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Excursion 3

HYDROGEOLOGY
of the
TANNEBEN-LURBACH-KARSTSYSTEM

Central Styrian Karst

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Time schedule of the excursion

8h: Departure from Graz in front of the main building of the University of Graz (Universitätsplatz 1, 8010 Graz).

8h30: First stop in/near Peggau. Overview of the Tanneben-Lurbach-Karstsystem, geology and topography (**stop 1** in Fig.1).

9h15: Lurgrotte Peggau, short introduction of the cave system, then visit of the water-active part of the cave up to the “Prinz” stalactite (**stop 2** in Fig.1).

11h45: Hammerbach spring, measuring and monitoring devices of the karst spring (**stop 3** in Fig.1).

12h30-14h: Lunch break at a restaurant in Peggau (Gasthof Salomon).

14h: Departure to Semriach.

14h30: Stop in the Semriach Basin, overview of the allogenic catchment (**stop 4** in Fig.1).

15h: Short stop at one of the small dolines located at the boundary between the schists (Semriach Basin) and limestones (Tanneben karst-plateau): Katzenbachschwinde, Neudorferschwinde or Eisgrube (**stop 5 and 6** in Fig.1).

15h30: Entrance Lurgrotte Semriach. Explanations and short visit into the cave to see the main sinkhole of the Lurbach stream (**stop 7** in Fig.1).

16h30: Expected departure time back to Graz (arrival at about 17h00 in Graz).

Topography

The Lurbach-Tanneben-Karstsystem is located approx. 20 km north of Graz and belongs to the Central Styrian Karst (Figs. 1, 2, 3). The autogenic recharge area (Tanneben karst massif) is bordered by three valleys, the river Mur in the west, the Badlgraben in the north and the Mitterbach-Taschen boundary in the south. The Semriach Basin in the east with the upper Lurbach catchment represents the allogenic recharge area of the whole Lurbach-Tanneben-Karstsystem.

