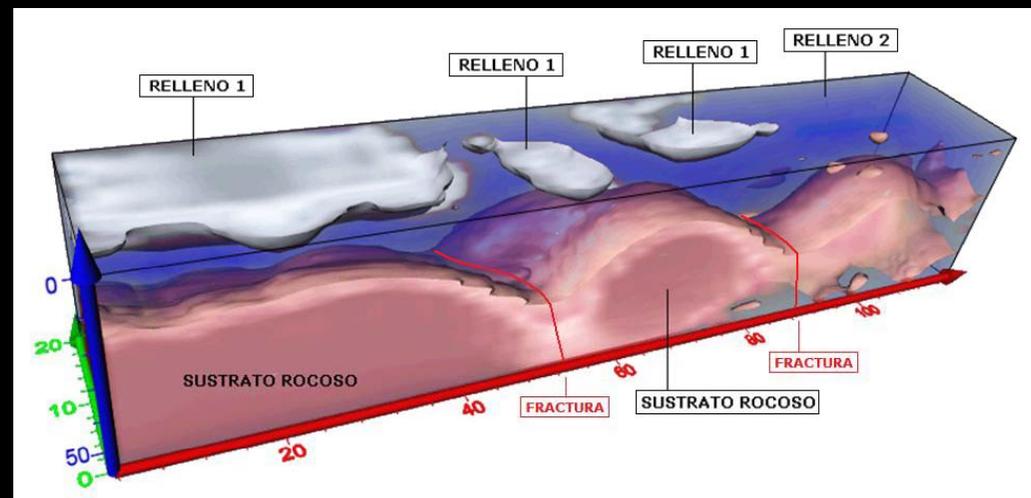


# "CONTROL DE CONTAMINACIÓN Y DE FILTRACIONES BAJO BALSAS DE RESIDUOS"

*Bilbao – 10 al 12 de Noviembre de 2010*



**Enrique Aracil**  
*Dr. En CC. Geológicas*





# Temario

## 1.- Introducción

Datos de partida

Resultados que pueden obtenerse

## 2.- Observación de la contaminación

Caracterización de Vertederos

Caracterización del sustrato. Fracturas

Caracterización del sustrato. Zonas Karstificadas

Balsas Mineras

Balsas de Residuos

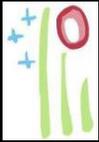
## 3.- Resumen y Conclusiones



S

AG



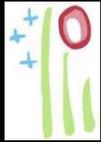


## Los datos de partida

Datos procedentes de campañas de prospección geofísica del subsuelo:

- Campañas de **Tomografía Eléctrica y Sísmica**
- Datos de **sondeos**
- Datos de **geología**





# Métodos geofísicos

## Métodos eléctricos

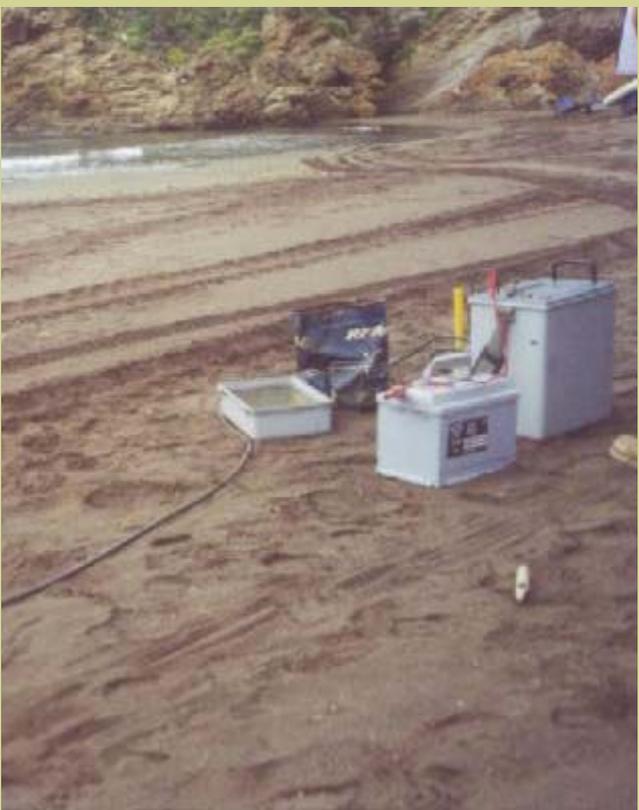
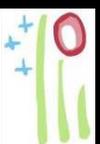
Se basan en el estudio de los materiales del subsuelo en función de su comportamiento eléctrico, concretamente en función de su diferente resistividad

---

*Resistividad*

*propiedad de las rocas para oponerse al paso de la corriente eléctrica a su través*



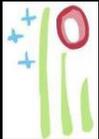


# Tomografía eléctrica

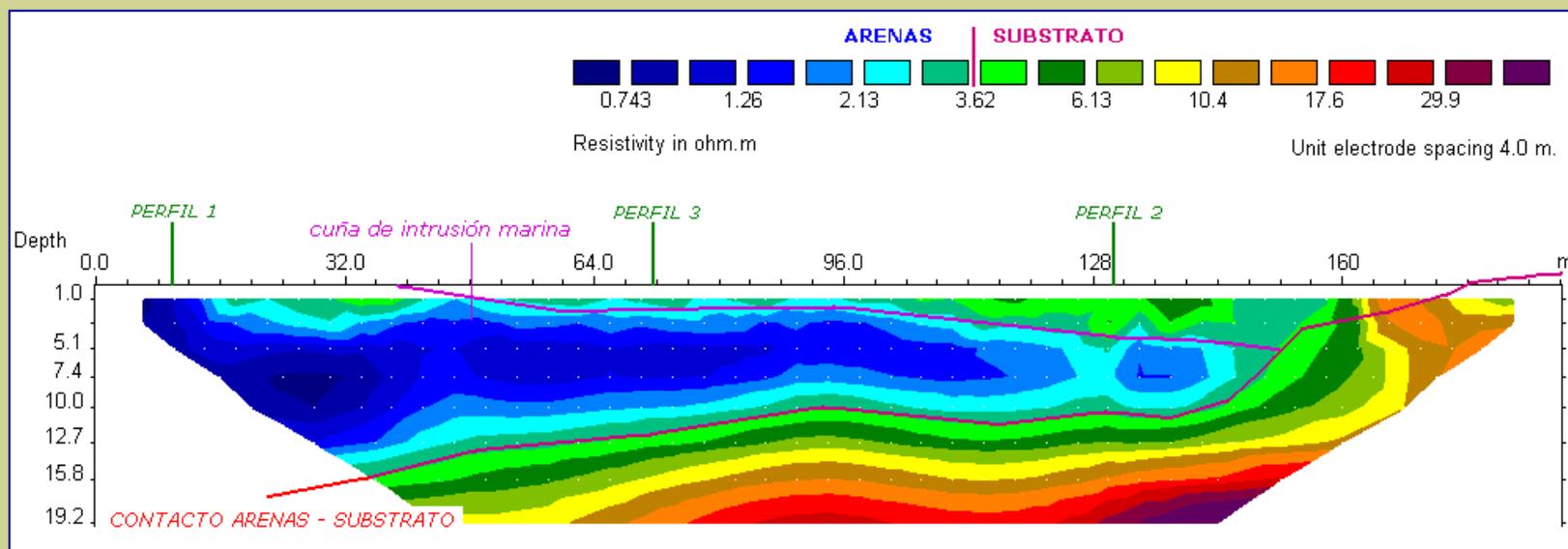


AGS





## Representación gráfica - Perfil

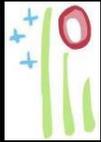


Playa de El Gorguel (Murcia)



Resultados de tomografía eléctrica





# Métodos geofísicos

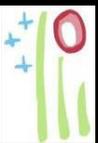
## Métodos sísmicos

Se basan en el estudio de los materiales del subsuelo en función de su velocidad de transmisión de las ondas sísmicas

---

*Las ondas sísmicas son las ondas sonoras que se transmiten por el subsuelo como consecuencia de una perturbación*



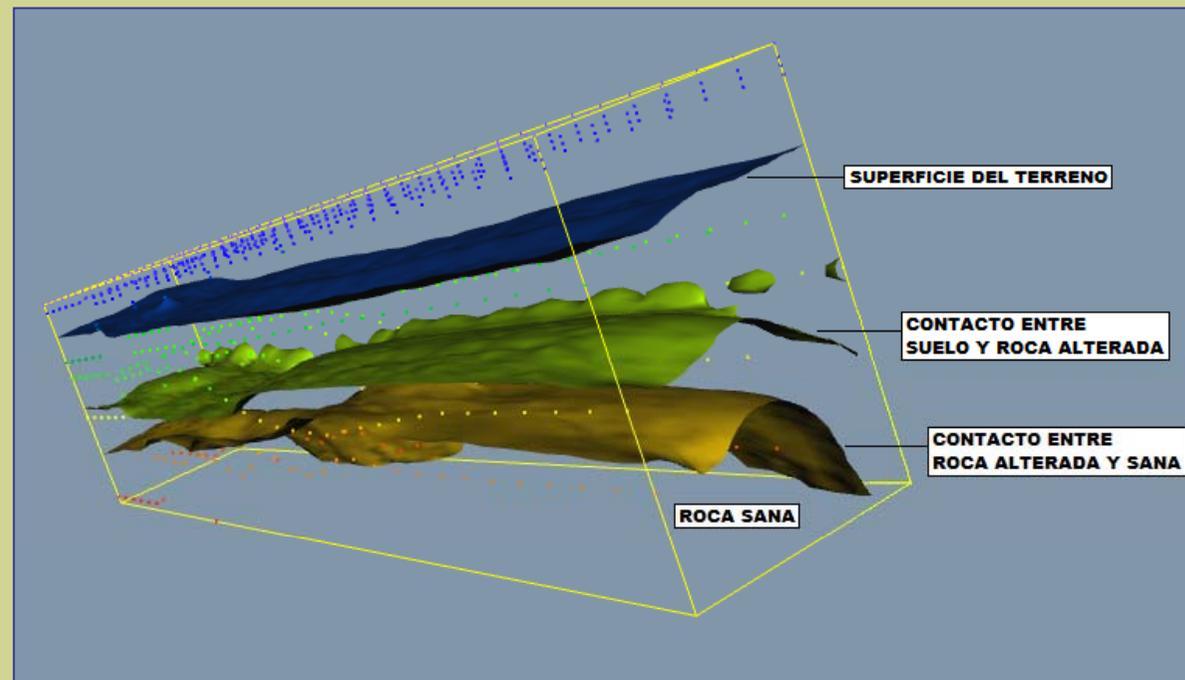
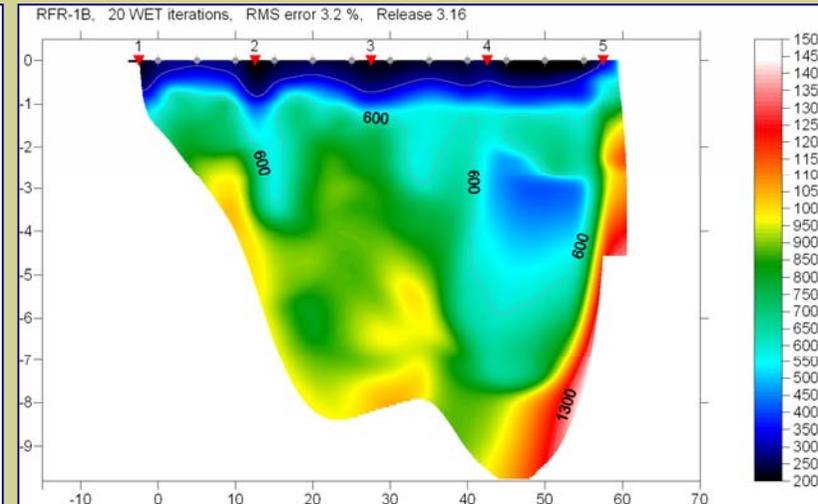
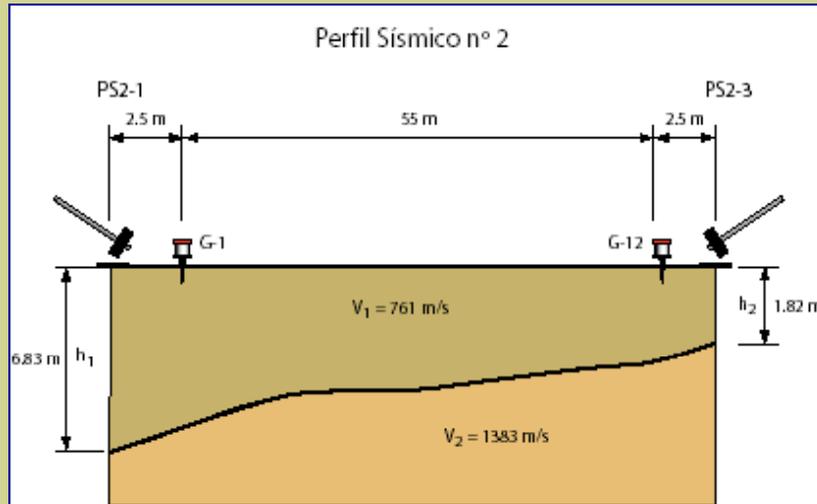


# Sísmica de refracción



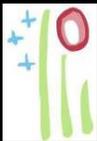
# Sísmica de Refracción

Resultados de sísmica



AGS





# Fichero X+Y+?

# Fichero X+Y+Z+?

	A1	X-location				
	A	B	C	D	E	F
1	X-location	Elevation	Resistivity			
2	4.961	1007.122	6804.7002			
3	6.96	1007.067	6501.1001			
4	8.959	1007.107	5409.6001			
5	10.958	1007.098	5763.7998			
6	12.958	1006.947	5070.1001			
7	14.958	1006.795	2946.6001			
8	16.957	1006.762	3183.7			
9	18.956	1006.753	4141.2002			
10	20.955	1006.79	3108			
11	22.954	1006.845	2777.7			
12			1001			
13			750.3			
14			1527.1			

#	EArray	Spa.1	Spa.2	Spa.3	Spa.4	Rho	Dev.	Sp
1	Dipole Dipole	0.00	2.50	5.00	7.50	113.54	0.0	-15.0
2	Dipole Dipole	0.00	2.50	7.50	10.00	77.07	0.0	7.6
3	Dipole Dipole	0.00	2.50	10.00	12.50	64.71	0.0	6.0
4	Dipole Dipole	0.00	2.50	12.50	15.00	69.61	0.0	-15.3
5	Dipole Dipole							
6	Dipole Dipole							
7	Dipole Dipole							
8	Dipole Dipole							
9	Dipole Dipole							
10	Dipole Dipole							
11	Dipole Dipole							
12	Dipole Dipole							
13	Dipole Dipole							
14	Dipole Dipole							
15	Dipole Dipole							
16	Dipole Dipole							
17	Dipole Dipole							
18	Dipole Dipole							
19	Dipole Dipole							
20	Dipole Dipole							
21	Dipole Dipole							
22	Dipole Dipole							
23	Dipole Dipole							
24	Dipole Dipole							
25	Dipole Dipole							
26	Dipole Dipole							
27	Dipole Dipole							
28	Dipole Dipole							
29	Dipole Dipole							
30	Dipole Dipole							
31	Dipole Dipole							
32	Dipole Dipole							
33	Dipole Dipole							
34	Dipole Dipole							
35	Dipole Dipole							
36	Dipole Dipole	0.00	12.50	70.00	82.50	1.54	0.0	14.8
37	Dipole Dipole	0.00	12.50	82.50	72.50	0.00	0.0	-20.3
38	Dipole Dipole	0.00	12.50	72.50	85.00	3.48	0.0	131.3
39	Dipole Dipole	0.00	12.50	85.00	75.00	0.00	0.0	-88.9
40	Dipole Dipole	0.00	12.50	75.00	87.50	3.87	0.0	-25.8
41	Dipole Dipole	0.00	15.00	80.00	95.00	0.00	0.0	14.5
42	Dipole Dipole	0.00	15.00	95.00	82.50	13.93	0.0	-3.6

X spacing	Y spacing	Z spacing
0.00	0.00	178.00
2.50	0.00	178.23
5.00	0.00	178.45
7.50	0.00	178.68
10.00	0.00	178.91
12.50	0.00	179.14
15.00	0.00	179.36
17.50	0.00	179.59
20.00	0.00	179.82
22.50	0.00	180.05
25.00	0.00	180.27
27.50	0.00	180.50
30.00	0.00	180.73
32.50	0.00	180.95
35.00	0.00	181.18
37.50	0.00	181.41



Ejemplo de generación de un bloque 3D

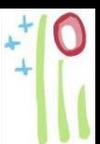
	A	B	C	D	E	F
1	Y	X	Z	Resistivity		
2		0	3	1008	2325	
3		0	5	1008	2398	
4		0	7	1008	2310	
5		0	9	1007	2446	
6		0	11	1007	2582	

# Introducción

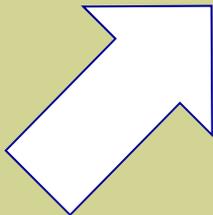
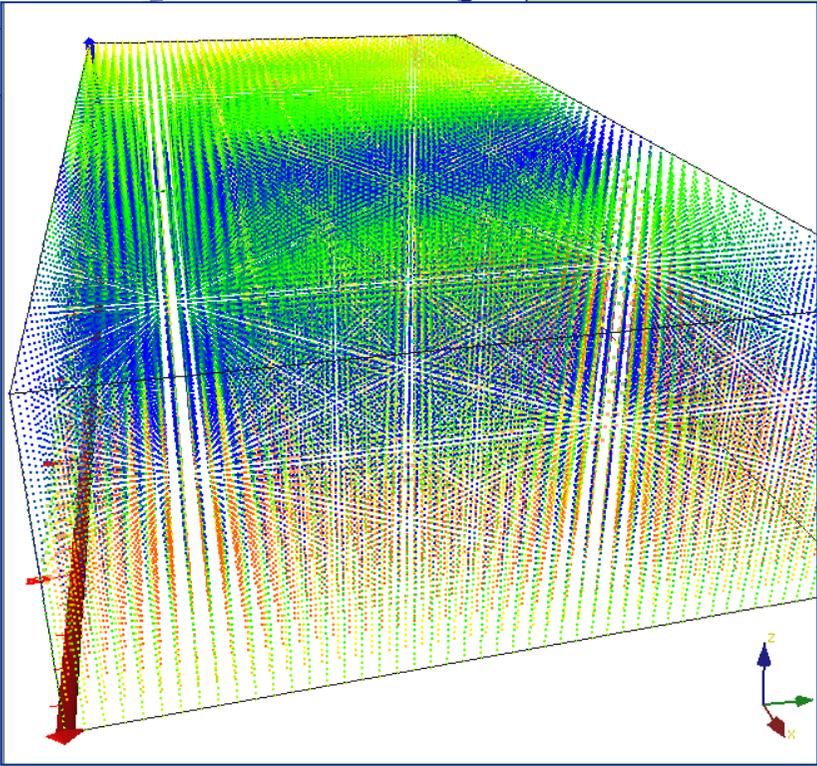
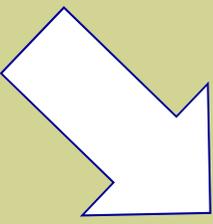
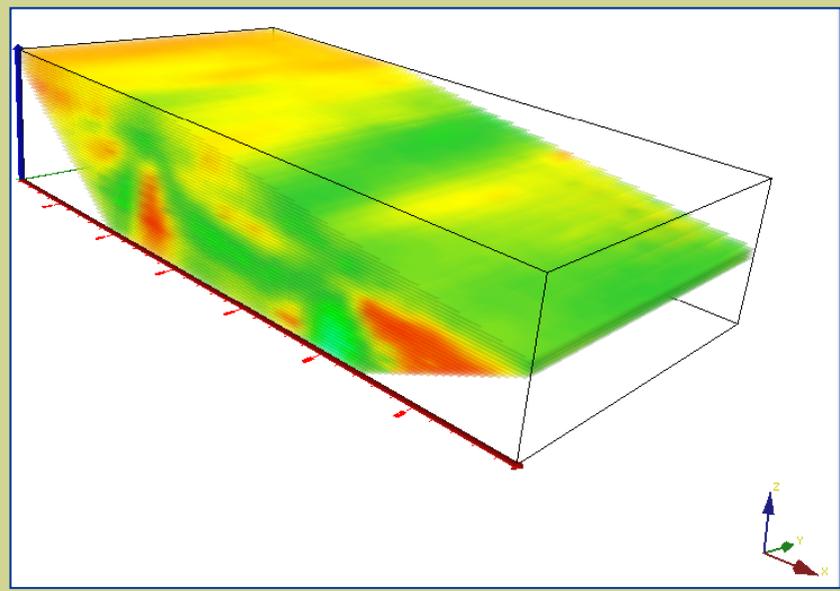
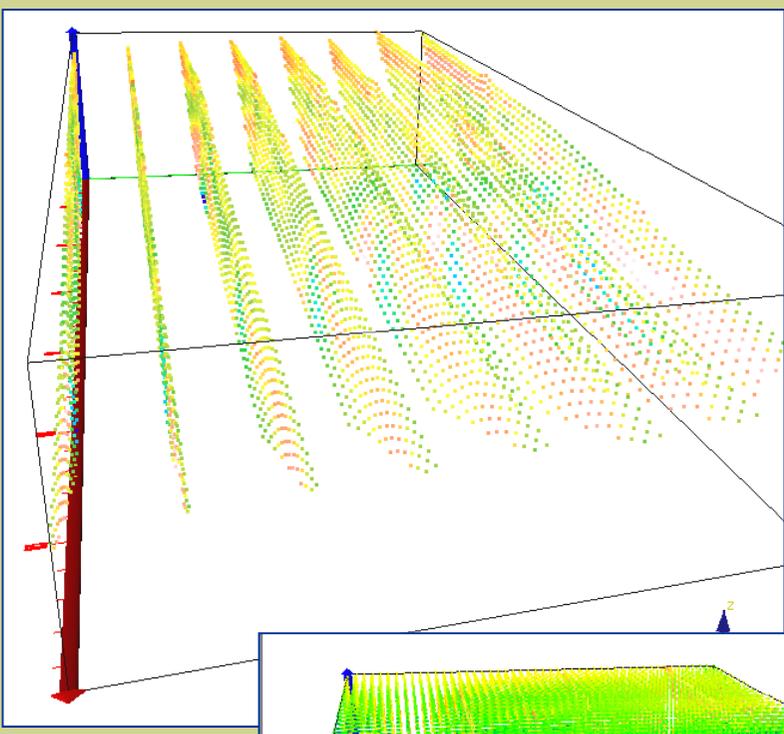


