Hydrogeological excursion to the Czech Republic

11 - 17 september 1994

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PREFACE

This is a report of the hydrogeological excursion to the Czech Republic held in the period from 11 to 17 september 1994. The report is written by one of the participating students, using the information of the excursion guide and the information collected in the field by the other students. We are grateful to Karin van der Hoeven for this excellent compilation.

We had the opportunity to enjoy the hospitality of many people in the Bohemia. First we would like to thank our guides Prof. Jan Šilar and Dr. Miroslav Sviták, who spent the whole week with us. Their contribution included more than only the hydrogeology. They introduced us also to the Czech Republic in every way, from breakfast till nightfall. We are also grateful to Prof. Pavel Kovar, Dr. Oldřich Novický, Mr. Rudolf Hancvencl, Mrs. Alena Kulasová, Dr. Jan Slezak and Dr. Vojen Lozek who guided us at some excursion points. Prof. Pavel Kovar has also put a lot of efforts in the organisation of the excursion. Besides some of the earlier mentioned persons he was supported by Dr. Jaroslav Vrba, Dr. Ladislav Kašpárek and Dr. Svatoplvle Matula.
Prof. S. Kroonenberg and Ing. R. M. van de Berg van Saparoea joined us to prepare their geological research on the terraces of the Ohrě river in Bohemia.
Hopefully this report is a good overview of what we have seen in the Czech Republic.

Dr. Henny van Lanen
Ing. Ben van de Weerd
Roel Dijksma

EXCURSION-PROGRAMME TO NORTH-WESTERN AND NORTHERN BOHEMIA

Sunday, 11 September 1994
- Departure from Department of Water Resources, Wageningen.
- Arrival in Czech Republic, accomodation in Mariánská, Jáchymov.

Monday, 12 September 1994
- Introductory lecture in Mariánská.
  Excursion to mineral springs of Mariánské Lázně and Sokolov Basin.
- Excursion to mineral springs of Mariánské Lázně, Prameny and hot springs of Karlovy Vary.

Tuesday, 13 September 1994
- Excursion to the Komorní Hůrka volcano.
- Excursion to the peat bogs of Soos,Hájek

Wednesday, 14 September 1994
- Excursion to the Krušné Hory and the coal basin near Most with a geotechnical case of moving a church in Most.
- Excursion along the Labe river driving to Ústí nad Labem, faultzone near Teplice.

Thursday, 15 September 1994
- Excursion to Stráz pod Ralskem with an explaination on hydrogeological and environmental problems due to uranium mining.
- Trip to Jizerské Hory, experimental watersheds of the Czech Hydrometeorological Institute.

Friday, 16 September 1994
- From Praha-Suchdal to Svatý Jan pod Skalou, geological explanation of the Barradian system and karst phenomena.

Saturday, 17 September 1994
- Return and arrival in Wageningen.

INTRODUCTION

The Czech Republic is situated in the heart of Europe (see figure 1), is rich in history and natural beauty. The Czech Republic covers an area of 78 860 km^2 and it has 10.3 million inhabitants.

Hydrogeology

The territory is divided into three main watersheds: the Elbe, Odra and Morava river basin. The major part of the Bohemia is drained into the North Sea by the Elbe River. The drainage area of the Elbe river covers 61% of the territory of the Czech Republic. The mean annual precipitation is 693 mm that represents an annual volume of about 55 km^3. Water in snow can accumulate up to 5 km^3.
The water balance components in percentage of precipitation for an average year are specified as:

- evaporation and soil moisture	68.5%
- surface runoff	28.8%
- accumulation in groundwater resources	2.7 %

Geology

General introduction

The region visited during the excursion is in the NW part of the Czech Republic. It belongs to the Bohemian Massif which is a part of the Variscan orogen (see table 1). It consists of a metamorphic and sedimentary foundation (Proterozoic and Early Paleozoic in age) pierced by granitoid intrusions. The Bohemian Massif was folded and consolidated during the Variscan orogeny and was covered by Late Paleozoic (Carboniferous and Permian) and Mesozoic (especially Cretaceous) sediments. In the Tertiary, the cratonic Bohemian Massif was faulted by Saxonic movements at the time of Alpine and Carpathian orogeny.

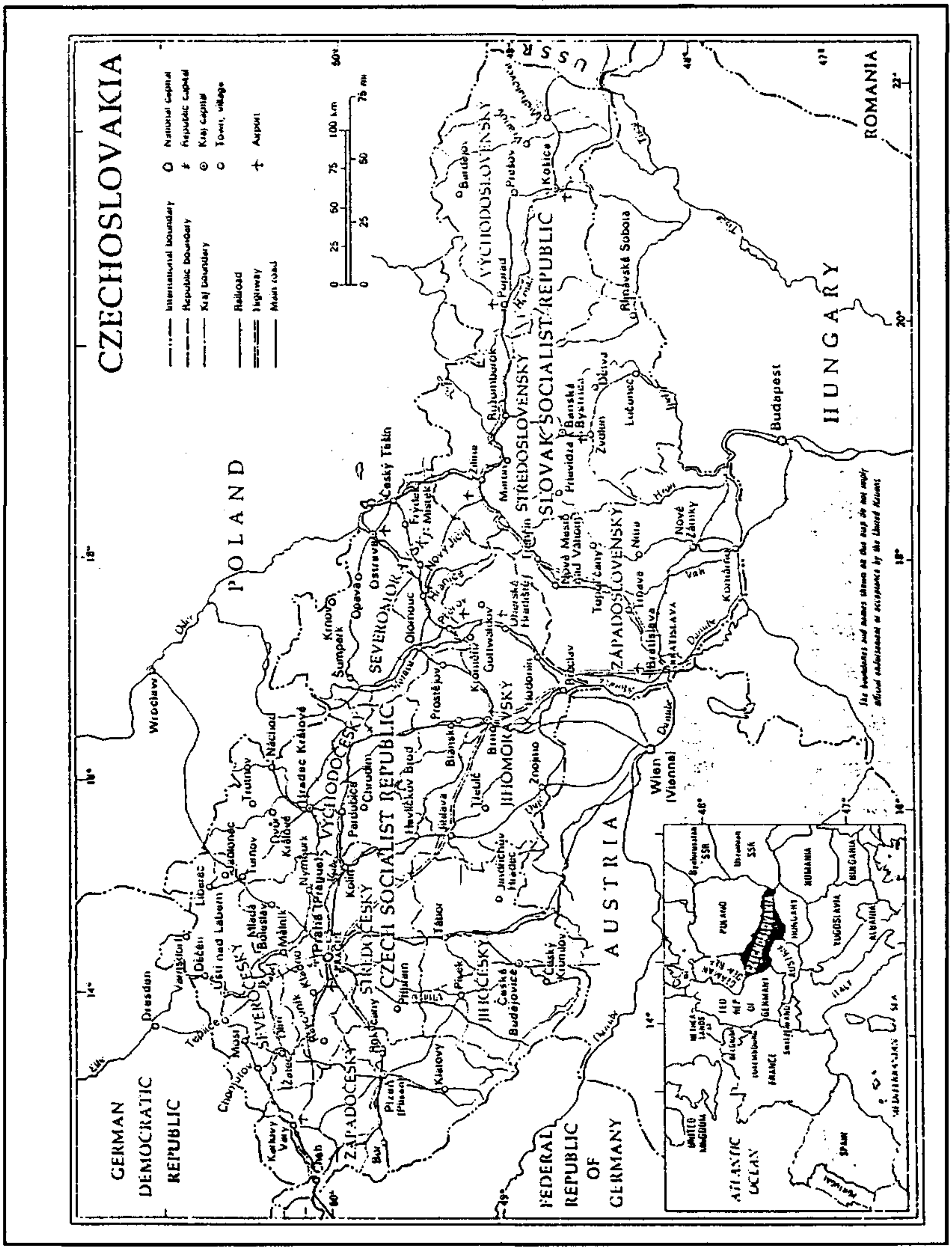


Figure 1. Geographic setting of the Czech Republic.

In the northern part of the Massif, this activity was accomplished by volcanism. The latest events of which reached as late as Pleistocene. Since Neogene, various parts of the Bohemian Massif have been uplifted or subsided along faults forming. This resulted in northern Bohemia in a system of horsts and grabens (see tabel 1 for geological time scale).

Table 1. Geological time scale.

	Eras		Approximate age (in years)	Subdivisions	Approximate duration (in years)
PHANEROZOIC	QUATERNARY		10,000	HOLOCENE	10,000
PHANEROZOIC	QUATERNARY		2 M	PLEISTOCENE	2 M
PHANEROZOIC	TERTIARY	Alpine	5 M	PLIOCENE	3 M
PHANEROZOIC	TERTIARY	Alpine	24 M	MIOCENE	19 M
PHANEROZOIC	TERTIARY	Alpine	37 M	OLIGOCENE	13 M
PHANEROZOIC	TERTIARY	Alpine	57 M	EOCENE	20 M
PHANEROZOIC	TERTIARY	Alpine	66 M	PALEOCENE	9 M
PHANEROZOIC	MESOZOIC	Alpine	144 M	CRETACEOUS	78 M
PHANEROZOIC	MESOZOIC	Alpine	208 M	JURASSIC	64 M
PHANEROZOIC	MESOZOIC	Alpine	245 M	TRIASSIC	37 M
PHANEROZOIC	PALEOZOIC	Caledonian Variscan orogeny*	286 M	PERMIAN	41 M
PHANEROZOIC	PALEOZOIC	Caledonian Variscan orogeny*	360 M	CARBONIFEROUS	74 M
PHANEROZOIC	PALEOZOIC	Caledonian Variscan orogeny*	408 M	DEVONIAN	48 M
PHANEROZOIC	PALEOZOIC	Caledonian Variscan orogeny*	438 M	SILURIAN	30 M
PHANEROZOIC	PALEOZOIC	Caledonian Variscan orogeny*	505 M	ORDOVICIAN	67 M
PHANEROZOIC	PALEOZOIC	Caledonian Variscan orogeny*	570 M	CAMBRIAN	65 M
	PRECAMBRIAN			Worldwide subdivisions not well established	2800 M+

Hydrogeology

The main groundwater resources are those in the Upper Cretaceous formations and in the Quatenary fluvial and glaciofluvial deposits.The average thickness of Cretaceous sediments is 300 m, reaching over 1000 m in some areas with a transmissivity of 10^{-3} to 10^{-5} m^2/s. The groundwater is usually potable, some groundwater has a high mineral content.The Quartenary deposits are often shallow aquifers therefore highly sensitive to contamination by intensive agriculture.

There are significant resources of mineral and therapeutic water. The total capacity is 180 l/s, out of which 55 % is used directly in spas or for distribution in bottles.The most important mineral water resources are located in north-western Bohemia and include Františkovy Lázně, Mariánské Lázně, Karlovy Vary, Jáchymov and Teplice (see figure 1

and 2), all used intensively as spas for medical purposes. The most popular water in Karlovy Vary is of the $Na\text{-}HCO_3\text{-}SO_4\text{-}Cl$ type with a temperature of 73°C.
Deep reaching faults and postvolcanic emanations of carbon dioxide are dominant factors controlling the origin of numerous mineral and thermal springs.
Problems connected with the captation of mineral water and the mining of coal and kaolin in north-western Bohemia have been considered for several centuries. In 1879, cessation of thermal-spring flow in Teplice, caused by coal mining was reported. Outbursts of hot gaseous mineral water in Karlovy Vary were mentioned by the poet J.W. Goethe in 1809.

Excursion points in the Bohemia

Krušné Hory ("Ore Mountains", in Germany Erzgebirge)

A SW-NE trending and 130 km long ridge along the border of the Czech Republic (see figure 2) and Germany. The highest peak is Klínovec, 1244 m above sea level. The NW slope declines gently to Germany whereas the SE slope along an outstanding fault is steep and separates the mountains from a series of Tertiary basins. A complex old crystalline system, the inner structure of which was formed by the Variscan orogeny accompanied with intrusions of granitoid rocks and origin of numerous ore deposits (mainly tin, polymetallic ores with silver, uranium). The morphological features were shaped by Tertiary faulting and uplift. Intensive mining activitieshave been going on since Middle Ages.

Jáchymov

An old mining town on the SE slope of the Krušné Hory Mts. In 1512, the discovery of silver started a boom of silver mining. Bohemian tolars were struck in a royal mint. After the gradual decline of silver minig, lead, cobalt, nickel and arsenic were mined during the 18th and 19th century. Uranium was mined in the Jáchymov area since the end of the 19th century and reached its peak after the 2nd world war. Almost all minig activities have been stopped by now. In the abandoned mines, springs of radioactive thermal water have been tapped by a 190 m deep bore hole drilled from a mining galery in metamorphic rocks (mainly schists) at 493 m below surface. The radioactive thermal water is coming from granites at 683 m below surface. The temperature of water is 28°C, its radioactivity due to radon is up to $3.4 \cdot 10^{-7}$ curie/l. The thermal water is used for bathing cures treating rheumatic deseases.

The Cheb Basin

It is an assymmetric graben which subsided along a NW-SE trending fault which separates the basin from the highland of Císařský les. It is filled with Tertiary lacustrine sediments. In the north it is crossed by NE-SW trending faults which actually are the continuation of the Krušné Hory graben system. In the west there is the basalt volcano Komorní Hůrka with a basalt dyke and pyroclastics overlying gravel which is considered Quaternary.

Komorní Hůrka

Is a Pleistocene volcano close to the Františkovy Lázně spa at the western margin of the Cheb Basin in the continuation of the Krušné Hory graben faults. It consists of a cinder cone with periclinal structure and a lava flow overlying a layer of gravel which is considered Pleistocene in age. In the cinder, fragments of underlying phyllite can be found.

Františkovy Lázně

A spa with cold carbon dioxide highly mineralized waters and peat bog which are used for treatment of gynecological, cardiac and rheumatic diseases. The confined mineral water issues from the base of Tertiary aquifers the thickness of which at Františkovy Lázně is about 80 m and increases towards the east. The Tertiary aquifer is underlain by Paleozoic phyllites which form a mantle for the biotite-muscovite granite body of the Smrčiny Mts. The contact of the granite in northwest and phyllite in southeast is tectonic. The surface of the crystalline rocks underlying the Tertiary is weathered, decomposed and dissected by NE-SW faults along which the magmatic carbon dioxide ascends. It saturates the confined mineral water in the overlying Tertiary sediments and participates in the geochemical processes forming the chemical composition of the mineral water which is rich in sodium and sulphate ions and contains as much as 13 g/l of dissolved solids. The mineral water penetrates through the Tertiary sediments to the peat bog on the surface in which the sulphates are reduced to sulphides.