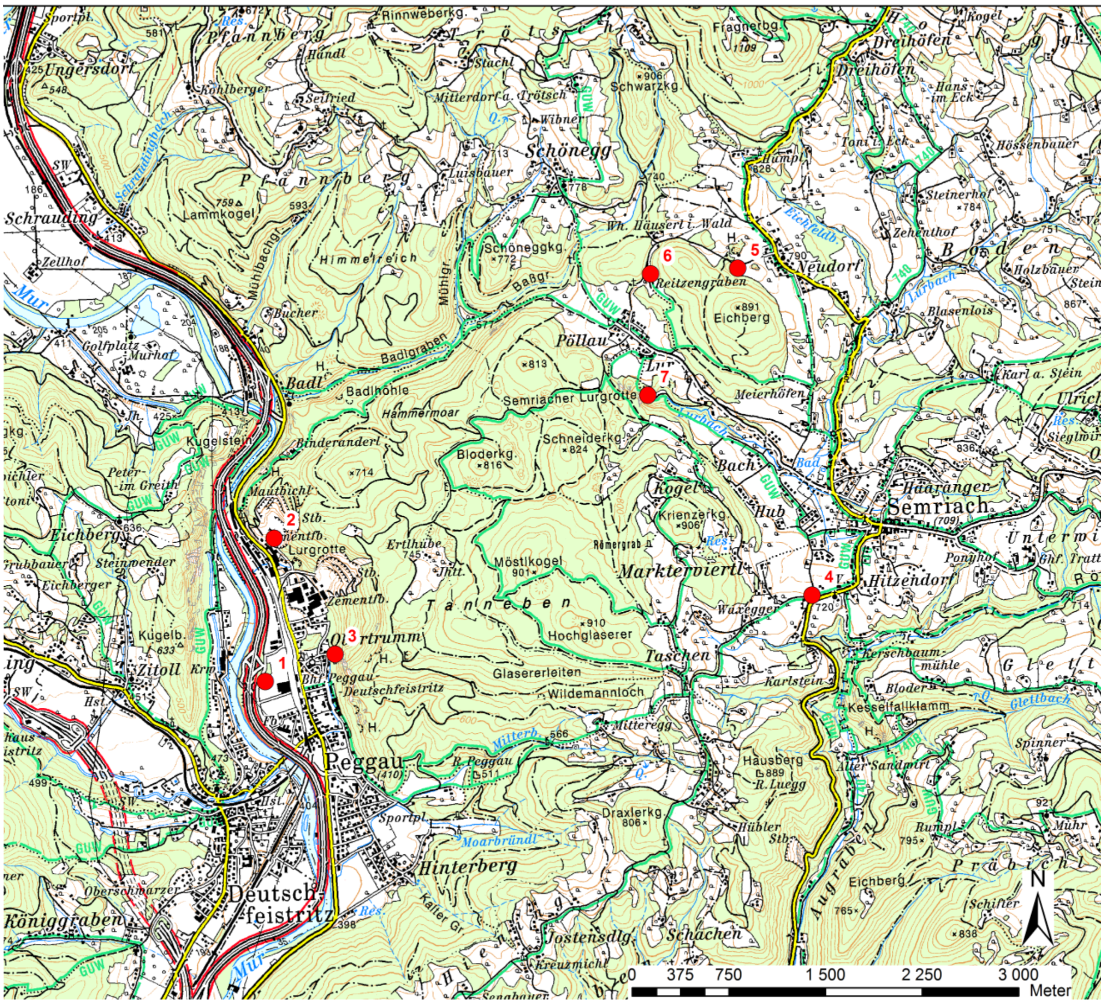


Figure 1: Topographic overview of the area (AMap Fly, 2005), red dots = excursion stops.

Karst area Tanneben:	8.3 km²	lowest point: 400 m a.s.l. (Peggau) highest point: 910 m a.s.l. (Hochglaserer)
Lurbach catchment:	14.5 km²	lowest point: 633 m a.s.l. (entrance Lurgrotte Semriach) highest point: 1109 m a.s.l. (Fragnerberg)

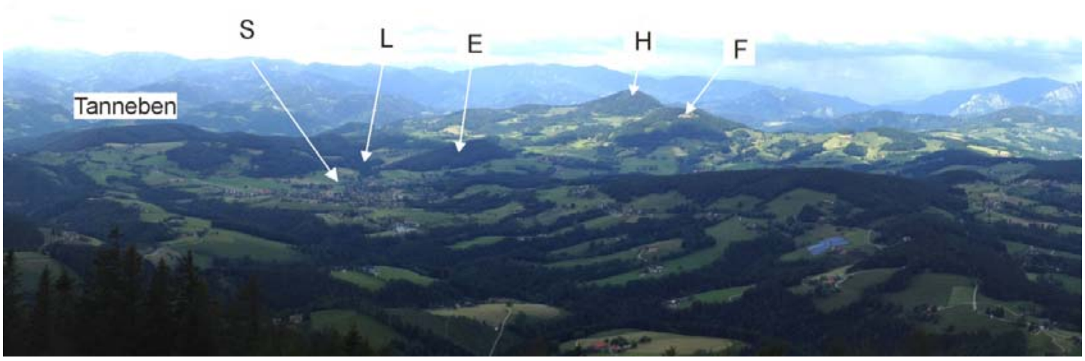


Figure 2: Overview of the Semriach Basin and the upper Lurbach catchment; view point from the Schöckl (1445 m a.s.l.) towards the NW. S = Semriach/church (709 m a.s.l.), L = Lurgrotte Semriach (633 m a.s.l.), E = Eichberg (891 a.s.l.), H = Hochtrötsch (1239 m a.s.l.), F = Fragnerberg (1109 m a.s.l.).

Geology

The karst area consists of a low grade metamorphic limestone (Middle Devonian Schöckel formation) overlaying older Paleozoic schist series (Semriach-Phyllite formation) representing the aquiclude (Fig. 3). Based on the nappe structure of the Paleozoic of Graz and the tectonic displacement of individual sections (e.g. Maurin, 1992; Gasser et al., 2009) the karst area can be clearly delimited from the Semriach Basin in the east and the Silurian-Devonian schist series (Taschen formation) of the Hiening in the south (Figs. 3, 4). The carbonate rocks of the Tanneben plateau reach below the present floor of the Mur valley which is filled with quaternary sediments. Drillings and surface geophysical investigations suggest an overdeepening of the valley of about 40 m below the present surface. Neogene sediments lie as relicts locally dispersed on the Tanneben plateau. High terrace and low terrace sediments (Riss and Würm age, respectively) were deposited in the Mur valley and still exist at its margins.

