HYDROTHERMAL TRANSPORT AND DEPOSITION OF SILICA

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The strong Si-O-bond under dry conditions and in absence of impurities needs high activation energy for mobilization. Chemical activation with water based on the reaction:

$$SiO_{2(s)} + nH_2O_{(g,f)} = SiO_2 \cdot nH_2O_{(g,f)}$$

lowers the energy barriers remarkably. Under normal conditions the equilibrium is extremely shifted to the left, however at increased temperatures and water-pressures (hydrothermal conditions) the reaction may cause strong chemical transport. The efficiency (rate) of transport depends on the physico-chemical and physical parameters (temperature, pressure, viscosity e.g.) as well as on the mechanism of flow.

The phase composition and micro-structure of the silica-deposit formed by the reverse process, strongly depends on rate of transport and deposition and on temperature of the substrate.

Experiments designed to study this were run in hydrothermal bombs with a cooling finger acting as substrate. The transport was achieved by convection due to density-differences in a temperature gradient. The experiments were carried out under mobilization-temperatures between 900 and 400°C and deposition-temperatures between 750 and 150°C with low to high rates of deposition.

The rate of deposition-temperature of substrate-field roughly may be divided into four domains:

1. high rate of deposition and high substrate temperature: prevailing deposition of cristobalite and cristobalite-tridymite disordered stacking polytypes with minor amounts of idiomorphic quartz and tridymite

2. low rate and high substrate temperature: prevailing deposition of idiomorphic quartz or chalcedony with minor amounts of quartz whiskers and idiomorphic tridymite

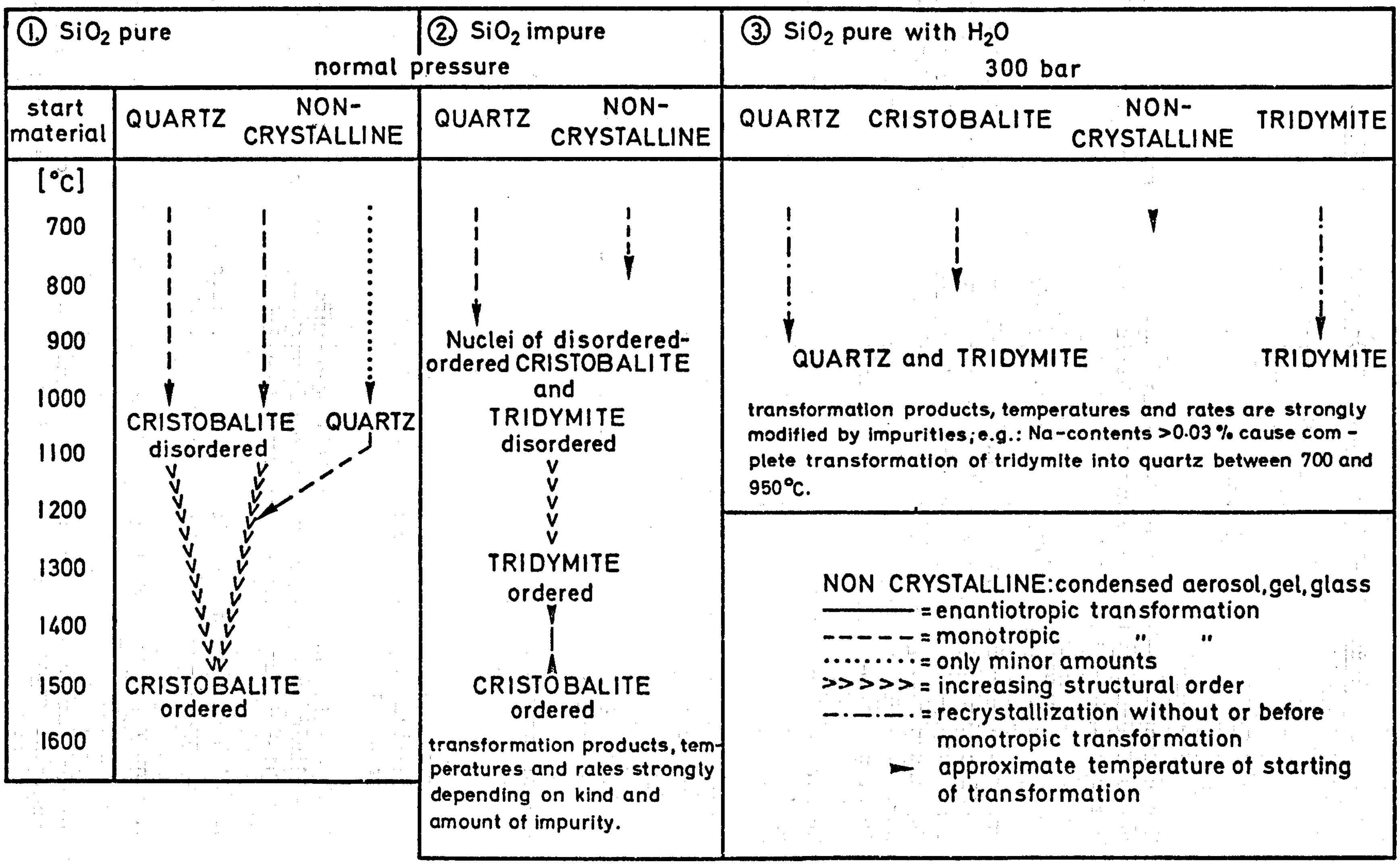
3. high rate of deposition and low substrate temperature: deposition of hyalite and minor amounts of opal-CT

