

11 AUSTRIA: WALDBACHURSPRUNG SPRING

11.1 Overview

The Dachstein massif represents one of the largest karst plateaus in Austria, covering an area of 40 km in length by 20 km in width and reaching an altitude of 2995 m above sea level (*Figure 38*). This region, the site of the prehistoric salt mine of Hallstatt, is a UNESCO World Heritage Site.

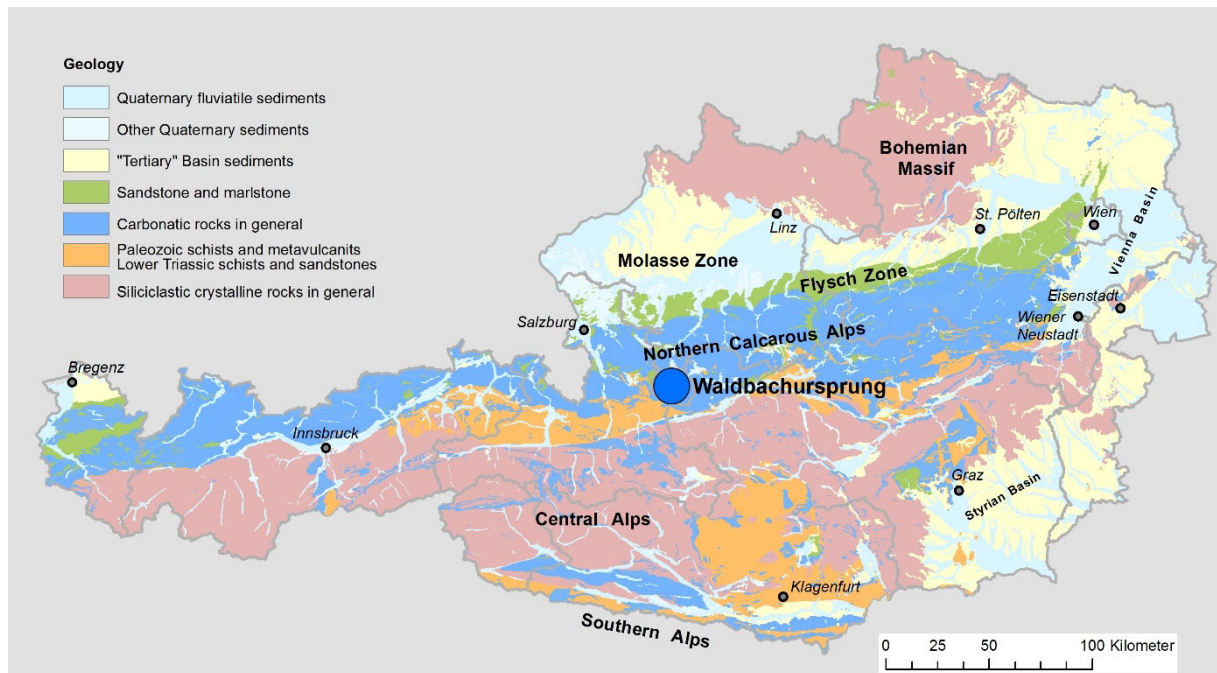


Figure 38: Location of the Waldbachursprung in Austria.

11.2 Geology

The main drainage of the Dachstein massif takes place in the very thick (approximately 1000 m) Dachstein limestone which slopes down towards the north and is highly karstified (*Figure 39*). It is underlain by dolomites with a thickness of up to 1000 m which act as a barrier that declines towards the north. In the southern extent, outcrops of the underlying dolomites are widespread. The dolomites themselves are underlain by a barrier of sandy/slaty rocks of the Permoskythian era.

