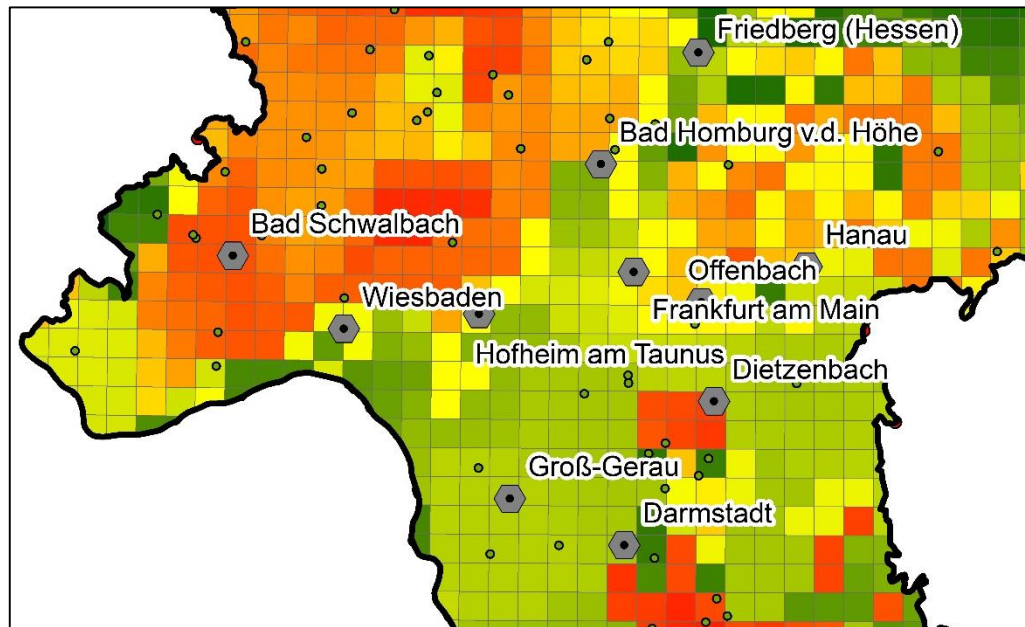


Designing a geology-based concept for the radon soil gas measuring campaign in Hessen, Germany

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Prague, 18.-20. September 2018

14th International Workshop GARRM

Background – new legislation

- 2013/59/EURATOM treaty of the EU-Commission
- German Radiation Protection Act §121: Identification of „RPAs“
- “RPAs” = the radon concentration (as an annual average) in a significant number of buildings is expected to exceed the national reference level of 300Bq/m³
- Hessian Ministry of the Environment asked for geoscientific support in designing a geology-based concept for the radon soil gas measuring campaign

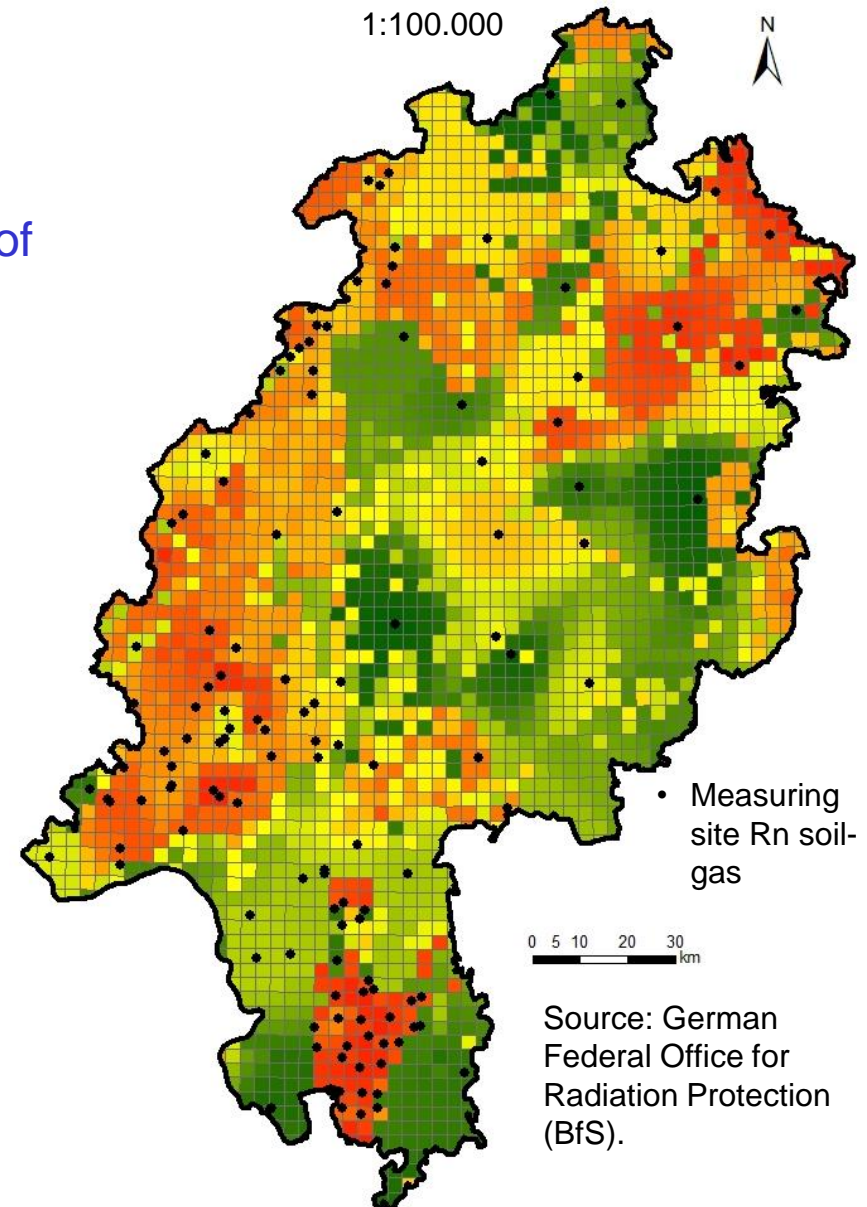


Location federal state of Hesse

(wikipedia)

