Tithonian–Barremian vertebrates of Galve (Teruel): 30 years of paleontological study[*]

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SUMMARY

The fossil record of Mesozoic vertebrates is well represented in continental sediments of the Jurassic–Cretaceous transition that crop out in Galve (Teruel). All localities have been placed in stratigraphic sequence, which has shown the succession of vertebrate associations, Representatives of "Pycnodontiformes", "Semionotiformes", "Amiiformes", "Hybodontiformes", "Rajiformes"", "Lamniformes", Chelonia, pterosaurs, Crocodylia, Ornithischia, Saurischia, Sauria, Amphibia and Mammalia have been found. The paleontological record consists mostly of isolated bones and teeth in different states of preservation. Various levels with dinosaur footprints have also been found in the Tithonian–Berriasian and Hauterivian. Eggshell fragments are abundant in the Barremian.

Keywords: Vertebrates, bones, teeth, eggshells, footprints, dinosaurs, Tithonian–Barremian interval

INTRODUCTION

Galve is known in the autonomous region by the discoveries of Mesozoic vertebrate fossils, especially dinosaurs. The set of localities found in Galve are among the ten largest sites of Spanish Mesozoic reptiles (Sanz *et al.,* 1990). For this reason, since the beginning of the nineties, the Departamento de Ciencias de la Tierra and the Museo Paleontológico of the Universidad de

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Zaragoza began a priority line of research in this area. The Departamento de Cultura of the DGA awarded our team different surveys and rescue excavations whose main objective was the protection and excavation of the remains most damaged by erosion and illegal workers. The numbers of cases were: 081/91, 100/92, 171/92, 099/93, 101/93, 035/94, 054/94, 106/94, 111/94. Another of the priorities of both our management and inventory was all deposits mostly known so far by Mr. Herrero, a resident of Galve. In addition to finding them, we place them in a stratigraphic series. Our scientific work has continued in Galve up to the present, which allowed us to have a comprehensive understanding of both the stratigraphy and the variability of the fossil record of Galve, which we synthesized in this publication, including references to all the publications on the Jurassic–Cretaceous transition in Galve.

Galve is a small town in the province of Teruel (Fig. 1) located near the Utrillas-Eschuca coalfields. It is accessed by National Route 420 both from Zaragoza, and from Teruel, and taking a detour that leads to Galve indicated by a sign marks the Conjunto Paleontológico of Galve. There are more than sixty vertebrate deposits distributed throughout the municipality. Dinosaur remains have been found in a dozen of them. The exact location of the deposits can be found in the Aragonese Paleontological Map available from the Servicio de Patrimonio of the Departamento de Cultura of the DGA.

The sedimentary record for the Lower Cretaceous Iberian Basin is a major sedimentary cycle limited by major significant discontinuities and has been called the Lower Cretaceous Supersequence or the Cretaceous Megasequence (Salas *et al.,* 1991). The different stratigraphic units used in this work are basically defined by these authors. The Galve area is located at the western end of the Galve sub-basin, forming a synclinal structure (Fig. 1), which involves a series of materials of nearly 1000 meters thick for the Upper Jurassic and Lower Cretaceous (Diaz-Molina and Yébenes 1987; Soria, 1997). In the Galve syncline, Diaz-Molina and Yébenes (1987) described the lithology of the units of the Jurassic–Cretaceous transition and identified six stratigraphic units correlated with the formations used in this paper (Soria, 1997).

HISTORY OF THE DISCOVERY OF GALVE

The first excavations of vertebrates in Galve were made in the 50's by a local neighbor named D. Jose Maria Herrero and an archaeology team from the Museo de Teruel. These early findings were published by Fernandez-Galiano (1958, 1960) and Lapparent (1960). The latter described the remains of two dinosaurs, a sauropod, which would later be defined as the new genus *Aragosaurus*, and an ornithischian, which is included in *Iguanodon,* from two separate sites now classic in Galve: Zabacheras at the base of the Castellar Formation and La Maca in the Camarillas Formation, respectively.

