14, Cromerian III?) disturbed by cryoturbation): *Anas strepera, Anas querquedula, Anas clypeata, Falco subbuteo, Falco peregrinus, Tetrao tetrix, Coturnix coturnix, Lymnocryptes minimus, Gallinago gallinago, Gallinago media, Tringa* sp., *Dolichon urbica.*

Analysis of nesting habits: Species that prevail build their nests in humid to swampy meadows whilst fewer species live near deciduous trees, in open landscapes or rock recesses.

Layer 16 (a soliflucted interglacial soil from a very cold climate): *Anas strepera, Anas querquedula, Anas clypeata, Bucephala clangula, Mergus serrator, Mergus merganser, Falco tinnunculus, Tetrao tetrix, Coturnix coturnix, Porzana* sp., *Fulica atra, Lymnocryptes minimus, Gallinago media, Scolopax rusticola, Numenius phaeopus, Columba palumbus, Athene noctua.*

Analysis of nesting habits: Most species require humid to swampy meadows. As well as the river valley proper there is park landscape ranging from deciduous to coniferous trees to small groves.

Layer 17 (Last Glacial): *Anas strepera, Anas clypeata, Anas querquedula, Falco tinnunculus, Coturnix coturnix, Plioperdix subfrancolinus.*

Detailed palaeoecological reconstruction based on birds[10]

A large proportion of the species from this site occur in the western palaearctic. The birds' range of activity is relatively large and they are a source of environmental information from the local surroundings of the site.

In terms of the bird finds, this is quantitatively the richest site studied of this period in Central Europe, not only in terms of the number of pieces found, but also in the number of climatically different periods of the finds in superposition at any one site. The bird bones are very numerous: about 1600 pieces, belonging to 23 families, 51 genera and 68 species. One extinct genus and seven extinct species were identified.

For the entire duration of sedimentation of all the talus cones and thick loess deposits (Menapian, Cromerian I, II and III?), in the flood plain below Stránská Skála there were swampy meadows to swamps, in places also deserted river arms with stagnant water. The riverbanks were lined with bushes and trees. In the wider surroundings there was a landscape of park character, open areas interchanging with small groves. It is clear that at times even continuous forest stands existed, and at other times a more open landscape. Another group of birds occurring throughout the period were those nesting in rock recesses or in tree cavities.

The associations of the individual layers do not change much in terms of species, they are more or less stable. But what changes, sometimes substantially, is the number of species requiring a different environment for building their nests.

The least number of species occurs in layer 1 (no species) and in layer 2 (five species). It is not known whether this was affected by the nature of the sediments (fluvial sediments) and thus the bird bone preservation or whether at this time fewer birds nested at Stránská Skála. However, the former possibility is more probable, because at the time of the heavy deposition of wind-blown loess the number of birds was already relatively high.

Layer 3 (Menapian, 16 species), layer 4 (Menapian, 22 species) and layer 5 (Cromerian I, 21 species) are climatically quite different, but correspond to one another from the species they contained. Sedimentation of the aeolian loess layer (layer 4) marks the onset in the number of species. This means that this climate did not affect the composition of the bird community. A change occurs only with the formation of sinter deposit B (lower part of layer 6, Cromerian I) in which the number of species drops conspicuously (five species). In terms of the birds' existence the climate must have been relatively adverse, but not cold, because in loess layer 4 there were many finds. It may have been connected with intense precipitation (sinter deposition!), because already in the upper part of the same talus cone (6) there is a substantial increase in the number of bird species (21 species).

Oscillations in the counts, however, recur again: layer 7 few species (six), layer 8 (loess intercalation!) and layer 9 many species (14 and 16 respectively), layer 10 only very few species (two, again sinter deposition!).

The highest number of species is found in layer 12 (Cromerian II, 48 species!), which constitutes the end of talus cone IV. All other layers were already disturbed by solifluction, so that the numbers of species may be incorrect. Worth mentioning is the solifluction of the sediments in layer 16, which is also relatively rich in birds (23 species).

---

10 Conclusions based on 118 taxa (Mlíkovský 1995).

It thus follows that the number and the diversity of bird species nesting at Stránská Skála or in its immediate vicinity was not affected by colder or warmer climate, but rather by extremely high precipitation. A great majority of bird species nested on humid meadows and swamps in the flood plain below Stránská Skála but an enormous increase in precipitation, which resulted in the formation of sinter depositions in the talus cones, evidently resulted in periodic inundation of the flood plain, making nesting impossible.

The number of species in layer 16 indicates a very close relation to layer 12, so that is seems probable that they are contemporaneous. It was not the climax stage in talus cone III (Cromerian I), but the Cromerian II (layer 12) that was optimal for birds.

According to Mlíkovský (1995), the absence of *Lagopus* and *Pyrrhocorax,* which are characteristic members of avian glacial taphocenosis since the Early Pleistocene, indicates that the bones were accumulated during a relatively warm interglacial period, not during the periglacial or even the glacial. This is supported also by the abundance of *Tetrao tetrix* and presence of such species as *Tetrax tetrax.*

The majority of the species found were closely connected with open marshes and smaller areas of water. Only 9 % of MNI required dry ground (*Perdix, Coturnix, Plioperdix, Tetrax*) and only about 6 % of MNI needed trees or shrubs (*Columba, Cuculus, Picus, Dendrocopus, Turdus* and most Corvidae). Species requiring extensive bodies of water are almost absent (<1 % of MNI, *Mergus*) (Mlíkovský 1995). This environmental analysis is quite different from that based on molluscs and again shows how important it is to base a study on a range of animal groups. It confirms that while Stránská Skála was always grassed, below it a river flowed in an alluvial flood plain with swamps and abandoned river arms filled with stagnant water. The environment of Stránská Skála proper and the nearest surroundings (the flood plain) were thus very different.

Animals with an extensive range

Large mammals

Large fauna derives mainly from sediments of the Cromerian complex (Woldřich 1916; Woldřich 1917; Jaroš 1926; Schirmeisen 1926; Stehlík 1934; Musil 1967; Musil 1968; Musil 1982; Musil 1995; Flerow/Reshetov 1972; Kahlke 1972; Kahlke 1995; Kurtén 1972; Thenius 1972). Although bones are found in different numbers in all layers, their highest concentration is in layer 12 (Cromerian II). To some extent this is connected with the human activity in the cave, situated above the exposure, which was then inhabited. In sediments of layer 12 stone tools, pieces of charcoal and evidently also bones of hunted animals (Musil 1969; Musil 1995a) were found. It appears that the soliflucted layer 16, whose original position was in the cave entrance, belongs to the same period.

Large mammals are capable of covering long distances. Not just through seasonal migration, but also by movements over shorter periods of time. Unlike the preceding groups this group can reconstruct the environmental picture of relatively distant regions.

Layer 2 (Menapian): *Bos* sp.or *Bison* sp. (very small form).

Layer 3 (Menapian): *Bos* sp. or *Bison* sp., *Cervus* sp.

Layer 4 (Menapian): *Bos* sp. or *Bison* sp. (very large form), cf. *Bison schoentensacki, Vulpes* sp., *Martes* sp., *Mustela* sp., *Cervus* sp., *Alces* sp. (?).

Layer 5 (Cromerian I): *Bos* sp. or *Bison* sp., *Cervus* sp. (*Cervus acoronatus/Cervus elaphus,* larger than red deer), *Cervus* sp. (similar to red deer).

Sinter Deposit B, upper part of layer 6 and layers 7, 8, (talus cone III, Cromerian I): Pisces (8 %), *Lacerta* sp. (6 %), *Erinaceus* sp., *Talpa* sp. (3 %), *Castor fiber, Canis mosbachensis* (2 %), *Martes* sp., *Mustela* sp. (both 5 %), *Ursus deningeri* (2 %), *Sus scrofa* (2 %), *Cervus* sp. (73 %), *Capreolus* sp. (5 %), *Bos* sp. or *Bison* sp. (3 %).

Layer 6 (Cromerian I): *Bos* sp. or *Bison* sp., *Cervus* sp. (*Cervus acoronatus/Cervus elaphus,* larger than red deer), *Capreolus* cf. *suessenbornensis, Cervidae* gen. et sp. indet.

Layer 7 (Cromerian I): *Cervus* sp. (*Cervus acoronatus/Cervus elaphus,* smaller than red deer), *Cervus* sp. (similar to red deer), *Cervidae* gen. et sp. indet., *Panthera pardus, Capreolus* cf. *suessenbornensis,* »*Cervus*« cf. *elaphoides.*

Layer 8 (Cromerian I): *Capreolus* cf. *suessenbornensis, Praemegaceros* cf. *verticornis.*

Layer 9 (loess intercalation): *Ursus deningeri, Cervus* sp. (larger than red deer), *Cervus* sp. (*Cervus acoronatus/Cervus elaphus,* similar to red deer), *Capreolus* sp., *Capreolus* cf. *suessenbornensis.*

Sinter Deposit C (Cromerian II): *Bos* sp.or *Bison* sp., *Cervus* sp. (*Cervus acoronatus/Cervus elaphus,* larger than red deer), *Cervus* sp. (smaller than red deer), *Cervus* sp. (similar to red deer), *Cervidae* gen. et sp. indet., *Lepus* sp., *Castor fiber.*

Layer 10 (Cromerian II): *Ursus deningeri, Cervus* sp. (*Cervus acoronatus/Cervus elaphus,* as the red deer).

Sinter Deposit C, layers 10, 11 and 12, (talus cone IV): Pisces (1 %), *Felis* sp. (1 %), *Homotherium moravicum, Hyaena* sp., *Canis mosbachensis* (6 %), *Vulpes* sp. (1 %), *Martes* sp., *Mustela* sp. (both 27 %), *Meles meles* (1 %), *Ursus deningeri* (9 %), *Dicerorhinus* sp., *Equus suessenbornensis* (3 %), *Sus scrofa, Cervus* sp. (37 %), *Capreolus suessenbornensis* (3 %), *Alces* sp.(?; 3 %), *Bos* sp. or *Bison* sp. (5 %).

