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Pelma erosion and climate

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Abstract

The base of the valley fill of the River Main was exposed during the construction of a sewage plant close to Bad Staffelstein. The valley fill above the valley base (pelma) consists of three fluments (terrace bodies) of Late Pleistocene age. The deepest but small erosion into the bedrock was created by a meandering river (? MIS 5), indicating warm conditions. Widespread and main erosion within the bedrock of the valley fill took place during late MIS 3 or early MIS 2 - under cold conditions; for the upper two fluments date to MIS 2. The Lower Jurassic bedrock under the valley fill was altered by diagenetical gleying (Dia-Gley).

Key words: pelma (base of the valley fill), fluvial stack, climate, L gravel, V gravel

Kurzfassung

Pelma-Erosion und Klima

Die Baugrube der Kläranlage Unterzettlitz für Bad Staffelstein bot Einblick in die Talfüllung bis hinab auf den Amaltheenton. Die Talfüllung besteht aus drei Flumenten (Terrassenkörpern) des Jungpleistozäns. Das tiefste zeigt in kleinem Ausschnitt einen Mäanderfluss, vermutlich aus dem MIS 5-Interglazial-Komplex — die tiefste Erosion geschah also warmzeitlich. Die Ausformung der weithin ausgedehnten Talerosion bis auf die Festgesteinsoberfläche unter der Talfüllung (das Pelma) fand während des späten MIS 3 oder frühen MIS 2 statt, denn das weithin aufliegende Flument datiert in das MIS 2. Die Basis der Talfüllung verursacht im obersten Amaltheenton eine diagenetische Vergleyung (Dia-Gley).

Schlüsselwörter: Pelma (Basis der Talfüllung), Flusssedimentstapel, Klima

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1 Introduction

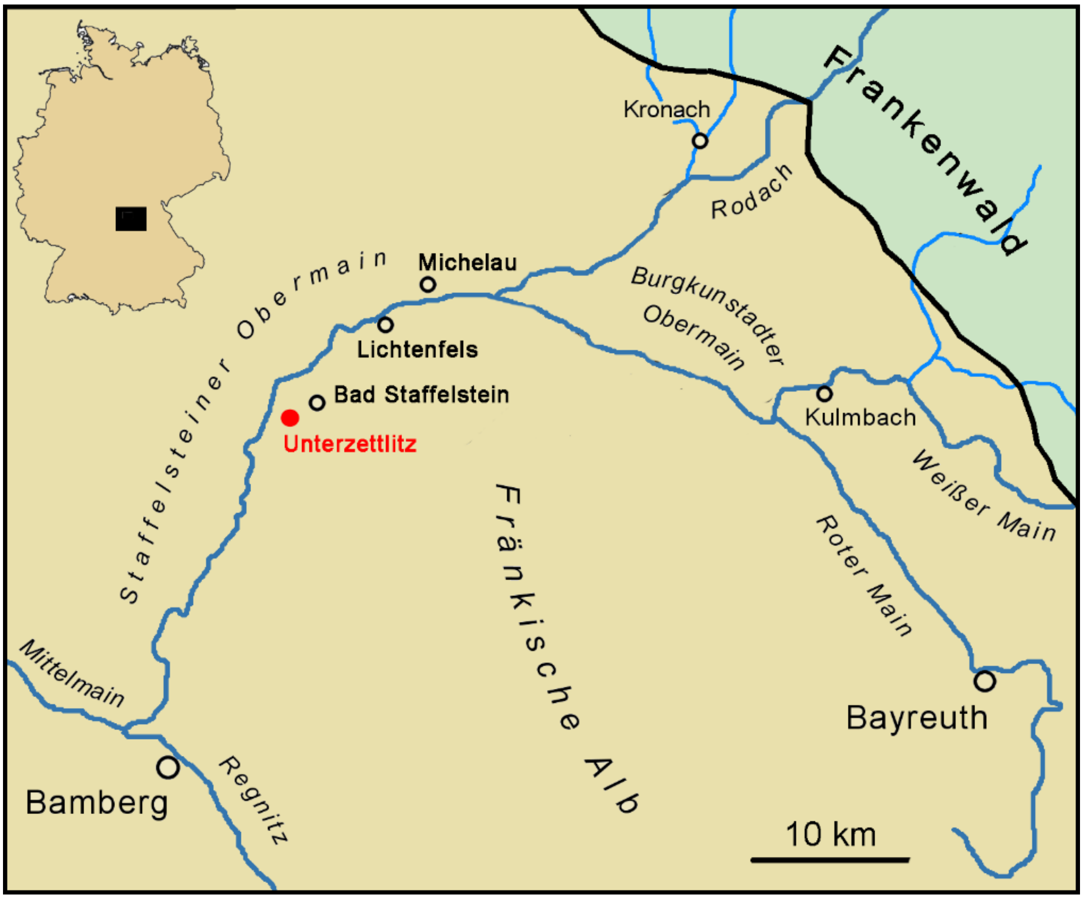

Fig. 1 Location map. Position of the Section Unterzettlitz is indicated in red.

