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BGS & UKHSA

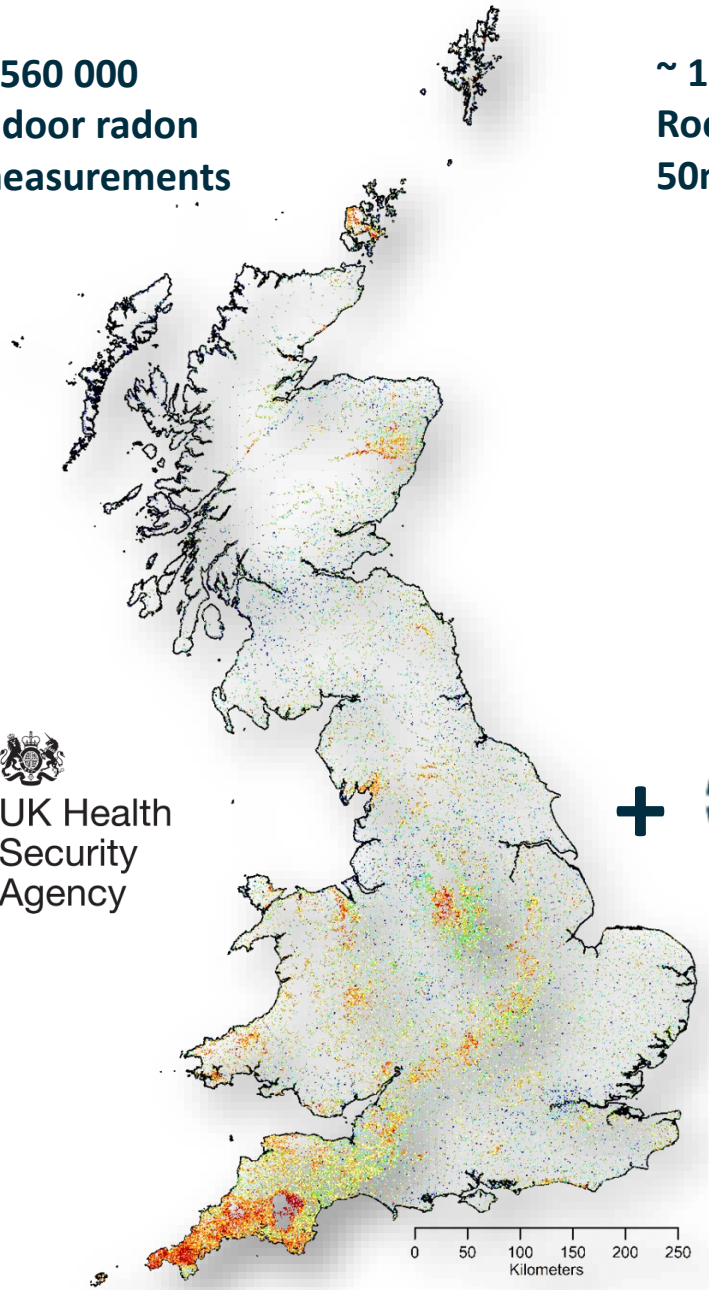
The New GB Radon Map
The Geology perspective

British Geological Survey

GARRM, Prague, 19th-21st September 2023

Use GEOLOGY for Radon Mapping?

> 560 000 indoor radon measurements



UK Health Security Agency

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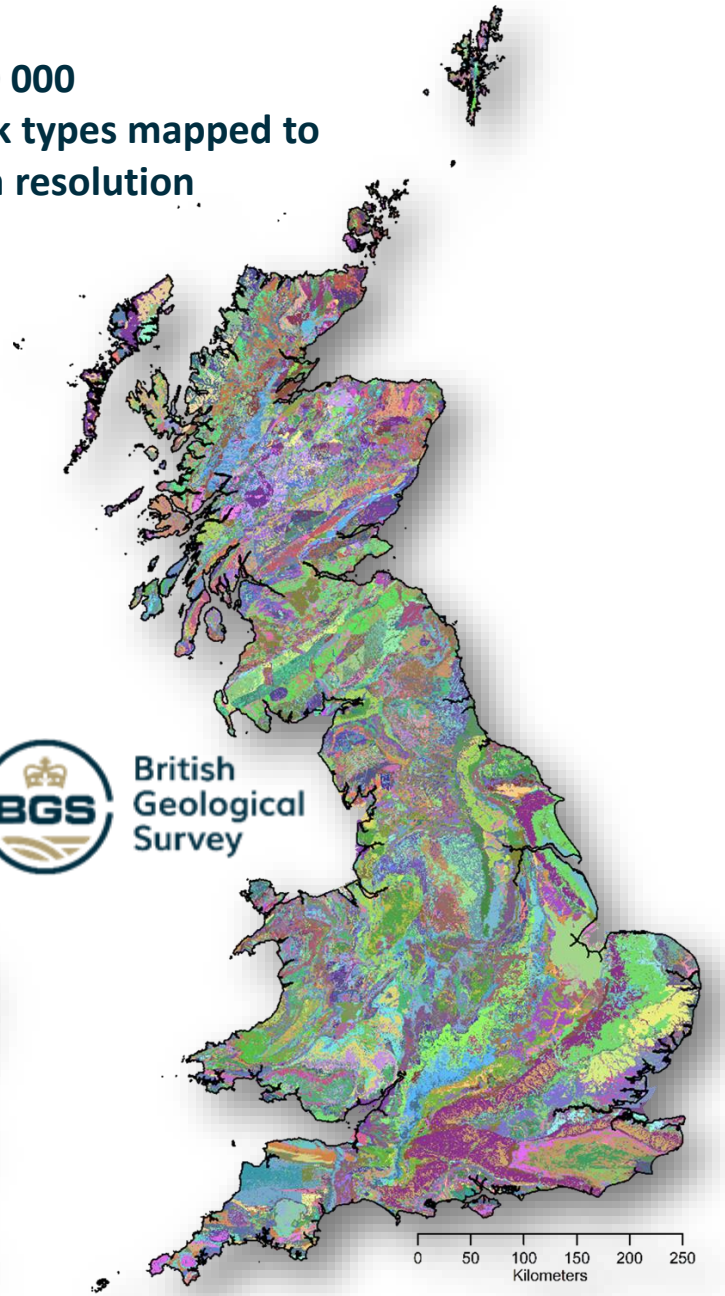
British Geological Survey

~ 10 000 Rock types mapped to 50m resolution



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Statistical model to combine source, pathway and receptor

Why making a new GB Radon Map version?
Geology Map Changes

Our data and understanding about Geology,

evolves much faster than the geology itself ;))

Since the last GB radon mapping (England and Wales, 2007 and Scotland, 2011) most of our geology map has had some form of update or resurvey, materialised in 5 successive updates of BGS mapped geology.

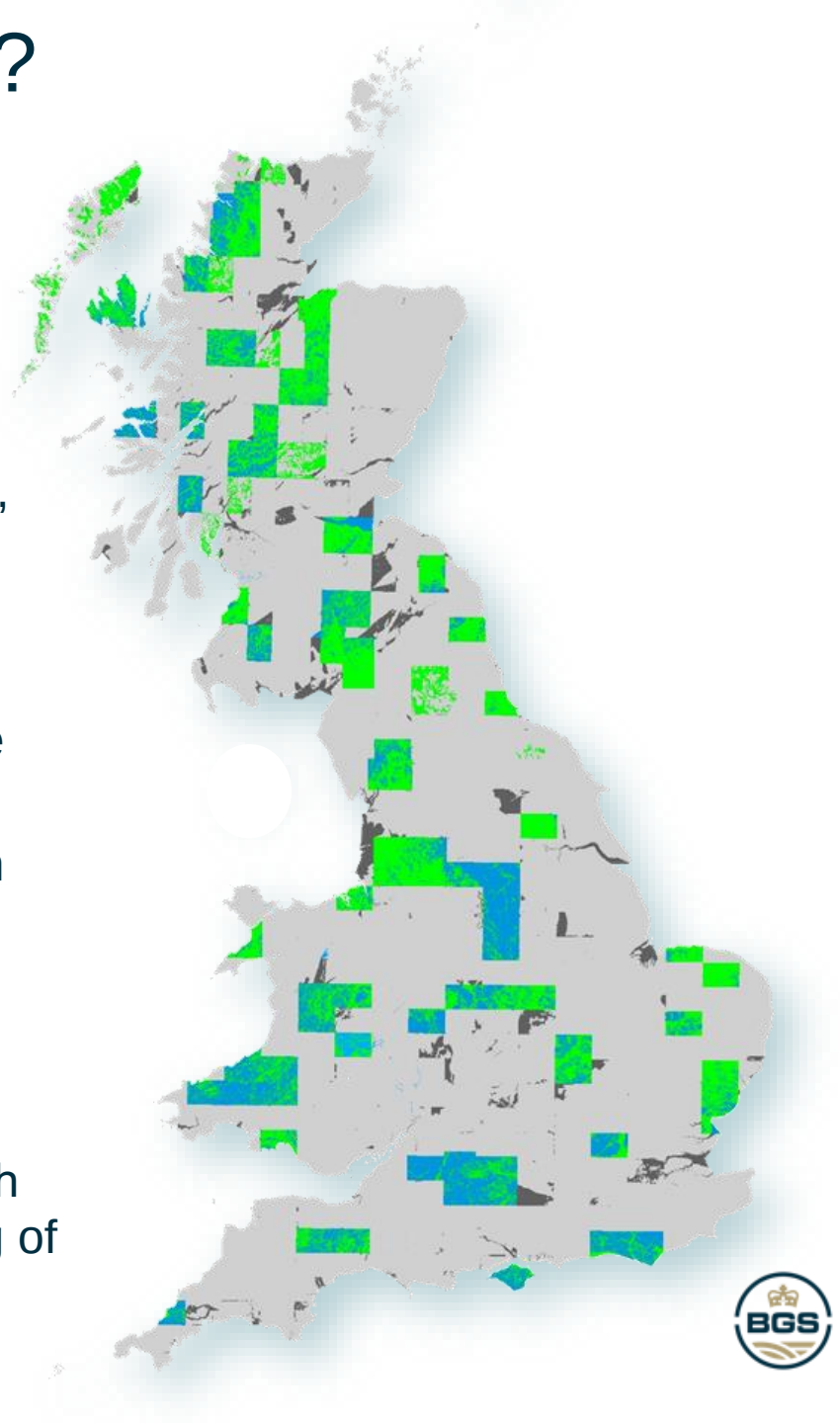
In the map shown,

. the green and blue areas are completely new maps, some in radon prone areas;

. the pale grey areas are where minor changes in nomenclature have been made;

. only the dark grey areas are completely unchanged since 2007;

Better maps (and faster computers) allow us to do more than we could in 2007. So, revisiting how we ‘combine’ areas of geology to use together with the UKHSA measurements, is a logical next step in improving the mapping of radon risk / radon prone areas.