# AGS





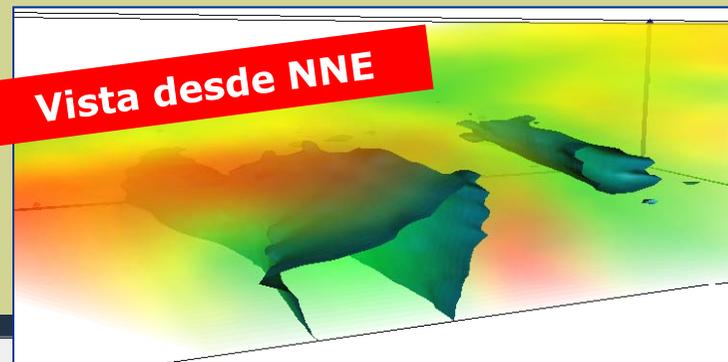
AGS



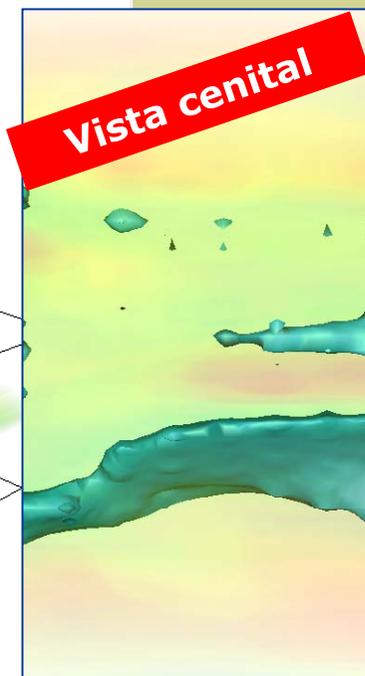
# Introducción



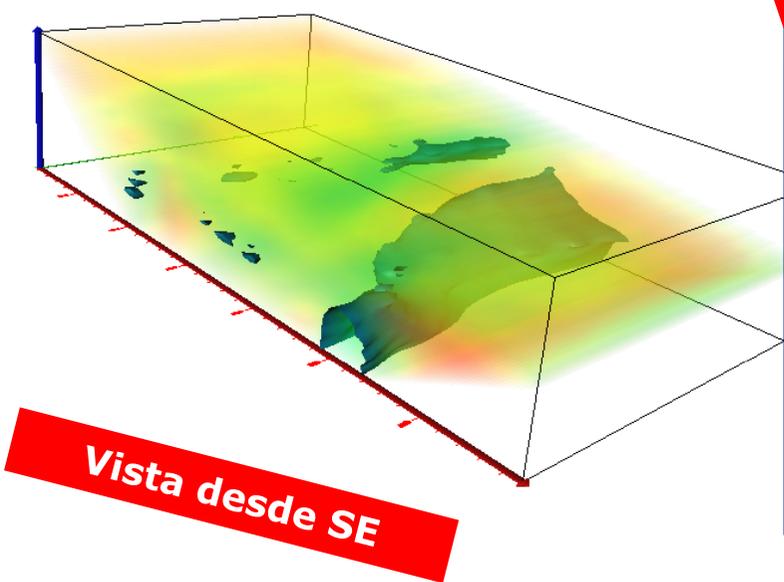
Vista desde NNE



Vista cenital



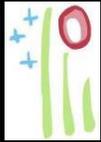
Vista desde SE



The screenshot displays the Voxler software interface. The main window shows a 3D topographic map with a color gradient from red to blue. The interface includes a menu bar (File, Edit, View, Create, Window, Help), a toolbar, and several panels:

- Module Library:** A list of modules including Teddy (Ortho), Torus (Iso), Vortex (Vec), Load Data..., Computations, ChangeType, DuplicateFi, ExclusionFi, Filter, Gradient, Gridder, Math, Merge, Resample, Slice, Subset, Transform, Data Source, FuncionLa, TestLattice, General Modul, Info, Light, Graphics Outp, Annotation, Axes, BoundingB, ClipPlane, Contours, HeightField, Isosurface, ObliqueIm, OrthoImag, ScatterPlot, StreamLine, Text, VectorPlot, and VolRender.
- Network:** A tree view showing the rendering pipeline: Viewer Window > Galeria-3D-topo-ok-XYZ.xls - Dipolo > Gridder > Transform > BoundingBo > Axes > VolRender > Isosurface > ClipPlane > ClipPlane 2 > ClipPlane 3 > ClipPlane 4 > ClipPlane 5 > ClipPlane 6 > ClipPlane 7.
- Properties:** A panel for the selected VolRender module, showing settings for Connected To (Transform), Render Method (2D Textures), ColorMap (Custom), Opacity (0.05405405405), Composition (Alpha Blending), Interpolation (Trilinear), and Legend (Show).
- Status Bar:** Displays "For Help, press F1" and "FPS = 21.6 / 579.3".





# Temario

## 1.- Introducción

Datos de partida

Resultados que pueden obtenerse

## 2.- Observación de la contaminación

Caracterización de Vertederos

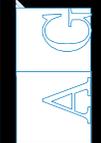
Caracterización del sustrato. Fracturas

Caracterización del sustrato. Zonas Karstificadas

Balsas Mineras

Balsas de Residuos

## 3.- Resumen y Conclusiones

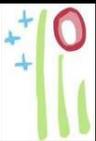


1

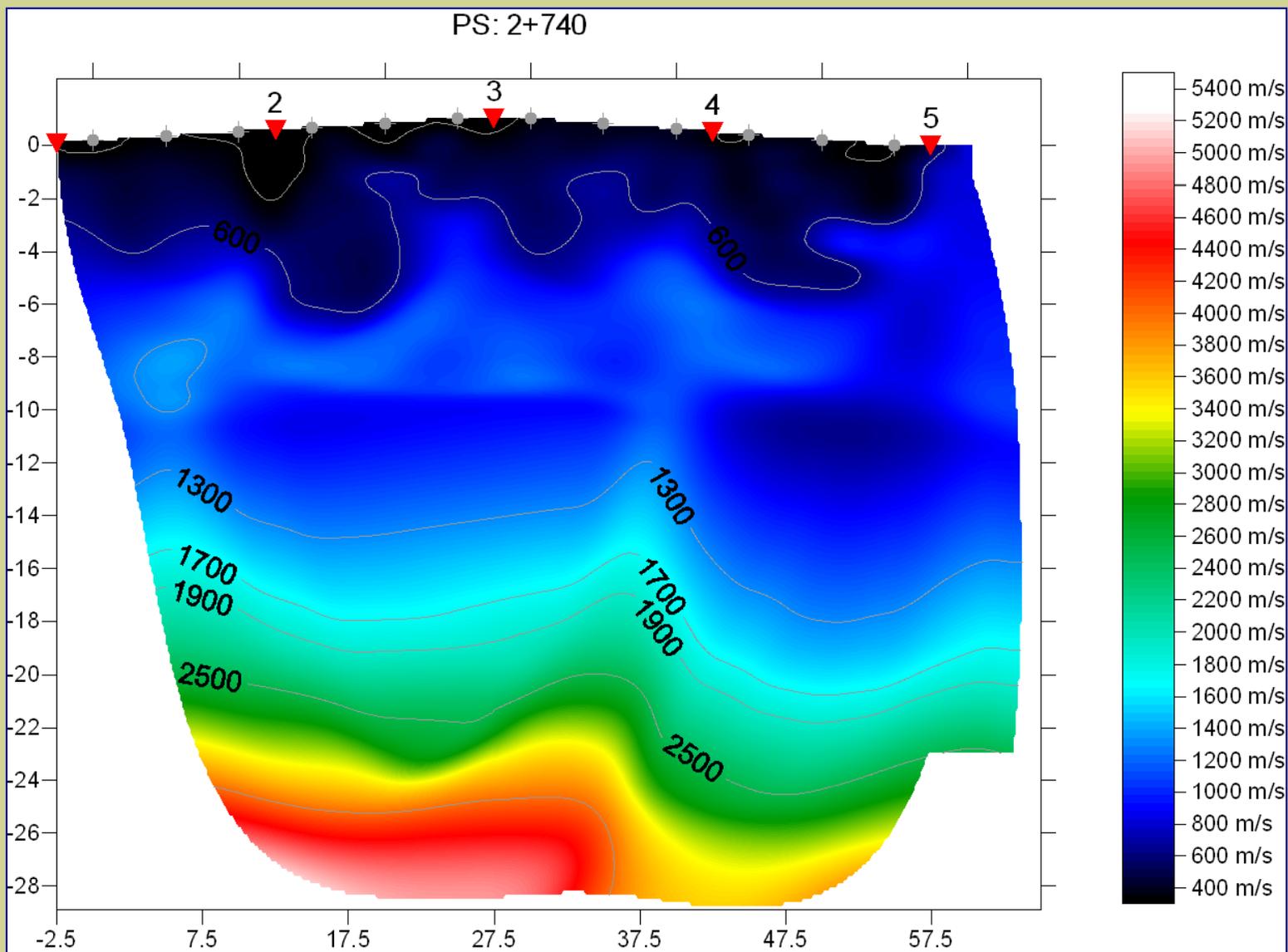
## CARACTERIZACIÓN DE VERTEDEROS

Disposición de capas y contactos en un vertedero





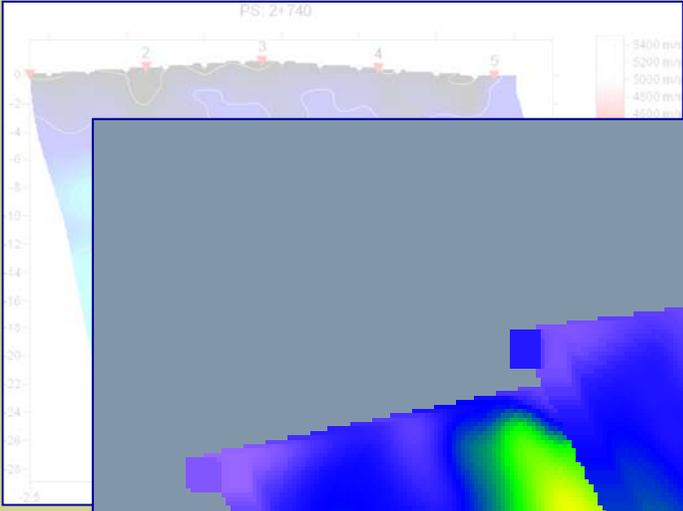
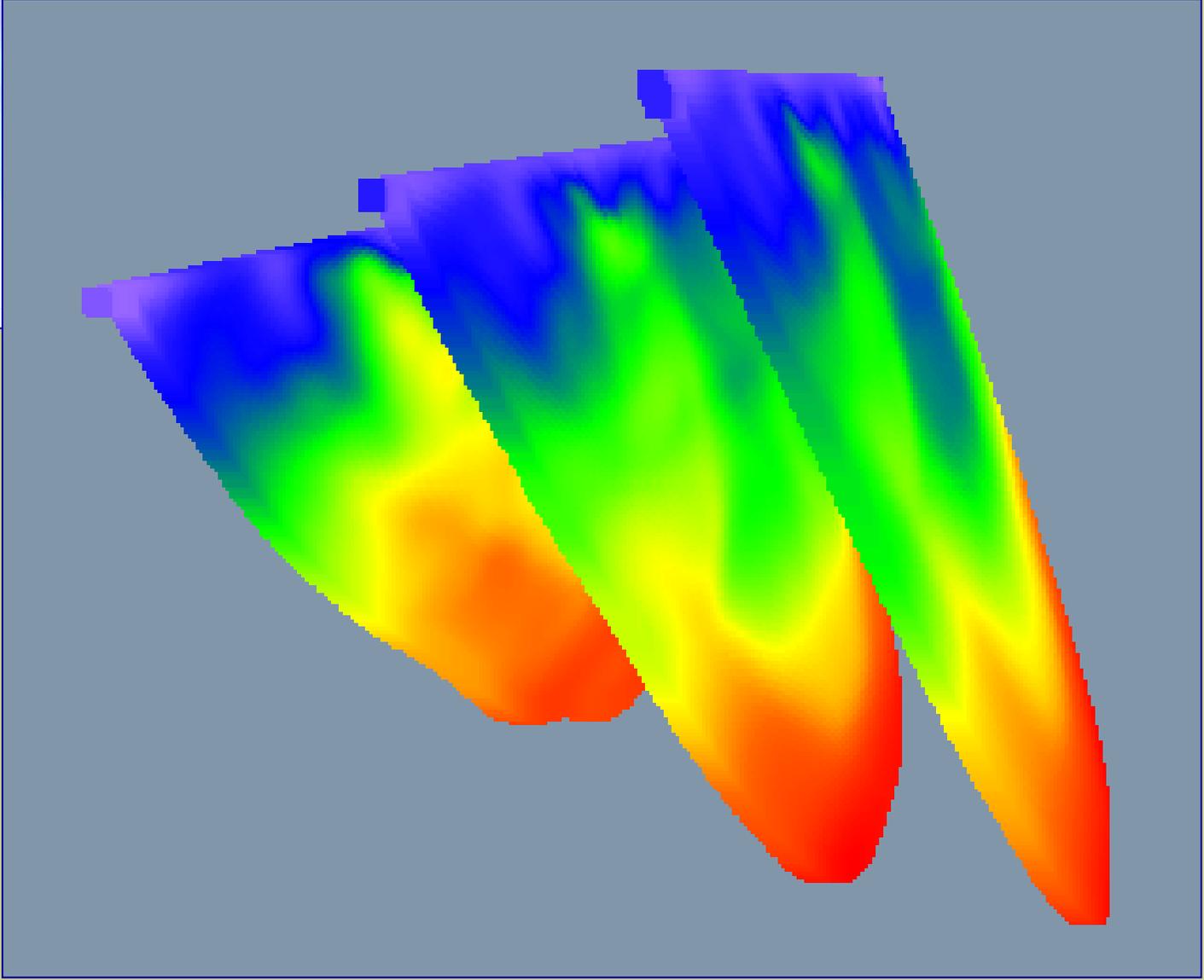
AGS



# Caracterización Vertederos - CONTACTOS

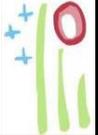


# Caracterización Vertederos - CONTACTOS

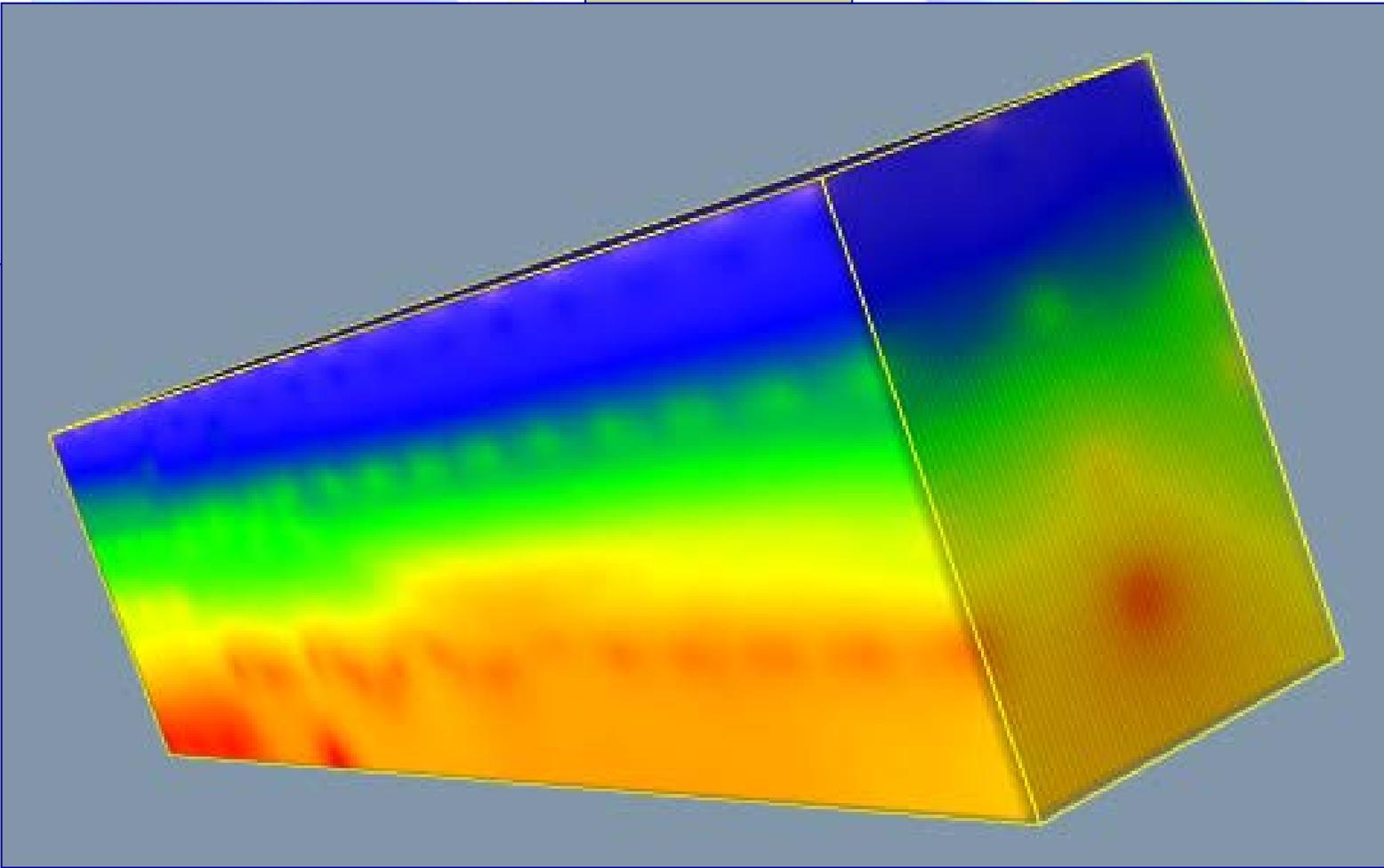
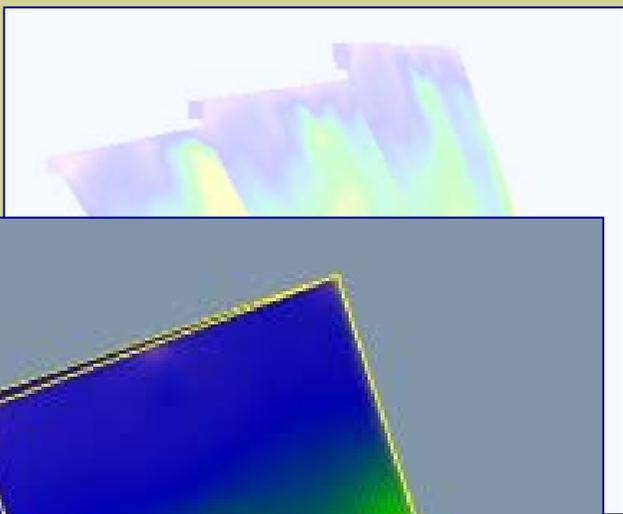
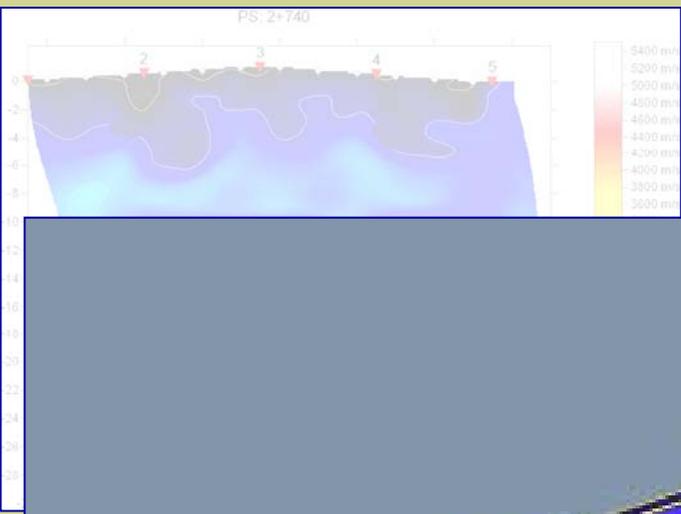


AGS





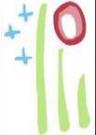
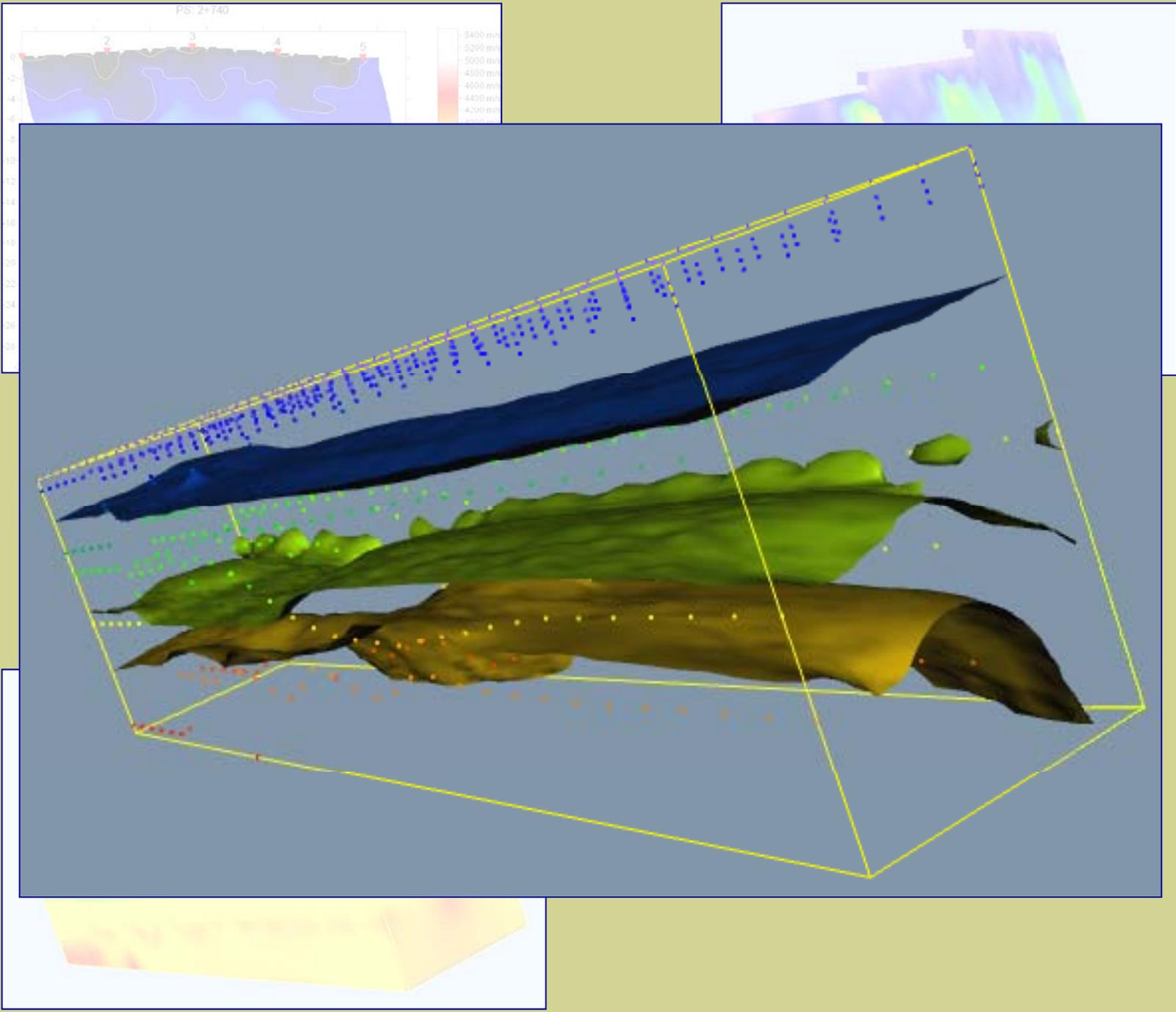
AGS