In the 60's Professor Kühne at the University of Berlin and the team of Professor Crusafont from Barcelona began new excavations with the techniques of microvertebrate extraction, with the aim of studying small vertebrates, especially mammals. Both teams found isolated teeth of mammals, thus constituting the first research done on the Mesozoic mammals of Spain (Crusafont-Pairó and Adrover, 1965, 1966). Kühne processed reservoir sediments from the Colladico Blanco locality (upper part of the Castellar Formation) and the Crusafont team from the Yacimiento Herrero site (basal part of the Camarillas Formation). Subsequently, the Berlin team has continued to work more or less continuously on the Mesozoic mammals of Spain (Krebs, 1980, 85), small squamate reptiles, crocodiles, reptile eggs, invertebrates, pollen and charophytes (Richter, 1994).

In the 80's investigation teams began at the Universidad Autónoma de Madrid and the Instituto de Paleontología de Sabadell (Sanz, 1984 Sanz *et al.* 1984a), who studied the remains of dinosaurs and crocodiles that were known at that time, identifying 35 taxa of vertebrates (Buscalioni and Sanz, 1987b). Most of this material belonged to Mr. Herrero, although some came from the excavations carried out in one of the sites. These works marked the beginning of the systematic study of Cretaceous vertebrates in our country. The first known dinosaur tracks in this part of the Iberian Range were also studied (Casanovas *et al.,* 1983-84).

A new stage began in 1991 since a team from the University of Zaragoza took on the paleontological study of the remains of fossil vertebrates from Galve. In the first phase all the known deposits have been cataloged, and placed in the local stratigraphic succession (Cuenca-Bescós *et al.,* 1994, Bescós Canudo and Cuenca, 1996, Canudo *et al.,* 1996a). This has

represented a significant advance, since in the literature Galve is often cited as a single locality or level with vertebrates of imprecise age. So far more than 60 vertebrate localities have been recorded, of which only 25 have been completely or partially published, which are distributed in 18 different stratigraphic levels. Regarding the systematic study, we focused on the study of dinosaurs, both direct and indirect remains (eggshells and footprints) and mammals.

As a result of the history of discoveries in Galve, excavated material is dispersed and has different owners. Most of the remains belong to the private collection of Mr Herrero, who prospected and excavated the sites for 40 years (until the early nineties). There is now a permanent exhibition that includes some of these remains with to the dinosaur collection at the Museum of Teruel. We know of three collections that are in public institutions: Universidad Autónoma de Madrid, Museo de Valencia, Instituto Miquel Crusafont de Sabadell, and University of Berlin (Germany). Only the small collection of microvertebrate remains obtained in the screenwashing campaigns of the Museu Paleontológico of the Universidad de Zaragoza and three excavations of vertebrate remains, Cuesta Lonsal, Camino Canales, and Julian Pajar Paricio 2 belong to the Autonomous Community of Aragon. There are also numerous illegally obtained remains in the hands of Spanish and foreign private collectors whose existence is known by indirect references.

In addition to vertebrates, there are remains of other fossil organisms in Galve on which there have been some publications. The bivalves have been studied by Mongin (1966), the charophytes by Schudack (1989), pollen by Mohr (1987) and Ten *et al.* (1995) and benthic foraminifera by Diaz-Molina *et al.* (1984).

THE FOSSIL VERTEBRATES OF GALVE

Our understanding of vertebrate fossils from the Jurassic–Cretaceous transition in Galve varies among groups, so for example some of the remains of mammals and archosaurs have been studied in more detail and their stratigraphic distribution can be observed. But there is less information for other groups, such as squamates, turtles, and amphibians. These taxa are present at all levels, but only have been studied in two localities. The faunal list of the fossil vertebrate

remains in Galve has been made from the work of Buscalioni and Sanz (see synthesis, 1987b) and Canudo *et al.* (1998), and unpublished results of ongoing research. For far 50 vertebrate taxa have been recognized in the Jurassic–Cretaceous transition of Galve, of which 9 have been defined for the first time in some of the deposits of this locality. The exact number of taxa is unknown, since, for example, vertebrates are represented by teeth and generally isolated postcranial elements, such as theropods that could belong to the same taxon. The material featured in this work with the MPZ acronym followed by a number is the registration number which is deposited in the Museu Paleontológico, Universidad de Zaragoza and has been obtained in the campaigns conducted under the DGA permit for prospecting and excavation.

