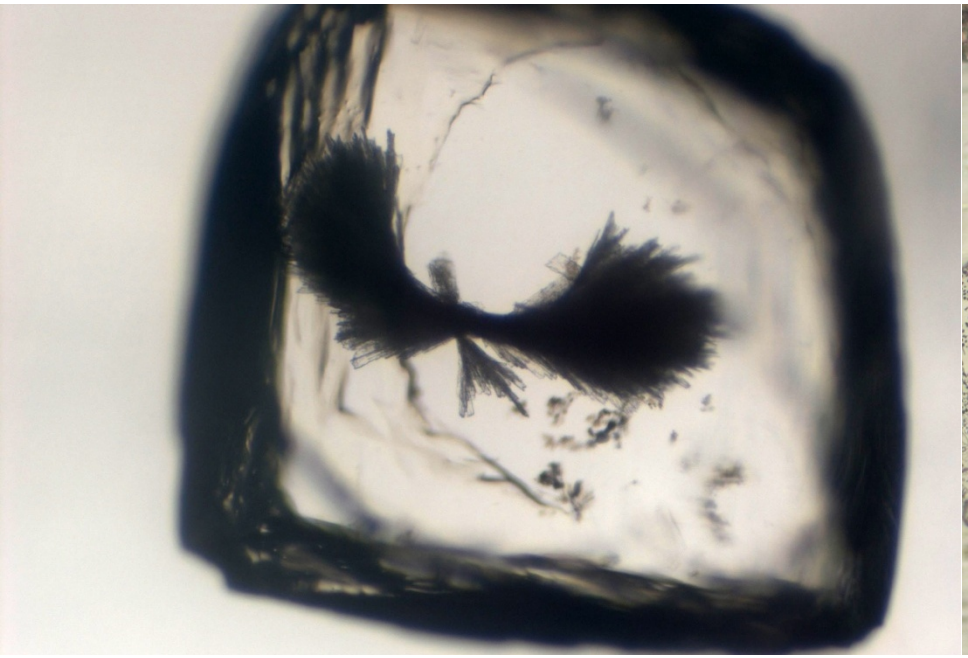
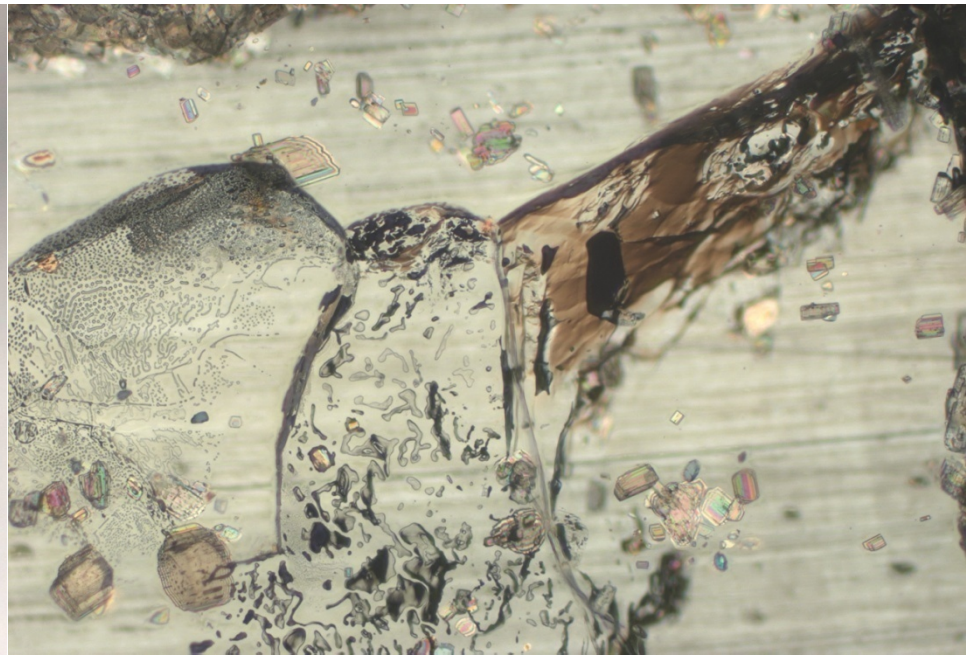
Petrography, fluid distribution, geochemistry and microstructures of halite rocks from WIPP-Site (and Gorleben)

Maximilian Pusch, Jörg Hammer, Christian Ostertag-Henning





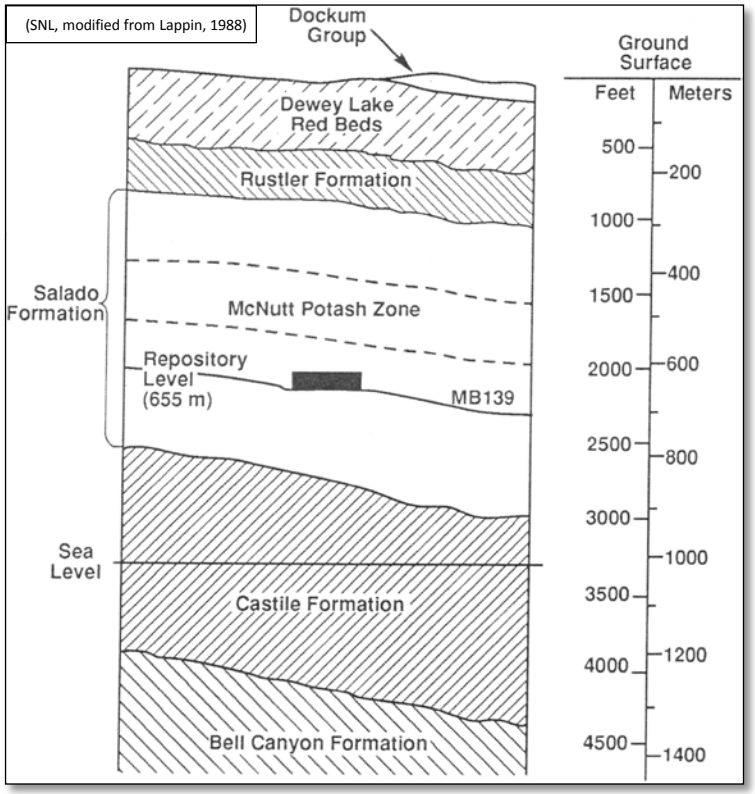
5th US/German Workshop on Salt Repository Research, Design, and Operation

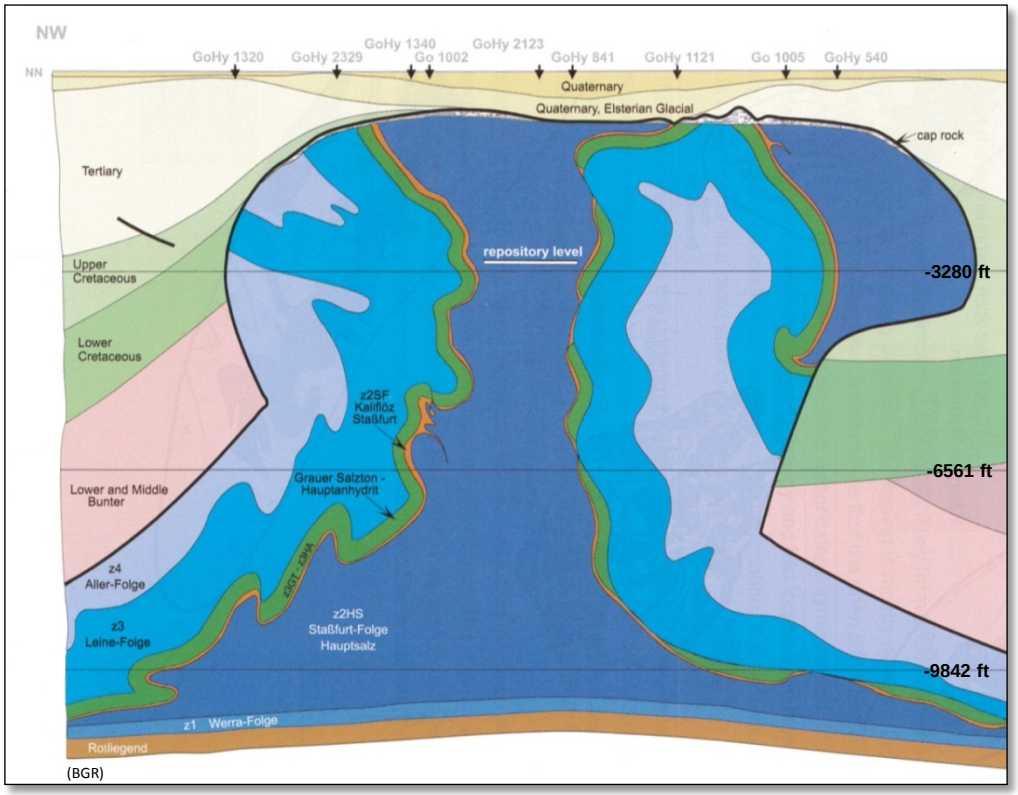
September 7 – 11, 2014 | Santa Fe, New Mexico

BGR Federal Institute for Geosciences and Natural Resources

GEOZENTRUM HANNOVER

Permian salt formations of WIPP (flat bedding; Delaware basin) & Gorleben (salt dome; North German basin) in comparison