# Caracterización Vertederos - CONTACTOS

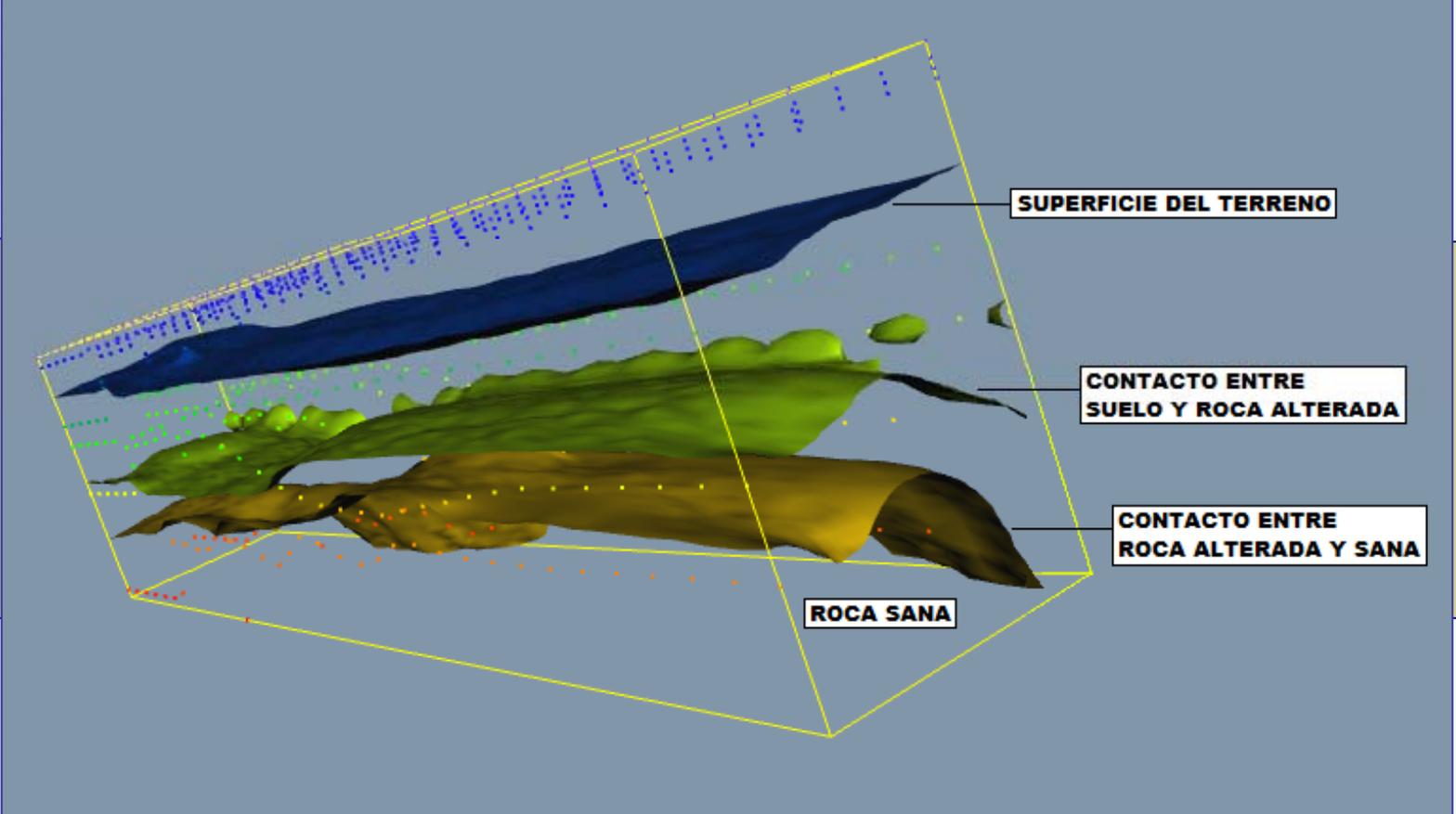
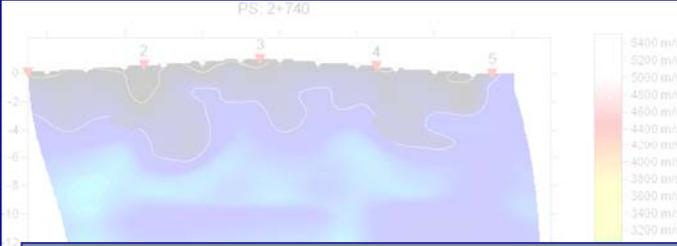
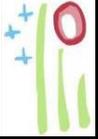


# Caracterización Vertederos - CONTACTOS



AGS

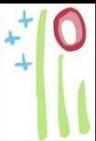




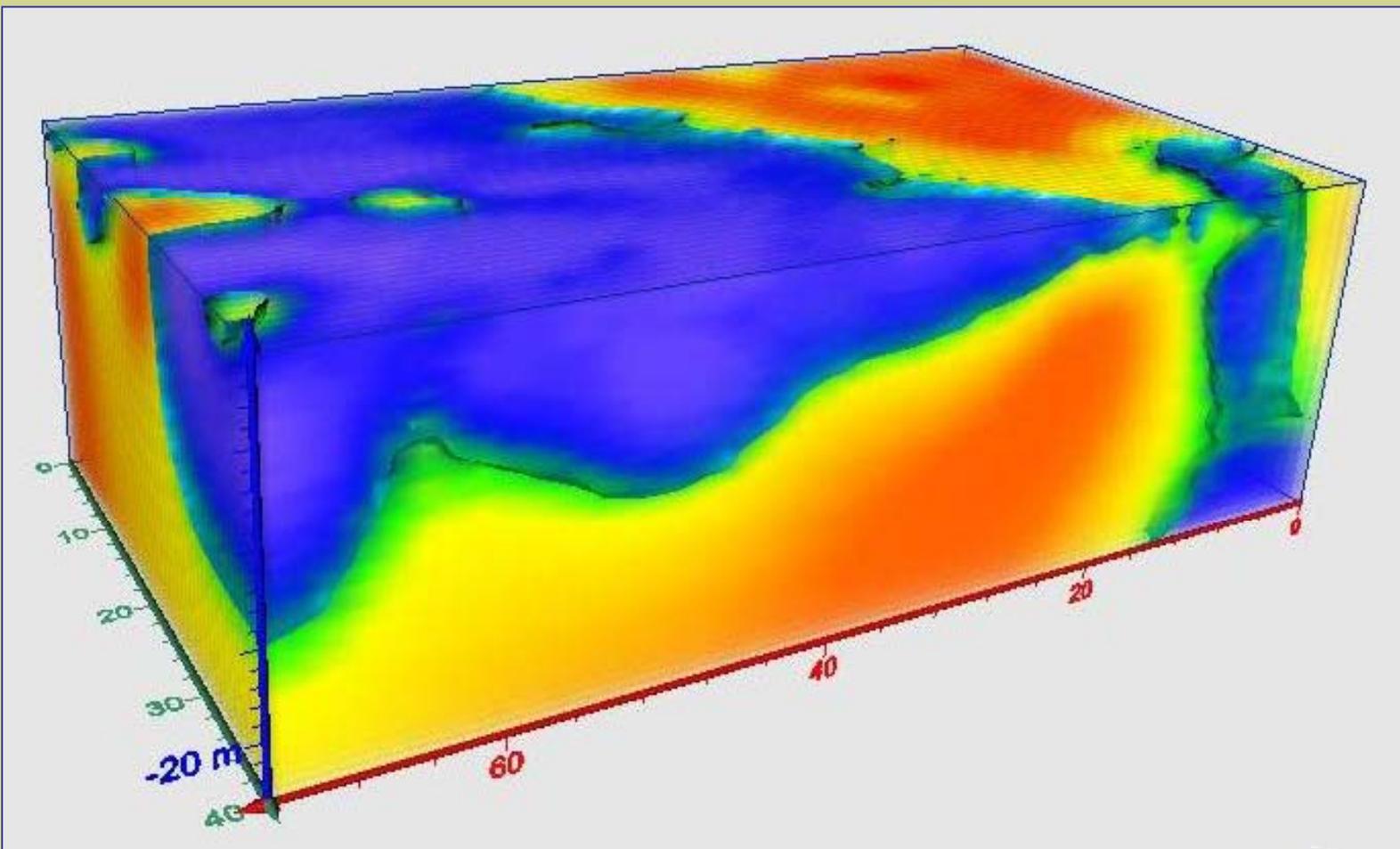
# Caracterización Vertederos - CONTACTOS



AGS

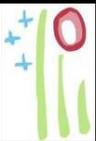


## VERTEDERO SOBRE SUSTRATO ROCOSO

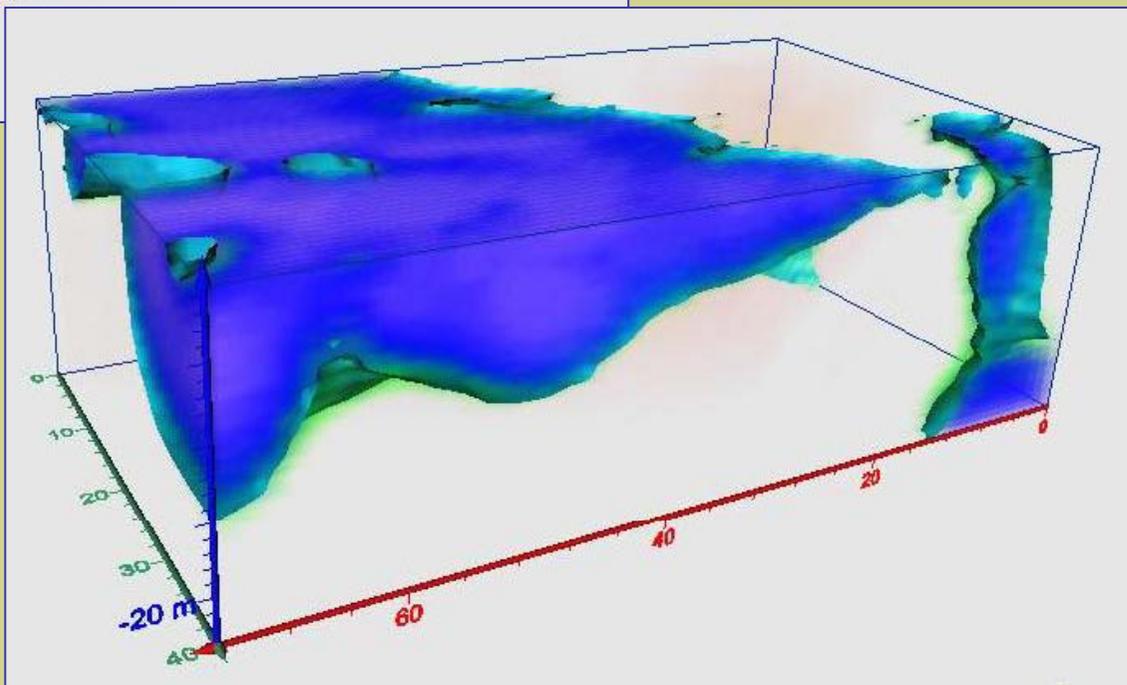
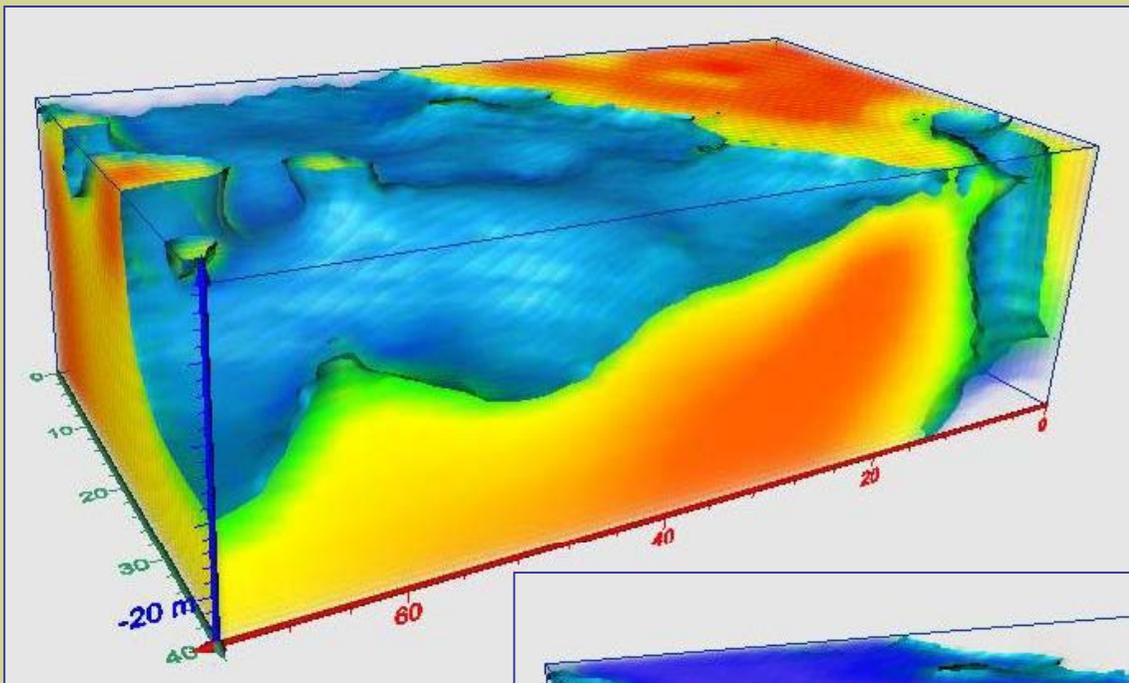


AGS





## VERTEDERO SOBRE SUSTRATO ROCOSO



Caracterización Vertederos - CONTACTOS



AGS

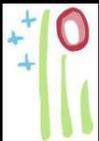


2

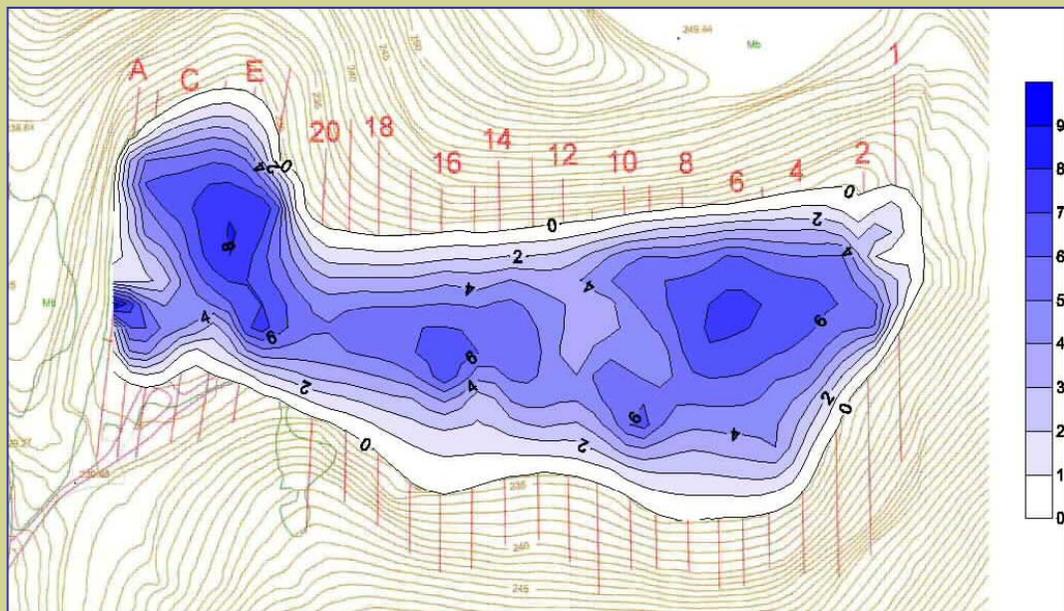
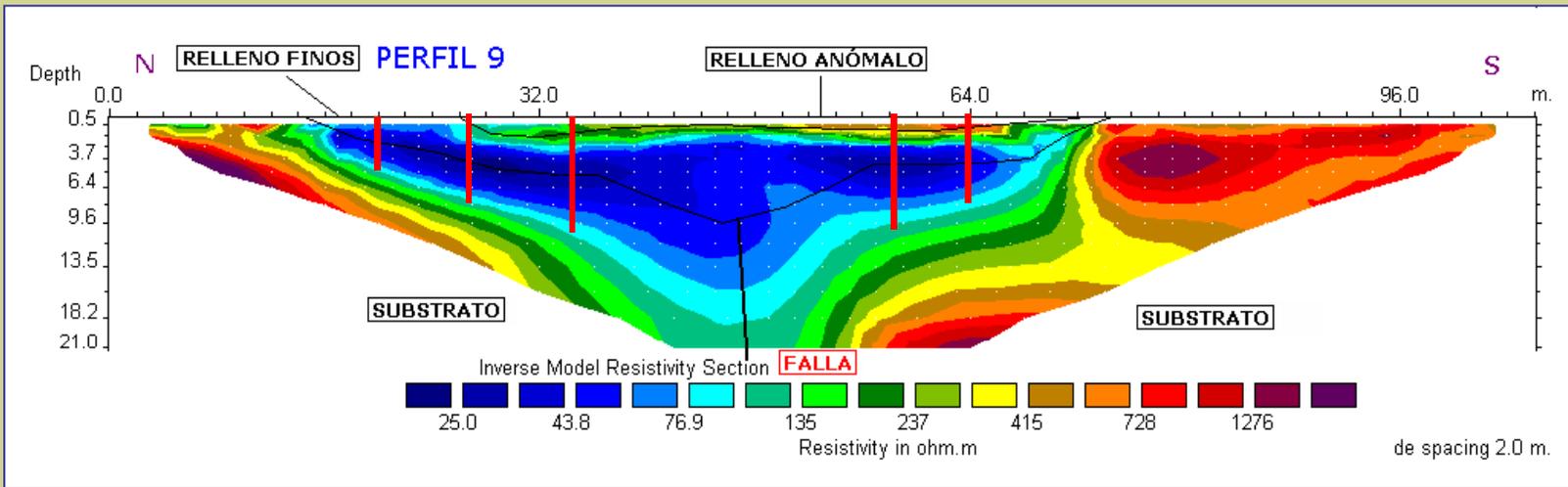
## ESTUDIO DE VERTEDEROS

Definición de espesores y volúmenes  
Diferenciación de rellenos





# ESPEORES

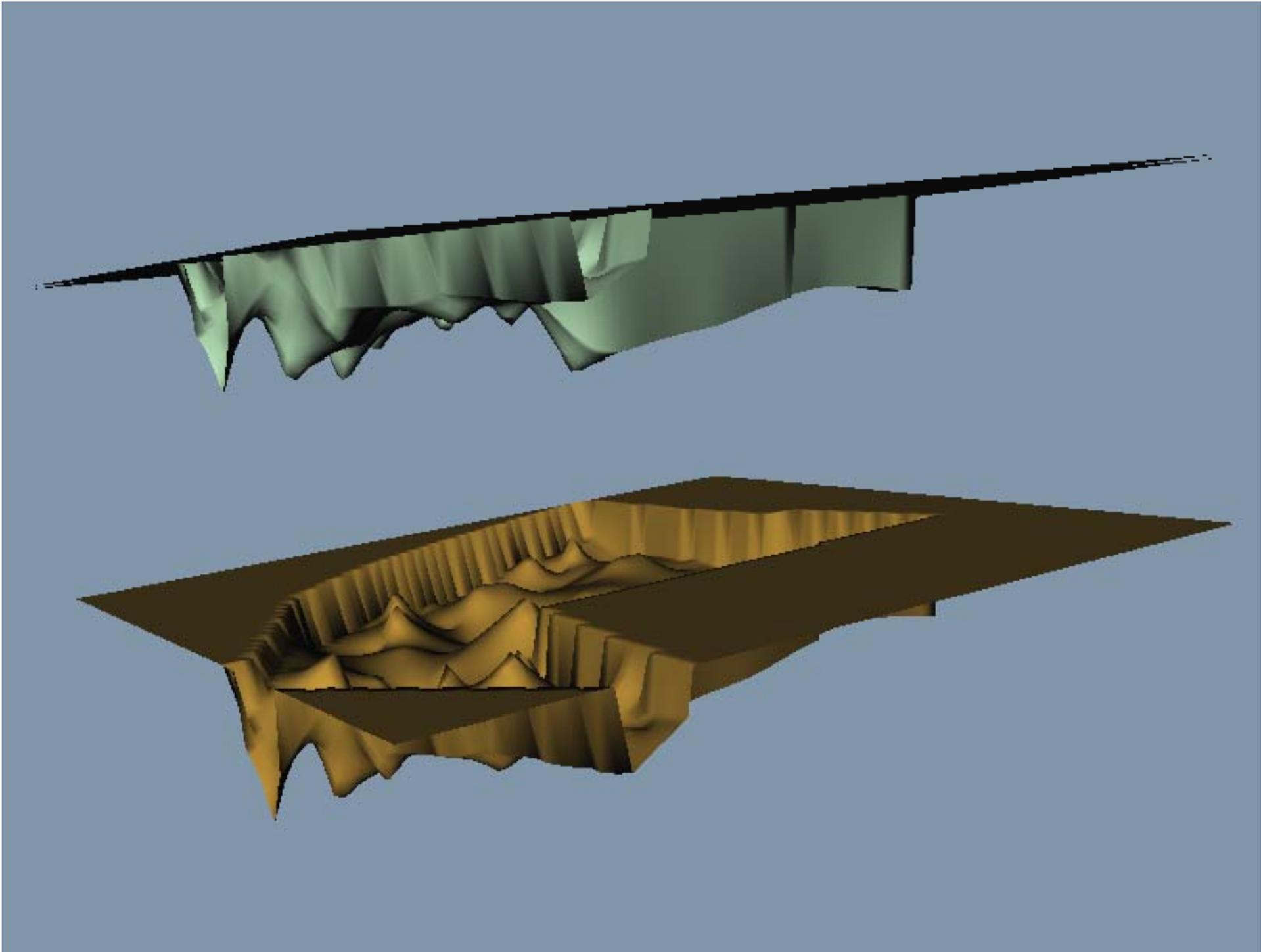


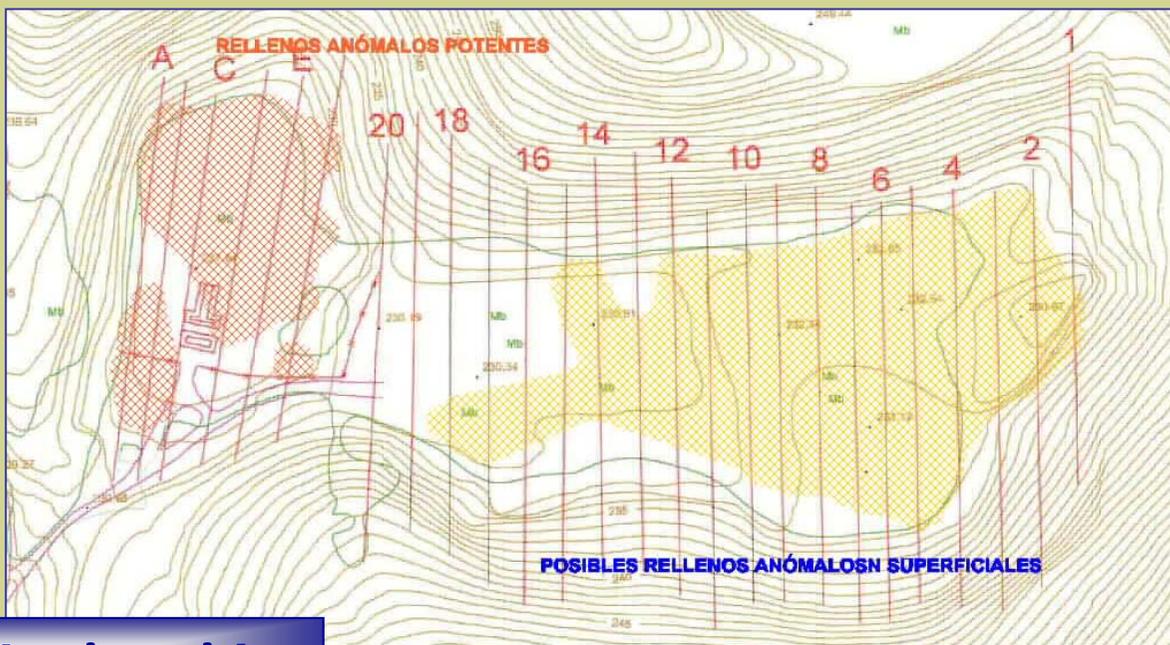
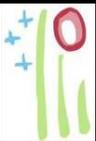
Mapa de distribución del espesor (en metros) del relleno del vertedero



