Quaternaire

Karst in conglomerates in Catalonia (Spain): morphological forms and sedimentary sequence types recorded on archaeological sites [Le karst en conglomérats en Catalogne (Espagne) : Morphologies et séquences sédimentaires en rapport à quelques sites archéologiques.]

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Résumé

Dans cet article nous voulons analyser les types de morphologies karstiques qui se présentent en conglomérats et, les types de dépôts sédimentaires qu'on y localise. Notre attention a été centrée sur des lieux où il y a des occupations préhistoriques : grotte de la Font Major (Espluga del Francoli, Tarragona), l'Hort de la Boquera, l'abri du Filador et l'abri dels Colls (Margalef de Montsant, Tarragona) et la grotte du Parco (Alòs de Balaguer, Lleida).
Les particularités archéologiques et sédimentaires qu'offrent les dépôts karstiques en conglomérats, sont également analysés.

Abstract

This article aims to make the karst morphological forms to be found in conglomerate rocks, as well as the sedimentary sequence recorded in such deposits, more widely known. Particular attention is paid to points where prehistoric occupation has been traced, sites as: the Font Major Cave (Espluga de Francoli, Tarragona), the Hort de la Boquera, the Filador Rock-shelter and the Colls (Margalef de Montsant, Tarragona), and the Parco Cave (Alòs de Balaguer, Lleida).
By means of this approach the characteristics of karst deposits in conglomerate rocks are analyzed both from an archaeological and sedimentary point of view.

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KARST IN CONGLOMERATES IN CATALONIA (SPAIN) : MORPHOLOGICAL FORMS AND SEDIMENTARY SEQUENCE TYPES RECORDED ON ARCHAEOLOGICAL SITES

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ABSTRACT

This article aims to make the karst morphological forms to be found in conglomerate rocks, as well as the sedimentary sequence types recorded in such deposits, more widely known. Particular attention is paid to points where prehistoric occupation has been traced, sites such as: the Font Major Cave (Espluga de Francolí, Tarragona), the *Hort de la Boquera*, the Filador Rock-shelter and the Colls Rock-shelter (Margalef de Montsant, Tarragona), and the Parco Cave (Alòs de Balaguer, Lleida).

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Key words: Karst, Conglomerate, Catalonia, Prehistory.

RÉSUMÉ

LE KARST EN CONGLOMÉRATS EN CATALOGNE (ESPAGNE) : MORPHOLOGIES ET SÉQUENCES SÉDIMENTAIRES EN RAPPORT À QUELQUES SITES ARCHÉOLOGIQUES

Dans cet article nous voulons analyser les types de morphologies karstiques qui se présentent en conglomérats et, les types de dépôts sédimentaires qu'on y localise. Notre attention a été centrée sur des lieux où il y a des occupations préhistoriques : grotte de la Font Major (Espluga del Francolí, Tarragona), l'Hort de la Boquera, l'abri du Filador et l'abri dels Colls (Margalef de Montsant, Tarragona) et la grotte du Parco (Alòs de Balaguer, Lleida).

Les particularités archéologiques et sédimentaires qu'offrent les dépôts karstiques en conglomérats, sont également analysés.

Mots clés : Karst, Conglomérat, Catalogne, Préhistoire.

1. INTRODUCTION

Among the great wealth of sites of archaeological interest in karst contexts in Catalonia, a number of examples which have a common characteristic have been selected; this is their location in limestone conglomerate massifs which reflect ancient Paleogenic river systems indicating the limits of the basin of the Tertiary Ebro Depression, lying between the Pyrenees and the littoral mountain chains of Catalonia.

Despite the evidently harsh nature of the environment, these relief features have been intensively used by human communities for settlement purposes from the Palaeolithic down to the present day. A rich variety of place-names is indicative of the special characteristics of the environment, as well as of the antiquity and continuity of settlement in these areas. The characteristic features of the process of karst scenery formation in conglomerates have given rise to the existence of dry cavities suitable for settlement and defence purposes, as well as for cultural practices; springs, whether spread out within the massif or concentrated in areas on its periphery, have formed privileged damper points within these dry surroundings, and the surface conditions of relief (gorges, channels, cliffs and *cuestas* etc.) have proved particularly suitable for the concentration of fauna and the establishment of lookout and hunting points.

2. THE CONGLOMERATE MASSIFS OF CATALONIA

2.1. THE STRUCTURE AND CHARACTERISTICS OF CONGLOMERATES

The great conglomerate relief features of Catalonia are tecto-sedimentary systems that fossilize Alpine supports,

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both on the south side of the Pyrenees (the southern face and the inland basins of the strata) and the contact between the Tertiary Ebro basin and the littoral mountain ranges of Catalonia (Fig. 1). They are Paleogene alluvial fan systems overlying the mountain façades that formed the limits of the Ebro Basin, the uppermost facies of which are made up of substantial accumulations of coarse conglomerates, with thicknesses of up to approximately one thousand metres, as they were synorogenic margins where discharge took place. Towards the interior of the basin these conglomerate bodies break down into cleft facies and subsequently lower lutite facies and marine contexts of carbonate platforms with reefs. These transition deposits started to be laid down during the lower Eocene and continued until the Oligocene. As from the Biarritzian there was a process of transgression which converted these sedimentary cones into deltas, and in some cases there began indentation of marine sediments on the fringes of conglomerate features.

At present, these deposits form wedge-shaped and prismatic features which stand out on top of the Palaeozoic and Mesozoic base, covering considerable areas (135 square kilometres in the case of Montsant), and which constitute marked elements within the relief (reaching heights of over one thousand metres), isolated in the landscape and interposed in the form of a discontinuous barrier between the Central or Ebro Basin and the surrounding mountain ranges.

Their basic petrological constitution comprises carbonate conglomerates, with (predominantly calcareous) pebbles of varying dimensions and types, within a sandy lutite matrix, the whole being bonded by calcite cement. These conglomerate features, consisting of grey massifs, are interspersed with more lutite intercalations and wedges of redder hue, which separate them in a vertical direction. As a whole, they are highly fractured with networks of joints that become more dense in the more competent levels, that is to say in those with a higher concentration of carbonates.

2.2. RELIEF SHAPING AND FORMS

Differential erosion gives rise to an isolated pattern of relief raised above its surroundings while internal erosion has been responsible for an internal pattern of relief consisting of walls, towers, needles and monoliths, separated by clefts, which collectively make up a remarkable landscape (Photo 1, cf. p. 349).

