13 ~~Atapuerca~~ 'The Ancients'

Three new human skulls from the Sima de los Huesos Middle Pleistocene site in Sierra de Atapuerca, Spain

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THREE important fossil hominids were found in July 1992 in the Middle Pleistocene cave site called Sima de los Huesos (Sierra de Atapuerca, Burgos, Northern Spain). One is a complete calvaria (cranium 4), the second a virtually complete cranium (cranium 5), the third represents a more fragmentary cranium of an immature individual (cranium 6). There is a large difference in size between the two adult specimens (for example endocranial volume 1,125 cm^3 versus 1,390 cm^3). The Atapuerca human remains are dated to >300,000 years. The Atapuerca cranial sample fits within the 'archaic *Homo sapiens*' group, but is well differentiated from the Asian *Homo erectus* group. The extensive Atapuerca human collection is the most complete sample of Middle Pleistocene humans yet discovered from one site, and appears to document an early stage in Neanderthal evolution.

The skulls (Fig. 1) were discovered in a bone-bearing breccia in the Sima de los Huesos cave site (Fig. 2). The Sima de los Huesos human sample so far recovered amounts to more than 700 fossils, belonging to at least 24 individuals (based on dental evidence, refs 1, 2 and J. M. Bermúdez de Castro, personal communication). The human fossils are mixed and without anatomical connections, but all skeletal elements are represented in the sample, without bias[3]. The absence of herbivore bones or stone implements in the site indicates the human fossils do not derive from a camp site or carnivore activity. The human bone accumulation, therefore could be anthropic or catastrophic[3]. The faunal composition of the breccia is mainly *Ursus deningeri*[4] (more than 250 individuals). There are also a few fossils of carnivores: *Panthera leo*, *Panthera* cf. *gombaszoegensis*, *Lynx pardina spelaea*, *Vulpes vulpes*, Canidae sp., Mustelidae sp.[5,6]. A speleothem overlying the human fossils has been dated to >300,000 years (300 kyr) (J. Bischoff, personal communication) (Fig. 2).

The cranial capacities of the Atapuerca adult specimens have been measured three times using millet seed, giving a figure of 1,390 cm^3 ($\pm$10 cm^3) for cranium 4 and 1,125 cm^3 ($\pm$10 cm^3) for cranium 5. Thus, although cranium 5 aligns with the smallest European or African Middle Pleistocene specimens (for example Steinheim, Ndutu), the cranial capacity of cranium 4 is one of the largest in the Middle Pleistocene record. On the basis of metrical comparisons with the two adult individuals, the cranial capacity of the immature individual is estimated at around 1,100 cm^3. The vault is high when observed in norma lateralis in cranium 4 (height/length index = 65.2) and cranium 5 (height/length index = 67.6; Neanderthal range = 60.0–66.6, $N = 10$; refs 7–10). The maximum cranial breadth of cranium 4 (164 mm) is much greater than in cranium 5 (145 mm) and is among the largest known in the human fossil record.

In the Atapuerca sample the occipital torus is straight in inferior and posterior views, fading towards the asterion. There is always a well defined rough and/or porous surface above the occipital torus, more or less flat but never depressed (which seems to foreshadow the suprainiac fossa found in Swanscombe[1] or in Neanderthals). In crania 4, 5 and 6, the opisthocranion lies at the upper margin of this suprainiac surface, but the cranial length is only slightly less at the nuchal torus. The lambda-inion-opisthion angles of cranium 4 (112.9°) and cranium 5 (116.5°) fall between the values of Petralona and Swanscombe[11] (Neanderthal range = 122.5°–129°, $N = 4$; ref. 8). The ratio (lambda-inion arc/lambda-opisthion arc) × 100 is 61.6 in cranium 4 and 56.5 in cranium 5 (Neanderthal range = 54.9–66.9, $N = 8$; refs 7–9).

The mastoid processes are big and projecting in the Atapuerca adult individuals. The juvenile individuals exhibit small mastoids, which project less than the occipitomastoid region, as is common in Neanderthals (both adults and juveniles) and modern human immatures, suggesting retention of the immature condition in Neanderthals.

