International excursion Hydrogeology - SLOVAKIA

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RAPPORT 69

November 1996

Vakgroep Waterhuishouding
Nieuwe Kanaal 11, 6709 PA Wageningen

ISSN 0926-230X

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PREFACE

This is a report of the hydrogeological excursion to Slovakia, held in the period from September 8 up to September 15, 1996. This report is a compilation of the work of the participating students, parts of the excursion guide and also information, provided by the Slovak excursion guides.

We had the opportunity to enjoy the hospitality of many people, in Slovakia and in the Czech Republic. First we would like to thank our Slovak guides Dr. Miriam Fendeková, Dr. Böhm and Dr. Peter Nemethý of the Comenius University Bratislava, who spent the whole week with us. Their contribution was of great importance for the hydrogeological part as well as for the social part of the excursion. The excursion locations and introductions were very well prepared (including a beautiful set of maps of Slovakia in general and Gabčíkovo in special). Their enthousiasm brought us not only to the planned excursion locations, but also to locations from which an extra insight in hydrogeological flow and/or social aspects was expected. This enthousiasm was endless: when the well (near Martin) with the finest mineral water of Slovakia is dry, then a nearby factory should be asked to give some bottles mineral water to the thirsty students. Also, when students were supposed to write their part of the excursion report, they always were prepared to help, even when it was already late in the evening.
We are also very grateful to Prof. Pavel Kovar of the Czech University of Agriculture in Prague. He provided accomodation in the student hostel for two nights (September 8/9 and September 14/15) for tired students and guides. It was a surprise to see that, even after a long intensive week, the students had enough energy left to pay a long visit to Prague!
At some excursion points, invited speakers were willing to give detailed information. In this we would like to thank mr. Maly, who is in charge of the drinking water stations Jergaly and Motyčky. With his help, not only water station Jergaly and the Harmanec tunnel could be visited, but also two smaller wells near Jergaly (old watermill and Jelence), and the Harmanec regulation station.
At excursion point Liptovská Ondrăsová we visited the Slovak Hydrometeorological Institute (SHMI). On this location, Dr. Holko and Dr. Kostka were our hosts. They showed us hydrogeological research in mountaineous areas (steep slopes, snow). The combination of fieldwork and skiing, as shown on slides, was new to most of the students. Also the comparison of several soil physical measuring techniques (gravimetric specific electricity method, TDR) and the use of isotope hydrology made this excursion location a very nice one.
An insight in the specific problems (and solutions) concerning the construction and use of the Gabčíkova dam was given by Dr. Varga. This gave us an idea about geology, hydrology and economy/politics in a big sedimentary basin with a big river (Danube).
As an extra service to the participants, Dr. Marian Fendek showed us a brand new atlas concerning hydrogeology and thermal/mineral water in Slovakia. In this atlas, made by Dr. Fendek and his team, Slovakia was presented in a very beautiful and detailed manner.
To finish this preface, it would be nice to give the name of the most beautiful excursion location. It's a pity on one hand, but very fortunate on the other hand that it is proven to be impossible to give the price for the best/nicest point to only one location. Apart from the already mentioned locations, we only have to bring back in to memory the Demänová caves (several participants thought that these caves are the most beautiful to visit in Europe), the Bešenova travertine (a combination of geology, hydrology, hydrochemistry, brought together in a very nice coloured rock (only dissonant was a wasps' nest)), the view and walk near Štrbské pleso (very nice waterfall (we even thought we

did see a goblin)), and the walk through the Prosiecka dolina. A walk through a bedding of a small brook towards a waterfall, and facing all kinds off difficulties (climbing steep walls, crossing the brook over flooded bridges, wading through the water, descending along cattle tracks and so on), together with a perfect combination of work (the hydrogeological system) and holiday like action made this excursion point unforgettable.

We hope that this excursion report will give a good impression of the way the participants and the guides experienced this perfect week in Slovakia.

Henny van Lanen
Roel Dijksma
Ben van de Weerd

EXCURSION PROGRAM SLOVAKIA

Sunday, September, 8, 1996

- Departure from Department of Water Resources, Wageningen.
- Arrival in Czech Republic. Excursion to nature reserve Soos (Cheb Basin).
- Accomodation at Prague Agricultural University Campus (Suchdol).

Monday, September 9, 1996

- Departure from University Campus.
- Arrival in Slovakia, accomodation in Lubochňa.
- Introduction to the hydrogreology of Slovakia.

Tuesday, September 10, 1996

- Excursion to the Jergaly drinking water station.
- Excursion to the Harmaneč tunnel water supply system.
- Introduction to the regional hydrological system of the neo-volcanic area near Podzamčok, including an excursion to an andesite quarry.

Wednesday, September, September 11, 1996

- Excursion to the Demänova caves.
- Excursion to the High Tatra: Štrbské Pleso.

Thursday, September 12, 1996

- Excursion to the Prosiecka dolina.
- Visit at the Slovak Hydrometeorological Institute at Liptovská Ondrášová.
- Excursion to Bešeňová (travertine).
- Visit of the Bešeňová mineral swimming pool (thermal water).

Friday, September 13, 1996

- Excursion to a rhyolite quarry at Revištské Podzámčie.
- Excursion to the Gabčikova dam, a hydraulic construction in the Danube Basin.
- Accomodation at Comenius University, Bratislava.

Saturday, September 14, 1996

- Departure to Prague.
- Accomodation at Prague Agricultural University Campus (Suchdol).

Sunday, September 15, 1996

- Departure to Wageningen

INTRODUCTION

The Carpathians

The Carpathians are a component part of the northern branch of the Alpine system (Alpine orogeny). They show a mountainous, in places even high-mountainous character, which sharply contrasts with the lowlands on the inner side and in the foreland of the mountain arc and with the depressions intervening between the individual ranges. The main structural elements rising to surface are Mesozoic and Cenozoic complexes. Mesozoic rocks, on the outer side along with the Paleogene (Early Tertiary), built up predominantly the mountain ranges. Neogene (Late Tertiary) fills the depressions and lowlands. In the inner part (Central West Carpathians), intensive folding and uplifts brought also Paleozoic and Precambrian formations to surface. In the outer belt (Flysch Carpathians) formations predating the Mesozoic are known only from fragments and pebbles of the conglomerates.

The Carpathians are a pronouncedly two-part mountain range, whose principal zones differ in their geomorphological character, general history and structure. Both systems are seperated by the narrow Klippen Belt which represents a tectonic and genetic link between them.

The Alpine-Carpatian mountain system is distinguished by a rich dissection into longitudinal geotectonic zones. Each of them has a special position in space and, consequently, particular facies and interfacies relations which depend mainly on the secondary differentiation.

The outer Carpathians

The belt of **foredeep** fringes the outer belt of the Flysch Carpathians, being partly hidden beneath their nappes. It envolved gradually during the orogenic movements of the flysch geosyncline on the complexes of the Bohemian Massif, whose uplifting character accounts for the relatively small with of the belt and the small thickness of its deposits. The Neogene molasse filling rests on the Paleozoic and earlier rocks of the Bohemian Massif.complexes.

The **Flysch belt** (Outer Carpathians), consists of Upper Cretaceous and Tertiary (Paleogene) sedimentary complexes; it is present in the Czech Republic, Slovakia, and also in Poland, Ukraine and Romania. These sedimentary complexes are composed of beds of sandstones and shales with subordinate lenses and beds of conglomerates.

The **Klippen belt** is a narrow, in place only a few kilometers wide tectonic zone, representing huge megabbreccia. It extends in a 500 km arc from the Vienna basin to the East Carpathians, forming the division of the Outer Carpathians (Flysch belt) and the Inner Carpatians (Central belt). Characteristic is the presence of Triassic and Jurassic klippen (Klippe = Nappe = Dui: Decke = Ned: dekblad) which are surrounded by Upper Cretaceous marls and shales.

Hydrogeologically the most important formations in the Carpathian foredeep are Miocene basal clastic sediments. Confined aquifers exist in them with water resources of the order of several hundred l/s. Ground water in the central parts of the foredeep has good quality, but near the fringes (Ned: randen) it has been affected by human activity.

The Inner West Carpathians

The belt of **Core mountains** is a wide zone consisting of several structural elevations aranged and divided by intermontane depressions and intramontane basins. In the structural elevations, blocks of the ancient basement- the Slovakian massif- rejuvenated during the Alpine orogeny rose to the surface. Their Mesozoic mantle has a complicated structure, in which the autochtonous cover and

nappes overthrusted from the the southerly zones participate. Among others, the following Core mountains have a mega-anticlinal (or mega-anticlinal horst) structure: the Malé Karpaty (Dui: Kleine Karpaten (N of Bratislava)), the Považký Inovec (S of Trenčin), the Vel'ká Fatra (Dui: Große Fatra (SE of Martin)), The Malá Fatra (Dui: Kleine Fatra (NW of Martin)), the Tatry (Dui: Hohe Tatra (NW of Poprad), the Nízke Tatry (Dui: Niedere Tatra (SW of Poprad)). The principal morphotectonic character and division into the partial structures did not develop before the Neogene folding. The mountain ranges were produced by vertical movements during its latest phases.
The **Slovenské rudohorie Mountains** (Dui: Slowak. Erzgebirge (E of Banská Bystica)) have a more monotonous topography than the Core mountain belt. It is essentially a huge arcuate mega-anticline. The mega-anticline shows a tectonic subsidence towards the west; it is buried by volcanic masses of the Slovenské stredohorie and by a thick cover of Neogene sediments further to the west.
The **foredeep** represents the transition between Bohemian Massif situated on the western and nortwestern side of this furrow, which is filled up by Neogene.
The **Inner Carpathians** (see fig 1 and fig 2) are characterized by Carboniferous crystalline schists, granitoids (Variscan orogeny; Upper Carboniferous), sediments and volcanic rocks of Late Paleozoic age, a nappe system, granitoids (metamorphism and magmatism; Alpine orogeny), and some "post-nappe" sedimentary and volcanogenic formations. The Nappe units are divided into two categories. The fist category nappes are built of pre-Upper Carboniferous basement and overlying later-Paleozoic and Mesozoic sediments. They are considered the basement nappes with dominant crystalline complexes. The second category nappes contain less thick, surficial, rootless nappes built of Mezozoic and partly of Late-Paleozoic rock. Examples of this category are nappes of the

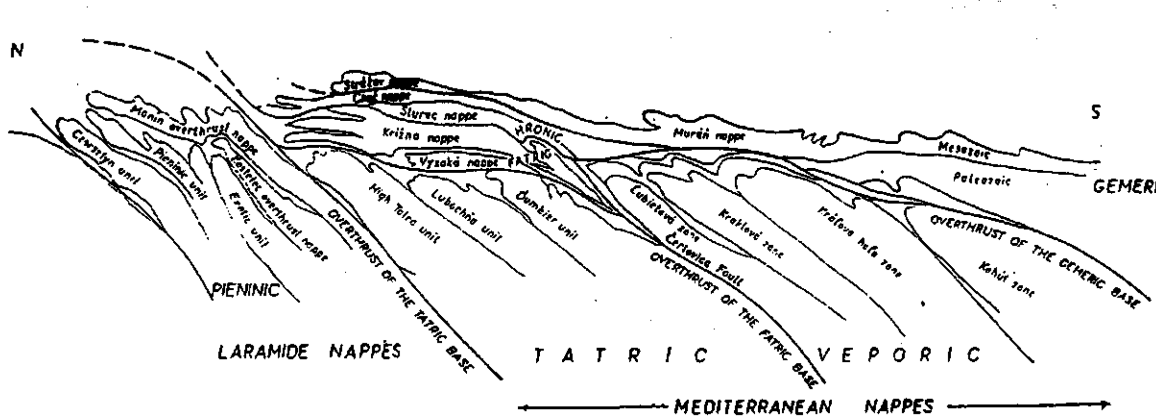

Fig 1 Scheme of pre-Paleogene tectonic units of the West Carpathians

Fatricum (Krížna and Vysoká nappes), Hronicum (Choč and Sturec nappes), and the Silicium (Murán Plateau, Stratenská Upland, Galmus, and several other nappes). During the early stages of the Alpine orogeny (Upper Cretaceous) the existing nappe system was deformed into folds and slices. This folding stage was followed during Neogene by vertical movement. The fold structure was broken into the present orographic units.

