Volume n° 1 - from PR01 to B15

32nd INTERNATIONAL GEOLOGICAL CONGRESS

ALPINE THERMAL GEOLOGY THERMAL WATER UTILIZATION IN SOUTHERN CARINTHIA (AUSTRIAN - ITALIAN BORDER)

Leader: W. Kollmann

Associate Leaders: F.W. Marsch, H. Zojer

Field Trip Guide Book - B14

Florence - Italy
August 20-28, 2004

Pre-Congress

B14

The scientific content of this guide is under the total responsibility of the Authors

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Series Editors:
Luca Guerrieri, Irene Rischia and Leonello Serva (APAT, Roma)

English Desk-copy Editors:
Paul Mazza (Università di Firenze), Jessica Ann Thonn (Università di Firenze), Nathalie Marléne Adams (Università di Firenze), Miriam Friedman (Università di Firenze), Kate Eadie (Freelance indipendent professional)

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AUTHORS:
W. Kollmann (Geological Survey of Austria GBA, Vienna)
F.W. Marsch (HydroAlpina, Hartberg - Vienna)
H. Zojer (Wrm, Joanneum Research, Graz)

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Front Cover:
Foto = Landscape of BKK area from cable car station Kaiserburg to North (Thermal springs and drillings catchment sandwich)

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Introduction

In high alpine regions (>1000 m above sea level) the occurrence of thermal springs (>33 degrees centigrade) is a unique particularity.

The excursion will leave from SMN Florence railway station. On the train journey from Florence to Villach some comments will be made concerning the landscape, geomorphology and geology, especially neotectonic, in the Val Canale, well-known for its disastrous earthquakes. After crossing the border into Austria (Visum?) through Tarvisio to Villach Univ. Prof. Dr. H. Zojer (WRM, Joanneum Research, Graz) will give a short introduction to the geothermal situation of Warmbad Villach (geology, hydrodynamics, chemical and isotopic monitoring investigations, recharge area).

Later on into the first day we will arrive at the Bad Kleinkirchheim spa in the Stangalm Mesozoic dolomite of the Carinthian mountains. In the evening there will be a lecture concerning the singularity

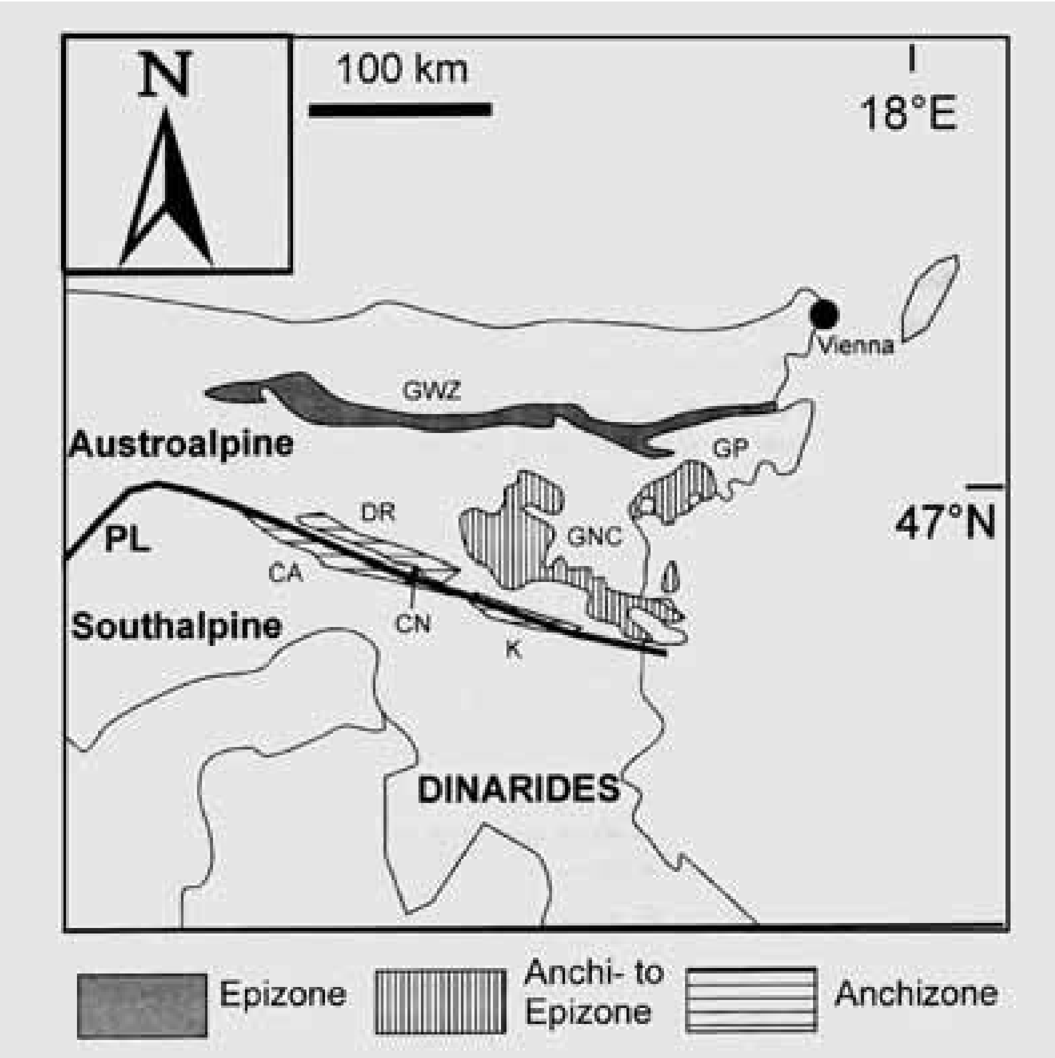


Figure 1- Location of the Gurktal Nappe Complex GNC after Rantitsch & Russegger (2000)

of thermal water >33 °C discharge in an elevated alpine valley and karstified recharge area (1100 - 2200m), in regard to the above mentioned topics (scientific details see 2nd Day). Then there will be a foot-excursion to the Kaiserburg cable car station on top of the mountain for an overview of the geological and tectonic setting of the Nock catchment area GNC (Fig. 1). Further bus-stops will be made in the area of the thermal springs and drilling at St. Katharina church. Finally the large Oswaldi-karstspring will be visited.

On the 3rd day the tour will touch the Radenthein Magnesite mine, Millstätter lake and the "Terra Mystica" at Bad Bleiberg spa. On the way to Tarvisio we will cross the Drau Range DR, Periadriatic Lineament PL, Carnic Alps CA and the Carboniferous strata of Nötsch CN.

Thermal water utilisation means an additional contribution to spa tourism for health and medical purposes. In the alpine region it supports other sports activities like mountain climbing, skiing, hunting and fishing.
The temperature of this natural groundwater, its dissolved mineral content and – if available – its gas content can be used for:

sick persons for healing illnesses
families with children for wellness
and sport purposes.

Thus the commercial effect on the people in the mountainous region of Carinthia is important.

