International excursion Hydrogeology - Poland

3 –10 September 2000

R. Dijksma (ed.)

Cover photo: Sculpture of Upper Cretaceous sandstone near Karlów, (© Roel Velner)

Rapport 97

Sub-department Water Resources
Nieuwe Kanaal 11, 6709 PA Wageningen
The Netherlands

ISSN 0926-230X

Supervisors:

Dutch guides
Henny van Lanen
Roel Dijksma

Polish guides
Andej Wojtkowiak
Krzysztof Horbowy

Participants:

1	Feddo Bax
2	Ronald van Buuren
3	Bert Bijkerk
4	Jonathan Coosen
5	Marieke Desmense
6	Anne-Geer de Groot
7	Otto de Keijzer
8	Stefan Kooman
9	Gaelene Kramers
10	Arnaut van Loon
11	Anja Menkveld
12	Tineke van der Ploeg
13	Femke Pos
14	Christian Siderius
15	Arnaud Soetens
16	Jelle Staverman
17	Marije Stronks
18	Desirée Uitdewilligen
19	Ype van der Velde
20	Roel Velner
21	Mark Verbunt
22	Anne Visscher
23	Saskia Vuurens
24	Harm-Matthijs van der Worp
25	Arjan van 't Zelfde

Preface

This is a report of the hydrogeological excursion to Poland, held from 3 - 10 September, 2000. This report is a compilation of the work of the participating students and information, provided by the Polish excursion guides.
The fist ideas about an hydrogeological excursion to Poland can be dated back to 1997. Maciej Kłonowski, from the Polish Geological Institute in Wrocław, worked for four months on a thesis on water flow and migration of nitrate in the Noor catchment. During his stay in the Netherlands, he joined the hydrogeological field excercises in the Belgian Ardennes. We mentioned the possibility of water flow through marbles (crystalline limestone). Maciej told us that the region of the "Bear cave" near Kletno was a good example of such water flow in metamorphic formations. As a result, we were discussing the hydrogeology of Lower Silesia and the possibility to have an excursion in this area. In 1999, we had a first field visit, with Maciej Kłonowski and Andrej Wojtkowiak as guides. First we had several good meetings with the director and co-director of the Institute, Stefan Cwojdziński and Marek Michniewicz. After that, for several days, we were transported through the beautiful area of Lower Silesia in a Lada Niva. By the end of the week there was hardly any free space left in the car, because of all the rocks. We were convinced that Lower Silesia would be a very nice region for a hydrogeological excursion. From that time on, Maciej put a lot of effort in preparing the excursion. Shortly before the excursion would take place, Maciej left for a 3-year project in Oslo. So unfortunately he couldn't join us. We really would like to thank him for all his efforts and concerns.
We had the opportunity to enjoy the hospitality of many people. First of all, we would like to thank the Polish Geological Institute, Lower Silesian Branch in Wrocław and especially Stefan Cwojdziński, that he agreed on organising this excursion. Over the years, quite some time was spent on this excursion by his staff.
Many thanks go to our Polish guides Andrej Wojtkowiak and Krzysztof Horbowy, who spent the whole week (3 – 10 September 2000) with us. Their contribution was of great importance for the hydrogeological part as well as for the social part of the excursion. Their enthousiasm brought us not only to the planned excursion locations, but also to locations like the Kaplica Czaszek in Kudowa-Czermna, where thousands of skulls stared at us. This is quite an astonishing little chapel, with even more skulls and bones in the basement.
Krzysztof did replace Maciej during this week. At first, the impression was that he would translate the hydrogeological explanations of Andrej. In fact, they were more or less an occasional duo. During the week they started to know each other, much better than they did before. It was very nice to see how such an occasional duo could develop so quickly to a perfect team.
On Tuesday, we were guest of the KGHM Polska Miedż SA, Oddzial Zaklad Hydrotechniczky. During our visit, dr. Andrej Krzysik showed us how modern management of waste from Copper mines is organised. We also were allowed to visit the storage reservoir.
At Marciszów, we visited the drinking water company. The manager showed us how this company manages to provide sufficient and good quality water for Wałbrzych. His explanation gave us an idea about the geology, hydrology of ground- and surface water and economy of such a drinking water plant.

Henny van Lanen
Roel Dijksma

EXCURSION POLAND

Introduction to the hydrogeology of Poland

Monday, September 4, 2000

Reported by Feddo Bax and Ronald van Buuren

Introduction

In the introduction of this excursion to Poland given by Andrej Wojtkowiak and Krzysztof Horbowy, both working at the Polish Geological Institute in Wrocław, the main subject was about the geology and hydrology of Poland in general and the Sudeten area in particular. First the general situation of Poland will be discussed, and secondly the situation of the Sudeten area.

Poland

Poland is a country with a surface of 312.000 km^2, which is about 10 times the surface of Holland. It has about 40 million inhabitants. The highest elevation point of Poland is in the Tatra mountains near Zakopane with a height of 2400 m a.s.l. The lowest point is at the mouth of the river Wisła near Gdansk.

The geomorfological processes, which were most important in Poland, were processes due to glaciation. In the north of Poland many lakes can be found. To the south lower and flat lands can be found. In the most south Poland has a mountainous area with the Sudeten in the south-west and the Carpathians concerning the Tatra in the south-east.

From an average precipitation of 600 mm a year, about 30% is discharged by rivers (mainly Odra and Wisła) while evapotranspiration takes another 40%. The rest (about 20 to 30%) is being transported via groundwater flow. Off course this is an average situation.

In the mountains precipitation is higher, by the uplifted clouds. Because of the hard rocks in this area the storage is less.

Now the tectonics of Poland will be focused on. The main orientation of geotectonics is NW-SE. There are 3 several tectonic parts of Poland, namely a part on the Precambrian East European Platform Shield, a part on the West European Palaeozoic Variscan and Caledonian belts and in the south a part of the Alpine province: the Carpathians and its Foredeep. This last part cannot be seen in the schematic cross-section which is included.

The Precambrian East European Platform is a tectonic quiet area. Therefore you find thick horizontal sedimentary layers mainly Triassic covered by Tertiary and Quaternary sediments.

In the west and south you will find Variscan and Caledonian massifs. This tectonic unit and the East European Platform are divided by the Thornquist Fault line in a NW-SE direction. Most part of the area is covered by Mesozoic sediment. In the SW of this area you'll find the Sudeten mountains. The Triasic sediments, situated NE of the Odra, form the so-called Monocline. A clearer view of these parts can be found in the included schematic SW-NE cross-section of Poland (Fig. 1).

The last tectonic unit is the Carpathians. During the Alpine orogeny, this part was uplifted. A bit to the north you'll find the Foredeep, a sedimentary basin of the Carpathians. At the same time the Sudeten rose as a part of the Bohemian massive which was uplifted by the same Alpine orogeny.

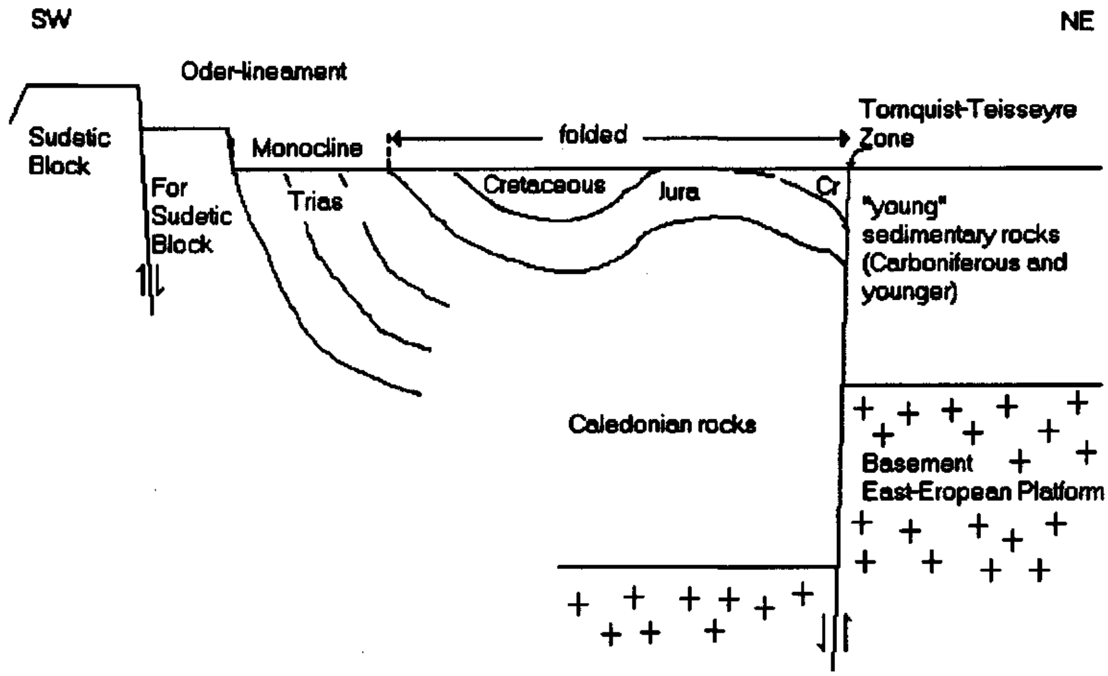


Fig. 1 Schematic Southwest-Northeast cross-section through Poland

Finally the parts of Poland which are important for the Polish economy because of their geology will be summed.
Near the Katowice industry area a very important coal area (Upper Carboniferous) is found. Nearly 100.000 persons have a job in these coal mines. Also in the Sudeten coal mines are found.
Copper (Permian) is found near Lubin in the South. Salt is gained in mines near Kraków (Tertiary). These mines are one of the oldest mines in Europe (800 years old). Furthermore salt is found in the central part of Poland.