Towards the north

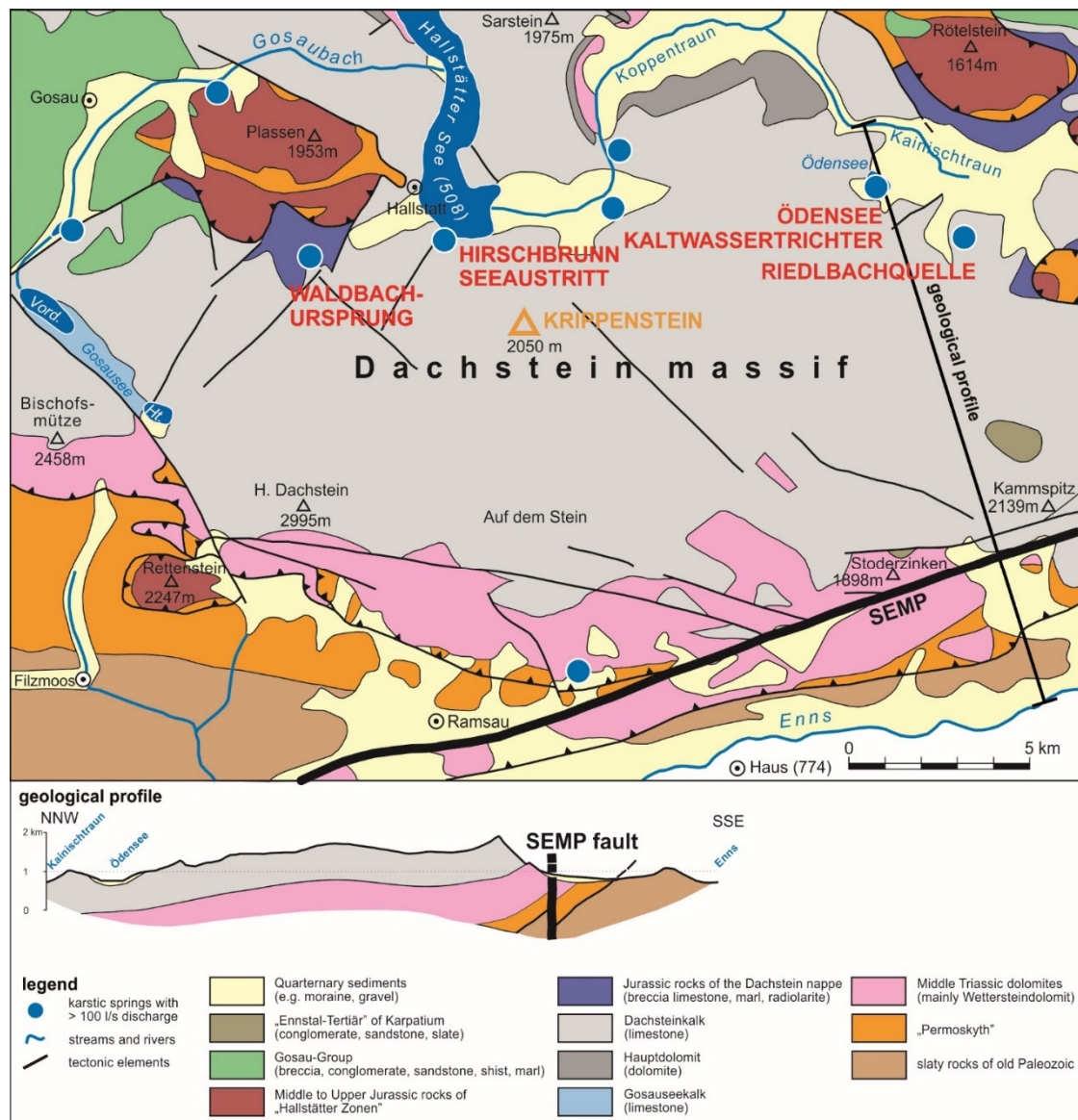


Figure 39: Dachstein massif with chosen springs (Waldbachursprung, Hirschbrunn-Seeaustritt, Ödensee-Kaltwassertrichter and Riedlbachquelle) and precipitation monitoring station (Krippenstein) (modified after Schubert, 2000).

11.3 Climate

The annual precipitation of the Dachstein region is approximately 2500 mm. Figure 40 provides an overview of daily precipitation including snow, and air temperature, for the monitoring station Krippenstein located at an elevation of 2050 m asl. (Figure 39 for location).

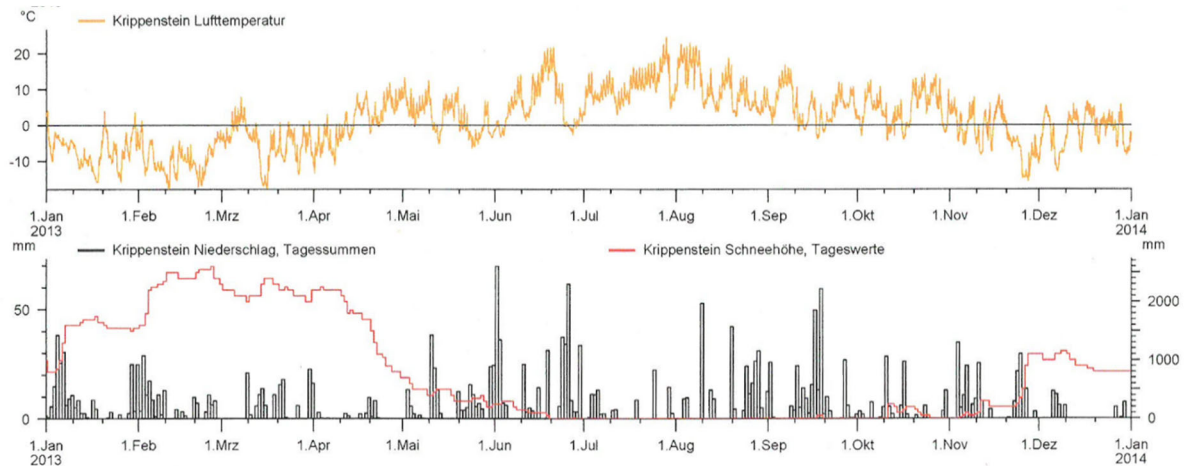


Figure 40: Precipitation, snow level, and air temperature of Krippenstein monitoring station (year 2013) (Völkl & Eybl, 2019).

11.4 Hydrogeology

There have been many tracer tests in the Dachstein massif. These investigations have been an important contribution to the progress of tracer techniques. Both Lycopodium spores and fluorescent dye tracers have been used. In the Dachstein region Lycopodium spores were used in 1953 by MAYR (1956). He injected tracer into a swallow hole on the shore of the lake Hinterer Gosausee (point F2 in *Figure 40*) and found connections to the karst spring Waldbachursprung (point E1) in the northeast and to the karst springs in the southern Gosau valley (point F4) in the north-west. In times of a high groundwater level this swallow hole acts as spring.

