Neogene Mammal sites from Molina de Aragón (Guadalajara, Spain): correlation to other karstic sites of the Iberian Chain, and Geoheritage values.

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Abstract

Corral de Lobato, a new karstic site in the area of Molina de Aragón is preliminary studied. Even though there are not many Neogene karstic sites in the Iberian Chain, it seems they can be grouped into four clusters, with ages ranging from latest middle Miocene (MN7/8) to early Pleistocene (MN17). The correlation between those clusters and the stratigraphical units of the Tagus basin, as well as with local and global events, is tentatively made. These karstic sites provide a complementary source of fossil vertebrate remains to that of the stratified sites formed lowland. The Heritage significance of such sites arises from the enhanced preservation of rare taxa or associations, and the operation of biotic concentrative processes.

Key words: Iberian Chain, Neogene, karst, Tagus basin

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Introduction

The Iberian Range is a complex orogenic system extending along over 500 Km in a general NW-SE direction in the NE part of the Iberian block. It constitutes the natural SW boundary of the Ebro basin and other Miocene basins, such as the Duero basin, or Tagus basin. Some other internal basins, such as the Alfambra, Jiloca or Calatayud basins form part of this orogenic complex (Fig.1). From a geological point of view, the Iberian range is formed by a Mesozoic, and partly, Cainozoic materials, deposited over the Palaeozoic basement, and deformed during the Alpine Orogeny. The big thickness and extension of carbonate rocks in this system has favoured the development of recent karstic complexes (Pleistocene-recent). On the contrary, the Cainozoic Fossil Record in karstic complexes is rather scarce. This fact may probably be linked to many different factors, but most of them surely related to the karstification process itself (Torres. 1998). Yet, it should be also taken into account the natural difficulties to find the karstic complexes, especially when they are included in ancient reliefs, near some mountain areas with a low population index, as it is usually the case in most parts of the Iberian System.

Karstic sites in the surroundings of Molina de Aragón

The city of Molina de Aragón is located in a geographic area known as the "Molina highs" (*Parameras de Molina*), a local geographical denomination that focuses the attention on the flatlands formed by Mesozoic (limestones and dolomites) from Triasic and Liasic to Cretaceous, at an altitude of 1200 to 1300 metres and cut by a deep fluvial network formed by the rivers Tagus, Gallo and Mesa. This area of the Iberian Range is known as "Castillian Branch" of the Iberian System and has worked as the geographic margin of the most important Cainozoic basins of the central part of the Iberian Peninsula (e.g. The Tagus basin, Duero-Almazán; Calatayud-Daroca and Teruel basin). For this reason, the stratified sites containing vertebrates are not very common (in fact they are extremely rare). Only in some exceptional cases some rare fossil sites, dated as Palaeogene, are found as the result of the tectonic elevation and deformation of previous deposits. Their role as source area of sediments that filled in these karstic cavities has been predominant and determinant from a geological point of view. However, the chemical composition and the strong tectonics affecting these levels, has clearly favoured the strong karstification processes, giving rise to numerous karstic complexes, which are at present in full activity. In the surroundings of Molina de Aragón, three karstic infillings are presently known. All them contain abundant Neogene fossil vertebrate remains (Fig. 1).

MOLINA DE ARAGÓN

This fossil site is located Eastwards from the city of Molina in a place near of the type locality of the mineral known as Aragonito. In fact, its discovery was due to a dutch student of the professor Peter Carls, who during a field trip in this locality found such fossil remains in the Karstic infillings developed in the surrounding limestones. It is a fossil site holding an exceptional richness in micromammals, allowing placing the fossil site in the local biozone H. Occasionally, some large mammals are found, the most relevant being the equid *Hipparion* sp., which allows dating the fossil site as early Vallesian (MN-9) at the base of the upper Miocene.

LA LOMILLA

The second Karstic-infilled site is located in the vicinities of the municipality of Setiles, within the landscape known as "La Lomilla". Up to the present, only the infilling of the cave is fully known. The remains, and the fossil content were found as a result of the agriculture works. The remains found were extracted and deposited by the local inhabitants in the farmland boundaries together with some big limestone blocks and some scarce speleothems. As in the former site, both the abundance, state of conservation and micromammal diversity, is remarkable, most particularly the rodent fauna. However, besides that, there's also a remarkable diversity of fishes, amphibians, reptiles, birds and large Mammals. The rodent association has been provisionally dated as close to the Vallesian-Turolian boundary.

CORRAL DE LOBATO

The site of Corral de Lobato, in active research at present, can be considered as the site showing better and more important heritage values. Its location at the East of the town of Molina de Aragón, not far from the city, on the hillside of some labour fields set on Jurassic outcrops, at a height close to 1.100 meters, makes it particularly interesting. The sediments containing the remains of large mammals; normally some breccia deposits (fig. 1), are directly set on the Jurassic dolomitic sediments, forming very different sorts of sediments, from cemented breccia until bone remains included in soft, clay deposits (Pérez et al., 2013). As a whole, the main features of this exceptional outcrop can be summarized as follows:

1) After the excavation campaigns (2012-2014) it could be proved that the bone breccia appeared as a continuous sediment, somewhat inclined in a N-S sense.

