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The late Pleistocene fossil avian remains from Grotta dei Fiori, Carbonia (SW Sardinia, Italy) ⁽¹⁾

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ABSTRACT – The results of the analysis of the fossil bird association from a clay and sandy-clay succession filling a karst cavity, known as Grotta dei Fiori, close to the town of Carbonia, SW Sardinia, are presented. A rich vertebrate association was sampled including mostly micromammal, scarce macromammal and bird remains. The micromammals allow to refer the whole association to the Late Pleistocene. The analysis of the fossil bird remains revealed the presence of the following taxa: *Ciconia nigra*, *Gypaetus barbatus*, *Aquila* sp., *Columba livia*, *Turdus viscivorus*, *Pyrrhocorax pyrrhocorax*, *Pyrrhocorax graculus*, *Corvus corone/fragilegus*, *Corvus corax*, *Emberiza cirrus/schoeniclus*. The bird assemblage contains no endemic taxa, on the contrary of the mammal assemblage, which is wholly formed by species endemic to Sardinia and Corsica. Particular interest is shown by the remains of *Ciconia nigra*, rarely reported as fossil; this species is quite common in the Grotta dei Fiori assemblage, even with unable-to-fly individuals, testifying its nesting status close to the cave. The fractures and conservation of the micromammal remains allow to hypothesize that their accumulation was partially due to the hunting activity of a *Strigiformes*, even if no fossil remains have been found.

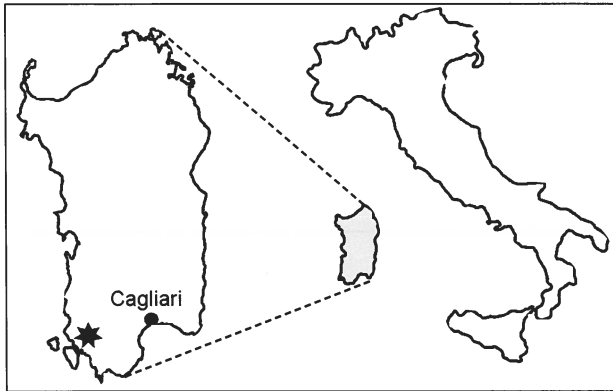
RIASSUNTO – [L'associazione a uccelli fossili del Pleistocene superiore di Grotta dei Fiori, Carbonia (Sardegna sudoccidentale, Italia)] – Vengono presentati i risultati dello studio dell'associazione ad uccelli fossili proveniente da una successione di strati argillosi e argilloso-sabbiosi formanti il riempimento di una grotta carsica, conosciuta come Grotta dei Fiori, nei pressi della città di Carbonia, nella Sardegna sudoccidentale. All'interno del riempimento è stata raccolta una ricca associazione a vertebrati comprendente numerosi resti di mammiferi, soprattutto micromammiferi, e più scarsi resti di uccelli. I taxa presenti, in particolare i micromammiferi, permettono di riferire l'associazione al Pleistocene superiore. Lo studio dei resti ornitologici ha permesso di riconoscere la presenza dei seguenti taxa: *Ciconia nigra*, *Gypaetus barbatus*, *Aquila* sp., *Columba livia*, *Turdus viscivorus*, *Pyrrhocorax pyrrhocorax*, *Pyrrhocorax graculus*, *Corvus corone/fragilegus*, *Corvus corax*, *Emberiza cirrus/schoeniclus*. La paleoavifauna di Grotta dei Fiori non presenta elementi endemici, al contrario di quanto si osserva nella mammalofauna che contiene solo specie estinte endemiche dell'Arcipelago Sardo-Corso. Di particolare interesse risultano i resti di *Ciconia nigra*, specie raramente segnalata allo stato fossile e presente nell'associazione di Grotta dei Fiori con numerosi resti, anche di individui non ancora in grado di volare, a testimonianza del fatto che la specie nidificasse nelle vicinanze della grotta. La tipologia delle fratturazioni e la conservazione dei resti di micromammiferi permettono inoltre di ipotizzare che l'origine dell'accumulo di queste ossa sia dovuto, almeno in parte, all'azione predatoria di *Strigiformi*, anche se non ne sono stati trovati i resti fossili.