4. low rate and low substrate temperature: deposition of opal-CT and some idiomorphic quartz.

The crystallagraphic properties of these deposits and the role of water-bonded as $(H_2O)_{mol}$ or $(H_2O)_{SiOH}$ in the silica-phases are discussed.

DISCLAIMER

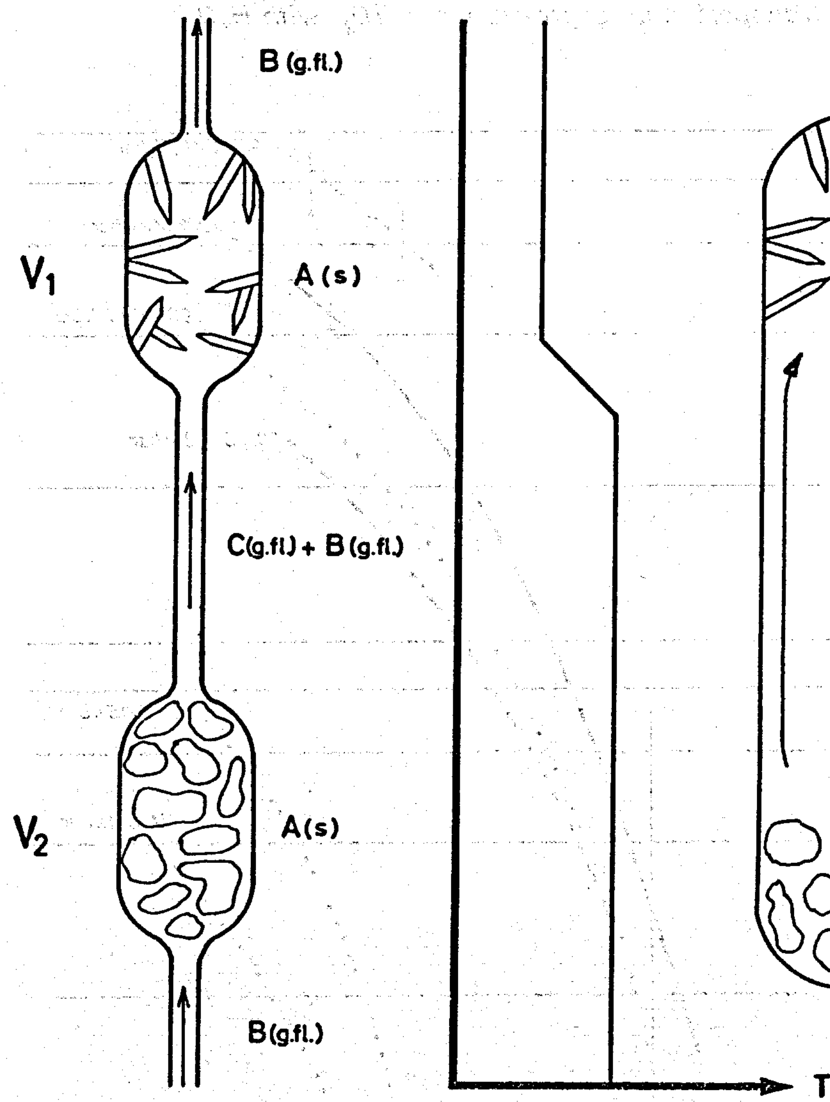
Transformation kinetics of pure (< 0.02 %) and impure (> 0.02 %) silica in absence of liquid; influence of time neglected