2) This bone breccia was in fact filing irregular cavities in the Mesozoic dolomites which, at least in the studied area, were acting as the solid ground of the outcrop (Fig. 2).

3) When sediments and bones are extracted from the cavities, a fine, plastic clay sediment is found at the base. These sediments witness a fine detritic sedimentary process, most probably contemporaneous of the breccia deposits.

4) When this clay film is withdrawn and the dolomite surface is cleaned these materials appear rounded (Fig 2) showing no cutting margins, probably as a consequence of an erosion process by water currents.

This can also be observed in many bone remains analysed, which are rounded by erosion, although in such cases they are also covered by carbonates.
5) Should a boundary exist in the eastern part of the outcrop is something that cannot actually be proved. However, it cannot be excluded that the outcrop was temporarily exposed as a result of the erosion of a stream running in a general N-S direction.
6) The Western part of the outcrop is formed, from top to bottom, by the present ground; Mesozoic dolomites; bone breccias and detritic materials, which are so far still not excavated. Future campaigns will surely indicate how the margin of this outcrop really is.
7) Backwards from the outcrop, at the other side of the river, only dolomitic materials are observed, the same as in the rest of the area, but showing no traces of karstification. Yet, such evidences are more common in areas closer to the outcrop, and can be recognised by the red colour of the decalcifying clays, which colour very clearly the surrounding rocks.
8) Occasionally, in the upper surfaces of the dolomites, some speleothemes can be found, but they are generally of very small size. From time to time they can fill in small cavities and fissures of the dolomites, in the contact with detritic sediments. Only locally, in some surface points we have found small speleotheme fragments. With the exception of a bigger one (5 cm thickness) they are normally of small size, and most of them clearly show their karstic origin.
9) It cannot be excluded the possibility that some speleothemes (because of their small size and thickness, and laminar development) might simply be the result of the infilling of small cavities and fissures of carbonates.
10) Some clear evidences of carbonate concretions; in many cases surrounding the preserved bones, that show rounding due to transport by water previous to the deposition, would constitute a clear empiric evidence of transport (and allochthony of the bone remains).
11: Such carbonate concretions and the rounding of the bone remains might be explained if the bones would be submerged in water for some time and, hence, serving as carbonate deposition nuclei.

Empiric evidences around the site of Corral de Lobato do not suggest the existence of stratified Cainozoic sedimentary deposits around the site or, at least, they are not visible or exposed at the studied fossil sites. In such case, the hypotheses of a karstic origin for the studied site appears as the most plausible. On one side, the environmental variety of sedimentary environments is usually very high and bone breccias similar to those found at this fossil site (the Corral de Lobato) are common. On the other, although some speleothemes found *in situ* are not necessarily of karstic origin, those found in surface are clearly of karstic origin. Some bone remains showing longitudinal fractures would indicate a long exposure to weather. Others show a clear erosion and rounding at the margins, suggesting a long remain under aquatic conditions. However, such processes also take place in karstic environments (i.e: under karstic conditions). We hope that further (and new) research and detailed geological work will contribute to better understand this very interesting outcrop.

The fossil site of Corral de Lobato is an extremely important and rich in large mammal fossils (fig. 2). Among them, particularly abundant are the remains of *Hipparion concudense*, which constitutes almost the 80% of the fossil remains found so far, followed by two types of bovid: *Gazella* aff. *deperdita* and *Tragoportax gaudryi*. Most particularly the fossil remains of the *Gazella* are represented by a high number of cranial horn-cores. Carnivore remains are represented by four forms: *Mustelidae* indet. (small size specimens), *Amphimachairodus giganteous*, and two diferent species of hyaenids (*Thalassictis hipparionum* and *Adcrocuta eximia*). The faunistic list is fulfilled with a rhinoceros remain: *Dihoplus schleiermarcheri*; a large size suid: *Hippopotamodon major* (Pickford, 2015); a cervid: *Pliocervus* aff. *matheroni*; and a large size giraffe, so far determined as Sivatheriinae indet.

