Sandia National Laboratories

Verantwortung für Generationen
Responsibility for Generations
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Discrepancy between modeling and measurement in the realization of seals

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Outline

- Pre-conditions & pilot seals in Germany
- Goals of the Asse seal project
- Test field & in situ investigations
- Calculation procedure and results
- Comparison of calculated and measured stresses
- Evaluation and conclusions 2008 & 2014

Pre-conditions

Pilot seal → but very few are realized

(1) Measuring data must be available

(2) Calculation results suitable for comparison must be available

(3) Good documentation status

(4) Advantageous: Finished project to avoid change of interpretation subsequently

(5) Measuring data as well as calculation results must be publicly available

(6) How to report about discrepancies between measurements and calculations?

Pilot seals in Germany

Projects:

- Shaft seal Salzdetfurth
- Asse-seal (Asse-Vordamm)
- Asse pilot flow barriers (PSB A1 and PSB A2)
- ERAM plug
- other seal projects (CARLA, Sondershausen)

→ Asse-seal is chosen for example

→ All reports were published in the framework of VSG thanks to BMUB and BfS

Goals of the Asse-seal Project (2001 - 2008)

"In context with the closure of the Morsleben repository (ERAM) the potential migration of brine and gas passing salt-concrete seals has to be evaluated. According to present knowledge the contact zone between the sealing body and the surrounding rock is an important migration path and thus is decisive for the permeability of the seal. In order to show that the hydraulic conductivity of the seal is sufficiently small, the permeability of the contact zone has to be quantified. Respectively, it has to be shown that no defects exist in the contact zone leading to an intolerable degree of permeability of the seal, i.e. exceeding a permeability of 10^{-18} m^2 on average. According to technical regulations in Germany investigations on comparable structures are required to assess the tightness of contact zones.

For this purpose a 10-year-old salt-concrete seal in the Asse mine in Lower Saxony has been investigated, whose structure is comparable to the seals planned for the ERAM. This seal had been built within the framework of an abandoned research project. A detailed investigation concept comprising in-situ measurements and laboratory tests was developed and a method has been established to transfer the boundary conditions of the Asse mine to the ERAM, where the seals will be constructed. " Source /Contribution WM-5233, Waste Management Conf. 2005/

Pilot seal test field

Boundary conditions for in situ investgations

- Depth 945 m
- Salt concrete (cement, NaCl-brine, crushed salt)
- 8 m in length, 5.5 m in width, 3.4 in height
- Built in 1992
- In situ investigations 2002 – 2004
- Laboratory tests until 2007
- Reporting 2008