Erosion down to the bedrock of the valley fill of the River Main was visible in the construction pit for the sewage plant of Bad Staffelstein close to the village of Unterzettlitz/Upper Franconia/Bavaria (Fig. 1) in 1992. Geologically, the surface layer is presented by the middle or younger of three Niederterrassen (Low Terraces), which all are of Late Pleistocene age (MIS 2) (Fig. 2 and Tab. 1).

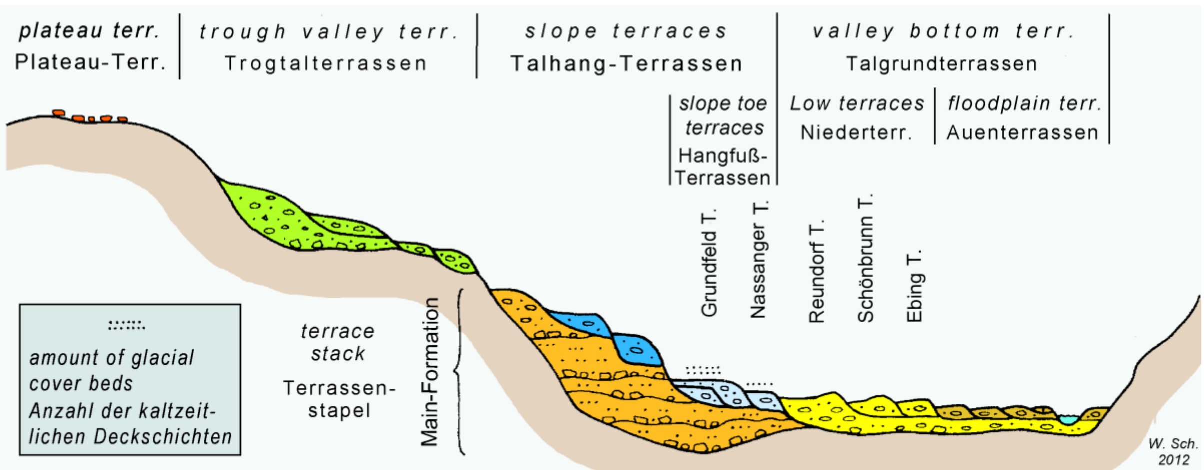

Fig. 2 Scheme of terrace flight of the Main River (from SCHIRMER 2010).

Tab. 1 Niederterrassen of the Main area and age of their fluments.

Terrace	**Flument**
Niederterrasse 3 (Ebing Terrace)	14.5 – 11.6 ka
Niederterrasse 2 (Schönbrunn Terrace)	c. 20 – 14.5 ka
Niederterrasse 1 (Reundorf Terrace)	(?70–) c. 30 – 20 ka

The pit (Fig. 3) reaches through the valley fill down to the bedrock to a depth of 4.5 m.

