



7th EUREGEO

EUropean
Congress
on REgional
GEOscientific
Cartography
and
Information
Systems



Bologna, 2012-06-14

GEOLOGICAL BASED SEISMIC MACROZONATION FOR PYRENEES

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- ✓ **CONTEXT: SISPYR PROJECT**
- ✓ **BACKGROUND FOR SEISMIC ZONATION**
 - Microzonation / Macrozonation
 - Proxys used for zonation
- ✓ **SEISMIC MACROZONATION OF PYRENEES**
 - Available homogeneous data
 - Method applied
 - Results
 - Back analysis



✓ **INTERREG IVA France-Spain-Andorra 2007-2013**

✓ **HEADFILE: IGC (Sp)**



✓ **PARTNERS:**

■ OMP (Toulouse P. Sabatier University)



■ BRGM



■ IGN



■ UPC



✓ **DURATION: 09-2009 / 12/2012**

✓ **FINANCIAL SUPPORT:**

■ FEDER



■ LANGUEDOC-ROUSSILLON REGION (Fr)



M1

M2

✓ Seismic data acquisition, exchange & sharing

- RT cross-border seismic observation network development
- Data exchange protocols

M3

✓ Seismic hazard knowledge

- Work on source in the Pyrenean context, moment tensors

M4

M5

✓ Seismic risk management

- Prevention: seismic scenarios
- Preparation to crisis management:
Pyrenean shake-map & EWS

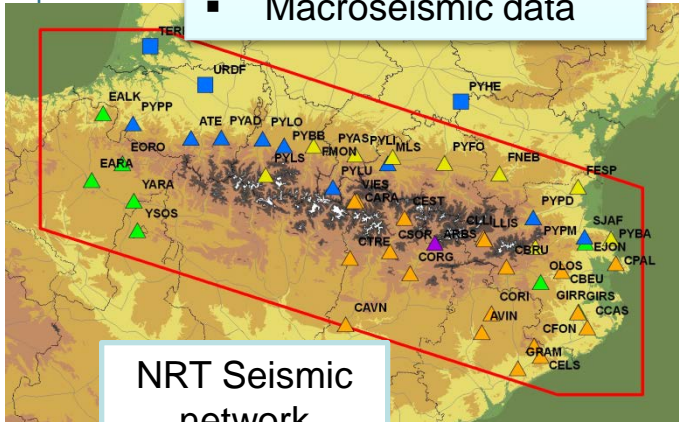
M6

✓ Dissemination (www.sispyr.eu)



EVENT DATA

- Local ground motion
- Macroseismic data



Automatic cross-border Pyrenean SHAKE-MAP

TRIGGER
AUTOMATIC
EARTHQUAKE
REGISTRATION

- ## PERMANENT DATA
- Attenuation laws
 - Amplification map
 - ...

NRT Seismic network

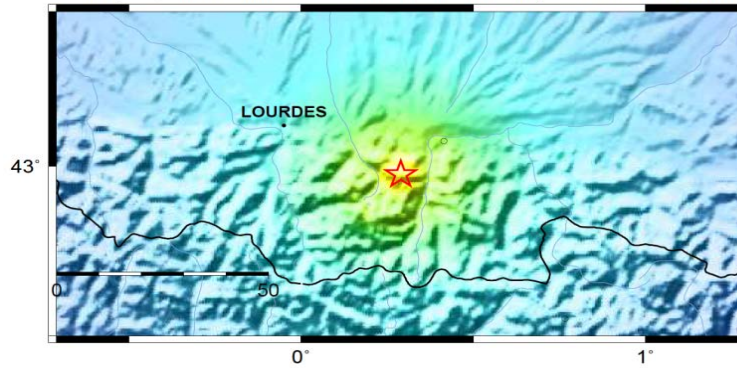
NRT Server

Observed ground motion

Interpreted macroseismic data

On-line macroseismic testimonies (IGC/IGN/BCSF)

SISPyR ShakeMap : Bagnesres IGC
Thu Apr 1, 2010 01:36:40 GMT M 4.6 N42.98 E0.29 Depth: 9.0km ID:1000013



Map Version 1 Processed Thu Mar 17, 2011 11:12:44 AM GST

	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
PERCEIVED SHAKING	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
POTENTIAL DAMAGE	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK ACC.(%g)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
PEAK VEL.(cm/s)	I	II-III	IV	V	VI	VII	VIII	IX	X+
INSTRUMENTAL INTENSITY									



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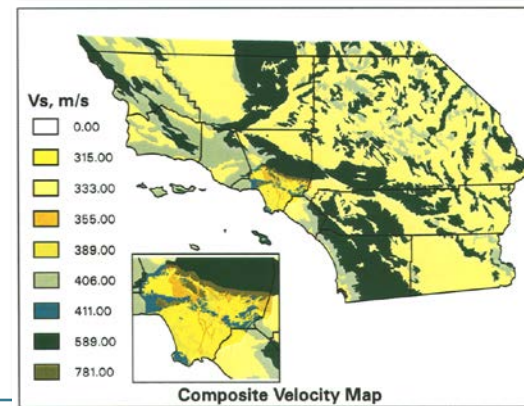
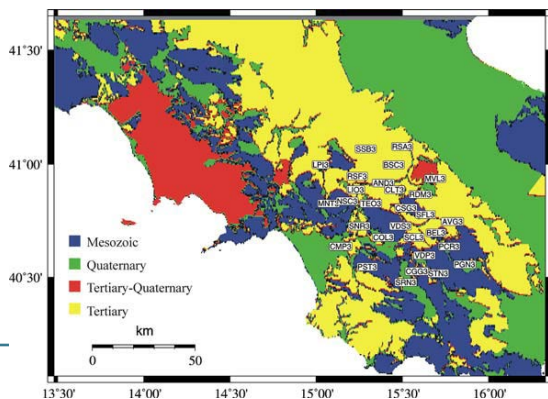
- ✓ **MICROZONATION / MACROZONATION**
 - Scale of work
 - Micro: municipality scale 1:10 000 to 1:25 000
 - Macro: regional scale up to 1:100 000 ... country
 - Means
 - Micro: field investigations, quantitative assesment
 - Macro: research of proxys
 - Valorization
 - Micro: seismic rules for building
 - Macro: prevention & information

EC8 rules are mainly based on V_{s30}
assesment for soil zonation → proxys ?



