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Human remains from Valdegoba Cave (Huérmeces, Burgos, Spain)

Systematic excavations, begun in 1987, at the Valdegoba cave site in northern Spain have yielded the remains of five individuals associated with a Middle Paleolithic stone tool technology and Pleistocene fauna. A fragmentary mandible of an adolescent (VB1), preserving nearly a full set of teeth, exhibits a symphyseal tubercle and slight incurvatio mandibulae anterior on the external symphysis. Both the superior and inferior transverse tori are present on the internal aspect. A second individual (VB2) is represented by a set of ten deciduous teeth consistent with an age at death of 6–9 months. A proximal manual phalanx (VB3) displays a relatively broad head, a characteristic which is found in both Neandertals, as well as European Middle Pleistocene hominids. VB4 is a fourth metatarsal that lacks the distal epiphysis, indicating it comes from an adolescent individual, and has a relatively high robusticity index. Finally, VB5 is a fifth metatarsal of an adult. The VB1 mandible shows a combination of archaic characteristics as well as more specific Neandertal morphological traits. The VB2 deciduous teeth are very small, and both the metrics and morphology seem more consistent with a modern human classification. The postcranial elements are undiagnostic, U-Th dating has provided an age of >350 ka for the base of the sequence and a date of <73·2 ± 5 ka for level 7, near the top. Faunal analysis and radiometric dates from other nearby Mousterian sites suggests that the Valdegoba site is correlative with oxygen isotope stages 3–6 on the Iberian peninsula, and an Upper Pleistocene age for the Valdegoba hominids seems most reasonable.

Keywords: Valdegoba, Neandertal, early modern human, Western Europe, Spain, mandible, deciduous teeth, hand phalanx, metatarsals.

Introduction

The site of Valdegoba is located near the town of Huérmeces, about 28 km northwest of the city of Burgos, in northern Spain (Figure 1). It is a small cave at the southern end of the Cantabrian Cordillera. It was formed in a large outcrop of Turonian limestone (Upper Cretaceous) which has been cut by the Urbel river, creating a small canyon which provides access to the

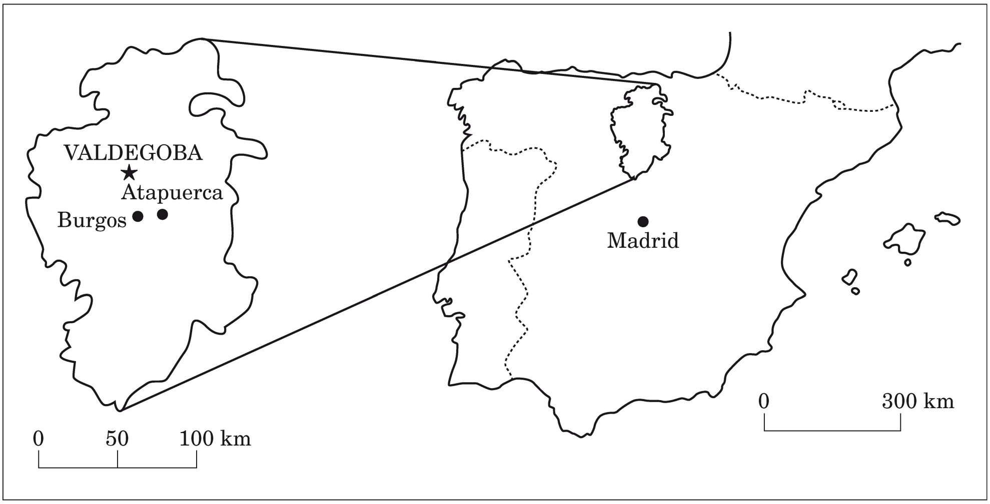

Figure 1. Location of the Valdegoba cave site.

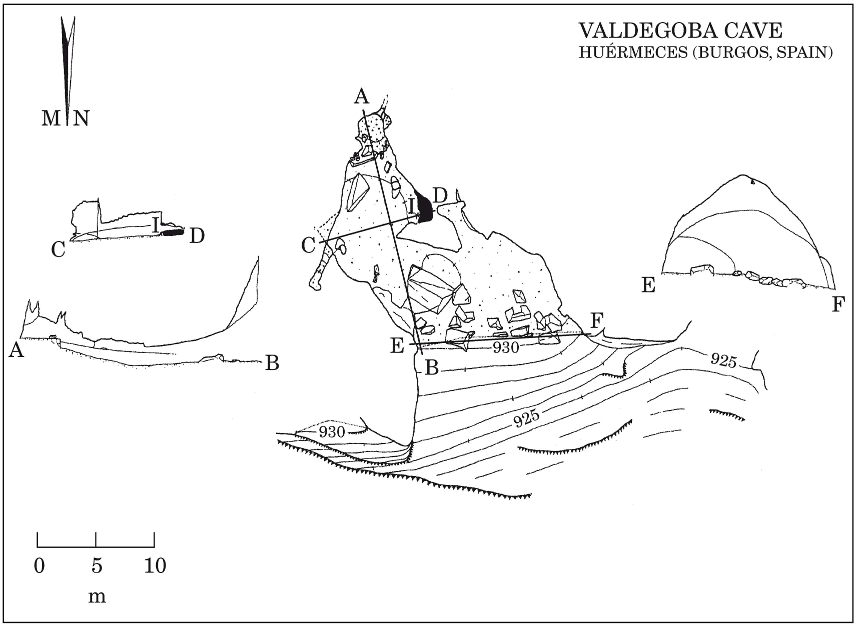

Figure 2. Layout and cross-sections of the Valdegoba cave site. The dark black section represents the area of excavation of *in situ* deposits where the human remains were found.

Tertiary basin of the Duero river. The cave opens to the north and the east of the Urbel river. It is 21 m long with a variable width from 14 m at the entrance to 6 m in the interior, with a height of 4 m at the entrance decreasing to 0·5 m towards the back (Figure 2).

Between 1987 and 1991 four field seasons were carried out. Six areas of the cave were excavated, but only one, located in the western section of the interior, contained *in situ* materials (darkened area in Figure 2 and levels 1–7 in Figure 3). The rest of the cave was affected by karstic reactivations during the Holocene, which eroded the deposits, removing ancient sediments and materials and depositing them on the downslope outside the cave (level 8 in Figure 3). There is also evidence of the activities of amateur collectors, which were responsible for some of the disturbance.

The stratigraphy (Figure 3), based on the undisturbed section, presents from bottom to top (Díez *et al.*, 1988, 1988–1989):

(1) Basal stalagmitic flowstone. Sterile. A sample was taken for U-series dating analysis (see below).

(2) Red clays with silts and sands comprise a 40 cm thick level. A sublevel of carbonated concretions was also identified. Sterile.

(3) Brown clays with silts and sands form a 10 cm thick level. Stalagmitic concretions were found at the top. Sterile.

(4) Brown clayish sands with calcareous rocks and a maximum thickness of 50 cm. Evidence of erosion is visible at the top. Stone tools and faunal remains are present.

(5) Numerous calcareous rocks in brown clays which show geological alteration at the top. Thickness is 20 cm and it is in erosive contact with the top of level 4. Stone tools, faunal and human remains are present.

(6) Breccia up to 20 cm thick encases calcareous rocks, stone tools, faunal and human remains. In continuity with level 5, only the cementation of the breccia allows a differentiation.

(7) Laminar stalagmitic concretion seals level 6. This concretion unites at several points along the walls and ceiling, with archaeological materials present in the roof of the cave. This is clear evidence of the previous ancient filling and erosion of this level. Two samples were taken for U-series dating analysis (see below).

(8) A level of clayish sediments 60 cm thick is in erosive contact with level 7. It contains a mixture of Paleolithic and Holocene archaeological materials, as well as human remains. This mixture is evidence of prior disturbance of this level, probably by amateur artefact collectors.

James Bischoff (U.S. Geological Survey, Menlo Park, California) analyzed three samples from Valdegoba cave for U-series dating analysis: one from the basal flowstone (level 1), and two from the capping speleothem (level 7). The basal sample gave excellent, clean results and showed full isotopic equilibrium, corresponding to an age of >350 ka. The two from the capping spelothem were highly contaminated with detrital Th, which usually makes the age appear too old. The nominal dates on these two samples are 95 ka and 73 ka. Therefore, Bischoff concluded that the capping speleothem (level 7) was probably less than 73 ka.

The lithic industry is abundant (nearly 2500 pieces), and was produced almost entirely on quartzite and flint. However, tools made of quartz and, more sporadically, limestone and sandstone are also present. The raw material comes from local sources, within a 10 km radius from the site. Rounded quartzite cobbles transported by the Urbel River, blocks of Neogene flint from this same river and nodules of Cretaceous flint from the same mountain in which the cave was formed were utilized. All the tool categories are represented at Valdegoba, with numerous first-order flakes recovered (with cortex present on the back), and this leads us to believe the production of the tools was carried out *in loci*. The bifacial centripetal production technique is most frequent, producing discoid nuclei, and flint was worked more intensively than was quartzite. Among the lithics made on flint,

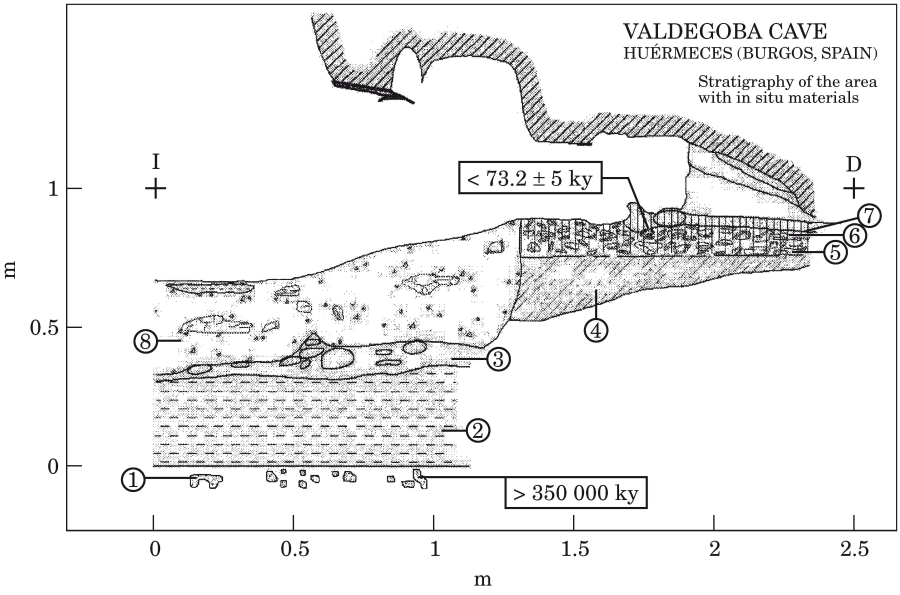

Figure 3. Stratigraphic profile of the *in situ* excavated area at the Valdegoba cave site.

complete exploitation of the nodules was frequent, producing many third-order flakes (without cortex) and many less than 3 cm in size. Among the lithics made on quartzite, cores with unifacial extraction (both centripetal and longitudinal) are abundant. Levallois nuclei are also present.

Several flint bifaces were recovered, but the main objective of the exploitation was the production of short flakes with smooth bases, which, in general, were not retouched. Many of them present a triangular morphology with cortex present on one side and absent on the other. There are a few Levallois laminar flakes, with faceted talons, but the percentage of all the laminar, Levallois and faceted pieces is low. Carenated flakes are also abundant. Retouched pieces constitute 18% of the assemblage. The unretouched flakes do not show any preference/selection with regard to raw material type, grade of cortex or faceted talons. The tools are mostly scrapers, both straight and convex, and show simple retouch as often as they are denticulated. Points and compound tools are well-represented. A few foliated and scalariform pieces, as well as some showing abrupt retouch, complete the tool repertory. There is also an abundance of ochre.

This tool industry can be included within the various Middle Paleolithic technocomplexes, and it is quite similar to those documented at other Upper Pleistocene sites from the same region. At La Ermita and Cueva Millán (Hortigüela, Burgos), the lithic assemblages show an almost exclusive use of flint and quartzite, with abundant first-order flakes, in particular quartzite, low laminar component, predominance of smooth talons and usage of scrapers (Moure & García-Soto, 1983*a*, 1983*b*; Moure *et al.*, 1997). The most appreciable differences at Valdegoba are the larger number of denticulates and a greater usage of scalariform retouch.

The presence of Middle Paleolithic stone tools at Valdegoba allows us to place the site within a regional context and suggests an upper chronological limit for the *in situ* layers. Radiometric dates are available for several nearby sites with Mousterian levels,

Table 1 **Inventory of the Valdegoba (VB) human remains**

Specimen	Level	Age	Preservation
VB1	8	13–14 years	Two mandibular fragments preserving the symphysis with RI_2–M_2 and LP_3–M_3
VB2	6	6–9 months	Deciduous dentition Upper Ldi1, Rdi2, Ldc, Rdm1, Ldm1, Ldm2 Lower Rdi1, Ldi2, Ldm1, Rdm2
VB3	5	Indet.	Distal half of a proximal phalanx Second or third ray from left manus
VB4	6	<15 years	Right metatarsal IV
VB5	8	Adult	Left metatarsal V

and these range from ca. 45 ka at Peña Miel to ca. 31 ka at La Ermita (Carbonell *et al.*, 2000). This suggests that the Middle Paleolithic layers at Valdegoba would not be more recent than ca. 31 ka.

The identified large and small mammal remains include: *Rupicapra rupicapra*, *Cervus elaphus*, *Equus caballus*, *Equus hydruntinus*, *Capra pyrenaica*, *Dicerorhinus hemitoechus*, *Sus scrofa*, *Capreolus capreolus*, *Bos*/*Bison* sp. *Canis lupus*, *Vulpes vulpes*, *Ursus spelaeus*, *Ursus arctos*, *Meles meles*, *Crocuta crocuta*, *Felis silvestris*, *Lynx pardinus spelaeus*, *Panthera pardus*, *Lutra lutra*, *Martes* sp., *Microtus arvalis-agrestis*, *Microtus nivalis*, *Pliomys lenki*, *Arvicola* sp., *Apodemus* cf. *sylvaticus*, *Castor fiber*, *Marmota* cf. *marmota*, *Sorex*, sp., *Neomys* sp., *Oryctolagus cuniculus* and *Hystrix* cf. *vinogradovii*.

All the human remains (Table 1) derive from the western section of the interior of the cave (Figure 2). The mandible (VB1) was recovered in 1987 (Díez, 1991) from the surface of the sediments during topographic work prior to the start of excavations that year. Several of the teeth of this specimen were also recovered in level 8 during the 1987 and 1988 field seasons, indicating the mandible originally derived from this level. However, this level shows evidence of disturbance (see above), and the VB1 mandible is, therefore, without precise stratigraphic context. The dental remains of an infant (VB2) were recovered during the 1988 field season and derive from level 6. The teeth were found close together, within a maximum distance of 80 cm. During this campaign, two metatarsals were also recovered. One of them (VB4) also comes from level 6. The other (VB5) was found in level 8 (as was the mandible VB1) and is, therefore, without precise stratigraphic context. Finally, a proximal manual phalanx (VB3) was recovered in level 5 during the 1989 field season, 45 cm below VB2. These three postcranial bones were not previously reported by Aguirre & Bermúdez de Castro (1991) in their inventory of the Spanish fossils. In summary, all the human remains found in stratigraphic context derive from levels 5 (VB3) and 6 (VB2 and VB4) and are associated with a Middle Paleolithic industry and a faunal assemblage characteristic of oxygen isotope stages (OIS) 3–6 on the Iberian Peninsula (see below).

Fauna from Valdegoba Cave

Herbivores comprise roughly 87% of the faunal assemblage, while carnivores represent 11%, with a small percentage of avifauna and micromammals also recovered (Díez *et al.*, 1988–1989). The most abundant taxa among the ungulates are *R. rupicapra* and *C. elaphus*, while *D. hemitoechus*, *S. scrofa*, *C. capreolus* and *Bos* sp. are less numerous (Table 2). *V. vulpes*, *C. crocuta*, *C. lupus* and *U. arctos* are the most abundant carnivore species. These four species make use of caves either as natal dens or

Table 2 Faunal remains from Valdegoba Cave

Artiodactyla	Rodentia	Carnivora
Cervus elaphas	*Microtus nivalis*	*Vulpes vulpes*
Rupicapra rupicapra	*Microtus arvalis-agrestis*	*Canis lupus*
Capreolus capreolus	*Pliomys lenki*	*Ursus arctos*
Capra pyrenaica	*Apodemus* cf. *sylvaticus*	*Ursus spelaeus*
Sus scrofa	*Arvicola* sp.	*Meles meles*
Bos/Bison sp.	*Marmota* cf. *marmota*	*Lutra lutra*
	Hystrix cf. *vinogradovii*	*Martes* sp.
Perissodactyla	*Castor fiber*	*Crocuta crocuta*
Equus hydruntinus		*Panthera pardus*
Equus caballus		
Dicerorhinus hemitoechus	Avian fauna	*Felis silvestris*
Chiroptera	*Anas* sp.	*Lynx pardinus spelaeus*
Neomys sp.	*Aegypius monachus*	
Lagomorpha	*Falco tinnunculus*	
Oryctolagus cuniculus	*Columba* sp.	
Insectivora	*Athene noctua*	
Sorex sp.	*Alectoris* sp.	
	Coturnix coturnix	
	Tardus sp.	
	Phyrrhocorax graculus	
	Phyrrhocorax phyrrhocorax	
	Passeriformes indet.	

hibernation refuges, and the diverse carnivore assemblage in Valdegoba cave could be a result of denning activities, especially given the presence of immature individuals. Among the identified small mammal remains, the presence of *M. nivalis*, *M. marmota*, *C. fiber* and *H. vinogradovii* are notable. The first three have traditionally been considered to represent cold-adapted mammals, while *H. vinogradovii* (porcupine) lived in warm habitats. The presence of *C. fiber* and *L. Lutra* is evidence for the close proximity of the cave to a river.

