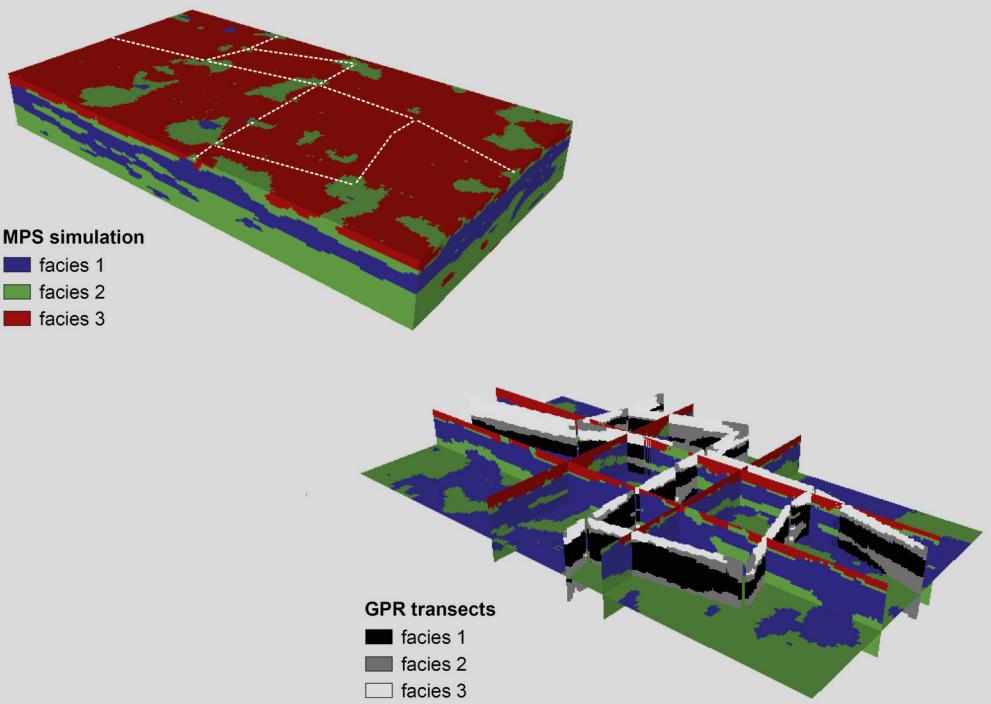


High resolution imaging and modeling of aquifer structure

Nils Gütting



Energie & Umwelt /
Energy & Environment
Band / Volume 383
ISBN 978-3-95806-253-5

 **JÜLICH**
FORSCHUNGSZENTRUM

Forschungszentrum Jülich GmbH
Institute of Bio- and Geosciences
Agrosphere (IBG-3)

High resolution imaging and modeling of aquifer structure

Nils Gütting

Schriften des Forschungszentrums Jülich
Reihe Energie & Umwelt / Energy & Environment

Band / Volume 383

ISSN 1866-1793

ISBN 978-3-95806-253-5

CONTENTS

ABSTRACT	v
ZUSAMMENFASSUNG	vii
1 INTRODUCTION	1
1.1 Statement of the problem	1
1.2 The need to account for spatial connectivity	2
1.3 Multiple-point statistics and training images	3
1.4 Benefits and drawbacks of geophysical imaging	5
1.5 Objectives and thesis outline	6
2 HIGH RESOLUTION IMAGING OF AQUIFER STRUCTURE USING CROSSHOLE GPR FULL-WAVEFORM INVERSION	9
2.1 Introduction	9
2.2 Material and methods	11
2.2.1 Study site	11
2.2.2 Crosshole ground penetrating radar tomography	13
2.2.3 Complex Refractive Index Model (CRIM)	15
2.2.4 Cone penetration tests	16
2.2.5 Hydraulic conductivity from flowmeter test and grain size	16
2.2.6 Cluster analysis	17
2.3 Results and discussion	18
2.3.1 GPR inversion results and comparison with CPT data	18
2.3.2 Cluster analysis of GPR and CPT data	24
2.4 Conclusions	33
3 THE BENEFIT OF GPR FULL-WAVEFORM INVERSION FOR HYDROGEOLOGICAL SITE CHARACTERIZATION	35
3.1 Introduction	35
3.2 Material and methods	38
3.2.1 Study site	38
3.2.2 Crosshole ground penetrating radar (GPR) tomography	38
3.2.3 Complex refractive index model (CRIM)	40
3.2.4 Logistic regression	41
3.2.5 Direct-push hydraulic measurements	42
3.2.6 Previous studies at the Krauthausen site	43
3.3 Results and discussion	46
3.3.1 GPR full-waveform inversion results	46
3.3.2 Comparison of GPR full-waveform inversion results with CPT neutron and electrical resistivity logs	49

3.3.3	Comparison of GPR full-waveform inversion results with direct-push hydraulic conductivity	51
3.3.4	Facies classification	54
3.3.5	Comparison of GPR predicted facies distribution with CPT cone resistance logs	57
3.3.6	Comparison of GPR predicted facies distribution with tracer breakthrough	58
3.3.7	Porosity of GPR facies	60
3.3.8	Hydraulic conductivity of GPR facies	60
3.4	Conclusions	63
4	3-D AQUIFER MODEL GENERATION USING MULTIPLE-POINT STATISTICS	65
4.1	Introduction	65
4.2	Material and methods	67
4.2.1	Study site and GPR data set	67
4.2.2	Multiple-point-statistical simulations	68
4.2.3	Evaluating the quality of a simulation outcome	71
4.3	Results	72
4.3.1	3-D reconstruction approach (stand-alone)	72
4.3.2	Sequential 2-D approach (stand-alone)	75
4.3.3	Combined approach	77
4.4	Discussion	80
4.4.1	General validity of findings	80
4.4.2	Optimal switching point	80
4.4.3	Possible future research directions	82
4.5	Conclusions	83
5	CONCLUSIONS AND OUTLOOK	85
5.1	Conclusions	85
5.2	Outlook	87
Bibliography		99
Acknowledgements		101
List of Publications		103
List of Figures		105
List of Tables		107

**Energie & Umwelt /
Energy & Environment
Band / Volume 383
ISBN 978-3-95806-253-5**