In this brief article we will discuss methods of exploration & production, which have led to the successful long-time exploitation of thermal water in three Carinthian health resorts: Villach-Warmbad, Bad Kleinkirchheim, Bad Bleiberg.

Regional geologic setting

In Austria south of the Graywacke Zone GWZ, in the Central-Alpine-Unit, a large area is occupied by different igneous and metasedimentary basement rocks, most of which were metamorphosed during the Variscan Orogeny (Schönlaub, H.P. 1997). Recent research, however, indicates a major Alpine overprint in certain areas. Locally, these complexes grade into weakly metamorphosed fossil-bearing Lower Palaeozoic series, e.g., the famous fossiliferous sequences in the vicinity of Graz GP, the area around Murau in western Styria, and in Middle Carinthia.

In this region the Palaeozoic sequence is unconformably overlain by Upper Carboniferous meta-sandstones. Permian red beds, and Triassic dolomites and limestones known, for example, south of Innsbruck, in Carinthia: the Krappfield area, St. Paul, the area surrounding Griffen, and from deeper parts of the Gurktal Nappe. Moreover, a considerably thicker and slightly varying Triassic to Cretaceous succession is recorded in the Northern Karawanken (K) Alps and the so-called Drauzug (DR) of Carinthia and the Eastern Tyrol. Elsewhere, however, within crystalline complexes unfossiliferous metasedimentary intercalations occur. This suggests caution regarding whether the basement-cover relationship is of a stratigraphic or tectonic nature, which is of main importance for thermal dynamics.

The southern boundary of the East-Alpine Nappe System is formed by a very prominent fault system that dissects the whole Alpine mountain chain, from the Tyrrhenian Sea to the Carpathians. In Austria the local names Pustertal Fault and Gailtal Fault, respectively, are applied. Associated with this vertical or steeply south-dipping fault are several minor granitic to tonalitic intrusive bodies of apparently Alpine age. Concerning lateral movements, in recent years convincing evidence has been presented in favour of significant dextral displacements along this fault system.

The area to the south of the Gailtal Fault (PL), i.e., the Carnic (CA) and Karawanken (K) Alps, belongs to the Southern Alps. Bounded by Italy and Slovenia on one side and Austria on the other, a belt up to 10 km wide consists of Palaeozoic strata that have long been famous for their rich fossil content and the diversity of rocks without major unconformities ranging from Ordovician to Upper Permian in age. In short, they represent the sedimentary basement of the Mesozoic development of the Southern Alps in Northern Italy and the Dinarides (Fig. 1).

Field itinerary

DAY 1

Villach - Warmbad

The program on the first day is to demonstrate the geology, hydrogeology and geothermal situation of the southernmost part of Austria.

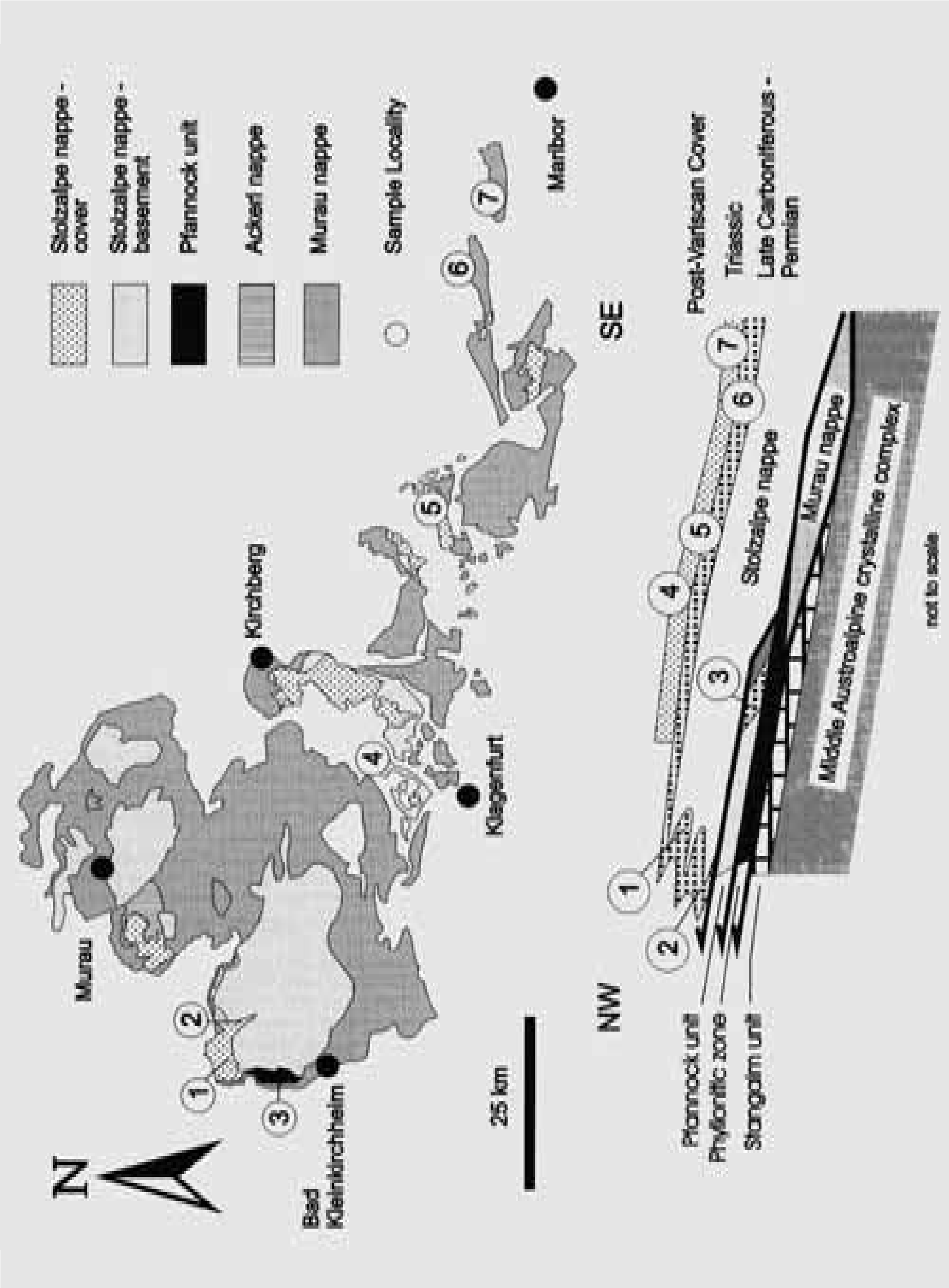


Figure 2 - Structural units and schematic cross-section of the Gurktal Nappe Complex GNC after Rantitsch & Russegger (2000)

