

A regional survey of radon in a karst area of Spain

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LaRUC, University of Cantabria

17th INTERNATIONAL WORKSHOP

GARRM

(on the GEOLOGICAL ASPECTS OF RADON RISK MAPPING)

RADON v.o.s. and Czech Geological Survey

September 16th – 18st, 2025, Prague, Czech Republic

Research sponsored by Spanish Nuclear Safety Council

WHO WE ARE.....

UNIVERSIDAD DE CANTABRIA

Grupo Radon

47 AÑOS CON LA RADIACION NATURAL

.- 14000 MEDIDAS DE RADON: VIVIENDAS Y PUESTOS DE TRABAJO

.-14000 ANALISIS DE MUESTRAS DE SUELOS

.- 10000 MEDIDAS DE RADIACION GAMMA EXTERNA



2 CATEDRATICOS

3 AYUDANTES DOCTOR

4 CONTRATADOS DE INVESTIGACION

ACCREDITED LABORATORY



.- TEST USING TRACKS
DETECTORS

.- CALIBRATION OF RADON
MONITORS AND
DETECTORS

Calibración – Verificación





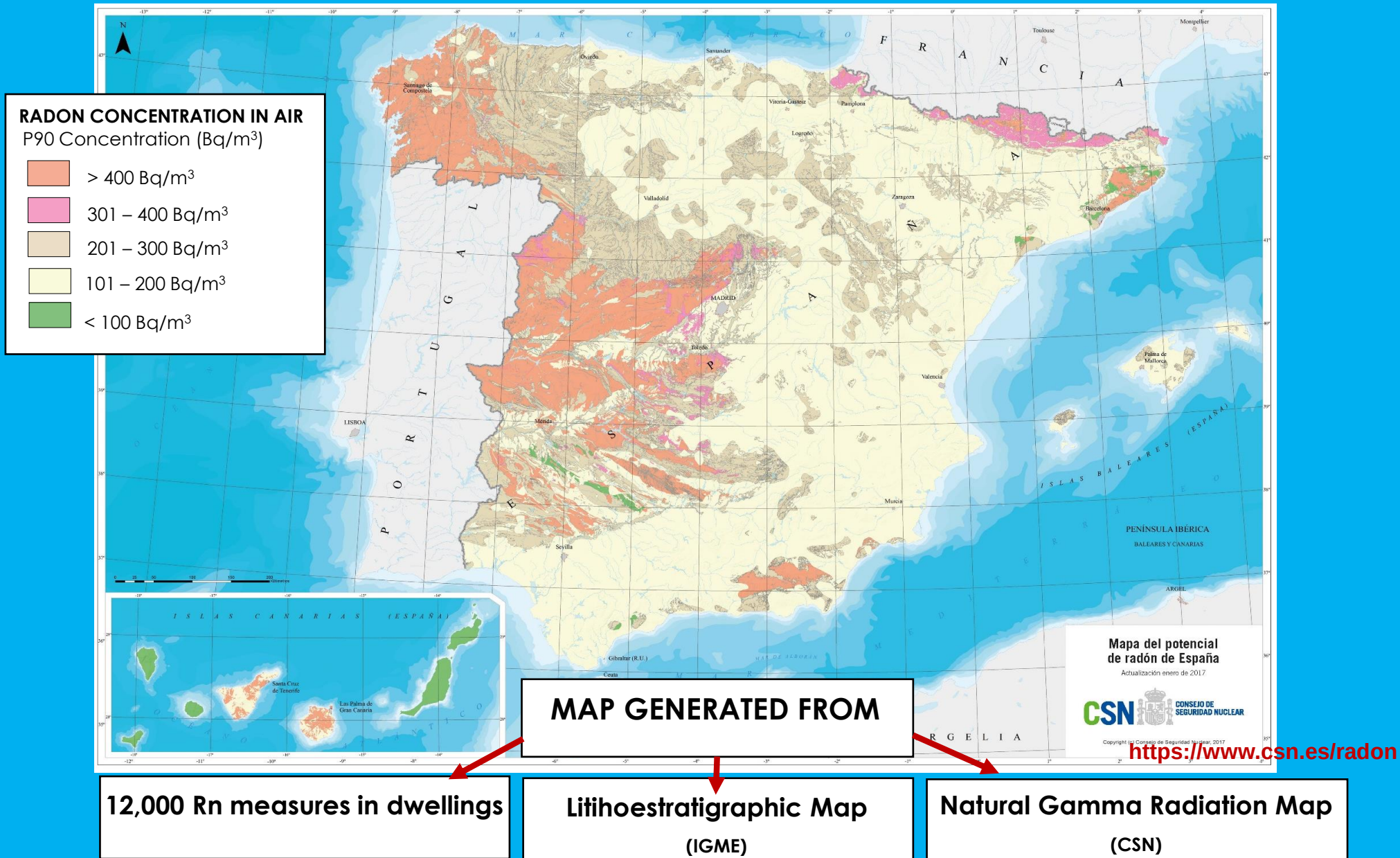
**Friedrich Ernst
Dorn**

1890

“emanation of
radium”

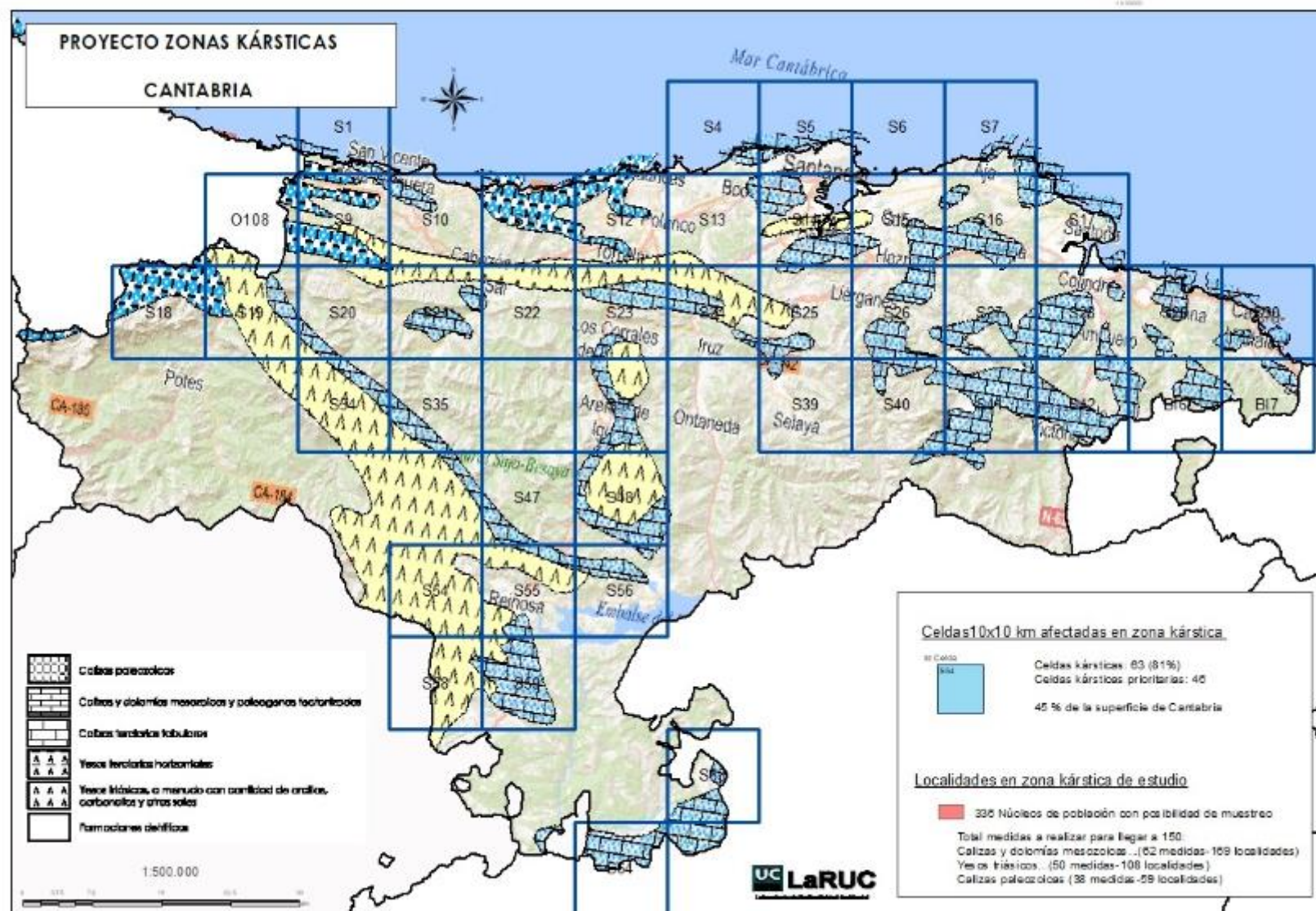
RADON POTENTIAL MAP IN SPAIN

Spanish Nuclear Safety Council (CSN)



PROYECTO ZONAS KÁRSTICAS

CANTABRIA



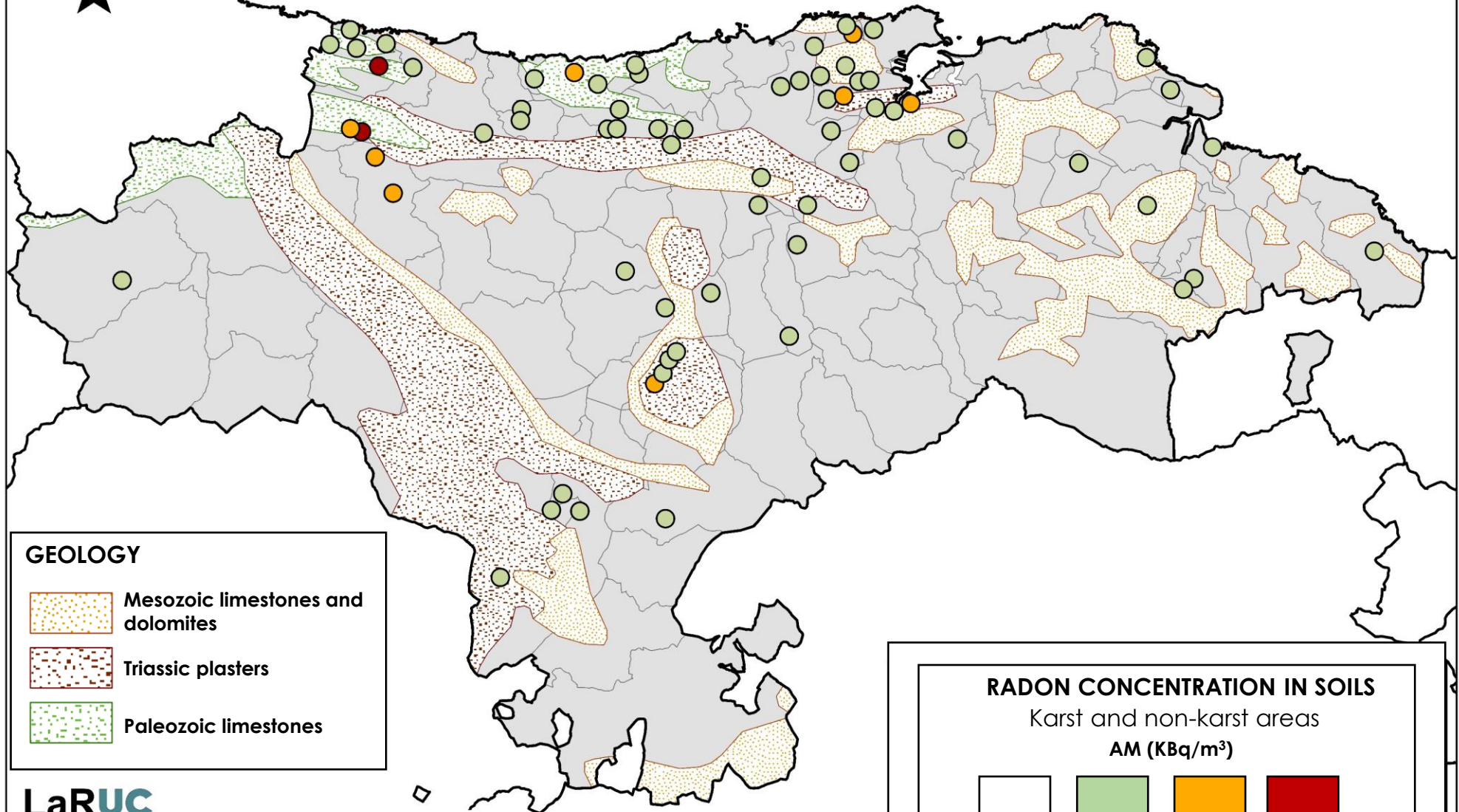
Variables analyzed

- .- Radon in soils
- .- Ra-226 in soils
- .- Th-232 in soils
- .- K-40 in soils
- .- Cs-137 in soils
- .- External gamma dose rate
- .- Radon exhalation rate
- .- Permeability of soils
- .- Radon in water
- .- RADON IN AIR