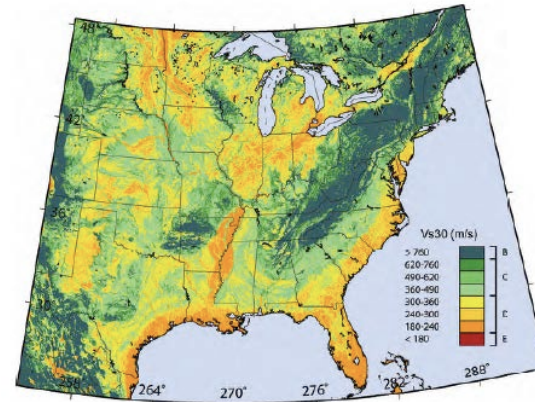
✓ PROXYS USED

- Geology – Terrain types
 - Joyner et al. (1981)
 - Tinsley & Fumal (1985) ... mapped quaternary deposits in the Los Angeles basin
 - Park & Elrick (1998) : Quaternary Tertiary Mesozoic (QTM)-based VS30 map grouped into nine units of VS₃₀ values.
 - Wills & Clahan (2006) Map geologically defined site conditions category in California
 - Matsuoka et al. (2006): average shearwaves
 - Convertito & al. (2009)

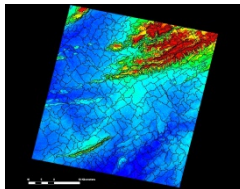


✓ PROXYS USED

- Slope gradient
 - Wald & Allen (2007)
- Hybrid methods:
 - Geomorphometry & Geology: Yong et al. (2008)
Iwahashi & Pike (2007)

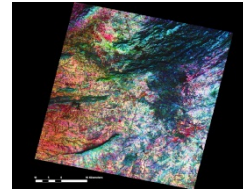


Terrain
Types
DEM

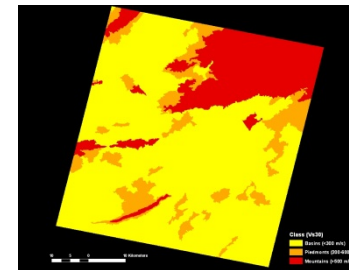


+

Spectral
Analysis



=



Satellite
based
Vs30 Map

Islamabad, Pakistan

- Slope gradient & geology: Thompson & Wald (2012)



✓ SITE EFFECTS METHODS USED IN SHAKE-MAP IMPLEMENTATIONS

Region	Site effects
Global	Topographic slope Wald and Allen (2007) Amplification: Borchardt (1994)
South California, default regression	Vs30: Wills et al.(2000) Amplification: Borchardt (1994)
North California, default regression	Vs30: Wills et al.(2000) Amplification: Borchardt (1994)
California	Vs30: Wills et al.(2000); and Wentworth (?)
New Madrid	Vs30: Bauer et al. (2001) Amplification: Borchardt (1994)
Ontario	Assume vertical component doesn't have amplification. Use H/V relations for each station for obtain the horizontal component. A rock site relation is assumed for no data stations.
Utah	Vs30: Ashland (2001), Ashland and McDonald (2003). Amplification: Borchardt (1994)
Italy	Geology simplification based on EC8. Amplification: Borchardt (1994)
Southeastern Alps	Geology simplification. Basic resolution. Amplification: Borchardt (1994)
Romania	Topographic slope Wald and Allen (2007)
Romania (Vrancea)	New method: determines the amplification functions from seismological information.

SISPYR method is based on a site condition map derived from geological map

Vs30 are deduced as a proxy from EC8 classification

Vs30 deduced from topographic slopes are not valorised

Amplification factors (Fa/Fv) derived from Borchardt (1994)