Layer 12 (Cromerian II): *Castor fiber, Hyaena brevirostris, Crocuta crocuta,* Xenocyon *spelaeoides, Vulpes cf. praeglacialis, Vulpes cf. angustidens, Vulpes* sp., *Ursus deningeri* (the highest number of finds), *Equus suessenbornensis* (the highest number of finds), *Bison priscus mediator, Bison* sp. (middle large animal). The highest number of bovid finds: *Ovibos* sp., *Cervus* sp. (middle large animal), *Cervus* sp. (smaller than red deer), *Cervus* sp. (*Cervus acoronatus/Cervus elaphus,* similar to red deer), *Alces* sp., *Capreolus* sp., Cervidae gen. et sp. indet., Praemageceros sp. (verticornis deer).

Layer 13, 14 and 15: *Mustela* sp., *Ursus deningeri, Equus suessenbornensis, Bos primigenius, Bison priscus* (medium sized), *Cervus* sp. (*Cervus acoronatus/Cervus elaphus*).

Layer 16: *Homotherium moravicum, Canis mosbachensis, Cervus* sp. (*Cervus acoronatus/Cervus elaphus,* larger than red deer), *Alces* sp., Cervidae gen. et sp. indet.

Layer 17 (Last Glacial): *Castor fiber.*

Palaeoecological evaluation of finds of large animals[11]

Irrespective of the persisting climate at the time of their sedimentation only finds of two families are found in the majority of layers: Bovidae and Cervidae. The majority of all the other species are found prevailingly in layer 12 (Cromerian II) with isolated occurrences

11 Conclusions based on 40 taxa (Musil 1995).

in some other layers. Finds with exact stratification are relatively few, although their distribution in the layers is significant. In no case are they concentrated in warm or colder periods. The animals lived here throughout the sedimentation of the Cromerian complex, without reacting to the ever changing climate. It may have been due to the fact that these climatic changes were not so great as to affect their presence.

Another conspicuous fact is their great accumulation in one layer (layer 12). This is so exceptional that even if no artifacts or pieces of charcoal from fireplaces had been found, one would be lead to the conclusion that their accumulation was mainly due to human activity. The vast majority are remains of hunted animals.

Let us draw our attention to this great bone concentration. As the site of their original deposition only the cave situated above the exposure comes into consideration. The first possibility offered is that the cave might have served as a den, in to which predatory animals dragged their prey. Then individual bones entered the talus cone which was being formed below the cave. Some bones do bear tooth marks from beasts of prey, but these are relatively small in number.

Another possibility is that the hunters inhabited this cave. Some artifacts have been found in the talus cone. Therefore, it cannot be excluded that the higher lying cave was for some time also inhabited by man and the bones found in layer 12 got there from the cave entrance. Thus the bones could be derived from animals hunted by hominids. In my opinion, this hypothesis seems to be the most acceptable.

This conception also corresponds to the species composition. Twenty per cent of bones in layer 12 belong to beasts of prey, eighty per cent to herbivores. As far as individual families are concerned, their quantitative share is as follows:

Herbivores:		Carnivores:	
Cervidae	54 %	Ursidae	63 %
Bovidae	29 %	Canidae	24 %
Equidae	16 %	Hyaenidae	10 %
Castoridae	1 %	Felidae	3 %

This composition is typical of anthropogenic assemblages. Amongst the beasts of prey it is necessary to consider the large proportion of bears, as it is difficult to decide whether this is due to hunting or the reason is to be found in the cave.

Further Schirmeisen reported a great number of finds of large mammals from the fill above the Holocene, approximately in the area of our excavations (layer 23). These sediments of different coloured soils and containing the osteological material came from the place of the cave mentioned. The bones belonged to the following species (Schirmeisen 1926): *Mammuthus trogontherii, Dicerorhinus etruscus, Equus* aff. *suessenbornensis,* small bison (most abundant), *Praeovibos priscus, Capreolus capreolus* (evidently *C. suessenbornensis*), *Cervus elaphus* (of maral size, evidently another species), *Alces latifrons, Sus scrofa, Lepus* cf. *medius* (many finds, evidently the genus *Hypolagus*), *Trogontherium cuvieri, Ursus priscus* (evidently *U. deningeri*), *Hyaena robusta, Canis mosbachensis,* *Canis lupus* (probably the genus *Xenocyon*), *Vulpes vulpes* (obviously another species), *Meles* cf. *atavus*, *Panthera leo* (smaller than modern lion, probably *P. gombaszögensis*), *Felis catus atava*, *Lynx lynx*, *Panthera pardus*, *Homotherium moravicum*. Considering the small size of the cave and its entrance, this is a strikingly large material rich in species.

I find it extremely likely that there is a parallel with the finds in layer 12 and that both are remains of hunted game.

Flora and fauna finds list

In earlier times great attention was paid only to finds of mammals and birds, the other groups were more or less neglected. In those investigations no attention was paid to detailed stratigraphy, all finds were considered as one unit coming from one single interglacial, which is now included in the complex of Cromerian interglacials. Only the investigation of the talus cones between 1964 and 1972 differentiated the finds according to the individual layers of the Cromerian complex. Unfortunately, finds of mammals in the excavated areas were not as numerous as in earlier investigations. That is why I considered it necessary to list all mammal finds from all investigations in this chapter, to understand which species were found in the above mentioned, mostly interglacial, sediment complexes at Stránská Skála.

In this list there are thus finds of all investigations, as far as they originated from the talus cones (open-air sediments). It can be confirmed that all investigations and finds from there were carried out roughly in the same area as those of 1964–1972. The finds are ranked (besides flora) systematically and all come from sediments described in chap. 3.

The list of flora and fauna shows convincingly the exceptional position of Stránská Skála in terms of the wealth of finds. In my opinion it is a unique site unparalleled in Central Europe.

Systematic list of finds

Flora

AP Taxaceae: *Taxus* sp.
AP Pinaceae: *Abies* sp., *Picea* sp., *Pinus* sp.
AP Ulmaceae: *Ulmus* sp., *Celtis* sp.
AP Betulaceae: *Alnus* sp., *Betula* sp., *Carpinus* sp., *Corylus* sp., *Fagus* sp., *Quercus* sp.
AP Tiliaceae: *Tilia* sp.
AP Salicaceae: *Salix* sp.
AP Ericaceae: *Calluna* sp.
AP Araliaceae: *Hedera* sp.
AP Oleaceae: *Fraxinus* sp.
AP Juglandaceae: *Carya* sp.
AP Elaeagnaceae: Hippophaë
AP Sciadopithyaceae: *Sciadopithys* sp.
NAP Algae
NAP Desmidiaceae
NAP Pteridophyta

NAP Equisetaceae: *Equisetum* sp.
NAP Polypodiaceae: t. *Dryopteris, Pteridium aquilinum*
NAP Bryophyta
NAP *Bryales* sp.
NAP *Sphagnum* sp.
NAP Nymphaeaceae: *Nuphar* sp.
NAP Silenaceae
NAP Rosaceae: *Filipendula* sp., *Potentilla* sp., *Sanquisorba* sp.
NAP Viciaceae
NAP Daucaceae
NAP Cyperaceae
NAP Gentianellaceae: *Gentianella* sp.
NAP Brassicaceae: t. *Barbarea* sp., t. *Cardamine* sp.
NAP Chenopodiaceae
NAP Cistaceae: *Helianthemum* sp.
NAP Asteraceae: *Artemisia* sp., t. *Achillea* sp., t. *Carduus* sp., t. *Cirsium* sp., *Centaurea jacea*
NAP Asteraceae Liguliflorae
NAP Asteraceae Tubiflorae
NAP Poaceae: t. *Phragmites* sp.
NAP Rubiaceae: *Galium* sp.

Fauna

Annelida
Lumbricidae: *Lumbricus* sp. (coprogenic elements)
Acarina
Elements of mites (Acari), particularly of the Oribatei
Ostracoda: a great number of conches from fluvial sediments, unprocessed.
Gastropoda
Valvatidae: *Valvata piscinalis*
Sphaeriidae: *Pisidum amnicum, Pisidum* sp.
Acmidae: *Acicula polita, Acicula diluviana*
Lymnaeidae: *Lymnaea peregra, Lymnaea truncatula, Lymnaea ovata, Lymnaea* cf. *palustris*
Planorbidae: *Anisus leucostomus, Planorbis planorbis*
Succineidae: *Succinea oblong, Succinea* cf. *putris*
Cochlicopidae: *Cochlicopa lubrica, Cochlicopa lubricella*
Pupillidae: *Vertigo* sp., *Vertigo pygmaea, Vertigo pusilla, Truncatellina claustralis, Truncatellina cylindrica, Orcula doliolum, Pupilla triplicata, Pupilla sterri, Pupilla muscorum, Pupilla muscorum densegyrata, Pupilla* sp., *Granaria frumentum, Columella columella*
Valloniidae: *Vallonia tenuilabris, Vallonia costata, Vallonia pulchella, Vallonia* sp., *Pyramidula rupestris*
Enidae: *Ena* sp., *Chondrula tridens*
Clausiliidae: *Cochlodina laminata, Ruthenica filograna, Clausilia cruciata triplicata, Clausila dubia, Macrogastra ventricosa, Macrogastra densestriata*
Endodontidae: *Punctum pygmaeum, Discus perspectivus, Discus ruderatus*