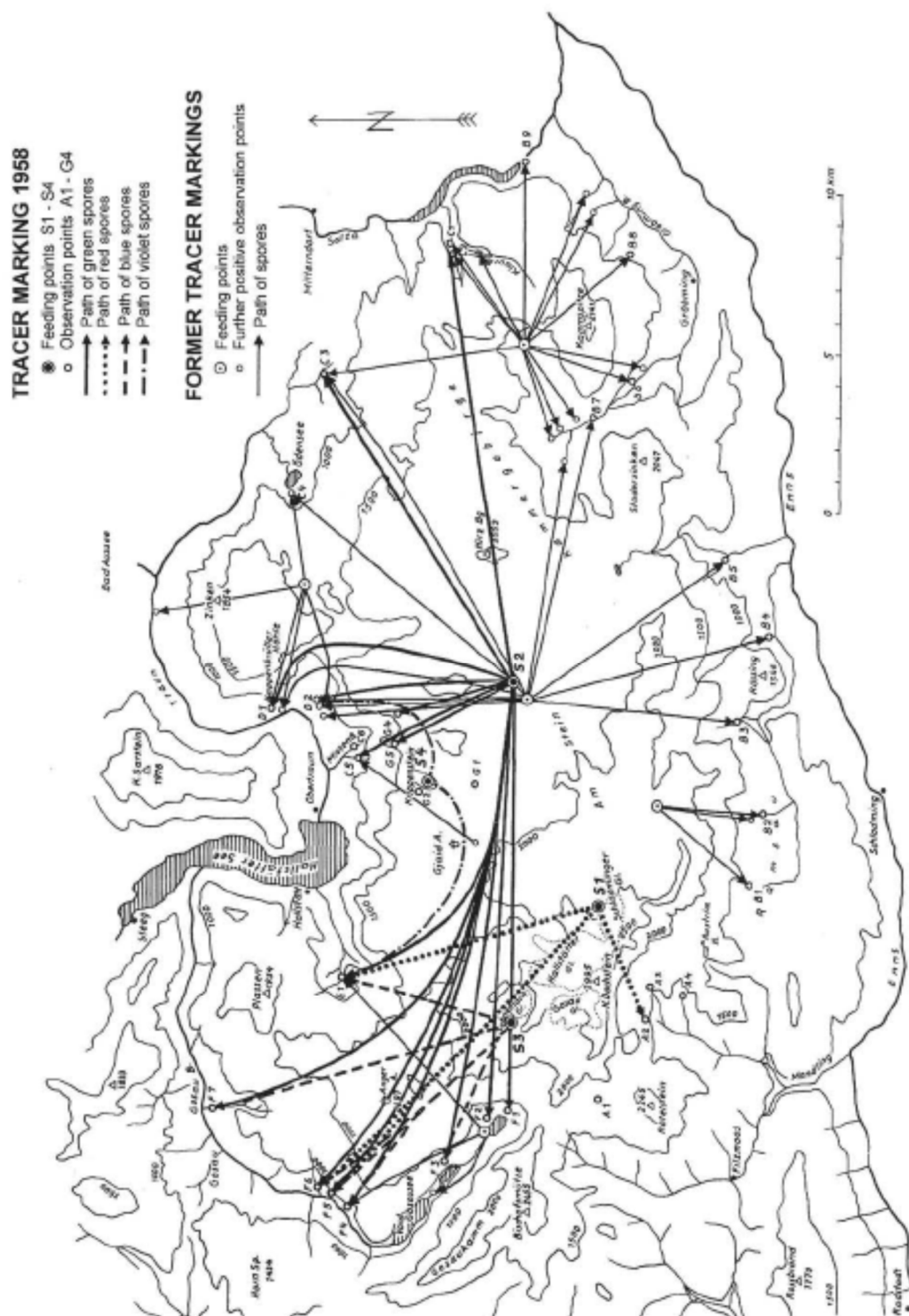


Figure 41: Results of the spore tracer tests in 1958 and earlier (MAURIN and ZOTL, 1959). The spore tracer tests led to the assumption of a radial karst discharge.

Due to a new method of dyeing Lycopodium spores in different colors (DECHANT, 1959), it became possible to apply Lycopodium spores simultaneously to several places within one area (Schubert, 2000). In 1956 and 1958, extensive spore tracer investigations were carried out in the whole Dachstein massif (MAURIN and ZÖTL, 1959). The results of these tracer tests led to the conclusion that the subsurface drainage of the Dachstein massif runs from the central region radially in all directions (Figure 41).

Extensive fluorescent dye tracer tests were carried out in 1984, 1985, and 1986, by BAUER (1989). They showed that the subsurface drainage of the Dachstein massif is essentially northwards (Figure 42) and not, as MAURIN and ZÖTL (1959) suggested, radial. A dye tracer was only found in springs on the southern side of the Dachstein massif in two cases (points l and m in Figure 42). BAUER (1989) assumed there is a subsurface drainage divide located in the southernmost part of the Dachstein massif. In his opinion, many of the connections found by spore tracer tests were not a result of subsurface runoff but a result of sample contamination. He suggested connections were only proven if the tracer concentrations in spring water produced a tracer breakthrough curve.

In 1990, the Federal Environment Agency (Vienna) carried out two further dye tracer tests in the western Dachstein region (HERLICKSKA and HOBIGER, 1991). The aim of these investigations was to explore the recharge area of karst springs located in the southern Gosau valley (points c, d, e, and q in Figure 41) and west of Hallstatt (point f) in detail. It became apparent that the recharge areas of these two spring groups overlap strongly. The velocities during high flow conditions were considerably higher than during low flow conditions.