Marine Tertiary sediments (Paleogene), deposited widely in the northern and and southern areas of the Inner Carpathians are seperated by the (geo-anticlinal) Slovak Ore Mountains, a section of the Velká Fatra Mountains, and the Low Tatra Mountains. These Marine Tertiary basin thus do form so called intermountaineous basins. The nortern Inner Carpathian Paleogene consists at its base of transgressive conglomerates and limestones and, higher up, of a thick complex of flysch sediments. The southern Inner Carpathian Paleogene consists mainly of beds of clay, sand, limestone, marl, sandstone and conglomerate. The thickness of fluvial deposits is on the average 6 - 15 m, depending on the subsidence intensity. Often, terrace steps are present, being Rissian (Saalian) or Wurmian (Weichselian) erosion terraces. The terraces are usually covered with loess layers. Laterally these layers are wedging out against eluvial loams (desintegrated rock found at the site where the rock originated), or into loamy, sandy, and gravel layers of extensive periglacial fluvial fans (up to 20m thick), forming a broad belt fringing foothills of adjacent mountain ridges.

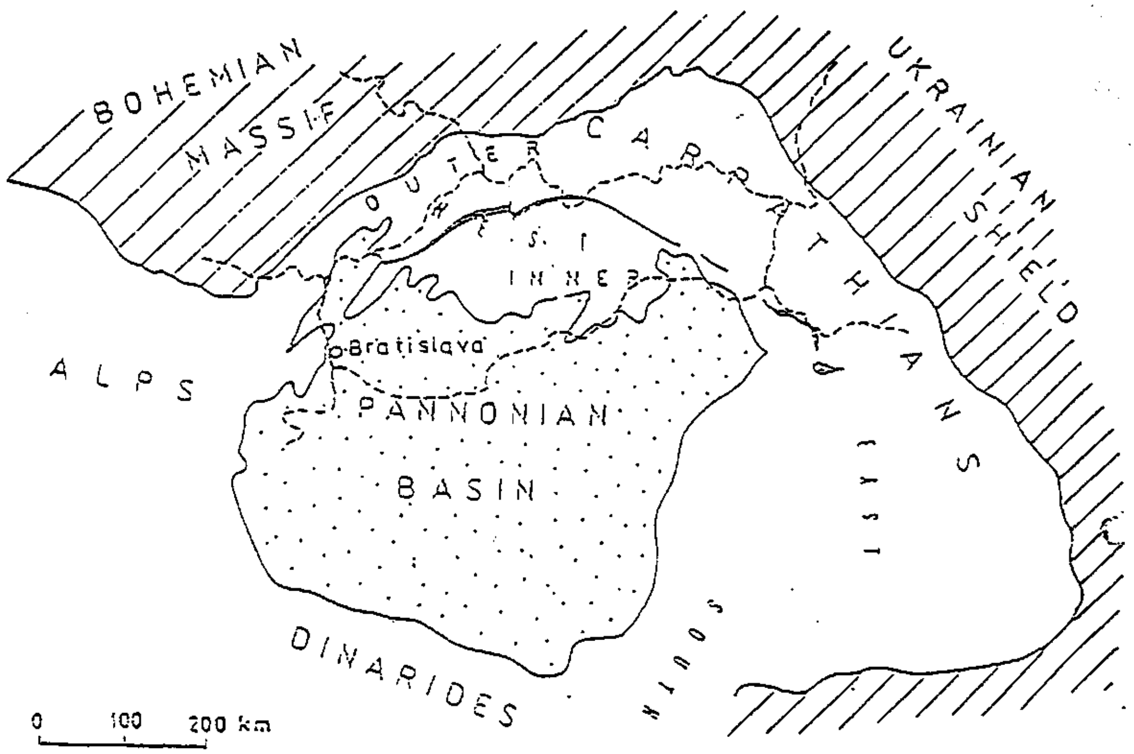

Fig 2 The Central Europe orogenetic units

Hydrogeology of the Inner West Carpathians

Ground water resources in the Carpathian system are associated with rocks ranging in age from pre-Mesozoic to Quaternary. The percentages of ground water resources in the several geologic formations are listed in table 1.

Table 1 Ground water sources in Slovakia

Formation	percentage
pre-Mesozoic	6
Mesozoic sediments	32
Paleogene sediments of Inner Carpathians	3
Sediments of klippen and flysch belts	8
Neogene volcanics	9
Neogene sediments	2
Quaternary sediments, lowlands	27
Quaternary sediments, alluvial	13
	100

Ground water availability (areal distribution, utilization for water supplies) is best in Mesozoic sediments, Neogene volcanics and, above all, in Quaternary sediments.

The Mesozoic, mainly carbonate formations, constitute a large part of the Core Mountains, and also part of the Ore Mountains. Ground water in these formations is mainly related to the intensive tectonism. Middle and Upper Triassic limestone and dolomite, and some Jurassic carbonates, contain the best aquifers (with an area of 3300 km^2). Many springs exist and those with an average yield of 5 - 50 l/s predominate. Annual precipitation is relatively high (900 - 1200 mm), and also evapotranspiration is relatively high (dense forest cover). Therefore the specific runoff of the groundwater is relatively low.

Neogene volcanic complexes comprise the greatest part of Central Slovakia, and a part of East Slovakia (5200 km^2). Their hydrogeological properties are determined chiefly by block structure. Neotectonic forces broke them into horsts and grabens seperated by crushed zones that create favourable conditions for ground water flow. The composition of neovolcanic rocks (mainly andesite, rhyolite, their volcano-clastics, and basalt) adds certain silicates to the ground water.

Quaternary deposits of varied origin, thickness and area fill a dense and long system of river valleys, intermontane depressions and extensive lowlands. Fluvial gravels and sands predominate; eolian, glacial and other deposits are less common. They occur the most in the Danube (Dui: Donau), East Slovakian and Záhorská lowlands (total 5600 km^2). Their thickness is 10 - 50 m, reaching up to 400 m in the Danube Lowland. The permeability of the sandy gravel and sand deposits is 10 - 10^2 m/d. The Danube Lowland is one of the most significant ground water reservoirs in Slovakia. Fluvial deposits in intermontane depressions cover some 3600 km^2, with a thickness ranging from 2 - 65 m (mostly 8 - 13 m).

In the Tatra mountains and their foreland, glacial deposits cover about 400 km^2 and range in thickness from 25 - 80 m. Their permeability is on the average 10^2 to 10^3 m/d. Glaciofluvial deposits have a lower permeability (10^{-2} m/d). Moraine deposits, however, show a permeability up to 10^5 m/d.

Mineral waters occur in all of the tectonic zones. In the Inner Carpathian belt, most mineral waters are found in Triassic carbonates and dolomites of the sedimentary envelopes and nappes. The water is of the Ca-Mg-HCO_3 and Ca-Mg-SO_4 types (up to 50 l/s; up to 70 ^{0}C). Also in Neogene sediments (sand, sandstone and conglomerate) of the Vienna basin, the Danube basin, the East Slovakia and South Slovakia basin mineral water are found. This water is mostly of the Na-HCO_3 and Na-Cl types (up to 24 l/s; up to 92 ^{0}C).

Ground water development

Ground water is mostly developed by means of technologies as captation of springs and drilling of vertical wells. In the case of karstic springs under favourable geologic conditions, horizontal galleries are also employed. Inclined wells have been used with succes for mineral water captation. The combined exploration of ground waterand springs in karst includes the captation of springs in periods of high yield, captation by siphon, and pumping by submersible pumps in extremely dry periods when extensive drawdown of ground water is inevitable. The protection of ground water from contamination in areas of fissure and fissure karst permeability is a special problem. The greatest attention is paid to the protection of open fissure zones draining ground water over long distances. Also numerous corrosion problems on well casings and pumps exist from carbonic and sulpuric acids and also incrustation problems from calcium bicarbonate occurs, especially in the case of mineral water.

Intensive industrial and agricultural activity and high density of population are a source of ground water contamination. The increasing number of ground water pollution cases over the past decades led the government to establish a long-term ground water protection system (installing monitoring weels near pollution sources, pump wells to remove the contaminant). If ground water contamination occurs in the future, the responsible polluters will have to reimburse the Government for the cleaning costs.

Sunday, September 8, 1996

Nature reserve Soos (Cheb-basin)

reported by Sytse Kroes and Lies Peters

The Soos basin is part of the Cheb-basin, which is located close to the German border in the Czech Republic. This Cheb-basin is a unit originated by block tectonics. It is bordered (on all sides) by mountain areas. In the Cheb-basin, numerous faults have developed, mainly in two directions: NE-SW and NW-SE. Because the surface level in this basin was continuously below the surface level of

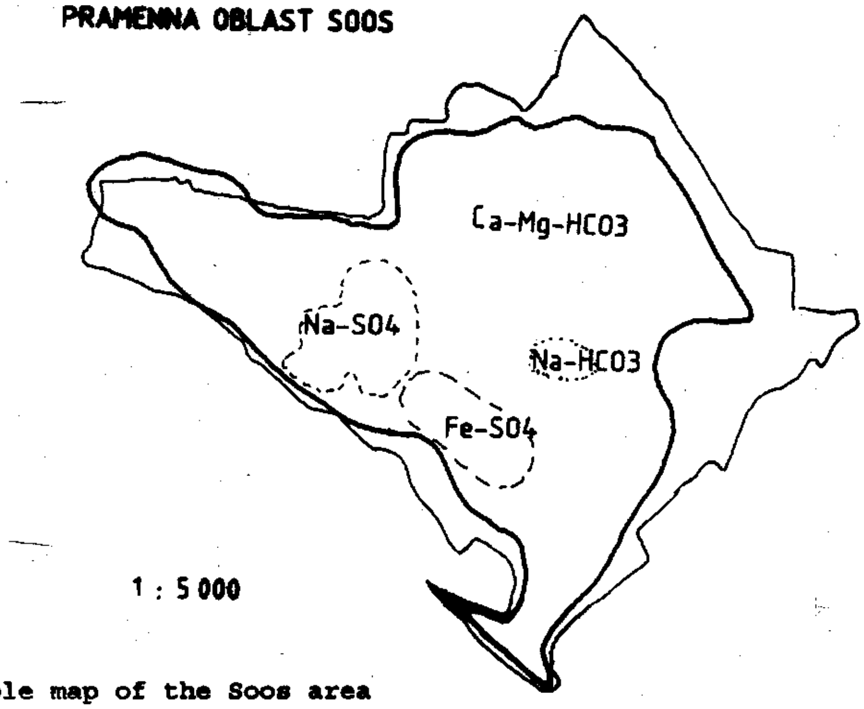

Fig 3 Simple map of the Soos area

its surrounding mountain ridges (from Tertiary onwards), it filled up with lacustrine sediments. At present, the Cheb-basin is the seismic most active part of the Bohemian Massive.

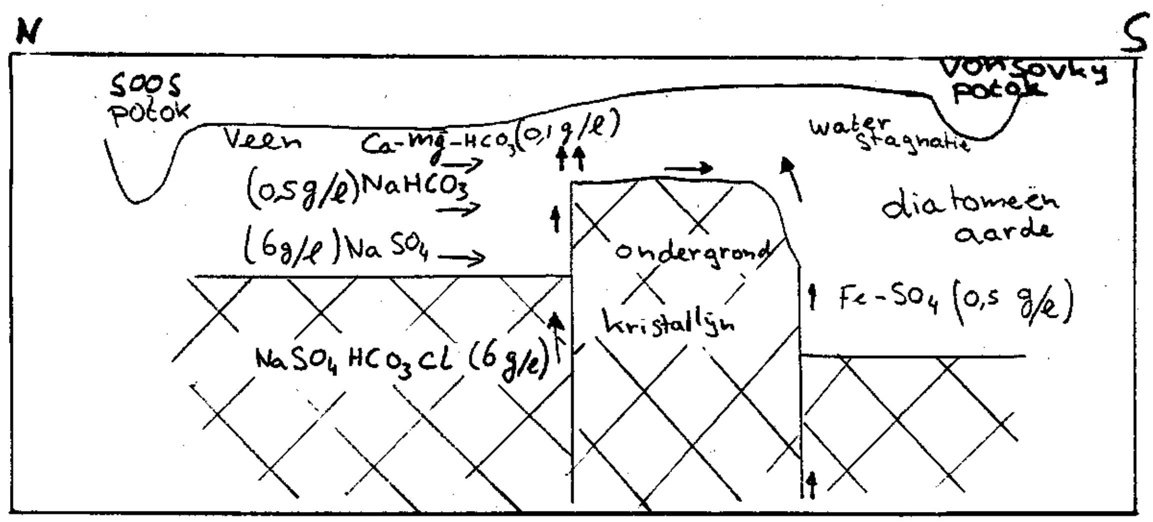

Fig 4 Cross section of the Soos area

The Soos basin is an 2200 m long and 1400 m wide depression, within the Cheb Basin. In the Soos-basin were at the end of Tertiary two flat basins, seperated by a sandy ridge. In fig. 3 a simple map of the Soos area is shown. The Soos basin is bordered on the northern side by the Soos potok (potok (Czech) = brook (English)) and on the southern side by the Vonšovský potok. Also the chemical composition of seepage water is shown. Figure 4 shows a cross section. The sandy ridge on this map is of tectonic origin. In fig. 5, the rock type at greater depth is shown (legenda in Szech and in Dutch). These deposits were formed during the Pleistocene.