Zonitidae: *Vitrea crystallina, Vitrea subrimata, Nesovitrea* sp., *Nesovitrea hammonis, Zonitoides sepultus,* cf. *Zonitoides nitidus,* cf. *Aegopis verticillus, Euconulus fulvus, Aegopinella* sp.
Vitrinidae: *Semilimax kotulae,* cf. *Vitrinobatrachum breve*
Limacidae div.
Helicidae: *Helicigona capeki, Drobacia banatica, Cepaea* cf. *nemoralis, Helix pomatia, Arianta arbustorum, Arianta* sp. or *Bradybaena* sp., *Bradybaena fruticum, Isognomostoma isognomostoma, Perforatella* cf. *vicina, Perforatella bidentata, Peforatella vicina* or *incarnata, Helicopsis striata, Euomphalia strigella*
Spaeriidae: *Sphaerium* sp. or *Corbicula* sp., *Pisidium* sp.
Elonidae: *Soosia diodonta*
Hygromiidae: *Trichia sericea x plebeia, Trichia* cf. *plebeia, Trichia* sp., *Trichia* cf. *hispida*
Bivalvia
Unionidae
Pisces: indeterminable genus and species
Amphibia
Bufonidae: *Bufo viridis, Bufo bufo, Bufo calamita*
Ranidae: *Rana temporaria, Rana esculenta*
Pelobatidae: *Pelobates fuscus*
Reptilia
Colubridae: *Natrix natrix, Natrix* sp., *Natrix* cf. *tesselata, Natrix* aff. *tesselata, Elaphe longissima, Coluber* sp., *Coluber* cf. *viridiflavus, Coluber* sp., *Coronella* aff. *Austriaca*(?), *Vipera* cf. *ammodytes, Vipera* cf. *ursinii, Vipera* sp.
Lacertidae: *Lacerta* sp.
Aves
Podicipedidae: *Podiceps griseigena, Podiceps cristatus*
Anatidae: *Anser* sp., *Anser fabalis, Anser erythropus, Anas strepera, Anas querquedula, Anas clypeata, Anas platyrhyncha, Mareca penelope, Dafila acuta, Nettion crecca, Aythia marila, Aythia ferina, Aythia nyroca, Aythia fuligula, Bucephala clangula, Mergus serrator, Mergus merganser, Mergus connectens, Mergus albellus, Branta bernicla*
Accipitridae: *Accipiter nisus, Pernis apivorus, Circaëtus gallicus*
Falconidae: *Falco tinnunculus, Falco subbuteo, Falco peregrinus, Erythropus vespertinus*
Tetraonidae: *Bonasa bonasia, Tetrao urogallus, Tetrao tetrix*
Phasianidae: *Perdix perdix, Coturnix coturnix, Plioperdix ponticus, Plioperdix capeki, Plioperdix subfrancolinus*
Rallidae: *Rallus aquaticus, Porzana* sp., *Crex crex, Gallinula gigantea, Fulica atra*
Otididae: *Tetrax tetrax*
Recurvirostridae: *Himantopus himantopus*
Charadriidae: *Charadrius* sp., *Pluvialis* cf. *squatarola, Vanellus vanellus, Charadrius morinellus*
Scolopacidae: *Calidris* sp., *Philomachus pugnax, Lymnocryptes minimus, Gallinago gallinago, Gallinago media, Scolopax rusticola, Limosa* limosa., *Numenius phaeopus, Tringa ochropus, Tringa totanus, Tringa nebularia*
Laridae: *Larus canus, Sterna hirundo, Chlidonias nigra*
Columbidae: *Columba palumbus*

Cuculidae: *Cuculus canorus*
Strigidae: *Athene noctua, Strix aluco, Asio flammeus, Surnia ulula, Otus scops, Aegolius* sp., *Nyctea* sp.
Caprimulgidae: *Caprimulgus europaeus*
Apodidae: *Apus apus*
Picidae: *Picus canus, Dendrocopos major*
Hirundinidae: *Riparia riparia, Hirundo rustica, Delichon urbica*
Motacillidae: *Anthus* sp., *Motacilla alba*
Turdidae: *Turdus* sp., *Turdus viscivorus, Turdus pilaris, Merula merula, Luscinia svecica, Saxicola rubetra, Prunella collaris*
Paridae: *Parus coeruleus, Parus major, Parus palustris*
Sittidae: *Sitta caesia, Sitta europaea*
Sylviidae: *Acrocephalus* sp., *Phylloscopus collybita, Philloscopus trochylus, Locustella naevia*
Sturnidae: *Sturnus vulagris*
Fringillidae: *Coccothraustes coccothraustes, Carduelis carduelis, Loxia curvirostra, Fringilla montifringilla, Emberiza* sp., *Emberiza citrinella, Emberiza calandra, Pyrrhula pyrrhula*
Alaudidae: *Alauda* sp., *Alauda arnensis, Galerida cristata*
Corvidae: *Garrulus glandarius, Pica pica, Nucifraga caryocatactes, Corvus pliocenus, Corvus* cf. *corone, Corvus moravicus, Corvus monedula, Corvus corax, Pyrrhocorax pyrrhocorax, Garrulus glandarius*
Insectivora
Erinaceidae: *Erinaceus europaeus*
Talpidae: *Talpa europaea, Talpa minor, Desmana moschata*
Soricidae: *Sorex minutus, Sorex araneuus, Sorex runtonensis, Beremendia fissidens, Crocidura* sp.
Chiroptera
Rhinolophidae: *Rhinolophus ferrumequinum*
Vespertilionidae: *Plecotus auritus, Myotis bechsteini, Myotis nattereri, Myotis daubentoni, Eptesicus serotinus*
Carnivora
Canidae: *Canis mosbachensis, Xenocyon spelaeoides, Nyctereutes* cf. *petényii, Vulpes* cf. *praeglacialis, Vulpes* cf. *angustidens, Cuon* sp. (?)
Ursidae: *Ursus deningeri*
Mustelidae: *Mustela* sp., *Martes* sp., *Putorius putorius, Gulo* sp.
Hyaenidae: *Hyaena brevirostris, Crocuta crocuta*
Felidae: *Homotherium moravicum, Panthera leo spelaea, Pamthera leo* subsp. indet., *Panthera pardus* subsp. indet., *Lynx lynx, Felis* sp., *Felis* cf. *silvestris*
Proboscidea
Elephantidae: *Mammuthus trogontherii*
Perissodactyla
Equidae: *Equus suessenbornensis*
Rhinocerotidae: *Dicerorhinus etruscus, Coelodonta antiquitatis* (from the Last Glacial)
Artiodactyla
Suidae: *Sus scrofa priscus*

Cervidae: *Alces latifrons, Alces alces, Rangifer* sp. (Last Glacial), *Cervus elaphus* (Last Glacial), *Praemegaceros* cf. *verticornis, Praemegaceros* sp., *Megaloceros giganteus germanicus* (Last Glacial), *Cervus* sp. (*Cervus acoronatus/Cervus elaphus*), »*Cervus*« cf. *elaphoides, Capreolus* cf. *suessenbornensis*
Bovidae: *Bison* cf. *schoetensacki, Bison priscus, Bos primigenius, Ovibos* sp.
Rodentia
Sciuridae: *Citellus* sp. (in size of *Citellus fulvus* or *Citellus undulatus*), *Citellus* cf. *citelloides, Citellus* cf. *primigenius, Marmota* sp.
Castoridae: *Castor fiber, Trogontherium cuvieri*
Dipodidae: *Allactaga jaculus*
Cricetidae: *Cricetus cricetus, Cricetus cricetus major, Cricetus cricetus* cf. *praeglacialis, Allocricetus bursae*
Arvicolidae: *Arvicola terrestris, Microtus gregalis, Microtus arvalinus, Microtus* ex gr. *oeconomus, Allophaiomys* sp., *Dicrostonyx torquatus, Lagurus* (*Prolagurus*) *lagurus, Mimomys savini, Mimomys* cf. *polonicus, Mimomys pusillus, Mimomys intermedius, Pliomys lenki, Pliomys episcopalis, Clethrionomys glareoluus, Myodes* cf. *glareolus, Pitimys hintoni, Pitimys arvaloides, Pitimys gregaloides, Lagurus pannonicus, Glis glis.*
Muridae: Mus sp., *Apodemus* sp.
Lagomorpha
Ochotonidae: *Ochotona pusilla*
Leporidae: *Lepus europaeus, Lepus timidus, Hypolagus beremendensis*

Fundamental geological and ecological processes

A large number of plant finds and the most varied groups of fauna in many layers of sediment at Stránská Skála provide good hypotheses for resolving climatic oscillations and the environment at the Early to Middle Pleistocene transition. Common groups of organisms allow the study of environmental changes at three levels: local, neighbouring and distant. These three perspectives, which are usually indistinguishable at any one site due to the absence of finds of diverse animal groups, have shown how utterly different an interpretation can be if based on only one single group. Such an interpretation can markedly differ from reality, as has also been shown in the preceding chapters of the present paper.

Let us now proceed to the interpretation of gradual environmental changes from the earliest preserved sediments formed before the Jaramillo subchron on the basis of all finds.

The period up to the Jaramillo subchron

In fluvial sediments that were developed as flood loams freshwater molluscs were common, hygrophilic molluscs were less common and terrestrial molluscs scarce. In the valley below Stránská Skála a river flowed in the flood plain. At that time there was an inconspicuously cold humid climate that can already be considered to be the beginning of subsequent milder climate. The existence of humid climate is also supported by the absence of loess or loess loams, which require arid climate for their formation. The landscape was unforested, with steppe vegetation. The higher precipitation resulted in increased erosion and in the formation of flood loams, as is known from the Holocene. Extensive inundations of the flood plains were evoked by intense spate of precipitation, resulting in increased erosion of sediments and in their resedimentation in the valleys. All sedimentary rocks and limestone debris of this period are strongly weathered.

