

## **THE GEOLOGICAL AND PALEONTOLOGICAL HERITAGE OF MANRESA MUNICIPALITY (CATALONIA, SPAIN)**

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### **RESUMEN**

Se ha llevado a cabo un inventario preliminar de 14 puntos de interés geológico en el término municipal de Manresa (Barcelona, Cataluña, España). La totalidad de las rocas que se encuentran en esta zona pertenecen al relleno sedimentario de la cuenca del Ebro que tuvo lugar durante el Eoceno. El municipio es relativamente pequeño pero concentra un patrimonio relevante de tipo sedimentológico, paleontológico y, en menor medida, geomorfológico y estructural.

La propuesta de puntos de interés geológico incluye varios afloramientos relativamente pequeños mostrando: geomorfología (un puente de roca), dos estructuras sedimentarias (un *slump* y estratificación cruzada), sedimentología clástica, un arrecife, fallas, diaclasas y dos terrazas fluviales. Otro punto combina geomorfología, sedimentología y mineralogía. Finalmente la geozona relativamente más grande de Malbalç es el punto más representativo e incluye paleontología, sedimentología y antiguas canteras. En 1926 esta zona fue visitada en el XIV Congreso Internacional de Geología. El conjunto de todos los puntos de interés geológico son ideales para la enseñanza de la geología desde un nivel divulgativo a académico.

### **ABSTRACT**

A preliminary inventory of 14 points of geological interest has been carried out in the Manresa municipality (Barcelona, Catalonia, Spain). All the rocks within this area belong to the sedimentary infill of the Ebro basin that took place during the Eocene. The municipality is relatively small and contains a relevant heritage of sedimentology, paleontology and, to a lesser extent, geomorphologic and structural.

The proposal of points of geological interests includes several relatively small outcrops that display: geomorphology (a rock bridge), two sedimentary structures (a slump and cross bedding), clastic sedimentology, a reef, faults, joints, and two fluvial

terraces. Another point combines geomorphology, sedimentology and mineralogy. Finally, the relatively larger Malbalç geozone is the most remarkable point and includes paleontology, sedimentology, geomorphology and ancient quarrying. In 1926 this zouctural.ne was visited as part of the XIV International Geological Congress. The whole set of points of geological interest are ideal to teach geology for the divulgative to academic level.

**Key words: geoheritage, Eocene, Catalonia, Spain, Ebro basin**

## 1-INTRODUCTION AND METHODS

The need to protect our natural environment and to promote sustainable development is leading several administrations to their cataloging and protection. The geological heritage is an essential part of our environment, but generally is poorly understood and protected if compared with the protection of flora or fauna. This is leading to several societies and administrations to promote Earth values in their preservation plans. Unfortunately, the popularization of the geoheritage is largely restricted to ‘spectacular’ outcrops. In this paper we describe a geological inventory of the Manresa municipality, where points of varying relevance are found.

Manresa is a town of 76.000 inhabitants located in the *Bages* shire (Catalonia, Spain) and has a territory of 42Km<sup>2</sup>. Despite being a relatively populated area, there are several points where nature is relatively well preserved. The territory is around 238 masl and is characterized by a set of hills and the Cardener and Llobregat river valleys.

The geological values of Manresa are not included in the year 2000 inventory of ‘Points of geological interests’, from the Catalan regional government (*Generalitat de Catalunya*). Similarly, the ‘Investigation area of the geological and mining heritage’ of the Spanish Geological Survey (*Instituto Geológico y Minero de España*, IGME) does not include any of the outcrops here described in his 2007 catalog.

On the contrary, Manresa outcrops are found in the middle of the geopark *Parc Geològic i Miner de la Catalunya Central* (European Geoparks network) and three of there are recognized as point of interest (points 1, 5, 6 and 10, see later). Manresa outcrops are not of worldwide significance, some of them are of remarkable quality, are very accessible and useful for teaching several geological concepts of sedimentary geology, geomorfology, paleontolgy and urban geology. In fact some areas are the target of field trips of different levels (secondary school, academic studies, popular etc.)