MAMMALS

The first Spanish Mesozoic mammal was found and studied in Galve (Crusafont-Pairó and Adrover, 1965, 1966). Later discoveries have been fruitful and nine species of Mammalia have been studied, distributed in the following taxa: Orders Multituberculata, Symmetrodonta, Dryolestida, Peramura, and Mammalia incertae sedis. Of these, six *(Spalacotherium henkeli, Eobaatar hispanicus, Parendotherium herreroi, Lavocatia alfambrensis, Galveodon nannothus, Pocamus pepelui)* were described for the first time and are exclusive to Galve (Crusafont and Gibert, 1976; Krebs, 1980, 1985, 1993, Hahn and Hahn, 1992, Cuenca-Bescós *et al.,* 1995; Canudo and Bescós Cuenca, 1996). The species *Crusafontia ciencana* found in Galve has been defined from another area of the Cordillera Ibérica (Uña, in Cuenca, Kühne, 1966). These species of mammals are described from isolated teeth. There are also postcranial remains but for the moment they have not been described. The abundance of taxa demonstrates that mammals of this age were well diversified and relatively abundant. Their scarcity in the localities is determined by taphonomic processes: most of the remains are found in unfavorable environments for the accumulation of vertebrates, usually meaning a transition or extensive flood plains where the concentration is practically zero. The most remarkable thing about the Galve mammals is that they are unique in the world, which could indicate an endemism of these faunas or simply that our knowledge of mammals of this age is very low.

The multituberculados are the most common group of mammals both by its diversity and its abundance in the deposits. There are representatives of the family Paulchoffatiidae *(Galveodon, Lavocatia)* which originated and developed in the Jurassic of Portugal and is known

until the Early Cretaceous of Europe and North Africa. There are also species of the subfamily Eobaatarinae (forms related to *Eobaatar* and *Loxaulax),* which is known only in the Lower Cretaceous of Europe and Asia. The species *Parendotherium herreroi* is a taxon of uncertain affinities that we are studying and reviewing currently. The dryolestids of Galve and *C. cuencana* are the last known record of non-tribosphenic therians in Europe (represented in the European Middle and Upper Jurassic), although this group continues its history in the Lower Cretaceous of Asia and the Upper Cretaceous of South America. The peramurids *(Pocamus)* are unique to the English Upper Jurassic and the Aptian–Albian of Mongolia, so the Spanish material extends the range of this group. The symmetrodonts *(Spalacotherium)* are a large group in the Upper Jurassic and are also found in the Upper Cretaceous in North America.

DINOSAURS

Dinosaurs are relatively abundant, although their remains are fragmentary and isolated. They have been recognized both from direct (bones and teeth) and indirect (footprints and eggshell fragments) remains. Remains were found of four of the five known suborders of dinosaurs: Sauropoda, Theropoda, Ornithopoda, and Thyreophora.

Sauropods

The sauropods are represented in the Galve area by postcranial remains, isolated teeth, and eggs. Two recently found levels with sauropod footprints from the Upper Jurassic (Barranco Luca 1 and 2) are unstudied. In addition, some circular structures of the Cerradicas and Corrales del Pelejón localities could represent subtracks of these dinosaurs (Cuenca *et al.,* 1993). Most sauropod remains have been found in the Villar del Arzobispo and Castellar formations.

The species *Aragosaurus ischiaticus* is a camarasaurid described by Sanz *et al.* (1987), which was known from a tooth initially identified Brachiosaurinae (Sanz, 1982) and part of the postcranial skeleton. The first to make known material of this dinosaur was Lapparent (1960), who described 8 caudal vertebrae, 10 cervical and thoracic rib fragments, a scapula, left radius and ulna, a metacarpal, eight fragments of metacarpals, two manual phalanges, ischium, pubis, femur, left tibia and fibula, and again considered it a camarasaurid. Sanz *et al.* (1987) also studied 5 caudal vertebrae, 7 chevrons, scapula and right ischium, left femur, a carpal? bone, and two phalanges, which allowed them to define the new species.

In the Tithonian (Villar del Arzobispo Formation) are the remains of another undescribed sauropod (Perez Oñate *et al.,* 1994) that was partially excavated by Mr. Herrero. In addition to unidentified remains are fragments of the pectoral girdle, both complete humeri, and cervical, dorsal, and caudal vertebrae. For now, the situation of private collection prevents us from studying this interesting sauropod dinosaur which is the most complete of the Spanish Jurassic. Recently a tooth was found that possibly belongs to a diplodocid, also in the Jurassic (Cuenca Bescós *et al.,* 1997), together with three other sauropod taxa described from isolated teeth: Camarasauridae indet. Form A, Camarasauridae indet. Form B, and cf. *Pleurocoelus* = *Astrodon* sp. (Sanz *et al.,* 1987) are the representation of this group.