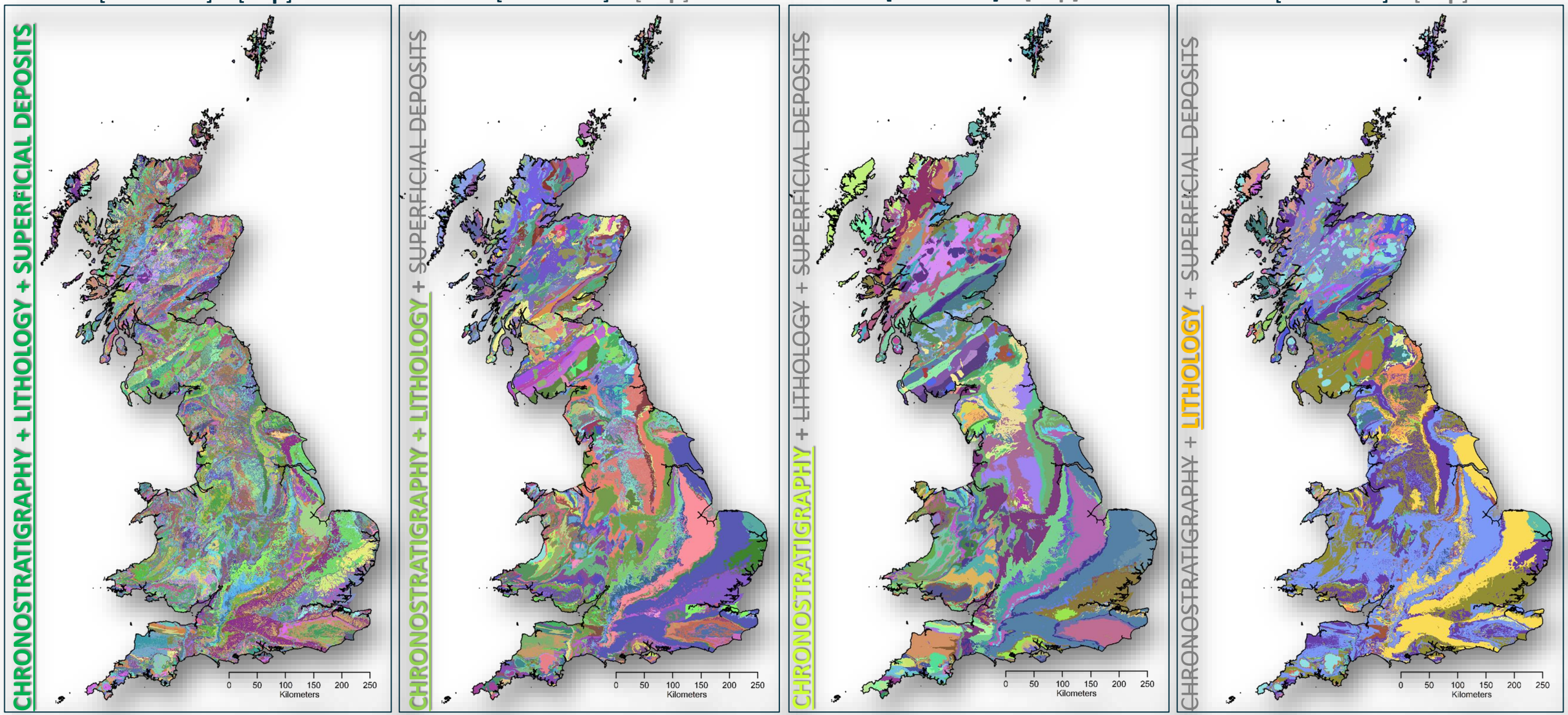
What else has changed between the previous and new versions?

	Previous edition (2007 / 2011)	New edition (2022)
Measurements	479000	560740 (80000+)
Geology map	Version **3**.14 (1:50 000)	Version **8**.25 (1:50 000)
Method: combining geology datasets	**one layer** of 'simplified' geology combinations (**COM**)	**four layers** of 'simplified' geology (**BS**, **BED**, **Lex**, **RCS**), with a hierarchical structure between them and decreasing geological complexity
Method: number of simplified geology combinations	**COM**: **2232** combinations (798 for Scotland + 1434 for England &Wales)	Layer 1 (**BS**): **9323** combinations Layer 2 (BED): 1674 combinations Layer 3 (Lex): 348 combinations Layer 4 (RCS): 45 combinations } Across GB
Method: other modifications	UKHSA gridding: **100 +** samples per COM; BGS gridding: - 100 samples per COM (**4 gridding methods** according to No. samples per COM: **10 + samples NOT ensured**) Wider use of expert judgement to 'fill' gaps	UKHSA gridding: **30 +** samples per BS; BGS gridding: - 30 samples per BS (**1 gridding method applied to 4 layers**, according to No. samples per Layer #: **10 + samples ensured**) Much reduced use of expert judgement (0.006%)

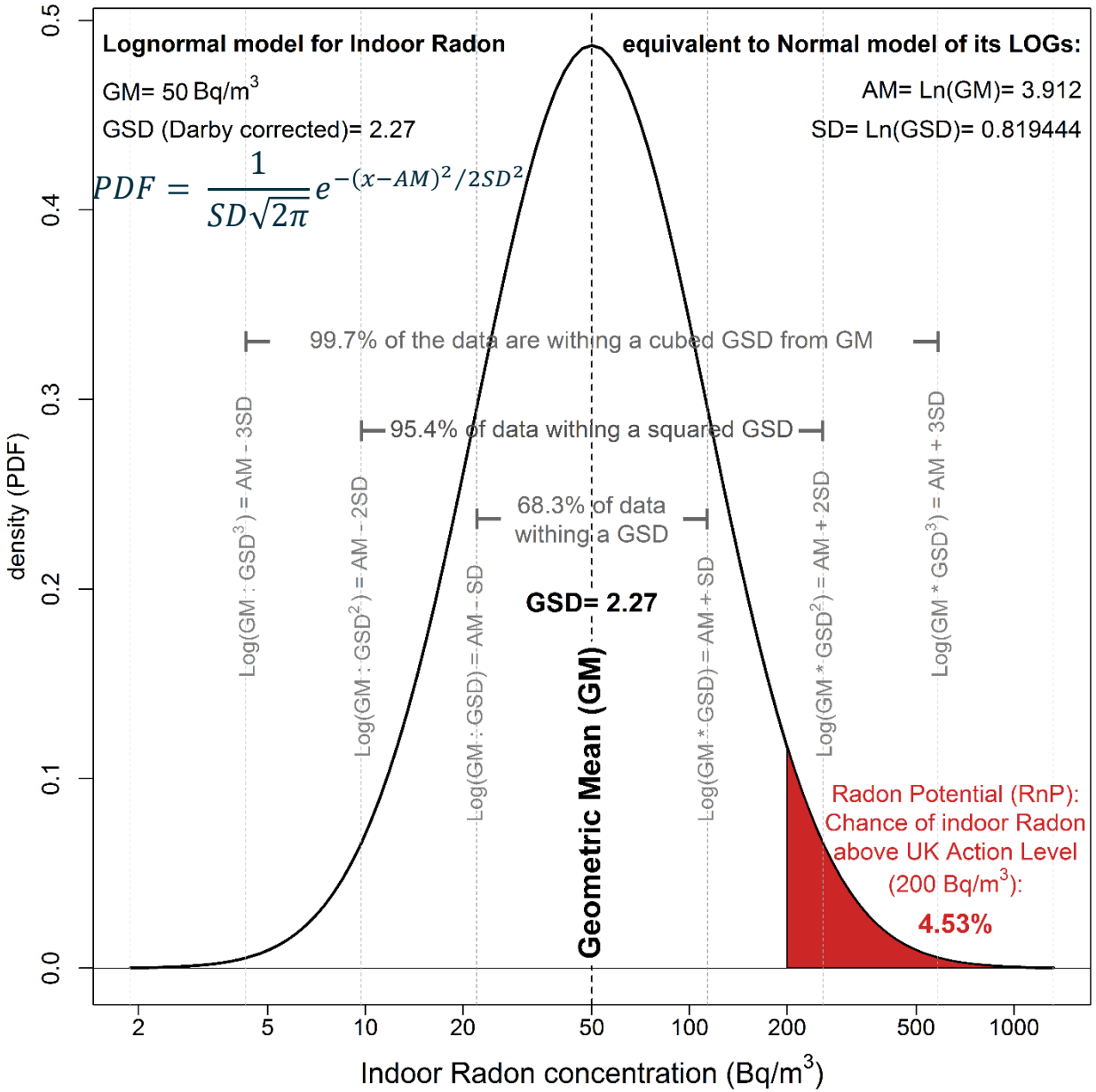
4 Layers of Simplified Geology (preference from left to right):

BS (N=9323) > **BED (N=1674)** > **Lex (N=348)** > **RCS (N=45)**

[Lex x RCS] x [Sup] | [Lex x RCS] x [~~Sup~~] | [Lex x ~~RCS~~] x [~~Sup~~] | [~~Lex~~ x RCS] x [~~Sup~~]



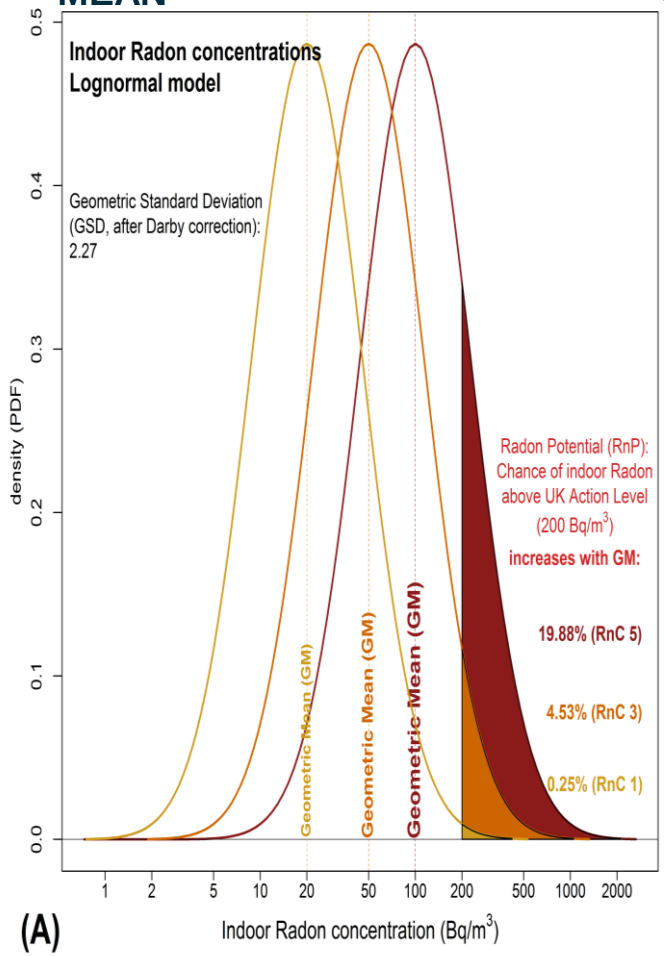
Computing Rn potential* in KMBS ‘cells’ from GM and GSD



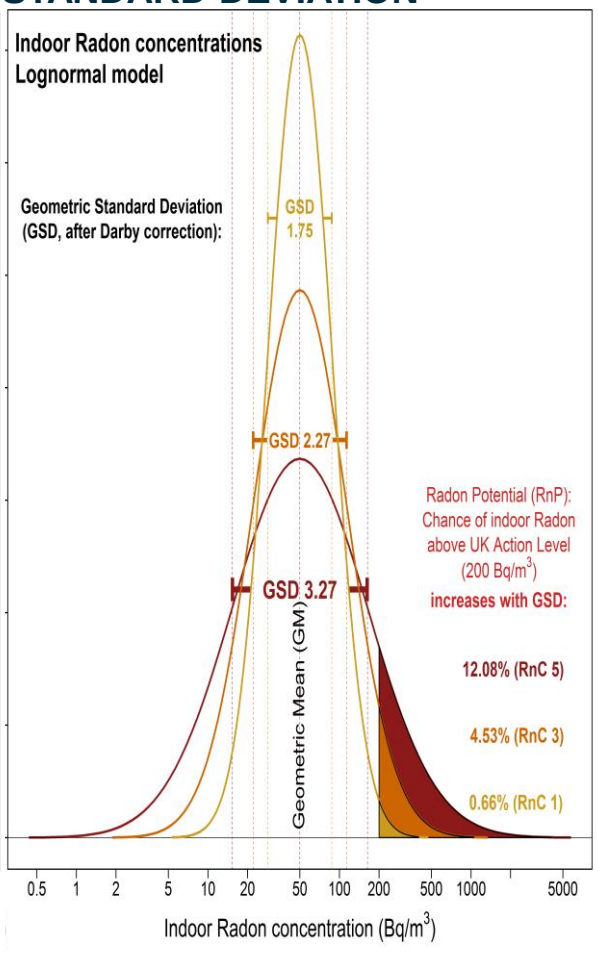
*as the probability of indoor radon exceeding 200 Bq/m^3