The Sudeten area
For this excursion the Sudetic area is the most interesting area. This area is 300 km long, 60 km wide, has a NW-SE orientation and is based on Variscan and Caledonian rocks. The Sudeten are separated from the rest of Poland by the Odra-Lineament. The Sudeten itself are separated into a mountainous area SE from the Great Sudetic Marginal Fault (the West-Sudeten) and a less mountainous area NE from this fault.
The West-Sudeten are also divided into several blocks by folding and blocktectonics. They can be considered as graben systems. Only the different blocks we have visited during the excursion, will be described shortly below.

The Iser- und Riesengebirge
This block consists of Precambrian crystalline rocks, which were uplifted during the Alpine orogeny. Most rocks are granite. At the sides of the crystalline pluton you'll find a mantle of metamorphous rocks like gneisses. In this area the Sniežka is situated. Jelenia Góra is at the North of the Riesengebirge.

The Boberkatzbachgebirge
The Boberkatzbachgebirge is situated North of Jelenia Góra near the Vorsudetischer Block. In this area we found an outcrop of Permian rhyolite.

The Eulengebirge
This mountainous area is actually not a part of the Sudeten, but of the Vorsudetischer Block. It consists of more resistent rocks (gneisses) which are now higher parts of the Vorsudetischer Block. It lies almost perpendicular to the Great Marginal Sudetic Fault near the Boberkatzbachgebirge.

The Adlergebirge and Schneegebirge
The Adlergebirge is situated East of the Innersudetische Mulde and consists mainly of micaschists (near Zieleniec). Due to blocktectonics and high amounts of precipitation peat bog areas are found here. The Schneegebirge is situated west of the Intersudetic Margin. Here, many kinds of metamorphic rocks are found like gneisses, schists and marbles. During the excursion we have visited a marble cave "Jaskinia Niedzwiedzia".

The Innersudetische Mulde
The Innersudetische Mulde consists of blocks, which sank more or less due to tensions of the Alpine orogeny. This was an inland sea in which Carboniferous, Permian and Cretaceous sediments were dropped. Therefore now at the edges coal containing molasse is found. The eroded forms of the Cretaceous sandstones near Karłow are also a part of the Innersudetische Mulde.

The Vorsudetischer Block
Between the Odra-lineament and the Great Sudetic Marginal Fault a big block is found. In the underground the rocks are quite similar to the Sudetic area, but due to the blocktectonics, these rocks are covered by Tertiary and Quaternary sediments (except the Eulengebirge).

Sneżka; Geomorphological developments in a mountaineous area and their hydrogeological impact.

Monday, September 4, 2000

Reported by Bert Bijkerk and Jonathan Coosen

Near the mountaintop of Sneżka, a few geological phenomena can be found.
First, a firn basin filled with water, created during the last ice age. Snow started to accumulate in the V-shaped valleys, which were above a certain altitude. As the ice age proceeded the snow turned into firn and later into glaciers. The glacier started flowing downhill, forming a U-shaped valley by eroding the sides due to frost-weathering. When the ice melted, a firn basin appeared, which later formed the source of a brook. Now one of the sides of the U-shaped valley is eroded further, forming an clearly visible alluvial fan at one side of the lake. At a higher level a smaller firn basin was visible, from which a little brook flowed into the lake, forming a small V-shaped valley. The brook, which flowed out of the lake, had a temperature of 10.0 °C at the time of measurement, which indicates that the lake has a rather large volume because the groundwater found in the region is colder. The EC was 15 μS/cm, which is low because the clean rainwater spends little in time in the weathering layer.

Secondly, a V-shaped valley formed by snow accumulation, avalanches and melting water. This is in fact an early stage of a firn basin in a U-shaped valley. A lot of big boulders were visible on the rather steep slope. They were brought there by avalanches and melting water in recent times. In the brook that flowed here a temperature of 6.6 °C and an EC of 29 μS/cm were measured. The temperature is low because it is groundwater and the annual average temperature on the mountain is low. The conductivity is low for the same reason as the previous measurement.

Karpacz: spring in weathered granite, water supply of Karpacz.

Monday, September 4, 2000

Reported by Marieke Desmense and Anne-Geer de Groot (1)

Decrease of thickness of the weathered layer

In granite units, a lot of small springs can be found. The most important reason for this is the change of thickness of the weathered layer of granite at the surface. When this layer gets very thin, for example because the bedrock underneath has a great resistance, the water flowing through it is forced to the surface and springs are formed. This is also the case at the spring we visited near Karpacz.

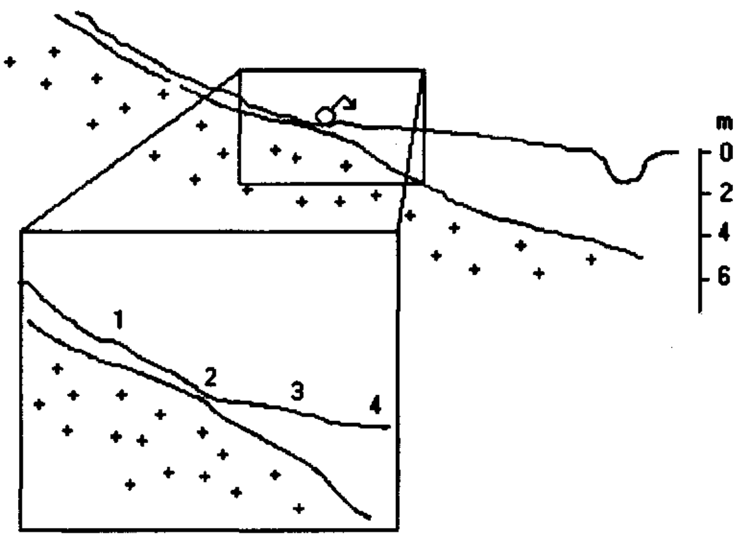


Fig. 2 Schematic cross section of the Karpacz spring

1. Thin weathered cover (fractured granite), 0,5 – 1,5 m thick.
2. Spring level
3. Bedrock dips away under weathering/sedimentation cover (coarse material)
4. Sediment/weathering cover > 2 m thick

Water supply of Karpacz

The village of Karpacz depends on springs, like the one we visited, for its water supply. This remains from the days Karpacz was a small village and didn't need a lot of water. Nowadays, for a town of the size of Karpacz we would try to get the water from the sedimentary layers down in the valley, which are good aquifers. Quick spreading of pollution could be a problem there.

Characteristics of the spring

The measured temperature of the water flowing out of the spring was 7.9 °C, which is the yearly average temperature of the soil at this location.

The measured Ec was 102 μS/cm. This is less than at Kowary, because this spring reacts more quickly on rainfall (this means a shorter residence time in the rocks) and because there are no aplite intrusions at this location.

The amount of Ca and HCO_3 is greater than at Kowary, more in the direction of the calcium-carbonate type, but it's not limestone yet. The amount of SO_4 is less, because the circulation of the water in the ground is less deep. Cl^-, Na^+, K^+ and Mg^{2+} occur in relatively low concentrations. There's still an amount of SiO_2.

This spring is also always flowing, like the one in Kowary. Especially the fractures in the granite contribute to the base flow. The amount of base flow through the weathered layer is much smaller.

Kowary: spring and weathered granite / aplite

Monday, September 4, 2000

Reported by Marieke Desmense and Anne-Geer de Groot (2)

Aplite intrusions

Kowary is located near the transition from the granite unit to the mantle unit. Its location is in the 'Riesengebirge', still in the large granite unit.

Normally granite has a very low permeability. Only the weathered granite layer, several meters thick, and the cracks in the granite rocks can transport water. The permeability of weathered granite is 1 to 5 m/day.

In Kowary there is another phenomenon, which increases the permeability of the granite unit. In this particular place there are so called aplite intrusions in the granite. These intrusions were formed by upcoming of fluid material (magma) from deeper regions, which was pushed into the cracks and weaker spots of the granite. During the weathering process, influenced by tectonic processes, the aplite zones weather faster than the granite ones due to a weaker consistence of the minerals in the aplite. For this reason the permeability of the aplite intrusions is much higher than that of the granite. Therefore most of the water flow through the rocks occurs in the aplite intrusion bodies. Only little water flow occurs trough the cracks in the granite.

Where aplite zones reach the surface, springs can be found. This is the case at the spring near Kowary.

Characteristics of the spring

The measured temperature of the water flowing out of the aplite spring was 7.8 °C. The fluctuation of the temperature was said to be 2 °C. The temperature of the water is the same as the yearly average temperature of the formation, where it is flowing through.

The measured Ec was 150 µS/cm. Rain in this area has an Ec of about 40 µS/cm. Evapotranspiration and weathered minerals cause the difference.

The main cations found are Ca^{2+}, Na^{+}, Mg^{2+} and K^{+}. The main anions SO_4^{2-}, SiO_2 and HCO_3^-. The great amount of SO_4^{2-} is a.o. the result of polluted rain, deep groundwater circulation and the nearby situated mantel rocks, which contain many minerals containing S. Silicates, which are very dominantly in the granite rocks, cause the great amount of SiO_2, despite of the low grade of weathering.

The water from the spring near Kowary is especially favorable for its natural concentration of radon. Radon is the only natural radioactive component, a product in the ^{238}U-decay series.

Isotope composition of oxygen-18 and deuterium shows the altitude of recharge to be 610-720 meters above sea level.

The spring always has a certain discharge. Rain and melting snow cause peaks in the discharge. Groundwater storage in the weathering layer, the cracks and the aplite intrusions cause an ever-flowing spring.

Copper Mines in the Lubin Global Region

Tuesday, September 5, 2000

Reported by Otto de Keijzer, Stefan Kooman and Gaelene Kramers

Hydrogeological Situation in the Area

In the Lubin area, copper is mined out of a thin marl layer of lower Zechstein. This layer is 10 meters thick and has a copper content of 4%. As is visible in Fig. 3, the layer is situated at an angle of 30 degrees underneath a thick horizontal Quaternary layer of glacial and fluvioglacial sediments. These sediments are mainly composed of gravels, sands and some clay layers. The Quaternary layer is on average 25 – 30 meters thick, 50 meters at the thickest and is, due to its relatively high permeability, an aquifer.