Hájek

A peat bog deposit with a layer of diatomaceous soil on Pliocene (Tertiary) deposits in the north-central part of the Cheb Basin. The peat bog is saturated with salts (mostly sulphates) brought by mineral water from the underlying rocks. During dry periods, various salts and minerals may be seen on the surface. In an area of about 3 km^2, there are about 20 mineral springs and numerous carbon dioxide vents. Hájek has been declared to a National Nature Reserve.

Picture 1. Upwelling of carbon dioxide in a spring in the National Nature Reserve of Soos.

The Sokolov Basin

A complex graben parallel to the Krušné Hory Mts which is separated from the Cheb Basin by the horst of Chlum Sv. Maří. The bedrock is porphyric granites with aplite, schists and phyllites with quartz veins. The crystalline is weathered and kaolinized.

Karlovy Vary

In the town of Karlovy Vary, hot springs of sodium-bicarbonate-sulphate-chloride water oversaturated with carbon dioxide are located in the deep valley of the Teplá River which is a tributary of Ohře. The geological structure of the hot-spring system is linked with a body of granite which pervades transversally the crystalline rocks of the Krušné Hory Mts. The springs occur on a diagonal fault zone of a NW-SE direction which at the place of the main spring is crossed by a perpendicular fault striking NE-SW.

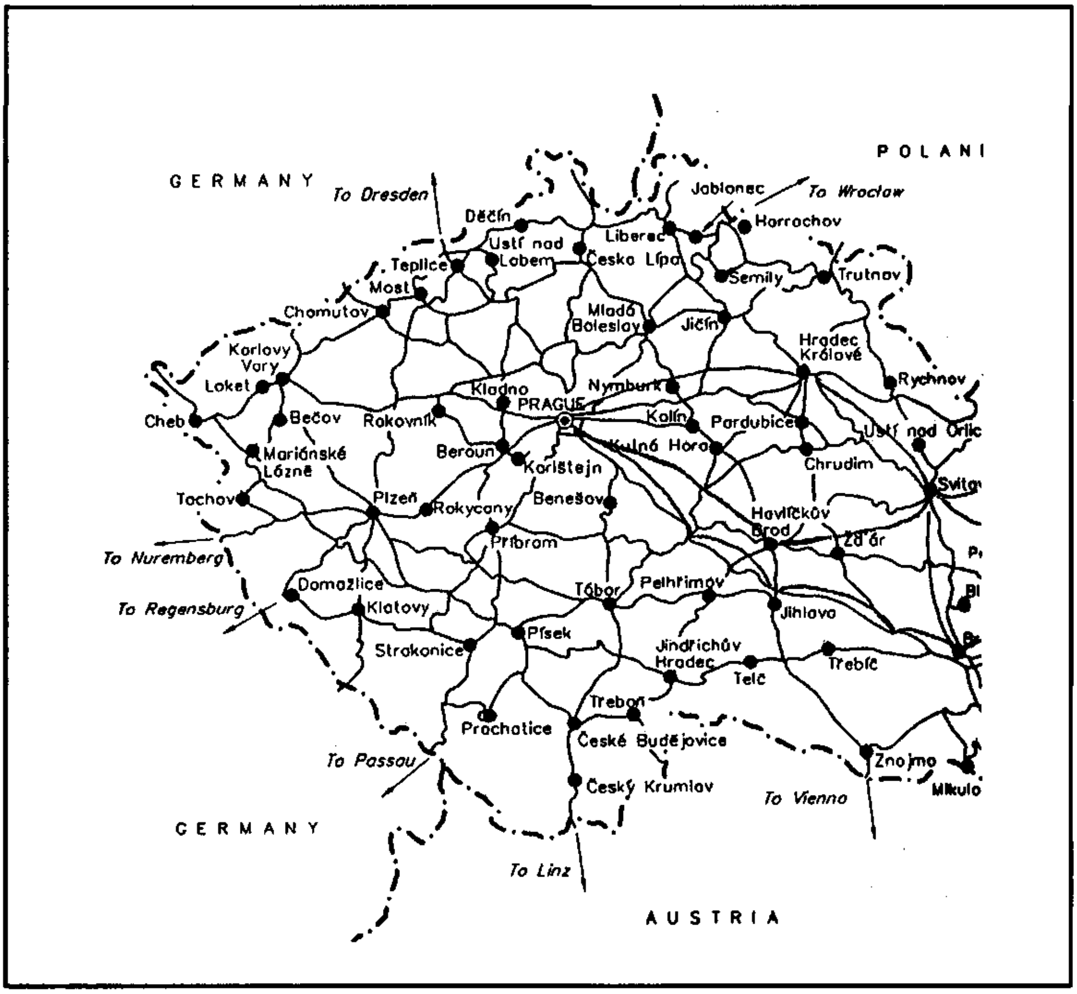


Figure 2. The Czech Republic.

Mariánské Lázně

The Mariánské Lázně spring area with the spas of Mariánské Lázně and Konstantinovy Lázně is an extensive area with issues of cold carbon dioxide waters of the sodium-bicarbonate-sulphate type. The crystalline rocks are fissured and often weathered and hydrothermally altered. This results in a very variated chemical composition of the mineral springs.

The Tertiary Northern Basin

The area (along the foot of the Krušné Hory Mts.) consists of a basement of crystalline rock complexes of the Krušné Hory Mts., including a large rhyolite extrusion (Teplice porphyry). Upper Cretaceous and Tertiary sediments and volcanic rocks comprise the platform cover above the crystalline basement. The major structure of this area is the Krušné Hory fault, which trends generally NE-SW with many related parallel and transverse faults. Movements along the faults plus uplift of the Krušné Hory Mts. resulted in the development of a horst along the southern part of the Tertiary basin. North Bohemian Tertiary basin was formed as a result of volcano-tectonic subsidence. The thick layer of tuffs and tuffites was deposited at the bottom over the larger part of the basin, folloved by the sedimentation of volcanogenic clay, with variable thickness up to 70 m. The coal-forming marshes and swamps developed almost throughout the whole area of the basin and during a long and relative quite period the main coal seam was formed. It has an average thickness of about 30 m and reaches in its optimum development from 50 to 60 m (in the vicinity of Most and Braňany). The development of the main coal seam was in some parts of the basin interrupted by the sedimentation of clays and sands which resulted in a sequence of coal seams seperated by clastic sediments.

Stráž pod Ralskem, Hamr

Stráž pod Ralskem has been a center of uranium mining during the past three decades. Sedimentary uranium ores occur in the surroundings of the village Hamr at the district town Česká Lípa. The deposits occur in the Cenomanian fresh-water and brackish sediments which are the lowermost Cretaceous strata.The Cenomanian strata consist (from bottom to the top) of about 17 m of fresh-water sediments, mainly wash, lacustrine and fluviatile sediments, about 35 m brackish soft sandstones and 443 m of marine sandstones.
A large part of the uranium deposit is being extracted with leaching by sulphuric acid. A system of hundreds of boreholes is used as injection and abstraction wells. To prevent the migration of the chemicals outside the mining area, another system of boreholes around the leaching area is used to pump water under pressure into the lower aquifer to increase the piezometric level.

The Barrandian (in Svatý Jan pod Skalou and in Srbsko)

The Barrandian comprises a geological unit consisting of non-metamorphosed Proterozoic and Lower Paleozoic rocks in a synclinal structure extending from Prague to the southwest. In the Silurian and Devonian limestones, karst phenomena are developed with caves, karst springs and travertine deposits. The tropical weathering and karstification seems at least Tertiary in age and are well pronounced on the old flat plateau above Svatý Jan pod Skalou and along the Berounka River valley. At Svatý Jan pod Skalou, a cascade of tuffa (travertine) was formed and is protected as a Middle and Upper Holocene stratotype.

Monday morning, 12 september 1994

Spas of Mariánské Lázně and Sokolov Basin
reported by Martin van den Akker, Jeanette van der Steeg and Cathelijne van Haselen.

Mariánská is a small village just south of Jáchymov in the Krušné Hory (Hory = mountain). Krušné Hory is a SW-NE 130 km long basic ridge along the border of Germany and the Czech Republik and was formed during the Variscan Orogeny. The mountains of Hory are seperated from the Sokolov Basin by a fault. The western part of Sokolov Basin basin is filled with Tertiary fresh water deposits. The centre consists partly of sediment and partly of crystalline rock. In the north-east the basin is partly filled with sediment and partly with volcanic rock (basalt and pyroclastics). Perpendicular on the SW-NE fault some transversale faults occur, which crossings cause permeable zones for upward CO_2-transmission. This CO_2 origins from post-volcanic activity. The CO_2 comes from the earth crust and flows upwards through the deep-reaching faults. These faults are permeable enough to transport CO_2 at greater depth, but not for groundwater to infiltrate very deep. At shallow depths (about 100 m) groundwater in the crystalline rocks mixes with the upcoming CO_2. The springs react very quickly on rainfall, and even flooding occur due to the shallow groundwater system.
There are two possibilities of CO_2 coming up the surface: the dry ones ('moffets') and those in contact with groundwater, which circulates in the fault system ('spa') which lead to carbon-dioxide containing water.

Mariánské Lázně is one of the villages well known by its cold mineral springs, which occur in various types of crystalline rock. The chemical composition of the mineral water is strongly influenced by the rock type and degree of weathering. There are two kinds of springs, the higher and lower one. The lowest are the Ferdinand and the Rudolf springs. Ferdinand I is a spring with a temperature of 8.7°C, a discharge of 119 l/min and TDS of 11000 ppm. Sodium and potassium are the prevailing cations together with calcium and magnesium. The prevailing anions are chloride and sulphate. The Rudolf spring has a completely different chemical composition, a TDS of 2000 ppm. Here HCO_3^- instead of sodium prevails, other cations are calcium and magnesium (see table 2).

Table 2. Composition of Mariánské Lázně springs, Ferdinand I and Rudolf.

	Ferdinand I conc (ppm)	Rudolf conc (ppm)
TDS	11000	2000
Na^+	3000	90
Ca^{2+}	-	200
Mg^{2+}	-	120
Cl^-	1200	-
SO_4^{2-}	3400	-
HCO_3^{2-}	3100	1400
CO_3^{2-}	significant	-

Different methods have been used to extract the mineral water (TDS > 1 mg/l is called mineral water in the Czech Republic). In the early days shallow wells were used (figure 3), but the disadvantage of this type was the vulnerability to pollution sometimes caused by flooding. Later on a structure was installed which captured the upcoming mineral water(figure 4). The third and best option is to drill deep wells (figure 5). At greater depths the calcium concentration and the CO_2 pressure is higher than closer to the surface (figure 5) which is more favourable for the spa-processing industry.

Figure 3. Extraction of mineral water from shallow wells.

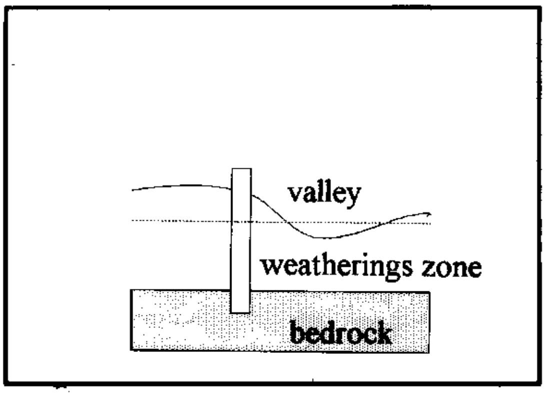


Figure 5. Extraction of mineral water from deep wells.

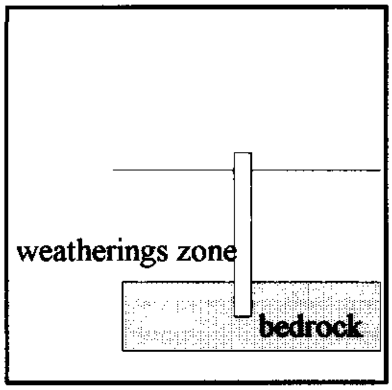
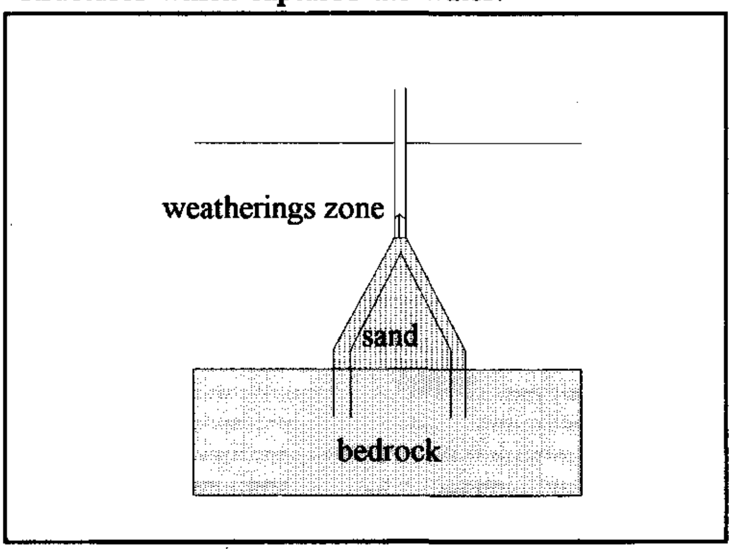


Figure 4. Extraction of mineral water from structures which captured the water.



The groundwater protection area around Mariánské Lázně consists of 3 zones:

- The innner zone, protection of wells;
- The forests around the city, no industry allowed in this area;
- The surrounding area, no activities which can influence the groundwater quality. Agriculture in this zone is only allowed with restrictions for instance on the use of manure.

Sokolov basin

Not all the Tertiary deposits containing lignite (brown coal) can be removed to the top of the crystalline rocks because of the risk of breaking of the bottom of the mine due to high water pressure (figure 6). In 1879 this happened in the mines 7 km from Teplice. The mine was flooded and the warm mineral springs of Teplice fell dry wthin 5 hours. All noble tourist, including the royal family of Vienna moved then to Karlovy Vary. In 1903 a similar disaster happened in the mine of Sokolov near Karlovy Vary. The controverse between the mining and the exploitation of the mineral water was the start of hydrogeological research in the Czech Republic.

