Stress relaxation of drill cores of the KTB main borehole

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Stress relaxation in drill cores results from the creation of a stress free surface by the drilling process. 4 Stages of relaxation can be distinguished:

1. **Elastic stress release during detachment of the core from host rock**
2. **Time dependent viscoelastic stress relaxation**
3. **Elastic stress release by secondary overcoring of the drill core**
4. **Time dependent viscoelastic stress release after secondary overcoring**

For all 4 stages the experimental methods and possible problems are briefly discussed.

1. Elastic stress release after detachment of the core from host rock

This effect is the basis of the door stopper measurement of in situ stress but can not be applied at greater depth. Elastic anisotropy due to microcrack formation, however, can be considered as a consequence of the stress release. It can be measured in the laboratory any time after core recovery and is systematically investigated by our group (e. g. ZANG, BERCKHEMER, WOLTER, KTB-Rep. 90-8, 1989).

2. Time dependent viscoelastic stress relaxation

The time dependent part of the stress relaxation can, after recovery of the core, be measured in a precision dilatometer. Many measurements of this kind have been carried out in the pilot hole (e. g. WOLTER and BERCKHEMER, Rock Mech. 22, 1989). So far about 15 cores from the main hole have been investigated. Compared to the pilot hole the following problems arose:

- Almost all of the cores investigated had been drilled with roller cone core bit with the effect that most of the residual stress has already be relaxed.
- The recovery of cores takes much more time (great depth, detachment of the drill pipes) with the consequence that most of the relaxation has already passed when inserting the specimen into the dilatometer.
- Core disking occured in some depth ranges which prevented to take sufficiently long samples to measure the vertical deformation (necessary for estimates of stress components).

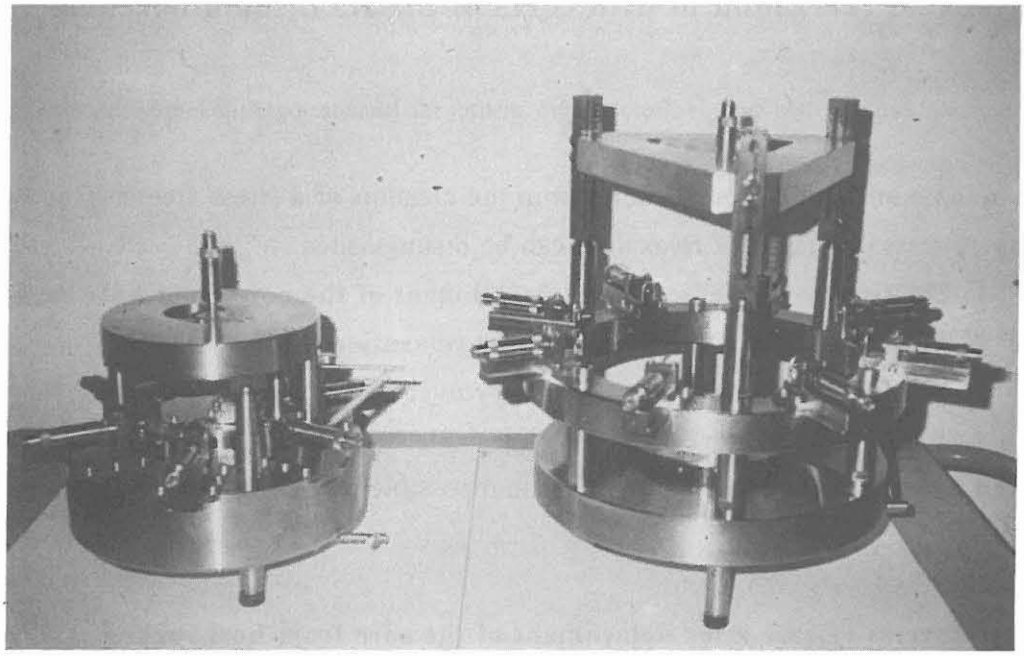

Fig. 1: Dilatometers for core diameter up to10cm (left) and up to 25cm (right).

Some cores, however, were drilled with a diamond bit. From these cores with large diameter of about 25cm considerably larger deformations are expected. For that purpose a new dilatometer with larger dimensions had been designed and built. Fig. 1 shows the previously used dilatometer for cores of 6-10cm diameter and the new one for cores of 10-25cm diameter. So far only measurement of one incomplete sample from the cataclasic zone could be carried out.

Further technical improvements of the system is a digital signal measuring device with 10 times higher resolution as hitherto. This was necessary to resolve the extremely small deformations sufficiently well. All quantities measured are graphically on line presented for a quick check of the course of the measurement. Now the time function of all ultracoustic emissions related to crack generation are stored in digital form for data analysis.

3. Elastic stress release by secondary overcoring

Secondary overcoring has the advantage that it can be performed any time after the lapse of the primary relaxation. For that reason and with regard to the above mentioned problems it is intended to make systematic use of this method, even our theoretical