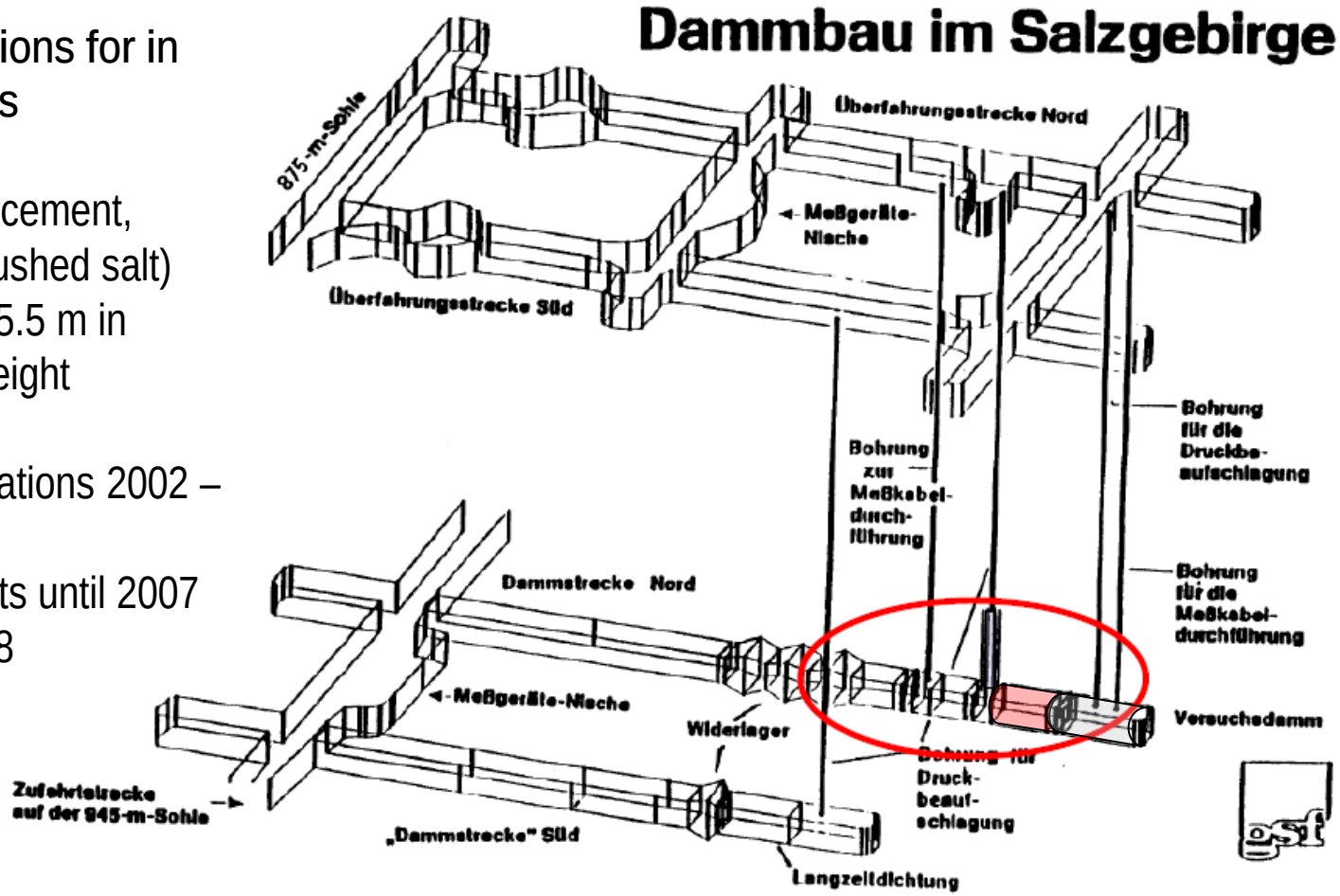


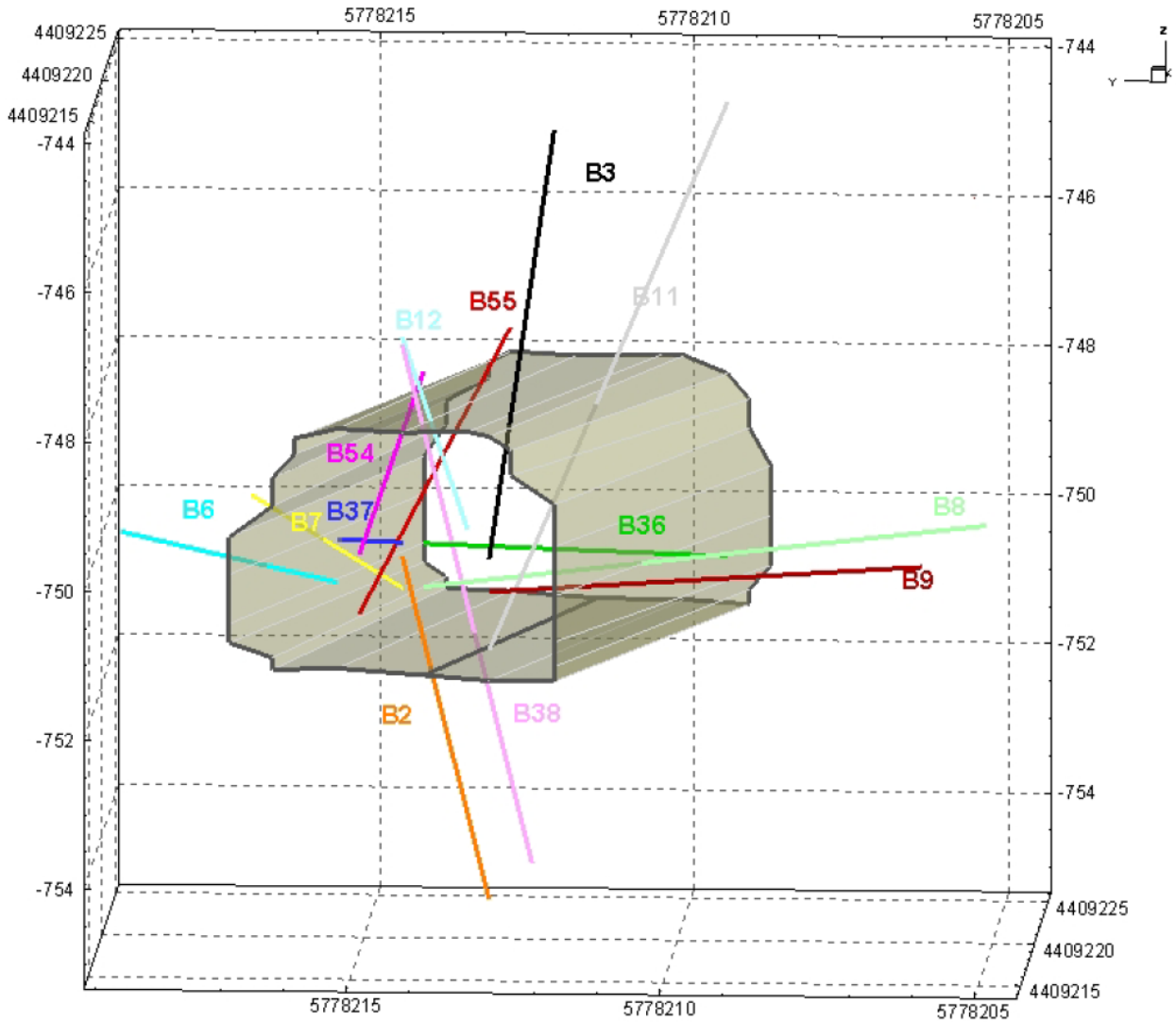
Abb. 2.1-1: Lage des Versuchsfeldes in isometrischer Darstellung