The preliminary dating of the site of Corral del Lobato would be Early Ventian, probably in the lower part of the unit MN 13 (fig. 2). The carnivore species, the rhinoceros *Dihoplus* and the bovids *Tragoportax* and *Hippotamodon* show very wide temporary intervals of distribution, and range at least the MN mentioned units. However, the species *Hipparion concudense*, has his last appearance in the stratigraphic unit MN 12. On the other hand, the species *Gazella deperdita* is more scarce in the Spanish outcrops, but has been quoted from the end of the level MN 11 to the beginning of the level MN 13. However, the species *Pliocervus aff. matheroni* has been recorded in the level MN13. Therefore, we find a Mammal association, which is practically unknown in other parts of the Iberian Miocene basins, but very similar to that known in the French site of Mount Leberon, also placed at the base of the stratigraphic unit MN 13. In the important fossil record of the basin of Teruel, the sites containing large mammals are very scarce, which makes the comparisons difficult and limited. However, it is worth noting the relative abundance of the mammal *Gazella deperdita*, which is the best represented mammal form after the genus *Hipparion concudense*. Generally, the forms of Gazella are particularly rare and scarce during the Turolian and Ventian ages, (MN 11 to MN 13), where are represented by few specimens. However, from early Pliocene onwards, they are the best represented ruminants in most of the karstic and stratified fossil sites of Spain, with few exceptions.

Other karstic sites of the Iberian System.

ESCOBOSA DE CALATAÑAZOR

Until the present times, the oldest karstic site known in this area is that of Escobosa de Calatañazor (MN7/8, upper Aragonian; middle Miocene). The karstic filling was found in a very poor state due to the works carried out for gravel extraction. However, in surface some remains were found *in situ* within the sedimentary infilling and, most of all, many isolated blocks, containing an extraordinary wealth of microvertebrates.

CUCALÓN (TERUEL)

The site of Cucalón was first published by Adrover *et al.* (1982). In this work, the authors provide a detailed, preliminary list of the fauna, making a first estimation of its age between units MN10 and MN 11. Subsequently, Mein et al., (1993) in a more general and detailed study of the rodent (Murids) determined the presence of *Huerzelerimys minor* in the site and considered it explicitly as a Karstic fisure.

ALGORA (GUADALAJARA)

This fossil site is located near the village of Algora (province of Guadalajara) in a quarry were Lower Jurassic limestones are being exploited for production of gravel. In this area, the lower Lias units are intensely folded and fractured, and the karstic infilling of the fissures and erosional holes can reach considerable dimensions. However, despite this fact, the only block containing fossil remains was found in the early eighties of the past century by the Drs. Manuel Hoyos and Carlos Martin Escorza. The block contained numerous vertebrate remains. The rodent remains found allowed dating the block (at least that block) as Ventian (= late Miocene).

ALMENARA (CASTELLÓN)

The Karstic complex of Almenara-Casablanca is emplaced in an abandoned quarry not far from the village of Almenara (Castellón de la Plana). The karst was developed over a limestone unit dated as middle Triassic. The whole set of infillings of the rocks hold a temporary range from late Miocene (Ventian) to early Pleistocene. Most particularly, in two cases, the infillings are clearly of pre-Pleistocene age. This is the case of the sites Almenara ACB M (Ventian) and Almenara ACB 4 (Villafranquian). Particularly, the site ACB M holds a most special systematic and biogeographic interest, due to the presence of taxa of African origin, which clearly indicate the geographic connections between the Iberian block and the north of Africa during this time (Agustí et al., 2011).

LAYNA (SORIA)

The karstic site of Layna is placed near the village of the same name. It also was the first palaeontological site protected in Spain by a public institution (ICONA, which in the early nineteen seventies depended of the Ministry of Agriculture) in the year 1973. The fossils found form the karstic infilling developed on the lower Lias unit known as Carniolas formation, which in the studied area is overimposed on the erosional surface of the so-called *Parameras de Molina*. The richness and diversity of the vertebrate fauna, most particularly of the smallest species, is one of the most remarkable of the Spanish palaeontological record. Although there are many different types of sedimentary infillings, the recorded faunal remains, at the present state of knowledge, seems homogeneous. The age of the site, based on the content of the Rodent faunal remains is dated as Ruscinian, MN15 (early Pliocene).

SARRIÓN (TERUEL)

The fossil site of Sarrión is located in the so-called *Cerro de los Espejos* (= *Mirror Hill*), a karstic cavity developed on the marls and limestones of the Upper Jurassic, and which is cut by the road N-234. A large part of this karstic complex, which had more important and wider dimensions, was intentionally destroyed during the works of construction of the road, because of the risks of detention of the works by the authorities. When it was first visited in 1971 by the palaeontologist Dr. Rafael Adrover, only few remains of sediment remained. Some fossil vertebrates, mainly micromammals, were obtained (Adrover, 1986). Later, the palaeontologist Carmen Sesé (2006) recognised two successive faunal associations: Sarrión 2 (MN15, Ruscinian), and Sarrión 1 (MN16, early Villafranquian).

MEDAS ISLANDS (GERONA)

The so-called Medas Islands are a set of small islands only 750m away from the catalan coastal chain, near of the so-called *Massif of the Montgrí*. This massif is considered as the most oriental of the pre-Pyrenean Range. The fossil site is located in the island called "*La Meda Grande*" (The "*Big Meda*"). This island is more largely formed by Upper Cretaceous limestones, which are strongly karstified. The supposed age generally attributed to the karstic fossiliferous infill, on the basis of their content of rodents, would be MN17, late Villafranquian (= early Pleistocene).

