XXXVIII IAH Congress

Groundwater Quality Sustainability

Krakow, 12–17 September 2010

Extended Abstracts

Editors:
Andrzej Zuber
Jarosław Kania
Ewa Kmiecik

University
of Silesia
Press 2010

abstract id: **173**

topic: **3**
Aquifer management

3.2
Transboundary aquifers

title: **Investigations of the aquifer characteristics of the dolomite formation on the Northern Calcareous Alps in Germany and Austria**

author(s): **Sylke Hilberg**
University of Salzburg, Department of Geography and Geology, Austria,
sylke.hilberg@sbg.ac.at

keywords: dolomite-formation, groundwater age, Northern Calcareous Alps, hydrochemistry, water supply

INTRODUCTION

At the northern edge of the Northern Calcareous Alps there are sectural problems in providing a stable and efficient drinking water supply. The existing waterworks extract from karst springs, delivering waters with extremely short residence times or from wells in porous groundwater bodies which, because of the intensive land use in the catchment areas includes a risk of significant pollutant levels.

Both methods of providing drinking water supply can only be used by defining extensive protection areas in which many restrictions are applied to land usage.

An alternative way of obtaining drinking water in the Northern Calcareous Alps region was investigated to ascertain the suitability of the widespread but rarely used Hauptdolomit (HD) feature. The typical HD-aquifer was described by Kassebaum, Zankl (2004) and Kassebaum (2006) as a medium of double porosity. The larger fractures representing fracture porosity are responsible for discharge. The micro fractures determine the matrix permeability which is responsible for filtering and retention capacity. In the context of these investigations the questions of the hydrochemical properties and the mean residence time of the waters in HD aquifer have not yet been answered satisfactory.

Within the region between Reit im Winkl and Waidhofen/Ybbs 12 groundwater withdrawals (springs and wells) were found suitable for use for the characterization of this special aquifer. Figure 1 shows the larger study area and the single measurement points.

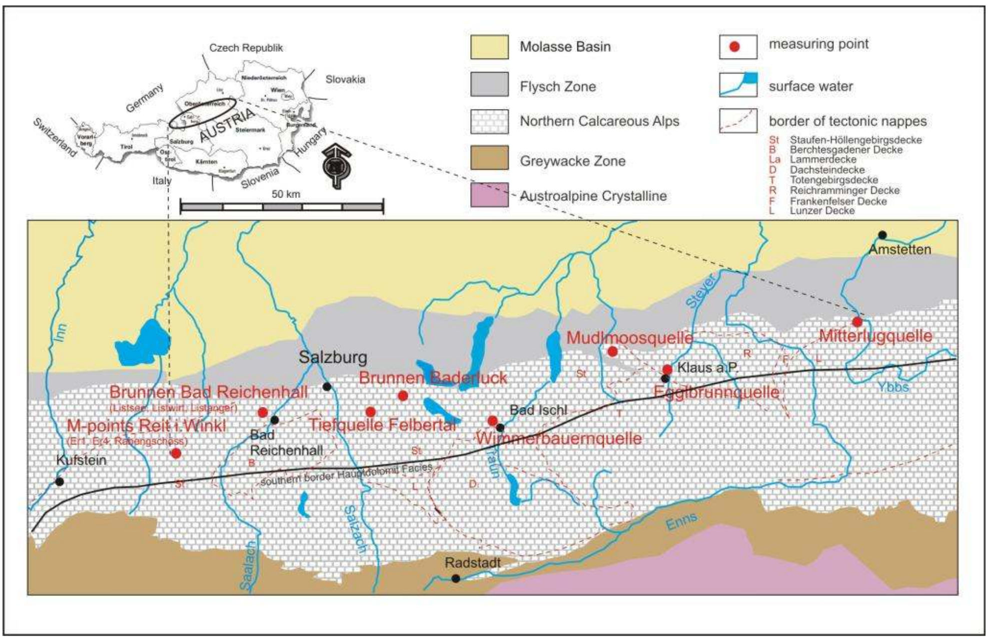


Figure 1. Overview of the study area (simplified after Beck-Mannagetta and Matura 1980, Geol. Karte von Österreich 1:1.500.000, supplemented after Tollmann 1976)

METHODS

Initially the orographical catchment areas of the chosen springs and wells were mapped geologically and hydro geologically in order to check the basic requirement to work in HD-dominated catchment areas. Further aims of mapping were to collect hydrogeological objects like seepages, swallow holes, further springs and signs of karstification. Field parameters like conductivity, water temperature and amounts of discharge were measured in samples from springs and surface waters.