The period between the Jaramillo subchron and the Brunhes-Matuyama boundary

The sedimentation of flood loams continues. The drop in the number of water molluscs and the beginning of the prevalence of terrestrial sediments indicate that at this time there were only a small number of sporadic floods. In the valley below Stránská Skála the river flowed as before, and its swampy meadows were spreading. The surrounding landscape was open, steppe, perhaps with isolated groves. Rocks found in the layer are strongly weathered. The accumulation of flood loams ends and talus cone II starts accumulating on their surface. At its base lies large limestone debris, sometimes the size of blocks, with well developed sinter deposition which reinforces the debris. The sinter deposition was thus formed syngenetically. Upwards the size of debris decreases. This development is quite similar to that known from the beginning of the Holocene and evidently always indicates the onset of markedly warm climate. The formation of the sinter deposition and large debris was necessarily conditioned by intense and ample precipitation. Also the whole period of the talus cone sedimentation must have been humid, because there was no accumulation of loess. Limestone debris, unlike in the upper talus cones, is still heavily weathered. Along the river there were swampy meadows, otherwise the landscape was open, grassed and mostly unforested. Altogether 85 % of the mollusc species collected indicate a forestless landscape. The same is documented by a great number of spermophiles. But the presence of small groves and even isolated deciduous trees cannot be excluded. At that time the number of bird finds increases rapidly.

The climate is still inconspicuously cold mildly warm (finds of lemmings), perhaps it represents a weak interstadial.

While the cold climate still persists, precipitation subsides and after a long period of humid climate it becomes gradually more and more arid. This results in a loss of vegetation cover in the higher areas of the surrounding upland and thus the possibility of loess formation. In the upper layer of the talus cone thick loess accumulates. However, this sedimentation does not proceed under stable arid conditions. Instead it is sedimented by western winds, the strength of which fluctuates greatly at the beginning, and at this time horizons of wind-blown sands are formed in loess. The strength of the wind was not constant, but increased and decreased in cycles.

The climate was quite unstable. At the time of sedimentation of the middle and upper parts of the loess layer there must have been extended periods of precipitation causing the repeated formation of gley positions in the loess. This implies interruptions of wind-blown loess, changes in climate from arid to humid and vice versa, thus in essence repeating oscillations of humid and arid climate. The foliated structure of loess in the upper part of the layer indicates freezing, maybe even the formation of permafrost, in any case very cold climate. Climatically the massive layer of loess (layer 4) was by no means uniform.

One could assume that this climate, which led to the accumulation of loess on the slopes of Stránská Skála, must also be reflected in the valley immediately below the site. Here however, the opposite is true. Beside the river there were still swampy meadows and swamps, the river was lined with bushes and trees. At Stránská Skála and in the immediate surroundings a biotope forms which is so well suited to birds that they increase in abundance. Stránská Skála proper and the hills in the surroundings are only covered with grass, but isolated bushes and trees, even deciduous ones, cannot be excluded. The steppe character is also confirmed by the finds of spermophiles which are most abundantly represented in this layer.

In the layer of loess on the slopes of Stránská Skála there are Rhizosoleniae, which are former roots of trees enveloped in liberated calcium carbonate. This proves again that in the course of the accumulation of the loess layer the slopes were not solely covered with grass, but isolated tree species were also present. At the same time this is proof of oscillations of humid climate (at which time $CaCO_3$ was washed down to the underlying bed of the loess layer) and arid climate (when the evaporation leads to the capillary rising of $CaCO_3$ to the surface and thus to the formation of Rhizosoleniae).

The climate was not uniform in the course of the loess accumulation. At the beginning the wind strength varied, then followed an oscillation of humid and arid climate. Whereas at the beginning the climate was not markedly cold, towards the end of the wind-blown loess phase it becomes very cold (foliated structure and finds of lemmings).

Brunhes-Matuyama boundary

This boundary lies within the layer of loess to loess loam. This layer (layer 5) is quite different from the underlying bed, not only optically, but also in its content. Here from the very beginning thermophilic tree species and plants requiring not only warm, but also humid climate are present. For the first time reptiles appear, which must be considered the onset of warm climate. Of course, also plants characteristic of steppe conditions are found. Spermophiles, which also indicate steppe, are relatively abundant, so that it is necessary to assume a patchwork landscape of park character, where open areas covered with grass interchange with areas covered with bushes and trees.

The river valley is still swampy, as not only the finds of birds, but also finds of reed and plants requiring a wet environment prove. The number of bird species changes little compared to earlier periods.

At the Brunhes-Matuyama boundary (Layer 5) a relatively rapid change of climate occurs. The prevailingly highly arid and cold climate ends relatively quickly and a climate of interglacial character sets in. It is a transitory period between the preceding glacial and the following interglacial which could be denoted as the beginning of the Cromerian interglacial or a transition towards it. Due to the fact that the sedimentation of layer 6 begins with large debris (talus cone III) and sinter deposition (Sinter Deposit B), i.e. a phenomenon always characterising the onset of a markedly warm period, only this layer can be stated to be the true beginning of Cromerian Interglacial I.

All sediments of this Interglacial I, constituting one unit of uninterrupted sedimentation, were labelled as talus cone III (Layers 6, 7, 8). Layers above the basal rough debris are dominated by smaller debris, by which at first sight they differ from the overlying layers of talus cone IV. As in talus cone II, the beginning of talus cone III again is characterised by increased precipitation. The period of sinter formation is marked by a strong drop in avian species; this period evidently being very unfavourable to them. In contrast, in the layer above the sinter formation, their number immediately increases. It is hard to believe that such a small number of bird species could only result from increased precipitation, but to date we have no other indications from this period. Due to a great prevalence of species building their nests in humid to swampy meadows for the entire period of sedimentation of the interglacial complex, it cannot be excluded that the repeated inundations in the flood plain would contribute to the restriction of birds at that time.

The organic find component reveals a great range of environment: the sunny rock biotope, xerothermic species, and steppe to forest steppe. Steppe areas must have been very extensive as most of the species found are from steppe habitats. The landscape was mostly open, with coniferous, but also deciduous trees; stones of the celtis tree are most abundant. In the soil increased biological activity is evident. The river continued to flow through the valley. As before, swampy meadows to swamps exist in its surroundings.

The overlying layers with large debris (Layers 7 and 8) surely imply a major climatic change. The mean temperature certainly did increase, the climate is humid, and finds of molluscs indicate even a climax stage (Layer 8) towards the end of this interglacial. Interglacial index species of molluscs appear, the number of forest species increases to 50 %. The number of snake species increases. Open grassed areas continue to persist, but their area decreases enormously. This is also evident in a small number of spermophiles. It cannot be excluded that steppe vegetation is found only at the rocky summit of Stránská Skála. In the surroundings one must expect closed forest units constituted by coniferous and deciduous trees of Mediterranean character.

Although humid meadows by the river are still found in the valley, the number of bird species decrease significantly.

The climate was unstable throughout the sedimentation of talus cone III, and the variation must have been considerable. This is testified by a high number of genetically different layers which at their base always have a small deposition of large debris. Within this interglacial period climatic cyclicity is certainly evident.

Layer 8 marks the end of this interglacial denoted as Cromerian I. It is characterised by a significant development of the molluscan assemblage and relatively large oscillations in the number of bird species. In the surroundings there are closed forest units. The climate is humid with high temperatures.

Layer 9 above the interglacial Cromerian I is composed of loess to loess loam, and in terms of high mean temperatures denotes a certain climatic deterioration. Although coniferous and deciduous trees still grow in the surroundings, the open landscape and steppe extend at their cost. The accumulation of loess also indicates a rapid change in the amount of precipitation, this was an arid period. Unlike layer 4 (thick loess layer) the thickness of this layer suggests only minor areas without plant cover. Bird species are still scarce, and they document humid to swampy meadows in the valley.

This phase may be characterised as an arid and, at the same time, relatively warm period.

The above loess layer is followed by another complex of layers, denoted as talus cone IV (layers 10, 11, 12), which belong to the interglacial Cromerian II. At its base lies again major boulder debris agglutinated with sinter (Sinter Deposit C) of syngenetic origin. The cyclicity of the climate is repeated. This evidently is a phenomenon typical of the majority, if not all, beginnings of conspicuously warm Pleistocene periods, in so far as the site is situated in a limestone region. The layers of this complex (talus cone IV) contain on average debris of larger dimensions than the preceding complex (talus cone III). Talus cone IV differs also climatically from the underlying cone.

It is possible that the last layer, number 12, was already affected by erosion and the layers (10, 11, 12) from the interglacial Cromerian II are only a torso of the whole interglacial. They are also the last layers that have not been affected by solifluction. The uninterrupted sedimentation from basal layer 1 ends with layer 12.

It therefore remains possible that the layer complex of talus cone IV (interglacial Cromerian II) did not originally end with layer 12, but instead continued further, with layers having been removed by subsequent denudation. One indication is the absence of a climax stage.

Talus cones III and IV also differ in finds of reptiles. Whereas these were very abundant in talus cone III and the diversity of this species was high, in talus cone IV the diversity decreases. Also the number of thermophilic species drops and psychrophilic species gain. The number of spermophiles is negligible, which may indicate a lack of open areas. At the beginning of the sedimentation of talus cone IV, as in the preceding interglacial complex Cromerian I, the number of bird species also drops considerably (only two species!).

Towards the top of this complex (Cromerian II) the climate gradually improves, although it does not reach the level of Cromerian I. There must have been an open landscape with thermophilic tree species. Large forest units consisting of coniferous and deciduous trees cannot be excluded either. The small amount of spermophile finds indicates a forested countryside.

The birds however are the most interesting. The last layer of this complex (layer 12) is the richest layer for avian remains. At this time the birds must have had optimum living conditions.

