Quartz Cementation History of the Heidelberg Sandstone, Germany: In Situ Microanalysis of δ18O*

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Abstract

Microcrystalline quartz prevents the growth of ordinary quartz cements and leads to anomalously high porosity in deeply buried petroleum reservoirs. Oxygen isotope analysis of microcrystalline quartz and other quartz cements provide data to help understand the growth mechanisms for porosity preserving microcrystalline quartz. High precision, in situ oxygen isotope analyses of Cretaceous Heidelberg Formation detrital grains and quartz cements show three varieties of authigenic quartz cement growing on detrital quartz grains. This micron-scale data provides evidence that: (1) Porosity preserving microcrystalline quartz forms on a chalcedony substrate, and (2) that there were two episodes of fluid influx into the Heidelberg Formation.

Detrital quartz has an average δ18O composition of +9.40/00 and mesoquartz (syntaxial overgrowth) has an average composition of +19.30/00, microcrystalline quartz has an average composition of 21.70/00. Estimates of the δ18O composition of chalcedonic quartz are complicated by the problem of isolating the microcrystalline quartz from the chalcedony; mixtures of the two give a consistently higher δ18O (27.40/00) than microcrystalline quartz. From oxygen isotope data, the formation of microcrystalline quartz and chalcedonic quartz is interpreted to have taken place in a small temperature range of between 80 and 140° C. Wavelength dispersive spectroscopy (WDS) data supports the paragenetic data and suggests that two episodes of enrichment in aluminum and iron in the microcrystalline quartz and chalcedony. These two distinct layers formed from two episodes of highly concentrated brines, emanating from a hydrothermal source associated with nearby faulting in the Harz Mountains mining district, Germany.

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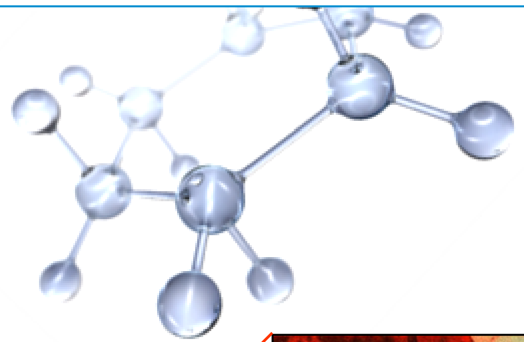

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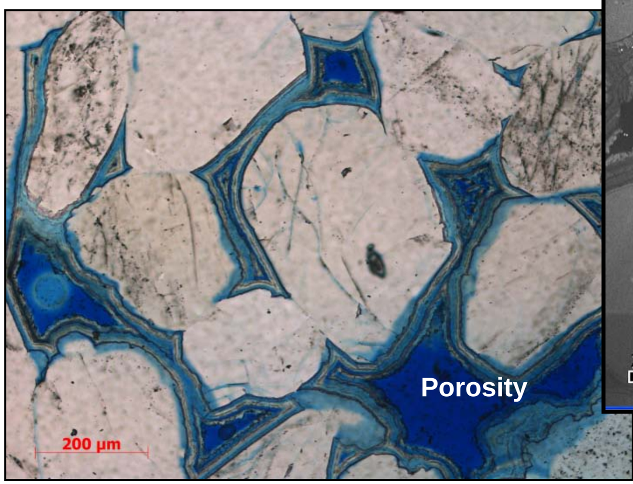
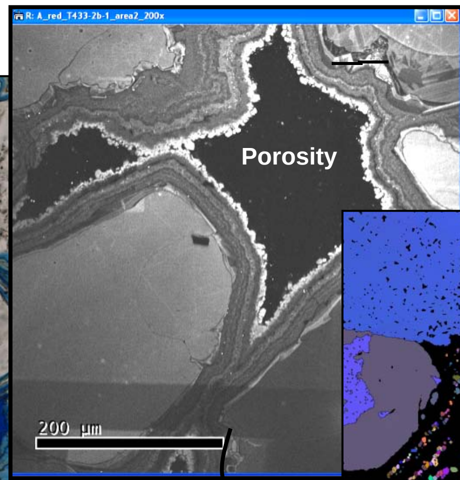
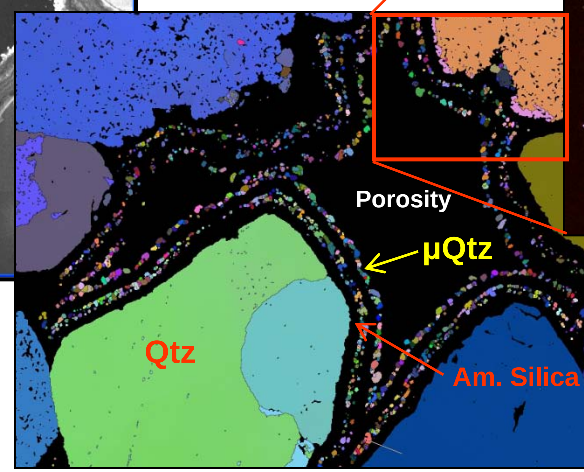
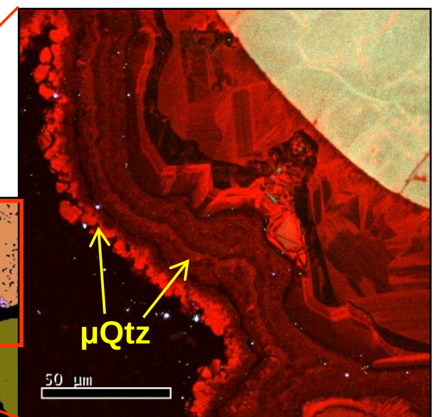
Diagenetic Effects on Clastic Reservoirs

