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# Observations on the corrosion potential in alpine caves

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Abstract
Several hundreds of water samples have been collected in Austrian alpine caves. It was possible to differentiate between karst waters in common sense and condensing waters. Due to lower temperatures at higher elevations the soil-biological activity is decreasing, hypercompensating the higher solubility of $CO^2$. Therefore the carbonate dissolution is lower. The opposite effect can be observed with the condensing waters as there is a higher uptake of $CO^2$ during condensation according to lower condensing temperatures in high alpine caves. Thus the mineralisation of condensing waters tends to increase with altitude. As the dissolution of common karst waters is more than compensated by the increase of precipitation with altitude, it can be concluded on the whole that a higher carbonate-dissolution is currently taking place in high alpine karst regions.

*Résumé*
*Plusieurs milliers d' échantillons d'eau, récoltés dans des grottes des Alpes autrichiennes, ont permis de différencier les eaux karstiques, au sens ordinaire du terme, des eaux de condensation. A cause des températures plus basses à haute altitude, l'activité pédo-biologique est réduite, ce qui compense, et bien au delà, la plus grande solubilité de $CO_2$; la dissolution des carbonates est donc diminuée.*
*L'effet contraire peut être observé avec les eaux de condensation, puisqu' il y a une absorption plus grande de $CO_2$ pendant la condensation, étant donné les températures plus basses de condensation dans les grottes alpines. Par conséquent, la minéralisation des eaux de condensation tend à s'accroître avec l'altitude. Comme la dissolution par les eaux karstiques ordinaires est plus que compensée par l'augmentation des précipitations avec l'altitude, on peut conclure, globalement, qu'une dissolution plus forte des carbonates s'effectue couramment dans les régions karstiques des hautes Alpes*

*Zusammenfassung*
*lm Zuge der Einsammlung hunderter Wasserproben in alpinen Karsthöhlen, konnte eine deutliche Differenzierung zwischen Tropfgewässern im eigentlichen Sinne und Kondensgewässern festgestellt werden. Während die Tropfgewässer bedingt durch abnehmende biologische Aktivität in der immer spärlicheren Bodenbedeckung mit der Seehöhe eine abnehmende "Mineralisation" aufweisen, wobei die hier infolge niedrigerer Temperatur bessere $CO_2$-Löslichkeit offenbar überkompensiert wird, zeigt sich der umgekehrte Fall bei den Kondensgewässern. Hier erfolgt die Kondensation der Luftfeuchtigkeit in den hochalpinen Höhlen bei niedrigerer Temperatur, mehr $CO_2$ wird gelöst und die "Mineralisation" dieser Gewässer ist demnach im allgemeinen höher. Die geringere Lösungsfracht der Tropfgewässer hochalpiner Höhlen scheint indessen durch die mit der Höhe zunehmende Niederschlagsmenge zumeist mehr als ausgeglichen zu werden, sodaβ im Gesamten im hochalpinen Bereich der unterirdische Kalkabtrag gröβer sein dürfte als in voralpinen Bereichen.*

## I. FOREWORD

As a byproduct of several speleological expeditions and investigations a large amount of water samples have been collected by cavers and scientists Having now this significant data-set of altitudes from 250 m to 2400 m is seems worth trying an overview with some remarks on the speleogenetic implications. At this stage the work is truly empiric and more or less general with some remaining peculiarities.

## II. TYPES OF CAVE WATERS AND THEIR CORROSION POTENTIAL

Besides the non-moving waters in caves one can encounter cave streams, more often dripping waters and sometimes condensing waters. The latter - showing significant dynamics in the cave atmosphere - are responsible for special features at cave walls and ceilings due to the aggressive chemical behaviour of these waters - especially in high alpine caves - caused by an altitude effect. As the average temperature decreases with altitude (Fig. 1) the potential CO,— solubility increases because the condensing temperature in the caves is getting lower too. Roughly one can say that the corrosion potential at 0 °C is 30 % higher than at 10 °C. Looking at some hydrochemical data of alpine condensing waters there is a trend towards a higher corrosion potential with altitude at least statistically reflecting the $CO_2$