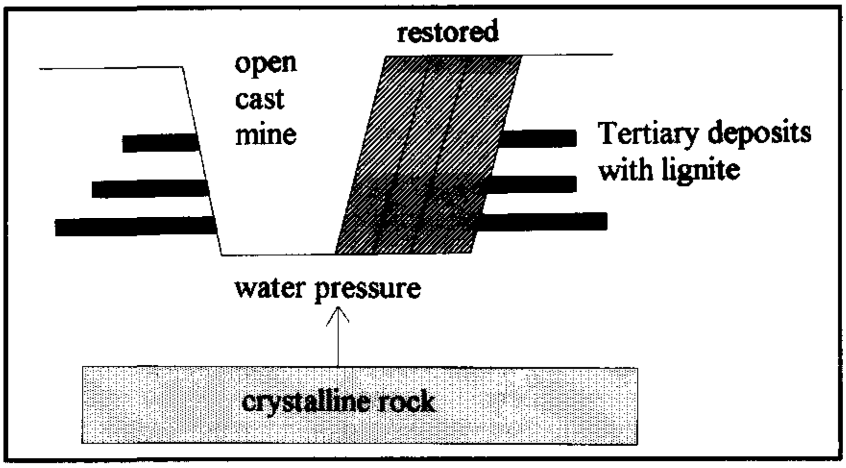


Figure 6. Principal of lignite mining in the Sokolov Basin.

Monday afternoon, 12 september 1994

Spas of Prameny and Karlovy Vary
reported by Mireille de Heer, Rianne van der Ven and Peter Verburg.

Prameny (Pramen is Czech for springs) is a small village situated northeast of Mariánské Lázně on the highland of the Císarský les (forest). This plateau forms a quasi-peneplain because it consists of metamorphic rocks which are not very resistant against erosion. In Prameny drillings for mineral water were carried out to a depth of 100 m.
Driving through this gently undulating landscape several outcrops of ultra-basic rocks (amphibolites, gabbros and serpentinites) can be seen. The serpentinite is metamorphosed basalt. These rocks form outcrops because they are slightly more resistant against erosion than the surrounding rocks. Their hardness limits their use for construction work.
The high Mg-content of the rocks is responsible for the Mg-content of the springs in Mariánské Lázně. The harsh climate on top of the plateau in combination with the high Mg-content of the soil on the outcrops results in a rare vegetation type with a.o. *Erica sp.* In order to preserve this vegetation the area is a nature reserve nowadays. This is also beneficial for protection of the area which is the catchment area of the mineral springs.

Heading towards **Karlovy Vary** (Carlsbad) we descend from the plateau into the deep valley of the Teplá-river. The Teplá-river drains the metamorphic plateau and granitoids of the pluton of Karlovy Vary which explains the rather low EC of the river water (293 μS/cm). A straight angle in the river course indicates perpendicular faults and associated fracture systems. At crossings of these faults and fractures hot springs bring curative water to the surface. This curative water is responsible for the wealth of the city because it is believed that one can recover from digestion, liver and kidney diseases after drinking of the water.
In contrast with the springs in Mariánské Lázně the chemical composition of all the springs in the spa area is similar. The water is of the sodium-bicarbonate-sulphate-chloride-type and oversaturated with carbon-dioxide. This type of water is typical for this area. The total amount of dissolved solids is 6000 mg/l while an EC of 7400 μS/cm was measured. The water contains relatively more sodium than calcium (only 130 mg/l). This composition of the spring water can be explained by the origin of the water from granitic rocks. Granitic rocks are acid and contain only very small amounts of Ca-containing minerals.
Some groundwater is estimated to come from a depth of about 2300 m. So groundwater circulation in the Karlovy Vary region is much deeper than in the Mariánské Lázně area. Therefore the temperature of the springs ranges from 32°C to 72.8°C. The main reasons for this high temperature are the fault structure, permitting the water to infiltrate deeper, and an increased thermal flux in the Krušné Hory piedmont-graben region. Differences in temperature between springs can be explained by different residence times of the water in the fissure system.

North of the main Krušné Hory graben no springs can be found. The reason for this was found during the construction of an anti air-raid gallery in the rocks near the main fault. The main fault appeared to be sealed with clay minerals which make the fault impermeable for water.
In the past aragonite ($CaCO_3$) clogged the springs from time to time. Argonite precipitates

because of the degassing at the surface. If the CO_2 pressure decreases, the water chemistry changes. Due to pressure of water and carbon dioxide the layer of aragonite was sometimes broken which resulted in small explosions. At present water is tapped from shallow boreholes which are periodically redrilled in order to avoid clogging with aragonite. After finding bacterial contamination of bottled spring water due to sewage water the main spring is tapped at a depth of 85 m below the surface to avoid future contamination. To prevent contamination of the spring water in the future the recharge area is divided into several ground-water protection zones taking into account the tectonic structure.

Tuesday morning, 13 september 1994

Komorní Hůrka volcano
reported by Karin de Boer, Johan Ellen and Maike Wickardt.

The Cheb basin is situated in the most western part of Bohemia. It is surrounded by the mountain ranges of Krušné Hory in the north and Slavkovsky les and Český les in the south. In the east the Cheb basin is bounded by the Mariánské Lázně fault.
Phasal tectonic movements caused the crossing of the tectonic grabens of the Krušné Hory system and the Český les system. The area of the crossing is subsided. These tectonic movements are still continuing and minor earthquakes are reported every year.
The bottom of the Cheb basin consist of crystalline rock: in the north granetoïds are found and in the south metamorphosed Proterozoicum and Paleozoicum, known as the phyllites of Cheb. On the top of the crystalline basement Tertiary sediments are depostited.
The stratigraphy of the Tertiary deposits in the Cheb basin is as follows:

-	Pliocene:	Sand and gravel
-	Miocene:	Cypris shales
		Antonin coal seam
		Volcanic tuffets of tuffs and clays
-	Oligocene:	Sandstaone, silicified

In the western part of the Cheb basin the Pleistocene volcano **Komorní Hůrka** is situated. This volcano shows a periclinial layering, which means that the volcano has a cinder shape due to an even distribution of the pyroclastics in all directions. Kormorní Hůrka itself is slightly eggshaped due to the prevailing wind direction at time of eruption (figure 7).
Komorní Hůrka consists of layered ashes, lappilli and some bombs. Also inclusions of phyllite and quartz can be found. These probably originate from the underlying Proterozoïcum and Paleozoïcum basement. On the top basaltic outcrop is found, this basalt does not have the typical columnar structure of basalt. It has a irregular structure. The basalt contains large amounts of olivine.
The age of the volcano must be Quartenary because pyroclastics are found on the top of the Pleistocene sands and gravels. The same sands and gravels can be found in the terraces of the Ohře river. Since these terraces are linked with Pleistocene glacial activity, the volcano must be of Quartenary age.
Part of the pyroclastics were excavated to be used for road constructions, but nowadays the slopes of the Komorní Hůrka are protected.

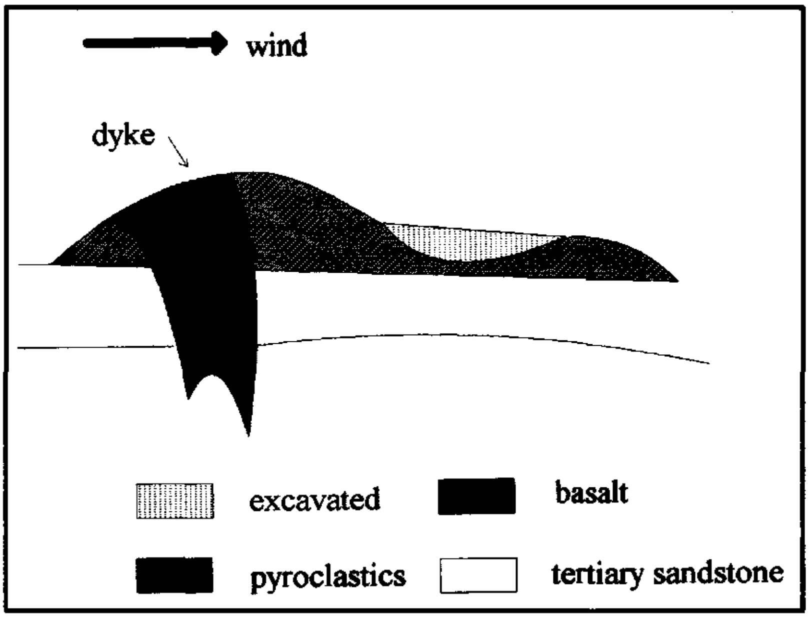


Figure 7. Komorní Hůrka volcano.

Basalt might be a good aquifer but this is not the case in this area or in other parts of the Czech Republic. The outcrops cover a to small area to receive sufficient recharge.

The city of **Františkovy Lázně** is situated on the crossing of two faults in the Cheb basin. The mineral springs of the city have a different chemical composition compared to the earlier described springs.
The Cheb basin is a large artesian basin. Along faults the crystalline bedrock is dissected, decomposed and weathered. Water satured with CO_2 of magmatic origine ascends through the fissures. On its way the water is enriched with large amounts of ions from the weathered bedrock, by way of cation exchange (from secundary clay minerals) and dissolution. The mineral water penetrates into the above-lying Tertiary sediments. The water contains a high amount of sulphates; these probably originate from leaching out of sulphate from sulphur- and nitrogen- rich organic layers in the lacustrine Tertiary sediments and from oxidation of pyrite. In the Tertiary sediments also some deposits of gypsum ($CaSO_4$) and Glaube soils (Na_2SO_4) can be found.

In the spa area of Františkovy Lázně three boreholes were drilled during the 1920's to collect a continuous amount of the mineral water. The wells are ranging in depth from 35 to 89 m. The total mineral content is about 16 g/l. The main compounds are sodium and sulphate. The water is used to threat rheumatic, cardiac and women's disseases. Mineralised peat and CO_2 gas are used as well.
In the late 1950's a drilling nearby made by the Geological Survey caused a water spouter. Groundwater heads and spring discharge significantly decreased. However the original situation could be restored again. Nowadays the piezometric level of the springs in Františkovy Lázně is lowered due to a recently (1960's) dug ditch. This ditch was dug to drain the surrounding marshes, for prevention against floods and mosquito-plaques. Most of the natural springs fell dry, but the deep boreholes remained unaffected.

Tuesday afternoon, 13 september 1994

Peat bogs of Soos,Hájek
reported by Timo Kroon, Evelien Gerritse and Wulf Vaarkamp.

In the north-central part of the Cheb Basin a large area of peat bog is situated near the village of Hájek. In 1964, 221 ha of this peat bog was declared to be a National Nature Reserve. In this area, with a total of 2,000,000 m^3 of peat, the maximum thickness of peat is 4.80 m. Over 200 wells of mineral water and dry carbon dioxide can be found in the national park. The area of Hájek is situated at about 425 m above sealevel. The mean annual precipitation rate is 589 mm.

Due to tectonic activity a large depression (2200 m length and 1400 m width) was formed in the Tertiary, in which a lake could develop. In the south it was bordered by the Vonsorsky creek, in the north by the Soos creek. At the end of the Tertiary the northern part was drained by the Soos creek. The southern part was hardly drained. The difference in water depth of these two parts later resulted in a thicker peat layer in the southern part.

Nowadays the system in figure 8 can be found:

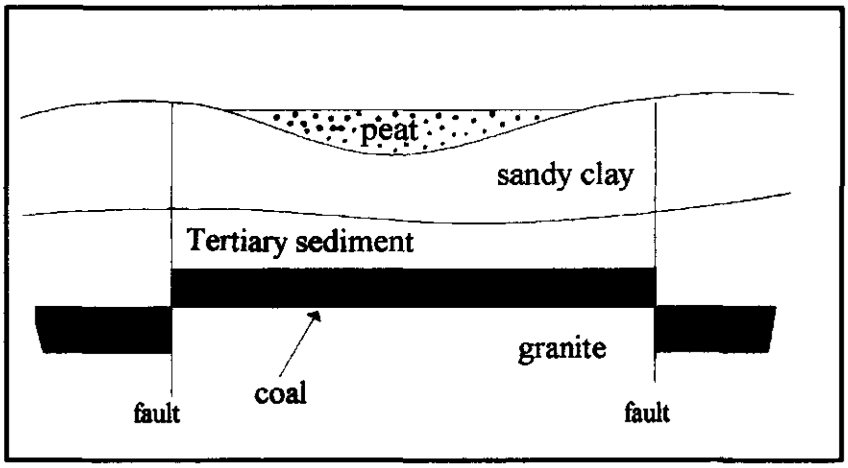


Figure 8. Geological system near Soos.

Picture 2. Spring in peat bog, Soos.

Growing conditions for diatomes were optimal in the Pliocene lakes, due to high salinity. Diatomaceous soil still can be found on numerous places. During dry periods various precipitates of salts may be seen on the surface. Due to the salty character of the area a lot of halophytes can be found.

Peat was excavated as fuel during the first half of this century. Nowadays peat is used only for curing all kinds of diseases. Furthermore people are trying to conserve the peat layer. Diatomaceous soils are used for industrial purposes such as a filtering medium (beer!) and insolation of boilers and blast furnaces.

Due to fissures associated with the faults, carbon dioxide is able to escape through the granite and Tertiary layer and to penetrate into the peat layer. In the Tertiary the water was highly mineralized, which now results in a high TDS of the spring water, as can be seen in the first column of table 3.

Table 3. Composition of a regular spring and the Vera spring in the peat bog near Soos.

	reg. spring	Vera spring
EC (μS/cm)	7000	680
Temp (°C)	17	-
pH	6	5.5
	conc in mg/l	conc in mg/l
CO	2500	-
Na^+	1575	17.1
Ca^{2+}	71.1	18.3
Cl^-	594.6	9.0
SO_4^{2-}	1769	14.1
HCO_3^{2-}	1469.3	112.9
Li^+	3.1	0.1
NH_4^+	0.01	0.5
K^+	37.1	5.4
Fe^{2+}	40.1	1.4
SiO_2	100.0	21.8

A different compositon of spring water can be found at the Vera spring in the peat bog, as can be seen in the second column of table 3. This is possibly due to a thinner Tertiary layer and to a different composition of this layer. The travel time through the layer and the faults in the underlying rock can also play an important role. The measured EC (688 μS/cm) of this system fed by rain water was higher than we expected, possibly due to pollution and to a different system.