April 25, 2012









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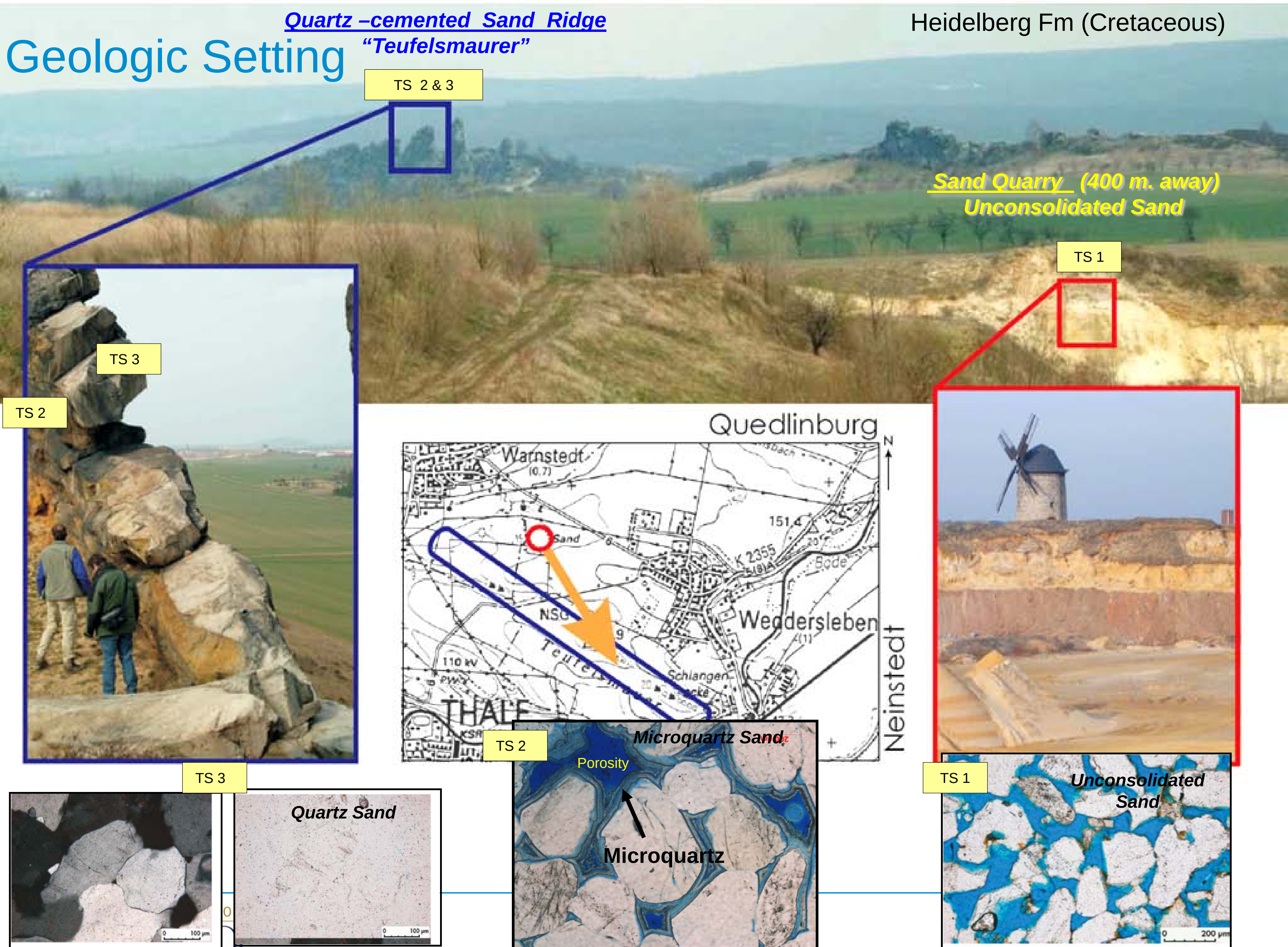
Overview

1) Porosity preserving mechanism → microquartz

2) Origin of microquartz = early meteoric diagenesis

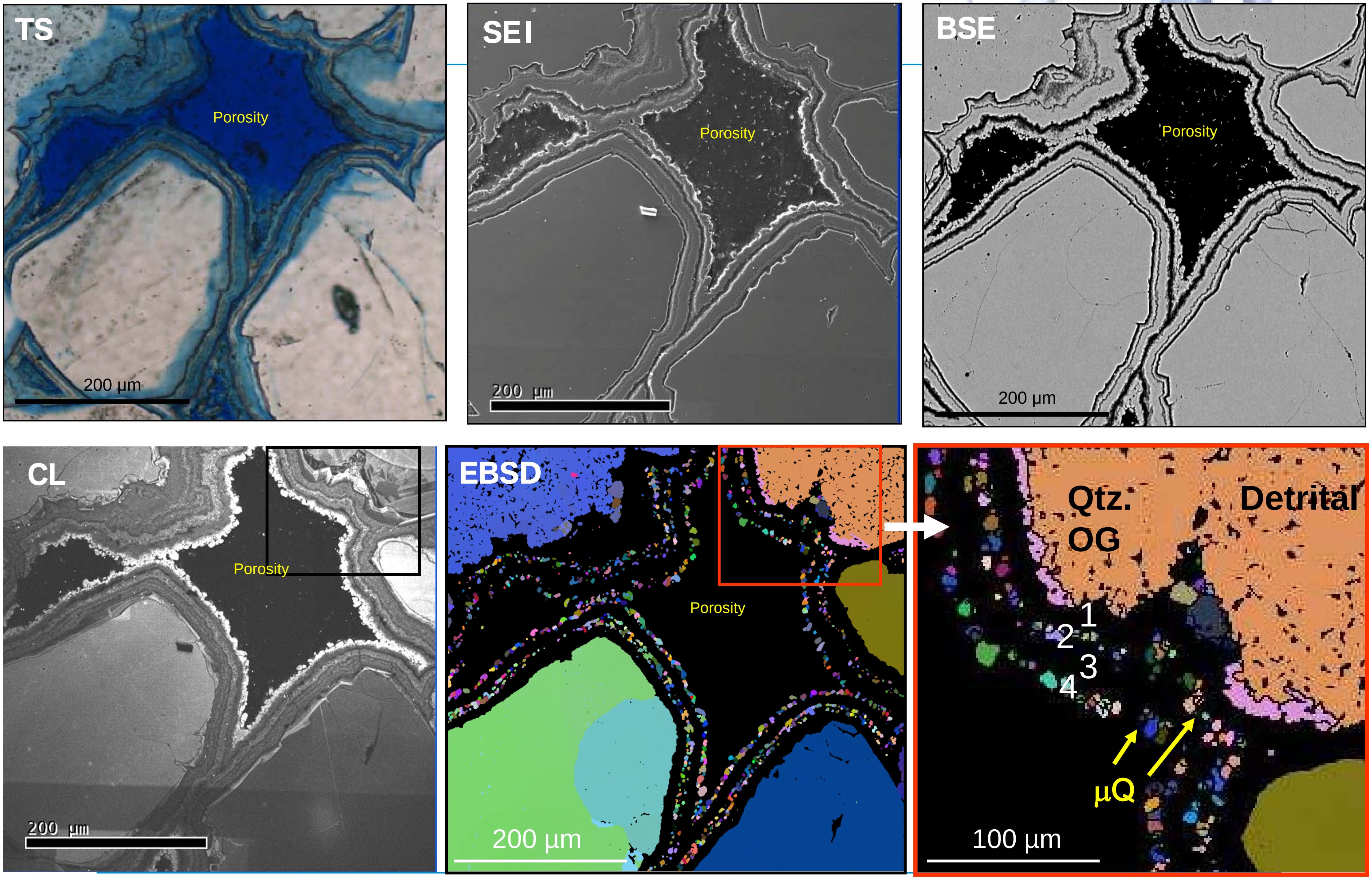
3) Isotope data confirms low temperature