In level 6, the remains of *Rupicapra* constitute the majority of the faunal material, and its frequency reduces in level 5 with a concomitant strong increase in horses and large bovid remains. In level 5, carnivores are as abundant as herbivores. These variations in the different levels most probably indicate behavioral changes. In the lower level, the human occupation was less intense than that manifested in the upper level, in contrast to the role played by carnivores. This intensity of human occupation is also reflected in the number of stone tools, which decreases steadily from top to bottom of the stratigraphic sequence. This probably reflects a change in subsistence strategies among the human occupants from the exploitation of gregarious animals in the valleys and plains to an increasing reliance on middle and high altitude mountainous species.

Chronology of the faunal assemblage (Figure 4)

Panthera pardus is represented by one adult and one immature individual at Valdegoba and is also present at several other Middle and Late Pleistocene European sites. The earliest documented occurrence of leopard in the Iberian Peninsula could be at the site of Lezetxiki in level VI (Altuna, 1972). Falguéres (personal communication) obtained ESR ages for this level of 230+92–44 ka and 200+129–58 ka. The Valdegoba *C. lupus* (four adults and two juveniles) are

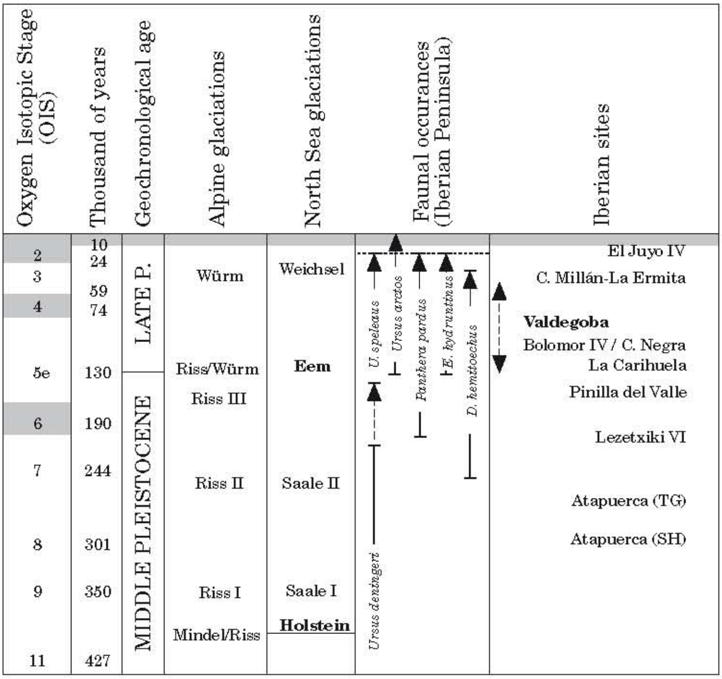

Figure 4. Chronological framework of the species represented in the Valdegoba fauna compared with other sites from the Iberian Peninsula. The North Sea glaciations in bold represent warm stages.

true wolves with large dimensions, which always fall within the range of variation of extant *C. lupus* populations. The canid remains from the Trinchera-Galería (Atapuerca) site represent a transitional form and are older than 180 ka (García & Arsuaga, 1998). Together, these two taxa suggest a maximum lower chronological limit for the Valdegoba assemblage.

U. spelaeus and *U. arctos* are both present at Valdegoba. We interpret the co-occurrence as indicating coexistence with a yearly alternation of cave occupation. Both species inhabited the area and made use of the cave for hibernation periodically. The brown bear remains are more abundant than those of the cave bear (MNI *U. spelaeus*=one adult; MNI *U. arctos*=three adults and three juveniles). True cave bears (*U. spelaeus*) appeared in Spain at the end of Riss times (OIS 6), and became more abundant between OIS 5 and 3, especially the later part. The latest documented occurrence of this species is at the early Magdalenian site of Erralla (represented by one phalanx). The *U. spelaeus* from Valdegoba represents an evolved form of the speloid lineage, showing a fully developed morphological pattern. Therefore, it cannot be close to the transitional *deningeri–spelaeus* populations dated at around 160 ka (García *et al.*, 1997) but, rather, is much closer to the Würm specimens.

The coexistence of *U. spelaeus* with *U. arctos* at Valdegoba cave is reported at a handful of other sites as well, but is not common. The first immigrants of *U. arctos* are likely to have arrived during the Eemian interglacial (OIS 5e) when they began coexisting with the speloid forms already inhabiting Iberia. This immigration could have occurred earlier if we accept Torres (1988) attribution of some enigmatic specimens from Pinilla del Valle and Mollet Racó to *U. prearctos*. At the time this coexistence began, around 130 ka ago, the cave bears were still transitional forms rather than the more advanced Würmian forms, such as those from Valdegoba. This leads us to favor a post-Eemian age for the Valdegoba assemblage.

The spotted hyena (*C. crocuta*) is well represented at Valdegoba, with both adult (MNI = 5) and immature individuals (MNI = 2) having been recovered, and it is likely that this carnivore used the cave as a den and/or a lair. The upper and lower carnassial measurements are within the range of both *C. c. spelaea* and extant populations of *C. crocuta*, indicating an evolutionary stage somewhat earlier than that of the larger glacial-age hyenas.

Equus hydruntinus occurs at European sites attributed to the Riss period. However, this small equid is only present at a few other Spanish sites, correlated with the Eemian and Würmian periods (Maldonado, 1996; Sarrión, 1990). Two of these have absolute dates: the lowest level of the Carihuela cave (Granada) is dated by U/Th to 117 ± 41 ka and by U-series to 146 ± 17 ka (Vega Toscano *et al.*, 1997), and level IV of Bolomor cave (Valencia) has been dated by thermoluminescence (TL) to 121 ± 18 ka (Fernández *et al.*, 1997). Thus, it seems that *E. hydruntinus* entered the Iberian peninsula at the end of the Middle Pleistocene or during the early Late Pleistocene (probably around the Eem interglacial). Maldonado (1996) has reported a decrease in the size of the dentition during the Upper Pleistocene and his results would place the Valdegoba equid with the more advanced smaller and slender forms from the later Upper Pleistocene.

The rest of the faunal assemblage does not provide detailed information on chronology. *L. pardinus spelaeus*, *F. silvestris*, *L. lutra*, *M. meles*, *Martes* sp., *V. vulpes*, *D. hemitoechus*, *C. fiber*, *Marmota* cf. *marmota* and *Hystrix* cf. *vinogradovii*, were already present in the Middle (and even Early) Pleistocene. While these species are extinct on the Iberian Peninsula today, they persisted through Magdalenian and, in some cases, into historical times. The Valdegoba faunal assemblage, then, could represent a wide chronological time span. However, a lower chronological limit of ca. 180 ka is suggested by the *C. lupus* remains, while other species are more consistent with an Upper Pleistocene age. The presence of Mousterian tools would place an upper limit of ca. 31 ka based on radiometric dates from other nearby sites. In summary, it seems most reasonable to correlate the site to OIS 3–6, and more probably to a Würmian period.

Materials

The VB1 mandible represents an adolescent individual who died around the age of 13–14 years, and the most informative morphological comparison is with other Paleolithic specimens of a similar biological age (Table 3). The recent *Homo sapiens* samples derive from Minugh-Purvis (1988) and Quam (1996). Minugh-Purvis analyzed archaeological samples of immature remains (n=163) from both the Libben site in Ohio and the site of Tepe Hissar in Iran, the latter dating to the third millennium BC. The most appropriate for comparison with VB1 are those specimens aged 12–18+, the “adolescent to maturity” interval defined by Minugh-Purvis (1988). Quam (1996) collected data on 42 adult modern human specimens from the site of Kish, Iraq, a Sumerian city-state located south of Baghdad, dated from the third millennium BC (Rathbun, 1984).

In addition to dental morphological observations, the mesiodistal (MD) and buccolingual (BL) dimensions of the VB1 teeth were recorded following the technique proposed by Flechier (1975), and using a caliper with wide, flat and pointed tips,

Table 3 **Comparative sample of similar-aged Neandertal and early modern human mandibles**

Specimen	Age (years)	Source
Valdegoba 1	13–14	
Neandertals		
Krapina C	11	Wolpoff (1979)
Malarnaud 1	11–13	Heim & Granat (1995)
Ehringsdorf 7	12	Minugh-Purvis (1988)
Montgaudier 1	12·5–14·5	Mann & Vandermeersch (1997)
Krapina D	15	Wolpoff (1979)
Krapina E	15	Wolpoff (1979)
Krapina F	17	Wolpoff (1979)
Le Moustier 1	16·5	Minugh-Purvis (1988)
Petit-Puymoyen 1	16–17	Minugh-Purvis (1988)
N. African archaic		
Jebel Irhoud 3	8–9	Hublin & Tillier (1981)
Early modern humans		
Sungir 3	11–12	Zubov & Kharitonov (1984)
Qafzeh 11	12–13	Tillier (1999)

Table 4 **List of specimens and samples whose MD and BL tooth measurements are used to calculate the interdental indices**

Specimen	Reference
Valdegoba 1	
Atapuerca-TD6 Hominid 1	Authors
Mauer	Howell (1960)
Atapuerca-SH	Authors
Arago 2 and 13	Authors
Montmaurin (mandible)	Authors
Neandertals from Europe and SW Asia	This sample includes the specimens listed in Table 6 of Bermúdez de Castro (1986), as well as the specimens of Tabun (de Lumley, 1973) and Shanidar (Trinkaus, 1983)
Skhul	de Lumley (1973)
Qafzeh	Vandermeersch (1981)
European Early Upper Paleolithic	Frayer (1977)
Aboriginals from Gran Canaria (Canary Islands)	Bermúdez de Castro (1985)

which allowed insertion between teeth still *in situ*. These measurements were further used to calculate several dental indices and to perform a principal components analysis. Because the lower dentition is nearly complete, the comparative samples differ somewhat from those used to compare the bony morphology of the more fragmentary mandible (see Table 4).

Morphological aspects of the Valdegoba 2 deciduous dentition are compared primarily with the dental remains of the Roc de Marsal Neandertal and La Madeleine 4 early modern human infants. Comparative samples of Neandertals, early modern humans and recent modern humans are provided for the metric comparisons. Finally, for the postcranial material (VB3, 4 and 5), we have used a sample of Neandertals and a multiracial (Euroamericans and Afroamericans) balanced sex sample from the Hamann-Todd collection,

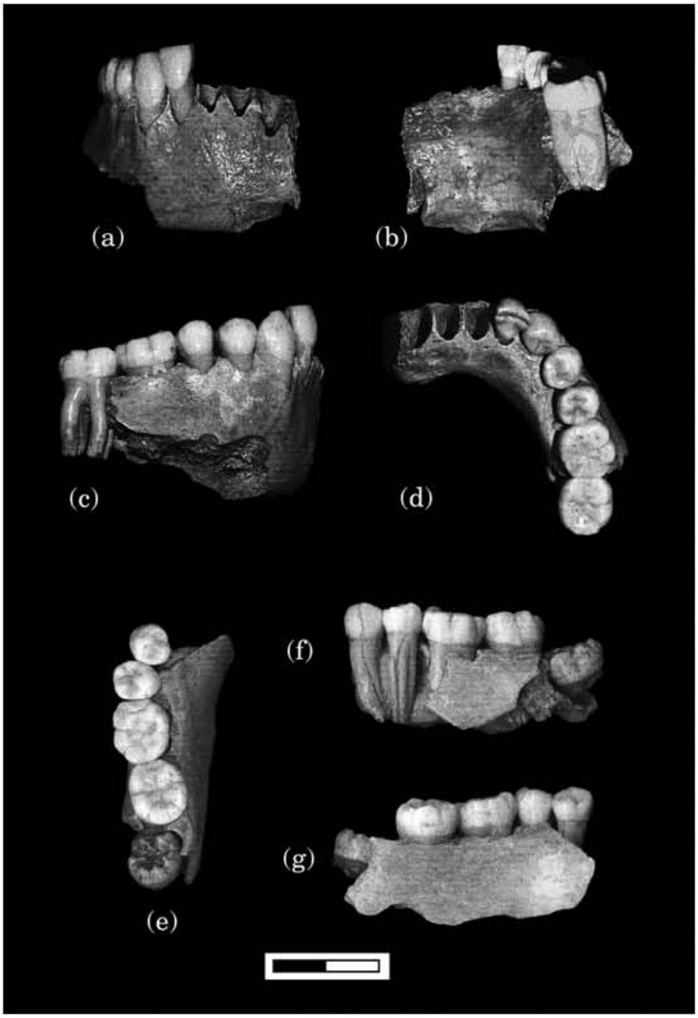

Figure 5. The Valdegoba 1 (VB1) mandible. (a) Anterior view; (b) internal symphysis; (c) right lateral view; (d) superior view; (e) superior view of left fragment; (f) lateral view of left fragment; (g) medial view of left fragment. Scale bar = 2 cm.

housed in the Cleveland Natural History Museum.

The Valdegoba 1 mandible (VB1)

The Valdegoba 1 mandible consists of two fragments of the corpus and 11 teeth, right I_2–M_2 and left P_3–M_3 (Figure 5). The bone is highly mineralized and dense, presenting a yellowish-tan coloring. The alveolar septa between the teeth are well preserved and show no sign of degradation. The larger fragment [Figure 5(a)–(d)] preserves the symphyseal area and part of the right corpus, with the alveolar margin and tooth sockets from left I_2 to right M_1 intact. The mesial wall of the left canine alveolus is also preserved. The inferior margin is missing along most of this length, but it is preserved from the midline to below the right canine. Posterior to this, only the superior half of the external aspect of the corpus is present as far as the M_1/M_2 septum. The internal aspect of the larger fragment preserves somewhat more of the corpus posteriorly and inferiorly.

The small fragment is from the left side of the mandible [Figure 5(e)–(f)]. While the inferior margin is missing entirely, the alveolar margin is present from just anterior to M_1 to just posterior to M_2, partially forming the crypt of the erupting M_3. Both the left M_1 and M_2 are present in the body of the mandible although their sockets are not completely preserved. Externally, only a small fragment of the body is present, enclosing both M_1 and M_2, but the internal aspect courses from about the level of P_3 to just posterior to M_2, enclosing the crypt of M_3 medially. Only the superior half of the corpus is preserved, and the apices of the roots of the left M_1 and M_2 are visible inferiorly.

The two fragments do not directly articulate with one another. Rather, the internal aspect of the left side of the symphysis on the larger fragment shows signs of slight abrasion, with some of the surface bone missing. The smaller fragment overlaps this area on the larger one, but does not contact it directly (Figure 6). A small amount of bone is missing between the junction of the two pieces.

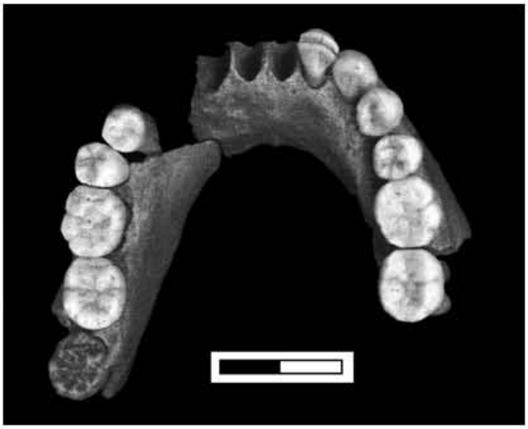

Figure 6. The reconstruction of the Valdegoba 1 mandible in occlusal view. Scale bar=2 cm.

Age at death

Assessing the age at death of immature Pleistocene individuals is currently an area of active research and debate. While most studies employ modern human developmental standards, it is not clear whether fossil populations followed similar growth trajectories. The majority of studies of dental development in fossil hominids has focused on australopithecines, while a few analyses have been carried out on Neandertal dental remains (Wolpoff, 1979; Dean *et al.*, 1986; Trinkaus & Tompkins, 1990; Stringer *et al.*, 1990; Mann *et al.*, 1991; Ramirez-Rozzi, 1993; Tompkins, 1996; Stringer & Dean, 1997). We have relied on both tooth formation stages based on modern humans and comparative tooth wear with other juvenile Paleolithic mandibles (see below) to arrive at an age at death. The tooth formation stages observed in the VB1 individual are provided in Table 5.

The M_2s lack distal contact facets, indicating that the M_3s were not fully erupted. All of the teeth which have not completed apical closure in the roots, and hence are the most useful for age estimation, suggest ages of between 12–14 years based on modern human standards (Smith, 1991). The mesial roots of both the M_2s show the apex is half closed and correspond to an age of 13·9 years in modern human males, while the distal roots show only the completion of root length and provide a younger estimate of 12·3 years. Thus, the calcification stage of the M_2s gives discordant age estimates. The P_4s show the root apex to be half closed, and provide an age estimate of 13·5 years in modern males. Finally, there is only an initiation of the root formation in the left M_3, which suggests a developmental age of 13·2 years. Taken together, the dental formation stages of all the teeth in the VB1 individual suggest that an age estimate of 13–14 years is reasonable.

