Rock-destabilisation by saline Na-K-Ca-Mg-Cl solutions: Natural and experimental corrosion at mineral surfaces of KTB-rocks

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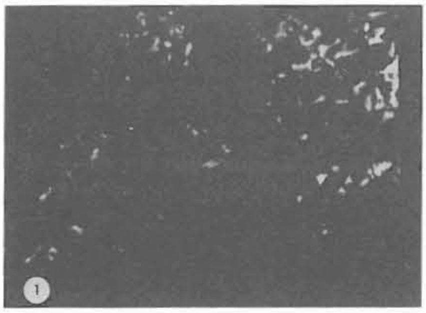
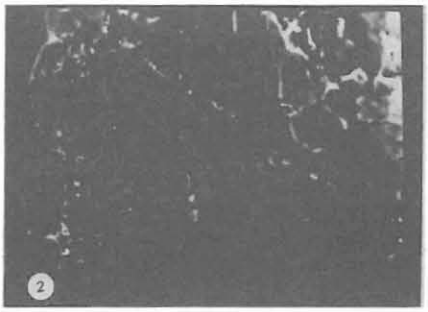
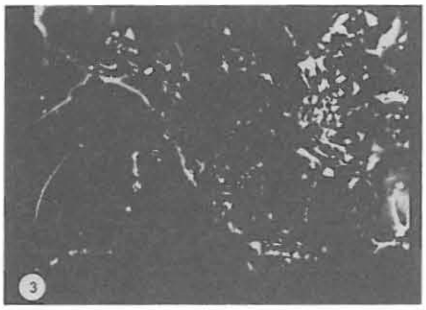






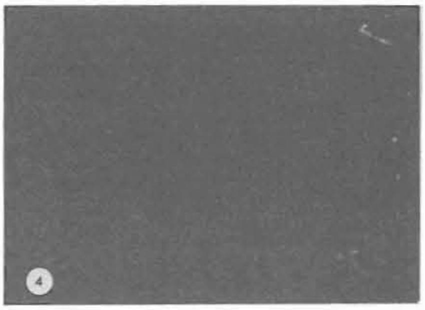


Fig. 1 & 2: Quartz from the KTB, depth: 400 m
Fig. 3: Quartz from the KTB, depth: 6669.73 m
Fig. 4: Quartz from the KTB, depth: 7402.17 m

Introduction

Routine SEM investigations of KTB cuttings show intensive surface corrosions of quartz. Characteristic features are:

- solution cavities
- etching pits
- rough surfaces
- precipitation of amorphous SiO_2 (Fig. 1 - 4)

Comparable corrosion patterns are also common in material from other sites of the European basement (i.e. Black Forest, Harz, Rheinisches Schiefergebirge). Surface corrosion is caused by mesozoic to recent saline solutions migrating through the rock pile. The existance of concentrated Ca-Na-Cl-water with Ca-contents of up to 15500 ppm, [1] has been proved at numerous sites in the drilling hole. Much higher concentrations of Ca were found in fluid inclusions.[2]

The connection between deep saline waters and surface corrosion was investigated in a series of preliminary experiments.
A first test dealt with the aggressiveness of saline solutions with regards to different types of KTB rock. Fragments of amphibolite and gneiss were cleaned in an ultrasonic bath, dried, weighed and added to 0.1, 0.5, 1.0 and 4.0 molale $CaCl_2$, KCl, NaCl and $MgCl_2$ solutions as well as in deionized water during a period of 50 days at a constant temperature of 80 °C .
Independent of the rock type the rate of decay is remarkably higher in $CaCl_2$ and $MgCl_2$ solutions than in NaCl and KCl solutions, and of course in deionized water (Fig. 5).
Another experiment was carried out with pure brasilian quartz. Crystals were crushed and seaved to obtain the 250-500 µm fraction. The grains were added to a $CaCl_2$ solution, sealed in hydrothermal bombs and heated to 280°C. After two weeks the quartz grains showed corroded surfaces (i.e. oriented v-shaped etch patterns, development of solution crevasses perpendicular to grain fracts) analogous to those of the natural material (Fig. 6-8).