The morphology of the supraorbital torus is very consistent in the sample: continuity of the lateral, orbital and glabellar segments and inflated glabellar region without a deep midline depression. A similar pattern can be observed in Bilzingsleben, Steinheim and Petralona, but not in Arago 21 (which resembles Broken Hill and Bodo). The supraorbital torus is well developed in all the specimens of the Atapuerca sample[12], including juveniles. Thickness at the midorbital and lateral points of the supraorbital torus[13] in cranium 5 (14.1 mm, 14.6 mm) is greater than in cranium 4 (12 mm, 11.5 mm) (Neanderthal ranges: 8.7–13.9 mm, 9.5–13.3 mm, $N = 9$). The nasal bones are projecting and the nasal root is at the same level as the glabella, as in Bilzingsleben and Neanderthals (but unlike Petralona and Steinheim). The nasiofrontal angle[14] is low (137°).

The total facial prognathism is remarkable in cranium 5. The prosthion angle of the upper facial triangle[14] (60.5°) is close to Petralona (60.2°; ref. 15) and to the lower limit of the Neanderthal range (59°–72.4°, $N = 7$; refs 7–10). The nasoalveolar clivus is inclined and the sagittal and transversal facial angles at subspinale indicate a marked midfacial projection, a derived trait shared with Neanderthals (zygomaxillary angle[14] = 111.2°; Neanderthal range = 105°–125°, $N = 8$; ref. 7). The ratio interorbital breadth/bifrontal breadth is high in cranium 4 (32.6) and cranium 5 (29.5) (Petralona = 28.7, ref. 15; Neanderthal range = 20.1–29.9, $N = 13$; ref. 7). The orbits are small (left side: breadth = 41.2 mm, height = 33 mm) and mesoconchic. Bimaxillary breadth (118.4 mm), cheek height (37 mm) and nasal aperture breadth (38 mm) are very large in absolute terms and even more in relative terms. The inferior nasal rim morphology

BOX 1 Main traits of the Atapuerca cranial sample

Invariant features. Maximum cranial breadth at the supramastoid crest ($N = 5$); opisthocranion ≠ inion ($N = 3$); occipital squama ≫ nuchal plane ($N = 4$); rough and/or porous suprainiac surface ($N = 5$); occipital torus reduced laterally ($N = 11$); high and rounded temporal squama ($N = 5$); absence of anterior mastoid tubercle ($N = 9$); developed postglenoid process ($N = 7$); tympanic highly angled to petrous ($N = 6$); absence of a fissure separating mastoid from tympanic ($N = 8$); not robust tympanic region ($N = 6$); ossified styloid process ($N = 8$); double arched and fused supraorbital torus ($N = 5$).

Variable features. Parietal wall sides convergent towards the top in cranium 4 and parallel in crania 5 and 6; parietal angular torus marked in cranium 4, weak in cranium 5, and absent in cranium 6 and two more specimens; sphenoid contributes to the medial wall of the glenoid fossa in crania 4, 6 and three more specimens and does not contribute in cranium 5 and two more specimens; big and projecting mastoid processes in adult individuals ($N = 5$), but small mastoids in juvenile individuals ($N = 3$); external occipital crest between superior and inferior nuchal lines present in cranium 4 and absent in crania 5, 6 and two more specimens; canine fossa absent in crania 5 and 6 and present in AT-404; zygomaxillary inferior margin high and broadly curving in cranium 5 and high but straight and more oblique in cranium 6 and AT-404.

Traits preserved in few specimens. Vertex not coincident with bregma in cranium 5; slight parietal keeling in crania 4 and 5; frontal keeling slight in cranium 4 and absent in cranium 5; midfacial projection in cranium 5.

is reminiscent of that of Broken Hill. There are no canine fossa in crania 5 and 6 (nor in Petralona and Arago 21). In contrast, a canine fossa is present in Steinheim and the Atapuerca specimen AT-404 (a large fragment of the left side of the face). In cranium 5, the maxillary pneumatization is extensive. The frontal sinuses in the Atapuerca sample are well developed but do not reach the supraorbital notch nor penetrate the frontal squama. Cranium 5 exhibits a high and broadly arching inferior zygomaxillary margin as in Bodo, Petralona, Broken Hill, Arago 21 or Steinheim[16] but there is no maxillary torus (as is clearly seen in Petralona, Arago 21 or Steinheim). The inferior zygomaxillary margin is also high in cranium 6 and AT-404, but it is straight and more oblique than in cranium 5.