Table 5 **Dental formation stages for Valdegoba 1**

Tooth	Formation stage	Age (male)	Age (female)
I_2	Ac	>8·9	>8·3
C	Ac	>12·4	>10·6
P_3	Ac	>12·7	>11·6
P_4	A 1/2	13·5	12·8
M_1	Ac	>8·5	>7·9
M_2	Mesial root=A 1/2	13·9	13·5
	Distal root=Rc	12·3	11·8
M_3	Ri	13·2	13·2

Formation stages after Smith (1991).

Comparison with adolescent mandibles from Krapina is also useful in establishing an age at death for VB1. Specifically, both the amount of dental wear and degree of tooth formation appears similar to Krapina E, which has been aged to about 15 years (Wolpoff, 1979). The crypt for the M_3 in Krapina E shows evidence of the initial cleft formation in the root (Radovčič *et al.*, 1988). This would make it slightly advanced compared with that seen in Valdegoba 1, where the M_3 shows no initial cleft formation.

Combining data from modern human dental formation rates and comparison with Paleolithic mandibles showing a similar degree of tooth calcification and wear as seen in Valdegoba 1, suggests an age at death of 13–14 years for this specimen.

Sex diagnosis

Diagnosing sex in skeletal remains is always difficult, and the fragmentary and juvenile nature of the VB1 specimen suggests caution in assessment of sex in this individual. Here we rely on morphological and metrical data from both the mandible and dentition of VB1 to make some observations.

Loth & Henneberg (1997) have recently suggested that the development of the incisura submentalis at the base of the symphysis can be used to diagnose sex in both modern and Paleolithic mandibles. Specifically, males tend to show a stronger and more frequent expression of this feature than do females. Unfortunately, the state of preservation in VB1 does not allow firm conclusions to be drawn regarding the expression of this feature.

When describing the adolescent mandible from Montgaudier it was argued by Mann & Vandermeersch (1997) that this specimen was a female, on the basis of small corpus dimensions, the lack of an alveolar planum and small size of the dentition. Thickness throughout the preserved mandibular corpus on VB1 exceeds the values observed among the majority of immature mandibles in both a Neandertal and early modern human sample. Further, the development of both a superior and inferior transverse torus on the internal aspect of the symphysis and the well-marked digastric fossae are evidence of the significant robusticity of the VB1 specimen, and suggest the specimen represents a male individual.

Indications from the dentition are more ambiguous. The presence of a canine distal accessory ridge (see below), one of the most sexually dimorphic of tooth traits in living humans, provides some additional support for a male classification (Scott, 1977). However, the modest MD length of this tooth is more consistent with the specimen being female (Garn *et al.*, 1977). Oxnard's (1987) study of sexual dimorphism in the dentition of hominids included a Neandertal sample, and he suggested that the canine BL breadth showed a clear bimodal distribution, with males exhibiting values ranging between 9·5–10·5 mm and females between 7·5–9·0 mm. The BL breadth of the canine in VB1 is 8·2 mm, and according to Oxnard's criteria would correspond to a female. Finally, in the PCA (see below), VB1 falls toward the lower end of the Neandertal distribution on the PC1, again suggesting a female assignment.

In Wolpoff's (1979) study of the Krapina dental remains, he noted that both large and small teeth could be found in the same individual and suggested that the size and bony morphology of the mandible were more reliable than dental dimensions when attempting to sex individuals. Placing a greater emphasis on the metrics and bony morphology preserved in the VB1 mandible, then, we tentatively conclude the specimen represents a male individual.

Morphology of the external symphysis

The most informative area morphologically in the VB1 specimen, as well as the best preserved, is the region of the symphysis. This region lacks only the basal margin left of the midline. Externally, a slight swelling along the midline a third of the way up from the base [Figure 5(a)] corresponds to the symphyseal tubercle (tuber symphyseos). However, this swelling does not extend laterally to form a mentum osseum, and the base of the symphysis is not clearly set off from the surrounding bone. While the basal margin is not preserved on the left side, there is no lateral tubercle (tuberculum laterale) present on the right. Nor is there a clearly identifiable raised triangle of bone on the anterior aspect of the symphysis. Consequently, a mental trigone (trigonum mentale) is lacking in the VB1 specimen. Above the symphyseal tubercle, a slight depression is visible and palpable just below the alveolar margin of the incisors. This corresponds to the incurvatio mandibulae anterior. A further slight depression is present laterally just below the alveolar margin between the right I_2 and canine. However, this is not located far enough inferiorly to be considered to represent a mental fossa.

In frontal view [Figure 5(a)], a downward projection of bone is present and visible centrally and corresponds to an extension of the mental spine on the internal aspect of the symphysis. A slight arc, corresponding to the incisura submentalis emanates laterally along the basal border on the right side of the midline as far as the bone is preserved. A strong arc is usually associated with well developed anterior marginal tubercles and is an indicator of general robusticity. It is a constant feature among the Middle Pleistocene mandibles from the Sima de los Huesos (SH) at Atapuerca (Rosas, 1995), and is present in both adult and immature Neandertal mandibles from Krapina. This feature is also present but much reduced in both the North African archaic juvenile specimen Jebel Irhoud 3 and in the early modern juvenile Qafzeh 11 specimen. The presence of an incisura submentalis is not taxonomically informative, but may be related to sexual variation, with males exhibiting a stronger arc (Loth & Henneberg, 1997). The strength of expression of this feature in the VB1 specimen is difficult to determine due to the state of preservation of the basal margin; however, its presence is suggestive of well developed anterior marginal tubercles.

Recently, Schwartz & Tattersall (2000) have published a comprehensive review of symphyseal morphology in a wide range of Pleistocene fossils. These authors define a chin as consisting of: "a raised central keel that flows into a distended inferior margin, a low-lying triangular mental tuberosity at the confluence of the keel and the inferior margin, and mental fossae that lie on either side of the keel and above the distended inferior margin" (Schwartz & Tattersall, 2000:407). The combination of characteristics in the VB1 mandible described above makes it

Figure 7. Comparison of the symphyseal profiles in VB1 (left) and Qafzeh 11 (right).

clear that this specimen does not possess all the elements of a true chin, even by Schwartz & Tattersall's criteria. In lateral view [Figure 5(c)], the symphysis is receding, and both the slight incurvatio mandibulae and the inferior central swelling, marking the symphyseal tubercle, are visible. However, the specimen lacks a mentum osseum, the lateral tubercles which complete the mental trigone and the mental fossae which demarcate this feature as a clearly defined structure.

When the VB1 specimen is compared to the adolescent Qafzeh 11 mandible (12–13 years), the difference in development of the chin structures is pronounced (Figure 7). The incurvatio mandibulae anterior, symphyseal tubercle, mental trigone and mental fossae are all well expressed in the early modern Qafzeh 11 individual, which exhibits a pronounced chin (Tillier, 1984, 1999). The Predmost VII mandible also seems to exhibit a symphyseal morphology similar to that of Qafzeh 11 (Matiegka, 1934). VB1, on the other hand, exhibits only a rudimentary expression of the incurvatio mandibulae anterior and symphyseal tubercle, documenting an earlier evolutionary stage in the emergence of the mental eminence.

The external symphyseal morphology of the VB1 specimen does compare favorably with similarly-aged Neandertals, which typically show the development of some of the features of a true chin. However, immature Neandertals are variable in terms of which chin structures, if any, are present. Le Petit-Puymoyen 1, for example, has a defined mental trigone with a symphyseal tubercle, but no incurvatio mandibulae anterior (Gabis, 1956). Only a faint mental trigone is reported for both Krapina D and F, while neither the Krapina C or E mandibles exhibit any of the elements of a true chin (Smith, 1976). The VB1 specimen finds a closer match in the Montgaudier 1 and the

Malarnaud 1 mandibles, both of which exhibit a symphyseal tubercle near the base of the symphysis (Heim & Granat, 1995; Mann & Vandermeersch, 1997). Finally, the Middle Pleistocene Ehringsdorf 7 juvenile mandible has a symphyseal tubercle located about midway down the symphysis. The external symphyseal morphology of the VB1 specimen, then, is most similar to the condition commonly seen in adolescent Neandertal mandibles, and differs from that found in early modern humans, even at a substantially younger age.

The lack of a chin in the VB1 specimen cannot be attributed to its adolescent status. Schwartz & Tattersall (2000) have argued that external symphyseal morphology in modern *Homo sapiens* is determined from a very early stage in ontogeny and they claim to be able to identify the elements which they define as comprising a modern human chin in neonates. Further, they argue that young Neandertal specimens, such as Roc de Marsal, Gibraltar 2 and Pech de l'Azé lack many or all of these diagnostic features.

Several other authors have also argued for an early ontogenetic distinction between Neandertals and modern humans in the details of symphyseal morphology. Specifically, Minugh-Purvis (1988) argues that when comparing the Neandertal specimen Pech de l'Azé 1 (2·5–3 years old), the relief of the mental trigone is significantly weaker than that seen in the 2·5–3-year-old early modern human specimen Isturitz 7. Further, the 10-month-old Amud 7 specimen has also been identified as a Neandertal partially on the basis of the absence of any evidence of chin development (Rak *et al.*, 1994).

Tillier's (1999) recent thorough study of the early modern human children from the site of Qafzeh is also important to consider here since mandibles representing different ontogenetic stages from birth to around 13 years of age are represented in this sample. The Qafzeh 13 neonate specimen preserves what is described as a slight depression on the anterior symphysis, but it is not clear whether this individual shows the inverted T configuration described by Schwartz & Tattersall (2000). The 6 year old Qafzeh 10 individual apparently shows a suite of characteristics which include a symphyseal tubercle, lateral tubercles and mental fossae on the external symphysis. The 7 year old Qafzeh 4 mandible also shares this same configuration, while the slightly older Qafzeh 15 specimen seems to display a mental trigone more clearly. Finally, the 12–13 year old Qafzeh 11 mandible shows the most marked development of chin structures in this immature sample.

Interestingly, both Tillier (1999) and Schwartz & Tattersall (2000) feel that differences in symphyseal morphology can be detected in subadult fossils, however, they differ in how the expression of these features changes from infants to adults. Based on the Qafzeh subadults, Tillier (1999) argues for a process of gracilization during the course of ontogeny involving an accentuation of the incurvatio mandibulae anterior and a verticalization of the internal symphysis, producing a more pronounced chin in older individuals. Within the Qafzeh subadult sample, then, Qafzeh 11 shows the strongest expression of the chin characteristics. Schwartz & Tattersall (2000), on the other hand, argue that diagnostic features of the chin in modern humans are more easily seen in younger individuals and become gradually less defined with age.

Despite these differences of opinion, the morphology seen in the VB1 specimen, is clearly more consistent with a Neandertal classification. The lack of most of the diagnostic criteria of a chin, combined with a well-developed alveolar planum (planum alveolare) on the internal aspect (see below), and an age at death of 13–14 years, would lead either Schwartz & Tattersall (2000) or Tillier (1999) to group the specimen with Neandertals.

Morphology of the internal symphysis

The internal aspect of the symphysis is entirely preserved right of the midline, with the left side showing some abrasion of the surface bone and missing most of the basal margin [Figure 5(b)]. The superior third of the internal aspect of the symphysis slopes obliquely posteriorly, producing a pronounced alveolar planum which is delimited inferiorly by a well developed superior transverse torus (Figure 6). A marked thickening of bone is easily seen in this area where the specimen is broken to the left of the midline. The superior transverse torus extends laterally to about the level of the P_4 on the right side where it becomes indistinguishable from the surrounding bone.

Just below this feature along the midline, a genioglossal fossa is present midway down the corpus, exhibiting a centrally located genial canal at its deepest point [Figure 5(b)]. The fossa is quite deep, 1·3 mm, and is produced by the two transverse tori. No genial tubercles are present, but a raised ridge of bone, the mental spine, courses inferiorly along the midline. It reaches its maximum thickness just below the genioglossal fossa where it courses over the marked inferior transverse torus. This latter feature extends laterally for only a short distance, terminating at the point of curvature in the body of the mandible separating the symphyseal region from the rest of the corpus. Just lateral to this on the right side, a shallow depression is present at the anterior termination of the mylohyoid line, corresponding to the sublingual fossa. The digastric fossae are present on the posterior basal aspect and are oriented posteriorly and inferiorly. While the left fossa is incomplete, the right is fully preserved and is well excavated and oval in shape. An interdigastric spine, the extension of the mental spine, separates the two along the midline and comes to a well defined point at gnathion, bisecting the incisura submentalis as mentioned above.

Comparison of cross-sections of the symphysis in VB1 and several other Paleolithic mandibles is presented in Figure 8. The symphysis is receding, and both the incurvatio mandibulae anterior and the symphyseal tubercle can be seen. Posteriorly, both the superior and inferior transverse tori are well developed and clearly visible, and a projection of bone at the base corresponds to the interdigastric spine. CT imaging (Figure 9) shows these structures to be the result of a marked thickening of the cortical bone on the internal aspect of the symphysis.

The presence of a distinct alveolar planum is a primitive hominid condition that is retained in some Neandertal specimens, but is less frequent among early modern humans and living populations. The Middle Pleistocene specimens of Mauer and Montmaurin both exhibit a well developed alveolar planum (Vallois, 1956), as do many of the mandibles from SH (Rosas, 1995). Adult Neandertal mandibles are more variable in their morphology. However, many specimens, for example La Chapelle-aux-Saints, show a reduced alveolar planum compared with their Middle Pleistocene precursors, and others lack this feature entirely, such as Amud 1 (Suzuki & Takai, 1970). Among the juvenile specimens, the Middle Pleistocene Ehringsdorf 7 mandible exhibits the strongest expression of this feature (see Figure 8), similar to that seen in VB1. Indeed, the expression of the alveolar planum in VB1 is remarkable, surpassing that seen even in many adult Neandertal specimens, and approaching more closely the morphology seen among European Middle Pleistocene mandibles. The inferior transverse torus is similarly well developed in the VB1 mandible, again surpassing most Neandertal specimens and finding a closer match among European Middle Pleistocene mandibles. The relief of both the internal tori in VB1 is evidence of a more archaic symphyseal morphology.

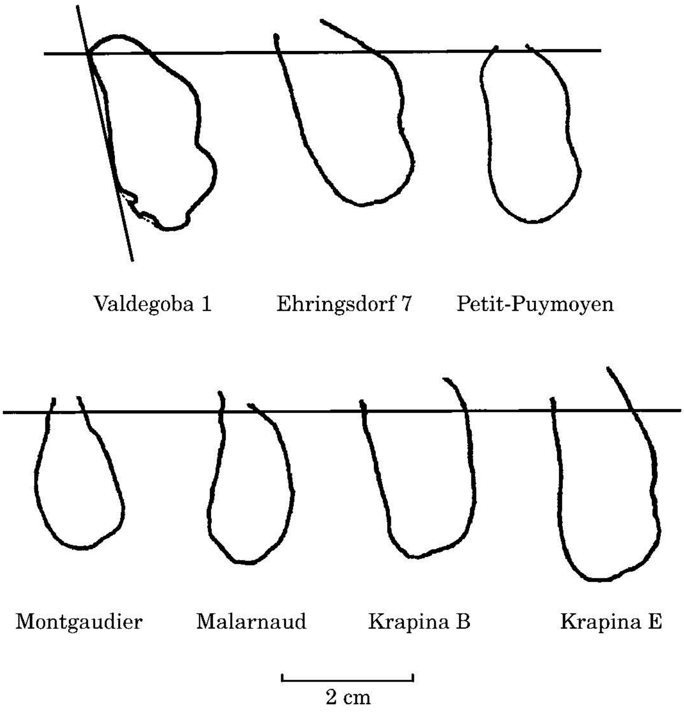

Figure 8. Cross-sectional symphyseal outlines of VB1 and selected Pleistocene hominids oriented in the alveolar plane (after Mann & Vandermeersch, 1997).

Symphyseal measurements
Measurements of the symphysis in VB1 are compared with similar-aged Neandertal and early modern human mandibles in Table 6. The VB1 specimen is thick and robust, both absolutely and relatively. The symphyseal thickness (15·5 mm) is greater than that of any of the similar-aged Paleolithic specimens, with the Middle Pleistocene Ehringsdorf 7 mandible approaching this value. Similarly, it is above the range of variation seen in an adolescent sample (12–18+ years) of recent *Homo sapiens* reported by Minugh-Purvis (1988). Finally, the symphyseal thickness of VB1 is in the middle of the range of variation reported in several adult mandibular samples of different taxonomic affinities.

On the other hand, symphyseal height in VB1 (30·6 mm) is not so distinct. This value is similar to that reported for the Paleolithic adolescent specimens Krapina F, Le Moustier 1 or Qafzeh 11. Among the adult samples, VB1 is at the lower end of the range of variation seen in European Neandertals or their Middle Pleistocene European ancestors from SH.