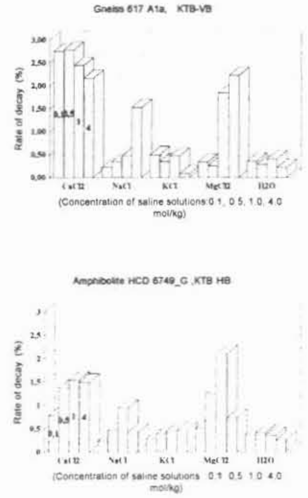
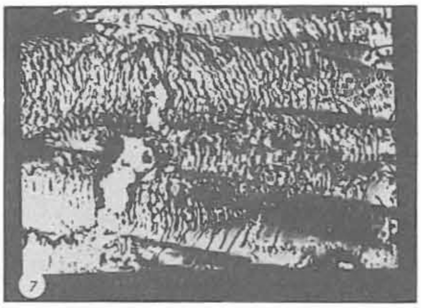
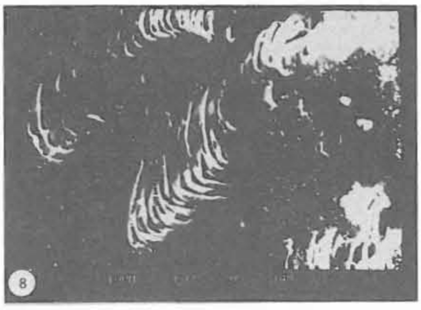


Fig 5





Conclusions

- A widespread high-saline solution system developed in the variscan basement under the postvariscian extensional regime. Original Na-K-Mg-Ca-Cl-solutions from the sedimentary cover descended gravitationnally down to depths of approx. 10 km. Ionic exchange with feldspars led to increasing Ca-concentration. Mobilisation to lateral and vertical directions was caused by seismotectonic pumping [3].
- On their migration path $CaCl_2$ solutions cause corrosional processes in the penetrated rock fabric. The quartz dissolution rate, in contrast to that in deionized water, is increased by interaction (adsorption) of cations at the crystal surface of quartz. This result in an increased accessibility of the Si-O-Si bonds [4]. Corroded mineral surfaces can be observed over the entire drilling profile. Corrosion intensity increases in zones of decreased well stability. Corrosive patterns are mostly developed at extension fractures and grain boundary fractures.
- The corrosive effects of $CaCl_2$-solutions were corroborated by laboratory experiments).
- The interaction of $CaCl_2$ water within the rock pile in an extensional regime produces zones of secondary porosity and permeability. It improves progressive infiltration and destabilisation of the rock fabric.
- The penetrative occurance of corrosional features in the deep drilling indicates continous activity of fluid flow under non-equilibrium conditions.
- Dissolved quartz is precipitated under changed conditions as veins and kristallrasen with inclusions of saline water [2]. Despite the intense cathodoluminescence contrast of quartz graines from cataclasis zones, corroded quartz graines do not show evidence of H_2O diffusion by SEM-CL. This suggests the corrosion to be a very young processe (presumably cretacious).
- It is suggested that the interaction of saline $CaCl_2$ waters with mineral surfaces is a promoting factor for destabilisation of the KTB well.

References

[1] Pekdeger,A., Sommer-von jarmersted,C. & Thomas, L. (1994). Scientific drilling (in press)
[2] Behr,H.J., Horn,E.E., v.d.Kerkhof,A.M., Reutel,C. & Topp,J. (1993). KTB-Report 93-2, 451-454
[3] Behr,H.J., Gerler,J., Hein,U. & Reutel,C. (1993). Gottinger Arb. Geol. Palaont. 58, 3-28
[4] Dove,P.M. & Crerar,D.A. (1990). Geochim. Cosmochim. Acta. 54, 955-969