Structural data were collected to explore the characteristics of the network of fissures in the catchment areas as this affects infiltration, flow velocity in the aquifer, variability of discharge. These are very important factors in deciding on the suitability of a spring for water supply and the hydrological broadening of the catchment area.

Parameters like temperature and conductivity were measured in the field. In addition laboratory analysis focused on the parameters calcium, magnesium, sodium, potassium, sulphate, chloride and hydrogen carbonate ion concentrations as these are the most important ions to be considered in the formations of the Northern Calcareous Alps.

The evaluation of the saturation indices for dolomite and calcite in combination with the calcium-magnesium ratio was used to distinguish between HD-waters, limestone-dominated waters and waters influenced by low mineralized run off of precipitation.

Stable isotopes were used to determine the mean elevation of the catchment areas. In addition Tritium was used to estimate the mean residence time and the age distribution of the investigated waters. To improve the result of isotope investigations micro pollutants like CFC and SF_6 were used.

RESULTS

The main results of the field survey are listed in table 1. The field survey in some of the studied areas in the range of Stauffen-Höllengebirgs nappe showed springs with their origins in steeply dipping macro fractures striking more or less in E–W or in N–S-direction. The more eastern situated springs are results of NW–SE (Egglbrunn) and N-S (Mitterlug)-striking fractures, whereas the main joint set in the catchment area of Mitterlugquelle is NW–SE and NE–SW-directed. Besides these bigger scale fractures, small-scale brittle structures play an important role in the dynamic behavior of the aquifer. As characteristic omnidirectional micro fractures in the HD-unit are regarded as responsible for infiltration and for retention capacity, these small scale structures were of special interest of the field survey. As table 1 shows the presence of micro fissure structures on the surface strongly differs in the study areas.

Table 1. Basic data of field survey in some of the studied areas. Whereas measuring points within Stauffen-Höllengebirgs nappe are based on N or E-striking fractures, the more eastern situated catchment areas are dominated by NW- or NE-striking structures. In every study area micro fissures are not developed laminary, further springs surface run offs etc. are rare in every area.

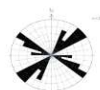
study area	geological formations besides HD	direction of main joint sets	direction of the spring relevant fracture	presence of micro fissures	spring situation in the catchment area	distinctions
Tiefquelle Felbertal	moraine		steep ENE striking fracture, open width decimeter	seperate mircofractured areas, HD for the most part massy	widespread diffuse discharge, only few small springs	scale deposits in the range of diffuse discharge
Brunnen Baderluck	limestones (Dachsteinkalk, Oberalmer Schichten) moraine		unknown	seperate mircofractured areas, HD for the most part massy	very rare diffuse run off, no further springs in the whole mapped area	black bituminous layers, distinctive banking
Wimmerbauernquelle	no extreneous units		steep N-striking joint sets	very few sperate microfractured areas, HD for the most part massy	no further springs, little creeks E nad W of the spring border the catchment area	relatively low conductivities and high temperatures, very steady discharge
Mudlmoosquelle	limestones (Plattenkalk) talus material		NNE-striking fracture under debris	no microfractured areas	many small springs, obviously near surface water	
Egglbrunnquelle	limestones (Riffkalke)		WNW-striking fractures	widespread strongly microfractured parts in the cachtment area, massy HD in the proximity of the spring	two other small springs lateral to eggelbrunn, no further springs	
Mitterlugquelle	no extreneous units		N-striking morphological structure, direction not found in exposures	microfissures widespread in the cathment area, HD-detritus	no further springs but some diffuse run offs	spring not bound to the main joint set in the catchment area

Table 2. Classification of springs and wells by different approaches. The measuring points in Reit im Winkl, Wimmerbauernquelle and Mitterlugquelle are identified as dolomitic waters, whereas all other points show a significant influence of limestones. Brunnen Listwirt Bad Reichenhall and Brunnen Baderluck show the influence of gypsum.