In the valley there are still humid meadows, sometimes even swamps, and bushes and trees grow close to the river-bank. At this time the small cave situated above the documented section was inhabited.

After the interglacial Cromerian II loess accumulation follows (layer 13). This period is characterised by cold climate and arid, steppe vegetation. The deterioration of the climate must have been much greater than that in loess layer 9.

Brown soil situated in the overlying layer (layer 14) can be described as a soil developed in a typical interglacial of warm humid climatic conditions, and most important, in a climatic optimum (Cromerian III?). At this time, unlike in the preceding interglacial layers, there was no debris formation. This soil is related to the underlying layer 12. A relatively high temperature is also indicated by the presence of snakes.

The landscape was mostly open with deciduous forests. Below Stránská Skála were still humid and swampy meadows. It is probable that the soil (layer 14) is a relic of interglacial Cromerian III.

After the sedimentation of layer 14 there again follows a very cold period. First there is an accumulation of loess (layer 15) and subsequently marked cooling, evidently also formation of permafrost, solifluction and cryoturbation phenomena. At that time there also occurred a great denudation of sediments and a solifluction transfer of interglacial sediments from the area in front of the cave entrance, situated immediately above the talus cone. This probably marks the beginning of the onsetting Elster (Mindel) glacial.

The overlying brown soil (layer 16), deriving from the cave entrance, is thus an allochthonous layer of Cromerian interglacial II, probably layer 12. In places it contained large amounts of small limestone debris, in places almost loam free. This small sharp-edged debris is a conspicuous product of a very cold glacial. Similar debris was not found in any underlying bed. This means that whereas the soil and the finds contained within are interglacial, the formation of the small limestone debris and the solifluctional transfer of these sediments is glacial. This evidently is the period of the Elster (Mindel) glacial.

This layer contained the greatest amount of bones of large mammals. This is logical, because these finds were originally situated in the cave entrance and they are from animals hunted by man. The pollen analysis has shown that in the surroundings there were coniferous and deciduous trees and below Stránská Skála again humid and swampy meadows. These finds characterise of course the preceding warm period and not the period of the solifluctional transfer.

After the Elster glacial there is a major hiatus in sedimentation. Only thin layers of sediment from the last glacial (layers 17 and 18) are present. In both layers there are still some solifluctional traces and sporadically several finds of Cromerian fauna, evidently redeposited from the cave entrance.

Above the overlying layers of loess from the last glacial a Holocene group of layers has developed.

Stránská Skála with a great amount of finds is a good example of how impossible it is to reconstruct the environment only on the basis of one group of organisms. If we made this reconstruction only on the basis of molluscs, we would have to state that almost for the whole chronological sequence there was a prevailingly arid and warm climate, in surroundings consisting of steppe or open park landscape with small groves. A similar reconstruction on the basis of birds would indicate a wet humid climate and moist and swampy meadows. The analysis on the basis of large mammals or on the basis of the plant cover would again indicate a different environment. When reconstructing the environment from only one group of finds and/or from low counts it is necessary to be very careful and avoid generalisations.

Stratigraphical information

The section at Stránská Skála is relatively complicated, including both fluvial sediments, and in its upper layers terrestrial sediments. In several talus cones a similar development is repeated.

The stratigraphic classification of sediments of Stránská Skála varies between different authors. Some attribute it to the Cromerian interglacial, others to the Holstein interglacial. They base their opinions largely erroneously on the fact that they assign the finds to only one single period.

In the stratigraphic discussion of Stránská Skála one must start from the age of the fluvial terraces. The aggradation terrace of Stránská Skála at the base of the entire section is situated above the Tuřany terrace, i. e. it is older. Still at the time of the accumulation of the Tuřany terrace the river flowed directly below Stránská Skála, and as shown by the avian finds, there was a valley with humid and swampy meadows throughout. Following the accumulation of the Tuřany terrace the stream ends below Stránská Skála and then is shifted further to the west. Since then the valley has been without a stream.

Approximately in the middle of the Tuřany terrace accumulation, not far from Stránská Skála lacustrine sediments, 120 cm thick, with a rich ostracod and molluscan fauna are found, dated palaeomagnetically to 500–600 000 years BP (Kočí 1982). On the surface of the fluvial sediments relics of soil ferretto have been preserved. Interglacial sediments from Stránská Skála are evidently contemporary with the fluvial sedimentation of the river flowing below Stránská Skála (the Tuřany terrace), which is also indicated by the finds of birds populating the humid meadows and/or requiring a water surface. These sediments cannot be earlier, but they are not later either.

Further evidence comes from palaeomagnetic dates. At the site the palaeomagnetic subchron Jaramillo and the Brunhes-Matuyama boundary (Kočí 1982) were established. Ultimately, also the pattern of the faunal assemblages of both vertebrates and molluscs evinces the Cromerian interglacial. Without making a detailed analysis, it can be stated that in interglacial sediments there are exclusively, and in large numbers, for instance horses of the species *Equus suessenbornensis*, which never occur in the sediments of the Holstein interglacial. There only horses of the caballoid type are found, i. e. *Equus mosbachensis*. Similarly, it would be possible to base hypotheses on a number of further animal species.

Talus cones III and IV and soils at Stránská Skála belong, according to existing information, to interglacials Cromerian I, II, and highly probably the overlying soil (Layer 14) to Cromerian III. The periods in between are then distinguished by phases of varying temperature intensity. The interval between Cromerian I and Cromerian II (Layer 9) was evidently warmer than the interval between Cromerian II and Cromerian III (Layer 13), which was extremely cold. Cromerian IV is missing at this site.

Before Cromerian I there occurs a strong deposition of wind-blown loess which I consider as belonging rather to the Menapian (Günz) glacial. This is also attested by the dating of the base of layer 2 into the subchron Jaramillo. In this case, at our site there would be missing below Cromerian a period labelled Bavelian which should be characterised by two warm periods divided by a cold period.

At Stránská Skála are best preserved sediments of the Menapian (Günz) glacial (OIS 27), loess of this glacial (OIS 26) and further sediments of the Cromerian with two loess intercalations (OIS 20–16; Cromerian IV is absent). The subsequent Elster (Mindel) glacial is preserved only in relics. After a major hiatus sediments of the last glacial and the Holocene are also present.

The Stránská Skála exposure allows the study of the development of the Cromerian complex and the immediately preceding period with the help of a large and varied number of finds. It can be regarded as a stratigraphical standard for this period in this part of Europe.

Rudolf Musil

The settlement of Stránská Skála in the Cromerian

The question of the presence of hominids at Stránská Skála was first indicated by the discoverer of the Early Pleistocene fauna J. Woldřich (1916) and assertively defended by K. Schirmeisen (1926) on the basis of finds of split animal bones. This view was not accepted by other researchers and the discussion, lasting several years, ended in that Stránská Skála was never settled at this time. Woldřich found the fauna in a small cave that had been destroyed by quarrying and Schirmeisen obtained the bones from nearby sediments, moved there by the quarry works, as was shown by R. Musil's investigation. During R. Musil's research from 1957–1972 stone artifacts were obtained for the first time both from intact slope sediments (Fig. 2, arrow 2), from the ruins of J. Woldřich's cave No. 8 (Fig. 2, arrow 4) and from cave No. 4 called the Water Cave (Fig. 2, arrow 5) (Valoch 1987; Valoch 1995). To obtain and document further archaeological material new investigations were carried out in 1996–1998, spatially extending the preceding work (Fig. 2, arrow 1) (Valoch 2003).

Fig. 2 Aerial view of Stránská Skalá. 1 Excavations of K. Valoch 1996–1998, 2 Excavations of R. Musil 1957–1967, 3 Knies' cave, 4 Cave No. 8, Woldřich's cave, 5 Cave No. 4, Water cave.

During archive work it was possible to find mention of the remains of another cave in the papers of J. Knies. It was situated in the area of the present rock platform artificially formed by the quarry (Fig. 2, arrow 3), where in 1916 J. Knies found fauna with *Homotherium moravicum* and elephant (*Elephas antiquus*). Up to 1926, when K. Schirmeisen began his excavation the remains of the cave were completely removed and the sediments from its filling shifted down the slope below the rock. From them K. Schirmeisen obtained a

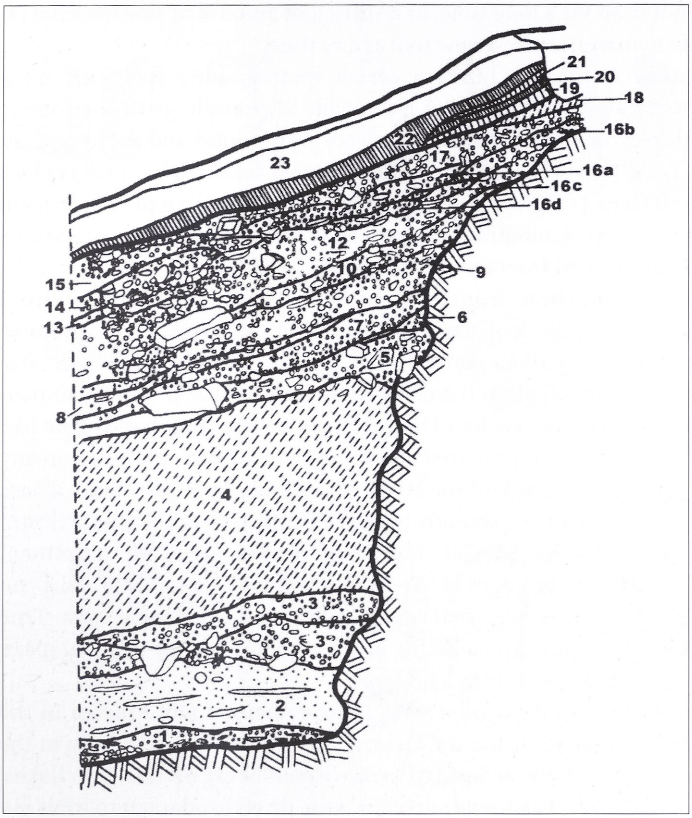

Fig. 3 Stránská Skála, section. Description of individual layers see text. Layer 11 was not present in this exposure (Drawing: R. Musil).

much larger collection of osteological material than that of his followers from intact slope sediments. This so-called Knies' cave and Woldřich's cave were evidently settled by hominids, like the small cave No. 4, from all of which artifacts are known (Valoch 2003).