Radon potential increases with:

Geometric MEAN

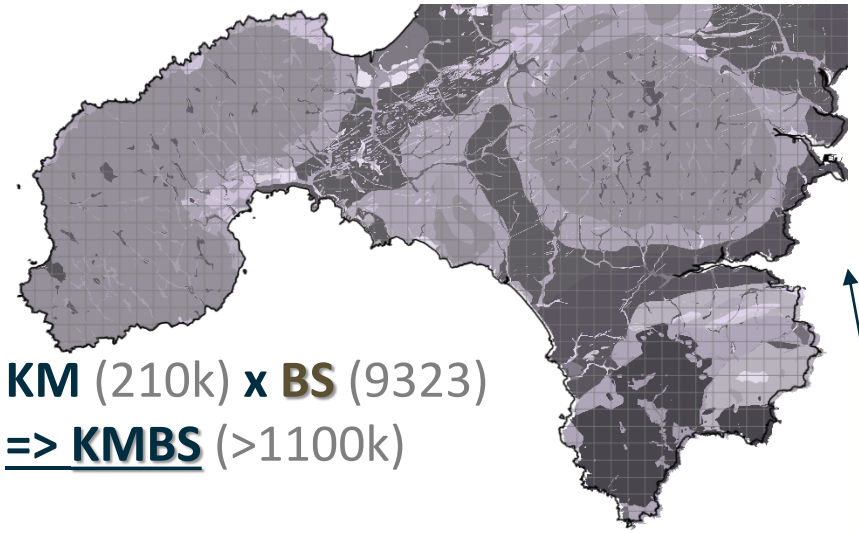


Geometric STANDARD DEVIATION

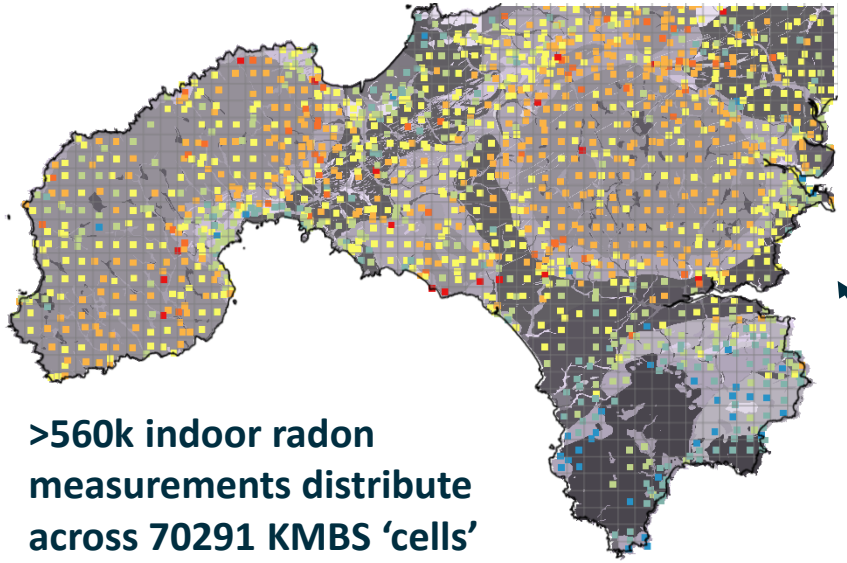


Assumption: **Radon is Lognormal**

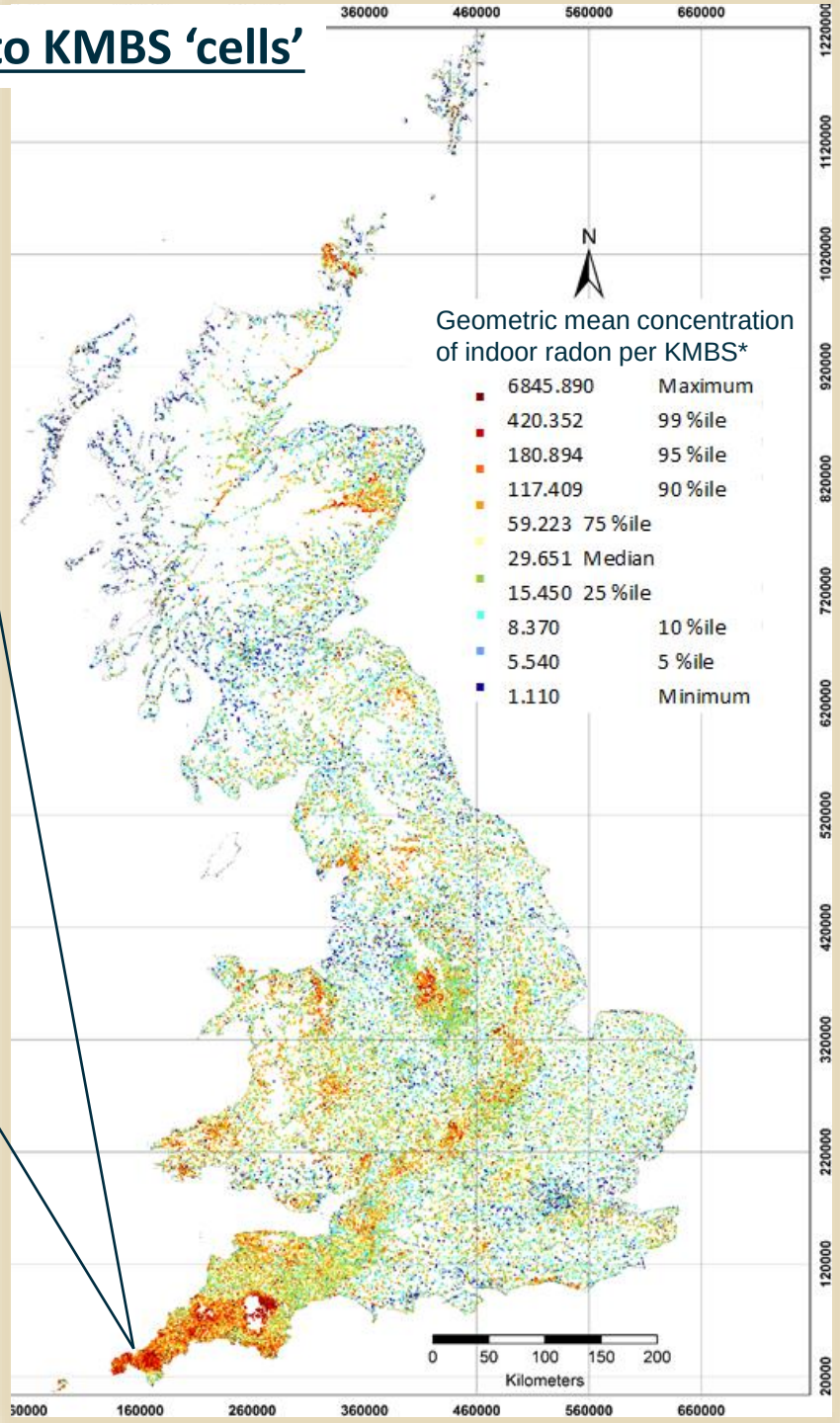
Indoor Radon Measurements assigned to KMBS 'cells'



KM (210k) **x BS** (9323)
=> KMBS (>1100k)

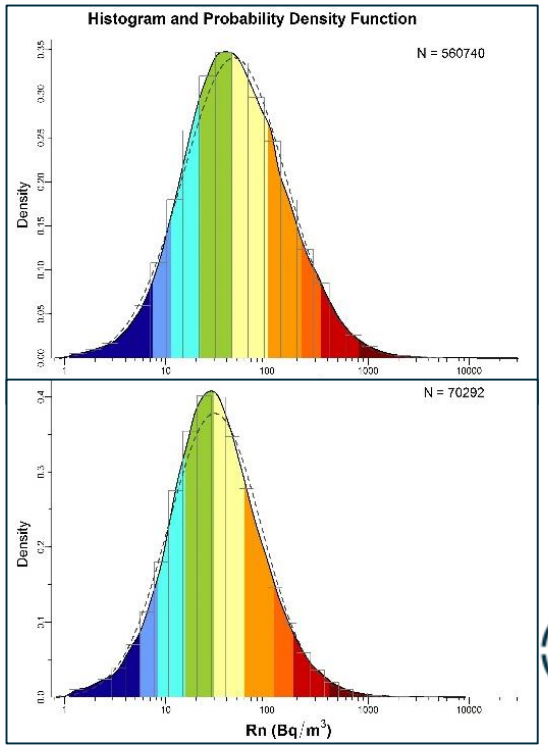


>560k indoor radon measurements distribute across 70291 KMBS 'cells'

