



The Dinosaur Route in El Castellar (Teruel, Spain): Palaeontology as a Factor of Territorial Development and Scientific Education in a Sparsely Inhabited Area

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Received: 19 November 2019 / Accepted: 20 May 2020 / Published online: 14 June 2020
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Abstract

Research into and conservation of geological heritage and the use of the knowledge gained for the education of the general public lay the groundwork for the creation and consolidation of specialised museums and the dissemination of knowledge among a more diverse audience. In this way, resources linked to Geology will become a territorial development factor and move societies to consider them as indispensable resources for their benefit. This, along with heritage laws, will ensure that these elements are provided with the stewardship to ensure their long-term care and maintenance. This action plan is being carried out with the geological and palaeontological heritage in some places of the province of Teruel (Spain) where, even in remote areas with little more than one inhabitant per square kilometre, the research, development and innovation have resulted in various museography actions in dinosaur sites. *The Dinosaur Route* in a small village called El Castellar, which already has other tourist attractions related to “terrible lizards”, is one example of research being placed at the service of territorial development in rural areas. The route is a 2.3-km walking trail that consists, mainly, of two dinosaur fossil sites that have been enabled for tourist visits which have great educational value for all audiences: Camino El Berzal, with tracks, and San Cristóbal, with various original bones of a stegosaurid. The latter is the first site in Spain where dinosaur fossils can be seen in situ in a permanent exhibition.

Keywords Dinosaur fossils · Stegosaurids · Museography · Socio-economic development · Depopulation

Introduction and Background About Depopulation

The province of Teruel, which occupies some 14,809 km², had 265,908 inhabitants in 1910 and 136,473 in 2000. It has been reduced to only 133,344 in 2019 according to the *Instituto Nacional de Estadística de España* (<https://www.ine.es>). This gives an average population density of nine inhabitants per square kilometre (almost a tenth of the Spanish average). In fact, 145 municipalities in the province (61%) have a population density of less than four inhabitants per square kilometre, and 196 of the 236 municipalities have less than 500 inhabitants. Of the provincial population, 26.7% is over 65 years of age, compared with the national average of

16.7%. In 2019, an average age of 56 years old was recorded in the 95 municipalities with less than 100 inhabitants, according to census (not all of which live in these towns year-round). Given all of this, Teruel and other interior provinces of Spain, known as Serranía Celtibérica, represent one of the least densely populated and most aged areas of Spain and Europe and suffer constant depopulation (Burillo Cuadrado et al. 2019).

However, over recent years, the province of Teruel has moved to recognise its geological heritage in order to foster development based on geotourism in an effort to reverse the trend of population loss. The dissemination of knowledge resulting from the geological findings and research carried out in the province plays an important role in territorial development and serves as a tool for formal and non-formal education. The most well-known initiative of this type is the palaeontological park Dinópolis (more than 3,159,000 visits as of December 2019, since its opening on June 1, 2001 (of those 2,632,827 visited the main Dinópolis park in the city of Teruel—population 35,890—with the rest distributed among the seven smaller Dinópolis centres across the province)). In

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addition, there are other projects scattered throughout the province that expand the offer for all those interested in Geology and/or Palaeontology (e.g. Barco et al. 2004; Escorihuela and Dowling 2015; Mampel and Hernández 2016; Alcalá 2018; Cobos et al. 2018; Moliner and Mampel 2019). Some of the latest initiatives planned for this purpose, such as *The Dinosaur Route* described in this article, have been carried out in El Castellar, a small village located in the Comarca of Gúdar-Javalambre, 40 km from the city of Teruel (Fig. 1). According to the *Instituto Nacional de Estadística*, El Castellar had 449 inhabitants in 1910, 97 in 2000 and only 58 in 2019 (38 men and 20 women, of which about 36 reside there throughout the year) and just over one inhabitant per square kilometre. No births have been recorded since 2005.

Cultural and Natural Heritage

El Castellar and its surroundings possess a rich natural and cultural heritage (Cobos and Alcalá 2018a; Cobos et al. 2018). Indeed, much of its surrounding area is included in the designated Areas of Community Interest (*Lugares de Interés Comunitario*) of *Maestrazgo y Sierra de Gúdar*, *Sabinares del Puerto de Escandón* (that form part of the Natura 2000 Network), and the *Reserva Natural Fluvial del Río Mijares*. In addition, the *Parque Cultural del Maestrazgo* and the *Parque Cultural del Chopo Cabecero del Alto Alfambra* are quite close (25 and 10 km by road respectively). The village also possesses ten *Assets of Cultural Interest* (*Bienes de Interés*

Cultural): its castle and five sites with rock art (*Monument* category), and four dinosaur tracksites (El Castellar, El Pozo, Camino El Berzal and El Hoyo sites) considered *Palaeontological Zone* category sensu Decree 18/2004, 27 January of the regional government of Aragon. These four tracksites are also recorded as *Places of Geological Interest* (*Lugares de Interés Geológico*) according to the Aragon Government. Furthermore, there is significant historical heritage related to the Spanish Civil War (1936–1939) as well as various archaeological sites from the Iron and Bronze ages.

Geological Context and Dinosaur Palaeontology

El Castellar, which geologically lies in the Peñagolosa Sub-basin (part of the Maestrazgo Basin) (Salas et al. 2001), has been the workplace of palaeontological activities by the *Fundación Conjunto Paleontológico de Teruel-Dinópolis* (FCPTD). From the palaeontological point of view, 73 sites with dinosaur bones or tracks have been inventoried in different lithostratigraphic units that range from the Upper Jurassic to the Lower Cretaceous (from the Kimmeridgian to the Barremian (see some references below)). From 2002 to date of publication, 36 scientific articles have been published (eleven of them in journals in the Science Citation Index) on the different palaeontological activities (a total of 30, including surveys, excavations and in situ restoration work) and parallel geological studies. Some dinosaur sites at El



Fig. 1 **a** Geographical location of El Castellar (Teruel, Spain), **b** aerial view of the village and its Mesozoic surroundings. Modified from Cobos and Alcalá (2018a)