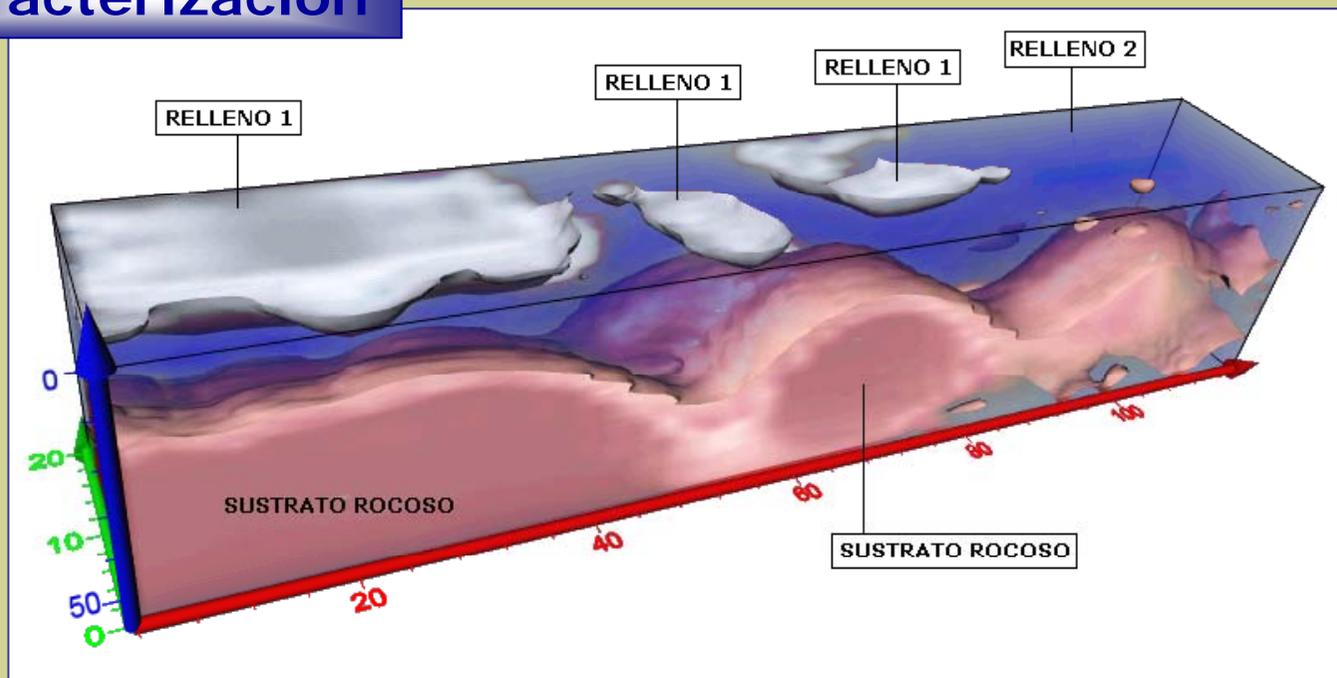
AGS







## Caracterización



AGS



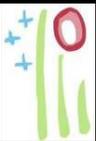


3

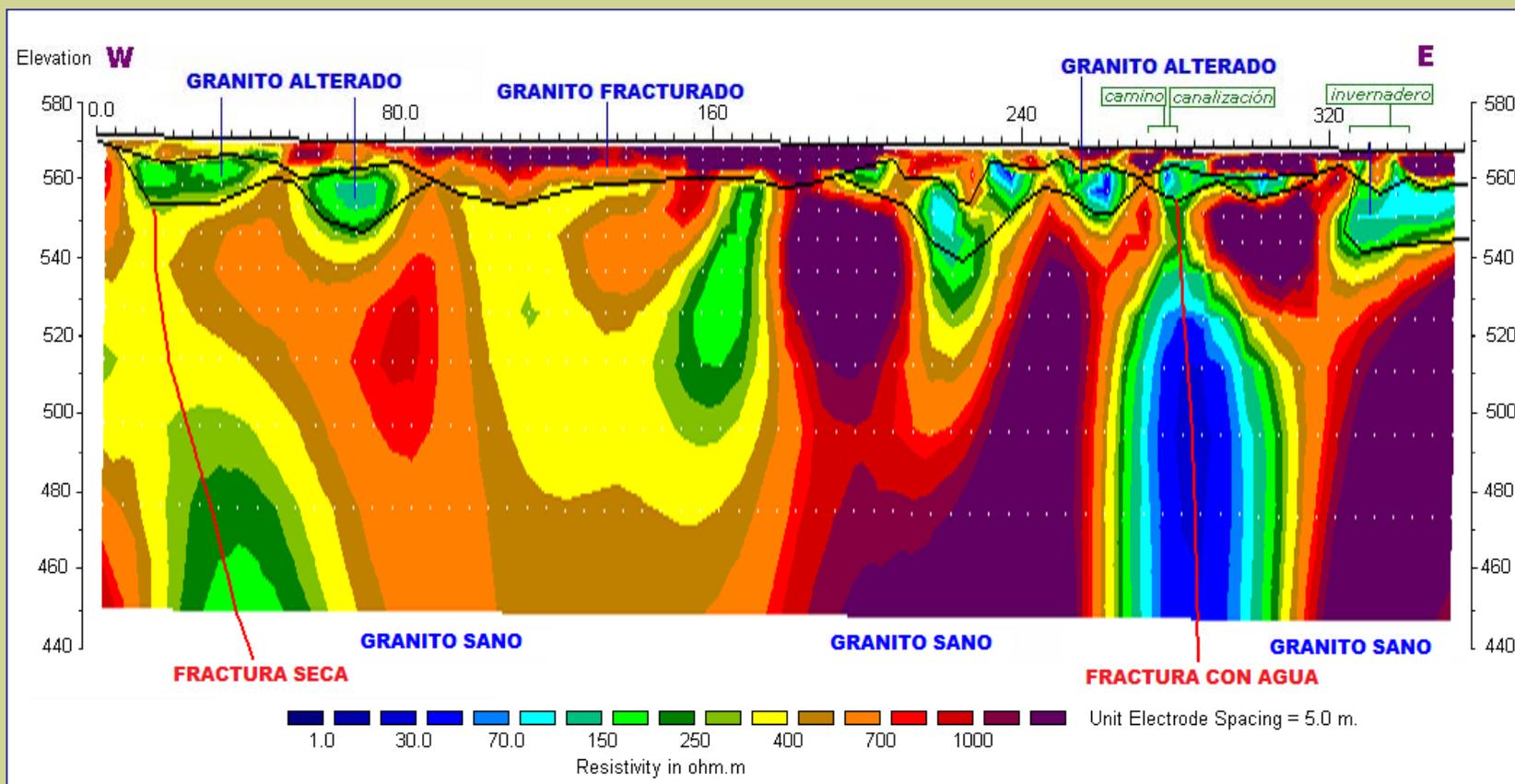
## CARACTERIZACIÓN SUSTRATO ROCOSO

Las fallas como vías de escape

Confirmación de existencia de fallas



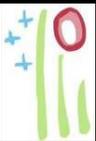
# CARACTERIZACIÓN DE FRACTURAS



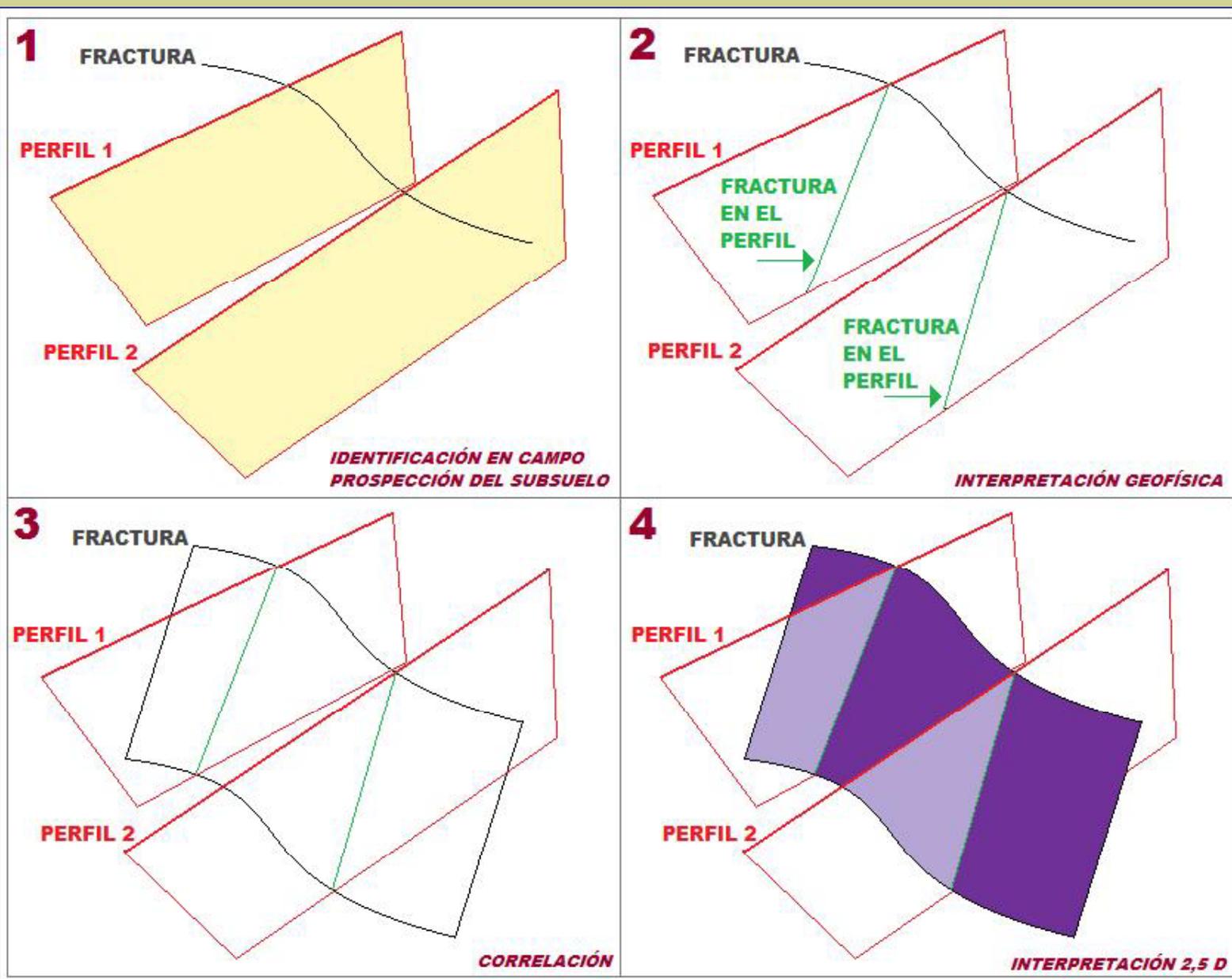
AGS

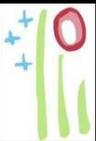
Caracterización Sustrato - FALLAS



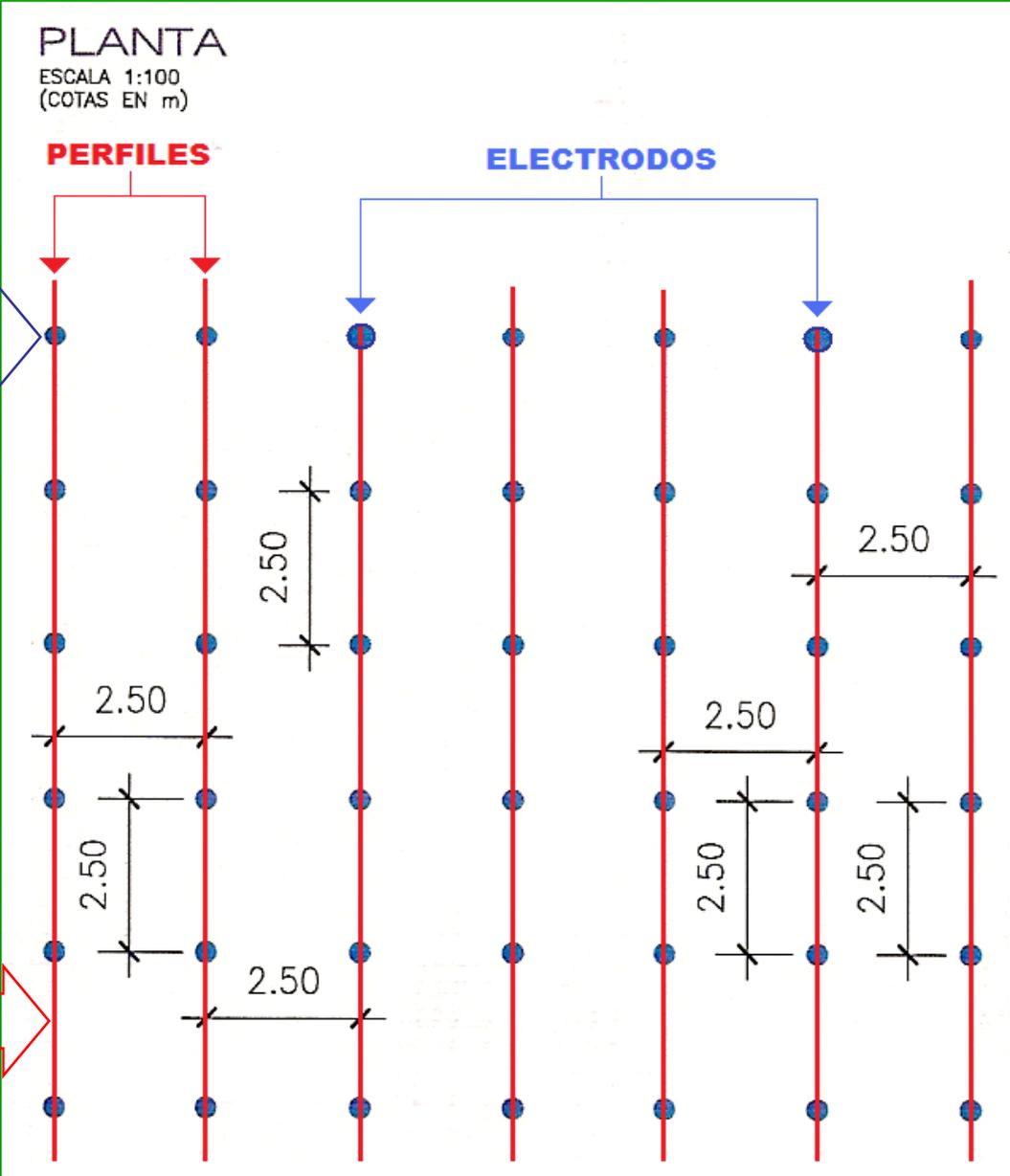


# ESTUDIO 2,5 D





# ESTUDIO 3D



2D  
3D

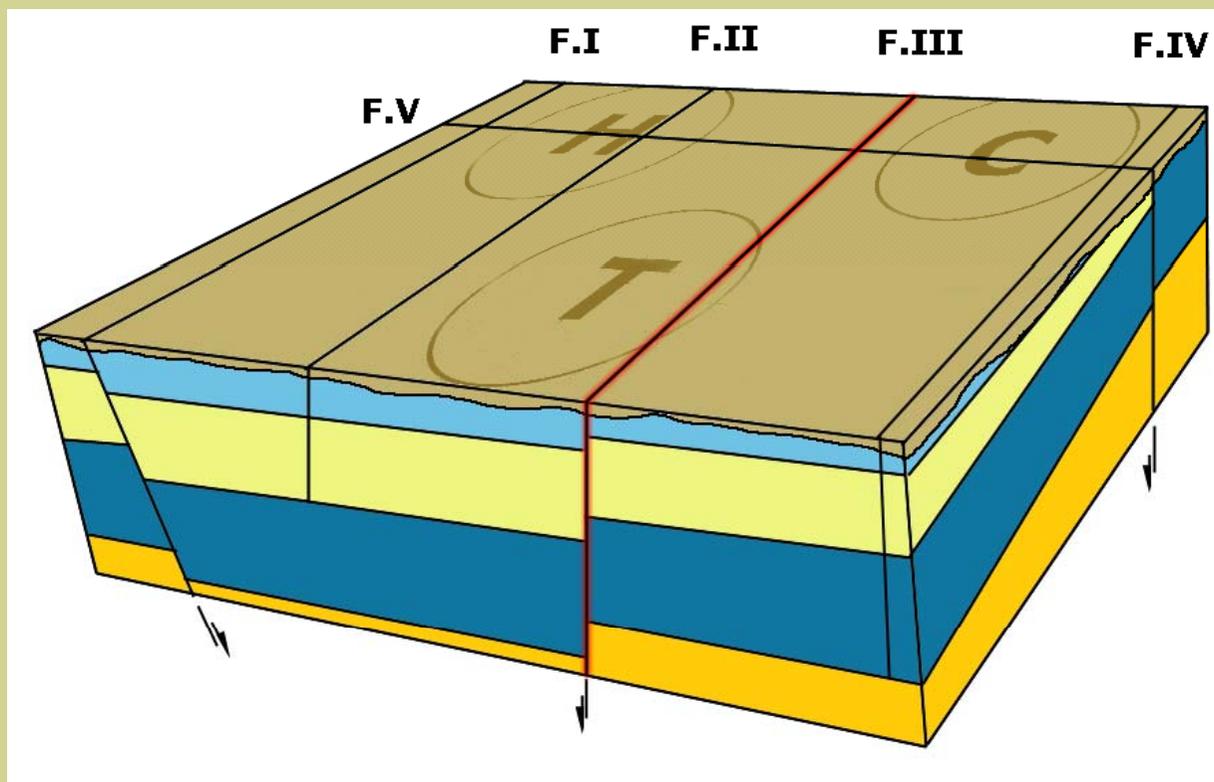
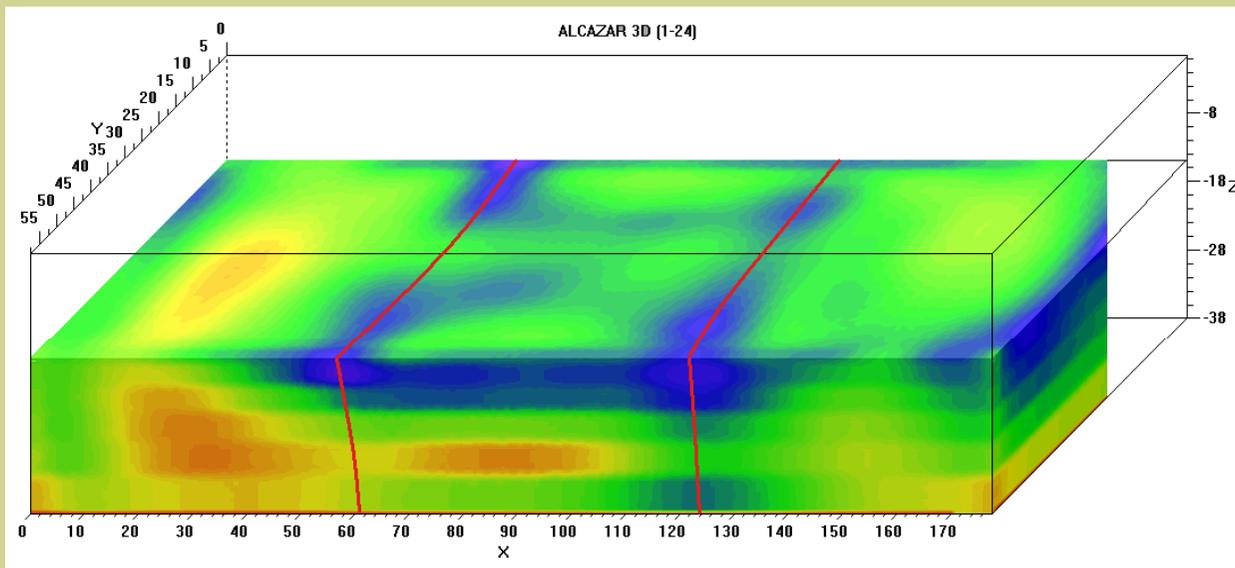
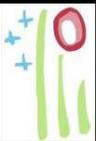
Caracterización Sustrato - FALLAS