Plesná, mine excavation

On this site sand is excavated, a product of weathered granite. The coarse sand has a monocyclic and poor character. Kaolinite is a by-product, this in contrast to Hájek, where kaolinite is excavated.
Hájek used to be situated in the lower parts, in the centre of the basin. The kaolinite was deposited in the depressions during the Tertiary, whereas sand was deposited in higher shallow parts and on the edges of the former lake.
Plesná was supposed to consist of purely weathered granite, but stratification proved that it consists of deposited weathered granite, which originated from higher parts of the area.

Wednesday morning, 14 september 1994

Krušné Hory and the North-Bohemian Tertiary Basin
reported by Arjanne Rohaan and Joca Jansen.

A geological unit of the Bohemian Massif is called the **Krušné Hory** Mountains. These mountains form a 130 km long ridge along the border of the Czech Republic and Germany. The ridge is situated in a NE-SW direction.
Various parts of the Bohemian Massif have been uplifted or subsided along faults forming a system of horsts and grabens. The major tectonic feature of this area is the Krušné Hory fault, which trends generally NE-SW with many related parallel and transverse faults. Movements along the faults and uplift of the Krušné Hory Mountains resulted in the development of the horst along the southern part of the Tertiary basin. A cros section of the basin is given in figure 9.

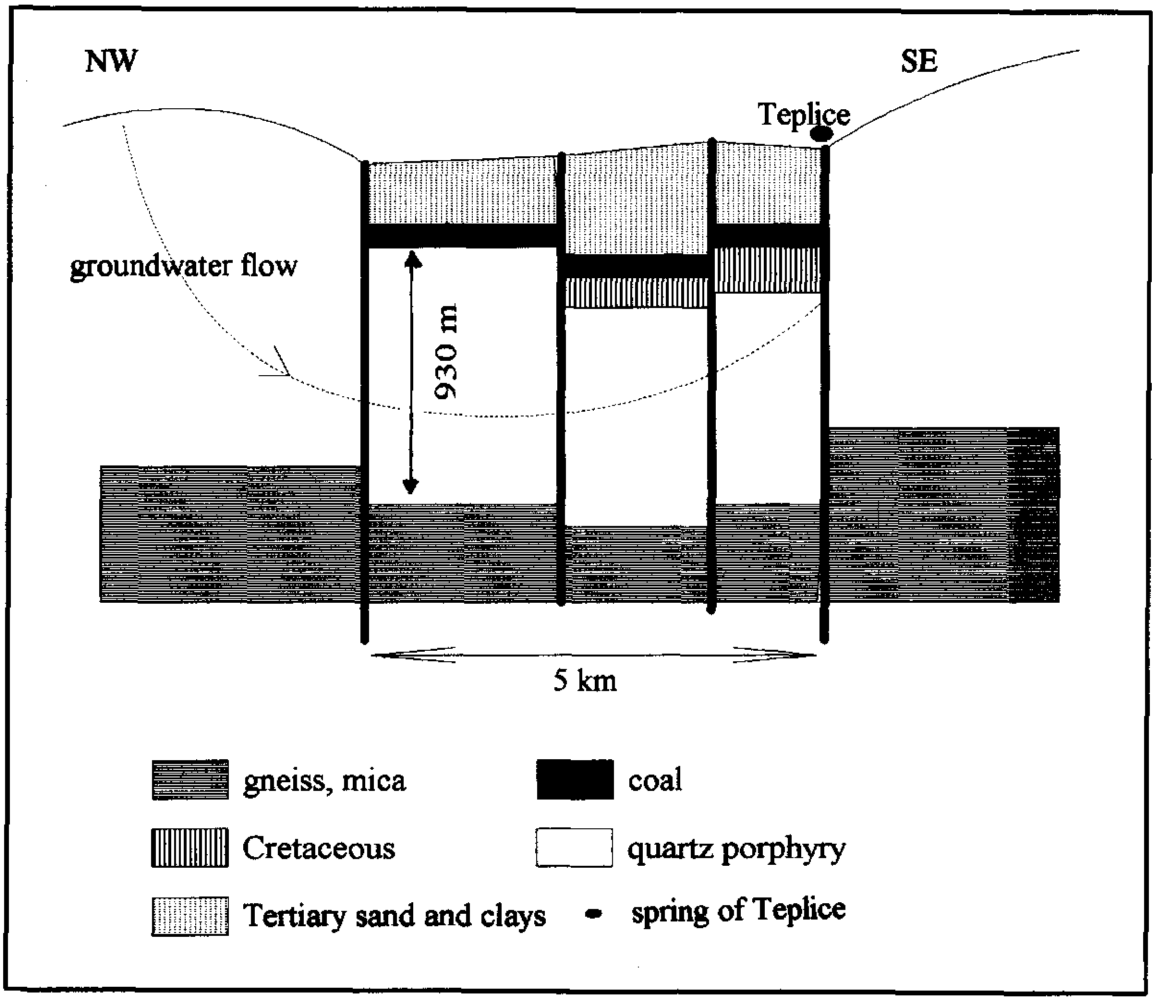


Figure 9. Cros section of the basin at the foot of Krušné Hory Mountains.

The basement and surroundings of the basin along the foot of the Krušné Hory Mountains consist of crystalline rock complexes including a large rhyolite extrusion (Teplice porphyry). The crystalline rocks consist of gneisses, mica schists and phyllites. The next

layer is an aquifer consisting of quartz-porphyry ignimbrites and rhyolites. This aquifer has a thickness of 930 m. The basin is filled with Cretaceous, Coal seams and Tertiary sand and clays. The coal seams have a thickness of 30 to 60 m. These coal seams are excavated in opencast mines. The largest opencast mines are at the foot of the Krušné Hory Mountains, in the vicinity of Most and Braňany. The coal-mining causes a lot of problems in this area.
Due to the mining of the underlying coal the whole town of Most was abandoned, torn down and build at its present site, except the late-Gothic church built in the first half of the 16th century. The whole church was reinforced by a steel construction, put on a concrete slab underneath and moved to a new site at a distance of 841.1 m with a speed of 2.8 cm per minute.
The coal-mines are situated in the old riverbed of the river Bílina. This is the reason that the river is flowing through a pipe now. Otherwise the coal-mines will be flooded.
Before the impermeable coal seams were excavated there was a hot spring (39°C) in Teplice. The flow direction of the water is explained in figure 9. The discharge of the spring decreased because of the decrease of the pressure head. The mineral water of Teplice is now extracted at a great depth.
An indirect problem of coal-mining are the acid deposits. The excavated coal contains a lot of sulfates. The coal is being used for energy production in local power plants, but it is also transported to Central Bohemian power plants. By burning the coal, the sulfates will be oxidized and pollute the air. The oxidized sulfates are the cause of the acid rains, which destroy the pine-forest. A solution can be the selection of tree-species which are not sensitive of acid rain. As a result of the dying of the forest the maximum discharge increased by 50 % which caused all kinds of design problems.
Currently at some power plants a desulphurfication treatment is applied. A better solution is to use another fuel for energy supply. Gradually the brown coal is replaced by Russian natural gas.

Wednesday afternoon, 14 september 1994

Faultzone near Teplice
reported by Michel Becks, Frans van Os and René Tank.

In **Teplice** mineral springs could be found. These springs owe their presence to the fault zone which runs in SW to NE direction. Rainwater infiltrates on the flanks of the fault zone into the permeable quartz-porphyry-layer. The groundwater flow and the most important layers can be seen in figure 9.

The quartz-porphyry, formed during the Variscan Orogeny are overlying impermeable Paleozoic gneisses. The infiltrated water is therefore forced to flow into the graben. The temperature of the groundwater in the quartz-porphyry layer increases to 39-45 °C. This groundwater flow system is called a thermosiphon.
In the graben an impermeable coal layer on the quartz-porphyry was formed, so that nowadays artesian conditions occur. The thermal water flows to the surface via fissures in the graben.
In the past there were some problems in maintaining the piezometric level because this level was influenced by mining activities close to the fault zone. If the mining takes place too close to the mineral springs, the springs can be endangered. For this reason deep boreholes were constructed. An attendant advantage of deep boreholes is they are less vulnerable to pollution.

Rhyolite extrusion at Teplice

Near Teplice the crystalline rock of the Krušné Hory Mountains is intermitted by a large rhyolite extrusion. A possible explanation of the appearance of this formation is a big eruption of a vulcano during the Lower Cretecaous. By tectonic movement both the crystalline rock and the rhyolite extrusion were uplifted. In Teplice an outcrop of this rock can be seen.
On basis of the three main determining factors (grainsize, chemical properties and origine) three different can be given to this rock:

1) grainsize: granite porphyry; the relative quik cooling of the lava stream results in a fine- grained rock. The granite porphory distinguishes itself by the contents of bigger cristals, the so called fenocrists.
2) chemical properties: rhyolite; chemically and mineralogically the rock has the features of a rhyolite.
3) origine: ignimbrite; hot gas with ash particles out of a vulcano forms a foam. In this foam pyroclastic material is catched After a while the pyroclastic material sinks. The sunken material melts together and form a layer. Therefore the ignimbrite looks like a normal rhyolite formed out of a real lava flow but the ignimbrite has a much greater mobility then the viscous rhyolite and the lower and upper part of the ignimbrite layer are not molten together.

The rock is formed out of acid magma and containts a high percentage silica. Therefore the rock is very resistant to weathering. The groundwater flowing in this formation is poor of dissolved solids.

Sandstones at Děčinské stěny

The Cretaceous sandstones in the long-shape graben in the NE of the Bohemia are formed during the Upper Cretaceous. During the Upper Cenomanian, the subsidence of the northeastern part of the Bohemian Massif continued and was followed by transgression of the sea. The sea level was $\pm$ 300 m above present sea level. The sea deposited a several hundred meter thick sequence of clastic sediments. They were consolidated to sandstones and marlstones with frequent horizontal as well as vertical transitions to each other.
In contrary to the Dutch, French or British Cretaceous sediments this Cretaceous rock is not a chalk. This phenomenon can be explained by the fact that the Czech Cretaceous rocks were formed in beach environment at that time. As a result there was less calcium deposition than in the sea.
Because of incision of the drainage system, occurrence of landslides, eolian action and chemical weathering the present landscape was formed. Landslides occur due to the saturation of the marlstone by water. The cohesion of the marlstone decreases and when the pressure of the vertical sandblocks is too high, landsliding will occure.

The beautiful arc which we saw at the top of the sandstone mountain is mainly formed by eolian action. The opinion about the importance of chemical weathering differs. One opinion was that the small round hollows of about 10 cm diameter are mainly due to chemical weathering. This in contrast to another theory which says that this phenomenon is mainly due to eolian weathering. Probably the round hollows were formed by both chemical and eolian weathering.

Picture 3. Sandstone arc at Děčinské stěny.

The Cretaceous sediments form a very important ground water resource in the Czech republic. It forms a very good aquifer because it is a thick (in some area's 1000m), pure sandstone (high percentage quartz and a low percentage of kaolonite). Due to this the layer has a reasonable transmissivity and a porosity of 20% (dual porosity medium). The area react smoothly to heavy rains; a quick response because of water flowing through the joints and a slow circulation through the pores.
In a brook in the Děčínske Stěny an EC was measured of 174 μS/cm and a temperature of 12.9 °C. The springs from the Děčínske Stěny are captured and the water is transported to Děčín.

Landforms along the Elbe

The following section is a description of the landforms along the Elbe between Usti and Hrensko, some 50 km north of Ústí nad Labem.
Along the banks of the Elbe between Ústí nad Labem and Děčín Cenozoic basalt and pyriclastics can be found. The basaltic bodies show a typical colomnar structure.
Between Děčín and Hřensko thick epicontinental sands, up to 300 m, have been deposited and consolidated during the Upper-Cretaceous. Only the lower part consists of an impermeable marlstone of about 10 m thick, deposited during the Turonian (lower stage of the Upper-Cretaceous). The sandstones have some minor intercalations of marl.
The Elbe-river has cut down into these Upper-Cretaceous deposits because of change of drainage base level. Base level has changed as a result of lowering of the sea level caused by extension of the continental ice sheets during the Pleistocene. Halfway Hřensko the river has cut down till the crystalline rock (consisting of granodiorite or schists). Therefore rapids can be found in this part of the river. The mountaineous area between Děčín and Hřensko is called Unter-Elbe-Schiffergebirge in German.
In the valley of the Elbe river terraces occur. Because of lowering of the drainage base level the river has to adjust its width, depth and stream velocity to lower base levels. In this situation the Elbe reacts by cutting down into the Upper-Cretaceous sediments. The abandoned floodplain is left above the new incised channel and hence forms a river terrace. Along the Labe (Elbe) river groundwater is extracted from the Quaternary river terraces (shallow aquifer: vulnerable to NO_3 pollution) and from the deep wells in the Turonian and Cenomanian sandstone (to 500-600 m depth).

Thursday morning, 15 september 1994

Uranium mining in Stráž pod Ralskem
reported by Rimbaud Laperre, Heidi Smit; guided by Dr. Jan Slezák

From Ústí nad Labem we continued our excursion to **Stráž pod Ralskem.** The first few kilometres (up to Lovosice) took us along the Labe river (Elbe). Typical for this area are the Cretaceous sandstones with basalt intrusions now and then, sometimes with a columnar structure. We are familiar with this structure since similar hexagonal basalt blocks have been used for dam/dyke reinforcement in the Netherlands. The Cretaceous basis is separated from the adjoining České Středohoří Mountains by several faults. Via the town of Litoměřice, where the Labe river and the Ohře river confluence, the landscape gradually changes.

According to lithological facies the region is subdivided in two distinct developments. The Lausitzer development with faults in which plutons developed in the north, while in the south Cretaceous sandstones prevail. The Jizerá development on the other hand is characterized by a transition from sandstone (permeable; aquifer) to mud (impermeable; aquiclude). In such a sequence artesian water conditions could develop.