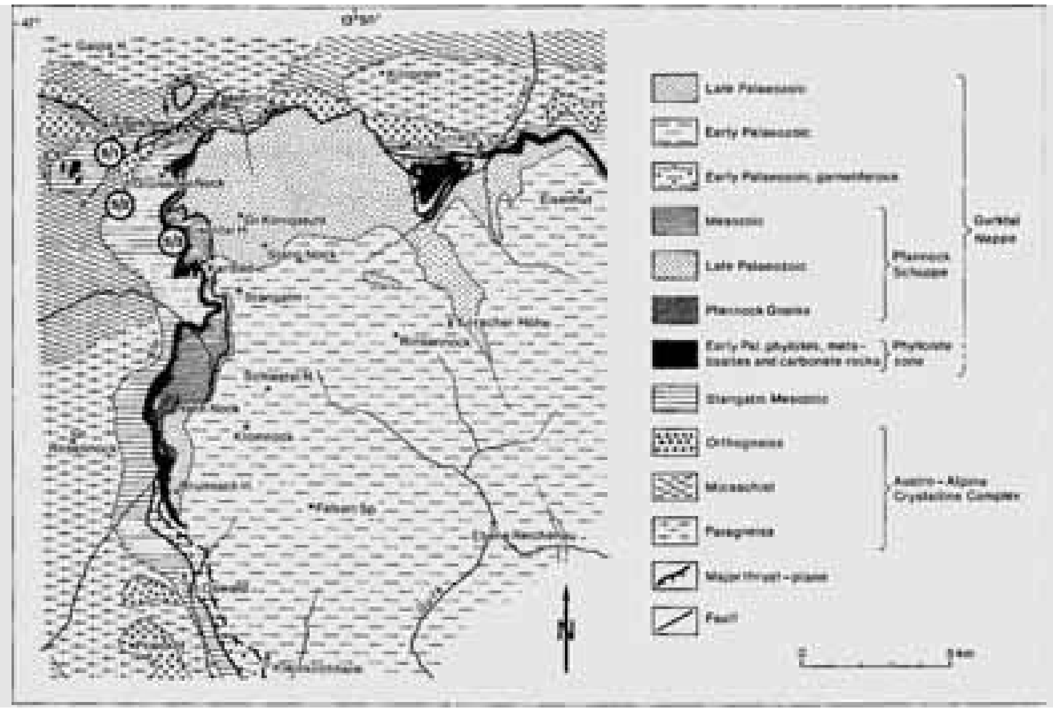


Figure 3 - Geological sketch-map of the BKK thermal catchment area after Pistotnik (1980)

The Periadriatic Lineament is the most prominent structure in this region. It is associated with a mylonite zone of considerable width and forms a strong topographic feature following the east-west trending furrow of the Lesach and Gail valleys in the excursion area where it can be traced for long distances in both directions.

This fault system is believed to have played an important role in the structural evolution of the southern part of the Alps, separating regions of different depositional and tectonic history during the Palaeozoic and Mesozoic. Considerable dextral but also vertical displacements are supposed to have occurred along this structure during late Alpine times. One of these is the reason for the natural outflow of the Warmbad Villach springs.

The thermal springs are of natural origin, therefore the area has been settled since the Neolithic period. The setting of the springs used today is up inside the floor of the thermal spa. Since the amount and character of the spring water depends on the time of year (melting snow, rainy periods), the overrun forms a small river (called Maibacherl = May-brook) occurring exclusively during the snow melt period in spring (May) and early summer. In that short period it is possible to take a moderately warm bath (= Warmbad) directly in the spring. Otherwise this small valley is dry until the following May. But for the congress-participants there is the possibility of visiting the permanently utilized captured thermal spring-water at the official spa.

The total discharge quantity of up to several hundred litres per second shows the influx of karstic origin. The reservoir rock is mainly fractured mesozoic dolomite of the Southern Calcareous Alps (SCA) near the well-known Periadriatic Lineament (PL).

Temperature (up to 29°C) and tritium content of the springs also change at different times of the year and show the complex and partly unknown process of thermal water migration. The natural hydrodynamic conditions are under investigation by isotope chemistry and tracer methods. It seems that the different conditions are the result of mixing a young cool groundwater component to the older thermal water. This hydrodynamic mechanism is similar to the thermal system in Bad Kleinkirchheim (see 2nd day).

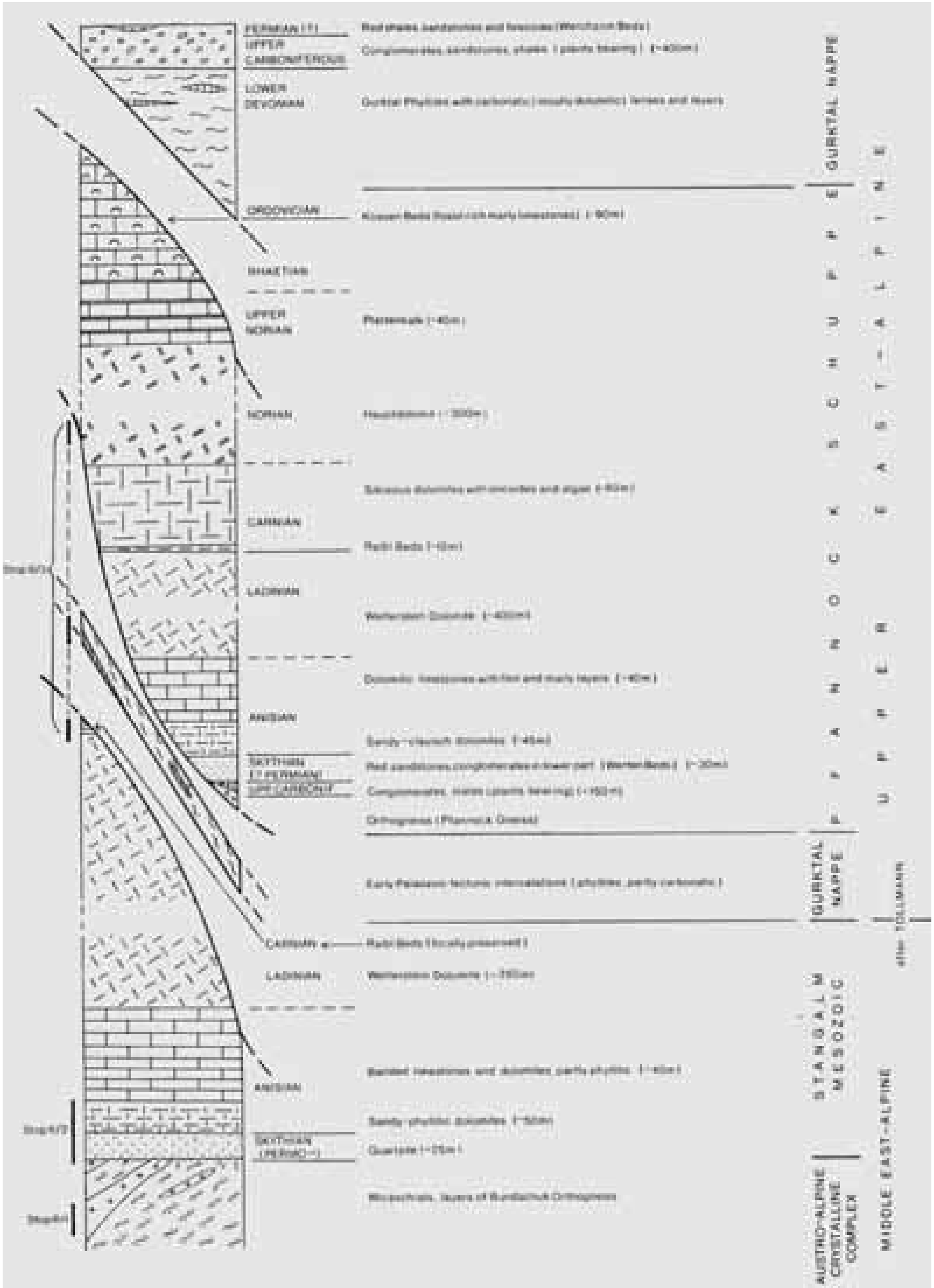


Figure 4 - Schematic section of the Stangalm Mesozoic, Pfannock Schuppe and Gurktal Nappe after Pistotnik (1980)