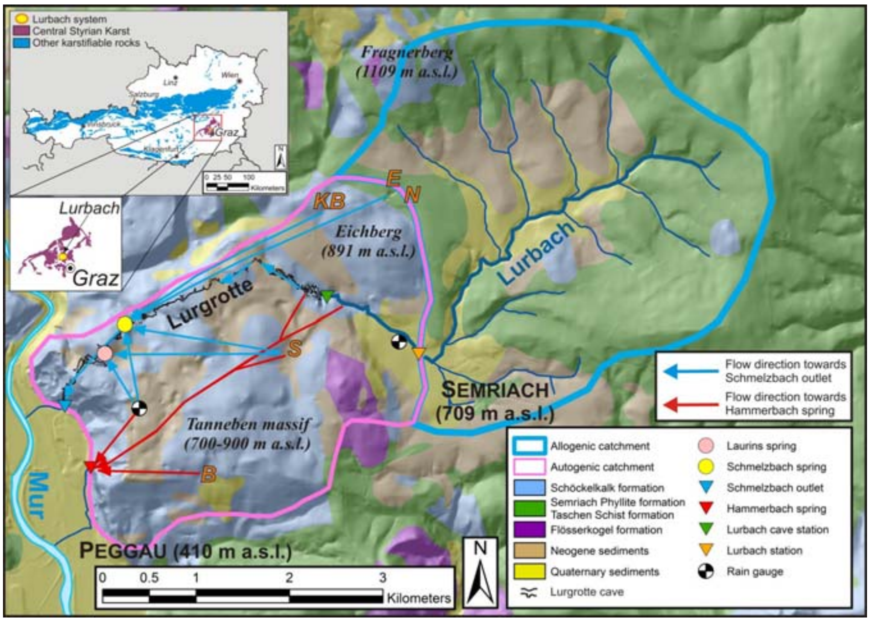


Figure 3: Geological and topographic overview of the Lurbach-Tanneben-Karst system. Tracer injection points: B=Brunngraben, S=Schneiderkogel, KB=Katzenbachschwinde, E=Eisgrube, N=Neudorfer Schwinde (modified after Mayaud et al., 2014).

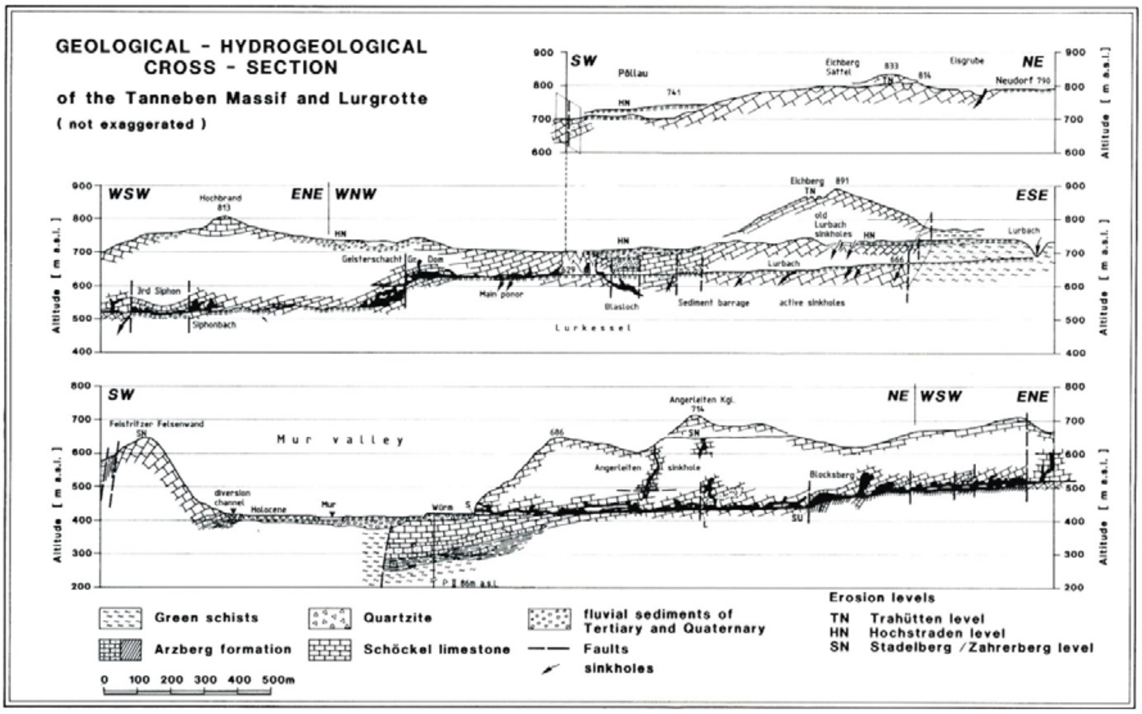


Figure 4: Geological cross section along the cave Lurgrotte (Maurin, 1992, based on Bock, 1929).