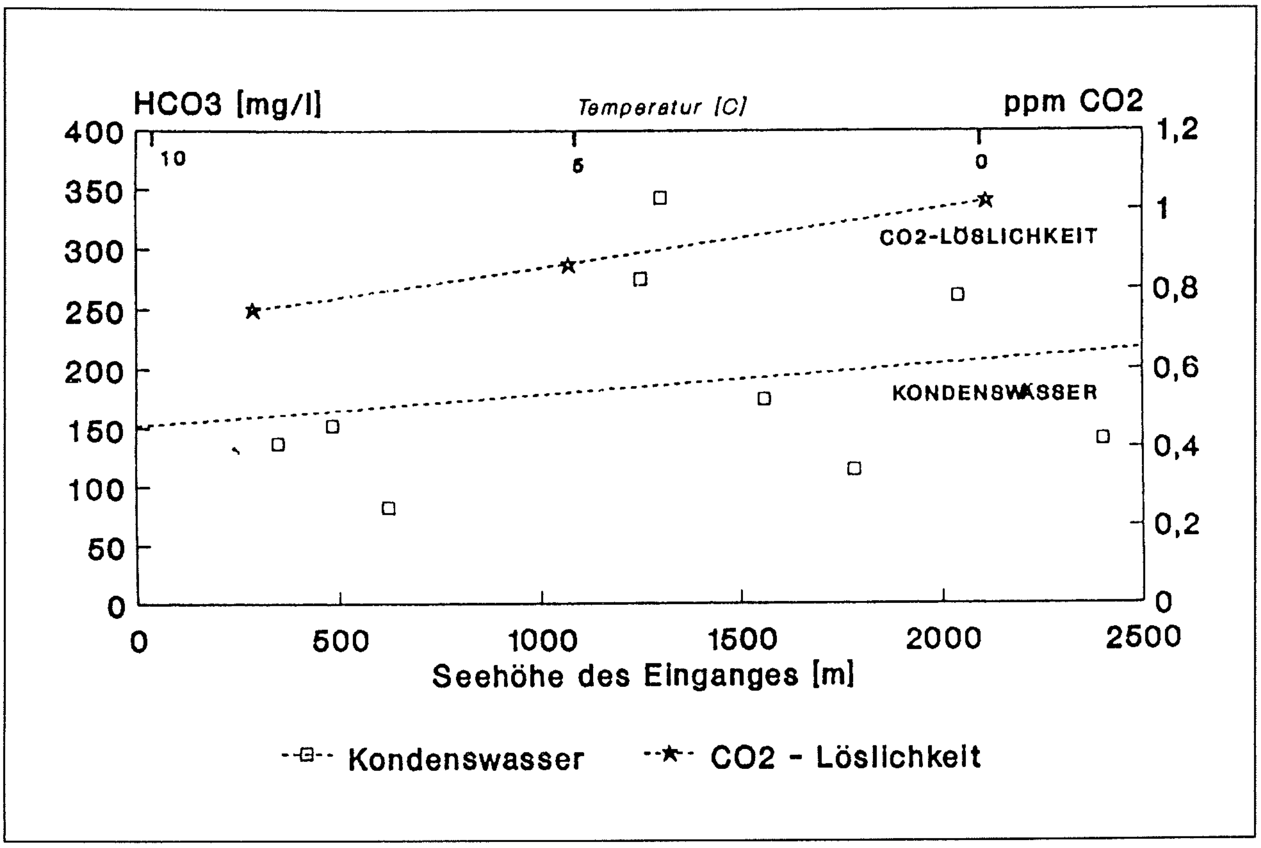


Figure 1 : $CO_2$-solubility and mineralisation of condensing waters in connection with altitude/temperature

In high alpine areas above 1000 m altitude the mineralisation of these condensing waters tends to be higher than those of the dripping waters (Fig. 2). Thus at some locations the overforming of the cave is much more influenced by condensing-water-corrosion than by solution caused by "normal" cave-waters and therefore becomes a distinct speleogenetic factor.

On the other hand the dripping waters and caves streams are showing a negative altitude effect because of the thinning of the soil and decreasing biological activity, probably mostly due to lower temperatures. Thus the $CO_2$ availability decreases with altitude overcompensating the higher $CO_2$-solubility at lower temperatures.

As there is sometimes almost no soil cover at altitudes above 1500 m and - on the other hand - the thickness and soil type is variable at low elevations there are much more significant variations from the regression line (Fig. 2) to observe. Furthermore this diagram does not take any seasonal or short-time variations - common in pre-alpine caves - into account (Fig. 3 and PAVUZA & MAIS, 1989).

Considering only the average mineralisation, pre-alpine karst areas sometimes could have twice the corrosion potential of the high alpine ones.