INTRODUCTION

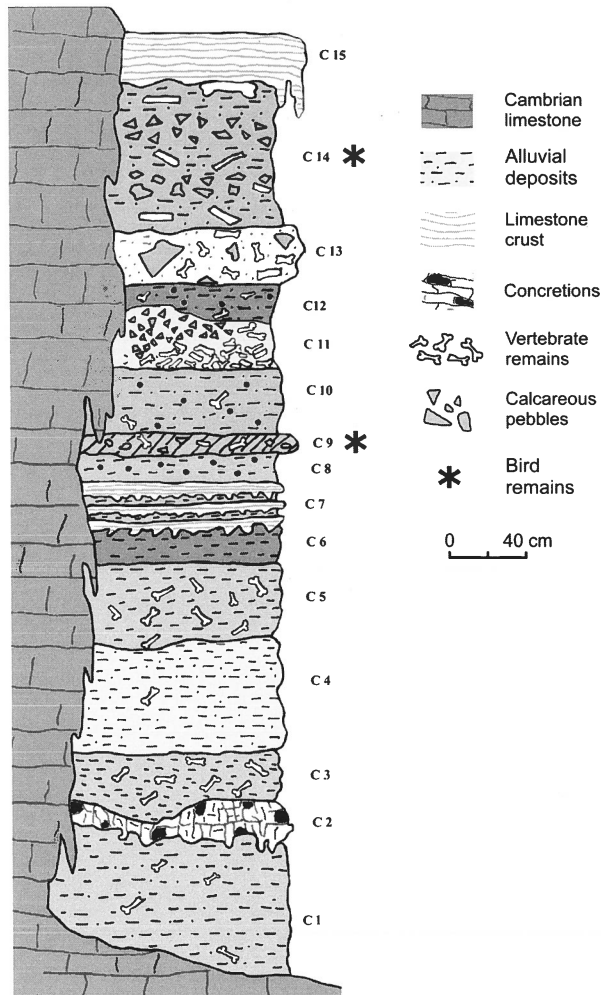
The Grotta dei Fiori cavity is situated in the south-western Sardinia, close to the town of Carbonia (Text-fig. 1). The cavity opens in the Cambrian sediments of the Santa Barbara and San Giovanni Formations (Pillola, 1990), constituted by metamorphic limestone and metamorphic dolomite. The cavity shows a dendritic development on different levels; the total surface of the Grotta dei Fiori is now estimated in more than 800 square metres, even if it has been supposed wider since some ducts are close by alluvial and chemical deposits (Villani, 2001). The evolution of the cavity has been characterised by different filling episodes, the first one probably dated to the Permo-Triassic interval, even if the most abundant sediments preserved in the various cavities of the Grotta dei Fiori are Pleistocene in age (Melis *et al.*, in press).

The bird fossil remains analysed in this paper have been collected in the section C (Text-fig. 2), among four studied in the cave (Fenza, 2000). In the section C, five metres thick, fourteen levels have been recognised; they are constituted mainly of an alternation of loose clay and sandy-clay levels, more heterometric in the upper part, closed by an alabaster crust twenty-five centimetres thick. Fossil vertebrates are presents in most levels of the succession, whereas the fossil bird remains have been collected in the levels C9 and C14, the remains of the biggest dimensions being present in the latter level especially.

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Textfig. 1 - Map of Sardinia with the position of the fossil locality.



Textfig. 2 - Stratigraphical scheme of the Section C of the Grotta dei Fiori (modified from Fenza, 2000).

A preliminary analysis of the fossil vertebrates collected in the Section C of the Grotta dei Fiori (Melis *et al.*, in press) recorded the following taxa: *Ciconia* cf. *C. nigra*, *Gypaetus barbatus*, *Aquila* sp., *Columba livia*, *Turdus viscivorus*, *Pyrhacorax pyrrhacorax*, *Pyrhacorax graculus*, *Corvus corone*, *Corvus corax*, *Talpa tyrrhenica*, *Asoriculus similis* (= *Nesiotites similis*), *Microtus* (*Tyrrhenicola*) *henseli*, *Ragamys orthodon*, *Prolagus sardous*, *Cynotherium sardous*.

The present analysis completes the study of the fossil bird remains taking into account also the smaller and fragmented remains.

SYSTEMATIC PALAEONTOLOGY

The fossil bird remains have been collected by the authors and by the researchers of the Museo Civico di Paleontologia e Speleologia "E.A. Martel" of Carbonia, the University of Cagliari and the "La Sapienza" University of Rome, in a recent survey organized to verify the presence of bird remains already quoted (Fenza, 2000).

The material analysed here is housed in the Museo Civico di Paleontologia e Speleologia "E.A. Martel" of Carbonia. The determinations have been made with direct comparisons with recent skeletal material stored in the "Dipartimento di Scienze della Terra" of the University of Torino (Marco Pavia Osteological Collection, MPOC), in the "Museo Civico di Storia Naturale" of Carmagnola (Italy) and in the Claude Bernard University, Lyon (France). The osteological terminology is from Baumel & Witmer (1993).