Passing Ceska Lípa we arrived at Stráž pod Ralskem, the centre of uranium-mining for the last 30 years. The uranium-ores are concentrated (0.1 %) in fresh-water deposits and brackish soft and marine sandstones from Cenomanian age (lower part of the Upper-Cretaceous). The uranium is a weathering product of the granite in the north. Water from Cenomanian aquifer is not used for drinking water anyhow because of the radioactivity of the uranium. These layers are overlain by Lower Turonian marlstones, claystones and siltstones. As such they function as a barrier to the circulation of water between the confined Cenomanian aquifer and the unconfined Middle-Turonian aquifer. Until recently, two different ways of uranium-mining were used. The first consists of traditional deep opencast mining, requiring dewatering up to considerable depth. An example of this is the Hamr-mine . More recently from 1968 on, in-situ leaching by means of chemicals is practized. This method is practized in the Stráž -mine (appendix A). In contrast to the first method where deep dewatering is required, in-situ leaching benefits from by high groudwater levels. Thus, over a short distance both high and low groundwater levels occur (figure 10). In the relative small area of the Stráž mine a system of more than 7500 boreholes (with a system of injection and abstraction wells) is in use for the in-situ leaching method ("like a cheese").

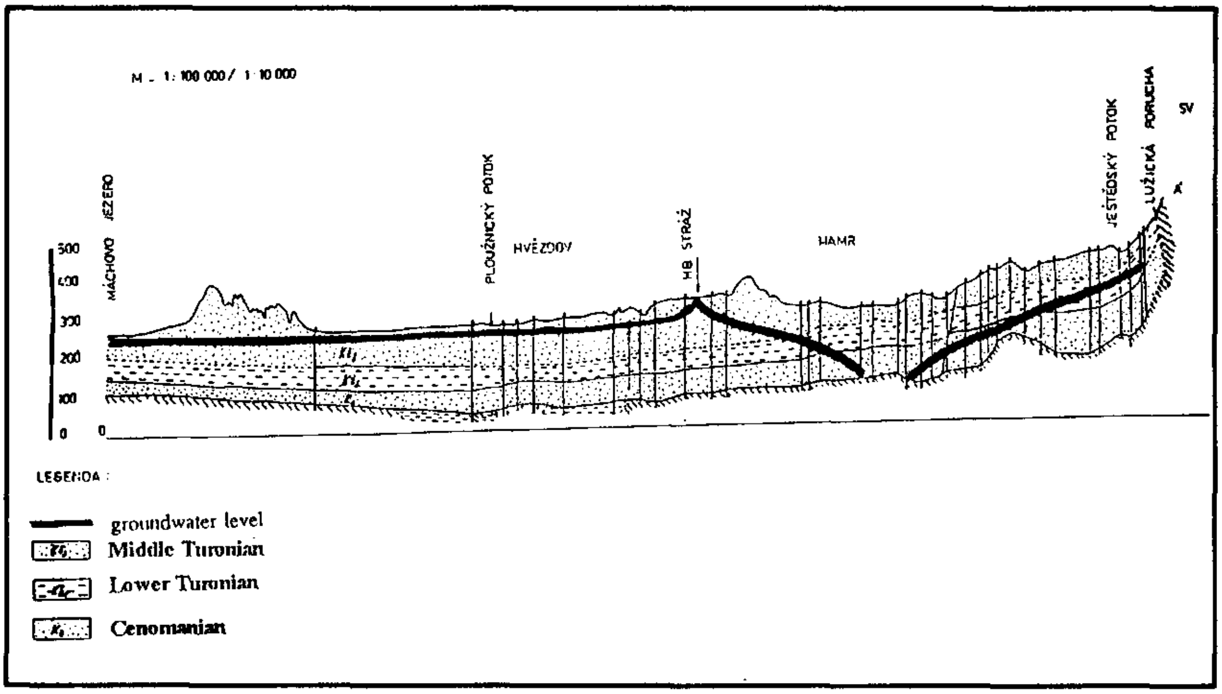


Figure 10. Geological profile and groundwater level in the Stráž area.

In-situ leaching requires at least 4 different chemicals:

1)	H_2SO_4:	facilitates uranium transport through the pipelines,
2)	HF:	for cleaning of the layers to prevent clogging,
3)	NH_3:	oxidises the immobile U^{4+} to mobile U^{6+} and
4)	HNO_3:	functions as a catalyst to the proces of precipitation of the saturated uranium 'porridge' in the setteling ponds.

All four chemicals show a diminishing application rate from the late seventies or early eighties on (an exception forms H_2SO_4 showing a second peak in 1988). This is illustrated in figure 11.

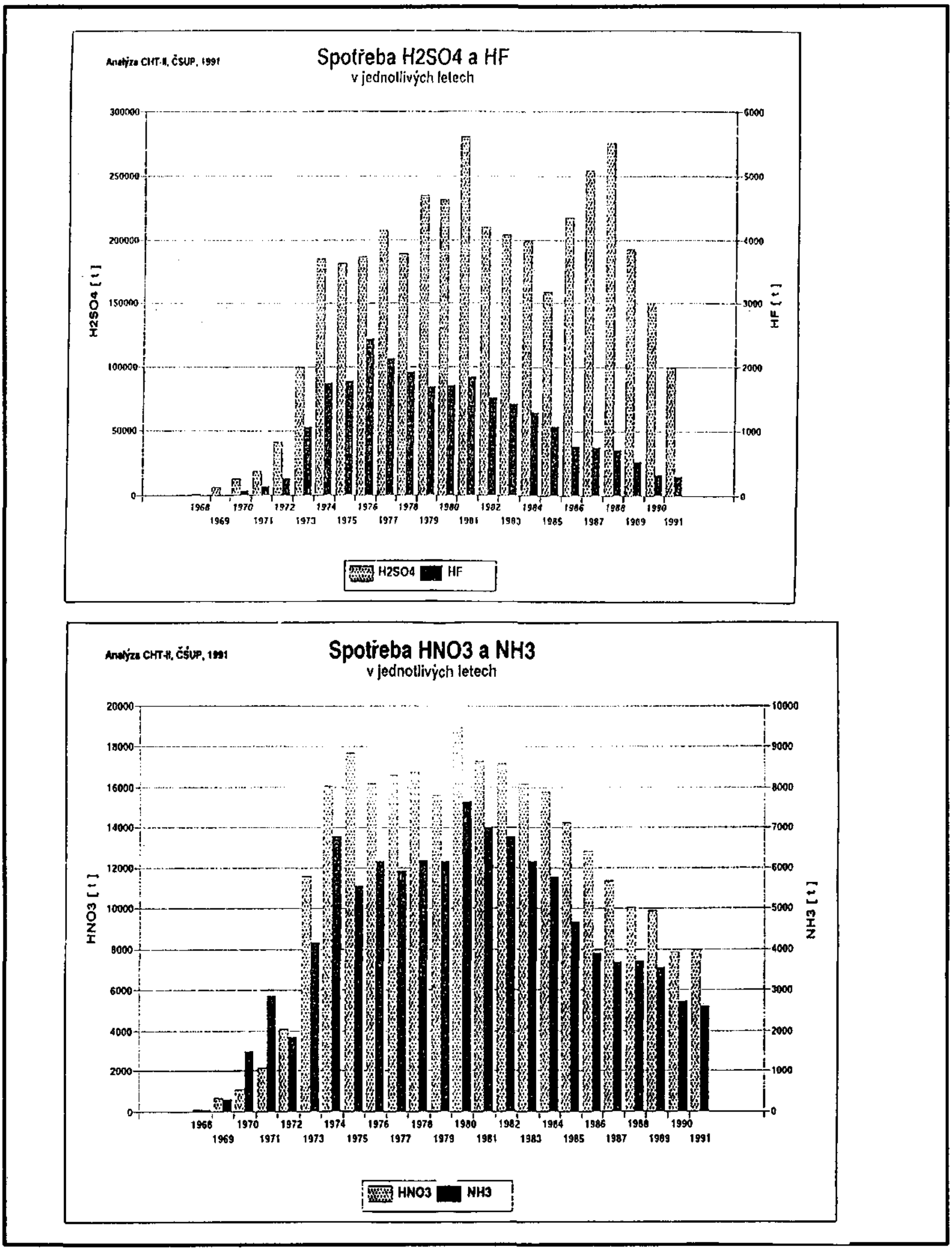


Figure 11. Use of four chemicals in the Stráž mine.

A hydrological barrier was created in the late 1970's and early 1980's, surrounding the leaching area enabling recycling of the used chemicals. So, the hydrological barrier with water pressures up to 150 m above surface, was installed more than 10 years after the start of the leakage process. This implies that in an area of about 20 km^2 (leaching area = 6.5 km^2) the Cenomanian aquifer is polluted. The main orientation of the pollution plume is in a southwestern direction to tributaries of the Elbe river. Of the four chemicals NH_3 forms the main ecological problem. During the last 20 years approximately 100,000 tons of NH_3 were pumped into the uranium containing layers. It was suggested that NH_3 causes a far more serious threat to the environment than the (slightly) radioactive uranium isotopes.

Between 1966 (start of mining) and 1991 a remarkable change in the water balance (see table 4) of the Cenomanian aquifer in the Stráž mining area (Stráž bloku) can be observed (see appendix B and C).

Table 4. Water balance of the Stráž mining area.

IN	1966 (l/s)	1991 (l/s)
Lužicka fault (eastern boundary)	36	121
northern boundary - east	0	66
northern boundary - west	0	15
leakage from Turonian - east	83	260
leakage from Turonian - west	0	0
total	119	462
OUT		
southern boundary - east	37	13.5
southern boundary - west	61.4	16.9
seapage to Turonian - east	0	0
seapage to Turonian - west	18	2
abstraction	0	429.6
total	116.4	462

The groundwater input into the Cenomanian aquifer of about 120 l/s in 1966 was increased to approximately 460 l/s as a result the groundwater abstraction of about 430 l/s from the Cenomanian aquifer. This abstraction was needed for the dewatering of the Hamr mine.

Though little pollution occurs on the surface a variety of chemicals, often in huge amounts and concentrations, is used. A sudden stop in artificial groundwater management, i.e. stopping the injection of groundwater for the hydrological barrier would increase the environmental problems. Then, the seepage in the western area from the Cenomanian to the Turoniam aquifer would increase from 2 to 18 l/s. The groundwater flow in the Cenomanian aquifer from the polluted area to the southwest would increase from 30.4 to 98.4 l/s.

Thursday afternoon, 15 september 1994

Experimental watersheds in Jizerské Hory
reported by Laurens Gerner and Albrecht Weerts; guided by Mr. R. Hancvenl, Mrs. A. Kulasová, Prof. Pavel Kovar and Dr. Oldřich Novický.

The **Jizerské Hory** or Jizera Mountains are sited in the nothern part of the Czech Republic close to the German and Polish border. The Jizera Mountains cover an area of about 200 km^2 and its highest peak reaches 1126 m above sea level. The mountains consist of a biotite granite with a very thin topsoil, this can be a podzol, brown soil or peat soil. The Jizera Mountains are a plutonic rock which have been uplifted in the Late Paleozic during the Variscan and later during the Alpine Orogenes. The average temperature is about
4 °C, the average rainfall is about 1300 mm, some other measured meteorological events in this area are:

- highest annual rainfall of 2000 mm (1926/27)
- highest rainfall event of 345 mm (1897)
- highest rainfall intensity of 122 mm/hour
- maximal thickness of snowpillow 2.20 m (with a water equivalent of 900 mm)

In this area there are 7 experimental catchments (2-20 km^2) of the Czech Hydrometeorological Institute. It started with measurement of the discharge in one catchment in the early 1950's because of possible water resources that could be used as drinking water. Nowadays surface water resevoirs in the Jizera Mountains provide the cities of Libere and Jablonec and Nissou with water. In the 1960's acid rain started to become a problem. Therefore, the number of experimental catchments was increased. A logical choice was to have two catchments, one at both sides of the waterdivide. Eventually 4 catchments were equiped which drain to the Baltic Sea (Odra river) and 3 catchments drain to the Nort Sea (Elbe river). In each of the catchments rainfall and its chemical composition (SO_2, heavy metals) and discharge were measured. The measured data are used by the CHMF Headquarters in Prague.

The effect of the acid rain are clearly visible, the mountains are significantly deforested. The original vegetation consisted of a combination of beech trees and spruce. Unfortunately this wood was used as fuel for the glass production. After cutting the trees a mono-species forest of spruce was planted. This spruce is more vulnerable to acid rain than the original forest. The dying process started some 20 years ago and reached its maximum about 5 years ago. After that the quality of the rain improved because of the reduction of SO_2-emission in Germany. Due to the deforestation the maximal discharge increased by 50%, the average discharge did not change significantly. This implies that the average net surplus fromprecipitation and evaporation has not changed.

We visisted a granite outcrop with an excellent view over the Czech-Polish-German Border area with a number of power plants responsible for the air pollution. Afterwards a peat occurrence was shown. The EC of the water in one of the peat lakes was 57 μs/cm and the temperature was 14.2°C.

Friday morning, 16 September 1994

The Barradian system, Svatý Jan pod Skalou and Srbsko
reported by Karin Groenesteijn and Irina Overeem; guided by Dr. Vojen Lozek.

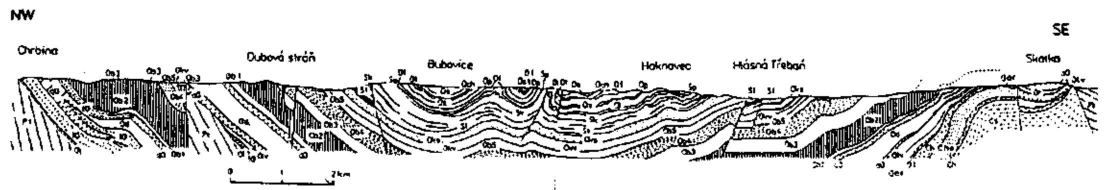
As a base for reconstructing the history of the **Barrandian system** appendix D is used.

The history of the Barrandian system starts with sedimentation of a cyclic character in the Proterozoic. The facies was a shallow marine basin, which subsided slowly so that sedimentation could keep up with this subsidence. This can result in enormous thick beds of sediments. Such a basin is called a eugeosyncline. The cyclic character is important for the hydrogeology because a differentiation in sediments affects the hydraulic conductivity.