## III. THE ALTITUDE EFFECT OF PRECIPITATION AND ITS IMPLICATIONS

Looking at the annual precipitation of different altitudes in the Alps there is - at least at a langer scale - a clear relationship between these two parameters. The values are ranging from about 500 mm at 200 m to 2500 mm

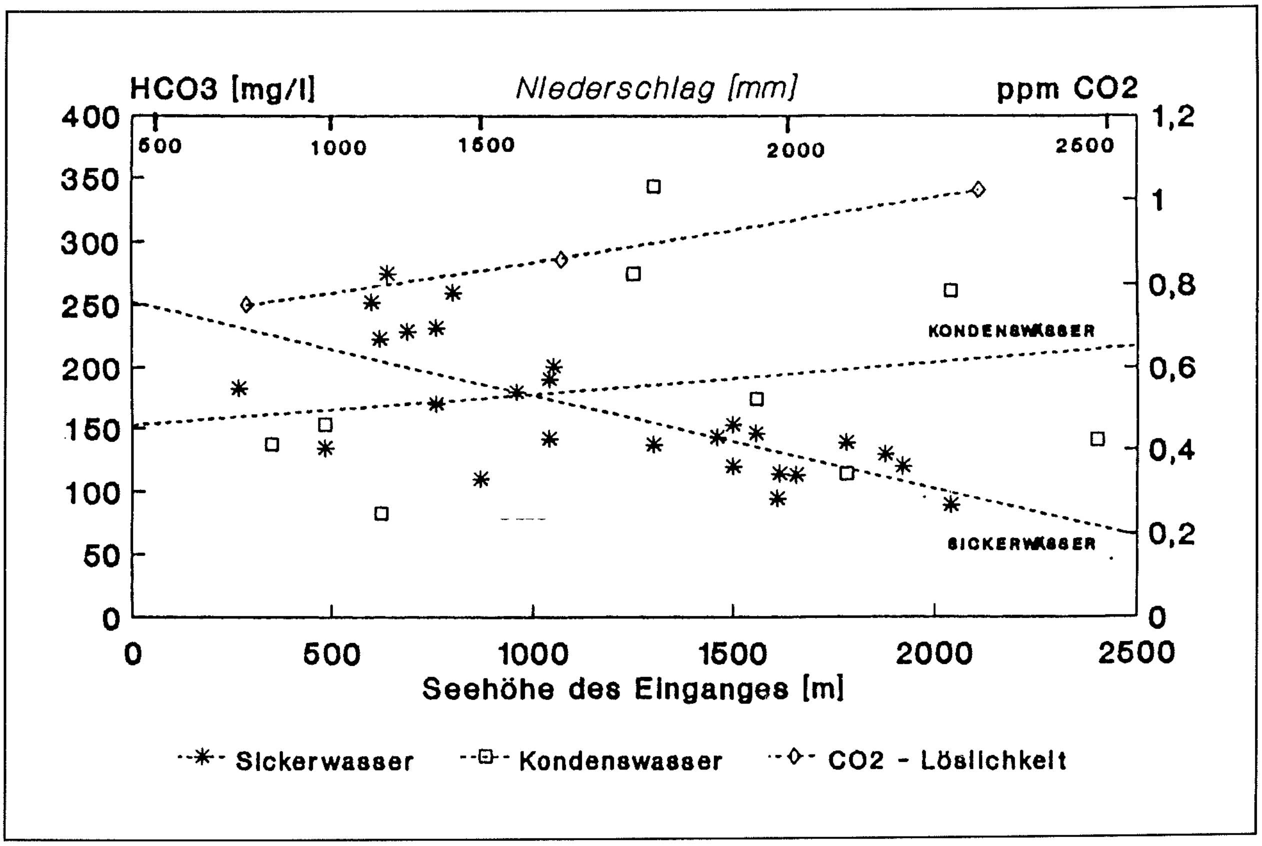


**Figure 2 :** Comparison of condensing waters and "normal" cave waters of alpine caves of Austria (seasonal variations not taken into account).