The Soos-basin is (and was) very poorly drained. Furthermore, because of its low position in this area, water wells up from the underground. This results in a very wet area. The upwelling water, which has a high mineral content, surfaces in many small springs.

On the northern side of the Soos-basin, the outlet via the Soos potok was limited and the basin slowly filled in with peat. The peat reached a maximum thickness of approximately 4.8m. Because of the upwelling of deeper groundwater the peat is very salty. In the southern part of the basin, there was practically no outlet. This resulted in a very wet area (with high salt concentrations) in which diatoms developed. These diatoms eventually formed a layer of diatomaceous earth (German: Kiezelguhr).

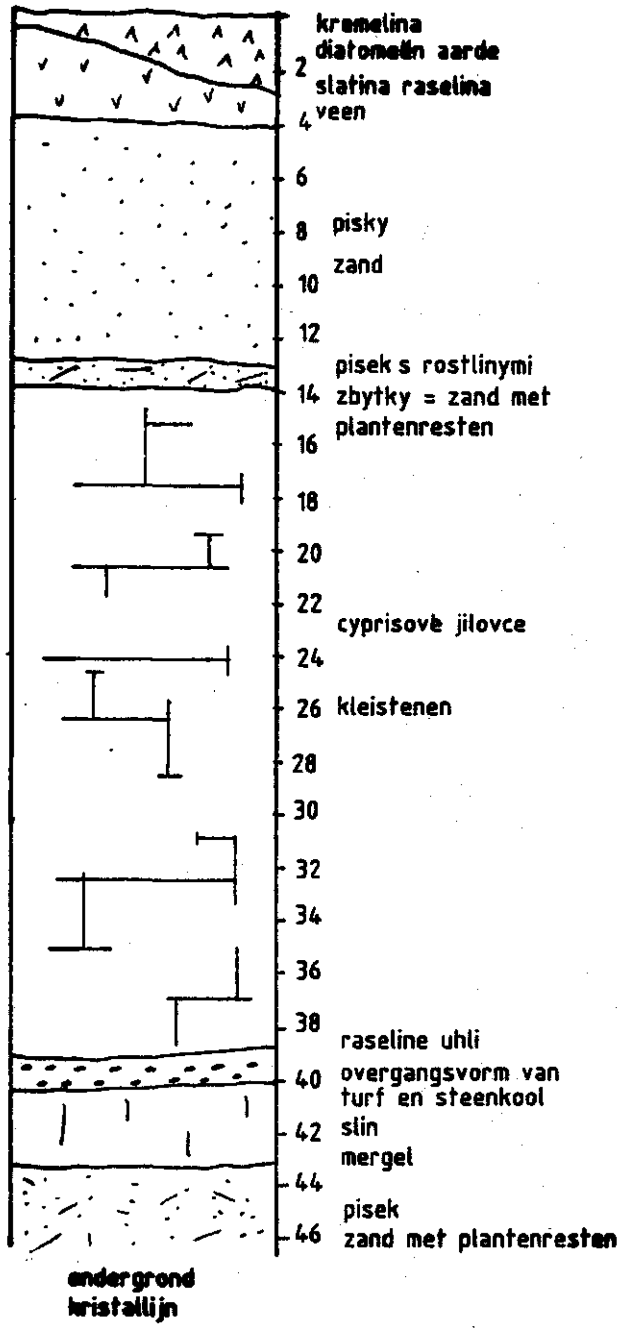

Fig 5 Deep geological section of Soos

In the Soos-basin are over 200 springs. Some are mineral water springs, some are dry CO_2 springs. The high mineral content of the water is caused by contact with the underlying rock. The mechanism is as follows. In first, rainwater infiltrates in the soil. This water flows through sediments and rocks and, after a long way, it comes to surface with a high amount of dissolved minerals. The mineral composition in the water than depends on the type of rock through which the water flowed. De CO_2 in the mineral water originates from deep post volcanic activity. It reaches the surface through deep faults. When this CO_2 passes water bodies, wells with CO_2 containing (mineral) water result. Otherwise a dry CO_2 spring will be formed. Some of the springs have a higher temperature because of mixing with deep warm water.

The composition of the springwater was highly variable (see table 2). The differences are caused by:
- the depth of the spring
- the pathway of the water through the various rocks
- contact time
- the amount of mixing with deep thermal water
- the amount of mixing with CO_2.

The first spring we visited was the "Kaizersquelle". This spring is situated in the northern part of the basin, the peat area. The high mineral content of this spring results in a high electric conductivity (Ec). In comparison, the Ec of rain water is some 10 to 50 μS/cm and the average annual air temperature is approximately 7°C. The (quantitively) most important solutes in the water of the "Kaizersquelle" are Na^+, SO_4^{2-}, HCO_3^-,Cl^-, CaO and MgO. Also Fe and S and some Be and As are present. We visited also a group of moffetes in the southern part off the Soos area. A moffeta is a place were dry CO_2 comes to surface. In a dry moffeta Ec and temperature can not be measured. When a moffeta contains water, Ec and temperature were easured. The result of these measurements are shown in table 2. The high variabilityis obvious. The first two moffeten were only half a metre apart. The other moffetes were on a distance of several metres of the first. So, clearly the water follows various paths through the deeper layers and through the topsoil. Finally we visited the Vera quelle. This spring is also in the northern area. The temperature and the Ec are rather low, compared to the other measurements. Probably the water is from a more shallow source than the water in the Kaizersquelle. The Vera quelle does contain high amounts of CO_2.

Table 2 Ec and temperature in the Soos Basin

	Ec (μS/cm)	temperature (°C)
Kaizersquelle	6060	17,4
moffeta in diatomaceous earth #1	12830	13,6
moffeta in diatomaceous earth #2	7400	14,0
moffeta in diatomaceous earth #3	6670	15,6
moffeta in diatomaceous earth #3	4300	13,1
moffeta in diatomaceous earth #4	6750	15,1
Vera quelle	236	9,8

Tuesday morning, September 10, 1996

The Jergaly drinkwater station

reported by Robert Smallegange and Erjan Zijlstra

Central drinking water station

The station iJergaly is located in Mesozoic rocks. Jurassic limestones and dolomites of the crystalline envelope series, but mainly Triassic limestones and dolomites of the Krizna nappe makes the water of this source of the Ca-Mg-HCO_3 type.

Especially in the limestone the karst is well developed. This results in a relative quick response of 14 days of the catchment to rainfall input. The residence time is much longer, but the system is sensitive to pollution.

The size and exact location of the catchment area (see Fig 6) is not accurately known because the system is much influenced by the karst in the limestone and dolomites. The location and direction of the individual flow paths are unkown and difficult to estimate. This makes it more problematic to determine the protective zone around this Jergaly drinking water wells.

At present, the only measure taken is safegaurding the roads in the area. This is important, becauce of the transport of various hazardous truckloads through the intake zone. Speedlimits are very strict and low speed, and every curve in the road is announced with at least one roadsign. This to prevent trucks and cars to crash and pollute the area.

As an example of the strong influence of karst in this area, two storage reservoirs were shown. These two are the oldest reservoirs in limestone, rich of karsts. At first they used the natural rock as bottom of the reservoir but the widened (by karst) cracks in the limestone caused complete drying up of these reservoirs. Therefore, concrete was used as reservoir bottom to prevent the water to flow away into the karsted limestone.

The advantage of the well developed karst, related to rock without karst, is that waterflow is possible, and thus extraction of water is possible. The water is used mainly for the town Banská Bystrica. The objective flow rate is determined at 250 l/s.

The average annual rainfall in the catchment area amounts 700 mm, whereas the average annual evapotranspiration amounts 400 mm.

The station consists originally of four wells at 50 meter depth. In wet periods the four wells produce easily the objective flow rate of 250 l/s and excess production flows straight back in the brook nearby. The maximum flow rate is 1000 l/s, the minimum flow rate 130 l/s. When free outflow becomes lower than 250 l/s, than measures have to be taken to maintain the demanded flow rate.

At first, it is possible to siphon water out of the wells. When this measure is taken, a pump will start the waterflow through the syphon. Than a steady flow can be maintained without further pumping. When the water level drops more thab 3-4 meter below siphon level, additional pumping (continiously) is needed.

In situations with extreme demands of water it is possible to pump another 500 l/s from two other wells, but only for a short period.

Two small wells in the area.

In the area belonging to the Jergaly drinking water station we also visited two other (smaller) wells. Both of them were near the road from Ružomberok and Banská Bystrica. To prevent the traffic polluting the wells small tunnels into the rock have been made to withdraw the water from the well before any pollution from traffic can infiltrate in the well.

We did see two small tunnels with very clean and cold water but with flow rates of no more then about 5 l/s. The station has more of these well and together they provide a reasonable contribution to the total amount of water, won in the area.

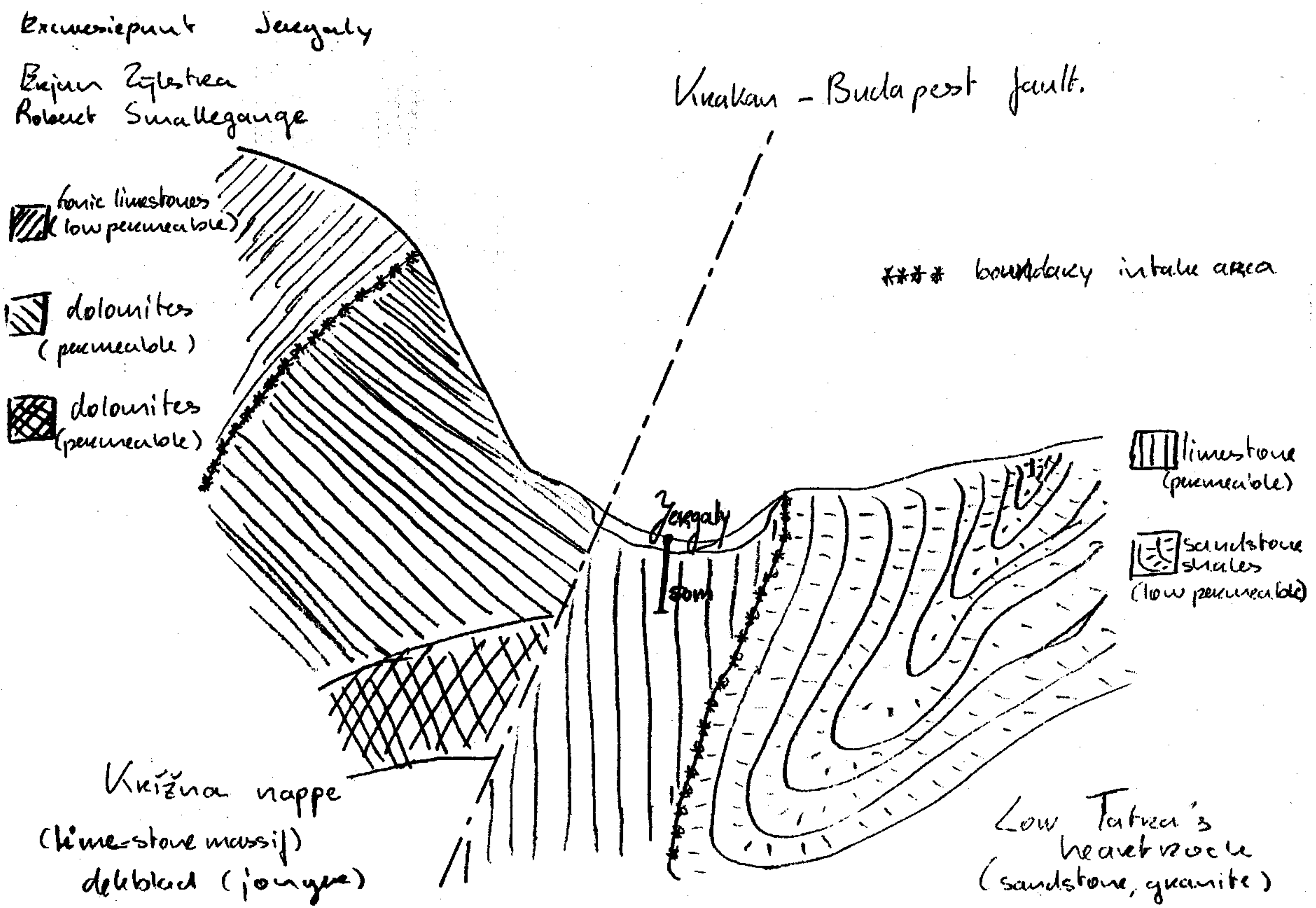

Fig 6 Cross section of the Jergaly intake area

Tuesday morning, September 10, 1996

The Harmaneč tunnel water supply system

Reported by Saske Poppema & André Niemeijer

The Harmanec tunnel is part of the railway line from Banská Bistrica to Martin. The railway, completed in 1938, crosses the Vel'ká Fatra. The geological structure consists of Middle to Upper Triassic formations of the Šturec nappe. This nappe belongs to the second Nappe unit category, built of Mezozoic and partly of Late-Paleozoic rock. During the early stages of the Alpine orogeny (Upper Cretaceous) the existing nappe system was deformed into folds and slices. The folding stage was folowed by vertical movement during Neogene. The fold structure was broken into the present orographic units. Figure 7, the geological structure in which the Harmanec tunnel is built, shows that relative young structures are overlain by relative older structures. This is caused by a reverse fault.