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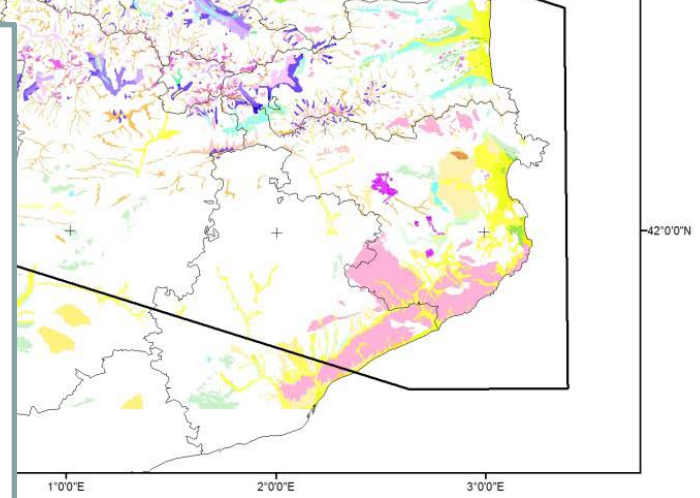
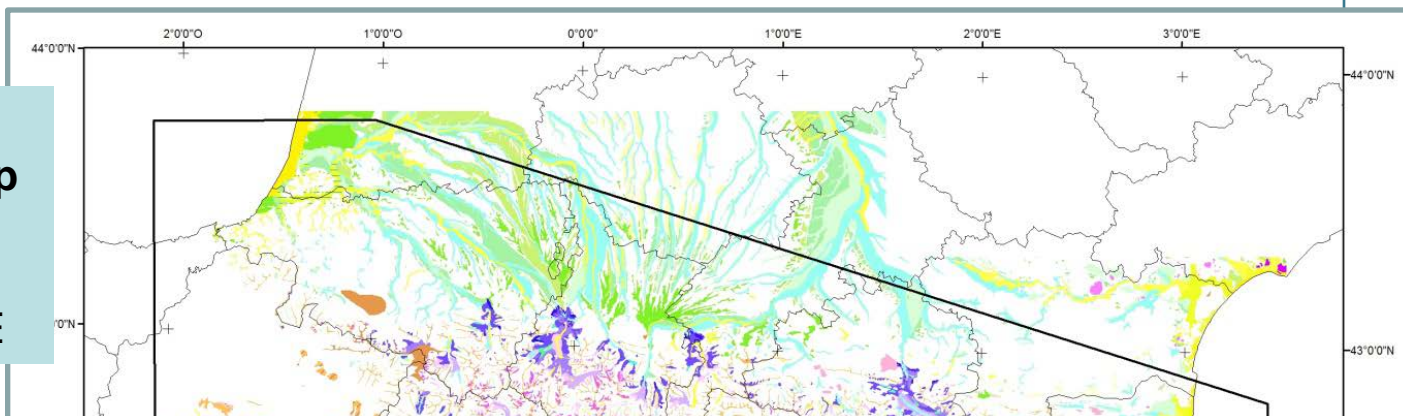
✓ AVAILABLE HOMOGENEOUS DATA

- Scale of work : 1:500 000 (500 m grid mesh)
- Geological & Quaternary deposits map 1:400 000 scale (IGME & BRGM) for all Pyrenees
- Geomechanical data
 - Study about a Vs_{30} map of France (Wald and Allen methodology) 2007
 - Boreholes databases:
 - French BSS (<http://infoterre.brgm.fr/>)
 - borehole from Ministerio de Medio Ambiente y Medio Rural y Marino (MARM)
 - borehole from Confederación Hidrográfica del Ebro (CHE) and Agència Catalana de l'Aigua (ACA)
- Bibliographic resources



SEISMIC MACROZONATION OF PYRENEES

**Quaternary
 deposits map
 of Pyrenees
 (1:400 000)
 BRGM-IGME**



**Geological map
 of Pyrenees
 (1:400 000)
 BRGM-IGME**

SEISMIC MACROZONATION OF PYRENEES

✓ METHOD

- Hybrid method based on terrain type & thicknesses
- Site condition map is defined from EC8 site classification defined from several parameters:

Ground type	Description of stratigraphic profile	Parameters		
		$v_{s,30}$ (m/s)	N_{SPT} (blows/30cm)	c_u (kPa)
A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	> 800	–	–
B	Deposits of very dense sand, gravel or very stiff clay, at least several tens of metres in thickness, characterised by a gradual increase of mechanical properties with depth.	360 – 800	> 50	> 250
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	180 – 360	15 - 50	70 - 250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< 15	< 70
E	A soil profile consisting of a surface alluvium layer with v_s values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with $v_s > 800$ m/s.			

- Lithology
- Geometry
- Compacity
- Geotechnical data
- Shear wave velocity

Main objective: qualify lithology / compacity / geometry for all territory

EC8 Pyrenean map



SEISMIC MACROZONATION OF PYRENEES

✓ METHOD

- 2 main steps:
 - Define a lithological classification (terrain types)
 - Determine the thickness attributes from geological regional context
- Lithological classification is adapted from works:

Terrain types

SOIL TYPE	Mainly Vs is...
HARD ROCK (HR)	> 800 m/s
SOFT ROCK (SR)	360 m/s < Vs < 800 m/s
ALTERED ROCK (Sra)	360 m/s < Vs < 800 m/s
SOFT SOIL (SS)	180 m/s < Vs < 360 m/s
VERY SOFT SOIL (VSS)	< 180 m/s

Boore & al. 1993
Convertito 2009



SEISMIC MACROZONATION OF PYRENEES

✓ METHOD

TYPE	AGE & CONTEXTE	LITHOLOGIE	1:400 000 MAPS		
			GEOL	QUAT	
VSS	QUATERNAIRE	VASE LITTORALES (VASE)	x	x	
SS	QUATERNAIRE	MORAINES (BLOCS)	x	x	
		CORDONS LITTORAUX (SABLE)	x	x	
		ALLUVIONS (SABLE, GRAVIER)	x	x	
		COLLUVIONS (ARGILE, BLOCS, LOESS)		x	
Sra	-	ARENE		x	
SR	TERTIAIRE NORD-PYRENEEN	ARGILE	x		
		MARNE	x		
		POUDINGUE	x		
		SABLE	x		
	TERTIAIRE SUD-PYRENEEN	MARNE	x		
HR	QUATERNAIRE	BASALTE	x		
	TERTIAIRE NORD-PYRENEEN	CALCAIRE	x		
		CONGLOMERAT	x		
		TERTIAIRE SUD-PYRENEEN	CALCAIRE	x	
	TERTIAIRE SUD-PYRENEEN	CONGLOMERAT	x		
		GYPSE	x		
		MARNE	x		
		TURBIDITE	x		
	SECONDAIRE	TERTIAIRE SUD-PYRENEEN	CALCAIRE	x	
			FLYSH	x	
GRES			x		
ROCHE BASIQUE			x		
PRIMAIRE	TERTIAIRE SUD-PYRENEEN	BASALTE	x		
		CALCAIRE	x		
		GABBRO	x		
		GNEISS	x		
		GRANITE	x		
		GRES	x		
		MIGMATITE	x		
		QUARTZITE	x		
		RHYOLITE	x		
		SCHISTE	x		