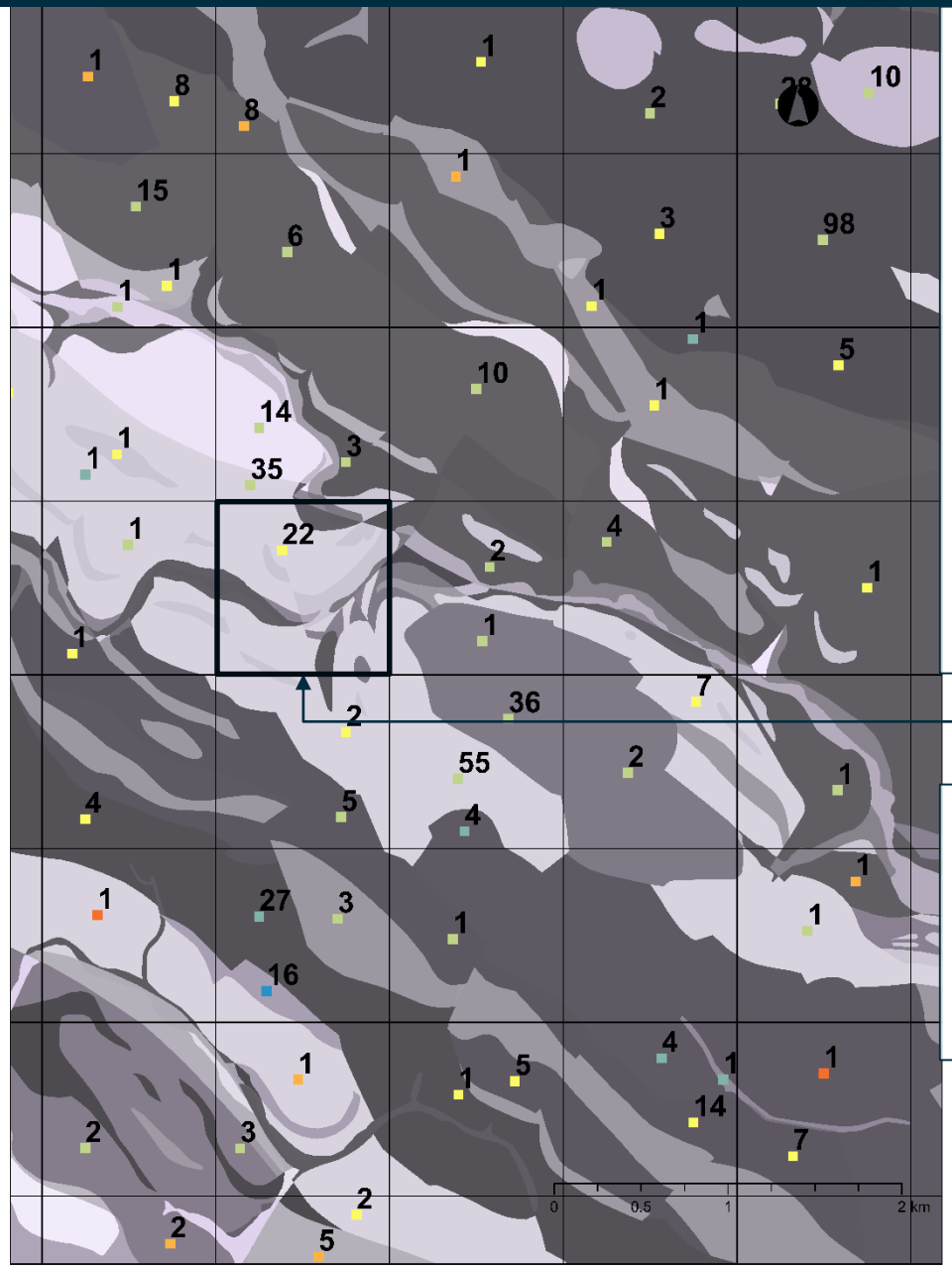


* **KMBS** (N=1183678) = **BS x KM**

- The basic non-standard (≤ 1Km^2) polygons resulting from the **split** of the **BS simplified geology** by the **1km^2 BNG.**
- To allocate the data points, providing **spatial (KM)** and **geological (BS) reference** while **ensuring anonymity of the data points;** the **+560k** data points distribute over **70291** KMBSs.
- The statistics and derived **radon potential are computed** at these indivisible 'cells' **relying on the** (nearest…) **data points IN the same simplified geology** only, and assuming lognormality of indoor radon data.



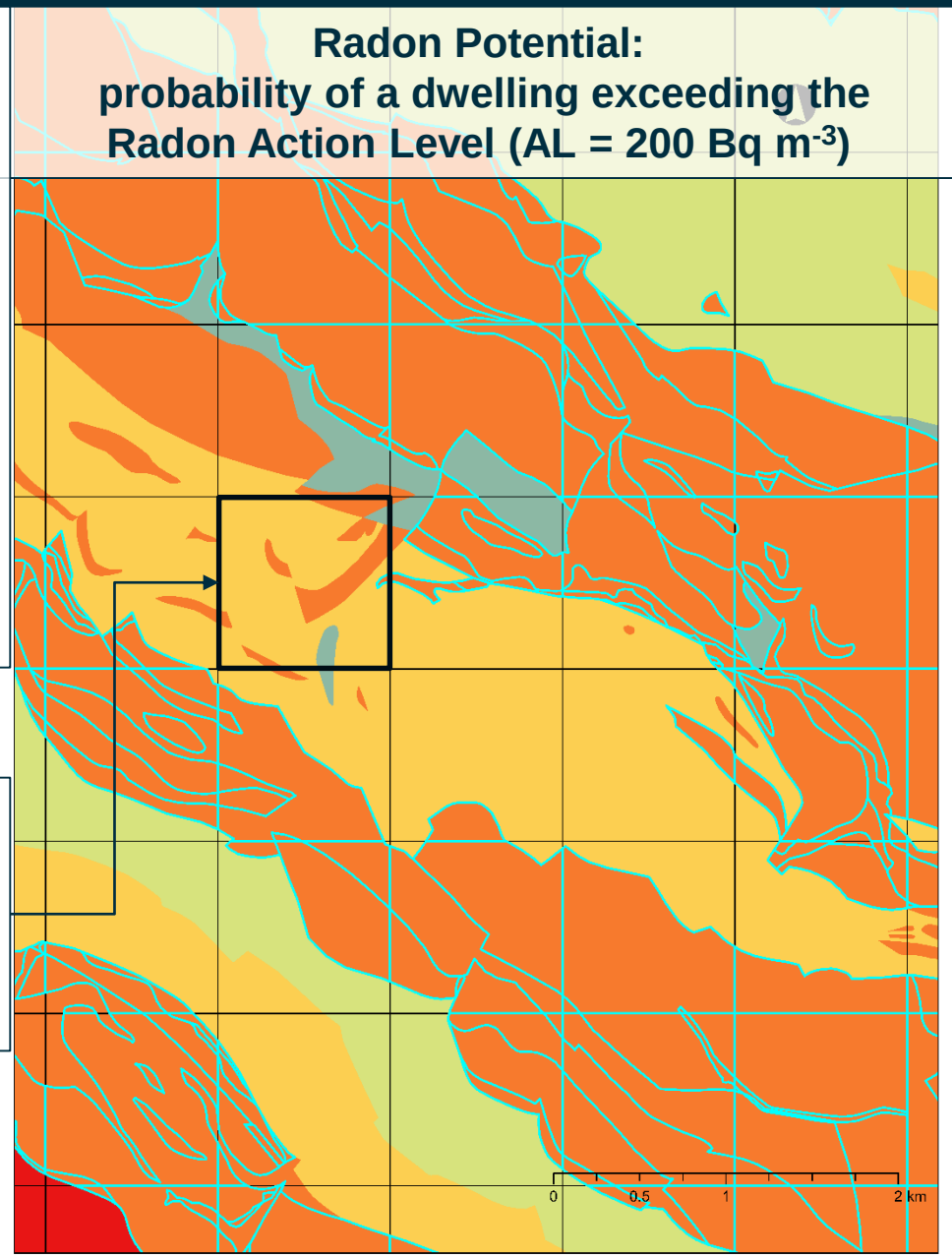
Computing Rn stats in KMBS ‘cells’



Each KM square may have multiple BS simplified geologies (ex.: TAMA.CZ, TAMA.CZ.AiC, TAMA.CZ.AiS, TAMA.CZ.RiC, TAMA.LS, TAMA.VC, DC.GB, DC.GB.AiC, DC.GB.AiS, DUCT.LS) **from which result the KMBS ‘cells’.**
Each indoor radon measurement is assigned to one of these KMBS ‘cells’.

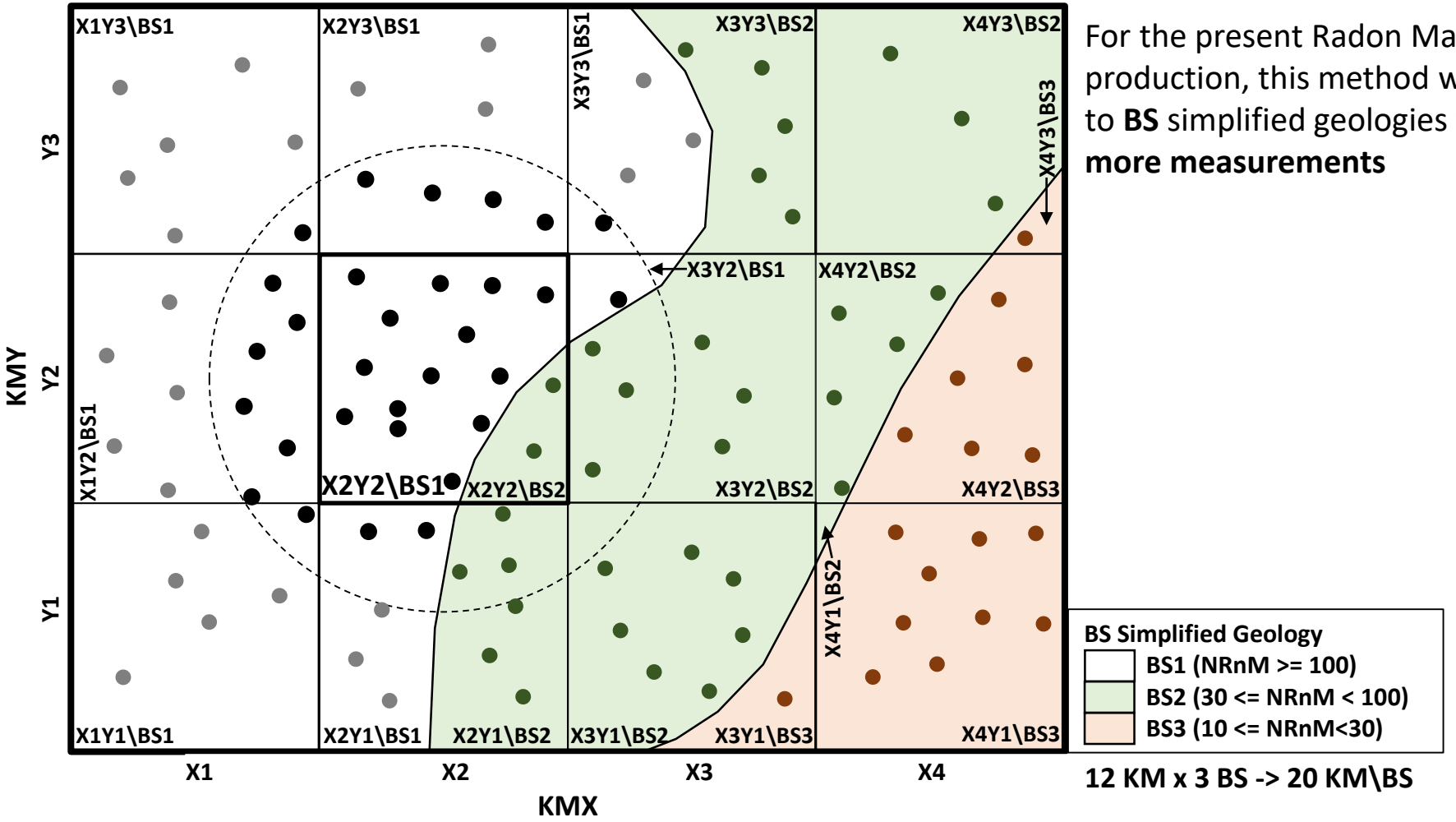
From the existence of multiple BS simplified geologies, a KM square may show several radon potential values.