The layer directly upon the marl layer is limestone and thus an important aquifer. It is about 25 – 30 meters thick. The layers under and above the mining layer and the limestone are hydrogeologically of little importance as they are virtually impermeable.

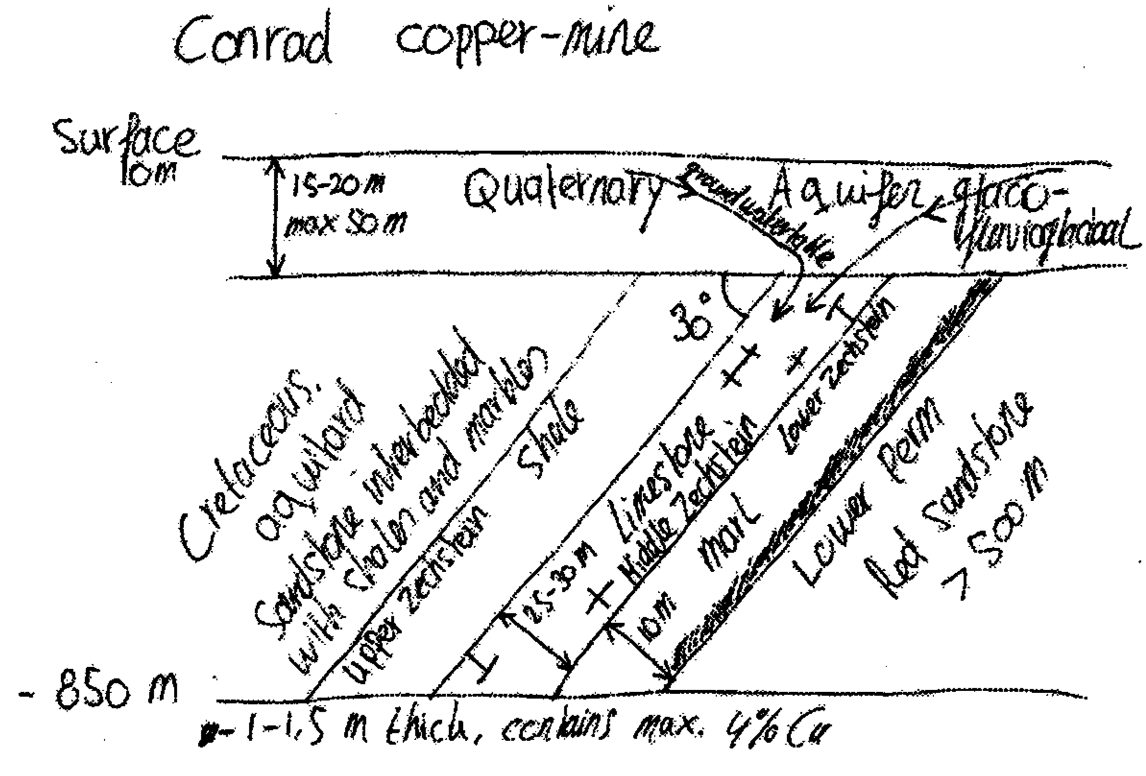


Fig. 3 Effects of copper mining on the hydrogeological situation

Since 1950 copper has been mined from the marl layer and at present the mines have reached a depth of 850 meter under the surface. The mines follow the marl layer along the 30-degree angle of the layer. The difference in water pressure head between the mining layer and the limestone aquifer is very high, around 27 atmospheres at maximum depth. This means that, in order to continue mining, lots of water has to be pumped away to keep the mines dry. The deeper the mining goes, the more water has to be pumped away, as you can see in table 1.

The excessive water is used as a water supply for the surrounding villages, where mostly miners live. Because of the reduced water pressure head in the limestone

aquifer, water seeps into this layer from the Quaternary layer above, causing a drop in the groundwater level in the surrounding area.
In other mining areas this is less of a problem as there is a thick Tertiary layer which acts as an aquitard and prevents seepage into the limestone aquifer. In the Lubin area, however, the Tertiary layer is very thin and has hardly any influence on the ground water flow.

Table 1 Intake levels and pump rates in the Conrad copper mine

Intake levels	Pumpingrate
240 m	2.5-3 [m^3/min]
550 m	± 5 [m^3/min]
615 m	± 9 [m^3/min]
830 m	± 25 [m^3/min]
	Σ 43.3 [m^3/min]
	~ 2600 [m^3/hr]
	~ 62.352 [m^3/day]
	~ 22.8 e 6 [m^3/yr]

The marl that is pumped up contains only 4% copper from which maximally 75% can be extracted. Thus 25% of the copper is left in the waste material. This copper has become mobile, due to the change of structure of the minerals. In addition to the copper there is zinc, cadmium and solution fluids from the copper extraction in the waste material. This waste is thus an environmental hazard that has to be dealt with.
The company we visited dumps its waste from the copper mines in a basin in a river valley. In the last 20 years this basin has grown to become the biggest in Europe. The waste is dumped in the basin and the dry material at the edges is used to make a dam, which is now about 40 meters high. This means that the basin with its surrounding dam is continually growing. If they will extract all the copper that they plan to do, the dam will reach a height of about 83 meters. Whether this will happen depends on the copper price, which determines the economical value of the mines. The higher the copper price, the more mines are being used.
The river valley that the basin lies in is composed of quaternary fluvioglacial and glacial sediments, which are very heterogeneous and discontinuous in their vertical and horizontal permeability. This makes it a complex hydrogeological system. In order to 'control' this system it is necessary to collect very detailed information about the geophysical situation. The company we visited obtains this information from a large number of boreholes and many piezometers, which are frequently monitored. All this information is stored in a large database, which is accessed via GIS (2d-view) and Earthvision(3d-view). As a result of this analysis it has been concluded that the layers under the basin are not entirely impermeable and that there is a reasonable leakage of the polluted water. This leakage is estimated at 0,8 m^3/s and is caused by the high water column in the basin (see Fig. 4). The higher the dam, the bigger this water head will become and thus the larger the pollution problem.

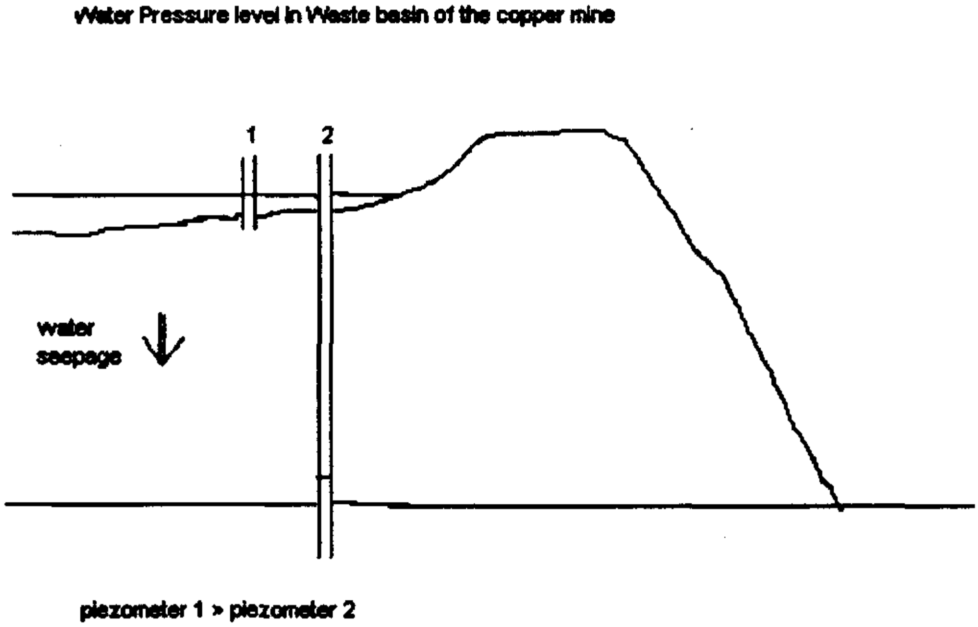


Fig. 4 Water heads in and under the reservoir

The leakage water has to be removed from the hydrological system surrounding the basin. This is achieved with a ditch around the dam downstream from the groundwater flow direction. Most of the leakage is caught by the ditches, in which the water has an EC of 3000-4000 µs /cm! The water from this ditch is partially cleaned and returned into the basin. The leakage water that passes by the ditches is caught further downstream, pumped up through boreholes and also partially cleaned and returned to the dam. Thus, by these abstraction wells, a hydrological shield is formed. This shield is formed due to a lowering, instead of an increase, of the pressure head, which would also have been a possibility. In the first case water has to be pumped away from the wells, in the second case the water has to be put in the system.

Apart from the hydrogeological problems in this situation there are other problems with the dump. Along the edges of the basin the sediment, which is fine grained, dries up and is blown easily away by the wind. This dust can travel quite far easily and can be hazardous for human health and nature. To prevent this, regularly, tar is sprinkled over the sediment by helicopters.

The waste problems and their solutions have been taken seriously since 1989, since the political system in Poland changed. In Poland in particular the economical possibilities for monitoring have not been very good. Nowadays, it is possible to spend money on the environment. This is a big change because the costs are high and it doesn't provide immediate (economical) profit.

Still the copper mining waste management is not water tight. The hydrological shield is not and the dust prevention is not. More important, the wasted ground water is moving very slowly down the valley. Regularly a bore hole has to be added to the hydrological shield. For the next tenths of years, the waste management is effective enough. For the future a lot of question marks still exist about what is going to happen with the wasted water.

Sędziszowa

Tuesday, September 5, 2000

Reported by Arnaut van Loon, Anja Menkveld and Tineke van der Ploeg (1)

We visited the site of Sędziszowa. Here we saw a rhyolitic flow with column-structure, which was originated during the Variscan orogeny in Perm. Column-structure is very exceptionally for a rhyolite.