Geologic Setting



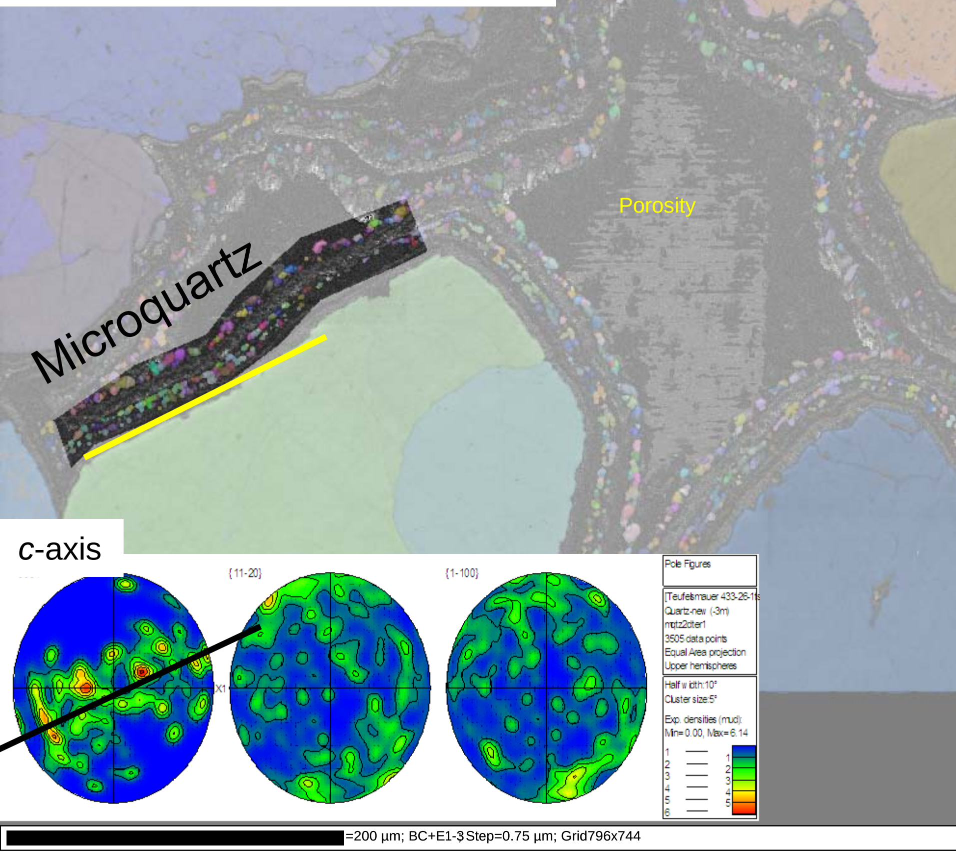
Waldman, S., Fischer, C., von Eynatten, H., 2006, Räumliche Diageneseaniostropien in kretazischen Quarzareniten: Schriften der Deutschen Gesellschaft für Geowissenschaften, v. 45, p. 181.

Methods



TS
Porosity
200 µm
SEI
Porosity
200 µm
BSE
Porosity
200 µm
CL
Porosity
200 µm
EBSD
Porosity
200 µm
Qtz. OG
Detrital
1
2
3
4
µQ
100 µm

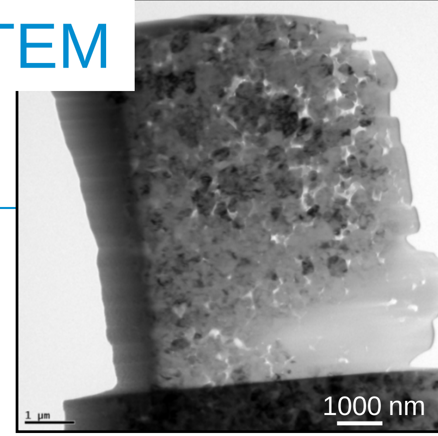
EBSD Orientation



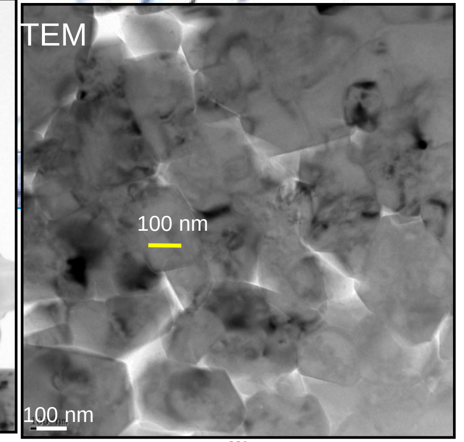
Girdle of microquartz rotating about the *c*-axis. The trace of a great circle matches the orientation of the face of the detrital grain on which the microquartz is growing.