Discussion: Successive stages of karstification

In Figure 3, a provisional attempt of correlation of all karstic outcrops of the Iberian range can be found. This attempt should allow classifying them, according to their age, into four successive assemblages that might be indicative of the successive stages of karstification.

1) Middle-Upper Miocene: The sites MN7/8-MN9 can correlate with the subunit II of the Intermediate Unit of the Tagus sedimentary basin. They could perhaps mean a reactivation of the Iberian relief, prior to the sedimentation of the upper part of the Intermediate Unit, with a general increase of humidity.

In the present state of our knowledge, the number of karstic sites recorded in the Iberian System is remarkably scarce. It is worth noting the absence of karstic fossil infilling prior to middle Miocene (c. 12 M. years) the site of Escobosa being the oldest site of all of them. Above this karstic site of Escobosa, over 30 m. of Miocene sedimentary materials are overimposed. These sediments are tentatively dated as Late Aragonian (MN7/8). The rodent association of Escobosa shows some similarities with that of the site of Nombrevilla-2. This last fossil site is also remarkable for being the sedimentary infilling of a fissure formed in terrigenous sediments of the Miocene sequence of Toril-Nombrevilla, which also shows evidence of common taxa with pre-Vallesian of the Catalonian sedimentary basin of Vallés-Penedés. These two fossil sites surely represent the transition to a trend of more humid conditions in the central Iberian Basins, in which soon afterwards, the lacustrine sedimentary facies would develop.

The fossil site of Molina de Aragón, is somewhat more recent, although the presence of some fossil remains of *Hipparion* would surely indicate an early Vallesian age (= earliest late Miocene), lower part of MN9, and local Zone H. Also, the infilling faunal remains of the site of Molina de Aragón can correlate quite well with that of Nombrevilla 1 (Calatayud-Teruel basin), this site being one of the classical fossil sites of the basin, similar to that of the locality of Manchones, where the sediments were included in a bone breccia that was infilling a fissure developed in Miocene sediments (López Martínez, 1989). The rodent faunal remains of Molina are also similar to that of the site of Ledanca, (in the Tagus basin), a fossil site that crops out between limestone levels, placed near the top of the Intermediate Unit but somewhat older than those of the site of Cendejas de la Torre 2, which is placed in the upper part of MN9 (local Zone I) and that is still placed below the stratigraphic boundary between the Intermediate and Upper units. The important discontinuity that marks this stratigraphic boundary can be recognised in the central parts of the basin by the intense karstification process showed by the carbonates at the top of the Intermediate Unit. In the terrigenous materials developed at the margin of the basin, the recognition of these materials is generally more difficult. It is precisely in these sediments of the Tagus basin where the pseudokarstic complex of the site of Cerro de los Batallones is developed. This fossil site, dated as late Vallesian (= early late Miocene), MN10, local Zones J2/J3, supplies a reliable age dating in order to know the age of the discontinuity between both units.

2) **Upper Miocene:** The sites MN10/MN11 correlate with the upper unit of the Tagus river basin, which is delimited in its base by a strong karstification surface. The development of this surface coincides with a generalised sedimentary hiatus, which is widely developed in wide areas in the Tagus and the Calatayud-Daroca basins.

The site of Cucalón (province of Teruel) has a probable age close to the top of the Vallesian stage (MN 10), in the zone J4 (east of the area of Daroca-Calamocha) and El Pobo de Dueñas (in the Eastern margin of the Teruel sedimentary basin) or even slightly more modern (MN-11). Theses materials, known as K zone, represent karstic infillings, which, by their age, are overimposed to the erosional sedimentary break between the Middle and Upper Units of the Tagus basin. A similar situation is found in the surroundings of the town of Daroca. In this area, the stratified sites of "Cañada 12 and 13", late Turolian in age, MN 12, local Zone L (López Guerrero et al., 2011) are overimposed to the sites of MN9 (which are equivalent in age to the sediments placed on top of the Intermediate Unit of the Tagus river basin). Such units mark the presence of a temporary hiatus, which approximately corresponds to the units MN 10 and MN 11, and the local zones J-K (López Guerrero et al., 2011). In the surroundings of the city of Calatayud, the situation is a bit more complex, since it includes the fossil sites of Cortasogas, dated as Zone J-K, and as associated to the stratigraphic discontinuity between the Intermediate and Upper Units. Apparently, they would still belong to the Intermediate Unit but the complexity of the zone has made the different authors not to be very conclusive with respect to this point (Van Dam & Sanz-Rubio, 2003).

3) **Ventian** (MN13), Ventian sites correlate with the end of the Upper Unit of the Tagus basin. The whole set of units appear quite heterogeneous. The fossil sites of Corral de Lobato and Algora might relate with an interval of intense regression during which a reactivation of the existing relief could have taken place. On the contrary, the unit of Almenara (ACB M) would rather be related with the drying of the Mediterranean sea.