Normally rhyolite has a very high viscosity in comparison of basalt. This is because the minerals which rhyolite contains have a different structure than the minerals of a basaltic flow. This is illustrated in Fig. 5.

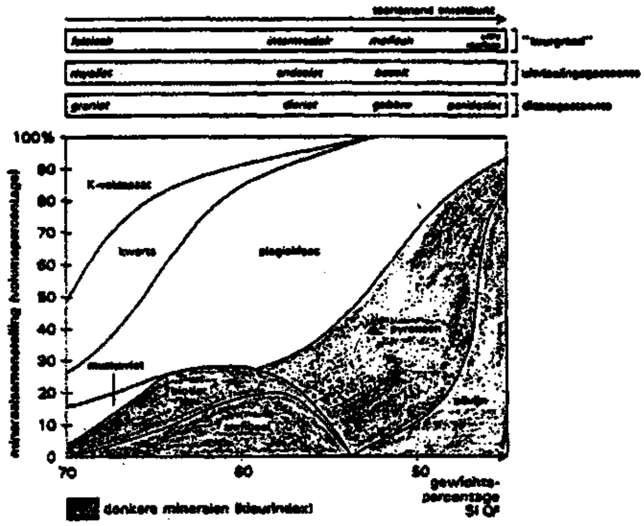


Fig. 5 Classification of plutonic and volcanic rock

In the rhyolite we can find phenocrists of quartz and potassium feldspar. It also contains a lot of SiO_2 (70%), whereas basalt has mainly pyroxeen, olivine and less SiO_2 (40%). These minerals have less stronger bindings then the white minerals of rhyolite and that is the reason why basalt flows easier than rhyolite. Basaltic flows come out of the volcano and have the time to cool down then. In basalt it is therefore very common to find a 3 or 6 angular column-structure.

When a rhyolitic flow rises to the surface and cool down, it forms a strong structure. If the main tunnel of the volcano is closed, the magma tries to find another way out. Eventually, all the tunnels are closed and no more magma can come at the surface. At that moment the gas pressure starts building up and when it is high enough, the volcano explodes. If the explosion is strong enough the whole volcano can be "blown away" and the remains are then called a caldera. After the explosion rhyolite can be found in a great distance from the former volcano.

As we have seen this did not happen with the volcano in the Boberkatzbachgebirge. The reason why this has happened could be that the temperature of the magma was higher then normally and therefore the lava did not stay in the magma chamber and closed tunnels, but flowed out the volcano, cooled down then and formed 4 or 5 angular blocks. All this makes the site so special that it became a geological monument.

In a rhyolite without column-structure water flow is minimal, since the effective porosity is very low. This rhyolite has a very good second porosity, so water flow is bigger.

Wieściszowiece

Tuesday, September 5, 2000

Reported by Arnaut van Loon, Anja Menkveld and Tineke van der Ploeg (2)

At Wieściszowiece lies the site of the former mine Krajobrazowy. It was being used to mine pyrite in the beginning of this century (1900-1925). This pyrite was used to make sulphur acids. Nowadays sulphur acids are being produced artificially.

The pyrite was formed out of sedimentary sands in a marine climate, which was interbedded with lavaflows and then metamorphosed. Later the layer was uplifted by the uplift of granite body, where it came to a minable level.

After the mine activities had stopped water filled the mines and formed lakes, which is coloured red by the sulphate. These lakes are being called the Purple lakes. The sand that was left after the mining was dumped on another site. Nowadays this dumping causes problems, because the sand contains heavy metals such as iron, copper, and tin.

The local population started to use the sand for building purposes. This caused the disappearance of the natural vegetation and erosion started. Rainwater washes the sand off the hill into the valley and thereby the heavy metals are being spread over a bigger area.

In the valley a water intake point is situated nearby the polluted stream, coming from the mountain. This is not being seen as a problem, because the polluted water is just a small fraction of the total amount of water used for drinking water. Although it is not being recognised as a problem, we think it could be one, because nobody knows how big the pollution is. This is also not being investigated, because the government sees no problem as long as local people do not have complaints. But the local people have no knowledge about the situation because there are no available data and this makes a circle.

A solution to handle the pollution could be to put all the waste back into the former mine since this is an isolated system and no pollution will leak to other aquifers, but there is no money for such an operation.

A cheap way to stop the erosion and thereby decreasing the pollution effects would be to put vegetation back on the mountain, but this is only possible when the inhabitants of the village stop using the sand and that they are informed about the risks of using it. To give this information to the inhabitants, so they become aware of the problem will be the real solution, because maybe then the government will do something about the situation.

Marciszów

Wednesday, September 6, 2000

Reported by Femke Pos, Christian Siderius and Arnaud Soetens

Introduction

Marciszów is situated in the valley of the river Bóbr. The valley of the Bóbr can be characterised geomorphologically as a fossil river valley. Near the town of Marciszów is a pumping station where water is taken from the groundwater and from the surface water.

Geomorphology of fossil river valleys

The Bóbr valley is found in the Intersudetic Depression. This depression is filled with Permian sandstone, which forms now the bedrock of the Bóbr valley.
During the Pleistocene ice ages, the valley was buried. The valley is 60-100 m deep in the Southern part of the valley and > 100 m in the North.

During Permian, the Intersudetic Depression was filled with marine sands. In a later stage this sands were compacted to sandstone. Before the Pleistocene ice ages a river flowed through the valley. The bedrock of this valley consisted of sandstone. The river dissected the bedrock and in this way a valley was created.
During the Pleistocene mountain-glaciers covered the valley (the Scandinavian ice sheets never reached southern Poland). The glaciers went through this valley, because the valley was a lower point in the landscape. The glaciers eroded the valley. In this way a U-shaped valley was formed (Fig. 6).
During a later ice age, the valley was not glaciated. The climate was cold and dry. Therefore, the river pattern changed into a braided pattern. In this period the river deposited gravels and course sands in the valley. These sands and gravels were erosion products from the area upstream of the river system. These deposits now form the deeper aquifer of the river valley.

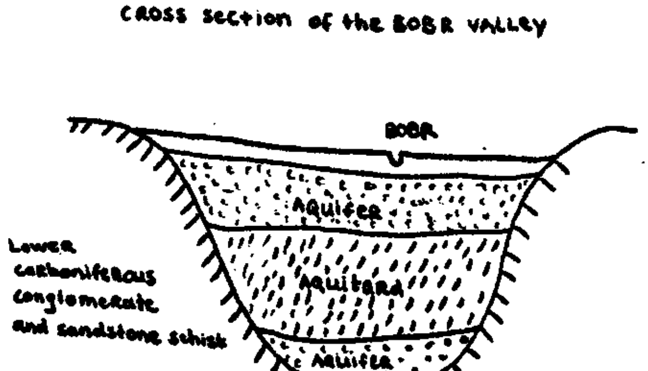


Fig. 6 Cross section of the Bóbr valley

In a later and warmer period löss was deposited. At first, the löss was wind blown to the area upstream and was deposited there. This löss was eroded from the upstream area and deposited in the river valley. Nowadays this löss is found in the aquitard of the system. During this period there were relatively short, warmer periods when clay was deposited. This clay can be found in the aquitard as laminated clay.

After this period, again the conditions changed so that the river took a braided pattern. The sediments that were deposited there consisted of rough sands.
After this last cold period also Holocene started and the climate became moderate. The river type changed into a meandering pattern.

Geophysical research
The underground of the Bóbr-valley was explored by the use of two different methods: In the southern part of the system boreholes were installed to investigate the geological structure and the related sequence of aquifers and aquitards. In the northern part of the area geo-electric methods were used to investigate the vertical profile.

Consequences of water intake in Marciszów
The buried valley in the Marciszów region is an important geological unit for the intake of water. At the Marciszów drinking water station, surface water as well as groundwater is cleaned. About 10.000 m^3 of surface water from the Bóbr river and about 12.000 m^3 of groundwater passes the station every day. In the past even larger amounts have been used. Of course this has had some consequences for the hydrological situation in the region.
First of all pumping of about 100 m^3 an hour from a well results in a 10 m deep depression cone for each well. This has had no further economic influences as agriculture and forestry were not much effected by it and these are the dominant forms of land-use in the region.
Secondly, before the intake from the second aquifer started the water in this region was (semi-) artesian. It was not known whether springs and seepage areas caused a sort of wetland, with accompanying vegetation. But when the demand of water rose in the 70's, together with the increasing mining and industrial activities in and around Wałbrzych, the groundwater stopped to be (semi-) artesian. It is unknown if this has had any consequences for nature. Forestry and agriculture were not affected.
Together with the political situation, the water-demand changed as well in early 90's. The closing of mines and partly a market system for the price of water for the individual people caused a reduction of the water use and therefore water intake by 37% in the last five years to the 50.000m^3/day as it is now. The well intake is now below the maximum intake. This means that the second aquifer is "recovering" and the groundwater head is rising again.

A double intake system as at the Marciszów station makes it possible to shift between the two systems in case of a pollution problem. River intake can be stopped when the water is too much polluted. Then the wells can be used more intensively. But this can last for only a short period.
Chemical analysis of the water shows that it has become much cleaner than 15-20 years ago. Even trout is seen again in the river. This makes it possible to shorten the cleaning process of the surface water. It is not expected that more surface water will be cleaned in the future at the expense of groundwater abstraction, as groundwater is still much cheaper. The groundwater is almost ready to be used, surface water needs to undergo the whole cleaning process. Also temporal changes in water quality makes it more expensive to clean the river water. In winter when runoff and organic processes are low it is easiest to clean. Still the costs of cleaning surface water are about two times as high. Next to that the amount of water taken from a small river as the Bóbr is already relatively large as it is now.

