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Gypsum Karst Areas in the World:
their protection and tourist development

a cura di
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Gessi Bolognesi: le morfologie del Buco delle Candele in una tavola di G. Capellini (1876) e nell'aspetto attuale (foto P. Grimandi).

Cover:
Gypsum karst area of Bologna (Italy): karst morphologies of the Buco delle Candele from G. Capellini (1876) and the same area in an actual view (photo P. Grimandi).

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ENVIRONMENTAL CONTROL OF CAVES IN THE GYPSUM KARST OF SORBAS

José Maria Calaforra [1], A. Fernández-Cortés [1], J.A. Gázquez-Parra [2]

Riassunto

Monitoraggio ambientale di grotte nell'area carsica gessosa di Sorbas.

Viene descritto un sistema di monitoraggio installato nelle grotte in gesso di Sorbas (Almeria, Spagna). Il sistema era stato inizialmente progettato per studiare le modificazioni indotte dalla frequentazione umana di una grotta a seguito della sua apertura al turismo. La trasmissione alla stazione dell'Univestità di Almeria dei dati sulla concentrazione dell'anidride carbonica, della temperatura e della umidità relativa assieme al numero di visitatori avviene in tempo reale attraverso un ponte radio. Le informazioni microclimatiche sono rese disponibili su internet (http://karst-yeso.ual.es) in maniera che chiunque sia in grado di conoscere in tempo reale la situazione dei parametri microclimatici della grotta e l'evoluzione degli stessi dopo che una visita è stata effettuata. La necessità di effettuare misure automatiche in una stazione remota, assieme al fatto che si rendeva necessario variare l'intervallo di lettura e di sensibilità dei singoli sensori in maniera dinamica, ha fatto sì che si sviluppasse un sistema hardware e software specifico per il monitoraggio in grotta. Tale sistema potrà in futuro essere un interessante mezzo per la gestione di altre grotte turistiche.

Parole chiave: grotte turistiche, grotte in gesso, sistemi di monitoraggio ambientale, telemetria, Spagna.

Abstract

A cave environment monitoring system installed in the gypsum caves of Sorbas (Almería, Spain) is described. The system was initially designed to study the antropogenic change of a cave due to the beginning of tourism activities. Data of carbon dioxide concentration, temperature, relative humidity and presence of visitors are send on real-time via radio to the University of Almería base station. The microclimatic information is published by internet (http://karst-yeso.ual.es) so everybody can check the microclimatic conditions of the cave and know the influence and environmental recovery after a real visit in real-time. The combination of a remote location and the need to dynamically alter how readings are taken led to the development of custom hardware and software for a cave-monitoring system. The system could be a very interesting tool for the management of a show cave.

***Keywords**: show cave, gypsum cave, environment monitoring system, telemetry, Spain.*

Environmental importance of the Gypsum Karst of Sorbas: some reasons for conserving the caves

The Sorbas Karst (Almería) is a small gypsiferous outcrop, 12km^2 in extent, which contains almost 1,000 sinkholes and caves (CALAFORRA, 1998; CALAFORRA & PULIDO-BOSCH, 1997). The enormous concentration and variety of surface and subterranean karstic formations (CALAFORRA & PULIDO-BOSCH, 1999) make it one of the most important gypsum karst environments in the world. On the other hand, some special environmental conditions like semiarid climate and high levels of soil salinity turns it into a biodiversity hot spot area. The criptogamic flora of the gypsum outcrop have the higest biodiversity level of the Iberian peninsula (GUTIÉRREZ & CASARES, 1994). The gypsum