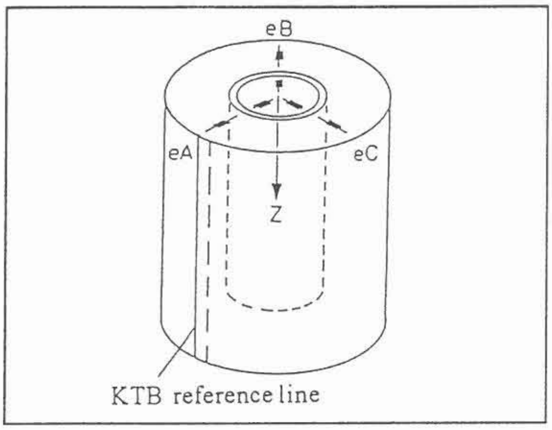

Fig. 2: Arrangement of strain gages for secondary overcoring experiment

understanding of the physical process is still incomplete (ZANG, Diploma thesis, Frankfurt 1987). The basic fact is that a residual stress remains "frozen" in the sample after relaxation of the primary stress. By concentric overcoring of the original core with smaller diameter a new free surface is created which causes an instantaneous and a time dependent deformation by redistribution of residual stresses. Fig. 2 shows the measurement principle. To measure components of the deformation tensor strain gages are applicated in 3 different directions on the inner core and the outer ring. For the inner core and the ring the principal deformations e1 and e2 can be calculated from the measured components. With the definition e1>e2 the following three cases can be distinguished: 0>e1>e2, e1>0>e2, e1>e2>0 (Fig. 3). All three cases have been observed in 8 experiments with cores from the pilot hole.

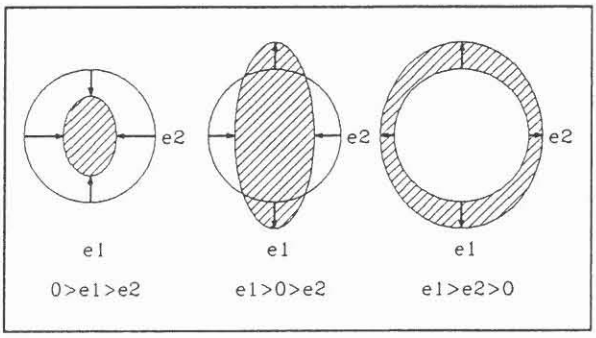

Fig. 3: Three cases for e1>e2:
1. contraction 2. undefined 3. dilatation

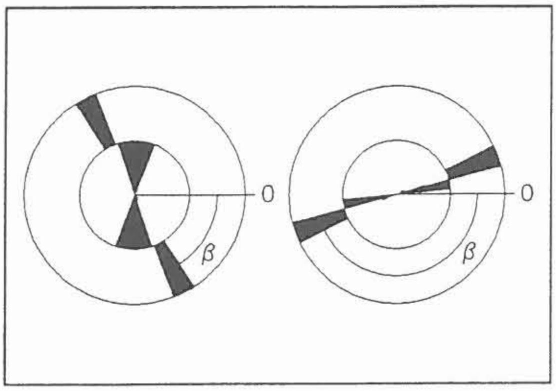

Fig. 4: e1 direction refer to KTB reference line: sample 741 (left) and 229 (right)

With secondary overcoring we are faced with the problem that the deformations are just above the limit of the resolution of the system since the secondary residual stresses are by more than an order of magnitude below the primary stress and variations in temperature, drift etc. might become critical. Fig. 4 and Table 1 show, as an example, the results for two cores. The direction of e1 of the inner and outer core shown as black sectors agree quite well with each other which proves that the results might be realistic. The reference directions (zero direction) is arbitrary. The width of the sectors indicates the uncertainty. In future experiments the above mentioned factors of disturbance will be reduced as far as possible.

Tab. 1: Strain amounts and directions

	Inner core				Outer core			
Sample	e1 [μ]	e2 [μ]	ß [°]	Case	e1 [μ]	e2 [μ]	ß [°]	Case
29	48±7	-73±8	170±5	2	-3±7	-84±12	160±5	1
741	22±6	-11±7	91±19	2	53±14	-30±7	63±5	2

4. Time dependent viscoelastic stress release after secondary overcoring

Analogous to the primary relaxation a time dependent relaxation of the inner core and outer ring is also to be expected after secondary overcoring. In order to observe these very weak effects the dilatometer discribed in section 2 will be used. The large cores from the main hole promis best results. However a test with a core from the pilot hole shows, that although very small, a time dependent deformation after secondary overcoring exists and can be measured (Fig. 5). The zero point of the time scale is the time of thermal equilibration (ca. 1h after secondary overcoring). The azimuth of e1 is the same as the direction of e1 of the elastic stress release (Fig. 4).

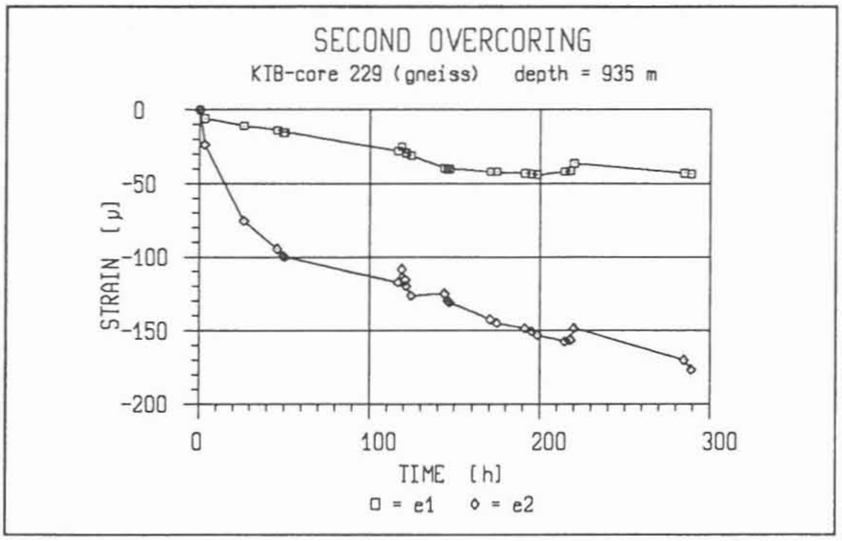

Fig. 5: Time dependent secondary relaxation of KTB pilot hole core 229