Drinking water

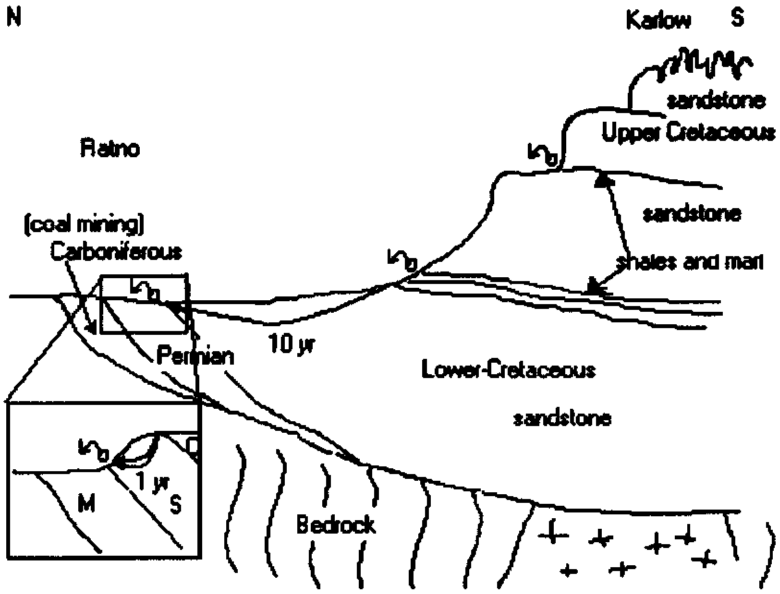
At this moment there are two types of producing drinking water in the Wałbrzych area. The first type of water production is water pumped up from one of the two aquifers (one aquifer is at a depth of 40 meters the other aquifer is at a depth of 60 meters). The other way of water production is a surface water intake, here the water of a river is collected and after a chemical treatment the water is ready for drinking. One of the surface water intakes is situated in Marciszów, with a production of 12.000 m^3/day. Surface water from the Bóbr river is collected in reservoirs. This water quality is not good enough for drinking, so it has to be cleaned. The water is pumped from the reservoirs into large basins (30.000 m^3). In this basin oxygen is added, therefore the bacterial growth induces so the bacteria absorb more parts from the water. After two days the larger parts are sedimented in the basin. After this biological cleaning the water is cleaned chemically. Several chemicals are used to clean the water. The amount of chemicals depends on the amount of pollutants in the basin (which is constantly is monitored). In the next step in the cleaning process, the water is brought to an active coal filter, which is 1.40 m thick. As a last step, chloride is put into the water. The water is now ready for drinking. At this moment 50.000 m^3 water per day is produced for the whole Wałbrzych area, from which 45% is produced in Marciszów (groundwater and surface water).

Ratno

Wednesday, September 6, 2000

Reported by Jelle Staverman and Marije Stronks (1)

Ratno is located in the Intersudetic Depression on (red) Permian sandstone.
Under the sandstone we find less permeable mudstone. Uphill we find layers of Cretaceous sandstone and layers of marl. These sediments were deposited close to the coastline from an inland sea. (Fig. 7)



M = mudstone
S = sandstone
C = Cretaceous

Fig. 7 Geological cross section of the Ratno area

In this area many springs can be found where de sandstone meets less permeable layers (mudstone or marl). In the case of Ratno, this is the mudstone layer. It is an assending spring, which means that the water comes out because a certain layer becomes saturated.

The location of the springs is variable because of two processes. The first one is sidewards and is caused by erosion of the weathered layer on top. This toplayer can come down and blocks the spring. Because the spring flows through the areas where the resistance is minimal, it will come out somewhere else (see Fig. 8).

The second process drives de spring backwards and is caused by erosion of the sandstone itself. When it becomes saturated, it falls down and is then the erosion products, what will be transported away from the spring.

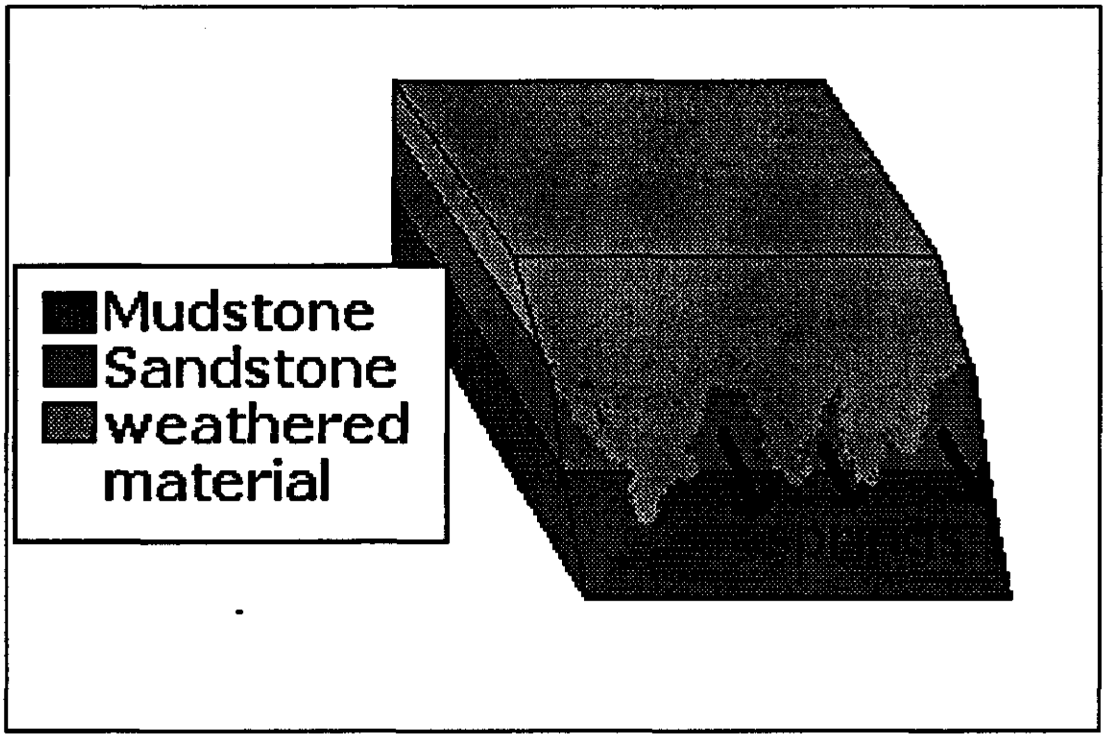


Fig. 8 Sideward movement of the Ratno spring

The spring near Ratno has an outflow of $100 m^3/h$ and has a temperature of 9°C. The Ec was 498 µs/cm. This Ec is higher then expected from the Permian sandstone alone. The Permian sandstone has a low Ec because it is deeply weathered and has very low exchange capacity, so the water must have flown (partly) through other sediments. This is the Cretaceous sandstone. This one is much richer because it is sedimented in an inland sea.

Karłów

Wednesday, September 6, 2000

Reported by Jelle Staverman and Marije Stronks (2)

Karłów is situated on top of the Cretaceous sandstones. When the sediments where deposited, it was the lowest part of the area. Because of tectonic movement during the alpine orogeny it is now the highest point in the area (see Fig. 9). The sandstones were exposed to extreme forms of physical erosion.

The resistance to weathering is not homogeneous. That's why some parts eroded slower away than others. Important factor in the weathering process is the presence of fractures in the sandstone formation. The more fractures, the quicker the erosion will take place. The parts with little or no fractures are therefore more resistant to erosion and will survive when the fractured parts will erode. This resulted in many upstanding forms like columns, pillars and rock pedestals.

At present, it is possible to "walk" through huge widened fractures and other nice hydrogeological features.

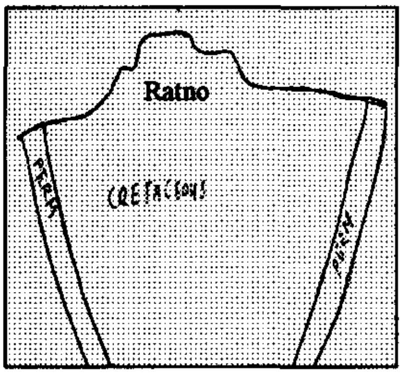


Fig. 9 geological cross section of Karłów area

Duszniki Zdrój

Thursday, September 7, 2000

Reported by Desirée Uitdewilligen and Ype van der Velde

Duszniki Zdrój (Bad Reinerz) is a bath-, tourist-, recover- and wintersport-centre in the valley of the "Weistritz" and its tributaries at a level of 530-570 m a.s.l.. The basis for the development of this bath-centre were mineral water springs, rich on iron and CO_2. At present, five springs are used for treatment of rheumatism, disorders of the "locomotive system", skin and feminine diseases, bronchialasthma, anaemia and blood circulation disorders.

We visited the Pieniawa Chopina. The spring has a depth of 78m, of which 14m pipeline, with a diameter of 270 mm. This is built in 1910, in the beginning of the industrial revolution. In this period the people became interested in groundwater due to the pollution of the surface water. The chemical composition of the water is shown in Table 2:

Table 2 Chemical composition of spring Pieniawa Chopina

Kations:	mg/dm^3	Anions:	mg/dm^3
Na^+	155	F^-	0.4
Ka^+	84	Cl^-	12.4
Li^+	<0.1	SO_4^{2-}	57.6
Be^+	0.002	HCO_3^-	144.5
Ca^{2+}	221.4	$HAsO_4^-$	0.25
Mg^{2+}	58.0		
Ba^{2+}	0.08	H_2TiO_3	<0.002
Sr^{2+}	0.33	H_2SiO_3	58.5
Fe^{2+}	15.1	CO_2	1980
Mn^{2+}	1.4	RN	0.4 nc/dm^3
Zn^{2+}	0.06		
Cu^{2+}	0.008		
Ni^{2+}	0.02		
CO_3^{2+}	0.003		
Al^{3+}	0.03		
Ag^+	0		

This composition can be explained by the geology. The spring is situated in the Kłodzko Depression and Bystrzyckie Mountains (Fig. 10). This area has a lot of very deep faults in the metamorphic micaceous slate series. Rainwater infiltrates in a massif nearby. Most water leaves the area by surface runoff. A small part goes very deep by the cracks. Through post volcanic processes in the faults CO_2 gas mixes with this water, and it gets acid: H_2CO_3. Due to that a lot of elements dissolve (1000-2000 mg/l), and the water gets the composition as in Table 2.