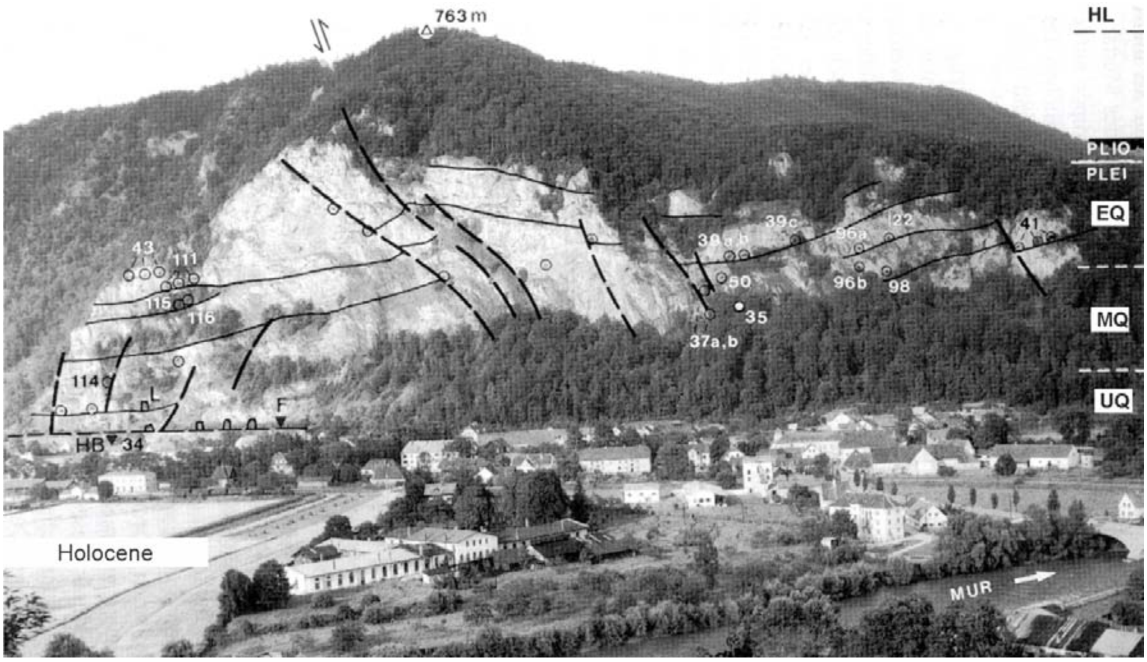


Figure 5: The cliffs of the Peggauer Wand with the cave locations and a thrust fault in the middle of the cliff dipping towards the south east. Caves are bound to bedding planes and faults. Elevation difference between valley floor and Tanneben karst-plateau is about 350 m. Black lines=bedding planes, dashed lines=faults, circles=location of registered caves (some with registry numbers), HL=Hochstraden level, Plio/Plei=Stadelberg/Zahrerberg level, EQ=Early Quaternary (Upper Terrace Group), MQ=Middle Quaternary (Middle Terrace Group), UQ=Upper Quaternary (Lower Terrace Group; including Würm and Riss terraces), HB=location of the Hammerbach spring, F=entrance level of the artificial tunnel system "Felshütte Peggau", approx. coincident with the Würm terrace level, L= Ventilation tunnel (photo: H. Maurin, modified after Maurin & Benischke, 1992)

Hydrogeology

The whole karst system is mainly drained by the Hammerbach spring and the Schmelzbach spring (Fig. 3). The recharge of the karst system comprises an allogenic and an autogenic recharge component. The allogenic component is the Lurbach stream which drains the Semriach Basin (14.5 km²) and totally infiltrates into the Tanneben karst-massif after passing the contact between shists and limestones. The last 100-200 m upstream of the cave entrance the stream passes a gorge and flows through a large collapse doline (Lurkessel, Fig. 4) and finally disappears in the sinkholes some meters behind the Lurgrotte cave entrance. During extreme flood events the Lurbach stream flows directly into and through the Lurgrotte cave system with a total length of about 6 km. In addition an autogenic recharge component on the karst plateau is obvious and could be proven by tracer tests (Fig. 3).