With a robusticity index of 50·6, VB1 is comparable to the most robust Neandertal specimens known, but is still exceeded by the North African Jebel Irhoud 3 mandible. Further, the value for VB1 is above those reported for the adult SH sample and at the upper end of the range of variation observed among adult samples of both Neandertals and recent modern humans. Rosas (1995) has shown that infero-superiorly shorter mandibles tend to have higher robusticity indices than do taller ones, and all of the adolescent Paleolithic specimens with higher robusticity indices than VB1 do indeed have shorter symphyses. In the Valdegoba 1

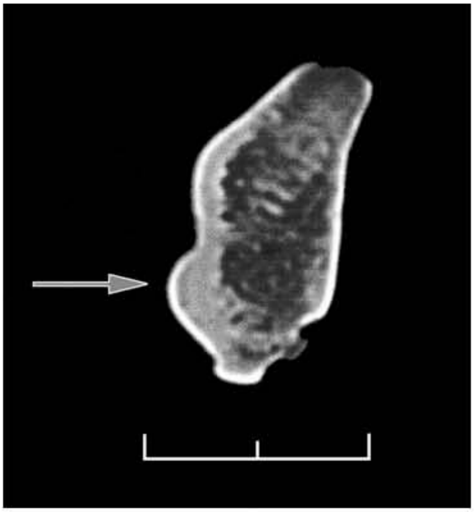

Figure 9. CT scan of the symphyseal profile of VB1. Note the marked thickening of bone (white arrow) on the internal symphysis. Scale bar=2 cm.

specimen, then, it is clearly the thickness which is producing the high value for the robusticity index.

In lateral view, the symphysis is receding (Figure 8) and this condition is similar to Neandertal and European Middle Pleistocene specimens. While the specimen is incomplete, enough of the alveolar margin is preserved to measure the angle of the symphysis. A line was drawn parallel to the alveolar margin, intersecting another which joins infradentale and pogonion. The angle between these two lines gives an indication of the degree of symphyseal retreat, with 90° indicating a vertical symphysis. In VB1, this angle measured 78°. Stefan & Trinkaus (1998*b*) report a mean value of 81·7 ± 8·1° for a sample of adult European Neandertals (n=11), showing VB1 to fall within the range of variation observed among these hominids.

Lateral corpus

Only the superior half of the lateral corpus is preserved on the VB1 specimen, and on the right side, the top half of a single mental foramen is preserved at the level of the P_4 [Figure 5(c)]. However, preservation of the specimen makes it impossible to know if more than one mental foramen was initially present. The foramen is more anteriorly placed than the majority of Neandertal specimens (Trinkaus, 1993), and a posterior position is commonly associated with pronounced midfacial prognathism. In VB1, then, the degree of midfacial prognathism was not greatly developed.

The mental foramen on the VB1 specimen is also located relatively high on the corpus, 11·7 mm below the aolveolar margin. This is a higher position than that reported in the Montgaudier 1 specimen (13·1 mm) (Mann & Vandermeersch, 1997), and well above the values observed in the SH sample (13·8–22·5 mm, n=11) (Rosas, 1997). In general, Neandertals have mental foramina located lower on the corpus relative to early modern humans. Because both the position and height of the mental foramen in adults are dependent on growth trajectories of the mandibular body, the values observed on the VB1 specimen could be at least partially a result of its adolescent age.

Internally, the mylohyoid line is visible on both fragments, but present along more of its course on the smaller of the two [Figure 5(g)], extending from the left M_3–M_1. It runs at a slight angle to the alveolar margin and dips inferiorly below the M_1/M_2 septum. On the larger fragment from the right side of the mandible, the mylohyoid line disappears at about the level of the P_4/M_1 septum. While little of the base of the internal face of the lateral corpus is present, the relief of the mylohyoid lines, where they are preserved on both sides, suggests the presence of defined submandibular fossae.

As with the symphysis, the lateral corpus is robust. Corpus thickness measurements were taken at several points, with the specimen oriented in the alveolar plane (Table 7). However, the basal margin is not present along the lateral corpus, and posterior to the canine only a minimum value is obtainable

Table 6 Symphyseal measurements (mm) for Valdegoba 1 and the comparative samples

Specimen	Age (years)	Height	Thickness	Index	Source
Valdegoba 1	13–14	30·6	15·5	50·6	
Neandertals					
Krapina C	11	29·6	14·8	50·0	Smith (1976)
Malarnaud 1	11–13	25·0	12·5	50·0	Filhol (1888)
Ehringsdorf 7	12	28·3	15·3	54·1	Minugh-Purvis (1988)
Montgaudier 1	12·5–14·5	22·0	11·8	53·6	Mann & Vandermeersch (1997)
Krapina D	15	33·0	13·5	40·9	Smith (1976)
Krapina E	15	34·8	14·2	40·8	Smith (1976)
Krapina F	17	31·2	14·2	45·5	Smith (1976)
Le Moustier 1*	16·5	30·0	15·0	50·0	Minugh-Purvis (1988)
Petit-Puymoyen 1	16–17	28·1	12·2	43·4	Minugh-Purvis (1988)
N. African Archaic					
Jebel Irhoud 3	8–9	26·7	13·7	51·3	Hublin & Tillier (1981)
Early Moderns					
Sungir 3	11–12	31·5	14·0	44·4	Minugh-Purvis (1988)
Qafzeh 11	12–13	30·0	14·0	44·1	Tillier (1999)
Modern *H. sapiens* (n=163)	12–18+	24·5–35·0	10·8–15·3	43·7–44·1	Minugh-Purvis (1988)
Modern *H. sapiens* (n=42)	Adult	25–38	11–18	33·3–60·0	Quam (1996)
European Neandertals (n=11)†	Adult	26·2–42·4	13·9–18·0	34·2–53·1	Heim (1976); Wolpoff *et al.* (1981)
Atapuerca SH (n=9)	Adult	28·3–41·2	13·5–16·7	39·0–48·1	Rosas (1997)

*Measurements on Le Moustier 1 taken on cast.

†Neandertal specimens include: La Ferrassie 1, La Chapelle, Spy 1, La Naulette, Regourdou 1, Krapina G, H, J, Vindija 206, 226, 231.

for the maximum thickness. Nevertheless, these values are quite high, and corpus thickness does not change significantly in VB1 from the canine to the M_2. The VB1 specimen is thicker along its corpus than most of the immature comparative specimens. This is especially true from C to P_4, while at the level of M_1, several specimens approach VB1 in thickness dimensions. Only the slightly younger Krapina C specimen regularly exceeds the VB1 mandible in thickness. Given that most of the measurements on VB1 represent minimum values, it is clear that the specimen does indeed possess a thick corpus.

The Valdegoba 1 dental remains

Eleven teeth were recovered pertaining to the Valdegoba 1 individual. They include the right I_2–M_2 and the left P_3–M_3. The larger mandibular fragment of this individual preserves the right I_2–M_1 *in situ*, while the smaller fragment from the left side of the corpus contains M_1 and M_2 in their alveolar sockets (Figure 5). The remaining teeth fell out of their sockets post-mortem. Nevertheless, the presence of interproximal contact facets, as well as the stage of development of the dentition make it reasonable to assume that all of the teeth pertain to the VB1 individual.

Enamel hypoplasias

Hypoplastic defects are present on the enamel surfaces of several of the teeth in the Valdegoba 1 individual (Figure 5). Enamel hypoplasias have a variety of possible causes, but most likely indicate periodic episodes of nutritional stress, during which enamel deposition was temporarily interrupted (Goodman & Rose, 1991; Hillson, 1996).

Table 7 Corpus thickness (mm) for Valdegoba 1 and the comparative samples

Specimen	Age	Canine	P3	P4	M1	M2	Source
Valdegoba 1*	13–14	(R) 17·0	(R) (16·9)	(R) (16·6)	(R) (16·6)	(L) (17·3)	
Neandertals							
Krapina C	11	17·4	17·9	17·5	17·1		Minugh-Purvis (1988)
Malarnaud 1	11–13	13·5	14·5			15·0	Filhol (1888)
Ehringsdorf 7	12–14	15·6	17·0		15·0		Minugh-Purvis (1988)
Montgaudier 1	12·5–14·5	12·15	13·7	13·45	13·55		Mann & Vandermeersch (1977)
Krapina E	15	15·0	14·8	14·4	16·5		Minugh-Purvis (1988)
Le Moustier 1†	16·5	15·0	14·2	15·2	16·6		Minugh-Purvis (1988)
N. African Archaic							
Jebel Irhoud 3	8–9	15·9	14·9	13·9	16·8		Minugh-Purvis (1988)
Early modern humans							
Sungir 3	11–12	11·5	12·5	12·5	13·5		Minugh-Purvis (1988)
Qafzeh 11	12	10·6	10·9	10·6	13·2		Minugh-Purvis (1988)

*Numbers in parentheses for Valdegoba indicate minimum values.
†Measurements taken on cast.

Ogilvie *et al.* (1989) report the presence of enamel hypoplasias in about 75% of Neandertal individuals, a value which places them at the upper end of the range of variation in frequencies documented among living populations. The presence of enamel hypoplasias in the Valdegoba 1 individual, then, is not surprising given the elevated frequencies in the Neandertal population of hypoplastic defects in the dentition.

Evidence of enamel hypoplasias can be found on several of the teeth and take different forms, most notably in the canine. This tooth shows a small cluster of pits toward the top of the labial face of the enamel. The premolars also show pits toward the tops of their buccal faces, which could represent the same episode of stress. On the labial surface of the right I_2 and the canine several faint horizontal grooves can be seen that appear to be exaggerations of the normal perikymata. These linear enamel hypoplasias (LEH) are located in the lower half of the enamel surface and lower in the incisor than in the canine. They could, then, represent the same episode of stress. The canine further shows a severe linear defect toward the base of the enamel surface on the labial face of the tooth. This defect does not follow the course of the normal perikymata, but rather runs obliquely and inferiorly from mesial to distal. This does not appear to be a product of taphonomic alterations, but represents a disruption of enamel formation. A similar defect is present on the root, approximately 2·5 mm below that on the enamel. Finally, numerous pits are present on both the sides and occlusal surface of the crown of both M_2s as well as the left M_3. These pits tend to appear together in clusters of two or three and are virtually absent from the M_1s. The pattern of distribution of hypoplasias in VB1 is remarkably similar to that reported by Ogilvie *et al.* (1989) for the Neandertal population as a whole. They identified both a similar pattern of distally increasing hypoplastic defects in the molars of Neandertals as well as a high frequency of defects specifically in the canine.

These hypoplastic defects can be used to infer a reasonable estimate of when these nutritional deficiencies occurred during the lifetime of the Valdegoba 1 individual. Following Smith's (1991) method for estimating biological age from tooth formation in modern humans, the earliest stress documented in the canine would have occurred before 2·5 years. The development of the LEH in the incisor and canine corresponds to an age of approximately 3·5 years, while the severe defect at the base of the canine enamel occurred at about 4·4 years. The pitting of the crowns of the M_2s would roughly correspond to this same time, approximately 4·3–4·9 years. Finally, the hypoplastic pits on the sides of the M_3 appear to have occurred at an age of approximately 10·5 years.

The age distribution of hypoplasias in VB1 is consistent with the pattern reported for Neandertals in a variety of studies (Molnar & Molnar, 1985; Ogilvie *et al.*, 1989; Skinner, 1996). Ogilvie *et al.* (1989) reported two peak stress levels in the Neandertal population. Most of the hypoplasias occurred between the ages of 2–5 years, with a peak age at stress of approximately 3·9 years. The second peak stress period was at 11·4 years of age and occurred primarily in the M_3. Skinner's (1996) results agree well with a peak age at stress of about 3·5 years among Neandertals, but show most of the hypoplasias to occur between 3·5 and 5·5 years of age. Further, he shows a much smaller peak later in life, at 10 and 13 years respectively. Finally, Molnar & Molnar (1985) show a tendency for M_3 hypoplasia in the Krapina population at an age of about 11 years.

The virtual lack of hypoplasias on the M_1s, as well as their absence on the deciduous dentition of the Valdegoba 2 individual (see below), suggests low levels of perinatal stress in the Valdegoba hominids. This is consistent with Skinner's (1996) finding of lower perinatal stress in the form of hypoplasias among Middle Paleolithic hominids, a pattern which contrasts sharply with Upper Paleolithic infants. Ogilvie *et al.* (1989) suggested the first peak in nutritional stress might be related to the age at weaning among Neandertals, which they would then place at about 4 years of age. Two episodes of stress on the VB1 canine occur roughly around this time, with the more severe defect occurring after weaning. The additional presence of hypoplastic defects on the left M_3 in VB1 further suggests that this individual suffered nutritional deficiencies (or infectious disease), albeit less severe ones, throughout the juvenile and adolescent periods, perhaps reflecting marked seasonality in resource availability. This is similar to the interpretation reported by Ogilvie *et al.* (1989) for the Neandertal population as a whole.

Tooth wear

In general, the teeth show only slight to moderate signs of wear, as would be expected in an adolescent individual [Figures 5(d) and 6]. In none of the teeth is the pulp cavity exposed, although individual cusps are worn flat and the secondary dentine is observable in some cases. None of the teeth shows evidence of caries. The right I_2 is clearly the most worn of all the preserved teeth, with the occlusal surface being reduced to a flat plane. A mesial interproximal wear facet for articulation with the I_1 is also present and may have reduced the mesiodistal length of this tooth slightly. The canine shows signs of wear as well, with the tip being flattened. The premolars show a slight rounding of the cusps, but in general are relatively unworn.

The first molars, on the other hand have several of the cusps flattened and secondary dentine is visible in places. The relief of the crown is reduced, with more wear visible along the buccal rather than the lingual margin. Both M_1s also possess anterior and posterior interproximal wear facets for articulation with the P_4s and M_2s respectively, and it is clear that this has reduced their mesiodistal dimensions. The M_2s present less wear than the M_1s as they erupted later during the life of the Valdegoba 1 individual. However, the right M_2 is more worn than the left, and again the wear is greater along the buccal margin. Both M_2s have anterior interproximal wear facets for articulation with the M_1s, but lack distal facets, indicating the M_3s had not reached functional occlusion. The left M_3 crown shows no sign of wear and was in the process of erupting at the time of death. Finally, none of the molars or premolars show signs of artificial toothpick grooves in the interproximal areas as has been reported on other Neandertal and Middle Pleistocene teeth (Frayer & Russell, 1987; Bermúdez de Castro *et al.*, 1997*b*).

The pattern of tooth wear observed in VB1 appears consistent with other Neandertal dentitions which demonstrate advanced wear on the anterior teeth compared with the posterior teeth. While the central incisor was not preserved in VB1, the lateral incisor shows a substantial amount of wear. The wear pattern seen in VB1 is remarkably similar to other Neandertal mandibles of a similar ontogenetic age, most notably Krapina mandibles D and E (Radovčič *et al.*, 1988).

Dental morphology

Anterior tooth sockets. The tooth sockets of the anterior dentition are preserved from the left I_2 to right canine (Figures 5 and 6). The central incisor root sockets show pronounced developmental grooves, and this feature is especially strong in the left lateral incisor root socket. Rather than curving posteriorly from the midline, the lateral incisors and canine follow a more or less straight line

Table 8 **Mesiodistal dimensions (mm) of the VB1 dentition compared with Pleistocene and recent humans**

Tooth	VB1 (R/L)	SH ($x \pm 1$ S.D.)	Neandertals ($x \pm 1$ S.D.)	Modern humans ($x \pm 1$ S.D.)
I_2	6·9/—	6·6 ± 0·3 $n=14$	6·7 ± 0·5 $n=22$	5·8 ± 0·4 $n=73$
C	7·6/—	7·6 ± 0·4 $n=16$	7·9 ± 0·5 $n=32$	6·6 ± 0·4 $n=126$
P_3	7·4/7·6	7·9 ± 0·4 $n=17$	7·9 ± 0·5 $n=37$	6·8 ± 0·5 $n=264$
P_4	7·3/7·4	7·2 ± 0·5 $n=21$	7·7 ± 0·5 $n=40$	7·0 ± 0·5 $n=297$
M_1	11·9/12·1	11·2 ± 0·5 $n=21$	11·8 ± 0·9 $n=47$	11·2 ± 0·7 $n=504$
M_2	12·2/12·1	11·0 ± 0·6 $n=22$	12·0 ± 0·9 $n=38$	10·8 ± 0·7 $n=507$
M_3	—/11·6	11·3 ± 0·8 $n=24$	11·7 ± 0·9 $n=36$	10·8 ± 0·8 $n=440$

Atapuerca sample represents the largest currently available number of teeth after 1998 field season.

Neandertal sample after Bermúdez de Castro & Nicolás (1995).

Modern human sample from Gran Canaria (Canary Islands) after Bermúdez de Castro (1985).

laterally, and the dental arcade curves more sharply posteriorly between the canine and P_3. This frontal disposition of the anterior teeth in the VB1 specimen is similar to that observed in other adult and adolescent Neandertal anterior dentitions, and it reaches its maximal expression in the adolescent specimen Krapina F (Smith, 1976; Radovčič *et al.*, 1988). This is different from the condition see in the Jebel Irhoud 3 mandible from North Africa (Hublin & Tillier, 1981, 1988). Interestingly, however, it is present in the juvenile early modern human specimen Qafzeh 11.

Lateral incisor. The lateral incisor shows a significant amount of wear, with the occlusal margin being worn flat (Figure 5). The buccal surface of the crown is convex and the root shows some post mortem alteration anteriorly. Lingually, the crown surface curves concavely toward the base, where a slight swelling is present. The mesial and distal marginal ridges are only weakly developed and the tooth is not shovel-shaped.

Metrically, the MD length of the lateral incisor (6·9 mm) is slightly above the mean of both the SH and Neandertal samples (Table 8), although the degree of interproximal wear may have affected the value in VB1 somewhat. The BL width (7·8 mm) is above the SH mean but equals that seen in the Neandertal sample (Table 9). In both dimensions, the Valdegoba values are well above the mean for the modern human sample.