Theropods

The remains of theropods have been found in virtually all localities, especially isolated teeth in the Castellar and Camarillas formations. The recovery of isolated teeth and other small fragments was performed in part by the screen-washing of several tons of certain deposits such as Cerrada-Roya or Camino Canales (Figures 2 and 3). Large (Megalosauridae indet.) and small (?Coeluridae indet.) teeth have been described, and large vertebrae identified as Theropoda indet. (Estes and Sanchiz, 1982; Buscalioni and Sanz, 1984 Sanz *et al.,* 1987) in addition to tracks of different sizes (Casanovas *et al.,* 1983-84; Cuenca *et al.,* 1993; Perez-Lorente *et al.,* 1997). Also ungual phalanges of different sizes, undescribed. In recent excavations have been found teeth of small theropods peculiar for the absence of any denticles on the margin,s and teeth of different dromaeosaurid taxa characterized by the absence of denticles on the mesial margin and distal denticles perpendicular to the distal margin (Ruiz Omeñaca *et al.,* 1998). Also known are theropod teeth with no denticles and "paronychodontid" teeth, an enigmatic group that is characterized by ornate teeth (Zinke and Rauhut 1994; Ruiz Omeñaca *et al.,* 1998). At the Instituto Miquel Crusafont de Sabadell is a large tooth that Crusafont-Pairó and Adrover (1966) identified as a form similar to *Carcharodontosaurus*, its stratigraphic position remaining unknown. We compared with teeth of this genus and it is morphologically different, so it has been determined as Theropoda indet (Ruiz Omeñaca *et al.,* 1998). There are also eggshell fragments in various localities of the top of Castellar Formation belonging to two different types of theropods. Amo (1998) identified three oospecies, *Prismatoolithus* sp. which relates to Troodontidae, and *Elongatoolithus* sp. and *Macroolithus* sp. which relate to Oviraptoridae.

Ornithopods

The ornithopods are most abundant dinosaurs from the Camarillas Formation. The small families are represented by Dryosauridae and Hypsilophodontidae, the latter with some hesitation. Isolated teeth and postcranial remains have appeared so far in various localities. Given the teeth, there are at least two hypsilophodontid taxa, one with teeth that have multiple crests on the face and one with teeth ornamented with a very strong central ridge and without secondary crests (Ruiz-Omeñaca, 1996). At the Poyales locality were found over a hundred remains of a young hypsilophodontids, possibly new, which is currently under study. It was initially identified as *Hypsilophodon foxii* (Sanz *et al.,* 1987), however the presence of a deep intertrochanteric furrow on the femur and no anterior intercondylar groove separate it from this taxon (Ruiz-Omeñaca and Cuenca-Bescós, 1995, Ruiz-Omeñaca, 1996).

Galve is the only place in Spain where dryosaurids are noted (a femur of cf. *Valdosaurus* sp., Sanz *et al.,* 1987). However, it has characters that approximate the hypsilophodontid of Poyales, although the absence of the distal femur does not allow specifying the taxonomic determination (Ruiz-Omeñaca, 1996).

Among the large-sized ornithopods are found representatives of the family Iguanodontidae. Of this group have recovered numerous postcranial remains (mainly vertebrae) and teeth of *Iguanodon bernissartensis* and *I. cf. atherfieldensis.* Some of the classic localities of this group are found in the Camarillas Formation. Sanz *et al.* (1984b, c) studied the remains of the iguanodontids from the San Cristobal and Santa Barbara localities. In San Cristobal, Sanz *et al.* (1984b) noted a dentary fragment of *I. bernissartensis,* and fragments of dentary, neurocranium, and atlas of *Iguanodon* cf. *mantelli* (= *I. atherfieldensis* following Norman and Weishampel, 1990). Metacarpals, and manual and pedal phalanges of *Iguanodon bernissartensis* and *Iguanodon* cf. *mantelli* (Sanz *et al.,* 1984c) have been descrtibed from Santa Barbara.