AGS





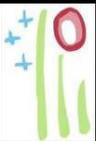


Caracterización Sustrato - FALLAS

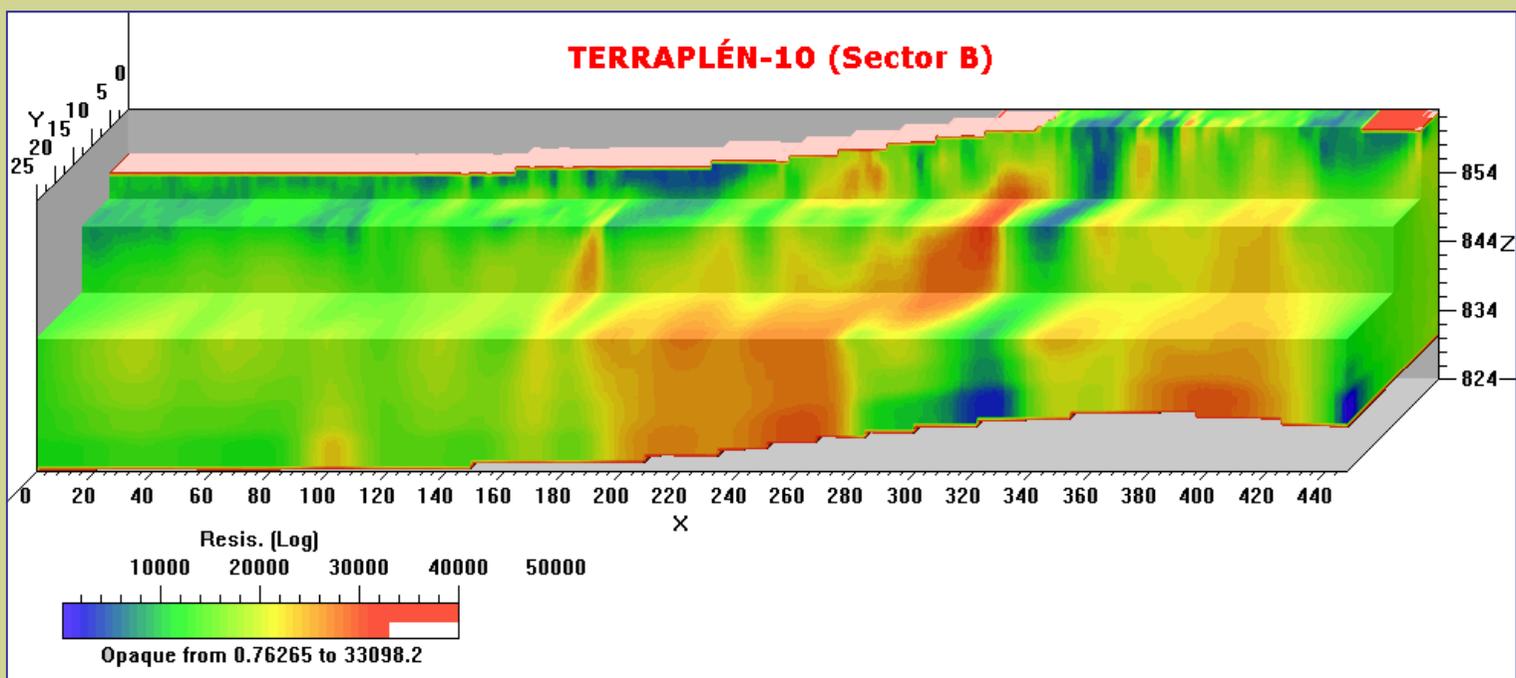
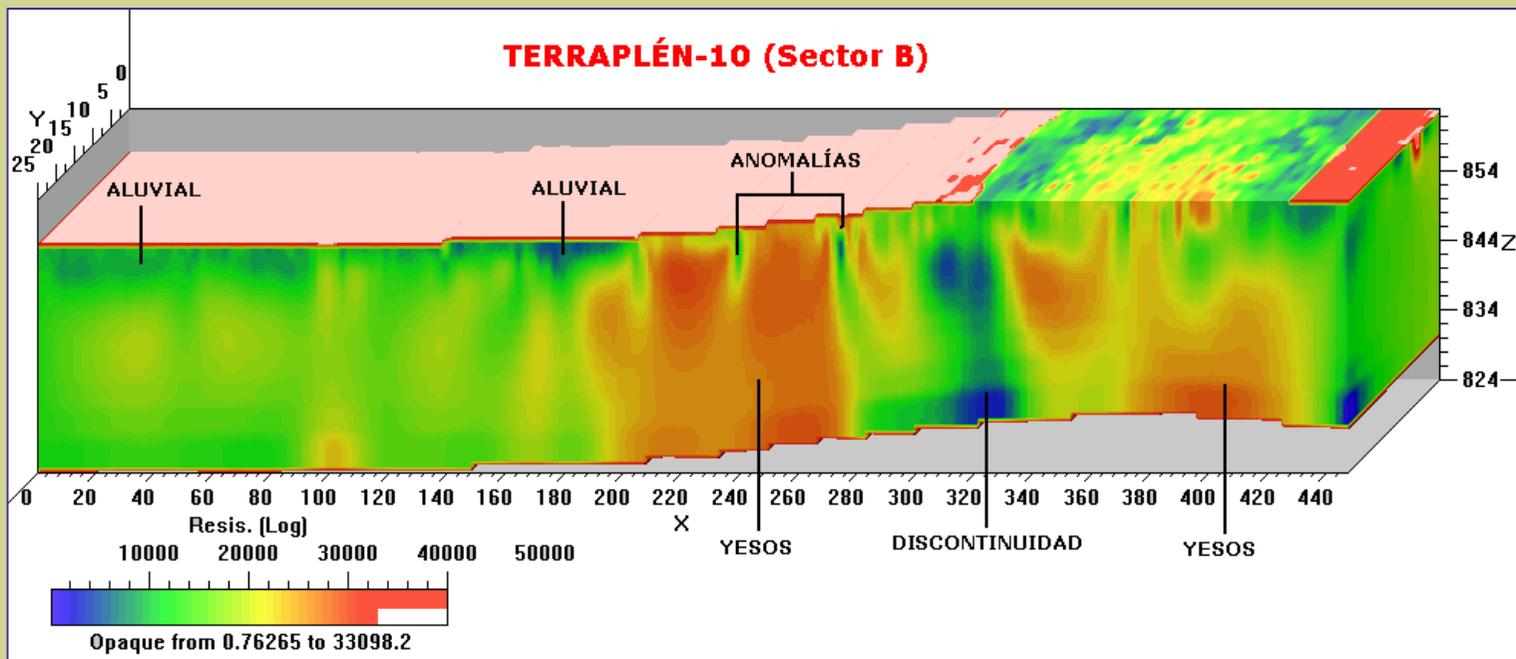


AGS



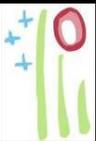


AGS

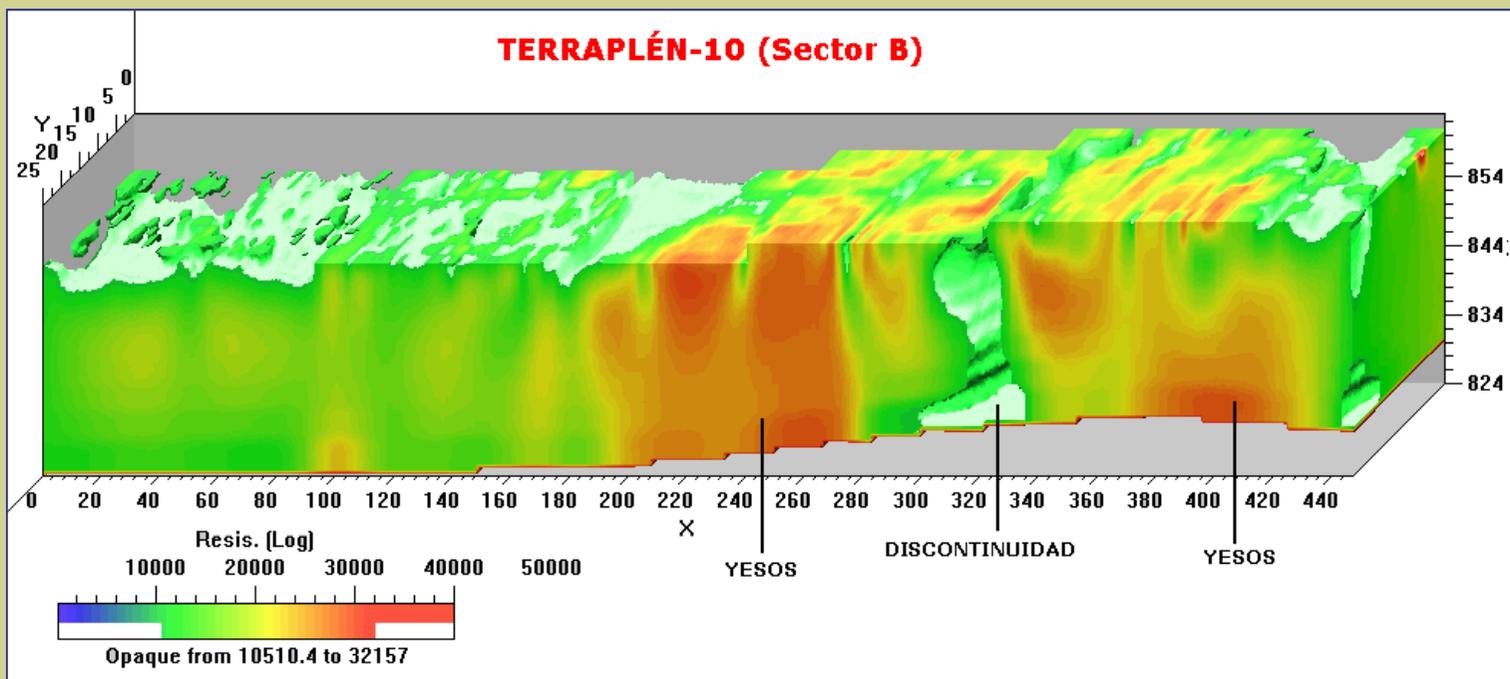
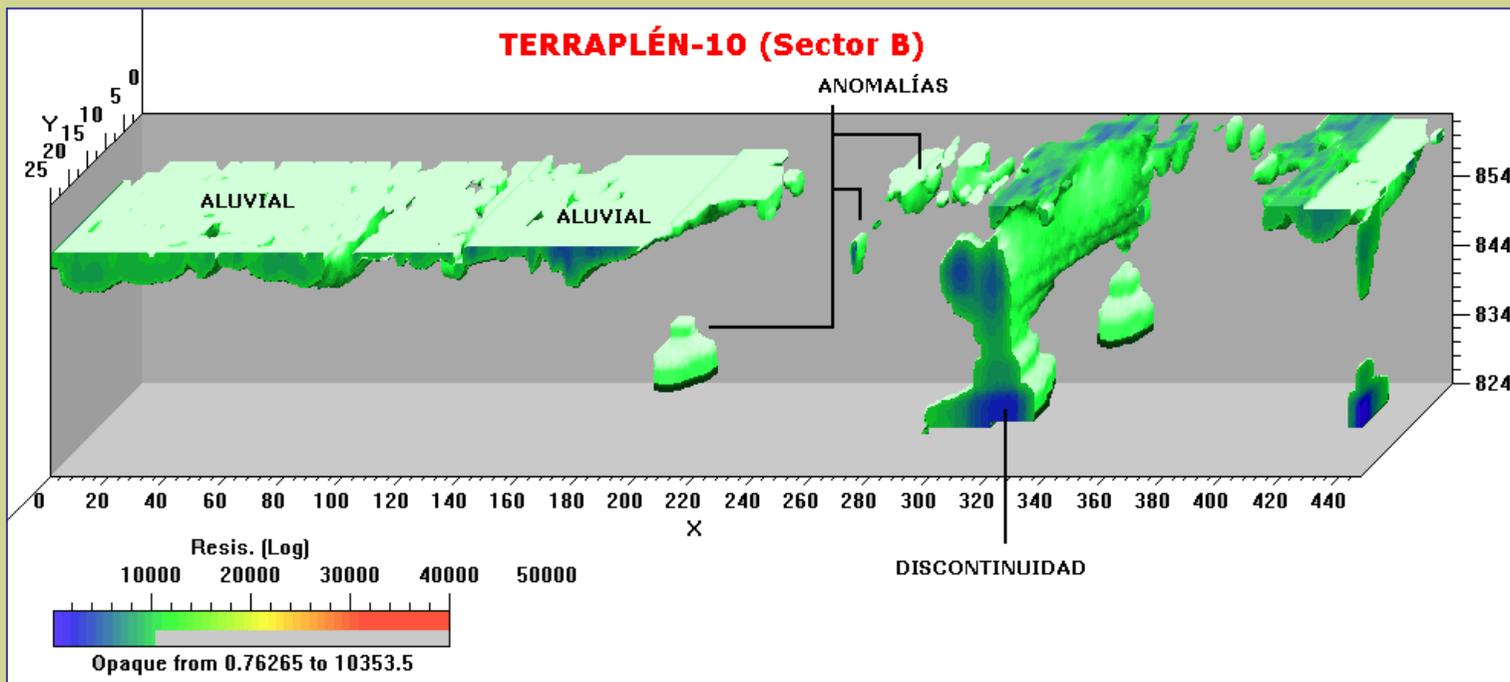


Caracterización Sustrato - FALLAS





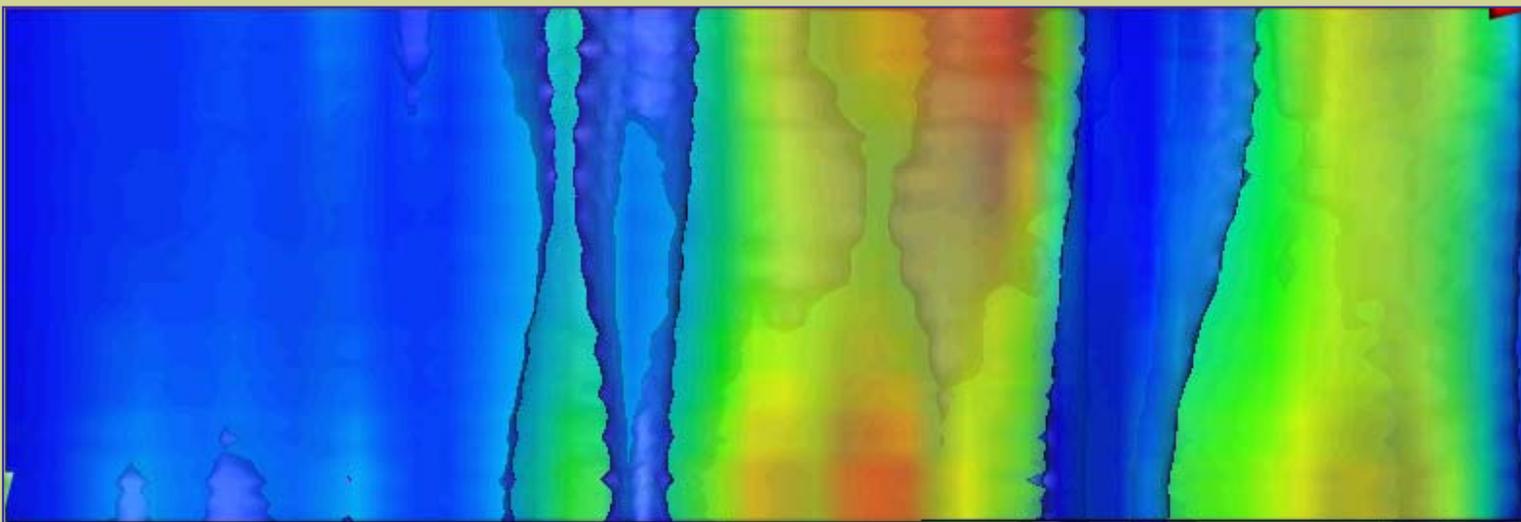
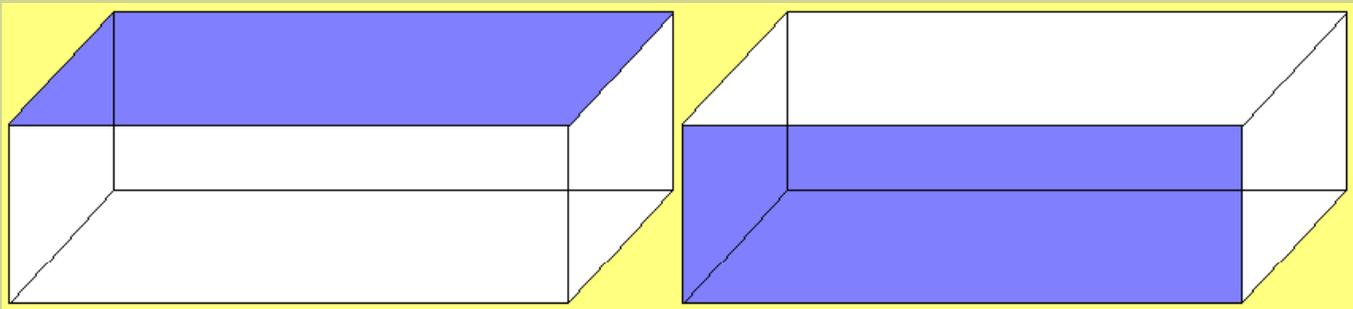
AGS