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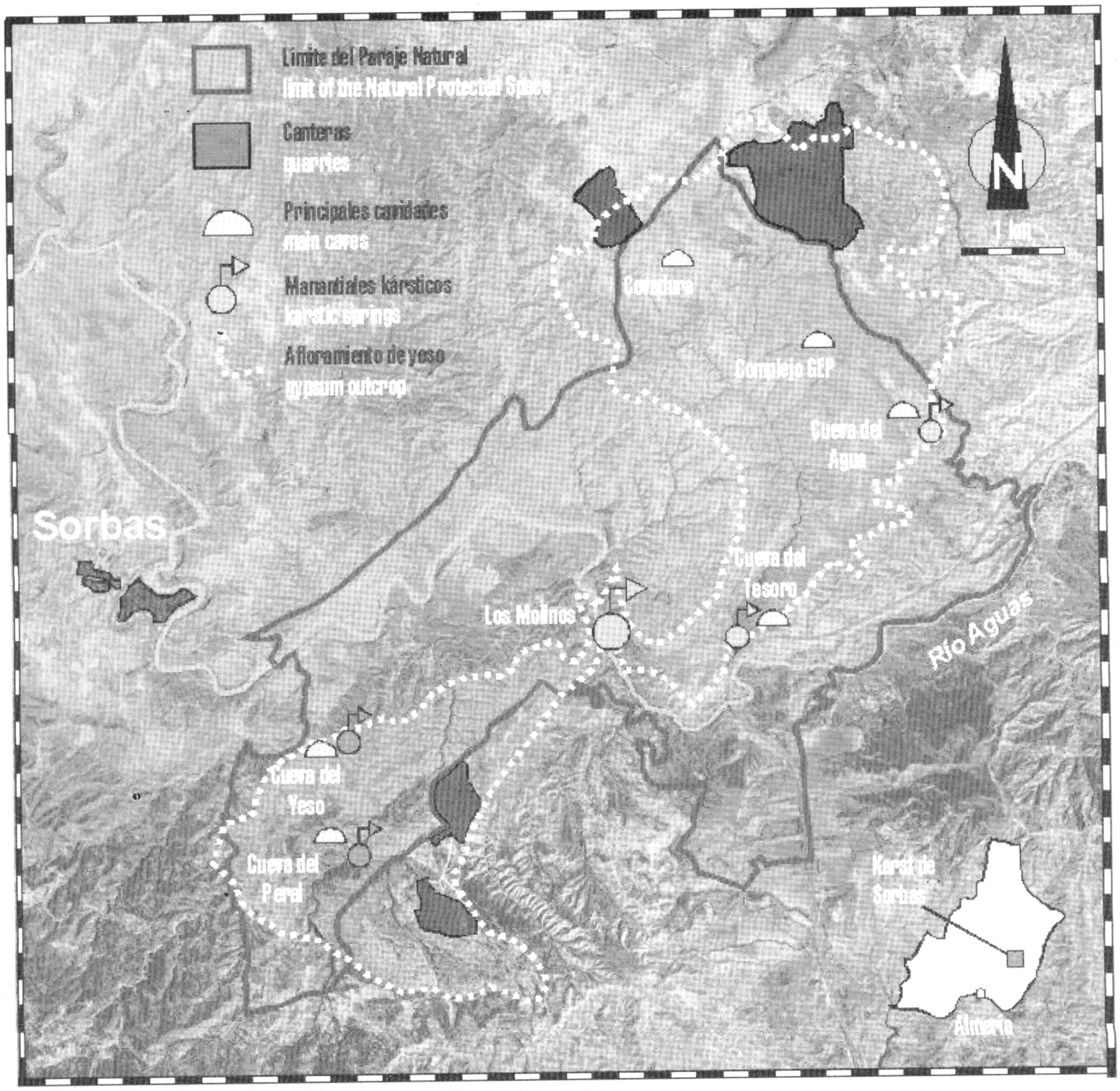

Fig. 1

Gypsum outcrop and Natural Space of the Karst of Sorbas, main caves and springs.

flora also attains a greater significance with three endemic species: *Narcisus tortifolius*, *Helianthemum alypoides* and *Teucrium turredanum*. With respect to the caves the research about cave entomofauna of Sorbas accomplished by University of Almería has provided, at present, the discovery of four new species: *Pseudosinella* sp. nov., *Chthonius* sp .nov., *Coletinia* sp. nov. and *Tychobythinus* sp. nov. (RUÍZ-PORTERO et al., 2000, 2002), *Palliduphantes cortesi* sp. nov., and *Palliduphantes gypsi* sp. nov. (RIBERA *et al.*, 2003).

In addition, the gypsum also comprises a mineral resource that has been exploited since the middle of the last century. The mining sector has played an important role in the development of the region and has forms the socio-economic base of the area. The annual production in 1998 was close to 23.5 million euro generating a quota of employment of about 400 direct and indirect employments (CONTRERAS-LÓPEZ & CALAFORRA, 2002). Lack of diversification of economic activities, together with the impact of mining on the environment have brought this karstic area to a situation of environmental unsustainability. The absence of a Natural Resources Ordenation Project neither planning the use and management of this natural area is the main problem nowdays. Development around the mineral resources has historically obviated the other functions and values of the natural heritage.

In 1988, the Spanish Administration recognized its rich environmental value and declared it a Protected Natural Space. An extension of 23.75 hectares was protected using the existent lineal infrastructures, specially highways and roads, as limits to define the protection area. For this reason the gypsum outcrop area is not totally protected,

Fig. 2

Main gallery of Sistema Covadura cave (Gypsum Karst of Sorbas).