Canine. The right canine shows only slight wear on the tip (Figure 5). Two severe defects are present on the buccal face of the crown (representing an incidence of hypoplasia) and the anterior aspect of the root. This latter defect does not appear to be caused by post-mortem taphonomic factors but, rather, represents a pathology which manifested itself during the lifetime of the individual. The mesial and distal marginal

Table 9 **Buccolingual dimensions (mm) of the VB1 dentition compared with Pleistocene and recent humans**

Tooth	VB1 (R/L)	SH ($x \pm 1$ S.D.)	Neandertals ($x \pm 1$ S.D.)	Modern humans ($x \pm 1$ S.D.)
I_2	7·8/—	7·3 ± 0·4 n=14	7·8 ± 0·6 n=24	6·3 ± 0·4 n=73
C	8·2/—	8·5 ± 0·9 n=16	9·1 ± 0·8 n=31	7·6 ± 0·6 n=126
P_3	9·0/8·8	8·9 ± 0·6 n=17	9·0 ± 0·7 n=37	7·8 ± 0·5 n=264
P_4	9·1/8·9	8·7 ± 0·7 n=21	9·1 ± 0·8 n=40	8·3 ± 0·6 n=297
M_1	11·0/11·0	10·4 ± 0·5 n=21	11·0 ± 0·7 n=47	10·7 ± 0·5 n=504
M_2	10·9/11·0	10·2 ± 0·6 n=22	11·1 ± 0·7 n=38	10·3 ± 0·6 n=507
M_3	—/10·3	9·8 ± 0·7 n=24	10·9 ± 1·0 n=36	10·2 ± 0·7 n=440

Atapuerca sample represents the largest currently available number of teeth after 1998 field season.

Neandertal sample after Bermúdez de Castro & Nicolás (1995).

Modern human sample from Gran Canaria (Canary Islands) after Bermúdez de Castro (1985).

ridges of the crown are moderately developed and the lingual aspect of the crown is concave. The canine exhibits a modest swelling at the base, but no cusp is present. A distal accessory ridge is also present on the lingual face between the apex and the distal margin, corresponding to stage 2 or 3 of the ASU dental anthropology system (Turner *et al.*, 1991). Scott (1977) has shown this to be one of the most sexually dimorphic features of the dentition, appearing more often in males than females across all ten of the modern human samples included in his study.

Metrically, the canine MD length (7·6 mm) is similar to the mean of the SH sample, below the Neandertal mean and large compared to modern humans (Table 8). Garn *et al.* (1977) suggest that the canine MD length is among the most sexually dimorphic of all the tooth dimensions in modern humans, and the modest value in VB1 is more consistent with a female sex diagnosis. The BL width (8·2 mm) is below the means of both the SH and Neandertal samples (Table 9), but still well above that of modern humans, showing that the Valdegoba 1 mandible possesses a moderately small canine compared with Pleistocene humans.

Premolars. All of the premolars show a dominant buccal cusp, and this is more pronounced in the P_3s than the P_4s (Figures 5 and 6). The crown of the right P_3 shows a simple U-shaped fissure pattern, with the lingual margin exhibiting three small cusps equal in size. The left P_3 crown shows a single lingual cusp bounded anteriorly by a prominant mesiolingual groove. The crown bulges markedly buccally, producing a cingulum swelling near the base. This same morphology is visible in a reduced form on the right P_3. The right P_4 presents two main lingual cusps, with the mesial cusp being larger and equal in height to the buccal cusp. The buccal and mesial lingual cusps are joined by an enamel ridge, delimiting an anterior fossa, and the distal marginal ridge is cut by a distal groove.

Figure 10. VB1 left P_3 in mesial (right) and distal (left) views showing bifurcation of the root. Scale bar=2 cm.

The left P_4 appears to have two lingual cusps, with the mesiolingual cusp being the largest and equal in height to the buccal cusp. Finally, the distal marginal ridge also exhibits a small cusp.

The root of the isolated left P_3 shows a simplified form of the so-called Tome's root (Figure 10). The lingual and buccal root components bifurcate at about 3·8–4·0 mm from the cervical enamel junction and are joined by a dentine sheet to just above the apex. A shallow distal groove and a deeper mesial groove clearly delimit the bifurcation, with the buccal root component being clearly dominant. Radiographic examination reveals the *in situ* right P_3 to also possess a bifurcated root.

Two-rooted lower P_3s are common among both australopithecines and earlier members of the genus *Homo* (Wood *et al.*, 1988). A variant of this morphology has also recently been described in the Early Pleistocene teeth from the Gran Dolina site in the Sierra de Atapuerca (Bermúdez de Castro *et al.*, 1997*a*, 1999). Double-rooted P_3s have also been identified in a Middle Pleistocene specimen from the Sima de los Huesos (AT-172), as well as among the Krapina teeth (Kallay, 1963), and are probably related to molarization of the premolars. Given the occurrence of this morphology in Middle and Late Pleistocene fossils, its distribution among fossil hominids from these time periods should be the subject of further study. The bifurcated root of the VB1 P_3 show an advanced degree of fusion relative to the Gran Dolina teeth and represents an intermediate stage in the pathway towards a single root.

The isolated left P_4 is single-rooted. The root is mesiodistally compressed and exhibits a thin and narrow mesial groove and a deeper and broader distal groove, but without any signs of roof bifurcation. Radiographic examination of the *in situ* right P_4 shows it has one root.

Metrically, the MD dimensions of the P_3s (Table 8) are below both the SH and Neandertal means, while the BL dimensions are more similar (Table 9). In both measures, the P_3s are considerably larger than those in a modern human sample. Both the MD and BL dimension of the P_4s fall between those recorded in the SH and Neandertal samples and above the recent human means.

Molars. Despite the degree of wear on some of the teeth, it is clear that all five preserved molars possess more than four cusps [Figures 5(d) and 6]. It is often difficult to be certain if a posterior fifth cusp is a true hypoconulid or represents an expression of cusp six in the absence of the hypoconulid. However, when only five cusps are present it is conventional to assume that the fifth cusp represents the hypoconulid (Hillson, 1996). All the M_1s and M_2s clearly possess large hypoconulids distally and slightly buccally on the posterior aspect of the crown. The left M_2 also shows the presence of a sixth cusp, the entoconulid, distally and lingually. It is possible the other molars also possessed a sixth cusp, but the degree of wear makes it difficult to be certain. A very small cusp seven is present along the lingual margin of both the left M_1 and M_2, and is slightly larger in the former. No trace of a protostylid is visible on the buccal surfaces of any of the molars. In both the M_1s and M_2s, the cusps are arranged in the typical dryopithecine “Y” pattern. In these teeth, the metaconid clearly makes contact with the hypoconid in the central fossa.

The crown morphology of the unworn M_3 is somewhat different, showing many small accessory grooves and enamel ridges [Figures 5(d) and 6]. However, six cusps are clearly visible. The entoconid appears reduced compared with the M_1s and M_2s. Two equal sized cusps, the hypoconulid and entoconulid, are present distally. Further, there is a very small expression of cusp 7 along the lingual margin. In contrast to the M_1s and M_2s, the cusp arrangement and fissure pattern is more complex in the unworn M_3, and this tooth exhibits a +6 morphology.

In all five of the preserved molars, an anterior fovea is present. This is a small depression on the occlusal surface at the mesial end of the crown, delimited posteriorly by a ridge of enamel joining the protoconid and metaconid. In living humans, anterior foveae are often present in first lower molars but less frequently in second and rarely in third lower molars and were considered to be of taxonomic value by Hrdlicka (1924). Turner *et al.* (1991) have more recently suggested that anterior foveae are present at a higher frequency in third lower molars among Pleistocene humans. In none of the Valdegoba 1 molars is a posterior fovea observed.

Numerous Neandertal dentitions do exhibit anterior foveae in their third molars. While an anterior fovea is observed in all of the VB1 molars, its strength is variably expressed and is most clearly seen on the left side, with the unworn left M_3 showing the strongest expression. Their weaker expression in the right molars is probably related to the greater wear on this side of the dentition. Specifically, their presence in all of the lower molars of a single individual in VB1 is similar to the condition seen in Hortus V (de Lumley, 1973), Le Moustier 1 (Hrdlicka, 1924) and probably the Breche de Genay and Shanidar 2 individuals (Trinkaus, 1983; de Lumley, 1987). The presence of anterior foveae in all of the teeth of VB1, then, is similar to Neandertal dentitions.

The anterior fovea in the lower molars is bounded anteriorly by the mesial marginal ridge and distally by a ridge of enamel joining the protoconid and metaconid. Variations in the form of this enamel ridge have been described by Wu & Turner (1993), who distinguish both a distal trigonid crest (DTC) and a middle trigonid crest (MTC) as possibly forming the distal border of the anterior fovea. Previously, only the DTC was defined as a distinct trait, and was said to be “A ridge or loph that bridges cusps 1 and 2” (Turner *et al.*, 1991: 23). With the subsequent recognition of the MTC as a possible variant, the scoring of both these features had to be modified. The main difference between these two variants seems to be whether the crest joins the protoconid and metaconid at their distal margins (DTC) or at their middle portions (MTC) (Wu & Turner, 1993). In a large series of modern human dental casts, they observed that the MTC usually occurred with an incomplete DTC in the same tooth. This makes it easy to identify the MTC, because there are two crests. However, when only one crest was present, they scored it as either DTC or MTC based on where it joined the protoconid and metaconid. Because tooth wear can easily obscure the differences between the DTC and MTC, they recommend scoring the trait only on individuals between 6–15 years of age. This dental trait, then, can be investigated in the VB1 individual.

With these observations in mind, the VB1 molars were examined for the presence of an MTC. Both the M_1s do indeed seem to show an MTC bounding the anterior fovea posteriorly. In these teeth, the crest joining the protoconid and metaconid appears to be located mesial of the distal margins of the cusps. The condition in the M_2s is more difficult to score. However, in the unworn M_3, two divergent crests branch off from the protoconid. One crest runs anteriorly and joins the base of the metaconid at its anterior margin, while the second crest runs distally and joins the base of the metaconid at its distal margin. This tooth appears to exhibit the two-crested condition described by Wu & Turner (1993). According to their criteria, the anterior crest is the MTC while the distal crest would be the DTC.

Wu & Turner (1993) observed the MTC most frequently in M_1 among African populations, with a much lower occurrence reported in non-African populations. Zubov (1992) claims to have observed the MTC in human fossil teeth representing a wide diversity of taxa, including Neandertals, and its expression should be the focus of a larger study in the fossils. The presence of the MTC in VB1, then, seems to be similar to other Neandertal dentitions.

The molars preserved with VB1 do not show any sign of the development of taurodontism. The loose right M_2 possesses two roots that appear long relative to the crown height [Figure 5(c)], but shows no indication of vertical expansion of the pulp chamber nor fusion of the roots which typically accompany taurodont molars. CT examination (Figure 11) further shows that the *in situ* right M_1 also lacks any evidence of taurodontism. The presence of taurodontism is well documented in numerous specimens from Krapina (Wolpoff, 1979) and Hortus (de Lumley, 1973), and it occurs at a relatively high frequency among Neandertals.

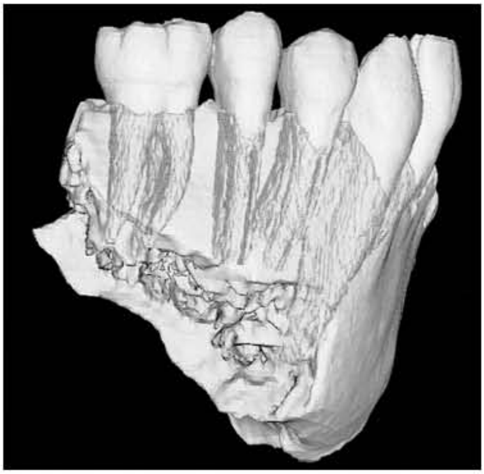

Figure 11. Three-dimensional reconstruction from CT images of the VB1 right mandibular fragment, showing the absence of taurodontism in M_1.

Metrically, the MD and BL dimensions of the Valdegoba 1 molars (Tables 8 and 9) are above the mean values observed among the SH sample, which demonstrates a marked reduction in posterior tooth size compared with other European Middle Pleistocene specimens (Bermúdez de Castro & Nicolás, 1995). The values in VB1 are more similar to the Neandertal means and larger than those observed among the modern human sample. On the left side, the relative size of the molars follows a $M_1=M_2>M_3$ pattern. On the right side, the $M_1<M_2$ pattern is seen, but the difference in size between the M_1 and M_2 is minimal.

Crown index

The crown index ($CI = BL \times 100/MD$) values of the VB1 individual are presented in Table 10, and in general they fall within one standard deviation of the Neandertal mean. The canine of VB1 is relatively narrow, and its low CI stands out in relation to the higher CI values of the premolars. The high CI values of the VB1 premolars, on the other hand, is relatively frequent in other Neandertals, such as La Quina H9, Spy 2

Table 10 Crown Index (CI=BL × 100/MD) of the mandibular teeth in VB1 (right side), the Atapuerca (SH) and Neandertal samples and the modern human sample from Gran Canaria (Canary Islands)

Valdegoba 1		Neandertals			Atapuerca-SH			Gran Canaria		
		n	*X*	S.D.	*n*	*X*	S.D.	*n*	*X*	S.D.
I_2	113·0	22	118·1	10·9	14	110·7	4·4	73	110·2	8·2
C	107·9	30	114·2	7·7	16	111·6	9·1	126	115·0	7·1
P_3	121·6	36	114·5	8·3	17	112·9	3·8	264	114·5	8·3
P_4	124·6	40	118·4	11·4	21	120·6	9·3	297	117·8	11·4
M_1	92·4	47	93·5	5·5	21	93·4	3·5	504	96·1	4·2
M_2	89·3	38	92·9	5·4	22	93·3	2·7	507	95·6	3·9
M_3 (left)	88·8	35	93·0	6·4	24	87·3	4·5	440	94·4	5·4

Abbreviations: *X*=mean; S.D.=standard deviation.

and Genay. Finally, the VB1 CI values also fall within the variability of the SH and modern human samples.

Interdental indices

In order to characterize the shape of the VB1 dentition, we calculated the computed crown areas (CCA=MD × BL) of several teeth to generate the following interdental indices: the ratio of I_2 breadth (BL) and M_1 (CCA) [BL I_2/(CCA) M_1], the ratio of P_3 and P_4 [(CCA) P_3/P_4] M_1 and M_2 [(CCA) M_1/M_2], and P_4 and M_1 [(CCA) P_4/M_1]. The M_1 was used as the reference tooth because it is the most stable tooth in the molar dental field (Dahlberg, 1945). Table 4 presents the comparative sample of *Homo* specimens used to calculate these indices.

BL I_2/(CCA) M_1 index. This index assesses the size relationship between the anterior and posterior dentition and shows a high level of discrimination between samples. Specimens whose incisors are relatively narrow and exhibit large posterior teeth yield low values. A higher index is produced in hominids which show either narrow incisors and smaller posterior teeth or have markedly expanded lower incisors.

Table 11 shows the value of the BL I_2/(CCA) M_1 index in VB1 and several European Pleistocene *Homo* specimens. In Neandertals, the lower lateral incisors are generally broad, frequently exceeding 8·0 mm in BL breadth. Further, the posterior dentition is reduced compared to most Lower and Middle Pleistocene *Homo* specimens (but not the SH sample). In consequence, the Neandertals usually exhibit a high BL I_2/(CCA) M_1 index. In VB1, the value of this index (5·96) is similar to the mean value of the Neandertal sample (6·08), demonstrating that it shares with other Neandertal specimens the relative expansion of the anterior compared with the posterior teeth which characterizes this population.

Interestingly, some Neandertal individuals, such as Genay, Krapina E and Krapina L, show a low BL I_2/(CCA) M_1 index (4·89, 5·24 and 4·63, respectively). In these specimens the posterior teeth are remarkably large, whereas the incisors do not exhibit proportionally large dimensions, demonstrating that the size variability of the anterior teeth is largely independent of the size variability of the posterior teeth (Bermúdez de Castro, 1993; Bermúdez de Castro *et al.*, 1999). Despite the low values in these individuals, the mean value of the Neandertals is considerably larger than that of early modern humans.

In general, values close to 6·0 or greater are only found in European Middle Pleistocene hominids, such as Mauer and the SH

Table 11 Values for BL I_2/(CCA) M_1 index and BL I_2 in selected hominids

	BL I_2/(CCA) M_1			BL I_2		
Specimen	*n*	X/x	S.D.	*n*	X/x	S.D.
Valdegoba 1		5·96			7·8	
Atapuerca-TD6 H1		5·42			7·8	
Mauer		5·92			7·7	
Atapuerca-SH	9	6·02	0·4	14	7·3	0·4
Neandertals	19	6·08	0·7	24	7·8	0·6
Skhul IV		5·43			7·0	
Skhul V		5·38			7·0	
Oafzeh 7		5·66			7·1	
Qafzeh 9		5·03			7·8	
European Early Upper Paleolithic*		5·49			7·0	
Gran Canaria*		5·24			6·3	

*European EUP and Gran Canaria are calculated from average values for these teeth.

individuals, and the later Neandertals. Earlier members of the genus *Homo*, generally show lower values for this index (except KNM-WT 15,000), and this is a consequence of larger posterior and smaller anterior teeth. Therefore, we suggest that a high value of the BL I_2/(CCA) M_1 index represents a derived trait within this European lineage and is produced by the combination of a size reduction in the posterior teeth together with large dimensions of the incisors. The evolution of modern human populations was characterized by a relatively greater size reduction of the anterior teeth. In consequence, a decrease of the BL I_2/(CCA) M_1 index is seen in these populations, and our findings parallel those suggested previously by Wolpoff (1979) for Europe and more recently by Stefan & Trinkaus (1998*a*) for Southwest Asia.