The next set of karstic sites was surely developed during the late Miocene, during the Ventian period. These are the karstic complexes of Corral de Lobato, Algora and Almenara (ACB M). The first of them, which is the main motive of the present work, seems to occupy a basal position within this period, as it has already been discussed. The site of Algora, containing important fossil remains of *Stephanomys ramblensis*, might correspond to the local zones M1 or M2 (Early Ventian), is almost synchronous with the stratified site of the Iberian quarries, the Tagus basin, placed in the carbonate facies of the Upper Unit of the Tagus basin. The site of Consuelo, which is included in fluvial facies presumably developed over the upper facies of the so-called Paramo, and represents a presumable age of early Pliocene for the top of this upper unit. Whilst the unit known as Almenara ACB M is clearly differentiated from the sites formerly described, by the association of such forms as *Paraethomys* and gerbilids, which would place them in the so-called N Zone (late Ventian). Also, as a clear difference with the formerly described fossil sites, this site is located close to the Mediterranean coast, just some few tens of meters above the actual coastline. Therefore, this site can be clearly related with the event known as "Messinian Salinity Crisis", which would have taken place between 5,6 and 5,33 Million Years, as a consequence of the drying of the Mediterranean sea (Agustí et al, 2011).

4) **Middle Pliocene**, MN15/MN16

This assemblage is developed between two sedimentary breaks widely recognised in different sedimentary basins (Iberomanchega I and II phases) prior to the development of the present fluvial system.

This last set of karstic sites has an age recognised as late Ruscinian to Early Villafranquian (Pliocene). The oldest sites are those of Layna and Sarrión-2. According to López-Martínez (unpublished manuscript) Layna would be a karstic infilling resulting from an erosional process posterior to the late infilling phase, which should presumably reflect a descent of the base level of the aquifers and a first kof the fluvial network, involving a balance and deformation of the structural surface (Known as Iberomanchega-I phase). During this phase, a new erosional surface was developed. Such erosional surface has been dated as intra-Pliocene, on the basis of the infilling fossils found in the site of Layna. Preliminary magnetostratigraphic studies suggested a normal polarity within the Gauss chron, and hence, suggesting a possible age between 3,41 and 3,17 million years (Hoyos et al.,1987).

The karstic formations of Sarrion are fossilised by a detritic sequence known as "Sarrion Formation" which, according to the faunal infilling, should have an age of (at least) early Villafranchian, (MN16) which would correspond to the most modern age of the site (Sarrión 1). Lying unconformably on this unit, is the unit known as "Formación La Puebla", which owes its name to the village of La Puebla de Valverde, where it was first defined. Its age is Early Villafranchian; MN17. Hence, the Karstic unit of Sarrión would be delimited in age by two units: The lower, Intra-late Ruscininian (MN15; or Ibero-Manchega 1), and the upper one; intra early Villafranchian: MN16-MN17 (Iberomanchega-II). Finally, the Karstic infillings of the sites of Almenara ACB 4 and Medas Islands, of a probable early Villafranquian age (MN16) constitute the more recent known evidence of fissure infilling within the Neogene, by their situation in the Mediterranean coast, as we have already mentioned for the site of Almenara ACS M. At this point, their relation with the fluctuations of the sea level have been clearly determinant. In fact, the infilling of the site of the Medas Islands is placed close to a coastal marine abrasion surface (or "Coastal flat surface") placed at about 40 meters above the present-day sea level.

Relevance as Geological and Palaeontological Heritage.

The karstic sites described and analysed in the present work have a great relevance within the important Geological and Palaeontological Heritage of Spain. On one hand, three of these palaeontological sites; Molina de Aragón, Corral de Lobato and La Lomilla are a part of the Geopark of Molina de Aragón-High Tagus river) which since 2014 is a part of the EGN (= European Geopark Network) and of the GGN (= Global Geopark Network). At the same time, the palaeontological site of Layna was the first palaeontological site to be formally protected by the Spanish State with the formal denomination of “Palaeontological Reserve of the Cerro de la Mina” (Aguirre, 1973), in the present time being a project of musealisation of the site.

Similarly, the sedimentary infillings of these palaeokarst deposits represent an exceptional source of information about the Middle Miocene to Pliocene continental vertebrate remains in the margins of some Cainozoic sedimentary basins of the Iberian Peninsula, spreading through a temporal range of ca. 10 million years. Such sedimentary basins are quite rich in palaeontological vertebrate sites, and their faunal composition shows a high diversity and composition clearly linked to the sedimentary conditions, generally in fluvial-lacustrine areas, in endorreic basins. On the contrary, the sedimentary-karstic infillings may represent diverse and complex features, including fossil associations of very different and diverse origin (Simms, 1994).