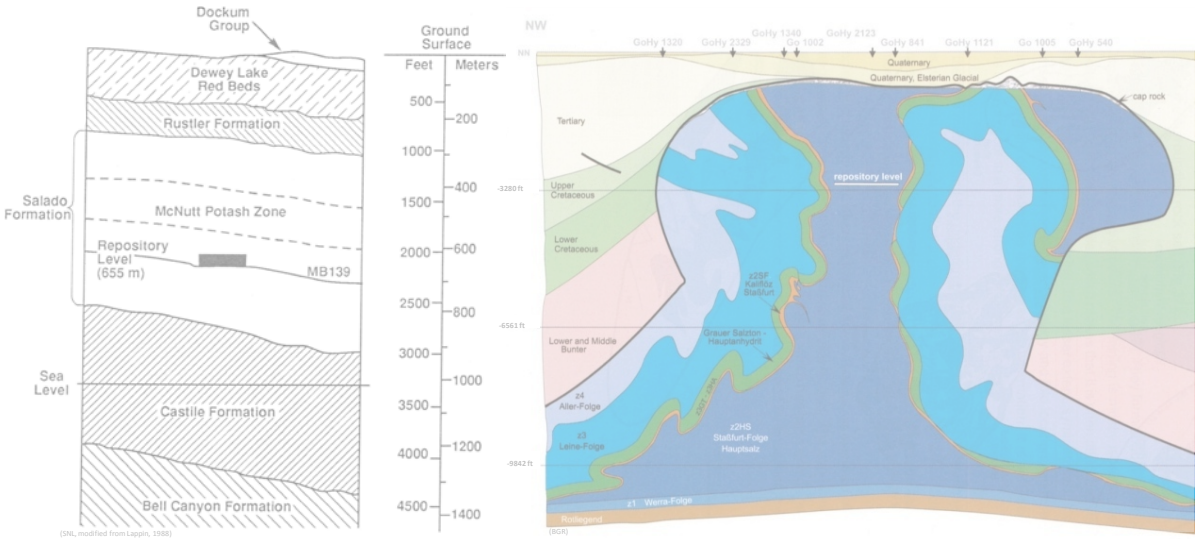




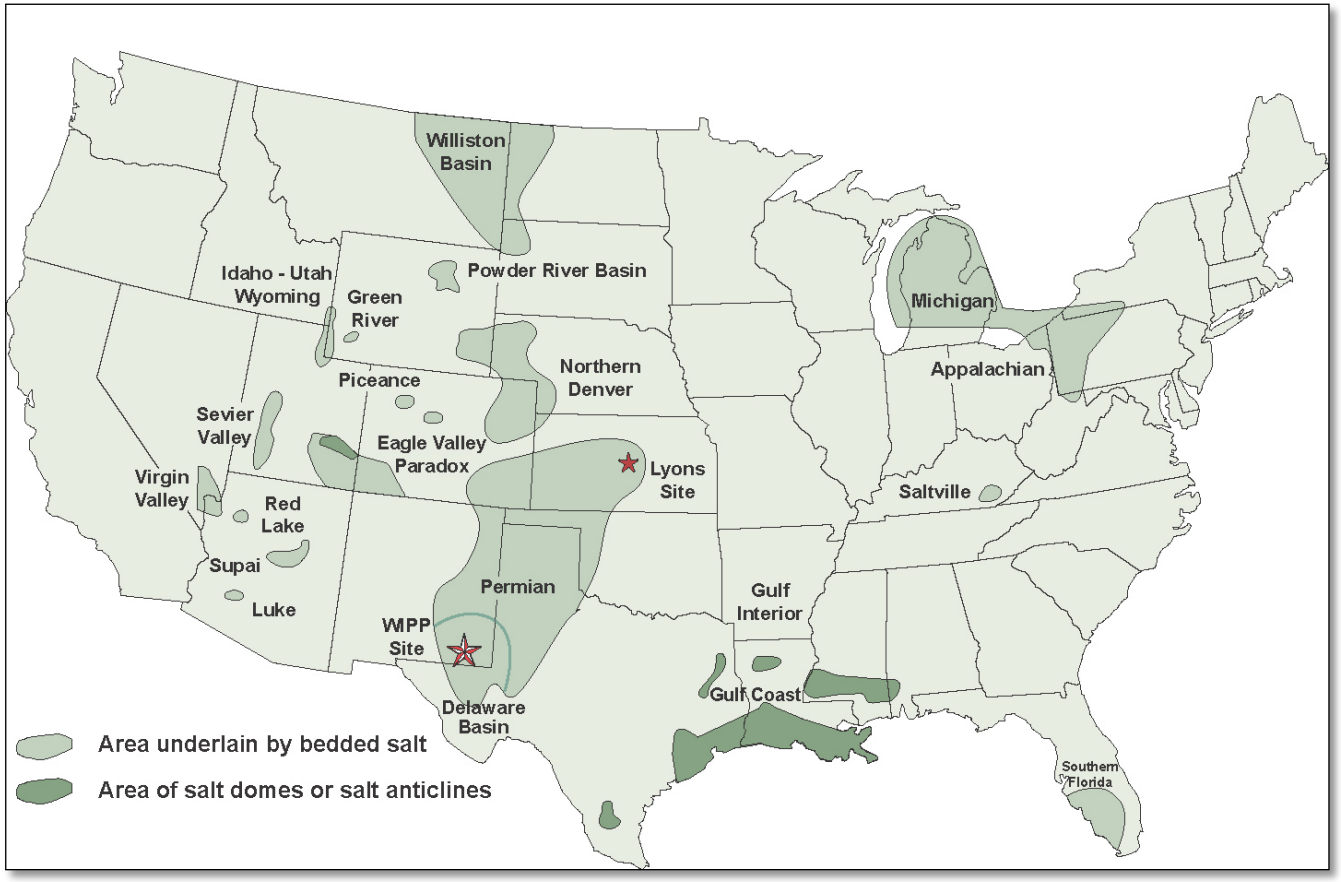
Permian salt formations of WIPP (flat bedding; Delaware basin) & Gorleben (salt dome; North German basin) in comparison

Comparison of halite rocks from flat bedding vs. salt dome

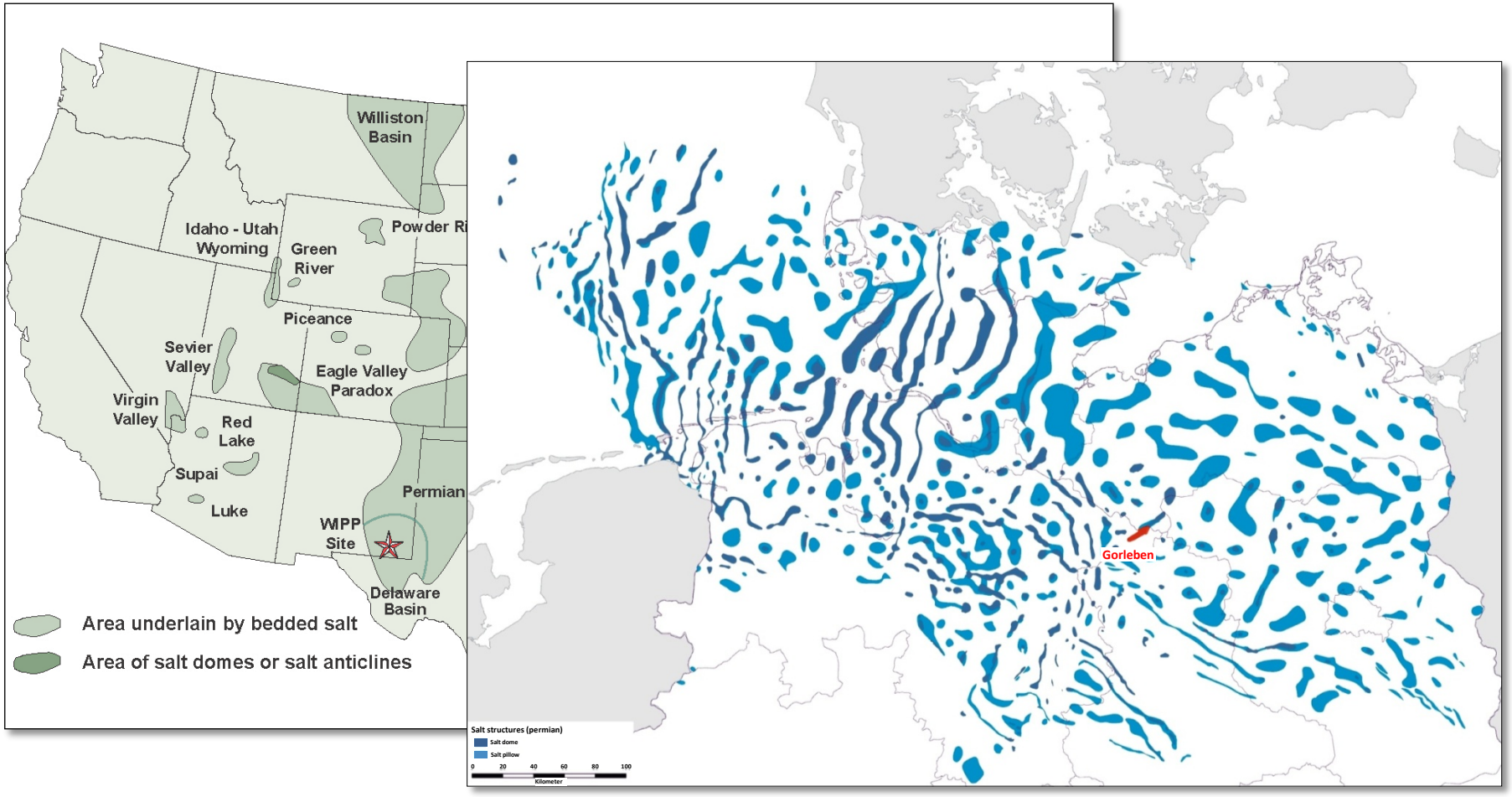
- petrography, mineralogical composition and microstructures
- moisture, composition and distribution of fluids
- concentration and composition of hydrocarbons within the host rocks
- differences in geochemical composition



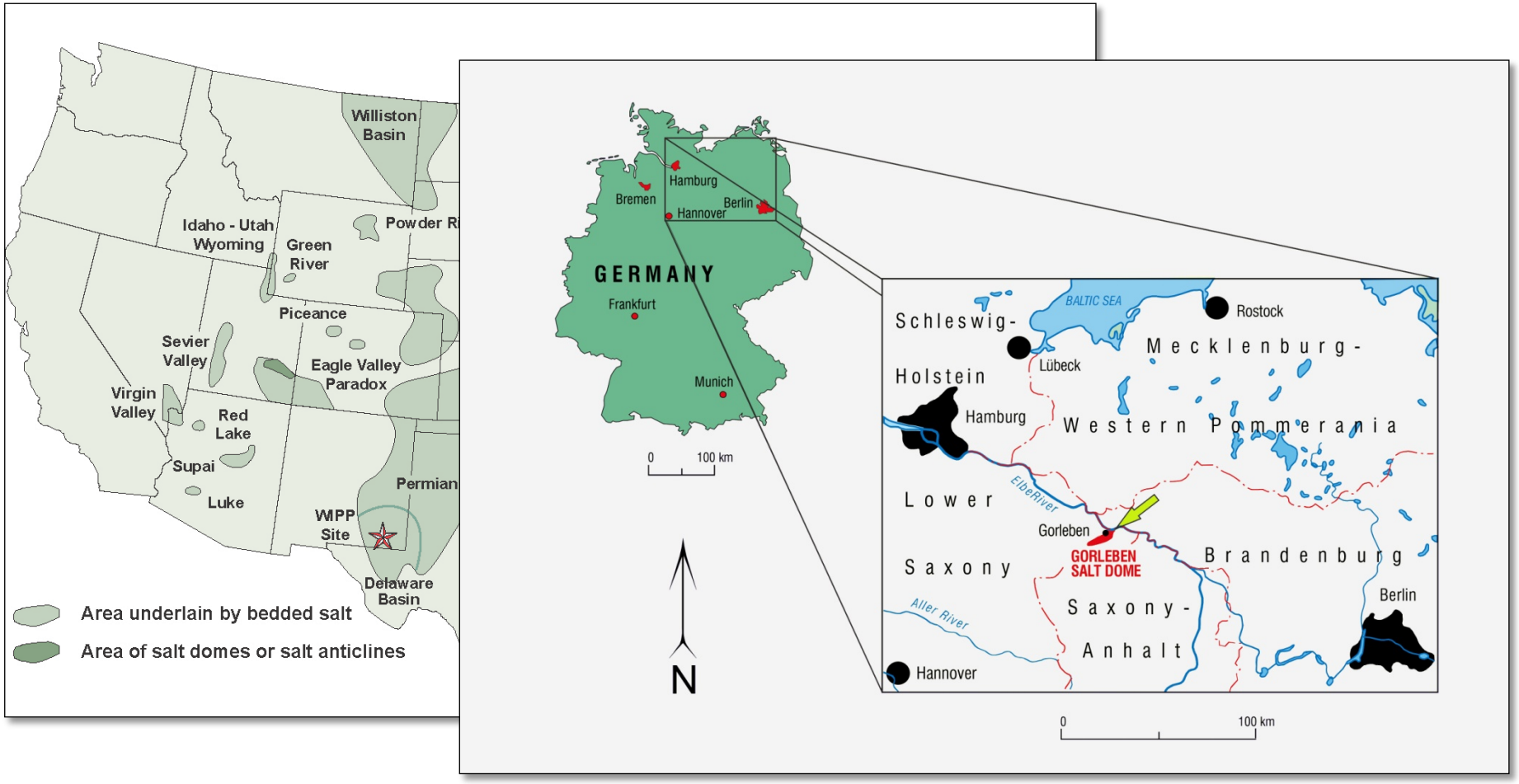
Location of WIPP (Delaware basin) & Gorleben (North German basin)