DAY 2

Round trip in the area of the Bad Kleinkirchheim spa (BKK)

Stop 1.1:

Landscape of BKK area

Topic: Overview from Kaiserburg mountain cable car station to N (Geo-sandwich and catchment of the thermal waters Fig.2):

The Austro-Alpine complex of the Nock area consists of the biotite-rich paragneisses, mica-schists (with garnet, staurolite, locally also kyanite) as well as intercalations of marbles and amphibolites (Pistotnik, J., 1980). Lamellas and lenses of granitic orthogneisses occur at many places. Their contact against the country rock is tectonic (Fig. 2). Structure and metamorphism of the Altkristallin (Middle Austroalpine crystalline complex in Fig. 2) were mainly caused by the Variscan orogeny. The (early) Alpine events (100 m.y.) are believed to be responsible for a low-grade metamorphism and phyllonitisation along major Alpine movement planes such as at the boundary of the underlying Lower Austro-Alpine quartz-phyllites of the Katschbergzone. The stratigraphic contact between the Altkristallin and its Permomesozoic sedimentary cover (Stangalm Mesozoic) is tectonized in many places. This Stangalm Mesozoic has also been affected by low-grade Alpine metamorphism.

The Upper Austro-Alpine Gurktal nappe comprising mainly Early Palaeozoic phyllites and greenschists rests with tectonic contact upon the Altkristallin and the Stangalm Mesozoic rocks. Due to Alpine movements these units are dipping eastwards under the Palaeozoic phyllites. The formation of biotites from the quartz-phyllites is dated early Alpine (appr. 100 m.y.). This zone is considered to have acted as a lubricant for the gliding of the Gurktal Nappe (comprising the Stolzalpe and Murau nappe) over the Stangalm Mesozoic dolomite unit (Fig.2 and 3).

The Permomesozoic assemblage of the Stangalm Mesozoic rests with unconformable contact upon deformed mica-schists of the Altkristallin (Fig. 2 and 4). The Stangalm Mesozoic underwent progressive Alpine low-grade metamorphism and karstification.

The succession begins with well-bedded quartzites with conglomeratic layers and cross-bedding. These quartzites are typical of the Central-Alpine Permoskythian. The quartzite turns into an alternation of quartzites, sericite schists, and carbonate layers (uppermost Skythian, Alpine Röt). They are overlain by dark-grey, partly banded, thin-bedded dolomites, layer-wise crinoid-bearing, with transitions into dolomite phyllites. These beds are stratigraphically correlated with well-established Lower Anisian strata.

The overlying Wetterstein Dolomite reaches a maximum thickness of about 400m. This pale, fine-crystalline, locally (mainly in the higher sections) banded dolomite is believed to have formed under lagoonal conditions. Locally a laminated texture is preserved. The stratigraphic position of the dolomite is considered to be (?Upper Anisian to) Ladinian. Afterwards this strata has been tectonically cut by the Aigener fault and karstificated. This permeable structure seems to be the transport mechanism for deeper thermal waters from the synclinal basis beneath south of Turrach.

The Pfannock Schuppe assemblage begins with plant-bearing Upper Carboniferous and is topped by Rhaetian strata. Its facies resembles the Mesozoic of the Northern Calcareous Alps as well as of the Drauzug.

Stop 1.2:

Thermal springs at Katharina-church

Topic: Geoscientific survey of Bad Kleinkirchheim's thermal springs and synclinal system:

The geoscientific data acquisition for the development of a thermal water model on the example of Bad Kleinkirchheim (Clar, E. et al., 1995), was based on a previous understanding of the geological build-up of the three-layer "sandwich": an Altkritallin basement, Wetterstein dolomite of the Stangalm Mesozoic, quartz phyllite of the Gurktal Nappe. Further investigations with the quite regular measurements of the thermal water, intensive exploration and a great number of analyses concerning cold and warm waters since 1956 have been performed.

The strategy of research and reconnaissance concerning the occurrence of thermal waters offered in combination with interdisciplinary methods (hydrogeological mapping, hydrometrical simultaneous discharge measurements of brooks, further on hydrochemistry, of isotope-hydrology, hydraulic methods, geothermometry calculations and statistic interpretation) provide more statements about watershed, descent, formation depth, storage,