Figure 6: Flood event (2009) at the entrance of Lurgrotte Peggau (left), Schmelzbach outlet at Peggau (middle), Schmelzbach spring in the Lurgrotte (right) (locations in Fig. 3).

General water balance data

After Harum & Stadler (1992)

Lurbach (observation period: 1965-1973, 1987-1989), mean annual discharge:	141 l/s
Hammerbach (observation period: 1965-1975, 1983-1989), mean annual discharge:	193 l/s
Schmelzbach (observation period: 1965-1970, 1983-1989), mean annual discharge:	79 l/s
Laurins spring (observation period: 1986-1987), mean annual discharge:	3.7 l/s

Water balance data of the Tanneben-Lurbach Karstsystem (period 1966-1970*):

mean annual air temperature:	7.4°C
mean annual precipitation:	648 l/s = 897 mm (=100 %)
mean annual real evapotranspiration after Turc:	322 l/s = 446 mm (=49.7 %)
mean annual discharge at the Hammerbach spring:	180 l/s = 249 mm (=27.8 %)
mean annual discharge at the Schmelzbach spring:	97 l/s = 134 mm (15.0%)
drain by minor springs or diffuse infiltration into the porous aquifer of the Mur valley:	49 l/s = 67 mm (=7.5%)

(*after Harum & Stadler, 1992; slightly modified)

Based on the valley formation of the river Mur and the shift of the river bed towards the west during the last 5 mio years (Fig. 7), the river Mur is now the recipient of the whole Tanneben-Lurbach-Karstsystem. Thus, the development of the karst system is bound to the valley formation and is characterized by a complex flow system (Maurin & Benischke, 1992; Wagner et al., 2010, 2011). Depending on the hydrometeorological conditions different hydraulic connectivities are distinguished at present. The hydraulic connectivity between the

Schmelzbach-system and the Hammerbach-system seems to be correlated to a discharge threshold of about 200 l/s at the Hammerbach spring (Harum & Stadler, 1992). A discharge above this threshold yields to an overflow towards the Schmelzbach system (Fig. 8).