Location of WIPP (Delaware basin) & Gorleben (North German basin)



Location of WIPP (Delaware basin) & Gorleben (North German basin)



Drill core segments used for sampling of WIPP salt

SNLCV302

1´4.73“

2´3.04“

SNLCV302

MB 139

3´4.55“

4´1.01“

SNLCV302

MB 139

5´2.99“

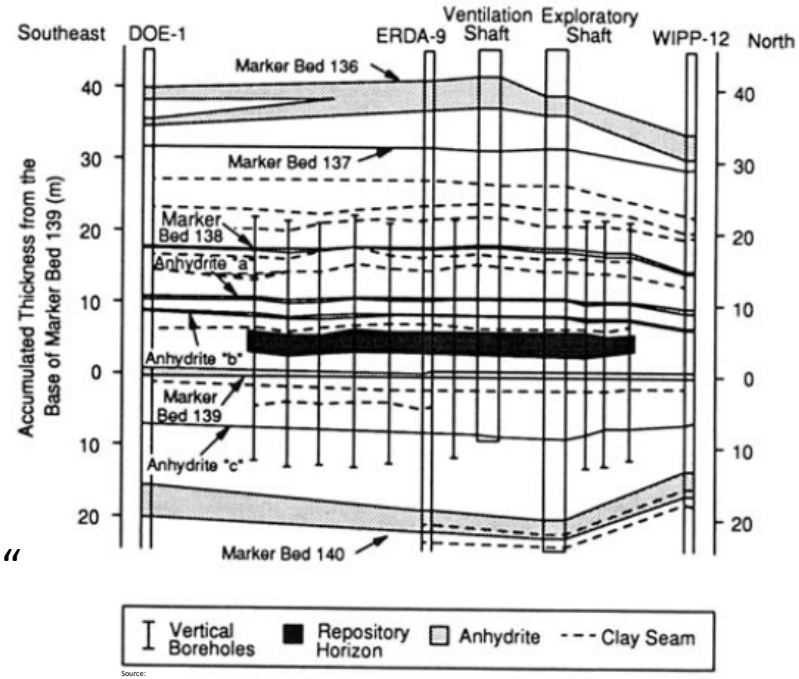
5´6.14“

SNLCV302

7´2.02“

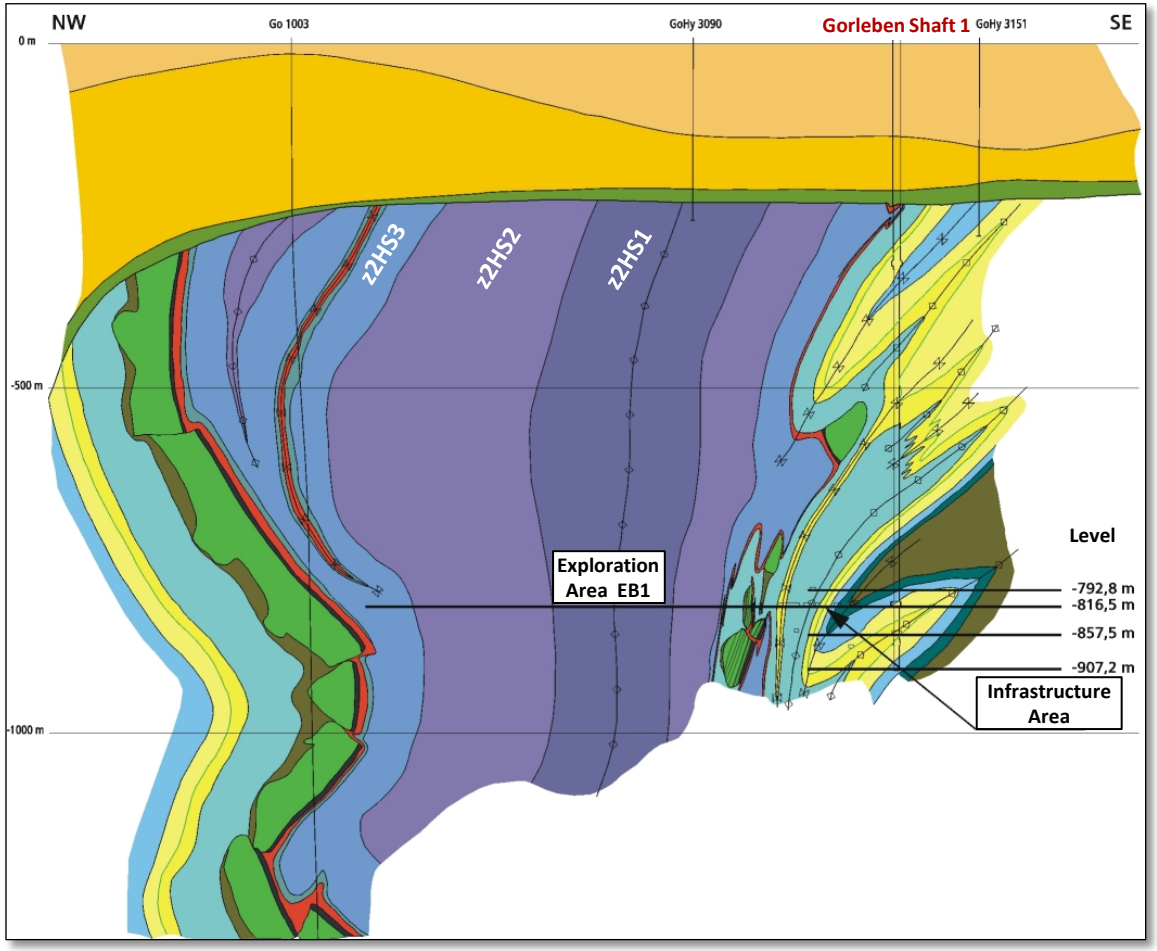
7´10.09“

WIPP-Site
Salado-Formation



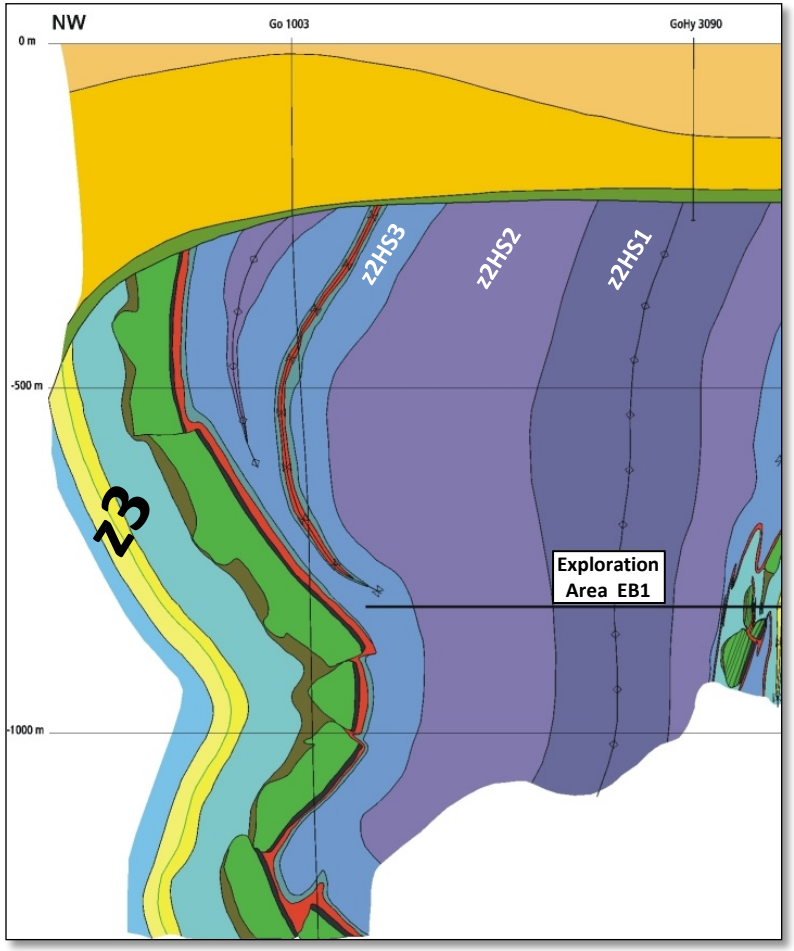
Source:
The Waste Isolation Pilot Plant:
A Potential Solution for the Disposal of Transuranic Waste
Committee on the Waste Isolation Pilot Plant, National Research Council (1996)

