The landscape biodiversity increase by utilizing a mined area and spoil heaps

Abstract

The well-preserved dry grasslands in the locality "Mezi lomy" inside the limestone quarry Mokrá have a long-time continuity. Thermophilous flora had formerly many localities around Mokrá and Horákov, which had a good connectivity (pollen, seed). Unfortunately most of them were destroyed during the 20th century, several due to the termination of pasturing or afforesting and other due to mining. Currently, some thermophilous species are surviving on forest edges and other close fragments of xerothermic localities are comparatively distant, therefore the smallish locality "Mezi lomy" became rather isolated. Some small populations surviving on relatively isolated fragments with high biodiversity tend to lose their genome diversity over time, which can further lead to their extinction.
Now a good opportunity arose there, because the mined area adjacent of the locality "Mezi lomy" was released to reclamation again. There is a good possibility to enlarge the area of current dry grassland locality using the suitable restoration design, which might help the local populations to become more stable. I proposed there restoration by directed succession method, which I combined with utilizing of spoil heap.

Introduction

The limestone mining history dates back approximately to the Neolithic, when people utilized limestone to make various tools as axe or hoe. People found out even more and more limestone utilization and its consumption slowly increased. The consumption break point in Central Europe came in the Middle Ages, when the lime production and utilization expanded (it was originated in the Middle East already during 8th millennium BC; www1). Despite increasing consumption of limestone, quarries were still comparatively small in this time (pits diameter rarely above 10 m and depth was only several meters). After leaving, these small patches often contributed to increasing diversity and landscape heterogeneity (Sádlo & Tichý 2002). Only the global expansion of modern mining methods during the last century gave rise to extensive quarries, which destroyed large parts of the landscape. Leaving of the mined areas went hand in hand with the progress of public demands on restoration. At first it was only technical reclamation, further came restorations (engineered restorations), which mainly comprised filling by thick layer of spoil overlay and planting of several tree species or non-native and ornamental species.
For many years there has been an apparent trend of increasing landscape homogenization (Ross et al. 2012), when many communities disappeared due to destruction of their localities by settlement and industry expansion, mining, abandonment of landscape, some communities of oligotrophic habitats got lost after the fertilizing or nitrogen fallout etc. Biologists soon began to point to the uniqueness of some abandoned mined areas, which became valuable part of nature only due to spontaneous succession (Prach et al. 2001). But there were many other mined areas, which were colonized mainly by alien plants. Scientists began to address this issue and in the 1980s emerged restoration ecology as a separate part of ecology.
Limestone has very interesting biological features such as unique chemistry and specific karsts topography, which cause special adaptations. Dry climate predominated in Central Europe during long time of last ice ages, long speciation in such conditions caused high species richness of calciphilous flora (Ewald 2003). Occurrence of many animals is connected with calciphilous plants, especially rare and endangered species of insects and molluscs (trophic relations). Therefore even small limestone areas are typical of high biodiversity.

Objectives

The aim of this project is to propose a suitable restoration design of the formerly mined horseshoe-shaped area (southeast part of "Korál" quarry), which borders with well-preserved locality "Mezi lomy" (bio-centre, biodiversity hot spot; Appendix 1). Optimal outcome of the restoration by directed succession method put together with utilizing of spoil heap is the extension of the sub-pannonic dry-grassland locality and biodiversity increase (both flora and fauna) by colonization of new biotopes formed on newly established slopes, left parts of rocks and small lakes. Local populations would become more stable by enlargement of the area containing suitable biotopes and subsequently spontaneous reinforcing. This will increase the natural and conservation value of restored area and simultaneously the fragment of stepic vegetation in locality "Mezi lomy".

Background information

The limestone quarry Mokrá is located in the south-east of the Maravian Karst, one of three areas with fully developed karsts phenomenon in the Czech Republic. It has a unique position on the edge of Ochoz plateau, high above Carpathian Foredeep. South slopes on the edge of mesophytic phytogeographical area permits exclave surviving of many thermophilous species of the Pannonian basin.
The locality "Mezi lomy" inside the quarry with a fertile population of strongly endangered pasqueflower (*Pulsatilla grandis*) was proposed to be incorporated into the EVL Moravský kras protected area (Natura 2000, EVL CZ0624130), which is located in the immediate vicinity of the quarry as well as of the CHKO Moravský kras. Currently the locality comprise a mosaic of stepic grassland dominated by vegetation of sub-pannonic dry grasslands, edged by herbaceous fringes with solitaire dwarf oaks (*Quercus pubescens*), cornelian cherry (*Cornus mas*) and rowan trees (*Sorbus torminalis*).