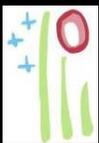
Caracterización Sustrato - FALLAS



## ESTUDIO 3D

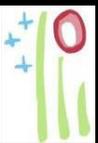


Caracterización Sustrato - FALLAS

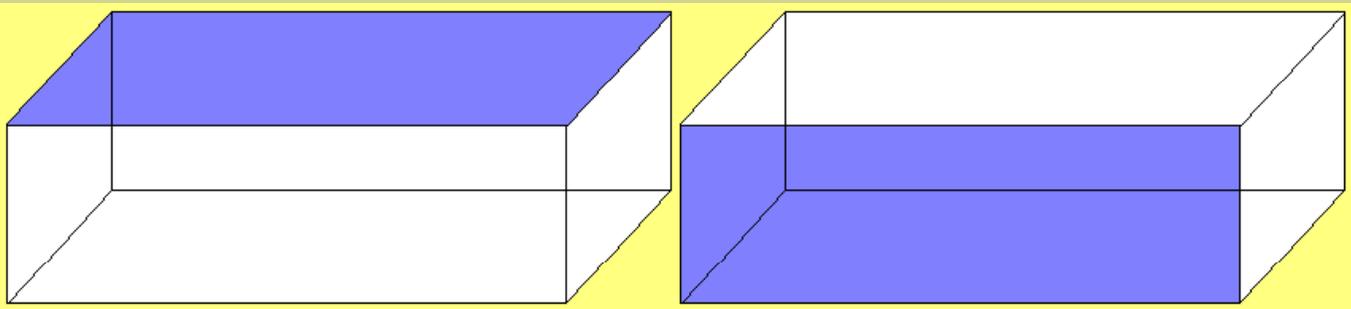


AGS





## ESTUDIO 3D

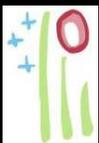


Caracterización Sustrato - FALLAS

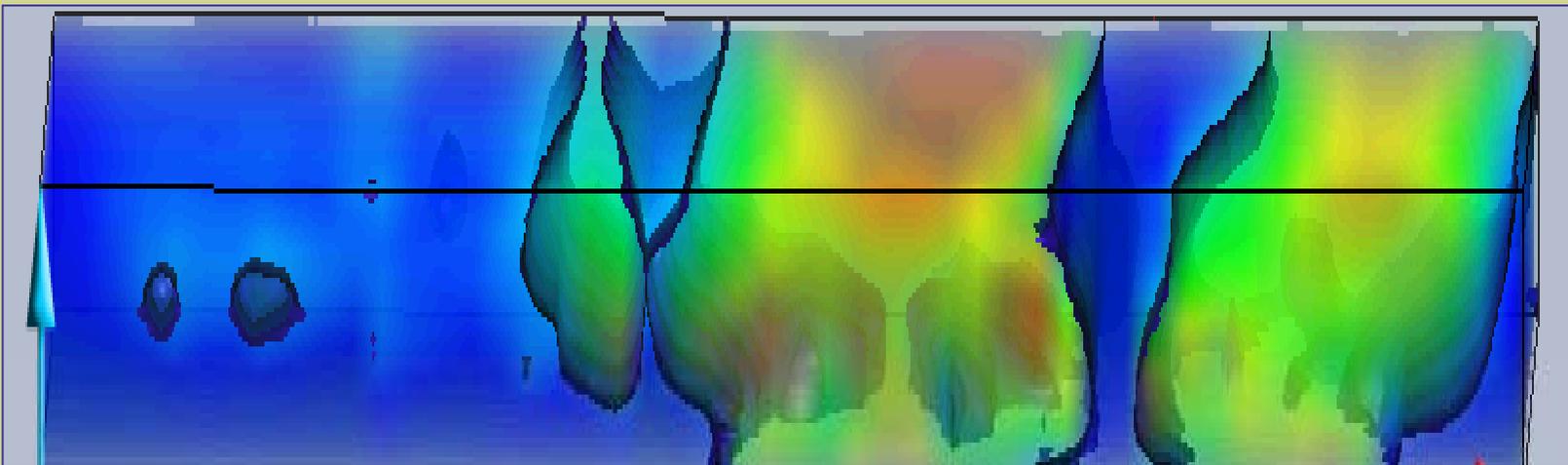


AGS





## ESTUDIO 3D



AGS

Caracterización Sustrato - FALLAS

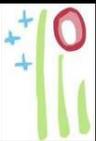


4

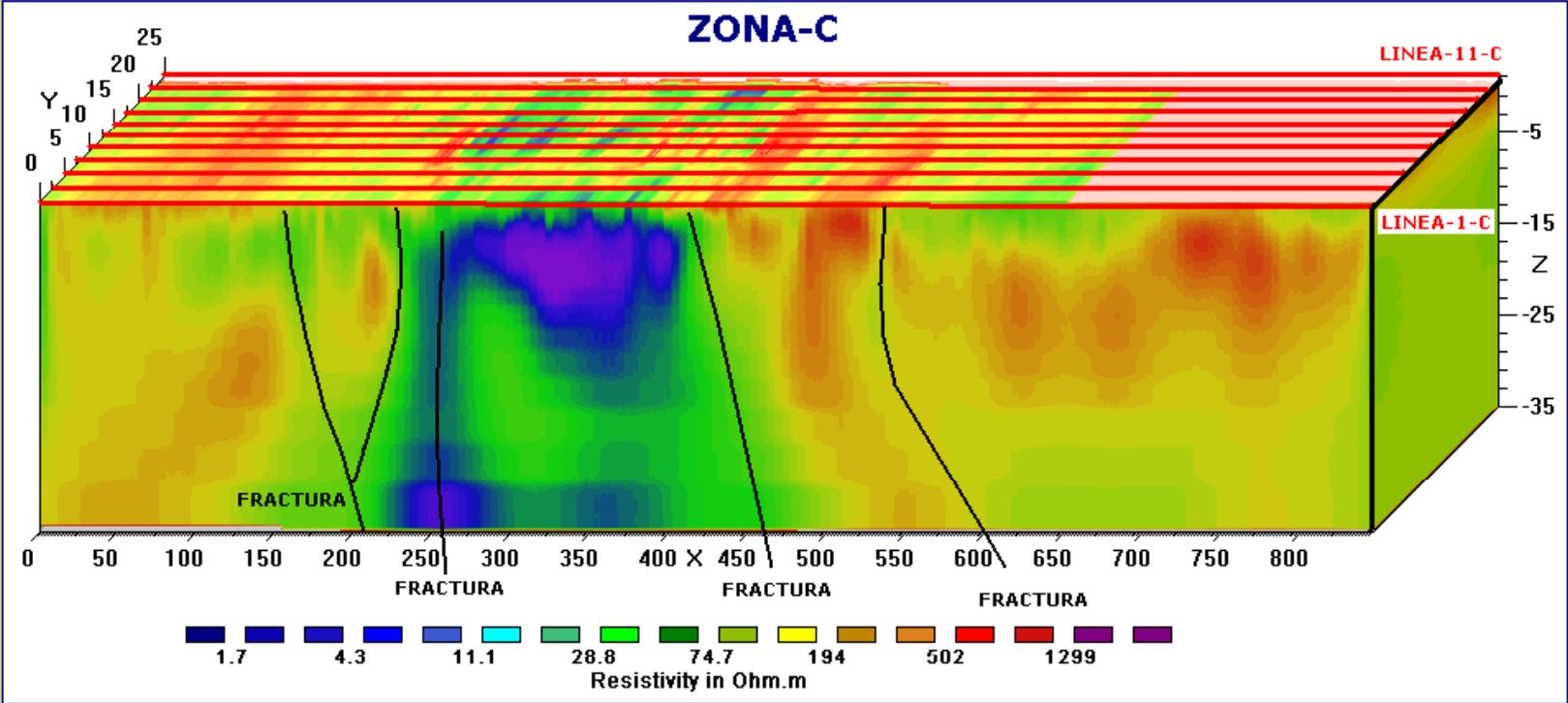
## CARACTERIZACIÓN SUSTRATO ROCOSO

Zonas karstificadas como vías de escape





# ESTUDIO 3D

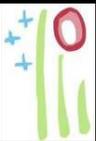


Caracterización Sustrato - KARST

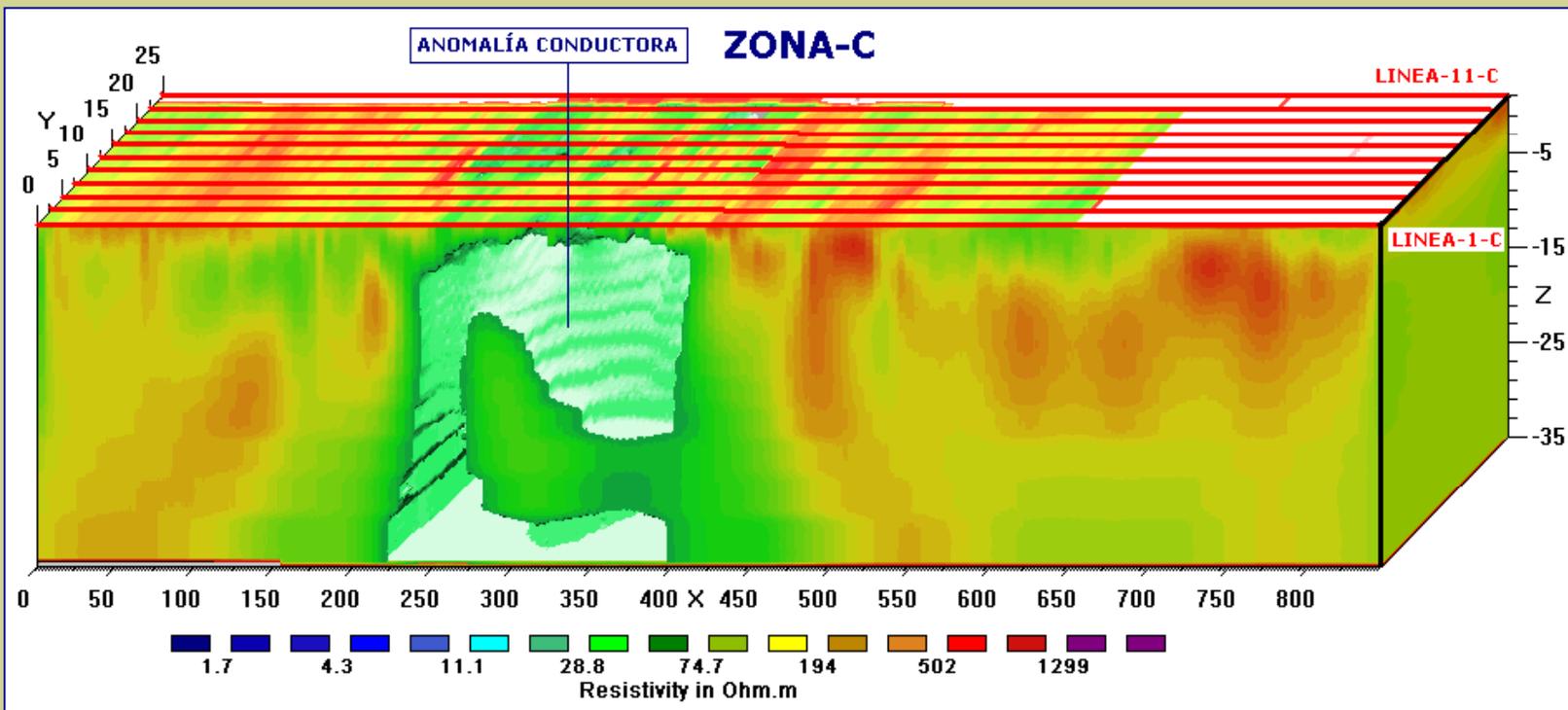


AGS





# ESTUDIO 3D

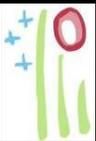


Caracterización Sustrato - KARST

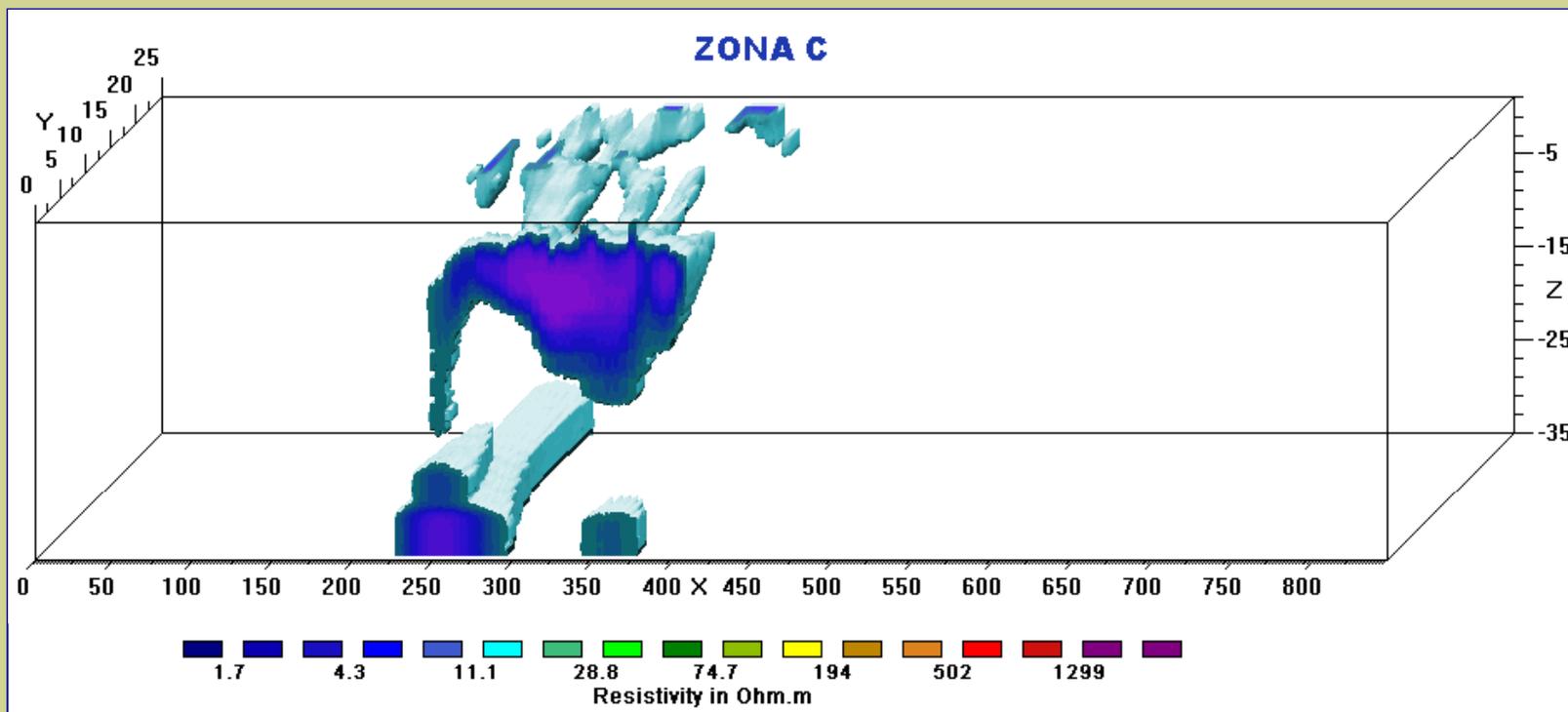


AGS





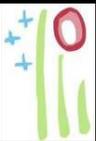
# ESTUDIO 3D



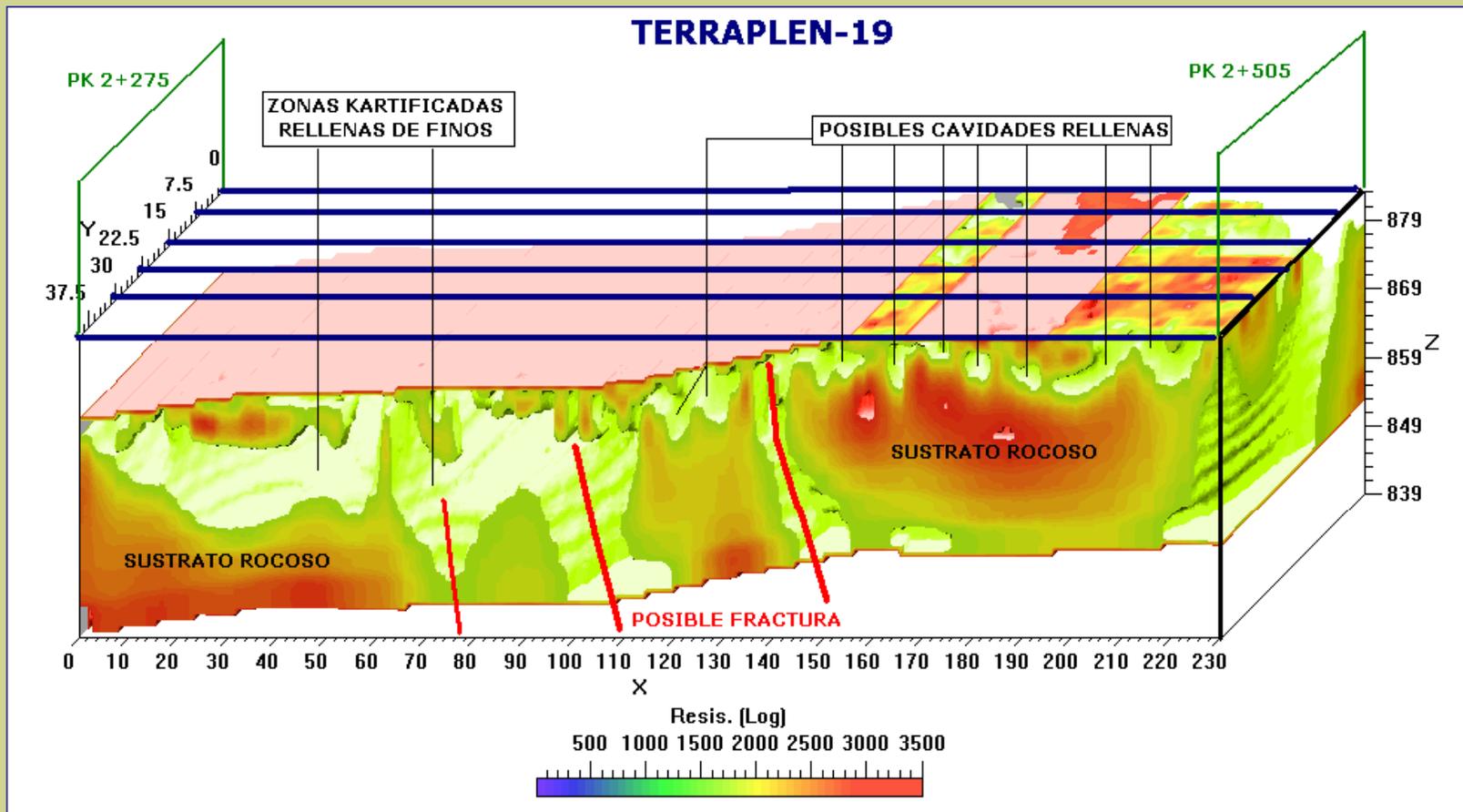
AGS

Caracterización Sustrato - **KARST**





# ESTUDIO 3D



Caracterización Sustrato - KARST



AGS





5

## BALSAS MINERAS ABANDONADAS

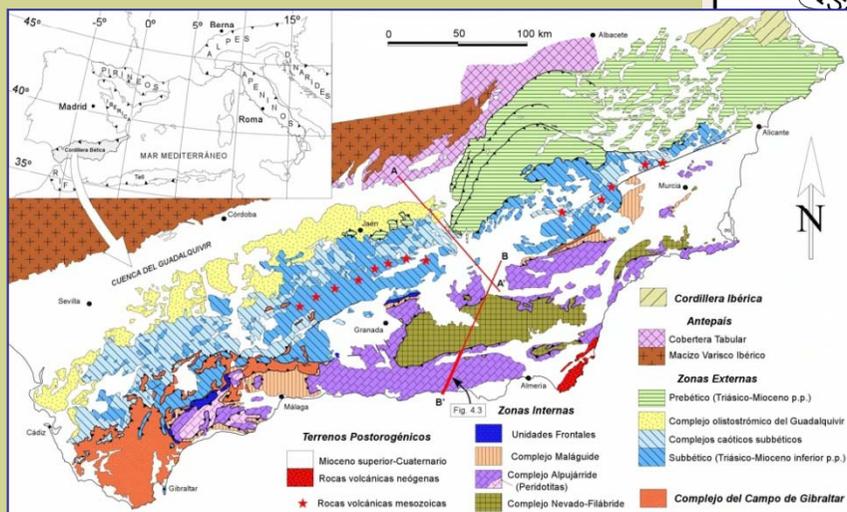
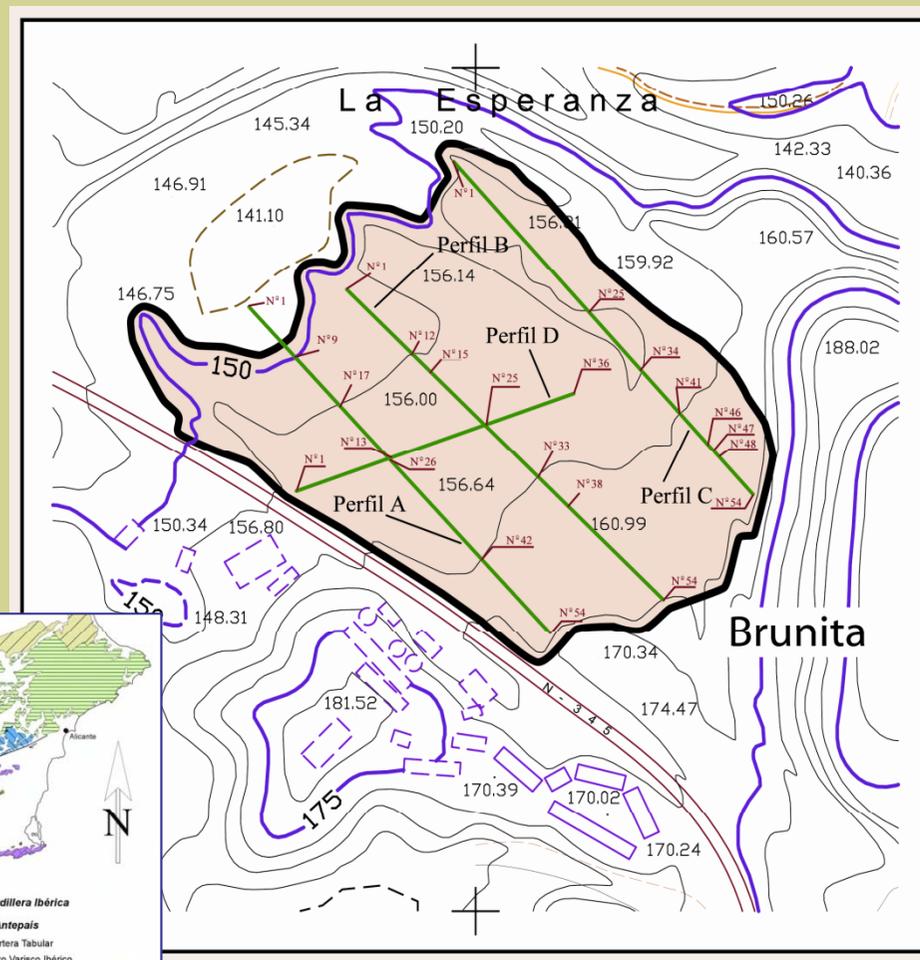
Cubicación de balsas

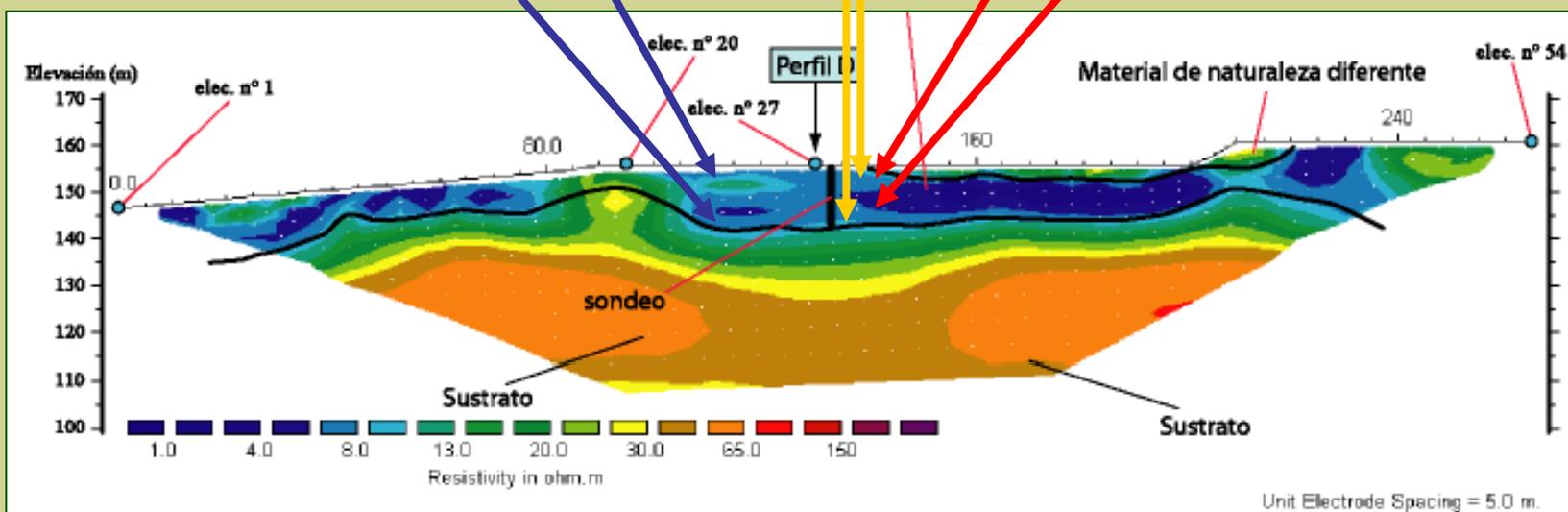
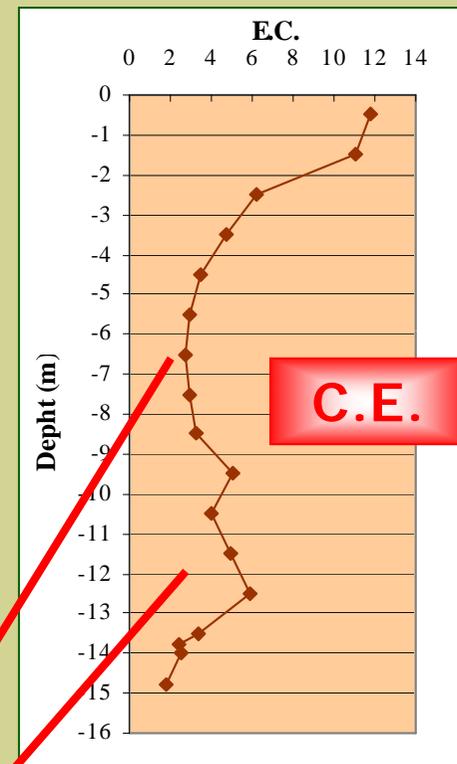
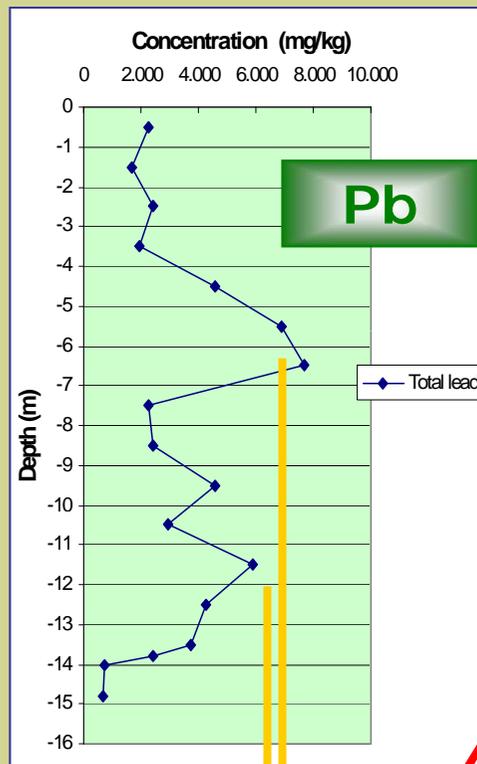
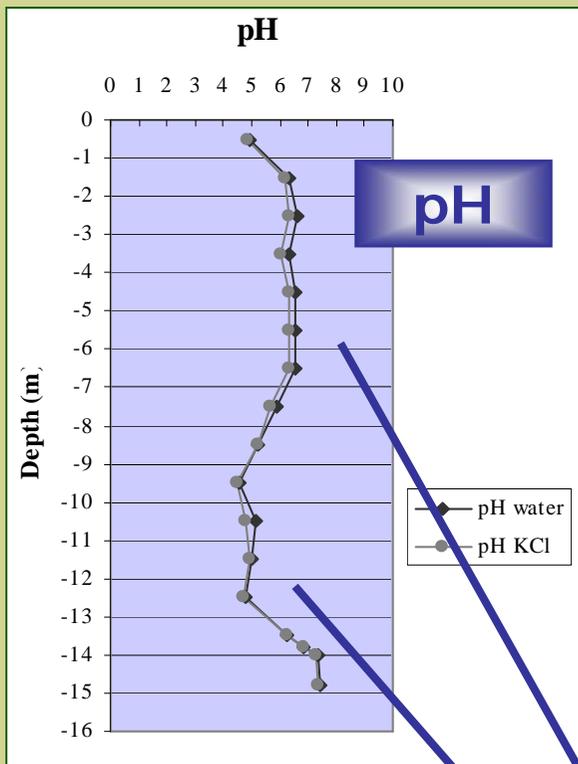
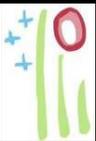
Caracterización de rellenos