Current Radon soil-gas map

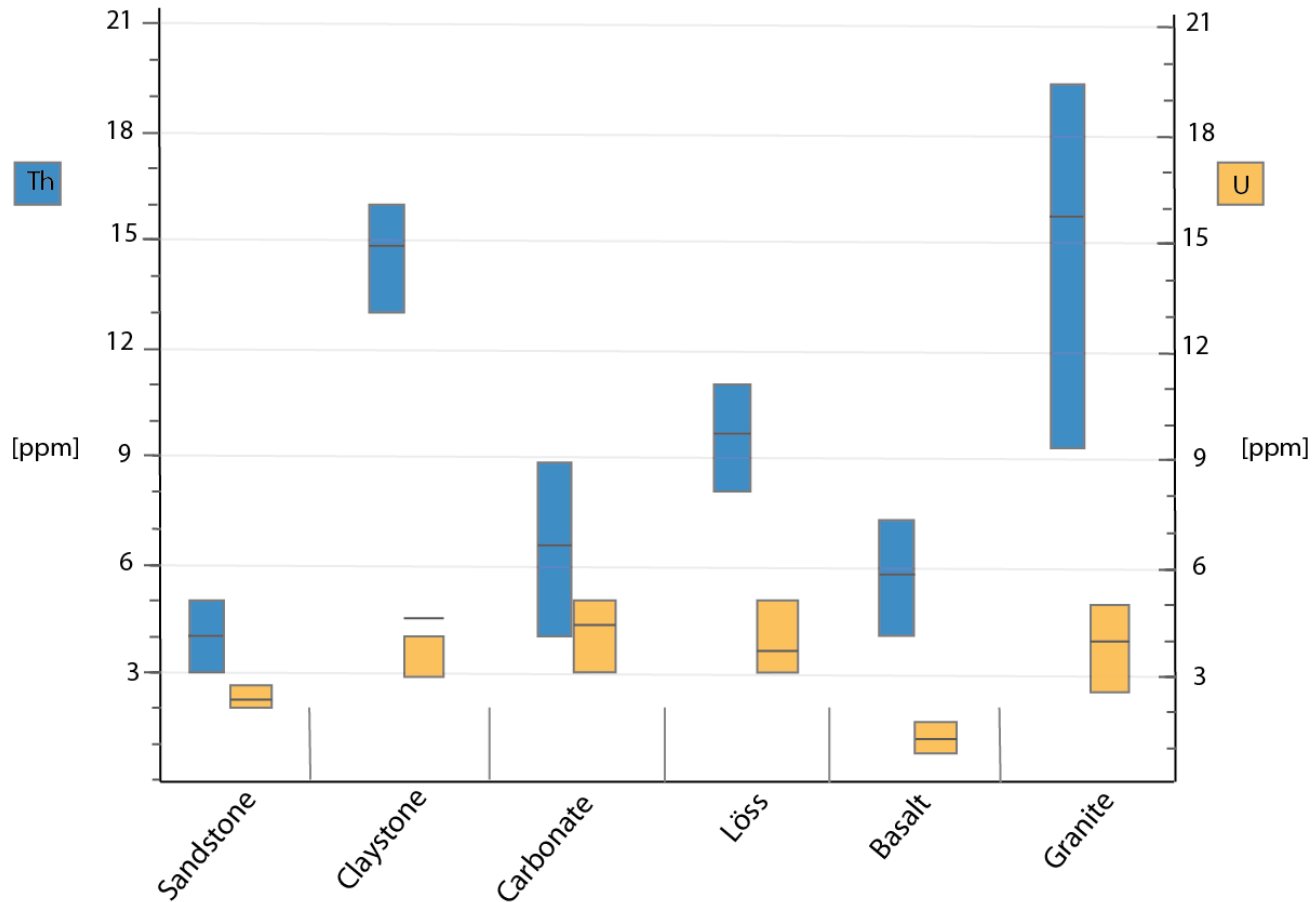
- Current map is based on interpolation of unevenly distributed Rn-soil-gas measurements
- Nevertheless: geological units can be identified → correlation of geology and amount of Rn in soil gas?



Radioactive decay of natural elements

- $^{238}\text{U} \rightarrow \dots ^{222}\text{Rn} (3,8\text{d}) \rightarrow \dots ^{206}\text{Pb}$
 - $^{232}\text{Th} \rightarrow \dots ^{220}\text{Rn} (55,6\text{s}) \rightarrow \dots ^{208}\text{Pb}$
- } >60% of natural radiation exposure
- U occurs with a few ppm in almost every rock type, bound in the crystal lattice of certain minerals such as
Feldspar, Zircon, Monazite, Titanite, Allanite, clay minerals and as secondary mineralizations.

Th- and U-content of different rock types



→ Th- and U-content of different rock types vary distinctly related to e.g. magmatic origin or sedimentation conditions.

→ Division into structural units.

Geology-based concept

1. Definition of geological (structural) units

Definition of geological (structural) units

Alluvial deposits

Quaternary Sediments

Tertiary Sediments

Tertiary Volcanic Rocks (mainly basalts, few differentiated)

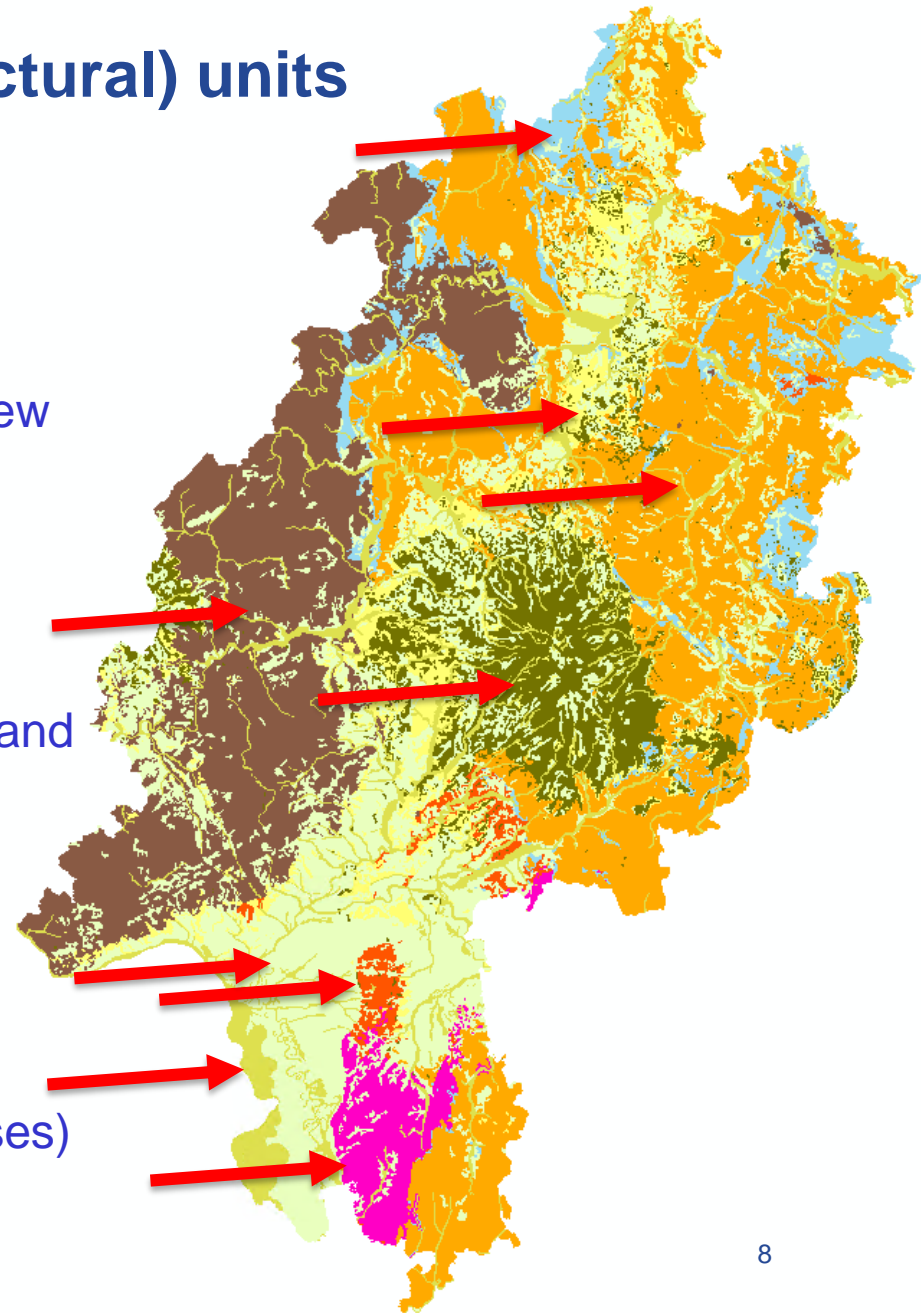
Bunter Sandstone

Mesozoic and Upper Permian (Zechstein)