Photo: Jabier Les

existing karstic areas to the north (Zona Jardín) and to the south (Cerrón Hueli) that are outside the limits the Natural Space and where the gypsun mines are located (Fig. 1). Note that activity and licenses of exploitation are previous to the declaration of Natural Space. Nowadays, the karst outcrop and the mining activity are in fragile environmental. Mining activity is located in the limits of protected area without existing a policie perimeter of control between them.

Tourism and caves into Gypsum Karst of Sorbas

At the present time, the tourist development of the Gypsum Karst of Sorbas is based in the adventure visit of several caves and represents the main sustainable economic alternative to the gypsum mines. There are some private companies that have concerted with the Administration visits of reduced groups (up to 20 visitors per group) in the Cueva del Yeso and in the most subsurface galleries in the Sistema Covadura (Fig. 2).

The "adventure tourism" is based on speleology-type visits with single electrical illumination and absence of paths or artificial structures faciliting the access. According to the data of control of visits 53 visitors daily access to the Cueva del Yeso. The tourist exploitation of these caves has considerable increased diary level last years.

The research project FEDER-SORBAS: Framework to sustainable management of show caves

Show cave management should be able to preserve the cave environment under risk limits and support a sustainable visitors capacity (CIGNA, 1993; CALAFORRA *et al.*, 2003). It is advisable to have some enviromental tools management which facilitate and characterize the main parameters of the cave and to obtain some environmental indicators under natural conditions. This database will be used as reference for the objective evaluation of the human impact during the tourist exploitation of the cave. In this sense, the research project FEDER-SORBAS (Spanish Interministerial Commission of Science, Project number: 1FD97-1577) constitutes the first phase of tourist potential possibilities of the Gypsum Karst of Sorbas: the opening of a show cave. On the other hand, many cases of exploitation of the environmental heritage assure their conservation, became the added economic and cultural value are reasons that can be used to develop their protection. A correct

environmental management of a show cave can impact favorably when fomenting the environmental education of the visitors.

Objetives of the research project FEDER-SORBAS

The main objectives of this research project are:
- To know the environment of the most significant caves of gypsum karst of Sorbas;
- To determine the inter-annual variation, inside and outside caves, of the environmental parameters: temperature (air-water-rock), relative humidity, natural ventilation, carbon dioxide concentration, relationship between the rainfall and cave drip water rate, etc.;
- To compare the microclimatic stability of each cave and their recovery inertia after different types of human presence;
- To determine the caves that are susceptible of tourist use, evaluating the environmental impact on them.

Intelligent environmental control system of caves

Monitoring of basic physical variables in show caves is highly recommendable because cave lighting and the presence of visitors immediately modify ambient conditions within the caves. A cave that receives a continuous stream of visitors can suffer changes in relative humidity, air temperature and CO_2 concentration, among other variables, as a result of the presence of visitors. Such variations could mean a change away from the optimal living conditions of the troglobite fauna, or changes in the growing conditions of speleothems. Therefore, measuring these variables is of great value for trying to achieve the appropriate environmental conservation of the cave.

The classical way of measuring and recording variables uses data-loggers and confers the advantage of independence in terms of placement of the instruments and autonomy in the acquisition and storage of the periodic measurements from the sensors. The limitations of such equipment derive from the battery life and the memory available for data storage and so these data acquisition systems require periodic servicing to replace the battery and download the data (Fig. 3). In addition, because they are isolated and have no communication to the exterior, the frequency of readings can not be easily modified according to external events.
In order to determine the influence of cave visits on environmental conditions inside the