Box 1 presents a summary of the morphology of the Atapuerca cranial sample. All appear to exhibit an occipital morphology that anticipates the Neanderthal pattern. The supraorbital torus morphology is Neanderthal-like. There is a clear midfacial projection and an inflated maxilla in cranium 5. Neanderthal

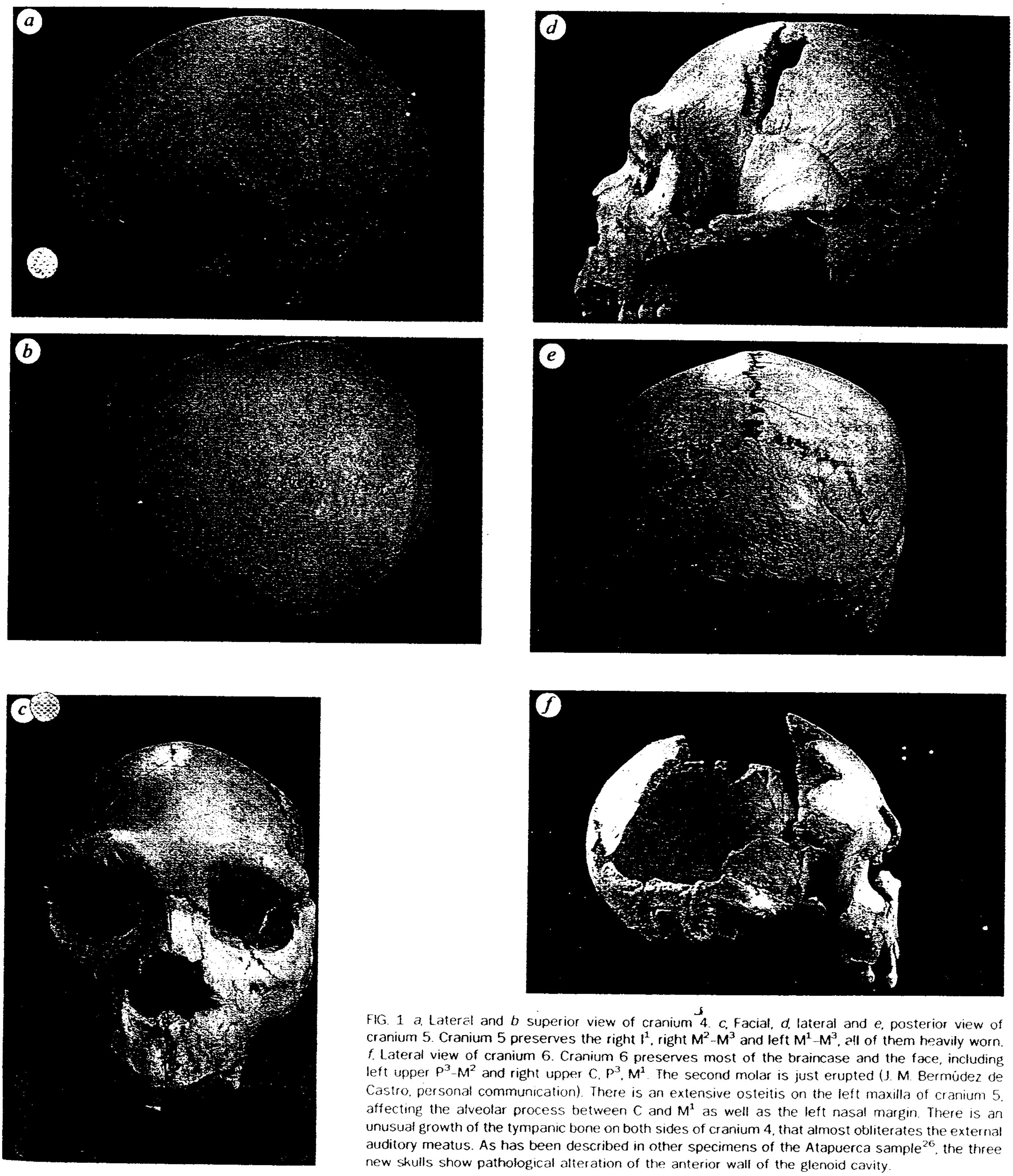

FIG. 1 *a*, Lateral and *b* superior view of cranium 4. *c*, Facial, *d*, lateral and *e*, posterior view of cranium 5. Cranium 5 preserves the right I^1, right M^2-M^3 and left M^1-M^3, all of them heavily worn. *f*, Lateral view of cranium 6. Cranium 6 preserves most of the braincase and the face, including left upper P^3-M^2 and right upper C, P^3, M^1. The second molar is just erupted (J. M. Bermúdez de Castro, personal communication). There is an extensive osteitis on the left maxilla of cranium 5, affecting the alveolar process between C and M^1 as well as the left nasal margin. There is an unusual growth of the tympanic bone on both sides of cranium 4, that almost obliterates the external auditory meatus. As has been described in other specimens of the Atapuerca sample[26], the three new skulls show pathological alteration of the anterior wall of the glenoid cavity.