An extensive spring monitoring program was conducted by the Federal Environment Agency in the years 1991 to 1994, the so-called "Karst-Water Dachstein" project (HERLICKSKA, 1994; SCHEIDLEDER, 2000). In this context, supplementary geological mapping was carried out by the Geological Survey of Austria (MANDL, 2000). Based on the new hydrographic, hydrochemical, isotopic, and geological data, the understanding of the subsurface runoff in the Dachstein massif was considerably improved (TRIMBORN et al. 2000; SCHUBERT, 2000). The results are summarized below.

The Dachstein massif consists of a generally northward dipping Triassic carbonate sequence, which belongs to the Dachstein nappe. The basal aquiclude of these carbonates comprises Permoskythian and Early Paleozoic slaty-siliciclastic strata of different tectonic origin. The upper part of the carbonate sequence consists of up to 1000 m thick, strongly-karstified Norian Dachstein Limestone. This limestone forms the main aquifer in the Dachstein region; with rapid subsurface runoff toward the big karst springs in the north (from here on called "the northern springs"). The Waldbachursprung is the biggest karst spring of the Dachstein region. The lower part of the carbonate sequence comprises a 1000 m thick, Anisian to Early Carnian dolomite succession (mainly Wetterstein Dolomite). Relative to the overlying Dachstein Limestone, the dolomite succession forms an aquitard. In the south of the Dachstein Massif, in the Enns valley, the dolomites crop out extensively. Here, several small springs rise within the base of the dolomites (From here on called "the southern springs").

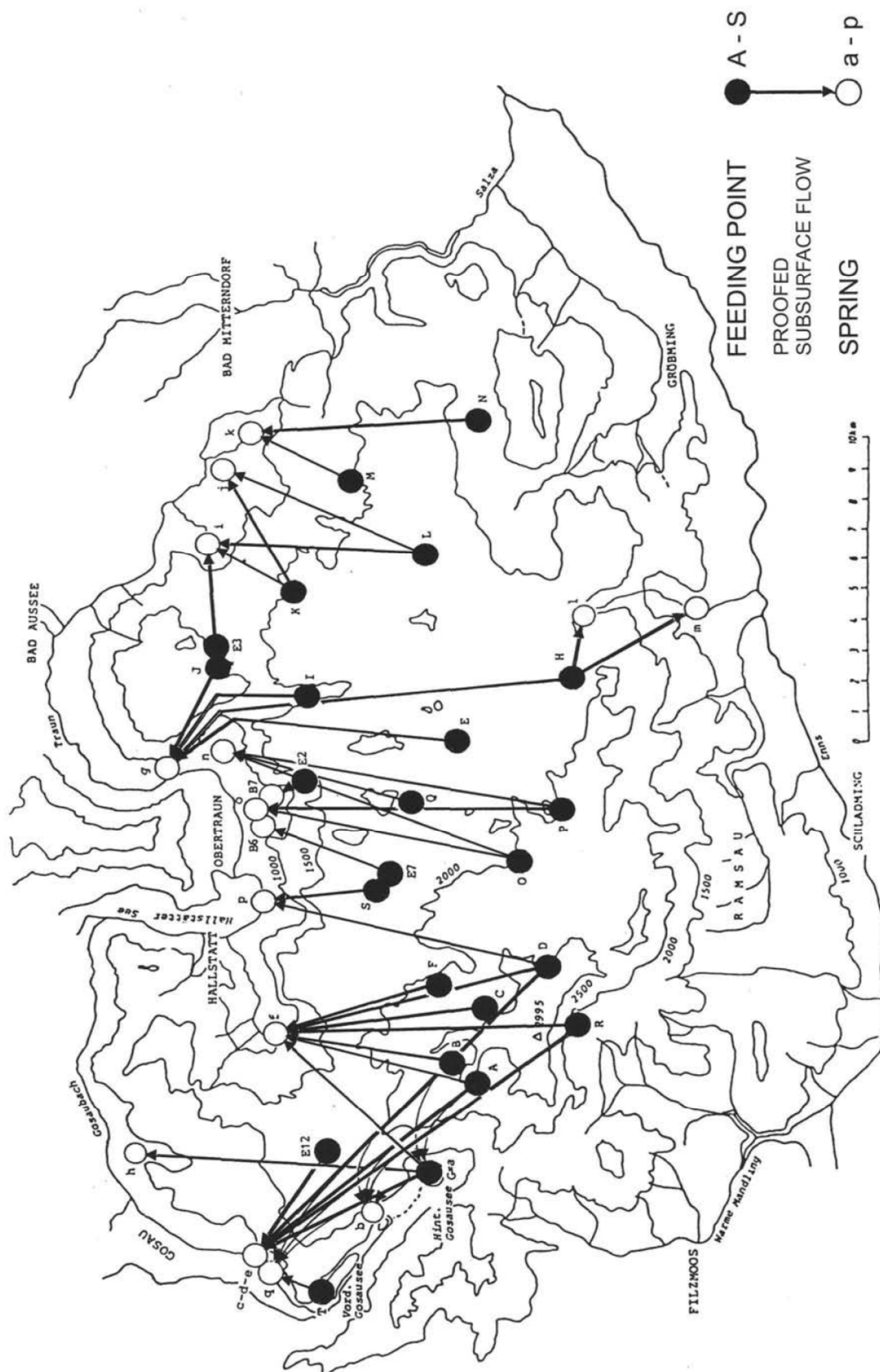


Figure 42: Results of the Dye tracer tests in 1984, 1985, and 1986 (BAUER, 1989). Based on a critical evaluation, BAUER (1989) infers a predominantly northwards subsurface drainage within the Dachstein massif, which is in contrast to MAURIN and ZÖTL (1959).