One of the most significant features of the studied sites is the richness in micro-vertebrates (most particularly, rodents and lagomorphs) of some of these fossil sites. But they also supply some key information about some key vertebrate groups, which are only very rarely found in other stratified sites. This is particularly the case of e.g. the serpent fossil association of the site of Algora and Layna, which includes a unique representation of any other fossil site with such serpent faunal remains in Europe (Szyndlar, 1985, 1988). A further important site (that of Layna) shows evidences of occupation not only by predatory birds but also by hyaenas. This allows making some taphonomic interpretations of high interest (Aguirre et al., 1981).

Finally, we can only remark the importance of the evidence of terrestrial faunal connections between the Iberian Peninsula and Africa, related to the so-called “Messinian crises” of salinity at the end of the Miocene, in the whole Mediterranean, as it can be deduced from the vertebrate associations of the sites of Algora and Almenara-M (Szyndlar, 1985; Agusti et al., 2011).

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FIGURE LEGEND

Figure 1: Geographic location of the karstic Neogene sites of the Iberian Range. C-CC Catalan Coastal Chain. C-IRA: Iberian Range (Aragonese Branch). C-IRC: Iberian Range (Castillian Branch). C-ISL: Iberian Range (SE; Levantian Sector). The sites are numbered from 1 to 10: 1): Escobosa de Calatañazor; 2): Molina de Aragón; 3): Cucalón; 4): Pobo de Dueñas; 5): Corral de Lobato; 6: Algora. 7): Almenara; ACM and ACB4. 8): Layna. 9): Sarrión (1 and 2) and 10): Medas ilands. Based on the Tectonical Map of Spain (IGME 2004).

Figure 2: General aspect of the excavation made in June of 2014 (including the preliminary results obtained) in the site of “El Corral de Lobato”. The fossiliferous sediments lie directly over the Jurassic dolomites, infilling some irregular holes. Once retired and after the dolomite surface has been cleaned it shows a certain degree of rounding.

Figure 3: Intent of correlation of the different karstic sites of the Iberian system. True Karstic sites appear in regular characters; Pseudokarstic sites are set in italics. The successive sedimentary breaks correspond to those recognised by López Martínez *et al.*, (1987) and by Calvo *et al*., (1993). 1: Middle Intra-Aragonian; 2: Upper Intra-Aragonian; 3: Upper Intra-Vallesian, 4: Intra Turolian; 5: Intra Ventian; 6: Upper Intra-Ventian; 7: Intra Ruscinian; 8: Intra Villafranquian. Alpine Orogenic phases are represented following the paper by Pickford and Morales (1994): VA: Valachian; RH: Rhodanian; AT: Attic: ST: Styrian. The approximate duration of the different phases is marked by black bars. International Chronostratigraphy and Megacycles represented according to Hilgen *et al*. (2012). Temperature Curve in Zachos *et al*., (2008). Humidity, according to that represented by Morales *et al*., (2015), Daams et al., (1999), and Dam (2006).