The town also hosts the ‘Geology Museum’ at *Universitat Politècnica de Catalunya*, has a long tradition in geological and mining studies and has been largely involved in the creation and development of the *Sociedad Española para la Defensa del Patrimonio Geológico y Minero de España* (SEDPGYM). Finally, the geology of Manresa is strongly related to its history, religion and traditions. In Manresa, the origins of the city and it’s urban growth from medieval times (location of the city walls etc.) until present day, is largely dependent on geological factors. Also the names of several places from Manresa are related to geomorphology or rocks.

In 2010 Manresa town-hall asked us for the identification of the geological points of interest in the frame of a general historic-artistic and natural heritage inventory. The unpublished rapport coordinated by Climent (2010) by contains full details. Our goal was to identify, locate and classify the points of major geological and paleontological interests of Manresa. Since the territory is relatively small and with a

limited geodiversity, we avoided a quantification of the interest of each point, although some comments are provided. Both small points (such as 150m<sup>2</sup>) and larger areas (up to 0,25 km<sup>2</sup>) were considered for the inventory. Also we incorporated information and proposals so that the inventory is also useful for territorial planning something (i.e., is something else than a 'simple list'). Thus we followed the scheme by Carcavilla *et al.* (2007), who consider the need to include (1) preliminary issues, (2) bibliographic and documental compilation, (3) summary of Geology, (4) searching of points of geological interest and (5) classification, ranking and selection of the described outcrops.

Both the criteria of importance and representativeness were considered, although most outcrops are of the latter category. Finally we have to consider that our inventory is the first one ever made, so is open to admit some new point.

## 2-GEOLOGICAL SETTING

### 2.1-ROCKS

Manresa and their surroundings are entirely located in sedimentary that belong to the Tertiary Ebro basin. This basin was bounded by three alpine fold and thrust belts: the Iberian Chain, The Pyrenees and the Catalan Coastal Ranges to the SW, N and SE, respectively (see figure 1). The basin infill has three main stages: a lower continental one (of Paleocene age), a middle Marine one (from the Eocene) and an upper continental one (uppermost Eocene, Oligocene and lower Miocene). Manresa is located at the very boundary between the middle and upper stages.