In the areas of the Plassen and Rettenstein mountains, as well as in the surroundings of Bad Mitterndorf, tectonic blocks consisting of a heterogeneous sediment sequence occur on the Dachstein nappe. This uppermost tectonic unit is called the Hallstatt zone. For example, the Permian evaporites of the salt mine in Hallstatt (Haselgebirge) belong to it. The springs rising within these tectonic blocks have mostly local recharge areas. As a consequence of the heterogeneous bedrocks, they have variable chemistries.

In the following, the characteristics of the northern springs (limestone type) and the southern springs (dolomite type) are considered. The northern springs are characterized by high $\text{Ca}^{2+}/\text{Mg}^{2+}$ -ratios (indicating calcareous inflow areas) and strongly varying discharges and $\delta^{18}\text{O}$ -concentrations (indicating rapid subsurface runoff). Most hydrographs of the northern springs indicate a runoff composition of 21 to 28 % of a younger component water (mean residence time <0.1 years) and 62 to 65% of an older water (mean residence time 3 years).

As the dye tracer tests show, the subsurface drainage of the Dachstein massif generally flows in a northerly direction (*Figure 43*). However, in the western Dachstein massif the subsurface runoff is split into the springs in the southern Gosau valley and into the spring district of the Waldbachursprung. This splitting is caused by the damming effect of the deep-drawing Permian and Early Triassic siliciclastic strata of the Hallstatt zone in the surroundings of Plassen.

The southern springs of the Dachstein massif are dominated by a dolomite-rich recharge area. This is indicated by the relatively low $\text{Ca}^{2+}/\text{Mg}^{2+}$ -ratios and by the relatively low and constant outflows, as well as low variations in $\delta^{18}\text{O}$ -concentrations. The $\text{Ca}^{2+}/\text{Mg}^{2+}$ -ratios lie between 1.6 and 3.6 with a few exceptions, which rise on the contact between the Dachstein limestone and dolomite. The relatively constant $\delta^{18}\text{O}$ -concentrations suggest high residence times. The longer $\delta^{18}\text{O}$ -hydrographs of the southern springs suggest an outflow composition of 3 to 14 % of younger component water (mean residence time 0.2 to 0.4 years) and 86 to 94% of an older component (3 to 6 years). Springs with a dolomite-dominated recharge area are, as a rule, characterized by a more constant outflow and higher residence time, due to the high fracture porosity and storage capacity of dolomite.

With regard to sulphate, the southern springs can be divided into a western group with high SO_4^{2-} -concentrations and an eastern group with low ones. Whereas in the southwest of the Dachstein massif the groundwater of the dolomite sequence has contact with evaporites belonging to the aquiclude, this is not the case in the east.