Methods

To propose a suitable restoration design, I studied appropriate literature and old maps. Firstly, I had to carefully survey the terrain and the vegetation in the area of interest inside the quarry (Appendix 1). I visited it on the 27th April, the 10th May and the 14th September.
It is possible to expect, that the simple anemochorous transport of diasporas from some close fragments of xerothermic localities (especially in the Říčky valley, prevailing westerly winds) might support the increase of the biodiversity of the whole landscape. It will be necessary to mulch newly established slopes with hay during the reclamation. Not all hay has to come from the adjacent locality "Mezi lomy". We should help to avoid declining of genome diversity, which is unfortunately often characteristic feature of small populations surviving on relatively isolated fragments. Simple way is to enrich the hay adding some hay coming from one of the suitable localities, because grass litter (hay) is a natural seed trap (Ruprecht & Szabó 2012). It is necessary to respect geographic origin and to use only localities distant approximately 5 km (Tichý 2005a). I selected these localities (Appendix 2):

- Velká Klajdovka – 6.5 km WSW, xerophilous shrubs and dry grasslands
- Kavky – 7 km WSW, xerophilous shrubs and dry grasslands
- Hádecká planinka – 6.5 km WSW, xerophilous dry grasslands and shrubs
- Šumbera – 6.5 km W, xerophilous dry grasslands in rocky patches inside dwarf forest
- Velký Hornek – 3.5 km W, xerophilous dry grasslands and shrubs, rocky vegetation
- Lysá hora – 2.5 km NW, xerophilous dry grasslands and shrubs, rocky vegetation

I did not include the well known dry grassland above Ochoz cave, because this locality does not give hay of sufficient quality. I surveyed the actual vegetation at selected localities of termophilous plants and supplemented my findings on recent literature data (Franc et al. 2005, Tichý 2005b, Tichý 2006, Franc et al. 2007, AOPK ČR 2012, Jurek & Tichý 2012).
I chose only thermophilous plants and plants of alternately drying habitats (if they occurred) for the analysis. I entered the data on 230 species into the TURBOVEG database (version 2.83; Hennekens & Schaminée 2001) and edited it using the JUICE program (version 7.0.65; Tichý 2002). I calculated Ellenberg indicator values for each locality (Ellenberg et al. 1992) and analyzed the presence/absence data in CANOCO for Windows 4.5 (ter Braak & Šmilauer 2002) using a multivariate statistical techniqe – detrended correspondence analysis (DCA). Relations among localities, thermophilous species, number of thermophilous species and Ellenberg indicator values are shown in resulting triplot (Appendix 3).
Then I compiled the reclamation recommendations.
The nomenclature was unified according to Kubát et al. (2002), the syntaxonomy according to (Chytrý et al. 2001) and threat status according to Procházka (2001).

Results and discussion

History of thermophilous vegetation around Mokrá

The historical process of the thermophilous vegetation surrounding the locality "Mezi lomy" is one of the key factors to prepare a suitable restoration design. The imperial imprints depict historical cadastral maps originating in 1826. These maps show extensive pastures in several part of current quarry and the locality "Mezi lomy" (Appendix 4, www3). Above the pastures there were light oak-hornbeam forests, which were probably grazed.
Podpěra (1932) described occurrence of many small dry terraced steppes with xerothermophytes on the forest edges of south slopes of Horákovský les and around Mokrá. These steppes were called "opuški" and represented habitats of thermophilous species (*Anthericum ramosum*, *Artemisia campestris*, *Aster amellus*, *Bupleurum falcatum*, *Gentiana ciliata*, *Prunella grandiflora*, *Pseudolysimachion spicatum*, *Salvia pratensis*, *Scabiosa ochroleuca*, *Senecio jacobaea*, *Seseli osseum*, *Veronica prostrata*). He wrote about dry and low oak and oak-hornbeam forests with thermophilous woods as well (*Euonymus verrucosa*, *Sorbus torminalis*). It is interesting that he described very nutrient poor oak forests closer to Hostěnice (*Calluna vulgaris*, *Nardus stricta*, *Danthonia decumbens*).
The historical orthophotomap from 1953 shows still natural forest canopy openings (Appendix 5, www4). If we interlay this map with current orthophotomap (Appendix 6, www4), we will find out that two larger forest canopy openings with thermophilous plants were completely destroyed by mining and another one exactly corresponds to the current locality "Mezi lomy" (old people from Mokrá draw the pasturing here in the mid-20th century).
The locality was in danger of running succession after the pasturing termination. Only the fragments of former vegetation survived, presumably due to heat-island effect of the rapidly increasing quarry, which causes extreme microclimatic conditions and partly inhibits succession.
As we can see, the locality "Mezi lomy" has long time continuity. Formerly it was in connectivity with many other patches of thermophilous plants, but it is isolated now.

The current mosaic of vegetation at the locality "Mezi lomy"

The terrain survey showed that the diverse mosaic of microbiotopes is formed mainly by edaphic conditions (structure and depth). Shallow gravels of various grain sizes alternate there with thin layers of rendzina (leptosol), what causes high microclimatic diversity of these grasslands. Shallow soil with patches of gravel fills grasslands bordering with the horseshoe-shaped mined area. Layer of raw gravels of depth about 4 cm are covered e. g. by *Potentilla arenaria* (C4a), *Sedum sexangulare*, *Thesium linophyllon*, *Hieracium pilosella*, *Euphorbia cyparissias*, *Stachys recta* and by *Alysum alyssoides* in the spring time (Appendix 7). Shallow gravelly soil of depth about 8 cm fills mainly the central part of the locality. Such conditions are optimal for narrow-leaved dry grassland (*Festucion valesiacae*) with many thermophilous species: *Festuca rupicola*, *Polygala comosa*, *Cytisus procumbens*, *Teucrium chamaedrys*, *Salvia pratensis* etc. (Appendix 8). The soil is a little deeper in the middle of the upper part (about 11 cm). *Cytisus procumbens*, *Salvia pratensis* and broad-leaved grasses e. g. *Brachypodium pinnatum* (Appendix 9) dominate there. We can find this deeper soil by the rock edge in the upper part of locality as well, where plants of the alternately drying soil, e. g. *Potentilla alba* (C4a), *Betonica officinalis* are growing (Appendix 10). The occurrence of strongly endangered pasqueflower *Pulsatilla grandis* (C2, Appendix 11) is bound to deeper soil of depth about 20 cm at the bottom part of the corner, where there is a mosaic of narrow-leaved and broad-leaved dry grassland (*Bromion erecti*), endangered *Carex michelii*, *Primula veris*, *Thalictrum minus*, *Veronica prostrata* (all C3) and next *Cerinthe minor* (C4a), *Phleum phleoides*, etc. grow there.