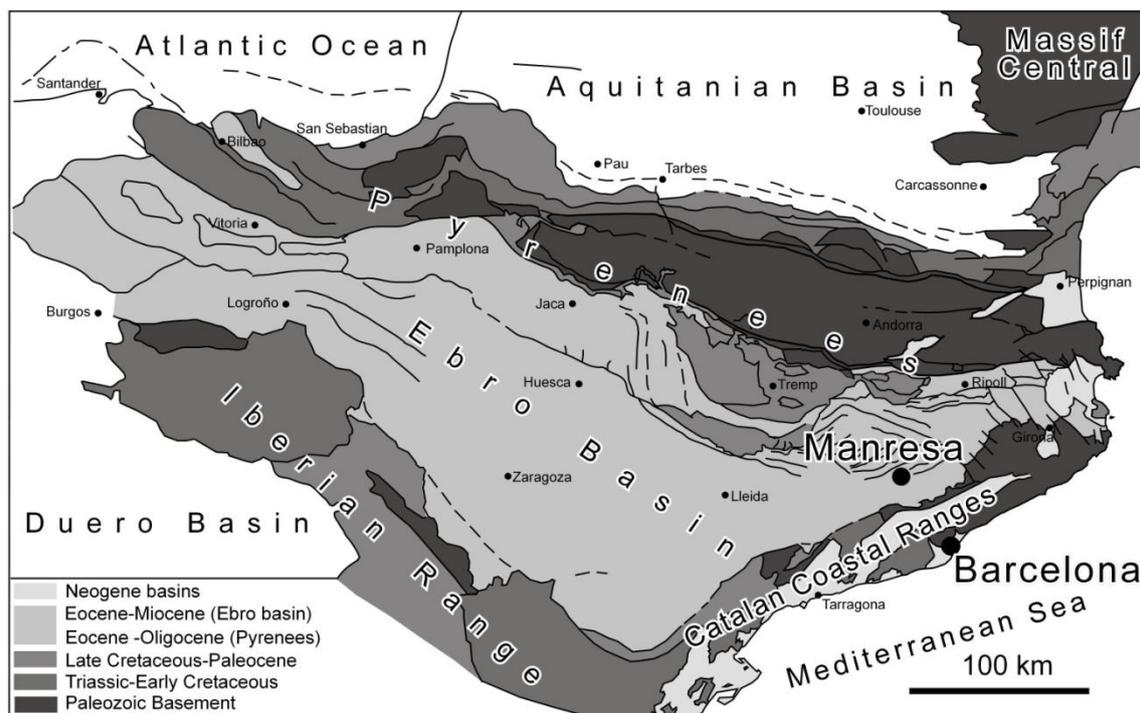


Figure 1 Location of Manresa within the geological map of the Ebro basin.

Middle (marine) stage is represented by the Santa Maria group and include conglomerates, sandstones (Collbàs fm.), marls (Igalada fm.) and limestones (Tossa fm.). The color of such units is brownish to bluish. Scarce coal layers are also found.

Upper (continental) stage is represented in Manresa by the Artés formation, which are red beds (mudstones, sandstones and few conglomerates).

Within the lower part of the Artés formation a so called transitional wedges are found. Such wedges represent an environment halfway from the earth and the sea (mangrove like). The other stratigraphic units are also related to a paleogeographic setting. Thus, the sands and conglomerate layers from the Santa Maria group belong to prograding delta bars, while marls represent the prodelta. La Tossa formation account for coral reef settings. Artés formation rocks are entirely fluvial environments.

Among sediments gravels and sands are found as fluvial terraces of Pleistocene age.

Mineralizations from Manresa are not economically important neither diverse. They include calcite, pyrite, hexahidrite ( $MgSO_4 \cdot 6H_2O$ ), and gypsum.

## 2.2 FOSSILS

Most abundant fossils from Manresa are from the marine strata and include several foraminífera (such as *nummulites*). Remarkable studies from this group were carried out by Valentí Masachs in the middle of the last century in the rock south of Manresa and Bages shire. Other common invertebrates are corals, which are common in reefs such as those of Malbalç or Transformador de les Marcetes. Bivalves include pectínids, ostreids and spondilids. Gastropods are diverse and include *Velates*, *Natica*, *Terebellum*, *Turritella*.

Other marine fossil organisms that can be found include sponges, bryozoans, polichaete worms, crustaceans, turtles, and sirenids. A species that is rather 'popular' due to its large size is *Cerithium (Campanille) gigantenum*, whose complete specimens are up to some 30 cm in length. Regarding echinoderms, most abundant are sea urchins of several morphologies.

Other fossil remains are the vegetal findings from the transitional wedges (palm-like *Nypa*) or in the Artés formation (*sabalites*); ichnites (invertebrate burrows such as *ophiomorpha* or *thalassinoides*).

In the Pleistocene fluvial terraces several large vertebrate remains have been found, including proboscideans, rhinoceros and hypos.

## 2.3-STRUCTURE AND GEOFORMS

Three factors influence the geofoms found in Manresa. First is the rock type, with a succession of competent and incompetent rocks. Second is structure, with all these strata slightly dipping to the northwest, a well developed joint system and some minor normal faults separating the *Pla de Cal Gravat* and *Bufulvent* from the *Viladordis* plain.

Erosional types include tabular reliefs, soft hills (*Puiberenguer*, *Pugiterrà* etc.) and entrenched meanders (*Gorg dels Esparvers*, *cingles de la Tolega* etc.). Differential erosion has made some sandstones and conglomerates to create the cliffs of (*La seu* or *Malbalç*) bounding cuestas (*La Balconada*, *Cal Gravat* etc.). Regarding depositional forms, the three quaternary river terraces created some flat surfaces that have been mostly quarried.