Order CICONIIFORMES

Family CICONIIDAE

CICONIA NIGRA (Linnaeus, 1758)

Pl. 1, figs. 1-4

Material – Three cranial fragments; four complete left coracoids plus one proximal part of left coracoid and one proximal part of right coracoid; three proximal part of left scapulae; two complete left humeri plus two proximal part of right humeri and two distal part of right humeri; one complete left ulna; one proximal part of right radius plus one distal part of right radius; one proximal part of left carpometacarpus; one complete right tibiotarsus plus one distal part of left tibiotarsus and one distal part of right tibiotarsus; one complete right tarsometatarsus plus four proximal part of right tarsometatarsus and three distal part of right tarsometatarsus; three vertebrae. Some very juvenile bones referable to this taxon are also present.

Description – The morphology of all bones is typical of the genus *Ciconia*. In the Middle and Late Pleistocene of Europe only two species are known so far: *Ciconia ciconia* and *C. nigra*, the latter slightly smaller. Some morphological differences between the two species in the cranial and post cranial elements have been point-

ed out by Gruber (1990). To determine the bones from Grotta dei Fiori we used the paper of Gruber (1990) together with direct comparisons with recent skeletons of both *Ciconia ciconia* and *C. nigra*; below we pointed out the most important characteristics shown by the fossil remains.

In the coracoid the two species are easily distinguishable for the shape of the sulcus musculi supracoracoidei, that forms a hollow under the facies articularis clavicularis in *Ciconia nigra* and in the fossil remains. In the furcula of *Ciconia ciconia* the area of the synsosseum interclavicularis is hollow and deep, while in the bones from Grotta dei Fiori is level, like also in *Ciconia nigra*. In the proximal humerus the outline of the crista bicipitalis is rounded and continue in the fossil material, as in *Ciconia nigra*, whereas in *C. ciconia* has a recess. In the diaphysis the linea musculi latissimi dorsi goes on distally in *Ciconia nigra* and in the fossil material, this characteristic being absent in *C. ciconia*. In the fossil proximal ulna the facies articularis radialis is distally pointed and has no a definite border with the cotyla dorsalis; this characteristic is typical of *Ciconia nigra*. In the proximal tarsometatarsus the eminentia intercotylaris is more pointed and protruding in *Ciconia nigra* and in the fossil record, than in *C. ciconia*; furthermore the sulcus ligamentosus of *Ciconia ciconia* shows a depression absent in *C. nigra* and in the fossil bones from Grotta dei Fiori. We determine the fossil remains as *Ciconia nigra* because all the morphological characteristics observed fit those of this taxon, including the measurements of the long bones.

Discussion – This species is known since the Pliocene of Saint Vallier (Mourer-Chauviré, pers. comm.). It is occasionally reported in the Pleistocene deposits of the Palaearctic, with four records until now, two of them even doubtful (Tyrberg, 1998, 2002). The scarcity of the fossil record is probably due also to the life habitats of the species, related to mature woods and cliffs, in which the fossil remains can rarely become fossilised.

Order ACCIPITRIFORMES
Family ACCIPITRIDAE
GYPÆTUS BARBATUS (Linnaeus, 1758)
Pl. 1, fig. 8

Material – One articular portion of left mandible.

Description – The general features of the remain accord to these of Accipitridae; the dimension are clearly bigger than all the other species of the family, except *Gypætus barbatus*, *Aegypius monachus* and *Gyps fulvus*. The latter two species can be excluded by the morphology shown by the fossil on the crista transversale fossae and the processus mandibulae medialis, that are identical to *Gypætus barbatus*.

Discussion – This species is commonly reported as fossils from the Middle Pleistocene (Tyrberg, 1998, 2002) even in the Mediterranean islands (Alcover *et al.*, 1992; Louchart, 2001).

AQUILA sp.
Pl. 1, fig. 6

Material – One articular portion of the right furcula.

Description – The dimensions and the shape of the remain are comparable with the ones of *Aquila*, particularly with those of *Aquila chrysaetos*. The different species of the genus *Aquila* show few morphological characteristics in the post-cranial osteology, thus is often difficult to separate them at specific levels, particularly in Sardinia deposits where different forms have been reported (Louchart, 2001). Furthermore the morphology of the furcula is not too significant to better the determination at the specific level.