Shrubs are concentrated along the lower margin of the locality. They change to dwarf sparse forest of *Quercus pubescens* (C4a, § 3, Appendix 12) with some shrubs of *Cornus mas* (C4a, §3), *Sorbus torminalis* (C4a), *Berberis vulgaris* (C4a) etc. to the east. Edges of shrubs are covered by some vulnerable fringe species (C3): *Pulmonaria mollis*, *Euphorbia epithymoides* and *Lithospermum purpurocaeruleum*. Several species of low endangered shrubs (C2) occur in rocky outcrop decays in lower and middle part of the locality: *Rosa spinosissima* (Appendix 13), *Prunus fruticosa*. Plant pillow of *Potentilla arenaria* (C4a) and *Potentilla heptaphylla* (Appendix 14) grow there too. We can find some rests of former orchard at upper hem of shrubs and trees.

There are some very interesting local processes, which are necessary to observe before reclamation proposing. We can observe running succession on several disturbed sites:

- Disturbed stones mound with a little soil at the upper part of the locality was colonized by *Teucrium chamaedrys*, *Hieracium pilosella*, *Sanguisorba minor*, *Solidago virgaurea* and *Carlina vulgaris* (Appendix 15).
- Disturbed unemployed unpaved road in the upper part of the locality was colonized by *Echium vulgare* and *Microrrhinum minus* (Appendix 16).

We can observe there some important adverse processes as well:

- The upper part close to the edge of the rock was colonized by *Pinus sylvestris*, which is not usually able to be successful in competition at most habitats, but here at extreme xeric conditions with lack of nutrients it becomes often expansive character. Even though majority of trees was removed during management actions, there are many seedlings and small trees reappeared again (Appendix 17, 18). Seedlings are able to germinate in very extreme microclimatic conditions.
- Succession is still running and sites with deeper soil tend to be overgrown with expansive grasses *Arrhenatherum elatius* and more dangerous *Calamagrostis epigejos* or shrubs (more expansive *Cornus sanguinea*). Currently there is no pasturing (which is probably more suitable especially for pasqueflower population), the cutting management with removing biomass is sufficient.

- The absence of pasturing is probably connected with mosses spreading in some parts of the locality. Mosses coverage helps to decrease the microclimatic extremes and prevent to seedling germination.

Current flora at the adjacent mined horseshoe-shaped area (south-east part of "Korál" quarry)

There are three types of coverage at the bottom of adjacent mined area:

- The south tip and eastern part in the middle is very dry and slowly colonized by several steppic species, which are adapted to grow on the raw gravel e. g. *Sedum acre* (Appendix 19), *Sedum sexangulare*, *Potentilla arenaria* (C4a, Appendix 20), *Seseli osseum*, *Echium vulgare*, *Sanguisorba minor*, *Daucus carota*, *Festuca rupicola*, *Scabiosa ochroleuca*, *Verbascum chaixii* ssp. *austriacum*. The hay and pruned branches originating form the locality "Mezi lomy" are thrown from the rock faces during management actions and they help colonizing and succession there (Appendix 21). The northern tip was probably a little mulched by previous reclamation in 2008.
- Almost whole western part and partly the central part are covered by thin layer of clay, which caused that some water is stagnating there or the surface tends to be moist. Therefore unasked grasses *Arrhenatherum elatius* and *Calamagrostis epigejos* expanded there (Appendix 22). Several tens of poplars (*Populus tremula*, *P. x canadensis*, *P. x canescens*) and willows (*Salix* spp.) occur there. Compact growth of *Calamagrostis epigejos* and brambles (*Rubus* spp.) continue further west.
- The northern part is in the middle and east almost without vegetation cover. There are only straggly plants of *Epilobium dodonaei* (Appendix 22) and one site near rock faces was obviously mulched with hay from other dry grasslands than the adjacent locality "Mezi lomy". There are evident rests of hay and nearby flower straggly plants of *Inula ensifolia* (C3, Appendix 24), *Acinos arvensis*, *Scabiosa ochroleuca*, *Pseudolysimachion spicatum* and *Erigeron acris* (Appendix 24).

High northern and eastern rock faces are not in decay yet, only several trees of *Pinus sylvestris* and *Picea abies* grow there. Against this the southern rock faces are relatively low and decay. Several interesting plants from species rich upper rocky outcrop edges e. g. *Prunus fruticosa* (C2), *Anthylis vulneraria* (Appendix 25) grow there.
There was a small lake digged between middle and southern part nearby rock faces, but this part of bottom is very dry and permeable, therefore no water has ever been there (Appendix 26).

