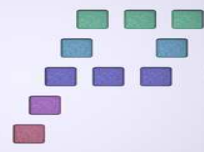


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**PFC**



**Gestión del Patrimonio Cultural**  
**Nuevas Tecnologías**

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**Year:**

November 2005

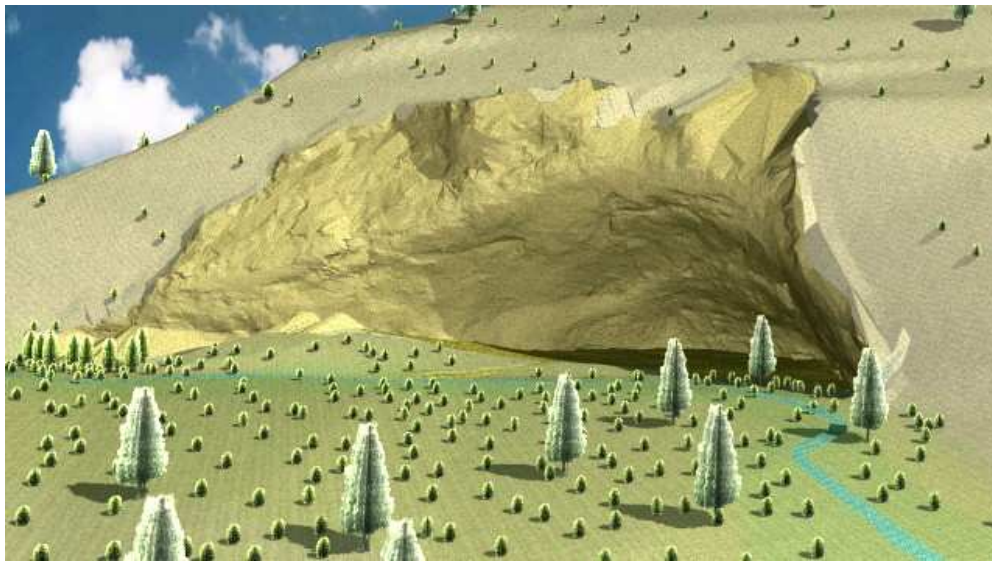
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**Method**

Classic topography

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**SUBJECT:** Project of establishment of a basic network by means of a GPS to connect the paleolithic refuge of Cova Gran. Obtaining of a cartography and a digital terrain model of the place.



## SUMMARY

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## ANNEXES

### ANEXO I. PLANS

## 1. INTRODUCTION

### 1.1 Objectives

This project is a collaboration between Polytechnic University of Madrid (UPM) and Autonomous University of Barcelona (UAB) on the archaeological Cova gran research work. This project is managed by three researchers, D. Raphaël Mora Torcal, professor of the Department of Social Anthropology and Prehistory of the Autonomous University of Barcelona, by D. Jorge Martínez Moreno, Doctor in the Prehistory of the UAB and researcher associated in the Centre of Historic Studies of the CSIC and by Paloma González Marcén, professor of the Department of Social Anthropology and Prehistory of Autonomous University of Barcelona.

The objective of this project is to obtain a cartography of the refuge and digital terrain model of the place.

### 1.2 Localisation

"Cova Gran" is around of a small village being called Santa Linya close to Balaguer (in the region of Noguera in the province of Lleida, in Catalonia), approximately 210km in the North-Northwest of Barcelona. The refuge is established in the centre of a small narrow ravine. It is supposed that this refuge was occupied several times by the hunters of the Tardiglaciari.



Figura 1: Cova Gran localization map

### 1.3. History

The excavation of the archaeological site began in 2002, one year after its discovery. The first results of the excavation indicate that "Cova Gran" was occupied several times during Pleistoceno and during Holoceno.

This archaeological site is important because the activity of hunting during these times was noticed as in the north part of Pyrenees as its south part. However archaeological sites on the south hillside are less numerous. This contrast between North and South, engenders important doubts as for the quality of natural barrier of Pyrenees during the

transition Pleistoceno-Holoceno. Also, doubts exist to know if the Southern coasts of Pyrenees can be considered as areas of attraction for the hunters of the Tardiglacial-Holoceno. From this point of view, the excavation of "Cova Gran" opens a door in past, which will improve the archaeological knowledge and will explain if this zone was a region lived during the last glacial period of the premature holoceno, and if yes why.

This work was important because it constituted a base of approach for the other deposits. The reader have to know that the same archaeological team works on another archaeological site with similar characteristics, located near Cova Gran and called " a Roche dels Bous".

## 2. GPS NETWORK

### 2.1. Primary network

The project's main objective was to create a basic network to connect the construction site with the official network.

Equipments used to make the observations are:

- three GPS-300 from Leica with radio-modem and accessories.
- three tripodes rigides.
- Meter

For the network's stake out, we used the maps of the archeological site zone and of its neighbourhood in the scale 1:50 000 and 1:25 000. These maps helped us to localize the best places to stake out the future points of the primary network. We used the following sheets:

1: 50 000	32-13 (327)
	33-13 (328)
1: 25 000	327(pages II y IV)
	328(pages I y III)

The sheets of 1:50 000 were obtained from the Army Geographical Service, those of 1:25 000 in the National Centre of Geographical Information.

Once we localized good places for the stake out of the network, we looked for their coordinates in WGS84 and REGENTE systems to be able to apply afterward our transformation. Coordinates were obtained on the web page of the Cartographic Institute of Catalonia ( ICC) - HTTP: // www.icc.es/. We decided to make the observation on a base of the DIRIGE network and on three bases of the ICC network.

Points and their coordinates :

COORDENADAS UTM 31 N				
NOMBRE ICC	X	Y	Z	NOMBRE RED BÁSICA
<b>253100001</b>	305811,041	4643786,978	1033,693	REGENTE2
<b>257103001</b>	321894,639	4636958,135	573,977	ICC1
<b>257101001</b>	320610,565	6460728,292	949,499	ICC2

With these points, we decided to stake out a fixed point in the zone of studies, in Sainte Linya's village. When we obtained it adjusted coordinates, from these last points, the fixed point would be used in the calculation of the Basic Network.

Afterward, we looked for the ideal places to stake out the points of the site network. The points of this network that must serve as base in the later campaigns, were chosen so that they are in stable enough zones. Their stability was more strengthened with some cement and steel bars 50cm long.

For the network observation, the fast static method was used with time of observation of 15 minutes. After the placement of the GPS receiver on the fixed point of Sainte Linya, an observation of the network was realized on nine points.

For the transformation calculation, we used the points of the basic network known in both systems. All the possible base lines were calculated in order of their observation, then we proceeded to the adjustment. By fixing a point and by leaving the other one as motive, we resolved the ambiguities for every observation.