1.RADON IN SOILS

(KBq/m³)

2. RADON IN SOILS (KBq/m³)



1.RADON IN SOILS (KBq/m³)

2.RADON IN SOILS Concentration (KBq/m ³)					
N° TOTAL mesurements	AM	DS AM	MIN	MED.	MAX
399	34	59.1	0	12	465

2.RADON IN SOILS Concentration (KBq/m ³)										
GEOLOGY	AM	DS AM	GM	MIN	MED	MAX	N° MEASUREMENTS	GEOLOGY NO KARST	AM	N° MES.
TOTAL	45	76.4	6	0	9	465	246	TOTAL	22	153
1001	38	64.0	6	1	7	465	51%			
2002	44	79.7	5	1	1	392	29%			
5004	67	96.3	9	0	16	356	20%			

1001-Paleozoic limestones

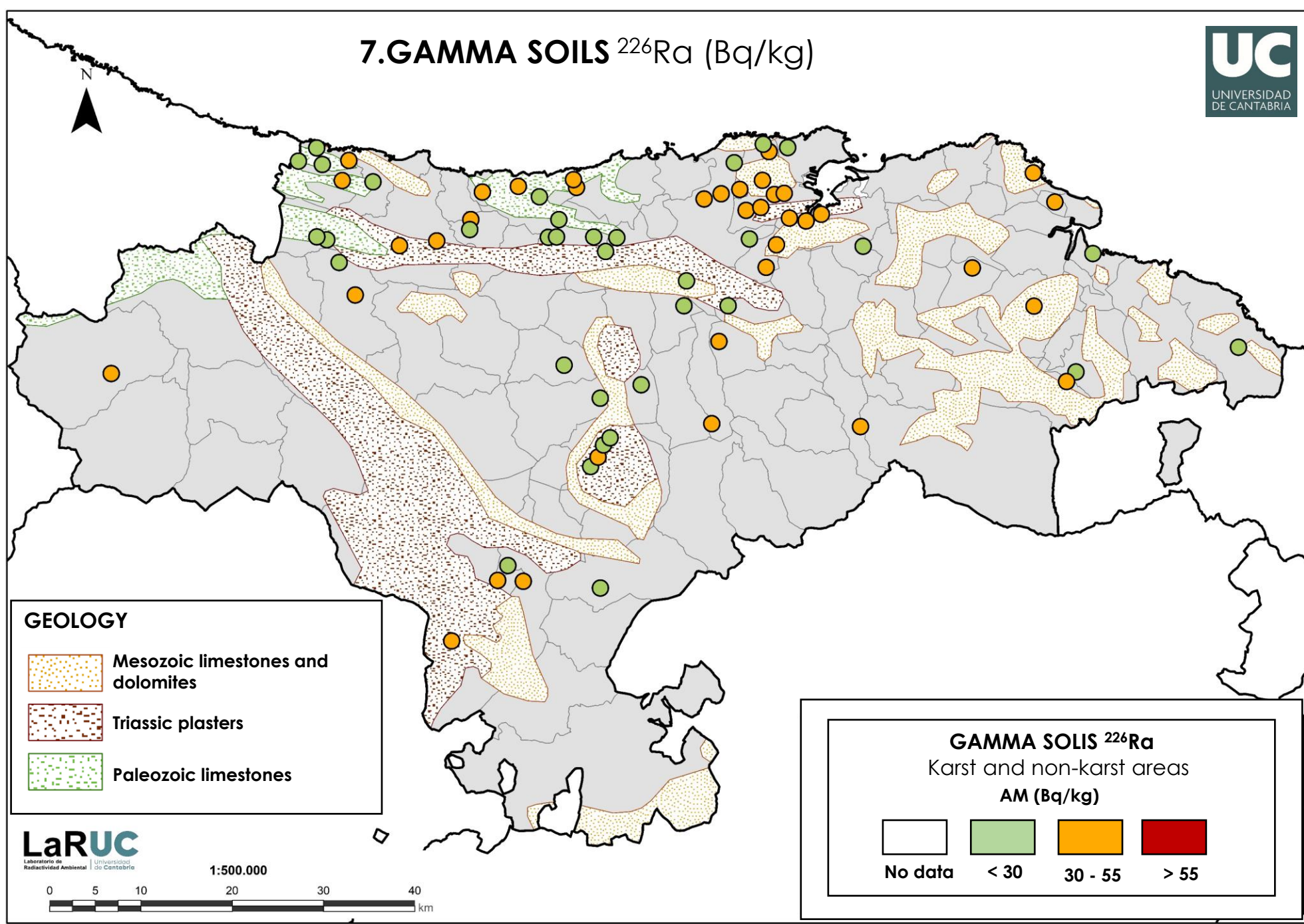
2002-Mesozoic limestones and dolomites

5004-Triassic Plasters

2. GAMMA SOILS: ^{226}Ra

(Bq/kg)

7.GAMMA SOILS ^{226}Ra (Bq/kg)



2.GAMMA SOILS ^{226}Ra (Bq/kg)

7.GAMMA SOIL ^{226}Ra (Bq/kg)					
Nº TOTAL measurements	AM	DS AM	MIN	MED.	MAX
193	31.5	12.3	4.0	30.3	84.0

7.GAMMA SOIL ^{226}Ra (Bq/kg)										
GEOLOGY	AM	DS AM	GM	MIN	MED	MAX	Nº MEASUREMENTS	GEOLOGY NO KARST	AM	Nº MES.
TOTAL	31.7	11.4	29.8	4.0	30.9	84.0	160	TOTAL	26.5	33
1001	32.3	11.3	30.1	4.0	21.8	74.9	52%			
2002	28.5	8.3	27.2	13.4	26.1	45.6	28%			
5004	34.8	14.2	32.8	20.0	31.6	84.0	20%			

1001-Paleozoic limestones

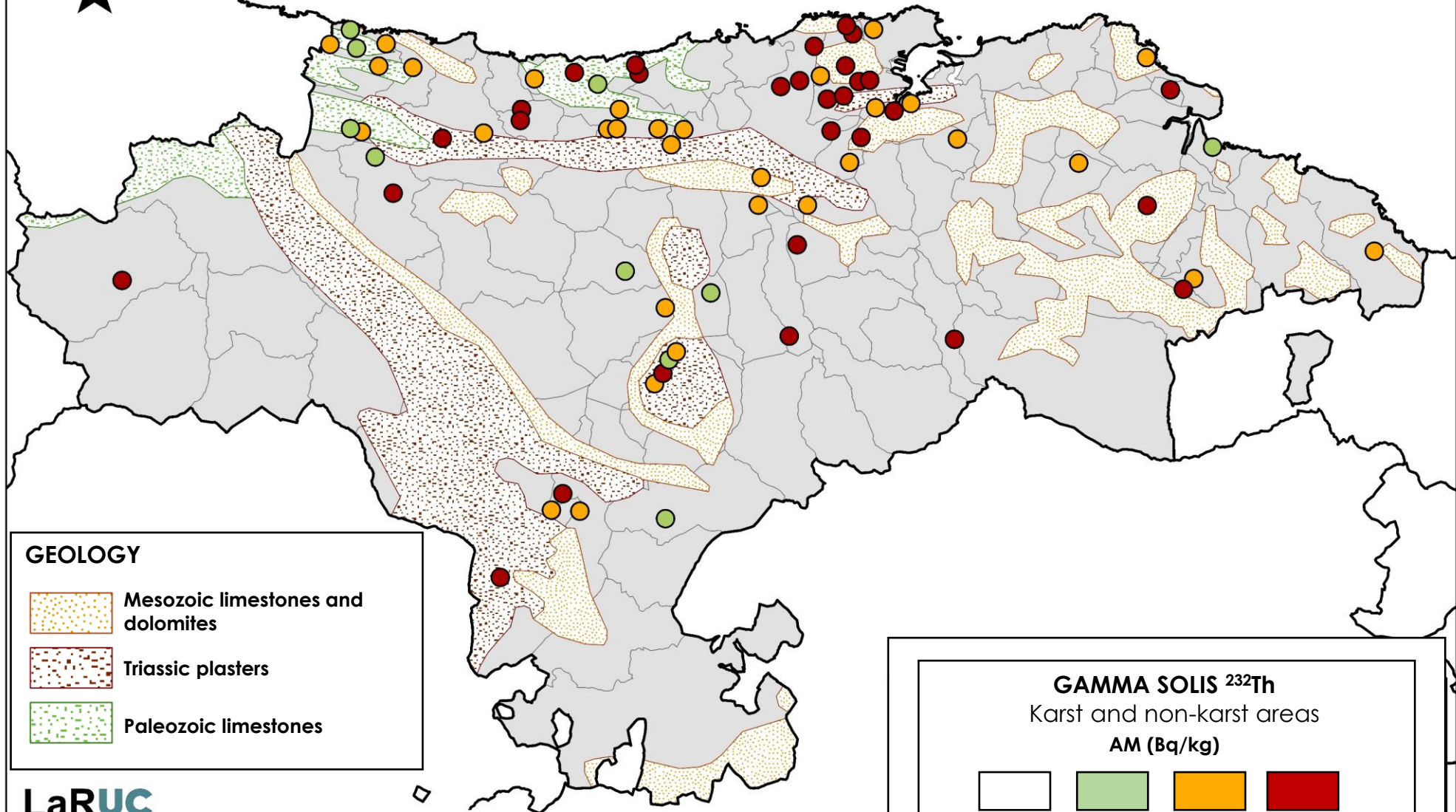
2002-Mesozoic limestones and dolomites

5004-Triassic Plasters

3. GAMMA SOILS: ^{232}Th

(Bq/kg)

7.GAMMA SOILS ^{232}Th (Bq/kg)



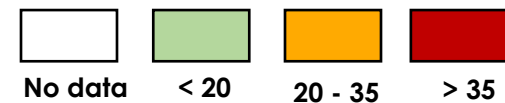
GEOLOGY

-  Mesozoic limestones and dolomites
-  Triassic plasters
-  Paleozoic limestones