Lower Permian (Rotliegend, sedimentary and igneous)

Rhenohercynian (metasedimentary and -volcanic rocks of the Devonian/Carboniferous)

Crystalline basement (granites and gneisses)



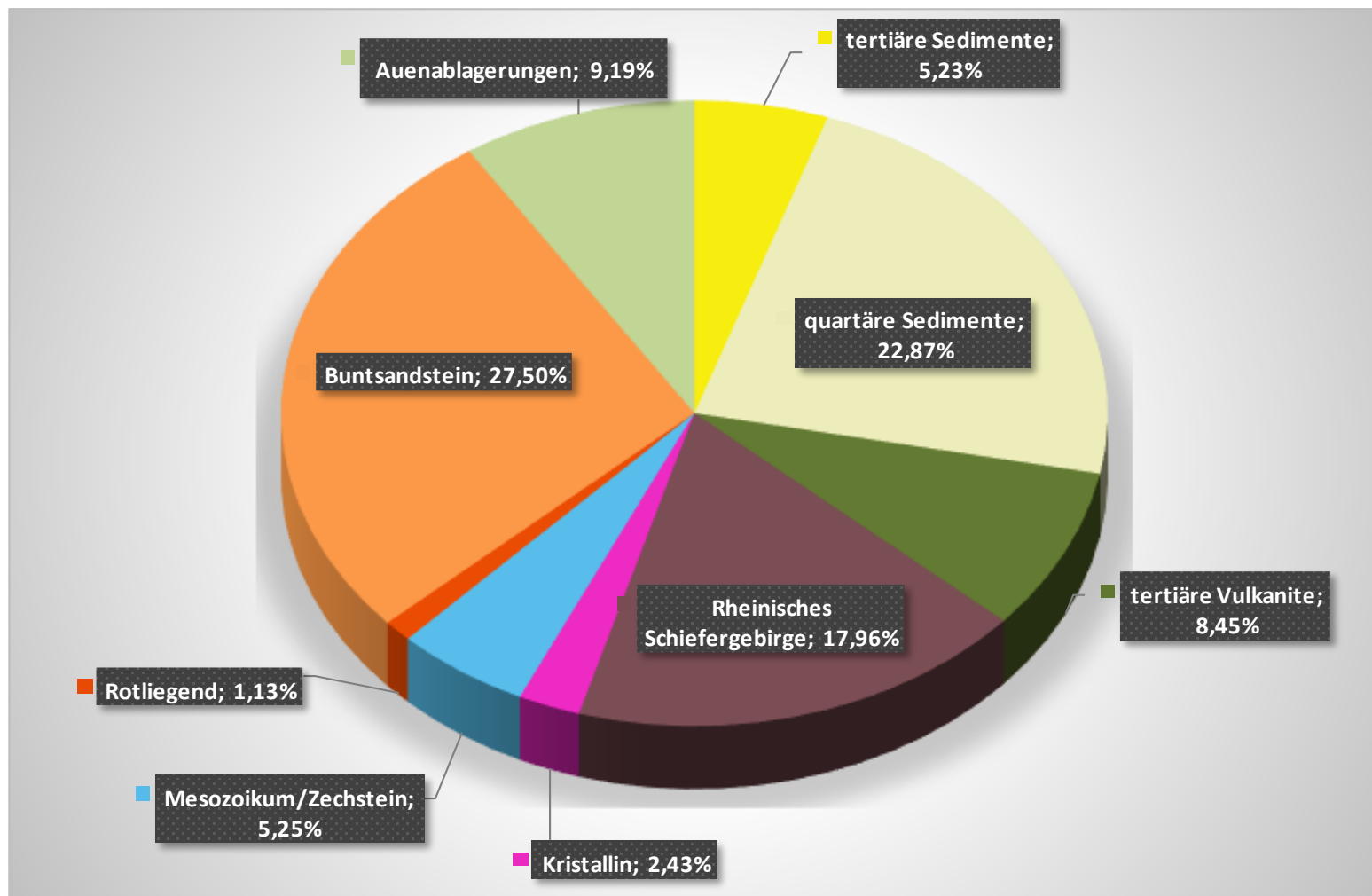
Geology-based concept

1. Definition of geological (structural) units
2. Spatial extent of structural units in Hessen

Spatial extent of structural units in Hessen

	area [km ²]	fraction [%]
Alluvial Deposits	1938,85	9,19
Quaternary Sediments	4827,43	22,87
Tertiary Sediments	1104,06	5,23
Tertiary Volcanics	1783,55	8,45
Bunter Sandstone	5804,06	27,50
Mesozoic/Upper Permian	1108,74	5,25
Lower Permian	239,57	1,13
Renohercynian	3790,17	17,96
Crystalline Basement	512,17	2,43
Total	21108,60	100,00

Spatial extent of structural units in Hessen



Geology-based concept

1. Definition of geological (structural) units
2. Spatial extent of structural units in Hessen
3. Measurements per structural unit

Measurements per structural unit

	area [km ²]	fraction [%]	Number of Measurements
Alluvial Deposits	1938,85	9,19	39
Quaternary Sediments	4827,43	22,87	172
Tertiary Sediments	1104,06	5,23	39
Tertiary Volcanics	1783,55	8,45	63
Bunter Sandstone	5804,06	27,50	207
Mesozoic/Upper Permian	1108,74	5,25	39
Lower Permian	239,57	1,13	8
Renohercynian	3790,17	17,96	135
Crystalline Basement	512,17	2,43	18
Total	21108,60	100,00	750