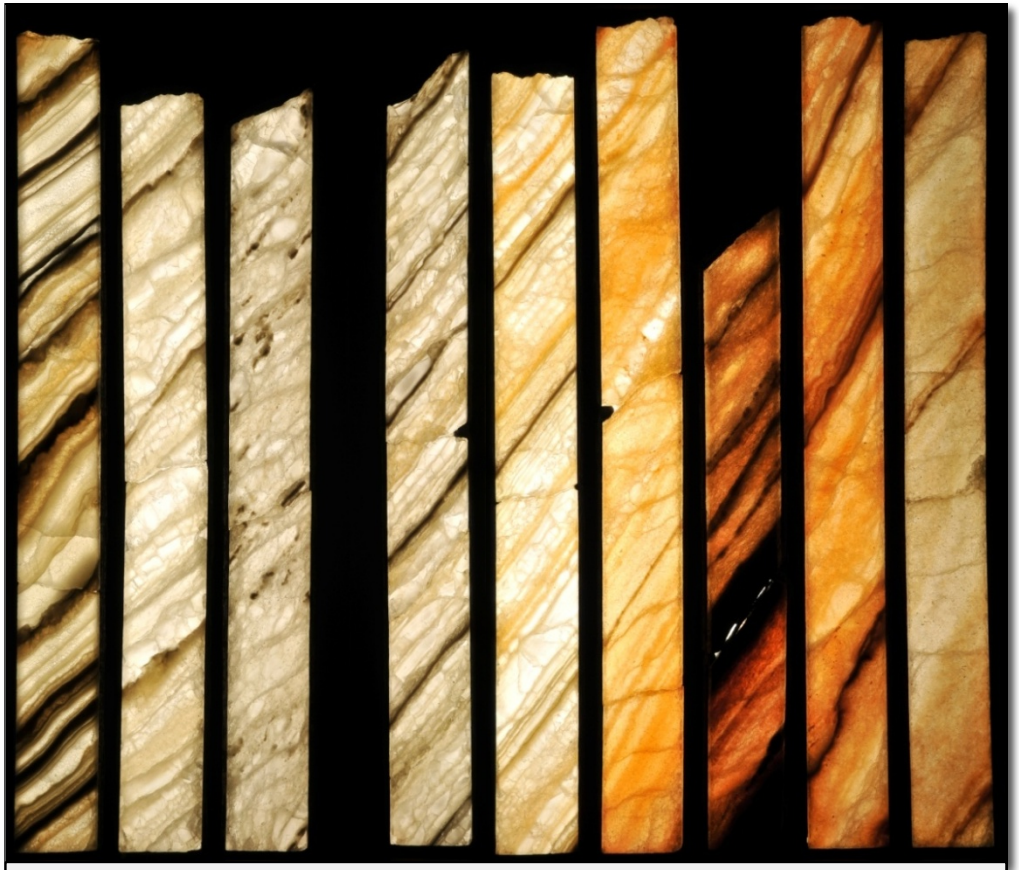
Bisected drill core showpieces of Zechstein z2 and z3 from Gorleben



Zechstein 2

Bisected drill core showpieces of z2 and z3 from Gorleben





Zechstein 3

Petrography, mineralogy and microstructures of WIPP salt

SNLCV302

1´4.73“

2´3.04“

3´4.55“

SNLCV302

MB 139

4´1.01“

SNLCV302

MB 139

5´2.99“

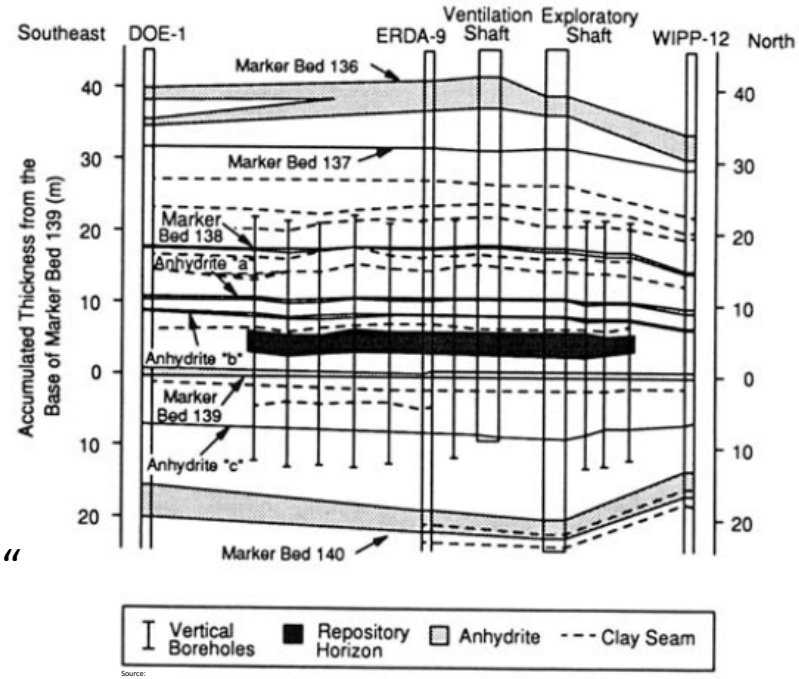
5´6.14“

7´2.02“

SNLCV302

7´10.09“

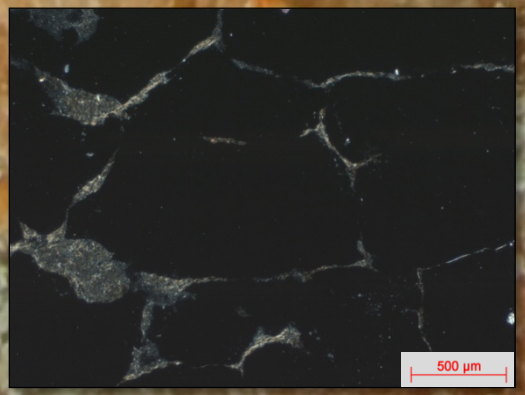
Halite, light orange
to light gray
(bottom of MB 139)

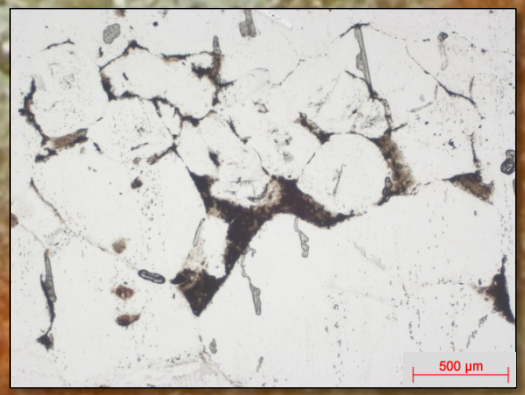


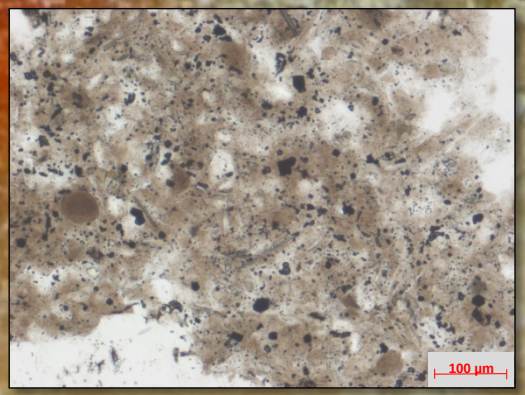
Source:
The Waste Isolation Pilot Plant:
A Potential Solution for the Disposal of Transuranic Waste
Committee on the Waste Isolation Pilot Plant, National Research Council (1996)

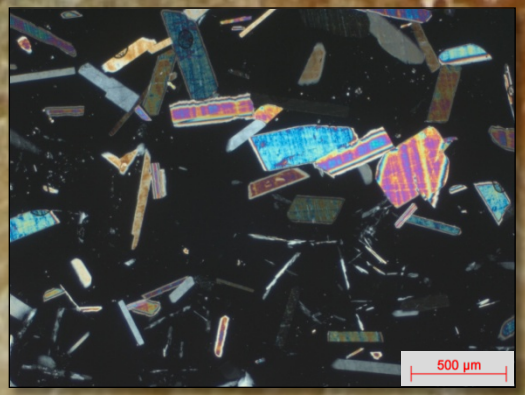
Characteristics of Halite (Bottom of MB 139)

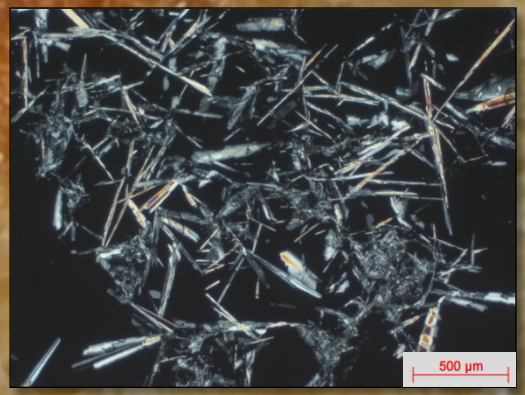
Thin sections from depth 7´2.61“ to 7´9.30“

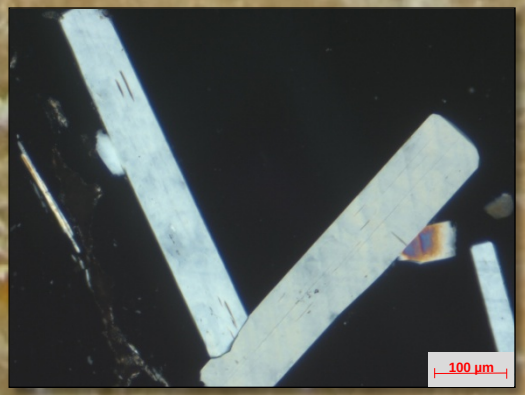












Drill core segments used for sampling of WIPP salt

SNLCV302

1´4.73“

2´3.04“

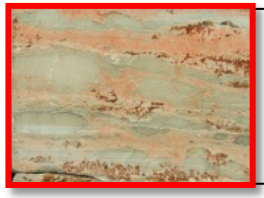
3´4.55“

SNLCV302

MB 139

4´1.01“

SNLCV302



MB 139

5´2.99“

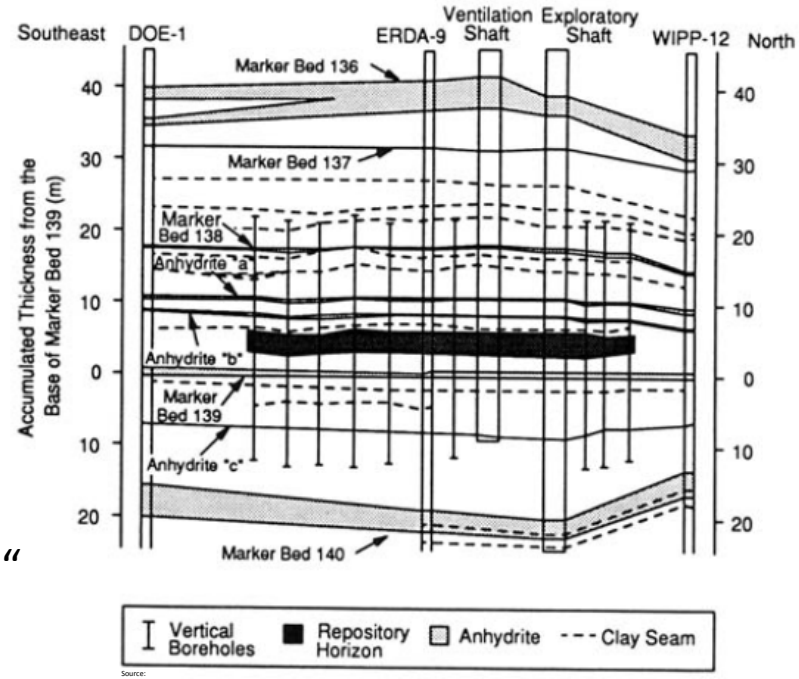
5´6.14“

7´2.02“

SNLCV302

7´10.09“

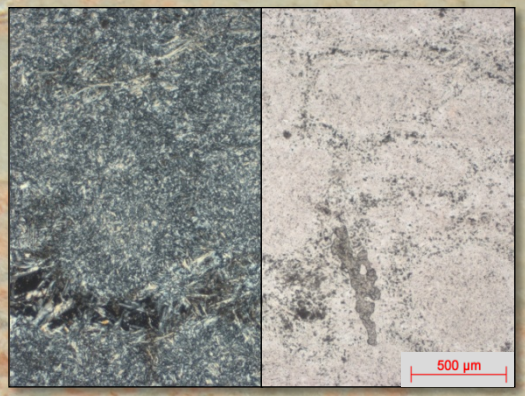
Polyhalitized zone
(MB 139)

