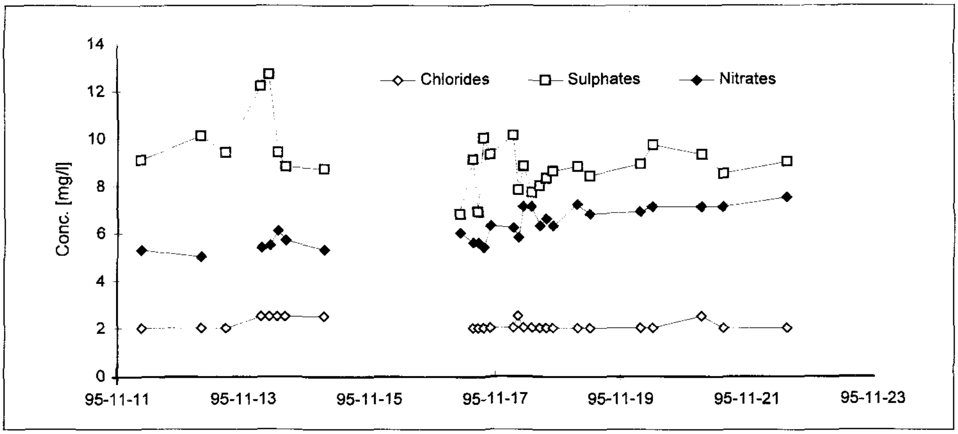

Fig. 4.23: Variations in the chloride, nitrate and sulfate contents during the Vipava water pulse in November 1995.

Determination of phosphate and chloride levels did not display any changes during the two water pulses, or, maybe they were so small that we did not register them. The phosphate concentration was at the limit of detection (0.01 mg PO_4^{3-}/l), and the chloride concentration 2 mg Cl^-/l (Fig. 4.22).

In the first water pulse we recorded a slight increase in nitrate levels of 1 mg NO_3^-/l. During the second water pulse the values only oscillated slightly. During both water pulses a small, but permanent increase in nitrate level was recorded.

The initial value of sulfate level, 9.5 mg SO_4^{2-}/l at the beginning of the first water pulse increased to 12.5 mg SO_4^{2-}/l during the maximal discharge and later it decreased. Similar increase was recorded at the beginning of the second water pulse (Fig. 4.23). When a discharge approached the starting value also the level of sulfate reached the starting value before both water pulses.

4.2.3. The Use of Silica to characterise the allogenic Flysch Component in Vipava Springs during the observation of Single Events

(V. ARMBRUSTER, C. LEIBUNDGUT)

4.2.3.1. Introduction

The Vipava springs show some characteristics of a karst spring, that is influenced by an allogenic flow component. Its catchment borders on Eocene flysch in the East, where sinking streams drain parts of the flysch area and probably have a connection towards Vipava springs.

The soils and the bedrock of the flysch area around Postojna release considerably more silica than those of the karst plateaux of Nanos and Hrušica. As a consequence, silica could be used as a natural tracer to make hydrograph separations of Vipava springs' water into karst water and allogenic flysch water during a runoff event. The dynamics of the allogenic flysch component could be characterized and a rough estimation of the Vipava catchment area, which is made up by flysch, could be given.

4.2.3.2. Methods

The kinetics of silica release are fast and thus, silica contents hardly depend on residence times, but almost exclusively on different flowpaths of water. Nevertheless, time dependent silica contents have been determined for the flysch as well as for the karst component. To obtain a representative silica content of the flysch component, the water of Lokva river on the flysch area has been sampled at Predjama Castle, where it sinks underground at the karst flysch border and has a proofed connection to Vipava springs. To obtain a representative silica content of the karst component, Hubelj karst springs has been sampled, which is uninfluenced by flysch areas. The samples of the two components and the samples of Vipava springs during a heavy precipitation event in April 1996 were analyzed photometrically for dissolved silica. A two component mixing model has been used for the hydrograph separations.