These conglomerate massifs are located around the Ebro depression, both on its northern or Pyrenean edge and towards the south-east and the littoral mountains of Catalonia. The rivers flowing down from the Pyrenees have scoured out routes through this barrier, often taking advantage of the peripheral depressions of these conglomerate features, thereby separating them from one another and contributing to their isolation. Such relief features, ubiquitous in the landscape of

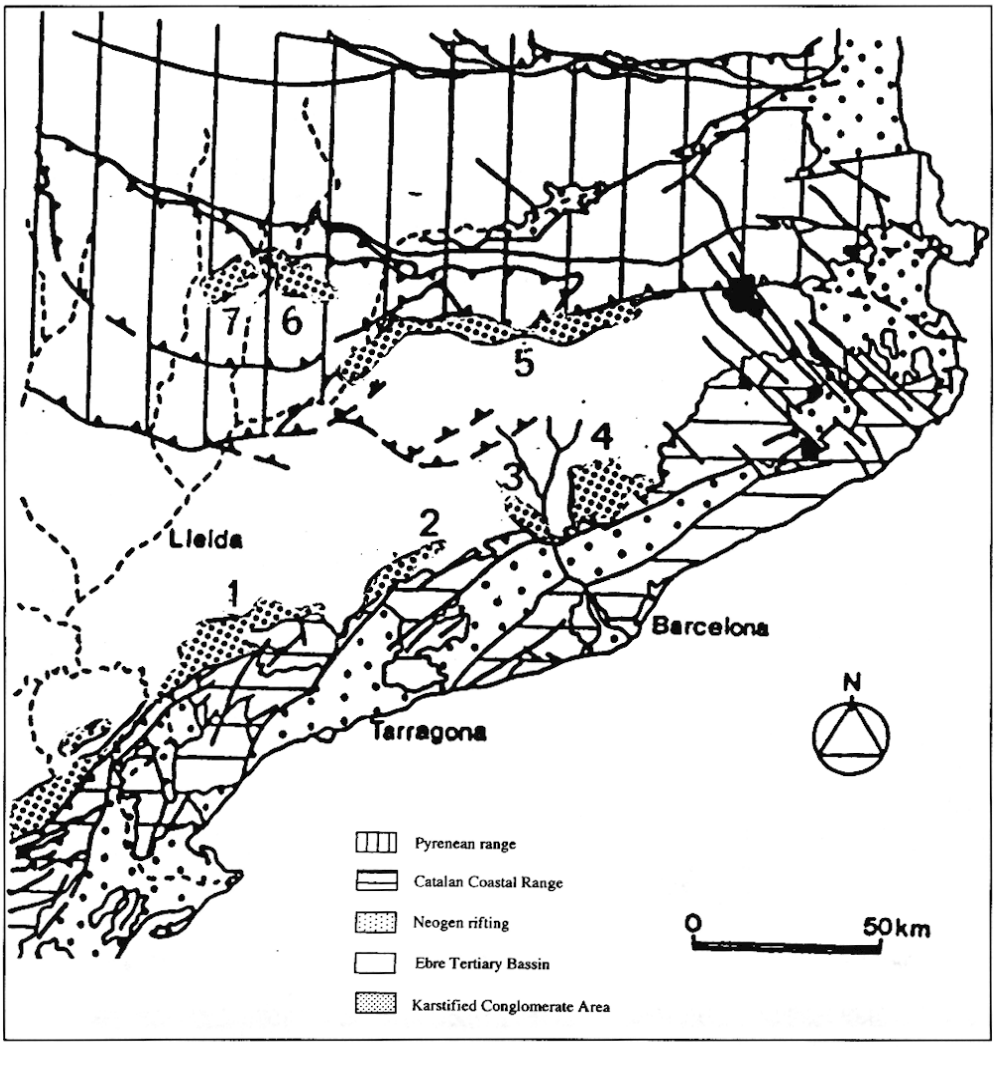

Fig. 1:
Geological units of Catalonia with Conglomerate Areas location:
1 - Montsant - Espluga de Francolí;
2 - Sant Miquel Montclar - Alt Gaià;
3 - Montserrat;
4 - Sant Llorenç del Munt-Serra de l'Obac;
5 - Berga- Busa-Oden-Segre;
6 - Montsor-Collegats-Pessonada;
7 - Serra de Lleràs.

Fig. 1 :
Les ensembles géologiques de Catalogne et la localisation des conglomérats.

Catalonia, constitute lofty walls which in certain cases stand out as islands within the relief of the countryside, reaching heights of over one thousand metres: such is the case of Montsant, 1 163 m; Montserrat, 1 236 m. and Sant Llorenç del Munt, 1 095 m.

Each of these massifs presents its own characteristics as far as its shape is concerned. Although there are certain common aspects, there also exist differences as regards petrographical composition (percentage of calcareous pebbles, nature of the matrix, etc.), sedimentary characteristics (stratigraphical thickness of the different levels, alternations and changes of facies between conglomerates, sandstones and lutites, etc) and the degree of fracturing and vertical penetrability of the joints. Nevertheless, in all cases erosion and chemoclastic processes are responsible for shaping both surface and underground relief patterns. Erosion is particularly significant in the case of the matrix from the moment when the calcite cement is dissolved. The pebbles and cobbles remain in relief, whatever their make-up might be (microlapiés frequently appear in calcareous boulders), and finally they break away and are removed through the action of water and gravity.

As a result of the action of these mechanisms, the original sedimentary forms gave rise to structural patterns of relief on the basis of the lithological heterogeneity responsible for forming the escarpments or *cuestas* and the ridges. These structural elements were subjected to intense erosion, while the dissolution processes concentrated in the joints led to the appearance of cliffs with a column-like morphology, known as *plecs de llibre* (book spines); the evolution of this morphology gave rise to the clefts which deeply cut each other and, eventually, sectors of the slope have been separated so as to form mono- or polylobed monoliths and fine needles and pinnacles, which in some cases adjoin each other along the original escarpment, while in others they form a labyrinthine network, more or less rectilinear in shape, separated by deep clefts and corridors. As a result of such a rocky and steeply-sloping environment, the channels and ledges at the foot of the escarpments are the most heavily wooded spaces in these massifs, as well as the points via which any communication routes must necessarily pass.

Of all the conglomerate massifs that are to be found in Catalonia - Roques d'en Benet, Penyes de l'Aliga, Montsant, Sant Miquel Montclar, Montserrat, Sant Llorenç del Munt - Serra de l'Obac, the Busa and Bastets ranges, Sant Honorat, Comiols, Lleràs, Collegats, etc., - Montserrat, because of its exceptional pattern of relief, is the most paradigmatic example, where such forms reach their climax; hence its name is applied to the type as a whole.

3. KARST IN CONGLOMERATES OR MONTSERRAT KARST

3.1. SPECIAL FEATURES

The conglomerate areas of Catalonia constitute an extremely unusual karst landscape. The petrological characteristics of the conglomerates that have been described, together with the geodynamic factors that have been present throughout the period in which their form was created in the Plio-Quaternary and which affect the potential for the formation of a karst landscape, have led to the extensive dissolution of the basically carbonate rock. Even though karst in conglomerates, or Montserrat karst, responds to the same physical and chemical mechanisms as the classic calcareous karst forms, it exhibits certain clear differences as regards its shape and its hydrogeological functioning. As far as its surface relief is concerned, the forms habitually to be found in other karst areas, such as swallow-holes and lapiés. The basic forms for absorption are grooves, which develop from joints, while walls and monoliths occupy the rocky inaccessible spaces between, which are to a greater or lesser degree isolated.