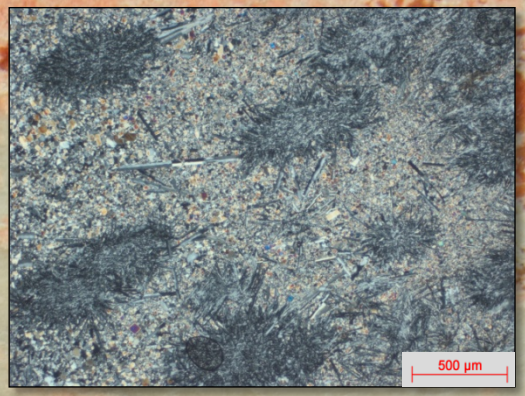


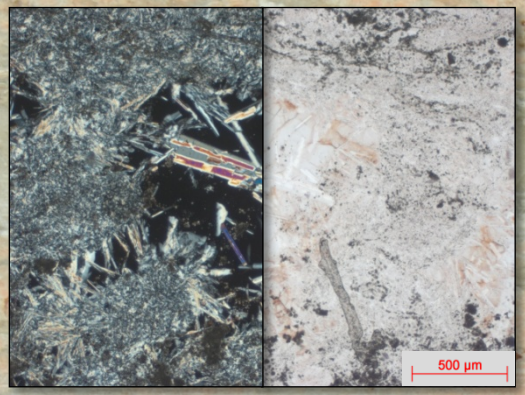
Source:
The Waste Isolation Pilot Plant:
A Potential Solution for the Disposal of Transuranic Waste
Committee on the Waste Isolation Pilot Plant, National Research Council (1996)

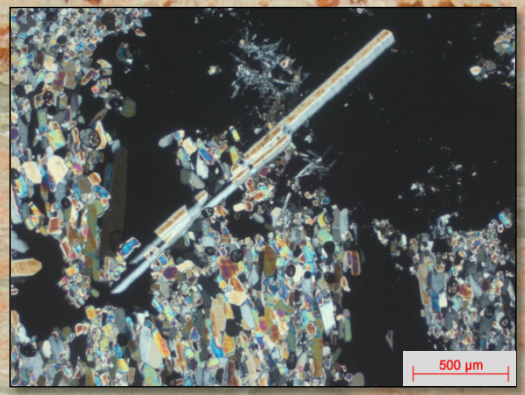
Characteristics of Polyhalite zone (MB 139)

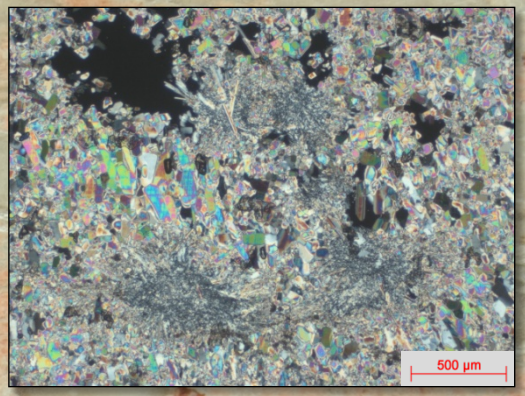
Thin sections from depth 5´2.99“ to 5´9.09“











Drill core segments used for sampling of WIPP salt

SNLCV302

1´4.73“

2´3.04“

SNLCV302

MB 139

3´4.55“

4´1.01“

SNLCV302

MB 139

5´2.99“

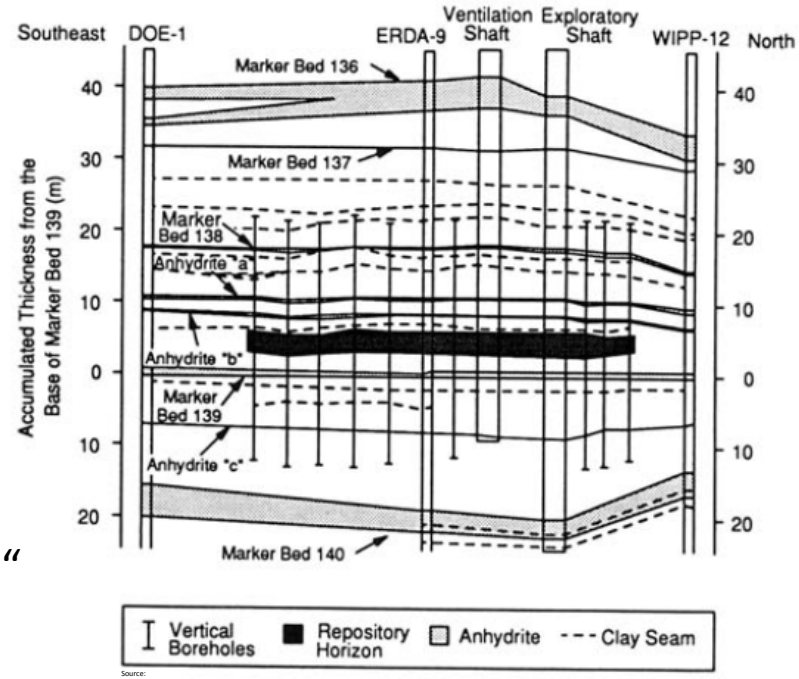
5´6.14“

SNLCV302

7´2.02“

7´10.09“

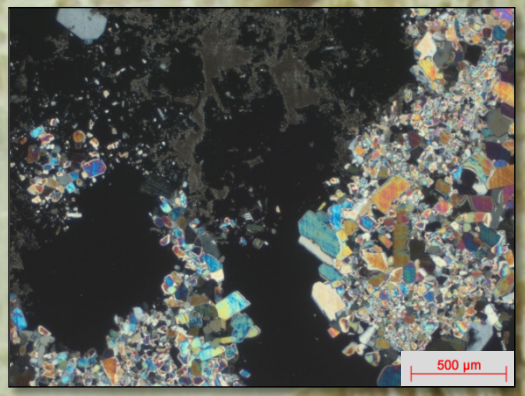
Anhydrite zone
(MB 139)

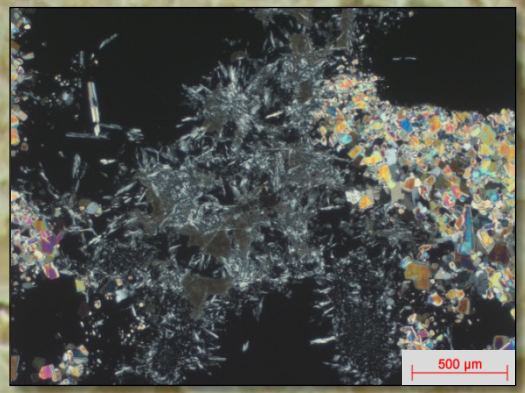


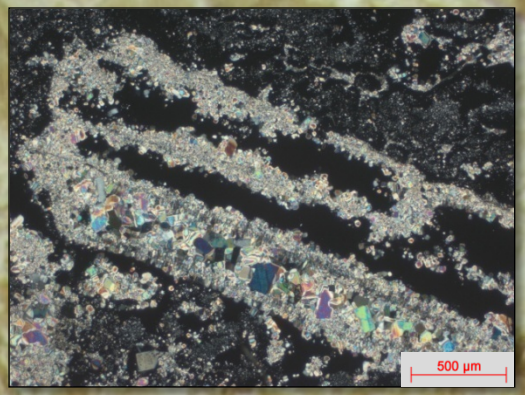
Source:
The Waste Isolation Pilot Plant:
A Potential Solution for the Disposal of Transuranic Waste
Committee on the Waste Isolation Pilot Plant, National Research Council (1996)

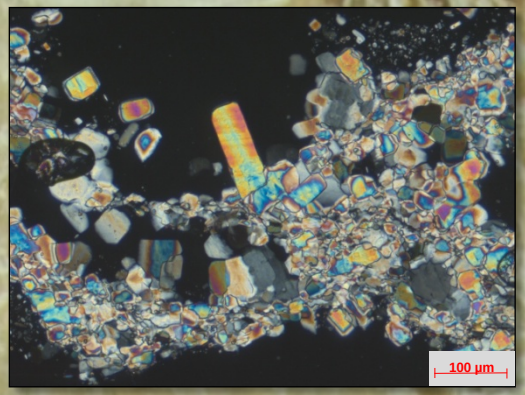
Characteristics of Anhydrite zone (MB 139)

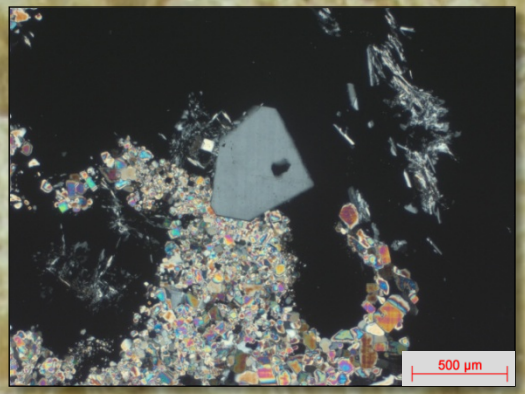
Thin sections from depth 1´9.26“ to 4´5.94“