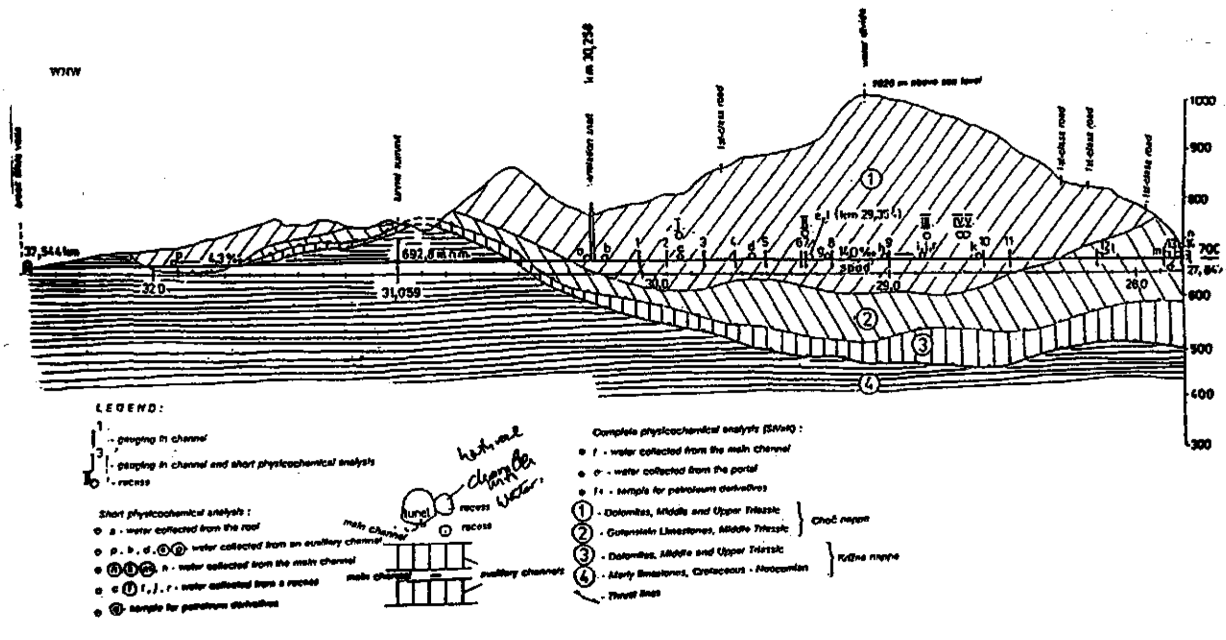

Fig 7 Longitudinal section of the Harmanec tunnel and geological formations

The hydrological base consists of the younger marly limestone structures formed in the period from Cretaceous to Neogene (Tertiary). The older structures, overlying these relative young rock, consist of dolomites and limestones. These dolomites and limestones form an aquifer, from which the productive part the dolomites from Middle to Upper Triassic is considered. The total structure lies in a sycline which originates from the reverse fault and the Alpine orogeny.

In first, the only objective was to build a railway tunnel. Due to the high permeability of the dolomites, a lot of water (800 l/s) was discharges through the tunnel during the construction period. This productivity was initially high because of the opening of major cracks. After finishing the constuction of the tunnel, these cracks stayed productive. Because of the high amount of water and its potable quality they start to use this water as drinking water.

In first, when exploration of this water was started, no techniques were used to prevent contamination of the water. Because of the natural mixing of oil (from the trains) and gravel, an

impermeable layer was formed in such a way that the natural water, flowing out of the cracks into a drain at the bottom of the tunnel, was protected against polution from the railway. When the railway transport changed from streamtrain to electric- and diesel-train the tunnel was deepened, because of the installation of electric wires. Together with this adjustment, also a new drainage system was installed, for a proper protection of contamination.
In general, the water quality is satisfactory, in terms of potability. The only quality problem of the water is the high concentration of chloride. During the excursion a value of 22 mg/l was mentioned, and in the excursion book you can find a concentration of 10 mg/l. The latter is may be a quality measure of a long time ago. The high concentration chloride, compared to a natural concentration, is induced by salt spreading on the road during the winter period. The use of salt has been stopped five years ago, but still a high chloride concentration is measured. This can lead to the conclusion that the residence time of the ground water is at least five years.

Tuesday afternoon, September 10, 1996

The Neo-volcanic area near Zvolen/ Podzamčok (andesite quarry)

reported by Frank Kortstee and Casper Hoefsloot.

The Zvolen Basin is situated north of Zvolen and has a north-south oriëntation. The basin is lying on the big faultline reaching from Krakow to Budapest. The occurence of this fault and smaller faults is the most important geomorfological process, responsible for the origine of the basin. Block-tectonical action resulted in the formation of horsts and grabens. At the western side of the area, pyroxene and hornblende andesite comes to surface. These rock formations are the result of volcanicactivity near the faults. At the east of the Zvolen Basin, rhyolite rocks from Miocene age come to surface. These vulcanic rocks are covering the cristalline rocks.
The basin/graben itself consists, from surface downwards, of fluvial deposits (Pleistocene), tuff (Miocene), and basalt (Miocene). This complex rests on a layer of carbonate rock (Upper- and Middle Triassic). The thickness of this layer is unknown. Probably beneath this carbonate rock, cristalline rock is present (see Fig. 8).

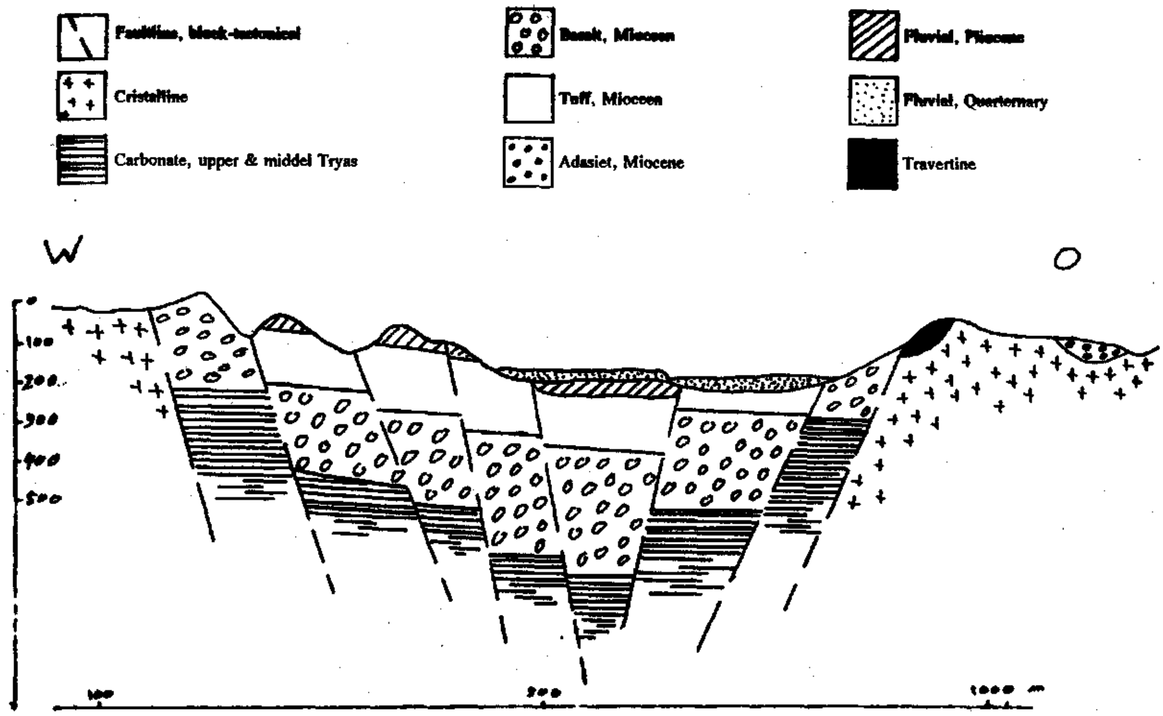

fig 8 Cross section of the Zvolen Basin

This geological profile can be explained by the geological processes in time. The structure is a result of a combination of a descended area (graben) on the faultline Krakow-Budapest and an uplifted area (horst) on both sides of this descended area. Erosion of the uplifted parts during Pleistocene results in relative old rock at surface, while sedimentation in the lowered parts generates relative young formations at surface.

<u>The Neogene area.</u>

This area is situated southern of Zvolen and consists mostly of volcanic rocks from Neogene age. The quarry we visited consists of andesite which is an intermediate, magmatic and porphyrical rock. In this quarry we found beautiful red granates. A clear explanation for the occurence of these granates is not available.

Hydrological aspects of the Neogene area.

Normaly volcanic rocks are not good aquifers because of their low permeability. In this area however, a lot of faults (cracks) are present, what enables watertransport from very great depth to surface. This is known because the temperature of the water varies between 14 and 18 °C, which is a relative high temperature. A high water temperature suggests contact with deeper rock. The cracks are narrow structures that only result in low discharges that can not provide enough (potable) water for the area. So, surface water is supplied from the region around Banská Bystrica.

In this Neogene area we finally visited a health centre which is used by people who believe the mineralwater from the deep wells has a healing effect on various diseases.

Wednesday morning, September 11, 1996

The Demänová cave

reported by Henri Mulder and Mariëlle Mulders

The Demänová cave system is the most extensive cave system of Slovakia and is situated in the Demänová dolina. This valley is a part of the Liptov Basin which is situated south of Liptovsky Mikulas.

A cross section (Fig. 9) shows the geological position of the cave system in relation to its surroundings. The High Tatra in the north and the Low Tatra in the South are the borders of the Liptov Basin and they both consist of unpermeable rocks. The basin has been filled up with Triassic dolomites and limestones which belong to the Choč and Krížna nappes. These rocks are strongly

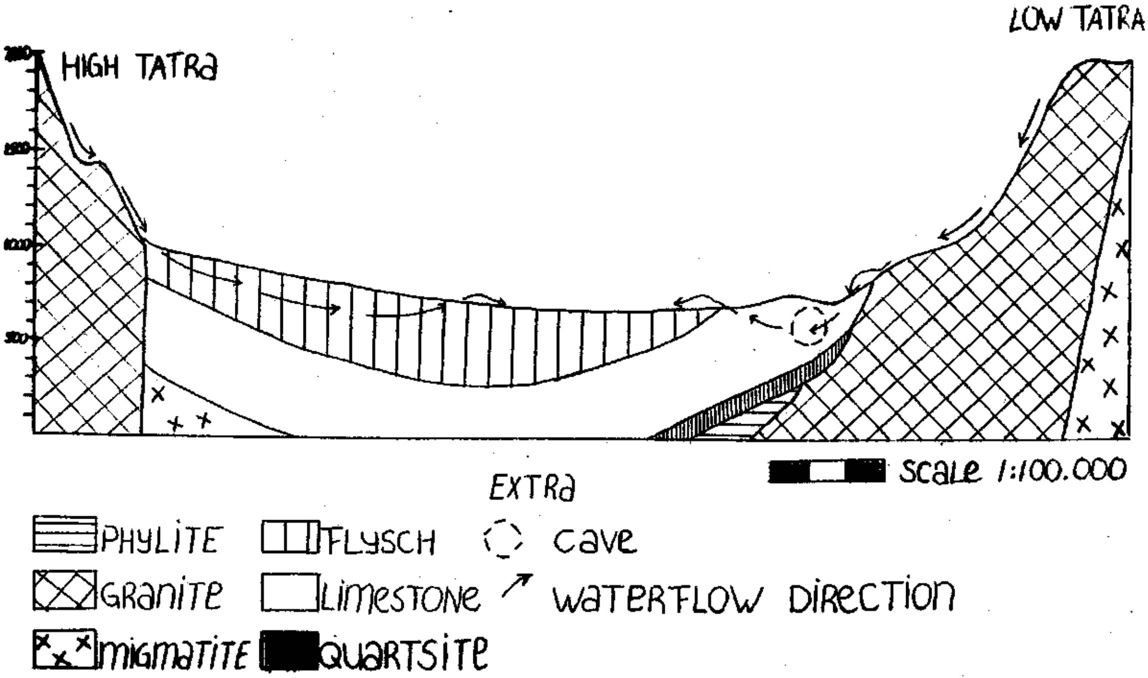

Fig 9 Cross section of the Demänová caves

fractured and have therefore a high (secondary) permeability. At the northern side of the Liptov Basin, flysch sediments are present, which are poorly permeable. In the southern part the Demänovka river flows mainly over the granite of the Low Tatra. Downstream the river enters the limestone by sinkholes of which we saw one by the entrance of the cave. The flow route through the rock system has a length of about 3 kilometers, then. Eventually the river reaches the surface in a karst spring. At Liptovský Mikuláš the Demänovka river flows into the river Váh. North of the cave system, the water flows mainly over granitic rock of the High Tatra and reaches the poorly permeable flysch.