→EBSD evidence indicates that the crystals of microquartz have grown with their c-axes <u>parallel to the surface of the grain like length-fast chalcedony.</u>

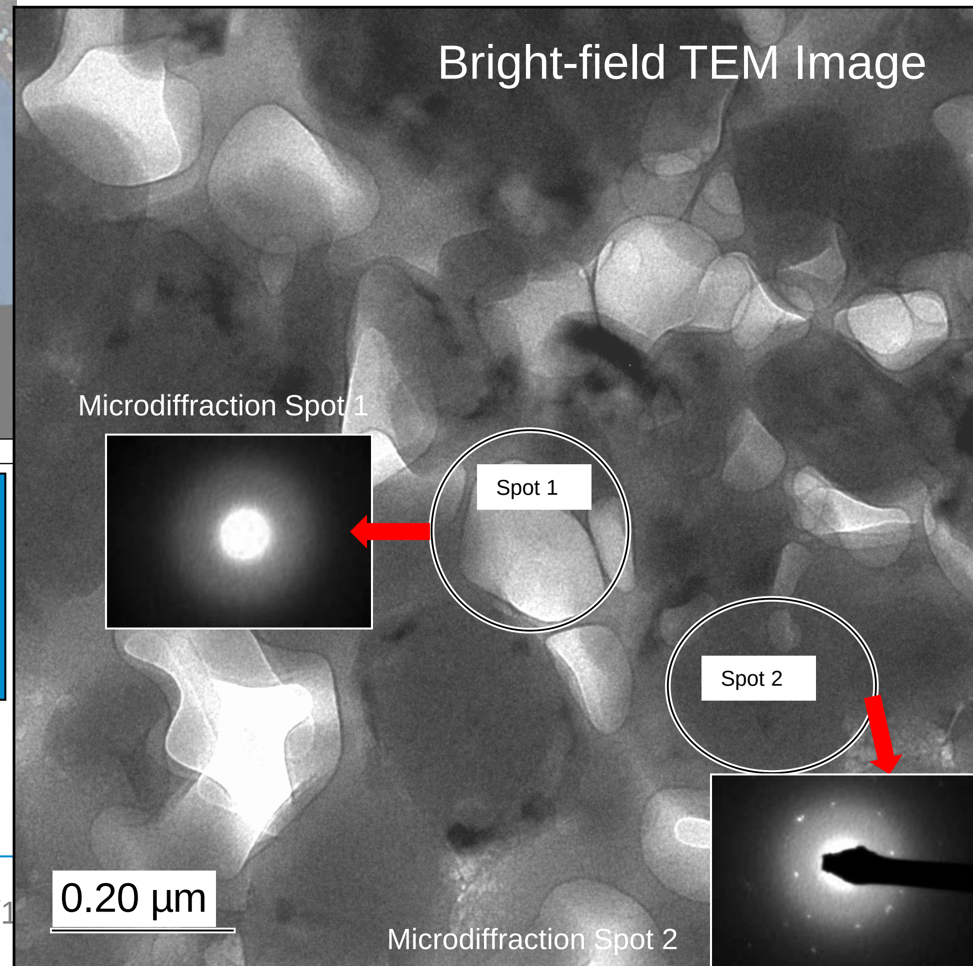
TEM



TEM sample from FIB



Nanocrystalline quartz

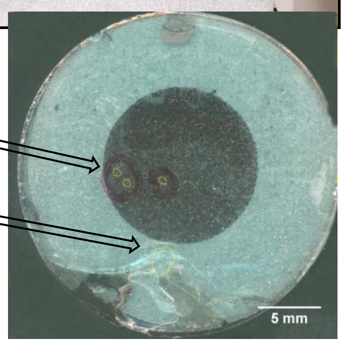