GAMMA SOLIS ^{232}Th

Karst and non-karst areas

AM (Bq/kg)



3.GAMMA SOILS ^{232}Th (Bq/kg)

7.GAMMA SOIL ^{232}Th (Bq/kg)					
Nº TOTAL mesurements	AM	DS AM	MIN	MED.	MAX
193	37.5	13.7	3.8	36.4	82.4

7.GAMMA SOIL ^{232}Th (Bq/kg)										
GEOLOGY	AM	DS AM	GM	MIN	MED	MAX	Nº MEASUREMENTS	GEOLOGY NO KARST	AM	Nº MES.
TOTAL	32.9	10.4	31.0	3.8	32.2	58.0	160	TOTAL	43.7	33
1001	33.0	10.9	30.8	3.8	32.4	56.0	52%			
2002	31.6	11.6	29.5	7.5	29.6	58.0	28%			
5004	34.4	7.0	33.7	18.1	33.6	53.5	20%			

1001-Paleozoic limestones

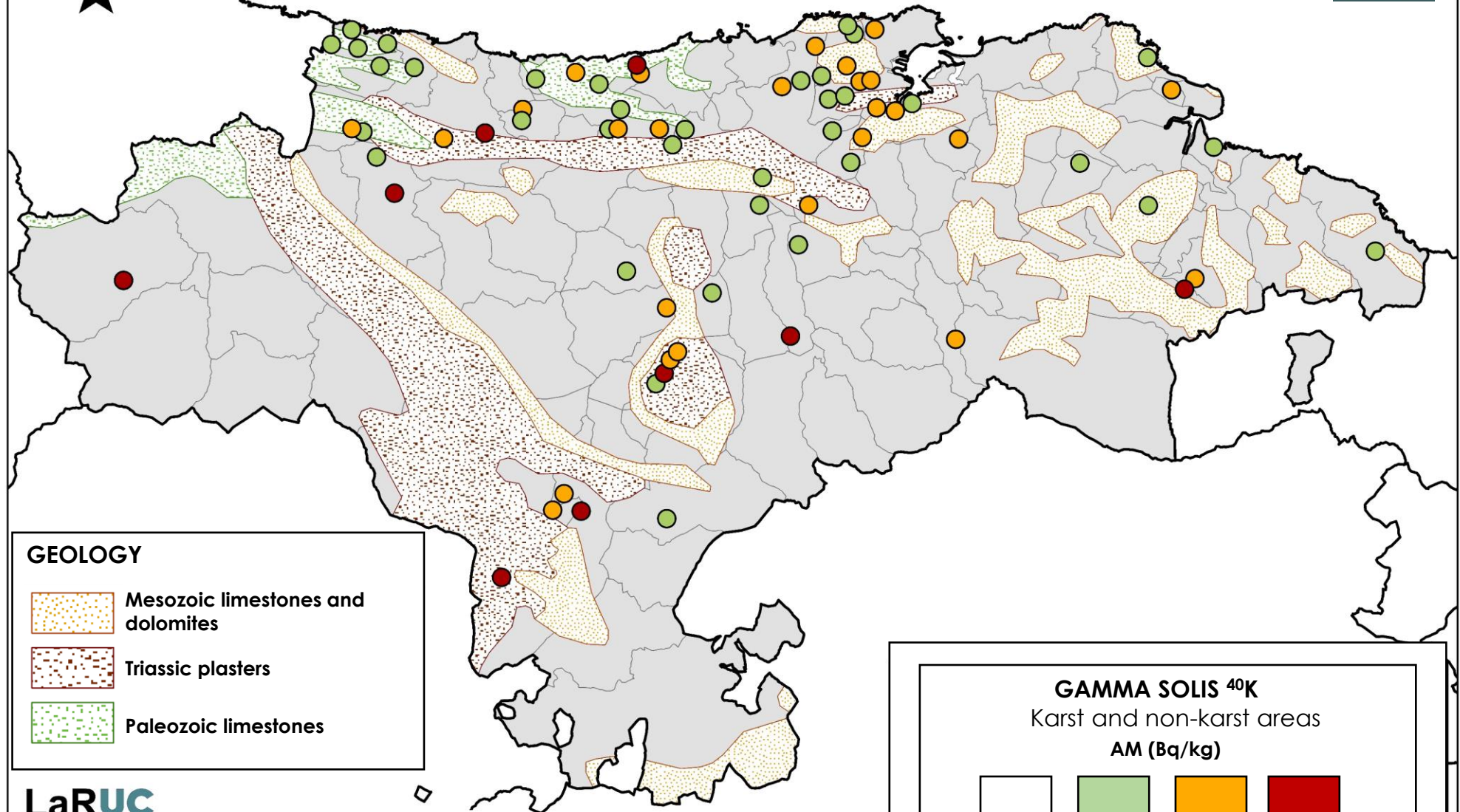
2002-Mesozoic limestones and dolomites

5004-Triassic Plasters

4.GAMMA SOILS: ^{40}K

(Bq/kg)

7.GAMMA SOILS ^{40}K (Bq/kg)



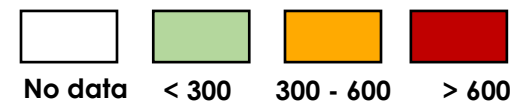
GEOLOGY

-  Mesozoic limestones and dolomites
-  Triassic plasters
-  Paleozoic limestones

GAMMA SOLIS ^{40}K

Karst and non-karst areas

AM (Bq/kg)



4.GAMMA SOILS ^{40}K (Bq/kg)

7.GAMMA SOIL ^{40}K (Bq/kg)					
Nº TOTAL measurements	AM	DS AM	MIN	MED.	MAX
193	355.8	226.9	39.2	287.7	1302.0

7.GAMMA SOIL ^{40}K (Bq/kg)										
GEOLOGY	AM	DS AM	GM	MIN	MED	MAX	Nº MEASUREMENTS	GEOLOGY NO KARST	AM	Nº MES.
TOTAL	306.9	176.0	265.6	39.2	262.2	1302.0	160	TOTAL	473.7	33
1001	275.6	105.4	255.7	46.4	248.0	559.0	55%			
2002	253.6	135.7	200.5	39.2	201.4	707.2	30%			
5004	487.7	244.2	453.3	168.0	480.5	1320.0	15%			

1001-Paleozoic limestones

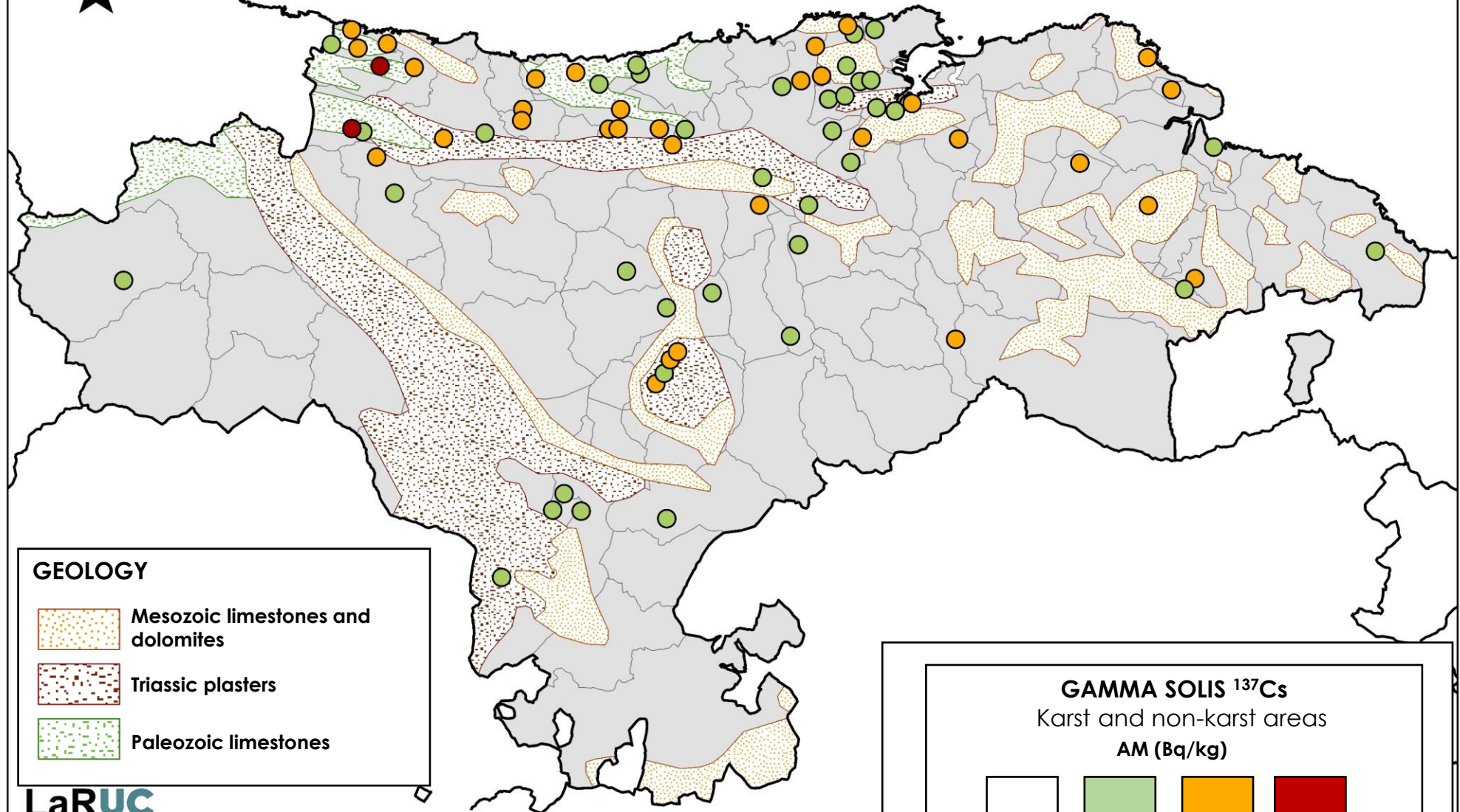
2002-Mesozoic limestones and dolomites

5004-Triassic Plasters

5.GAMMA SOILS: ^{137}Cs

(Bq/kg)

7. GAMMA SOILS ^{137}Cs (Bq/kg)



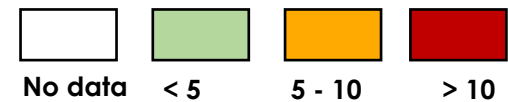
GEOLOGY

- Mesozoic limestones and dolomites
- Triassic plasters
- Paleozoic limestones

GAMMA SOLIS ^{137}Cs

Karst and non-karst areas

AM (Bq/kg)



5.GAMMA SOILS ^{137}Cs (Bq/kg)

7.GAMMA SOIL ^{137}Cs (Bq/kg)					
Nº TOTAL measurements	AM	DS AM	MIN	MED.	MAX
193	5.3	3.2	1.0	4.6	14.3

7.GAMMA SOIL ^{137}Cs (Bq/kg)										
GEOLOGY	AM	DS AM	GM	MIN	MED	MAX	Nº MEASUREMENTS	GEOLOGY NO KARST	AM	Nº MES.
TOTAL	4.8	2.9	3.9	1.0	4.2	12.5	160	TOTAL	5.6	33
1001	4.8	2.7	4.0	1.0	4.2	12.5	55%			
2002	6.0	3.0	5.0	1.1	6.1	11.6	30%			
5004	3.3	2.7	2.6	1.5	2.0	12.5	15%			