In the Castellar Formation are found traces showing the presence of large ornithopods (Pelejón Corrales, Cuenca *et al.,* 1993). At stratigraphically lower levels (lower or middle Berriasian) there is ichnological evidence of small, quadrupedal ornithopods (Las Cerradicas locality). The importance of these remains is that they are the oldest and smallest quadrupedal tracks of iguanodontids ever found in the world (Perez-Lorente *et al.,* 1997, Cuenca Bescós *et al.* 1997). In Las Cerradicas can be seen a set of four tracks, three of them subparallel and another

that cross them (40 steps in total). These tracks were produced in an intertidal marine environment, which at the time of production should have been soaked in water, since conservation is excellent. The current ripples (produced by a sheet of water) must have occurred prior to the tracks. Traces 1, 2 and 3 are typically tridactyl tracks, produced by a small dinosaur, which could have been a theropod or an ornithopod. The most interesting track is 4, since it is the oldest evidence of quadrupedal ornithopod locomotion. 9 tracks of this type have been published in the world, of which those of Las Cerradicas are the smallest of all. This trail is typically ornithopod, possibly a small iguanodontid (Perez-Lorente *et al.* 1997).

Thyreophora

The armored dinosaurs (Thyreophora) are present in Galve, but rare. They are represented by a tooth of aff. *Echinodon* sp. (Estes and Sanchiz, 1982), a caudal spike of Stegosauridae indet., and an dermatoskeletal spine of Nodosauridae indet. still being studied (Canudo *et al.,* 1966a).

CROCODILES

The remains of crocodiles are abundant and appear in almost all sites, being represented mainly by isolated teeth, postcranial remains, eggshell fragments, osteoderms, and two complete skulls, one unstudied. Kuhne (1966) was the first to note teeth and dermal ossifications of crocodilians. Almost at the same time the German team, Crusafont-Pairó and Adrover (1966a, 1966b), and subsequently Crusafont and Berg (1970), cited the discovery of molariform teeth they assigned to *Allognathosuchus*, which subsequently were included in *Bernissartia* sp. (Buffetaut and Ford, 1979). The first study of crocodile teeth of was Estes and Sanchiz (1982) who cited three types of dinosaurs: ?Atoposauridae, ?Pholidosauridae and cf. *Bernissartia* sp.

Later Sanz *et al.* (1984a) noted four morphotypes of crocodile teeth in Galve: *Bernissartia,* cf. *Theriosuchus* sp., cf. *Machimosaurus* sp., and Goniopholididae (= ?Pholidosauridae of Estes and Sanchiz, 1982). Later Buscalioni and Sanz (1984) defined four morphotypes of crocodile teeth, assigning them to Goniopholididae indet., Bernissartidae indet., and cf. *Theriosuchus* sp. (Atoposauridae). Buscalioni *et al.* (1984) studied a complete skull of a juvenile specimen, which they attributed to *Bernissartia.* Buscalioni and Sanz (1987a, 1987b)

recognized three Metamesosuchia: *Goniopholis* sp., *Goniopholis* cf. *crassidens, Theriosuchus* sp., and *Bernissartia* sp. as well as vertebrae of Mesosuchia indet. Finally, Buscalioni and Sanz (1990) assigned the skull of a *Bernissartia* to *Bernissartia fagesii* and included the three genera present in Galve *(Bernissartia, Goniopholis*, and *Theriosuchus)* in the clade Neosuchia.

Crocodile eggshell fragments are abundant in the Collades Blanco level; Kohring (1990) was the first to identify them and noted that they are the oldest known. These shells have a labyrinthine pattern, with subparallel walls, slightly meandering ridges and furrows. They have irregular pores of subelliptical contour, ridges and furrows, and secondary pores of smaller size. Basal shell units of conical form are distinguished in radial view. Amo (1998) identified two different ootaxa (Krokolithidae indet.) in the Cuesta de los Corrales 2 and Camino Canales localities.