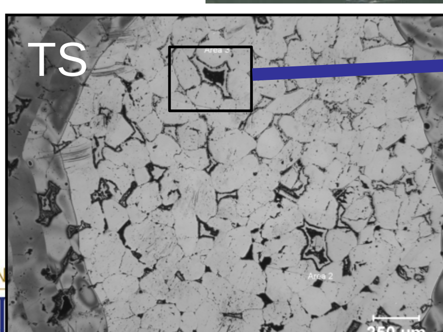
Secondary Ion Mass Spectrometry

Cameca N50 Nano SIMS

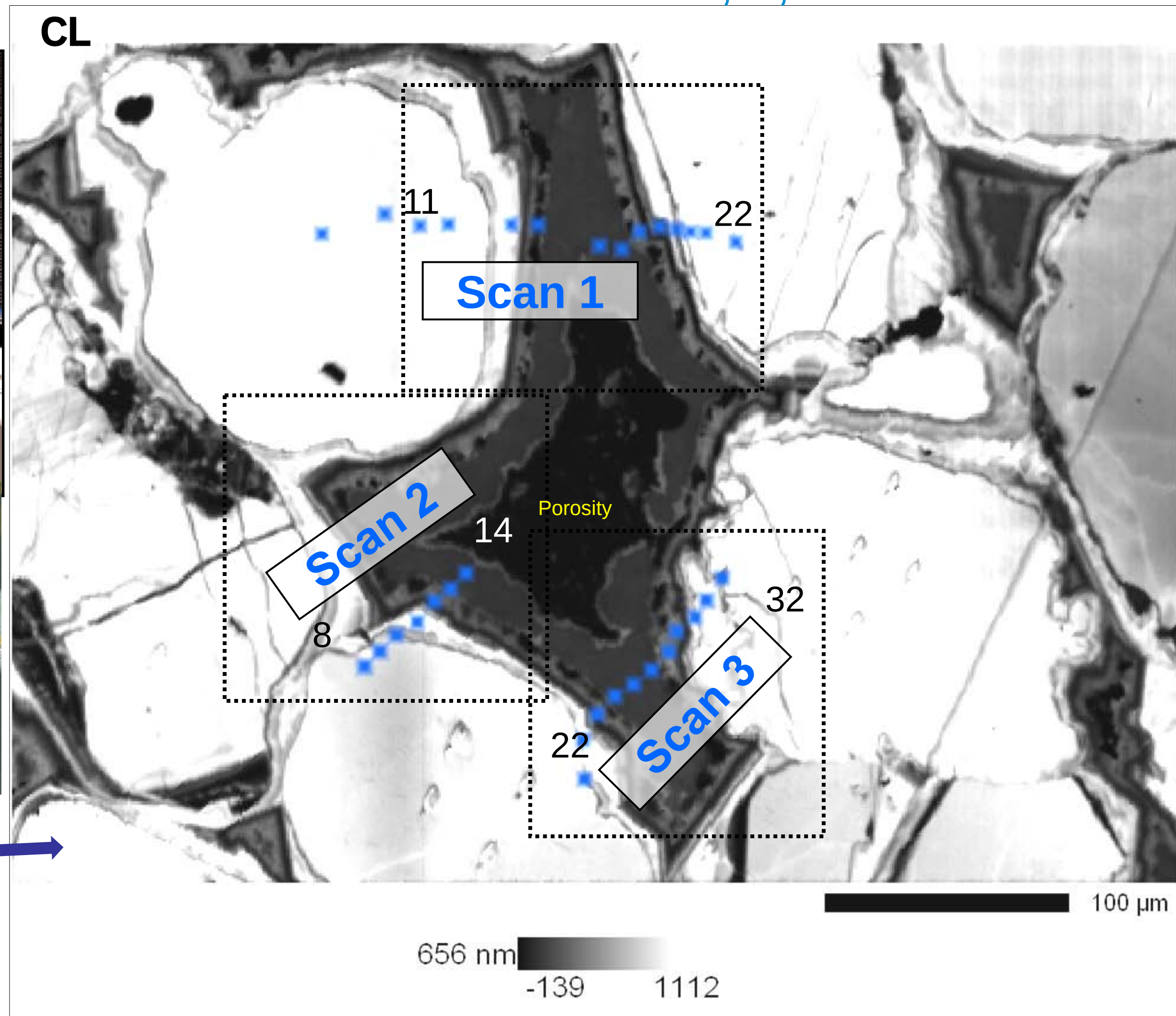
Sample Area

UW-1 Standard

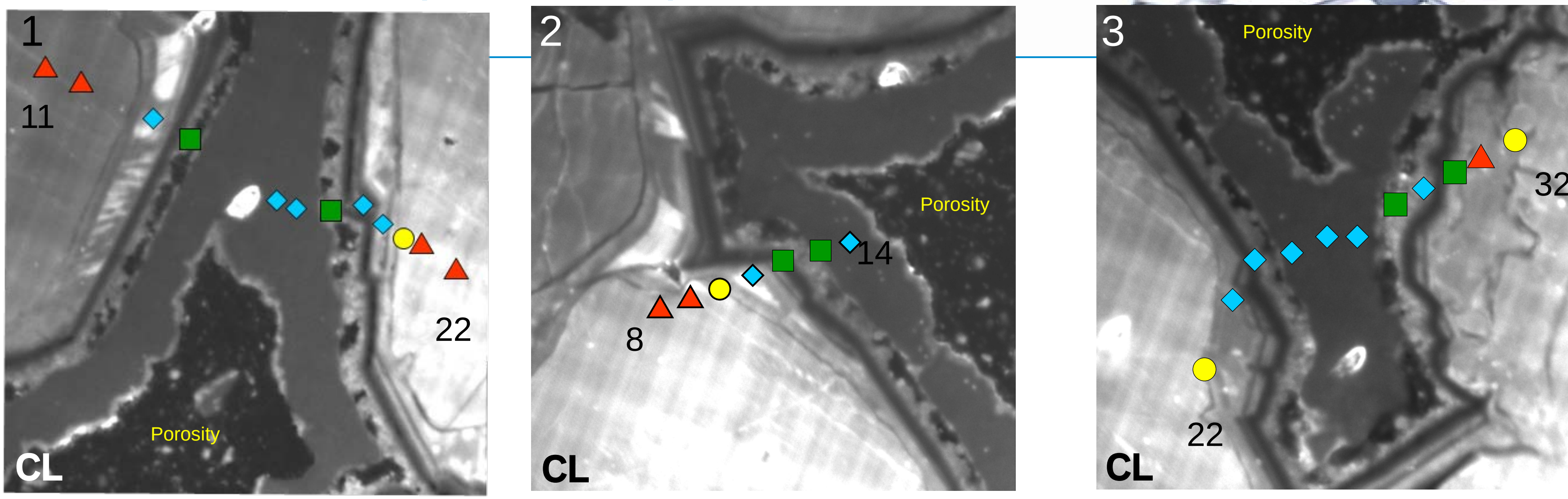


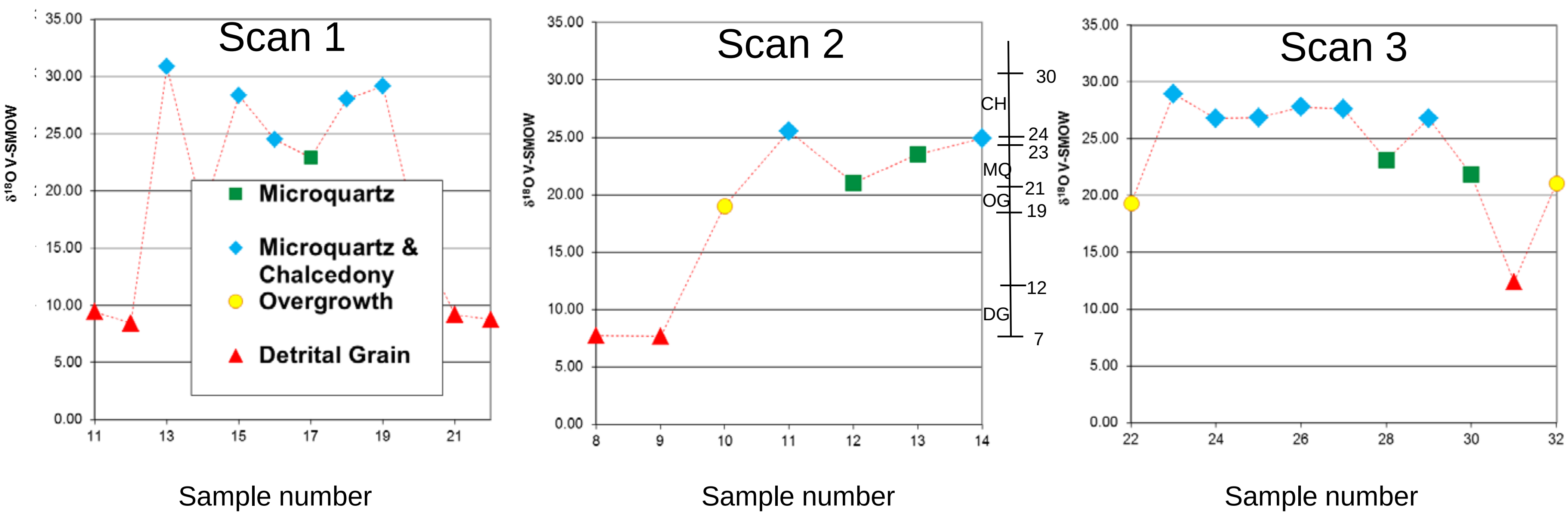


$\delta^{18}O$ Locations: Scan 1, 2, and 3



δ^{18}O Values (V-SMOW)