Restoration proposal

In restoration ecology spoil heaps are often connected with engineered restorations (Prach et al. 2001), what leads to unique habitat losses particularly due to plantations of non-native or ornamental plants. Although there are some techniques how to restore spoil heaps by natural way, but we loose the habitats heterogeneity of mined quarry (Tichý 2010). There is a contradiction, because miners produce continually a lot of spoil, which is necessary to store for purpose of next use to restoration according to the law.
The formerly mined horseshoe-shaped area (sout-heast part of "Korál" quarry) bordering with well-preserved locality "Mezi lomy" represents an opportunity to combine spoil heaps unfavoured by ecologists with high habitats heterogeneity. Suitable restoration design using directed succession method should lead to extension and stabilization of populations of the sub-pannonic dry-grassland locality and biodiversity increase.

The 1st stage – accumulation of spoil heap (approximately 3 years)

- If possible, I recommend to protect the part "without spoil heaps" (Appendix 27) from heavy machines or vehicles travelling, because there is already a valuable initial stage of dry grasslands without any expansive or alien plants occurring on the flat bottom (succession to steppic grassland; it will help to fast colonizing of newly established slopes).
- Firstly the accumulation of spoil will start. The area shown in the outline (Appendix 27) should be filled, but an uncovered belt of about 1-2 m will remain along the border with open space (south and west side; spoil heap will touch the rock faces). The accumulation of this heap should be stopped, when it will be no higher than 1 m.
- Than it will be advisable to shape whole this approximately 1 m high heap to very gentle slopes, which should be sloping down into two proposed small lakes (Appendix 27). The shaped heap has to be compacted.
- This shaped heap should be whole overlapped by 20-30 cm of clay (originated from overburdens inside the quarry; cheaper and long-lasting solution than various foils). The clay has to form the compact layer, which will cause that water from whole heap will saturate the small lakes.
- Than the accumulation of spoil may continue (Appendix 28, 29). The upper level of heap should lay 2-3 m below the upper rock faces edge (habitat of chasmophytic vegetation; decay colonization mainly from species rich upper rocky outcrop edges; the height of rock faces fluctuates between approximately 9 m - south and 15 m - north). The newly established heap will have the maximal height at the contact with the rock faces. The largest part of this heap should comprise upper gently slopes (inclination 3°-5°) with south or south-west orientation. Edges of these slopes should incline steeply to the bottom. Certainly it is necessary to reinforce such steep slopes e. g. supporting with large stones. It is crucial that the steep slope foots have to be sharp without any other spoil layer on the plain bottom of mined quarry. Finally the heap surface should be compacted.

The 2nd stage – spoil heap surface shaping

- Now it is appropriate to remove all poplars (*Populus* spp.) growing in the rest of area, which is not covered with spoil heap. It is necessary to rake out the entire surface containing rhizomes of *Calamagrostis epigejos* grass with some bulldozer, which covered great part of the rest area and presents one of the biggest after-reclamation risks. All the material containing rhizomes should be removed. Pine trees (*Pinus sylvestris*) are necessary to remove from rock faces and north rocky outcrops belonging to the edge of locality "Mezi lomy" as well.
- Whole spoil heap should be overlapped by approximately 50 cm thick layer of compact limestone gravel chippings, which will stop the germination of spoil heap seed bank. The gravel layer will slow the succession due to xeric and warm microclimatic conditions of their surface (perennial ruderal plants restriction, but suitable conditions for thermophilous plants). This step should follow shortly after the final heap surface compacting.
- Lower parts of west steep slopes should be arranged to ravine slopes with large stones and boulders due to adding this limestone material on the lower half of the slopes. This part should represent habitat suitable for deciduous woods of ravines. The fissures between stones are suitable for various fauna, e. g. spiders and insect.

- Upper parts of the shaped heap (gentle slopes) should be overlap with a very slight and mosaic layer of soil (about 3 cm). This layer has not to be thicker than 5 cm at any site, because it would be a great opportunity for ruderal and unasked species. The soil layer will be washed off into the gravel subsoil. The soil should come from some overburden inside the quarry. If possible, soil coming from steep forest edges would be the best, because there is a danger of ruderal and alien seed bank within soil coming from abandoned sites and spoils. This step should be done shortly before mulching (about May-June; see 3rd stage) and it is not necessary that this step follow directly after gravel overlapping.
- Finally, now the lakes can be digged at proposed sites (Appendix 27). The lakes should border directly with slope foots.

The 3rd stage – start of greening part of the reclamation

- The main part contains mulching of the newly established slopes with hay, which demands timing of soil layer overlapping (see 2nd stage) and dry grassland cutting to get hay with matured diasporas.
- Many of grass species diasporas mature in the end of June and beginning of July, therefore this is the best time to cutting and mulching. It is necessary to be careful during the hay collecting and choose consistently only the hay without unasked species, mainly *Calamagrostis epigejos* and *Arrhenatherum elatius*.
- The hay coming from the locality "Mezi lomy" should be mulched in thin layer with many gaps, firstly on the new established south steep slopes. The rest of this hay should be mulched on the new established upper gently slopes. I do not recommend using thicker layer of hay mainly because of occurrence of the unasked grass *Calamagrostis epigejos* surroundings and their expansions during formerly performed reclamation.
- The adding of some hay coming from one of selected localities will improve the mulching. A little of this hay should be spread into the mulching gaps. The locality "Mezi lomy" is located in the middle of main gradient of the detrended correspondence analysis. The species composition of selected localities is similar (only Šumbera has more forest character), therefore hay coming from any locality is possible to use (Appendix 3).