### 3-THE INVENTORY OF POINTS OF GEOLOGICAL INTEREST.

Our proposal contains the following 14 points of geological interest that can be located in figure 2. Nine points ('1' to '8' and '11') are located in the Eocene marine rocks, one in the Eocene continental ones ('14') and two in the transitional ones ('12' and '13'). Two other points ('9' and '10') are Pleistocene fluvial terraces.

**1-Pont Foradat or Pont de Les Arnaules.** Located in the *Raval* of Manresa, is one of the most remarkable natural bridges from Catalonia.

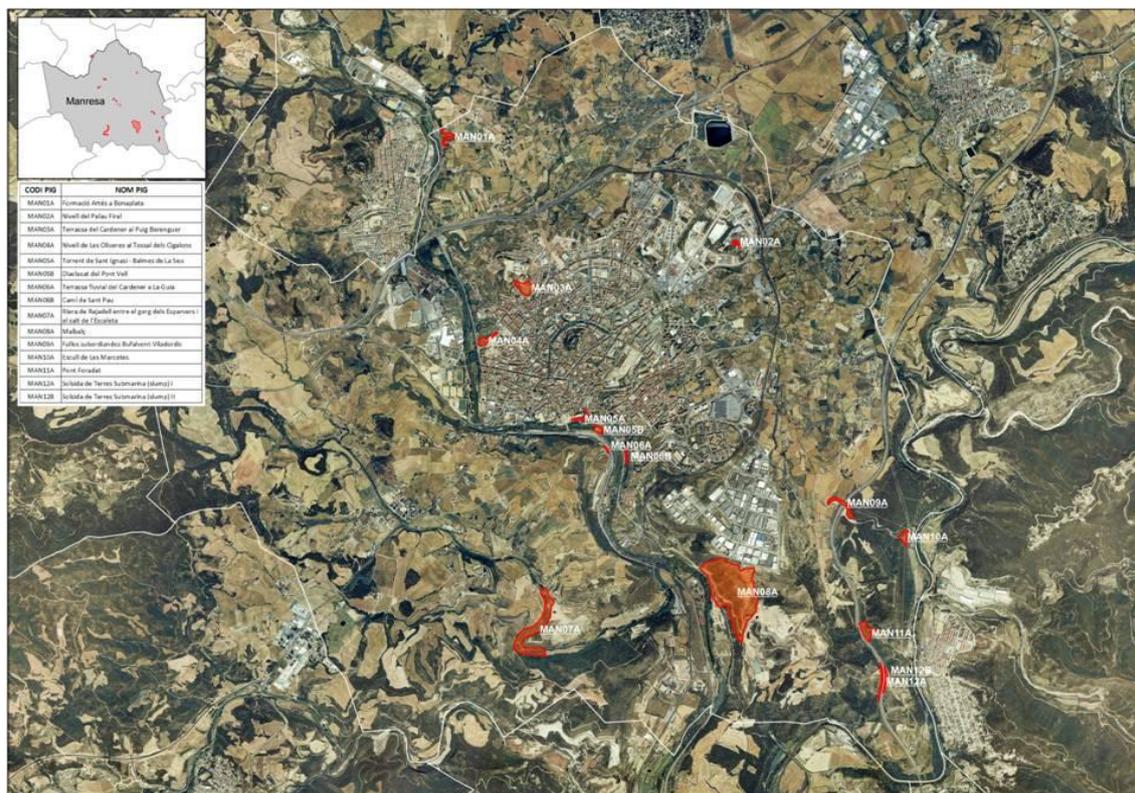


Figure 2 Aerial view of the Manresa municipality and location of the 14 points of geological interest, from Climent, 2010). Design by G. Gual.

**2-Slump at Turó del Jeroni.** Outcropping in the artificial Cliff of highway C-16, by the *Raval de Manresa* is a remarkable sedimentary structure that can be observed at the two sides of the road. This outcrop can only be observed from the distance (top of the cliff) due to its dangerous position by the highway.

**3-Reef by the Les Marcetes hydroelectric power plant.** This coral reef is complementary to the nearby Malbalç reef. Recent (2011) road works strongly damaged the prograding delta sequence capping the reef.