Order COLUMBIFORMES
Family COLUMBIDAE
COLUMBA LIVIA Gmelin, 1789
Pl. 1, figs. 5, 7

Material – One complete left coracoid plus one proximal part of left coracoid and one diaphysal part of left coracoid; three complete left humeri plus two complete right humeri, one distal part of right humerus and two diaphysal portion of right humeri; one complete left ulna plus one proximal part of left ulna, two distal part of left ulnae and one complete right ulna; one complete left radius; one complete left carpometacarpus plus one distal part of left carpometacarpus; one distal part of left tarsometatarsus.

Description – The general morphology is typical of the members of Columbidae. Among the various European species, *Columba palumbus* is the biggest one for all the skeletal elements, and even bigger than the fossil bones

from Grotta dei Fiori; on the contrary *Streptopelia turtur* is the smallest and smaller than the remains studied here. *Columba livia* and *C. oenas* are almost identical in size, but can be separate for some morphological differences in the long bones, like in the proximal part of the ulna, as also reported by Fick (1974). In the proximal part of the humerus the tuberculum ventrale is ventrally more expanded in *Columba oenas* than in *C. livia* and in the fossil remains from Grotta dei Fiori; moreover the outline of the crus ventrale fossae is more curved in *Columba livia* and in the fossil remains than in *C. oenas*. In conclusion, the morphological characteristics of the fossil material allow us to determine the remains as *Columba livia*.

Order PASSERIFORMES
Family TURDIDAE
TURDUS VISCIVORUS Linnaeus, 1758
Pl. 1, fig. 12

Material – One complete right ulna.

Description – This fossil shows the features of Turdidae and differs from those of the genus *Sturnus* because the olecranon, in the proximal epiphysis, occupies a central position up to the cotyla ventralis, whereas in *Sturnus* the olecranon is shifted ventrally. Though the morphology of the ulnae is not usually diagnostic at specific levels, the dimensions of the specimen of Grotta dei Fiori are bigger than all the other species of Turdidae, so that the fossil can be determined as *Turdus viscivorus*, which is the biggest Palearctic species of the genus *Turdus*.

Discussion – The species of the genus *Turdus* are commonly recorded in the Mediterranean islands (Alcover *et al.*, 1992). In the Pleistocene of Crete and Corsica a Turdidae of big size has been reported by Weesie (1988) as *Zoothera dauma*, but it has been recently suggested it represents a new species (Louchart, 2001). The morphological observation about this taxon have been made on the cranial remains and on the humerus, while the ulna is unknown so far. For this reason we proper to kept our remain as *Turdus viscivorus*, though provisionally.

Family CORVIDAE
CORVUS CORONE/FRUGILEGUS

Material – One proximal part of left humerus.

Description – The features are typical of the Corvidae and the dimensions are comparable with those of both *Corvus corone* and *C. frugilegus*. The bone is incomplete and bad preserved, even the proximal epiphysis. For this taphonomic reason it is not possible to better the determination, even if the criteria proposed by Tomek & Bochensky (2000) to distinguish the humerus of those two species are based on the proximal part of the bone.

PYRRHOCORAX PYRRHOCORAX (Linnaeus, 1758)
Pl. 1, fig. 9

Material – One complete left ulna.

Description – The ulna is stout following to the general features of the genus. The total length is bigger than the congeneric *Pyrrhocorax graculus* (Bedetti, 1999; Tomek & Bochensky, 2000) and is comparable both with *Pyrrhocorax pyrrhocorax* and *Corvus monedula*, but the latter is clearly thinner.

EXPLANATION OF PLATE 1

- Figs. 1-4 - *Ciconia nigra* (Linnaeus, 1758) - 1) Left humerus, posterior view. 2) Left carpometacarpus, internal view. 3) Left coracoid, posterior view. 4) Right tarsometatarsus, anterior view.
Fig. 5 - *Columba livia* Gmelin, 1789: right humerus, posterior view.
Fig. 6 - *Aquila* sp.: articular portion of the right furcula, external view.
Fig. 7 - *Columba livia* Gmelin, 1789: right ulna, internal view.
Fig. 8 - *Gypaetus barbatus* (Linnaeus, 1758): articular portion of left emimandible.
Fig. 9 - *Pyrrhocorax pyrrhocorax* (Linnaeus, 1758): left ulna, anterior view.
Fig. 10 - *Pyrrhocorax graculus* (Linnaeus, 1766): right humerus, posterior view.
Fig. 11 - *Emberiza cirius/schoeniclus*: right humerus, posterior view.
Fig. 12 - *Turdus viscivorus* Linnaeus, 1758: right ulna, anterior view.
Fig. 13 - *Corvus corax* Linnaeus, 1758: right ulna lacking the two epiphyses, external view.
Fig. 14 - *Corvus corax* Linnaeus, 1758: right ulna, external view (Recent specimen, MPOC 136).
Scale bars = 1 cm. Specimens coated with ammonium chloride to enhance details.