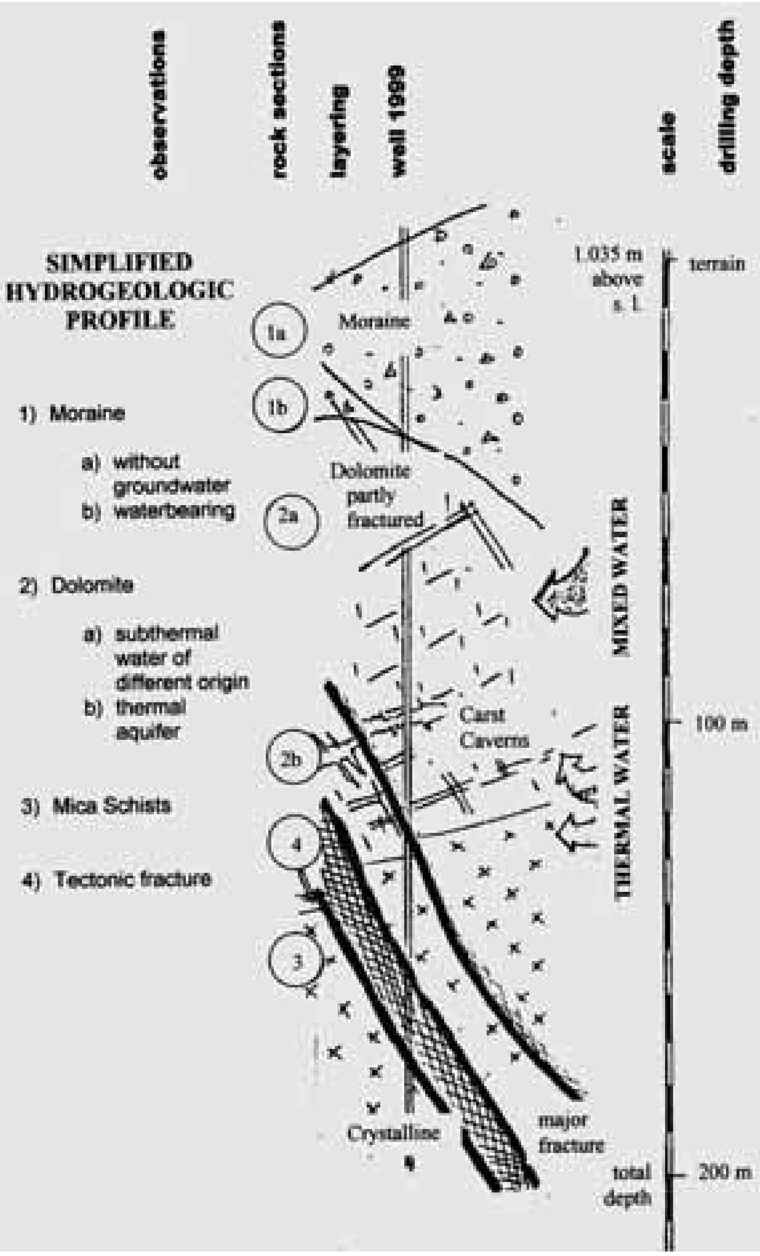


Figure 5 - Geological drilling log after Marsch & Kollmann (2000)

underground water passages, residence time, mixture, withdrawal causes, possibilities for improvement and development, trends and prognosis.

The improvements in temperature and discharge by shallow drilling exploitation (< 200 m depth) were successful indeed (Fig. 5). This increasing effect was possible by an evaluation of a model geological setting. A sandwich-like geo-structure is typical (e.g. a McDonalds "Big-Mac" with a titbit inside: mesozoic dolomite between basal crystalline basement and overburden schists Fig. 2). The sandwich has been built by tectonic nappe transport and cut by several faults the slip being on the path of deeper thermal water, running out of a 1400 m deep reservoir (calculated by geothermometry after Hochstein, M. & Klein, P. 1978).

In doing so, new results were discerned, such as the significance of the tectonic and then karstificated fault zone (Aigener fault) and a minimal fissured porosity of nf = 5% was calculated according to a geothermometer giving indications of the heating origin at 1400 m, depending on the geometry of the mylonite zone. This was geologically reasonable only if additional storage was assumed within the dolomite, reaching far into the Gurktal nappe to the East. This was an imperative correspondence to the Radiocarbon dating (16,700 years) for the primary high temperature component in this lineament.

A sectional cooling of the pumped combined waters was caused by additional cold karstwater after the infiltration of precipitation and surface water, which was proved by simultaneous hydrometric

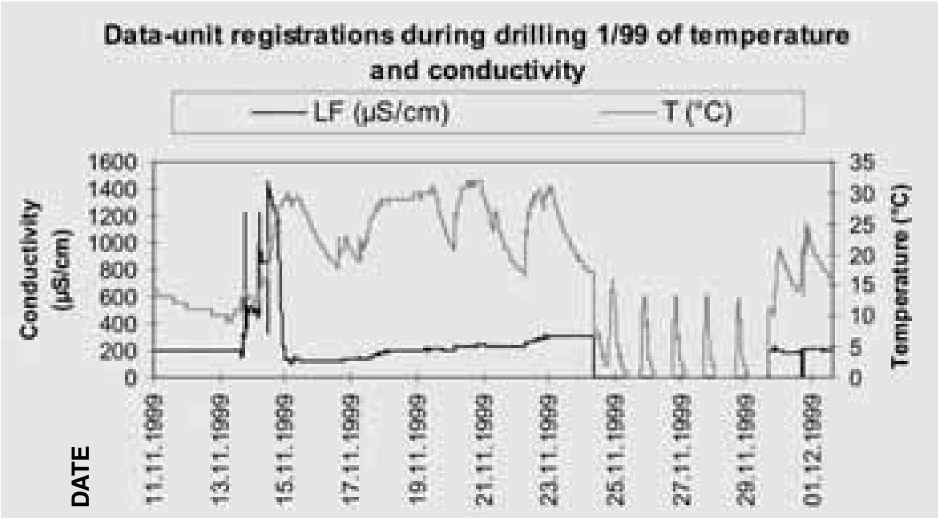


Figure 6 - Temperature and conductivity online registrations during drilling 1/99

measurements and locally limited. These components (cold water and deep hot water) were determined for all drill holes by chemical mixing ratio using the specific thermodynamic solubility of some trace elements (F, Mo, Ba) and a tritium contents.

It turned out that the cold water components of the supply wells were about 25 to 37% of the exploitation until throttling (autumn 1990). The success of the throttling showed that the cooling is a result of the abstraction (23 l/s) since 1976 and is fortunately reversible. However, the cooling was still in process and therefore further operational steps were necessary (continuing the throttling, searching for better spots for the wells).

For future measures, at least for a limited time similar or intensified throttling was recommended to guarantee an optimal use of the high temperature components. To protect these, on the one hand qualitative from emission and on the other hand quantitative from mining, a decree for a protection zone should be issued also considering the Aigener fault and future exploration.

Stop 1.3:

Thermal drillings innovation success

Topic: Results of thermal exploitation innovation, improvement by drillings 1972 - 1999:

In the nappe of the Austoalpine Crystalline Complex new prospecting for additional thermal water exploitation followed the modern hydrogeological scheme of thermal exploration: The order was to find

- thermal fresh water B 6 l/sec.
- with temperatures >30 °C
- at a vertical drilling depth of maximum 200m
- inside the village of BKK

Thus the exploration concept has been adapted to the specific hydrogeological questions (Fig. 5 and 8):

Where can the thermal water migrate from a dolomite syncline through a deep fracture system near the earth's surface?
How to locate optimal drilling points in the field?
Which engineering construction for drilling, well casing, producing and completion?
Risk evaluation: Long-time protection of the resources, how much is it?

A package of methods in the fields of applied geology, geophysics, hydrochemistry, geotechnical engineering and balneomedical consulting was carried out by a team of experts under the management of the Department of Hydrogeology of the Geological Survey of Austria.

The field operation was conducted by the engineering bureau HydroAlpina. The positive results can be seen during the field trip:

1.3.1. Starting-point

The year before scientifically modern site descriptions (soil-temperature and gas scanning, online monitoring measurements) were carried out to provide the new drill 1/99 location.

Wasseranalyse

(analysed by Fresenius-Institut)

Geologische Bundesanstalt
FA Hydrogeologie - FA Geochemie

Bad Kleinkirchheim 1/99							
Hydrogeologie-Nr.		Koordinaten (BMN)			GOK	Filterstrecke (m ab GOK)	
Bezeichnung	BKK500330	M	RW	HW	(m ü. A.)	von	bis
Probenahmedatum	21.10.1999	-	-	-	-	-	-

Feldparameter		
Parameter	IP ***	Messwert
Schüttung (l/s)		-
Temperatur (°C)	25	n.b.
Leitf. (µS/cm)	2500	301
pH	6,5 - 9,5	n.b.