Geology-based concept

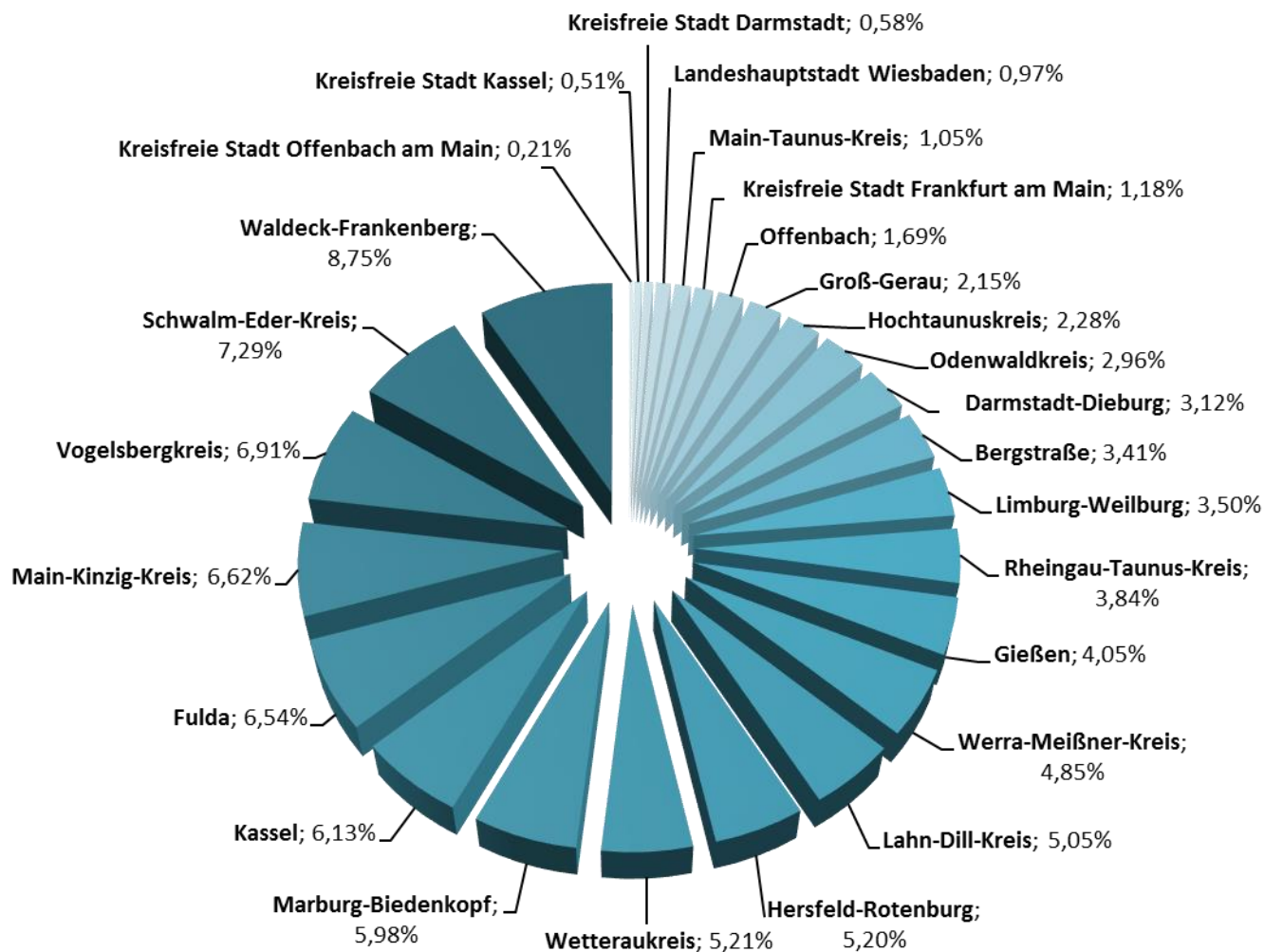
1. Definition of geological (structural) units
2. Spatial extent of structural units in Hessen
3. Measurements per structural unit
4. Spatial extent of structural unit per county

Counties in Hessen

Identification of “radon-prone” areas on the organizational level of counties



Areal fraction of counties in Hessen



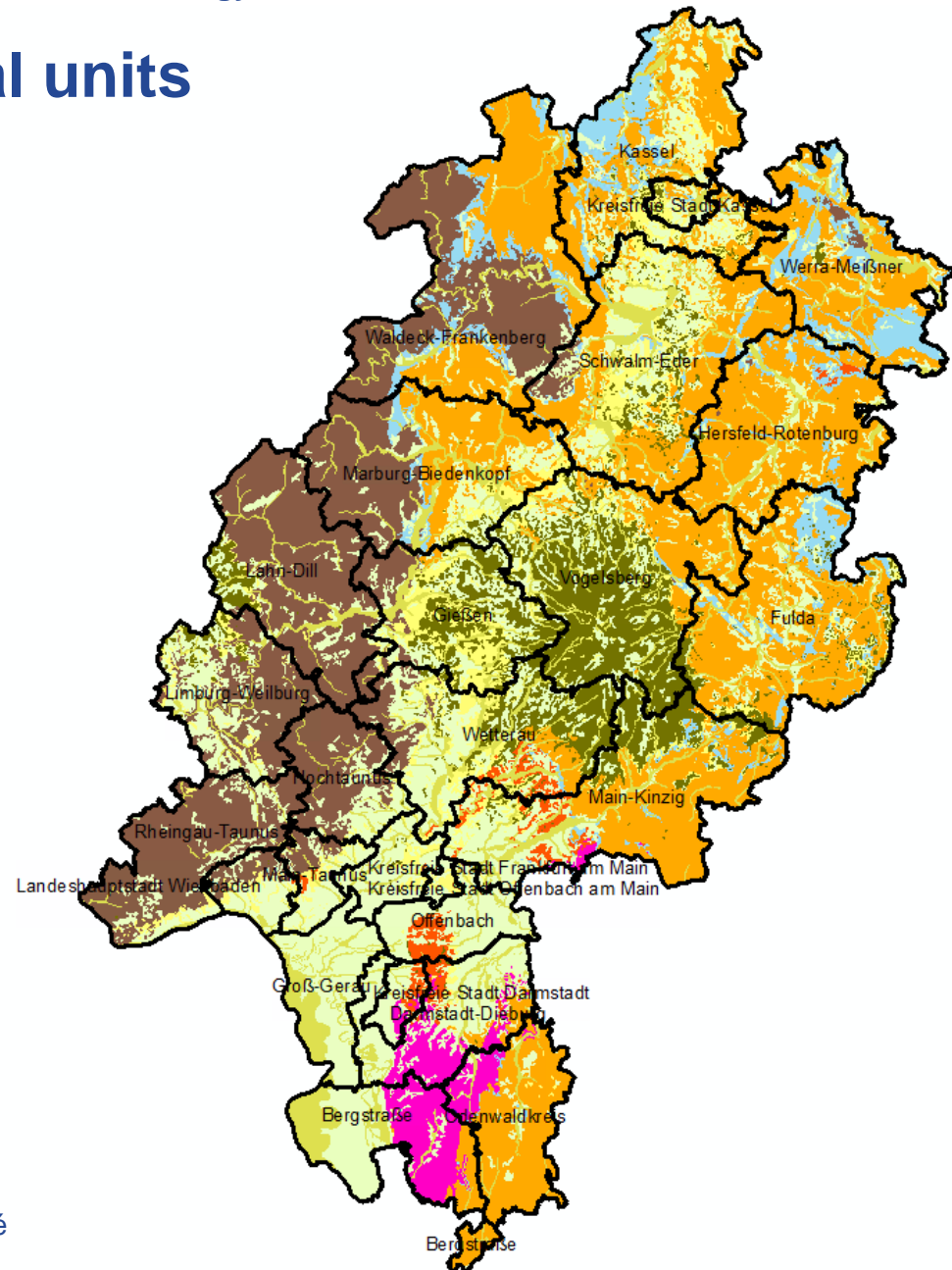
Geology-based concept

1. Definition of geological (structural) units
2. Spatial extent of structural units in Hessen
3. Measurements per structural unit
4. Spatial extent of structural unit per county
5. Measurements per county