1001-Paleozoic limestones

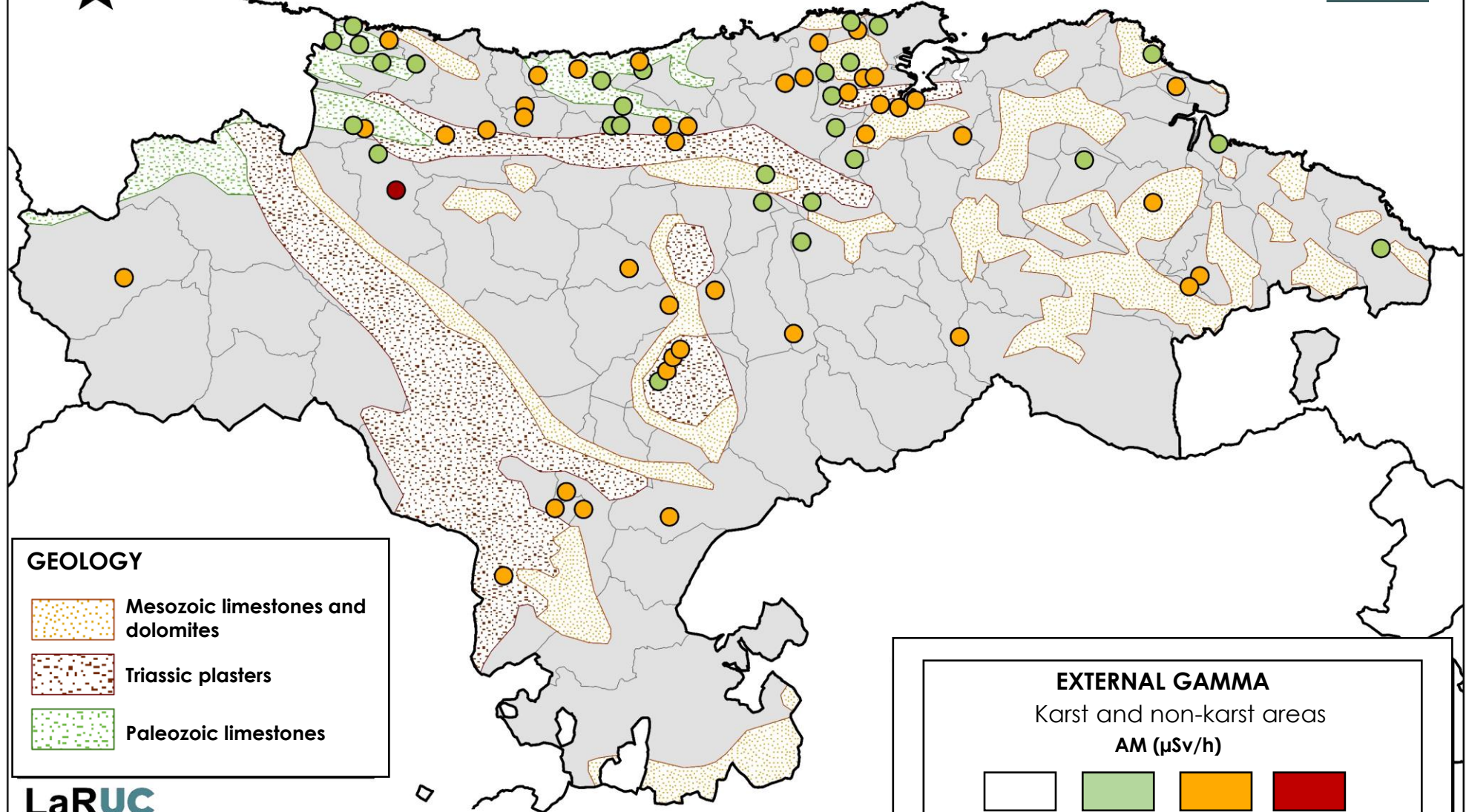
2002-Mesozoic limestones and dolomites

5004-Triassic Plasters

6.EXTERNAL GAMMA DOSE RATE

($\mu\text{Sv/h}$)

3. External gamma dose rate ($\mu\text{Sv/h}$)



GEOLOGY

- Mesozoic limestones and dolomites
- Triassic plasters
- Paleozoic limestones

EXTERNAL GAMMA

Karst and non-karst areas

AM ($\mu\text{Sv/h}$)



No data < 0,065 0,065-0,090 > 0,090

6.EXTERNAL GAMA Dose rate ($\mu\text{Sv/h}$)

3.GAMMA EXTERNAL Dose rate ($\mu\text{Sv/h}$)					
Nº TOTAL measurements	AM	DS AM	MIN	MED.	MAX
193	0.064	0.02	0.026	0.065	0.110

3.GAMMA EXTERNAL Dose rate ($\mu\text{Sv/h}$)										
GEOLOGY	AM	DS AM	GM	MIN	MED	MAX	Nº MEASUREMENTS	GEOLOGY NO KARST	AM	Nº MES.
TOTAL	0.068	0.01	0.066	0.040	0.068	0.110	160	TOTAL	0.051	33
1001	0.066	0.01	0.065	0.040	0.067	0.106	52%			
2002	0.066	0.02	0.064	0.040	0.065	0.101	28%			
5004	0.075	0.01	0.074	0.045	0.073	0.110	20%			

1001-Paleozoic limestones

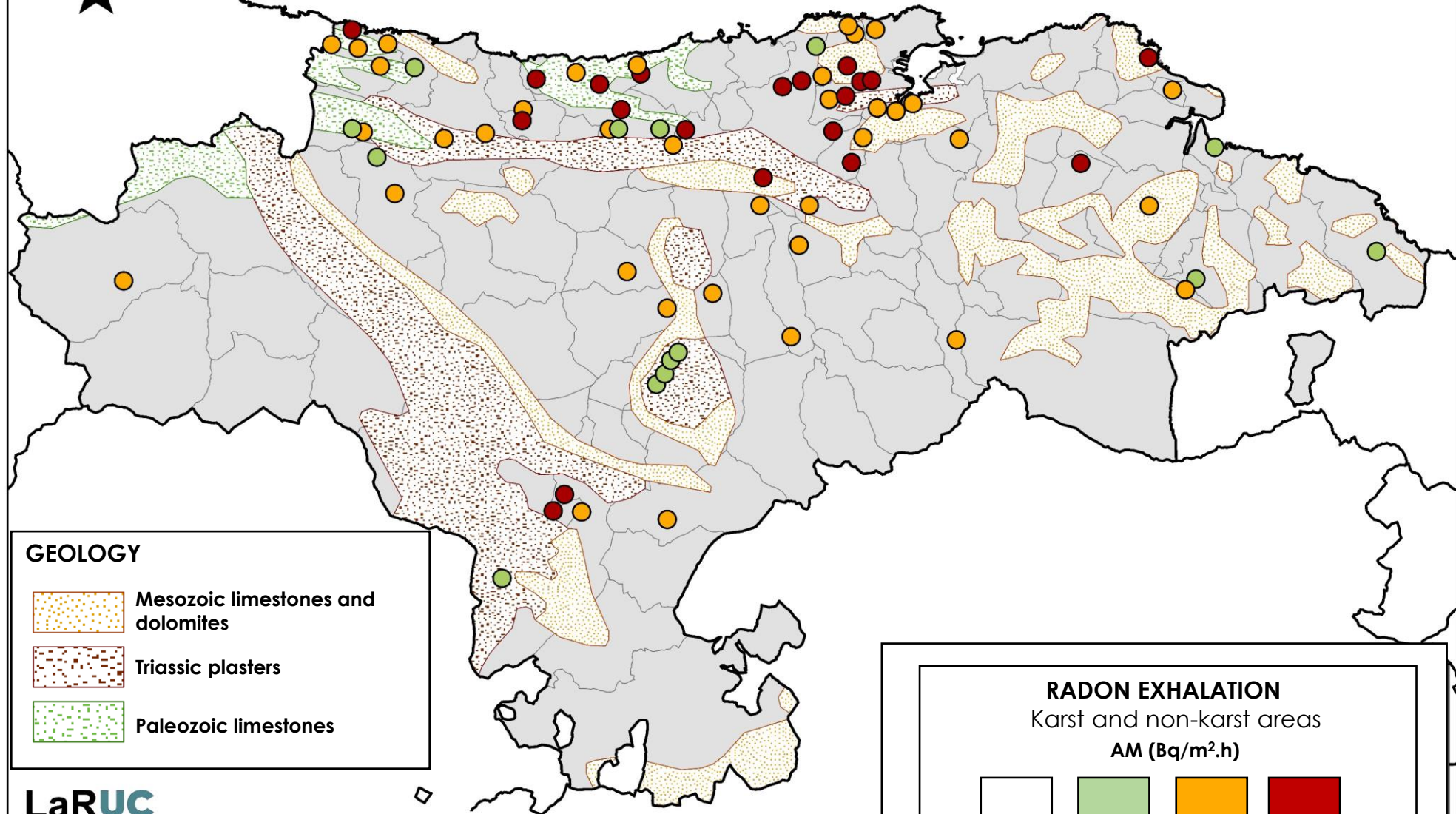
2002-Mesozoic limestones and dolomites

5004-Triassic Plasters

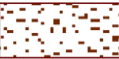
7.RADON EXHALATION RATE

(Bq/m².h)

4. RADON EXHALATION (Bq/m².h)



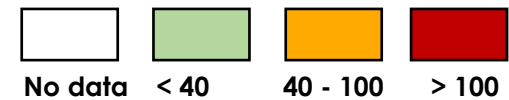
GEOLOGY

-  Mesozoic limestones and dolomites
-  Triassic plasters
-  Paleozoic limestones

RADON EXHALATION

Karst and non-karst areas

AM (Bq/m².h)



.RADON EXHALATION (Bq/m².h)

4.RADON EXHALATION (Bq/m ² .h)					
N° TOTAL mesurements	AM	DS AM	MIN	MED.	MAX
630	92	75.5	30	40	299

4.RADON EXHALATION (Bq/m ² .h)										
GEOLOGY	AM	DS AM	GM	MIN	MED	MAX	N° MEASUREMENTS	GEOLOGY NO KARST	AM	N° MES.
TOTAL	82	70.0	62	40	40	290	615	TOTAL	42	15
1001	83	70.4	63	40	40	282	52%			
2002	86	72.2	65	40	40	282	29%			
5004	73	64.9	56	40	40	290	19%			