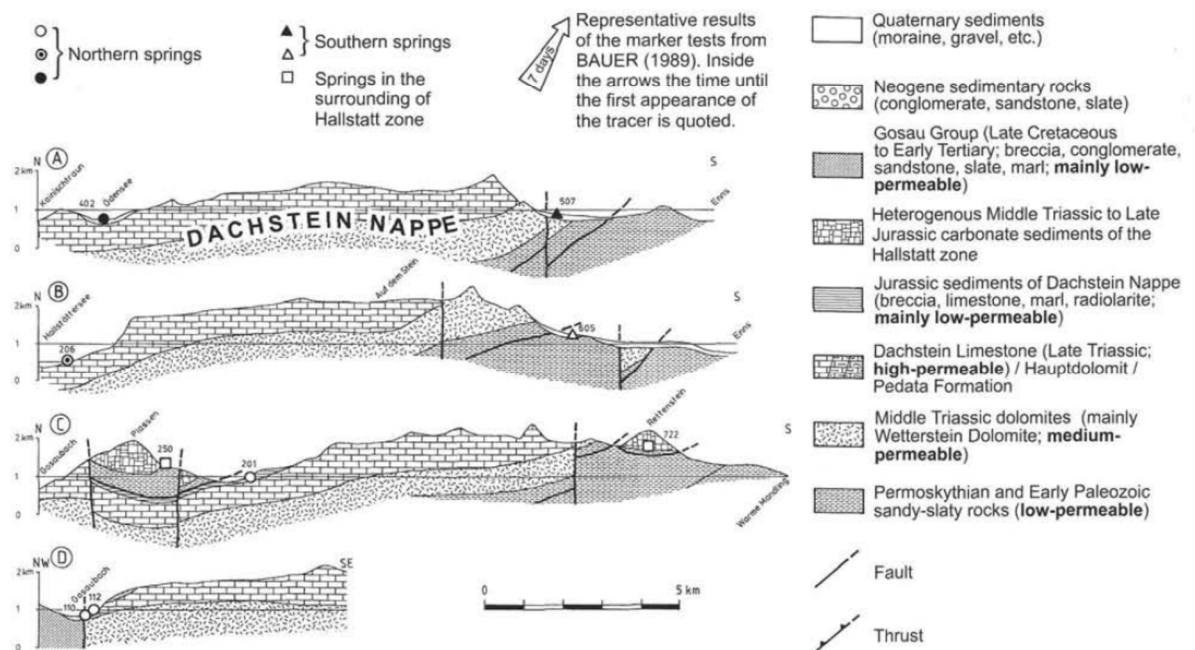
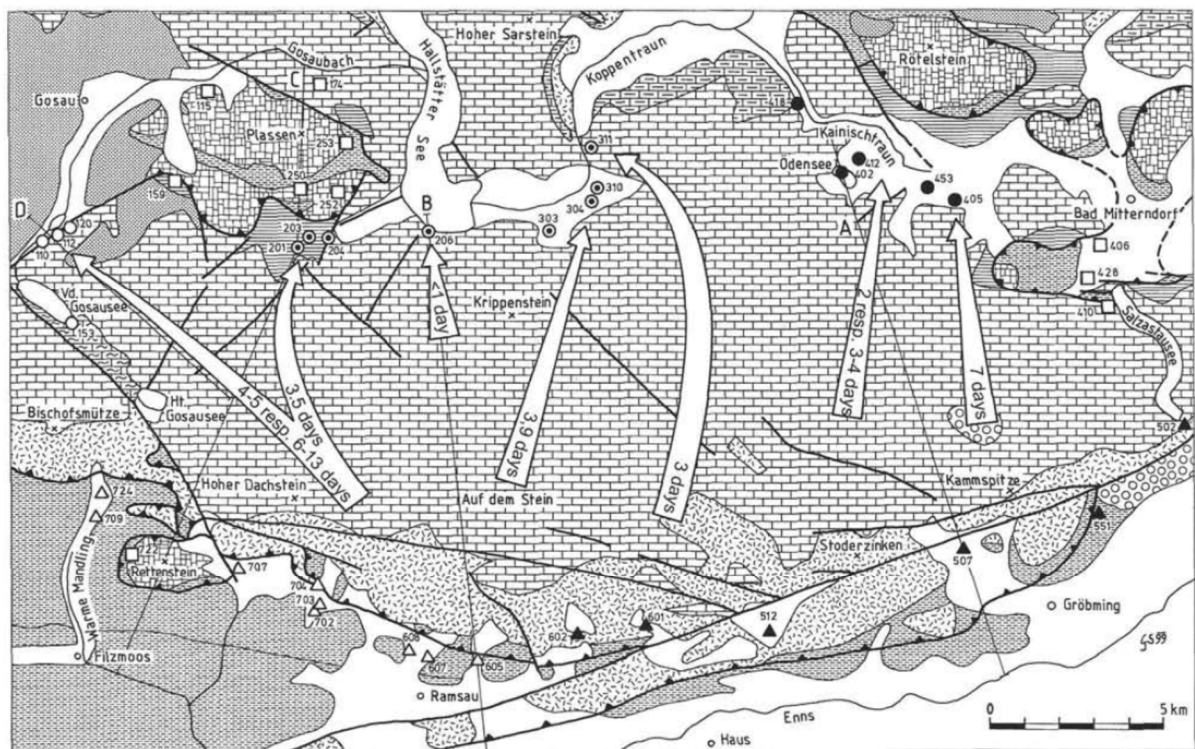


Figure 43: Hydrogeological outline map and cross sections of the Dachstein massif (SCHUBERT, 2000; geology after MANDL, 2000 and TOLLMANN, 1960).

11.5 Hydrodynamic characteristics of the springs

Figure 44 provides an overview of the discharge of the Waldbachursprung, Riedbachquelle, Ödensee-Kaltwassertrichter and Hirschbrunn-Seeaustritt springs in relation to precipitation, snow level and air temperature.