Measuring point	Water type	Ca-Mg-ratio	Classfication by sulphate concentration	Classification by hydrochemical modelling
	(>20%)	(<=1,2)	sulphate > 10 mg/l	
Reit i. Winkl, ER1	Ca-Mg-HCO_3	Dolomitewater	free of sulphate	mature dolomite water
Reit i. Winkl, ER4	Ca-Mg-HCO_3	Dolomitewater	free of sulphate	mature dolomite water
Reit i. Winkl, Rabengschöss	Ca-Mg-HCO_3	Dolomitewater	free of sulphate	mature dolomite water
Bad Reichenhall, Listanger	Ca-Mg-HCO_3	mixed water	sulphate	mature mixed water
Bad Reichenhall, Listsee	Ca-Mg-HCO_3	mixed water	sulphate	mature mixed water
Bad Reichenhall, Listwirt	Ca-Mg-HCO_3-SO_4	mixed water	sulphate	mature mixed water
Tiefquelle Felbertal	Ca-Mg-HCO_3	mixed water	free of sulphate	undersaturated mixed water
Brunnen Baderluck	Ca-Mg-HCO_3-SO_4	mixed water	sulphate	undersaturated mixed water
Wimmerbauernquelle	Ca-Mg-HCO_3	Dolomitewater	free of sulphate	mature dolomite water
Mudlmoosquelle	Ca-Mg-HCO_3	mixed water	sulphate	undersaturated mixed water
Egglbrunnquelle	Ca-Mg-HCO_3	mixed water	free of sulphate	undersaturated mixed water
Mitterlugquelle	Ca-Mg-HCO_3	Dolomitewater	free of sulphate	mature dolomite water

Table 3. Basic results of groundwater dating considering geological and hydrochemical results of the study. The highest amount of young water (>10% younger than one year) and the lowest amount of old water (<1% older than 50 years) are found in those springs delivering unsaturated water. There is no significant difference in age distribution between dolomite and mixed water. Both mature water types show amounts of very young water (1 to 10% younger than one year) and of very old water (1 to 12% older than 50 years) except Wimmerbauernquelle which exhibits more than 75% old waters.

Measuring point	Geological units	Classfication by hydrochemical modelling	Best fitting discharge modell	Calculated mean residence modell	Components younger than one year	Components older than 50 years
				years	%	%
Reit i.Winkl Rabengschóss	Hauptdolomit	mature dolomite water	EM	10.5	9.1	0.9
B ad Reichenhall, Listanger	Hauptdolomit + Wettersteinkalk	mature mixed water	EPM(75%)	EM 11,PM15,5	6.5	5
Bad Reichenhall, Listsee	Hauptdolomit + Wettersteinkalk	mature mixed water	EPM(50%)	EM24, PM17,5	2	6.2
Bad Reichenhall, Listwirt	Hauptdolomit + Wettersteinkalk	mature mixed water	EPM(75%)	EM27, PM16	5.4	11.8
Tiefąuelle Felbertal	Hauptdolomit	undersaturated mixed water	EM	9	11.5	0.4
Brunnen Baderluck	Hauptdolomit	undersaturated mixed water	EM	7,5-10	13.5	0.1
Wimmerbauernquelle	Hauptdolomit	mature dolomite water	EPM(30%)	EM30, PM>100	1	75.7
Mudlmoosąuelle	Hauptdolomit, Dachsteinkalk, Plattenkalk	undersaturated mixed water	EPM(90%)	EM8,5, PM6	10	0.1
Egglbrunnquelle	Hauptdolomit, Kossener Schichten	undersaturated mixed water	EM	9-10	10	0.4
Mitterlugąuelle	Hauptdolomit	mature dolomite water	EM	10-14,5	9.5	5.7

EM = exponential modeli, PM = pistonflow modeli, EPM(75%)= combined modeli, 75% exponential component

To evaluate the influence of the mapped geological features on the aquifer behavior it must be seen in context of the discharge dynamics of the studied springs. Although the frequency of measurements and the observed time ranges differ strongly, the measured discharge variations can be used to characterize each aquifer. The measured values are shown in figure 2.