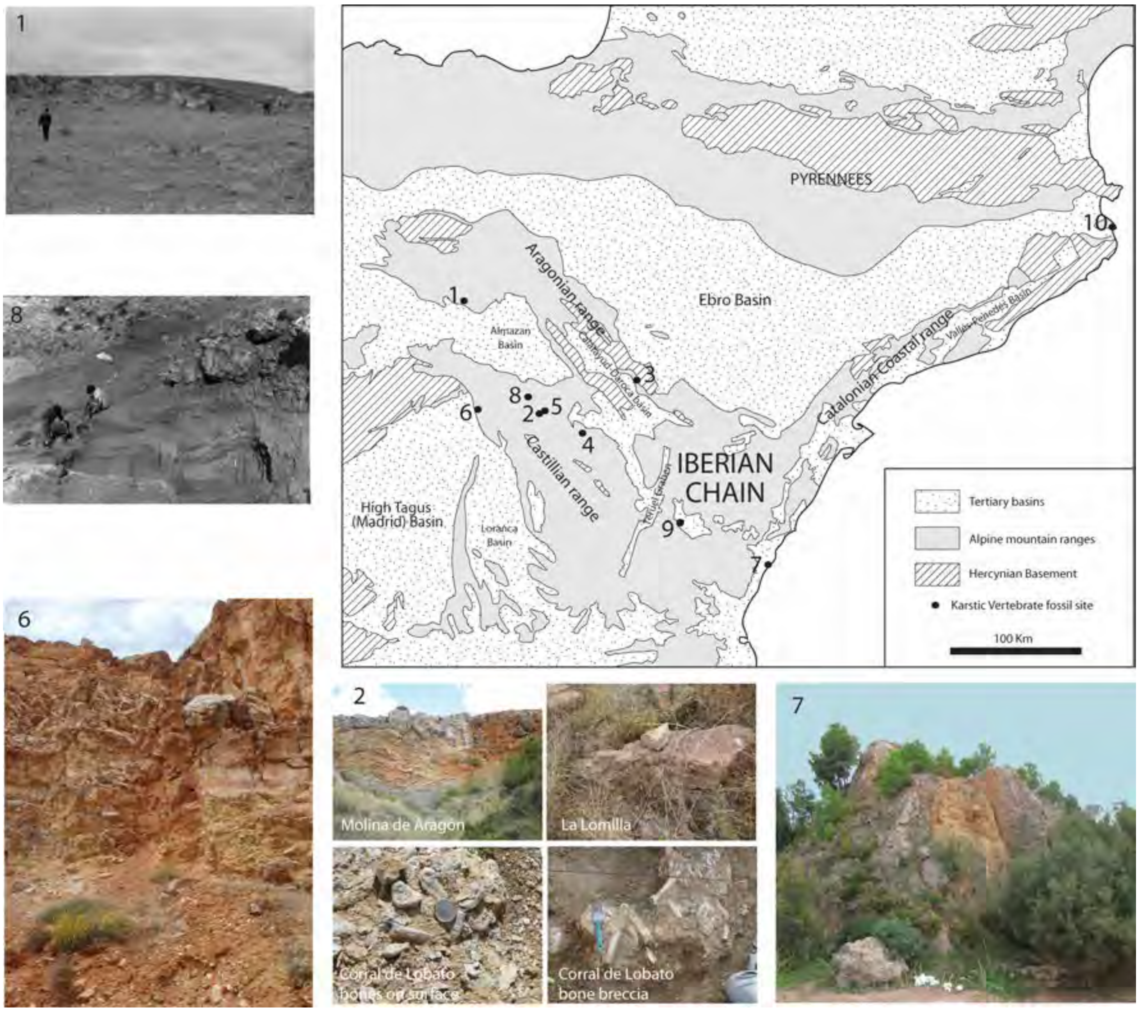
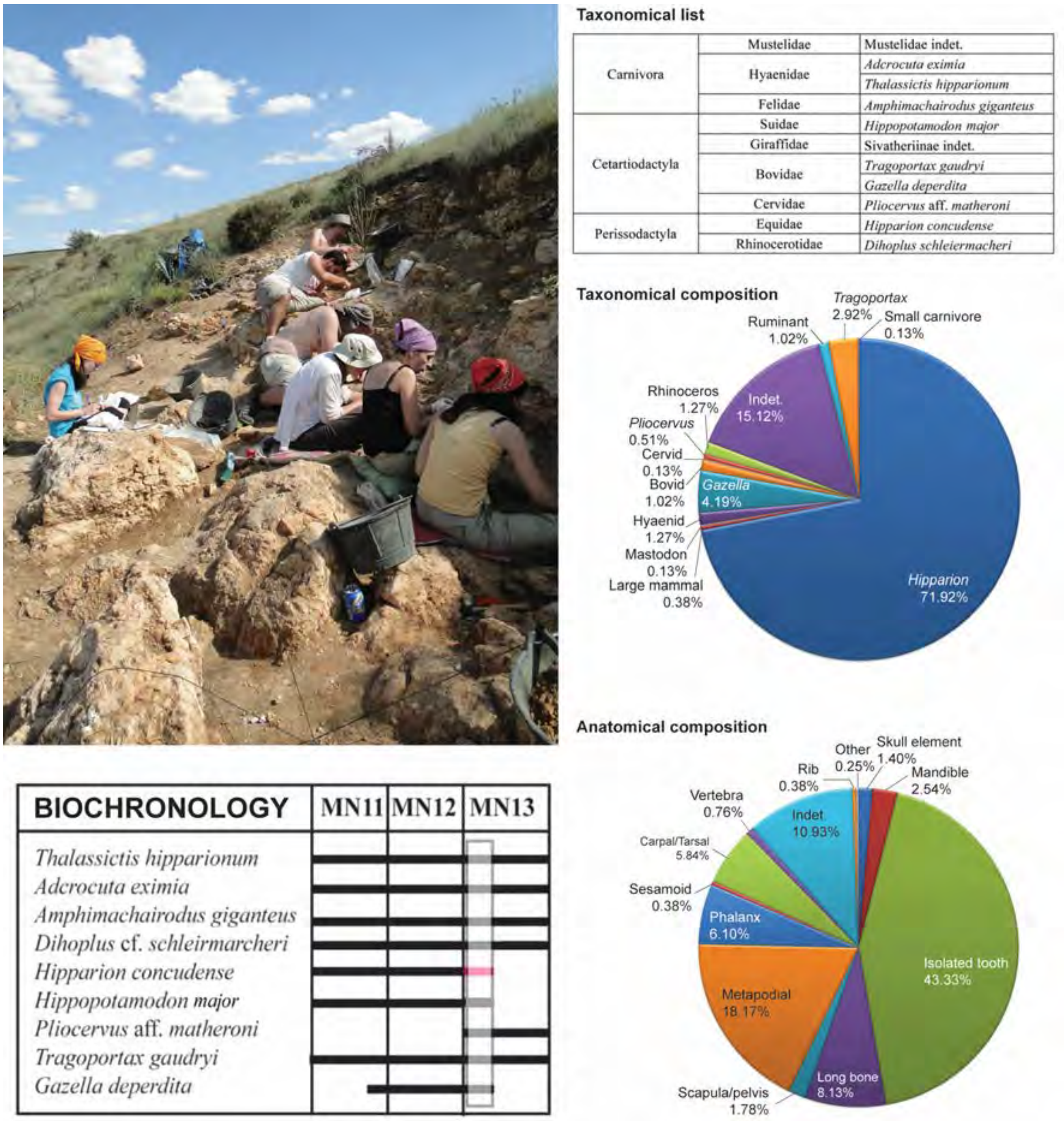