In situ investigations

- Permeability tests at representative measuring positions (mainly contact zone)
- Ultrasonic measurements covering the whole contact zone to underpin representativeness of permeability tests
- Hydrofrac-measurements to determine present stress state to asses stress and deformation history in order to transfer results to ERAM conditions

- Additionally, long-term measurements (temperature, deformation, stress) at the pilot seal test field were available because the test field was included into geotechnical surveillance of the Asse mine

Borehole positions

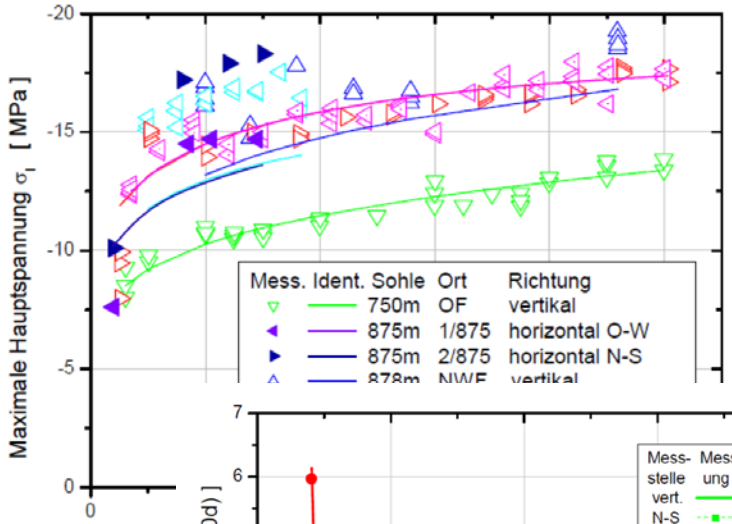


Permeability:
all boreholes

Hydrofrac:
B2, B3, B6,
B7, B8, B9,
B11, B38

Calibration of calculation model

- Calibration of the calculation model of the test field using geotechnical surveillance measurements



