Erodibility of loess depending on its moisture content and weathering state: field experiments

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Introduction

- Why it is important to study loess erosion?
  - Loess covers about ten percent of the Earth land surface
  - Loess is susceptible to piping, formation of gullies and intense erosion of agricultural soil
  - It is interesting silt-rich material which on one hand supports high vertical cliffs but on the other hand is highly erodible
- What is piping?
  - Erosion process in which cracks and macropores extend into channels with a diameter of cm or more

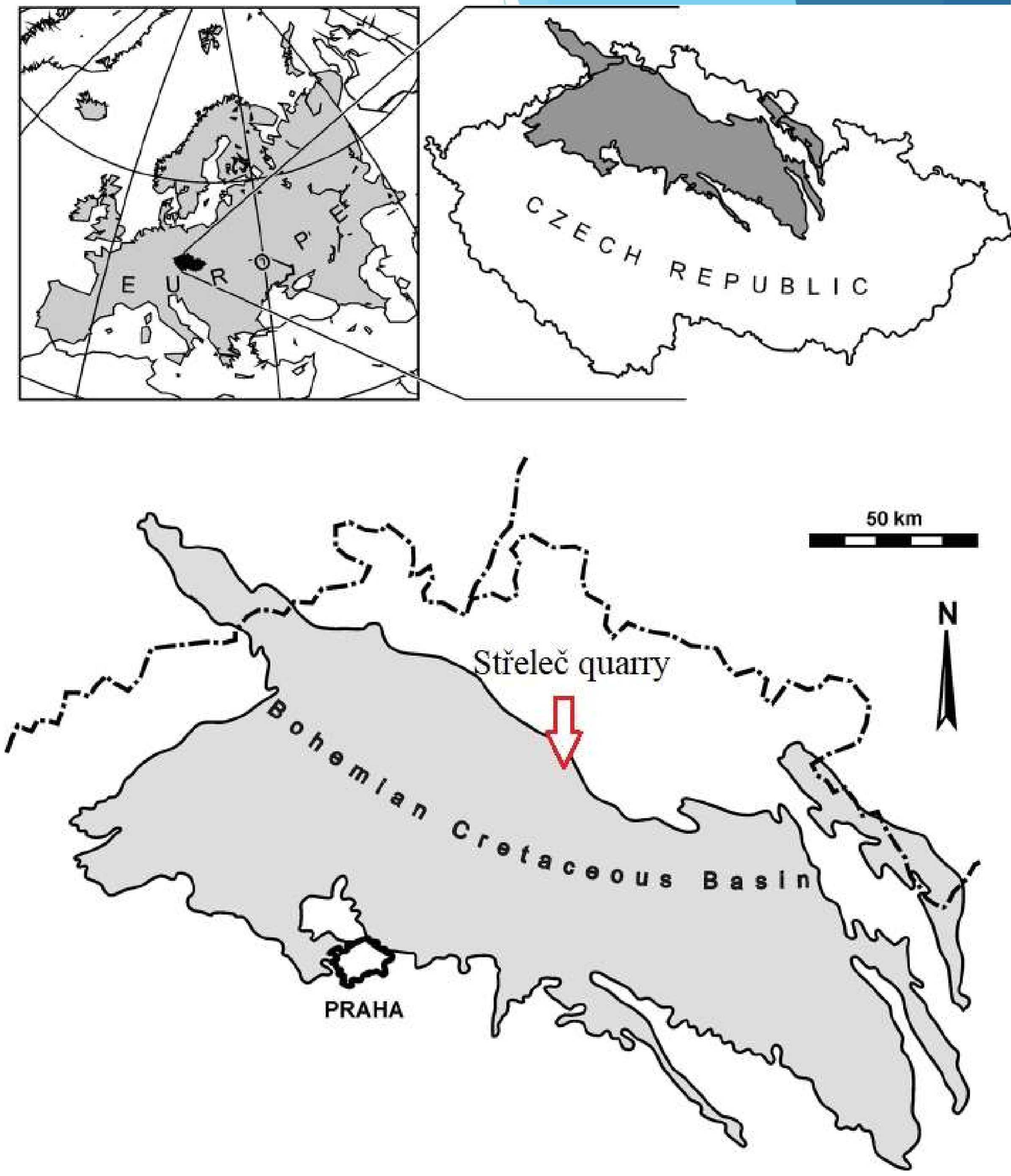
Example of erosional channel in the loess.

Focus and objective of the work

- Objective of this study was to characterize factors which affect erosion of loess
- Three diferent types of water application were used to induce erosion:
  - Water trickle at quarry face (water flowing on surface)
  - Water injected into pre-drilled hole
  - Water applied in form of droplets

Area of interest

- Střeleč quarry
  - Quarry located in Bohemian Cretaceous Basin
  - Quartz sandstones are mined, which are covered by about 10 m thick loess cover in the upper part of the quarry
  - In some parts loess contains cracks and macropores
  - Rill erosion and piping conduits are formed in the loess cover at exposed quarry faces



Area of interest

The upper part of the quarry with loess cove, where experiments took place.