Radon Potential:
probability of a dwelling exceeding the Radon Action Level (AL = 200 Bq m^{-3})



Computing Rn potential in KMBS ‘cells’ by UKHSA

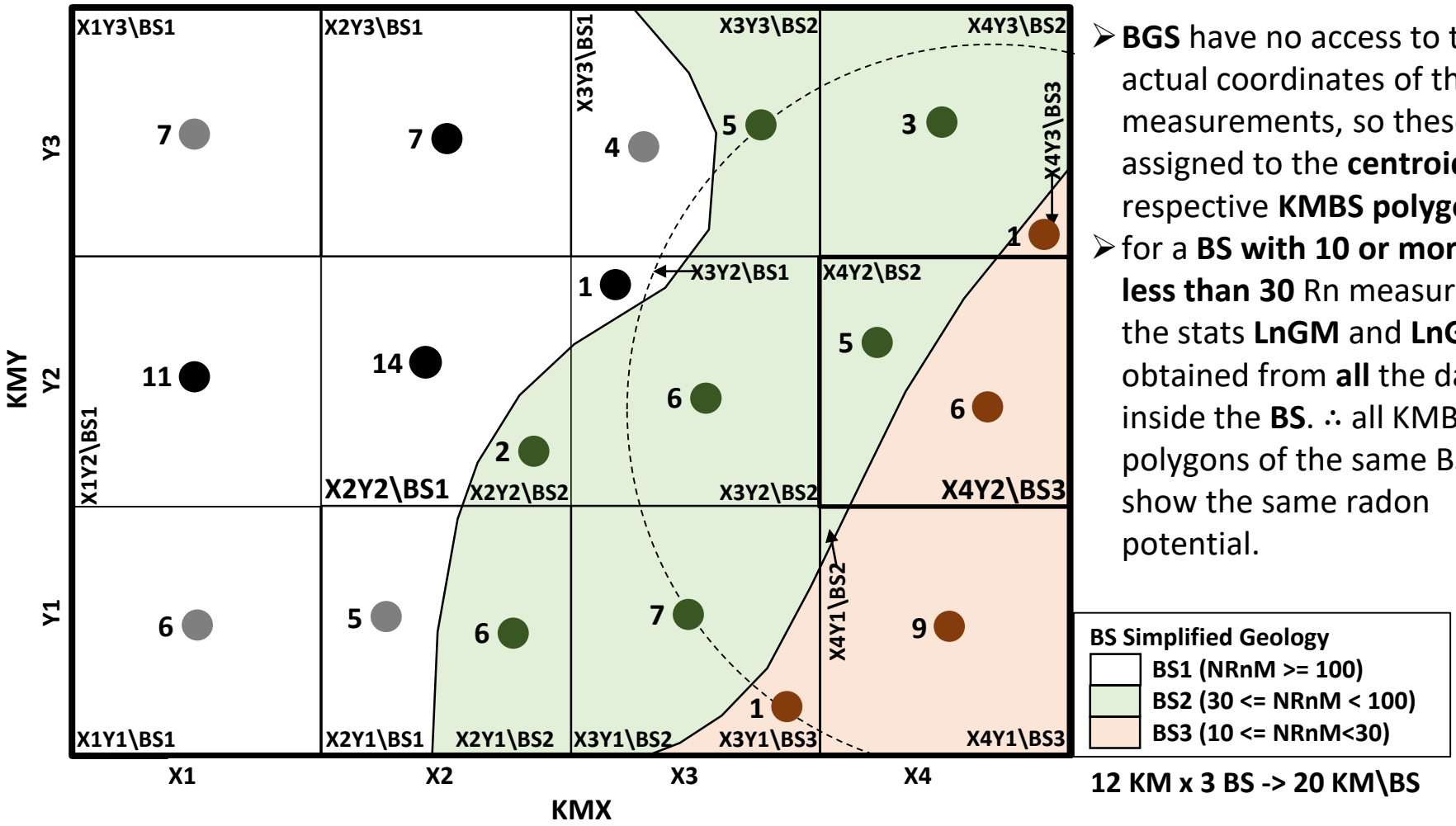
- **UKHSA** grids areas covered by the **BS** simplified geologies with **30 or more** Rn measurements
- **LnGM** and **LnGSD** are computed from **ALL measurements inside the target KMBS** or **the 30 nearest**
- **Ex.:** the 30 Rn measurements - **black dots**: 14 inside + nearest 16 in **BS1** only - used to compute the stats for the **X2Y2\BS1** KMBS



For the present Radon Map production, this method was applied to **BS** simplified geologies **with 30 or more measurements**

Computing Rn potential in KMBS 'cells' by BGS

- **BGS** grids the **BS**s with **less than 30** Rn measurements using one of the 4 layers of simplified geology (**BS, BED, Lex, RCS**)
- Example for **BS**s with **more than 10 and less than 30** Rn measurements (method **GBS**):
- **LnGM** and **LnGSD** are computed from **all** Radon measurements **inside the BS polygon**
- **Ex.:** for the **X4Y2\BS3** KMBS polygon **all** data inside the **BS3** (dark orange dots) are used to compute the stats (**17**: 6+1+9+1).

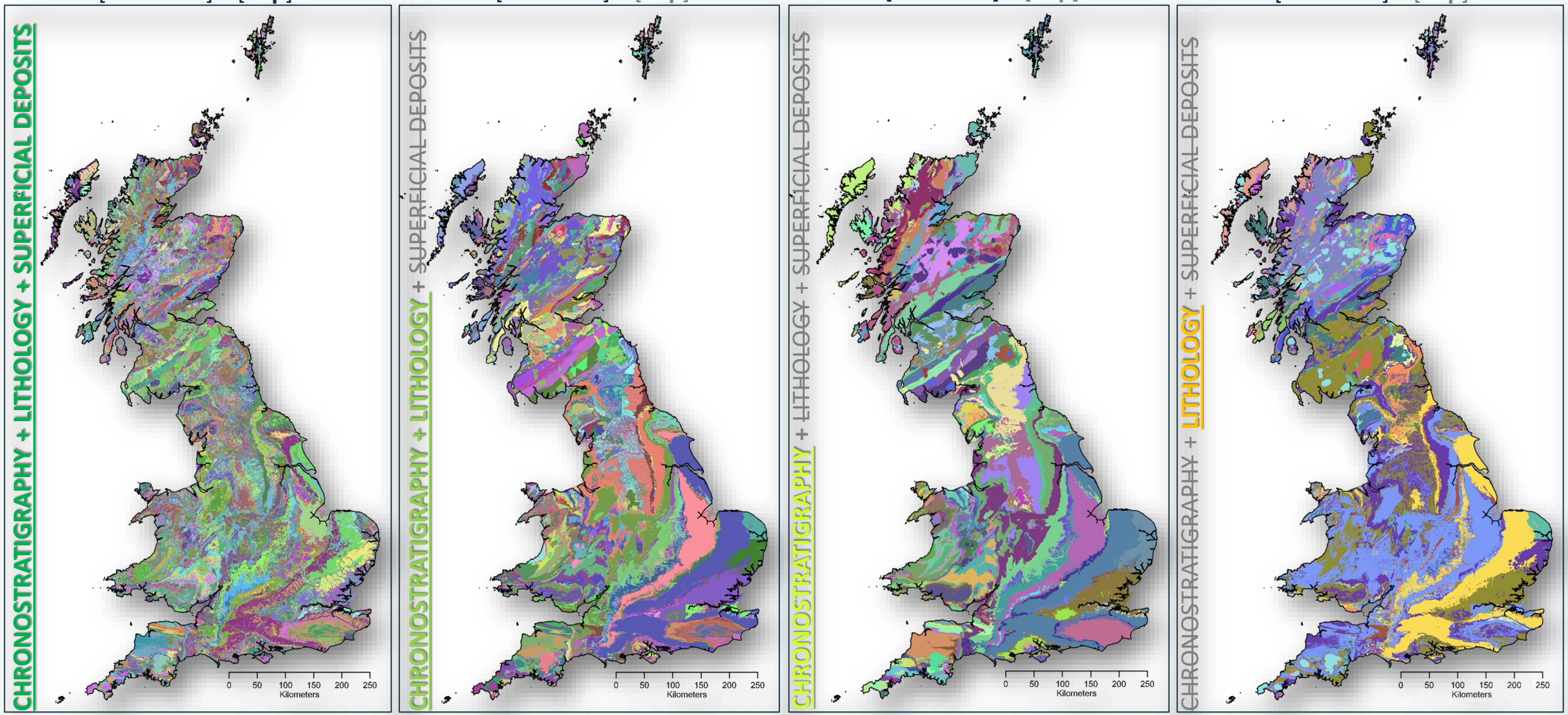


- **BGS** have no access to the actual coordinates of the Rn measurements, so these are assigned to the **centroid** of the respective **KMBS polygon**.
- for a **BS with 10 or more and less than 30** Rn measurements, the stats **LnGM** and **LnGSD** are obtained from **all** the data inside the **BS**. ∴ all KMBS polygons of the same BS will show the same radon potential.

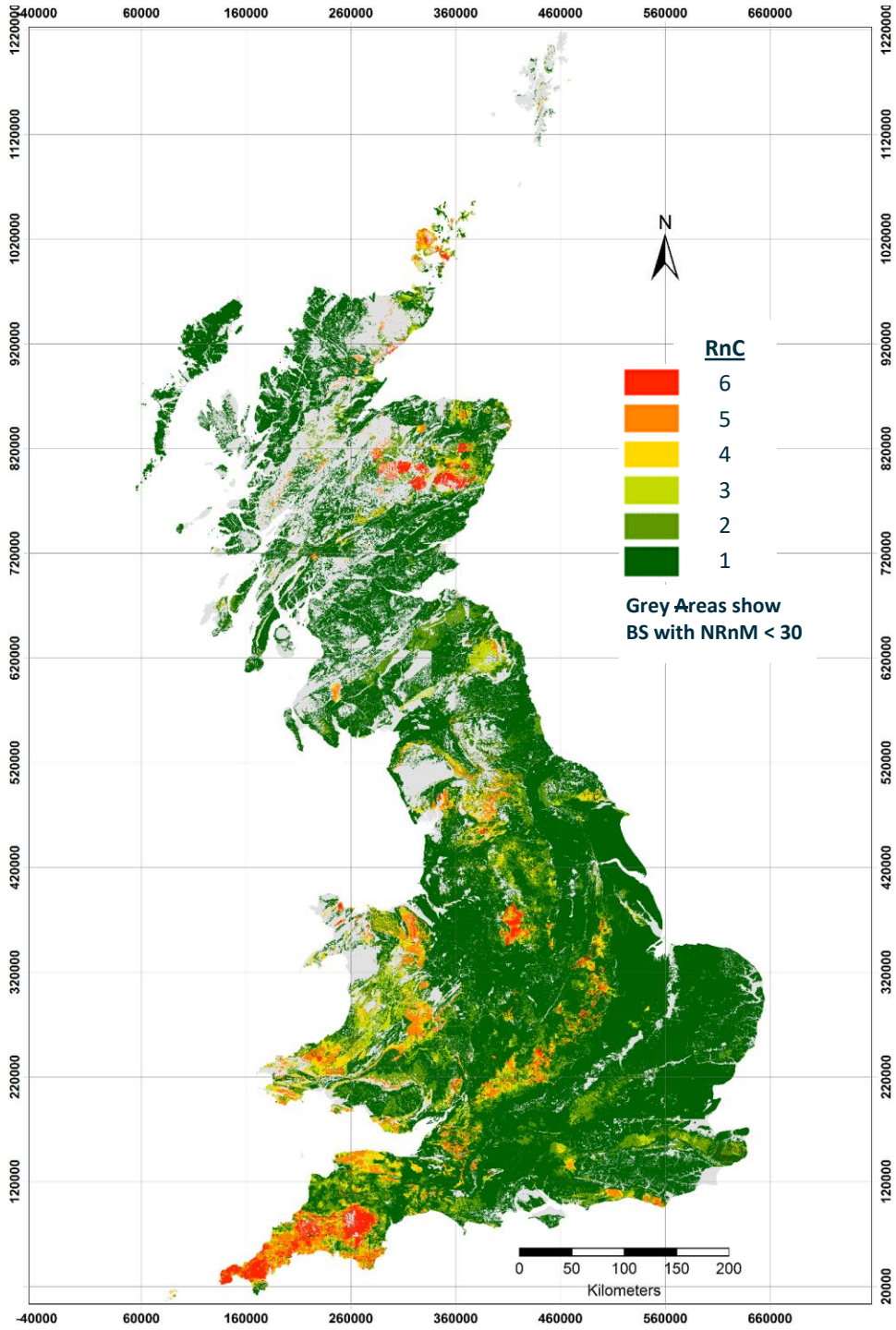
4 Layers of Simplified Geology (preference from left to right):