(CCA) P_3/P_4 index. The (CCA) P_3/P_4 index is another way to assess the size relationship between the anterior and posterior teeth, although the results show more overlap between samples. For reasons discussed in Bermúdez de Castro (1993), we include the P_3 with the anterior dentition. The size of the P_3 seems to be affected by the size variation of both the anterior and posterior teeth (Bermúdez de Castro, 1993; Bermúdez de Castro *et al.*, 1999). The P_3>P_4 sequence seems to characterize the European Middle Pleistocene hominids as well as Neandertals. In Valdegoba 1, the (CCA) P_3/P_4 index (104·2) is identical to the mean value of the Neandertal sample (104·3) (Table 12), and generally above the values reported for early modern humans (except Skhul 5), thus reflecting the dominance of the anterior teeth in this specimen. Note the extreme situation of the SH hominids, where the $P_3 \gg P_4$ sequence occurs, which is a consequence of the strong size decrease of the posterior teeth in these hominids.

(CCA) P_4/M_1 and (CCA) M_1/M_2. The general size of the posterior teeth can be assessed by the (CCA) P_4/M_1 and the (CCA) M_1/M_2 indices, which evaluate the size of the two teeth adjacent to the M_1, the most conservative tooth (in size and shape) of the molar field. It is well known that the reduction of the posterior dentition in the genus *Homo* is not proportional but differential. Thus, the size decrease of the P_4 and M_2 was relatively greater than that of the M_1. However, the relative size decrease of these teeth was not perfectly synchronized, so that a strong reduction of the P_4 in

Table 12 Values for the indices (CCA) P_3/P_4, (CCA) P_4/M_1 and (CCA) M_1/M_2 in selected hominids

	(CCA) P_3/P_4			(CCA) P_4/M_1			(CCA) M_1/M_2		
Specimen/sample	*n*	*X/x*	S.D.	*n*	*X/x*	S.D.	*n*	*X/x*	S.D.
Valdegoba 1		104·2			49·5			100·0	
Atapuerca-TD6 H1		111·6			58·1			88·8	
Mauer		105·6			53·1			85·2	
Arago 2		—			56·5			92·4	
Arago 13		101·5			58·3			88·4	
Atapuerca-SH	9	120·3	8·7	13	51·5	4·7	16	103·2	4·9
Montmaurin		—			—			102·9	
Neandertals	22	104·3	9·0	24	53·5	4·8	25	97·5	7·1
Skhul IV		91·3			48·9			114·6	
Skhul V		106·2			53·9			98·3	
Qafzeh 7		97·8			53·3			104·1	
Qafzeh 9		99·6			56·2			99·1	
European Early Upper Paleolithic*		94·8			51·4			104·2	
Gran Canaria*		91·2			48·5			107·1	

*European EUP and Gran Canaria are calculated from average values for these teeth.

one specimen or sample does not necessarily imply a proportional reduction of the M_2, and *vice versa*. In general terms, a low (CCA) P_4/M_1 index and a high (CCA) M_1/M_2 index suggest a reduced posterior dentition (Table 12).

The Neandertals exhibit a marked reduction of the posterior teeth compared to other European Lower and Middle Pleistocene hominids, such as Atapuerca-TD6 and Arago, but not as reduced as that seen in modern humans. The mean values of the (CCA) P_4/M_1 (53·5) and (CCA) M_1/M_2 (97·5) indices obtained for the Neandertal sample define well the degree of size decrease of their posterior teeth. The (CCA) P_4/M_1 index in VB1 is low (49·5) and it is among the lowest values of the Neandertal sample. As far as the (CCA) M_1/M_2 index is concerned, the VB1 figure (100) is only slightly greater than the mean value of the Neandertal sample. The $M_1 \leq M_2$ sequence observed in Valdegoba 1 is among the most common in Neandertals.

Principal components analysis

To further assess phenetic similarities between the Valdegoba 1 individual and other hominids, a principal component analysis (PCA) was carried out using 12 dental variables: the MD and BL dimensions of I_2–M_2 (raw data). In this analysis the following *Homo* specimens were used for comparative purposes: individuals II, III, VII, XII, and XXIII from Atapuerca SH, Hominid 1 from Atapuerca-TD6, Mauer (Howell, 1960), OH 7 (Tobias, 1991), KNM-ER 992 (Leakey & Wood, 1973), KNM-WT 15,000 (Brown & Walker, 1993), Tighenif 3, Dmanisi (Gabunia & Vekua, 1995), Arcy II, Ehringsdorf 7, Genay, Le Moustier, Spy II, Ochoz, Krapina D, E, H, and L, Skhul IV (De Lumley, 1973), Skhul V (De Lumley, 1973) and 35 modern *H. sapiens* specimens (Aboriginals from Gran Canaria, Canary Islands). The statistical package *SSPS* was used to make this analysis.

The first three components of the PCA account for 87·6% of the total variance in the data (Table 13). The first component (PC1) explains 74·9% of the total variance. This is a size component, with all dental variables showing similar, high and positive loadings. The second component (PC2) explains 8·6% of the total variance. This is a

Table 13 **Principal component analysis of the VB1 dental variables**

		Factor 1	Factor 2	Factor 3
% of the variance		74·9	8·6	4·1
Cumulative variance		74·9	83·5	87·6
I_2	MD	0·853	−0·257	−0·268
	BL	0·805	−0·424	−0·007
C	MD	0·912	−0·222	0·002
	BL	0·901	−0·246	0·124
P_3	MD	0·936	−0·007	−0·122
	BL	0·902	−0·239	0·200
P_4	MD	0·842	0·340	−0·253
	BL	0·906	−0·003	0·275
M_1	MD	0·798	0·460	−0·151
	BL	0·728	0·483	0·311
M_2	MD	0·884	0·131	−0·245
	BL	0·897	0·199	0·144

shape component, and it reflects the variability of the size relationship between the anterior teeth (I_2, C, and P_3) and the posterior teeth (P_4, M_1, and M_2). In the PC2, negative and positive loadings are obtained for the dental variables of the anterior and posterior teeth, respectively. The PC2 gives high positive loadings for the MD and BL of the M_1, and MD of the P_4, and high negative loadings for the BL of the I_2 (see the BL I_2/(CCA) M_1 index section). The PC3 is another shape component, which only accounts for 4·1% of the total variance. This component is not particularly informative, and suggests a contrast between the MD and BL dimensions. The MD and BL variables have, respectively, negative and positive loadings on the PC3.

Figure 12 shows the scatter diagram for the PC1 *vs.* PC2 of the dental variables. The PC1 spreads the specimens and samples according to the general size of their teeth, and this component places VB1 near the lower extreme of the size variability of the Neandertals (near Krapina D). The PC2 reveals a pattern in the distribution. Those specimens whose anterior tooth size clearly predominates over the size of the posterior teeth are placed in the negative region of the PC2. This is the case of the SH hominids. In contrast, those specimens whose posterior tooth size predominates over the size of the anterior teeth are placed in the positive region of the PC2. This is the case of the OH 7 and Dmanisi specimens, as well as the Zhoukoudian sample. For the PC2, VB1 falls close to the majority of the Neandertal specimens, Mauer and some SH individuals, and near the point representing the mean value of the Neandertals. This demonstrates the expansion of the anterior teeth relative to the posterior dentition in VB1.

The Valdegoba 2 (VB2) individual

The Valdegoba 2 individual is represented by ten deciduous teeth (Table 1), all of which preserve the crowns and exhibit variable amounts of root formation (Figure 13). Since neither the mandible nor the maxilla of VB2 were preserved, the identification of each tooth is based on their individual morphology. At least one of each of the tooth crowns is represented in the VB2 individual, with the exception of the lower dc. The good preservation of nearly all of the teeth as well as their roots, except for the right dm_2, which shows signs of abrasion, indicates that postdepositional alteration has been minimal, and they provide a reliable estimate of

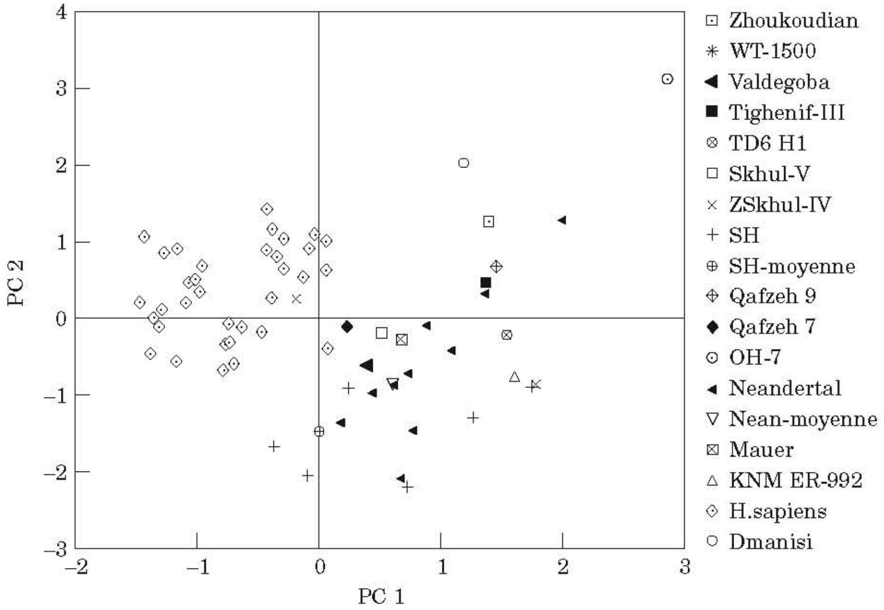

Figure 12. Scatterplot of the PCA analysis. Note the position of VB1 among the Neandertals and near the mean value for this sample.

the age at death of the Valdegoba 2 individual. From the pattern of crown and root development, it is clear all the deciduous teeth correspond to a single individual.

Age at death

With a relatively complete set of deciduous teeth represented, a fairly accurate age can be estimated for the Valdegoba 2 individual. No permanent tooth germs were preserved, so age at death is determined based on crown and root formation stages for the deciduous dentition (Table 14). Both the di^1 and di$_1$ crowns are completely developed and the roots have reached about one quarter of their total length. The di^2 is at an identical stage of formation, but the di$_2$ shows only an initial root development. Both the dm^1 and dm$_1$ also display an initial root development that is only just visible below the completed crown. The dc$_1$ does not show any evidence of root development and is just entering crown completion stage. Finally, the dm^2 shows a crown about three quarters complete and the dm$_2$ is somewhere between one half and three quarters complete. The degree of deciduous crown and root formation suggests an age of 6–9 months (Ferembach *et al.*, 1980).

The degree of tooth calcification in Valdegoba 2 is similar to that seen in Shanidar 7, and Trinkaus (1983) has suggested an age at death of 6–9 months and more probably close to eight months. The Kebara 4 dentition shows a greater amount of root development in several of the teeth than that seen in Valdegoba 2. Smith & Tillier (1989) suggest an age at death of between nine months and one year for this individual. Thus, compared with these two Middle Paleolithic infants, an age at death estimate of 6–9 months for Valdegoba 2 seems reasonable.

Enamel hypoplasias

The VB2 deciduous dentition shows no evidence of either caries or hypoplastic defects,

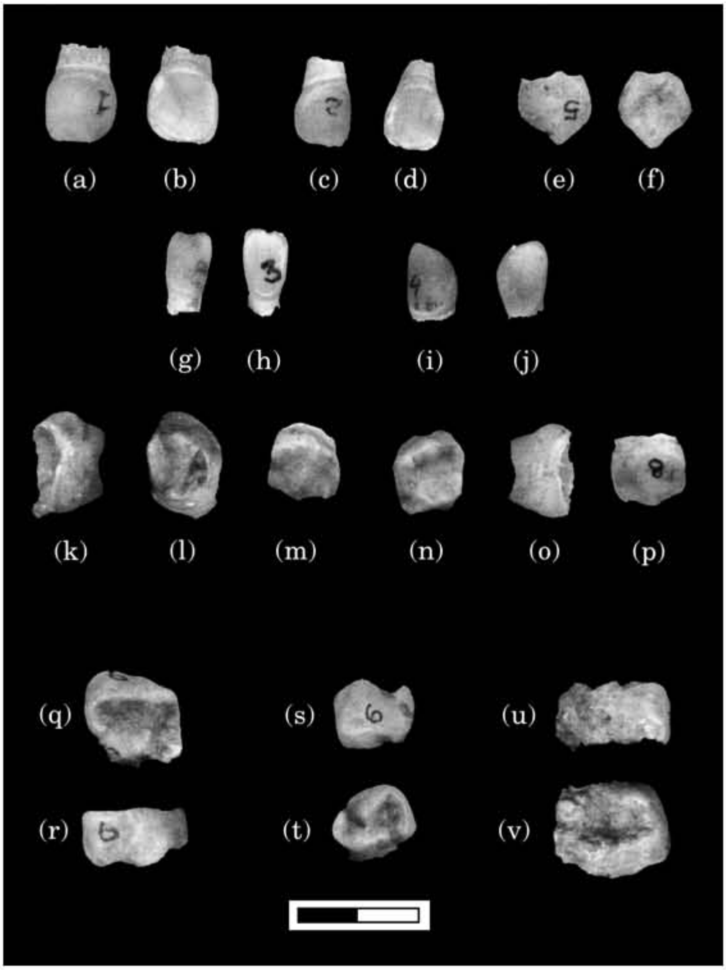

Figure 13. The Valdegoba 2 deciduous teeth. Note the absence of hypoplasias and the formation stages of the teeth. (a) Buccal view of Ldi^1; (b) lingual view of Ldi^1; (c) buccal view of Rdi^2; (d) lingual view of Rdi^2; (e) buccal view of Ldc^1; (f) lingual view of Ldc^1; (g) buccal view of Rdi$_1$; (h) lingual view of Rdi$_1$; (i) buccal view of Ldi$_2$; (j) lingual view of Ldi$_2$; (k) mesial view of Ldm^1; (l) occlusal view of Ldm^1; (m) buccal view of Ldm^1; (n) occlusal view of Rdm^1; (o) mesial view of Rdm^1; (p) buccal view of Rdm^1; (q) occlusal view of Ldm^2; (r) buccal view of Ldm^2; (s) buccal view of Ldm$_1$; (t) occlusal view of Ldm$_1$; (u) buccal view of Rdm$_2$; (v) occlusal view of Rdm$_2$. Scale bar=1 cm.

neither in the form of linear enamel hypoplasias on the anterior dentition nor pitting on any of the teeth (Figure 13). Further, no neonatal line is visible on any of the teeth. Ogilvie *et al.* (1989) recorded hypoplastic defects in only one Neandertal infant prior to weaning age, Pech-de-l'Azé 1, while Skinner (1996) reported their presence in about 7% of Neandertal deciduous teeth. It is only during the Upper Paleolithic when enamel hypoplasias are seen in early infancy.

Dental morphology

Deciduous incisors. The left di^1, right di^2, right di$_1$ and left di$_2$ are preserved [Figure 13(a)–(d), (g)–(j)]. Both the central and lateral maxillary deciduous incisors show

Table 14 Dental formation stages for Valdegoba 2

Tooth	Formation stage	Total crown/root length of preserved tooth
Maxillary		
Ldi^1	R1/4	8·4
Rdi^2	R1/4	7·8
Ldc	Cr3/4-Crc	6·3
Ldm^1	Ri	6·7
Rdm^1	Ri	6·5
Ldm^2	Cr3/4	5·5
Mandibular		
Rdi_1	R1/4	7·4
Ldi_2	Ri	6·6
Ldm_1	Ri	6·1
Rdm_2	Cr1/2–3/4	5·8

Formation stages after Smith (1991).

evidence of slight shovelling. Specifically, both display a swelling at the lingual base of the crown, but no distinct lingual tubercle is present. Marginal ridges are present on both teeth and are more prominent along the mesial borders, but are found on the distal and occlusal margins as well. Their presence is seen most clearly on the mesial border of the right maxillary di^2. The mandibular deciduous incisors are not shovelled. The di_2 has a less pronounced lingual swelling, but a marginal ridge is present along the lateral margin. This tooth also shows a distinct reduction of the distal marginal lobe, producing a more rounded incisal edge distally. The other incisors show more even incisal edges with no evidence of reduced distal lobes.

The absence of lingual tubercles on the upper incisors in VB2 seems to be a common condition of both Neandertal and early modern human deciduous teeth (Smith, 1989), although the Roc de Marsal Neandertal infant is reported to have small lingual tubercles on the maxillary incisors (Madre-Depouy, 1992). The marginal ridges on the di^1 in VB2 are weaker than in Roc de Marsal, where this tooth is clearly shovelled. However, the expression of marginal ridges in the di^2 in both these fossils is similar. The expression of marginal ridges on the upper incisors in the Magdalenian infant from La Madeleine is not reported, but these teeth are characterized by an absence of a lingual tubercle (Heim, 1991). The reduced distal lobe in the di_2 is said to be characteristic of Neandertal dentitions (Smith, 1978), and the Roc de Marsal infant is similar to VB2 in this regard.

Deciduous canine. The VB2 infant preserves a single left upper deciduous canine [Figure 13(e), (f)]. Morphologically, the apex is displaced slightly distally, and the buccal surface of the crown exhibits a gently convex contour. The mesial ridge is slightly concave and longer than the more convex distal ridge. The distal marginal ridge is more buttressed than the mesial, but only a shallow concavity is present on the lingual face of the tooth. A slight swelling is present at the lingual base of the crown, but there is no tubercle and the tooth is not shovel-shaped.