**4-Faults related to the Bufalvent-Viladordis fault.** Such faults display how *Bufalvent* plain is interrupted and is latter found in a lower topographic position at *Viladordis*. This is a rather local interest.

**5-Malbalç geozone.** This is the most important point of geological interest from the list. In 1926 this zone was visited as part of -the XIV International Geological Congress and is commonly used to train geology students in field work and it has been the subject of

several scientific studies. Under a paleontological point of view this is a remarkable point for the occurrence of coral reefs and several other fossils such as *Cerithium (Campanille) gigantenum*. In terms of sequence stratigraphy, this is also an excellent area to observe stacking patterns and regressive- transgressive cycles. For sure, the natural outcrops from the area together with those from the abandoned quarries, are very relevant points to observe sedimentologic features of the deltaic sands of the Collbàs formation. See figure 3 A and C.

**6-Torrent de Sant Ignasi (Sant Marc) - Balmes de La Seu.** This area is within the city, at the north bank of the *Cardener* river. It displays the marine sandstones of the Collbàs formation, where several rock shelters-caves are found (including the famous *Cova de Sant Ignasi*). This area is also interesting to see sedimentary structures and the presence of hexahedrite ( $MgSO_4 \cdot 6H_2O$ ), a rather scarce mineral that here is quite frequent. Also of local geologic - historic interest is the mining of very poor coal beds by the railway station.

**7-Road to Sant Pau.** At this point large scale cross bedding in the marine strata can be easily observed. This is a complementary outcrop to those of points '5' and '6'.

**8-Joints by the Pont Vell.** The *Cardener* river bedrock displays a clear arrangement of parallel and steady-spaced joints. This outcrop is close to points '6', '7' and '9' and you can get a nice view of the outcrop from the *Pont vell* ('old bridge').

**9-Fluvial terrace of the Cardener river at La Guia.** This outcrop and terrace is located some 30 meters above the present day river. In the literature this terrace is known as the *Tossal dels Cigalons* terrace (T2), where the proboscidean *Elephas antiquus* was found. The outcrop at *La guia* also contains the contact between the terrace and the Eocene bedrock. See figure 3B.

**10- Turó de Puigberenguer fluvial terrace** This terrace is located some 87 metres above the present river (also known as T3). This is the best terrace outcrop from Manresa, and still contains old quarrying constructions. Remarkably, the contact with the underlying Artés formation is very clear. The basal gravels are here cemented forming a conglomerate. This terrace has delivered fossil remains of the proboscidean *Mammuthus meridionalis*, hypos, rhinoceros and horses.

**11- Riera de Rajadell at Gorg dels Esparvers – Salt de l'escaleta sector.** Geomorphology is here well exposed along the *Riera de Rajadell* creek. On a large scale, the creek swings in a well developed entrenched meander. At small scale (such as at *Gorg de l'Escaleta*) differential erosion produce a peculiar water fall. Complementary, sedimentological features and a fluvial terrace can be also observed. Similar characteristics can be observed at the *Cingles de la Tolega* cliffs, in the Llobregat river valley at the northeastern part of the municipality, which could be also considered for the inventory.

**12- Oliveres level al Tossal dels Cigalons.** This level refers to one of the transitional wedges exposed along the lower part of Martí i Pol street, within Manresa.

**13- Transitional wedge at Palau firal (exhibition center).** This outcrop displays the lateral continuity of another wedge within Artés formation.

**14- Artés formation at Sant Joan junction ('Bonaplata').** This outcrop (see figure 3D), located by bridge leading to the north of *Sant Joan de Vilatorrada* village is the best one of the Artés formation in Manresa. This interest is rather local, since in surrounding areas out of the municipality other good outcrops are found.