BS (N=9323) > **BED (N=1674)** > **Lex (N=348)** > **RCS (N=45)**

[Lex x RCS] x [Sup] | [Lex x RCS] x [~~Sup~~] | [Lex x ~~RCS~~] x [~~Sup~~] | [~~Lex~~ x RCS] x [~~Sup~~]



Radon Classes (RnC) using BS computed by UKHSA



Radon Classes (RnC)

based on
GM, GSD and RnP statistics of the nearest 30 measurements

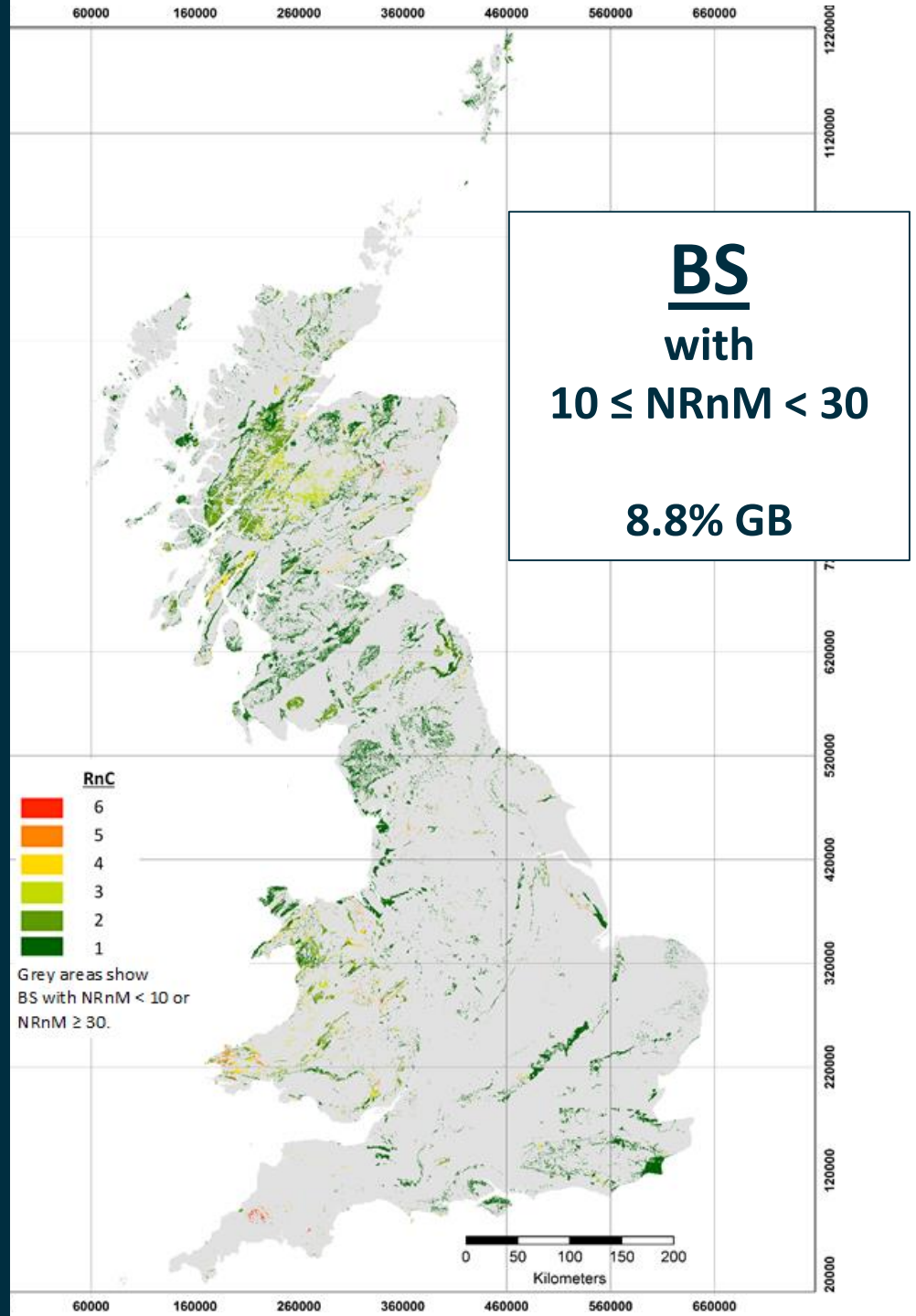
for
BS simplified geologies with NRnM ≥ 30

computed by
UKHSA

75.7% of GB covered

BS: detailed simplified geology
GM: geometric mean
GSD: geometric standard deviation
NRnM: Number of Radon Measurements

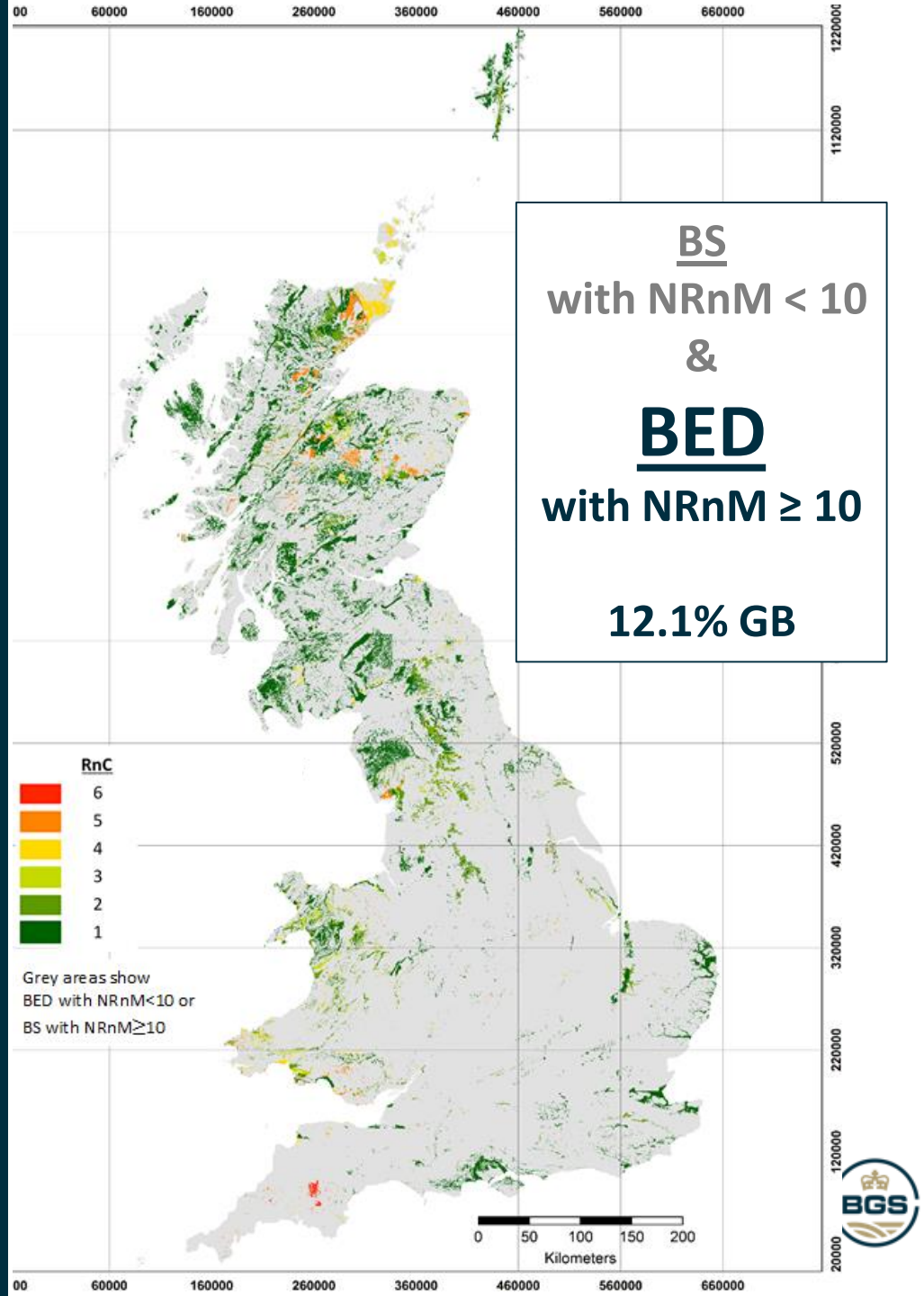
Radon Classes (RnC) using BS computed by BGS



BS
with
10 ≤ NRnM < 30

8.8% GB

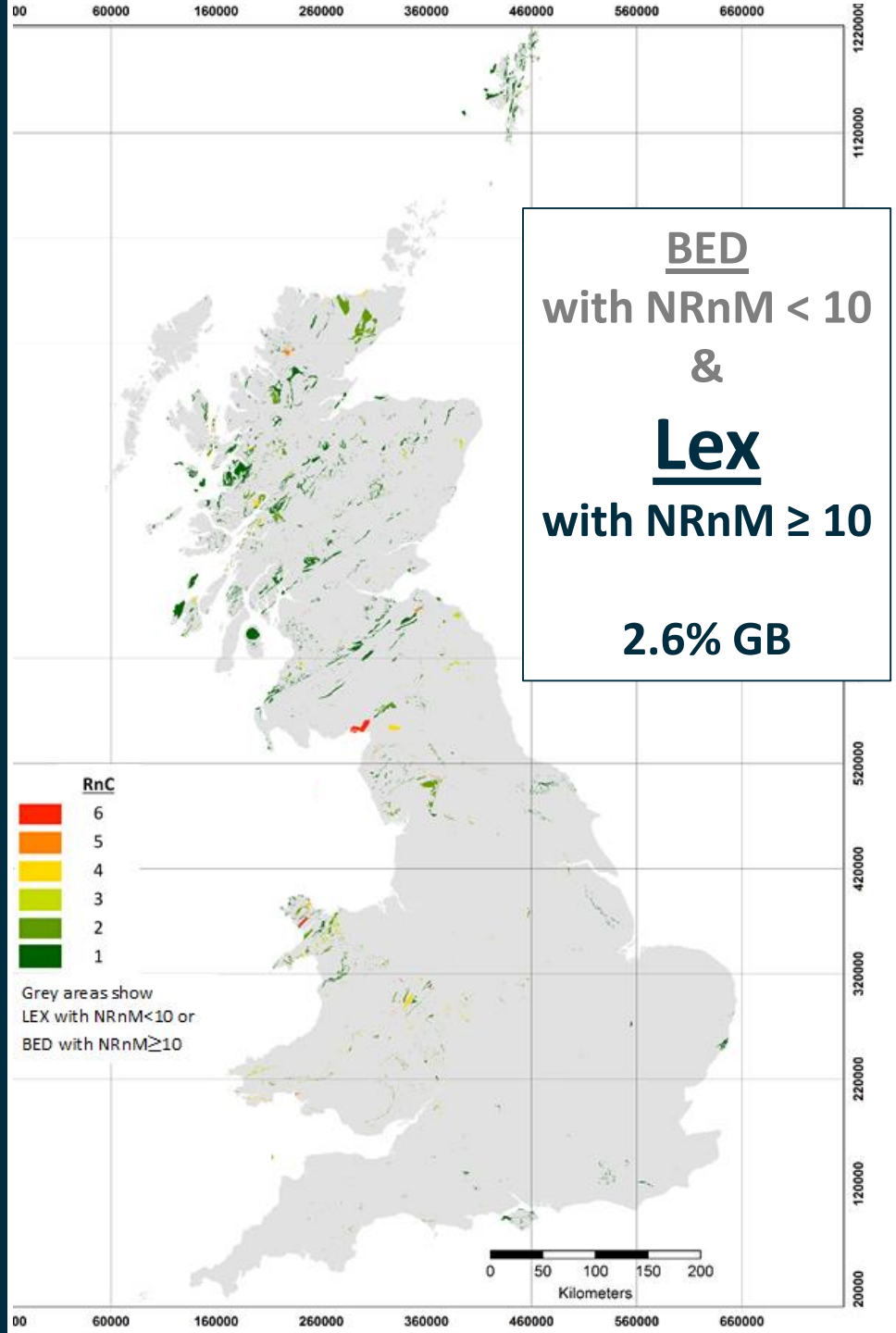
Radon Classes (RnC) using BED computed by BGS