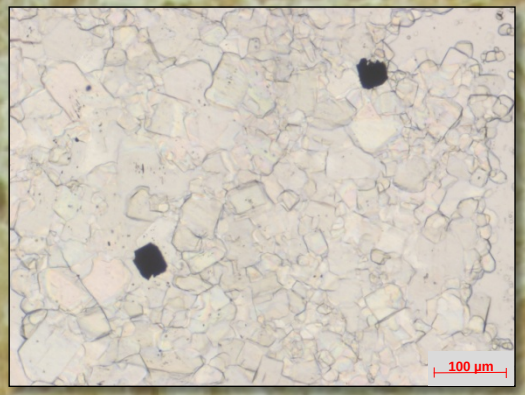












Drill core segments used for sampling of WIPP salt

SNLCV302

1´4.73“

2´3.04“

SNLCV302

3´4.55“

4´1.01“

SNLCV302

5´2.99“

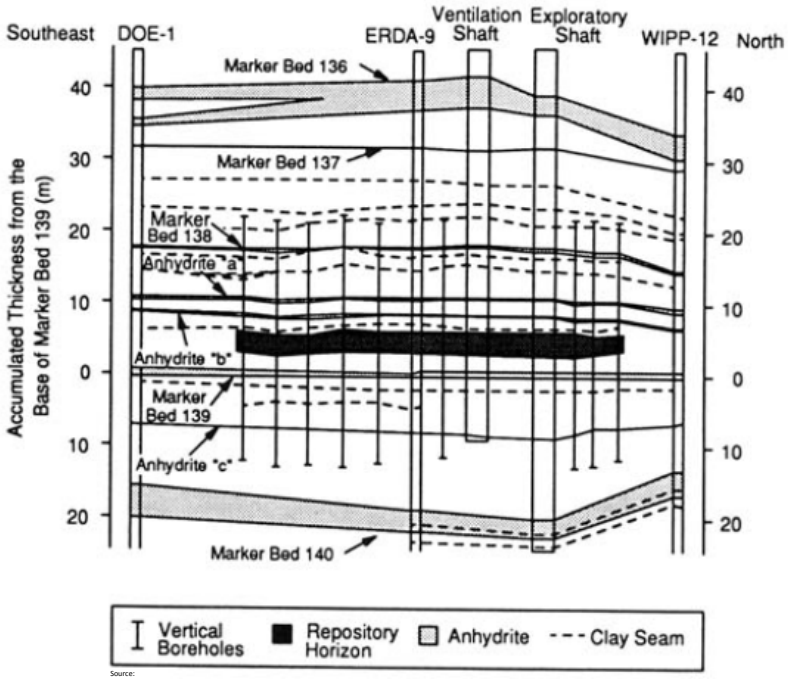
5´6.14

SNLCV302

7´2.02

7´10.0

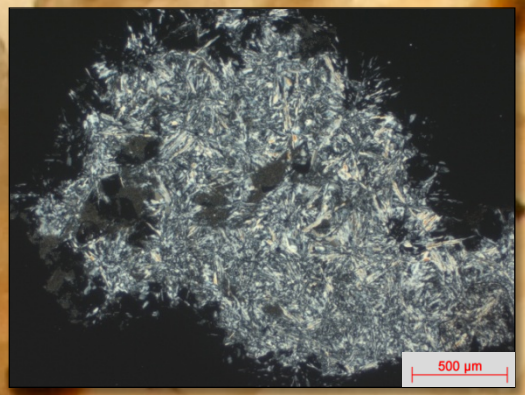
Halite, clear with plebs
of polyhalite
(top of MB 139)

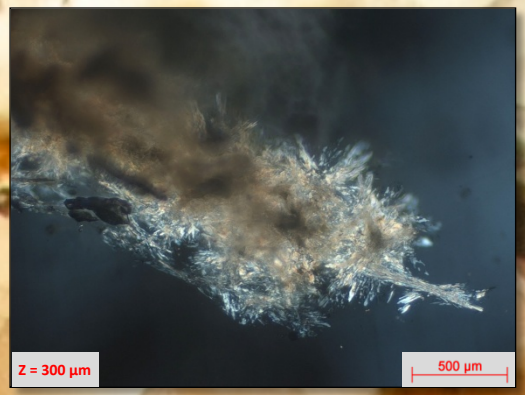


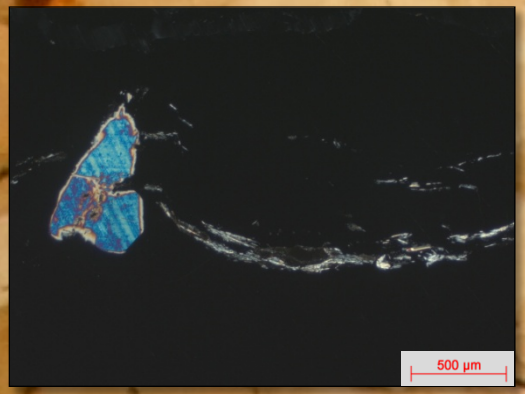
Source:
The Waste Isolation Pilot Plant:
A Potential Solution for the Disposal of Transuranic Waste
Committee on the Waste Isolation Pilot Plant, National Research Council (1996)

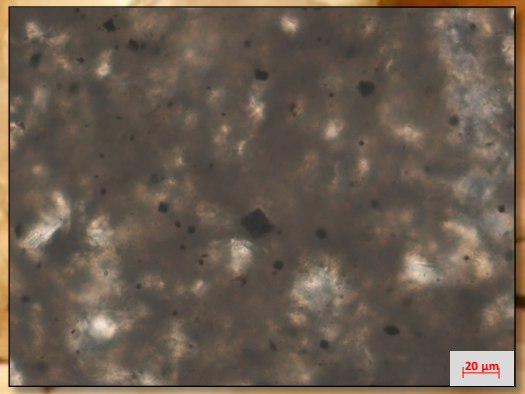
Characteristics of Halite at the top of Anhydrite (MB 139)

Thin sections from depth 1´2.57“ to 1´9.26“









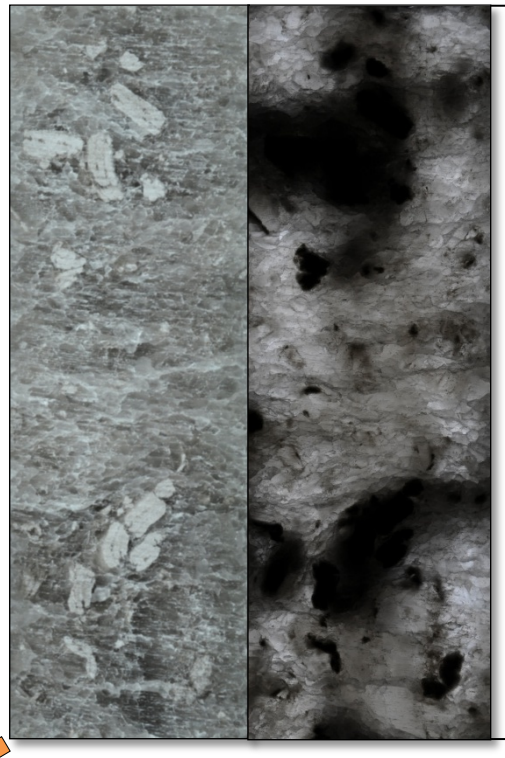
Stratigraphic position and drill core segments of Gorleben salt

Division	Group	Formation	Thickness [m]
Zechstein 3	Anhydritmittelsalz		60
	Buntes Salz		12
	Bank-/Bändersalz		14
	Orangesalz		50
	Liniensalz		31
	Basissalz		16
	Hauptanhydrit		40 bis 80
	Leine-Karbonat		1,5
	Grauer Salzton		2,5
boundary Zechstein2 / Zechstein3			
Zechstein 2	Gebänderter Deckanhydrit		1,5
	Decksteinsalz		0,5
	Kaliflöz Staßfurt		0 bis17
	Kieseritische Übergangsschichten		2,5
	Hangendsalz		10
	Hauptsalz		700 bis 800
		Kristallbrockensalz	
		Streifensalz	
		Knäuelsalz	

Legend

- predominantly rock salt
- potash
- anhydrite
- Salzton
- carbonate

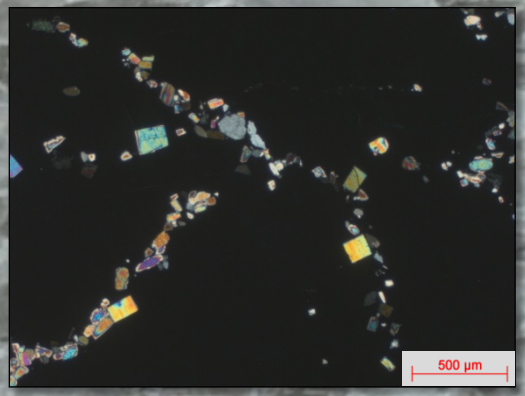
02YEQ02\RB655

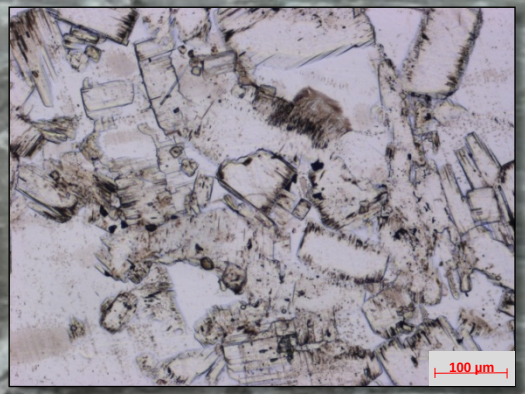


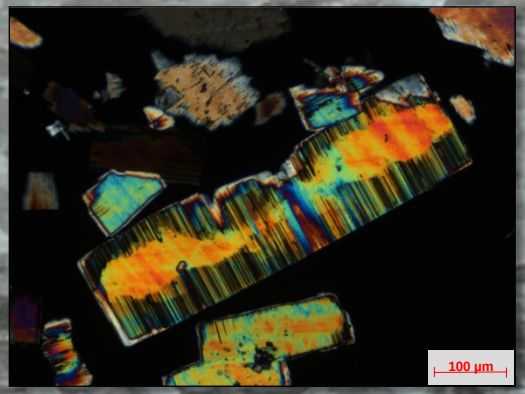
Gorleben exploration mine
main rock salt z2HS1
“Knäuelsalz“

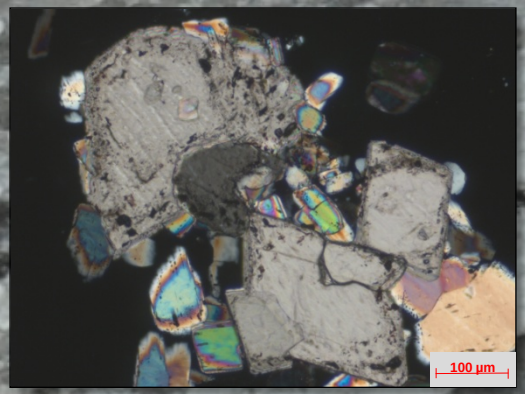
Characteristics of Halite (z2HS1 – “Knäuelsalz“) from Gorleben