As a result of a Precambrian orogeny (the Cadomian orogeny) these sediments were slightly uplifted. Due to this the Cambrian lies on the Proterozoic with an angular unconformity. In the Cambrian there were different sedimentation environments. It was a succession of land (Lower Cambrian), invading of the sea (Middle Cambrian) and retreat of the sea (Upper Cambrian). During the continental facies the products of volcanic activity and the sediments that later formed sandstones and conglomerates were deposited. The Cambrian rocks were affected by low grade metamorphism. Due to this metamorphism the Cambrian rocks act as an impermeable basement for the later deposited sediments of the Ordovician, Silurian and Devonian.
The Ordovician is deposited on both Proterozoic and Cambrian beds. The Ordovician forms a sequence of shallow water sandy, deeper water shaly and basaltoid volcanic deposits. In these beds the shales form less permeable layers.
The Silurian period starts with sedimentation of black graptolite shales which is followed by limestone facies, because the depth of the sea increases. Submarine volcanic series are formed, which consists of diabases and tuffas. The diabases can be an impermeable layer in this sequence but the permeability of the diabases is dependent on the degree of fracturing due to folding. The permeability of the limestone is also strongly dependent on the number of fractures, but this can also be affected by solution (karstic permeability). In the limestones of the Barrandian system the well-known Koněprusy caves, south of Beroun, are developed
The Devonian forms the central part of the Barrandian synclinorium. It mainly consist of limestones: Some shales and sandstones are present due to a retreat of the sea. Different facies appear in the limestone; shallow water bioclastic (Lower Devonian) and deep water fine grained limestones (Middle Devonian). In Belgium and Germany the Middle Devonian limestones are deposited nearer to the coast because the continent was closer there than to the present Czech. The deposits of the Frasnian and Fammennian (Upper Devonian) are lacking in the Barrandian. In the Devonian the abundant occurrence of fossils makes a detailed biostratigraphical description possible.
During the Hercynian orogeny the whole complex was folded, resulting in a big synclinorium.
Remarkably of the next 290 million years only some remnants from the Cretaceous period are left. These remnants are lying as limestone nappes over the other deposits, but due to their small areal extent they are not as important as water bearing layers as the Cretaceous nappes are in the rest of the Bohemian Massif. The lack of sediments of the Permian, Carboniferous,Triassic and Jurassic may be explained by the fact that the

present Czech Republic was a continent at that time (see appendix E).

The Alpine orogeny caused faults perpendicular to the axis of the synclinorium, along these faults uplift and subsidence occurred. The structure is comparable to the compartmented structure of the Gulpen and Vaals Formation in Limburg. In figure 12 a transect through the area is shown on which the synclinal structure and the compartimentation is very clear.
The Berounka and Loděnice follow the faults and have eroded deep valleys into the syncline since the Tertiary. Several river terraces formed due to this. The morphology of these rivers is comparable with rivers in the Eifel and Ardennes.
The rocks of the Barrandian were never really strongly affected by orogenies, they always stayed as unmetamorphosed stable block in the Bohemian Massif.Nowadays no uplift or subsidence takes place (figure 13) . The fact that they are unmetamorphosed gives them a higher potential as an aquifer.



3.0 Geological section of the north-eastern part of the Barrandian (V. Havlíček 1981) Pt — Proterozoic, Cs — Sádek Member, Ch — Hellštn Conglomerate, Che — Hořice Sandstones, Ot — Třenice and Milín Formations, Oar — Klabava Formation, Olv — Šárka Formation, tO — basalt tuffs, Od — black shales of Klabava Formation, qO — quartzose sandstones of Dobrotivá and Libeň Formations, Obl — black shales of Libeň Formation, Ol? — Letná Form., Ob3 — Vinice Form., Sl — Liteň Form., Sk — Kopanina Form., Ob4 — Zahořany Form., Ob5 — Bohdalec Form., Okv — Králův Dvůr Form., Oks — Kosov Form., Sp — Přídolí Form., Dl — Lochkov Form., Dt — Třebotov Form., Ds — Srbsko Form. Silurian basalts — in black

Figure 12. A transect through the northeastern part of the Barrandian area.

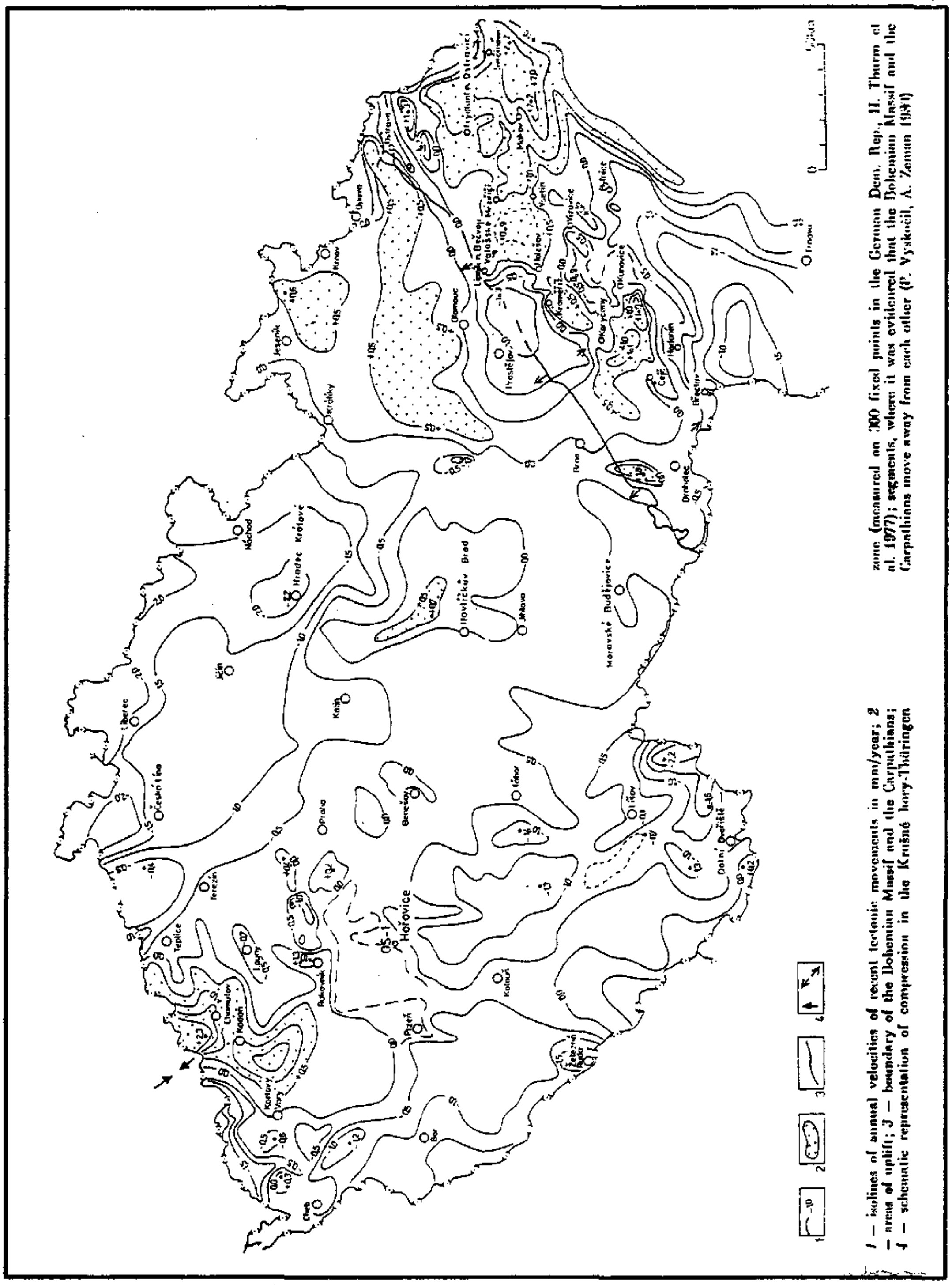


Figure 13. Tectonic movement in the Czech Republic.

Excursion sites

We started our trip through the Barrandian with a first glimpse of the synclinorium, the river terraces of the Berounka and of the Cretaceous table land.

Our first stop was in the Lower Silurian. There we saw the submarine formed diabase and the contact with slightly metamorphosed claystones. In these claystones graptolites occurred, see figure 14.

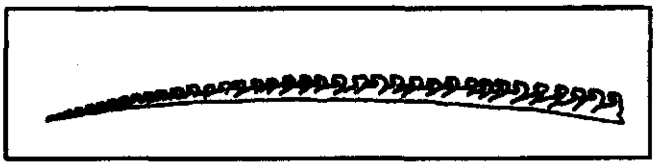


Figure 14. A graptolite.

The graptolites lived in sea and formed, bound to a stem, long floating colonies. The organisms evoluted relatively fast and were widespread, which makes them an important trace fossil. This importance was shown at the next stop, where we saw the official international transition between the Silurian and the Devonian.

At the following stop we had a good view on the terraces of the Berounka. Here the hydrogeology of the synclinorium was explained. Because of the uplift and subsidence along the faults (perpendicular to the axis of the synclinorium) different blocks are formed (see figure 12). Because of this, permeable layers (limestone) which once formed a continuous hydrological system, were now broken down in different compartiments (see figure 15).

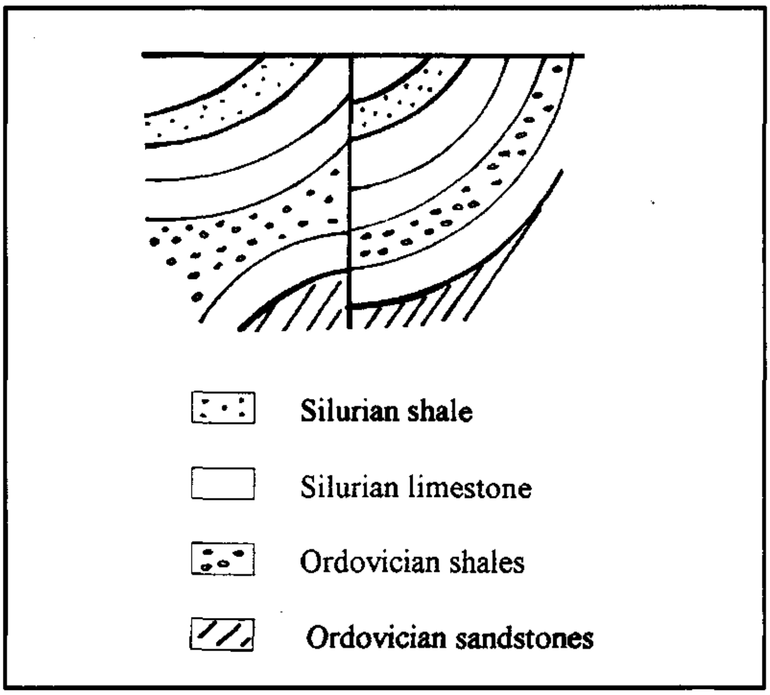


Figure 15. Hydro - geological system, broken down in compartiments.

Due to this, contacts formed between permeable and less permeable layers. At these contacts (along the faults) water seeps out.
The Berounka and Loděnice drain this system, but water seems to leak from the rivers

and to disappear in the bedrock. There are several points of similarity with the Condroz system in the Ardennes. There are also differences; in the Condroz the permeable layers are less broken, and the water from the permeable limestone can exfiltrate where the river cuts into this layer. The compartimentation of the Barrandian system makes this system more complex. Still, this does not explain the disappearance of the water from the rivers. Karst in the deeper limestone could form an explanation.
The travertine springs that can be found in the area confirm the large-scale solution of the limestone. We saw an example of travertine tuffa at Svaty Jan pod Skalou. The sedimentation rate can be very high, proved by the fact that the one to two meters of this tuffa profile were deposited in the Holocene (last 10.000 years).
Afterwards we walked through the different Devonian limestone and shale facies. Along the way beautiful gravitational folding could be observed in the limestone. Suddenly, our path crossed Devonian shales in which fossils of early terrestrial flora were present. This shale was dated as the uppermost of the Middle Devonian (Givetien).
Continuing in the limestone we visited a cave which was of archeological importance. Traces of paleolithic and neolithic habitation were found there.
The last site was a travertine stream and spring. Due to the sludge which is used as manure in the infiltration area of the spring, the water is enriched in nutrients. These nutrients cause an accelerated growth of the moss vegetation, due to which the travertine precipitation is increased.

At three points the EC was measured;
(remark that the EC is rather high due to the enrichment in nutrients; naturally an EC of 500-600 μS/cm can be expected in such limestone springs).

- downstream	678 μS/cm	(temp 12.8°C)
- halfway	716 μS/cm	(temp 11.7°C)
- at the spring	852 μS/cm	(temp 11.4°C)

From these data can be concluded that the stream must be fed on the way with non-polluted water (dilution).

BIBLIOGRAPHY

Čadek, J. (1987):The North Bohemian Tertiary Basin.In: Excursion Guide, International Workshop Geomon, April 30 - May 1, 1987 Czechoslovakia, Geological Survey Prague, p. 33-34.

Dovolil,M. (1961):Hydrogeologie oblasti kyselek v Mariánských lázních a jejich širokém okolí. - Thesis, Faculty of Nat.Sciences Charles Univerity, Praha.

Herčík,F., Maršalko,P. (1975):Deposit of sedimentary ores in the Cenomanian of the Bohemian Massif. - in Homola,V., Klír,S.: Hydrogeologie ČSSR,III., Academia, Praha, p.286-295.

Hynie, O. Hydrogeology of Czechoslovakia, Czechoslovak Academy of Sciences, Praha,vol. I and II.

Kačura,G.,Franko,O.,Gazda,S.,Šilar,J. (1969):Thermal and mineral waters of Czechoslovakia.Proceedings of Symposium II Mineral and Thermal Waters of the World, A Europe, Academia, Prague, p.17-29.

Mareš,S.,Šilar,J. (1978):Application of isotope techniques and well logging in investigating ground water influenced by mining.Water in Mining and Underground Works, vol.I, SIAMOS, Granada, p. 199-205.

Myslil,V., Franko,O. (1967):Ground water and mineral waters of Czechoslovakia.- Guide to excursion 21 AC, International Geological Congress, XXIII Session Prague 1968, 51 p.

Pačes,T. (1974):Springs of carbon-dioxide water in northwestern Bohemia.Field trip guide, International Symposium on Water-Rock Interaction, Geological Survey Prague, 82 p.

Regional Geology of Czechoslovakia (1967), Atlas of 1:1000000 maps, Central Geological Institute, Praha.