Kationen						
	GSwV *	MAP **	IP ***	Messwert		
Ion	mg/l	mg/l	mg/l	mg/l	meq/l	eq%
Na^+	90		200	22,4	0,97	27,24
Ca^{2+}				31,9	1,59	44,60
Mg^{2+}				11,7	0,96	26,91
K^+	12			1,3	0,03	0,93
Li^+				n.b.	n.b.	n.b.
Sr^{2+}				0,23	0,01	0,15
NH_4^+	0,3		0,5	< 0,02	0,00	0,0
Fe^{2+}			0,2	0,009	0,00	0,0
Mn^{2+}			0,05	0,14	0,01	0,1
Al^{3+}	0,12		0,2	0,01	0,00	0,0
Cu^{2+}	0,06	2		0,04	0,00	0,0
Cr^{3+}	0,03	0,05		< 0,002	0,00	0,0
Cd^{2+}	0,003	0,005		< 0,0005	0,00	0,0
Pb^{2+}	0,03	0,05		< 0,002	0,00	0,0
Zn^{2+}	1,8			0,014	0,00	0,0
Hg^{2+}	0,001	0,001				
Ni^{2+}	0,03	0,02		< 0,002	0,00	0,0
Ba^{2+}				0,11	0,00	0,0
			Σ Kationen	67,85	3,6	100,0

Anionen						
	GSwV *	MAP **	IP ***	Messwert		
Ion	mg/l	mg/l	mg/l	mg/l	meq/l	eq%
Cl^-	60		200	10,5	0,30	8,2
SO_4^{2-}			250	29	0,60	16,7
HCO_3^-				159	2,61	72,0
NO_3^-	45	50		< 0,3	0,00	0,0
NO_2^-	0,06	0,1		< 0,02	0,00	0,0
PO_4^{3-}	0,3			< 0,04	0,00	0,0
F^-	0,9	1,5		2,2	0,12	3,2
Br^-				n.b.	n.b.	n.b.
I^-				n.b.	n.b.	n.b.
S^{2-}				n.b.	n.b.	n.b.
			Σ Anionen	200,70	3,6	100,0

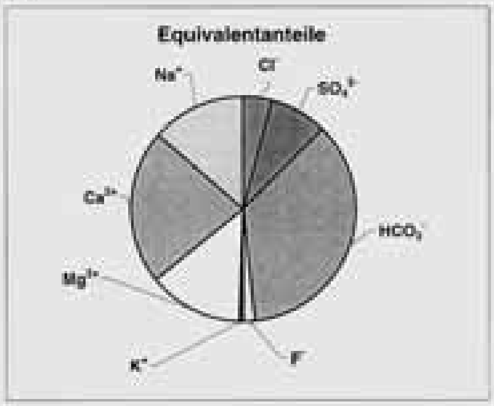
Ges. Ionengehalt (mg/l)	269
Ionenbilanz (%)	-0,6

Härten	
Gesamthärte (° dH)	7,2
Karbonathärte(° dH)	7,2
Nichtkarbonathärte (°dH)	0,0

Berechnung des freien CO_2		
lg(pCO_2)	mg/l	mmol/l
n.b.	n.b.	n.b.

Berechneter Ammoniakgehalt	
NH_3 (mg/l)	n.b.

Spezielle Parameter	
H_2SiO_3 (mg/l)	n.b.
HBO2 (mg/l)	0,33
As (mg/l)	0,001
Mo (mg/l)	0,075



n.b. ... nicht bestimmt

* ... Grundwasserschwellenwertverordnung (BGBl. 502/1991 idgF)

** ... Mindestanforderungsparameter aus der Trinkwasserverordnung - TWV (BGBl. II 304/2001)

*** ... Indikatorparameter aus der Trinkwasserverordnung - TWV (BGBl. II 304/2001)

Figure 7 - Hydrochemical composition of the pumped thermal water 1/99

		MINIMUM	MAXIMUM
recharge area	(km^2)	70	207
brutto-aquiferkubatur	(km^3)	25	62.5
5% eff. reservoire volume	(km^3)	1.25	3.13
aquifer overburden	(km)	0.75	1
geothermal Gradient/Crystalline	(°Ckm^{-1})	/	50
altitude of well production	(m a.s.l.)	/	1050
altitude of infiltration	(m a.s.l.)	/	1500
precipitation temperature	(°C)	1	/
ass. max. aquifer temperature	(°C)	38	50
quantity of precipitation	(mio. m^3a^{-1})	70	207
quantity of drainage	(mio. m^3a^{-1})		?
anthropog. production (rate 16 ls^{-1})	(mio. m^3a^{-1})	0.5	/
assumed migration time	(a)	(2500)	
energy output, at moment	(MWh^{-1})	1	/
possible max. cumulative output	(MWh^{-1})	/	7.5

Figure 8 - Data for a thermal water and energy input – output balance in BKK

This was given priority because the old wells of 1974 were in bad condition and in need of repair after non-stop usage for a quarter of a century. The interpretation of the monthly measurements of temperature and yield showed generally positive results which were calculated by a program for trend analysis. In a long term comparison the cooling trend had been broken by the throttling since 1985. A comparison of the projected results proved a constant temperature. When before only 31.6°C were predicted for the old well 1/74, 31.9°C could be expected now. Well 2/74 showed even better results. Until further notice the adjusted discharge of pumping is optimal and should be maintained. For the year 2000 a target temperature of 30.8°C instead of 30.1°C was calculated by the software program Erlgraph-Statistica, developed by the GBA.

Even the short-term tendency had improved noticeably since the start of throttling in 1991. Thanks to the previous geological advice and the the throttling, that was requested by Prof. Kahler and Prof. Clar time and again, the consultation was