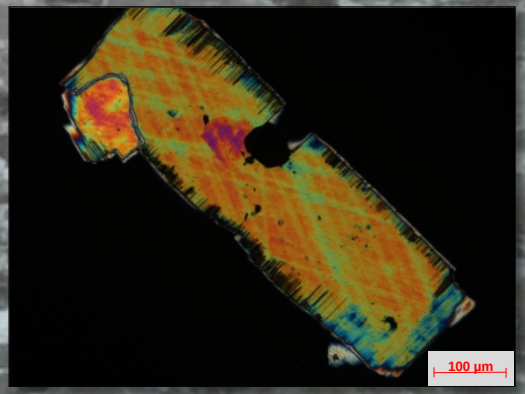
Crosscut 1 West - Thin sections beyond Excavation Damaged Zone (depth 9´11.29“ to 18´1.71“)







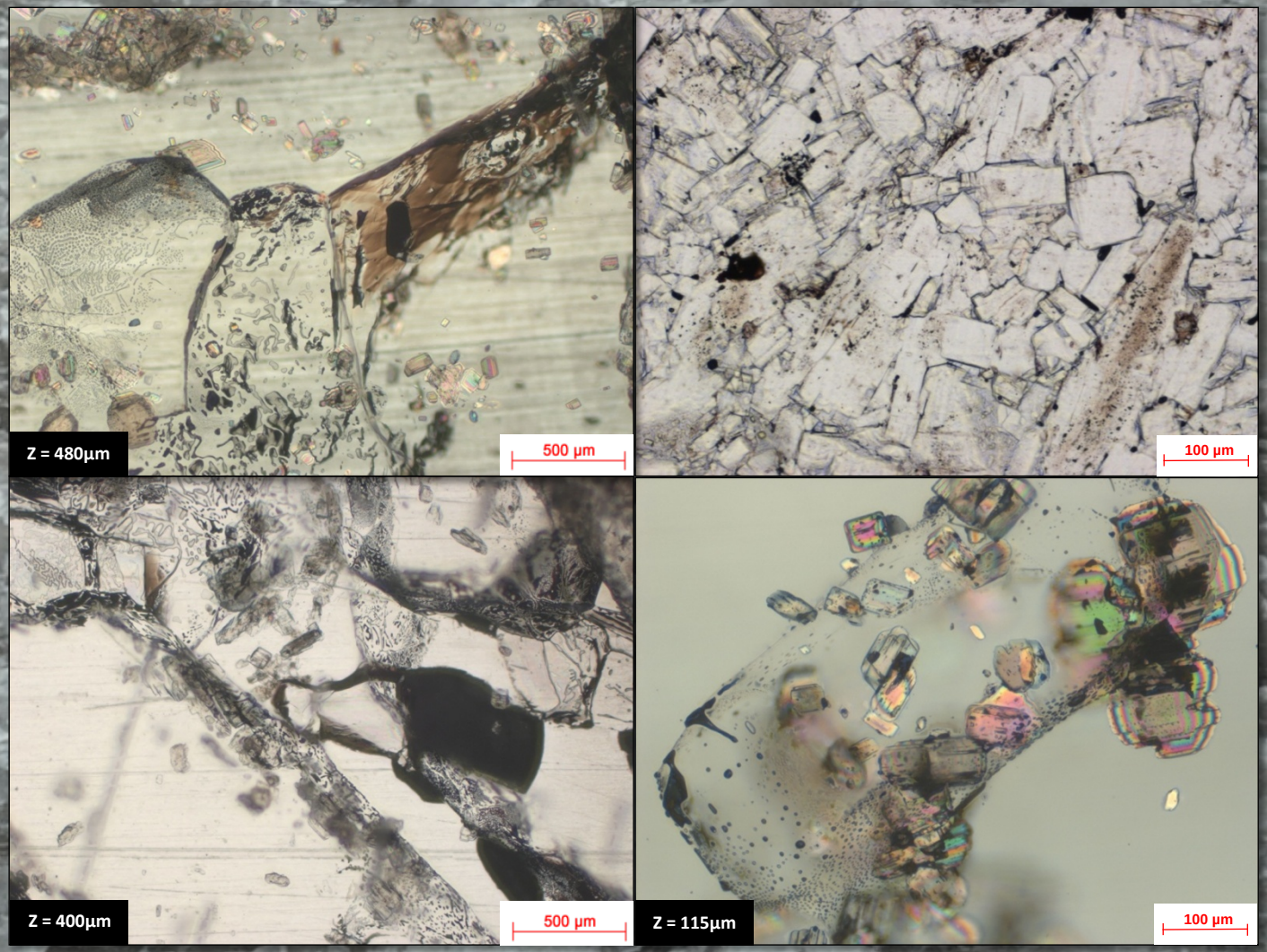




Mineralogical composition of the z2HS (“Hauptsalz“) host rocks

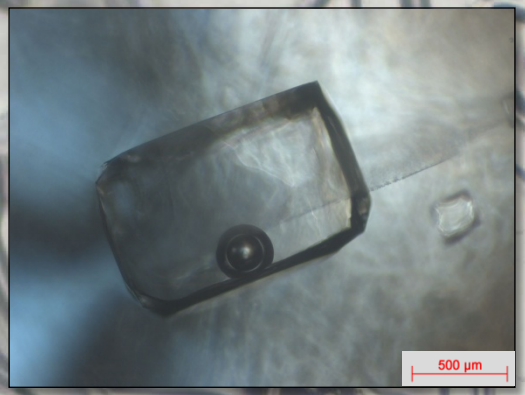
		Halite wt.-%	Anhydrite wt.-%	"Rest" wt.-%	µgBr/g Halite
z2HS1 – mineralogical composition	min	71,7	0,4	0,0	55,2
	max	99,9	22,2	0,1	90,0
	mean	93,3	6,0	0,0	66,7
z2HS2 – mineralogical composition	min	77,3	0,2	0,0	53,3
	max	100,1	20,4	0,1	100,4
	mean	94,4	4,8	0,0	79,7
z2HS3 – mineralogical composition	min	95,3	0,0	0,0	93,0
	max	99,7	5,2	0,1	173,4
	mean	97,6	2,0	0,0	136,9

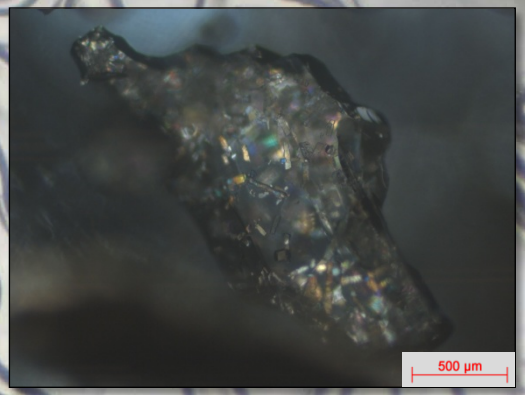
Hydrocarbons at grain boundaries within z2HS1 (“Knäuelsalz“)

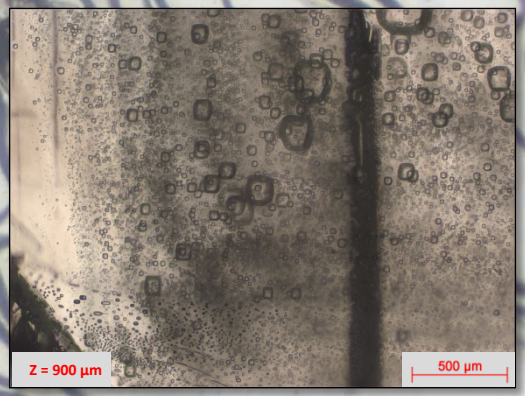


Fluid inclusions in Halite from WIPP (Top of MB 139)

Observed in salt chunks used for thin sections from depth 1´7.29“ to 2´2.37“





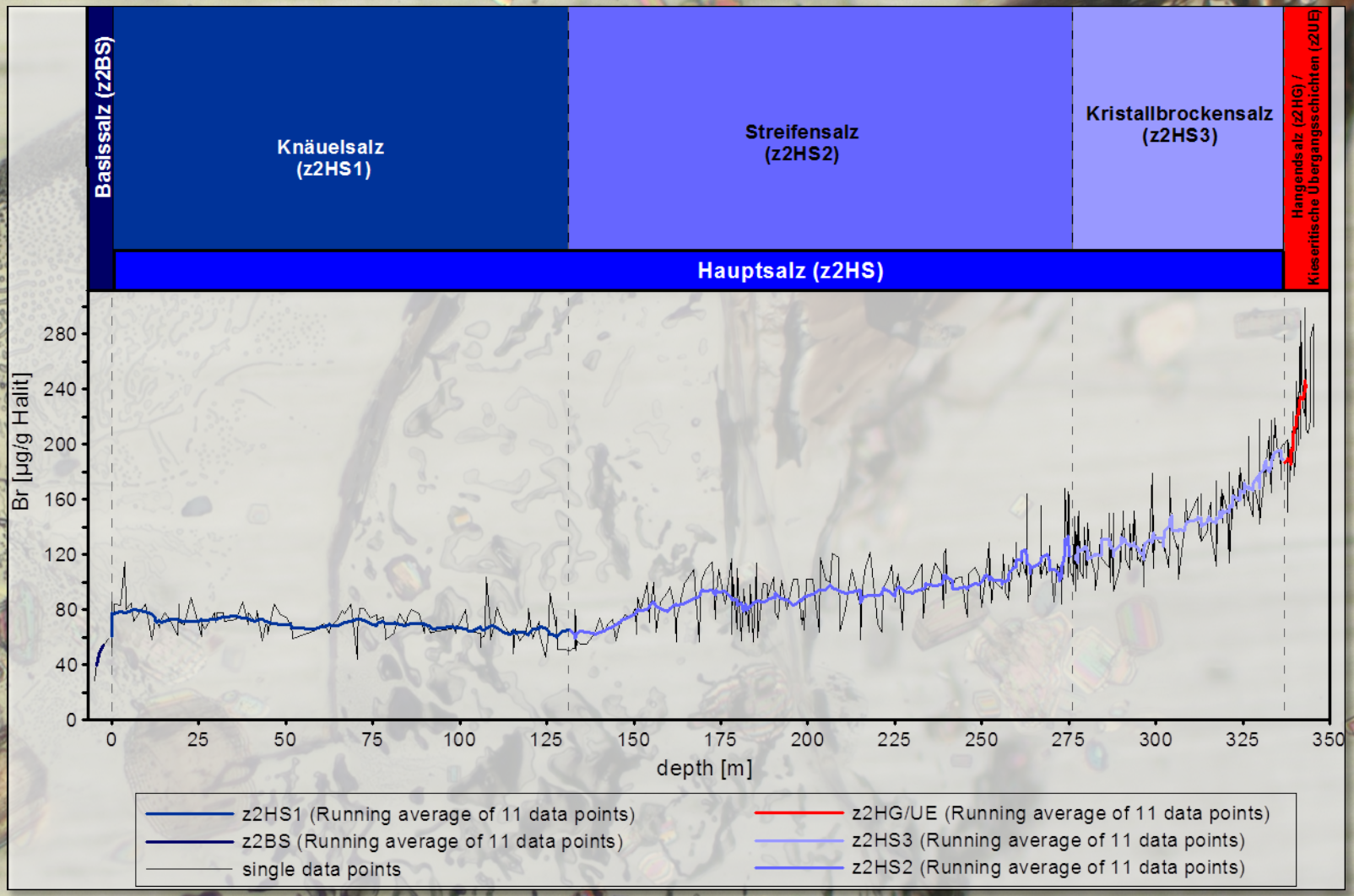


Water content WIPP: approx. 1-(2 wt.-%)