Castellar are placed in the Villar del Arzobispo Formation (Kimmeridgian-Tithonian) sensu Campos-Soto et al. (2017, 2019), which is partially considered Cedrillas and Aguilar del Alfambra Formations (Kimmeridgian-Berriasian) by Aurell et al. (2019). Ichnites from sauropods, theropods, ornithopods and thyreophorans have been documented in these outcrops (Cobos et al. 2010, 2014; Alcalá et al. 2014a, 2014b). The El Castellar site (CT-1) stands out because it is the type locality of two ichnotaxa: *Deltapodus ibericus* Cobos, Royo-Torres, Luque, Alcalá, Mampel 2010 and *Iberosauripus grandis* Cobos, Lockley, Gascó, Royo-Torres, Alcalá 2014 (attributed to stegosaurid and a megalosaurid trackmakers respectively) and because this site shows an occurrence of large (*Megalosauripus* cf. *transjuranicus*) and giant (*Iberosauripus grandis*) theropod tracks (Belvedere et al. 2019). The El Pozo site (CT-2) is known scientifically mainly for the sauropod tracks and trackways of small ornithopods in quadruped walking (Alcalá et al. 2014a, 2014b). The Camino El Berzal site (CT-3) is known for sauropod and theropod tracks (see below). Dinosaur bones include several postcranial elements of the stegosaurid *Dacentrurus* found at the site of San Cristóbal (Cobos et al. 2010; see below), sauropod remains from the site of La Tejería, and a vertebral centrum of *Diplodocoidea* indet. from the Los Canales site (Cobos et al. 2015).

In the Lower Cretaceous (upper Hauterivian-lower Barremian), the El Castellar Formation has provided a tooth assigned to the sauropod *Opliosaurus armatus* Gervais, 1852 (Royo-Torres and Cobos 2007), plus several remains of at least three individuals of two different but indeterminate iguanodontians (a large genus related to *Magnamanus* and *Iguanodon*, and a middle-sized one related to *Morelladon*), which are tentatively ascribed to the Styracosterna clade by Verdú et al. (2019). The Camarillas Formation (lower Barremian) has provided abundant *Taenidium* ichnofacies in the El Hoyo site (CT-4), and small-medium-sized theropod tracks (Rodríguez-Tovar et al. 2016; Cobos et al. 2018) plus those of large ornithopods (Cobos and Gascó 2012) assigned to the ichnogenus *Caririchnium* (Díaz-Martínez et al. 2015). This Formation and the overlying Artoles Formation (upper Barremian) yield several sites with ichnites conserved as natural casts (see below). In addition, an isolated theropod tooth classified as *Coelurosauria* indet. has been described (Torrente et al. 2018). Finally, in a site representing the transition between the Upper Barremian and the Lower Aptian, several postcranial remains of the sauropod *Tastavinsaurus sanzi* Canudo, Royo-Torres and Cuenca-Bescós 2008 have been found (Royo-Torres et al. 2012). El Castellar therefore has an important palaeontological heritage related to dinosaurs and other vertebrates (for example the oldest known evidence of a dortokid turtle sensu Pérez-García et al. (2017) has been recorded in the El Castellar Formation).

Diffusion of Knowledge and Specific Activities Until 2019

Aside from specific activities focused on the dissemination of this heritage through scientific congresses or teacher training, it was not until 2015 when the first major museographic project was carried out. On March 29, the *DINOpaseo por El Castellar (DINOWalk)* was inaugurated, where tourists can admire the diversity of the dinosaurs and their tracks in the municipality by following a route through the streets of the village. Subsequently, on July 25, 2016, the dinosaur tracksite called El Castellar (CT-1) was adapted for tourist visits. Another project was the installation of equipment with geological information for a new kind of climbing activity in the *Jurassic Via Ferrata*. One fact to point out is that these initiatives have been carried out with public grants applied for through the village of El Castellar and not through larger administrative bodies (see details in Cobos and Alcalá 2018a).

These museographic initiatives mentioned above facilitate the dissemination of geological and palaeontological knowledge by making the information more accessible and attractive for tourists, as well as teachers and students at different educational levels. The value these projects offer as educational support material has led to some activities being carried out in the municipality. For example, these resources are usually included in the summer course on Palaeontology and Development at the Campus of Teruel (University of Zaragoza)—with the XVIII edition of the course, held in 2019, there are six events held in El Castellar (a total of 150 students)—and, for the last 8 years, in the field trips of the Master's of Advanced Palaeontology of the Complutense University of Madrid (approximately 120 students), among others. Other scientific dissemination events have also been added, such as *Geolodía—Geoloday* in English (an initiative that emerged in Aliaga (Teruel) in 2005. It is currently the most popular geological activity in Spain, as it takes place one weekend a year in all provinces of the country, in which specialists share the interpretation of some remarkable geological feature with attendees) (Crespo-Blanc et al. 2011). This activity, held in El Castellar on May 12, 2018, with the title “Geolonight: dinosaur tracks under the Moon light” (Fig. 2), attracted more than 200 people who partook in a nocturnal palaeontological observation of the dinosaur tracks at the El Castellar site. This nighttime activity rounded off a day's worth of geological diffusion activities: A route that shows basic concepts of the marine Jurassic on the way to the *Jurassic Via Ferrata*, an educational activity called *DINOvelocity* which shows how to calculate the speed at which the dinosaurs walked and the *DINOWalk*. In addition, all of the *Geoloday 2018* attendees received a complete colour guide (Cobos and Alcalá 2018b) and, by way of anecdote, had the chance to try a menu that the village restaurant had



Fig. 2 *Geology* in El Castellar: **a** cover of the scientific guide, **b** showing tracks at night in the El Castellar site, **c** guided visit to the surroundings of the Jurassic Via Ferrata, **d** DINOvelocity educational workshop

prepared for the occasion. This menu included dishes prepared with ingredients that were “scientifically” related to the local palaeontological heritage, such as beans with clams from the Cretaceous Sea, *Diplodocus* steak or stratified cakes. Furthermore, in El Castellar was held in October 2018 the First Conference about the Commitment for the Survival of Our Villages (*I Jornadas sobre el Compromiso para la Supervivencia de Nuestros Pueblos*). This conference was promoted by the *Federación de Asociaciones de Vecinos de Teruel* and focused on the underlying theme of dinosaurs.