Nombre	XUTM	YUTM	Z	dX	dY	dZ
100	3187194,689	46440287,942	4115,993	0,020	0,019	0,017
200	3188009,826	46440119,964	4088,356	0,018	0,019	0,016
300	3181867,731	46439027,752	4206,569	0,018	0,019	0,014
400	3183277,795	46440107,793	4372,215	0,019	0,019	0,017
500	3185318,200	46438530,029	4560,780	0,018	0,019	0,016
600	3187995,774	46437950,836	4782,540	0,021	0,019	0,019
700	3189733,569	46437598,604	4748,838	0,023	0,019	0,020
800	3188383,003	46441491,703	5134,536	0,018	0,019	0,020
900	3186670,585	46442122,929	5185,822	0,018	0,019	0,020

## 2.2. Secondary network

Once the observation of the basic network made, we began the observation of the points of the secondary network which are going to help us to obtain the coordinates of the archaeological site.

Four points were chosen to be endowed with coordinates. These points were chosen and localized to the office previously. In the same way in the previous observation, an observation by GPS was made by using the fast static method, and by taking as control point the point of Sainte Linya.

By applying the transformation, we obtained the coordinates of the points of the secondary network from which we are going to be made the stake out of the site.

Nombre	XUTM	YUTM	Z	dX	dY	dZ
<b>10 000</b>	3186302,995	4644055,451	4012,313	0,018	0,019	0,020
<b>20 000</b>	3186727,489	46440094,679	3967,021	0,018	0,018	0,012
<b>40 000</b>	3185777,987	46440494,795	4006,847	0,018	0,019	0,015
<b>50 000</b>	3185294,415	46440338,772	4020,601	0,018	0,018	0,018

### 3. POLYGONALE MADE BY CLASSIC TOPOGRAPHY MEANS

The objective of the secondary network was to densify the network and to endow with coordinates the points which we couldn't observed by GPS, points on whom we shall aim and where from we can realize the stake out of the refuge.

We used the total station TCR 705 from Leica company. This station allowed us to make distance measurements without prism-reflector, only by means of a visible laser (LR). Also the total station had an infrared distance-meter for the measure with reflector (IR).

Equipment characteristics :

- Angle measurement deviation:  $\pm 0.5mgon$
- Focus: 30 X
- Distances measurement deviation:
  - Without prism reflector: 3mm + 2ppm
  - With prism reflector: 2mm + 2ppm
- Axis compensator.

Others instruments employed:

- Wood Tripode Leica.
- Prisms reflectors Leica.
- Jalons.
- Meter.
- Steel bars and steel nails



Figura 3: stacion totale TCR 705 from Leica

We made a polygonation. The angles and distances measurements were made in direct and inverse observation on previous and posterior points than that of the station, by noting the azimuthal readings by making an aim towards the lowest part of the staff, with the objective of reducing as much as possible the error of direction. The zenithal readings and the distances measurements were made by aiming at the centre of the prism.

The polygonal includes four points measured previously by GPS. For the calculation of the polygonal, these points have reliable coordinates. The obtained coordinates are with a acceptable degree of accuracy. We present them here:

Nombre	XUTM	YUTM	Z
30 000	318633,437	4644084,298	399,309
60 000	318651,220	4644058,512	398,623
70 000	318600,920	4644080,132	399,423
80 000	318591,352	4644087,625	400,060

#### **4. LASER SCANNER SURVEY**

With this method, we determined the coordinates of the necessary points for the three-dimensional model.

In this phase, we used a total station TCR 705 of the company Leica. This material facilitated the work, especially for remote points because this device does not need a prism reflector.

Aims were made by parking the instrument on the points of the network implanted previously. We directed by observing to the most distant and best defined point by the network. Horizontal and vertical readings on these references were made before and after the observations in itself to check possible movement of the instrument during the observation phase.

Beforehand, grounds sketches of zones to be surveyed had been made since each of the future stations, to note during every station the surveyed point's position and number, to facilitate the edition of the data. We also noted the distance of the most far surveyed point, which became established to 254 metres.

As regards to the survey accuracy, we calculated the longitudinal and transverse maximal errors. By calculating the quadratic component of this value with the planimetry accuracy of the point on which we parked, we have a planimetric error of 8.8mm, which is included in the work's tolerance, we tolerate 40mm error. The altimetric error calculated is 11.4mm. This result is included in the work tolerance. This result is good enough.

#### **5. CARTOGRAPHY DESIGN ET TOPOGRAPHIC PLAN EDITION**

The survey of the cave and its treatment gave a cloud of points from which, a topographic plan is elaborated in the scale 1:200, by means of the sketches of field. To do it, we used CAD Microstation.

##### **5.1. Plans design**

In this phase, we proceed to the correct unification of points, by means of sketches designed on the field and the code introduced in the instrument when we record points.



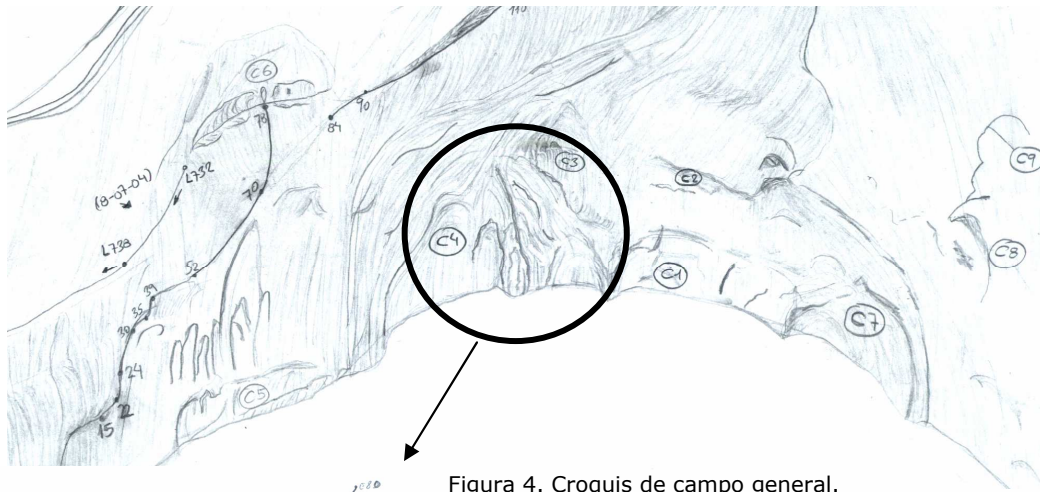


Figura 4. Croquis de campo general.