1001-Paleozoic limestones

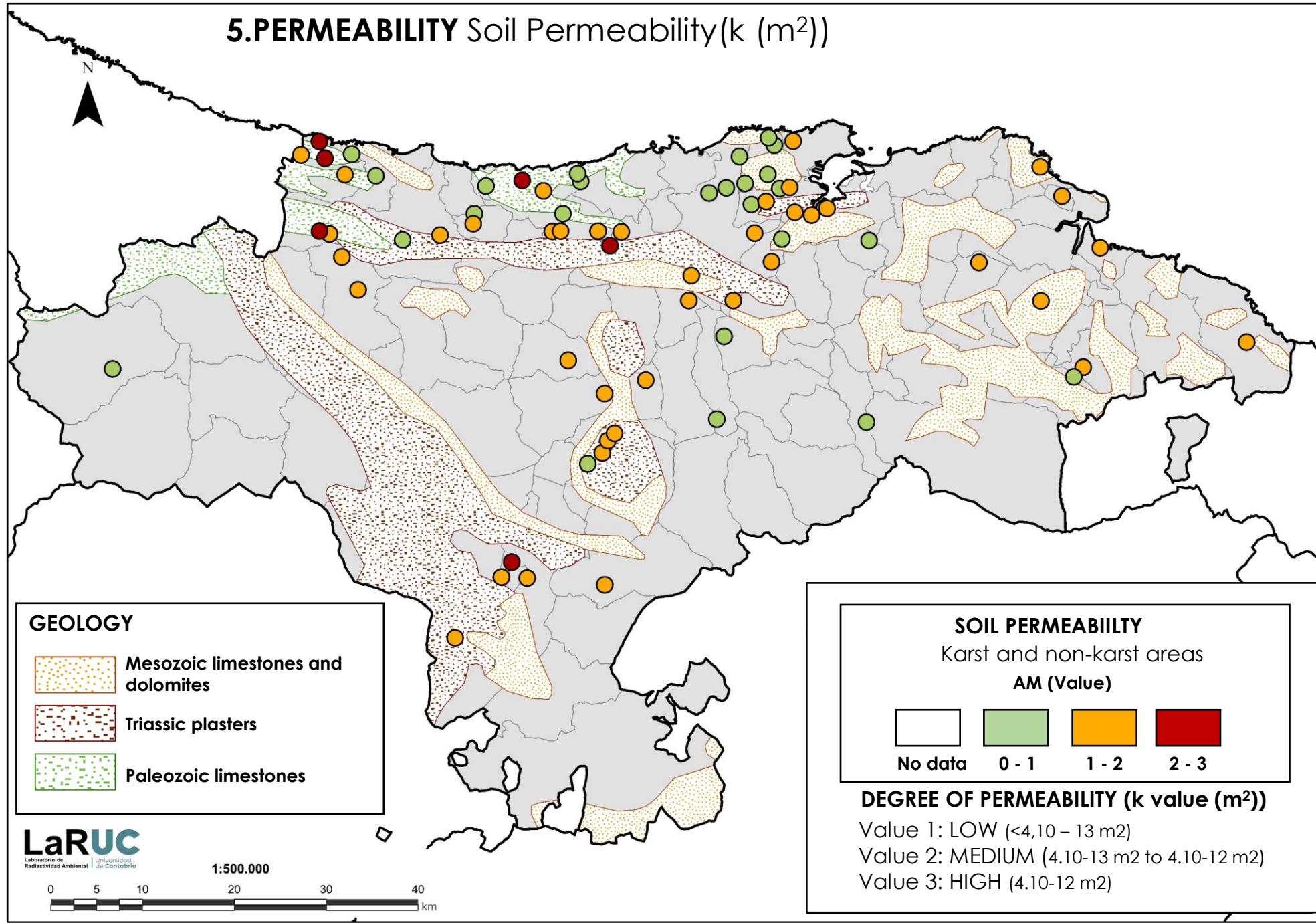
2002-Mesozoic limestones and dolomites

5004-Triassic Plasters

8. PERMEABILITY OF SOILS

$(k \text{ (m}^2\text{)})$

5.PERMEABILITY Soil Permeability(k (m^2))



8.PERMEABILITY Soil Permeability(k (m²))

5.PERMEABILITY Soil Permability (k value (m ²))					
Nº TOTAL mesurements	AM	DS AM	MIN	MED.	MAX
279	2.017	0.9	1	2	3

5.PERMEABILITY

Soil Permeability (k value (m²))

Degree of permeability

VALUE 1 Low(<4.10-13m²)

VALUE 2 Medium (4.10-13m² a 4.10-12m²)

VALUE 3 Higt(4.10-12m²)

GEOLOGY	AM	DS AM	GM	MIN	MED	MAX	Nº MEASUREMENTS	GEOLOGY NO KARST	AM	Nº MES.
TOTAL	2.01	0.7	1.40	1	1	3	160	TOTAL	2.34	119
1001	1.42	0.6	1.33	1	1	3	46%			
2002	1.67	0.7	1.53	1	2	3	25%			
5004	1.59	0.8	1.43	1	1	3	29%			

1001-Paleozoic limestones

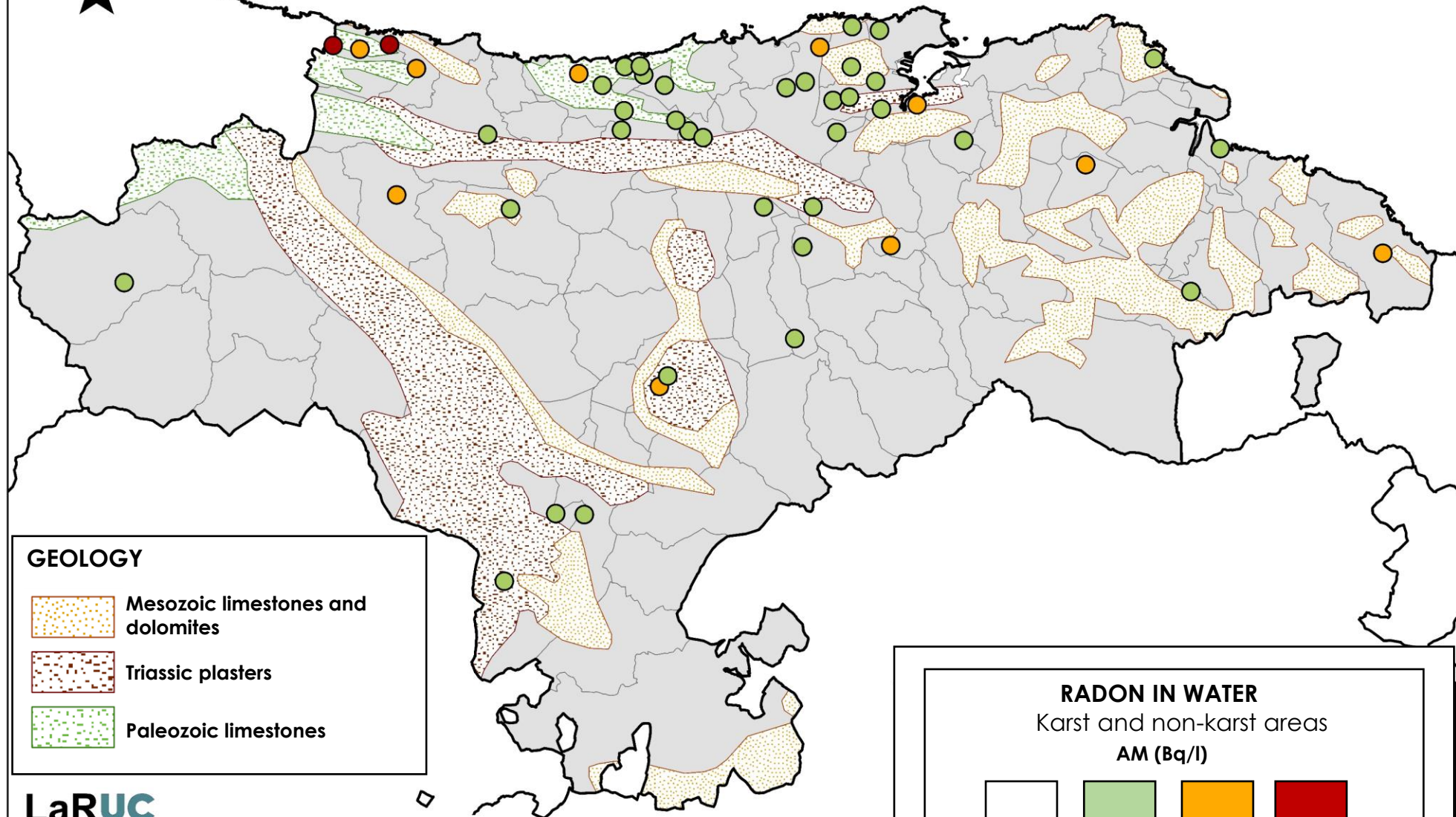
2002-Mesozoic limestones and dolomites

5004-Triassic Plasters

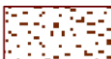
9. RADON IN WATER

(Bq/l)

6. RADON IN WATER (Bq/l)



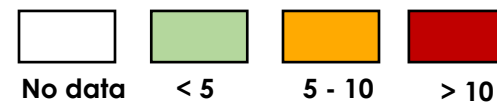
GEOLOGY

-  Mesozoic limestones and dolomites
-  Triassic plasters
-  Paleozoic limestones

RADON IN WATER

Karst and non-karst areas

AM (Bq/l)



9.RADON IN WATER (Bq/l)

6.RADON IN Water Concentration (Bq/l)					
Nº TOTAL measurements	AM	DS AM	MIN	MED.	MAX
70	9.63	31.4	1.400	3.670	224.460

6.RADON IN WATER Concentration (Bq/l)										
GEOLOGY	AM	DS AM	GM	MIN	MED	MAX	Nº MEASUREMENTS	GEOLOGY NO KARST	AM	Nº MES.
TOTAL	9.63	31.4	3.97	1.40	3.67	224.46	70	TOTAL	-	0
1001	3.60	2.2	2.99	1.40	3.14	9.620	47%			
2002	13.90	46.0	4.48	1.99	3.91	224.46	33%			
5004	15.96	37.4	5.95	1.75	4.00	152.00	20%			