The 4th stage – continuation of greening part of the reclamation

- If needed, attention should be pay to the consistent removing of invasive, non-natural and unasked species during first years, (*Pinus sylvestris*, *Populus* spp., *Robinia pseudacacia*, *Solidago* spp. etc). Removing of small poplars and solidagos should be done handmade.
- Next mulching of steep slopes with hay coming from the locality "Mezi lomy" and any selected locality, if it will be appropriate.
- Thermophilous plant species seed collecting during the growing season and planting during autumn. It is possible to collect seeds from plants growing inside the quarry Mokrá, it can be also collected from any of selected localities. This increases plant species richness and extend food possibilities for insect and molluscs.
- Waterfowl will help to spontaneous colonization of newly established lakes, where will settle amphibians as well. It will be possible to take there a little part of rare algae, which occur only in first succession stage of oligotrophic lime lakes.

Expected added value for biodiversity, society and company

This proposal puts together utilizing of spoil heap with directed succession method, which should lead to increase of natural, conservational and cultural value of the landscape and rise of the long-term potential of the current locality "Mezi lomy". Concurrently HeidelbergCement will utilize large part of the interested area to storage and disposal of large amount of waste mined material.
Habitats established within the proposed restoration:

- Dry grasslands on gently slopes (less xeric microclimatic conditions)
- Dry grasslands on steep slopes (more xeric microclimatic conditions)
- Dry grasslands on the flat rocky bottom (accumulation of soil over time)
- Open rocky outcrops (chasmophytic vegetation)
- Decays of rocky outcrops (xerothermophilous vegetation with shrubs)
- Ravine slopes
- Oligotrophic lakes

Conclusions

Regardless the global demand on mining of mineral resources was increased over time and nature had to defer to heavy machines, now the mined quarries give us an opportunity to partly restore some biotopes which formerly disappeared. We should not throw this opportunity away, because other destroyers as settlement or industry destroyed the nature mostly irreversible. I believe that restoration using directed succession method put together with utilizing of spoil heap gives increase to the biodiversity and the local populations would become more stable. This idea is supported also by the history of species rich vegetation of dry grasslands of NPR Hádecká planinka. This locality is secondary, because the former locality was mined over time and the rare vegetation moved to abandoned fields during mining (south part of current national nature reserve). I suppose similar processes in the quarry Mokrá.