# CARACTERIZACIÓN GEOFÍSICA DE BALSAS

## BALSAS MINERAS





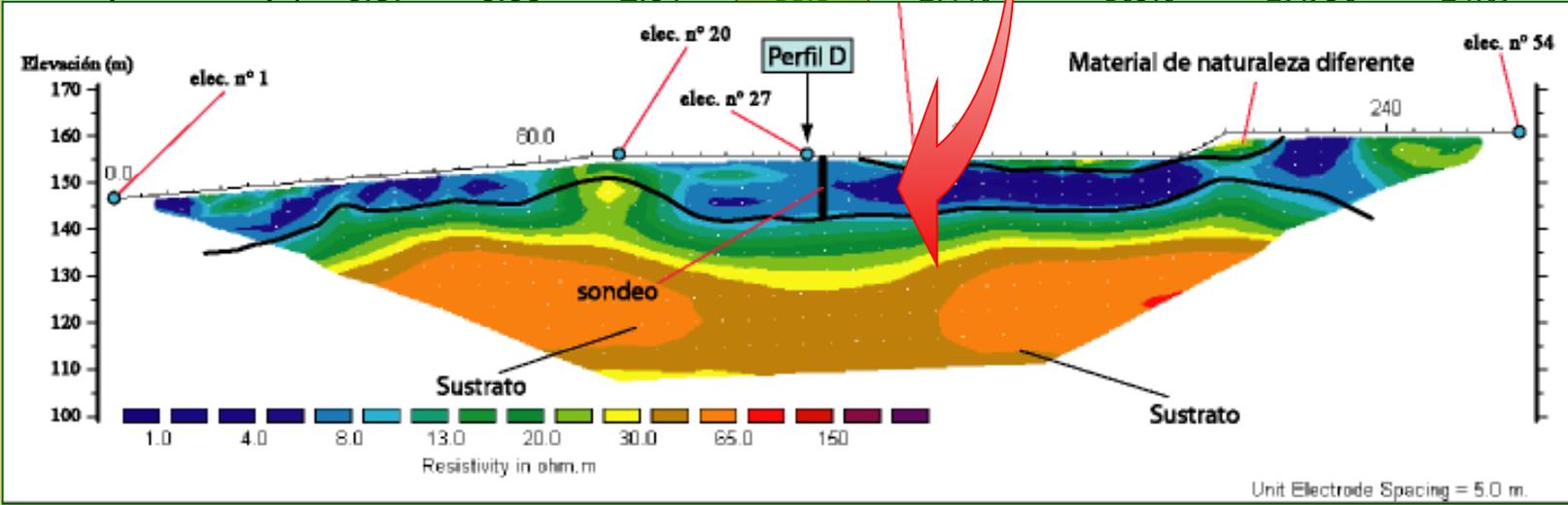
# BALSAS MINERAS

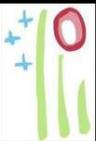




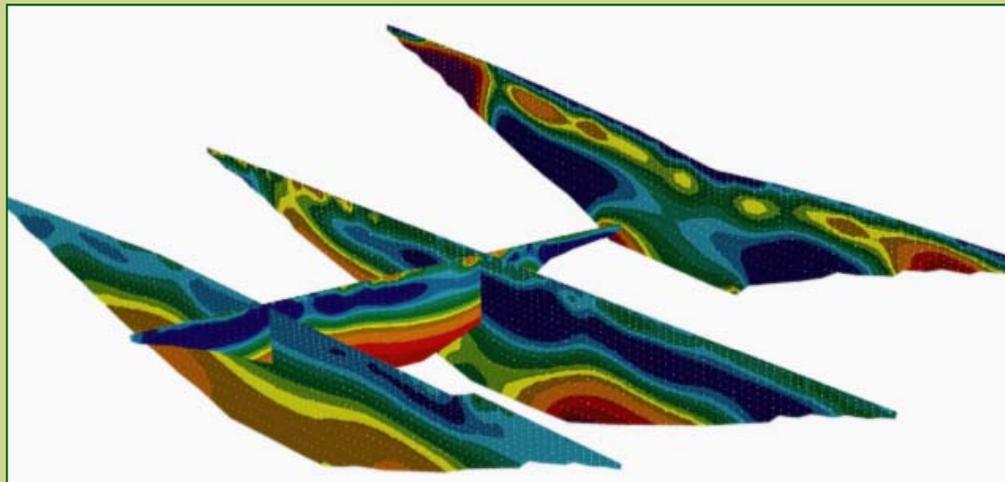
# BALSAS MINERAS

Depth (meters)	pH water	pH KCl	E.C. (ds/m)	% Clay	Pb (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Cd (mg/kg)
0-1	4.89	4.84	11.83	5.2	2.240	125.7	6.084	11.72
1-2	6.31	6.16	11.05	3.2	1.705	174.9	8.060	20.16
2-3	6.64	6.35	6.22	3.8	2.434	142.4	9.999	29.25
3-4	6.36	6.04	4.70	7.7	1.934	395.1	4.943	10.26
4-5	6.55	6.29	3.45	2.9	4.558	211.4	7.315	117.2
5-6	6.55	6.30	2.98	3.5	6.874	306.6	8.330	21.16
6-7	6.57	6.31	2.76	2.8	7.687	231.1	7.692	17.80
7-8	5.88	5.63	2.90	27.4	2.265	402.9	4.107	16.53
8-9	5.24	5.21	3.31	3.8	2.209	407.5	2.835	12.52
9-10	4.59	4.50	5.06	3.8	4.558	229.0	13.358	35.71
10-11	5.12	4.78	4.04	1.0	2.963	153.7	12.890	33.67
11-12	5.01	4.90	4.91	2.3	5.884	128.0	10.009	30.98
12-13	4.79	4.69	5.87	2.6	4.242	144.3	16.068	44.38
13-14	6.22	6.26	3.38	5.8	3.761	175.2	14.131	44.01
13.8 (substrate)	6.87	6.85	2.51	11.1	2.440	165.6	29.936	24.09

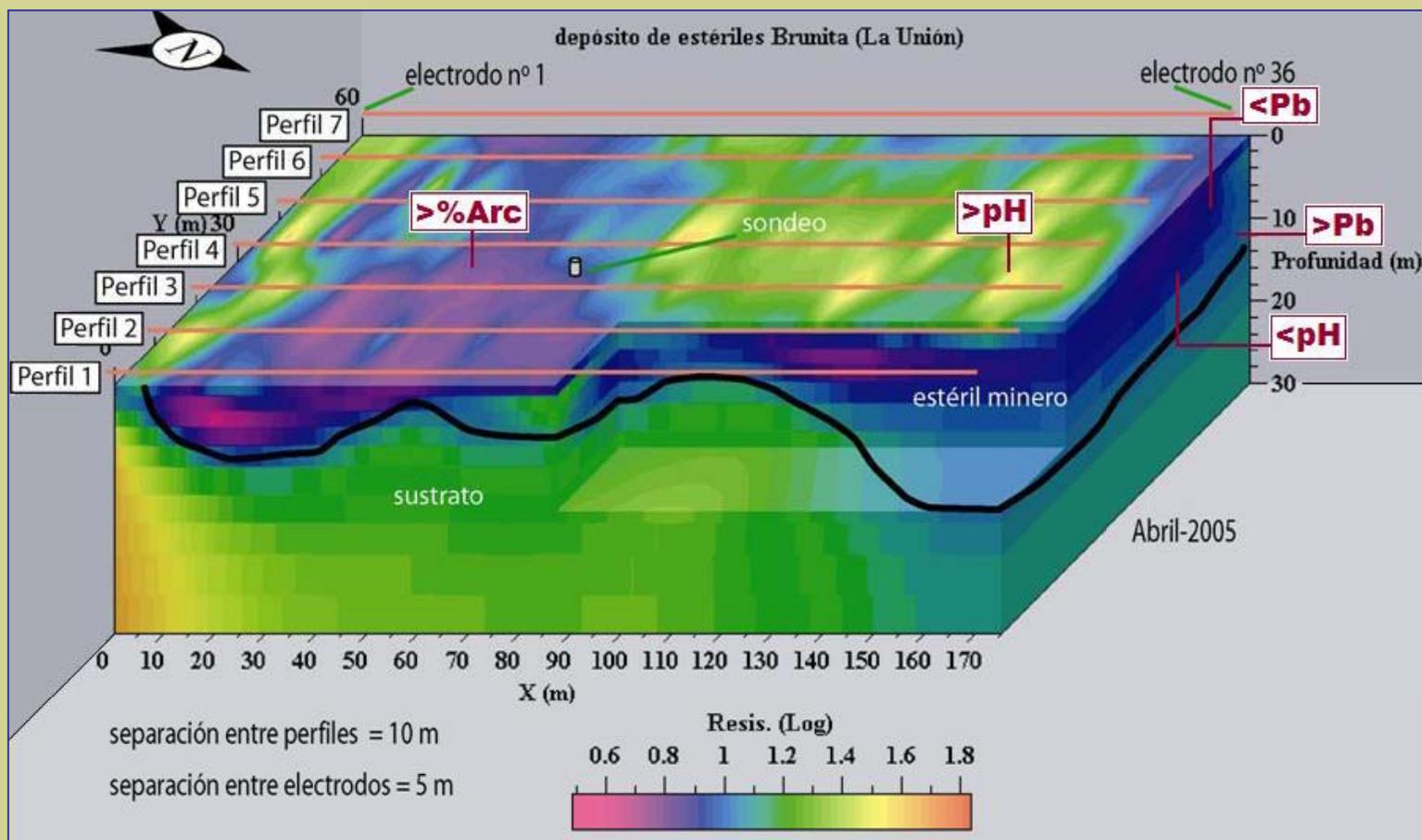


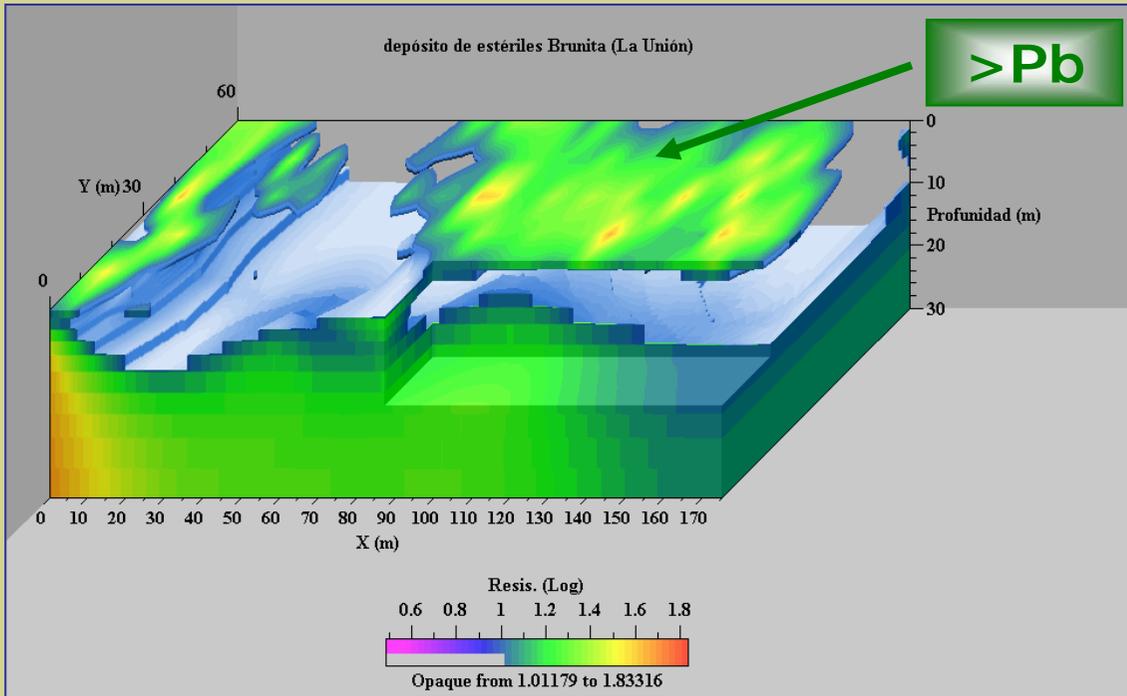


## ESTUDIO 2,5D



## ESTUDIO 3D

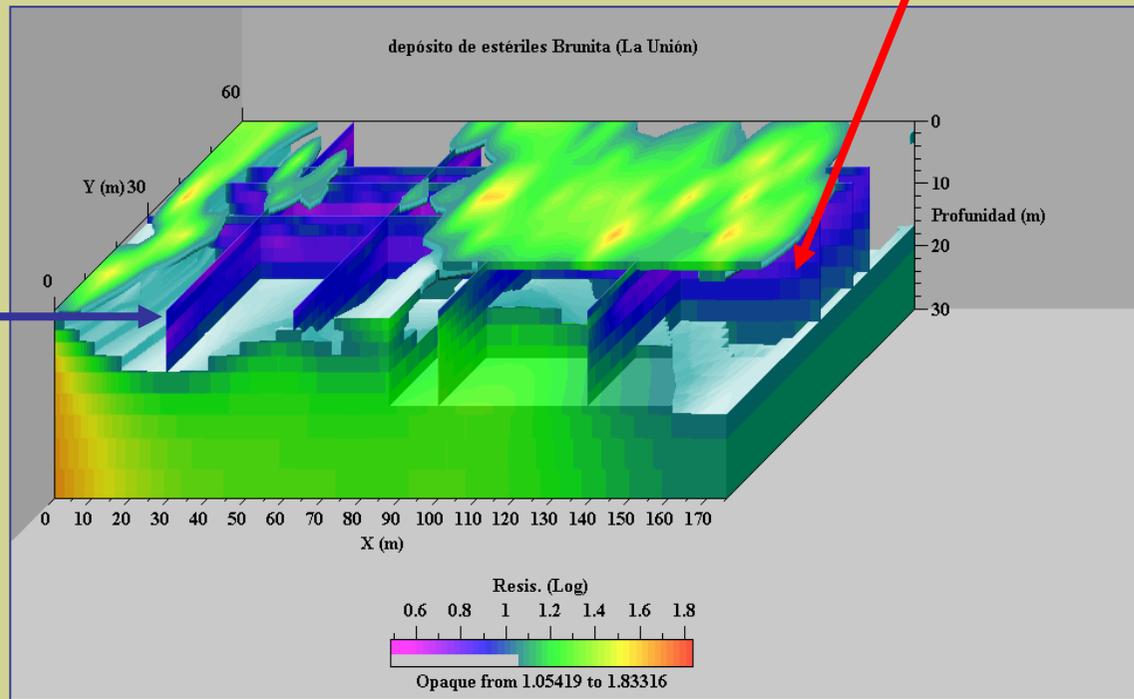




**ESTUDIO 3D**

**>C.E.**

**<pH**



**BALSAS MINERAS**



AGS

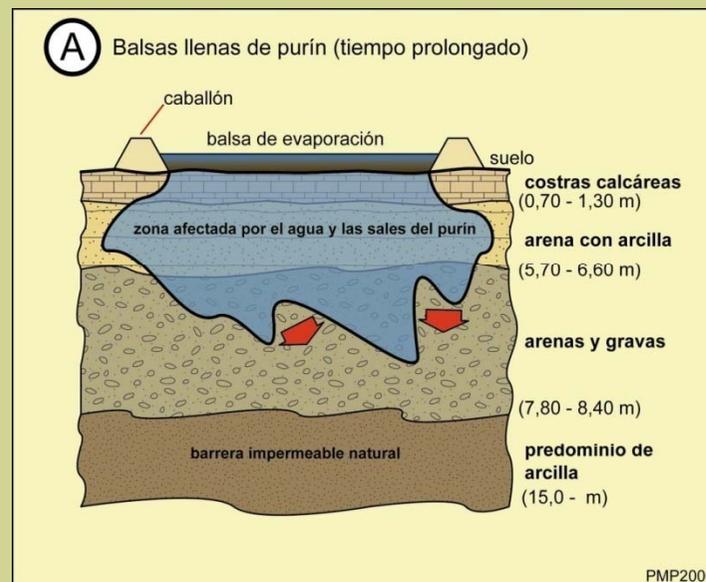
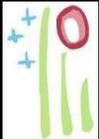




6

## BALSAS DE RESIDUOS ORGÁNICOS

Relación con el sustrato rocoso  
Fugas de lixiviados



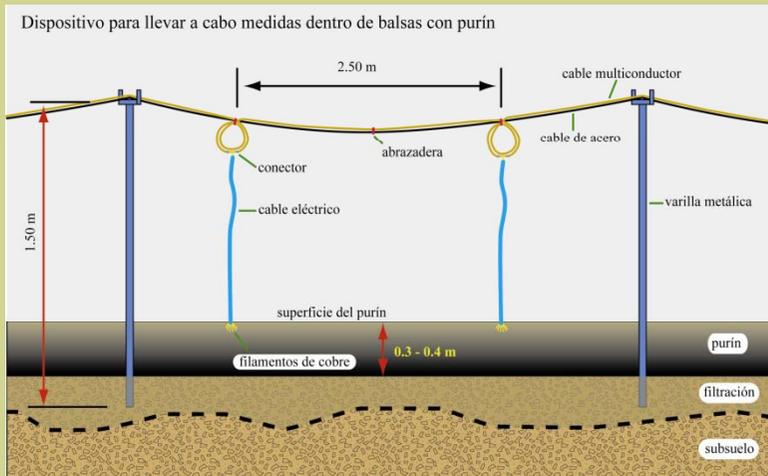
PMP2006

**BALSAS DE RESIDUOS ORGÁNICOS**



AGS



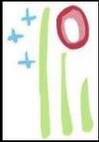


Instalación adaptada para medir dentro de balsas con purín



BALSAS DE RESIDUOS ORGÁNICOS



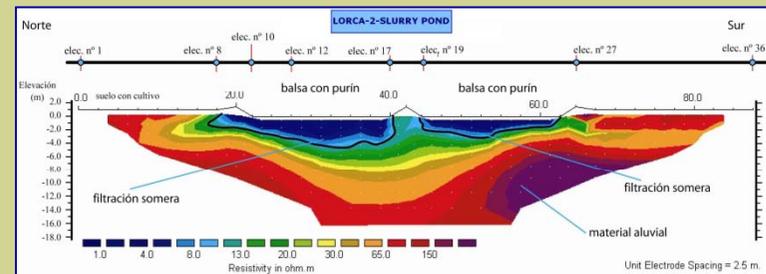
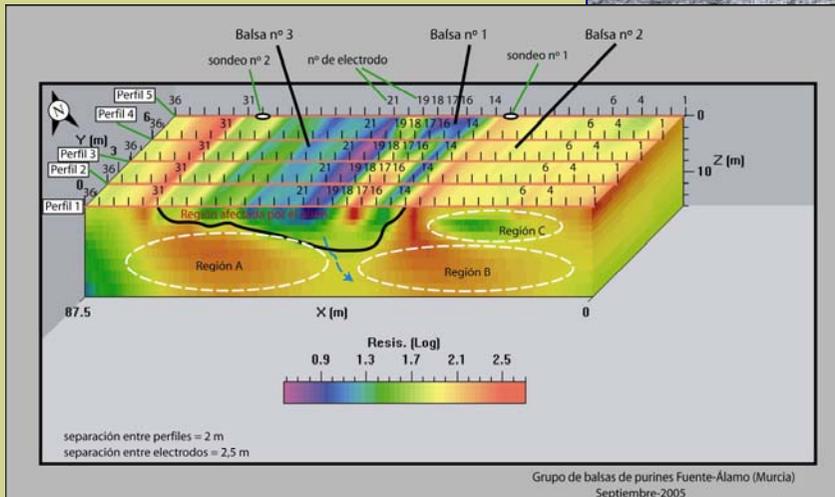


# Objetivos

# Contaminación de acuíferos

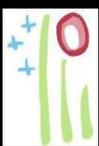
BALSAS DE RESIDUOS ORGÁNICOS

LORCA (MURCIA)