The morphology of the VB2 canine contrasts with that seen in the Roc de Marsal infant. Specifically, the latter has a stronger expression of the marginal ridges and lingual cingulum with two distinct lingual tubercles also present (Madre-Dupouy, 1992). With regard to these structures, the VB2 infant appears closer to the morphology reported for the La Madeleine 4 specimen (Heim, 1991).

Upper first deciduous molars. The right and left dm^1s are preserved in VB2 [Figure 13(k)–(p)], and in both teeth three cusps are visible. The two main buccal and lingual cusps are roughly equal in height and separated by a deep central fossa. A very small third cusp is also present along the buccal margin just distal to the main cusp and is more pronounced on the left tooth. Both teeth possess a continuous mesial marginal ridge, but the distal marginal ridge is cut by a fissure from the central fossa. No distolingual cusp is present on either of the dm^1s.

Both teeth also show a marked swelling of the mesiobuccal corner of the crown near the base.

The number of cusps is variable in Neandertal and modern human deciduous dentitions. The majority of Neandertal dm^{1}s appear to possess four cusps, often with a large hypocone. However, the Roc de Marsal Neandertal infant shows three cusps on each of the dm^{1}s, with two main buccal and lingual cusps and a reduced distobuccal cusp. The number and expression of the three cusps on the VB2 dm^1 is similar to Roc de Marsal, and these teeth are less molarized than most Neandertals. Recent humans show a further reduction in the number of cusps, with the two-cusped form being the most common, and this condition characterizes the Madeleine infant.

Smith (1978, 1989; Smith & Arensburg, 1977) has suggested a distinctive dm^1 morphology for Neandertals, based initially on the Kebara 1 Neandertal infant. The axis of the cusps on the occlusal surface is said to form an oblique angle with respect to the MD axis of the tooth. Usually, four cusps are present, with a marked oblique ridge joining the protocone and metacone, and intercusp distances are reduced, which result in a pronounced occlusal tapering of the crown.

This suite of characters is said to differentiate Southwest Asian Neandertals from the early modern human specimens from Skhul and Qafzeh which generally show an alignment of cusps parallel to the MD axis of the tooth. Further, the crowns have a more squarish outline, with mesial and distal borders being roughly parallel, and show at least partial fusion of the paracone and metacone (Smith, 1978; Smith & Arensburg, 1977). These same criteria seem to differentiate two dm^{1}s (representing different individuals) from the site of Kebara, and it is possible that two different hominid groups are represented in the deciduous teeth from this site (Smith & Tillier, 1989).

Although this distinction was first described in specimens from Southwest Asia, Neandertal and early modern human infants in Europe have been suggested to differ in similar regards (Tillier, 1979; Madre-Dupouy, 1992). However, in her recent thorough study of the Qafzeh children, Tillier (1999) has argued against this dichotomy and suggests little to no difference between the Qafzeh teeth and those of other Mousterian individuals.

The morphology of the dm^{1}s in VB2 seems closer to the modern human condition than to Neandertal dentitions. The paracone and metacone are not fused in this individual, but the latter is very much reduced and not located as far distally from the paracone as seen in the Kebara 1 infant. The cusp alignment seems to follow the MD axis of the tooth, and there is no oblique crest joining the protocone and metacone in VB2. However, the distinctive morphology of Neandertals is seen most clearly in teeth which possess four cusps, and the reduced number of cusps in VB2 makes the distinction less apparent. Nevertheless, despite the similar number of cusps between Roc de Marsal and VB2, the dm^1 in Roc de Marsal seems to conform to the Neandertal condition in having the occlusal surface at an oblique angle to the MD axis (Madre-Dupouy, 1992). The dm^1 in the infant from La Madeleine is similar to the majority of recent Europeans which show only two cusps on the dm^1 and does not exhibit an oblique ridge (Heim, 1991). The orientation of the cusps in this specimen is not described. However, the Magdalenian infant from Figuier shows a cusp alignment parallel to the MD axis of the tooth (Billy, 1979). Finally, the mesiobuccal cingulum swelling seen in VB2 seems to be a ubiquitous character of Pleistocene deciduous teeth and is present in both Neandertal as well as early modern human dentitions. Thus, the crown morphology of the dm^1 in VB2 seems more similar to early modern humans than Neandertals.

Upper second deciduous molar. The left dm^2 is present and exhibits four main cusps [Figure 13(q), (r)]. The two buccal cusps and the mesiolingual cusp are equal in size and height and are joined by crests that clearly delimit the trigone basin. A smaller fourth cusp is present distally, and is separated from the mesiolingual cusp by a deep groove. There is no trace of a cusp of Carabelli and only a slight indication of mesiobuccal swelling of the cingulum.

In the number of cusps, as well as the weaker expression of the mesiobuccal swelling as compared with the dm^1, the morphology seen in the VB2 dm^2 is similar to that seen in both Roc de Marsal and La Madeleine, and there appears to be no real distinction between Neandertals and early modern humans in this tooth.

Lower first deciduous molar. The left dm_1 exhibits three cusps [Figure 13(s), (t)], with the mesiobuccal cusp being the most prominent and separated from the smaller distobuccal cusp by a groove. A single large lingual cusp is also present. The mesial marginal ridge descends steeply from buccal to lingual and is cut by a deep groove just anterior to the lingual cusp. The anterior fovea is delimited posteriorly by the protoconid and metaconid, although a groove joins the anterior fovea with the large central fossa. There is no trace of a posterior fovea. Finally, there is a pronounced cingulum swelling at the mesiobuccal corner of the crown near the base.

The presence of only three cusps in the Valdegoba 2 infant contrasts with a more molarized dm_1 in Neandertals, which usually show a full complement of five cusps. The Roc de Marsal infant shows five cusps on the left tooth and six on the right (Madre-Dupouy, 1992). The presence of a small posterior fovea in Roc de Marsal is a further point of divergence between these two specimens. The dm_1 in La Madeleine has four cusps and is also more molarized than VB2. However, the absence of a posterior fovea is similar between the two specimens. The mesiobuccal cingulum swelling seems to be a general character in Pleistocene deciduous dentitions. In general the dm_1 in VB2 differs from the more molarized teeth commonly found in Neandertals and approaches a more modern condition.

Lower second deciduous molar. The right dm_2 shows some post-mortem degradation of the tooth crown, but five cusps can be seen, three buccally and two lingually [Figure 13(u), (v)]. There is no anterior or posterior fovea present. Rather, there is a single large central fossa. The protoconid and metaconid are roughly equal in size, while the hypoconid and the entoconid are somewhat reduced. Finally, a hypoconulid is present disto-bucally. A buccal groove is present between the protoconid and hypoconid. Although the crown is incompletely calcified, it appears there is a cingulum swelling at the mesiobuccal corner.

In cusp number, the VB2 dm_2 is similar to Neandertal and modern human dentitions. However, Neandertal teeth often show both an anterior and posterior fovea, and both these structures are identifiable in the Roc de Marsal and Molare dm_2s. Madre-Dupouy (1992) and Mallegni & Ronchitelli (1989) argue that these characteristics are either primitive or rarely found in modern human deciduous teeth. The La Madeleine dm_2 shows four cusps with a small anterior fovea and no posterior fovea (Heim, 1991). The morphology seen in the VB2, dm_2, then, differs from Neandertal teeth and is more similar to the condition seen in modern humans.

Metric comparison

Metric comparison of the deciduous dentition with that of Roc de Marsal, La Madeleine 4, Neandertals and early modern humans show Valdegoba 2 to possess small teeth (Tables 15 & 16). Roc de Marsal uniformly shows larger dimensions than VB2 in every tooth preserved, while the La Madeleine infant shows values similar to VB2 for most teeth. When compared with a sample of Neandertals, Valdegoba 2 again shows small teeth, with the values falling either at the lower end or outside the range of variation. In most cases, a similarly low value can be found among the Neandertal sample. However, the consistently small dimensions of all the teeth in VB2 is not seen in any other Neandertal specimen, and several teeth fall completely outside the known Neandertal range of variation. The smaller number of molar cusps on Valdegoba 2 could partially explain the small size of these teeth, but the anterior dentition shows similarly small dimensions. Finally, in almost all cases, the dental dimensions of Valdegoba 2 are within the ranges of variation seen among recent modern humans.

Among the maxillary teeth, the La Madeleine 4 infant compares most favorably with Valdegoba 2, while Roc de Marsal has larger teeth. Among Neandertals, the Subalyuk 2 and Chateauneuf 2 infants, which also possess small teeth, are most similar to VB2. However, the MD lengths of the di^2 (5·3 mm) and dm^1 (6·6 mm) in VB2 are unmatched in the Neandertal sample, and the BL diameter (8·3 mm) of the dm^1 is only matched by La Quina H18 among the Neandertals. In these dimensions the specimen clearly clusters with the early modern humans. Considering the maxillary dentition as a whole, the summed MD (33·6 mm), BL (33·7 mm) and CCA (233·6 mm^2) values in VB2 are smaller than any other known Pleistocene specimen (Table 17). While the means for a limited sample of Neandertals and early modern humans are nearly the same, the low value in VB2 indicates an important reduction in tooth size in this individual.

Within the mandibular dentition, VB2 shows values similar to the La Madeleine 4 infant, while Roc de Marsal possesses larger teeth. Among Neandertals, Chateauneuf 2 again shows similar dimensions to VB2 in several teeth. However, the MD and BL dimensions of the di_1 show complete separation of Neandertals and early modern humans, with VB2 falling clearly within the modern range of variation. Considering the mandibular dentition as a whole is more difficult since VB2 lacks an associated lower dc. However, from the small dimensions of all the other preserved teeth, it is likely that the summed dimensions of the mandibular teeth would compare more favorably with values from Upper Paleolithic infants, rather than Neandertals.

Postcranial remains

Three postcranial bones were recovered during 1988 and 1989 at the Valdegoba site (Table 1): a distal half of a proximal phalanx of the hand (VB3), a right fourth metatarsal (VB4) and a left fifth metatarsal (VB5) (Figure 14). Two or three different individuals are represented in the postcranial remains. The VB3 phalanx lacks the base and its developmental status is indeterminate. The VB4 metatarsal had not completed fusion of the head and is a subadult, and the VB5 metatarsal had reached maturity.

Valdegoba 3 (VB3)

This is a distal half of a manual proximal phalanx recovered in 1989 from level 5. The asymmetry of the trochlear condyles and the development of the ridges for the attachment of the flexor sheath muscles [Figure 14(a), (b)] indicate that the bone belonged to the second or third ray of the left hand. In the proximal fracture and on the dorsal and palmar diaphyseal surfaces, carnivore toothmarks can be observed.

Table 18 compares the absolute and relative dimensions of VB3 with Neandertals

Table 15 **Mesiodistal lengths (mm) of the Valdegoba 2 deciduous dentition compared with Roc de Marsal, La Madeleine 4, Upper Pleistocene and recent humans**

	Valdegoba 2		Roc de Marsal (1)		La Madeleine 4 (2)		European Neandertals (1) (*x* ± 1 S.D.)	EUP Modern Humans (3) (*x* ± 1 S.D.)	Recent Euroamericans (3)	
	Right	Left	Right	Left	Right	Left			Male (*x* ± 1 S.D.)	Female (*x* ± 1 S.D.)
Maxillary										
di^1		**6·4**	8·0	7·7	6·8	6·8	7·6 ± 0·5 *n*=14	6·9–7·1 *n*=69	6·4 ± 0·4 *n*=64	6·5 ± 0·3
di^2	**5·3**		6·4	6·3	5·2	5·2	6·6 ± 0·6 *n*=10	5·4–5·8 *n*=3	5·2 ± 0·4 *n*=69	5·3 ± 0·4 *n*=64
dc		**6·6**	7·6	7·8	7·0	7·0	7·4 ± 0·6 *n*=17	7·2–7·6 *n*=2	6·8 ± 0·4 *n*=69	6·7 ± 0·4 *n*=64
dm^1	**6·5**	**6·6**	8·2	8·5	6·3	6·5	8·1 ± 0·5 *n*=18	7·3 ± 0·6 *n*=10	6·7 ± 0·5 *n*=69	6·6 ± 0·5 *n*=64
dm^2		**8·7**	9·5	9·6		8·9	9·9 ± 0·7 *n*=23	9·6 ± 0·8 *n*=5	8·8 ± 0·6 *n*=69	8·8 ± 0·5 *n*=64
Mandibular										
di$_1$	**4·1**		5·1	5·0	4·1	4·2	5·0 ± 0·3 *n*=7	4·0 *n*=1	4·0 ± 0·3 *n*=69	4·1 ± 0·3 *n*=64
di$_2$		**4·8**	5·8	5·9	4·7	4·8	5·5 ± 0·5 *n*=8	4·8 *n*=1	4·6 ± 0·4 *n*=69	4·7 ± 0·4 *n*=64
dm$_1$		**8·2**	9·0	8·8	7·5	7·2	8·8 ± 0·5 *n*=17	8·1 ± 0·8 *n*=12	7·9 ± 0·4 *n*=69	7·7 ± 0·4 *n*=64
dm$_2$	**9·8**		10·6	10·6	10·3	10·1	10·4 ± 0·6 *n*=27	10·3 ± 0·8 *n*=20	9·9 ± 0·5 *n*=69	9·7 ± 0·5 *n*=64

Sources: (1) Madre-Dupouy (1992); (2) Heim (1991); (3) Trinkaus (1983).

Table 16 Buccolingual breadths (mm) of the Valdegoba 2 deciduous dentition compared with Roc de Marsal, La Madeleine 4, Upper Pleistocene and recent humans

	Valdegoba 2		Roc de Marsal (1)		La Madeleine 4 (2)		European Neandertals (1) (x ± 1 S.D.)	EUP Modern Humans (3) (x ± 1 S.D.)	Recent Euroamericans (3)	
	Right	Left	Right	Left	Right	Left			Male (x ± 1 S.D.)	Female (x ± 1 S.D.)
Maxillary										
di^1		**5·5**	5·9	6·0	5·2	5·0	6·1 ± 0·4 n=14	5·0–5·6 n=3	5·1 ± 0·4 n=69	5·2 ± 0·5 n=64
di^2	**5·1**		5·3	5·3	5·2	5·0	5·5 ± 0·4 n=10	4·8–5·4 n=3	4·7 ± 0·4 n=69	4·6 ± 0·4 n=64
dc		**5·8**	6·8	7·0	6·7	6·3	6·7 ± 0·5 n=18	6·5–6·8 n=2	6·1 ± 0·4 n=69	6·0 ± 0·4 n=64
dm^1	**8·4**	**8·3**	8·7	9·0	8·9	9·0	9·1 ± 0·4 n=18	8·7 ± 0·6 n=9	8·8 ± 0·5 n=69	8·6 ± 0·6 n=64
dm^2		**9·0**	10·1	10·4		9·9	10·6 ± 0·5 n=23	10·5 ± 0·5 n=10	9·5 ± 0·5 n=69	9·4 ± 0·5 n=64
Mandibular										
di$_1$	**4·1**		4·6	4·5	3·6	3·6	4·7 ± 0·4 n=7	3·6 n=1	3·9 ± 0·4 n=69	3·8 ± 0·3 n=64
di$_2$		**4·7**	4·8	4·7	4·3	4·1	4·9 ± 0·4 n=8	4·1 n=1	4·4 ± 0·4 n=69	4·4 ± 0·3 n=64
dm$_1$		**6·5**	7·3	7·5	6·9	6·6	7·6 ± 0·6 n=17	7·1 ± 0·5 n=12	7·4 ± 0·5 n=69	7·3 ± 0·4 n=64

Sources: (1) Madre-Dupouy (1992); (2) Heim (1991); (3) Trinkaus (1983).

Table 17 **Summed dimensions (mm) of the maxillary dentition in Valdegoba 2 compared with Neandertals and early modern humans**

Specimen	MD (mm)	BL (mm)	CCA	Reference
Valdegoba 2	33·6	33·7	233·6	
KDP 1	40·7	38·5	318·4	Wolfpoff (1979)
KDP 2	42·2	39·0	339·5	Wolfpoff (1979)
Chateauneuf 2 (R)	37·3	36·7	280·6	Tillier (1979)
Chateauneuf 2 (L)	36·5	37·4	279·8	Tillier (1979)
Roc de Marsal	39·8	37·4	306·6	Madre-Dupouy (1992)
La Ferrassie 8	39·7	37·8	316·5	Heim (1982)
Subalyuk 2	34·4	34·5	250·8	Pap *et al.* (1996)
Engis 2	38·6	37·1	296·7	Madre-Dupouy (1992)
Shanidar 7	36·7	36·7	276·8	Trinkaus (1983)
Kebara 1	38·0	38·8	303·4	Smith & Tillier (1989)
Neandertal mean	38·4	37·4	296·9	
S.D.	2·3	1·3	25·6	
Qafzeh 10 (R)	40·3	37·9	313·9	Tillier (1999)
Qafzeh 10 (L)	39·3	37·9	307·2	Tillier (1999)
La Madeleine 4	34·4	35·2	250·7	Heim (1991)
Early modern mean	38·0	37·0	290·6	
S.D.	3·2	1·6	34·7	

and modern humans. In absolute size, VB3 is a small bone. The phalanx head index of VB3 (60·0) is low in comparison with modern human sample means (2·75 and 2·87 S.D. below the means for the second and third rays, respectively) and is closer, although still below, the Neandertal means calculated for these two digits. A low value for this index indicates either a wider or a shorter distal end. VB3 shares with Neandertals a relatively, but not absolutely wide distal end of the manual phalanx, and this characteristic is also present in the Middle Pleistocene SH fossils (Musgrave, 1970; Trinkaus, 1983; Lorenzo *et al.*, 1999).