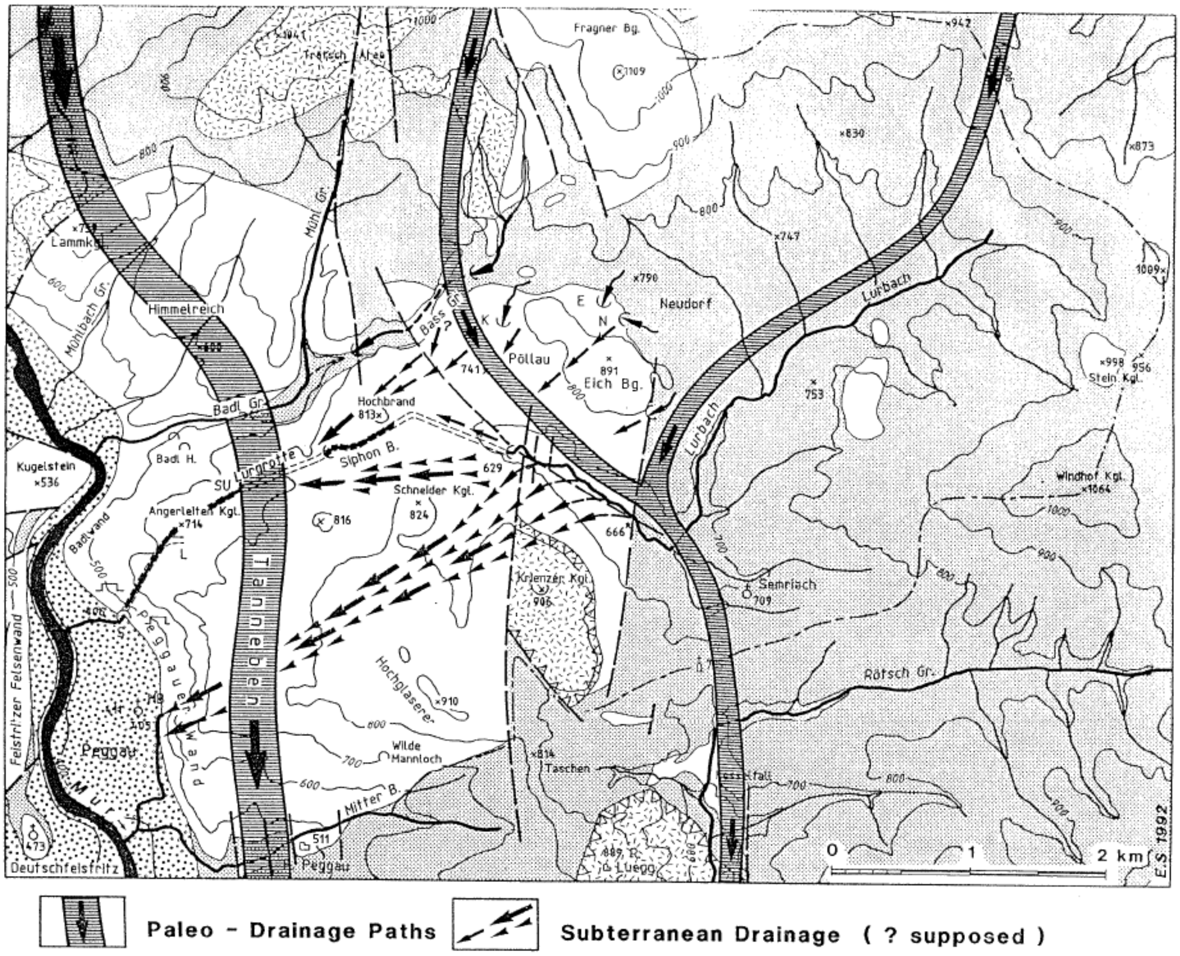


Figure 7: Drainage evolution of the Semriach Basin and the Tanneben karst plateau (Maurin & Benischke, 1992)

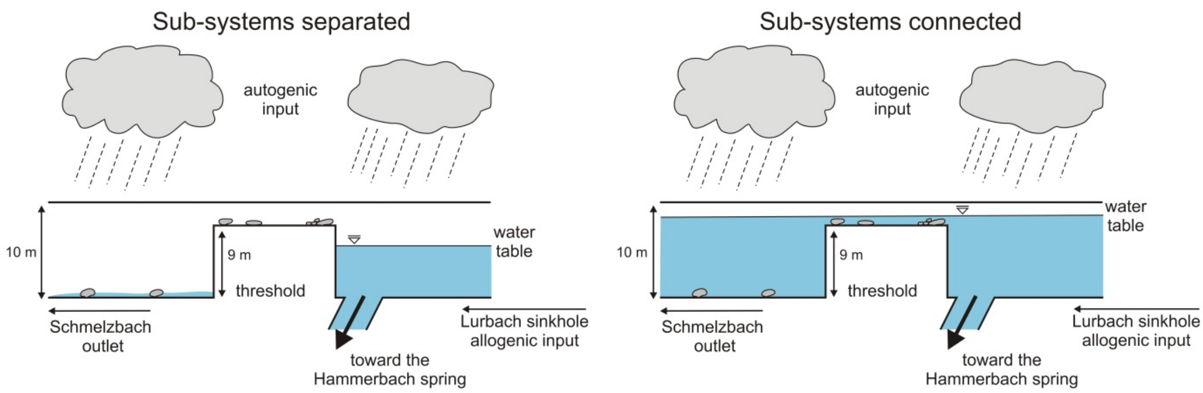


Figure 8: Drainage principle and hydraulic separation (left) or connectivity (right) of Hammerbach and Schmelzbach systems (Mayaud et al, 2014)