Mobilization of SiO_2 with H_2O

$$SiO_{2\,(s)} + n\,H_2O_{\,(g,f)} = SiO_2 \cdot n\,H_2O_{\,(g,f)}$$

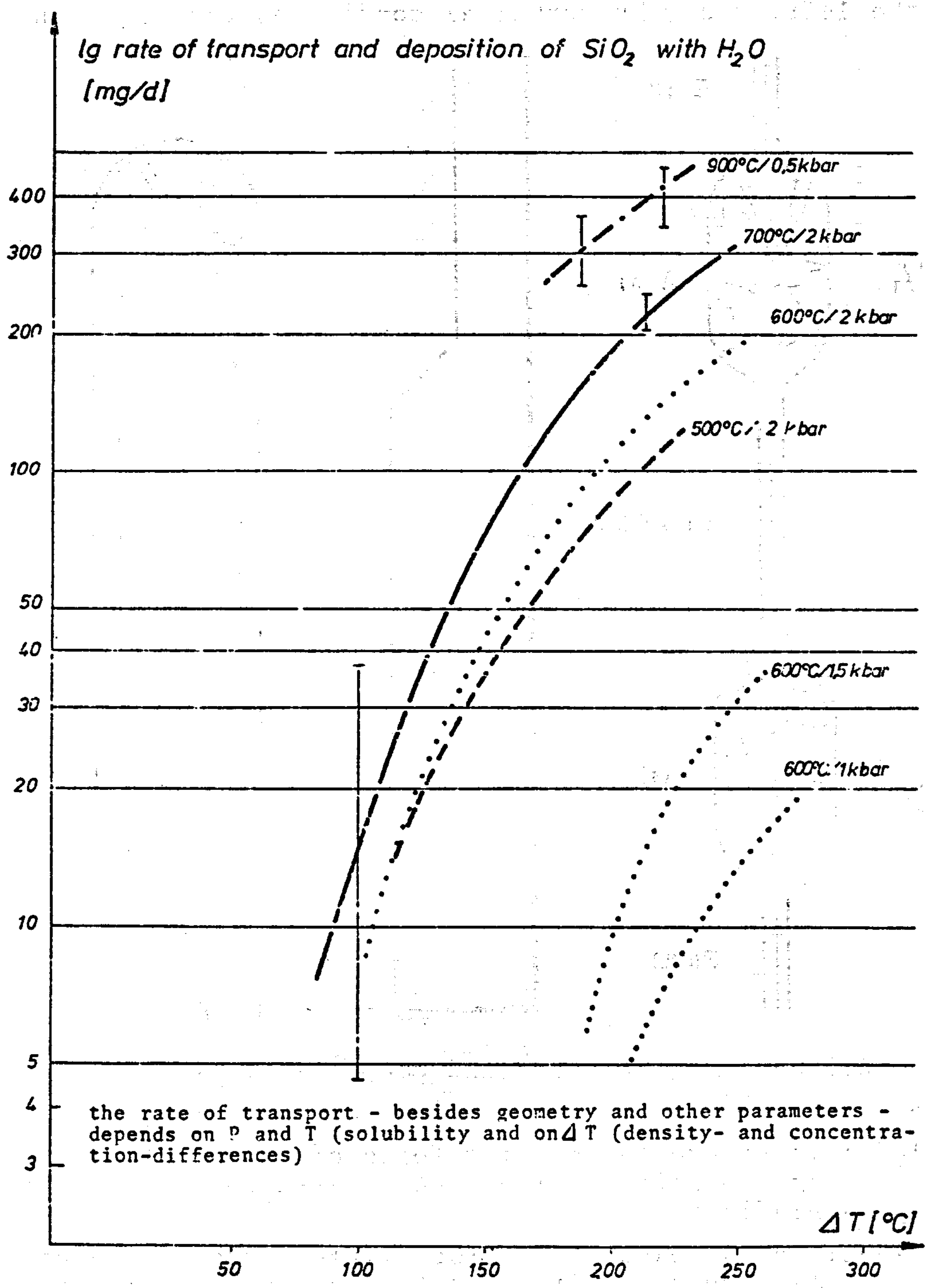
at normal conditions the equilibrium is extremely shifted to the left, under hydrothermal conditions the reaction