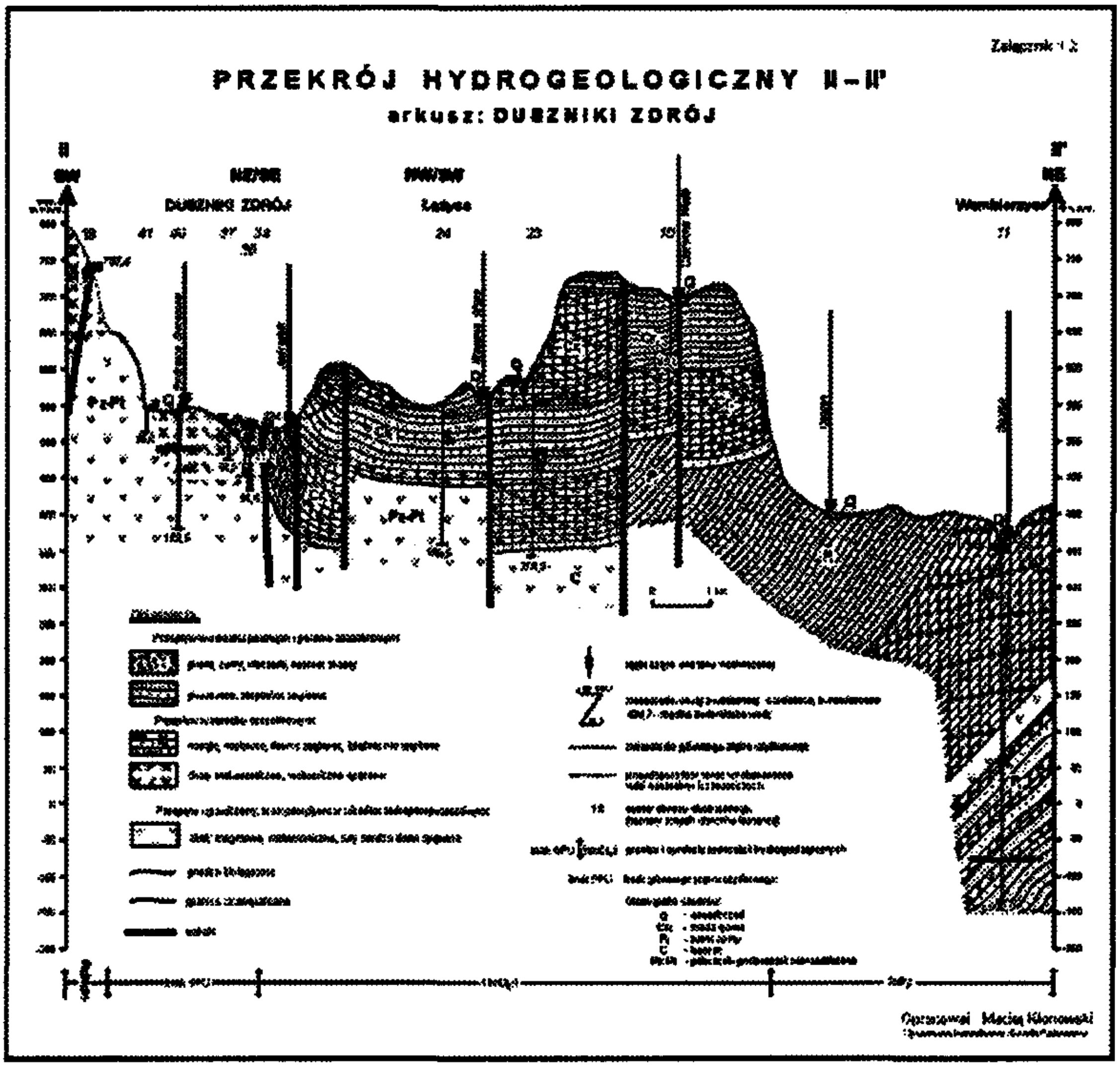


Fig 10 Cross section at Duszniki Zdrój

The main elements are Ca^{2+} and HCO_3^-. This can be explained by the high CO_2 (g) concentration in the underground and the Ca^{2+} comes from the Cretaceous sandstone on top, which is rich of Ca^{2+} (Fig. 11).

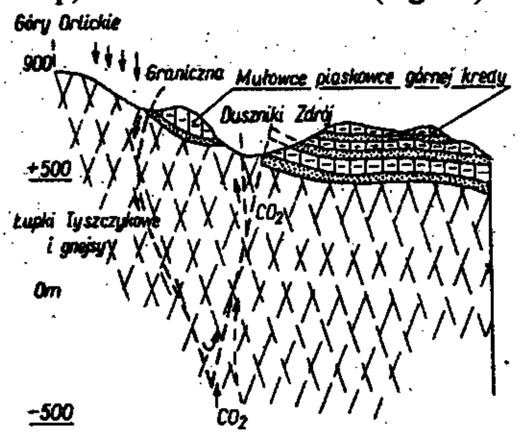


Fig 11 Scheme of the origin of mineral waters of Duszniki Zdrój.

The protection of the intake area of the spring is very difficult. You have to know how the water flows through the cracks and this is hard to determine. So you don't know exactly how big the intake area is, and where it is located. At the moment there is a protection zone, and this is based on some faults, but it is not accurate.
The second spring we visited was named the Szczytna Saska. It was situated in the lower level cretaceous sandstone. It is shown in Fig. 10 on de feet of the first sandstone hill on the left of Duszniki Zdrój. This spring is situated there, because the impermeable marlstone reaches the surface.
The spring has a constant discharge of 9 l/s. It is independent of the actual weather conditions, due to the double porosity system. Flow through the cracks and the matrix of the sandstone makes the spring have a high and a constant discharge. The spring has a quick as well as a slow responding component, which causes the constant discharge. (Fig 12)

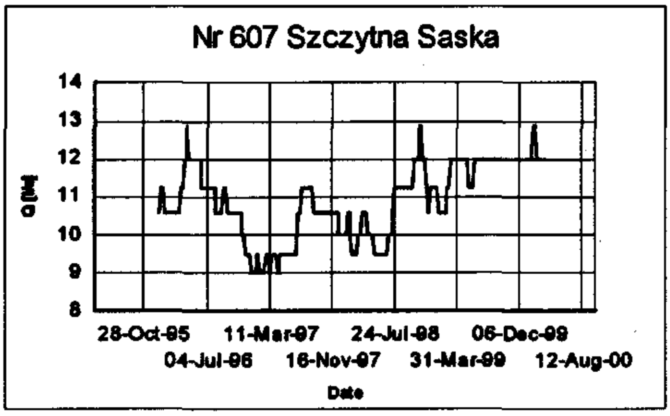


Fig. 12 Discharge of spring Szczytna Saska.

The electric conductivity of the water was 418 μS/cm. It is also a $Ca(HCO_3)_2$ type, due to the sandstone which is rich of calcium.

Table 3 Chemical analyses of spring Szczytna Saska.

kations	(mg/l)		anions	(mg/l)
NH_4	0.005		HCO_3	207
Ca	77.1		SO_4	27.7
Mg	5.6		Cl	7.1
Na	1.9		NO_2	0.03
K	1.0		NO_3	14.8
Fe	0.01		F	0.1
Mn	1.0		HPO_4	1.0
Zn	5.0			
Cu	5.0			
Pb	0.05		SiO_2	9.38
Ba	23			
Al	0.05			
B	0.03			

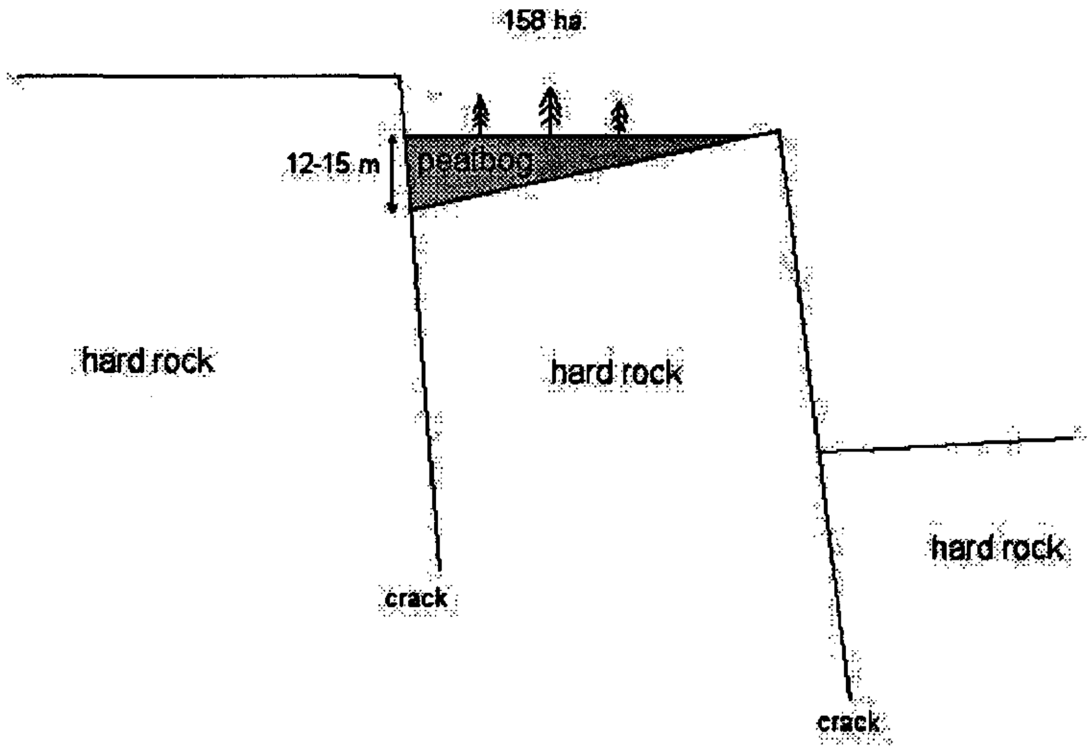
Zielenec: peat bog area

Thursday, September 7, 2000

Reported by Roel Velner and Mark Verbunt (1)

Near Zieleniec the bedrock consist of Proterozoic mica schists. Because of geological activity, a crack was formed which causes that one rock unit became lower positioned then the other one next to it (Fig. 13). In the low situated bowl, a pioneer vegetation has been formed after the last glaciation, about twelve thousand years ago. Because of wet conditions this vegetation resulted in a peat bog area. Nowadays the area of the peat bog is 158 ha with an average altitude of 750 m a.s.l., with a precipitation of about 1000-1100 mm/y. Because of these wet conditions, there used to be this peat bog area with a few low trees until a few years ago. The trees didn't grow higher then about ten meters because of the unstable weak underground. The period from 1988 till 1994 was very dry, so that the underground became more stable and was it possible for trees to grow higher. This caused a higher evapotranspiration, which also lead to a dryer and more stable underground. These conditions are fatal for the development of a peat bog area and finally it will disappear and an area with a lot of trees without any peat will develop. Only when a very wet period occurs, which would kill the trees, the peat would be able to regenerate. At the moment the thickness of the peat layer ranges from two to fifteen meters. The water in this area has an Ec about 50 µS/cm and the pH of this water is about 4.8.