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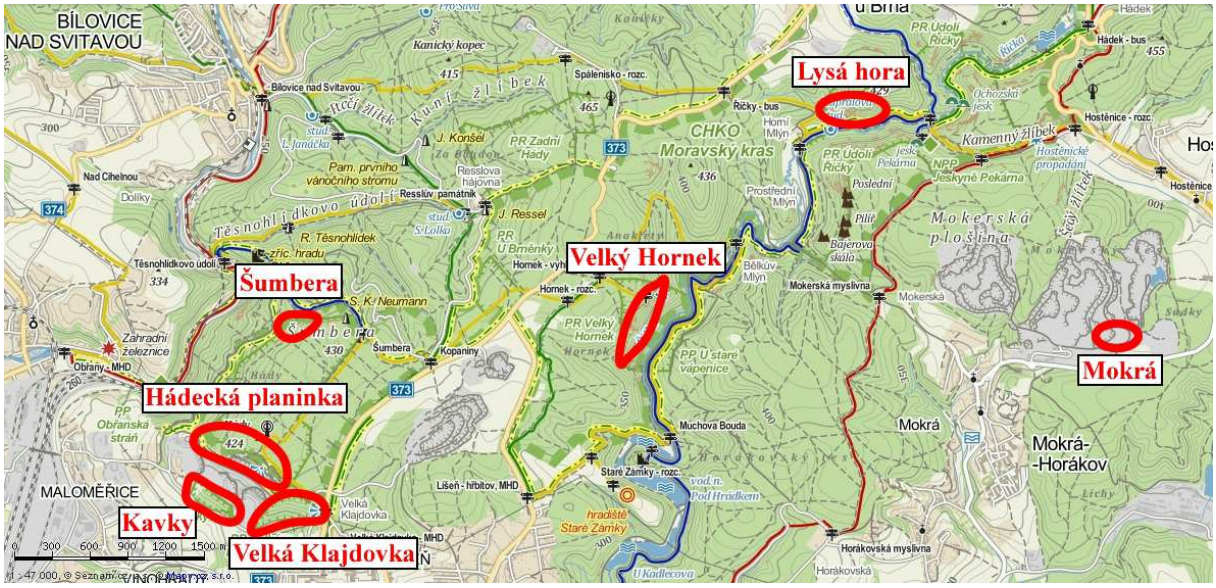
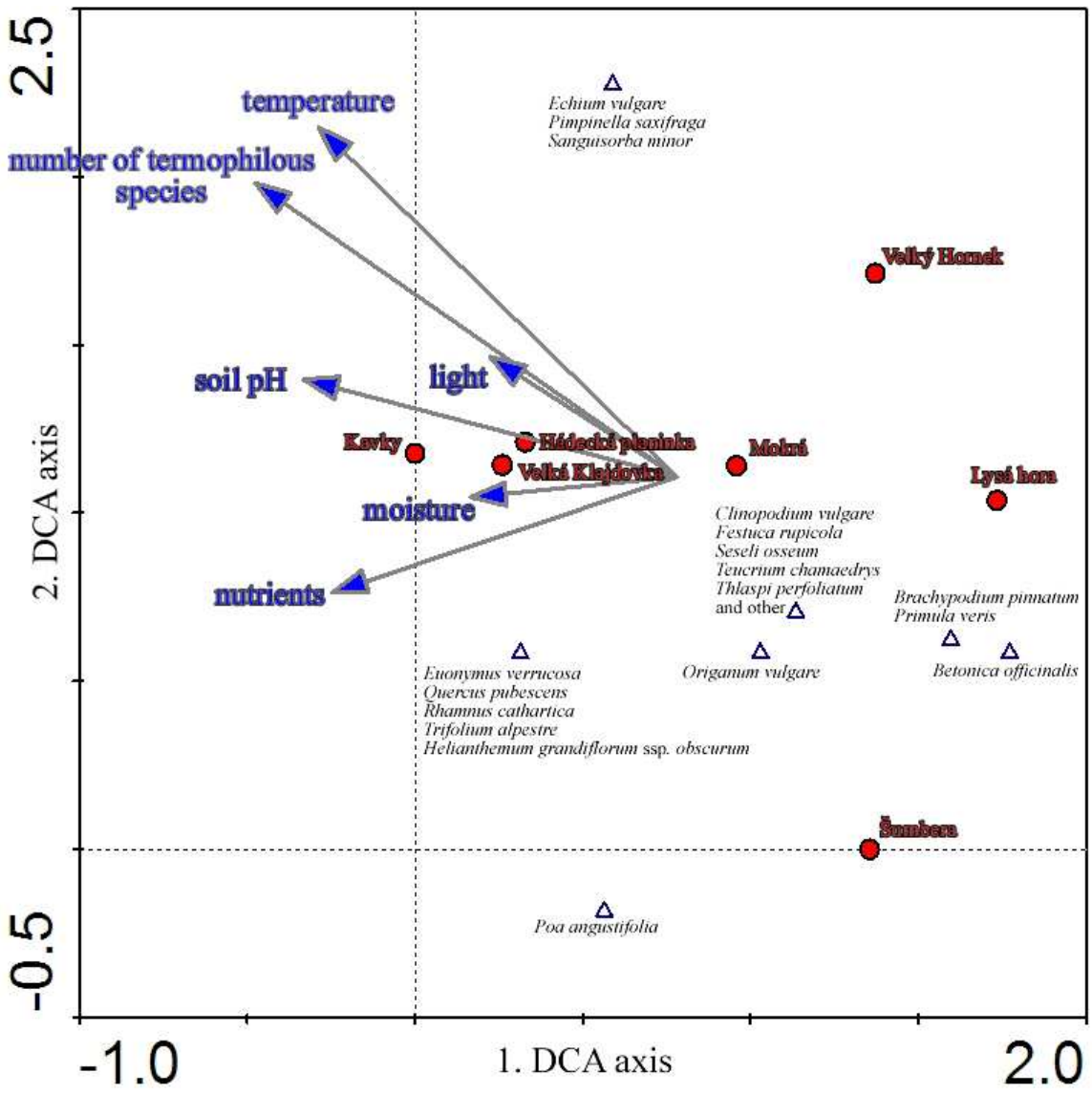
Appendixes

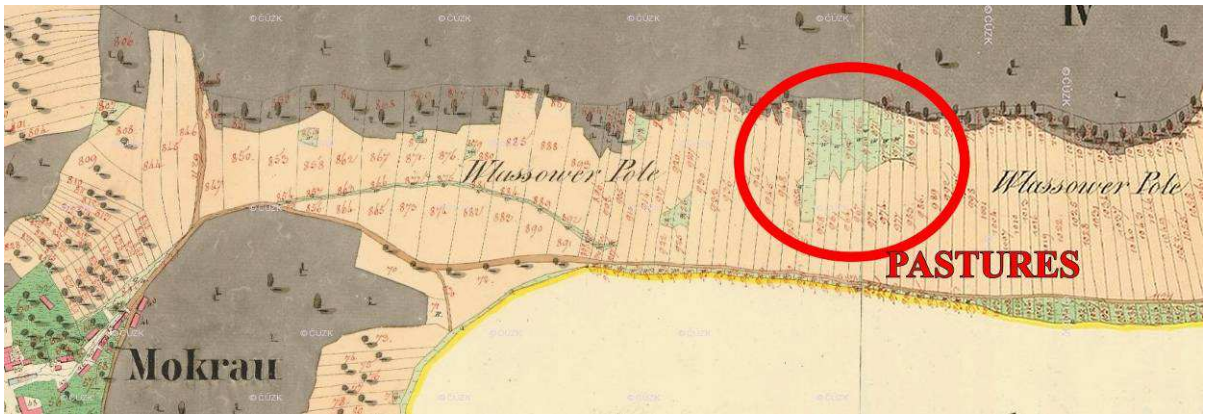
Appendix 1: The area of interest, the locality “Mezi lomy”in the right side and the formerly mined horseshoe-shaped area suitable for restoration in the left side of the red ellipse.