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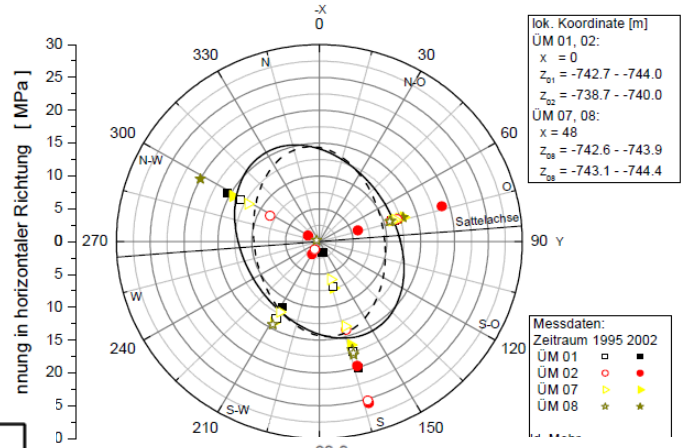
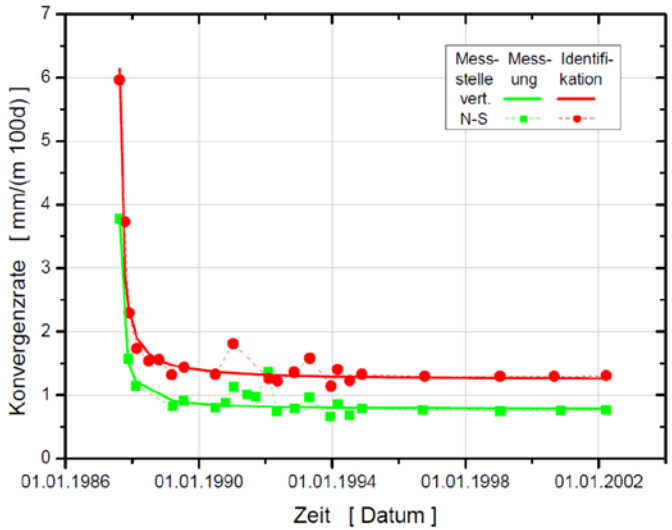
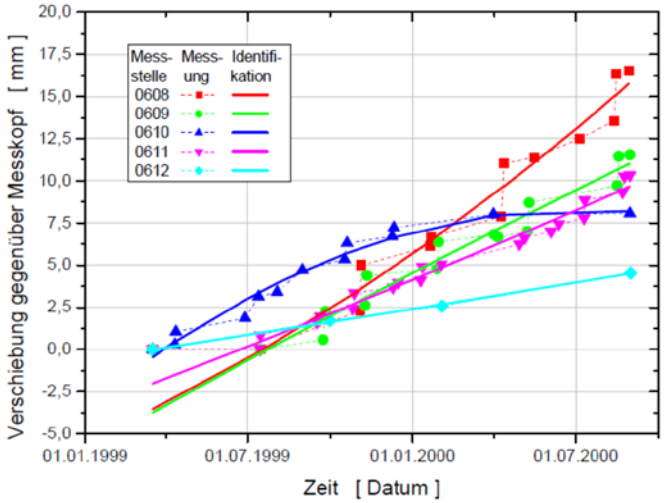
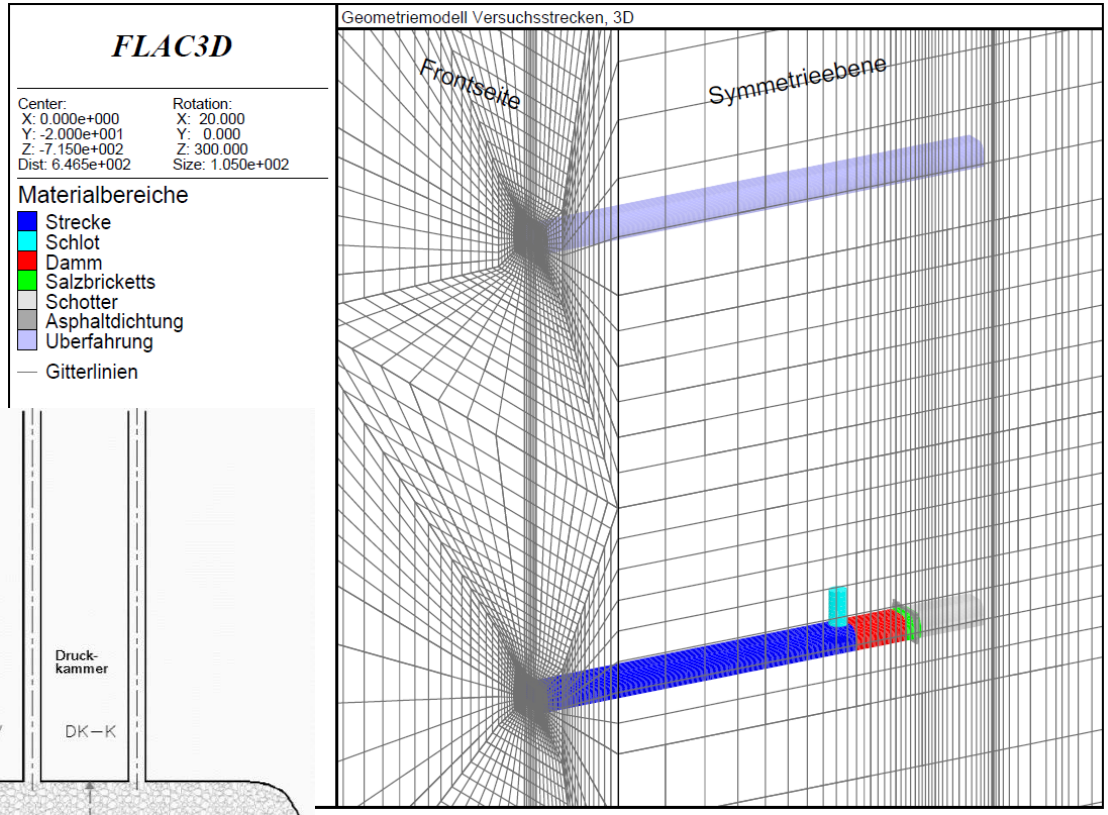