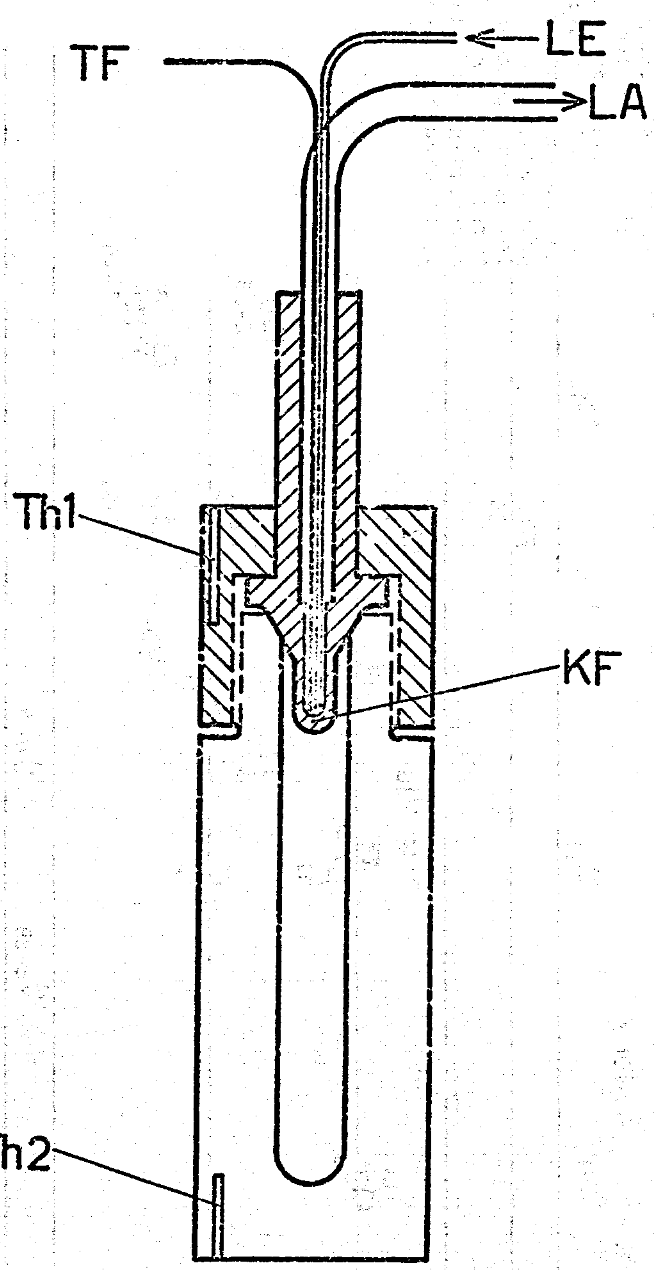


gets more and more balanced and chemical transport may take place.

at left: in nature the driving force of transport is an expansion current with pressure- and temperature-gradients