3.2. HYDROGEOLOGY

As far as hydrology is concerned, water basically circulates underground, an upper zone of infiltration or of vertical circulation being distinguishable from a saturated lower zone where sub-horizontal drainage axes with a great capacity for transferring water and storage features are found. The infiltration zone is of great complexity, owing to the resistance that the lutite intercalations offer to the vertical circulation of water. Such more impervious levels produce horizontal movements of water that trickle down or seep out at different heights of the massif, with a limited flow, and which may infiltrate once again a few metres lower down, always depending on the lithological diversity.

The main permanently-flowing springs together with a series of temporary springs and trop-pleins (outflows) which are capable of evacuating substantial flows at certain specific moments (of several m3/s) can be found at the foot of the mountain. These springs are the reflection of the current circulation, characterized by the limited storage capacity of the more developed karst space at higher levels than lower ones, where aquifers are practically fissured. A significant characteristic of hydrodynamics is the time required for water to pass through the system, which provides hydrograms of limited width and considerable extent (at Rellinars and Sant Llorenç del Munt, the time required is 100 days) (Fig. 2) (Freixes, 1986) as a consequence of the delays in infiltration; this fact is important for the availability of water throughout the year at different levels in the massif.

When the conglomerates are crossed by rivers flowing from outside the massif (allochthonous ones), narrow, incised valleys and meandering gorges are formed, as is the case of Montsant and Collegats. These create a damp space along which movements can take place, where the typical fluvial processes occur: erosion, formation of rock-shelters, terracing, etc. Underground water emerges on the slopes or on the riverbed itself from the base level. Such outflows are often accompanied by travertine deposits.

Surface water circulation also gives rise to rock-shelters which are found at points where there is a variety of lithology within the conglomerate itself (Photo 2, cf. p. 349) or where rocks of differing degrees of resistance alternate, as is the case of the Montsant zone (Colombo, 1986), where the conglomerates are found in association with sandstones and lutites, and, as a result, differential processes of erosion are

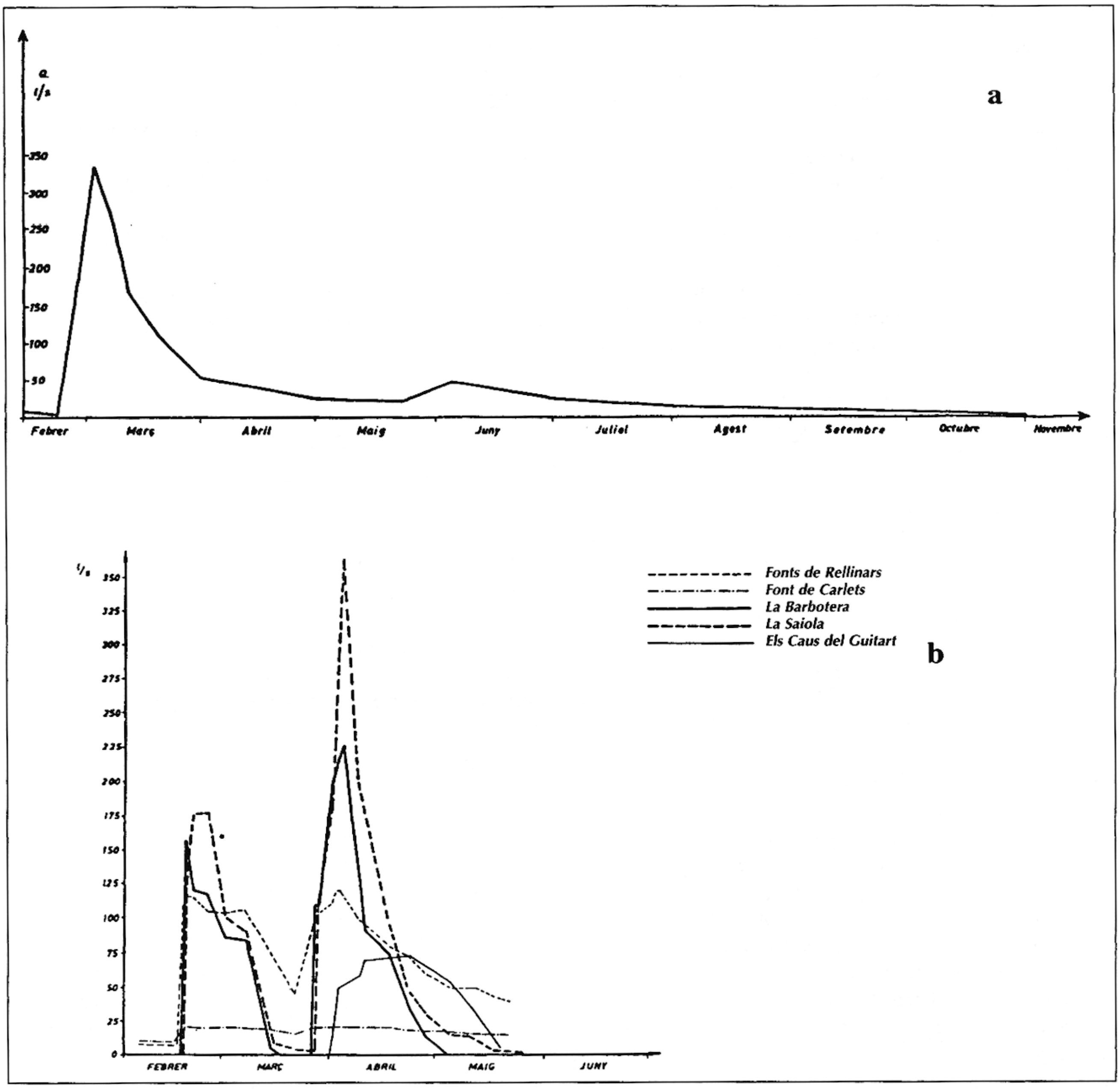

Fig. 2: a - Hydrograph discharge Experimental Karst of Rellinars (Sant Llorenç del Munt-Serra de l'Obac);
b - Springs hydrograph.
*Fig. 2 : **a** - Hydrographie du bassin karstique expérimental de Rellinars (Sant Llorenç del Munt – Serra de l'Obac).*
***b** - Hydrographie des sources et trop-pleins pendant une crue.*

brought about (the softer materials being eroded more easily than the harder ones), which gives rise to such formations.

3.3. KARST CAVITIES

In these massifs, underground cavities tend to cover a large area. Vertical cavities or *avencs* (pot-holes) develop from the fractures formed by grooves, while horizontal openings, or *coves* (caves), are located in the more fissured carbonated levels, and are sometimes limited by intercalated impervious materials. Cavity distribution is spread out throughout the massif, the highest parts often being where the most developed and oldest conduits are to be found. Taken as a whole, this forms a simple karst, but the evolution of these massifs means that a multiphased karst, characterized by a loss of the potential for creating karst scenery as a result of the progressive isolation of the conglomerate relief, has been produced. This means that the highest cavities (the most ancient ones) are residual forms of karst systems of great extent, often with catchment basins of a binary nature.