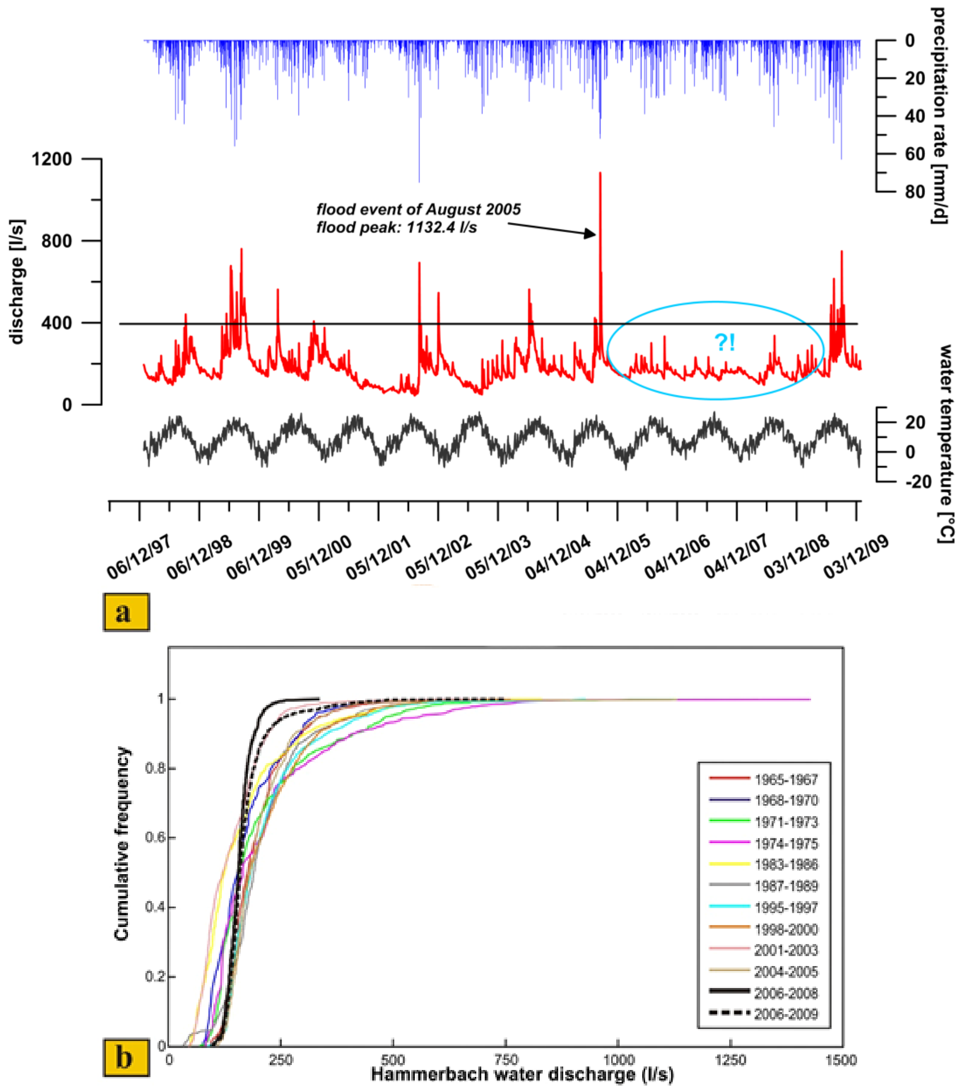
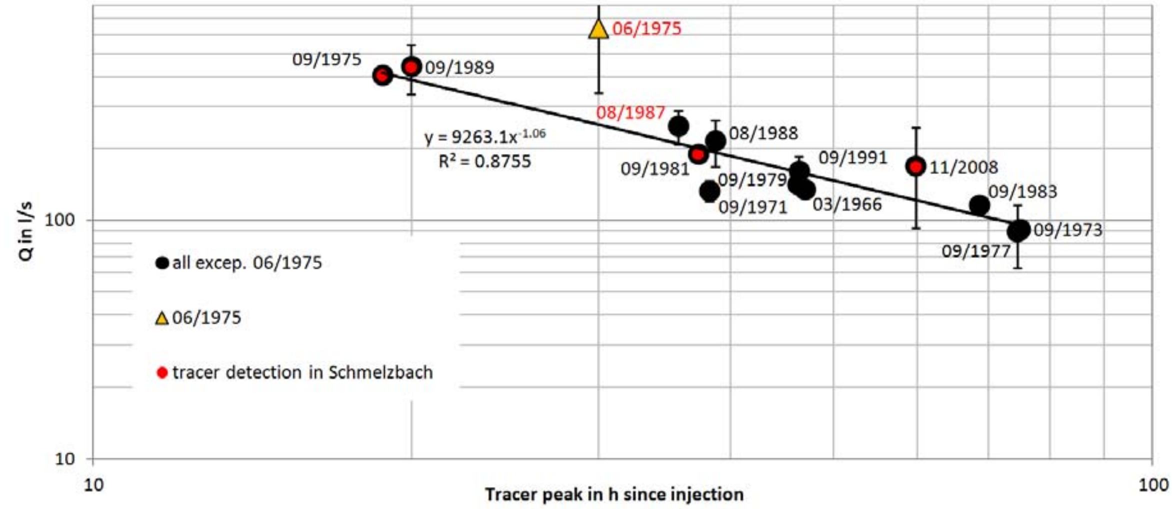
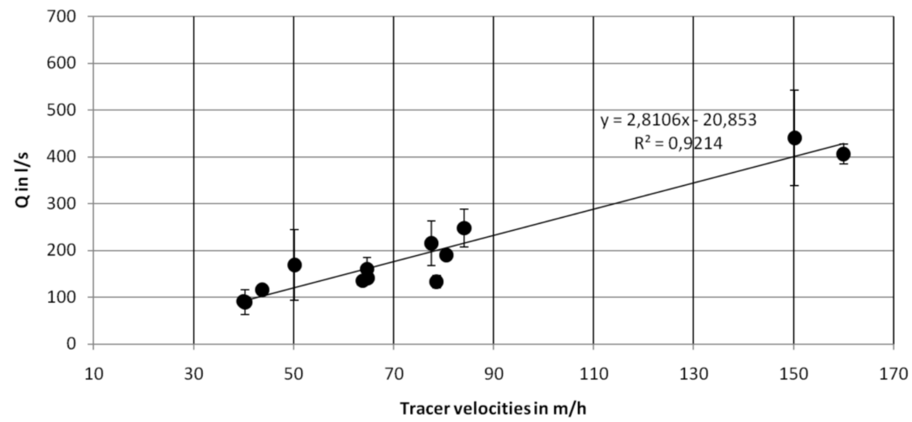