The results obtained with respect to the number of visitors from 2015 until the end of 2018 are not precisely quantifiable because there is no official counting method. Cobos and Alcalá (2018a) made a conservative estimate of 2376 visitors between June 2015 and August 2016. This allows for a reasonable estimate of 8500 visitors up until 2018 in a village which currently has 58 inhabitants. In addition, we can say that 10,000 tourist brochures were distributed in the same village from 2015 to 2018. These visits have led to positive economic synergies reflected in the number of customers in the bar-restaurant (officially open in July 2016 with space for 52 diners) and in the tenancy of the five existing private rural houses with a combined maximum capacity of 49 guests (especially on weekends and holidays) (see below). One of them, commercially known as “*Dinorural*”, was opened in 2015 after the *DINOwalk* was inaugurated. This background is the main reason why a charming rural hotel (*Hotel Rural Curia*)

with 10 rooms for 32 guests, built with municipal funds, has found commercial managers since 1 October 2018 (personal communication with Modesto Pérez, mayor of El Castellar since 1995). The local business owners and inhabitants attribute this uptick in activity to the media impact of years of scientific and museographic initiatives in a village that was previously almost unknown from a touristic point of view (personal communication from Francisco Berrón, president of the cultural association “*El Castellar, Pueblo en Acción*”, and statements from the manager of Hotel Rural Curia to the *Diario de Teruel* on 28 July 2019: “*Si no se hubiera hecho lo de los dinosaurios, El Castellar estaría muerto*”—“If the dinosaur stuff had not been done, El Castellar would be dead”). This has occurred despite the lack of formal marketing for the wide range of palaeontological tourism in the municipality. Because of these results, they continue to propose new museographic projects as part of a strategic plan that consists of using the palaeontological and natural heritage of El Castellar as the main driving forces for the municipality. *The Dinosaur Route* is the most recent project carried out as part of the plan.

The Dinosaur Route

The *Dinosaur Route* is a 2.3-km walk (4.6 km round trip) through two main sites with fossils of vertebrates that have been prepared for the visit: the tracksite called Camino El

Berzal (Alcalá et al. 2014b; Cobos et al. 2014) (600 m from the start of the route) and the site called San Cristóbal with the original bones of a stegosaurid (Cobos et al. 2010) at the end (Fig. 3). The new project, carried out during 2018 and officially inaugurated on February 10, 2019, greatly expands the offer of scientific dissemination in the municipality mentioned in the “Introduction” section. This is achieved through the new exhibition of tracks and, above all, of original dinosaur bones. To this end, palaeontological work has been carried out (excavation and preparation of fossils *in situ*) and routes have been conditioned with walkways, roofs, glass barriers, interpretation panels, beacons and indicator arrows along the route, replicas and other resources (see details below). The various museological and palaeontological projects carried out have been planned and supervised by the palaeontologists of the Fundación Conjunto Paleontológico de Teruel-Dinópolis, authors of this contribution. The initiative has been promoted by the City Council of El Castellar (special importance should be given to this fact, given that in this municipality palaeontological-related investment has taken precedence over other types, such as architectural ones services), and financed mainly by the Teruel Investment Fund of 2017, to the sum of €103,087.55.

1. Start of the route (stop 1)

The start of the tour is located 300 m from the village’s Plaza Mayor (Main Square). The site serves as a viewpoint for

the outcrops of the Lower Cretaceous of the Sierra del Chaparral (belonging to the Place of Community Interest Maestrazgo and Sierra de Gúdar of the Natura 2000 Network) (Cobos et al. 2018). As a route logo, a 6-m-long metal silhouette that artistically represents a stegosaurid has been installed (Fig. 4). These ornithischian quadruped dinosaurs, which were herbivorous and could reach up to 10 m in length, are characterised mainly by two rows of upright dermal plates and/or spines, one on each side of the midline from the neck to the end of the tail (Maidment et al. 2008; Cobos et al. 2010). The type of dinosaur for the sculpture has not been chosen at random, since the beginning of the route is only 200 m from the El Castellar tracksite (type site of the icnotaxon *Deltapodus ibericus*, whose trackmaker has been assigned to stegosaurids) (Cobos et al. 2010). This site was already conditioned for the tourist visit in 2016 (Cobos and Alcalá 2018a). In this way, both the beginning and end of the route at the San Cristóbal site are related to fossils of these thyreophorans, making them the protagonists of the excursion.

2. La Carrasca site (stop 2)

The walk on asphalt, track and path almost entirely crosses sediments of the Late Jurassic of Tithonian age (Campos-Soto et al. 2017). Visitors take the tour freely and are guided by fifteen beacons and four indicating arrows along on the route. One of the information panels has been installed in La Carrasca (CT-62) site (Fig. 5). In this site, you can see several



Fig. 3 Situation of the different museographic projects on dinosaurs carried out in El Castellar (among them, *The Dinosaur Route* with the two main sites)

Fig. 4 Six-metre-long metallic silhouette that artistically represents a stegosaurid (right) and that serves as the Route logo (left)



tracks preserved as convex hyporeliefs, a result of the footprints in mud being filled with sand. These hyporeliefs do not have skin impression marks, toes or manus of the trackmakers. That is why it is not easy to attribute them to a specific group of dinosaurs. However, their general morphology suggests that the footprints were probably produced by sauropods. This statement is reinforced by the fact that on the same slope where the tracks are located, just 15 m away, a half moon-shaped fill, typical of this type of dinosaur, was discovered.

3. Camino El Berzal site (stop 3) (Figs. 6, 7 and 8)

The Camino El Berzal site was declared an Asset of Cultural Interest (Bien de Interés Cultural) by the Government of Aragon in 2004 with the figure of Set of Cultural Interest-Palaeontological Zone (Conjunto de Interés Cultural-Zona Paleontológica). This affords the highest degree of legal protection in Spain for a palaeontological site.

In the Camino El Berzal, there are four tracks belonging to the trackway of a theropod, assigned by Cobos et al. (2014) to *Bueckeburgichnus*-like. This site also has about 50 tracks of sauropod dinosaurs (some of which were more than 1 m in diameter) (Alcalá et al. 2014b; Cobos et al. 2014). However, it cannot be ruled out that some of the oval tracks present were produced by stegosaurids because, as Cobos et al. (2010)

showed, in the absence of toe marks, the differentiation between the tracks of one and another trackmaker is not straightforward. In the Upper Jurassic of El Castellar, in addition to the sauropod tracks of the Camino El Berzal and El Pozo sites, bones of this type of dinosaur have also been found. We must highlight the fossils found in the La Tejería site (CT-30), where seventeen tail vertebrae of a single individual were excavated with their respective chevrons. They are currently in display in the dinosaur hall of the Palaeontological Museum of Dinópolis in the city of Teruel. The most relevant aspect of these fossils is that they are attributed to a diplodocid sauropod (research in process), as is the isolated vertebral centrum described by Cobos et al. (2015).