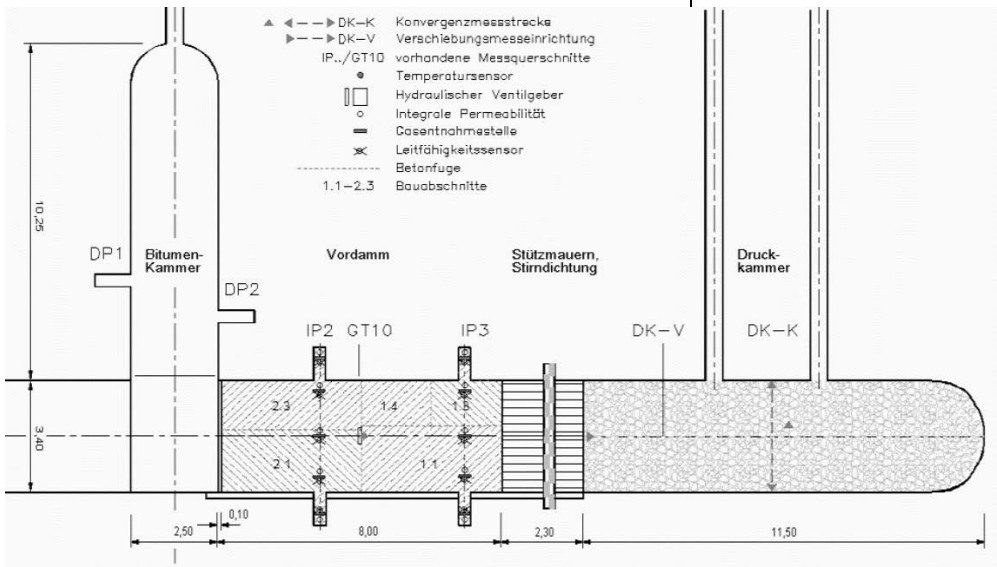




Calibration of calculation model

- A large number of variants were calculated and ranked against each other





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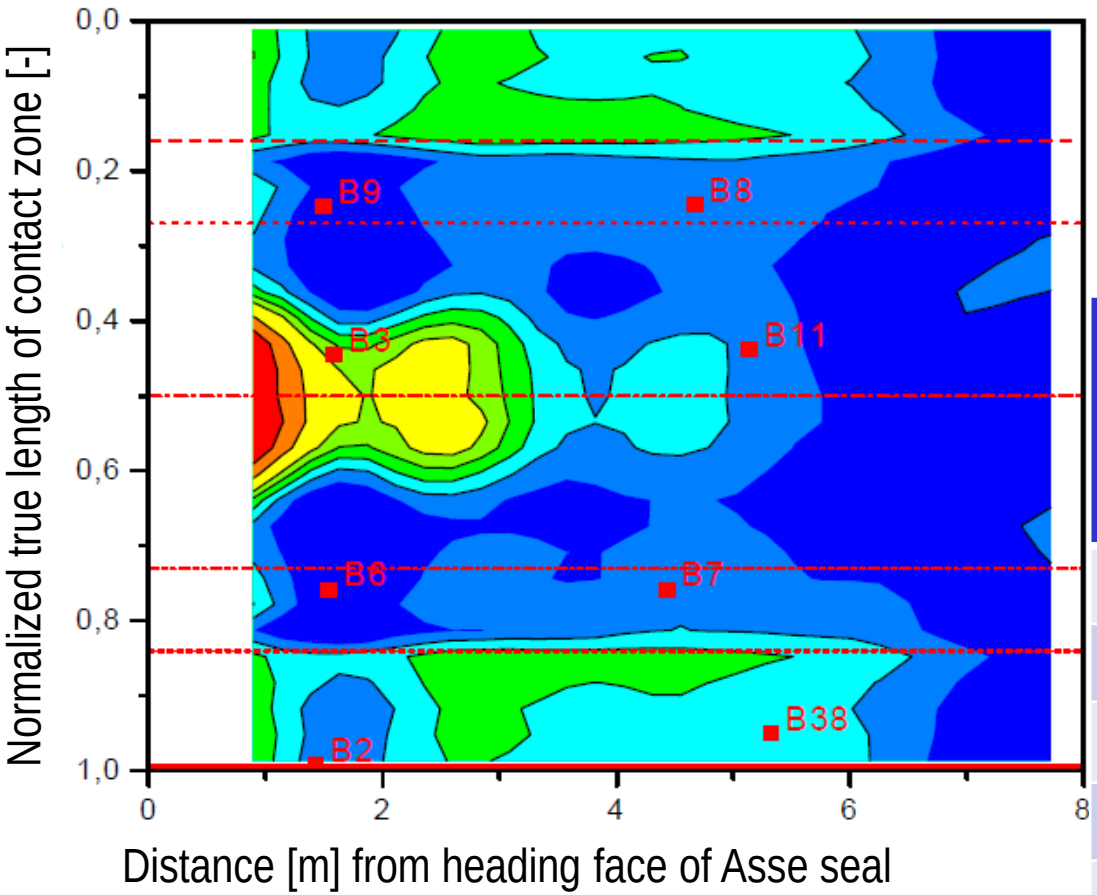
Calibration of calculation model

- The “best fit” was not unique
- Three “best fits” showing a slight anisotropy
- The influence of boundary conditions was negligible (sf/uf)

Variant	Boundary conditions		Stress component [MPa]			Stress invariants [MPa]	
	stress	displ.	σ_{xx}	σ_{yy}	σ_{zz}	σ_0	σ_{eff}
M32	sf	uf	-20	-20	-20	-20	0
M27	sf	uf	-18.0	-20.0	-20.0	-19.3	2,00
M41	sf	uf	-18.5	-19.0	-20.0	-19.2	1.32
M29	sf	uf	-17.0	-17.5	-19.6	-18.0	2.39
M35	sf	-	-15.0	-17.0	-19.0	-17.0	3.46
M15	-	uf	-15.0	-16.0	-20.0	-17.0	4.58

Calculated vs. measured stress (hydrofrac)



- Centre floor
- Intersection floor/southern wall
- Centre southern wall
- Centre roof
- Centre northern wall
- Intersection northern wall/floor