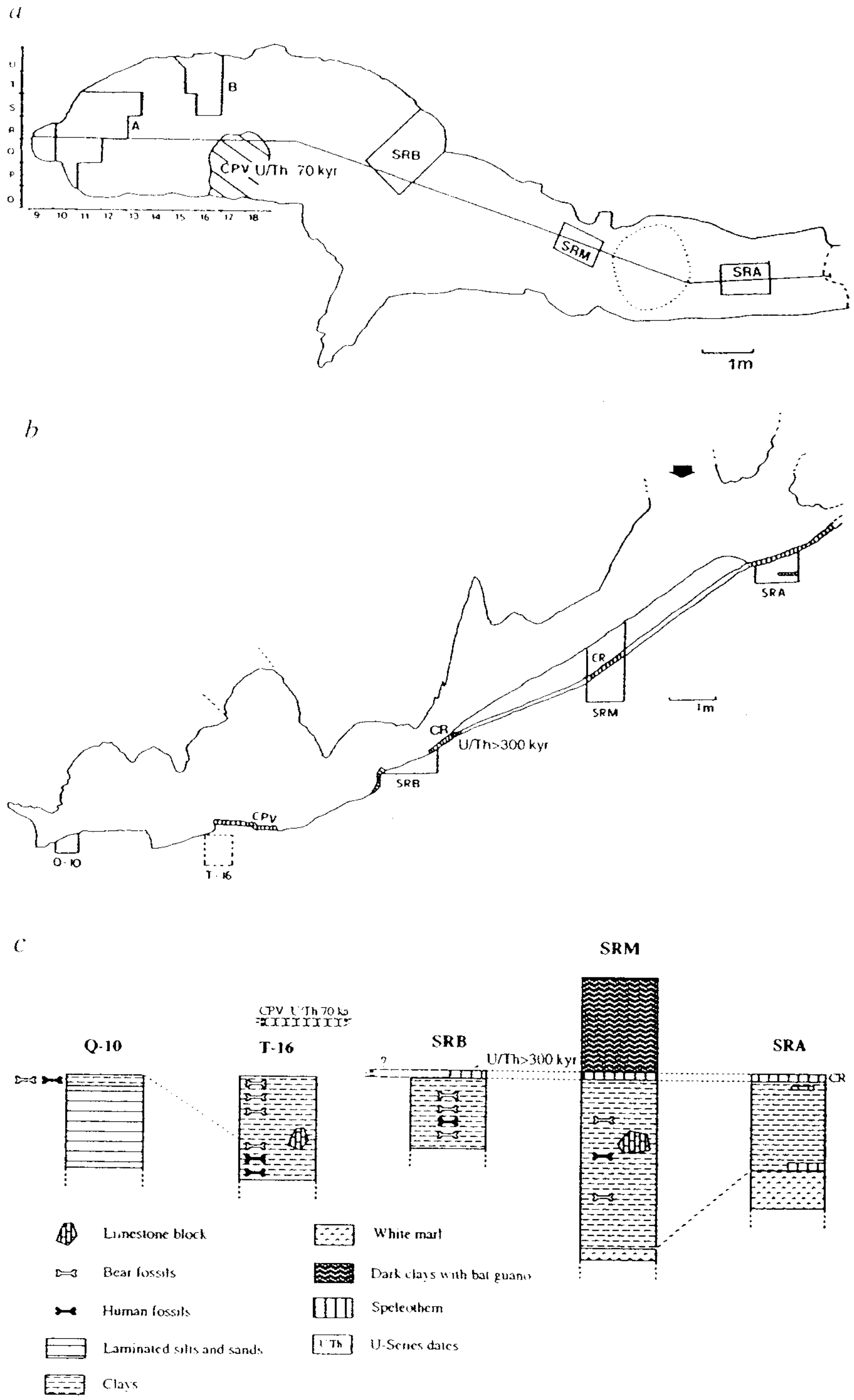

FIG. 2 Map and sections of Sima de los Huesos. *a*, Plan view of main excavation areas. *b*, Projected section along polygonal line in *a*. *c*, Stratigraphy and correlations. The Sima de los Huesos is more than 500 m from the entrance of the Cueva Mayor karst system, although geophysical studies from the surface suggests a nearby ancient entrance, now collapsed and filled (J. Bergamin, personal communication). Access to the site is through a 13 m shaft (arrow in *b*). CR is a continuous stalagmitic floor extending from SRA to SRB, mostly covered by sterile dark clays rich in bat guano. Bear fossils and five human fossils were found in SRM below CR and overlying sterile white marl (*c*). In SRB there is a major accumulation of bear fossils (*Ursus deningeri*), some articulated below CR crust, together with human fossils. Human fossils (including cranium 4, cranium 5 and cranium 6) were found in excavation area B, together with some bear bones (*U. deningeri*) and below a bone breccia containing only carnivore bones. Other human fossils were found in area A (with bear fossils) in a level of plastic clays which overlays sterile laminated silts and sands. Speleothem CPV covers the bone breccia in a limited area (squares R/O-16/18). Uranium series dating has been done on all speleothems exposed to date within the Sima (J. Bischoff, personal communication). A date of 70 kyr was obtained for the CPV speleothem, providing a minimum date. Multiple analyses of speleothem CR above the section at SRB showed full isotopic equilibrium indicating a date of >300 kyr. It is tempting to project this speleothem across to the top of area B, where the skulls were recovered, but whether it pinches out in the interval, or was mechanically removed by earlier exploitation by cavers is not clear at present. The presence of human fossils below CR, however, indicates a minimum age of 300 kyr for the human assemblage. Drawings were provided by A. I. Ortega and Grupo Espeleológico Edelweiss.