1
8
6
PYRENNEES
Aragonian range
Ebro Basin
Almazan Basin
Castillian range
High Tagus (Madrid) Basin
Loranca Basin
IBERIAN CHAIN
Teruel Graben
Catalonian Coastal range
Vallès-Penedès Basin
1
2
3
4
5
6
7
8
9
10
Tertiary basins
Alpine mountain ranges
Hercynian Basement
Karstic Vertebrate fossil site
100 Km
2
Molina de Aragón
La Lomilla
Corral de Lobato bones on surface
Corral de Lobato bone breccia
7

Fig.1



Taxonomical list
Carnivora
Mustelidae
Mustelidae indet.
Hyaenidae
Adcrocuta eximia
Thalassictis hipparionum
Felidae
Amphimachairodus giganteus
Cetartiodactyla
Suidae
Hippopotamodon major
Giraffidae
Sivatheriinae indet.
Bovidae
Tragoportax gaudryi
Gazella deperdita
Cervidae
Pliocervus aff. matheroni
Perissodactyla
Equidae
Hipparion concudense
Rhinocerotidae
Dihoplus schleiermacheri
Taxonomical composition
Tragoportax 2.92%
Small carnivore 0.13%
Ruminant 1.02%
Rhinoceros 1.27%
Indet. 15.12%
Pliocervus 0.51%
Cervid 0.13%
Bovid 1.02%
Gazella 4.19%
Hyaenid 1.27%
Mastodon 0.13%
Large mammal 0.38%
Hipparion 71.92%
Anatomical composition
Other 0.25%
Skull element 1.40%
Rib 0.38%
Mandible 2.54%
Vertebra 0.76%
Indet. 10.93%
Carpal/Tarsal 5.84%
Sesamoid 0.38%
Phalanx 6.10%
Isolated tooth 43.33%
Metapodial 18.17%
Long bone 8.13%
Scapula/pelvis 1.78%
BIOCHRONOLOGY
MN11
MN12
MN13
Thalassictis hipparionum
Adcrocuta eximia
Amphimachairodus giganteus
Dihoplus cf. schleirmarcheri
Hipparion concudense
Hippopotamodon major
Pliocervus aff. matheroni
Tragoportax gaudryi
Gazella deperdita

Fig 2.

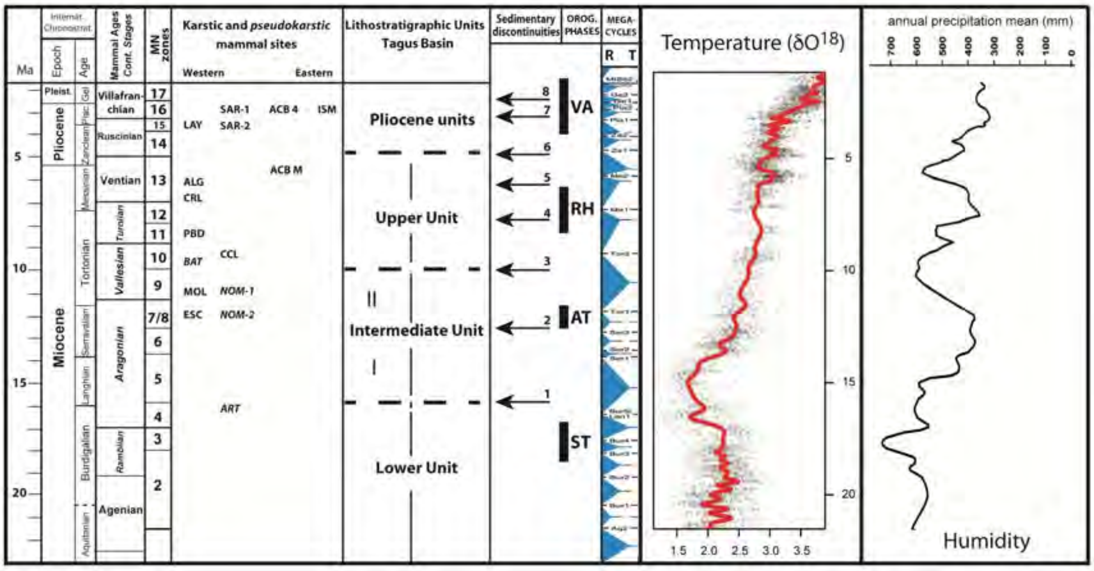


Fig 3.