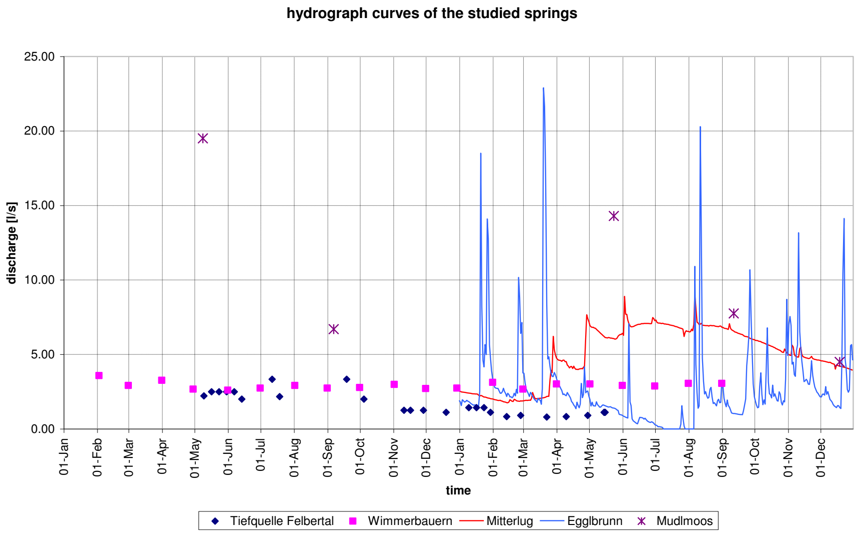


Figure 2. Discharge variations of some of the studied springs. Steady discharge in Wimmerbauernquelle, Tiefquelle Felbertal and Mitterlugquelle is significantly different from strong variations in discharge in Mudlmoosquelle and Egglbrunnquelle.

Comparing the discharge variations seen in the results of the field survey it is evident that the presence of karstified limestone in the catchment area significantly influences to flow behaviour of a spring. This is also the case if the main aquifer is dominated by little karstfied HD.

The relation between Ca–Mg-ratio and the saturation index of dolomite is shown in figure 3. Here three groups of water types can be defined: dolomite waters in equilibrium with the phases calcite and dolomite, saturated mixed waters and unsaturated mixed waters.

The different approaches to classify the investigated aquifers on the base of their hydrochemical settings are shown in table 2.

The table shows that pure dolomite waters are Ca-Mg-HCO_3-water type, free of sulphate (and other extraneous parameters) and saturated in dolomite.

To determine the mean residence times tritium concentrations were measured in the period of 2005 and 2006. Some older samples were available for the measurement points in Bad Reichenhall (Brunnen Listsee, Listanger and Listwirt) and for Mitterlugquelle. In combination with CFC and SF_6-data measured in Mitterlugquelle, Egglbrunnquelle and Brunnen Baderluck, the mean residence times of the waters were calculated by using the software MULTIS by Richter and Szymczak (1992). Regarding the hydrogeological situation and the hydrochemical classification of the measuring points the best fit between output function and measured values was calculated.