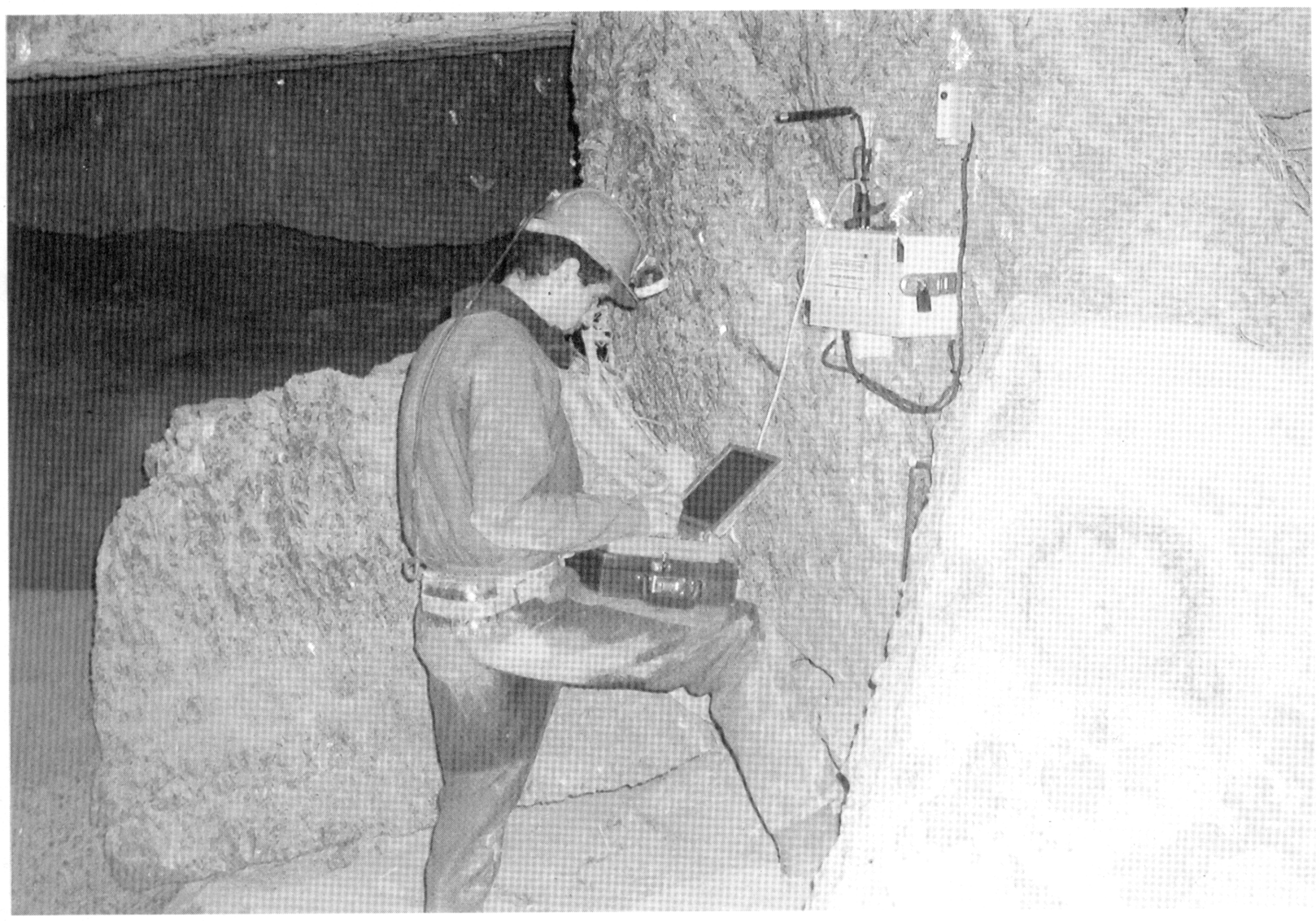

Fig. 3

Single environmental control station locates inside Cueva del Yeso (Gypsum Karst of Sorbas).