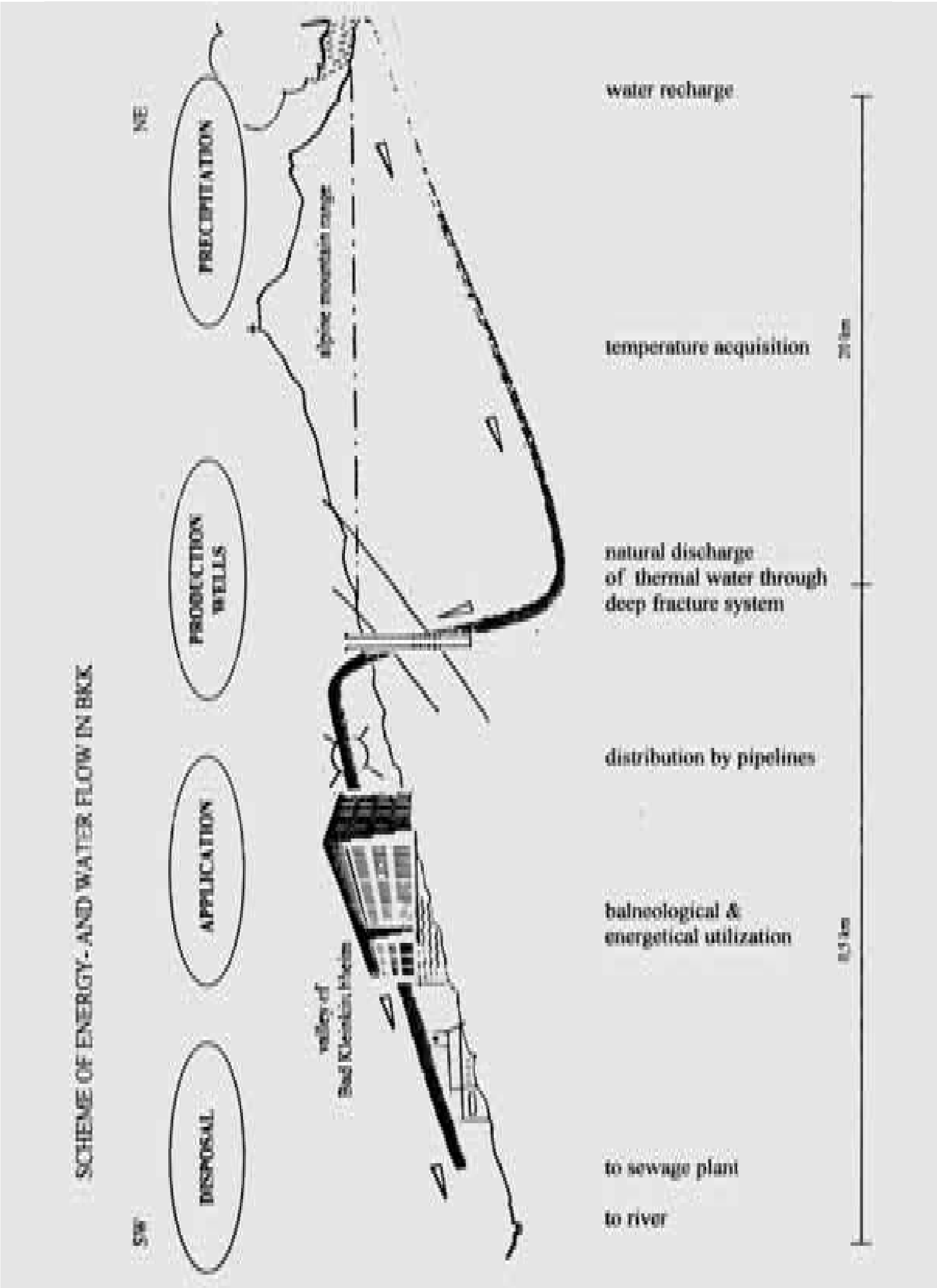


Figure 9 - Scheme of energy- and water flow

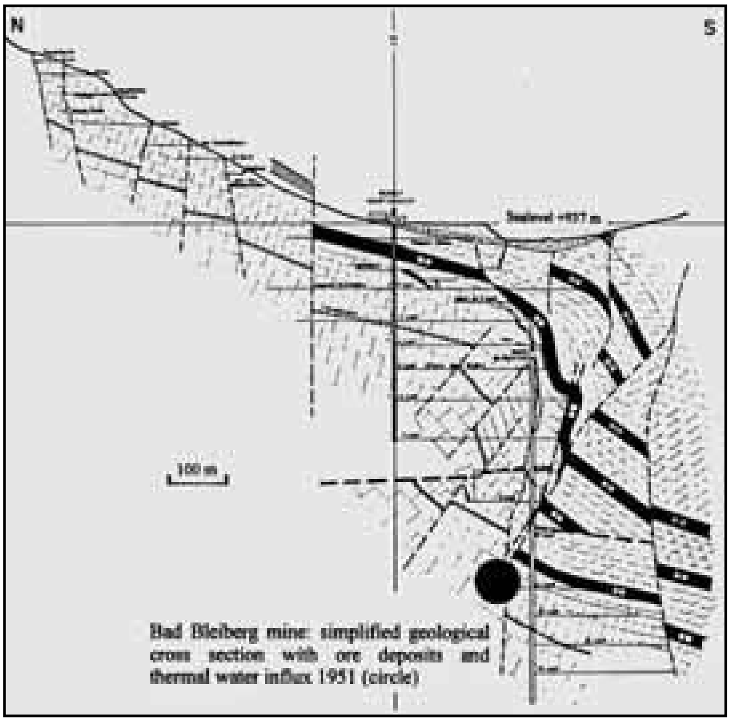


Figure 10 - Bad Bleiberg mine: simplified geological cross section with ore deposits and thermal water influx 1951 (circle)

confirmed as correct and appropriate by GBA which is certainly something to take pride in.

1.3.2. Accompanying drilling control

A drilling depth of 200m was successfully reached (Fig: 5). Priority was given by the geoscientific project control to prevent a negative influence on the current and future operation of the thermal springs and wells.

For geological and safety reasons (to compensate the threat of the infiltration of pollutants from the surface; to master the positive artesian head from below) a conductor was cemented 12m into the medium clayey fine sand of the moraine from the last Ice Age (10,000 years ago), which corresponded perfectly to the geological prognosis. After cement setting and casing telescopy the Quaternary sedimentary filling of the valley, which formed a low permeably protective layer, was equally thick as in the prognosis and was cemented to the top of the dolomite, 44m deep. After further casing telescoping a steel-pipe (124m long; 7”) was solidly cemented into the bore-hole diameter (9 7/8”) according to the submitted project and the calculations including the overburden pressure (psi). During the work severe geological and technical problems appeared because of the cavernously karstified dolomite and the high artesian water pressure. These were successfully resolved by the engineering of the deep-drill company Etschel & Meyer (Styria / Bavaria).

The new drill 1/99, a geological test hole, was drilled deep into the crystalline basement rock in order to test possible influxes from greater depths. In doing so and using additionally log-interpretation (Formation Micro Scanner, Flowmeter log, Temperature scanning) the top of the crystalline basement was reached at almost 130m. Influxes coming from the formation in the deeper part were very low and also colder (Fig. 6).

The short pumping tests after measuring the artesian pressure (+11m) showed a maximum of 33.2°C with a positive tendency towards 34°C at a pumping discharge of 5 l/s with a low dropping of 17m (stat.) after 6 hours and a quick recovery of only a few minutes. This proved to give substantially better conditions then the ones that had been used until now in BKK.

From three wells up to 23 l/sec. of fresh water (Akrato-thermal, Fig. 7) with mean temperatures of up to 31°C can supply swimming pools with a cumulative area of ca. 6300 m^2 to two five-star hotels and two large public swimming facilities (Fig. 8 and 9).