Measurements per county

	area [km ²]	fraction [%]	No. Measurements
Kreisfreie Stadt Offenbach am Main	44,86	0,21	2
Kreisfreie Stadt Kassel	106,67	0,51	4
Kreisfreie Stadt Darmstadt	122,13	0,58	4
Landeshauptstadt Wiesbaden	203,73	0,97	7
Main-Taunus-Kreis	222,32	1,05	8
Kreisfreie Stadt Frankfurt am Main	248,16	1,18	9
Offenbach	355,96	1,69	13
Groß-Gerau	452,7	2,15	16
Hochtaunuskreis	481,51	2,28	17
Odenwaldkreis	623,56	2,96	22
Darmstadt-Dieburg	657,93	3,12	23
Bergstraße	718,9	3,41	26
Limburg-Weilburg	737,94	3,5	26
Rheingau-Taunus-Kreis	810,82	3,84	29
Gießen	853,9	4,05	30
Werra-Meißner-Kreis	1023,94	4,85	36
Lahn-Dill-Kreis	1065,35	5,05	38
Hersfeld-Rotenburg	1096,88	5,2	39
Wetteraukreis	1099,84	5,21	39
Marburg-Biedenkopf	1261,48	5,98	45
Kassel	1292,36	6,13	46
Fulda	1379,64	6,54	49
Main-Kinzig-Kreis	1396,04	6,62	50
Vogelsbergkreis	1457,63	6,91	52
Schwalm-Eder-Kreis	1537,83	7,29	55
Waldeck-Frankenberg	1847,23	8,75	66
Total	21099,31	100	750

Areal fraction of structural units vs. counties



Measurements per county and structural unit

	Alluvial Deposits	Bunter Sandstone	Crystalline Basement	Renohercynian	Lower Permian	Quaternary Sediments	Tertiary Sediments	Tertiary Volcanics	Mesozoic/ Lower Permian
Kreisfreie Stadt Darmstadt			1		1	3			
Kreisfreie Stadt Frankfurt am Main	1					7	1		
Kreisfreie Stadt Offenbach am Main						1	1		
Landeshauptstadt Wiesbaden	1			2		3	1		
Bergstraße	6	4	9			8			
Darmstadt-Dieburg	2	1	5		1	12			
Groß-Gerau	5					11			
Hochtaunuskreis	1			11		4			
Main-Kinzig-Kreis	5	20	1		2	10	3	8	2
Main-Taunus-Kreis	1			2		4	1		
Odenwaldkreis	1	16	3			1			
Offenbach	1				2	10			
Rheingau-Taunus-Kreis	1			22		5	1		
Wetteraukreis	5	2		4	2	13	4	9	
Gießen	3			5		7	6	9	
Lahn-Dill-Kreis	2			28		4	1	2	
Limburg-Weilburg	1			13		9	2	1	
Marburg-Biedenkopf	5	13		16		7	2	1	2
Vogelsbergkreis	5	11				10	3	24	
Kreisfreie Stadt Kassel	1	1				1	1		
Fulda	3	28				7	1	4	6
Hersfeld-Rotenburg	3	28			1	4			3
Kassel	3	20				11	4	1	8
Schwalm-Eder-Kreis	6	21		2		14	7	4	2
Waldeck-Frankenberg	4	23		29		3			7
Werra-Meißner-Kreis	3	19		1		3			10
SUM	69	207	18	135	8	172	39	63	39

Geology-based concept

1. Definition of geological (structural) units
2. Spatial extent of structural units in Hessen
3. Measurements per structural unit
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5. Measurements per county
6. Definition technical limitations (probing, moisture)

Definition of technical limitations – probing

„Digability“

10: Oberboden

20: fließende Bodenarten (BA)

31: leicht lösbare BA (speziell Kiese)

31: leicht lösbare BA (Rest)

32: leicht lösbare BA (feste Torfe)

40: mittelschwer lösbare BA (Rest ohne SS, Lehmtone)

51: schwer lösbare BA (Rest mit GBAnt 5)

51: schwer lösbare BA (Auswahl mit GBAnt 4)

52: schwer lösbare BA (Auswahl mit GBAnt 4)