3.1 Digs and palaeontological preparation (Fig. 6)

For the museography of Camino El Berzal, a series of digging and preparatory tasks were undertaken in 2018 by the FCPTD team. This work basically consisted of the extraction, from an area of about 10 m², of an upper layer of clay that covers the layer of sandstones that contains the tracks. However, the Camino el Berzal site had already undergone, some years ago, other conservation interventions by the Government of Aragon's III Palaeontological Restoration Workshop (*Escuela Taller de Restauración Paleontológica III del Gobierno de Aragón*). Specifically, in 2009 restoration work was carried out at the site as it was in a very poor state of conservation (No. exp.: 233/2009, unpublished report of the Escuela Taller entitled in Spanish "Memoria técnica conservación yacimiento "Camino El Berzal" (El Castellar, Teruel)"). Fortunately, the set of actions carried out that year (very similar to those described by Ballano et al. (2008) in El Pozo) remedied its very high degree of deterioration and regained its scientific, social and touristic value. However, as no periodic maintenance or preservation work had been carried out in situ between 2009 and 2018, some tracks were significantly altered. Therefore, before its inclusion in *The Dinosaur Route*, new excavation and preparatory work on the site



Fig. 5 Dinosaur tracks preserved as convex hyporeliefs and information panel at the La Carrasca site (CT-62)

Fig. 6 Restoration work in 2009 in the Camino El Berzal site. Note the tracks before and after the work



has been necessary. The projects in 2009 and 2018 mainly consisted of:

- Surface cleaning. As a general rule, before applying any product to any deposit, it is important to clean the area properly to ensure good adhesion with the rock surface. On the Camino El Berzal, the elements that were not part of the site (e.g. rock fragments detached from the nearby slope, cattle droppings, anthills) were removed. This task was done manually with the help of brooms, vacuum cleaners, brushes and sharp tools.
- Elimination of vegetation. All the vegetation surrounding the site whose roots reached the layer that contains the tracks was removed. In general, the vegetation consisted of herbaceous plants, bushes and small shrubs. All of them were removed with pruning shears, pliers and metal tools.
- Stabilisation of the layer with tracks. This process was especially intense and thorough in 2009. To avoid the loss of blocks of rocks that form the layer and contain the dinosaur tracks, the most vulnerable areas, mainly around the perimeter of the site, were compacted. To do this, a mortar composed of sandy limestone and cement (in a 1:1 ratio) was used. Prior to the application of the mortar, the substrate is usually impregnated with a grout of cement with water to favour the subsequent grip of the mortar. It was applied by pouring and with the help of brushes. The mortar then was softened with a moistened sponge that also erased the marks produced by the tool used during its application.
- Adhesion of broken or detached fragments. Loose rock fragments that were part of a track or constituted a



Fig. 7 General view of the Camino El Berzal site after the work carried out in 2018: **a** museography, **b** main outcrop with tracks

significant area of the site were returned to their original positions. To do this, the fragments were cleaned with brushes and scalpels. Finally, the areas to be joined were cleaned with acetone to facilitate the opening of the pores in the rock and ensure good adhesion. Quick-drying epoxy resins were used in the areas that required some filler and structural adhesion. For more immediate joints that involved smaller fragments, cyanoacrylate-based adhesives were used.

In addition, in 2010, the students of the Palaeontological Restoration Workshop School made several moulds of some of the most significant sauropod and theropod tracks in the site. These moulds have been used to make several fibreglass replicas that are now exhibited in the dinosaur hall of the Dinópolis Palaeontological Museum in Teruel, at two of the stops of the *DINOWalk* and in the museography of the site itself. The process of making the moulds and the replicas is similar to the one reported in Cobos et al. (2018) for the El Hoyo site and according to the methodology described by Aberasturi et al. (2008). In addition, a photogrammetry/3D scanning study of the site was undertaken (Alcalá et al. 2014b).

3.2 Museographic conditioning (Figs. 7 and 8)

Any museographic action must develop an action plan based on the characteristics of the site and its environment and adapted to available budget. The main objective should be to appropriately inform and disseminate the heritage resource to promote visitor satisfaction, while ensuring the preservation of the asset. The Camino El Berzal site has been conditioned and its accessibility by foot has been improved. A panel and three interpretation boards have been placed, as well as perimeter fences that prevent the passage of vehicles, people or animals and two elevated walkways as a viewpoint that allow a clear vision of the outcrop and the natural environment. All furniture is made of pinewood treated in autoclave IV and custom designed. A colourless compact polycarbonate roof covers much of the site. In this way, insolation and direct precipitation are minimised and the impact of runoff waters on the tracks is reduced. Two replicas have been installed on the wooden structures so that the visitors can “quench” their need to touch the fossils and facilitate the interpretation of the location of the tracks.

4. San Cristóbal site (stop 4) (Figs. 9, 10 and 11)

The standout resource of the route is the exhibition of dinosaur bones in San Cristóbal (CT-28), because it is the only site in Spain where fossils of these vertebrates can be observed in situ in a permanent exhibition.

4.1 Digs and palaeontological preparation (Figs. 9 and 10)

San Cristóbal was listed in 2005 after the discovery of some seemingly unimportant bone fragments on the surface. Two years later, after conducting several prospecting surveys in order to locate the specific level from which the loose fragments came, a palaeontological excavation was undertaken. Fossils corresponding to the sacrum, pelvic girdle, and several caudal (tail) and dorsal (back) vertebrae of the same individual were found. These fossils, already restored, form part of the collections of the Museo Aragonés de Paleontología (FCPTD). In preliminary research, these bones have been attributed to the stegosaurid *Dacentrurus* because the dorsal surface of the distal ischial shaft is straight (Cobos et al. 2010; Cobos and Gascó 2013). In the 2007 campaign, some fossils had to be left in the field because the height of the slope made their extraction by hand impossible. In 2015, after several successive campaigns and with the help of manual methods and heavy machinery, the levels with fossils which can be today observed in situ were reached: mainly complete dorsal vertebrae, several ribs and very fragmented appendicular elements. The set of fossils excavated from the stegosaurid of San Cristóbal makes it the most complete of those known scientifically in Spain so far. In addition, this specimen is

Fig. 8 a Wooden structures, replica and information panel at the Camino El Berzal site, **b** some examples of the didactic panels at this site (explanations are made by an imaginary palaeontologist called Dr. Fundi—an abbreviation of Fundación)



very important in the knowledge of the diversity of the Iberian stegosaurids because, together with other fossils described in Teruel, they show autapomorphies (see Figs. 2 and 3 in Cobos et al. 2010) both of *Dacentrurus armatus* and *Miragaia longicollum* according to the revised diagnosis of Costa and Mateus (2019). This implies a contradiction which questions the validity of that diagnosis. Therefore, the fossils from Teruel must be attributed to the first defined genus, which is *Dacentrurus*.

