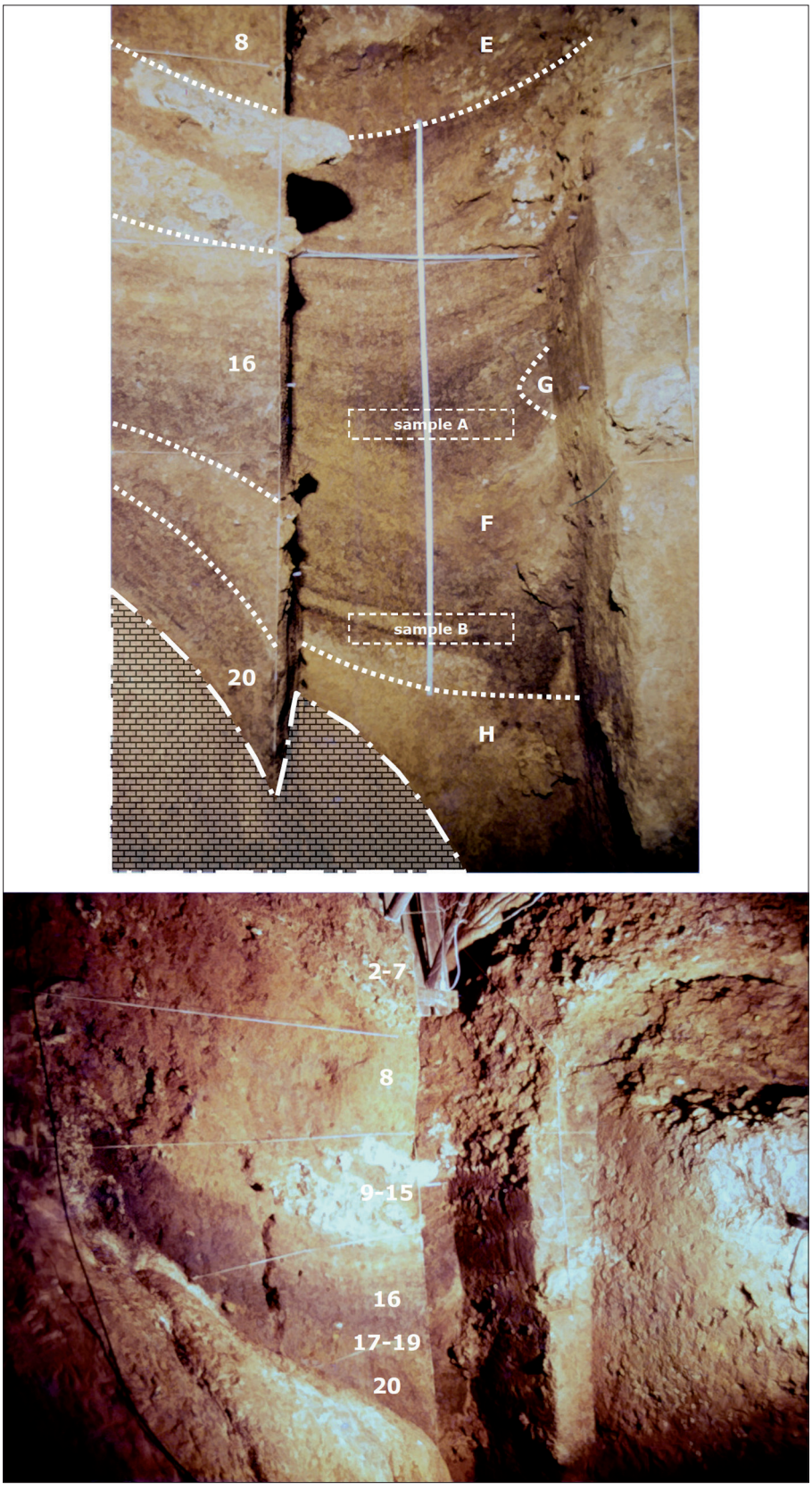

Fig. 5. Roche et al.'s 1986 profiles (digital scans of 15 x 10 cm color prints of pictures filed with the field report at the archaeological heritage archive of the Ministry of Culture in Lisbon; the pictures had been lighted with tungsten lamps and were treated for fading and digital noise, color balance and removal of the color cast by J. Zilhão using tools provided by Corel Paint Shop Pro X3 software). Top: frontal view of the 1986 trench, showing the equivalence between the unit designations given at the time and those used by Roche in the 1970s; the position of the bulk samples of carbonaceous sediment collected in 2003 and radiocarbon dated in Cologne in 2003-05 is indicated. Bottom: oblique view over the face of the 1973 profile and the trench excavated into it in 1986, labeled with the level designations used in 1973.