The chronological position of artifacts was the same in both investigations. In the section of R. Musil (Fig. 3) it was layer 12 (former layer 13) that contained rich Cromerian fauna (Musil 1995) with which layers 11 and 12 of Valoch's new investigation can be correlated.

What evidence do we have for the presence of hominids at Stránská Skála in the Middle Pleistocene (Cromerian interglacial complex)? On several animal bones from earlier investigations (Woldřich's cave) it was possible to identify intentional manipulation (Patou-Mathis 1995). Investigations of open-air sediments from the1964–1972 (R. Musil) and the1996–1998 (K. Valoch) campaigns produced burnt bone fragments (Valoch 1987, Fig. 14.24; Přichystal/Strnad 1995). From the small cave No. 8 (Woldřich's cave) comes a craquelated flake of chert (Valoch 1987, Fig. 14.1) and from the last investigation three chert flakes with traces of the effect of fire (Valoch 2003, Fig. 9.7,13.13,14). The attached microscopical study of A. Šajnerová (2003) clearly demonstrated traces of human activity on four artifacts. The low quantity of use-wear traces can be explained by the fact that the artifacts were not used for a long time, as a sufficient amount of raw material on the site made it possible to manufacture a new tool at any time.

The collection of stone artifacts exhibits a certain petrographic spectrum, even though all materials probably derive from the immediate surroundings of the former settlement. In the first investigation (R. Musil) 41 pieces were found and in the second (K. Valoch) 81 artifacts. Local Jurassic cherts dominate (77,87 %), followed by small pebbles of quartz (11,4 %) and quartzite (1,64 %), further pebbles of chert coming primarily from Miocene sediments (5,74 %), two modified fragments of limolite (1,64 %), a flake of limestone (0,82 %) and a retouched fragment of spongolite (0,82 %).

The natural modus of Jurassic cherts from Stránská Skála used by hominids is either a nodule or a fragment, both of quite irregular shapes. If one can judge from the cores found, their processing technology was varied. One chert pebble hammerstone was found, but diffuse bulbs of percussion on the debitage reveal the use of a soft hammerstone made of antler or wood. On the one hand broad flakes, on the other hand blade-like flakes were obtained. The cores are unprepared and there is no striking platform on any product. On 43 pieces both the bulbus and the striking platform were preserved. These platforms are either cortical (44,19 %), smooth (27,91 %), linear (16,28 %), punctiform (6,98 %) and exceptionally battered (4,65 %). The bulbi are flat (37,21 %), prominent (39,53 %) and diffused (37,21 %). The edges of the flakes and blades are mostly sharp, on some of them small retouches can be seen that can be considered as traces of wear. True retouched tools are few. These are prevailingly notches, denticulates, side scrapers, exceptionally a burin and a Tayac point (Fig. 4 and 5).

Chert pebbles were processed in a similar way, there remained more pieces in the form of core artifacts than as flakes or blades. Quartz and quartzite appear only in the form of pebbles which were directly processed to tools without being divided into flakes. One small cortical flake of quartz was found. Pebbles were directly adapted to tools either by continuous steep retouch (side scrapers) or notches. Three large pebbles are classified as choppers.

All artifacts are macroscopically quite fresh, almost unpatinated; they have neither rounded or otherwise deformed edges nor a glossy surface. They do not seem to be subject to any post-depositional processes that would deform their shape and appearance in any way. The microscopical analysis of A. Šajnerová has, however, proved certain post-depositional changes.

Microwear analysis

The microwear analysis was carried out in 1997/98 by A. Šajnerová on the sample of chipped industry from the Lower Palaeolithic site Stránská Skála I. All chert artifacts (n=75) were chosen for the study. The analysis was applied using a combination of both the low power and high power approach (Keeley 1974; Odell 1975). For the high power approach, implements were examined with an incident light microscope (Olympus) using magnifications ranging from 150x to 300x.

Unfortunately, the surface of the artifacts had to be chemically cleaned before the analysis to remove a calcite crust. A very weak solution of hydrochloric acid (5 %) was used for cleaning and possible negative effects to the surface were prevented by saturating the

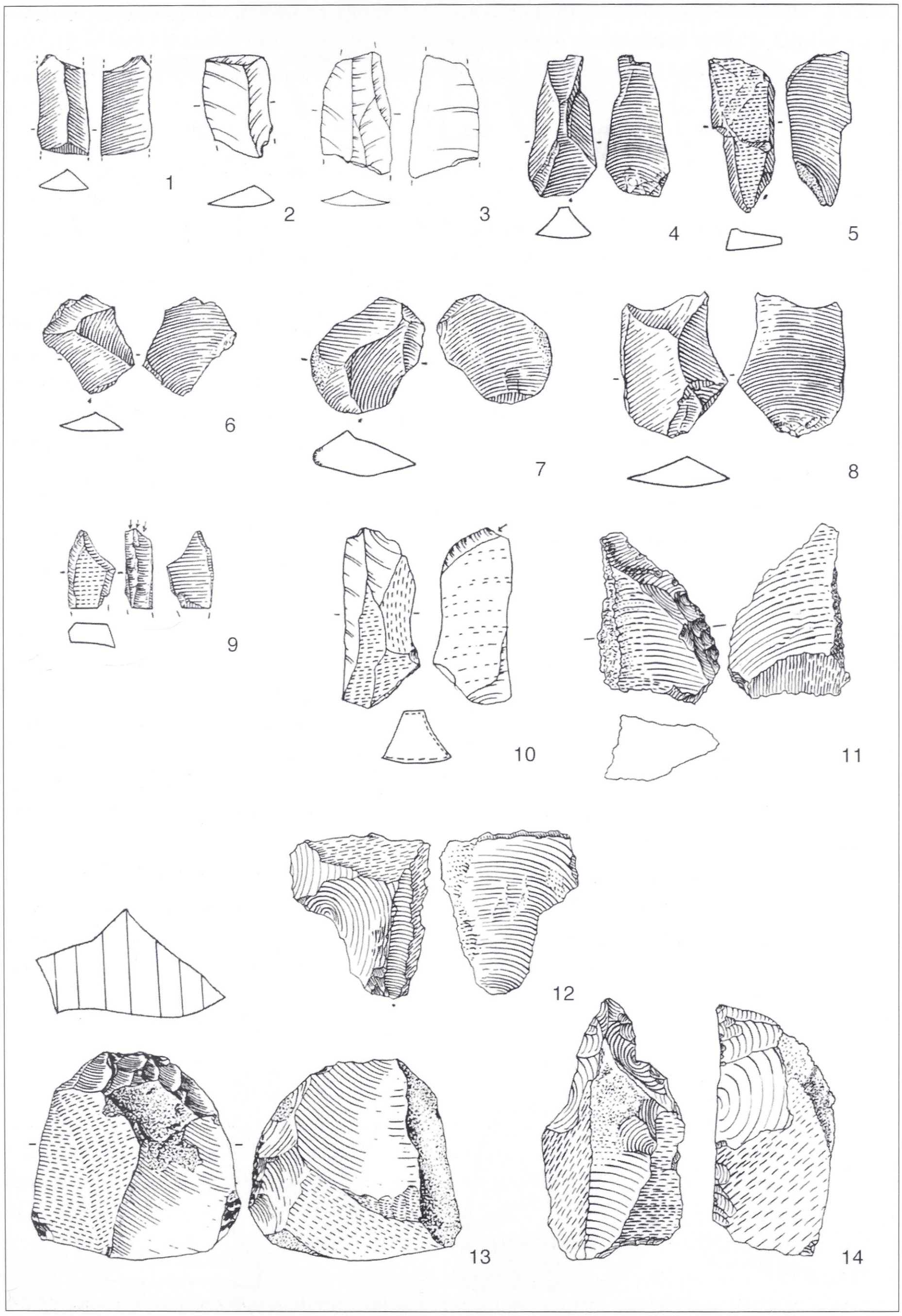

Fig. 4 Stránská Skála I. Artifacts with indication of use-wear traces (dots) and the direction of edge motion (arrows). M. 1:2.