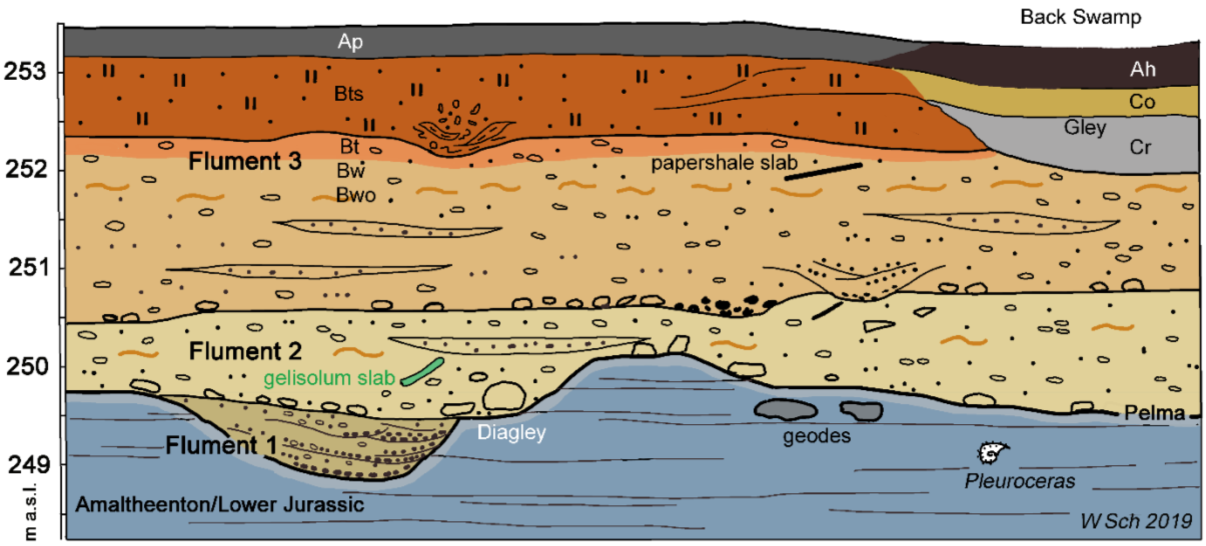

Fig. 3 Schematical sketch of the construction pit of the sewage Unterzettlitz close to Bad Staffelstein/Bavaria. Length about 100 m. Height enlarged about eight times.

The questions are, are there one or more valley fills, of what kind and age are these fills, and what is the nature of the contact to the bedrock? When and under which climate did the erosion reach the bedrock?

2 The valley fill of the sewage plant and its age (Fig. 3)

Definitions:

1. Flument (Fig. 4): Up to now the term river terrace is often used for the morphological river terrace, as well as, for the entirety of the sedimentary terrace. The latter is replaced by the term "flument" (SCHIRMER 2019). Flument is derived from Latin flumen = stream or river.

2. Pelma: Greek: pélma = sole. Pelma defines the very base of a valley fill, under which follows the bedrock.

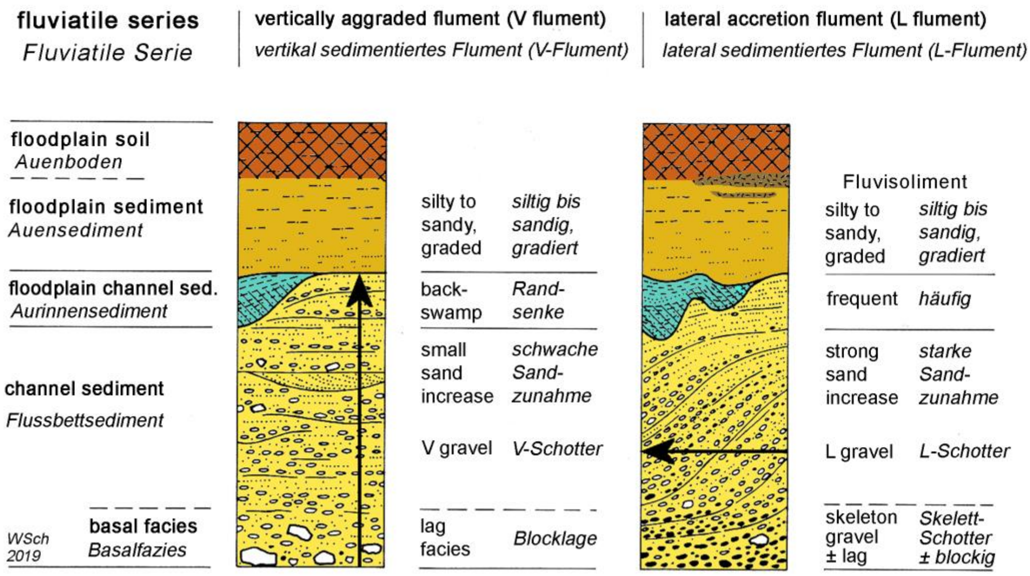

Fig. 4 Flument (terrace fill) presenting the fluviatile series with its parts, shown for a vertically aggraded flument (V flument) and a lateral accretion flument (L flument). The former is mostly realized in braided rivers, the latter in meandering rivers. Oblique hatching means gleying within the floodplain channel sediments. Modified after SCHIRMER (1983: 25).

The valley fill in this pit shows three fluvial units (fluments) (Fig. 3).

Flument 3: Floodplain deposit with floodplain soil underlain by an upper gravelly channel deposit
———unconformity
Flument 2: lower gravelly channel deposit
——— unconformity
Flument 1: Basal gravel channel
——— unconformity: Pelma: Bedrock contact of the valley fill
Bedrock: Amaltheenton Formation (Lower Jurassic)

Geological log of the valley fill (27.09.1992):

Location: Sewage plant Bad Staffelstein-Unterzettlitz, 27, 09, 1992
Gauss-Krüger coordinates: R 4426353, H 5551923; Elevation of the top: 253.50 m a.s.l., i.e., about 3.50 m above the Main River level.