While research on this material was ongoing, a proposal from the FCPTD was made to different public institutions so that most of the fossils excavated since 2015 would not be extracted and an innovative museographic project could be undertaken. All of this was done so that the site could be conditioned for visits and thus become a unique and differentiating element in the wide palaeontological offer of the province. After several projects and unfruitful attempts, in 2018 the necessary financing from the FITE (Teruel Investment Fund) was obtained through the municipality of El Castellar in the framework of this project called *The Dinosaur Route* (inaugurated in 2019).

Between 2015 and 2018, the conservation state of the bones of the site was monitored. By the end of 2018, when the financing for the project was approved, a series of actions were developed aimed at the conservation and restoration of fossils in situ, so that they could be perfectly protected and

properly observed by researchers and visitors. The palaeontological initiative consisted of the application of a series of treatments on the bones in the site itself, which were mainly made up of:

- Mechanical surface cleaning. During the palaeontological work, most of the matrix covering the fossils was removed to outline their morphology and allow for their optimal observation. For this, brushes, hammers chisels, screwdrivers, vacuum cleaners etc. were used. When the matrix to be removed was harder, percussion pencils of varying power were used.
- Physical cleaning. To remove impurities and dirt from the surface, the bones were brushed with an aqueous solution of water and/or acetone and with cotton buds and swabs.
- Adhesion. Fractured fossils were fixed with various adhesives: cyanoacrylates for smaller cracks that joined perfectly and epoxy resins when a structural reinforcement was necessary to fill an existing hole.
- Consolidation. Throughout the process, the internal structure of the fossils was impregnated with an acrylic resin dissolved in acetone in order to recover the original internal cohesion. This substance was also applied to the surface of the bones with brushes. In addition to serving as a protective barrier against dust, dirt and other environmental agents, it provides a clearer visualisation for visitors of the site.



Fig. 9 Various phases of the excavations of the San Cristóbal site: 2016 (above) and 2018 (below)



Fig. 10 Some details of the preparation and conservation of fossils in situ

4.2 Museographic conditioning (Fig. 11)

The museographic actions carried out at this site consist of the installation of a protective building with pillars, an enclosure, an exterior walkway (all in pine wood with autoclave IV) and a laminated spruce wood roof covered by plates of colourless compact polycarbonate. The protective structure consists of an enclosure made of wooden boards with large safety-glass windows and a wooden entrance. This way the visitor can see the well-protected fossils inside clearly without entering the enclosure. The building also has anti-graffiti digital prints on laminated vinyl with UV protection, both externally and internally, which include visual information on the different phases of dinosaur excavation. Other palaeontological information is also reflected in an educational panel and two lecterns.

5. *The Dinosaur Route* as an educational resource

The sites of *The Dinosaur Route* are good resources to use as part of a scientific educational activity. One of main objectives is to show the visitor in general how fossils are arranged in the sites and how scientists obtain knowledge through them. The resources (fossils, the geological context and the various museographic elements) allow the visitor to interact visually.

They also invite the visitor to reflect on what they are observing based on their previous ideas and the basic scientific concepts transmitted in the educational explanations. These explanations speak about sedimentary rocks, the period of geological time, the fossils that are observed (both tracks and bones) and how they can be identified through scientific study. Looking at the sites in their natural environment allows visitors to understand the relationship between fossils, the strata that contain them and their integration with the landscape. The visitors can appreciate how original dinosaur fossils (usually exhibited in museums) are arranged in a site, while also reflecting on the evolution of living beings on our planet. Another educational objective of the route is to allow the visitor to discover a group of dinosaurs, the stegosaurids. The route presents the fossils and their geological context as an example of how palaeontologists can reconstruct a living being from the past and answer the question of what the stegosaurids were like and where they lived, etc.

The Dinosaur Route can be used specifically in formal education so that a specific interest in geology can be

Fig. 11 Several perspectives of the museography in the San Cristóbal site. Official inauguration of *The Dinosaur Route* on February 10, 2019 (bottom right)



developed. Visual interaction with fossils is a key element for successful teaching. Depending on the different educational levels, the teacher can use this route as part of a project on this topic previously worked on in the classroom. Then, during the visit itself or later, a debate can be generated among the students about the concepts learned in the tour. In addition, the route generates a desire for discovery and respect for the environment which is more difficult to obtain in a museum or in a masterclass activity. It also features some interdisciplinary educational aspects, such as the use of geological resources for tourism, among others.

Past and Present Perspectives

As mentioned above and below in the present article, the museographic projects carried out in El Castellar have enabled the development of an emerging tourism sector that helps support small local businesses and expand the offer of others located in nearby villages. However, one of the fundamental collateral aspects, which is not usually given so much importance, is the increase in awareness of the scientific heritage in the local population (typically scarce, ageing and quite traditional). Museographic actions and awareness days have served to enlighten those people who formerly thought that these “holes” in the rocks were nothing more than marks left by the pack animals that were used daily in agriculture centuries ago. We can mention here the use that some of the inhabitants of the village gave to the “holes” until half a century ago. They used some of the holes in a ravine near the village to create small wells and spread the rose hips around them (fruits of the bushes of the wild rose—which are also called by the

zone “galabardos” or “tapaculos”). The objective was that the birds, especially thrushes, went there to eat and drink and that, after “stumbling” over small sticks that supported some stone slabs, they would be trapped underneath them. They then sold the birds in nearby villages. Today, everyone knows that these small wells are the tracks of dinosaurs at the El Castellar site (Cobos et al. 2010, 2014). Other inhabitants of El Castellar report that the levels with tracks of the El Pozo site emerged after the manual extraction of limestone in order to lift the stone walls that currently delimit the agricultural plots. In Formiche Alto (a village located 12 km from El Castellar), some of the sauropod tracks in the El Molino site (Cobos et al. 2005) were used as feeders to feed the chickens. The rural inhabitants’ lack of knowledge about the true origin of the dinosaur tracks is not unique to this area. In many regions of Spain (e.g. Aguirrezabala and Viera 1980; Moratalla et al. 1997) and around the world (e.g. Mayor and Sarjeant 2001; Xing et al. 2011), fossils of this type have been related with mythological beings, flying horses, giant birds, witchcraft etc. These few examples show a close relationship between humans and tracks in rural areas and a lack of knowledge about their origin. However, in recent times, there are more frequent consultations on the possible presence of dinosaur fossils in El Castellar and other nearby villages.