4.2.3.3. Results

During the sampled period from March the 27th until April the 12th 1996, the karst plateaus were partly snow-covered, and the discharge of Hubelj and Vipava springs was relatively high, as snowmelt was taking place. During a heavy precipitation event on April the 1st and 2nd about 90 mm of rain were falling on the Vipava catchment (Fig. 4.24: (A)) and caused strong rises in the discharge of the karst springs. During the precipitation event the rain turned into snow and covered the karst plateaus completely. On the lower neighboring flysch area near Postojna, no snow was deposited and the rainfall amounted to 110 mm, causing extreme floods in the flysch streams. After the precipitation event the discharge of Hubelj and Vipava springs decreased until April the 5th. Then warm and sunny weather caused a strong snowmelt runoff event with daily discharge fluctuations in the karst springs (Fig. 4.24: (C)-(D)).

Flysch Water

Fig. 4.24 (B) shows the assumed discharge of water from the flysch area, drained by sinking streams, and its silica content during the observed period. On the basis of the peak discharge of the two biggest sinking streams Lokva and Belščica and the water level record of the Belščica the discharge was

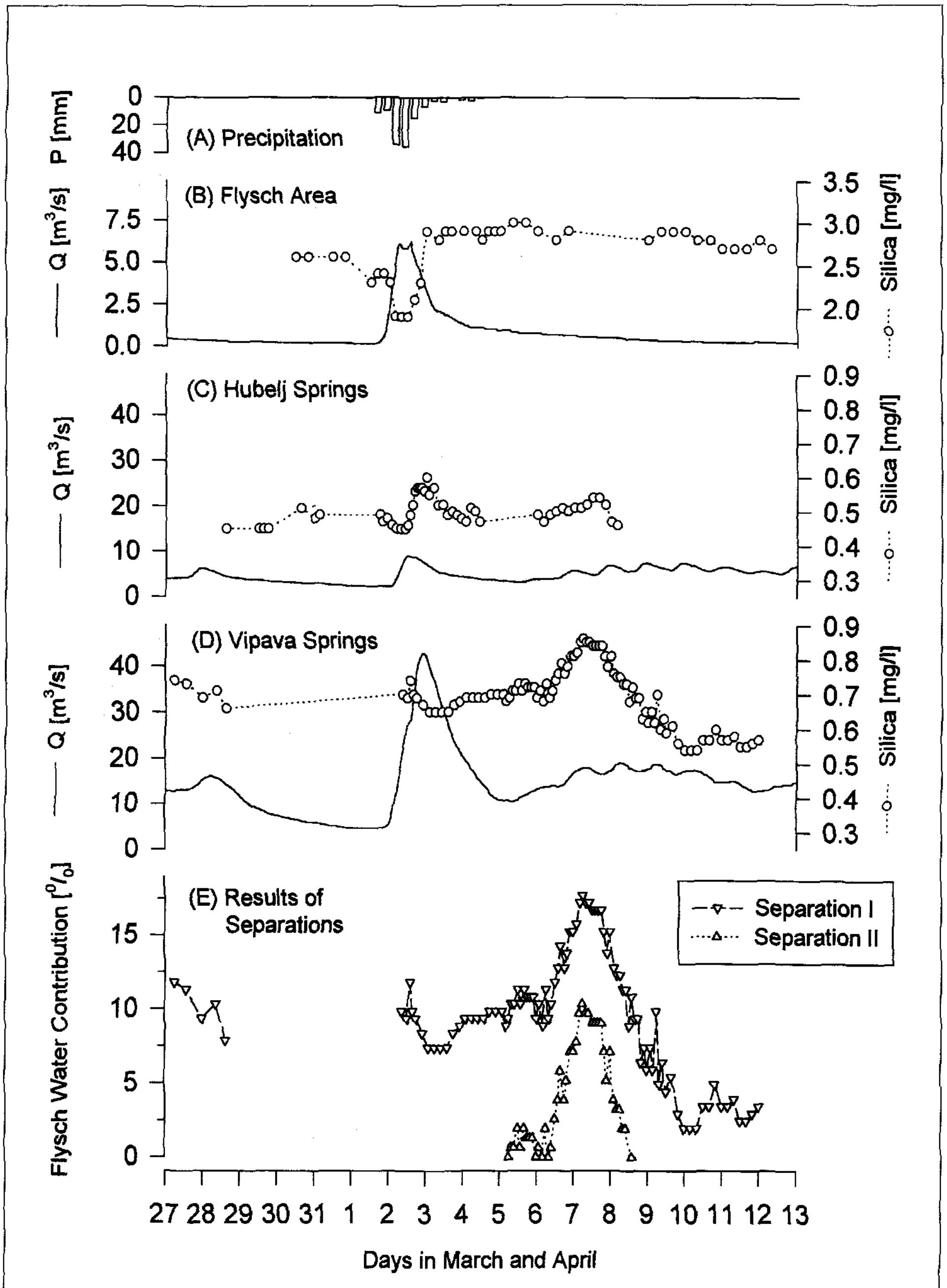
P [mm]
0
20
40
(A) Precipitation
(B) Flysch Area
Q [m³/s]
7.5
5.0
2.5
0.0
3.5
3.0
2.5
2.0
Silica [mg/l]
(C) Hubelj Springs
Q [m³/s]
40
30
20
10
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Silica [mg/l]
(D) Vipava Springs
Q [m³/s]
Silica [mg/l]
(E) Results of Separations
Separation I
Separation II
Flysch Water Contribution [%]
15
10
5
0
27 28 29 30 31 1 2 3 4 5 6 7 8 9 10 11 12 13
Days in March and April