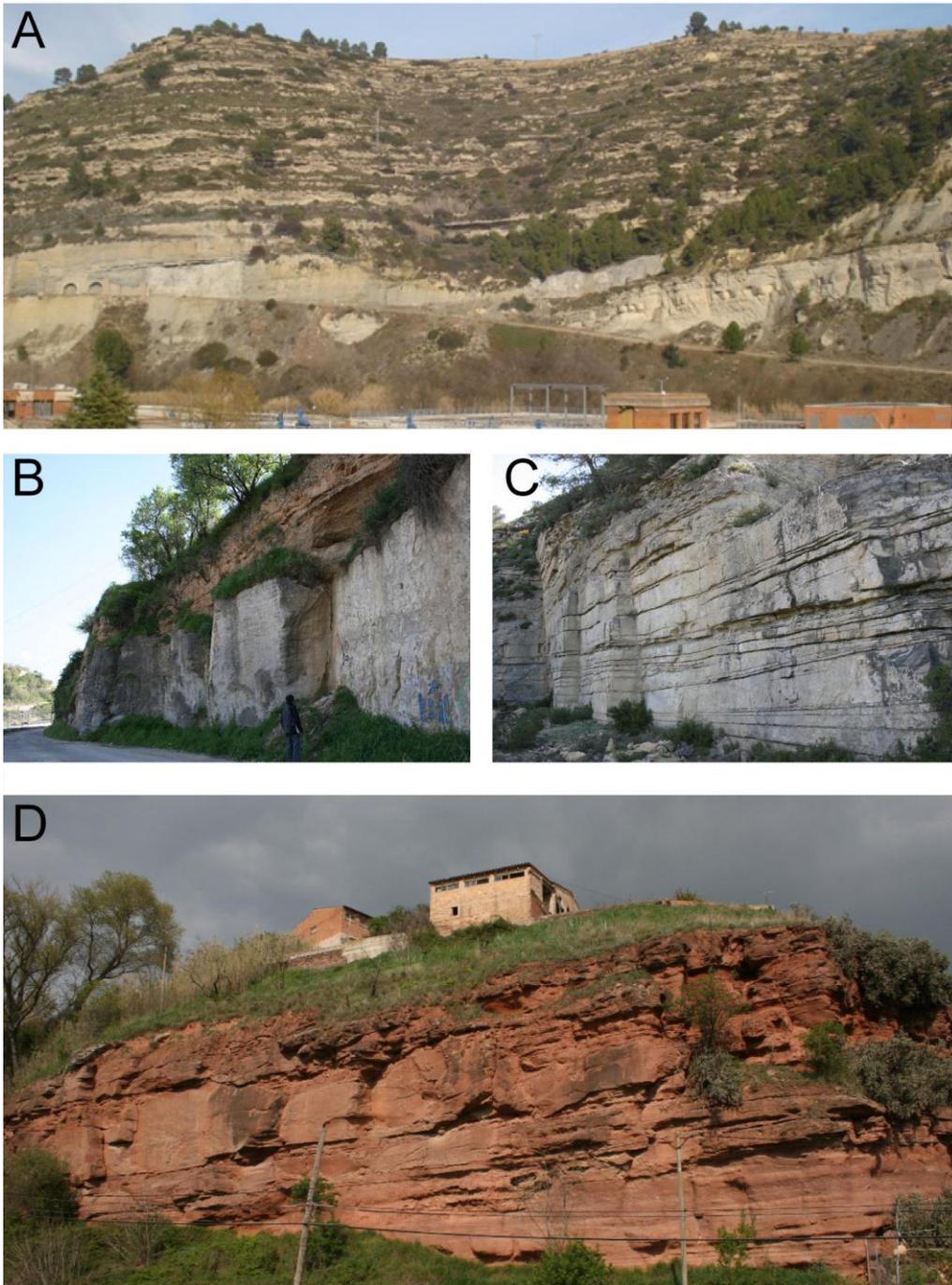


Figure 3. View of several points of geological interest from Manresa. A: Malbalç geozone (point '5'). B: Pleistocene fluvial terrace (top) and marine Eocene rocks (bottom) at La guia (point '9'). C: Detail of the Malbalç old quarries (point ) and D: Continental rocks of the Artés formation close to Sant Joan de Vilatorrada (point '14').



Figure 4. The point of geological interest number 1: *Pont Foradat* or *Pont de Les - Arnaules*, close to the *El Raval* of Manresa.

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