The presence of the cave system is the result of:

- presence of limestone (water soluble)
- well developed relief
- the presence of joints
- well developed bedding planes
- relative high precipitation amounts

The Demänová cave system is developed in Middle Triassic limestone and is, in comparison to the

Belgium Middle Devonian limestone, very young. This can be explained by the considerable fracturing of the limestone, during the Alpine orogeny. After this development of fractures in the Triassic limestone, karst developed. The relative high precipitation amounts (1500 mm/year), the very thin limestone beds, and the well developed relief initiated the widening of the initial cracks, and eventually the formation of a cave system.
The Váh river did cut into the Liptov Basin and therefore lowered the drainage base for the Demänovka river. As a result the last mentioned river started cutting into its substrate. Water, originally flowing over the old bedding plane, will start to flow through cracks in this bedding plane to a lower bedding plane. Then this lower bedding plane will be effected by karst. This process resulted in the development of six horizons in the Demänová cave, each level representing a

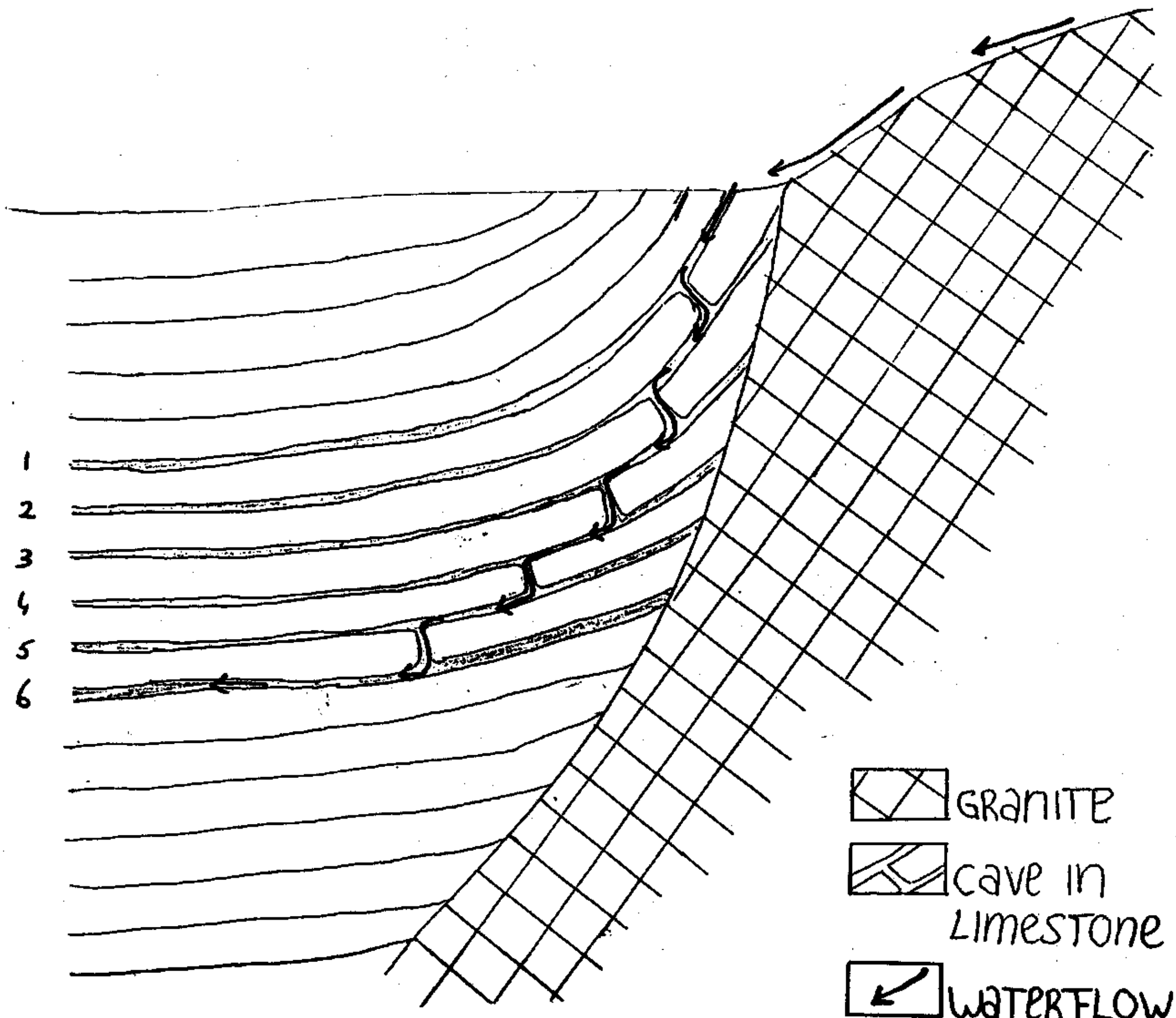

Fig 10 Waterflow through the limestone

(formal) drainage base. (Fig. 10). The present Demänovka river bed is the lowmost level. When we walked through the cave we followed the limestone planes. Also we descended several stairs in big fractures through limestone beddings to reach lower limestone beddings. In contrast with the Demänovka river we also climbed through a couple of fractures and finally reached the same height as our starting possition.
The air-temperature in the cave is constant over a year (7 °C), the air-humidity is also constant (98%). The water of the Demänovka river in the cave has a temperature of 2 to 5 °C and an Ec of 296 μS/cm. This is a low Ec value for water that flows through limestone. This indicates that there has not been much interaction between water and limestone. So, the contact time should be short

(short residence time). Therefore the cave system must be a quite fast responding system.
In the cave, beautiful stalagmites (pillars which stand), stalactites (pillars which hang) and stalagnates (pillars which stands and also touch the ceiling) are present. These structures are the result of the following process. Water with a high content of Calciumbicarbonate (close to saturation) flows to the cave. Evaporation of water (together with a low water velocity: dripping water) in the cave causes oversaturation. Than the Calciumcarbonate will form "sheets" on the surface, either on the ceiling of the cave (stalactites), on the floor beneath these stalactites (stalagmites). The calciumcarbonate shows a variety of (orange) colours due to different chemical compositions (in space and in time) of the water. When water did flow through iron-poor rocks or sediments the Calciumcarbonate shows a pale orange colour. However, when the water did flow through iron-rich rocks or sediments a dark orange clour occurs. The variety of orange colours shows that the Demänovka river flowed through different rocks and sediments in the past.
Finally, there were also some horizontal hanging conglomerate plates in the Demänová cave. These plates are the result of the fixation of coarse sediments with Calciumcarbonate. This proces takes place at the edges of the river bed. After dissolving the limestone beneath this layer a hanging conglomerate plane remains.

Wednesday afternoon, September 11, 1996

High Tatra: Štrbské Pleso

reported by Falentijn Assinck and Anke van Dellen

Štrbské Pleso is a glacier lake which is situated at the south side of the Tatry in the North of Sovakia, NW of Poprad.

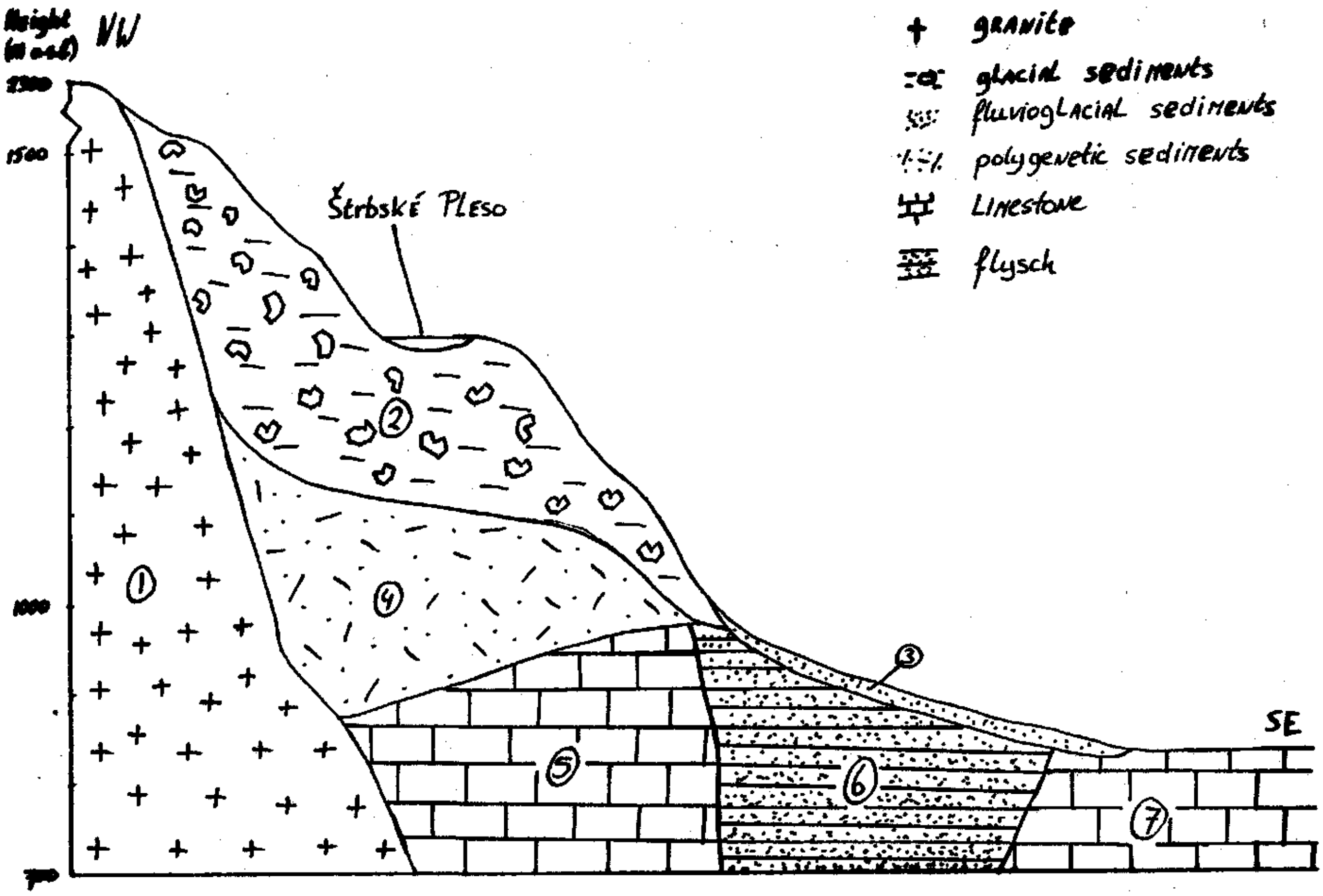

Fig 11 Cross section of the Tatry

Near Štrbské Pleso a cross section of the Tatry was shown (Fig 11). This north-south oriented section starts high in the Tatry (±2350 m a.s.l.) and ends in the Váh valley (±700 m a.s.l.). The inner mountains consist of granite (1). Granite is an felsic, magmatic rock which is (near surface) influenced by physical weathering. Downhill, glacial sediments (morenes) (2) and fluvioglacial sediments (3) were deposited. Beneath the glacial sediments there's a layer of polygenetic sediments (4). These sediments are weathered and transported several times. The origin of these sediments is unknown. Underneath these polygenetic sediments, a layer of Middle Triassic limestone is present (5). South of the fluvioglacial sediments, there is a flysch layer. Flysch is a sedimentary rock, typically consisting of a thick sequence of interbedded marine shales and sandstones (6). South-east of the flysch, Middle Triassic limestones can be found (7).