Fig. 13 Cross section of the peat area



Zielenec: spring

Thursday, September 7, 2000

Reported by Roel Velner and Mark Verbunt (2)

Water intake at Zieleniec

Downstream of the previous discussed peat bog area a water intake is situated in the river. By making a dam in the river water can be forced into a pipeline which transports this water to Duszniki Zdrój, after only a short chemical cleaning treatment. The Ec about 219 µS/cm and the temperature is 9.1 °C. A second water intake for the village Duszniki Zdrój is situated at the slope of a hill where water is taken from the weathering layer by a drainage system. This intake is very sensitive to pollution because an important highway is situated next to this intake. Oil and salt can easily flush away from the road and cause pollution in the drinking water. These two methods, intake from the river and intake by a drainage system are used to supply Duszniki Zdrój from drinking water.

A third method, which can be used, for the winning of drinking water is the use of a natural captured well. Nearby the Czech border there is such a natural well. It is the biggest spring, which drains Precambrian crystalline mica schists. Twenty years ago this well and the brook were covered by dense vegetation. After a huge storm in which the wind blew away most of the vegetation, the well became visible. Nowadays vegetation starts to grow again and the spring and the brook will maybe covered by vegetation again in twenty or fifty years and the previous situation will be restored then. The discharge of the well ranges from 80 l/s (winter) to 150 l/s (April) The high discharge in April is caused by the melt of snow, which has been stored during the winter months and melts due to higher temperatures. At one of the wells a water intake is situated to supply the demand of water for the border police. This intake can deliver 50 m^3/d and the pH of the water has a relative high value of 8. A reason for this could be the high amount of $CaCO_3$, caused by the flow of this water through metamorphic limestone. The Ec of this water has a value of 140 µS/cm. This value is relatively low for water that is assumed to flow through limestone. At the moment there is no reasonable explanation for this low value. This water intake from a natural captured well is the third example of possible water winning methods.

Kletno: waterflow through marbles; quarries, caves and springs

Friday, September 8, 2000

Reported by Anne Visscher and Saskia Vuurens

Introduction

Attracted by being able to see groundwater flow through marbles (crystalline limestone), these features played a major role in organising the hydrogeological excursion to Poland.

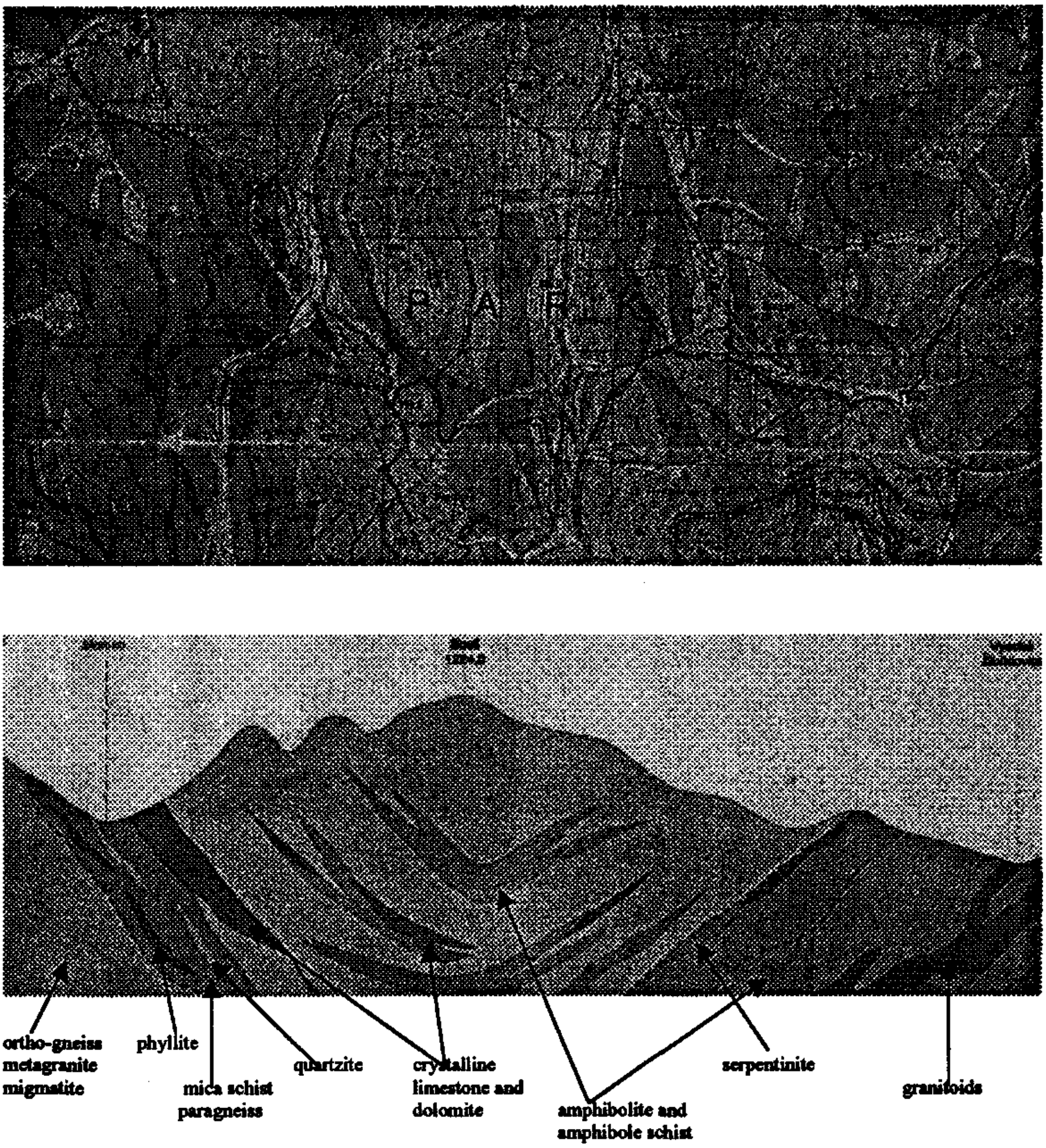


Fig. 14 Geological map and cross-section of the Kletno area

The visited sites are situated in the Králický Sněžník Mountains, which themselves are part of the Eastern Sudeten. At al larger scale this can be viewed as a unit of the Northeast part of the Bohemian Massif. Covered by sea during the Precambrian (1000

Ma) unicellular organisms accumulated at the bottom. Changed into limestone, these deposits were subsequently metamorphosed into marbles from the Upper Proterozoic to the Middle Cambrian (650 – 550 Ma). Because of both the Variscan and Alpine orogeny, the area was uplifted and densely fractured and now reaches a height of about 800 meters a.s.l.. The marbles extend up to a few kilometers in length and cover some 500 meters in depth.

Quarries
After the WOII the situation was such that people could afford to buy items apart from the ones covering basic needs. This meant that marbles in this area could be mined for use as ornamental stone. In the same period of time uranium quarries were initiated because of profitable use for fuelling nuclear power plants and development of nuclear weapons. The average amount of people carrying diseases is clearly surmounted in the area around the quarries. Presence of uranium is indicated by the mineral Fluorite. In 1966 during mining activities of marbles in quarry Kletno III, a cave containing animal bones was discovered. As a large part of the bones seemed to belong to a certain kind of bears it was later called "Bear Cave".

Caves

- The processes enabling formation of caves in general will be discussed in this paragraph. As mentioned above, the area composed of marbles was fractured during orogenies. Through these cracks water would flow vertically until it reached the local level of drainage. After this it would proceed horizontally towards the nearest brook. Because of different atmospheric circumstances within the system of fractures, water can contain more CO_2 than on entering. The pH will fall; thus the marbles ($CaCO_3$) interacting with the water will dissolve up to saturation. When it reaches a space where p[CO_2] is lower, CO_2 will escape and $CaCO_3$ will precipitate in various ways (stalagmites, stalactites, stalagnates, helectites, travertine hollows). Shades of colour are realised because of integrated Fe_2O_3 and Mn. In case of the "Bear Cave", the climatic conditions are constant. Annual temperature remains 5,0 or 6,2 °C[1] and humidity is about 100%.