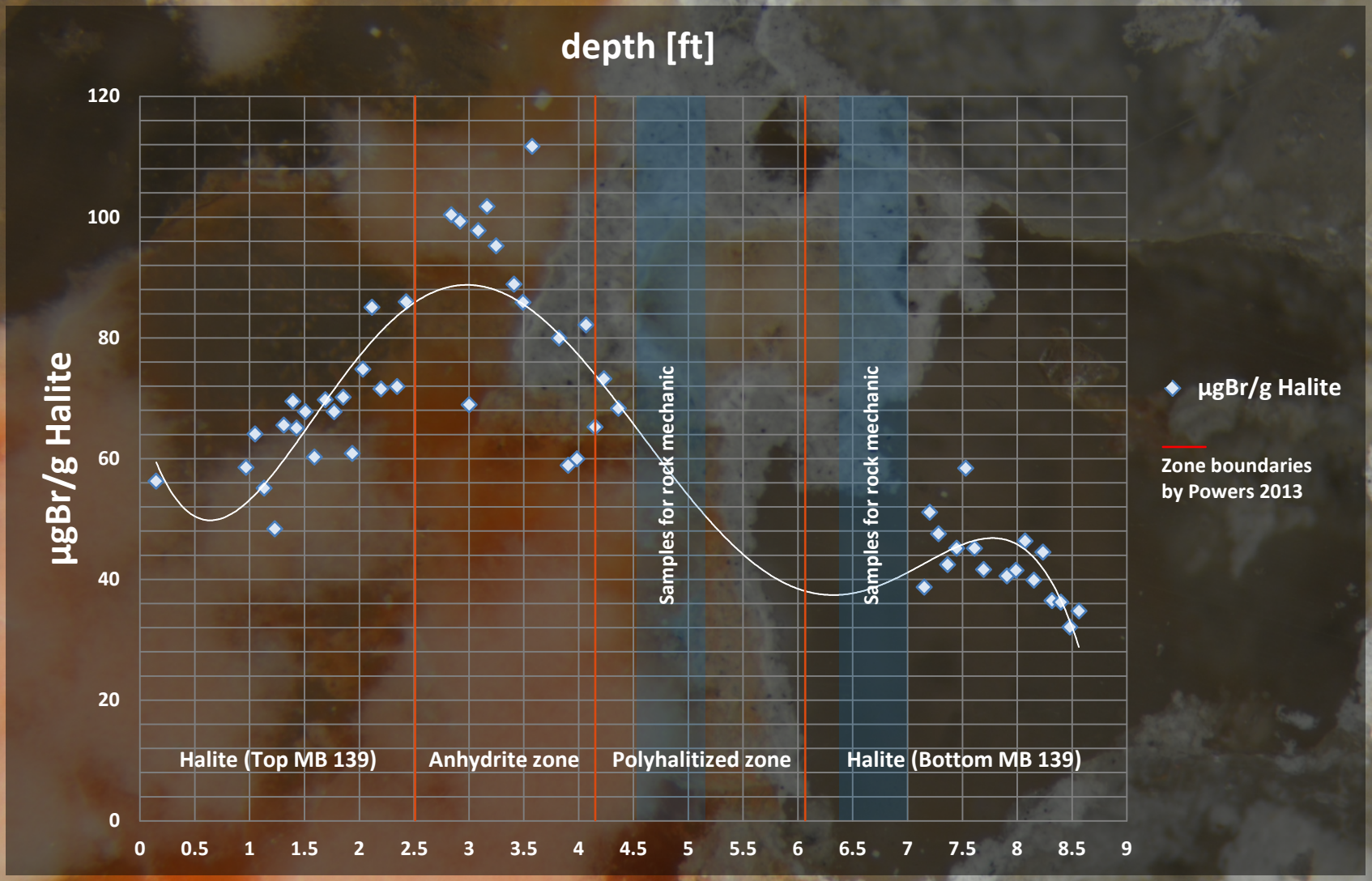
Water content Gorleben: approx. ~ 0,02 wt.-%

Hydrocarbon content in Gorleben main rock salt and WIPP-Halite

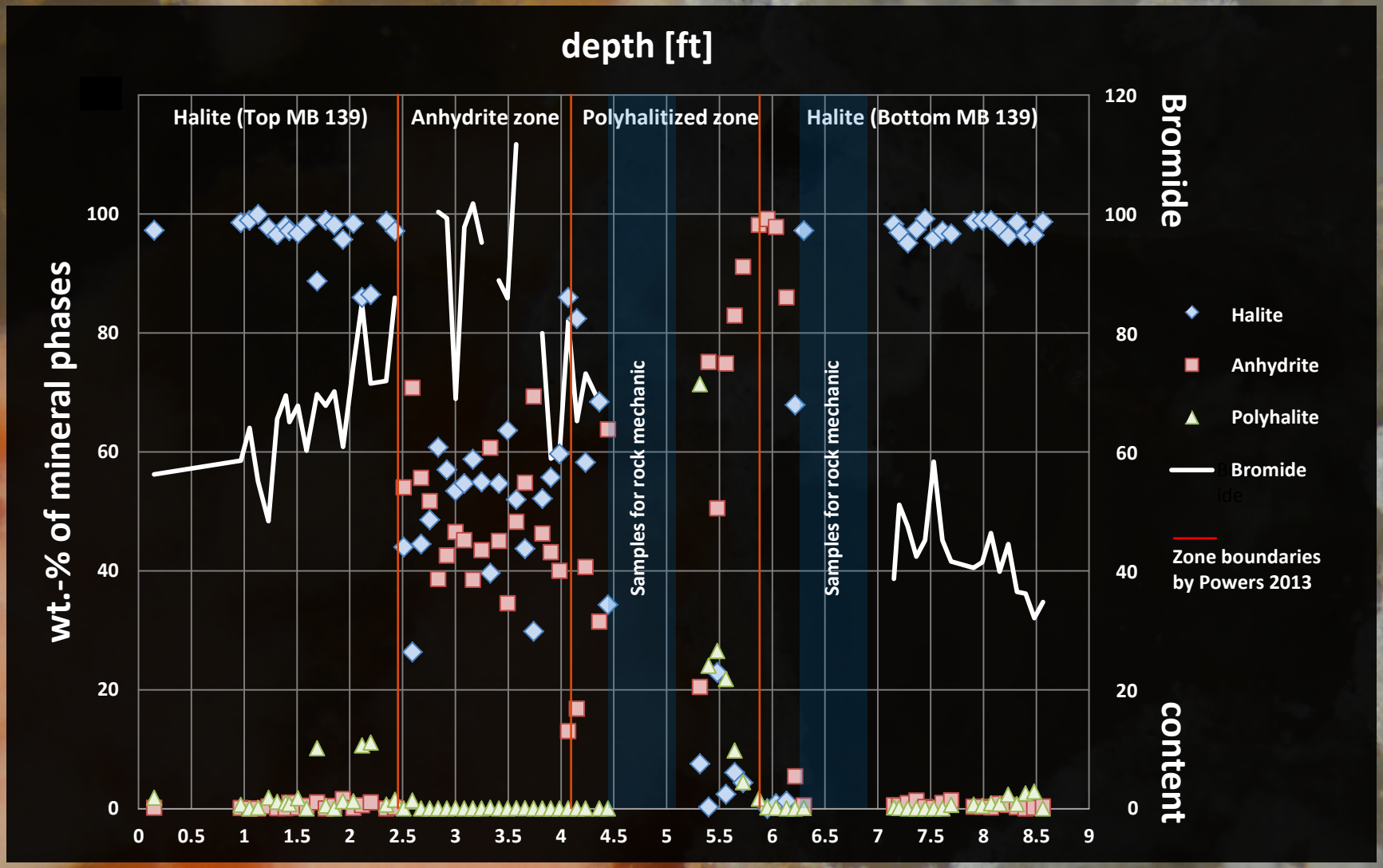
Bromide-Standard-Profile of Zechstein 2 (Gorleben)



Br^--cocentration of samples from drilling SNLCV302



Composition (main minerals) of samples from drilling SNLCV302



Summary - Differences between WIPP and Gorleben

WIPP-Site (flat bedding)

- Large lithological variations
- Main minerals:
  - Halite (NaCl)
  - Polyhalite ($K_2Ca_2Mg(SO)_4 \cdot 2H_2O$)
  - Celestine ($SrSO_4$)
  - (Pyrite; FeS_2)
- Lots of large fluid inclusions with gases, solid crystal of evaporite minerals or clay
- Higher water content; approx. 1-(2 wt.-%)
- Hydrocarbon concentration **(C_1 to C_{10})** below response level; content of **(C_{10} to C_{40})** up to 4,1 mg/kg; immatured organic matter (rooted plants)
- Br^- - content: seems to be the result of an synsedimentary or diagenetic alteration

Gorleben (salt dome)

- Large homogeneous areas
- Main minerals:
  - Halite (NaCl)
  - Anhydrite ($CaSO_4$)
  - Carbonate ($CaCO_3$; $CaMg(CO_3)_2$; $MgCO_3$)
  - (Pyrite; FeS_2)
- Small fluid inclusions along fissures / grain boundaries & relics of primary inclusions
- Lower water content; approx. ~0,02 wt.-%
- Small amount of hydrocarbons with a max. up to 443 mg/kg **(C_1 to C_{40})**; matured oil
- Br^- - content: is the result of incremental progressive evaporation with some metamorphic zones