Terrain types

> 16

Class of ground assigned according to its genesis and age:

- VSS: coastal, deltaic and swamp Holocene deposits
- SS: Glacial, fluvial, alluvial and colluvial quaternary deposits
- SR: part of Neogene deposits and altered rocks
- HR: Paleozoic, Mesozoic and Paleogene materials and Q. volcanic rocks

SEISMIC MACROZONATION OF PYRENEES

✓ METHOD

- Intersection by GIS treatment of “geological” & “quaternary” maps provides soil column all over the study area:

Terrain types

		QUATERNARY DEPOSITS				
		HR (volcanics)	SR (altered HR)	SS	VSS	x (no deposit)
GEOLOGICAL MAP	HR	x/HR	Sra/HR	SS/HR	VSS/HR	x/HR
	SR	x/HR	Sra/HR	SS/SR	VSS/SR	x/SR
	SS	x/HR	Sra/HR	SS/?	VSS/?	SS/?
	VSS	x/HR	Sra/HR	SS/?	VSS/?	VSS/?

↓

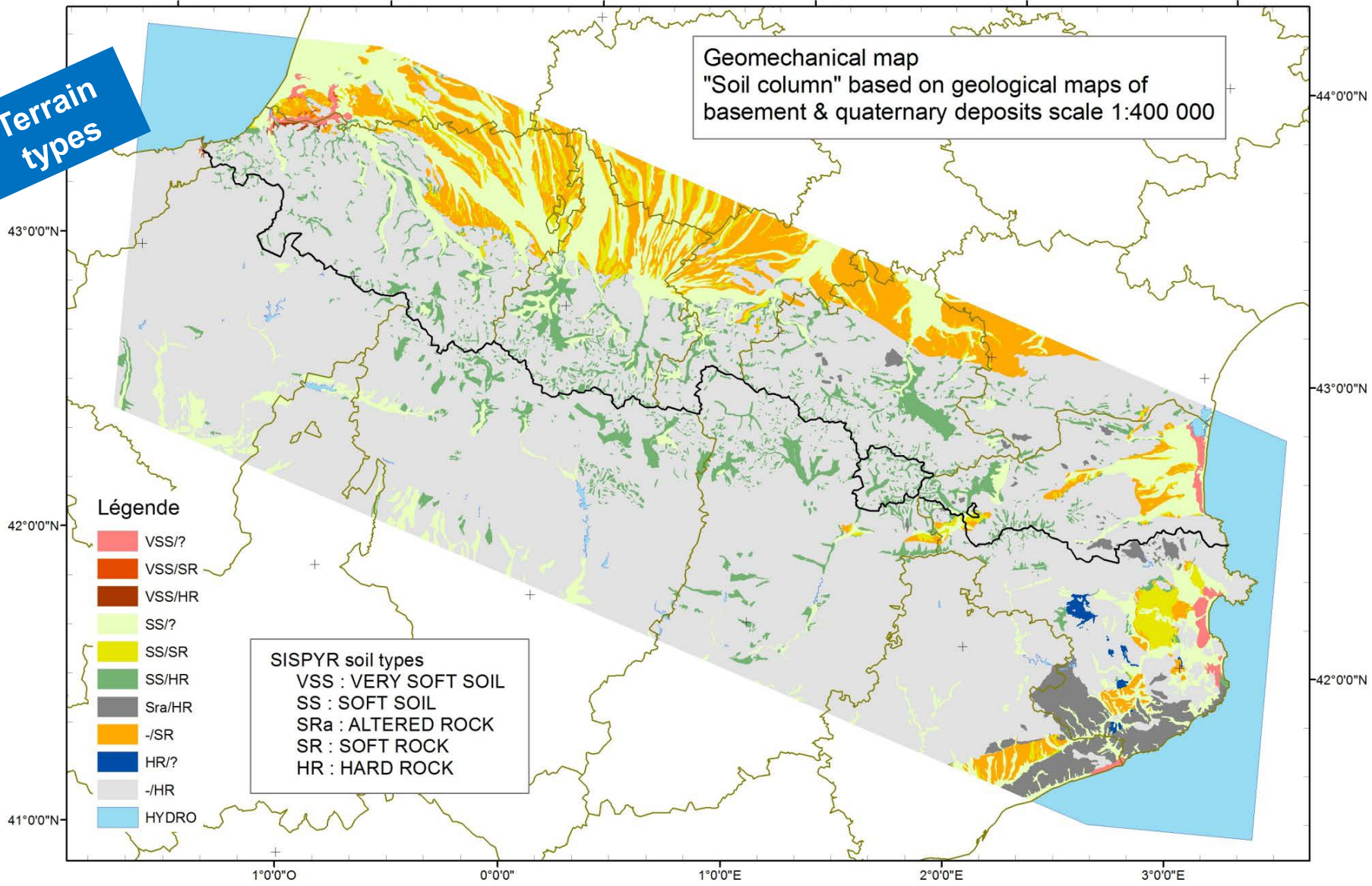
“2,5D” geological classification map which represents a zonation of soil column all over Pyrenees