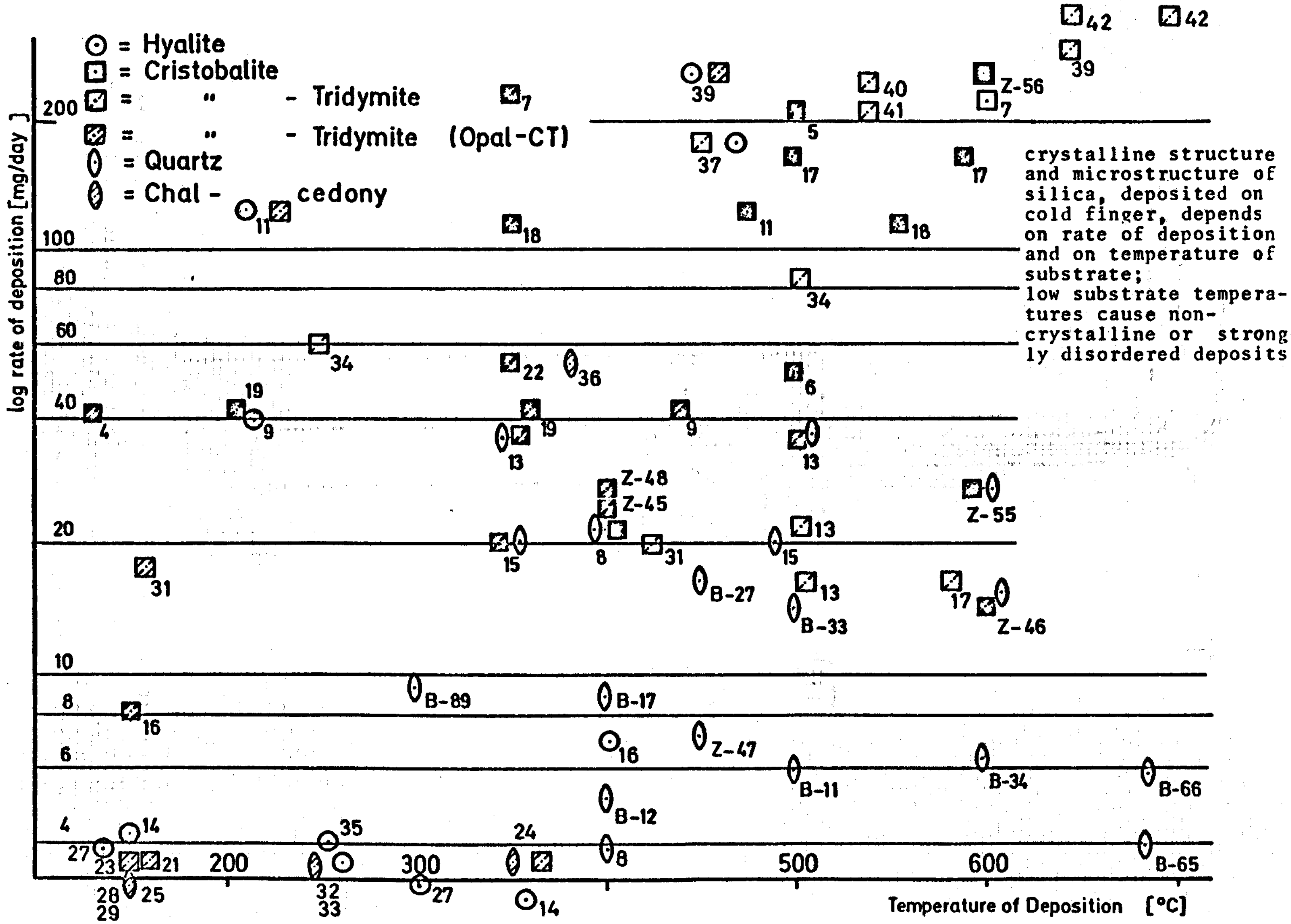
at right: in the experiments the driving force was a convection current with density- and temperature-gradients


lg rate of transport and deposition of SiO_2 with H_2O
[mg/d]
900°C/0,5kbar
700°C/2kbar
600°C/2kbar
500°C/2kbar
600°C/1,5kbar
600°C/1kbar
400
300
200
100
50
40
30
20
10
5
4
3
the rate of transport - besides geometry and other parameters - depends on P and T (solubility and on ΔT (density- and concentration-differences)
ΔT [°C]
50
100
150
200
250
300