Current perspectives are quite promising because the increase in scientific knowledge is accompanied by museographic projects that help protect and disseminate local palaeontological resources. Periodic investments over 5 years in the sector (approximately €250,000 in total—see this article and details in Cobos and Alcalá (2018a)) are attracting visitors to El Castellar with very different profiles, knowledge and interests:

- Researchers. The specialists, besides seeing the geological and palaeontological context of this territory in situ, are interested in the museographic projects carried out in this small village. The researchers from the Fundación Dinópolis have accompanied visiting researchers from a diverse range of countries: China, France, Japan, Spain, Switzerland, Tanzania, the Republic of Korea, the UK and the USA (in addition to the specialists who attend the fieldwork sections of palaeontological congresses in the province of Teruel).
 - Tourists. The present family tourism, habitual in almost everything related to dinosaurs, seeks a cultural plus beyond entertainment itself (such as that which can occur in a theme park in the strict sense). That is, they intend to see the dinosaur fossils in their natural geological environment. The same applies to other tourists (private visitors, hiking groups, associations, etc.)—in a year and a half the rural hotel has received guests from twenty different nationalities. That does not mean that all of these tourists are attracted to the village exclusively by the dinosaurs, but it is true that everybody who visits the village is informed about the palaeontological heritage on offer. They generally display interest in visiting the adapted areas (personal communication from the manager). In order to promote visits, after the inauguration of the *Dinosaur Route* in 2019, 7500 new tourist brochures have been published regarding the situation of the spaces for visitors (Fig. 12). The tourist can self-guide through the open-air museum which the natural environment of El Castellar is becoming. Although it is too early to quantify the impact on the number of visitors after the inauguration, we can confirm that approximately 17,500 brochures have been distributed from 2015 to the date of publication. However, the end goal is not to excessively increase the number of visitors, rather to extend the stays in the village (personal communication with the mayor of El Castellar).
 - Media. With the *Dinosaur Route*, the media is increasingly mentioning the heritage in El Castellar and the now frequent projects. Several television programs have filmed reports of these resources in 2019. Among them, programs produced for Spanish state television (national news and the program *España Directo*) and the regional public channel Aragón Televisión (news reports, *Aragón en Abierto*, *Territorio Vivo*, etc.). Furthermore, various radio stations and press and online publications have produced programs and articles specifically about the *Dinosaur Route*. Recently, in an article titled “Teruel: Spain’s best kept secret” from the British newspaper, *The Times* (January 2020), the province was described as being replete with palaeontological sites and that in El Castellar dinosaur tracks can be seen (<https://www.thetimes.co.uk/article/teruel-spains-best-kept-secret-tcg3qcv57>). Additionally as the installations can be used to illustrate news about geology and palaeontology, the media frequently use the sites as filming locations. This has converted the San Cristóbal site into a go-to resource to film images of dinosaur bones and illustrate news about geology or palaeontology, even when they do not have a direct relationship with the village.
 - Education. In addition to the institutions and examples mentioned above, in 2019, fifty students from the Primary Education Teaching Degree of the Teruel Campus of the University of Zaragoza (*Grado de Magisterio en Educación Primaria, Facultad de Ciencias Sociales y Humanas de Teruel, Campus de Teruel de la Universidad de Zaragoza*) went on field trips to learn about these resources as possible tools in their future teaching activities. The educational potential is evident and the visits of all schools, at the very least those from nearby areas, should be encouraged by the relevant administrations. This way a semblance of youth would be returned to a village which has a particularly elderly population and which has been practically bereft of children over the past 22 years since the closure of the primary school. One example of this is the visit by 60 primary and preschool students from the Colegio La Fuenfresca de Teruel.
 - Local population. According to data from the *Instituto Nacional de Estadística* (<https://www.ine.es>), El Castellar has shown the fifth largest proportional growth in the province in 2019. This piece of information may seem trifling, but we should underscore the importance of reversing the trend of inhabitant loss for municipalities of this type (the village showed growth from 52 to 58 inhabitants). The mayor, in a personal communication, revealed that the hotel staff and new entrepreneurs make up the bulk of the new inhabitants. The mayor was also quoted in the *Diario de Teruel* on the 25 of February, 2019: “El Castellar has been transformed. New employment has been created and the services sector has been energised. The local restaurant is now so busy that reservations are needed for the weekend and there is a charming new hotel in the same square. The inhabitants recognise that this recent turnaround would have been unthinkable before the El Castellar dinosaurs appeared. Admittedly during the week the village is less active and few people are about, but during the weekend everything changes and more and more tourists arrive to see the resources that have been prepared over recent years.”
- Some of the cultural and sports activities carried out in the municipality that are organised by the cultural association—whose logo is *Iberosauripus*—contain expressions of palaeontological content (Fig. 13) which differentiates them from similar ones carried out in other places. For example, in

2019, the *II DINOruta Senderista* (a walking trip of several kilometres) passed through the Mesozoic sediments in which the dinosaur sites are. The participants (up to a maximum of 150) received scientific brochures and gifts related to the topic (Fig. 13a–d). Some inhabitants have begun to put weather vanes with silhouettes of dinosaurs discovered in the province of Teruel on their houses (Fig. 13e) and the bar-restaurant, whose logo is a megalosaurid theropod, displays a mural with dozens of scientific and journalistic publications about the dinosaurs of the municipality on its ground floor (Fig. 13f). Even new and young entrepreneurs use dinosaurs as a commercial emblem. Such is the case of a company—called *La Tartufería*—dedicated to the processing and packaging of black truffles that uses a stegosaurid as part of its corporate image. All these actions that have been developed during the last 5 years make El Castellar begin to be known in the local media as “the most palaeontological village” (Diario de Teruel, 11 February 2019). This is some achievement as in the same province of Teruel there are other municipalities, such as Galve, in which the dinosaurs are an important factor of territorial development for decades. The first dinosaur defined in Spain was discovered there: *Aragosaurus ischiaticus* Sanz et al. 1987 (Royo-Torres et al. 2014) and research has been conducted in the sites which were subsequently adapted for touristic use. This is the case of the tracksite called Las Cerradicas (Castanera et al. 2011; Cobos et al. 2018). Therefore, both El Castellar and Galve have become important palaeontological icons.