  Relevant formulae:

  $$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$$

  $$HCO_3^- \Leftrightarrow H^+ + CO_3^{2-}$$

  $$CaCO_3 + H^+ \Leftrightarrow Ca^{2+} + HCO_3^-$$

[1] Depending on source of information

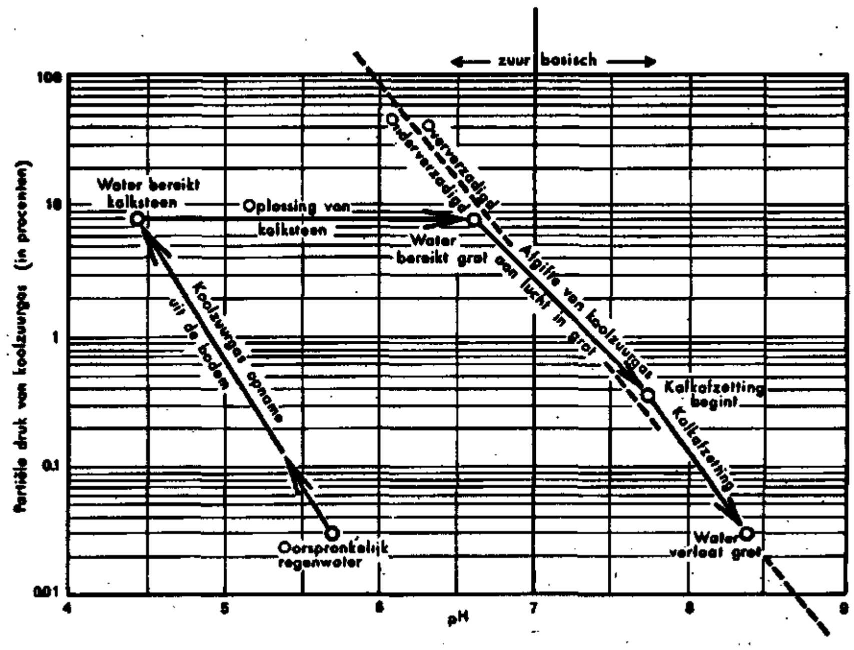


Fig. 15 The dissolution and precipitation of $CaCO_3$.

- The Bear cave displays three distinct horizontal levels of connected spaces. The climatic conditions during the Pleistocene, together with continuous tectonic uplifting, probably defined the intensity with which water would flow across a specific section during a period of time. At first, the stream did flow over the marbles towards its drainage base. During colder periods (ice age), the drainage base was lowered, because the river did cut in its substratum. As a result, water started to flow preferably through fractures in the marbles, creating the highest level of the cave. When during Pleistocene the area was uplifted some more, and new ice ages occurred, the drainage basis was lowered further (relative to the cave). The water in the cave took as a result also lower levels. The deepest level is thus the youngest (and most intact) level. It is possible to detect cycles of warm and cold periods at a smaller scale within the three main levels. Observing the layers of sediment deposited in each can do this.

Springs

The chemical constituents of water having flown through an area of marbles for 5 – 7 years can be represented by the water of "Marian Spring". The main elements are Ca^{2+}, Mg^{2+} and HCO_3^-, together making up for about 75% of total dissolved elements (0.15 g/l). The pH of this spring is 8.5 – 9 and the temperature of the water is about 6.5 ^{0}C, comparable to that of the Bear Cave.

Lądek Zdrój

Friday, September 8, 2000

Reported by Harm-Matthijs van der Worp and Arjan van 't Zelfde (1)

Geology

Ladek Zdrój is situated in the Snieznik Massive, easterly of the Intersudetic Depression and it is the NE part of the Bohemian Massive. The Snieznik Massive contains metamorphic rocks like gneiss, orthogneiss, granulite, metagranite and migmatite. These rocks are formed in the Lower Paleozoïc and have risen up during the Alpine folding. Because of that folding the Massive contains a lot of deep faults and a lot of joints. Northerly of Ladek Zdrój there is some Quaternary basalt on top of Tertiary gravels, important for the mineral wells at Ladek Zdrój.

Hydrology

The area around Ladek Zdrój is an important water reservoir. The recharge area of this area is situated in the mountains 16 km ahead, 800 meters higher than the wells. These mountains are the higher part of the nie nik Massive. From this recharge area the water flows through deep cracks to the depth of 1 km to L dek Zdrój, where the water reaches the surface. Because of this the temperature of the water at the surface can be 40 °C. From the volcanic deposits in the deeper ground, mostly basalt flows, CO_2 can dissolve in this water. The pH will become lower and rocks can be weathered easier. The rainfall in this area is 800-1200 mm per year. The time the water needs to flow from the mountains to the wells is expected to be 8000-12000 years, which makes this a slow reacting system.

There are six wells in Ladek Zdrój of which five are used. The water from these wells can differ in composition by following different cracks to the surface. In Table 4 we can see that the wells contain high contents of Na^+, HCO_3^- and SO_4^{2-}. The pH is high because the H^+ formed during dissolving CO_2 is used for weathering minerals. Some of the wells have a high H_2S-content, of which Dobrowka has the highest concentration.

Table 4 Chemical data of springs in Lądek Zdrój

Chemical analyses of springs in Lądek Zdrój (mg/l)																
	pH	NCI/I	H_2S	H_2SiO_3	Na^+	K^+	Ca^{2+}	Mg^{2+}	Sr^{2+}	Fe^{2+}	Ba^{2+}	F	Cl^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}
1	9.2	4.09	3.06	39.0	52.0	1.0	3.10	0.47	0.5	0.66	0.1	10	8.86	16.5	42.63	21
2	9.1	3.36	2.55	41.0	47.6	0.75	3.88	0.71	0.5	0.06	0.1	10	8.86	20.0	39.66	15
3	8.9	3.92	2.55	39.0	47.0	1.0	4.26	0.47	0.5	0.04	0.1	9	8.86	22.0	39.58	15
4	8.9	7.27	1.70	39.0	45.5	1.0	4.26	0.47	0.5	-	0.1	9	8.86	19.2	40.27	15
5	9.1	3.61	3.57	39.0	44.5	0.75	5.03	0.47	0.5	0.14	0.1	9	8.86	16.5	42.61	15
6	8.9	34.41	3.06	36.4	40.0	1.0	5.81	0.94	0.5	-	0.1	8	6.65	16.5	42.61	15
7	8.6	1.30	0.42	33.8	39.5	0.85	6.73	0.24	-	0.05	-	8	7.09	28.0	42.10	6

In Ladek Zdrój we have been to a building (Pijalnia) where people can drink water from the wells. In this Pijalnia we could drink water from two wells: Marie-Curie-Sklodowska en Wojcieg. We examined the taste of the two wells. The compositions of the wells according to the signs were as shown in the Table 5.

Table 5 Chemical composition of two wells in L dek Zdrój

Main ions within the two wells in the Pijalnia					
	Na^+ (mg/l)	HCO_3^- (mg/l)	SO_4^{2-} (mg/l)	PH	H_2S (mg/l)
Marie-Curie-Sklodowska	42.3	42.7	22.1	9.8	-
Wojcieg	50.0	42.7	22.0	9.4	1.36

There were four tapping points. First we thought there were four different wells. When we tasted the different waters, the first one was quite okay, the second one was terrible, the third one was good and the last one was like the second one. When we discovered that the first and third and the second and fourth were the same, we wondered why we tasted a difference between the first one and the third one. We tasted these again, but still we thought there was a slight difference in taste. The difference in taste was probably caused by the difference in temperature of the water. It was clear that the H_2S-content in one of the wells was very dominant in the taste of this water. This was especially noticeable in a well we saw outside the building (Dobrowka), the one that has the highest H_2S-content. This was also noticeable because of the rotten-egg-smell. At the well we found information, as shown in Table 6.

Table 6 Dobrowka

Some data of the well "Dobrowka"	
Established in	1828
Yield	20.2 l/min
T	20.1 °C
PH	8.7

Idzików

Friday, September 8, 2000

Reported by Harm-Matthijs van der Worp and Arjan van 't Zelfde (2)

Geology

After our visit to Ladek Zdrój we drove up again and ended on the Westside of the Intersudetic Depression. At this last excursion point we had a nice view over this depression.

The depression is formed during the Hercynian folding and was later filled with Cretaceous sediments. These sediments are deposited here because in this depression an inner sea developed. This caused overlaying layers of sand, silt and clays, enriched by $CaCO_3$. The clay was deposited in quiet periods, as sand and silt were deposited in rougher periods. From these deposits, sandstone, siltstone and marlstone have developed.

The Alpine folding has caused an unequal rising of these layers. The table mountains we saw earlier this week are now situated much higher than the Cretaceous deposits we were looking at here in the depression. These deposits have been lifted equally with the surrounding area. The Alpine folding had various consequences for the Cretaceous deposits in the depression. Most of the layers remained horizontal but bent and folded at the edges due to pressure and uplifting. The layers have also been strongly influenced by block tectonics. Block tectonics are caused by cracks which are formed in the rocks parallel to the direction of the tectonic movement. This especially happens in the sand- and siltstones. The blocks slide alongside each other so that the horizontal layers are no longer continuous but broken by the blocks. This has great consequences for the aquifers of the system.

Hydrology

As mentioned before the area of Idzików is part of the Intersudetic Depression, formed in the Upper Cretaceous, and contains a mixture of deposits of sand, silt and clay. Because of the marlstone layers, and sometimes mudstone, in between the sand- and siltstone layers one can say there is a multiple aquifer-system in the area. Since the Alpine folding (block tectonics) has caused a lot of deep faults and a lot of fractures in the sedimentary rocks, most of the water flows through the fractures and joints as fracture flow (secondary permeability). Only a small part of the water will flow through the pores as intergranular flow (primary permeability). The difference of those two is rather large, 10-12 m/day for the fracture flow and just 0.01 m/day for the inter-granular flow. Because of the thick layer of the deposits the transmissivity (kD) of the formation is also rather high (2000 m^2/d).

The intake area of Idzików is about 24 km^2 large with the metamorphic rocks on both sides as natural boundary. The amount of water available for the area, villages and agriculture, is approximately 13 million m^3/y. This is not much, compared to the Bóbr Marciszów area (50 million m^3/y), but it's enough for Idzików. The water is enriched by $CaCO_3$, this because of the marlstone.