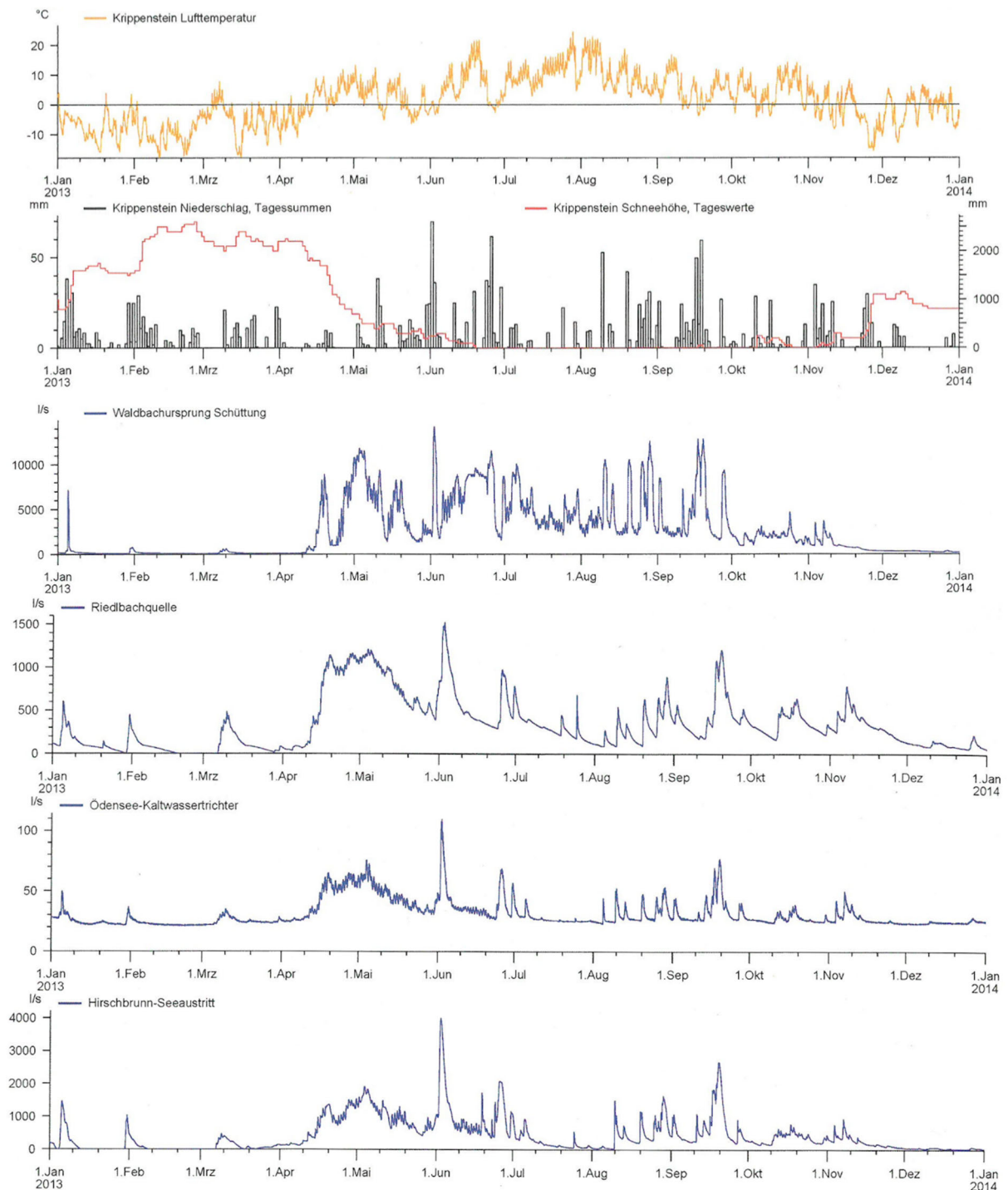


Figure 44: Precipitation, snow level, and air temperature of the Krippenstein monitoring station (year 2013) and discharge of spring monitoring stations at Waldbachursprung,

Riedlbachquelle, Ödensee-Kaltwassertrichter, Hirschbrunn Seeaustritt (year 2013) (Völkl & Eybl, 2019)



Figure 45: Waldbachursprung (picture: Eybl, BMNT, Abteilung I/4 Wasserhaushalt).



Figure 46: Hirschbrunn-Seeaustritt (picture: Eybl, BMNT, Abteilung I/4 Wasserhaushalt).



Figure 47: Ödensee-Kaltwassertrichter (picture: Eybl, BMNT, Abteilung I/4 Wasserhaushalt).

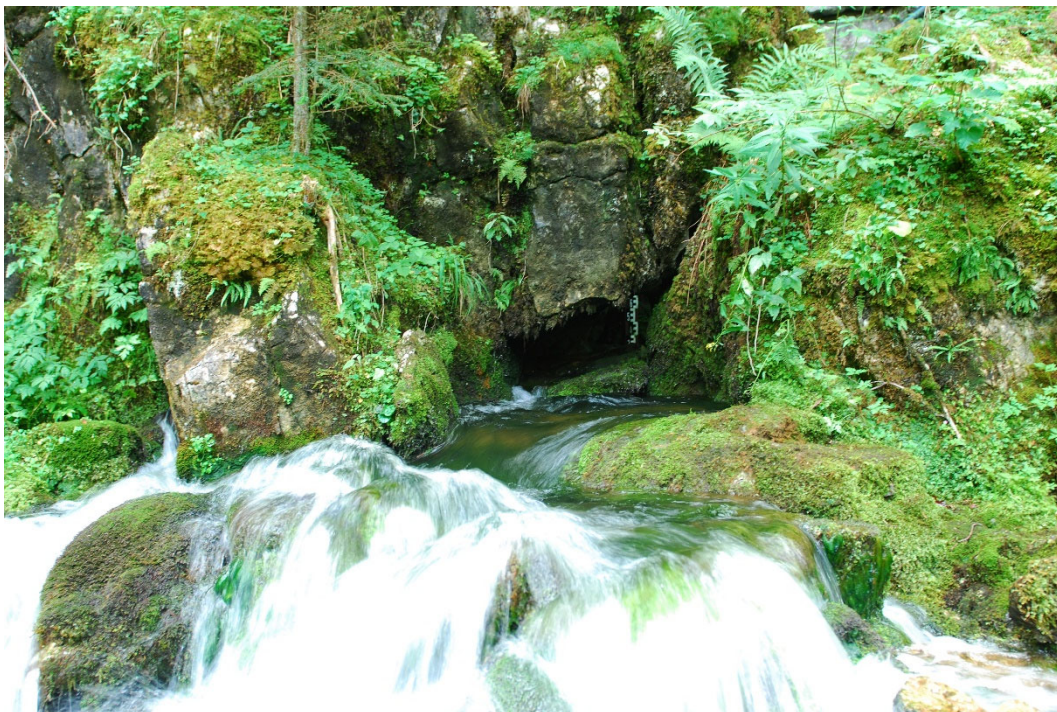


Figure 48: Riedlbachquelle (picture: Eybl, BMNT, Abteilung I/4 Wasserhaushalt).