The typology of underground morphology is highly diverse, the vertical cavities transversing the more carbonated levels forming lengthy conduits starting from the joints. Dissolution may have been substantial, forming substantial holes and halls as a consequence of the conjunction of different fractures.

Small hydrogeological features that transverse an entire conglomerate feature are often formed, and vertical cavities can be related with horizontal conduits at a lower level (Fig. 3). Horizontal cavities may acquire great topographical complexity, covering a distance of several kilometres, with the galleries attaining considerable dimensions. In the interior of conduits, a development of the different sections can be observed on the

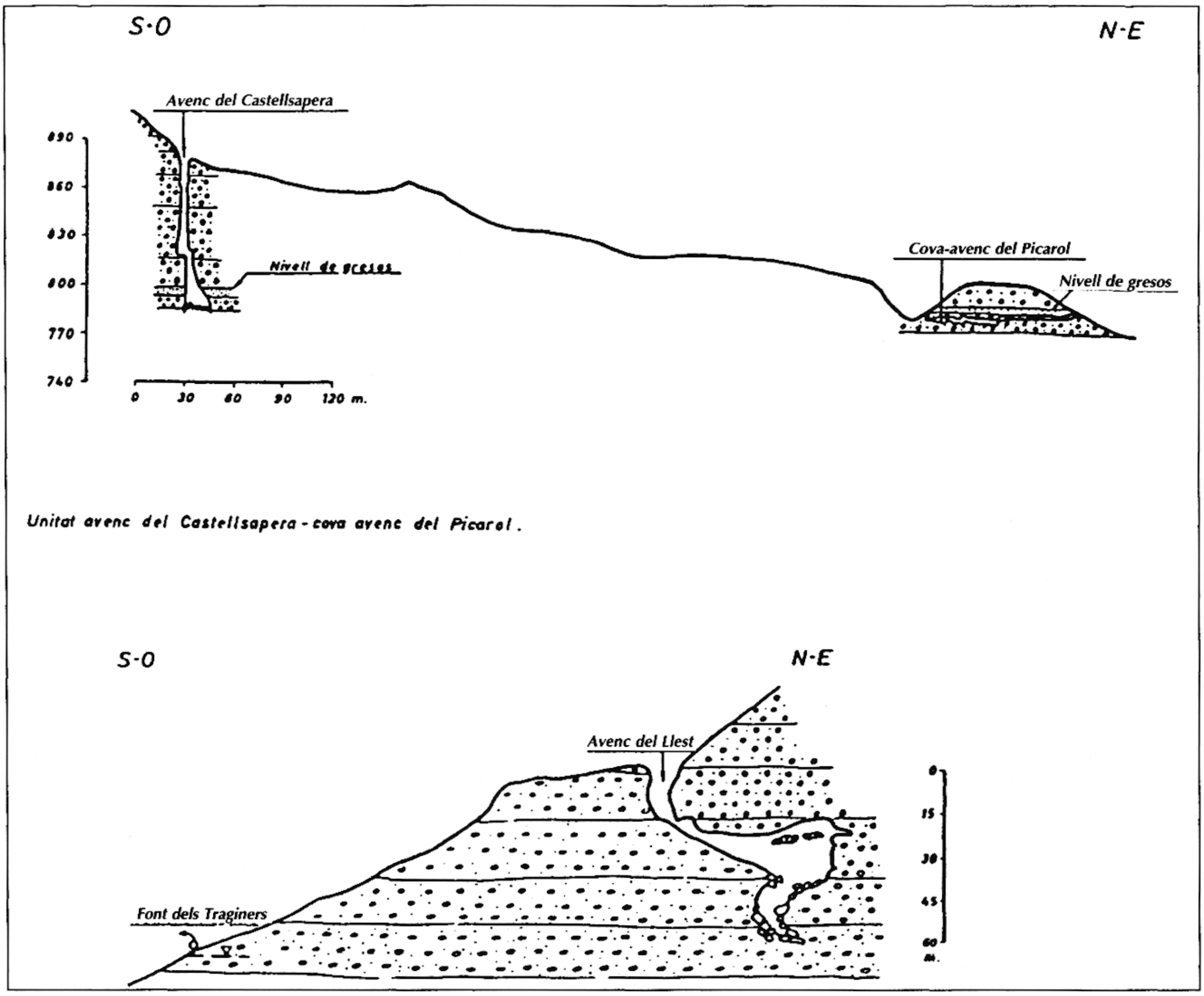

Fig. 3: Relation between caves, vertical shaft and springs. Two examples from Sant Llorenç del Munt-Serra de l'Obac area.
Fig. 3 : Relation entre grottes, gouffres et sources. Deux exemples dans le massif de Sant Llorenç del Munt – Serra de l'Obac.

basis of the relationship between vertical continuity (fractures) and horizontal continuity (strata); in the first instance, in a saturated context circular or elliptical conduits are created, the bases of which are subsequently excavated to form keyhole galleries, as a result of a progression to a fluvial context in a non-saturated environment. Existing sections reflect this evolution by conduit segments and meanders which are an indication of the dissolution in the roof and the gradual scouring away of the river-bed and side terracing on the walls. The absence of dissolution marks of scallop type in conglomerates should be noted, although niches and cavitations of less then a metre in size, which can only with difficulty be used to indicate the direction of early waterflows, can be observed.

All the conglomerate massifs have caves of these characteristics, which constitute prehistoric sites of some interest. In Montsant, the *cova Santa*, located in the highest part of the massif, and the Taverna Cave, on a stream flowing into the river Montsant valley, with several openings caused by the erosion of the above-ground stream, should be noted. The latter cavity contains one of the few examples of Palaeolithic engravings in Catalonia. This engraving was identified on a limestone block within the conglomerate in 1983. It represents the figure of an adult cervid with large antlers, finely engraved with lines averaging 1 mm. in width. The animal was represented by a continuous lines that depicted the start of the hindquarters or back, the rump, the neck, the forehead and which ended with the muzzle; the eye can be made out, though with a certain degree of difficulty, as can the ear. The rear of the animal was made by taking advantage of a relief curve in the rock; towards the top it merges with the engraved line, whereas towards the bottom it is lost without there being any indication of a tail or legs. This lack is also to be noticed as regards the front limbs, which are not depicted either. As far as its date is concerned, researchers consider that it could be assigned to the closing stages of the Upper Palaeolithic (Fullola and Viñas, 1985; Fullola, 1987).

On Montserrat, the Collbató caves are of particular interest: the Salnitre Cave, the *cova Gran* and the *Cova Freda*, among others, make up a group of Neolithic, Bronze Age and Iberian period sites. The early Neolithic cardial-impressed ware from the site, also known as Montserrat ware, because this was the type-site where it was first identified, should also be noted (Colomines, 1925).