DAY 3

Travel back to Villach via Bad Bleiberg

The Western Drauzug (Lienzer Dolomiten mountains, Gailtal Alps) to the north comprises an assemblage of crystalline, Palaeozoic and Mesozoic rocks (Matura & Summesberger, 1980). According to its position in a region of strong compression the beds are generally steeply inclined and hypothesized previous stratigraphic contacts are tectonized. The lithofacial feature of the Permomesozoic suite are considered to be of an intermediate type between the North-Alpine and South-Alpine facies. Extensive Pb-Zn-mineralization of Carnian Beds (upper Wetterstein Limestone and lower Raibl Beds) has been exploited extensively in the famous Bleiberg mine in the eastern part of the Gailtail Alps near Villach. The Carnic Alps as the northernmost part of the Southern Alps extend

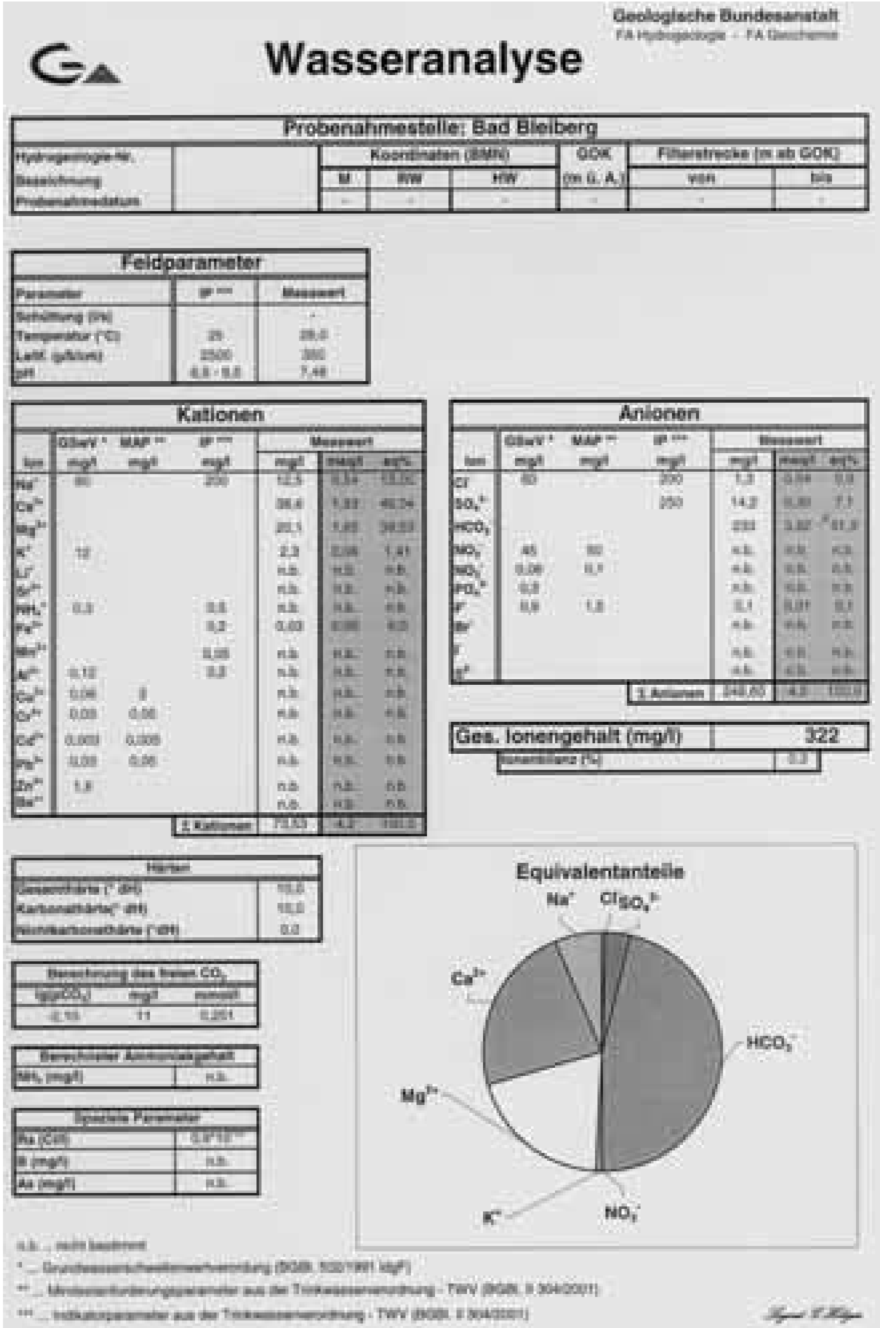


Figure 11- Hydrochemical composition

south of the Lesach and Gail valley.

Only a narrow marginal section of the Southern Alps is exposed in Austria comprising mainly Palaeozoic and fewer Mesozoic rocks. Variscan folding and thrusting and subsequent erosion separates two sedimentary cycles. The earlier cycle begins during the Ordovician and is terminated by the flyschoid Hochwipfel formation (Upper Carboniferous). The later cycle begins with the uppermost Carboniferous Auernig beds and continues into the Mesozoic.

North of the village Nötsch outcrops of Carboniferous age are exposed, belonging to a tectonically isolated block the size of which can now be traced over an area of 8×2.5km. Most of the Lower and Upper Carboniferous sediments and volcanics, however, are covered by glacial deposits. Tectonically, this sequence may be regarded as the original molasse-type cover of crystalline rocks north of the Gail valley; its link with the Permomesozoic of the Drauzug has been a matter of discussion for an even longer time (Schönlaub, 1980).

Synsedimentary tectonic activities at the Lower/ Middle Permian boundary led to the destruction of the carbonate platform. Conglomerates and breccias were deposited in local depressions (Travis Breccia).

In the Mesozoic Bad Bleiberg mountain range discussed above there is the formerly important Pb-Cu-mine. The tunnels and shafts reach depths up to 700m under the surface and show the internal geologic structures.

Once more karstic parts of the fractured mesozoic dolomite bear water of different origin, age, temperature and quantity. Diagonal NW and NE striking fractures show maximum distortion of tectonic strain, followed by problems of tunnel stability after cavity opening. These fractures are the migration paths for artesian thermal water.

In the fifties of the 20th century the mine was partly flushed by a natural break-in of water. Up to 50 litres per second of the Ca-Mg-HCO_3-water with 28°C were dammed and diverted to the earth's surface. The chemical composition of the thermal water is an Akrato thermal type with a light amount of Radon (Fig. 11). Today about 15 l/s are pumped to supply a hotel & spa complex.

Although ore production finished in the nineties, the production of thermal water out of this mine is still going on.

Conclusions

Natural springs of thermal water at the earth's surface (Villach-Warmbad), mining for ore deposits including chance production of thermal water (Bad Bleiberg), or modern search for thermal aquifers (Bad Kleinkirchheim) have been presented with examples. In the Carinthia Alps additional reservoirs of thermal water are available and can be produced after conducting the correct exploration.

Acknowledgements

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Back Cover:

map = Field trip itinerary and geology

Train: 1. day to Villach

Bus: 2. day Bad Kleinkirchheim

Bus: 3. day Route back via Bad Bleiberg to Villach

sketched on the Mineral-Thermal-Map of Austria

FIELD TRIP MAP

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