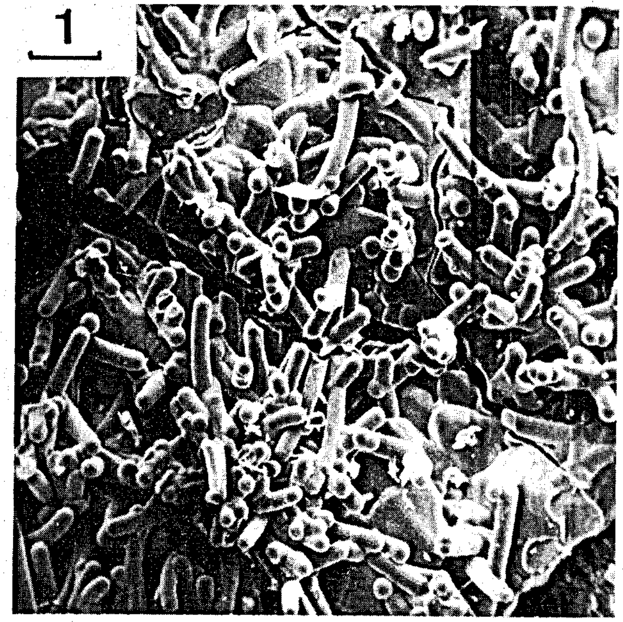


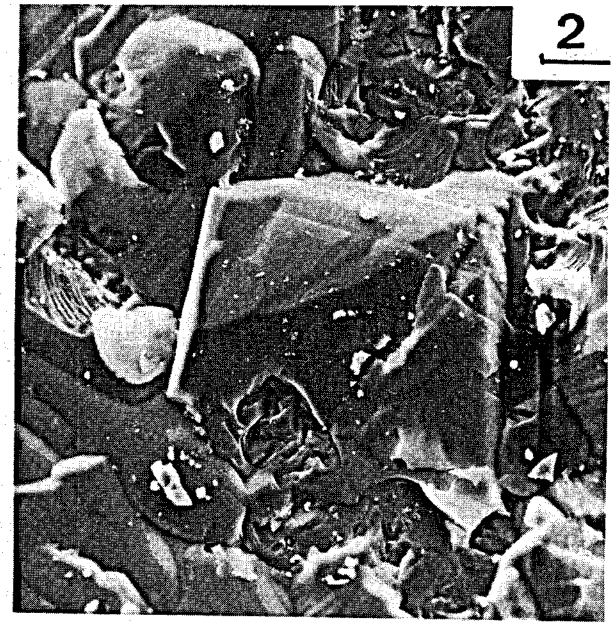
hydrothermal bomb with cold finger, used in the experiments

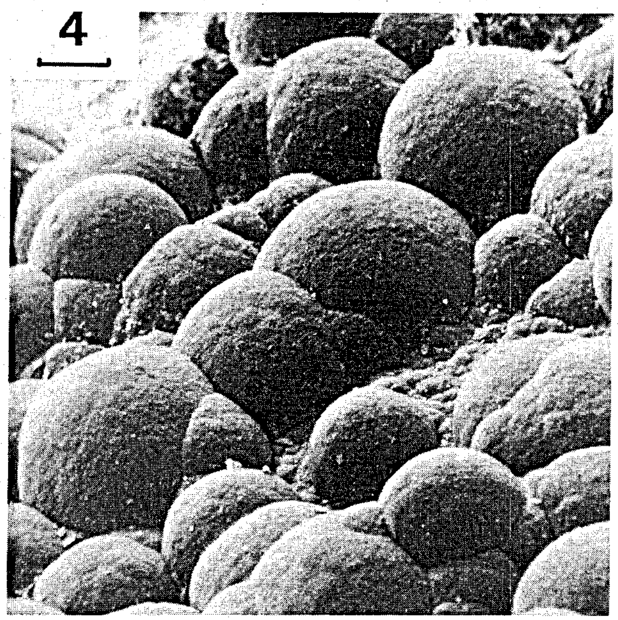
KF = cold finger; LE = air inlet; LA = air outlet; Th1 = bore for upper, Th2 for lower thermocouple; TF = thermocouple in cold finger;
diameter of reaction volume = 12 mm, length = 120 mm