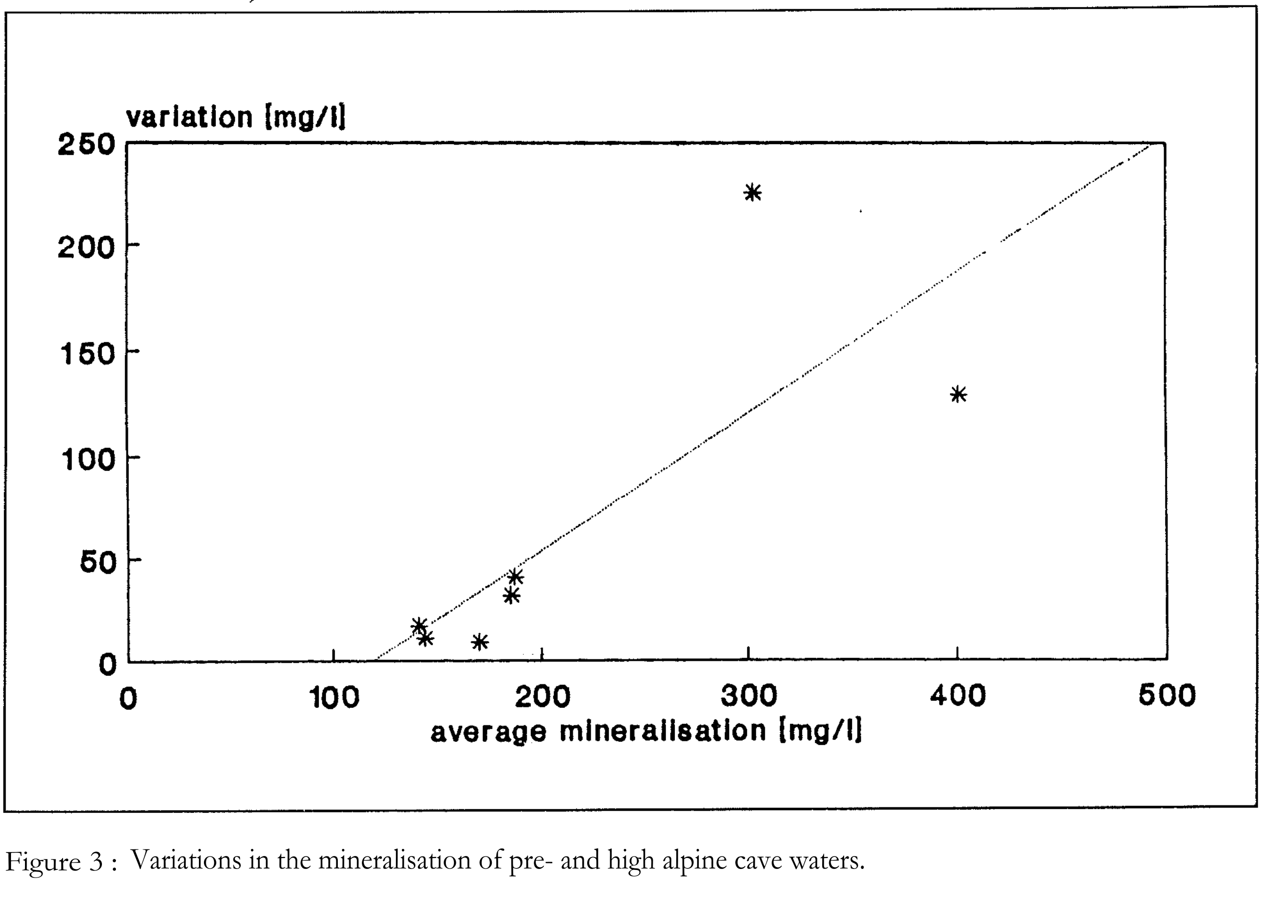


Figure 3 : Variations in the mineralisation of pre- and high alpine cave waters.