SEISMIC MACROZONATION OF PYRENEES

Terrain types

Geomechanical map
 "Soil column" based on geological maps of basement & quaternary deposits scale 1:400 000



✓ METHOD

- Characterization of the thickness of deposits from different approaches from both sides of the border:
 - Deterministic approach based on expert and bibliography information in Spain (articles and boreholes databases)

Geometry

Epigraph	Geological description	Location	Generic interval thickness
11	Fluvial-lacustrine deposits of lateral plugging at the beginning of glacial retreat	Gallego, Ara and Cinqueta river valleys	5-20 m
15	Valley-side covered by colluvial deposits over final phase of disjunction moraines, southern exposure usually	Cinca and Gallego headwaters	5-20 m
17	T-5: highest terrace	Gallego river	<5 m
18	T-4: high terraces with high alteration	Segre river	5-20 m
19	High glacia, correlative with high terraces	Aragon and Cinca rivers	<5 m
20	T-3: medium terraces with high alteration	Zidacos, Aragón, Alcanadre, Cinca and Segre rivers	5-20 m
21	T-2: lower terraces with moderately alteration	Pyrenees rivers	5-20 m

Report GEOCAT: "Synthesis of Quaternary deposits and Neogene basins in the Iberian sector, July 2011"

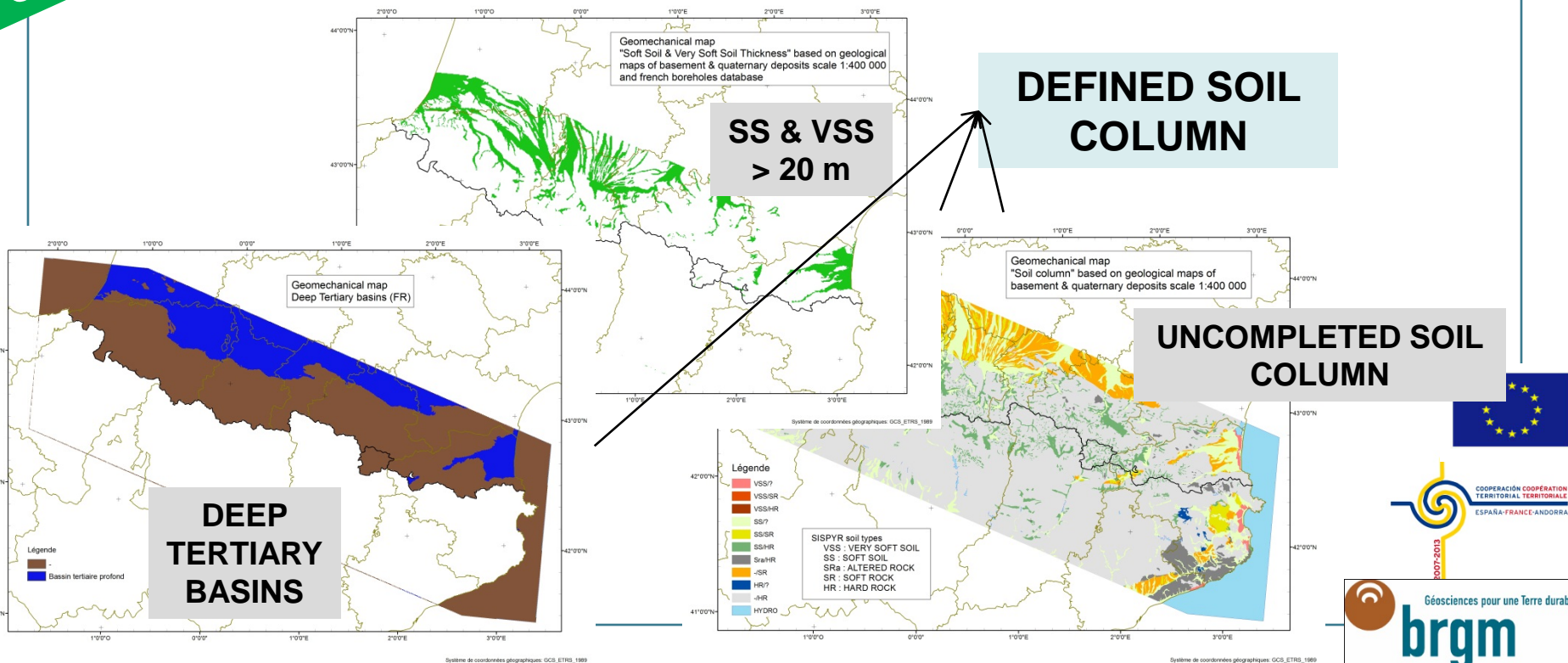


SEISMIC MACROZONATION OF PYRENEES

METHOD

- Global GIS approach in France based on main geological domains and bibliography information (boreholes databases and geological structures)