11.6 Data available for the project

Data can be provided for the Waldbachursprung, Riedlbachquelle, Ödensee-Kaltwassertrichter and Hirschbrunn-Seeaustritt springs. Furthermore it is possible to contribute precipitation data.

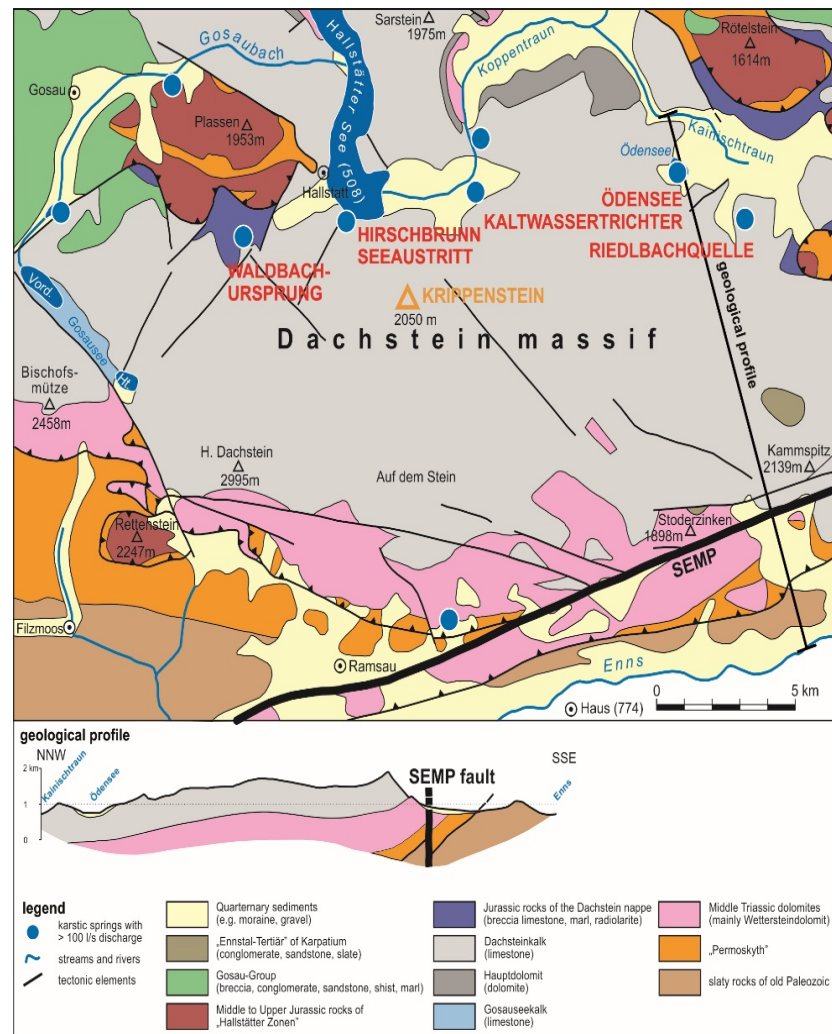
Name	Parameter	Time period
Krippenstein	Precipitation (mm/d)	1/1995-8/2019: daily value; 15 min: 2013
Waldbachursprung	EC ($\mu\text{S}/\text{cm}$), Q (l/s), T ($^{\circ}\text{C}$)	2/1996-12/2018:daily values; 15 min: 2013
Riedlbachquelle	EC ($\mu\text{S}/\text{cm}$), Q (l/s), T ($^{\circ}\text{C}$)	1/2008-7/2018: daily values; 15 min: 2013
Ödensee-Kaltwassertrichter	EC ($\mu\text{S}/\text{cm}$), Q (l/s), T ($^{\circ}\text{C}$)	7/1998-1/2019: daily values; 15 min: 2013
Hirschbrunn-Seeaustritt	EC ($\mu\text{S}/\text{cm}$), Q (l/s), T ($^{\circ}\text{C}$); Turbidity only in 2013	5/2008-1/2019: daily values; 15 min: 2013,

11.7 Summary

Pilot name	Waldbachursprung spring		
Country	Austria	EU-region	Alpine
Area (km ²)	40x20	Lithology	Limestone

Short description:

The Dachstein massif consists of a northward dipping Triassic carbonate sequence, which belongs to the Dachstein nappe. The basal aquiclude of these carbonates comprises Permoskythian and Early Paleozoic slaty-siliciclastic strata of different tectonic origin. The upper part of the carbonate sequence consists of up to 1000 m thick, strongly-karstified Norian Dachstein Limestone. This limestone forms the main aquifer in the Dachstein region; with rapid subsurface runoff toward the big karst springs in the north. A representative example is the Waldbachursprung because it is the biggest karst spring of the Dachstein region.



Monitored objects

Four springs (Waldbachursprung, Riedlbachquelle, Ödensee-Kaltwassertrichter, Hirschbrunn-Seeaustritt) and a precipitation monitoring station (Krippenstein)

Monitored data

Discharge, temperature, electrical conductivity, turbidity

Contact person

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11.8 References

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