60: leicht lösbarer Fels (Bk/Br) mit Grobbodenanteil 5/6

60: leicht lösbarer Fels (Rest ohne Kiese) mit GBAnt 6

70: schwer lösbarer Fels

loose material

organics/peat

sand

medium gravel

clay

coarse gravel

rock

Definition of technical limitations - moisture

0 = suitable

1 = groundwater soil wetness 4-6

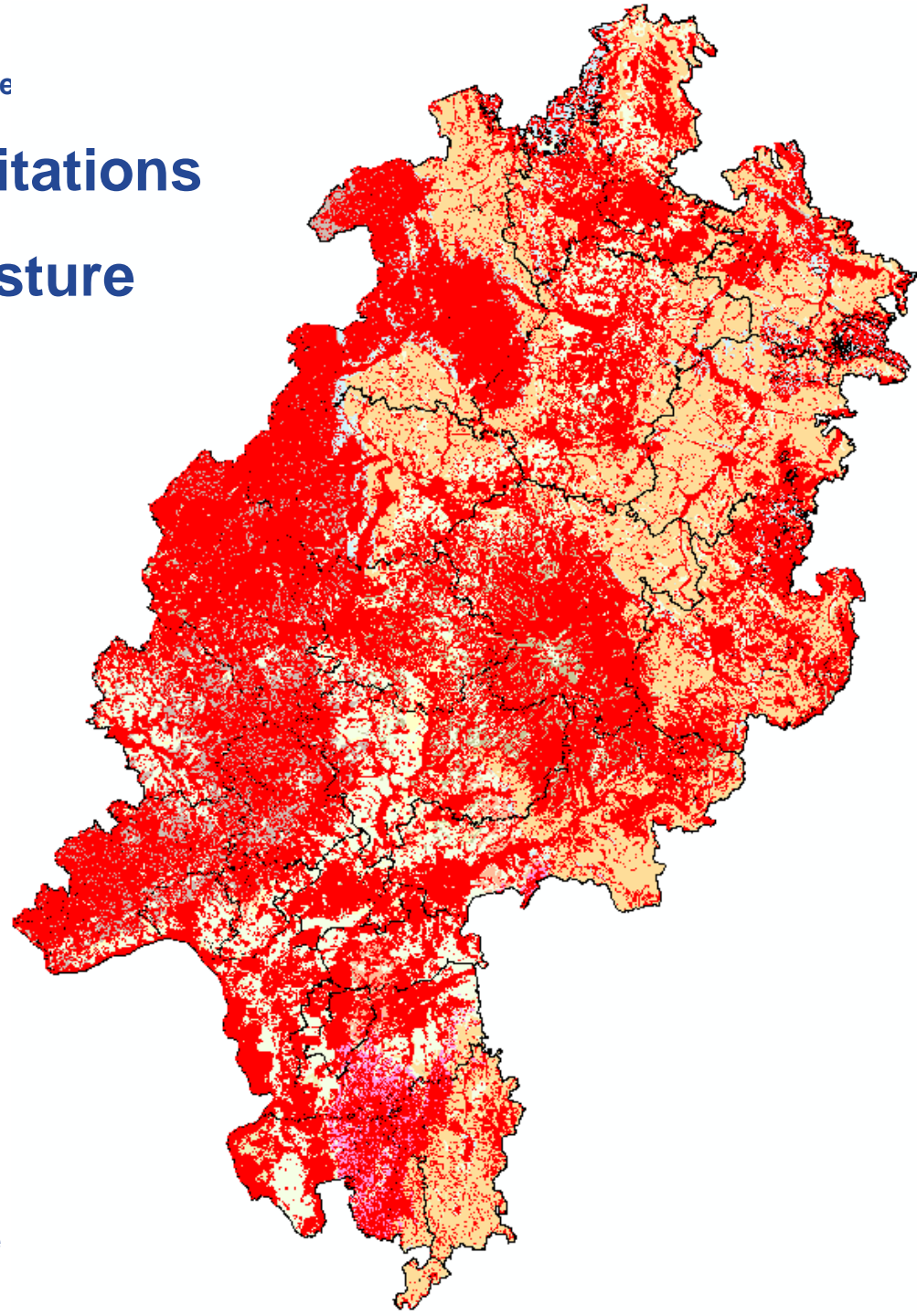
2 = groundwater soil wetness 1-3

3 = soil wetness 3-6 and hillside soil wetness 3-6

Definition of technical limitations

– probing/digability + moisture

 = unsuitable



Geology-based concept

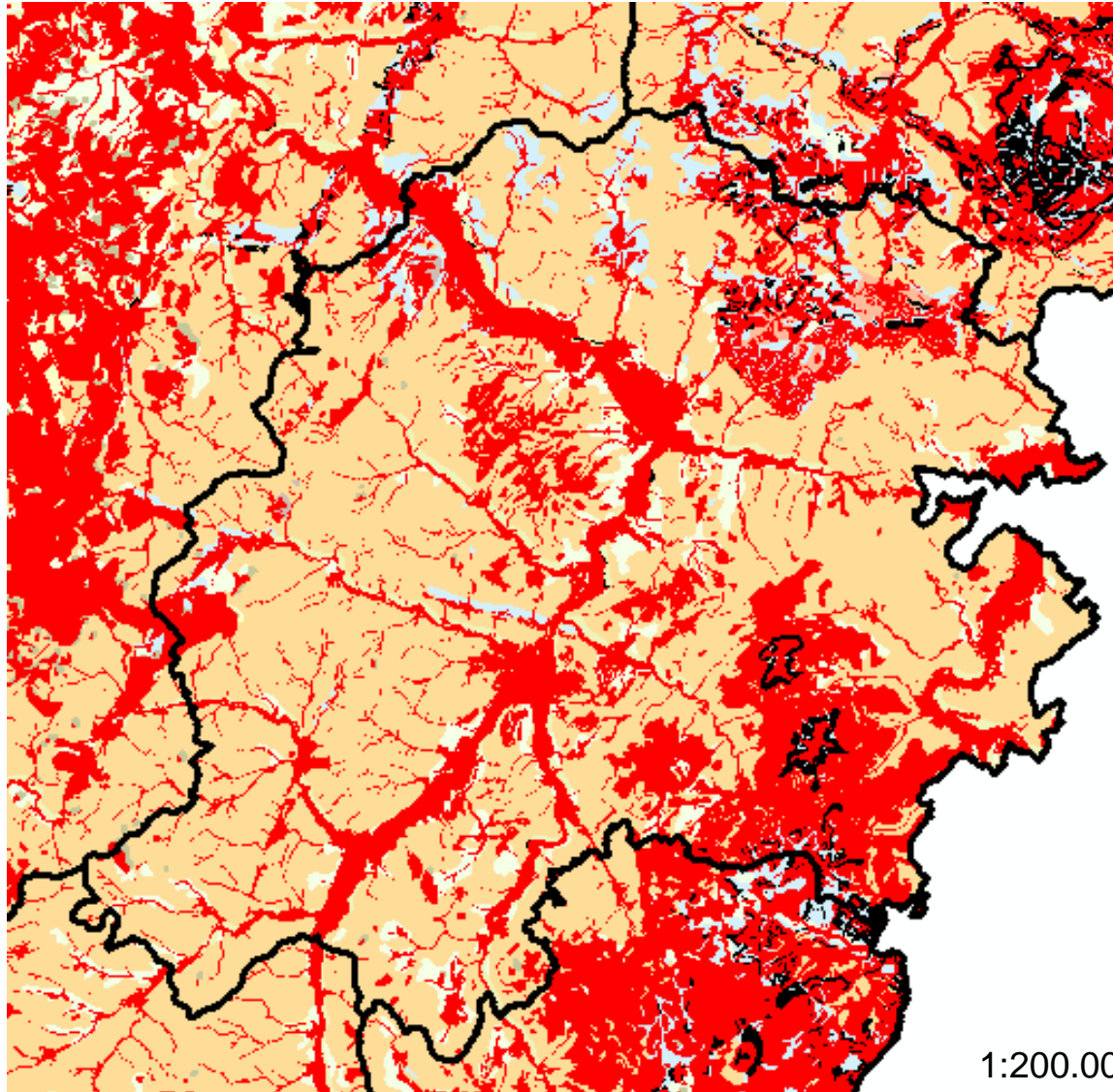
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7. Determining potential measuring sites

Determining potential measuring sites

Example: County of Hersfeld-Rotenburg

	area [km ²]	fraction [%]	measurements
Alluvial Deposits	76,16	6,96	2,72
Quaternary Sediments	109,73	10,03	3,91
Tertiary Sediments	2,31	0,21	0,08
Tertiary Volcanics	6,74	0,62	0,24
Bunter Sandstone	798,29	72,98	28,46
Mesozoic/Upper Permian	87,22	7,97	3,11
Lower Permian	11,61	1,06	0,41
Renohercynian	1,78	0,16	0,06
Crystalline Basement	0,00	0,00	0,00
Total	1093,85	100,00	39,00