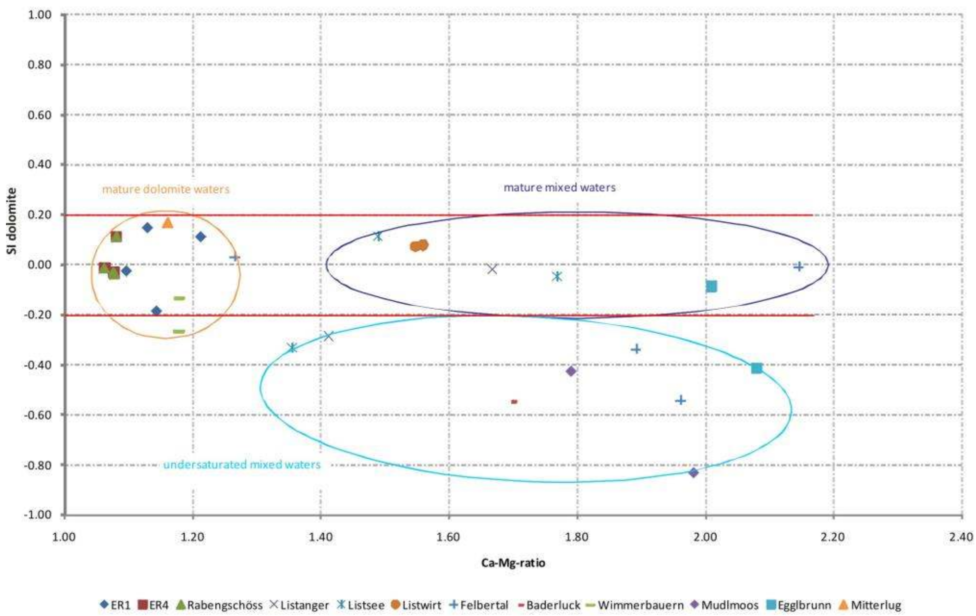
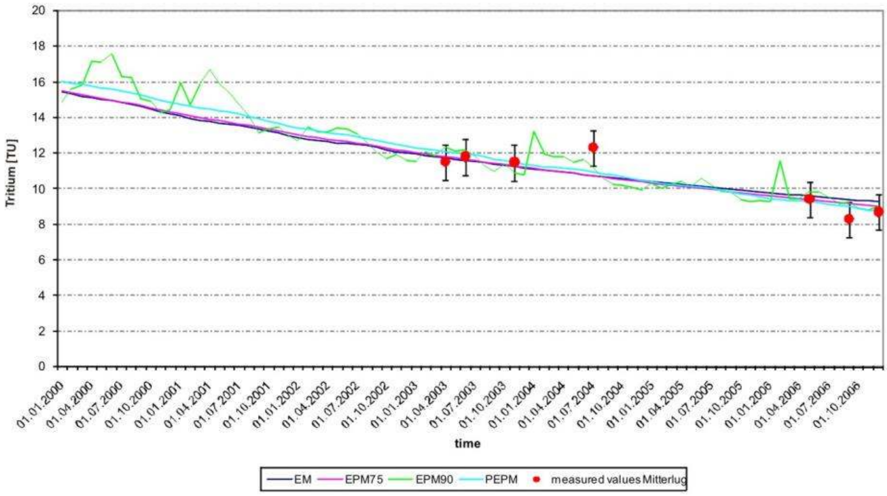


Figure 3. Ca-Mg ratio versus SI Dolomite. Three groups of waters can be defined considering Ca-Mg-ratio and saturation indices of dolomite. Mature dolomite waters show a Ca-Mg-ratio < 1.2 and are saturated in the dolomite phase. The influence of limestone in the range of the aquifer leads to a widespread group of mature mixed waters or unsaturated waters.

Generally the exponential model represents the situation in a dolomite aquifer as micro fracturing allows a perfect mixing in every part of the aquifer. Karstification in limestone dominated units as well as the lack of micro fractures in the dolomite-dominated sections lead to a partial conduit flow and a mixed discharge model with a more or less important participation of piston flow components.

For some of the measuring points the dating via tritium was verified by measuring the concentrations of CFC (Mitterlugquelle) or SF_6 (Tiefbrunnen Baderluck and Egglbrunnquelle). By means of the example Mitterlugquelle the approach is shown in figure 4.



Mean residence times after different calculation approaches [years]

tracer	Tritium		CFC11	
flow model	EM	PM	EM	PM
EM	10		14.5	
EPM75	16.5	65	5	29.5
EPM90	10	23	13.5	22
PEPM	14 (65%)	14	12 (99%)	12

EM exponential modell EMP75 exponential pistonflow modell (75% EM-portion)

EMP90 exponential pistonflow modell (90%EM-portion)

PEPM exponential pistonflow model (50% EM-Portion) combinated with a fixed pistonflow portion