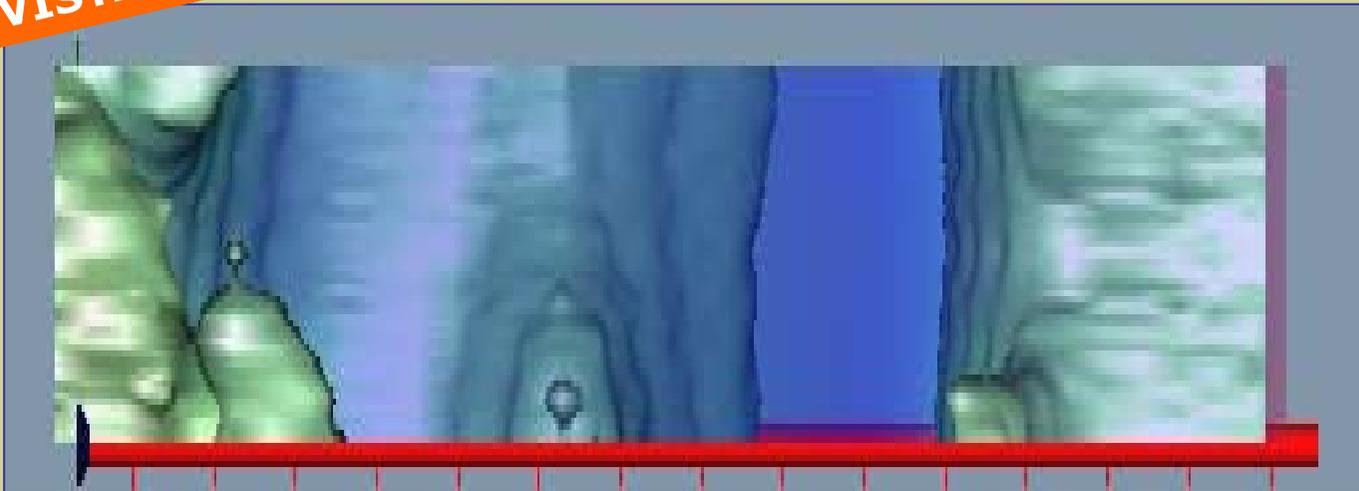


AGS

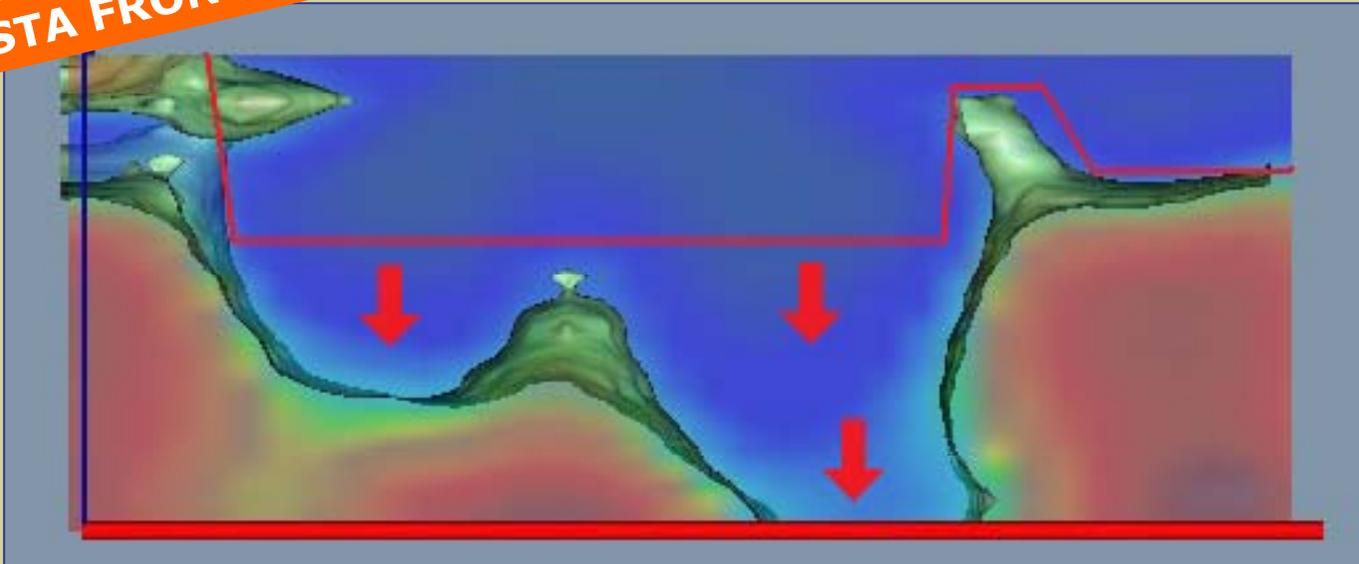




VISTA CENTRAL



VISTA FRONTAL

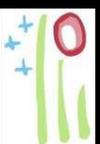
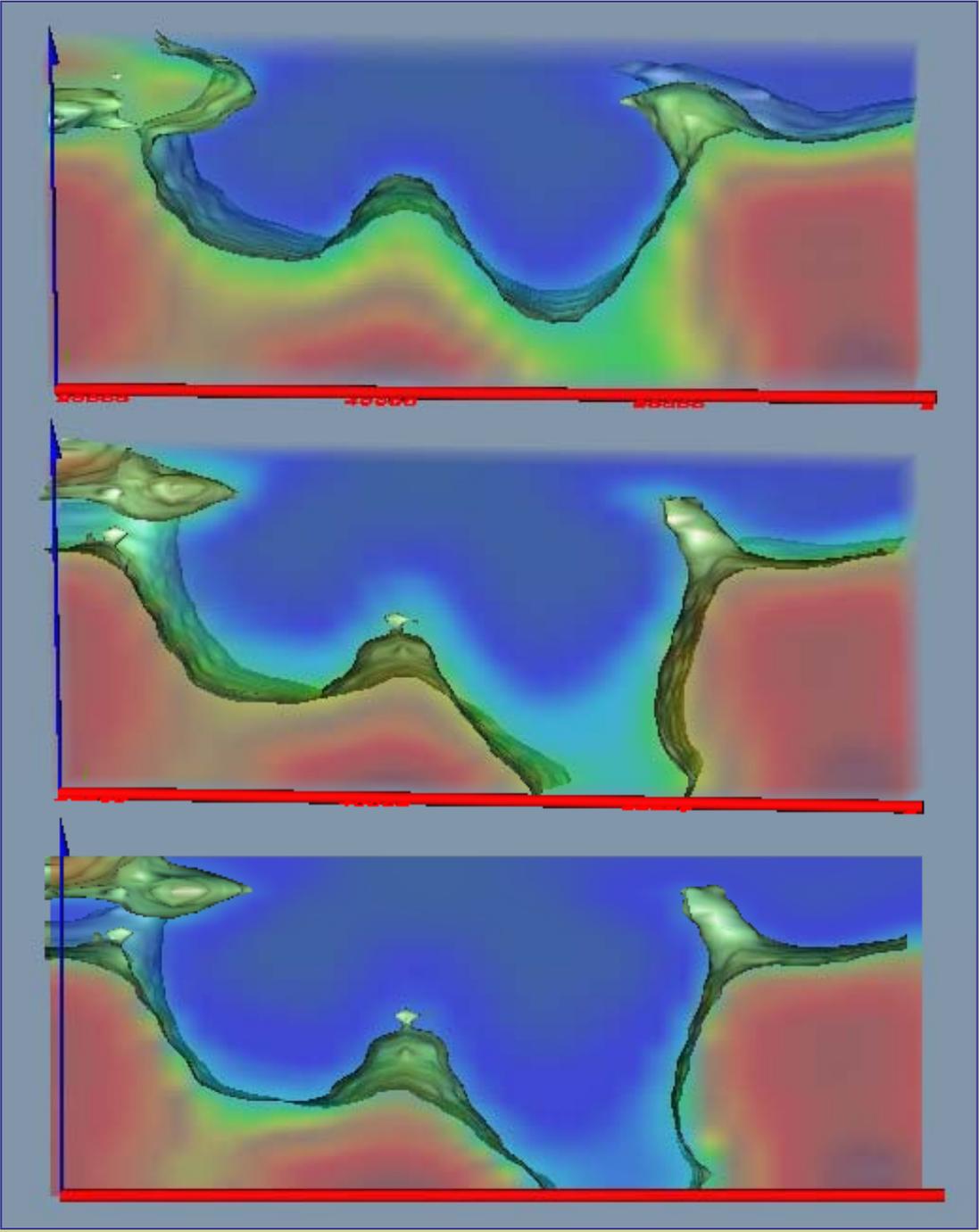


AGS

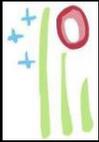
BALSAS DE RESIDUOS ORGÁNICOS



# BALSAS DE RESIDUOS ORGÁNICOS



AGS



# Temario

## 1.- Introducción

Datos de partida

Resultados que pueden obtenerse

## 2.- Observación de la contaminación

Caracterización de Vertederos

Caracterización del sustrato. Fracturas

Caracterización del sustrato. Zonas Karstificadas

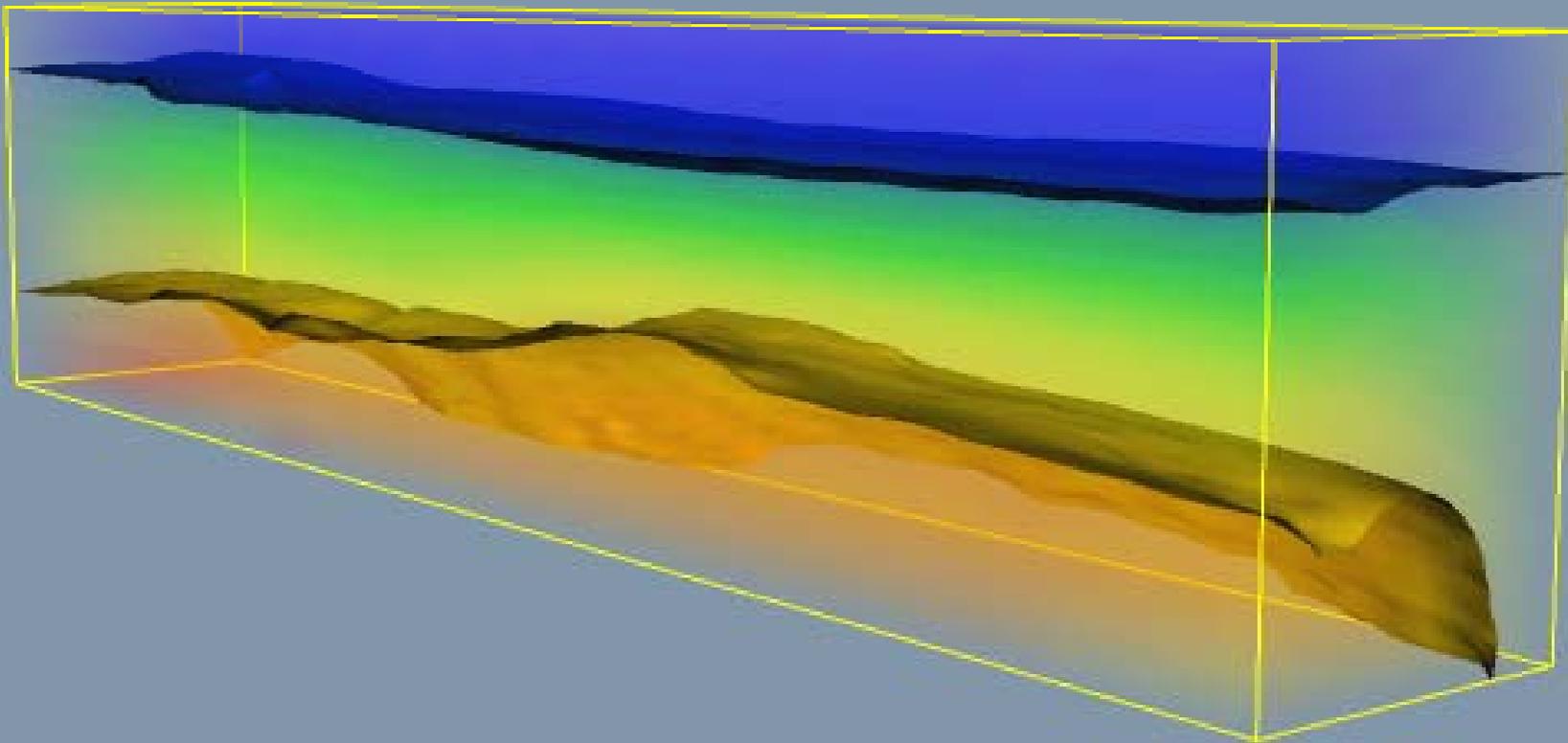
Balsas Mineras

Balsas de Residuos

## 3.- Resumen y Conclusiones

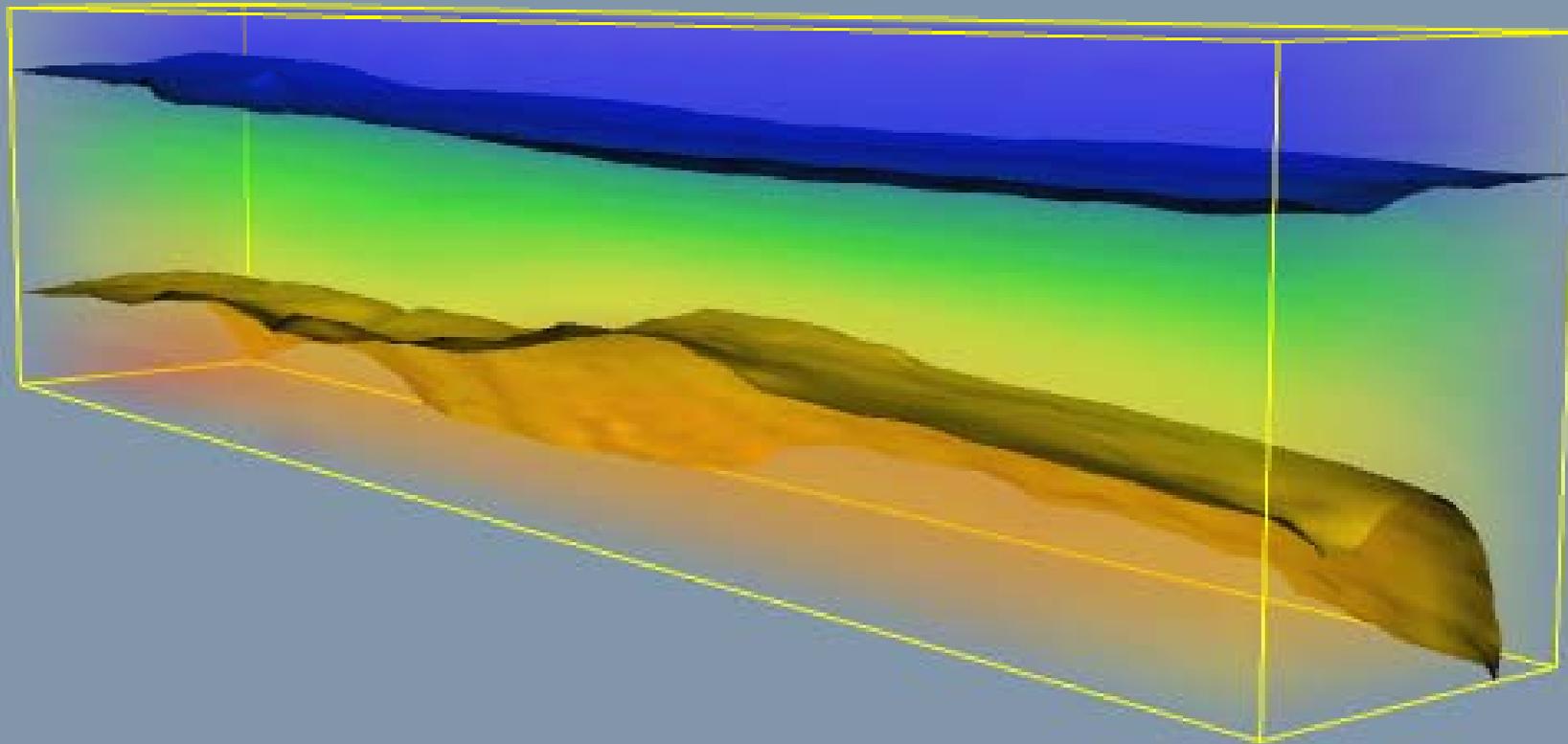


Con un sustrato 3D y un problema 3D, la **solución** debe pasar por **3D**



Con un sustrato 3D y un problema 3D, la **solución** debe pasar por **3D**

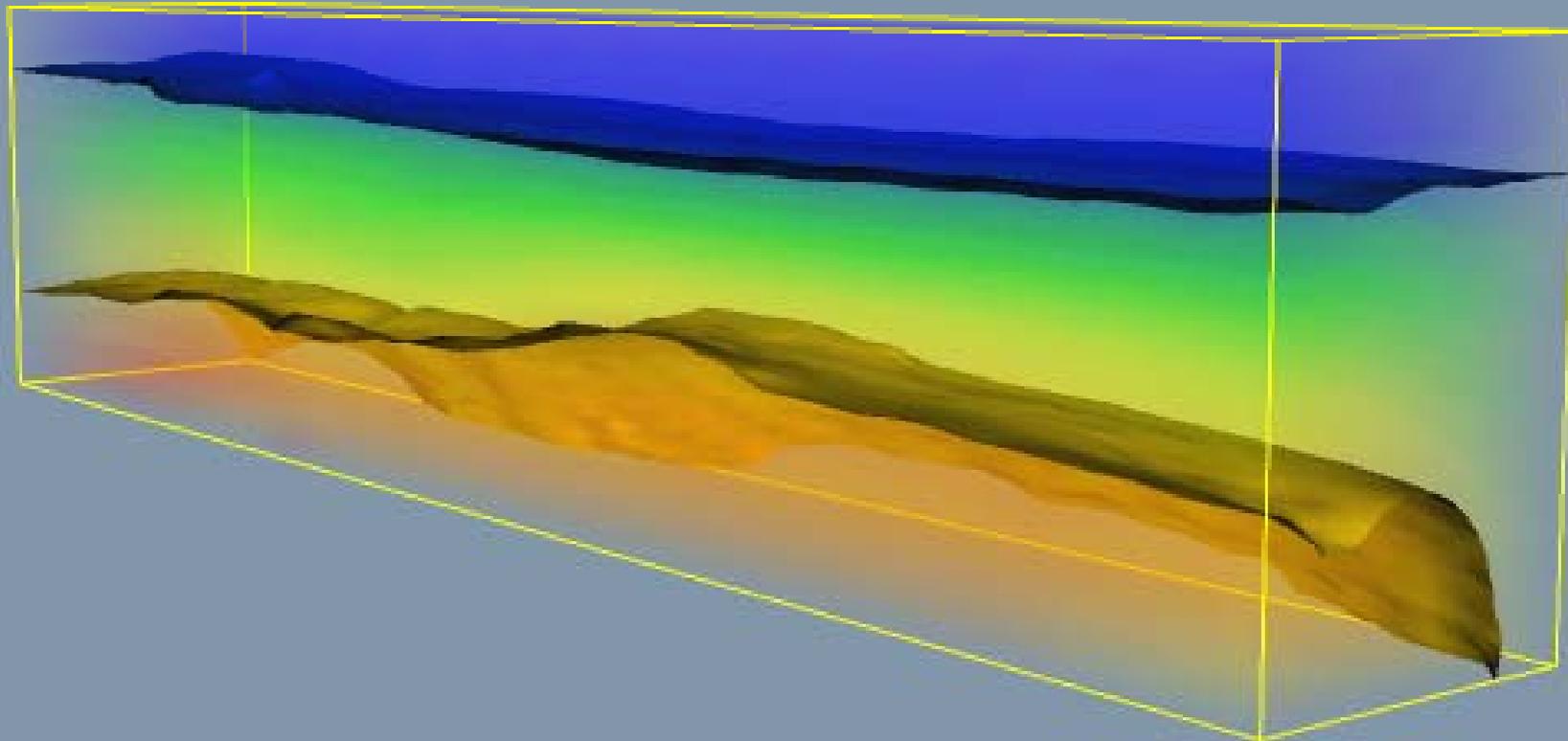
La **investigación** del subsuelo deberá ser **no invasiva**



Con un sustrato 3D y un problema 3D, la **solución** debe pasar por **3D**

La **investigación** del subsuelo deberá ser **no invasiva**

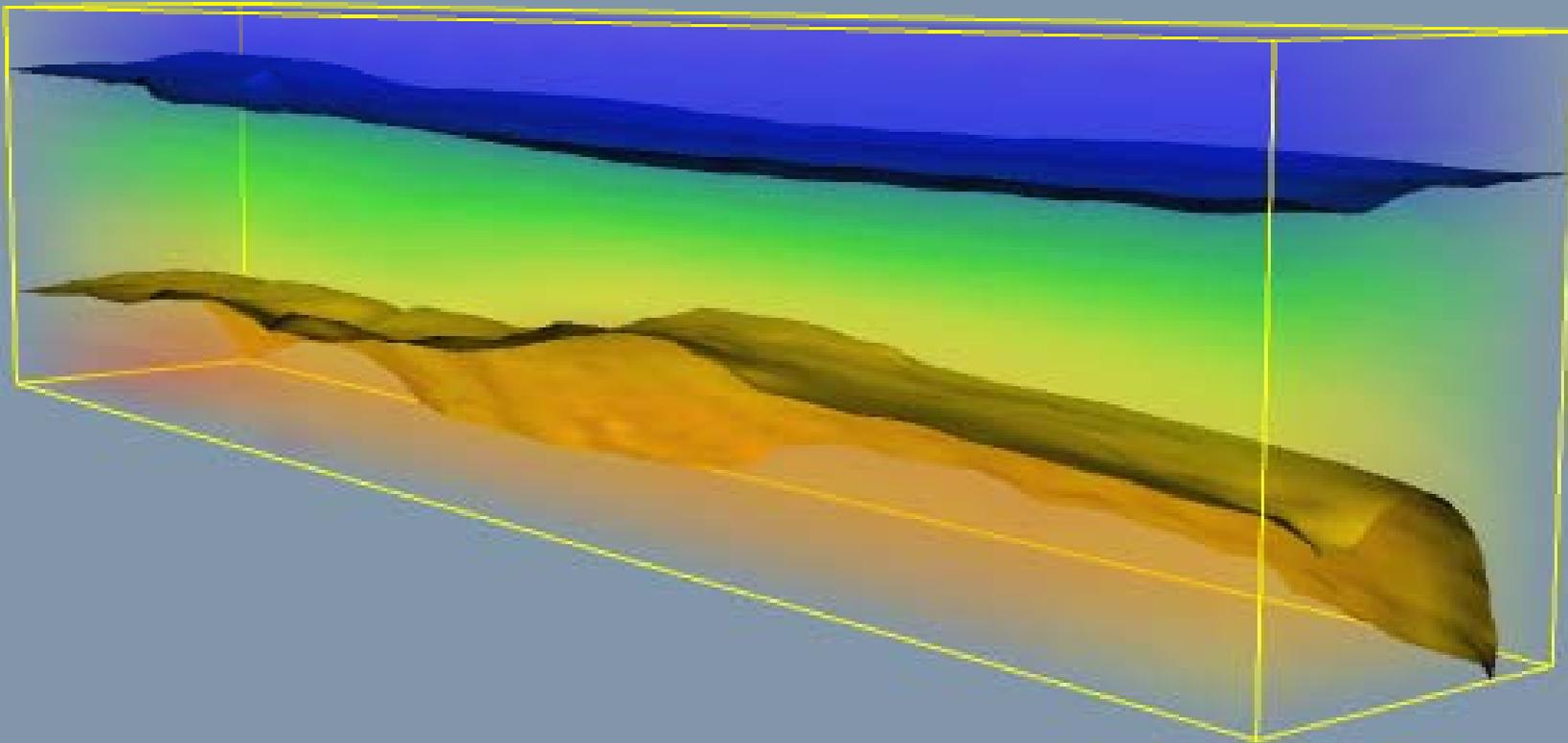
**Existen técnicas** de investigación no invasiva del subsuelo



Con un sustrato 3D y un problema 3D, la **solución** debe pasar por **3D**

La **investigación** del subsuelo deberá ser **no invasiva**

**Existen técnicas** de investigación no invasiva del subsuelo



El **procesado y representación 3D** facilitan el control