BS
with NRnM < 10
&
BED
with NRnM ≥ 10

12.1% GB

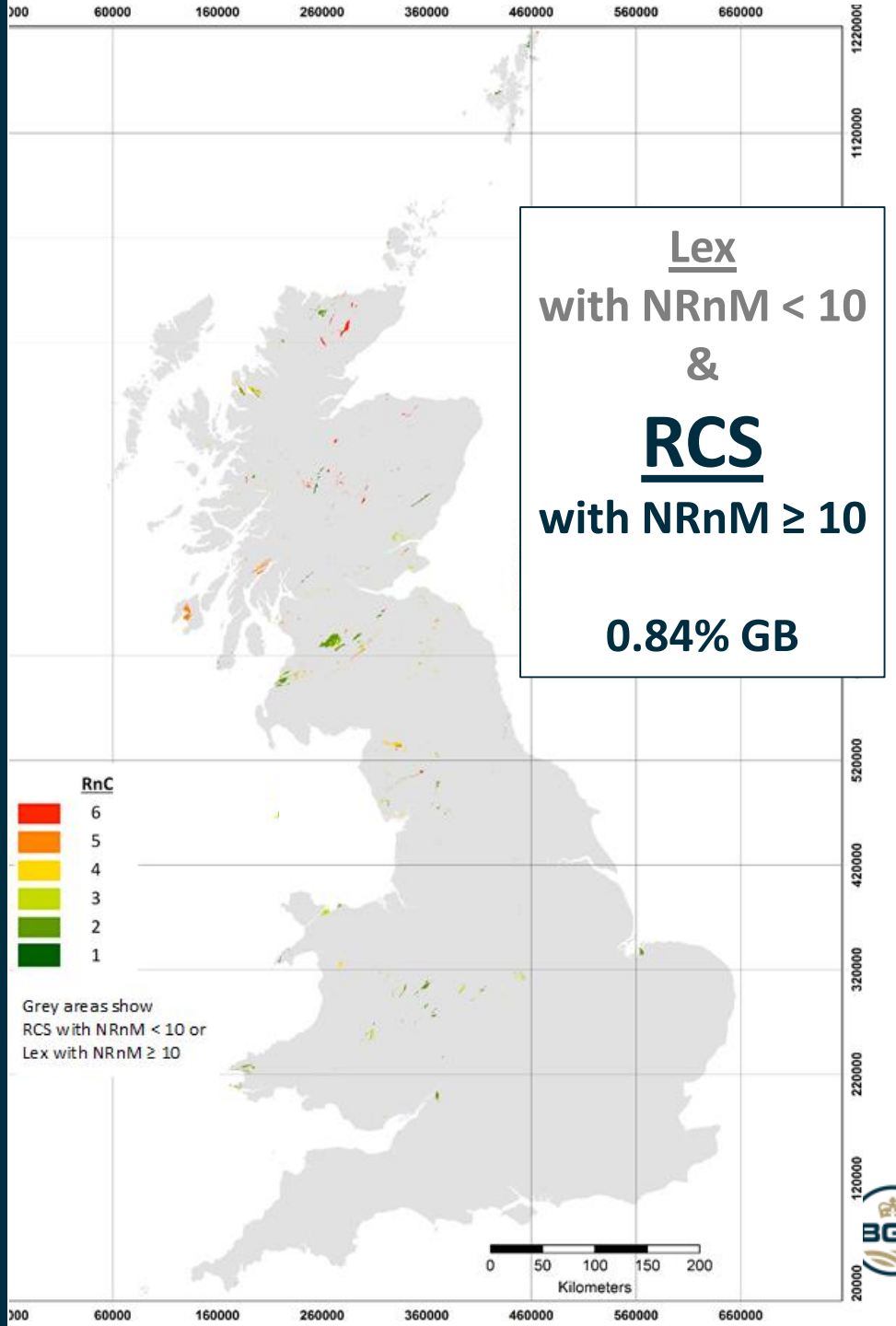
Radon Classes (RnC) after Lex computed by BGS



BED
with NRnM < 10
&
Lex
with NRnM ≥ 10

2.6% GB

Radon Classes (RnC) after RCS computed by BGS

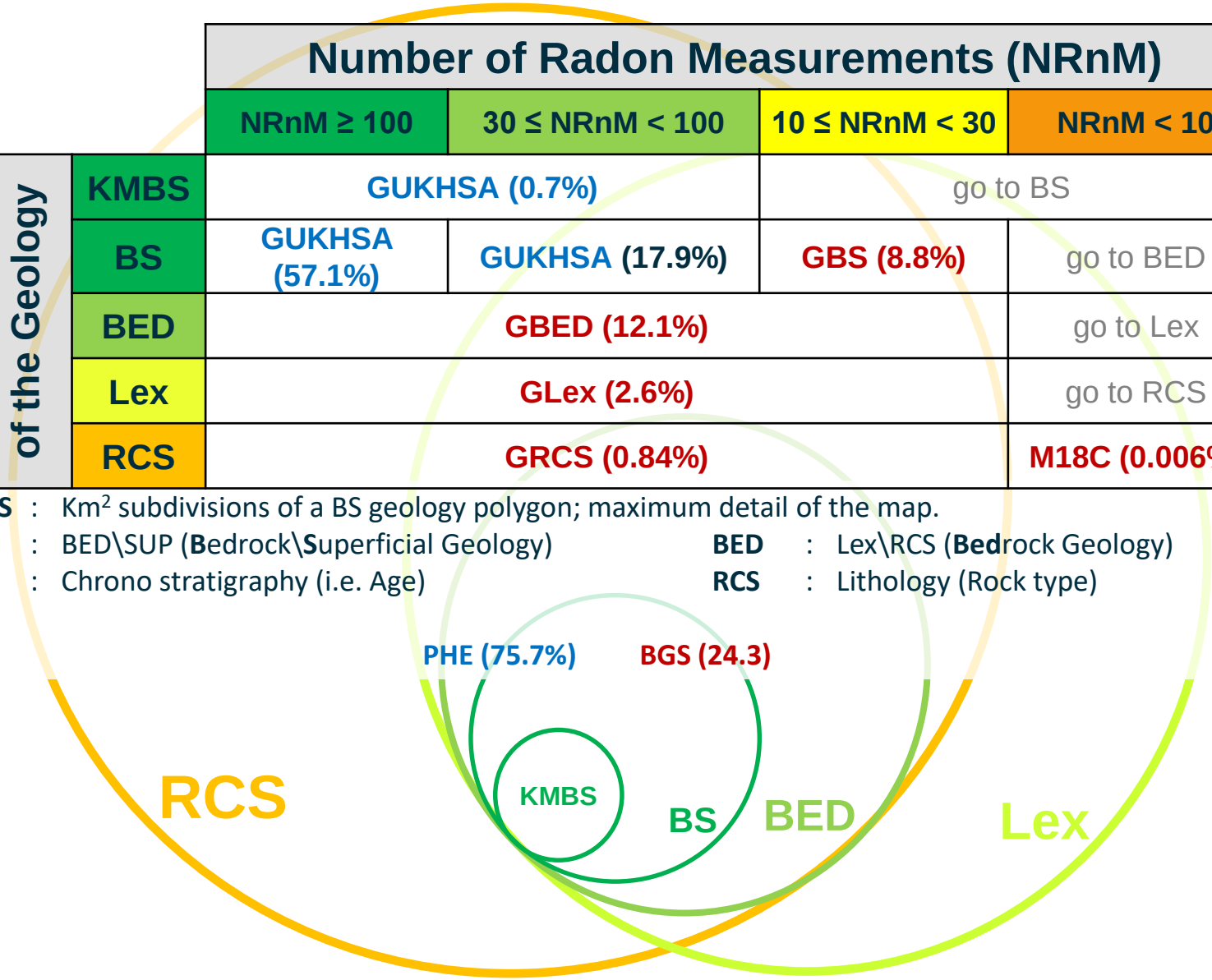


Lex
with NRnM < 10
&
RCS
with NRnM ≥ 10

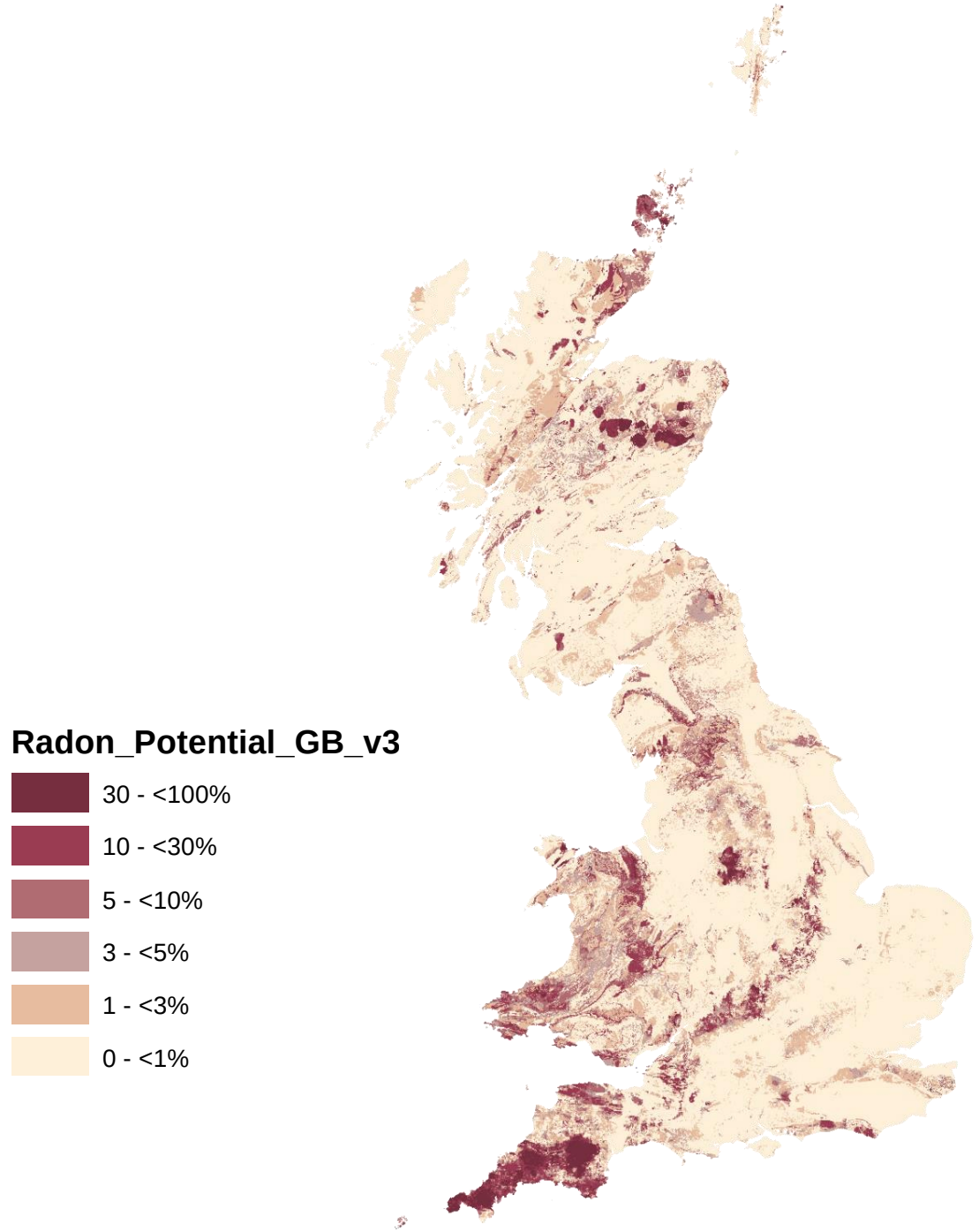
0.84% GB

Level of detail of the Geology	Number of Radon Measurements (NRnM)			
	NRnM ≥ 100	30 ≤ NRnM < 100	10 ≤ NRnM < 30	NRnM < 10
KMBS	GUKHSA (0.7%)		go to BS	
BS	GUKHSA (57.1%)	GUKHSA (17.9%)	GBS (8.8%)	go to BED
BED	GBED (12.1%)			go to Lex
Lex	GLex (2.6%)			go to RCS
RCS	GRCS (0.84%)			M18C (0.006%)