Figure 9: Hammerbach discharge between 1998 and 2009 with corresponding air temperature and rainfall time-series of the region (a), and flow duration curves for the period 1965 - 2009 (b) (modified after Mayaud et al., 2013). Note the rather dampened discharge characteristics after a flood event in August 2005.

Based on a number of tracer experiments conducted in the Lurbach-Tanneben-Karstsystem, a correlation between discharge at the Hammerbach spring and the tracer peak travel times after injection at the Lurbach sinkhole (or along the Lurbach stream for the experiment 11/2008) can be established (Fig.10a). The tracer experiments allow to infer predominant phreatic conditions towards the Hammerbach and can be characterised by the linear regression model between discharge and tracer peak flow velocities (Fig.10b). In addition the overflow towards the Schmelzbach spring only occurs if the discharge at Hammerbach is above a certain threshold (usually ~200 l/s). Interestingly, during the tracer test conducted in Nov. 2008, overflow could be recorded already at lower discharge (~135 l/s). This temporal change seems to be related to a flood event in August 2005 and caused a dampening of the Hammerbach discharge probably due to sediment redistributions within the karst system itself (Wagner et al., 2013; Birk et al., 2014; Mayaud et al., 2014).



a)



b)

Figure 10: (a) Discharge at the Hammerbach spring versus transport times from injection points (usually the Lurbach sinkhole) based on a number of tracer experiments. Red dots indicate that Uranine tracer was also detected at the Schmelzbach outlet and the overflow was active. During an experiment 08/1988 only particle tracers were detected at the Schmelzbach outlet. The latest tracer experiment was conducted in Nov. 2008 where Uranine was detected at the Schmelzbach stream although discharge at the Hammerbach stream was well below the threshold value of ~200 l/s. (b) Correlation between Hammerbach spring discharge and calculated tracer peak flow velocities.

A binary karst system like the Tanneben-Lurbach-Karstsystem is a complex and evolving system which is prone to changes due to climate changes and anthropogenic influences (e.g. changes in land use). Corrosion and erosion developed and will develop new flow paths and sediment redistribution as well as collapse events in conduits had constricted and further will constrict flow paths at least temporarily. Thus, karst systems need to be regarded as temporarily changing systems over time where hydraulic characteristics and behavior are hard to predict.

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