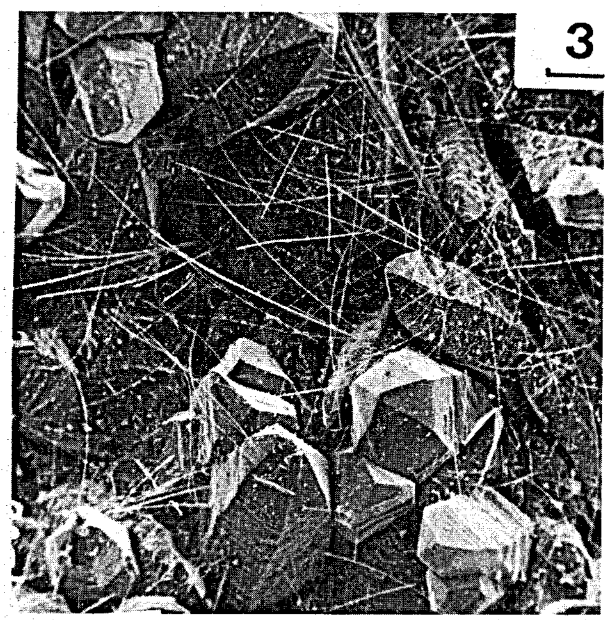


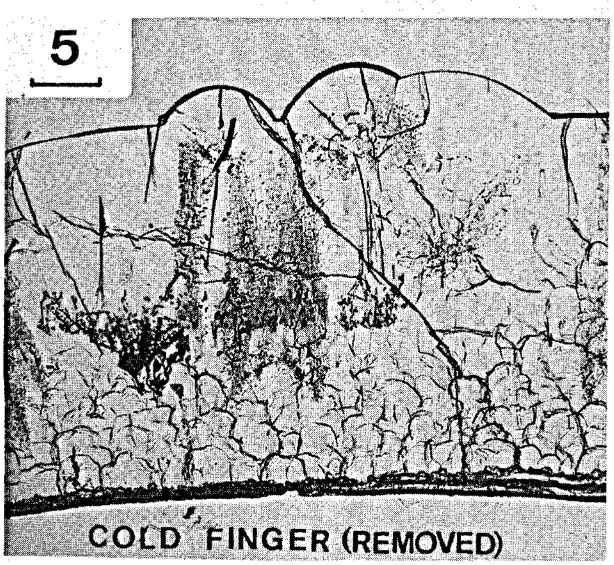
⊙ = Hyalite
⊡ = Cristobalite
= " - Tridymite
= " - Tridymite (Opal-CT)
= Quartz
= Chal - cedony
log rate of deposition [mg/day]
200
100
80
60
40
20
10
8
6
4
200
300
500
600
Temperature of Deposition [°C]
crystalline structure and microstructure of silica, deposited on cold finger, depends on rate of deposition and on temperature of substrate;
low substrate temperatures cause non-crystalline or strongly disordered deposits











SEM-photographs: ⊢⊣

1.	T(dep) low,	rate	(dep)	high	33 μm
2.	" high	"	"	high	33
3.	" high	"	"	low	100
4.	" low	"	"	low	100

1. hyalite (hydrous silica glass); 2. cristobalite; 3. quartz and quartz-whiskers; 4. opal-CT.

Micro-photograph:
5. thin section of deposit on cold finger; lower part T (dep) and rate (dep) high - well ordered cristobalite; upper part T(dep) and rate(dep) low - opal-CT (⊢⊣ 100 μm).