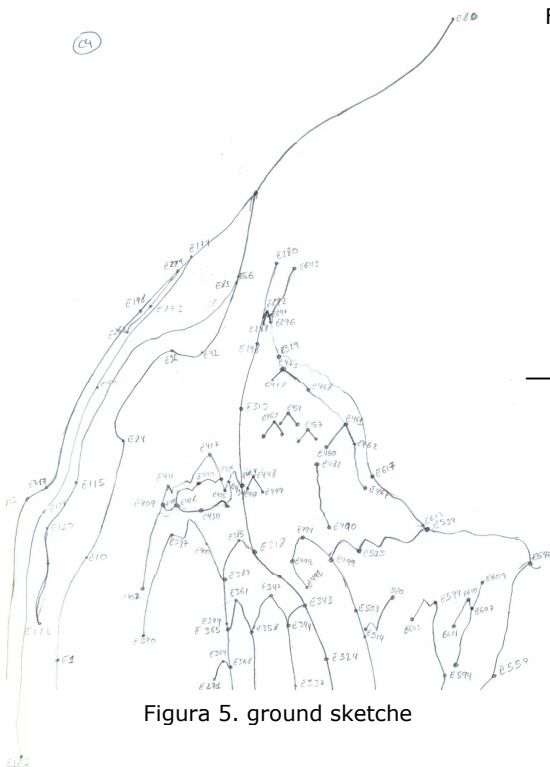


Figura 5. ground sketche

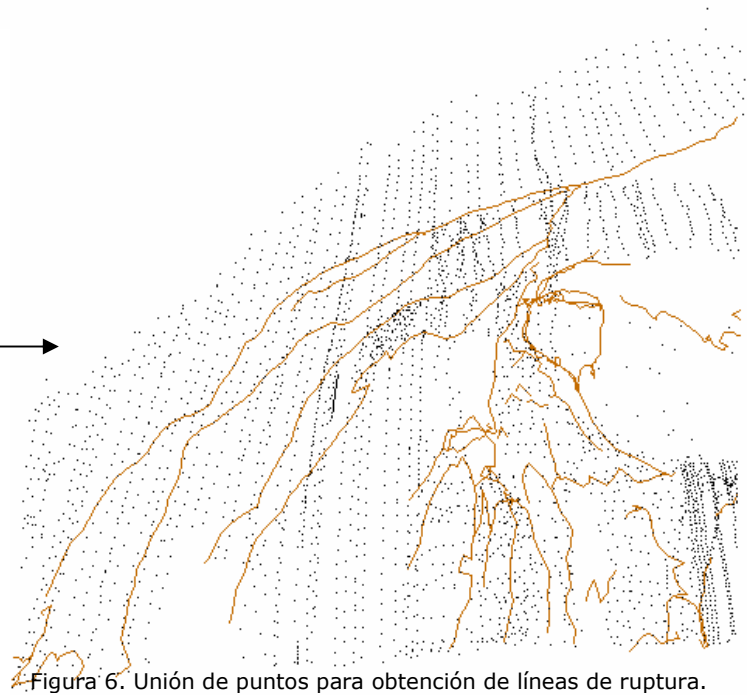
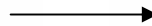


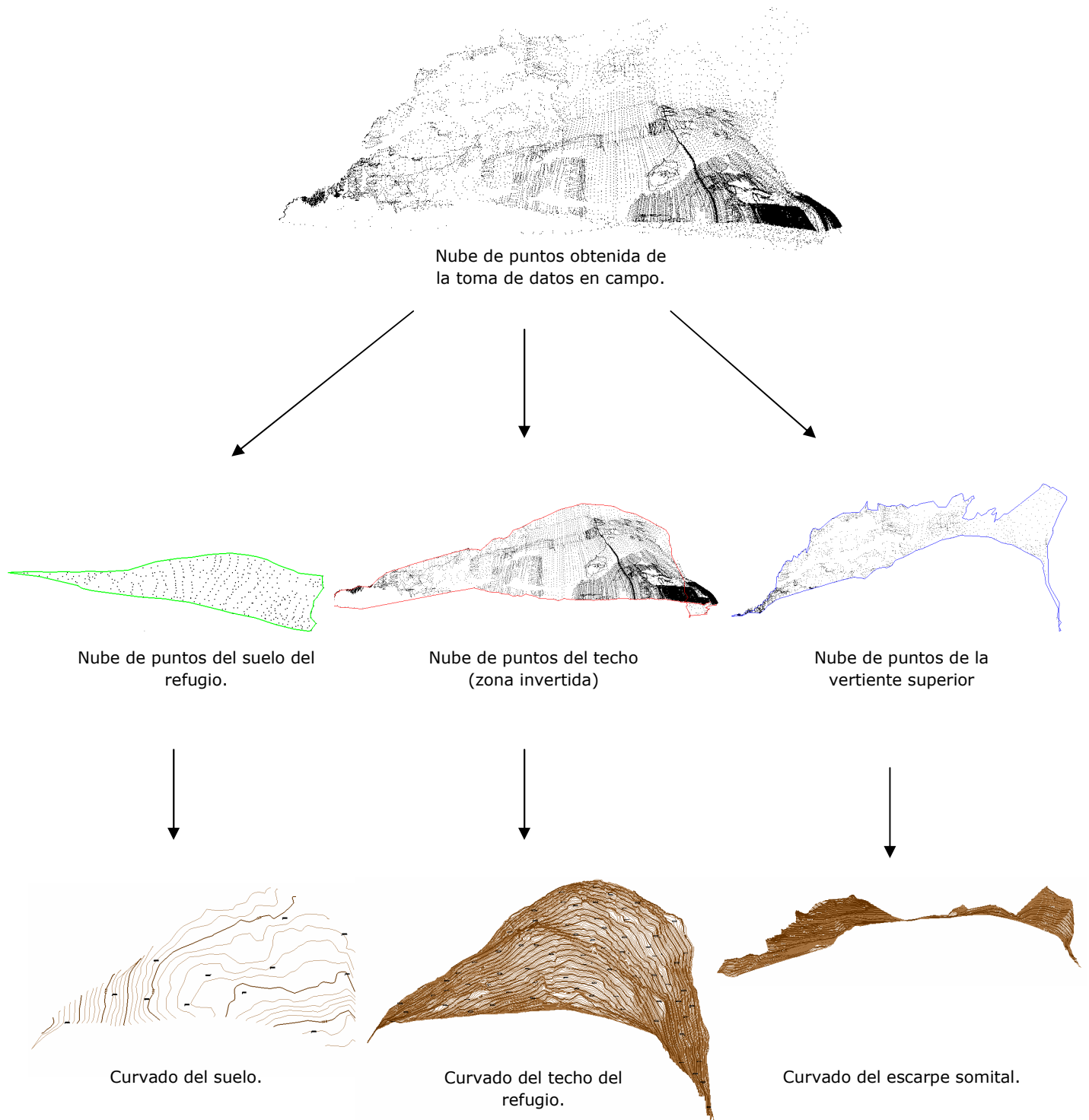
Figura 6. Unión de puntos para obtención de líneas de ruptura.