In summary, actions such as those in El Castellar and others existing in the Teruel province are a differentiating and necessary complement that adds to the offer of

thematic exhibitions, museums or palaeontological parks such as Dinópolis, thereby enhancing the concept of Teruel as a palaeontological territory. In addition, and although the economic perspectives of the rural tourism are much smaller than those of the general tourism in absolute terms, from the qualitative point of view, they are sufficient to significantly contribute to maintaining the rural populations. Similar museographic initiatives related to dinosaur tracksites have been carried out in other provinces of Spain with demographic problems similar to those of Teruel, such as Soria (Castanera et al. 2018) and La Rioja (Fuertes-Gutiérrez et al. 2015). The role that the geological and palaeontological resources must continue to play in these places should not be put on hold or forgotten, but enhanced. The immediate future of countless villages may depend on the work in a small rural accommodation, in artisan workshops or family-run restaurants.

A Proposal for a Feasibility Study for the Declaration of a Protected Natural Space

Fortunately, the palaeontological richness of dinosaurs in El Castellar is important enough to ensure that the research, conservation and dissemination continue. There are still several tracksites (for example El Pozo—Asset of Cultural Interest) that are suitable for the tourist visit with work similar to that in El Castellar. This site is located near the village next to a paved road with sufficient space for a car park. In addition, other tracksites, such as El Hoyo (Cobos et al. 2018), may be



Fig. 12 Tourist brochure related to dinosaur palaeontology in El Castellar



Fig. 13 II DINORuta Senderista (a walking trip of several kilometres): **a** registration poster, **b** some participants next to the *Allosaurus* in the playground, **c**, **d** gifts to all participants with the *Iberosaurus* track, **e**

weathervane of *Dacentrurus* on a village house, **f** large mural with dozens of scientific and journalistic publications in the village bar/restaurant

points of interest on nature routes that will continue to focus on Palaeontological topics.

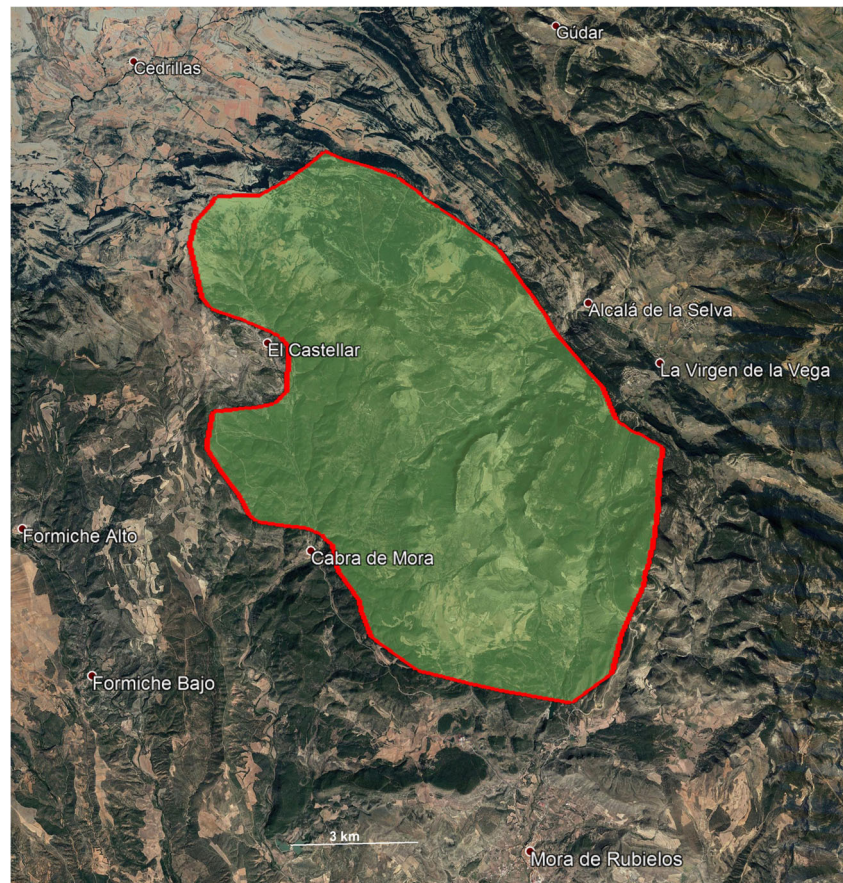
All these actions would reinforce the enormous possibilities that the El Castellar environment has (individually, or together with other surrounding municipalities with El Castellar as a hub, such as Alcalá de la Selva, Cabra de Mora, Cedrillas, Mora de Rubielos—where dinosaur sites are also located, although in smaller number) for their declaration as some category of Protected Natural Spaces provided in Legislative Decree 1/2015, of July 29, of the Government of Aragon (Fig. 14). Thus, the future of this area in the province of Teruel would be linked to the research, conservation and dissemination of its natural resources (including fossils). It should be noted that this sector lies within the area designated as the Maestrazgo and Sierra de Gúdar Place of Community Interest, which occupies some 81,000 ha in the centre-west of the Province of Teruel on land that forms part of the Natura 2000 Network.