Fig. 4.24: Data of a single precipitation event in the period from March the 27th till April the 12th 1996: (A) Precipitation heights of 6 hours intervals of precipitation station Podkraj. (B) Silica content and assumed discharge of water from the flysch area near Postojna, drained by sinking streams towards Vipava springs. (C)/ (D) Silica content and discharge of Hubelj and Vipava springs. (E) Contributions of flysch water in Vipava springs, according to two different separations (I and II).

calculated, while the silica content was measured in the Lokva river. The flysch water shows a slight dilution effect during the runoff event, and the silica content ranges from 1.9 mg/l to 3.0 mg/l.

Two different representative silica contents were calculated for the flysch water:

- The discharge weighted mean of the silica contents during the whole period. This is considered to be the best estimation of the silica content in general. It amounts to 2.53 mg/l.
- The discharge weighted mean of silica contents during a 35 hours period of highest silica load. This is considered to be the representative silica content of the flysch flood. It amounts to 2.25 mg/l.

Karst Water

Fig. 4.24 (C) shows the discharge and the silica content of Hubelj springs during the observed period. The silica content of karst water is on a much lower level and ranges from 0.45 mg/l to 0.6 mg/l. Two separate slight rises in silica can be observed, one during the precipitation and the other one during the snowmelt. Possible reasons might be:

- Soil water, being higher in silica, is pressed out by infiltrating event water.
- Deposited sediments within the karst system are mobilised by higher water levels and are releasing silica.
- Deep phreatic water is activated by higher pressure. This water is higher in silica, due to the contact with the flysch basis.

With the available information it was not possible to favour one of the possibilities. The discharge weighted mean of silica contents of all samples amounts to 0.50 mg/l and is used as the representative silica content of karst water, uninfluenced by an allogenic flysch water component.

Vipava Springs' Water

Fig. 4.24 (D) shows the discharge and the silica content of Vipava springs during the observed period. The silica content of the Vipava springs is on a level between those of the karst and the flysch water and ranges from 0.54 mg/l to 0.86 mg/l. It can be seen, that there is no silica rise during the strong precipitation event. Thus, the above listed mechanisms, that might cause a silica rise, seem not to be active in the Vipava system. The high silica peak from April the 6th until the 8th happens to coincide with the snowmelt event, but has no causal connection to it, as all driving forces of the above mentioned mechanisms are weaker than during the precipitation event.