PYRRHOCORAX GRACULUS (Linnaeus, 1766)
Pl. 1, fig. 10

Material – One complete right humerus and one distal part of right radius.

Description – The stocky shape of the humerus is typical of the genus *Pyrrhocorax* and clearly distinguishes itself from the other Corvidae. The measurements of the Grotta dei Fiori remain fit well with ones of *Pyrrhocorax graculus* reported by Bedetti (1999), Mourer-Chauviré (1975), Tomek & Bochensky (2000), our fossils are also smaller than the measurements of *Pyrrhocorax pyrrhocorax* indicated by Mourer-Chauviré (1975) and Tomek & Bochensky (2000).

CORVUS CORAX Linnaeus, 1758
Pl. 1, fig. 13

Material – One right ulna lacking the two epiphyses.

Description – The bone shows the typical features of the Passeriformes, with the papillae remigalis caudalis and the impressio brachialis well pronounced. The dimensions are bigger than any other Passeriformes except for *Corvus corax*.

Discussion – The ulna coming from Grotta dei Fiori is slightly smaller than the ulna of the modern *Corvus corax* specimens used for comparison; this is in according to the fact that the body size of the local population of *Corvus corax* inhabiting Sardinia is smaller than the one of the mainland population (Cramp & Perrins, 1994).

Family EMBERIZIDAE
EMBERIZA CIRLUS/SCHOENICLUS
Pl. 1, fig. 11

Material – One complete right humerus.

Description – The morphology of the bone fits well with that of the genus *Emberiza*, even following the criteria pointed out by Janossy (1983); in particular the proximal humerus shows two deep fossae, the fossa pneumotricipitalis and the fossa pneumoanconaea. This characteristic is shared with other families, particularly Fringillidae and Passeridae, but the humerus of *Emberiza* is more slender, with the crus ventrale fossae and the tuberculum ventrale wider and with the two fossae merged distally. The dimensions of the bone are comparable to those indicated by Janossy (1983) and Weesie (1988) for the following European species of the genus *Emberiza*: *E. cirlus*, *E. schoeniclus* and *E. cia*. The latter one is a typical mountain species while the others two are more widespread. For these reasons we attribute the remain from Grotta dei Fiori or to *Emberiza cirlus* or to *E. schoeniclus*.

CONCLUSIONS

The fossil bird association of the Grotta dei Fiori contains not extinct species, unlike the fossil mammal assemblage which includes only extinct species endemic of the Late Pleistocene Sardinian-Corsican Archipelago (Melis *et al.*, in press). The fossil avian taxa recognised in the assemblage are present and commonly breeding in the Mediterranean basin, particularly in Sardinia and Corsica, apart for *Ciconia nigra* known in both islands only as regular migratory species (Snow & Perrins, 1998). The fossil bird association give us some palaeoenvironmental indications; in fact the most part of the species is closely related to the cliffs still present in the area. Moreover some taxa such as *Gypaetus barbatus*, *Columba livia* and *Emberiza cirlus/schoeniclus* suggest the presence of open spaces in which they were feeding. *Ciconia nigra* finally testifies the presence, in the Late Pleistocene, of a surface hydrographical network wider than the modern one, with some open low energy water.

The preliminary morphological analysis of the surface of the micromammal bones and their conservation suggests that an important role in the accumulation of the assemblage was probably made by Strigiformes, even if no fossil remains of this Order have been determined in the association. In fact the breakage of the cranial and post-cranial remains of the different micromammal species and their conservation degree are very similar to that observed by Andrews (1990) for the Strigiformes. For this reason the accumulation of the small vertebrate remains found in the Section C of the Grotta dei Fiori is regarded as the product of the hunting activity of a big Strigiformes, like *Bubo insularis*, an extinct species endemic to the Sardinian-Corsican Archipelago relatively widespread in the two islands from the Middle Pleistocene to the Holocene (Louchart, 2001).

The study of this fossil avian assemblage contributes to the knowledge of the fossil bird from Sardinia, at the present time known only from scattered localities, mostly of the Late Pleistocene (Alcover *et al.*, 1992; Louchart, 2001; Lydekker, 1891; Malatesta & Suriano, 1970; Mlikovsky, 2000; Mourer-Chauviré & Weesie, 1986; Pavia, 1999; Weesie, 1999).

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