1001-Paleozoic limestones

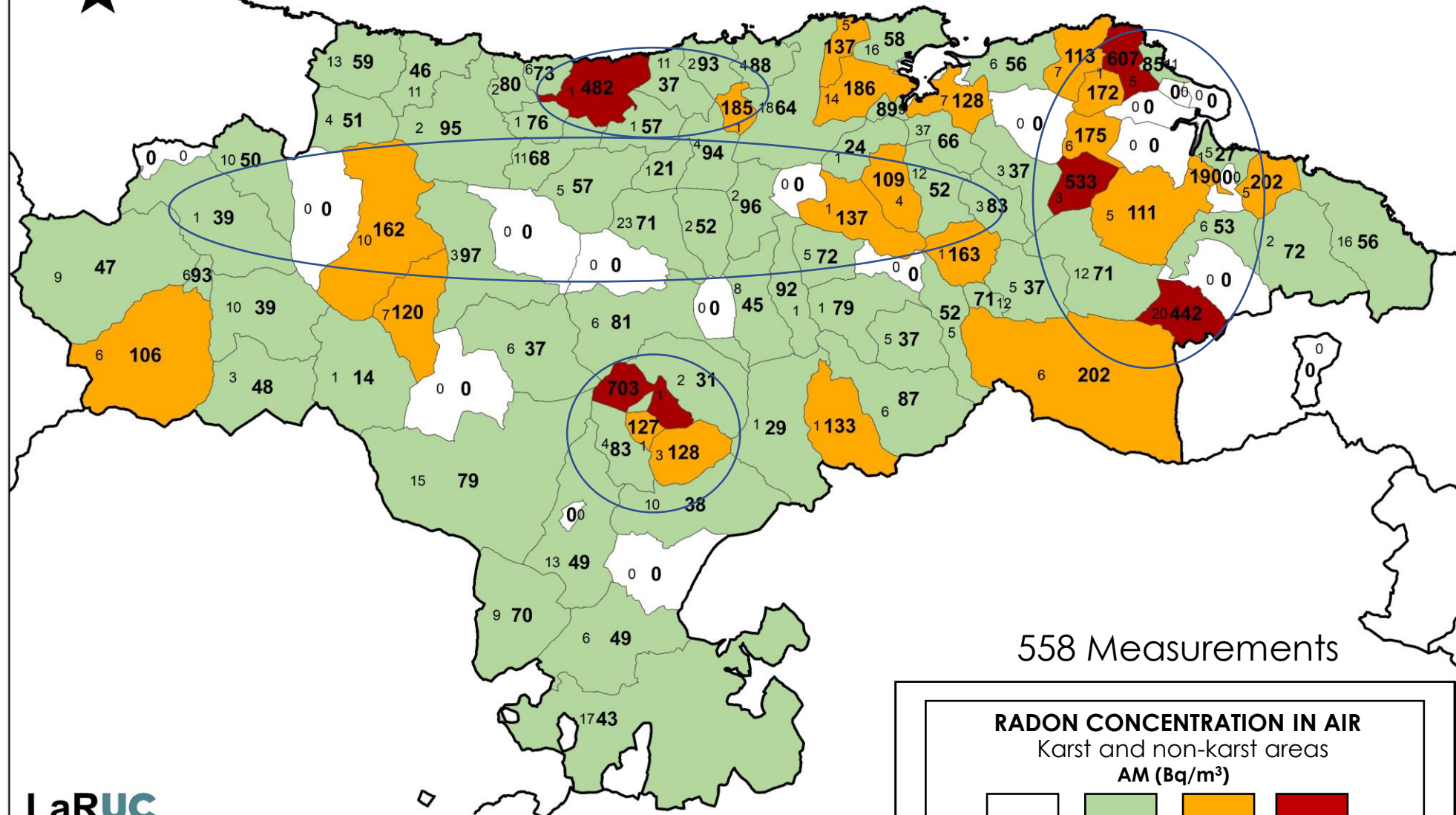
2002-Mesozoic limestones and dolomites

5004-Triassic Plasters

10.RADON IN AIR

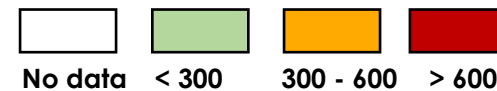
(Bq/m³)

1. RADON IN AIR (Bq/m³)



558 Measurements

RADON CONCENTRATION IN AIR
Karst and non-karst areas
AM (Bq/m³)



10.RADON IN AIR (Bq/m³)

1.RADON IN AIR Concentration (Bq/m ³)					
N° TOTAL mesurements	AM	DS AM	MIN	MED.	MAX
258	122	256.2	10	52	2090

1.RADON IN AIR Concentration (Bq/m ³)										
GEOLOGY	AM	DS AM	GM	MIN	MED	MAX	N° MEASUREMENTS	GEOLOGY NO KARST	AM	N° MES.
TOTAL	122	256.2	59	10	52	2090	258	TOTAL	78	300
1001	142	306.0	63	10	54	2090	57%			
2002	78	95.2	56	10	54	482	11%			
5004	88	119.5	53	10	47	703	32%			

1001-Paleozoic limestones

2002-Mesozoic limestones and dolomites

5004-Triassic Plasters

SUMMARY TABLE

	KARST AREA (AM)				NO KARST AREA (AM)
	GEOLOGY 1001	GEOLOGY 2002	GEOLOGY 5004	AVERAGE	AVERAGE
1.RADON IN AIR Concentration (Bq/m ³)	78	142	88	122	78
2.RADON IN SOLIS Concentration (KBq/m ³)	44	38	67	45	22
4.GAMMA EXTERNAL Dose (μSv/h)	0.066	0.066	0.075	0.068	0.051
5.GAMMA SOIL ²³⁸ U (Bq/kg)	24.1	25.9	25.7	25.3	15.667
5.GAMMA SOIL ²²⁶ Ra (Bq/kg)	28.5	32.3	34.8	31.7	26.542
5.GAMMA SOIL ²³² Th (Bq/kg)	31.6	33.0	34.4	32.9	43.676
5.GAMMA SOIL ⁴⁰ K (Bq/kg)	253.9	275.6	487.7	306.9	473.461
5.GAMMA SOIL ¹³⁷ Cs (Bq/kg)	6.0	4.8	3.3	4.8	5.648
6.RADON EXHALATION (Bq/m ² .h)	86	83	73	82	42
7.RADON IN WATER Concentración (Bq/l)	13.90	3.60	15.96	9.63	-
8.PERMEABILITY Soil permeability (k (m ²)) Degree of permeability VALUE 1 Low(<4.10 ⁻¹³ m ²) VALUE 2 Medium (4.10 ⁻¹³ m ² a 4.10 ⁻¹² m ²) VALUE 3 Higt (4.10 ⁻¹² m ²)	1.67	1.42	1.59	1.53	2.34

1001-Paleozoic limestones

2002-Mesozoic limestones and dolomites

5004-Triassic Plasters

.- The percentage of houses with levels over 300 Bq/m³ is around 4% very similar to found for the total of the country and basically located in the border of faults inside the karst. This value is lower than that found in areas of radon potential in the country of 10%.

but.....

Radon in workplaces

- .- A new legislation has been approved in the Spanish legislation: IS-47



BOLETÍN OFICIAL DEL ESTADO



Núm. 105

Jueves 1 de mayo de 2025

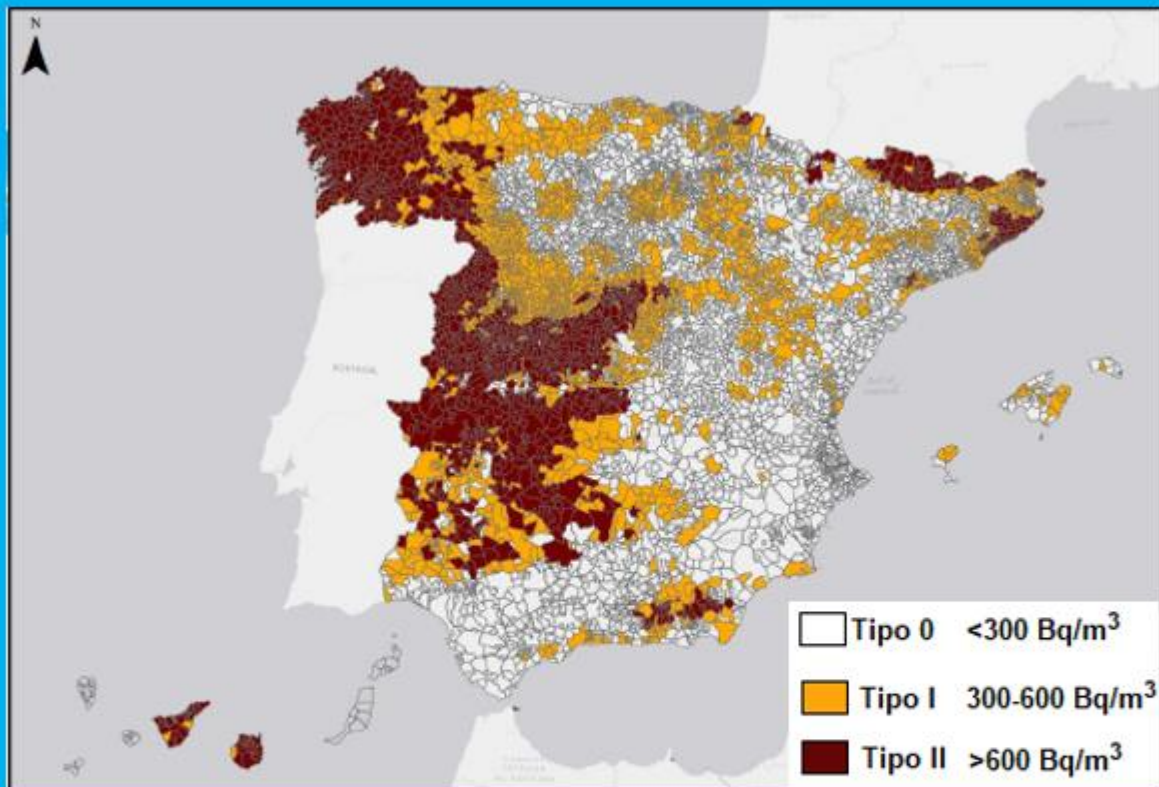
Sec. III. Pág. 59229

III. OTRAS DISPOSICIONES

CONSEJO DE SEGURIDAD NUCLEAR

8734

Instrucción IS-47, de 9 de abril de 2025, del Consejo de Seguridad Nuclear, por la que se aprueba el listado de términos municipales de actuación prioritaria contra el radón y se establecen directrices para las mediciones de radón en el aire interior de los centros de trabajo ubicados en ellos.



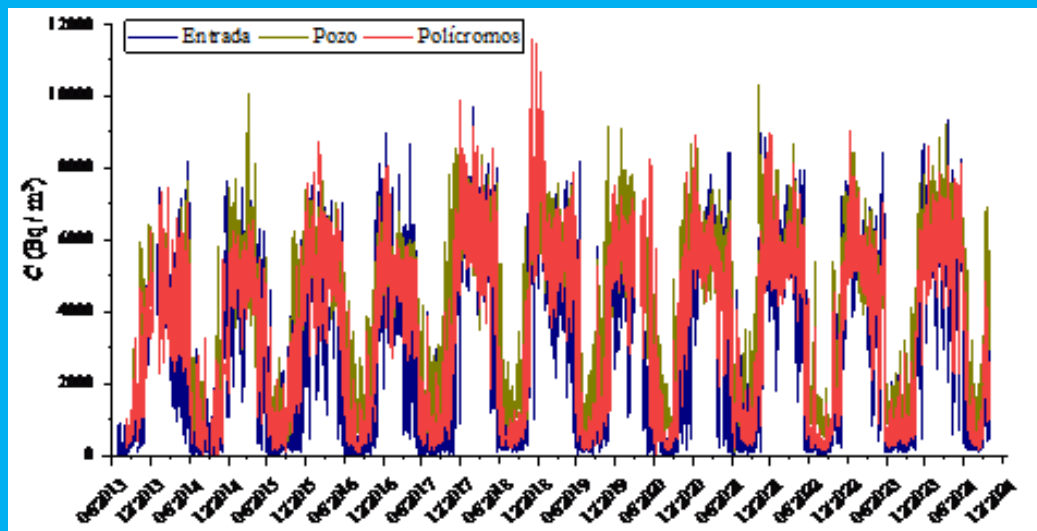
~ 4500 Municipios en Tipo 0

~ 2400 Tipo I y ~ 1600 Tipo II

Radon measurement is MANDATORY in all workplaces in type II municipalities. *iii* more than 1 million of measurements*iii*

In our karst región the situation is:

- There are TWO spas in Cantabria with the highest radon concentraci3n in the w3ter in Spain (approx. 700 Bq/l) after the Arnedillo Spa in Logroño (1500 Bq/l) with high radon levels on the premises (over 2000 Bq/m³)
- There are more that 20 tourist caves in Cantabria with stationary variation of radon concentrations as shown in the figure.
- There are many underground workplaces in the regi3n with values higher tan 1000 Bq/m³



iiiHIGH DOSES FOR WORKERS, IN GENERAL MORE THAN 6 mSv/y iii

CONCLUSION

.- While Cantabria is out of type II the concentration of radon in workplaces is an important issue because the presence of many in caves, spas and underground places.