Flument 3: *One of the younger Low Terraces (Niederterrassen) (see Tab.1)*		
Ap	- 0.30 m	***Floodplain deposit with floodplain soil**:* Loam, medium sandy, humic, non-carbonaceous
Bts	- 0.90 m	Loam, medium sand, weakly coarse sandy, few gravel, reddish brown, polyhedral to prismatic structure with red brown clay coatings, vertical light grey bleaching streaks with rusty seams, non-carbonaceous
Bts	- 1.10 m	Medium sand, coarse sandy, fine to medium gravelly, loamy, reddish brown, loam stripes, locally cryoturbations, gravel spread in a disordered way, clay coatings around pebbles, vertical light grey bleaching streaks with rusty seams, free of limestone, non-carbonaceous
Bt	-1.50 m	***Channel deposit*** *(V flument, see Fig. 4)*: Gravel, medium to coarse grained, few stones, reddish grey, clay coatings around pebbles, non-carbonaceous, free of limestone
Bw	-1.80 m	Gravel, medium to coarse grained, few stones, scarce papershale slabs from the Posidonienschiefer Formation, light brown, free of limestone, non-carbonaceous
Bwo	- 3.00 m	Gravel, medium to coarse grained, few stones, brownish grey, rusty streaks, non-carbonaceous, limestones with strong chalky halo, at base locally skeleton gravel and stone/block layer.
- - - - unconformity, flattish		
Flument 2: *Socle of the Reundorf Terrace (Niederterrasse 1), „qpo1“ of the Bavarian Geological Survey*		
Co	- 4.00 m	***Channel deposit*** *(V flument)*: 0.35–1.30 m gravel, medium to coarse grained, rich in stones, scarce papershale slabs from the Posidonienschiefer Formation (Lower Jurassic), many through-shaped sand interlayers up to 20 m in length, sharp-edged thin plate of sand medium grained and loamy, 40 x 1.5 cm in size (former gelisolum slab), light yellow grey, rusty streaks, carbonaceous, at base stone to boulder layer (up to 40 cm in diameter)
- - - - unconformity, flattish		
Flument 1: *Local channel 40 m in length and 0,90 in depth (?Eem interglacial)*		
C	- 4.90 m	***Channel deposit*** *(L flument)*: Gravel, medium to coarse grained, and sand, medium to coarse grained, yellow grey, non-carbonaceous, free of limestone, bedding shows large-scale, low-angle cross-bedding (= lateral accretion type, respectively L-gravel type)
- - - - unconformity (formed by the pelma): undulate		
Bedrock: *Lower Jurassic Amaltheenton Formation*		
dBwro	- 5.00 m	Clayey marlstone, softer than beneath, lighter in color, olive brown oxidized, dBwro = diagenetically weathered Bwro horizon
C	- 6.50 m	Clayey marlstone, dark grey, well bedded, some septarian calcareous geodes up to 50 cm in diameter, ammonites *Pleuroceras spinatum* (BRUGUIÈRE).
Base of the pit		

Survey of the valley fill

The aggradation of the valley fill is often composed of different fills of various types and various ages. In the case presented herein, it shows three fluviatile accumulation bodies, i.e., three fluments, lying in superposition.

Flument 1: Is preserved as a localized channel of 40 m in length and 0,90 m in depth. Its base is cut into the bedrock and represents a flat scour hole in the pelma. Gravel deposits associated with Flument 1 show bedding of a meandering river (L flument).

Flument 2: An up to 1.3 m thick gravel fill presents even or trough bedding representing a braided river (V flument). It covers and overlaps Flument 1, thus forming the pelma to the side of Flument 1.

Flument 3: A distinct unconformity separates Flument 2 from Flument 3. It is underlined by a boulder/block layer at the base of Flument 3. Above an up to 3 m thick gravelly channel deposit presents even or trough bedding of a braided river (V flument; as observed in Flument 2). Its floodplain deposit, up to 1,3 m thick, is composed of finer sandy to silty loam. During its deposition a back swamp developed near the valley edge (right side of Fig. 3). Towards the end of the floodplain sedimentation, floods sporadically deposited fines alternating with soil formation. The soil type is classified as a luvisol. In the back swamp a Humic Gleysol formed.

Ages of the three fluments

Flument 2 of the pit can be assigned - after the study of extensive areas of the valley fill - to the first of the three Niederterrassen, the so-called Reundorf Terrace of the Main River of Weichselian age with bulk deposition during early Late Weichselian age (Tab. 1).