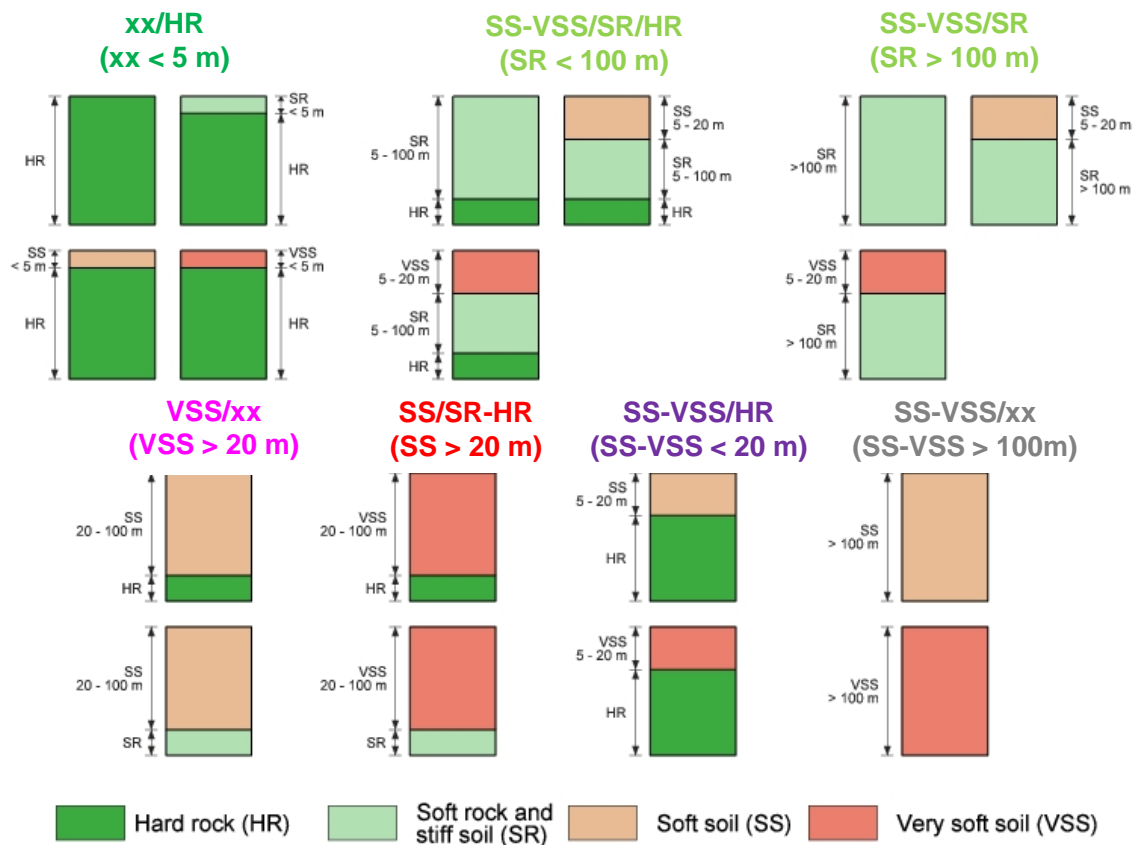
Geometry



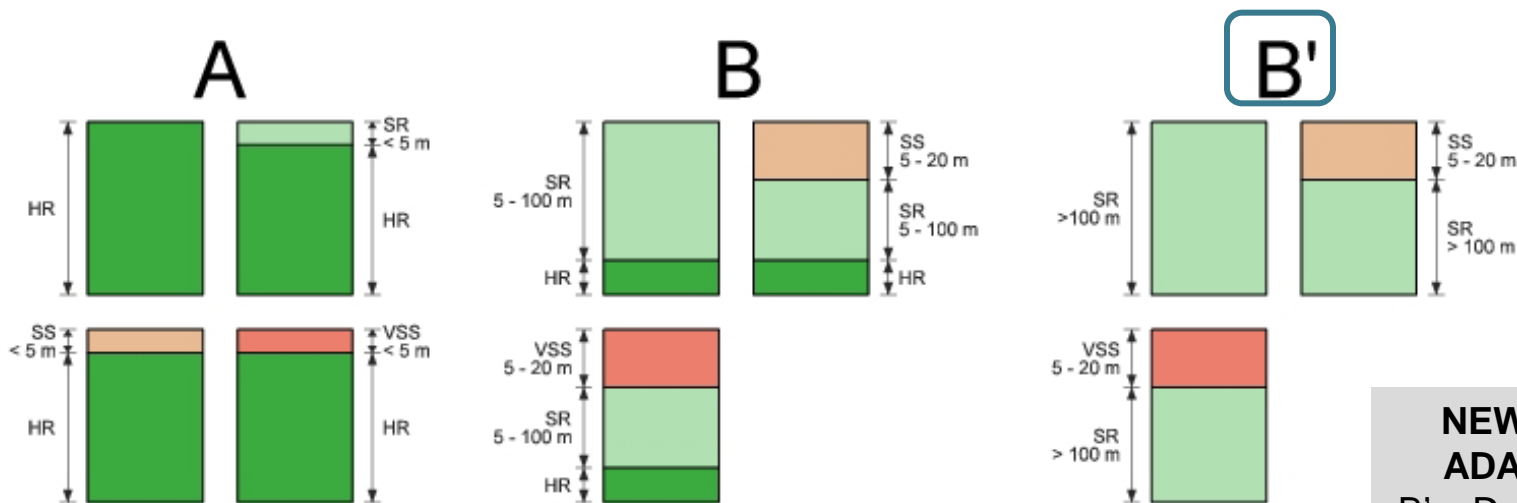
SEISMIC MACROZONATION OF PYRENEES

✓ RESULTS

- Definition of “**terrain type colum**” all over Pyrenees
- Homogeneous results from both sides of border (!)