The area of El Castellar is located in the foothills of one of the southern mountain ranges of the Gúdar Massif (specifically in the “Sierra del Chaparral”). This range, located between 1300 and 1800 m of altitude, visually dominates the depression of La Puebla-Sarrión. The Gúdar Massif in general, and this sector specifically, contains landscape, cultural and ecological values that needs to be protected in order to be preserved for future generations according to Decree 233/1999, of December 22, of the Government of Aragon. That decree highlights three environmental units that require different degrees of protection. Concerning one such area, the document highlights “the area between the Alcalá River Valley and the

source of the Mijares River (public utility mountains number 164, 165, 171, 173 and 175) for its excellent state of conservation and ecological value, and for its geomorphological, botanical and faunal uniqueness, which provides a splendid and majestic landscape with excellent views, among which is the typical masovera panorama (high density of traditional farmhouses), with crops (often terraced) and mosaic grassland by wooded areas” (in Spanish: “el área comprendida entre el Valle del río Alcalá y el nacimiento del río Mijares (montes de utilidad pública números 164, 165, 171, 173 y 175) por su excelente estado de conservación y valor ecológico, y por su singularidad geomorfológica, botánica y faunística, que proporciona un espléndido y majestuoso paisaje de excelentes vistas, entre las que se encuentra la típica panorámica masovera (elevada densidad de masías), con cultivos (muchas veces abancalados) y pastizales en mosaico con rodales boscosos”).

Now, after 20 years since the publication of the aforementioned decree, most of the 73 dinosaur sites inventoried from 2003 to 2019 are located in this area of El Castellar and surroundings. Some are of special scientific relevance (see references in Cobos and Alcalá (2018a) and this article) and others are currently being excavated and researched. Regarding the latter, it should be noted that, for those included in the aforementioned natural area, the sites are mainly of tracks. Some are located in the Camarillas Sandstone Formation (usually in the upper levels) and others in their gradual transition to the overlying Artoles Limestone and Loams Formation. In this stratigraphic sector of Barremian age, most of the tracks identified were produced by ornithopod dinosaurs. However, there

Fig. 14 Google Earth Pro photo with the approximate area (10,219 ha), belonging to the municipalities of Alcalá de la Selva, Cabra de Mora, Cedrillas, El Castellar and Mora de Rubielos, which could be studied for their possible declaration as a protected natural space in Aragón



are also some from theropods and, in lesser amounts, from sauropods and ankylosaurids. They are observed as convex hyporeliefs at the base of flat-to-convex and tabular bodies of sandstone, pebbly sandstone, sandy conglomerate, and even poorly sorted sandy-bioclastic sandstone in the Artoles Formation, which may penetrate several decimetres into the underlying siliciclastic mudstone. Many of the natural casts are extraordinarily well-preserved and even preserve the evidence of distal limb kinematics of the trackmaker by recording the movement of the feet during trackmaking. This feature is mainly recorded in the infillings of the deep true tracks that show impressions of reticulated skin, toe pads and scratch marks made by the scales during footfall dynamics which Cobos et al. (2016) designated as “4D tracks”. Towards the upper part of the Artoles Formation, the natural casts become less abundant and more poorly preserved. They are observed at the base of sandy to silty limestone and, less commonly, at the base of bioclastic sandstone. The infillings may penetrate up to 65 cm into the sediment, composed of burrowed marl, and also into sandy-bioclastic limestone displaying flaser, wavy or lenticular bedding (Benito et al. 2015).

Therefore, this paleontological heritage clearly increases the number of cultural and natural resources of this area, thereby boosting the possibilities of declaring it a Protected Natural Space. Depending on the assets, values and dimensions to be

protected, it could be in one of the categories of Protected Natural Spaces provided in Legislative Decree 1/2015, of July 29, of the Government of Aragón (Natural Monument, Nature Reserve, Protected Landscape, Natural Park or National Park). It should be noted that Teruel and Valladolid are the only two provinces in Spain (out of a total of 50) that do not have protected areas under the category of Natural Park. This is strange in the case of Teruel if one takes into account that over 48 spaces are included in the Natura 2000 Network. In the case that, as we propose here, this territory is granted the status of a protected natural area of Aragón, a widely recognised, both nationally and internationally, seal of quality of the natural environment would be obtained, similar to other important natural areas in the world that stand out for their dinosaur palaeontological sites, like for example the *Dinosaur National Monument* in the USA (West and Chure 1984), the *Dinosaur Provincial Park* in Canada (Currie and Koppelhus 2005) or different geoparks or similar spaces in Asia (Mohd Shafeea Leman et al. 2008). Thus, for example, the “Natural Park of the Dinosaurs of the Sierra de Gúdar” would be a boon for these extremely depopulated regions of southern Europe. This protected natural space would not affect the environments of already existing tourist complexes in this area (such as the Valdelinares Ski Resort), rather it would help areas that are not currently affected by urban planning.

Conclusions

The museographic project called *The Dinosaur Route* in El Castellar (Teruel) is the final result of an action model that has opted for investment in the research, education and conservation of a resource (the geological heritage) in a sparsely inhabited area with little more than one inhabitant per square kilometre. The route is a walking tour through sediments of the Upper Jurassic that has mainly two dinosaur fossil sites that have been museographically prepared for touristic visits: Camino El Berzal, with tracks, and San Cristóbal, with various original bones of a stegosaurid. The latter is the first site in Spain where dinosaur fossils can be observed in situ in a permanent exhibition. *The Dinosaur Route*, together with other developed previously projects on the same topic, is an important socio-economic spur in this small village and in its immediate surroundings. The modest investments made since 2015 have given rise to an exponential increase in the presence of researchers, tourists and media, while enabling the development of educational activities. All this means that the local population wants to continue using the palaeontological heritage as the main focus point of the municipality. In this sense, a feasibility study on the declaration of a protected natural area in the surroundings of El Castellar is proposed here, focused on its palaeontological heritage and based on the sum of landscape, cultural and ecological assets with the existing geological resources.

Acknowledgements The authors thank the Town Council and inhabitants of El Castellar (Jaume Grau alerted about the first findings in 2002), José Antonio Berrón for the aerial view, Ciarán Rowe Hibbits for language assistance, and two anonymous reviewers.

Funding Information This research was funded by the Departamento de Innovación, Investigación and Universidad (Gobierno de Aragón) and Fondos FEDER ARAGÓN 2014-2020 “Construyendo Europa desde Aragón -Research Group E04_17R FOCONTUR”, the Departamento de Educación, Cultura y Deporte (Gobierno de Aragón), the Instituto Aragonés de Fomento, Dinópolis, and the Ministerio de Ciencia, Innovación y Universidades (Gobierno de España) (Project PGC2018-094034-B-C22).

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