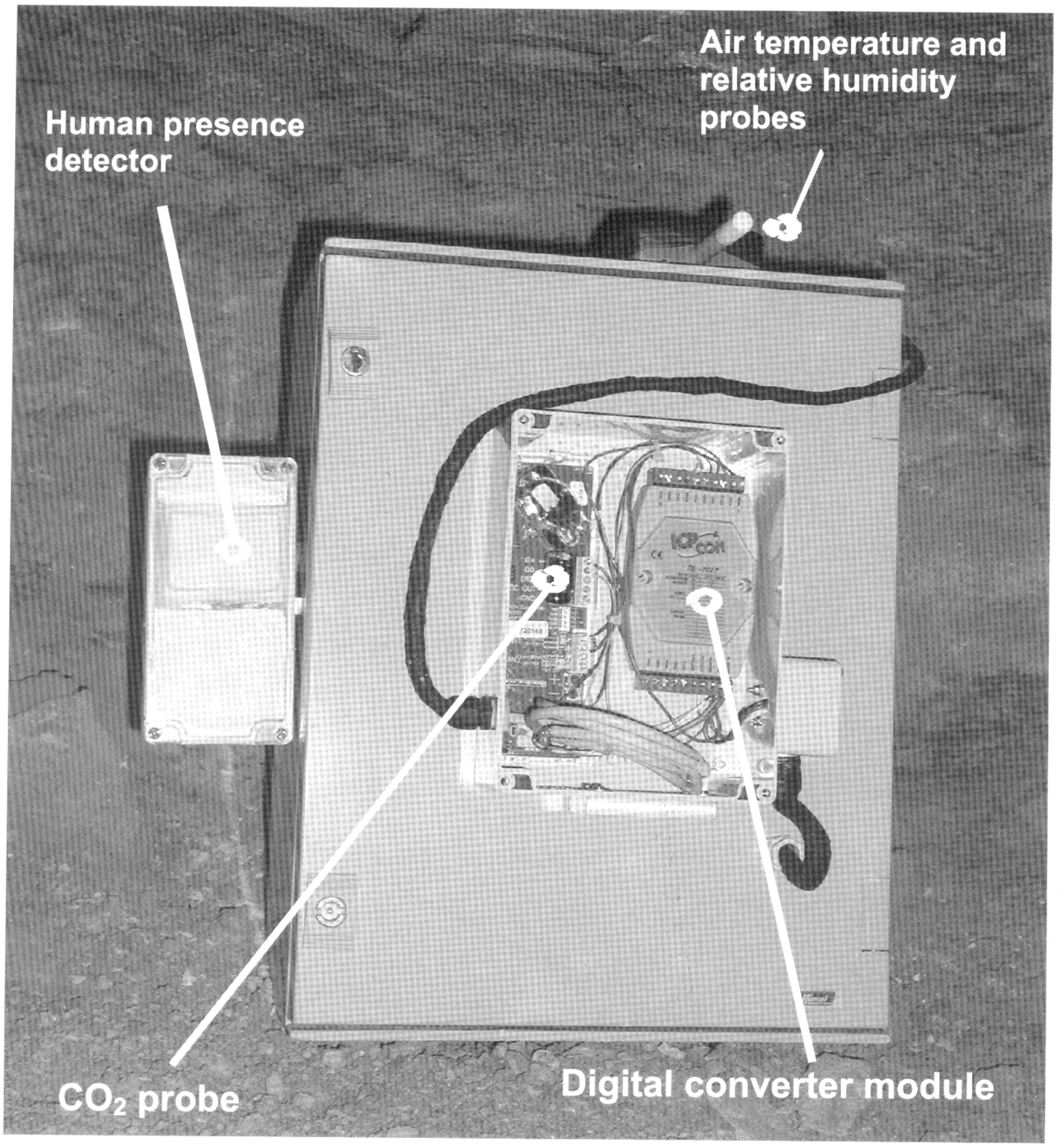

Fig. 4
View of a remote microclimatic control station inside Sistema Covadura cave.

cave, and to assess the degree of impact in terms of physical and biological conservation, it would be useful to automatically increase the frequency of data acquisition of all the sensors in the cave, for example, when people are detected inside. In the Karst of Sorbas these situations have been solved with the installation of microclimatic control system based on techniques of distributed control and telemetry, to allow intelligent and customized dates acquisition. This system supports the measurement and a real time transmission to the station located in the University of Almería.

Environmental control stations

The environmental control stations have the function of acquiring the different variables and to transmit these data to a central station, who is responsible of the storage, treatment and diffusion of this information. Each sampling station contains the following set of environmental sensors with an analog output: (1) carbon dioxide concentration, in ppm, (2) temperature, in ºC and (3) relative air humidity as a percentage. It also incorporates a human presence detector to monitor visitors to the cave (Fig. 4). Data is digitized using a commercial data acquisition module.

Data communication and control network

In first instance, the information collected by the various data-sensors at the remote stations is transferred to a local computer situated in a small building close to the cave. This computer is responsible for formatting the data received from the sensors. Subsequently, the information is sent to a central computer for data processing and storage located at the University of Almería. To perform these functions, a mixed communications system was required. The first stage (remote stations

– local computer) utilizes 1km long cable RS-485 communication, while the second (local computer – central computer) requires a wireless communication via radio (GÀZQUEZ *et al.*, 2003). The adquisition data system have a protocol who allows the local computer to identify, every 30 seconds, whether there are people present in the cave or not, and so to establish the polling rate for data acquisition using the following criterion:

- (1 min): measurements every minute if human presence was last detected less than one hour ago;
- (1 h): measurements every hour if human presence was last detected more than one hour ago.

The system permits the sampling frequency to be increased to allow a more detailed study of the impact of a visit on the environmental parameters in the cave. In addition, the established intervals of 1 min or 1h can be adjusted if necessary.