Before the Alpine orogeny started, the granite rock was covered with a layer of Middle Triassic limestones. During the Alpine orogenese the Tatry area was uplifted and folded, many fractures occured because of this. The typical shape of the surface of the Tatry is the result of river erosion, followed by glacial erosion during glacial ages. The glaciers developed during these glacial ages and moved downhill. These glaciers physically deformed the landscape in sharp mountain ridges, pyramid like peeks and deep, wide U-shape valleys. (Fluvio-)glacial morenes were formed in the valleys on top of the limestone and granite layers. The flysch is thought to be derived from the erosion of rapidly rising fold mountains and is itself deformed in the later stages of the orogenese. Morenes (glacial sediments in Fig 11) consist of all kind of erosion products (ranging from clay up to huge boulders), which were transported downhill by the glaciers. An accumulation of these materials can normally be found at the foothill. Uphill of the morene-wall, melt water was blocked. Glacier Lakes like Štrbské Pleso (Ec 31µS/cm) developed.

In the Tatry area the average annual precipitation is 2000 mm. From October until May the mountain peeks are covered with snow. The hydrological system reacts quickly on precipatation and melting events because the discharge water flows superficial through the regolith (weathered toplayer of granite). The drainage density of the granite area is high and therefore there are a lot of brooks and waterfalls like the Studenovodské vodopády (cold waterfalls).

The discharge water (of this waterfall) has a low Ec (23.8 µS/cm), because of the poor mineral composition of granite rock. Therefore the chemical compositon of the discharge is almost the same as the chemical composition of precipitation.

Because of the uplifting, folding and chemical weathering, the limestone in the Tatry has a high secondary porosity and permeability. When surface water reaches limestone formations, it infiltrates easily into these cracks. In the fraction zone between the Tatry and the Váh valley the water out of the limestone rises to the surface in several (mineral) springs. In this area there are also several dry CO_2 springs.

Thursday morning, September 12, 1996

Prosiecka dolina

reported by Jan-Peter Ruitenbeek and Thomas de Meij

Introduction

The Prosiecka Dolina (literally: valley near Prosiecka) is a deep and narrow incised brook valley which is cut into a limestone layer. During the excursion the upper course of the brooklet was dry, only after heavy rainfalls one can see high discharges here. The present brooklet flows down a waterfall into the canyon. The excursion consisted of a walk from the start of the canyon (where the brooklet flows into the Liptov Basin) up towards the plateau, consisting of flysch layers. During the walk the Ec-value and the temperature were measured in different sources and in the brook itself.

Geology

The area of the Prosiecka Dolina consists of a limestone cover which, by tectonics, is lifted up onto the existing crystalline core mountains. The cover consists of two layers; the upper Chočské nappe (with little water) and the lower Križňanský nappe (containing a lot of water). Also, so called flysch has been formed, consisting of shales and sandstones. In the lower parts the flysch has been accumulated.

Triggered by tectonic movement, the covers are divided in blocks by fractures (block tectonics), of which some has been lifted up again. This process resulted in relative high limestone plateaus with on top a flysch nappe and low-lying basins where the surface also consists of flysch.

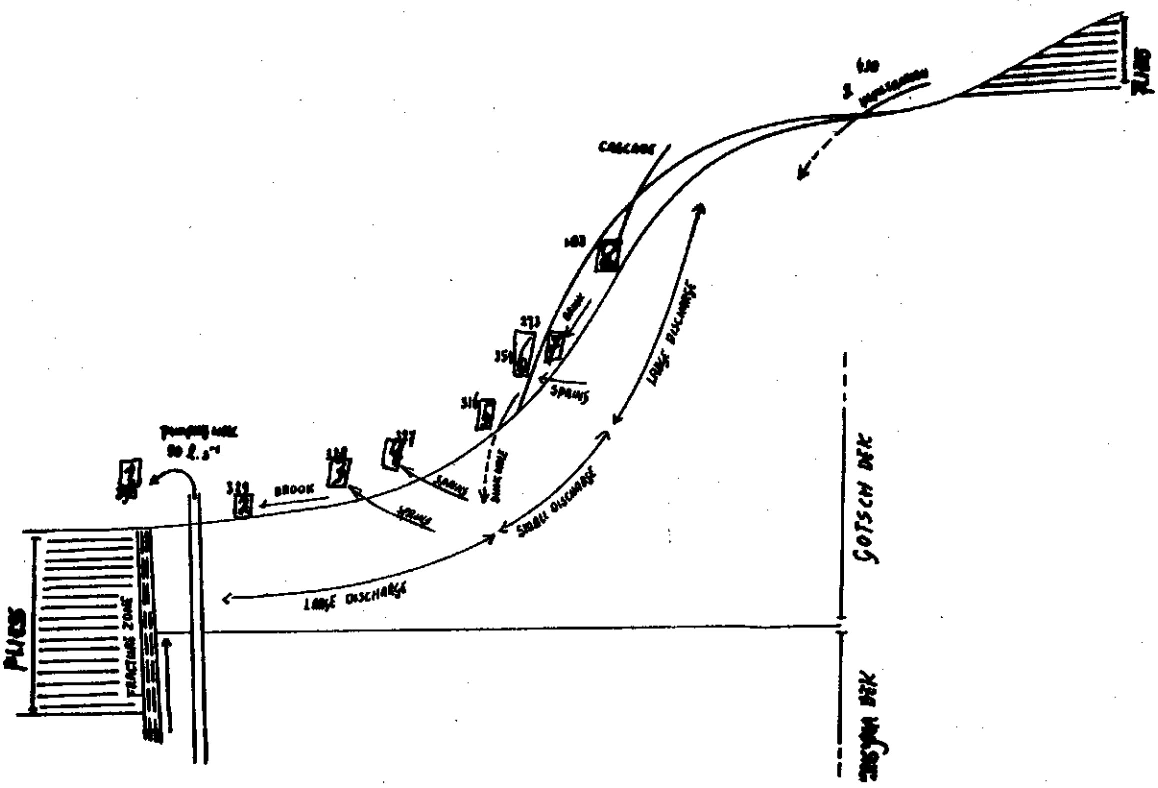

Fig 12 **Cross section of the Prosiecka dolina**

The Prosiecka Dolina has been developed by water flowing from the plateau and cutting its way through the limestone. Down the canyon, where the brook flows into the basin, a flysch nappe and a fracture are situated (Fig. 12). Because of this, water accumulates in the subsoil (the Križňanský nappe). Here a pumping-well is placed, which pumps water with a discharge of 50 l/s. The water surplus flows into the brooklet. By using a Qh relationship (discharge &waterlevel), the discharge on the excursion day was estimated to be 30 liters per second.

EC-measurements

In total there were measurements taken on 8 locations in the valley (see Fig 12). Measurement 1 was taken in the discharge of the pump-well. The Ec (390 µS/cm) is representative for the deep Križňanský nappe. The spring sources which flow into the brook, upstream from the pump-well (measurements 3, 4 and 6), are probably coming from the Chočské nappe. This is indicated by the Ec values of location 3 and 4 (327 µS/cm), which is significantly lower than the Ec value of the water in the pump-well. For the high value of measurement 6 (354 µS/cm), it seems hard to give an explanation.

When the course of the Ec-measurements is followed from the upper flysch plateau downstream, one can draw some interesting conclusions about the hydrology of the Dolina area. To start with, the quality of the water from the plateau reaches that of rainwater (183 µS/cm). In the days before the measurement it had rained a lot, so it seems that the rainfall on the plateau is transported rapidly through the flysch nappe. We also can see that the Ec of the water increases quickly as soon as it flows through the limestone of the valley (measurement 7: 273 µS/cm). Further down, the brook gets water from an ion-rich source (354 µS/cm). In the field a strong decline of the discharge was seen further on, this was at a place were, according to our Slowakian guides, in dry times the water dissapears completely in the ground (a sinkhole). The Ec of the brook-water was here 316 µS/cm (measurement 5). After this the brook is filled with water from the before mentioned sources (meusurements 3 and 4). The Ec of the surface water seems to be almost the same as that of the sources.

Summarizing, one can say that water in the brook at the top consists of rain water and shallow ground water. Then, coming from the plateau, its water is slowly enriched with ions, while flowing through the limestone. Halfway downstream in the valley, this water disapears in the ground. Further downstream, several sources add a lot of water to the brook. The chemical composition of the water of these sources is very close to that of deeper ground water. The chemical composition of the brook water is therefore, downstream of these sources, mainly of the groundwater type.

Upper course of the brook

After visiting the place where the waterfall flows in the canyon, the excursion went higher up through the dry valley, which gradually becomes narrower and steeper. The last part of the plateau consisted of very spectacular steep walls, where in wet periods the water does make waterfalls. It is not possible then to walk in the valley.

The shift from valley into plateau gave a last surprise. Here was a big bowl formed, as a result of backward erosion. Downunder this bowl there was a small outlet to the brook. Because of the swampy soil it was clear to see, that water is continuously accumulated here. That this water is in contact with limestone is acceptable, taking the high Ec value of 430 μS/cm in account. This was affirmed by the discovery of *Triglochin palustris*, a relatively rare plant of basenrich graslands.

Some remarks

- The Slowakian word "dolina" means valley and has no meaning at all with the Dutch word "doline" (The Slowakian word for that is "szavert").
- The relation to measure the discharge in the particular discharge measurement structure at the outlet of the pump-well is the following:

  $Q = 1.86\ b\ h^{3/2}$

  in which: Q: discharge m^3s^{-1}

  b: width, was 0.51 m

  h: waterheight, was 0.10 m

Thursday afternoon, September 12, 1996

Slovak Hydrometeorological Institute (SHMI) at Liptovská Ondrášová

reported by Marc Balemans, Bas Kennis, Ellen Weide and André Schmidt

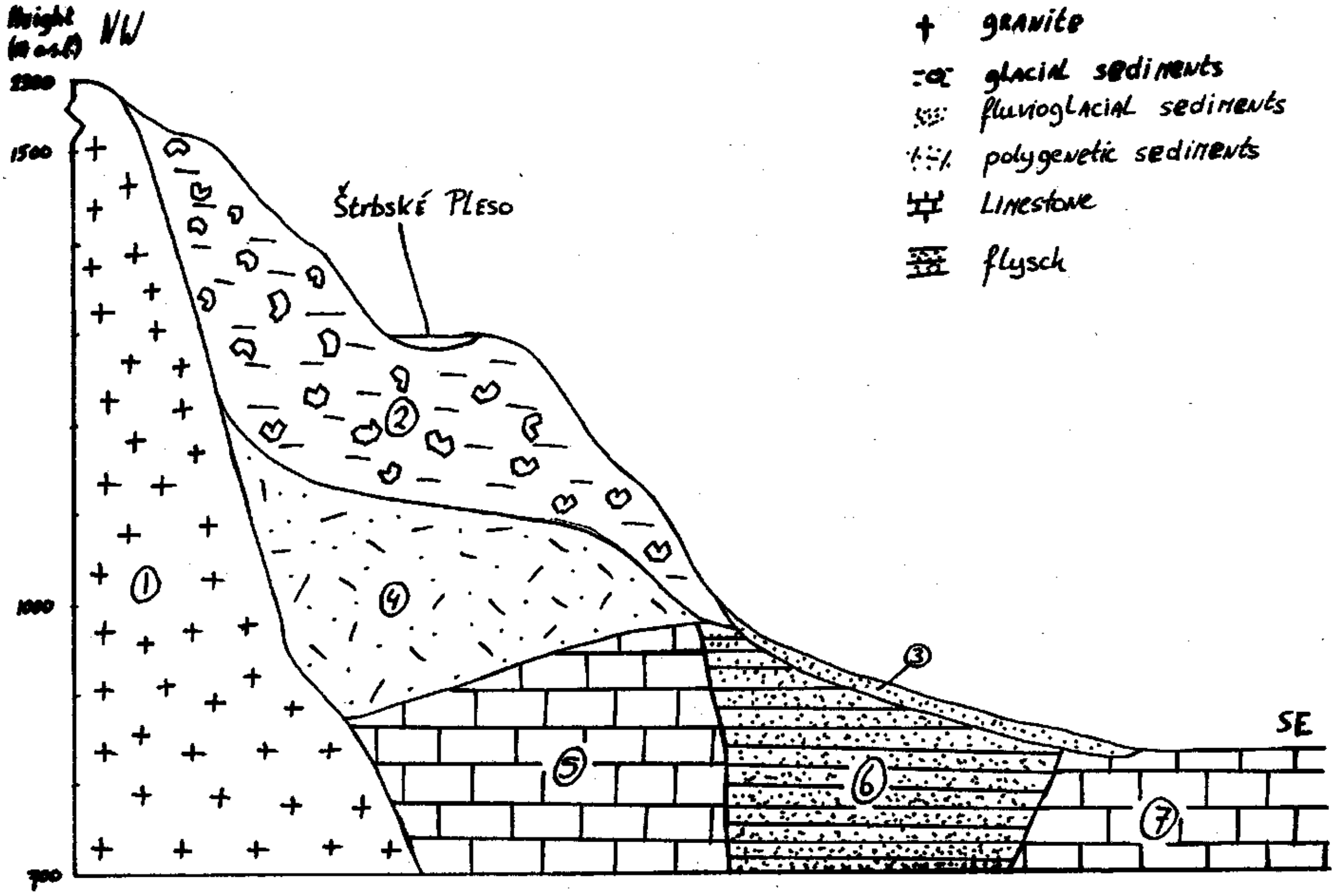

Fig 13 Cross section of the Tatry

Major aim

At the southside of the west Carpathians one can find Ondrásová, where one of the research plants of the Slovak Hydrometeorological Institute is settled. For a NW-SE cross section of this tatry, see Fig 13. At this moment the water balance components and water processes in mountainous areas are studied here. The major objectives of the research are:

- processes in the soil-plant-atmosphere system
- transport of water and polution in the saturated and unsaturated zone
- snowcover-hydrology

Jalovecký potok research catchment

In order to achieve the objectives mentioned above a catchment area was selected for research at the western part of the higher Tatra. This area, called the Jalovecký potok research catchment, is the catchment area of the Jalovecký river, which discharges into the Liptovská Mara (Liptov Lake). The research started in 1986.