On Sant Llorenç del Munt the Simanya Cave, the Ànimes Cave and the Frare Cave, the latter with interesting deposits dating from the Neolithic to the Iron Age, are particularly noteworthy (Martín et al., 1985).

Among the conglomerates to the south of the Pyrenees, the Lleràs ranges stands out because of the dimensions of its cavities (Cuberes Cave, 12.8 kilometres in length and with a difference in level of 327 metres) and for the Serradell archaeological cave complex. On the Marginals ranges of Sant Mamet can be found the Parco Cave, a cavity associated with the network of vertical fractures that cut the Oligocenic conglomerates that outcrop in the Segre valley. This cave is of particular interest for the Upper Palaeolithic (Magdalenian) (Fullola et al., 1988; Bergadà, 1991).

A very different case is that of the Font Major Cave in l'Espluga de Francolí, a large karst tunnel, still connected to current circulation, with a remarkable sedimentary sequence, of river and lacustrian endokarst origins, and also of local origins related with the external opening and different phases of occupation from the early Neolithic onwards (Vilaseca, 1969). Remains of Pleistocene fauna have recently been traced within these deposits (Genera, 1995).

The conglomerate karst of l'Espluga de Francolí is to be found at the point of geological contact between the Prades bloc (in the pre-littoral range) and the Ebro depression. The Poblet fault leads to an abrupt change in level of more than 800 metres between the peaks and the plain. The Karst system develops in the Oligocene conglomerates of the Montsant unit, which at this point, as they lie towards the fringes, are not so massive but rather worn away, forming thick, carbonated channelled levels in the middle of the mainly Lutite facies in the bedding of the basin. The organization of the system is binary, with an allochthnous input coming from the drainage network of the Prades mountain system, with streams that drop 800 metres in a short physical space, and which, when they reach the foot of the mountain (Poblet fault), filter into the piedmont Quaternary formations, which, lower down, join up with the lower terrace of the River Francolí. In this alluvial formation (La Mata), made up by pebbles and blocks of different sizes and origins (granodiorites, porphyry, schists, slates, limestone, sandstones, etc.) with a sandy matrix, there is an absoption zone with a large area of swallow-holes which we call the « covered karst of la Mata ».

A basic different between the karst of l'Espluga de Francolí and the other conglomerate massifs studied here should be mentioned: while in the case of Montserrat, Sant Llorenç del Munt, Montsant, Collegats, Lleràs, etc., the conglomerates represent the pattern of relief, often isolated and upstanding in relationship to the immediate surroundings, in that of l'Espluga de Francolí the conglomerates are located at the foot of a steep mountain slope. The highly transmissive aquifer system is restricted to a conglomerate stratum located within a thick impervious lutite. For this reason, we should not talk of the underground forms being distributed en echelon, but rather of a single conduit, of considerable dimensions, which has gradually evolved as a result of the concentration of drainage. The water drained by this karst feature, with a catchment basin of 37 km^2, is led to towards the Francolí valley where it resurfaces at the Font Major, the principal source of water for the region and, in practice, the source of the river Francolí. The final underground length runs under the town of l'Espluga, forming a subterranean river which flows along spacious galleries that can be explored for some 3.6 kilometres (Photo 3, cf. p. 349). The location of the town of l'Espluga is effectively closely associated with the cavity that gives it its name (Espluga = *spelunca*) and which has determined its historical, economic and demographic evolution, thanks to the hydrological resources that it represents, of particular value in a dry regional context (Cervelló and Freixes, 1989).

4. KARST AS A SEDIMENTARY CONTEXT

The sedimentary bedding of karst deposits in conglomerates can have two different origins: endokarst and extern origins.

4.1. ENDOKARST ORIGINS

Palaeokarst (in a hydrogeological sense) implies the non-functioning or the malfunctioning of an aquifer, or of part of one, that has the ability to maintain ancient drainage features or fragments of them. These hollows are transformed from hydrogeological contexts to geological ones in which processes of sedimentation, chemical precipitation etc., take place.

The infilling may go so far as to totally fossilize the ancient conduits or to block them partially. This sedimentation constitutes a register of great palaeoenvironmental and geochronological value that can cover a period ranging from the end of the Tertiary down to recent times.

The sediments indicate the palaeofunction of the karst systems and their binary or monadic nature. The Montserrat karsts, because of the nature of the country-rock and their frequent binary organization, retain a considerable circulation of solids within their hollows. When these movements cease to function, this detrital material accumulates. The results are complex sequences, often of decreasing granule size. At moments when the system functions at low levels, fine sediments are deposited, more or less rhythmically, whereas high-density periods can lead to thicker and coarser bedding.

Of all the endokarst sediments, speleothems are the most characteristic and peculiar. When there is little movement in the context, they tend to be precipitated at the end of periods when conditions are becoming drier (Fig. 4). The properties of calco-carbonic balance and the conditions of crystallization make them particularly interesting as palaeoenvironmental registers and geological time-clocks. Their growth, especially in the case of stalagmite pavements, indicates seasonal variations, conditions in the catchment basin, etc. A typical speleotheme in Montserrat karst is that of mixed type, that is to say of banded structure, in which laminas with crystalline Palisade facies alternate with detrital laminas with a greater or lesser degree of continuity.

An example of this type of bedding is provided by the sedimentary and archaeological sequence of the Font Major Cave.

4.1.1 - Font Major Cave (l'Espluga de Francolí, Tarragona)

The Font Major Cave in l'Espluga de Francolí is one of the largest known conglomerate cavities. It has proved possible to explore it over a distance of 3.6 kilometres by passing through a flooded gallery as far as a second siphon, which has not been crossed. The cavity is formed, in the first instance, by a wide, dry conduit that intersects an underground river some 250 metres from the entrance. Downstream the water penetrates by means of a series of narrow galleries which form a grid pattern from the joints as far as the Font Major spring. Upstream the gallery is spacious, with sections 3 metres high and 5 metres in width. The water varies in depth; at moments when the level rises it can reach the ceiling at many points of the gallery. At the end of the gallery the Can Biela chamber (15 x 35 x 8 metres) can be found; there are large clast blocks on the ground and remains of river terraces on the upper parts of the walls. The water emerges through a siphon which is at present modified and retained by a water-catchment dam for supplying the town, with a wall 4 metres in height. After a flooded length, one can follow a further 650 metres of galleries as far as the second sector with a siphon. The whole cavity lies some 20 metres below ground level and the urban area of l'Espluga. One of the man-made accesses is within a private house (Can Palletes) where the hitherto unknown cave galleries were broken into in 1853 when a well was being dug in order to supply water to the house.

The detrital complexes that fill the cavity are of considerable extent and interest. Throughout the cavity there are levels of terraces with coarse fluvial sediments and, on top of them, settled clays that may have come to occupy the whole conduit. The formation of speleothems is of no importance within the cavity and no stalagmite formations of interest are to be found. Clastic processes are restricted to certain points where large parallelpiped blocks are found.