The second stage of the communication network is the transfer of information from the local computer to the central station located in the University of Almería. The Sorbas caves lie in a rather remote area with no telephone lines and so the two options available for data transmission are digital mobile telephone or autonomous communication using radiomodem. The second option is better-suited to monitoring of ambient conditions inside show caves because a constant connection is

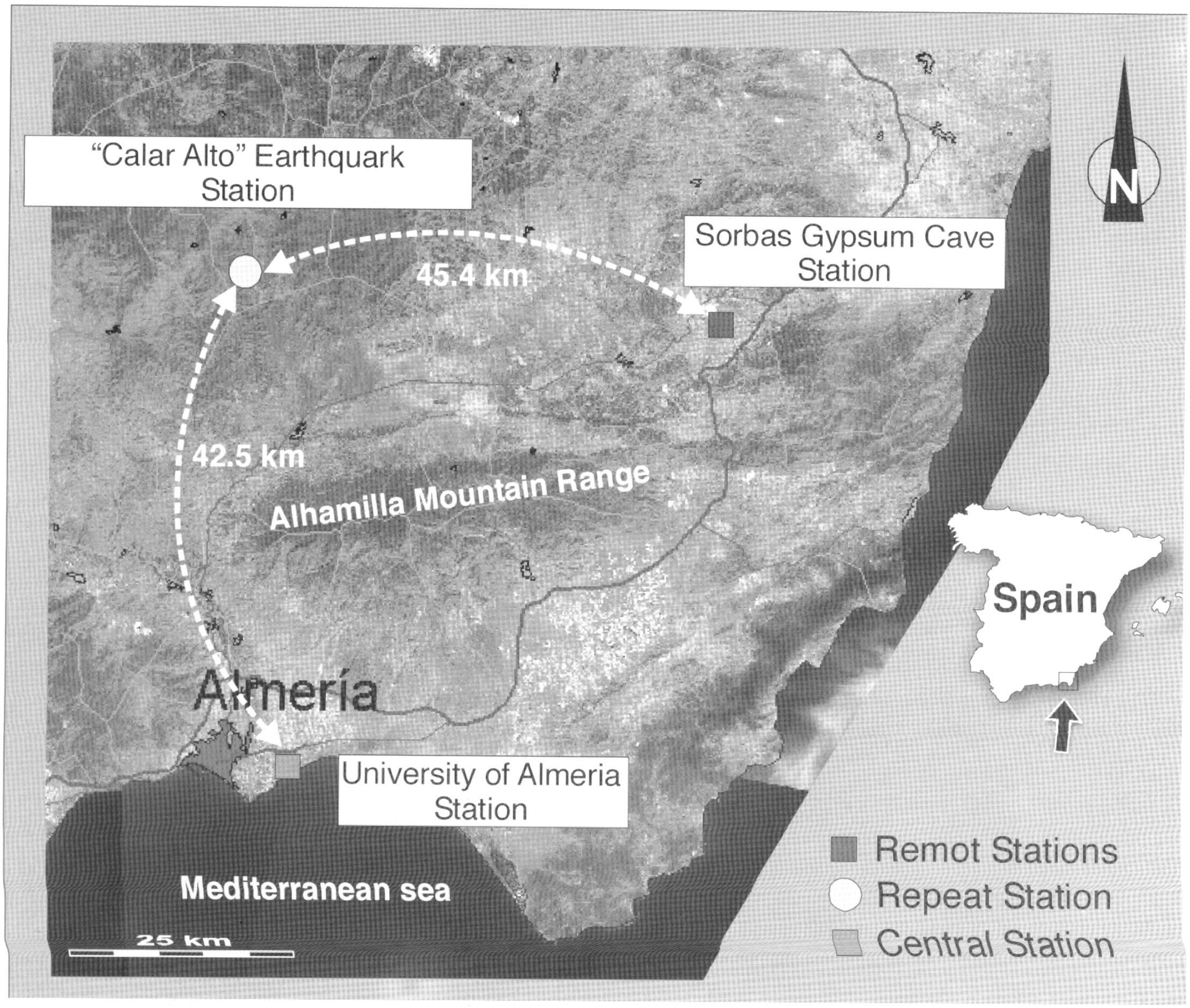

Fig. 5 - Radio communications between local station (Sistema Covadura, Gypsum Karst of Sorbas) and central station (University of Almería).

possible and does not require operators. In addition, the abrupt topography of the province of Almería prohibits a direct connection, due to the lack of cover between the local station in the Sorbas Karst (cave) and the central station (University of Almería). As a result, a repeater had to be installed that is covered by both stations. This repeater radiomodem was placed at the Seismological Station belonging to the Instituto Andaluz de Geofísica. The figure 5 shows the geographical distribution of the data transmission network.