Loess erosion in heavy rain.

Method

- Observation of the existing conduits in loess eroded by overland flow
- Experiments focused on the evolution of conduits and erosion of loess blocks centimeters to decimeters in size
  - Erosion rate of the loess by water trickle at quarry face
  - Erosion under the impact of the droplets
  - Erosion of the pre-drilled hole
- Time-lapse photos of erosion to observe erosion progress
- Erosion retreat at surface of quarry face was measured at installed screws by caliper

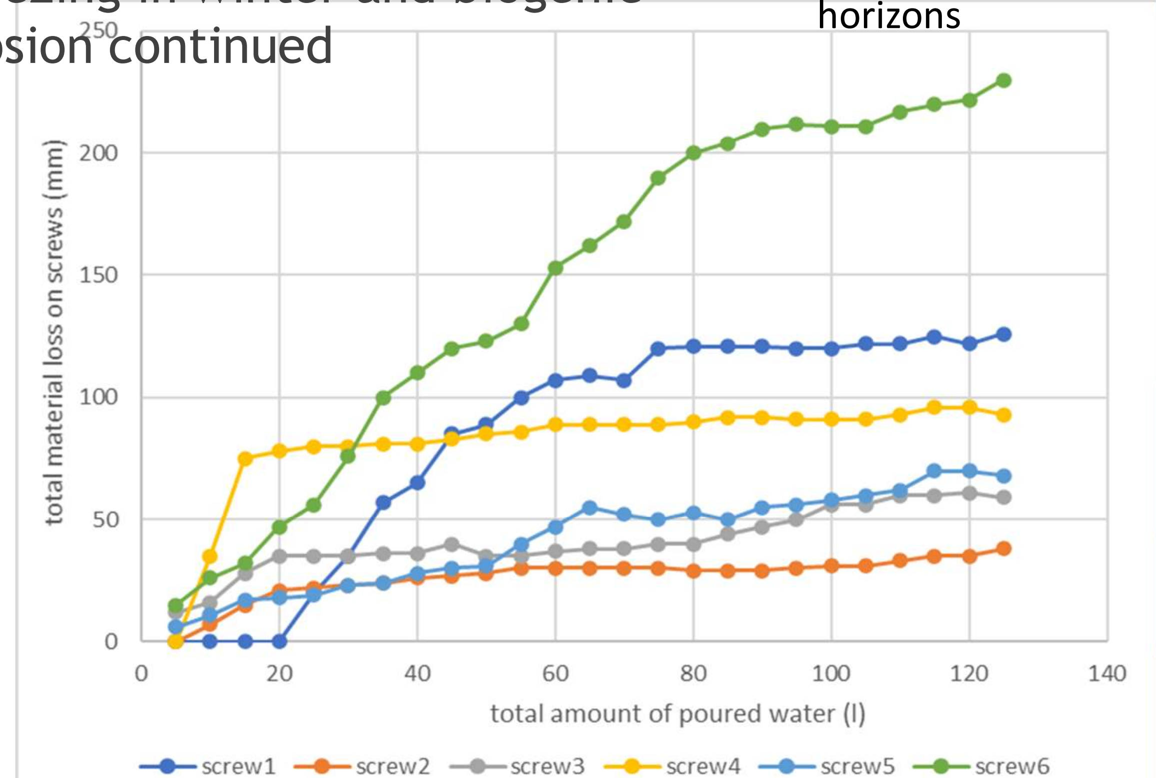
Approach and results: erosion rate by water trickle at quarry face

- Water repeatedly slowly poured from a bucket with a volume of 5l (cca 0,1 l/s) with counting the total volume of applied water
- Water poured on a horizontal surface, to small ditch then flowing spontaneously down the quarry face
- Erosion rate of the newly formed rills was measured using long screws screwed directly into the quarry face
    - After every cycle (a certain number of buckets), the loss of material on the screws was measured and photographs were taken

Example of erosion by water trickle at quarry face.