TURTLES

Turtles (Chelonia) are represented in almost all localities in Galve. Kühne (1966) and Krebs (1985) cited turtle shell fragments in Colladico Blanco. Three different types of turtles have been recognized from egg fragments, one of which was identified as Batagurinae (Kohring, 1990), although this identification is doubtful (Murelaga, 1998). These fragments are abundant in the "Colladico Blanco" level and are characterized by a gently undulating outer surface with subcircular pores of large diameter. The inner surface has a labyrinthine structure of the basal shell units, and the spaces between units are the openings of the respiratory canals. In radial view the shells are formed by relatively low, wide units that are funnel-shaped. Amo (1998) identified two ootaxa at the Camino Canales locality, which are *Testudoolithus* sp. and *Testudoflexolilthus* sp. The skeletal remains of turtles, some quite comprehensive, remain unstudied.

LIZARDS

The remains of lizards (Squamata, Sauria) are scarce and fragmentary. Crusafont-Pairó and Adrover (1965, 1966) cited small-sized varanids at Yacimiento Herrero, and Kühne (1966) and Krebs (1985) noted teeth and squamate dermal ossifications (Lacertilia) in Colladico Blanco. Five taxa have subsequently been recognized: Lacertilia *incertae sedis* in Yacimiento Herrero (Estes and Sanchiz, 1982), *Ilerdaesaurus* sp. in Cerrada Roya (Richter, 1994a), Paramacellodidae indet. in Poca, *Paramacellodus* sp. in Pelejón 2 (P2, equivalent to Colladico

Blanco), and Scincidae *incertae sedis* in Colladico Blanco (Richter, 1994b).

PTEROSAURS

Flying reptiles (pterosaurs) remain unstudied. They are represented by teeth at the Colladico Blanco locality (Kühne, 1966; Krebs, 1985), a phalanx of great size from Corrales del Pelejón-2 without systematic attribution, and small fragments of phalanges attributable to Pterosauria from Yacimiento Herrero (Pterosauria indet. in Canudo *et al.* 1996a).

AMPHIBIANS

Amphibians are scarce, being represented by fragments of postcranial skeleton, maxillae, and mandibles. Kühne (1966) cited urodele mandibles and vertebrae in Colladico Blanco. Only the amphibians of Yacimiento Herrero have been studied, where three species of amphibians have been recognized (Estes and Sanchiz, 1982): two salamanders (Caudata), *Albanerpeton* cf. *megacephalus, Galverpeton ibericum* and a frog (Anura), *Eodiscoglossus santojae*, plus a Caudata *incertae sedis*. The genus *Galverpeton* is defined in Galve from an isolated vertebra from the collection of the Museo de Sabadell. Finally, Krebs (1985) noted teeth and postcranial elements of urodeles and anurans in the "Weald" of Galve (Colladico Blanco), and Canudo *et al.,* (1996a) cited Prosirenidae indet. and Discoglossidae indet. in these levels.

"FISHES"

The first citations on the fishes of Galve are those of Crusafont-Pairó and Adrover (1965, 1966) and Crusafont and Gibert (1976), who found abundant remains of "fishes" in Yacimiento Herrero, some of which were classified as pycnodonts. Kühne (1966) cited *Acrodus* teeth (hybodontid shark), and holostean teeth and scales in Colladico Blanco. Krebs (1985) noted teeth of Chondricthyes, and scales and teeth of Osteichthyes. The fishes have been recognized in all localities with microfauna, although they have been studied in detail at three, and published only from Yacimiento Herrero (Estes and Sanchiz, 1982).

The cartilaginous "fishes" (Chondrichthyes), which include sharks and rays, are represented by teeth, dermal plates, and spines of hybodontids (primitive sharks), such as *Hybodus*? *parvidens* and *Lissodus microselachos*, identified in the Yacimiento Herrero locality from isolated teeth. The holotype is deposited in the Museum of Teruel. Teeth have also been

found of a ray *(Rhinobatos* sp.) in the Cerrada Roya-Mina level, and modern sharks (Lamniformes indet.) in Pajar Julian Paricio (Canudo *et al.,* 1996a, undescribed). In the Herrero collection are some coprolites whose spiral shape is similar to those attributed to selachians.

The bony "fishes" (Osteichthyes) are numerically most abundant in the Galve localities and the least studied. In most of the localities there are scales, loose teeth, and palatal fragments of *Lepidotes* sp., and teeth from four other undetermined taxa have also been described: Amiidae indet., Pycnodontidae indet., "Holostei" indet., and "Teleostei" indet. (Estes and Sanchiz, 1982).

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