Accessibility to the environmental control of caves in the Gypsum Karst of Sorbas

The data acquisition system installed inside the caves of Sorbas is allowing an intelligent environmental control of great interest for the future management agents of show caves. This system has been operated during last year and they already have a considerable volume of data. On the other hand, the automatic increase of the frequency of data acquisition for the system, according to the presence or absence of visits, offers detailed temporary series of the main environmental variables of a cave. This register will allow to

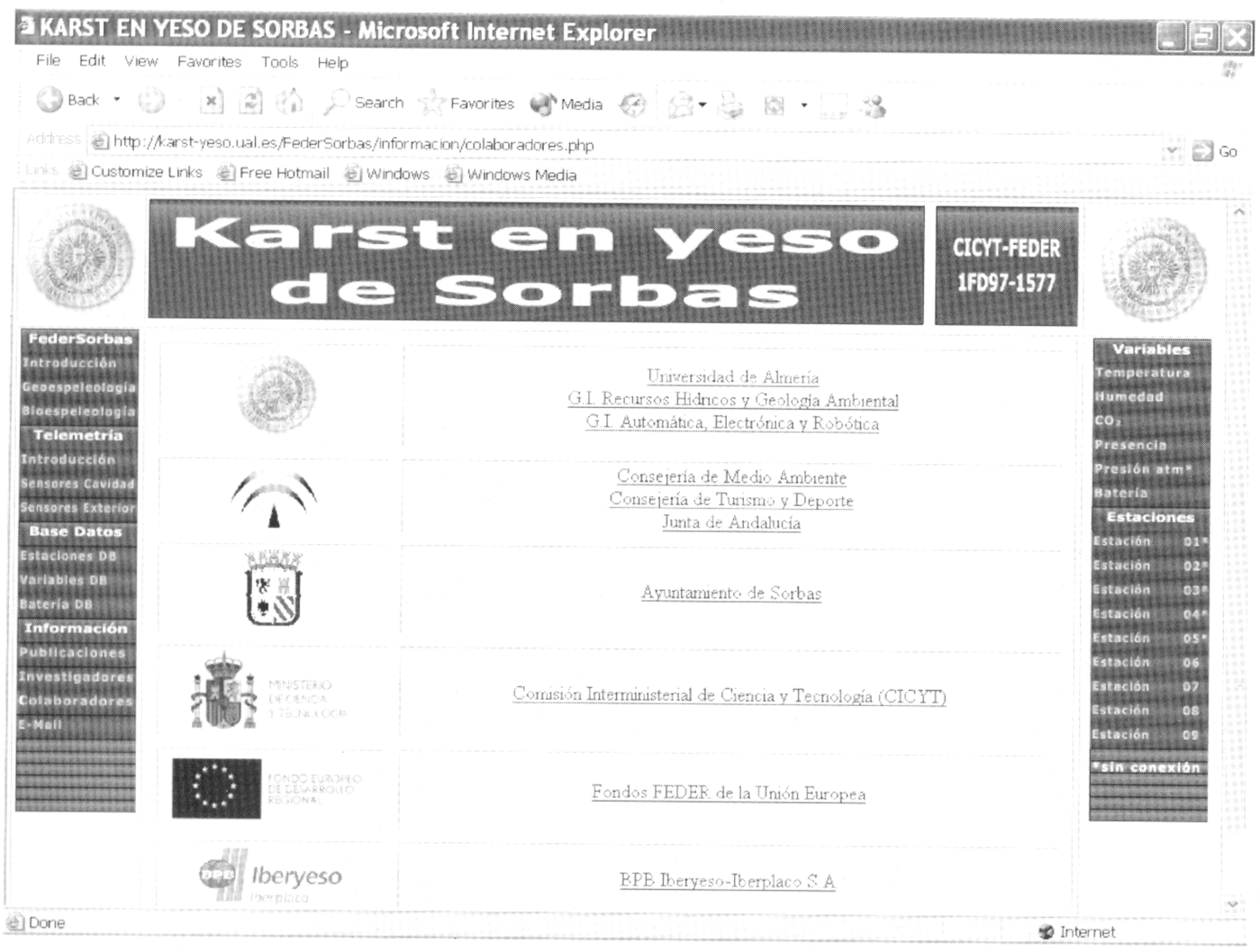

Fig. 6
Main web page of the research project FEDER-SORBAS.