For the drawing of the symbols, we took into account the cartographic standards established for the scale in which were made plans and logical rules which allow a good reading.

The representation of the relief was made by means of the lines contour of 0.2m of equidistance in the plan at the scale 1:200, completed with a series of altimetric points. To obtain lines contour in zones where ground is vertical, the information was separated and the models were realized for every zone. Indeed, the programs cannot resolve yet the conflicts which are engendered by this type of topography.

We present here a diagram which explains the progress of the various work phases which consisted in treating separately the parts of the cave.





From this shape existed three sets of lines contour, one of the ground of the cavity, other one of its ceiling and the last one of the superior hillside. All overlap in the same horizontal space.

A problem appeared, it was necessary to stack the various sets of contour lines. The intersection of contour lines was inevitable. To face, we redrew lines belonging to lower level using discontinuing lines.

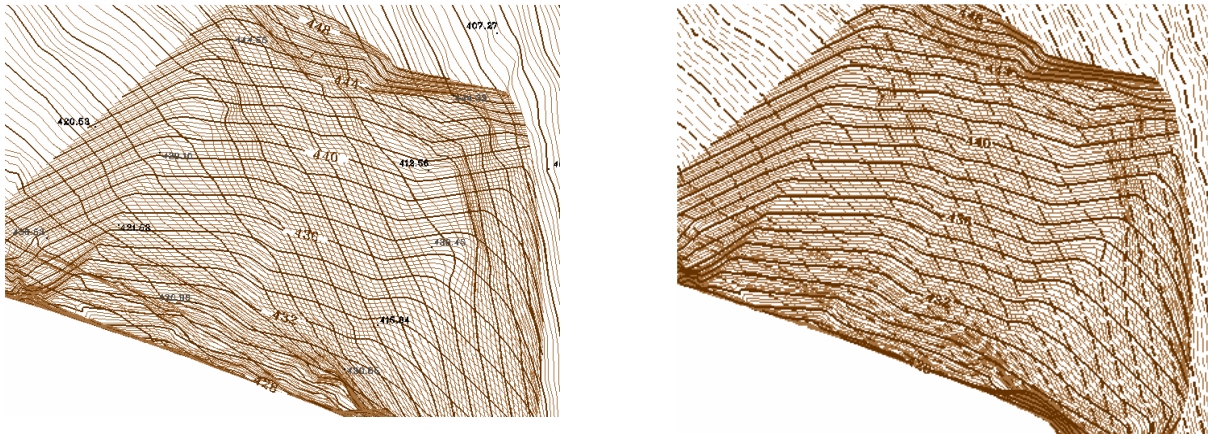


Figura 7: Curvado sin y con líneas discontinuas

In these zones of intersection, we added lines marking the perimeter of the zone or there were the contour lines of lower quotation. This process was applied everywhere it improved the reading of the plan.

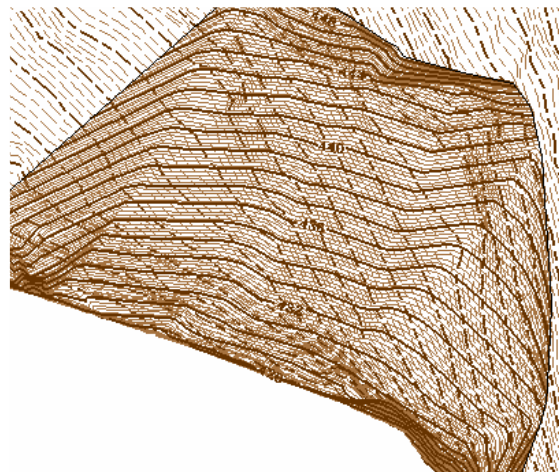


Figura 8: Curvado con líneas discontinuas y perimetrales

This solution engendered a representation still a little bit vague. We decided to attribute a color to the various groups of contour lines: grey for the contour lines of the lower and brown zones for the contour lines of the superior zones.

Finally, to differentiate well the ceiling of the cavity of the ground, we used artificial symbols. For the ground, a from representing the ground was used. For the part in massive rock, one used another color. In this way, we obtained a fast and clear reading of the plan.

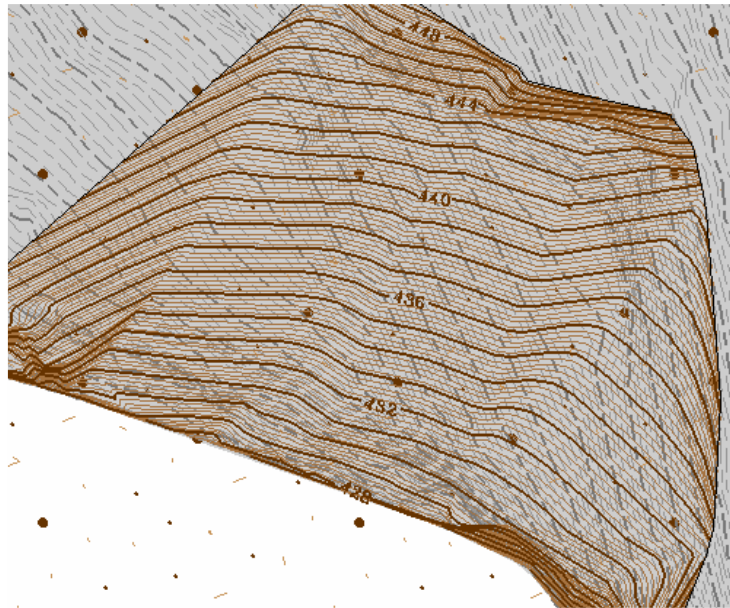


Figura 9. Roca maciza en gris continuo. Suelo patrón superficial puntos y rayas marrones. En la cavidad ambos patrones coinciden superficialmente.

## 6. CAVE DIGITAL MODEL

To make the cavity digital model, we used the MGE program, which Terrain Analyst application is specific for the creation, manipulation, edition, the display and digital models analysis.

To make the MDT, it was necessary to draw the principal lines of the ground (the lines which indicate a change of abrupt slope in the relief) and the dark zones (the zones in which we do not wish that the digital model appears).