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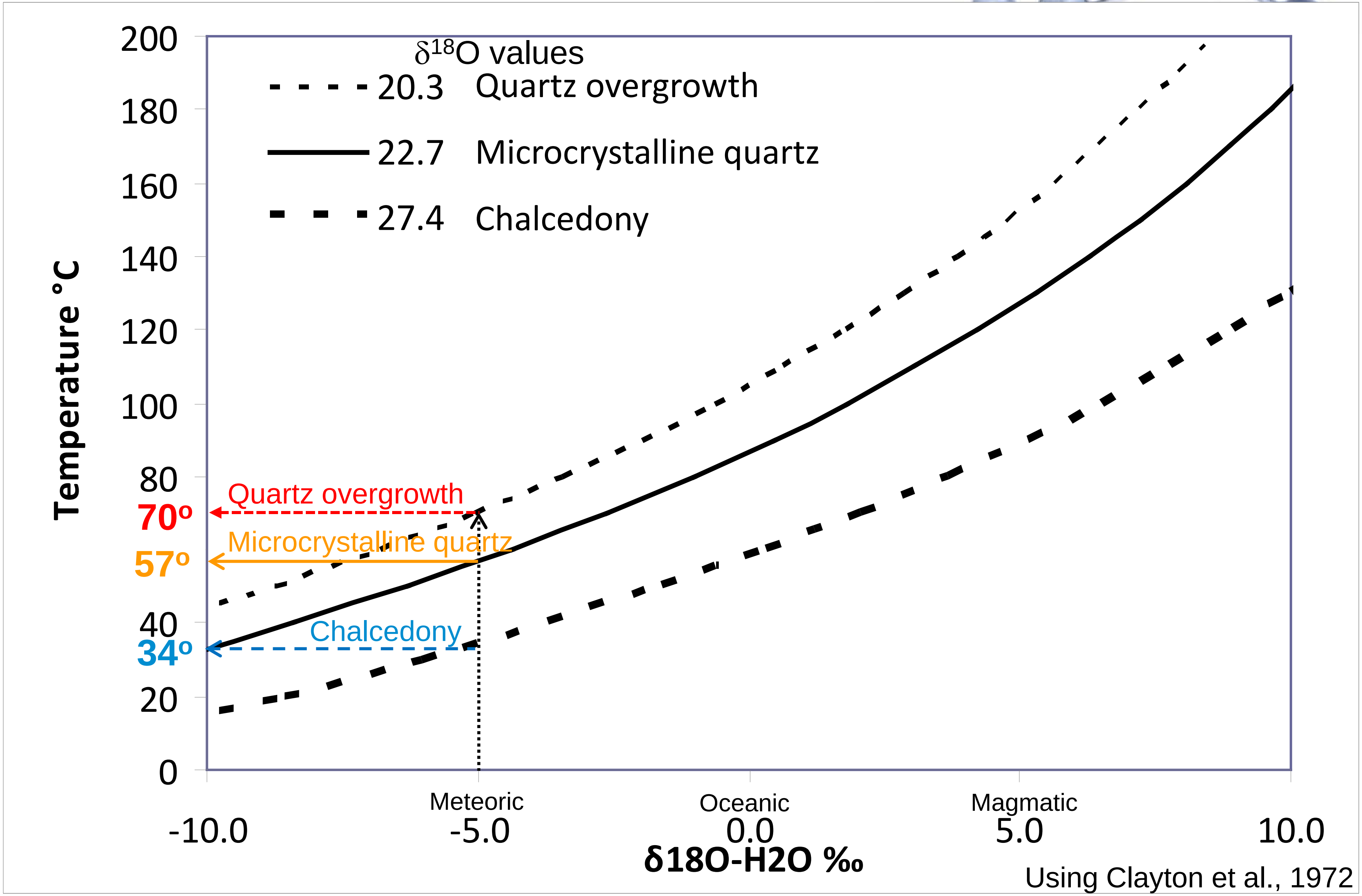