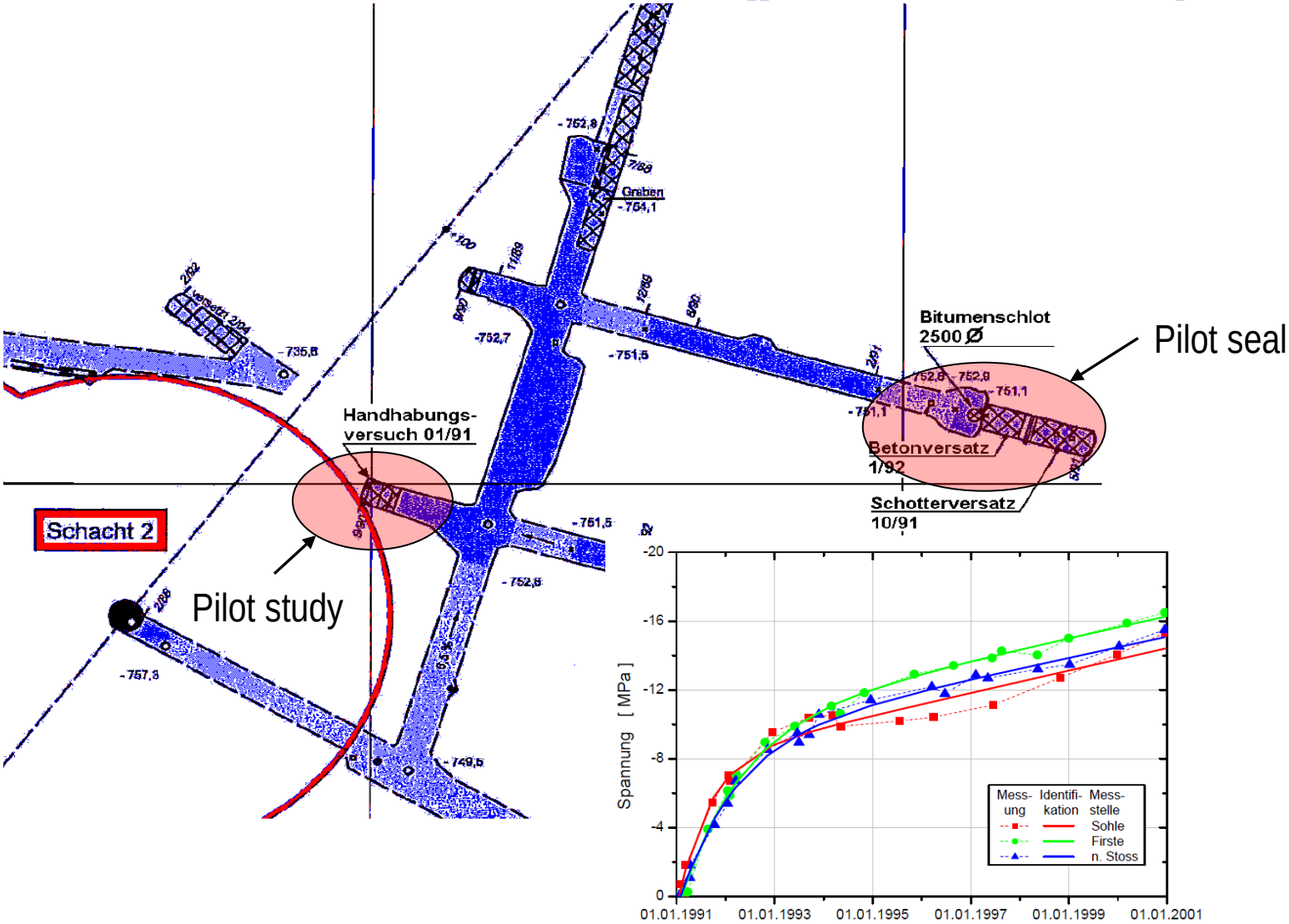
Pos.	Meas. values	Calculated variants		
		mean	max.	min.
B2	3.45	-16,2	-15.5	-17.2
B3	n. m.	-14.0	-13.5	-14.9
B6	2.53	-17.3	-16.9	-18.2
B7	6.93	-16.3	-15.8	-17.4
B8	13.09	-16.4	-15.9	-17.5
B9	6.64	-18.1	-17.6	-19.1
B11	2.05	-17.5	-16.8	-18.3
B38	15.59	-15.7	-14.9	-16.6

Calculated vs. measured stresses (hydrofrac)

- Approximately comparable calculated stresses at similar positions, only slight deviations due to anisotropic stress boundary conditions
- Wide range of measured stresses (hydrofrac) at comparable positions
- Large discrepancies between calculated and measured stresses, good agreement only at 2 (out of 8) positions (B8 and B38)