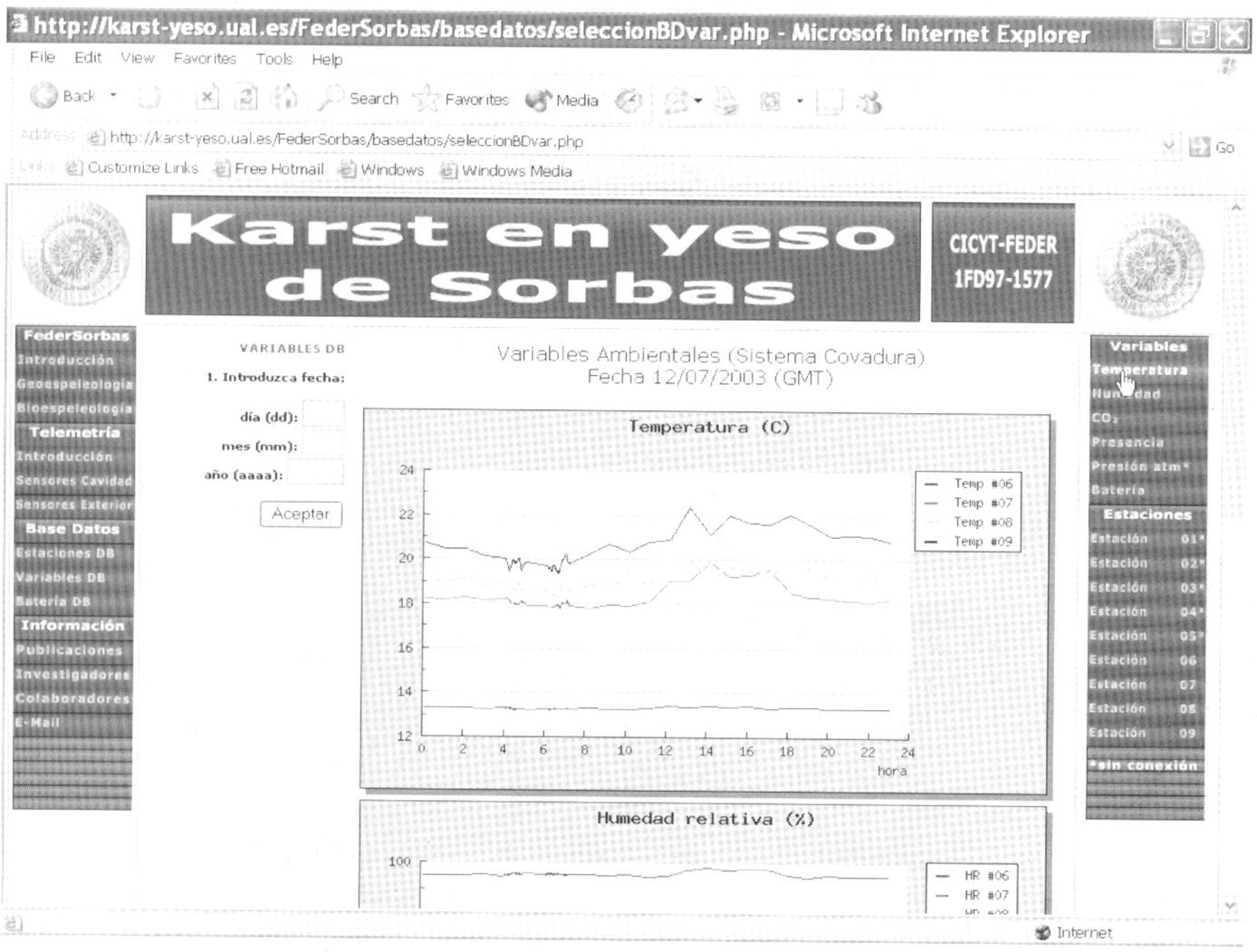

Fig. 7
Real time graph of air temperature inside Sistema Covadura cave (web karst-yeso.ual.es).

determine the ideal regimen of visits, in function of the incidence on each parameter and in many areas of the cave (9 stations with 36 sensors in total has been installed).

Lastly, the transfer of the research results would be direct, since these would have an immediate use for the Administration responsible of caves (Environment and Tourism offices of the Autonomous Government of Andalusia, City council of Sorbas and speleo-adventure companies). With these results the promotion of the rural tourism in these interior districts would be increased. This could suppose the possibility to change or to diversify the economic dependence of this area. The information is published on real time by means of the http://karst-yeso.ual.es page web (Figures 6 and 7), so that everybody can consult the microclimatic conditions of the cave and to know the influence and environmental recovery after a real visit.

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