Experiments at quarry face

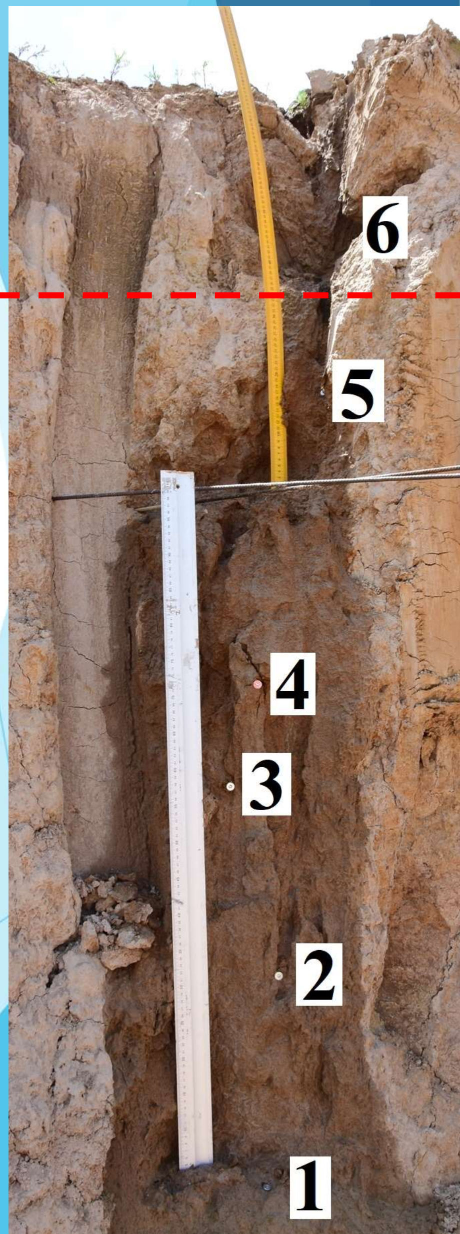
- Experiment with pouring water into horizontal ditch, from which water spontaneously flowed into vertical face of quarry
- At the beginning the erosion was rapid, then it gradually slowed down and at most measuring points it ceased
- Only at screw 6, which was situated in uppermost part with shallow loess with structure damaged by freezing in winter and biogenic activity (roots, earthworms) the erosion continued
- This shows that while loess with damaged structure is highly erodible (retreat 200 mm of loess/120 l of water applied) the underlying loess with intact structure is easily erodible only close to surface, where is probably damaged by repeated drying
- Undamaged loess in situ showed surprisingly low erodibility (few mm/100 l of applied water)



Relationship between erosion retreat of surface and volume of applied water.

Few tens of cms thick surficial zone of loess with structure damaged by biogenic activity, wetting/drying and freezing

Loess with undamaged structure in deeper horizons



Screws position.

Experiment at quarry face

- Small piping conduits developed rapidly by pouring water into small desiccation cracks on the loess surface with damaged structure
- Inlet of the newly formed conduit is marked on the photo (upper-right) by the blue arrow
- The bottom-right photo shows an eroded vertical quarry face below the outlet of the newly formed conduit
- About 150 l of water was poured into desiccation cracks within experiment

Desiccation cracks on the surface, newly formed conduit and eroded vertical quarry wall.

Erosion of the pre-drilled hole

- drill hole 10 mm in diameter and X0 cm in length was drilled through the edge of quarry face (from horizontal surface into vertical face), then roughly constant water flow was applied through it by a garden watering can
- 8 l of water were poured into the hole
- surprisingly the pre-drilled hole was not expanded by erosion at all except its mouth in loess with damaged structure where about 1 kg of material was eroded
- this indicates that piping in loess with undamaged structure might need either the existence of some discontinuities or pre-existing macropores (fractures, burrows) or that loess needs to be damaged

Erosion of the drill hole.

Drill hole at the beginning.

Drill hole at the end.

Erosion under the impact of the droplets

- experiments with pouring water on different sized blocks and blocks of different humidity
- dry and pre-wetted samples were used
- water was poured as drops from a garden watering can
- about 25 l of water was poured on the block on photos



Example of gradual erosion of a dried loess block by impact of the droplets.

Erosion under the impact of the droplets

- moisture content at beginning of experiment have strong impact on erosion rate of small loess blocks
- dry blocks began to disintegrate relatively quickly into incoherent material due to air slaking
- pre-wetted samples did not disintegrated and more or less kept their initial shape
- this shows that slaking is responsible for disintegration of small dry blocks on loess surface

Conclusion

- rapid erosion occurred within first tens of centimeters on quarry face
  - in this zone the primary structure of loess is disintegrated by frost, wetting-drying cycles or by biogenic activity
- below this zone, the erosion rate was surprisingly low
- this shows that undamaged loess is far less erodible than its surficial and weathered zone
- study indicates that piping will not evolve in undamaged loess and sone kind of discontinuities are needed such as fractures or burrows
- erosion is affected by the moisture content of the material
  - the drier the block, the greater the intensity of erosion due to air-slaking which is far more effective in dry soil

Acknowledgement

- We acknowledge the management of the Střeleč Quarry, namely L. Horák, for enabling the fieldworks in quarry and to all those helped in the field
- Research was supported by Charles University Grant Agency (GAUK #1292119)