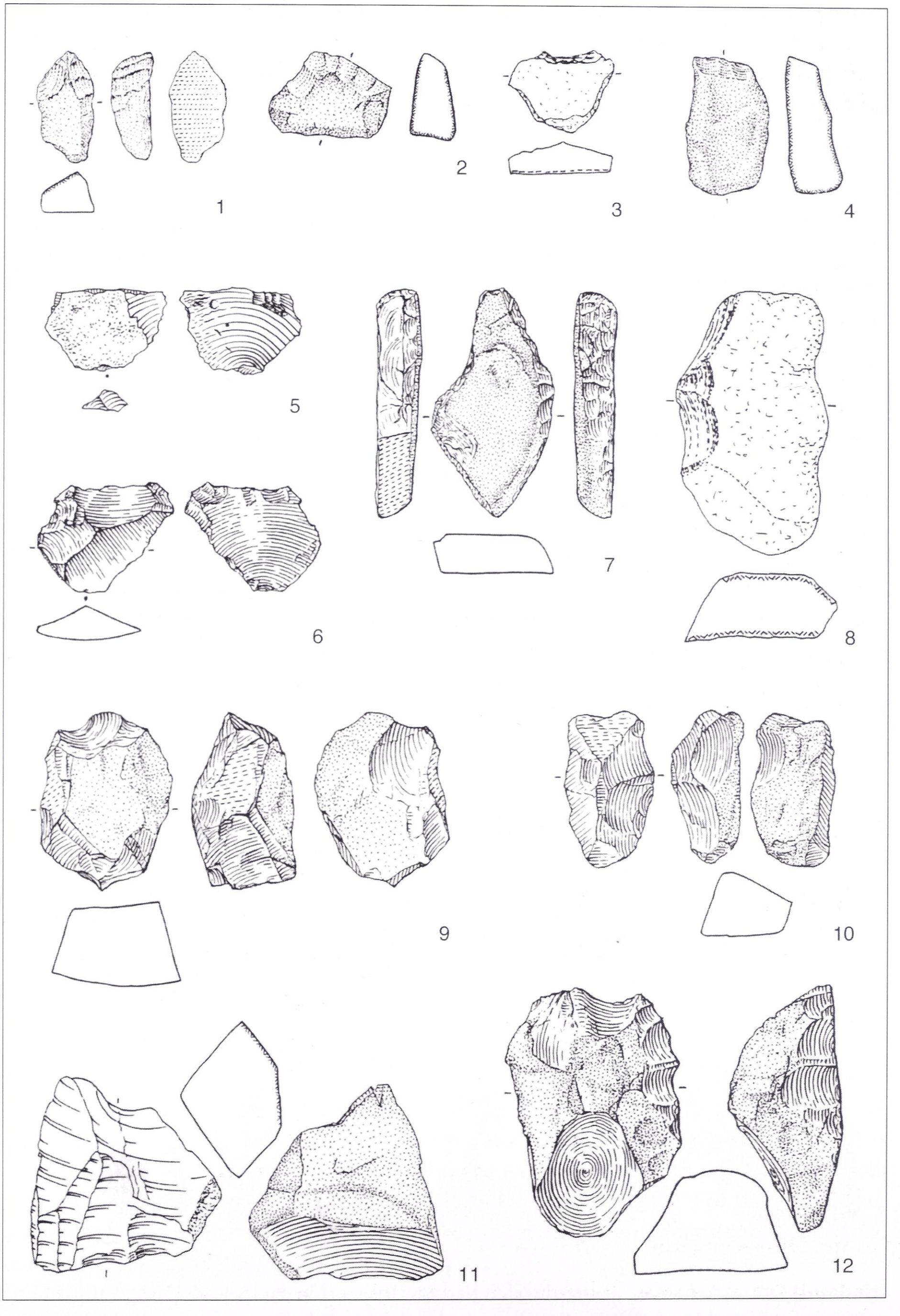

Fig. 5 Stránská Skála I. Artifacts with indication of use-wear traces (dots) and the direction of edge motion (arrows). M. 1:2.

artifacts in water prior to cleaning to reduce the penetration of the acid molecules into the surface. After cleaning the possible acid residues were neutralised with a soluble soap. During the examination the artifacts were cleaned with alcohol (60 %) to remove finger grease.

Preservation

The surfaces of all artifacts have been altered by post-depositional modification (patina, abrasion) which is to be expected considering their antiquity. However, the first expectation, that the artifact may be unsuitable for analysis as the surface may have been altered, proved to be unfounded. On the contrary, the surface of most artifacts was relatively well-preserved, much better than on those artifacts analysed previously from the Upper Palaeolithic site Stránská Skála II and III, which had a heavy white patination.

The intensity of post-depositional modifications varied greatly not only between artifacts but also on separate areas of a single artifact. Quite often one side of an artifact (either dorsal or ventral) had been altered by patination whilst the second one appeared pristine. No relationship to one specific side could be recognised. A similar effect has also been reported from the Middle Palaeolithic site Maastricht-Belvedere (Roebroeks et al. 1997).

A variety of friction glosses which were very frequent on most artifacts proved to be very interesting. Although the use usually required a very flat surface, without any directional features, in this study two types of friction glosses have been identified. With the exception of the usual flat spots, there were glosses displaying directionality and these were vaguely similar to polishes developed from working with mineral soils. However, the distribution along the edge and other characteristics did not correspond to use-wear traces. Therefore these glosses were not considered as interpretation of artifact usage.

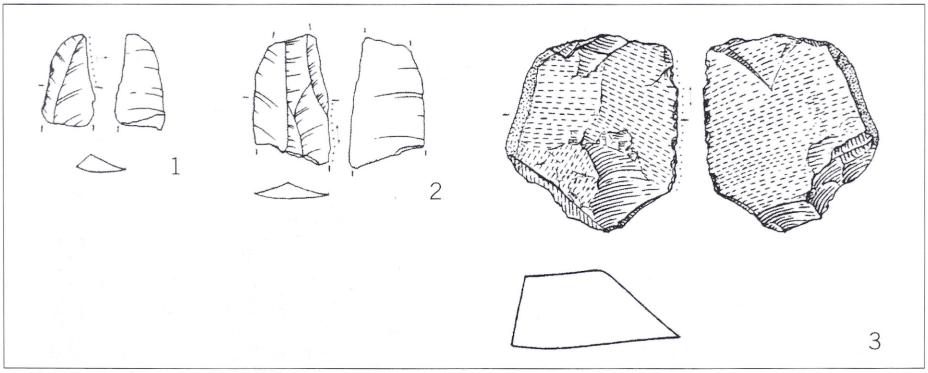

Fig. 6 Stránská Skála I. Artifacts with indication of use-wear traces (dots) and the direction of edge motion (arrows). M. 1:2.

Results and discussion

No interpretable use-wear polishes have been found on the analysed artifacts. This may relate to the age of the artifacts, but as the surface has not been greatly altered it could be expected that potential polishes were not missed due to their removal by post-depositional modification. Of the 75 artifacts examined only four (No. 1–3) displayed possible traces of wear, however, their interpretation is less certain and must be based only on the low power approach. Two artifacts (Fig. 6, No. 1–2) were interpreted as being used for transversal motion and the other two (Fig. 6, No. 3) for longitudinal motion. All these artifacts were used for working a hard or semi-hard material and were probably used only briefly as neither had developed a polish nor were the edge removals extensive. Three other artifacts had been burnt but these did not display any interpretable use-wear traces. Most of the artifacts had very sharp edges, not rounded by post-depositional modifications or abrasion. This suggests that the absence of use-wear traces in this sample can be regarded as genuine. The reason may be the availability of a very local source of raw material for tool knapping. The tools can only have been used for a short time as use-wear traces were undeveloped.

Karel Valoch

Literaturverzeichnis

Adamová 1982
M. Adamová, Charakter zastoupení stopových prvků v kvartérních sedimentech (půdách a spraších) v okolí Brna. Studia Geographica 80, 1982, 139–143.

Fejfar 1971
O. Fejfar, Die Wühlmäuse (Microtidae, Mammalia) der älteren Sammlungen aus Stránská skála bei Brno. Anthropos 20 (= N.S. 12), 1971, 165–176.

Flerow/Reshetov 1972
C. C. Flerow/V. J. Reshetov, Fossil Bison and Bos from Stránská Skála. Anthropos 20 (= N.S. 12), 1972, 177–179 [conf. Kahlke 1972, 193].

Heller 1972
F. Heller, Die Hamster- und Zieselreste aus den Ablagerungen von Stránská skála bei Brno. Anthropos 20 (= N.S. 12), 1972, 147–164.

Ivanov 1978
M. Ivanov, Pleistocene reptiles at the locality of the Stránská Skála hill. Anthropos 26 (N.S.8),1978,93–109.

Ivanov 1997
M. Ivanov, Hadi evropského kenozoika. PhD thesis, Přírodovědecká fakulta Masarykovy university (1997) 1–217.

Jánossy 1972
D. Jánossy, Die mittelpleistozäne Vogelfauna der Stránská skála. Anthropos 20 (= N.S. 12), 1972, 35–64.

Jaroš 1926
Z. Jaroš, Machairodi v moravském diluviu. Příroda 19, 1926, 1–4.

Kahlke 1972
H. D. Kahlke, Die Cerviden-Reste der Stránská skála bei Brno. Anthropos 20 (= N.S. 12), 1972, 193–197.

Kahlke 1995
H. D. Kahlke, Neue Cerviden-Reste der Stránská skála bei Brno. Anthropos 26 (= N.S. 12), 1995, 85–91.

Keeley 1974
L. H. Keeley, Technique and methodology in microwear studies: a critical review. World Archaeology 5, 1974, 323–336.

Knies 1925
J. Knies, Přehled moravského paleolithu. Obzor praehistorický 4, 1925, 89–116.

Kočí 1982
A. Kočí, Paleomagnetický výzkum sedimentů Brněnské kotliny. In. R. Musil (Ed.), Kvartér Brněnské kotliny. Stránská skála IV, Studia geographica 80 (o. O. 1982) 153–170.

Kormos 1933
T.Kormos, Zur Altersfrage der Fauna des Lateiner Berges (Stránská skála) bei Brünn. Verhandl. naturforsch. Verein Brünn 64, 1933, 151–160.

Kovanda 1972
J. Kovanda, Die alten Weichtiersammlungen aus der Lokalität Stránská skála bei Brno. Anthropos 20 (= N.S. 12), 1972, 19–20.

Kovanda 1995
J. Kovanda, Palaeomallacoanalysis of the lower part of the talus cone profile at the Stránská Skála hill near Brno. Anthropos 26 (= N.S. 8), 1995, 137–144.

Kovanda 1995a
J. Kovanda, Revision of fossil molluscs of the upper part of the talus cone profile at the Stránská Skála hill near Brno. Anthropos 26 (= N.S. 8), 1995, 127–136.