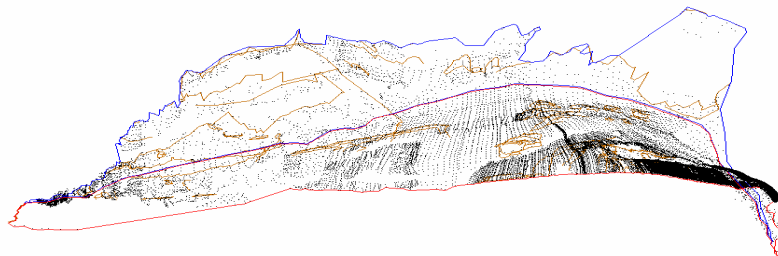


Fig. 8. Clouds of points, lines of structure and edges.

The following phase was the creation of a triangular network. From this network, we engendered by a linear interpolation, the curved surface of the model corresponding to the plan in a scale 1:200. The equidistance is 0,2m. Once the curved surface was made, we edited contour lines. We eliminated the errors introduced by the curving application.

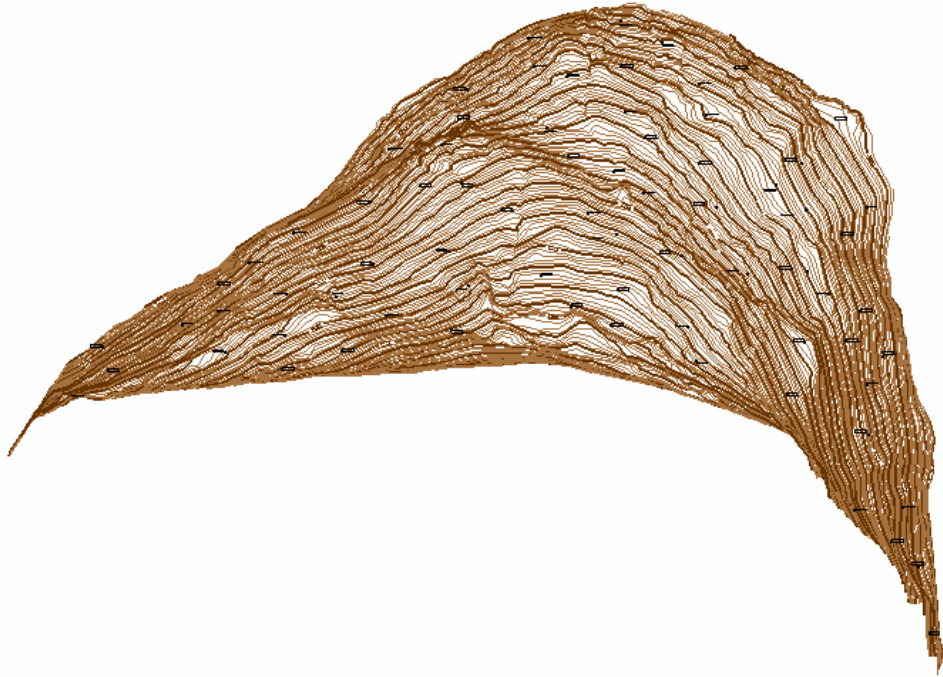


Figura 9: Imagen del curvado en planta del techo de la cavidad

Then, we made an interpolation to create the regular network GRID. The objective was to obtain a refuge three-dimensional display. We selected several sights of the result obtained from the three-dimensional vision of the cave and from its environment. We present them here:



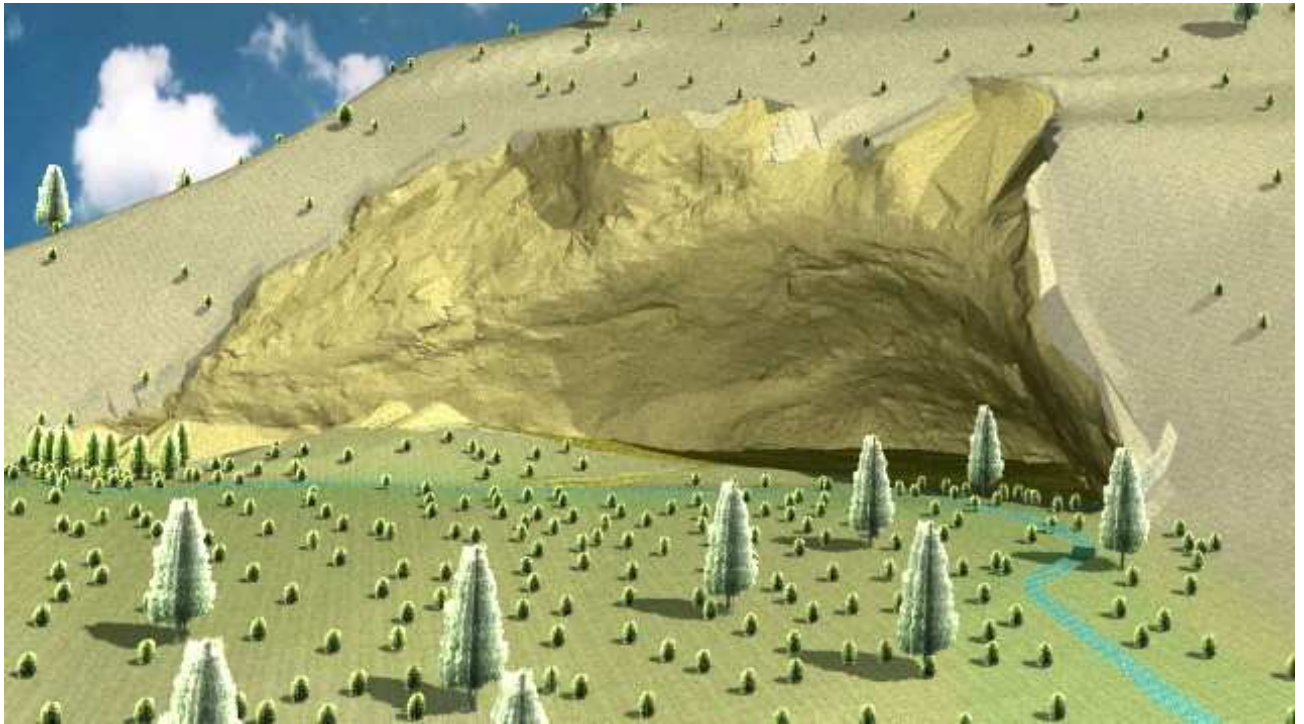


Figura 10. Refuge general view

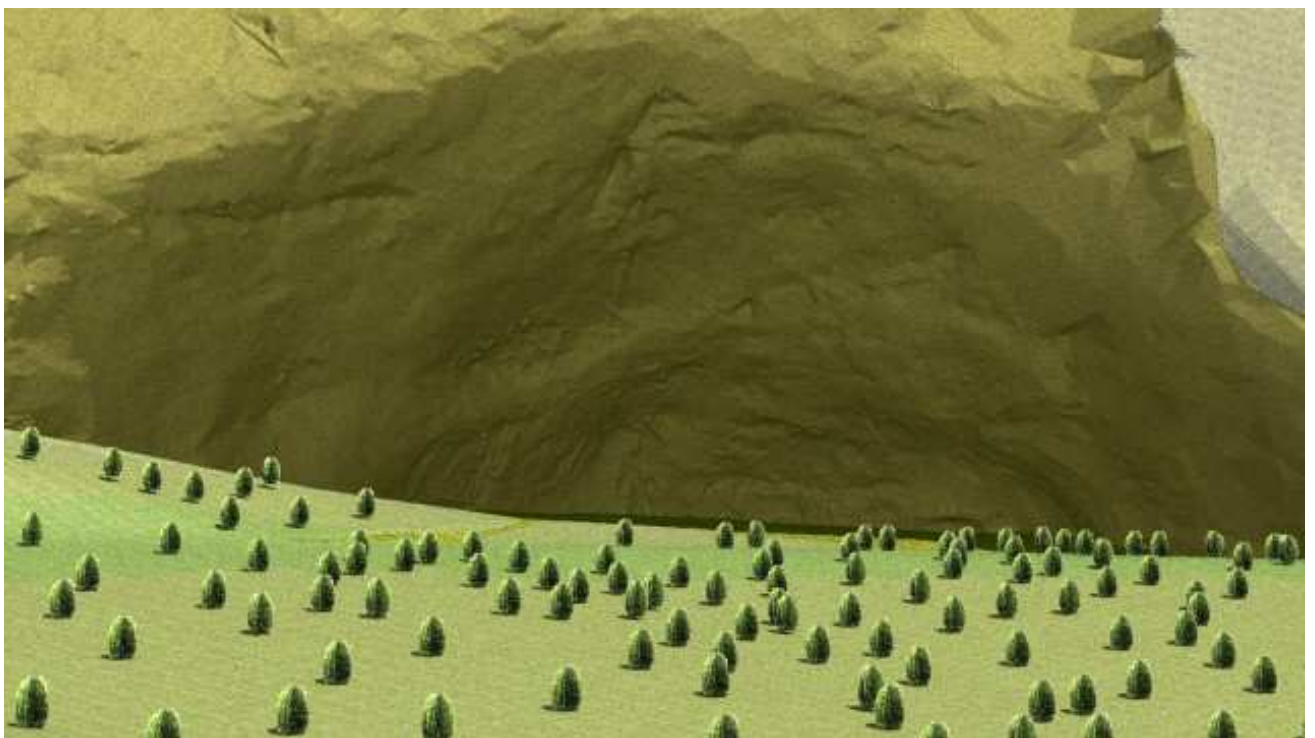


Figura 11. Cavity face view

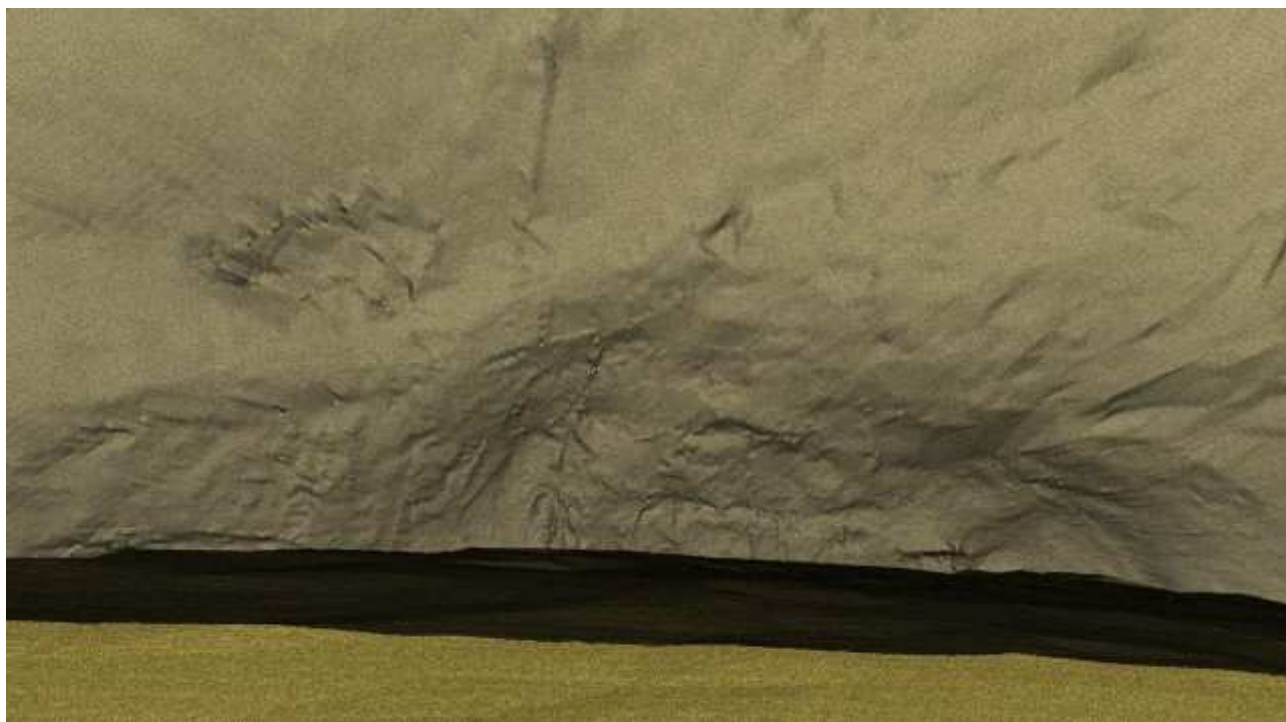


Figura 12. View showing the accuracy of the work

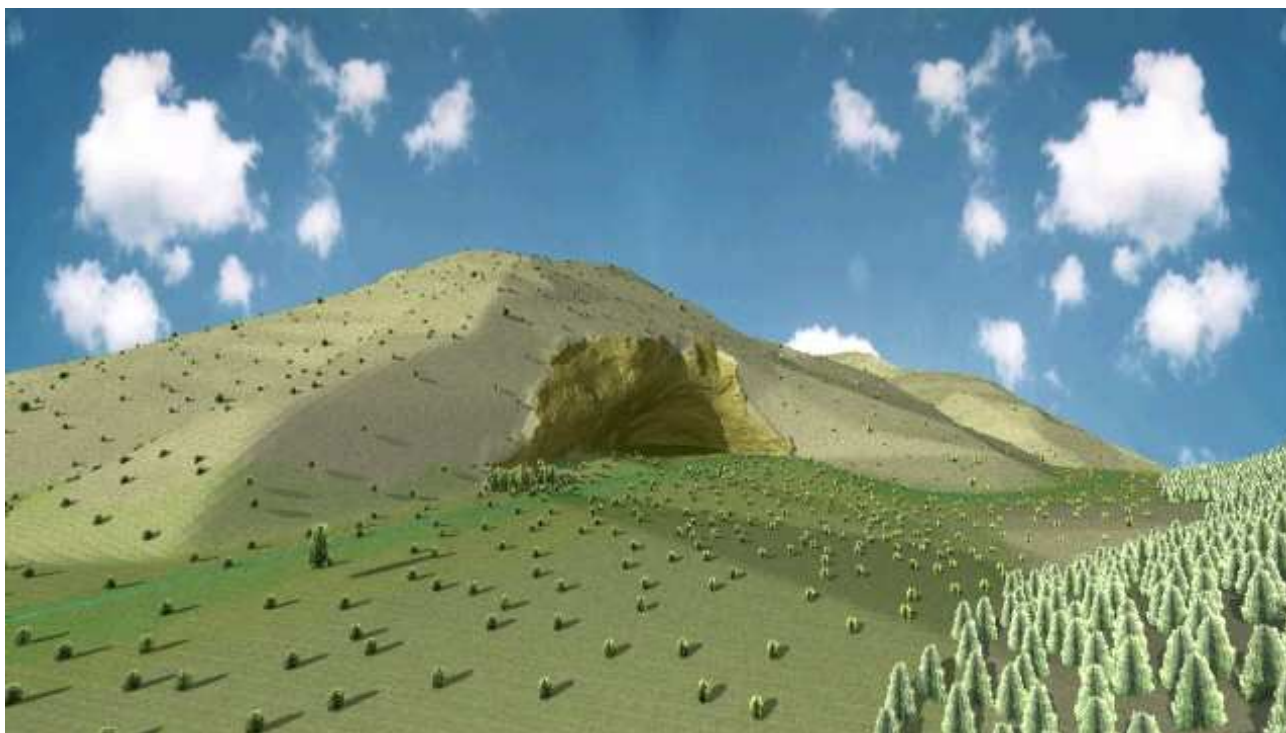


Figura 13. Refuge environment view



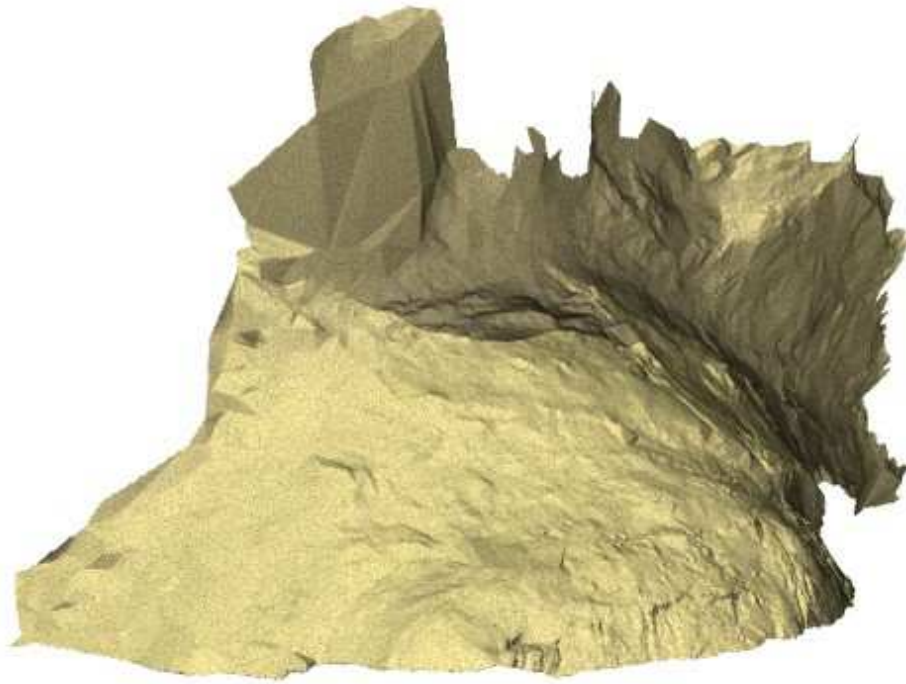


Figura 14. Other view

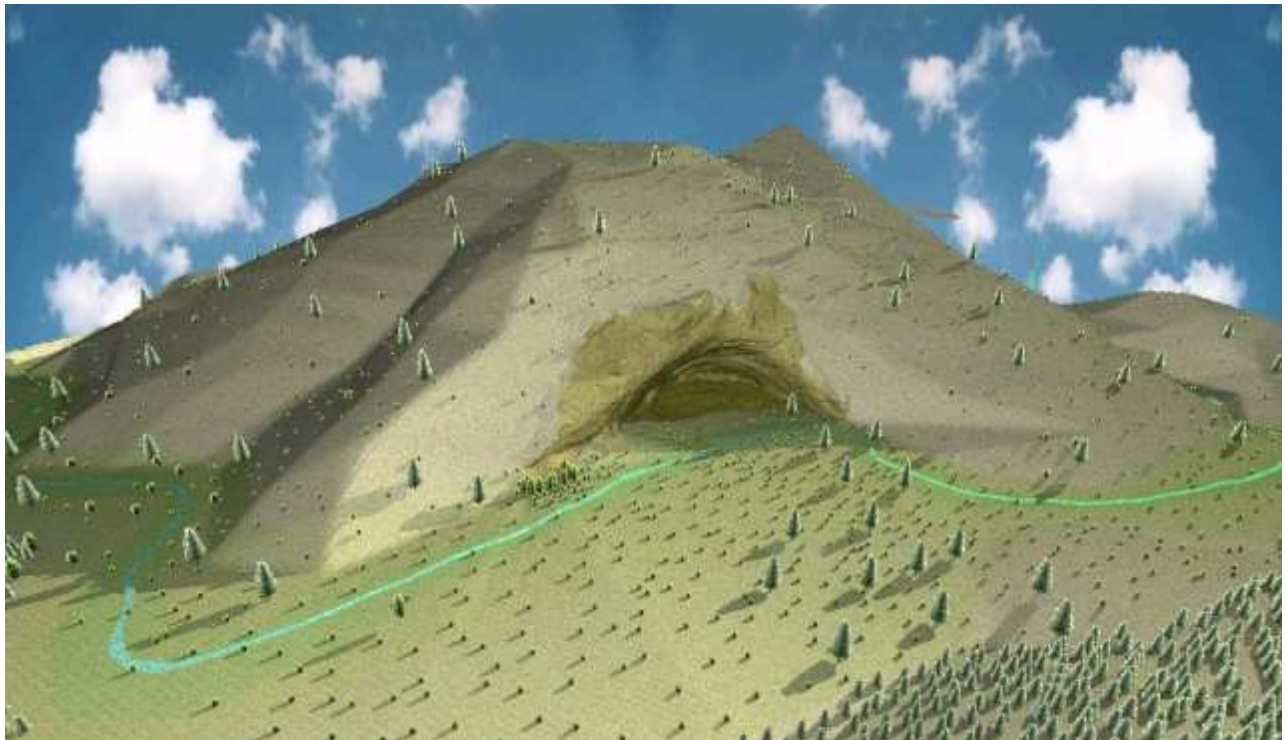


Figura 15. Cave general view with a 9:00 am light.



## 7. BUDGET

This budget was made with Microsoft Project.

	Nombre de tarea	Costo total
1	<input type="checkbox"/> <b>Cova Gran</b>	<b>40.374,00 €</b>
2	<input type="checkbox"/> <b>Trabajos preliminares</b>	<b>1.069,00 €</b>
10	<input type="checkbox"/> <b>Trabajo de campo</b>	<b>7.145,00 €</b>
27	<input type="checkbox"/> <b>Trabajo de gabinete</b>	<b>32.160,00 €</b>
2	<input type="checkbox"/> <b>Trabajos preliminares</b>	<b>1.069,00 €</b>
3	Recopilación de informes	440,00 €
4	<input type="checkbox"/> <b>Preparación del trabajo</b>	<b>629,00 €</b>
5	Obtención de cartografía y fotografías	110,00 €
6	Identificación de vértices	60,00 €
7	Obtención de coordenadas	60,00 €
8	Preparación del equipo de trabajo	399,00 €
9	Fin de los trabajos preliminares	0,00 €
10	<input type="checkbox"/> <b>Trabajo de campo</b>	<b>7.145,00 €</b>
11	<input type="checkbox"/> <b>GPS</b>	<b>1.210,00 €</b>
12	<input type="checkbox"/> <b>Red</b>	<b>850,00 €</b>
13	Reconocimiento de la zona	130,00 €
14	Localización de vértices	260,00 €
15	Observación con señalización	460,00 €
16	<input type="checkbox"/> <b>Poligonal</b>	<b>360,00 €</b>
17	Implantación	130,00 €
18	Observación	230,00 €
19	<input type="checkbox"/> <b>Topografía clásica</b>	<b>5.535,00 €</b>