Fluvial dynamics have been of fundamental importance in the history of the cavity; in the dry entrance gallery the conduit is half occupied by a basal gravel deposit with a sandy matrix, on top of which a rhythmic (or varved) succession of sand, silt and clay is found against the walls, sometimes up to ceiling level.

Two detrital complexes have been distinguished (Fig. 5) :
- a lower gravel complex
- an upper clayey complex (clay, silt and sand).

This bedding seals an earlier deposit located, in the lower part of the conduit, on top of terrace levels situated below the modern artifical floor level. These deposits, which do not exceed 40 centimetres in thickness, are contemporary with the excavation of the gallery; they comprise dark muds and Pleistocene faunal remains of *Cervus elaphus, Crocuta spelaea, Dicerorhinus mercki* and *Equus caballus* have recently been located in them.

The lower detrital complex, with a maximum thickness of 2 metres over the axis of the conduit, contains poorly graded gravel of varying particle size, with rounded and angular pebbles of different classes (granodiorites, diorites, porphyry, slates, schists, quartzes, limestones, sandstones..,.) in a sandy matrix of the same petrological characteristics. This composition reflects the highly diverse geology of the allochthonous catchment basin (Palaeozoic base and Triassic overlay) and is identical to that of the Quaternary alluvial formation at la Mata. The dating of this unit is in doubt; it fossilizes the Pleistocene terraces and seems to respond to a reactivation

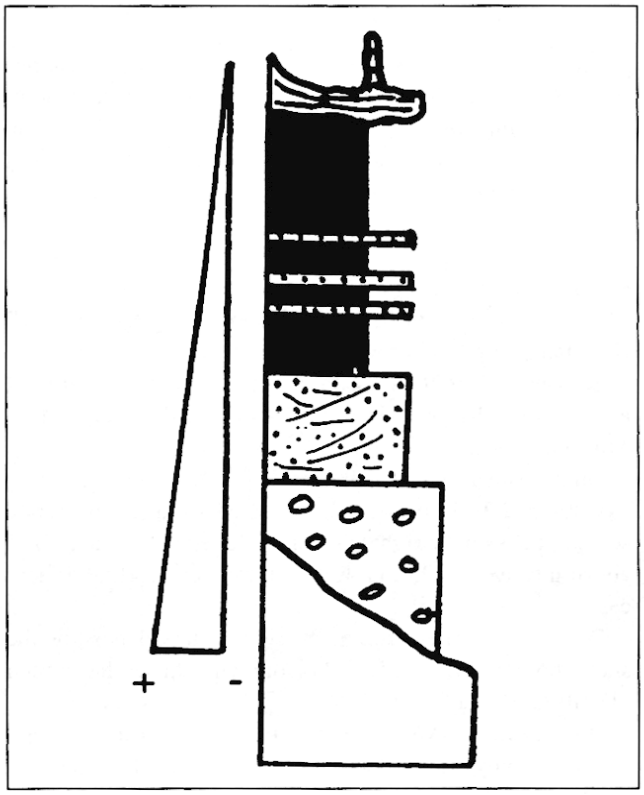

Fig. 4: Drying sequence related decrease of potential of karsitification.
Fig. 4 : Séquence d'assèchement en rapport à la diminution du potentiel de karstification.

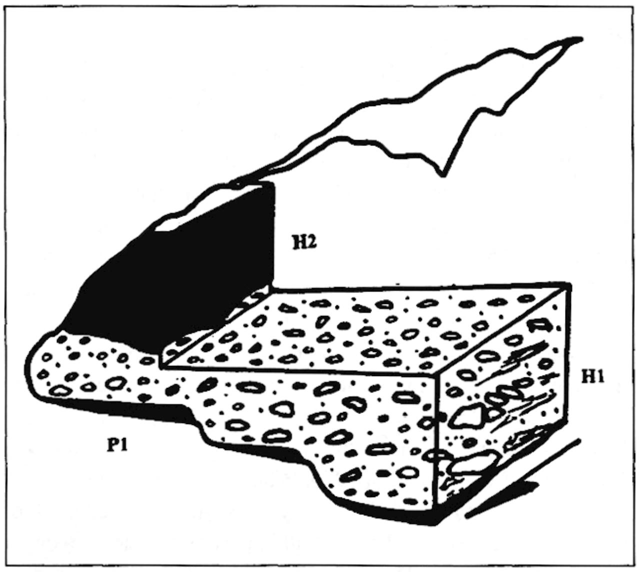

Fig. 5: Cave sediments in the Font Major karst system (l'Espugla de Francolí, Tarragona):
H2 Holocene - Upper clays complex (lateral equivalence with Neolithic archeological site); **H1 Holocene** - Lower gravels complex; **PL Pleistocene terraces complex** - The highest with mammalian fauna.
Fig. 5 : Coupe sédimentaire dans le système karstique de la grotte Font Major (L'Espluga de Francolí, Tarragona) :
***H2 Holocène** - Complexe argileux supérieur (équivalence latérale avec les niveaux archéologiques du Néolithique ancien).*
***H1 Holocène** - Complexe détritique inférieur.*
***PL Terrasses pléistocènes** - La plus haute avec de la faune mammifère.*

due to an intense hydrological flow in a cold, damp climate, with a deforested catchment area subject to considerable erosion. It contains neither fauna nor stone tools, with the exception of a few atypical flints found in the upper part of the unit. Vilaseca hinted at a possible Epipalaeolithic attribution. A late or post-glacial date, i.e. an early Holocene one, can be suggested.

The upper detrital complex, separated from the basal unit by erosive contact, is formed by a laminated bedding of sand, silt and clay. This reflects very different environmental conditions from those of the lower complex, indicating calmer conditions within the cavity with alternate phases of settling of fine suspended material, followed by phases of sedimentation of coarser material (silts and sands) carried by weak alluvial currents whose strength was not strong enough to carry larger karst fragments (boulders and blocks) through the system. This clayey complex is the lateral equivalent of the archaeological levels located in the area adjoining the entrance, now totally excavated, which contained fauna, stone tools and human remains ranging from the cardial Early Neolithic to the Bronze Age. This infilling of local origin, with exogenous piedmont and man-made contributions, culminated in levels containing Roman tiles. The presence of coins of the Emperors Galba and Domitian, incrusted in carbonated travertine material and in thin stalagmite sheets, enables us to date the end of the deposit to the 1st century A.D. From then on, the Capuig piedmont obstructed the cavity.

Another zone of sedimentary and archaeological interest in the cavity lies at the end of the entrance gallery, between 200 and 250 metres from the mouth, in the area where it joins the undergound river. At the point where this subterranean river turned towards the now-dry entrance gallery, which, however, was its natural continuation prior to the cutting of the present galleries that provide access to the *Font Major*, there is a very coarse deposit in the form of a central bar in the conduit, with well worn and imbricated blocks and boulders of varying types. Coarse granite sands and levels of clay and silt of varying colour with alternate fine sands were deposited on top of this bar. This filling, one metre in thickness, contains abundant pottery as well as glass and metal objects of Iberian date. The clayey upper level contains many charcoal remains (possibly derived from torches) (Photo 4, cf. p. 349). It would seem that this site, at the precise point of access to the undergound river, might reflect ritual practices or votive offerings.