Appendix 2: Position of selected localities, www2.



Appendix 3: Triplot of Detrended Correspondence Analysis shows relations among localities, thermophilous species, number of thermophilous species and Ellenberg indicator values. The diagram shows only species in weight range 70-100%.



Appendix 4: The imperial imprints depict historical cadastral maps originating from 1826, www3.

Appendix 5: The historical orthophotomap from 1953 shows still natural forest canopy openings, www4.

Appendix 6: The historical orthophotomap interlay with current orthophotomap, on the left two larger forest canopy openings with thermophilous plants were completely destroyed by mining and on the right the smaller one exactly corresponds to the locality “Mezi lomy”, www4.

Appendix 7: Raw gravels are covered by *Alysum alyssoides* at the locality “Mezi lomy” in the spring time, 27.4.2012.

Appendix 8: *Cytisus procumbens* on shallow gravelly soil in the central part of the locality “Mezi lomy”, 10.5.2012.

Appendix 9: *Cytisus procumbens* and *Salvia pratensis* dominate in the middle of the upper part of the locality “Mezi lomy”, 10.5.2012.

Appendix 10: *Potentilla alba* by the rock edge in the upper part of the locality “Mezi lomy”, 10.5.2012.

Appendix 11: Strongly endangered pasqueflower *Pulsatilla grandis* (C2) with matured achenes in the locality “Mezi lomy”, 10.5.2012.

Appendix 12: Dwarf trees of *Quercus pubescens* (C4a, § 3) form along the lower margin of the locality “Mezi lomy” very open forest, 27.4.2012.


Appendix 13: Shrubs of endangered *Rosa spinosissima* (C2) grow in rocky outcrop decays in lower and middle part of the locality “Mezi lomy”. Low plant pillow of *Potentilla arenaria* (C4a) grows under the shrub in the right picture, 27.4.2012.

Appendix 14: Plant pillow of *Potentilla heptaphylla* in rocky outcrop decays in lower and middle part of the locality “Mezi lomy”, 27.4.2012.

Appendix 15: Disturbed stones mound with a little soil at the upper part of the locality "Mezi lomy" was colonized by *Teucrium chamaedrys, Hieracium pilosella*, *Sanguisorba minor, Solidago virgaurea* and *Carlina vulgaris*, 27.4.2012.

Appendix 16: Disturbed unemployed unpaved road in the upper part of the locality “Mezi lomy” was colonized by *Echium vulgare* and *Microrrhinum minus*, 14.9.2012.

Appendix 17: Even though majority of trees of *Pinus sylvestris* was removed, there are many seedlings and small trees reappeared again, 27.4.2012.

Appendix 18: Even though majority of trees *Pinus sylvestris* was removed, there are many seedlings and small trees reappeared again. Here with expanding grass *Calamagrostis epigejos*, 14.9.2012.

Appendix 19: The northern tip and eastern part in the middle of the mined area are slowly colonized by several steppic species e. g. *Sedum acre*, 27.4.2012.

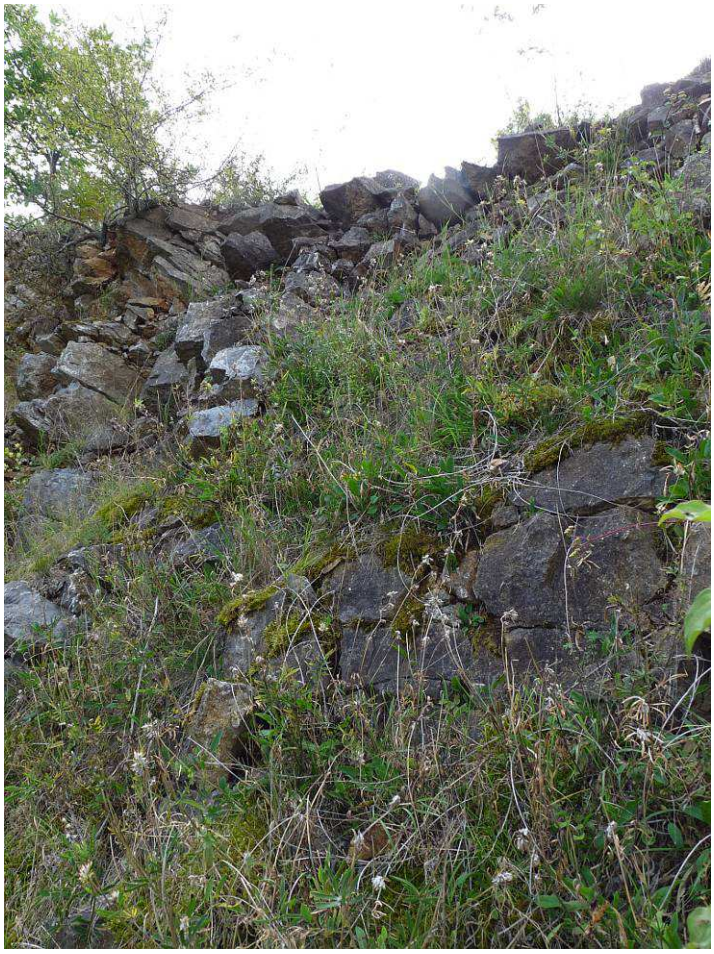
Appendix 20: The northern tip and eastern part in the middle of the mined area are slowly colonized by several steppic species e. g. *Potentilla arenaria*, 27.4.2012.