20	<input type="checkbox"/> <b>Poligonal</b>	<b>299,00 €</b>
21	Implantación de bases intermedias	130,00 €
22	Observación	169,00 €
23	<input type="checkbox"/> <b>Radiación</b>	<b>5.236,00 €</b>
24	Toma de puntos	5.236,00 €
25	Toma de fotografías para el modelo	400,00 €
26	Fin del trabajo de campo	0,00 €

27	<input type="checkbox"/> <b>Trabajo de gabinete</b>	<b>32.160,00 €</b>
28	<input type="checkbox"/> <b>GPS</b>	<b>840,00 €</b>
29	Volcado de datos y edición de datos	240,00 €
30	Cálculo de coordenadas y ajuste	600,00 €
31	<input type="checkbox"/> <b>Topografía clásica</b>	<b>960,00 €</b>
32	Volcado de datos y edición de datos	240,00 €
33	Cálculo de coordenadas y ajuste	720,00 €
34	<input type="checkbox"/> <b>Diseño cartográfico</b>	<b>1.560,00 €</b>
35	Diseño de los planos	720,00 €
36	Edición de los planos	600,00 €
37	Impresión de los planos	240,00 €
38	<input type="checkbox"/> <b>Reconstrucción tridimensional del refugio</b>	<b>4.800,00 €</b>
39	Dibujo del refugio	2.400,00 €
40	Asignación de materiales y de la iluminación	2.400,00 €
41	<input type="checkbox"/> <b>Formación del modelo digital</b>	<b>600,00 €</b>
42	Creación del modelo	600,00 €
43	Generación de la película	600,00 €
44	<input type="checkbox"/> <b>Edición de la información</b>	<b>5.760,00 €</b>
45	Edición de la memoria	3.600,00 €
46	Edición de las imágenes	1.800,00 €
47	Edición de los videos	360,00 €
48	Fin del trabajo de gabinete	17.040,00 €

The total cost is 53.858 euros.

## 8. CONCLUSIONS

For the stake out of the network, the use of the GPS showed itself decisive by producing important time saving. However, we were not able to observe all the points we wished, with the GPS.

Thanks to the methods of classic topography, we were able to end the network used for the survey of the refuge. Beforehand, we have of to study sites for bases so that these last ones were inter visible.