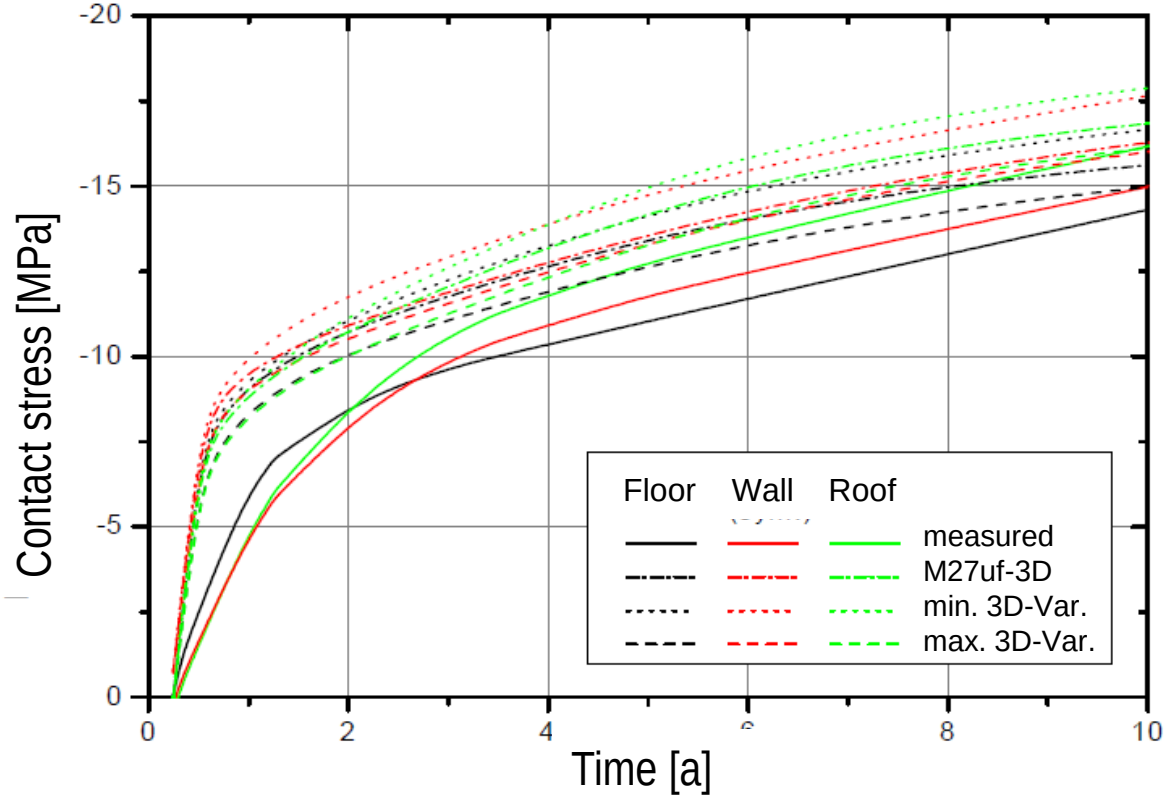
- Explanation?

Stress measurements (pressure cells)



Measured stresses (pressure cells) in contact zone of pilot study

Calculated vs. measured stress (pressure cells)



Good agreement of calculated and measured stress

Explanation: The direction of least principal stress and contact stress is not identical!

Evaluation & conclusion 2008

- The discrepancy between calculated and measured stresses (hydrofrac) lead to detailed investigations
- Fortunately, additional stress measurements (pressure cells) were available
  - Applying pressure cells the direction of measured stress is fixed, the stress component within the stress tensor may vary
  - Applying hydraulic fracturing the least principal stress is measured, the direction may vary
  - Calculated stresses and measured stresses from pressure cells agree well
  - Hydraulic fracturing shows wide range of least principal stresses and varying directions in the contact zone

➢ In 2008 permeability was assumed to be constant material property → The goals of the Asse seal project were successfully achieved showing a sufficiently low permeability of the contact zone

Evaluation & conclusion 2014

- Review of 2008 results: The discrepancy itself was explained but the origin of the wide range and varying directions hydrofrac measurements is still an open question
- Residual stresses from construction process ?
- Restraint stresses due to different material properties of salt concrete sealing body and surrounding rock salt?

➢ **From todays knowledge this aspect needs further investigation as permeability of tight and damaged rock salt depends – due to strong hydromechanically coupling - on the effective least principal stress**

Acknowledgements

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Thank you
for your attention!