Flument 3 represents one of the two younger Niederterrassen, the Schönbrunn or Ebing Terrace (Tab. 1). A detailed terrace mapping of this area is missed up to now. Cryoturbations within the floodplain deposit - visible in the midleft portion of Fig. 3 – as well as the black soil formation in the back swamp depression are characteristics of both terraces.

Flument 1 has been formed by a meandering river manifested by the slip-off-slope bedding, skeleton gravel and L gravel type (Fig. 4). Those river types normally indicate warm climate (see item 3).

3 Pelma: The surface of the valley base

By looking at a complete vertical cut of the valley fill two questions arise:
During which climate was the valley ground scoured out?
How does the pelma (bedrock surface) of the valley ground look like?

The base of the valley fill, the pelma, is the main concern of this paper. It is scoured into Mesozoic rocks. This bedrock is a bedded marlstone of the Amaltheenton Formation of middle Lower Jurassic age. Fossil ammonites like *Pleuroceras spinatum (*BRUGUIÈRE) indicate the higher part of the Amaltheenton Formation for this bedrock. Likewise, thick septarian concretions (calcareous geodes) occur in this upper part of the Amaltheenton Formation.

Within 100 meters lateral distance and with differences in altitude up to 1.4 m the pelma of Flument 1 and 2 gives the impression of a very defined and horizontal line drawn very even in some places and very rough in other places.

This base relief is interesting in three concerns:

3.1 Difference in altitude of the pelma

Local depressions of the pelma may be caused by locally deeper erosion of the flument or may likewise be caused by a relic of an older flument channel that has been preserved within a depression below the erosional base of a younger flument.

In a coring that would really hit the perfectly hidden Flument 1, hardly anyone would recognize an older relic of a flument unconformably cut by a younger flument.

3.2 Under which climate does a river reach the pelma?

The deepest fluvial erosion in the outcrop discussed herein was created by Flument 1. As it is preserved only locally, it is discussed below.

The largest parts of the base of the valley fill were formed by the base of Flument 2. This essential erosion took place already before the deposition of the flument that belongs to the Niederterrasse 1 (Reundorf Terrace). Beyond this locality this flument hosts ice wedges, mammoth teeth of *Mammonteus primigenius* - dated by ^{14}C to 23 415±475 years BP- and the peaty interstadial “Abtswiesen Beds“ 14 km upvalley from here, dated by C_{14} to 20 525±410 years BP and by interstadial pollen (SCHIRMER 1978: 151). Thus, the erosion happened during the middle part of the last ice age (MIS 3) or in the very beginning of MIS 2 - in any case during a milder phase of the later Last Glacial period.

Moreover, there is still the earlier erosion indicated by the basal remnant of the Flument 1 preserved in a scour hole. This remnant clearly implies a warmer period. Great probability points to the last interglacial complex. In the Upper Main River area, the penultimate glacial left a river terrace of unusual low elevation, unusual in comparison to the Lower Main and Rhine area. It is the Nassanger Terrace of MIS 6 age (pm3 terrace of the Bavarian Geological Survey). Its surface in this area lies approximately 5.5 - 6.5 m above the Main River level. The same low level of this terrace is recorded from the Regnitz River, located 43 km to south of here in Wannbach (SCHIRMER & FUCHS 2018). Thus, it is likely that - from the low initial position - the meandering river of the following last interglacial (MIS 5) could cut deeply into the bedrock.

The same procedure is visible during our recent warm period. Though by the Reundorf Flument the largest portion of the recent valley base was scoured out, there are punctual places where Holocene fluments scour likewise down to the Mesozoic bedrock. It is, in this special case, the flument of the Zettlitz Terrace of Iron-Roman age (200 BC-250 AD; SCHIRMER 1983: 23) southeastern of Michelau, about 13 km upriver from here.

As conclusion it can be stated, that during warm, interglacial periods erosion may reach the lowest depth in the valley ground, even though the larger portions of extensive erosion to the pelma happened during mild phases of the ice age.

3.3 Alteration of the bedrock below the pelma

Where rocks rich in pore volume overlie rocks poor in pore volume, the water saturated pore-rich rocks react with the drier rocks beneath. The result is gleying of the basal rock. This is especially visible when sand or gravel overlie clay. This effect takes place at greater depth below the recent surface soil. It is not bound to a certain time or climate, to an influence of the atmosphere, or biosphere, as it is working with the surficial soil formation. It is a hydrological effect initiated by water presence of the overlying aquifer. Therefore, it is a process of diagenesis rather than a subaerial part of the surface soil.

In the case presented here it is a diagenetical Gley or Dia-Gley. The affected horizon in Unterzettlitz shows decomposition, gleying and oxidation of the upper 10 cm of the marlstone.

4 Acknowledgements

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