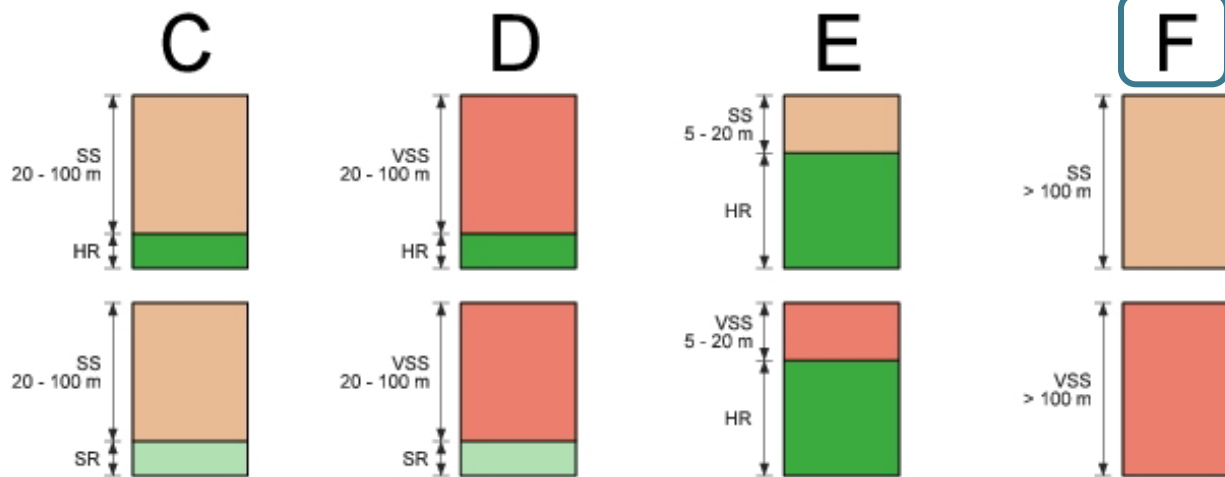
SEISMIC MACROZONATION OF PYRENEES



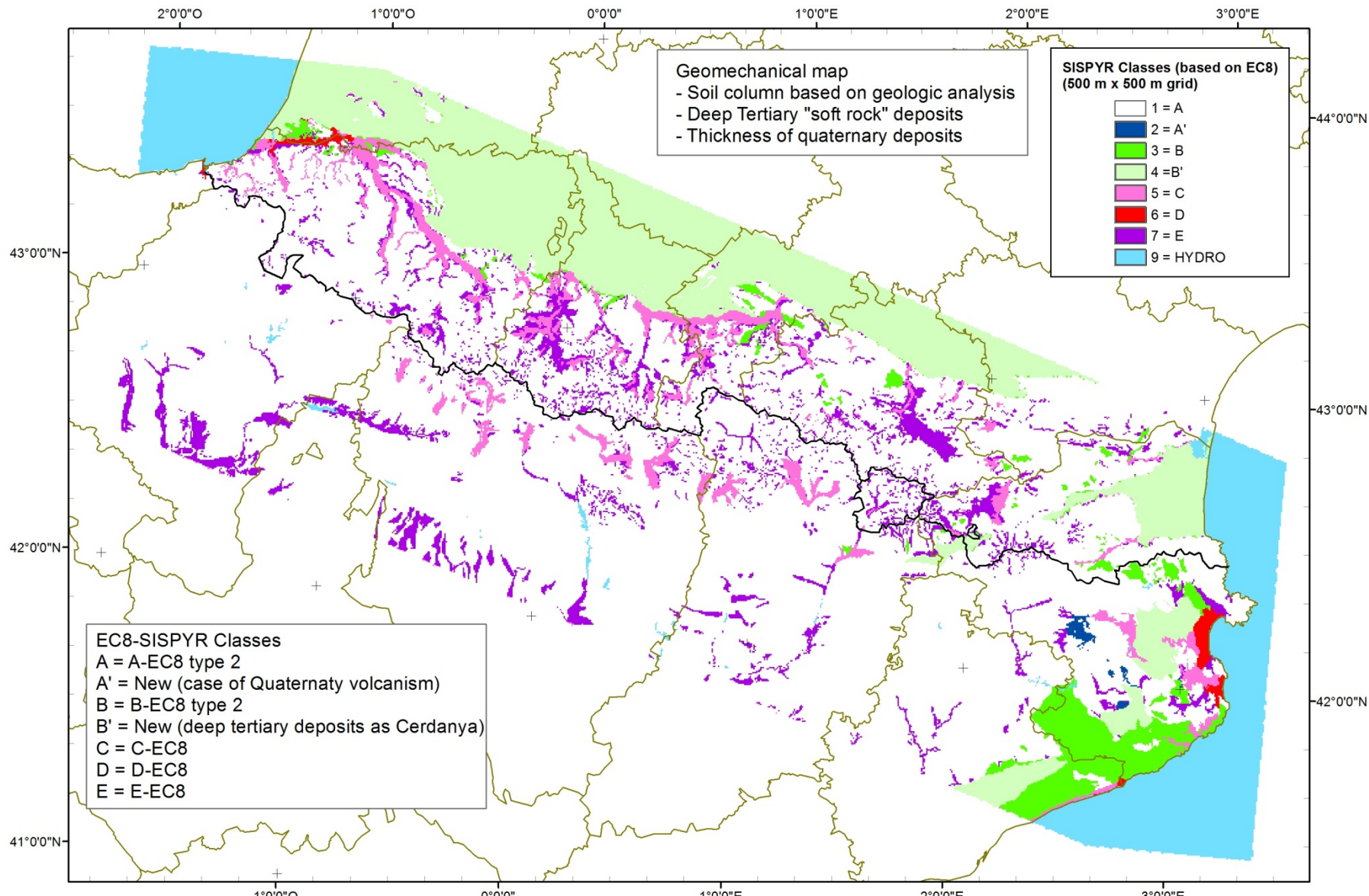
**NEW EC8-SISPYR
 ADAPTED CLASS**

B' = Deep tertiary basins
 as Cerdanya

F = Deep holocene
 deposits as Barcelona
 delta (out of area)