Kowalski 1972
K. Kowalski, Chiroptera from Stránská Skála near Brno. Anthropos 20 (= N.S. 12), 1972, 71–75.

Kurtén 1972
B. Kurtén, Fossil Hyaenidae from the excavations at Stránská Skála. Anthropos 20 (= N.S. 12), 1972, 113–120.
Ložek/Fejfar 1957
V. Ložek/J. Fejfar, Kotázce staropleistocenní fauny ze Stránské skály u Brna. Věstník Ústředního ústavu geologického 32/4, 1957, 290–294.
Mlíkovský 1995
J. Mlíkovský, Early Pleistocene birds of Stránská Skála hill, Czech Republic: 1. Musil´s talus cone. Anthropos 26 (= N.S. 8), 1995, 111–126.
Musil 1963
R. Musil, Stránská skála, kvartérní sedimenty a fauna.-Sjezdový průvodce XIV. sjezdu Společnosti pro mineralogii a geologii při ČSAV, 1963, 108–110.
Musil 1965
R. Musil, Aus der Geschichte der Stránská skála. Acta Musei Moraviae 50, 1965, 75–106.
Musil 1967
R. Musil, Stránská skála. Early Pleistocene Fauna. Guide to the Exkursion 25 AC, Quaternary. Intern. Geol. Kongress Praque (Prag 1967) 35–38.
Musil 1968
R. Musil, Stránská skála – Early Pleistocene fauna. In: Quaternary of the Bohemian Massif and Carpathian Foredeep. Guide to the Excursion 25 AC. Int. Geol. Congress, XXIII Session (Prague 1968) 35–38.
Musil 1968a
R. Musil, Neue Ergebnisse der Forschungen an der Lokalität Stránská skála. Acta Musei Moraviae Brno 53, 1968, 139–162.
Musil 1968b
R. Musil, Stránská skála: Its Meaning for Pleistocene Studies. Current Anthropology 9/5, 1968, 534–539.
Musil 1969
R. Musil, Erste Artefaktfunde in jungbiharischen Ablagerungen auf der Stránská skála. Jahresschr. Mitteldt. Vorgesch. 53, 1969, 35–43.
Musil 1971
R. Musil (Hrsg.), Stránská skála I, 1910–1945. Anthropos 20 (= N. S. 12), 1971, 1–204.
Musil 1972
R. Musil, Die Bären der Stránská skála. Anthropos 20 (= N. S. 12), 1972, 107–112.
Musil 1972a
R. Musil, Die Caniden der Stránská skála. Anthropos 20 (= N. S. 12), 1972, 77–106.
Musil 1972b
R. Musil, Die Elefantenüberreste der Lokalität Stránská skála. Anthropos 20 (= N. S. 12), 1972, 181–184.
Musil 1972c
R. Musil, Die Geschichte der Pleistozänforschung an der Lokalität Stránská skála bei Brno. Anthropos 20 (= N. S. 12), 1972, 9–14.
Musil 1972d
R. Musil, Die Pferdefunde der Lokalität Stránská skála. Anthropos 20 (= N. S. 12), 1972, 185–192.
Musil 1979
R. Musil, Stránská skála. In: Guide to Excursions (A Moravia, B Bohemia, C Slovakia). Int. Geol. Correlation Programme. 6th Session of the Project 24 »Quaternary Glaciations in the Northern Hemisphere«, Czechoslovakia (Ostrava 1979) 56–58.
Musil 1982
R. Musil, Kvartér Brněnské kotliny. Stránská skála IV. Studia Geographica 80, 1982, 1–283.
Musil 1982a
R. Musil, Nálezy pleistocenních obratlovců v sedimentech Brněnské kotliny. Studia Geographica 80, 1982, 171–179.
Musil 1995
R. Musil, Large fauna of talus cone at the Stránská Skála hill. Anthropos 26 (= N. S. 18), 1995, 65–83.
Musil 1995a
R. Musil, Research at the Stránská Skála hill 1945–1950. Anthropos 26 (= N. S. 18), 1995, 1–28.
Musil 1995b
R. Musil, Exceptional status of layer 13 at Stránská skála hill. Anthropos 26 (= N. S. 18), 1995, 65–83.
R. Musil (Ed.) 1995
R. Musil (Ed.), Stránská skála Hill. Excavations of open-air sediments. Anthropos 26 (= N. S. 18), 1995, 1–213.
Němec 1972
J. Němec, Osteology of isolated anuran bones from Stránská Skála near Brno (Lower Quaternary). Anthropos 20 (= N. S. 12), 1972, 21–33.
Odell 1975
G. H. Odell, Micro-wear in perspective: a sympathetic response to Lawrence H. Keeley. World Archaeology 7, 1975, 226–240.
Patou-Mathis 1995
M. Patou-Mathis, Étude préliminaire de certaines pièces osseuses de Stránská skála (Moravie) présentant des stigmates d´intervention humaine. In: R. Musil (Ed.), Stránská skála Hill. Excavation on the open-air sediments 1964–1972. Anthropos 26, (N.S. 18), 1995, 169–176.
Pelíšek 1972
J. Pelíšek, Übersicht der Geschichte von Forschungsarbeiten der Quartärsedimente im Gebiet von Stránská skála bei Brno. Anthropos 20 (= N. S. 12), 1972, 15–16.
Pelíšek 1995
J. Pelíšek, Geochemistry and granulometric composition of talus cone deposits. Anthropos 26 (= N. S. 18), 1995, 47–52.
Přichystal/Strnad 1995
A. Přichystal/M. Strnad, The evidence of fire use by the hominids of the species Homo erectus at the Stránská skála Hill in Brno. In: R. Musil (Ed.), Stránská skála Hill. Excavation on the open-air sediments 1964–1972. Anthropos 26 (= N. S. 18), 1995, 149–152.
Roebroeks u. a. 1997
W. Roebroeks/J. Kolen/M. Van Poecke/A. L. Van Gijn, Site J: An Early Weichselian (Middle Palaeolithic) Flint Scatter at Maastricht-Belvedere, The Netherlands. Paleo 9, 1995, 143–172.

Rzebik-Kowalska 1971
B. Rzebik-Kowalska, The insectivora from Stránská Skála near Brno. In: R. Musil (Hrsg.), Stránská Skála I. 1910–1945. Anthropos 20 (= N. S. 12), 1971, 65–70.

Schirmeisen 1926
K. Schirmeisen, Altdiluviale Mahlzeitreste auf dem Lateiner Berge bei Brünn. Verhandl. naturforsch. Verein Brünn 60, 1926, 29–51.

Smolíková 1995
L. Smolíková, Palaeopedological research at the Stránská Skála hill in Brno. Anthropos 26 (= N.S. 8), 1995, 53–64.

Stehlík 1934
A. Stehlík, Fosilní savci ze Stránské skály u Brna. Práce moravské. přírodovědecké společnosti 9, 1934, 1–94.

Svobodová 1995
H. Svobodová, Pollen analysis of the Cromerian interglacial from the site Stránská Skála I. In: R. Musil (Ed.), Stránská skála Hill. Excavations of open-air sediments. Anthropos 26 (= N. S. 8), 1995, 145–148.

Šajnerová 2003
A. Šajnerová, Mikroskopická analýza staropaleolitických artefaktů z lokality Stránská skála I (Microwear analysis of the artifacts from the Lower Palaeolithic site Stránská Skála I). Acta Musei Moraviae, Sci. soc. 83, 2003, 67–73.

Thenius 1972
E. Thenius, Die Feliden (Carnivora) aus dem Pleistozän von Stránská skála. Anthropos 20 (= N.S. 12), 1972, 121–135.

Tobien 1972
H. Tobien, Citellus (Rodentia) und Lagomorpha aus den älteren Aufsammlungen an der pleistozänen Lokalität Stránská skála bei Brno (ČSSR). Anthropos 20 (= N. S. 12), 1972, 137–146.

Valoch 1987
K. Valoch, The Early Palaeolithic Site Stránská skála I near Brno (Czechoslovakia). Anthropologie 25/2, 1987, 125–142.

Valoch 1995
K. Valoch, Early human activities at the Stránská skála Hill. In: R. Musil (Ed.), Stránská skála Hill. Excavation of the open-air sediments 1964–1972. Anthropos 26, (= N. S. 18), 1995, 159–167.

Valoch 2003
K. Valoch, Výzkum staropaleolitické lokality Stránská skála I v Brně-Slatině (The excavation of the Lower Palaeolithic site Stránská Skála I in Brno-Slatina). Acta Musei Moraviae, Sci. soc. 83, 2003, 3–65.

Woldřich 1916
J. Woldřich, První nálezy Machaerodů v jeskynním diluviu moravském a dolnorakouském. Rozpravy České akademie císaře Fr.Josefa pro vědy, slovesnost a umění, tř. II, 25/12, 1916, 1–8.

Woldřich 1917
J. Woldřich, Machairodus im Höhlendiluvium von Mähren und Niederösterreich. Centralblatt f. Mineralogie, Geologie u. Paläontologie 1917, 134–137.

Abbildungsnachweis

1 N. Seeländer, LDA
2 M. Bálek
3 R. Musil
4–5 nach Valoch 2003
6 nach Šajnerová 2003

Anschrift

Prof. RNDr. Rudolf Musil DrSc.
Institute of Geological Sciences
Faculty of Science, Masaryk University,
611 37 Brno
Kotlářská Street 2
Czech Republic
e-mail: rudolf@sci.muni.cz

Doz. PhDr. Karel Valoch DrSc.
Moravian Museum
Institute Anthropos
Zelný trh 7
659 37 Brno
Czech Republic
e-mail: kvaloch@mzm.cz