The Font Major cave site remained preserved until the entrance was unblocked in 1956. When Vilaseca carried out his archaeological study of the cavity, unsystematic removal of sediments had destroyed a substantial part of the site, to a depth of some two metres. The cavity has recently been conditioned as an undergound museum and is open to the public.

4.2. EXTERN ORIGINS

In the deposits of the archaeological sequences studied, the origin of the filling is indicative of two types of dynamics :

- fluvial flows, reflected in the area of the middle lengths of the River Montsant (Margalef de Montsant, Tarragona)
- surface creep, detected at the site of the Parco Cave (Alòs de Balaguer, Lleida).

4.2.1. The middle lengths of the River Montsant (Margalef de Montsant, Tarragona)

The sedimentary bedding of these rock-shelters is produced by Quaternary accumulation deposits, largely the fluvial contribution of the River Montsant (Bergadà et al., 1990; Bergadà, 1996; García-Argüelles et al., 1993).

The terraces of the River Montsant in this area follow a stepped system in which the presence or continuity of the different levels is conditioned by the width of the thalweg at the moment of sedimentation. The River Montsant was established over the subhorizontal Tertiary materials by means of deep linear incisions creating deep valleys in which the width of the bottom and the gradient of the sides are directly related to the local lithological characteristics. At each point, the process of cutting goes through two phases: a slow one in which the hard rocks (conglomerates) are eroded, and a fast one of the soft rocks (sandstones and lutites). As a result, a narrow valley with steep-sided incised meanders has been created.

In addition to the present floodbed (T0), three levels of terraces have been identified :

Table of the river terrace levels identified in the middle lengths of the River Montsant (Bergadà, 1996).

Terrace levels	Heights
T0	existing bed
T1a	3 - 8 m
T1b	13 - 17 m
T2	20 - 25 m
T3	+ 36 m

The majority of these terrace levels, formed by calcareous pebbles and occasional blocks of quartzite, schist, conglomerate and flint, are found in most of the prehistoric settlement sites as base levels, although the greater part of the filling of the archaeological site corresponds to the floodplain levels (Bergadà, 1996).

Among these sites the following should be noted :

- Hort de la Boquera

This site was identified by the team led by Dr. Josep M[a] Fullola, professor of Prehistory at the University of Barcelona, in 1979 as a consequence of a programme of archaeological prospection carried out in the Margalef de Monstant zone.

On this site a small, totally-infilled rock-shelter measuring 3 x 1.7 x 2,3 is preserved, protected by a conglomerate screen. It lies on the right bank of the River Montsant, 24,7 m above the river itself and 400 m above sea level, and faces east.

During the examination of the sedimentary deposit on the site (Photo 5, cf. p. 350), the following facies have been identified (Bergadà, 1996) :

- at the base (N. IV), gravel of rounded tabular morphology with a sandy matrix derived from the alluvial flood deposits of the River Montsant.
- a level of granular-sorted sand (N. III) derived from the alluvial contributions of the River Montsant in a period of less flow than the previous one.

- a level of sandy silt with charcoal fragments (N. II) without any granular sorting; this indicates deposits of fluvial origin and material from the slopes is also found.
- in the upper part, sandy silt with blocks (N. I) derived from slope creep, well-structured by the process of soil formation, together with blocks falling from the conglomerate screen.

The archaeological material in surface finds and the date available for N. II (9 420 ± 80 BP) places this site at the end of the Upper Palaeolithic or perhaps the beginning of the Epipalaeolithic (Fullola, 1978).

• Filador Rock-shelter

This site was discovered and excavated by S. Vilaseca in the 1930s; subsequently further excavations, which have continued until the present-day, have been carried out by the team led by Dr. Pilar García-Argüelles of the University of Barcelona.

The Filador is a NNE-facing rock-shelter of more than 100 metres in length although the sector undergoing excavation is 15 metres in length and 4 metres wide. It lies on the left bank of the River Montsant, 13.1 metres above the level of the river and 380 above sea level (Photo 6, cf. p. 350).

The following facies have been distinguished as a result of the examination of the sedimentary deposit of the rock-shelter (Bergadà, 1996) :

- at the base (N. XII), gravel and blocks of subrounded morphology derived from the alluvial flood deposits of the River Montsant.
- a level of medium-grained sand (N. XI) deposited by the river at a time of less flow.
- a level of medium and coarse sand (N. X), indicative of a slight increase in the tendency of the river to flood.
- levels of fine sand with silt-clay laminations (N. VIII-IX), corresponding to intermittent periods of river flooding.
- levels of sandy silts of alluvial origin with biological disturbances (N. VII-N. D and probably N. IV). This is a deposit formed in an environment in which seasonal river discharges, together with cone dejection contributions recorded in one sector of the rock-shelter, took place.
- levels of fine sand (N. E which probably corresponds to N. V-VI). This period of river flooding is recorded only in one sector of the rock-shelter.
- a level of calcareous gravel of subangular morphology (N. C) derived from the dejection cone. This deposit extends irregularly over all the site.
- a level of fine sand of alluvial origin with some local additions (N. B).
- in the upper part a level of fragmented calcareous gravel derived from the break-up of the roof and the cone (N. A).

The cultural attributions of the sequence ranges from the Epipalaeolithic (N. VIII-IX with a microlith facies and N. VII to N. IV with a geometric facies), dated by radiocarbon to between 9.830 ± 160 (N. VII) and 9.460 ± 160 (N. IV) BP (García-Argüelles, 1993), to the early Neolithic in N. II (Cebrià et al., 1981).

• Colls Rock-shelter

The first references to this archaeological site are also a consequence of the work carried out by S. Vilaseca in this area in the 1930s. Archaeological excavation started in 1982, under the direction of Dr. Josep Mª Fullola, and continued until 1992.

This is a southwest-facing rock-shelter of more than 50 metres in length, between 2 and 8 metres in height and up to 6 metres in depth in some sectors. It lies on the right bank of the River Montsant, 20.7 metres above the level of the river and 400 metres above sea level.

The following facies have been distinguished as a result of the examination of the sedimentary deposit (Bergadà, 1996) (Photo 7, cf. p. 350) :

- at the base, limestone and marl blocks (N. VIII);
- fine sand derived from the alluvial deposits of the River Montsant (N. VII);
- gravel and sand of alluvial origin (N. VI);
- an increase in gravel and blocks derived from the conglomerate together with fine alluvial sand (N. V);
- sandy silt of alluvial origin with biological disturbances with soil formation processes (N. IV);
- fall of conglomerate blocks (N. III);
- sandy silt of alluvial origin and charcoal fragments with considerable biological disturbances (N. II).