The Jalovecký catchment has a total area of 46 km^2, of which 23,4 km^2 is used for research. Some other features aregiven in table 3.

Table 3 Features of the Jalovecký catchment

forest cover (%)	elev. max. (m a.s.l.)	elev. min. (m a.s.l.)	elev. av. (m a.s.l.)	percipitation (mm/year)	runoff (mm/year)	Specific yield (/ls/km)
49.6	2177	825	1500	1278	689	21.8

The geology of the catchment area is mainly characterised by granites and metamorphic rocks. Only 7% consists of mesozoic rock (dolomite and limestone). In the lower part of the catchment morenes are found. The slope angle is quite steep (27°). The vegetation-cover consists of the following vegetation-types (from the lower parts of the catchment to the higher parts):

- forest (up to 1500m)
- meadows with dwarfpines
- bare rock

measurements

For the research in the Jalovecký research catchment the most important data are the following:

Discharge: This is measured at the outlet of the basin, at 3 different stations. (mean: 500-800 l/s, low: 100-300 l/s, high: 2000 l/s)

Precipitation: There are two devices with which the precipitation is measured: the tipping-bucket (only in summer) and the storage gauge (1x month). Data-analysis of these measurements showed a big difference in precipitation between the higher and the lower part of the catchment (lower part: ±800 mm, higher part ± 1600 mm).

Evapotranspiration

Soil moisture content: This is measured with tree different methods:
1) Gravimetric method
2) Specific Electric Resistivity method
3) TDR

Snowcover analysis: When analysing the snowcover, the color, the watercontent and the chemical composistion of the snow is measured.

Research examples

Soil moisture content

When studying the soil moisture content, the spatial distribution of soil moisture of the catchment is described using a Geographic Information System (IDRISI/MAPINFO). The soil moisture is measured at 23 different locations in the catchment, which differ in slope, vegetation-cover and hight above sea level. The relation between the climat-, vegetation-, and topology-parameters and the soil moisture contents of these locations was figured out. All these parameters and their relations were put in a GIS. This soil moisture study of the catchment makes is possible to:

- make inter- & extrapolations of the soil moisture distribution.
- make estimations about the re- and discharge of the catchment area.
- get a better insight in the ecology of the area.

Estimations about the contribution of groundwater to the runoff using isotope-hydrology

To get a good understanding of the contributions of groundwater to the runoff one can use the ratio between the lighter (^1H) and the heavier (^2H) isotope of the H-atom in water.

Higher in the catchment, the water will be lighter. This results in a difference in weight between water that was in the soil for a while (groundwater), which is called old water in this research, and water just fallen from the air (percipitation), which is called new water. The former comes from the higher parts of the catchment and is lighter, the latter is heavier. Using isotope-analysis one has been able to find out that when in spring the snow starts to melt, this melt-water pushes forward the groundwater that was stored in the gound. The discharge first consists of 'old' groundwater, and only after a while the melt-water start to contribute. At the end of the melting-period the difference in weight between the watertypes is too small, which makes the measurements impossible.

Thursday afternoon, September 12, 1996

Bešenova travertine

reported by Karin de Bruin en Wim de Vries

<u>Geology of Bešenova</u>

Bešenova is located in the Liptov Basin in the nothern part of Slovakia. This Liptov Basin contains mineral springs. The occurence of these springs can be explained by looking at thegeology. Figure 14 shows a north-south cross section of the Liptov Basin. The hydrogeological base consists

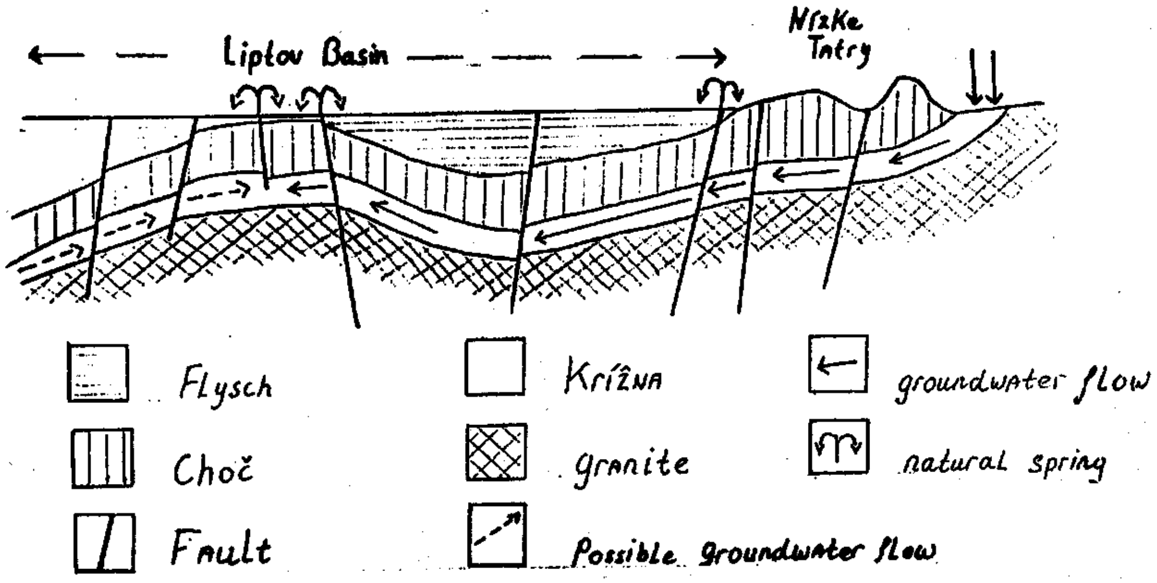

Fig. 14 Cross section of the Liptov Basin

of crystalline rock: granite. On top of this granite two nappes, consisting of limestone and dolomite, are present: the Choč nappe and the Krížna nappe. On top of this, flysch of Paleogene age is found. In this area many faults occur. The mineral springs (for the location of these springs: see fig 14) are associated with the Triassic dolomites and limestones which belong to the Choč and Krížna nappes. Their outflow concentrates on the northern part of the Liptov Basin at its tectonic edge, in the center of the basin (Bešenova) and on the southern transgressive edge of the basin (Liptovská Štiavnica, Vyšný, Sliač and Liptovský Ján). The temperature of the springs ranges from 20-34 °C, containing CO_2 and, in Vyšný, Sliač and Liptovský Ján, also H_2S.

The infiltration area of the mineral springs of the Liptov basin can be divided in two sub-areas. The springs at Lucky Spa have their infiltration area on the southern slopes of the High Tatry, and from the Nízke Tatry. The springs in the southern part of the Liptov Basin have their infiltration area on the northern slopes of the Nízke Tatry. The occurence of these mineral water springs is connected with the intersection of longitudinal and transversal faults in the basin, and the high groundwater head in these deeper aquifers (compared to the phreatic aquifer).

The Springs

The natural springs bring water and gasses from the Krížna and Choč nappe to surface. The chemical composition of the groundwater of these two nappes is not very different. Therefore it's impossible to predict the source off a well by its chemical composition. Near the Nízke Tatry, a pumping station has a pump well into the Choč nappe. This could be a reason for the fact that most of the springwater that flows out of the natural spring is from the Krížna nappe (and little from the Choč nappe). If the transmissivity of both nappes would be equal, and when no resistant layer is present, than both nappes would act as one aquifer. Mixing of (Krížna and Choč) water within this aquifer is likely to occur. Because the transmissivity of both nappes is not equal and because it is likely that there will be some resistance between the nappes, mixing is difficult. Keeping in mind the before mentioned pump well in the Choč nappe, it is explained that most water comes from the Krížna nappe.

Table 4 Results of Ec and Temperature measurements at the springs

spring nr.	T (0C)	Ec (μS/cm)
1	14,3	3090
2	15,3	3140
3	19,9	2930
4	21,1	2870

From this measurements can be concluded that water from the different springs has the same origin. There are no big differences in temperature and Ec (Table 4). The relatively high temperature indicates a deep groundwater circulation.

Travertine

The springs at Bešenova initiate the development of travertine. The mechanism behind the development of travertine is as follows. The water of the springs contains CO_2 in solution as CO_3^{2-} and HCO_3^-. When water reaches the surface, the CO_2 can evaporate and Ca^{2+} CO_3^{2-} dissolves. This process of precipitation is accelerated by algae, which use CO_2. Precipitation of $CaCO_3$ kills algae. The process of precipitation of $CaCO_3$ and the influence of algae causes the development of a porous, layered rock:travertine. The colour of the travertine is caused by the admixture of other elements, such as Fe, Mn.

The Dam

Near Bešenova a dam is constructed in the Liptov Basin. The construction of this dam did cause a change in drainage base and the erosion base of the river Váh. Upstream of the dam, the drainage base is higher than before construction. Old springs, which were dry before the dam was build, have considerable flow since the construction. These old springs have the highest yield in the whole area.

The springs do not come to surface on the same spot all the time. Water will allways follow the easy way to surface. This easiest way can change in time.
The groundwater level near the spring was also measured in a piezometer. The level in this piezometer was 4.4 m below reference (upper end piezometer). In march the level was 9.1 m below reference. So, the groundwater level did rise 4.7 meter over this period because of the wet conditions.

The boreholes

In the Liptov Basin two boreholes were constructed. The first one had a depth of 450 m. This borehole was drilled to obtain water for recreational purposes. It is never used intensively because of corrosion of the equipment. After the closing of this borehole natural springs, which initially went dry, became active again. This, because the water could not flow to the surface through the borehole anymore. This fist borehole had a water temperature of 34 °C. The outflow was some 22 l/s. After the closing of the first one a second borehole was made. This borehole has a depth of 1987 m and penetrated three times the same sequence of Cretaceous and Jurassic rock. This is due to intensive folding of the nappes. Because this drilling also penetrates Keuper (Triassic) rock, the water contains sulphates. None of the natural springs contains such high amounts of sulphates. The water from this deep borehole has a temperature of 61 °C and the outflow is 28 l/s. The water is used for the swimming poolof Bešeňová. The warm bath of the swimming pool has a temperature of 28-32 °C. This is a very good temperature for swimming and bathing, as we noticed later that afternoon.