SEISMIC MACROZONATION OF PYRENEES



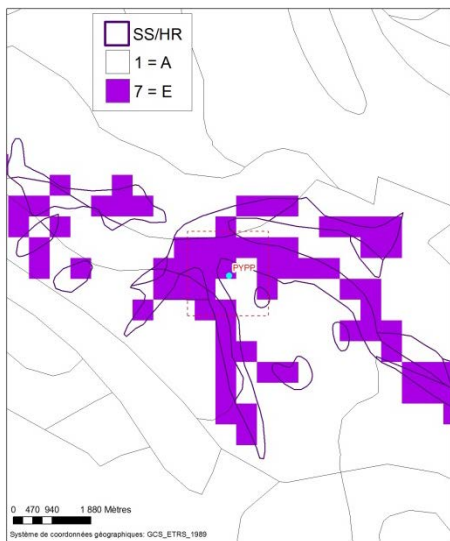
✓ BACK ANALYSIS

- Available data are described as:
 - Regional: local seismic **microzonation** in Pyrenees (Lourdes, Bagnères, Cerdanya, Val Aran-Luchon, Girona) → going on
 - Punctual EC8 class definition from:
 - stations from NRT seismic network
 - boreholes (Fr) → going on



✓ BACK ANALYSIS

■ Stations from NRT seismic network



Nb of stations	EC8-station					Sum
	EC8-map	A	A'	A or B	B	
A	22				1	23
A'		1				1
B				1	1	2
B'						0
C	2					2
E	5				1	6
Sum	29	1	1	1	3	34

74 % (25/34) with agreement (main for Aclass)

26% (9/34) with conflict

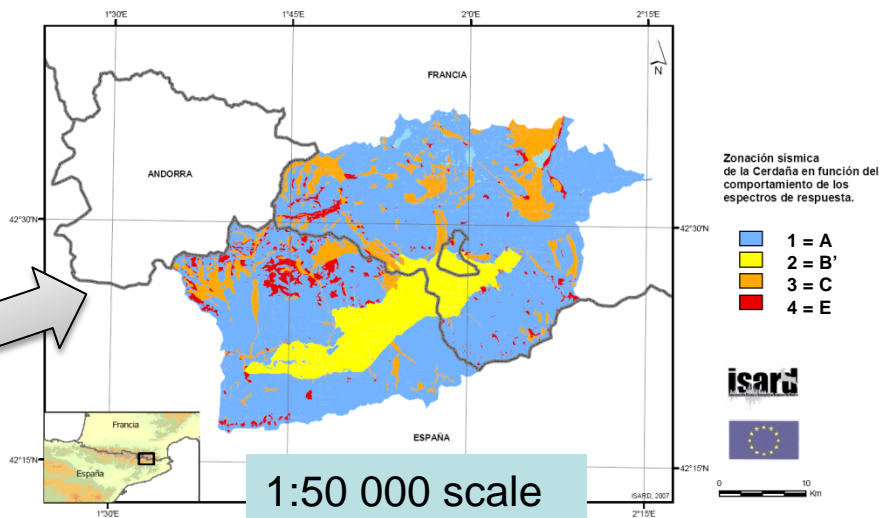
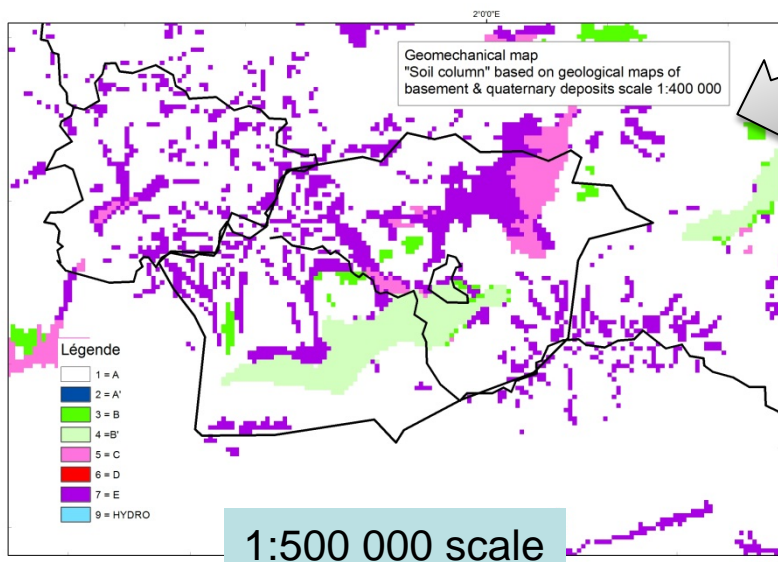
- 14% (5/34) attributed to grid interpolation
- 9% (3/34) attributed to low quality of EC8 determination
- 3% (1/34) attributed to geological/interpreted mapping (glacial deposits)



SEISMIC MACROZONATION OF PYRENEES

✓ BACK ANALYSIS

■ LOCAL STUDIES



global good significance... but:

- over estimated areas of C/E classes
- over estimated E class vs C
- small quaternary deposits not represented: 1:400 000 geological maps contours are of course first responsible of these differences



THANKS FOR YOUR ATTENTION

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