KMBS : Km^2 subdivisions of a BS geology polygon; maximum detail of the map.
BS : BED\SUP (**B**edrock**S**uperficial Geology)
Lex : Chrono stratigraphy (i.e. Age)
BED : Lex\RCS (**Bed**rock Geology)
RCS : Lithology (Rock type)



6 Radon Classes for GB



Radon Classes (RnC)

for GB (100% coverage)

after ALL frames (UKHSA, BS, BED, Lex, RCS)

computed by UKHSA and BGS

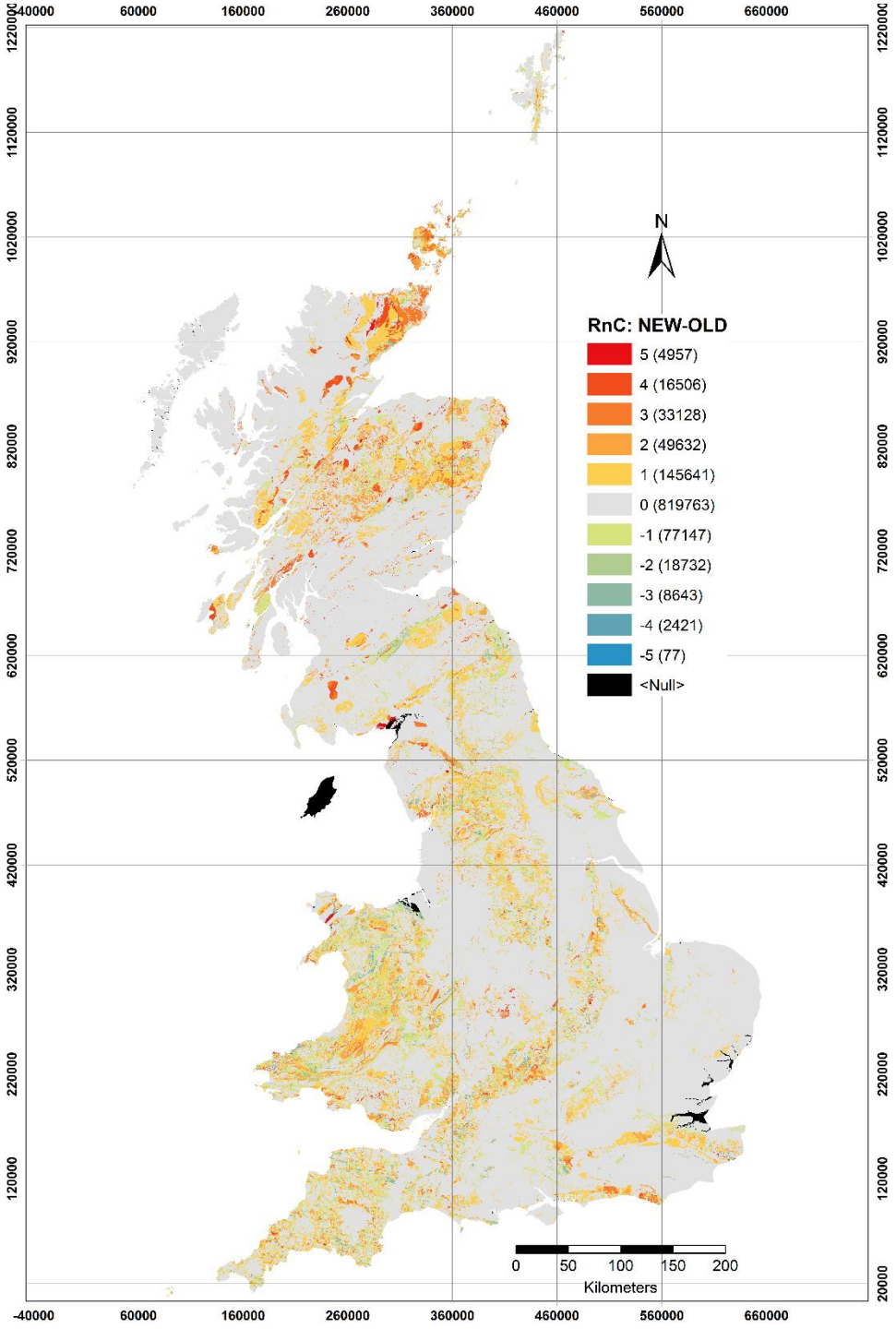
Difference (% area) between the OLD and the NEW versions of the GB Radon Map

		OLD								
	Class	**1**	**2**	**3**	**4**	**5**	**6**	**SBD_H**	**SAD_H**	**$SABD_H$**
NEW	**1**	**68.47**	3.65	0.59	0.29	0.12	0.01		4.67	4.67
	2	7.16	**3.65**	0.90	0.38	0.14	0.01	7.16	1.43	8.59
	3	1.61	1.28	**0.72**	0.46	0.15	0.01	2.89	0.62	3.51
	4	1.23	0.91	0.61	**1.00**	0.44	0.02	2.76	0.46	3.22
	5	1.10	0.42	0.30	0.69	**1.75**	0.19	2.50	0.19	2.69
	6	0.16	0.04	0.02	0.09	0.61	**0.80**	0.93		0.93
	SAD_V		3.65	1.49	1.14	0.86	0.24	**76.39[d]**	**7.38[a]**	
	SBD_V	11.26	2.65	0.93	0.77	0.61		**16.23[b]**	**23.61[c]**	
	SABDv	11.26	6.30	2.43	1.91	1.47	0.24			

SAD_H: row (horizontal) sum above diagonal;
$SABD_H$: row (horizontal) sum off diagonal;
SAD_V: column (vertical) sum above diagonal;
a: sum above diagonal (SAD);
c: sum off diagonal (SABD=SAD+SBD);

SBD_H: row (horizontal) sum below diagonal;
SBD_V: column (vertical) sum below diagonal;
$SABD_V$: column (vertical) sum off diagonal;
b: sum below diagonal (SBD);
d: Sum on diagonal (SOD)

Radon Classes (RnC) NEW - OLD



Difference between

the previous version (OLD) and the NEW GB Radon Map

a positive value means a revision towards a RnC increasing

Geological units associated with higher Radon Potential in GB

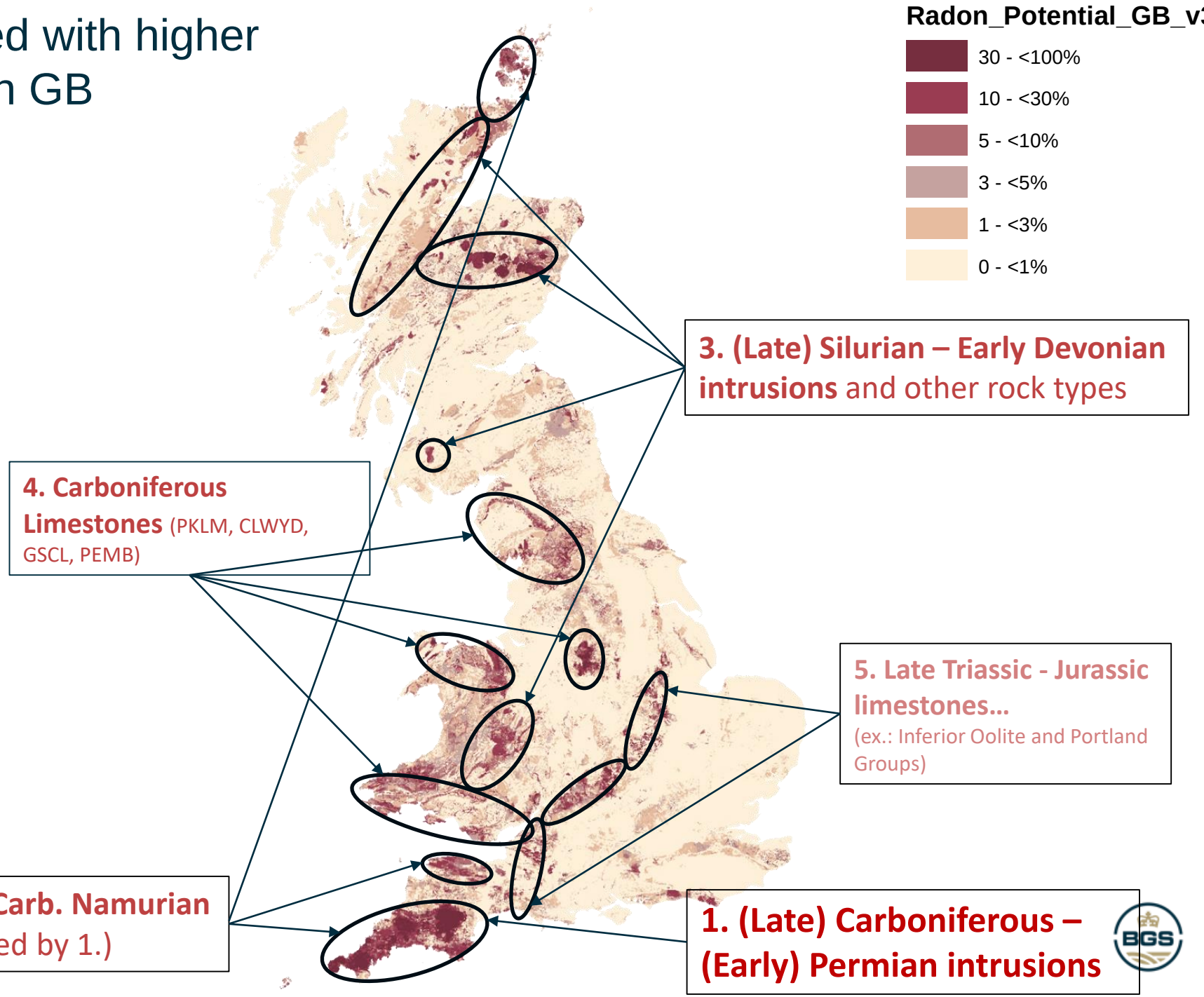
1. **(Late) Carboniferous – (Early) Permian intrusions** are the reason for the largest radon hotspot in Great Britain

2. Many **Devonian – Carboniferous** rocks namely those affected by the above intrusions

3. **(Late) Silurian – Early Devonian intrusions** namely in Scotland and **other Silurian rock types** in Wales – West Midlands

4. **Carboniferous Limestones** (ex.: North England, Peak District, North and South Wales)

5. Some **Late Triassic - Jurassic carbonate-rich rocks**



THANK YOU!

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