Appendix 21: The hay originating form the locality "Mezi lomy" is during management actions thrown from the rock faces and help to the colonizing and succession on the adjacent mined area, 14.9.2012.

Appendix 22: Almost all western part and partly the central part of the bottom of the adjacent mined area are covered by *Calamagrostis epigejos*, 14.9.2012.

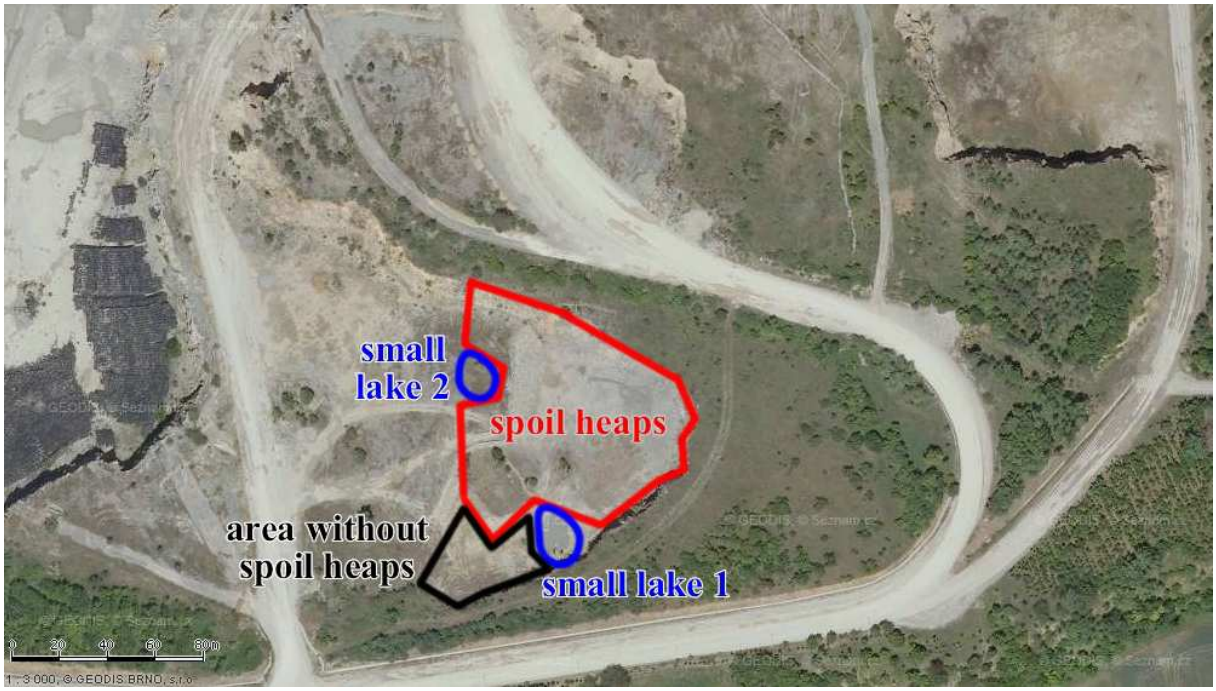
Appendix 23: There are straggly plants of *Epilobium dodonaei* in the middle and east of northern part of bottom of the mined area, 14.9.2012.

Appendix 24: One site near rock faces was obviously mulched, there flower straggly plants of *Inula ensifolia* (C3) and *Erigeron acris*, 14.9.2012.



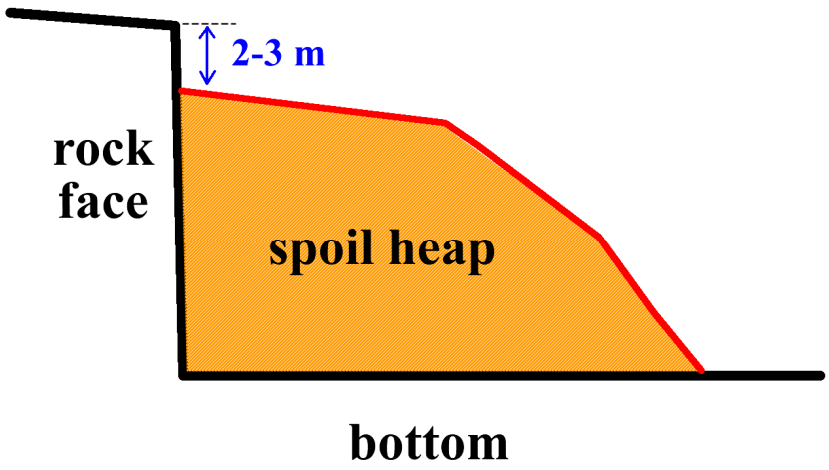
Appendix 25: Southern rock faces are relatively low and decay, there grow some plants from species rich upper rocky outcrop edges e. g. *Anthylis vulneraria*, 14.9.2012.

Appendix 26: Small lake was digged nearby rock faces, but no water has ever been there, 14.9.2012.



Appendix 27: The outline of spoil heap extent, www2.

Appendix 28: The outline of final spoil heap approximate border, the upper level of heap should lay 2-3 m below the upper rock faces edge, 27.4.2012.



Appendix 29: The outline of spoil heap