apomorphies have also been found in the Atapuerca mandibular sample[17,18]. In the postcranial skeleton there are also many traits shared with Neanderthals, but these could be plesiomorphies[12]. The juvenile specimen cranium 6 shows that the morphological pattern of the Atapuerca sample arises early in ontogeny, with the exception of the development of the mastoid processes and the facial prognathism. Apart from the Neanderthal apomorphies, the Atapuerca cranial sample displays a set of traits which are polymorphic and should therefore be used carefully in phylogenetic reconstruction[19-21]. The Atapuerca cranial sample departs from the condition generally observed in Asian *H. erectus*[22-25] in several traits: more elevated cranial vault, separation of vertex from bregma, doble arched supraorbital torus, less angulated occipital bone with opisthocranion not coincident with inion, occipital torus reduced laterally, weak tympanic bone, high and rounded temporal squama. Although the lower limit of the cranial capacity range in Atapuerca (and in 'archaic *Homo sapiens*') overlaps the upper limit of the Asian *Homo erectus* sample, there is a substantial overall increase in brain size.

As a whole, Atapuerca and the European Middle Pleistocene cranial sample fit a model of local evolution with increasing frequencies of Neanderthal traits, although a more accurate chronological framework is needed to establish the evolutionary tempo.

Study of the whole Atapuerca cranial, dental, and postcranial sample (which is likely to increase with further excavations) will provide an unprecedented documentation of Middle

74

Pleistocene human variation, and permit more accurate phylogenetic reconstruction through establishment of polarities for many characters. □

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