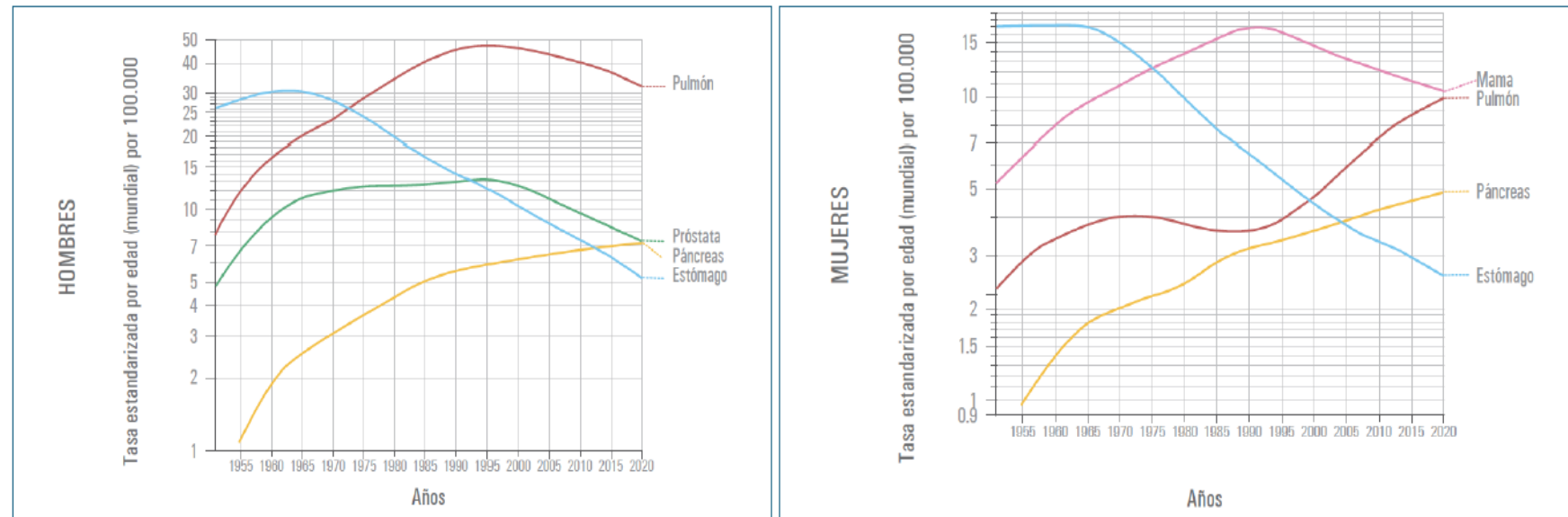
Then an finally.....

A brief comments about

RADON AND LUNG CANCER

EVOLUTION OF LUNG CANCER IN SPAIN

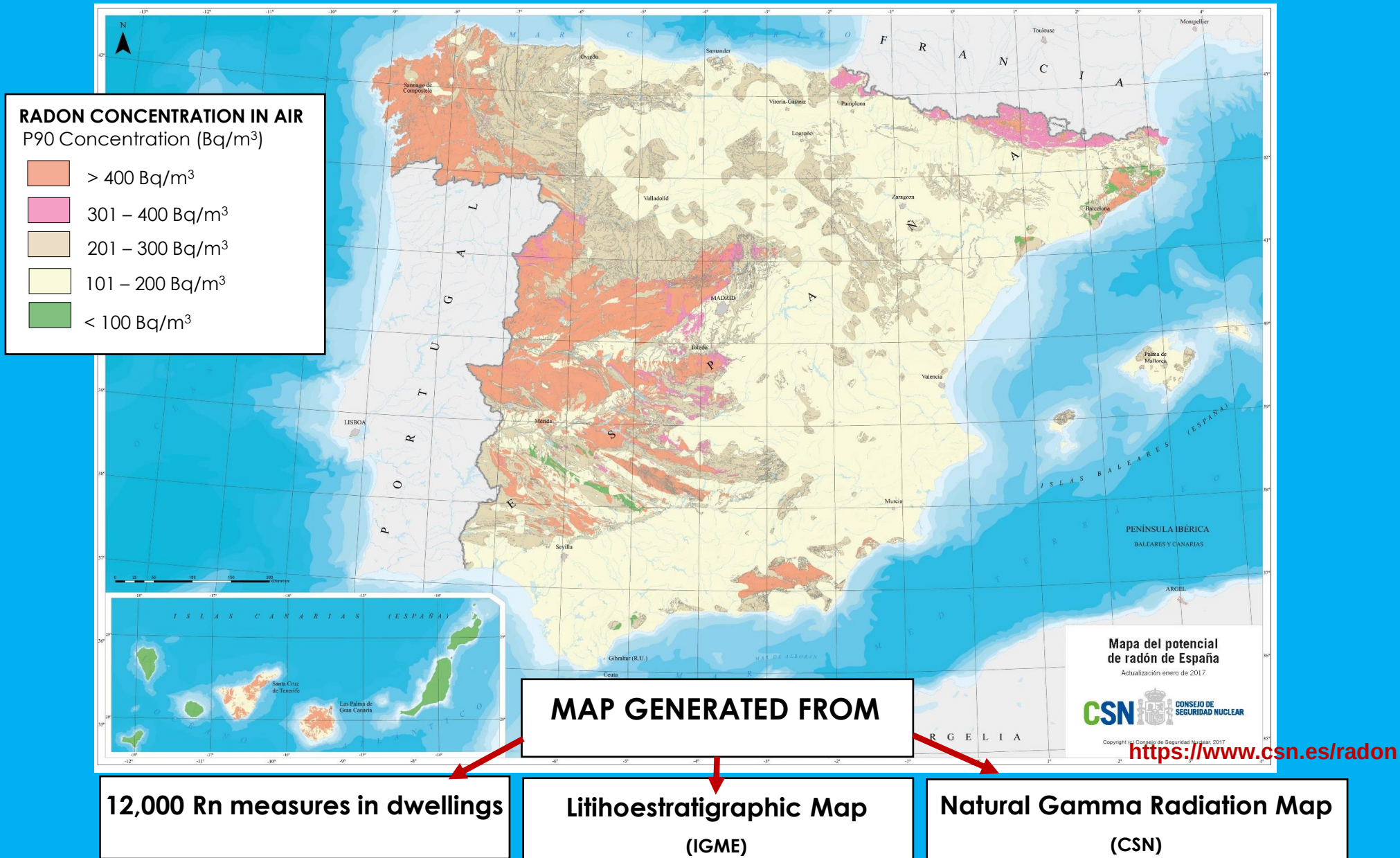
22000 deaths in 2024

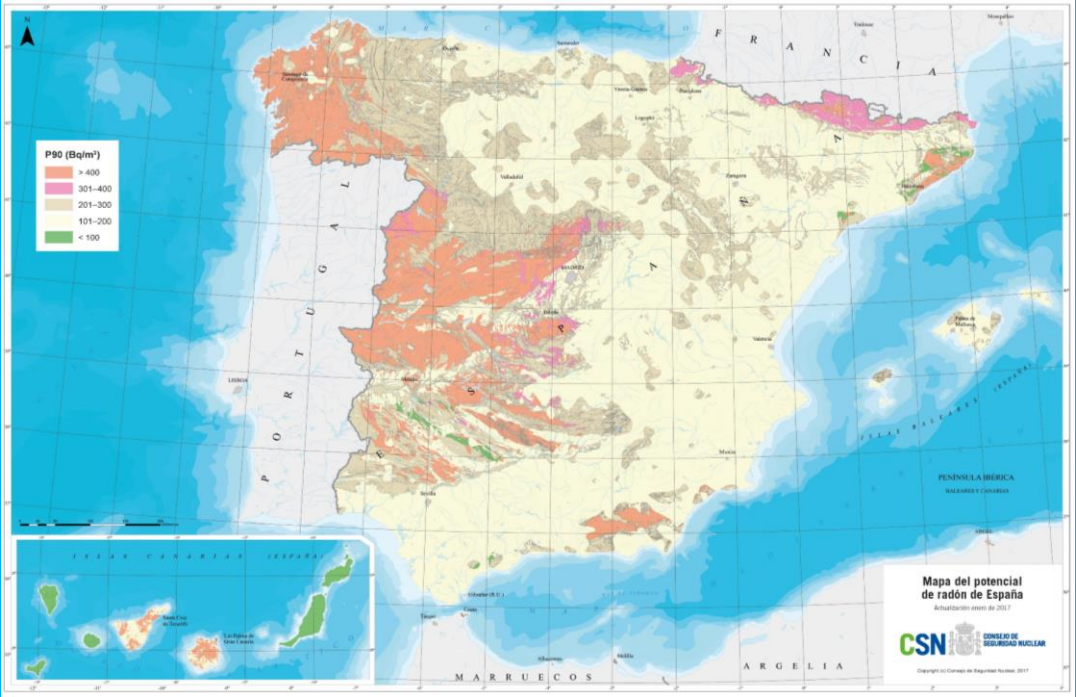
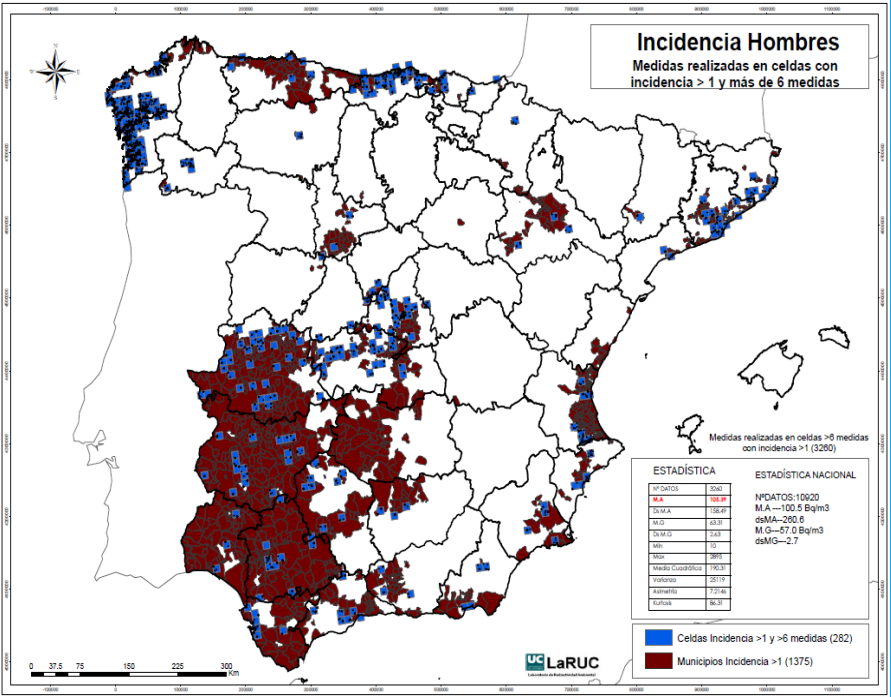