County of Hersfeld-Rotenburg - limitations



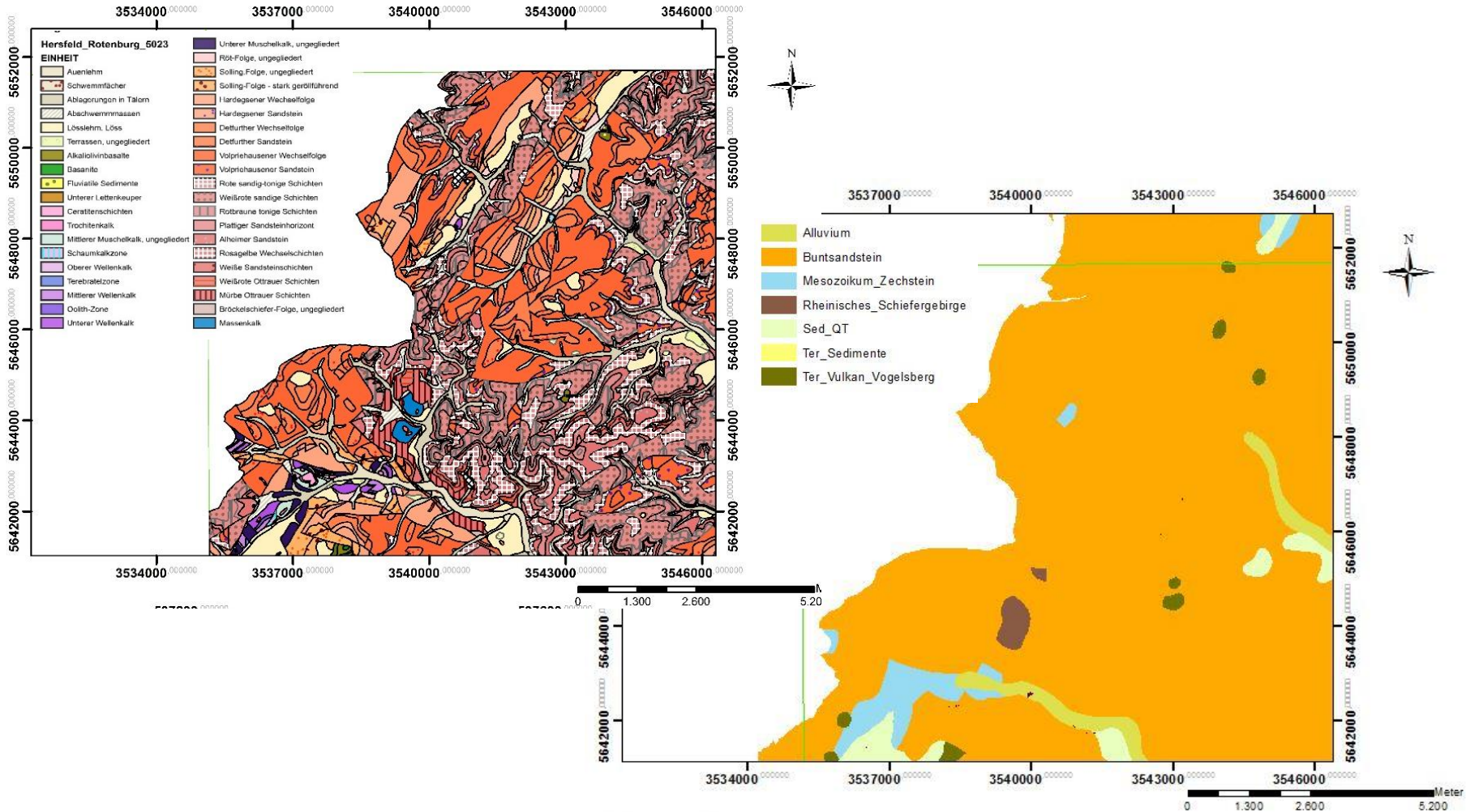
 = unsuitable

1:200.000

Geology-based concept

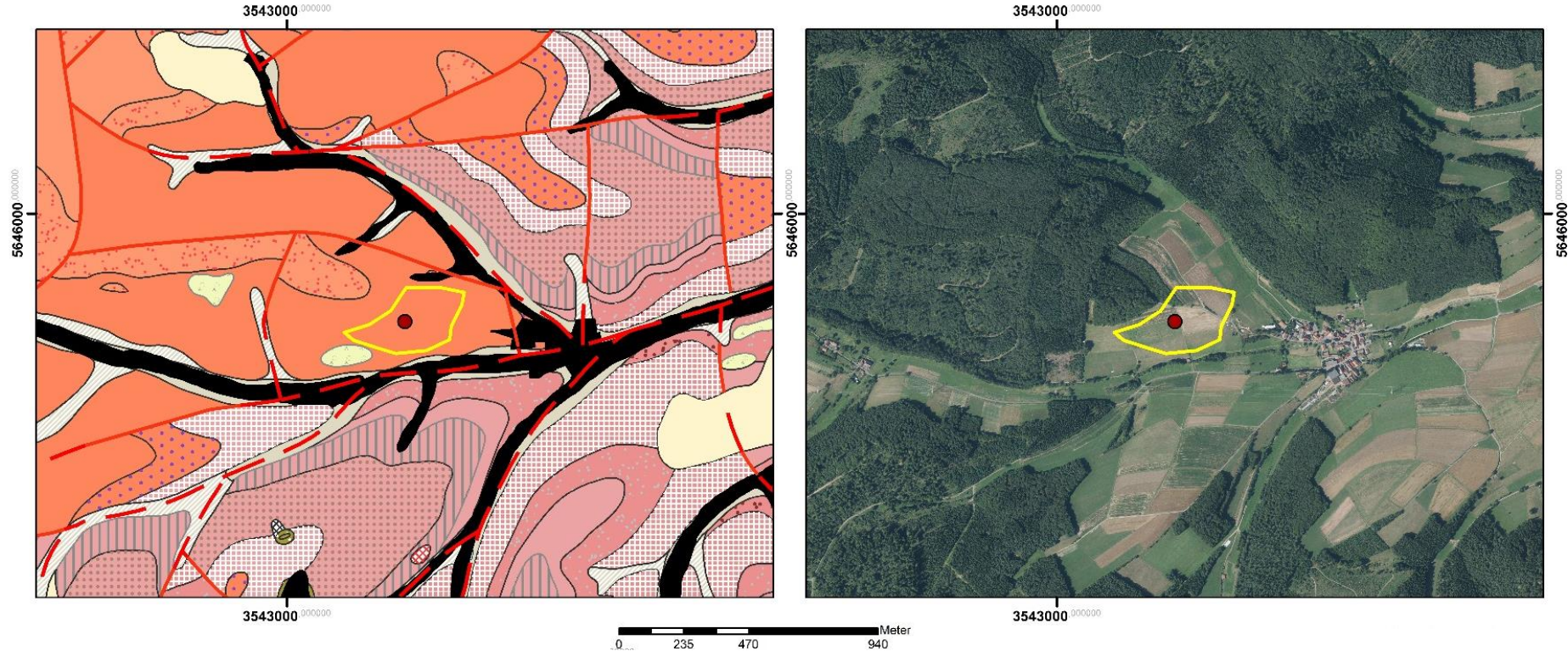
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6. Definition technical limitations (probing, moisture)
7. Determining potential measuring sites
8. Verification of potential measuring sites

Verification of potential measuring sites: GK25



Selection of measuring sites based on variability in stratigraphy and lithology.

Verification of potential measuring sites: GK25



- Areal fraction of geological unit
- Avoid faults/shear zones
- Different land use (forest vs. field)

Geology-based concept

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7. Determining potential measuring sites
8. Verification of potential measuring sites
9. Creation of map sheets