As a consequence, this peak is attributed to an allogenic flysch component, appearing at Vipava springs and bringing flysch water. Following points support this interpretation:

- In Vipava springs much higher concentrations of silica occur than in Hubelj springs, indicating that other mechanisms are active.
- The overall course of the silica content in Vipava springs can be plausibly explained, assuming that a flysch water component exists. Before the precipitation event a mixture of karst and flysch water in the Vipava aquifer is discharging. During the precipitation event recharge to the aquifer from the flysch area is very high, since there precipitation falls exclusively as rain. As it has a long distance to pass, it arrives at the springs with a big time lag and causes the silica rise. The discharge time series show, that a strong snowmelt event follows. During this event, the only sources of recharge are the higher, snow-covered karst plateaux, causing a decrease in silica to a very low level.
- The travel time of the flysch component was calculated with the time of peak silica load in the Lokva river and the time of peak silica concentration in Vipava springs and amounts to 4 days and 12 hours. This time is well comparable to results from the Uranine tracing experiment from April 1994. There, the tracer, that had been injected in the Lokva stream, arrived at Vipava springs after 6 days and 14 hours. The longer travel time can be plausibly explained by the less extreme hydrological conditions during the uranine experiment (HQ: 25 m^3/s).

Hydrograph Separations

It can be evaluated, how much of the Vipava springs' water comes from the actual flysch flood on the flysch area. The rest of the water, discharging at Vipava springs, is a mixture of water from karst recharge areas and 'older' water from flysch recharge areas. Thus, it further can be evaluated, how much of the Vipava springs' water comes from the karst recharge areas and how much from the flysch recharge areas. Consequently, it is distinguished between two different separations:

- separation I:
  into flysch recharge water (any age) and karst recharge water (any age)
- separation II
  into 'young' flysch flood water and water, that has been in the karst system before the arrival of the flysch flood water (karst water + 'old' flysch water)

For separation I a silica content of 0.5 mg/l is used for the karst water component, while a silica content of 2.53 mg/l is used for the flysch water component. For separation II a silica content of 0.7 mg/l - the mean of the silica contents in Vipava springs before the arrival of flysch flood water - is used for the water in the karst system, while 2.25 mg/l is used for the flysch flood water component. Fig. 4.24 (E) shows the results of both separations.

The results of separation I show, that before the arrival of the allogenic component the flysch recharge water contribution is on a level of about 9%. This is the best estimation of the mean flysch recharge water contribution, that is available from the short observation period. Due to the extreme hydrological conditions, this contribution varies between 3 % and 18 %.

The results of separation II show, that the contribution of the actual flysch flood water rises up to 10 % and that it mainly discharges during a short time of about 2 days. It has to be considered, that the contributions are probably low limits, since snowmelt water from the karst plateaus (lower in silica) was probably already contributing.

4.2.3.4. Conclusions

It could be shown, that during a precipitation runoff event silica could be well used as a natural tracer to detect the allogenic flysch water component in the Vipava karst springs. The rise of the silica content in Vipava springs could be plausibly attributed to the arrival of allogenic flysch water from the flysch area near Postojna. Silica helps to describe the dynamics of the flysch water component, which comes during a relatively short time period and has a travel time of 4 days and 12 hours. This is one third less than the travel time of uranine from the artificial tracer experiment in April 1994, but still comparable, since the hydrological conditions were extreme.

In the single event analyses from November the 16th 1995, there were no hints of an allogenic flysch component though. Unfortunately, silica has not been analyzed. It is possible, that the used parameters were simply not suitable to detect the allogenic flysch component or that the different meteorological conditions were responsible for the different results. During the precipitation event in April, there was snow deposition beside rain on the karst plateaus, resulting in a relatively heavier recharge to the karst aquifer from the flysch area compared to the karst plateaus. The November event was a pure rainfall event.

A hydrograph separation showed, that during the time of peak flysch water contribution, at least 10 % of Vipava springs' discharge was made up by water from the actual flysch flood on the flysch area. Another hydrograph separation into karst recharge water and flysch recharge water showed, that before the arrival of concentrated allogenic flysch water the contribution of flysch recharge water is on a relatively constant level of 9 %. This might give a very rough estimation of the part of the Vipava catchment, that is made up by flysch. Thus, about 9 % or about 13 km^2 of the Vipava catchment would be on flysch areas. It is critical to draw conclusions on long term conditions on the basis of an observation period of only two weeks, but the results are in realistic ranges.

For further investigations in karst systems with an allogenic flysch component, it might be promising to make long term silica observations (at least one year), in order to obtain information on the part of the catchment, that is made up by flysch. With the same network of automatic samplers a short term sampling during single runoff events could be done, in order to characterize the dynamics of the allogenic flysch component under different hydrological conditions.