Šilar,J. (1968):Czechoslovak mineral springs.Geotimes, May-June 1968, p.10-13.

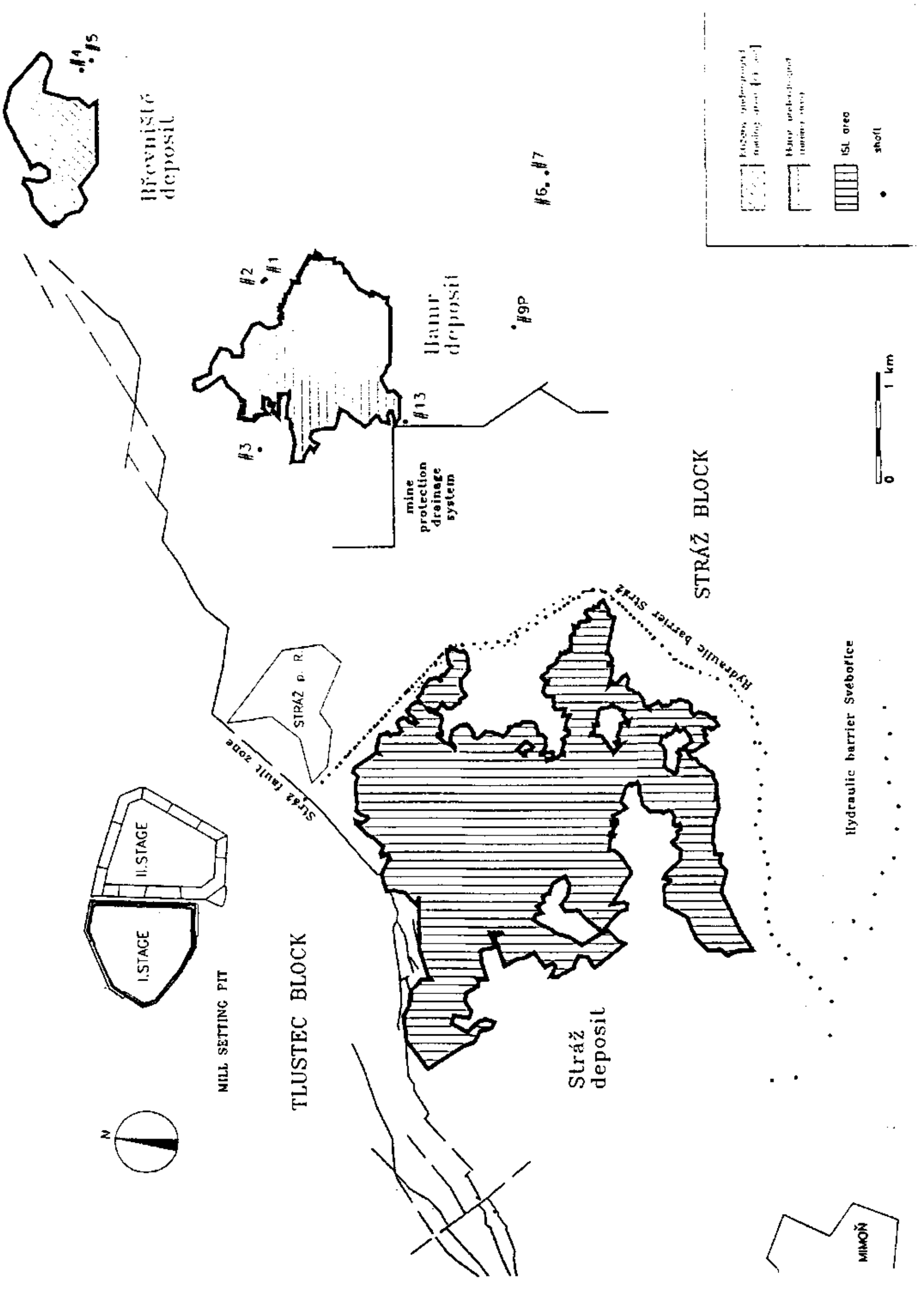
Skorepa, J.et al. (1982): Occurence of nitrogen materials in groundwater in the territory of the middle Elbe River in Bohemia. Memoires IAH, Praha, Vol. I.

Skorepa, J., Vrba, J.(1985):Hydrogeological investigation of crystalline rocks of the Czech Massif. Memoires IAH, USA.

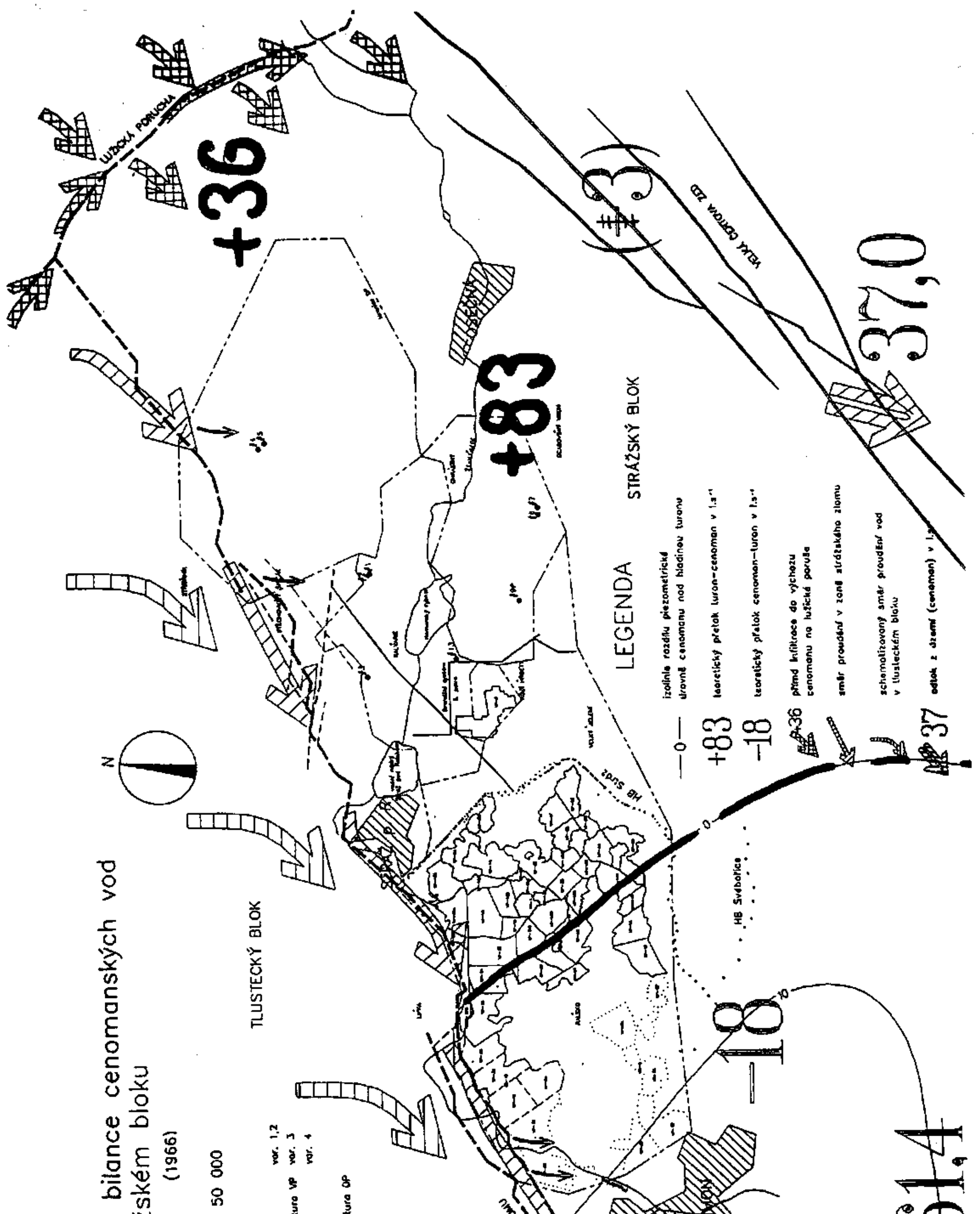
Svoboda, J. et al.(1964): Regional geology of Czechoslovakia, Czechoslovak Academy of Sciences, Praha, Vol. I and II.

Vrba, J. (1966): Hydrogeological zoning of Czechoslovakia, Praha.

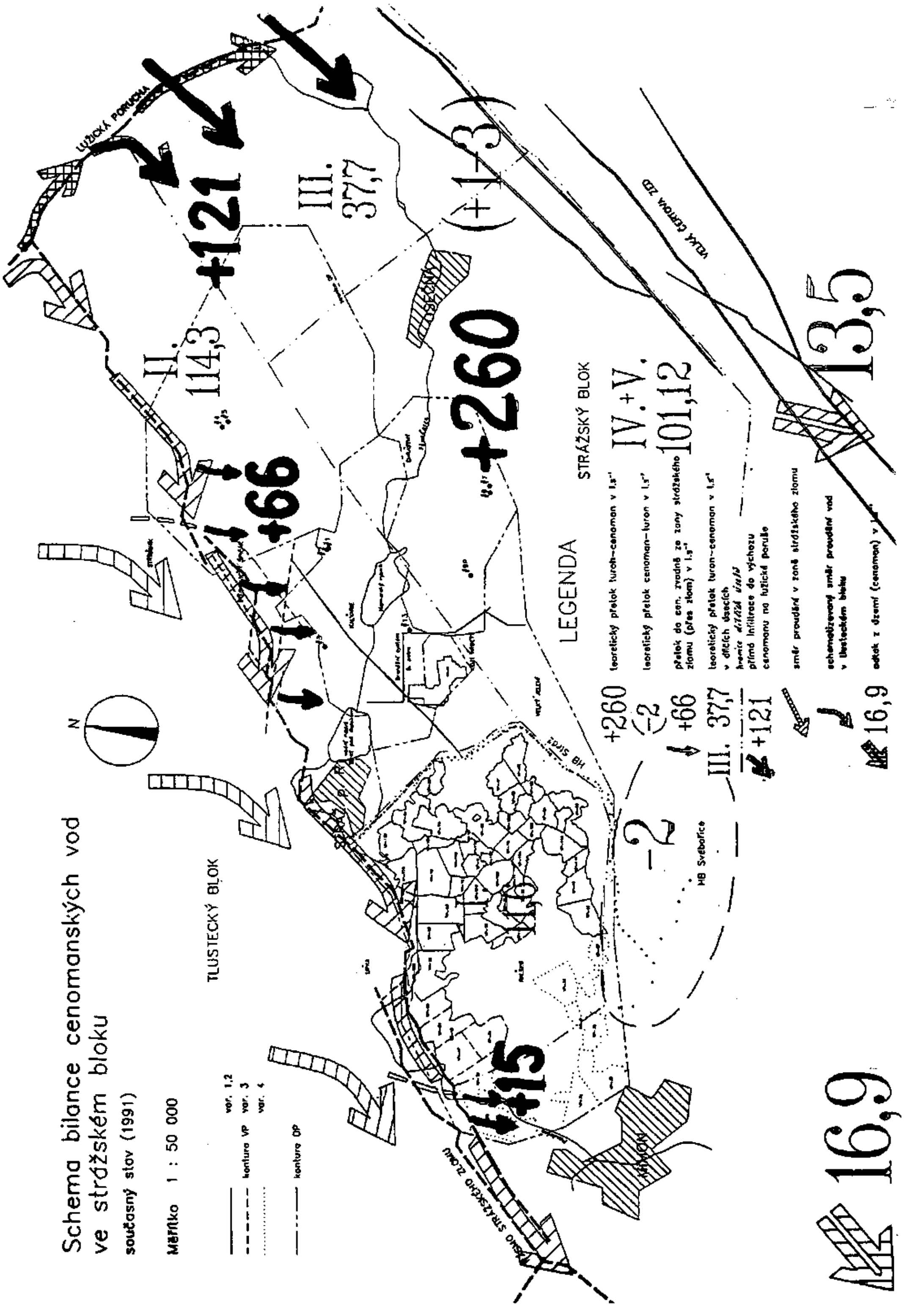
appendix A Location of the Stráž-mine



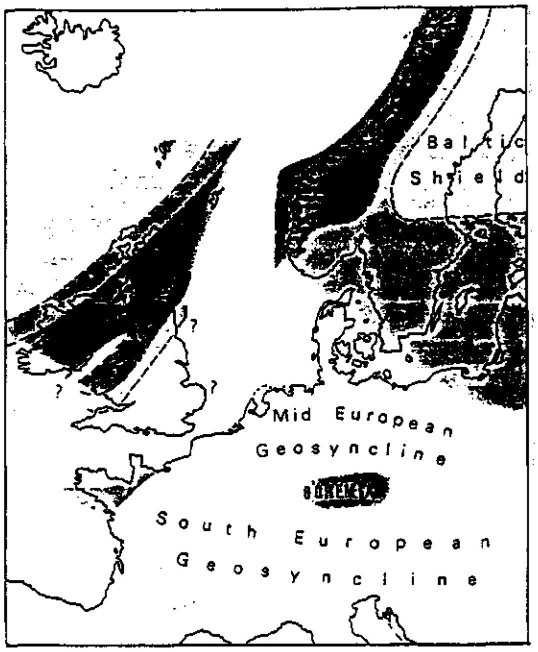
appendix B Water balance the Stráž-mine in 1966