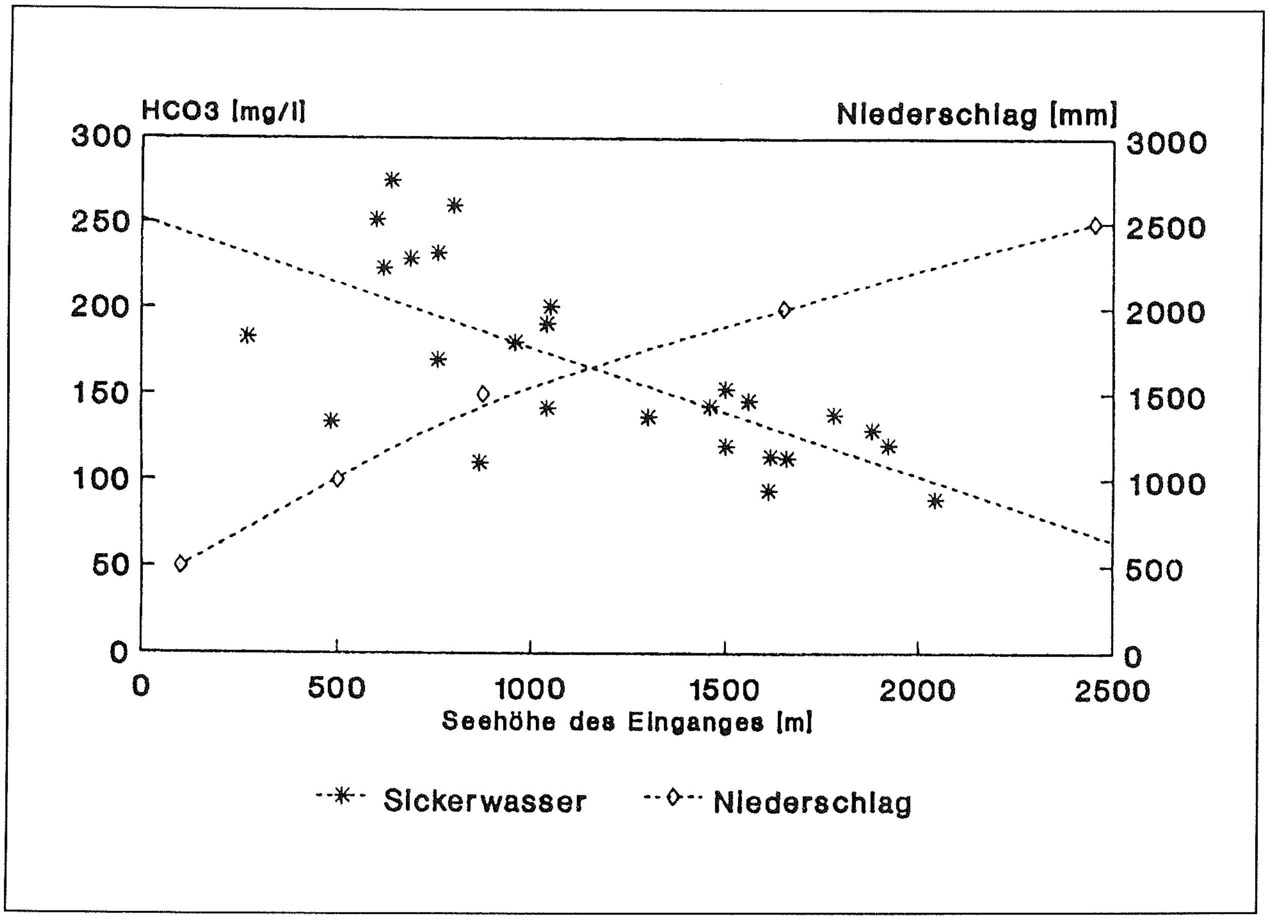


**Figure 4 :** Altitude effects on precipitation and mineralisation.

at 2500 m altitude yielding a higher volume of water available for karstification in the high alpine regions. Remembering the decreasing mineralisation of the high alpine karst waters, it is worth testing these two effects against each other (Fig. 4) : the result is a surprisingly similar corrosion potential from this point of view.

Finally bearing in mind the significant variations in cave waters of low altitudes (PAVUZA & MAIS, 1989) that show remarkable breakdowns of mineralisation at the time of peak discharge, it seems that the overall dissolution rate at higher altitudes is ultimately higher than in pre-alpine regions, always remembering the large scale character of this conclusion.

| | $HCO_3$ | $SO_4$ [mg/1] |
|---|---|---|
| Location 1 : Karl-Ludwig Tunnel | 262 | 25 . |
| Location 2 : gegenüber Grab | 138 | 212 |
| Location 3 : Dietrichshalle | 138 | 41 |
| Location 4 : Weisse Kluft | 259 | 19 |

Table 1 : Comparison of cave waters in an area of 75 x 35 m in the Hermannshöhle (Niederösterreich, Austria). Data from 19884991

## IV. LOCAL VARIATIONS OF CAVE HYDROCHEMISTRY - EXAMPLE AND CONCLUSION

Karst hydrogeological investigations often analyze a lot of springs with hydrochemical methods regarding the gap between the input points of precipitation and its reappearance in the springs as a "black box". Using hydrochemical and isotopic data, some conclusions about the catchment areas are drawn. To show the risk of such and approach an example from a pre-alpine cave is given:

Four location with dripping waters have been investigated twice a month for 4 years. These locations are within an area of 75 x 35 m at about the same altitude.

The complexity within the catchment areas is obvious and spring analysis without an idea is getting somewhat difficult. Thus collecting cave waters seems to be a good help in investigating and understanding the hydrodynamics and hydrochemistry of karst aquifers. Besides that some speleogenetic conclusions may be drawn.

## V. REFERENCES

PAVUZA, R. & MAIS, K., 1989. Some aspects on Hydrogeochemistry in Alpine Caves of Austria. - *Proc. int. Congr. Speleol.,* Tbilisi 1987, Tbilisi: 214-217.

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