Valdegoba 4 (VB4)

This is a right fourth metatarsal of an immature individual (lacking the distal epiphysis) recovered in 1988 from level 6. In modern humans, the distal epiphysis of the metatarsal bone fuses with the diaphysis around the 15th or 16th year of life (Krogman & Iscan, 1986). According to this criterion, VB4 belonged to an individual less than 15 years old. Although judging by the size of the bone, it was close to this age and similar to that determined for the mandibular fragment VB1 (13–14 years).

Morphologically, the articular facet for the cuboid is slightly convex and the facet for the fifth metatarsal is nearly flat and dorsally placed [Figure 14(e)–(g)]. Metrically, VB4 is close to recent human values in its absolute dimensions (Table 19), but it is a robust metatarsal. The mean robusticity index for the Neandertal sample (11·9 ± 0·6, $n=6$) is slightly below the Hamman–Todd mean for this same index (12·1 ± 0·8, $n=47$), although the differences are not statistically significant ($P>0·05$). The VB4 fourth metatarsal, although within the ranges of variation of the Neandertal and Hamman–Todd samples, has a robusticity index (13·4) that is 2·5 S.D. above the Neandertal mean and 1·7 S.D. above recent human samples.

Valdegoba 5 (VB5)

This is a complete left adult fifth metatarsal recovered during the 1988 field season [Figure 14(c), (d)]. It represents a different

Figure 14. The Valdegoba postcranial remains. (a) VB3 in dorsal view; (b) VB3 in palmar view; (c) VB5 in dorsal view; (d) VB5 in plantar view; (e) VB4 in distal view; (f) VB4 in dorsal view; (g) VB4 in lateral view. Scale bar=2 cm.

individual from VB4 because the epiphysis is completely fused and no trace of the metaphyseal line is visible. VB5 has a broad and strong proximolateral tuberosity for the insertion of the *M.* peroneus brevis. On the superomedial border of the base there is a small area, partially eroded, for the attachment of the *M.* peroneus tertius. The cuboid facet and the fourth metatarsal articular facet are flat, and the sulcus for the tendon of the *M.* abductor digiti minimi is absent. There is a rough area on the distal lateral side of the diaphysis, close to the head, for the attachment of the *M.* opponens digiti minimi.

There are no significant differences between Neandertals and modern humans in the fifth metatarsal robusticity index (Trinkaus, 1978, 1983) and we did not find differences between the Neandertal mean and our modern human sample mean ($P>0{\cdot}05$) (Table 20). The robusticity index of VB5 (14·9) is above the Neandertal mean (13·7 ± 1·0, $n=5$) and coincident with the Hamman–Todd recent human sample mean (14·9 ± 1·2, $n=47$). The proximal epiphysis breadth index (proximal maximum breadth/articular length) of VB5 (34·9) is above the Hamman–Todd sample mean (32·2 ± 2·3, $n=47$) and closer to the Neandertal mean (34·7 ± 2·8, $n=6$), but again, the differences between the two samples are not significant ($P>0{\cdot}05$).

Stature estimation

The stature of one individual can be estimated using formulae derived from modern humans of known stature and the length of the metatarsal bones. Since VB4 is a juvenile individual and lacks the head, we

Table 18 Dimensions (mm) and comparisons of the Valdegoba phalanx (VB3)

	Midshaft height ($x \pm 1$ S.D.)	Distal breadth ($x \pm 1$ S.D.)	Distal height ($x \pm 1$ S.D.)	Head index ($x \pm 1$ S.D.)
VB3	[5·6]	11·0	6·6	60
Neandertals				
2nd ray	6·4 ± 0·9 (n=7)	12·1 ± 1·7 (n=6)	7·5 ± 0·9 (n=7)	62·6 ± 3·5 (n=6)
3rd ray	7·0 ± 0·7 (n=6)	13·3 ± 1·5 (n=5)	8·3 ± 0·8 (n=5)	62·2 ± 2·1 (n=5)
Hamman–Todd (n=99)				
2nd ray	6·5 ± 0·7	11·4 ± 1·0	8·0 ± 0·7	69·9 ± 3·6
3rd ray	7·1 ± 0·8	12·1 ± 1·1	8·3 ± 0·8	68·9 ± 3·1

Variable definitions as in Musgrave (1970).

Head index=(distal breadth/distal height) × 100.

Neandertal sample: Krapina 204·5, 204·6, 204·7, 204·8, Kebara 2 and Tabun 1 (by the authors); Shanidar 3, 4 and 6 from Trinkaus (1983).

have used only VB5 to estimate the stature. We are aware of the problems of applying formulae derived from modern human samples to estimate the stature of fossil hominids.

Byers *et al.* (1989) provide a regression formula to estimate stature based on the metatarsal bones and derived from two modern human samples from the Terry collection (Euroamericans, n=106 and Afroamericans, n=16). In their work, the articular length of the metatarsals was used instead of maximum length in order to avoid the problems associated with development of the proximal styloid process in this bone. The correlation coefficients between articular length of the fifth metatarsal and stature range between r=0·60 and r=0·78 depending on the different sex or race (Byers *et al.*, 1989).

Since the sex and racial affinities of the VB5 individual is indeterminate, the combined regression formulae of Byers *et al.* (1989) for both Euroamericans and Afroamericans as well as pooled-sex samples were used to estimate stature. Nevertheless, several authors prefer to use the regression formulae derived from European samples, mainly because of the more similar body proportions between Neandertals and modern European populations (Vandermeersch & Trinkaus, 1995; Holliday, 1997). Using the three formulae derived from the multiracial pooled-sex sample, the Euroamerican male sample and the Euroamerican female sample, we obtain stature estimations of 164·6 ± 7·6 cm, 169·2 ± 7·2 cm and 162·3 ± 6·3 cm, respectively. A resultant average stature of 165·4 cm may be the best available estimate for the VB5 individual.

This tentative stature estimate falls close to a pooled-sex Neandertal mean stature calculated by us with the individual data reported by several authors (166·0 ± 5·8, n=18; Carretero, 1994), and the means reported by Vandermeersch & Trinkaus (1995) for pooled-sex Western European Neandertals (165·3 ± 5·1, n=9) and Near Eastern Neandertals (167·8 ± 7·3, n=9).

Implications of the Valdegoba hominids for human evolution in Europe during the Pleistocene

Given the relative scarcity of Pleistocene fossilized human remains from the Iberian Peninsula (with the notable exception of the

Table 19 Dimensions (mm) and comparisons of the Valdegoba fourth metatarsal (VB4)

	Side	Maximum length (x ± 1 S.D.)	Articular length (x ± 1 S.D.)	Proximal maximum breadth (x ± 1 S.D.)	Proximal maximum height (x ± 1 S.D.)	Proximal articular breadth (x ± 1 S.D.)	Proximal articular height (x ± 1 S.D.)	Midshaft breadth (x ± 1 S.D.)	Midshaft height (x ± 1 S.D.)
VB-4	Right	(70·6)	—	14·0	19·1	12·8	18·3	8·3	10·2
Neandertals		72·1 ± 4·3 (n=3)	68·9 ± 4·9 (n=9)	15·1 ± 1·5 (n=9)	20·4 ± 1·7 (n=4)	11 (n=1)	19 (n=1)	7·3 ± 0·7 (n=7)	9·2 ± 1·1 (n=7)
Hamman–Todd (n=47)		70·7 ± 5·2	68·9 ± 4·9	13·9 ± 1·3	18·0 ± 1·9	10·7 ± 1·2	16·7 ± 2·2	7·1 ± 1·1	9·6 ± 1·2

*The maximum length has been estimated adding 10 mm (approximately the length of the metatarsal head) to the preserved portion (60·6 mm length).

Neandertal sample: Krapina 248·1, Krapina 248·2, Krapina 248·3 and Tabun 1 (own data); La Ferrassie 1, 2, and Kiik-Koba (Heim, 1982); Shanidar 1, 4, 6 and 8 (Trinkaus, 1983).

Table 20 Dimensions (mm) and comparison of Valdegoba left fifth metatarsal (VB5)

	Side	Maximum length ($x \pm 1$ S.D.)	Articular length ($x \pm 1$ S.D.)	Proximal maximum breadth ($x \pm 1$ S.D.)	Proximal maximum height ($x \pm 1$ S.D.)	Proximal articular breadth ($x \pm 1$ S.D.)	Proximal articular height ($x \pm 1$ S.D.)	Midshaft breadth ($x \pm 1$ S.D.)	Midshaft height ($x \pm 1$ S.D.)
VB-5	Left	67·9	58·8	21·2	13·8	12·3	11·8	10·5	7·6
Neandertals		74·6 ± 5·4 (n=5)	67·2 ± 2·2 (n=6)	23·4 ± 2·0 (n=7)	16·1 ± 1·1 (n=7)	14·5 ± 1·7 (n=5)	15·0 ± 1·0 (n=7)	9·4 ± 1·7 (n=7)	8·6 ± 1·8 (n=7)
Hamman–Todd (n=47)		70·8 ± 5·4	63·2 ± 4·6	20·3 ± 1·5	14·7 ± 1·4	13·3 ± 1·4	13·4 ± 1·3	11·3 ± 1·4	7·5 ± 1·1

Neandertal sample: Krapina 249·1, Krapina 249·3, Krapina 249·4 and Tabun 1 (own data); La Ferrassie 1 and 2, and Kiik-Koba (Heim, 1982); Vindija 203 from Wolpoff *et al.* (1981); Shanidar 1, 4, 6 and 8 from Trinkaus (1983).

Atapuerca sites), the Valdegoba hominids provide important information bearing on the course of human evolution in Western Europe. The VB1 mandible and dentition provide new data on Neandertal variability and raise questions about retention of archaic characteristics within the Neandertal lineage. Indeed, the well developed alveolar planum seems unmatched among known Upper Pleistocene specimens, and VB1 provides a useful comparison with the large series of pre-Neandertal mandibles from the Middle Pleistocene SH site at Atapuerca. The expression of Neandertal features in these specimens is variable (Rosas, 2001) and comparison with later-in-time mandibles sheds light on the evolutionary process which gave rise to the Neandertals of the Upper Pleistocene.

While no individual morphological trait is likely to show a completely dichotomous expression between Neandertals and early modern humans (but see Schwartz & Tattersall, 2000), studying the pattern of expression of several characteristics in combination will prove more informative in delineating both evolutionary processes and different groups of hominids (Stefan & Trinkaus, 1998*a*,*b*; Rosas, 2001). The strong expression of the alveolar planum represents a retention of an archaic characteristic which is ubiquitous among the SH hominids. Further, the presence of a Tome's root in the lower P_3s is another archaic trait that appears more frequently in earlier populations. In contrast, while the position of the mental foramen under the P4 in VB1 is also characteristic of earlier hominids, the degree of variation among Neandertals in this feature (Trinkaus, 1993), as well as the more posterior position in the Middle Pleistocene SH hominids, suggests that its location in VB1 is a product of individual variation within Neandertals. It does imply, however, that the degree of midfacial prognathism in VB1 was not as developed as in Neandertals generally. The absence of taurodontism in the molars of VB1 also seems to be a product of individual variation for similar reasons. The VB1 specimen does show a degree of anterior tooth expansion similar to that seen among Neandertals. The SH hominids are also characterized by an expanded anterior dentition, and indicate that this feature developed by at least the Middle Pleistocene in Europe (Bermúdez de Castro *et al.*, 1999). Finally, the frontal alignment of the anterior teeth in VB1 does not follow strict taxonomic lines, however, it is similar to numerous other Neandertal dentitions.

In summary, the morphological features in VB1 represent a combination of archaic retentions, individual variation and possible Neandertal-derived characteristics. Comparison with the mandibles from SH, which also vary in their expression of some morphological traits, indicates that the evolutionary process which gave rise to the Neandertals in Western Europe was probably marked by individuals who show varying combinations of different characteristics. Although the derived facial and mandibular characteristics are apparently some of the first to appear within the Neandertal lineage (Arsuaga *et al.*, 1997; Hublin, 1998), Neandertal traits are more difficult to identify in VB1. It would be tempting, on this basis, to attribute this individual to the Middle Pleistocene, given the uncertainties regarding the age of the specimen. However, morphological dating of specimens is fraught with error. It does not consider the importance of individual variation within a population and it produces a circularity in reasoning when trying to understand the evolutionary process. In light of this, the analysis of VB1 points out the importance of studying the causes of variation in different morphological traits to arrive at a sound taxonomic assignment for any one individual. The most parsimonious interpretation is that the Valdegoba 1 individual is a Neandertal.

The VB2 specimen is represented only by a nearly complete set of deciduous teeth. As such, no information from the cranium or postcranial skeleton is available to aid in the identification of the taxonomic affinities of this individual. The analysis of the VB2 infant relies on both metric and morphological comparison with a sample of Neandertals and early modern humans. While a fairly complete set of teeth allows us to study the entire dentition, there has been some disagreement as to whether deciduous teeth are reliable taxonomic discriminators (see Smith, 1878, 1989; Tillier, 1999 for contrasting opinions).

It is difficult to interpret the significance of the smaller dental dimensions in Valdegoba 2. One possibility is that this was a female individual. The low values for all the teeth make this possible. However, sexing subadult specimens even among living modern humans is difficult, and it is unclear whether deciduous dental dimensions are reliable in this regard.

Conflicting scenarios regarding evolutionary changes in deciduous dental dimensions in Pleistocene humans have been proposed. Smith (1978) argued that deciduous teeth show a consistent reduction in size throughout the Pleistocene, from the Lower Paleolithic teeth from Arago to living humans, although reduction to present dimensions was only completed by about 6000 years ago. Further, she argues that, even so, deciduous dental dimensions have not changed dramatically since the early Upper Pleistocene.

Wolpoff (1979, 1999), on the other hand, has argued for an increase in deciduous tooth size throughout the Middle and Upper Pleistocene. He also starts with the Arago sample as the oldest deciduous dental remains in Europe and notes that the Krapina teeth, which date to the very end of the Middle Pleistocene, are larger. This trend continues in the Upper Pleistocene European Neandertals, and Wolpoff suggests a possible selection for larger deciduous tooth dimensions due to an earlier age at weaning in these hominids. The conflicting scenarios presented in these two models require further examination, but in any case, the small size of the Valdegoba 2 teeth stand out as exceptional compared with Neandertals.

Yet another possibility that would explain this small tooth size is that the VB2 infant represents an early modern human and not a Neandertal, despite its clear *in situ* association with a Mousterian tool technology in Western Europe. Throughout the dentition, the VB2 infant shows similarities with early modern human teeth from both the early sites of Skhul and Qafzeh as well as European Upper Paleolithic specimens. The lack of lingual tubercles and weakly developed marginal ridges in the upper canines in VB2 contrasts with the condition seen in Roc de Marsal, and some other Neandertals, and seems more similar to early modern infants. The reduced number of cusps in both the upper and lower first molars and the consistently small size of all the teeth, some of which fall outside the known Neandertal range of variation, is a further point of divergence from Neandertals. Finally, the specific morphology of the dm^1 in VB2 seems closest to the early modern human condition. Thus, both the morphology and metrics indicate closer affinities with early modern humans than Neandertals for the VB2 individual. Nevertheless, given the lack of consensus regarding the taxonomic utility of deciduous teeth, an early modern classification for VB2, and the important implications which would accompany it, must await a more thorough study of Pleistocene deciduous teeth.

Conclusions

The mandibular, dental and postcranial remains from Valdegoba comprise new additions to the growing sample of Paleolithic human remains from the Iberian Peninsula. The VB1 mandibular and dental remains correspond to a 13–14 year old, probably male, individual. Taken as a whole, the morphology seen in the VB1 individual demonstrates both retention of archaic traits, such as the internal symphyseal tori and Tome's root, as well as development of more common Neandertal traits, such as the anterior tooth expansion, frontal disposition of the anterior teeth and external symphyseal morphology. The VB1 specimen provides new information on mandibular and dental morphology and variation in the Neandertal lineage which emerges in the European Middle Pleistocene (Rosas, 1995, 1997), and ends with the last known Neandertal in Western Europe from Zafarraya (Hublin *et al.*, 1995).

The VB2 deciduous dentition was recovered from *in situ* deposits associated with a Mousterian industry and belonged to an individual who was 6–9 months old at the time of death. Several lines of evidence suggest that VB2 has its closest affinities with early modern humans. These include: the morphology and metrics of the upper dm^1, the morphology of the other preserved teeth and the consistently small size of all the teeth compared with Neandertals, some of which fall outside the known Neandertal range of variation. Nevertheless, in light of the current uncertainties in making taxonomic assignments based on the deciduous dentition, an early modern classification for VB2 must await further comparative study of Pleistocene deciduous teeth.

The hand phalanx VB3 displays a relatively broad head, and in this regard is similar to both Neandertals and their European Middle Pleistocene precursors. Although there are no significant differences between Neandertals and modern humans in metatarsal bone dimensions and robusticity, the robusticity index of VB4 is well above the means of both our Neandertal and modern human samples. Stature estimation, based on the VB5 metatarsal, provides a value which is similar to the estimated mean stature among Neandertals.

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