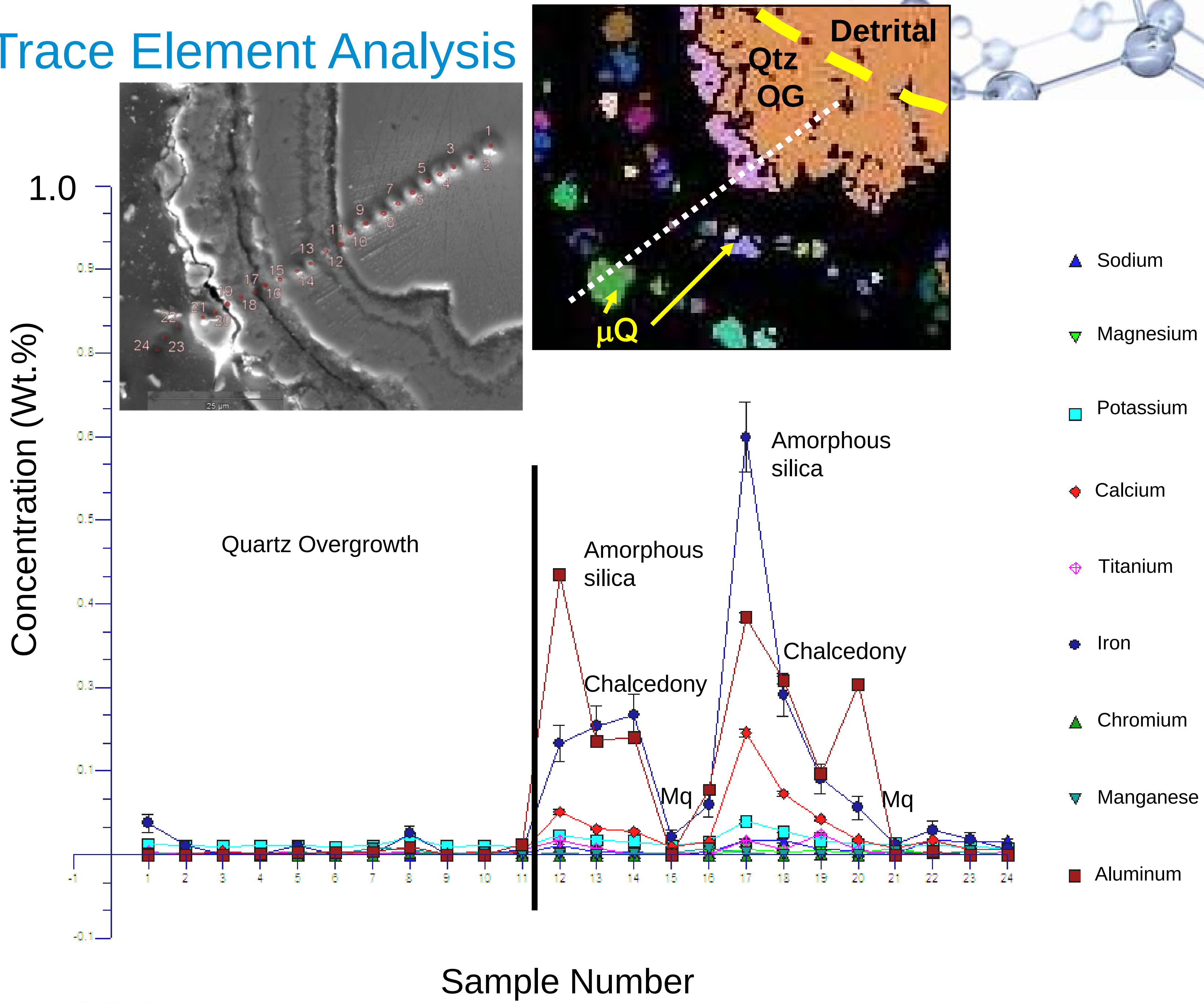
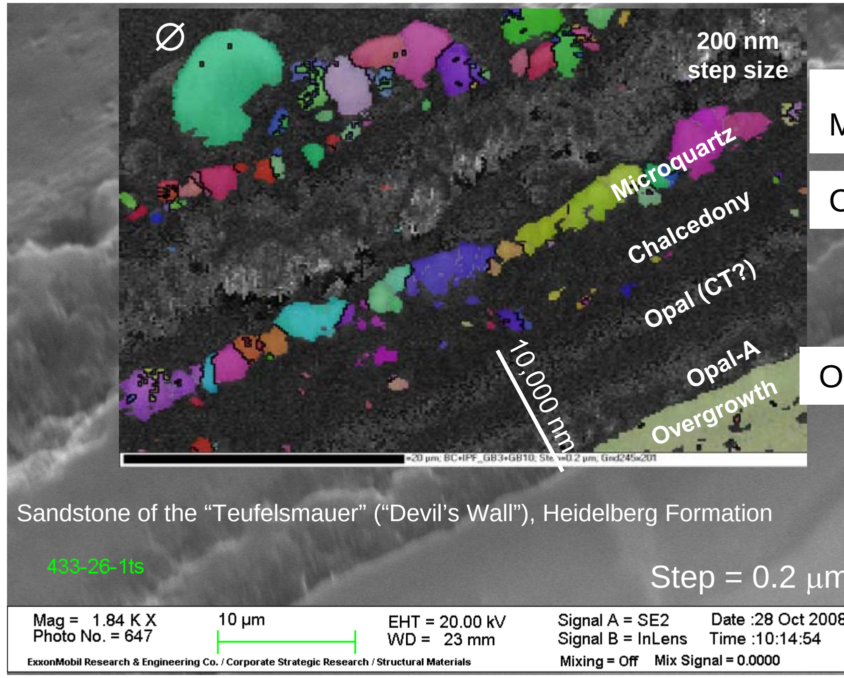
Calculated Temperature Curves