appendix C Water balance the Stráž-mine in 1991



appendix D The history of the Barrandian system



Map 1 Europe in Lower Palaeozoic Times

Land Areas

Shallow Seas

Geosyncline

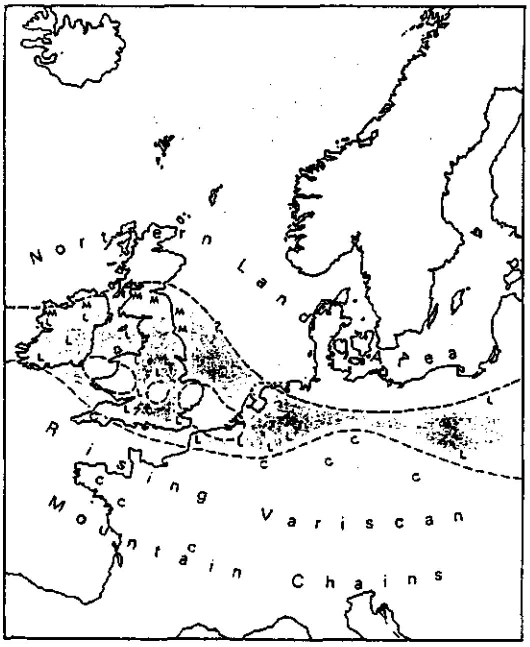
Map 2 Europe during the Devonian Period

Areas of Old Red Sandstone

L Limestone facies

Land Areas

Shallow Seas



Map 3 Europe in Lower Carboniferous Times

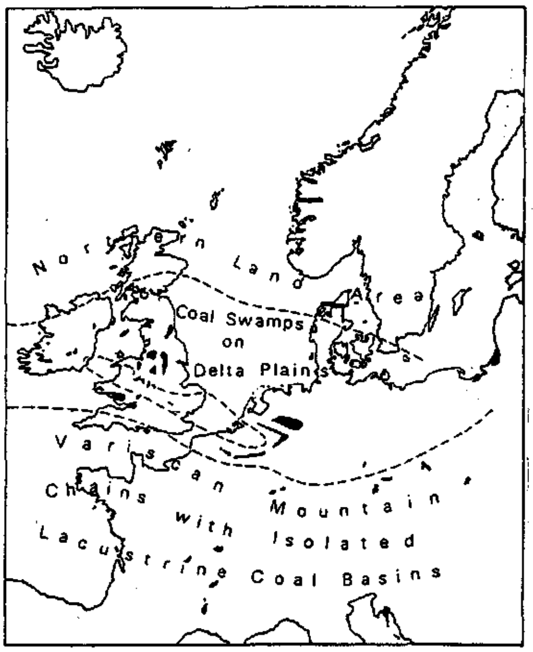
Shallow Seas

Land Areas

C Culm facies

L Limestone facies

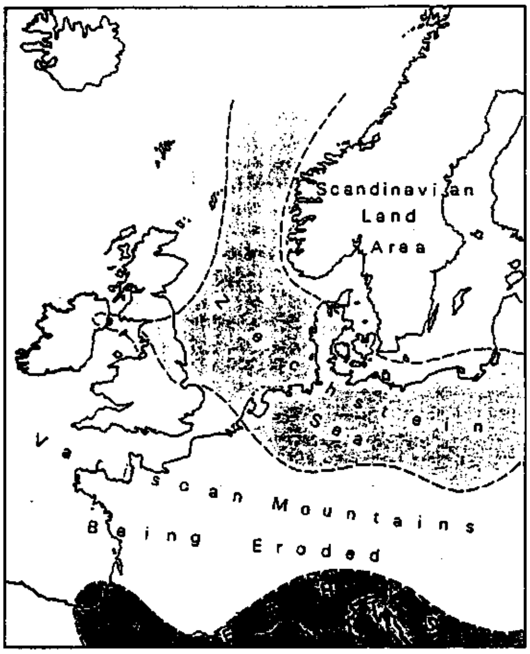
M Mixed facies



Map 4 Europe in Upper Carboniferous Times

Land Areas

Coal Fields

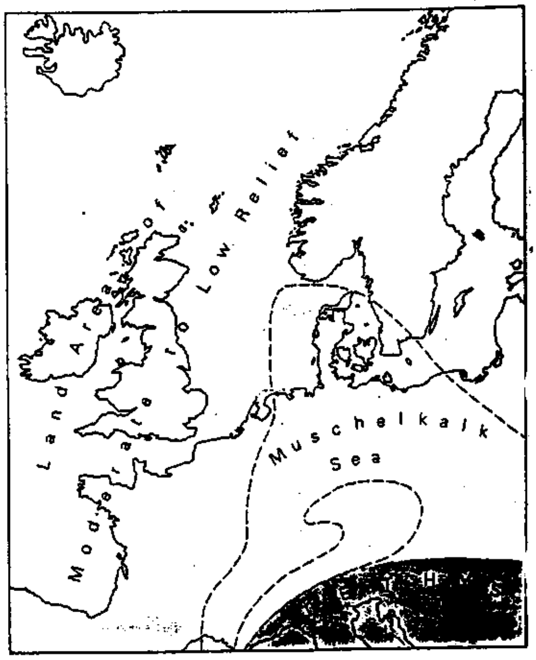


Map 5 Europe during the Permian Period

Land Areas

Shallow Seas

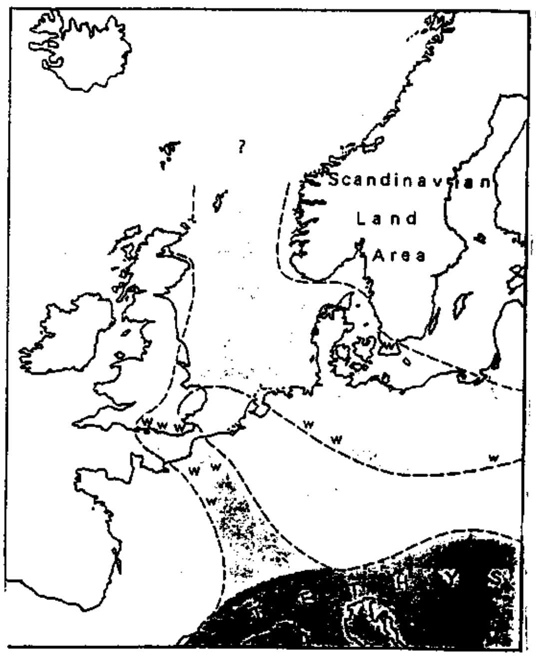
Geosyncline



Europe during the Triassic Period

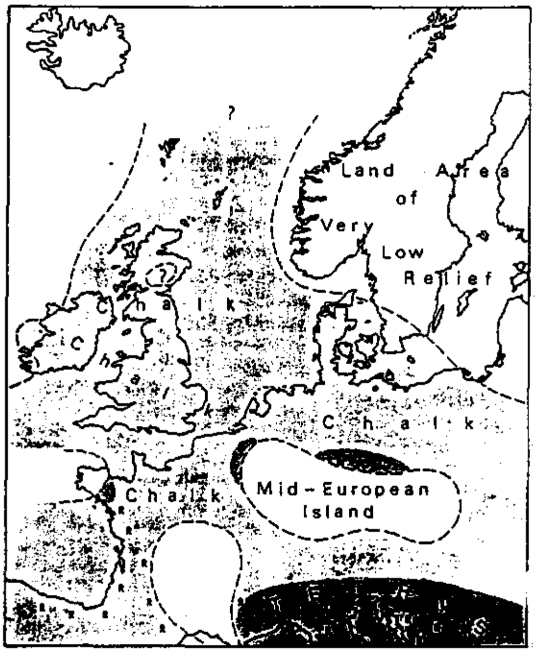
Europe during the Jurassic Period

C Coral reefs



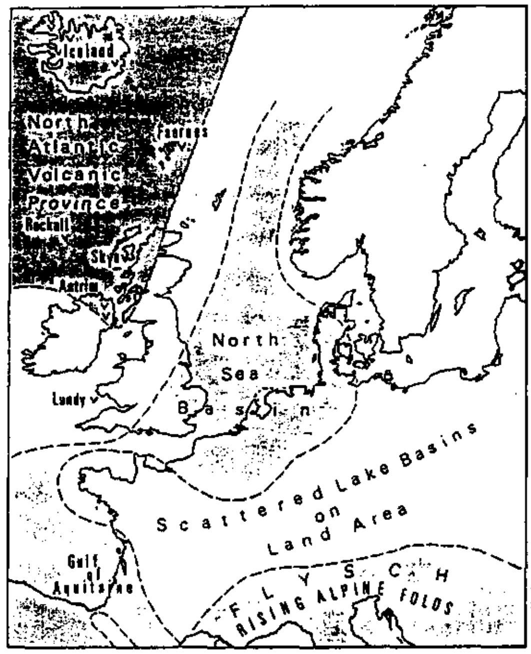
Europe during Lower Cretaceous Times

W Wealden beds

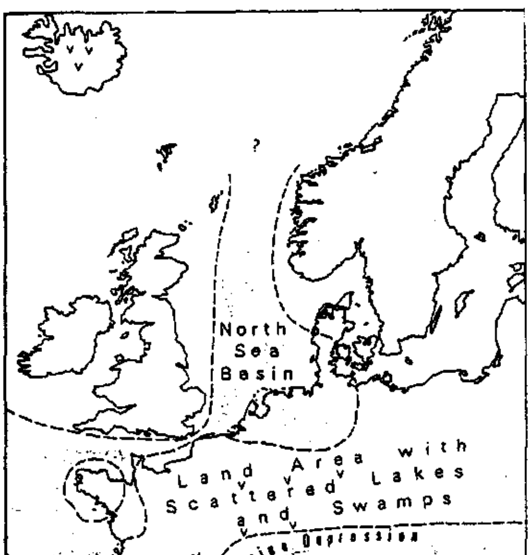


Map 10 Europe during Upper Cretaceous Times

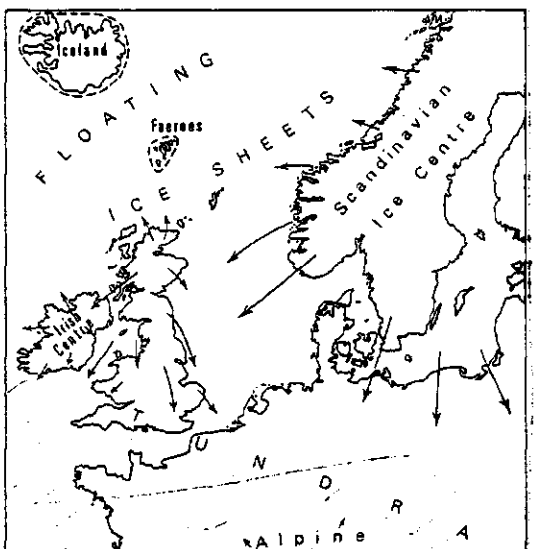
R Rudistid Limestones



Europe during the Lower Tertiary



Europe during the Upper Tertiary

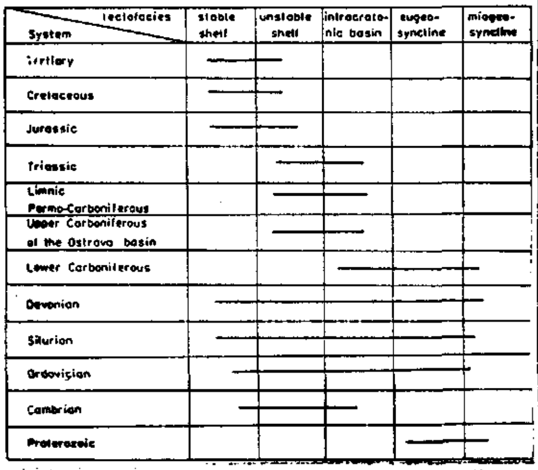


Map 13 Pleistocene Europe

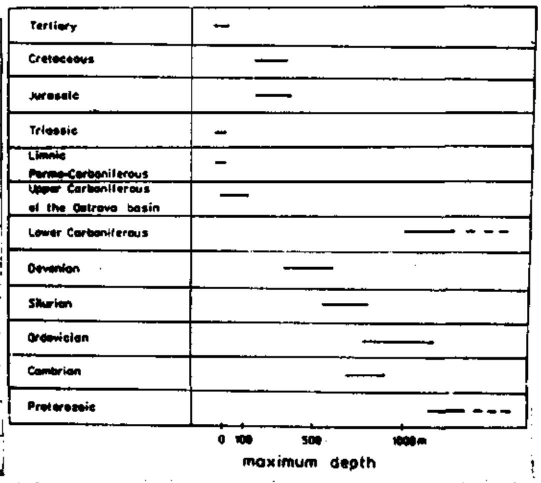
Unglaciated areas

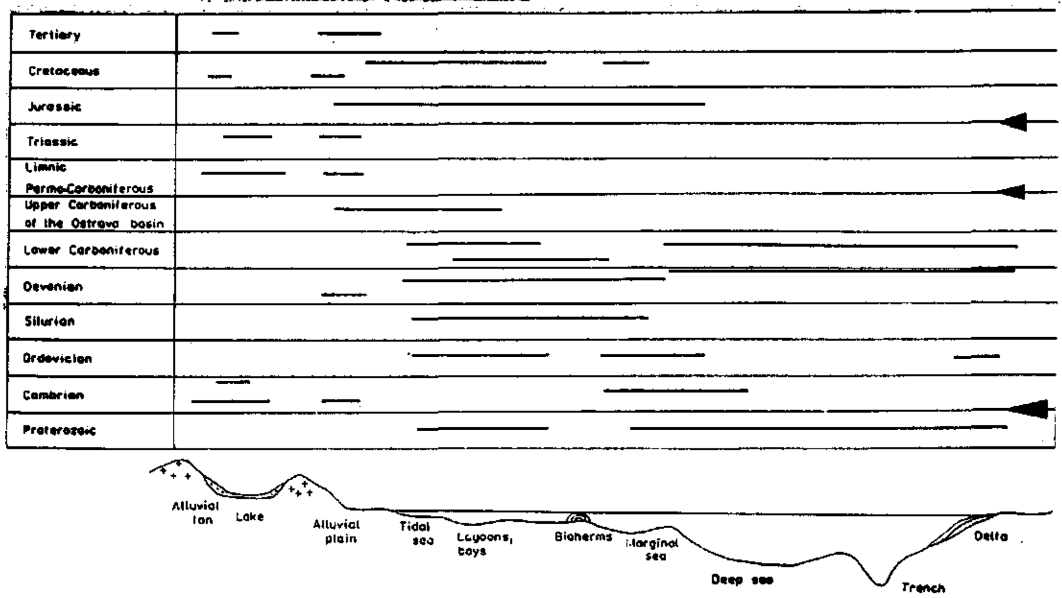
appendix E Europe in geological history

Evolution of sedimentary environments in the Bohemian Massif. Heavy lines in systems denote the range of environment. Black wedges on the right — abrupt and great changes in sedimentary environments (Z. Kukal, orig.)



Maximum depths of basins in the sedimentary history of the Bohemian Massif. They are shown by line segments and not by points, because reconstruction, especially for great depths, is uncertain (Z. Kukal, orig.)





Tectofacies in the sedimentary history of the Bohemian Massif (Z. Kukal, orig.)