

Here it hit, there it missed: Late Quaternary patterns of deposition and fluvial incision, Steinberg am Roфан (Northern Calcareous Alps)

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The Quaternary near Steinberg am Roфан records ?pre-Würmian to Würmian fluvial bedrock incision that was followed, during advance of glaciers in buildup of the Last Glacial Maximum, by rapid sediment aggradation which, in turn, was succeeded by late-Glacial to Holocene re-incision of rivers. Fluvial re-incision led to re-activation of old bedrock channels in some river reaches, whereas along other reaches, bedrock incision took a new course. Different reaches of a bedrock-incised mountain river thus may originate during distinct intervals of time and may have different geological histories. Fluvial incision changing with aggradation and re-incision resulted in “jig-saw” dissection of bedrock along a truncation surface of highly complicated shape.

The investigated area has a rock substrate of middle and upper Triassic shallow-water carbonates (Wettersteindolomit, Hauptdolomit), unconformably overlain by a variegated Quaternary succession. The main rivers draining the area are Grundache and Mühlbach. Both these rivers show bedrock-incised reaches as well as reaches incised into un lithified Quaternary deposits. From bottom to top, the Quaternary succession consists of fluvial gravels and sand, overlain by proglacial-lacustrine banded silts that, in turn, interfinger with and are overlain by foreset-to-topset packages of Gilbert-type deltas. Above, a reworked glacial moraine rich in garnet amphibolite (index lithology of Inn glacier of the LGM) is overlain by a late-Glacial to Holocene succession mainly of fossil rock glaciers, of relict talus fans, and of inactive and active talus slopes. Today, both the rock glaciers and talus fans are deeply incised by Grundache and Mühlbach, and by their tributaries.

The southwestern and eastern part of the area is drained along Grundache-Klamm, a bedrock-incised gorge debouching into Brandenberger Ache. Whereas the downstream (eastern) reach of Grundache-Klamm is incised into bedrock at the base of a V-shaped valley, the upstream (southwestern) reach is incised into an overall U-shaped valley formed, probably, by glacial erosion. In the upper reach, a dry but perfectly preserved bedrock gorge („Trockene Klamm“) about 600 m in length, and linked with a dry waterfall chute to a perfectly preserved dry river bed immediately upstream, is present. Today, the dry river bed is elevated above the floor of the active Grundache-Klamm by about 15 meters in altitude. Downstream, both Trockene Klamm and Grundache-Klamm merge at the same level; this strongly suggests that Trockene Klamm was cut off drainage by re-activation of Grundache-Klamm only short time ago (well-after the LGM). On the bedrock cliff along Grundache, where Trockene Klamm branches off, a fluvial

conglomerate is preserved. Th-U age-dating of calcite cement of the conglomerate yielded a cementation age of 30 ka. This indicates that this reach of Grundache-Klamm was incised into bedrock at or before the Last Glacial Maximum. In addition to Trockene Klamm, at two other locations, well-preserved dry waterfalls and bedrock chutes were found.

The described Quaternary succession, drainage patterns and radiometric age of calcite cement are integrated into the following history. At least that reach of Grundache-Klamm wherein the age-dated conglomerate cements were found existed before 30 ka bp. Both the fluvial gravels at the base of the Quaternary succession and the overlying lacustrine-deltaic package accumulated upon marked local base-level rise associated with blocking of Grundache valley by an advancing glacier in the trunk valley. During lacustrine-deltaic deposition, at least along its entire upper (southwestern) reach, the “old” Grundache-Klamm was buried by sediments. Subsequent to lake deposition, during the LGM, the entire area was overridden by ice. During the late-Glacial, high sediment input from carbonate rock terrains (Rofan, Guffert-Unnutz) led to another pulse of sedimentation mainly as rock glaciers and talus fans. Only subsequently, upon persistent warm climate and hillslope stabilization, erosional re-incision commenced and continues til today. The re-incision of Grundache commenced in the thick upper Würmian to post-Glacial sediment cover. As a result, the older (buried) bedrock-incised course of Grundache became re-activated, or “hit again”, only along some reaches while other old reaches were “missed” by the newly down-cutting river, and new reaches became incised that are late-Glacial to post-Glacial in age. Trockene Klamm is interpreted as a post-LGM bedrock gorge formed during rapid fluvial re-incision, but that fell dry when erosion had attained the level of the old, pre-existing Grundache bedrock gorge. Marked sediment accumulation changing with fluvial incision led to dissection of the bedrock into steep-flanked hills and elongate, steep-flanked ridges. Our data show that in bedrock-incised mountain rivers, different reaches of the river course can have originated during distinct intervals of time and have different geological histories.