In cultural terms the site can be placed at a moment in the final stages of the Upper Palaeolithic and is dated by radiocarbon to between 12.150 ± 120 BP (N. V) and 10.950 ± 120 BP (N. II).

4.2.2. Parco Cave (Alòs de Balaguer, Lleida)

The first archaeological work on this site, under the direction of Dr. Maluquer of the University of Barcelona, dates back to 1974, and the results obtained encouraged Dr. Josep Mª Fullola's team to recommence research in 1987.

Occupation of the site covers the period from the Upper Palaeolithic (Magdalenian) down to the Bronze Age although the levels corresponding to the Neolithic, Copper Age and Bronze Age were almost totally excavated by Dr. Maluquer.

In morphological terms, the site of the Parco Cave is made up of a cave which opens into a rock-shelter towards the west.

The cave is formed by a single gallery of triangular ground plan, 4.5 metres in width at the mouth by 10.5 metres in depth. The line of the cave is straight, but it can be divided in two lengths: the first, towards the exterior, is wider (4,5) and is where the sedimentary bedding is found (Photo 8, cf. p. 350) the second, towards the interior, is narrower (2 m) and comprises a large accumulation of blocks.

The origin of the cavity and its filling are highly conditioned by a joint which follows the same direction as the axis of the cave. The fracture networks are mainly found in the ceiling and end wall of the cave. Concretion arising from the precipitation and recrystallization of $CaCO_3$ is of little importance, and regular water circulation is no longer to be observed; this may be a result of the fact that the fractures are largely sealed by concretions.

The rock-shelter, which was used for corralling animals, is closed by a wall that delimits an enclosure of 5.5 by 11 metres.

The sedimentation of the Parco Cave is formed by a series of deposits resulting from surface creep, in which a series of facies can be distinguished (Bergadà, 1996) :

- Silty sand and gravel together with charcoal fragments. This is made up by a matrix of silty sand and gravel together with a large quantity of material of human origin. It is represented above all in N. XI, X and VIII. The origin is the result of a weak process of surface creep.

- Sandy silt found in N. IX. This facies was formed as a consequence of a very weak process of surface creep.
- Silty sand of grey colour with $CaCO_3$ and charcoal fragments recorded in N. VII. It is characterized by a considerable accumulation of material resulting from human activity (principally carbon and bone remains) and by the accumulation of $CaCO_3$ crust fragments. It is also a result of weak surface creep.
- Granular-graded silty sand with gravel. This deposit was formed as a consequence of a strong surface creep; the material is granular-graded owing to a substantial water presence. This facies is found in levels VI, V and IV.
- Gravel with silty sand. This is made up by gravel derived from the break-up of the wall and by sedimentary material laid down by a weak flow (N. III and N. II).
- Granular-graded sand with blocks and gravel. This last facies is represented in N.I. One of the aspects of this level that should be emphasized is its thickness in sedimentary terms (117 cms). It is made up by blocks and gravel with medium to fine granular-graded sand. For this reason, the origin of this facies is considered to be the result of strong creep deposits and periods of weaker intensity accompanied by the fall of blocks and the break-up of the cave wall.

In cultural terms, levels XI to VII should be assigned to the early and middle Magdalenian; level XI is dated to 14.300 ± 150 BP and level VII to 14.040 ± 140 BP. Levels VI to III correspond to the Magdalenian and can be dated to between 13.950 ± 150 BP (M. VI) and 13.070 ± 140 BP (N. III). Level II should be assigned to the final Upper Magdalenian and can be dated to 10.390 ± 300 BP; and finally level I belongs to the Epipalaeolithic and in chronological terms stretches from 10.930 ± 100 to 10.190 BP ± 100 BP (Bergadà, in press; Fullola et al., in press).

5. CONCLUSIONS

To conclude, the following aspects should be emphasized :

1. Morphology

The conglomerate relief feaures of Catalonia are tecto-sedimentary systems that fossilize Alpine overtrusths. These marginal deposits started to be laid down during Paleogene age and covering substantial areas which form vigorous relief features (reaching heights of over a thousand metres) and operate as a discontinuous barrier between the Central or Ebro Basin and the surrounding mountain ranges.

2. Petrology

Their basic petrology consists of carbonate conglomerates with pebbles of varying (predominantly calcareous) origins and dimensions, bound by a sandy lutite matrix, the whole being held together a calcite cement. The conglomerate features, grey massifs, are superimposed by redder intercalations and wedges with greater lutite contents, which separate them vertically. As a whole, the complex is highly fractured with networks of joints that become denser in the more competent levels, in other words those with a higher carbonate content.

3. Surface relief

The habitual forms found in other areas of karst scenery, such as swallow-holes or lapiés surfaces do not exist. The basic forms for absorption are grooves, which develop from joints, while walls and monoliths occupy the rocky, inhospitable spaces between, which are to a greater or lesser degree isolated.

4. Hydrology
   - Water circulation is basically underground. Zones of percolation or vertical circulation can be distinguished from saturated zones where highly transmissive sub-horizontal drainage axes and storage structures develop. The main permanent springs can be found at the foot of such mountains, as in the case of Sant Llorenç del Munt.
   - In those cases where the conglomerate rocks are crossed by rivers coming from outside the massif (allochthonous rivers), highly incised valleys and meandering gorges are formed, as is the case of Montsant and Collegats, where the characteristic fluvial processes take place. Underground water emerges on the slopes or on the riverbed itself from its base level. These outflows are often accompanied by travertine deposits.
5. Cavity morphology
   - Vertical cavities or potholes develop from the fractures formed by grooves.
   - Caves, which are the horizontal channel of a karst system, are located at those levels with greater concentrations of both carbonates and fissures; at times they are limited by more impervious intercalated materials. Cavities are distributed en echelon throughout the massif, the most developed and oldest conduits often being found in the highest parts. Small hydrogeological systems that transverse a complete conglomerate feature are often formed, and vertical cavities can be related to horizontal conduits situated at the lowest level, as, for example, the Taverna Cave (Margalef de Montsant, Tarragona). Horizontal cavities can come to have great topographical complexity, a course covering several kilometres and galleries of considerable dimensions as is the case of the Font Major Cave (Espluga de Francolí, Tarragona).
   Cavities associated with the series of vertical fractures that penetrate conglomerate rocks, such as the Parco Cave (Alòs de Balaguer, Lleida), are also to be found.
   - The erosion produced by the circulation of surface water causes the formation of rock-shelters which develop taking advantage of the lithological diversity of conglomerate massifs. Such is the case of the caverns along the middle length of the River Montsant (Margalef de Montsant, Tarragona).
   The relief pattern of conglomerate rocks shapes a very special morphology, producing escarpments, gorges..., places suitable for the location of prehistoric settlement sites since they are points where a substantial proportion of the subsistence resources (springs, fauna, etc...) of an area are concentrated and they are also areas suitable for establishing lookout and hunting points.

This series of factors meant that all these cavities were amply used by prehistoric man.

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