Friday morning, September 13, 1996

Basalt flow and rhyolite at Revištské Podzámčie

reported by Karin Moll and Ferdinand Borsje

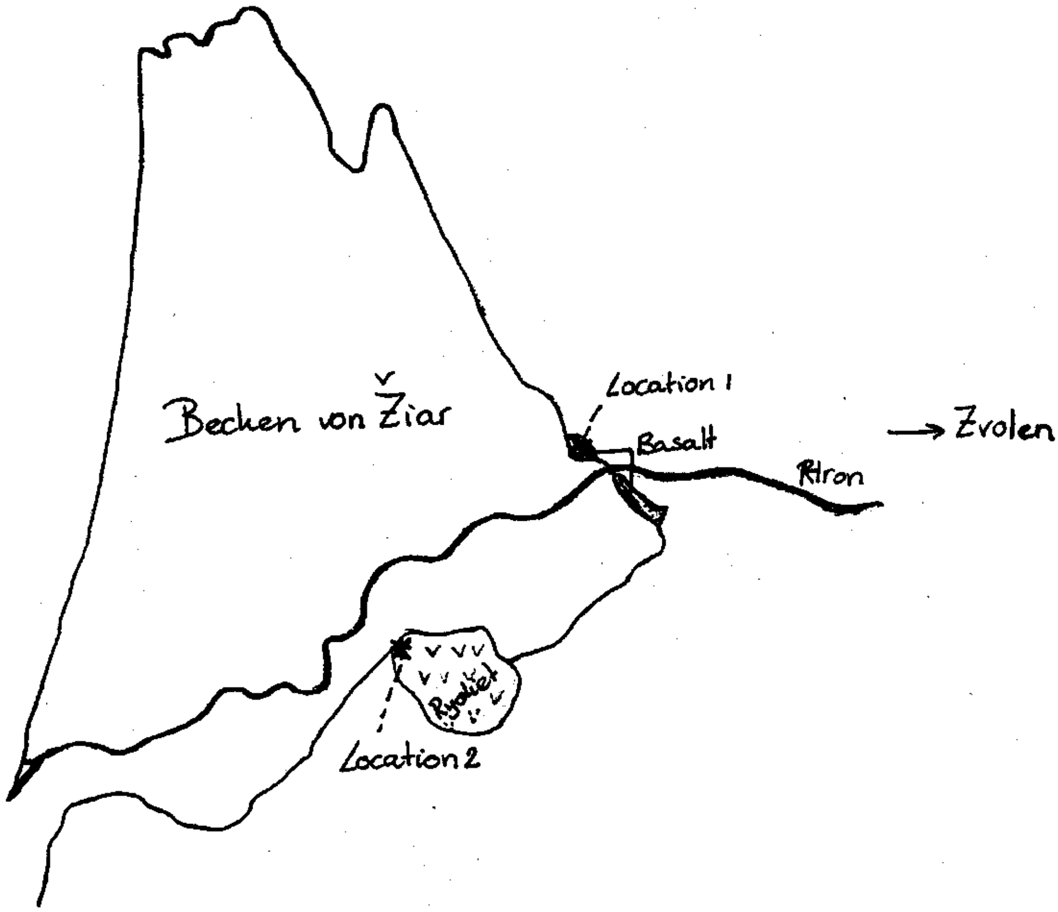

Fig 15. Map of the Žiar Basin

Two points were visited, a basalt dome flow and a rhyolite quarry. Both points are situated in the Inner Carpatians at the south east border of the Žiar Basin (Figure 15). This basin consists of Neogene and Quarternary sediments. It is surrounded by volcanic rock of Neogene age. These volcanic rocks consist are of the felsic, intermediate and mafic type (respectively rhyolite, andesite and basalt).

Basalt is formed from a silica poor magma (49% SiO_2) with a high density and a low viscosity (very fluid). Because of its low viscosity the gas present can easily leave the lava and a dense (gas poor) rock is the result (3000 kg m^{-3}).

Rhyolite (the extrusive form of granite) is formed from a silica rich magma (74% SiO_2) with a high viscosity. This high viscous lava results in a relatively light rock with gas enclosures (2600 kg m^{-3}). The viscosity of felsic (acid) magma depends on the fact that acid lava flows are relatively cold flows (800-600 ^0C), and on the relatively high content of SiO_2. The SiO_4 (originally as tetrahedron) will form polymeric SiO_2 chains. These polimeric networks hamper lava flow, and block crater a very explosive character of felsic (acid) volcanism.

The basalt dome

This basalt dome is of late Tertiary or early Quarternary age. The basalt flow, working its way up to the surface, pushed the Tertiary sand up and aside. The result is a small basalt dome with Tertiary sand alongside it (Fig. 16). Some sand got mixed in the basalt, which left a beautiful curly structure in the top of the basalt dome. Baking phenomena (contact metamorphism) should be present (visible), but, from the point of view where we stood, we failed to see any change in colour of the sand (directly next to the basalt flow). On the edges of the dome on this location, also no metmorphism could be seen.

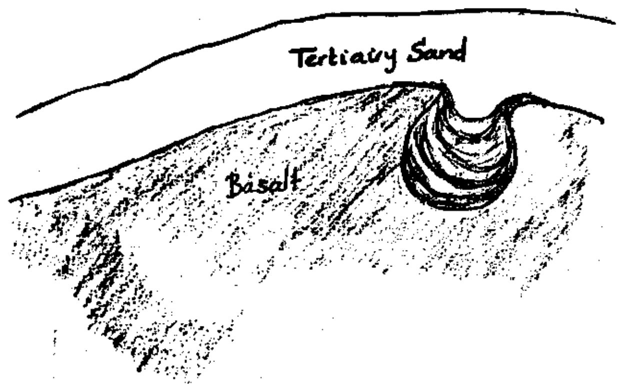

Fig 16 Cross section of the basalt dome

As mentioned before, basalt rock does not contain many pores. Nevertheless, due to cooling effects (shrinking), it often shows a very fragmented, regular structure. The hexagon pillars leave space for water to travel through (secondary permeability). The permeability of influenced by the conditions during the cooling down of the lava. On the excursion location, no hexagon pillars were formed because lava cooled down fast from above as well as from the sides. In most cases basalt rock is not of interest for water retention, as is the case with the point visited, but sometimes, in a layered structure of basalt, fragmentation occurs and small aquifers occur between these layers.

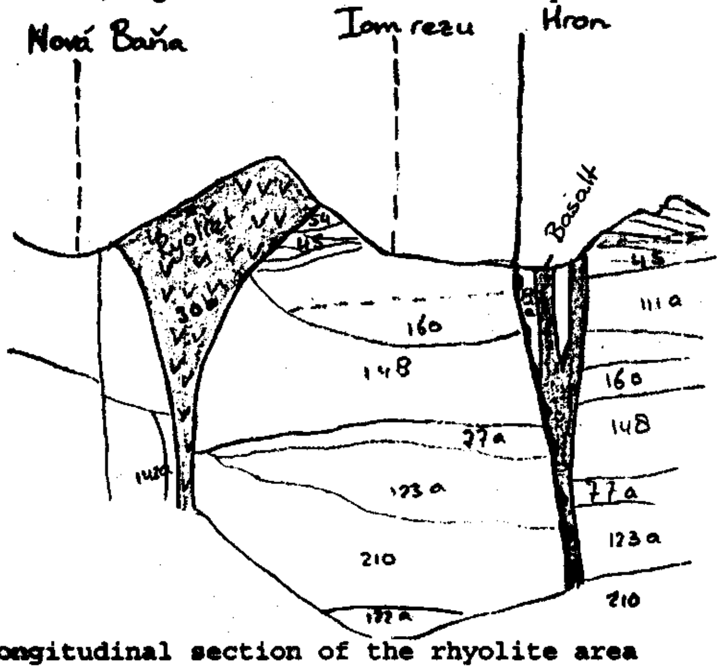

Fig 17 Longitudinal section of the rhyolite area

The rhyolite quarry

On the south east border of the Žiar Basin, a rhyolite quarry was visited (Fig. 17). As mentioned, rhyolite is an extrusive volcanic rock. When the rhyolite is formed it is filled with gas, which results in a poreus rock. These pores are not interconnected. Rhyolite is therefore not very interesting for water retention. Its physical features (colour, density, hardness) makes rhyolite very suitable for building purposes, rhyolite is impermeable also is the reason why it is used for the construction of bridges and houses. In former times rhyolite was also used as millstone.

At this excursion location, a special phenomenon occurs. In winter, cold air enters the wide diaklases in this quarry. In summertime, the air temperature rises. Because cold air is heavier than hot air, the cold air in the diaklases can't get out during these summers (it shoult flow upwards first). Where the diaklases reach the surface a steep temperature gradient occurs. The water in the relatively hot air outside the diaklases will condensate (and sometimes even freeze).

Friday afternoon, September 13, 1996

Danube Basin/Gabčikova dam

reported by Marcel Frederik and Gerjan Verhoef

<u>Hydrogeological discription</u>

The Gabcikovo dam is located in south-west Slovakia, approximately 50 km south-east of Bratislava, in the Danube Basin. This basin is surrounded by the Alps (west), the Carpatians (north and east) and the Diarides (south). It originates from the Alpine orogeny, resulting in thick Tertiary and Quaternary deposits (Fig. 18). From Oligocene onwards formation of a system of intermontane basins started and was comleted mostly in the Pliocene and Quaternary periods. The layers close to surface are dissected during the Holocene era because of erosion by the large rivers.

The Tertiary and Quaternary formations consist mainly of gravel and sand beds, with a high permeability (10 - 100 m/d). The thickness of Quaternary deposits is 10-50 meter. In the Danube Lowland it can reach up to 400 m.

Because of the high permeability and the thick layers, the Danube Basin is the most significant groundwater reservoir in Slovakia.

<u>Gabčikova dam</u>.

The Gabčikovo dam is constructed in a new channel, just north of the old course of the Danube. The water level of the Danube is controlled by this dam, located between the villages Gabcikovo and Nagymaros.

Initially, the Gabčikovo project was a Slowakian-Hungarian joint project. Political changes and correlated changes in point of view concerning ecological effect of the project, the Hungarian part was skipped. Therefore it ended as a Slovakian project.

The channel and dam were constructed for four different purposes;

- A big reservoir of water and a major jump in waterlevel enabled the construction of a big hydro-power plant.
- In first, the movement of ships in the old Danube was difficult, because of the many bends and shallow waterdepths. The channel made transport of goods much easier.
- Big floods in 1965 triggered the search for a better managable Danube course. The agreement in 1977 (to start the Gabčikova project), was the first step to a better protection against floods.
- Erosion by the Danube would be reduced. When dams upstream of Slovalia in the Danube river were constructed, the sediment load in the river was reduced. Because of this, the river started eroding the downstream part. A deeper Danube river bed was the result, and therefore a deeper drainage basis. So, also the groundwater level was lowered. The Gabčikovo project caused a high level in the channel, and higher levels in the old Danube course. Because of this, also the groundwaterlevels started to rise. The transmissivity of the sediments is high. The effect of the project is therefore measured at great distances of the channel.

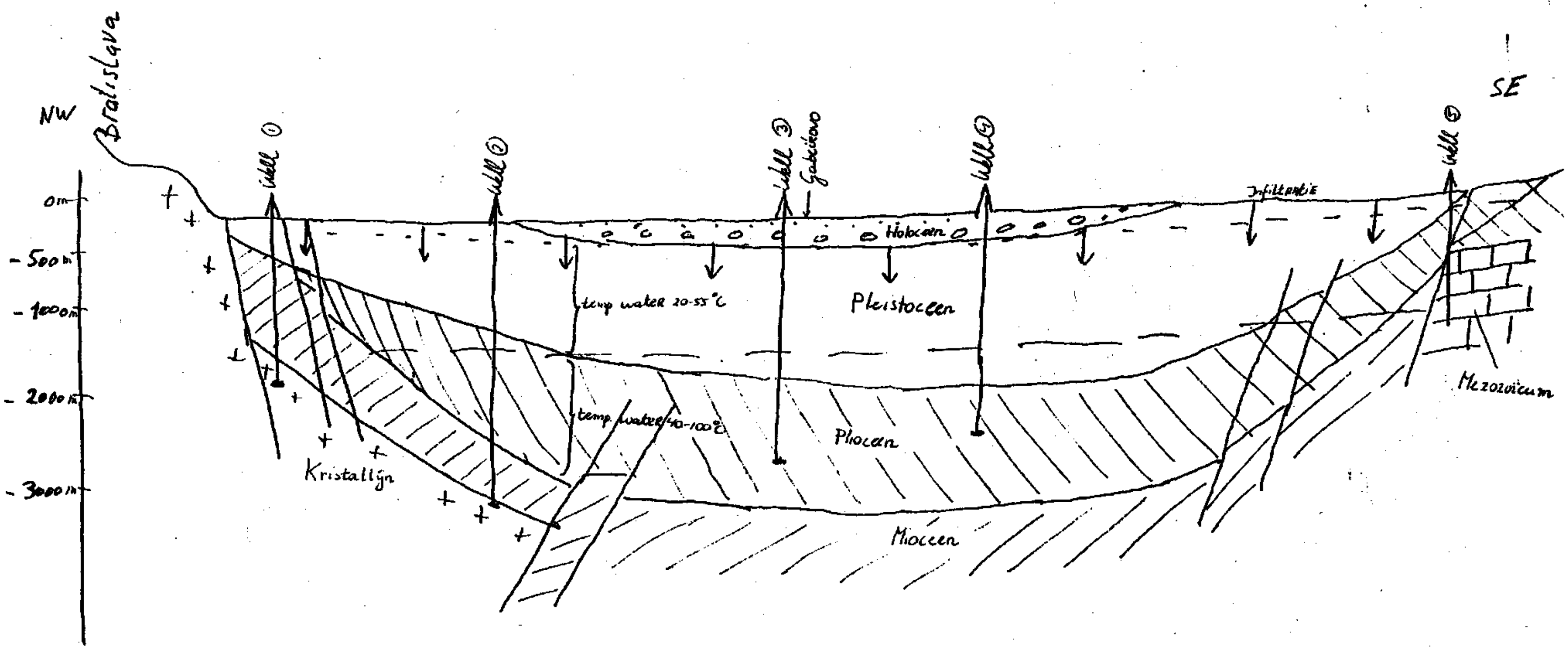

Fig 18 Cross section of the Danube Basin

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