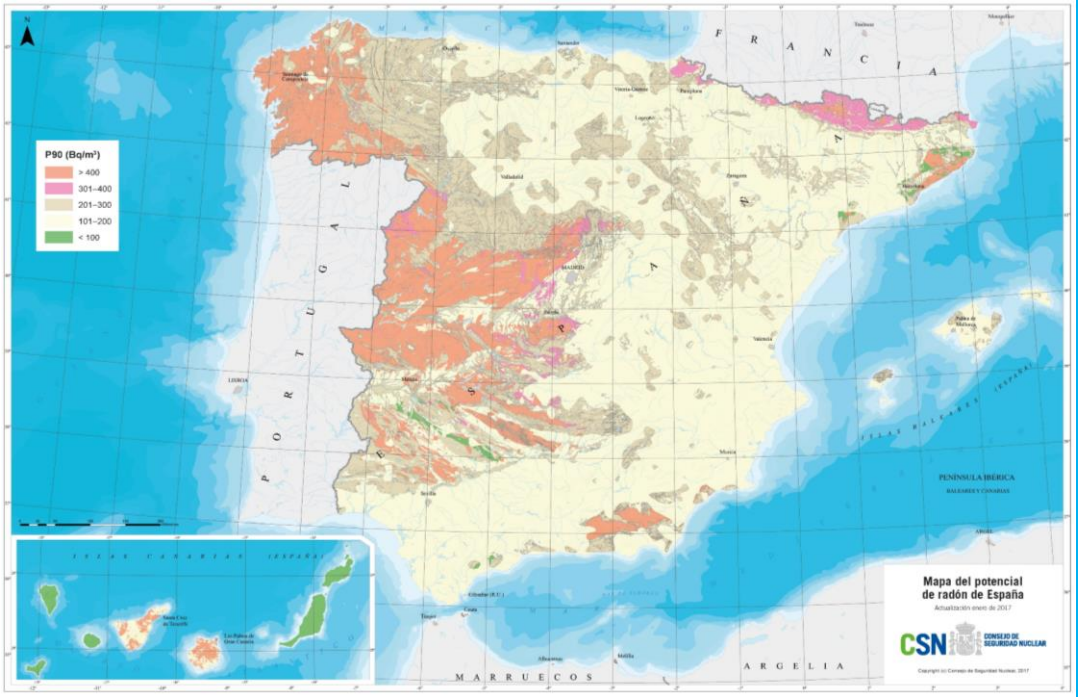
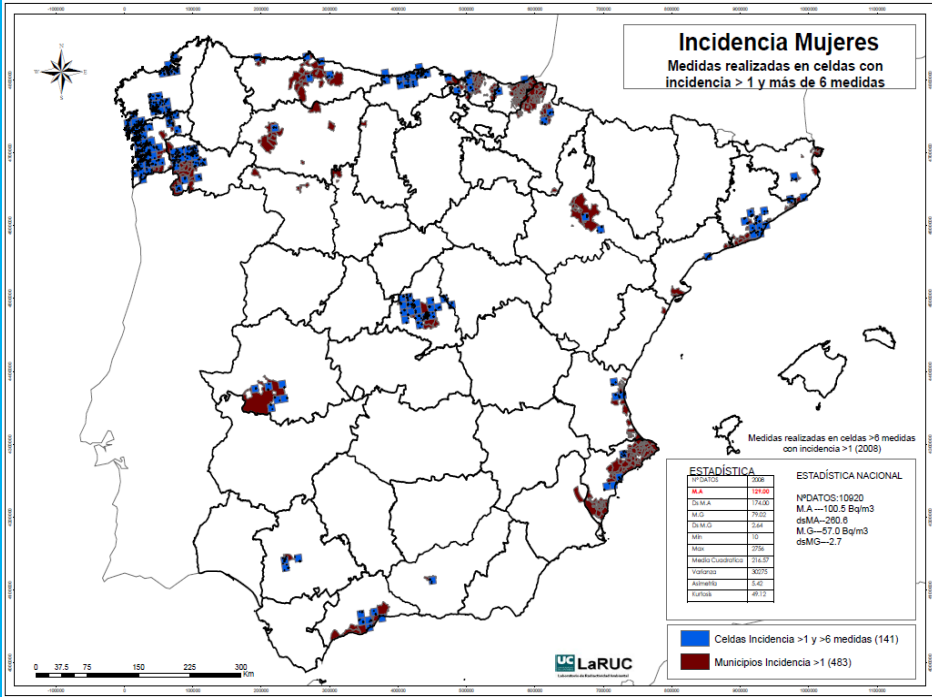
Ref. Carlos III Institute, Madrid

RADON POTENTIAL MAP IN SPAIN

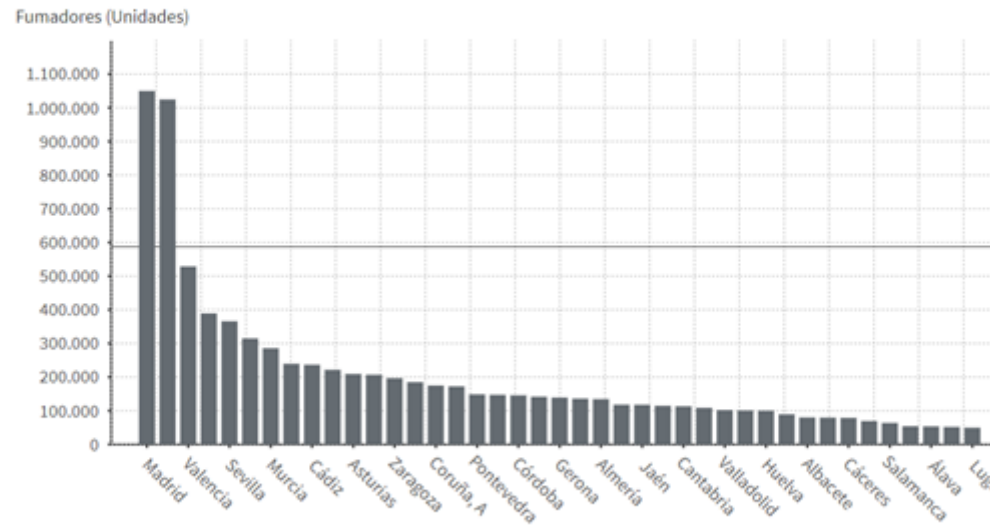
Spanish Nuclear Safety Council (CSN)







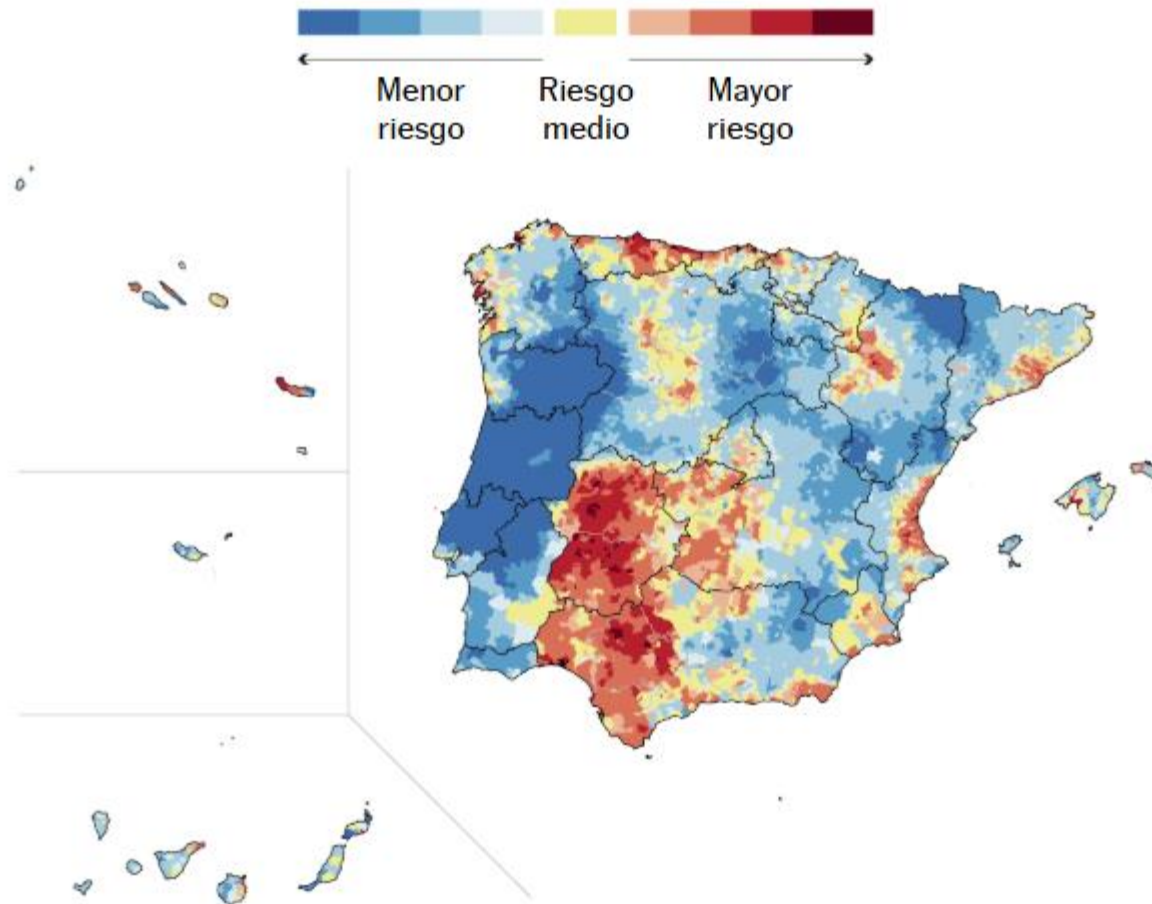
Ranquin provincial de consumo de tabaco



Fuente: AECC, epdata

AECC: Spanish Association against cancer

Mapa del cáncer de pulmón



CONCLUSION

- .- The correlation of potencial of radon and lung cancer for a general point of view coul be correct but still remain study other factors unknow today besides tobacco use.

THREE MORE SLIDES.....

Development of an innovative system for indoor radon management with AI capabilities



Luis Santiago Quindós Poncela¹
Carlos Sainz Fernández¹
Ricardo Pol Sánchez²
Raúl Rodríguez Alas²

Ismael Fuente Merino¹
Daniel Rabago Gómez¹
Diego Sánchez Quintás²

¹ LaRUC University of Cantabria
² Siglo 21 Consultores



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Fondos Europeos



AÑO JUBILAR
LEBANIEGO
2023·2024



Esta entidad ha recibido una ayuda cofinanciada por el Fondo Europeo de Desarrollo Regional a través del Programa Operativo FEDER 2021-2027 de Cantabria por medio de la línea de subvenciones "Ayudas a proyectos de investigación con alto potencial industrial de agentes tecnológicos de excelencia para la competitividad industrial TCNIC.

MEDIDA DE FACTOR DE EQUILIBRIO Y FRACCION LIBRE EN CUEVAS TURISTICAS (ACTE)

Financiacion: Grupo Radon

Dose evaluation

$$E(\text{mSv}) = \frac{C (\text{Bq/m}^3) \cdot F \cdot t(\text{h})}{170 \cdot 3700} \cdot DCF (\text{mSv/WLM})$$

CRn anual average = 300 Bq/m³

$t = 2000$ hours per year

$$E(\text{mSv}) = \frac{300 \text{ Bq/m}^3 \cdot 0,4 \cdot 2000 \text{ h}}{170 \cdot 3700} \cdot 10 \text{ mSv/WLM} \approx 4 \text{ mSv}$$

Vivienda

CRn anual average = 300 Bq/m³

$t = 7000$ hours per year

$$E(\text{mSv}) = \frac{300 \text{ Bq/m}^3 \cdot 0,4 \cdot 7000 \text{ h}}{170 \cdot 3700} \cdot 10 \text{ mSv/WLM} \approx 14 \text{ mSv}$$

¿Why repeat old mistakes when there
are so many new ones to make?

Bertrand Russell

- Thanks for your attention

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