Trace Element Analysis



Conclusions



	$\delta^{18}O$	Temp.
Microquartz	+22.7‰.	57°C
Chalcedony	+27.4‰	34˚C
Overgrowth	+20.3‰	70˚C

1) Porosity preserving mechanism → microquartz
2) Origin of microquartz = early meteoric diagenesis
3) Isotope data confirms low temperature

Generalized Silica Sinter Sequence
Amorphous/Opal-A → Opal-CT → Chalcedony → Microquartz

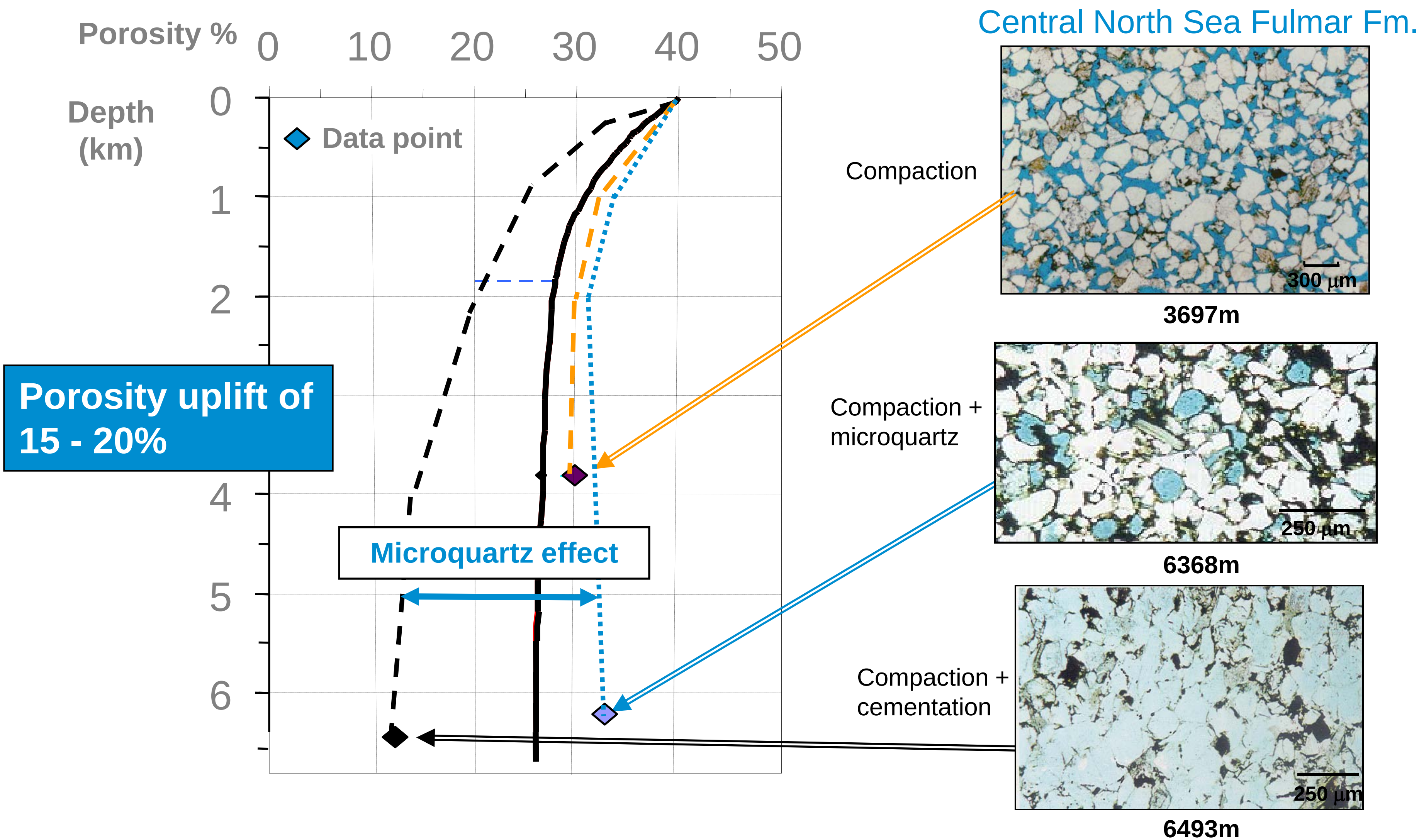
Isotope Values versus Literature

Oxygen Isotope Values from the Heidelberg Formation versus Literature in V-SMOW							
		DG	OG	MQ	MQ/Chal.	Cristobalite	Bio. Opal
Heidelberg Fm.	Average	**9.4**	**20.3**	**22.7**	**27.4**		
Literature Average		12.2	20.0	23.8	28.3	29.4	37.4
Heidelberg Fm.	Range	**7.7_12.4**	**19.0_21.9**	**21.0_23.5**	**24.5_30.8**		
Literature Range		4.2_24.1	12.6_32.4		24.9_32.4	27.9_30.4	

Heidelberg Formation silica polymorphs:
DG = Detrital Silica
OG = Quartz Overgrowths
MQ = Microcrystalline Quartz
MQ/Chal. = Microquartz and Chalcedony

Literature data from: Blatt, 1987; Vagle et al., 1994; Murata et al., 1977; Harwood et al., 2010; Pollington et al., 2011; Marchand et al., 2002; O'Neil and Hay, 1972; Knauth and Epstein, 1976; Abruzzese et al., 2005; Williams et al., 1997; and Harvig et al., 1995.

Porosity Uplift from Microquartz Coatings



Central N. Sea Fulmar, Ajdukiewicz, 1994, U. Jurassic sands at 3 to 4 km in the Southern North Sea (Aase et al., 1996)

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