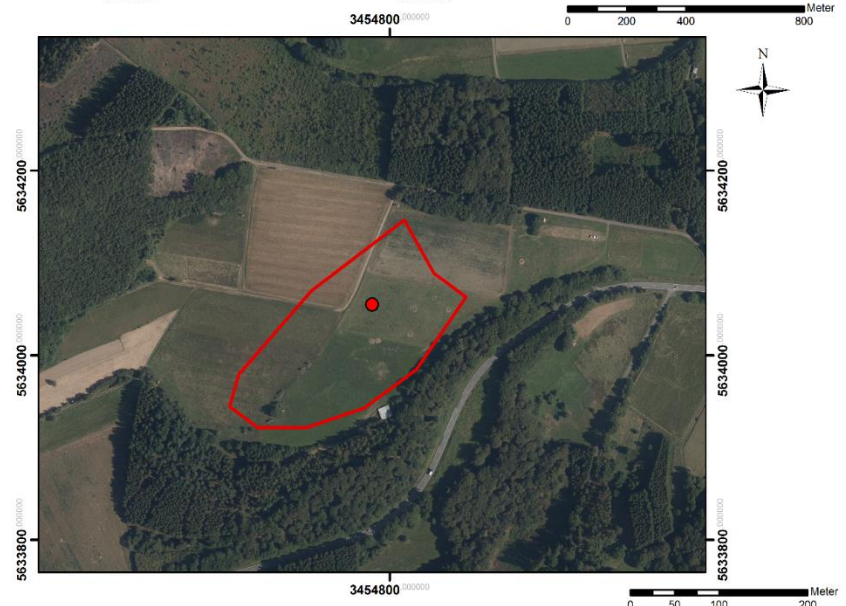
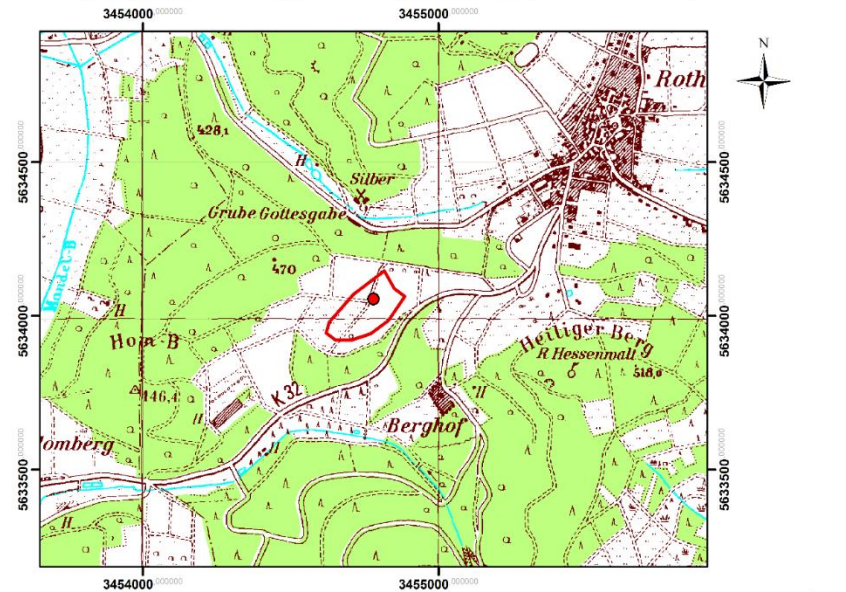
Creation of map sheets

accessibility of measuring site by car must be guaranteed

Final layout of map sheets include:

- Topographic map (1:10.000)
- Satellite image (1:5.000)
- Coordinates and identification code of measuring site

County: Lahn-Dill
Geological Unit Rhenohercynian. Measuring site LDK-RS-23 (X:3454780 Y:5634055)

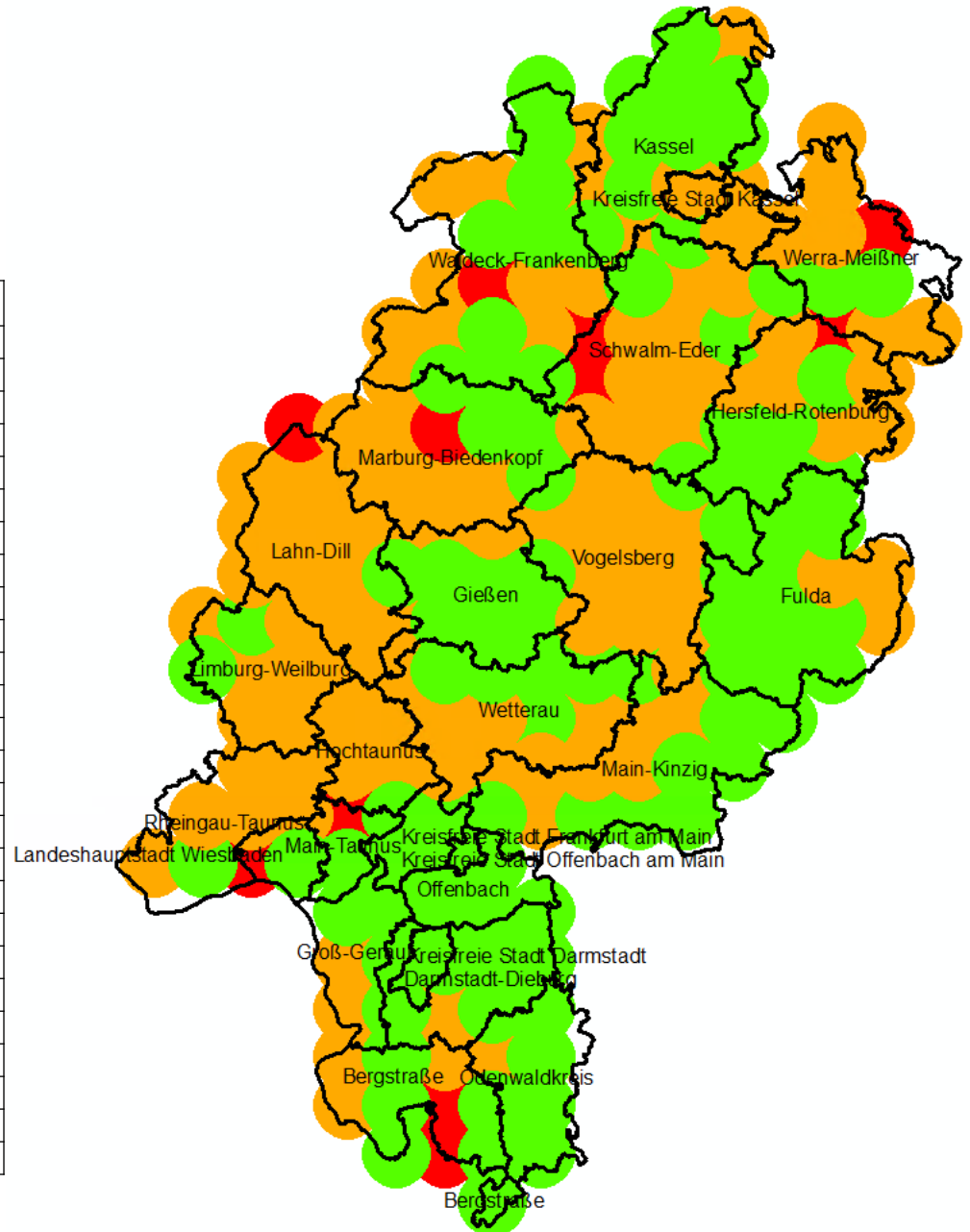


Source: Topographic Map, Satellite image (HVBG)
Coordinate system: DHDN_3_Degree_Gauss_Zone_3
WKID: Authority: 31467 (EPSG)
Authors: Abimbola Olukeuwu, Annemarie Militzer, Rouven Lehné
December 2017

Order of processing

Priority: clarify orange areas

Order	County
1	Hochtaunus
2	Hersfeld-Rotenburg
3	Lahn-Dill
4	Vogelsberg
5	Limburg-Weilburg
6	Schwalm-Eder
7	Rheingau-Taunus
8	Wetterau
9	Werra-Meißner
10	Marburg-Biedenkopf
11	Bergstraße
12	Waldeck-Frankenberg
13	Main-Kinzig
14	Groß-Gerau
15	Kreisfreie Stadt Kassel
16	Kassel
17	Fulda
18	Darmstadt-Dieburg
19	Odenwaldkreis
20	Landeshauptstadt Wiesbaden
21	Main-Taunus
22	Gießen
23	Offenbach
24	Kreisfreie Stadt Frankfurt am Main
25	Kreisfreie Stadt Darmstadt
26	Kreisfreie Stadt Offenbach am Main



Thank you for your attention!