Finally, we made a three-dimensional ground model and a mapping of the place. We note that the current computing tools allow the creation of these models, but they are not prepared to resolve conflicts engendered by representing vertical walls. This

problem forced us to separate the information to treat it in best. These tasks were the most laborious.

#### Acknowledgment

To the students José Manuel Castaño y Fabián Estebarán, and all the supervisors and students who made possible the project and this report.

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- **INTERGRAPH.** Manuales de Microstation J.
- **INTERGRAPH.** Manuales de MGE Terrain Analyst.
- **LEICA.** Manuales GPS Leica System 300.
- **LEICA.** Manual Leica TPS Performance Series.
- Diccionario de la Real Academia de la Lengua Española.
- Enciclopedia interactiva "Encarta 2005".

#### Projects :

- **Bohigas Roldán, Ana.** "Topografía arqueológica. Obtención de la cartografía a escala 1: 100 del yacimiento arqueológico de Tuqueibah (Emirato de Sharjah)". No publicado.
- **Alonso Rodríguez, Miguel Ángel.** "Levantamiento topográfico del interior de la cúpula de la basílica del Monasterio del Escorial". No publicado.
- **Bodas Bodas, Carlos; Vélez Martínez, José Juan.** "Proyecto e implantación de una Red Básica mediante GPS para posteriores levantamientos de detalle arqueológicos en el yacimiento de Tuqueibah (Emirato de Sharjah). Levantamiento a escala 1: 1 000 con receptores GPS". No publicado.

#### Web sites:

- <http://www.icc.es/>
- <http://www.leica-geosystems.com>
- <http://seneca.uab.es/arqueologia.htm/>

# **ANNEXE I. PLANS**

ANNEXE I. PLANS