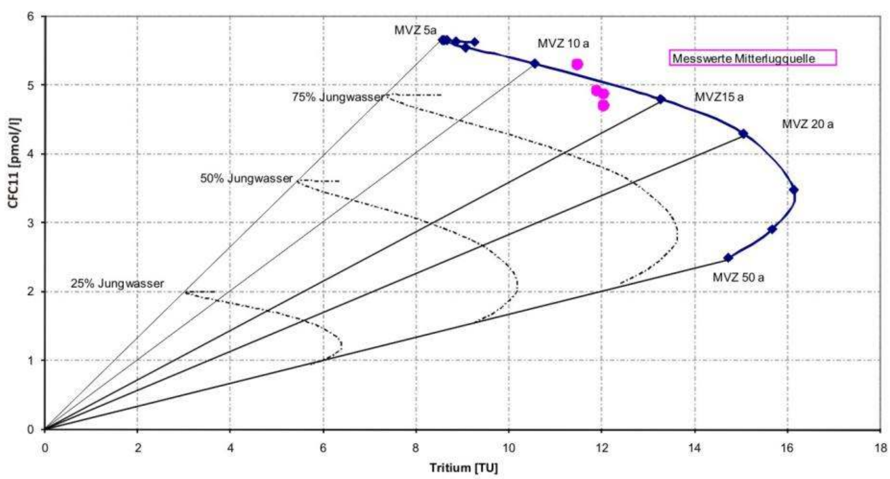


Figure 4. Groundwater dating by means of tritium and CFC-data measured in Mitterlugquelle. Top diagram shows the very few differences between the different output function. It is not possible to identify the current function only by comparing with the measured values. For finding the best fitting output function a second tracer (CFC11) was used. As shown in the figures middle part the best accordance is found in using the exponential flow model. The combination of tritium and CFC11 is shown in bottom diagram, according to BAUER et al. (2002).

CONCLUSIONS

Hydrogeological mapping in the different study areas showed that the expected typical micro fractured weathering structures are not developed consistently over the HD-dominated catchment areas. Of more importance is the presence of limestone units in the orographic catchment areas. Obviously karstified limestone units overlying the HD-formation impact the tendency for internal karstification of the HD-aquifer. In those cases HD-aquifer acts like a karst aquifer and looses the advantages of a typical double porosity medium considering the suitability for water supply.

The comparison of the hydrochemical composition of the samples generally supports the above statement as the classification by hydrochemical modelling leads to the three groups mature dolomite waters, mature mixed waters and unsaturated mixed waters. Conductivity obviously is not a significant parameter to identify HD-dominated waters.

Groundwater dating had the aim to find out if there are significant differences in age distribution between pure dolomite waters and limestone influenced aquifers. The assumption that pure dolomite aquifers show significantly longer mean residence times without any contingents of very young waters was associated with the advantage of smaller protection areas and fewer restrictions within these areas. It was shown that there is no significant difference in age distribution between pure dolomite waters and mature mixed waters. As the mean residence times differ between 10 and about 30 years the contingent of young components (< 1 year) varies between 2 and 9.5% while the contingent of old components (> 50 years) are in the range of 0.9 to 6.2% independent of the classification of the catchment area.

REFERENCES

Bauer M., Selg M., Eichinger L., 2002: *Pflanzenschutzmittel im Kluft- und Karstgrundwasserleiter des Oberjuras in Baden-Württemberg (Acricultural pesticides in joint and karstic aquifers in upper jurassic units in Baden-Württemberg).*Abh. L.-Amt f. Geologie, Rohstoffe und Bergbau Baden-Württemberg, Freiburg im Breisgau, Heft 15, pp. 149–221.

Kassebaum C., Zankl H., 2004: *Grundwassererkundung in Bayern 2003/2004 (Groundwater investatigations in Bavaria 2003/2004).* Kennz. 18.17, kalkalpine Randzone (KAR) Untersuchungsgebiet Reit im Winkl – unv. Bericht im Auftrag Bayrisches Landesamt für Wasserwirtschaft, 170 pp., 37 Abb., 55 Tab., 7 Anl., Marburg

Kassebaum C., 2006: *Exploration von Trinkwasser aus geklüftetem Hauptdolomit in den Nördlichen Kalkalpen Rottach-Egern/Kreuth (Lkr. Miesbach) und Reit im Winkl (Lkr. Traunstein) (Exploration of drinking water supply in joint dolomite units in the Northern Calcareous Alps Rottach-Egern/Kreuth (District Miesbach) and Reit im Winkl (District Traunstein))*. unv. Diss. Philipps-Universität Marburg, 118 p., 30 Abb., 19 Tab., 14 Anl., Marburg

Richter J., Szymczak P., 1992: *MULTIS. Ein Computerprogramm zur Auswertung isotopenhydrologischer Daten auf Grundlage gekoppelter konzeptioneller Boxmodelle (MULTIS a software for the analysis of isotope-hydrological data on the base of conceptual boxmodells)*. Veröff. TU Freiberg, Lehrstuhl f. Hydrogeologie, Freiberg.

Tollmann A., 1976: *Der Bau der Nördlichen Kalkalpen (The structure of the Northern Calcareous Alps).* Verlag Franz Deuticke, 449 p., Wien.

International Association of Hydrogeologists

AGH University of Science and Technology

2-vol. set + CD
ISSN 0208-6336
ISBN 978-83-226-1979-0