Abb. 5. *Profile aus Roche et al. 1986 (digital abgetastet aus 15x10 cm-Farbabzügen von Bildern, aus dem Grabungsbericht, der im Archiv des Kulturministeriums in Lissabon hinterlegt ist; die Bilder wurden mit Wolframlampen beleuchtet und von J. Zilhão mit Hilfe von Corel Paint Shop Pro X3 nachbearbeitet). Oben: Vorderansicht des Schnitts aus 1986 unter Zuordnung der damaligen Schichtbezeichnungen von Roche; die Position der Holzkohle führenden Sedimentproben, die 2003 entnommen und in Köln 2003-05 datiert wurden, ist angegeben. Unten: Blick über die Außenfläche des Profils von 1973 sowie den 1986 durchgeführten Schnitt; die Schichtbezeichnungen von 1973 wurden eingetragen.*

bone tool from the site's basal Mousterian by U-series using the Diffusion/Adsorption (D/A) approach advocated by Millard & Hedges (1996); (d) examination of the unpublished field reports concerning Roche's work at the site filed at the archaeological heritage archive of the Ministry of Culture in Lisbon; and (e) cross-checking of the information contained in those reports with Veiga Ferreira's field documents, namely his excavation diary, as reproduced in Cardoso et al. (2002) and Cardoso (2006).

In the following, we present our results, and discuss their implications. In brief, we conclude that (1)

the Mousterian sequence of Gruta Nova is of "normal" Mousterian age and its basal levels, unquestionably in situ, contained important fire features, (2) carbon of Upper Palaeolithic (or more recent) age is present in the remnant deposits from the back part of the cave excavated and profiled in 1971-73 and 1986, and (3) the association of the "young" results obtained for these deposits with the Mousterian levels excavated by the Geological Survey of Portugal in 1962 is based on an assumption of lateral stratigraphic continuity that examination of the field documents fails to support.

The Hanover date

Details concerning the Hanover result first mentioned by Veiga Ferreira (1984) were found in the archive of the Cologne Radiocarbon Laboratory, to which the sample was originally submitted in January 1963, alongside material from the Mesolithic shell-midden of Cabeço da Amoreira. The samples were delivered by Vera Leisner, and the associated submission information was sent a month later accompanied by a letter dated February 11, 1963 and signed by the director of the Geological Survey, F. Moitinho de Almeida. The Gruta Nova sample received the Lab Code KN-199, and the corresponding submission form and chemical processing records provide information on its composition, size and provenience. It consisted of a tin box containing 60 g of middle sized wood charcoal and burnt bone fragments, along with what the laboratory called *grus* (i.e. tiny, mm-size particles). The sample was apparently submitted without any post-collection sieving, sorting or other form of physical pretreatment, and provenanced to an ash-, charcoal- and bone-yielding breccia located at a depth of some ten meters, as measured from the ground surface above the cave.

Eventually, the sample was measured not in Cologne but in Hanover, where it arrived April 4, 1966 (Manfred Frechen, personal communication, e-mail message to J. Zilhão dated February 26, 2003). The Hanover submission documents reproduce the information as recorded in the Cologne forms, with no additional details except for the result obtained (22 350 ± 990 ^{14}C BP) and the associated Lab Code (Hv-1350). This result, as well as the date when the information was received (June 7, 1967), was added to the Cologne filing card, but we have no information on when exactly it was then forwarded to the Geological Survey in Portugal. All we know is that Veiga Ferreira reacted in writing to the result, as the translated excerpt of a letter to that effect is quoted by Hermanfrid Schubart, from the Madrid delegation of the *Deutsches Archäologisches Institut* (German Archaeological Institute), in subsequent correspondence on this matter, dated November 26, 1971, whereby Schubart conveys Veiga Ferreira's reaction to the Cologne laboratory. According to that excerpt, Veiga Ferreira sustained that a major error must have been made, as (a) the sample came from the base of a Mousterian sequence with seven different levels and should therefore date in excess of 35 000 years and (b) the results obtained for other sites in the same sample batch [presumably, Cabeço da Amoreira] were in agreement with the archaeological dating *[Bei der Probe von Columbeira muss ein grosser Irrtum unterlaufen sein, denn dort gibt es nur 7 Schichten mit "Musteriense ibérico" mit Würmfauna und dem Zahn eines Neanderthalers. Die Datierung müsste mehr als 35.000 Jahre ergeben, da die Proben zusammen mit den entsprechenden Geräteformen und Knochen geborgen wurden. Was mag mit der Probe geschehen sein? Die Ergebnisse der anderen Proben decken sich mit den archäologischen Datierungen der Plätze].*

Why Veiga Ferreira later used the Hanover result without citing the actually measured value and Lab Code and as indicating an age for level 8 of around 25 000 instead of around 22 000 years remains unclear. One possibility is that he decided to round out the numerical result and, in order to make it more palatable, to do so beyond the older limit of the two sigma probability interval. More likely, it may simply be that he was writing from memory, without the actual documents at hand, inadvertently erring in the process — understandably, as the paper's publication date is 1984, more than a decade after the exchange quoted in Schubart's letter. That such may have been the case is further suggested by three other important factual errors made by Veiga Ferreira in that 1984 paper:

(a) firstly, in a footnote, Veiga Ferreira sources his acquaintance with the Hanover date to a "letter from Schubart dated January 19, 1972 communicating the result of Prof. Schwabedissen's analysis of the Gruta Nova;" as Schubart's letter to Schwabedissen conveying Veiga Ferreira's reaction to that result is from November 26, 1971, it follows that Veiga Ferreira had been informed for at least a few months before the date given in this footnote;

(b) secondly, in the body of the text, Hermann Schwabedissen's academic affiliation is wrongly given as Hanover instead of Cologne, where he was Chair of Pre- and Proto-History from 1957 and until his retirement in 1976 (http://dendro.phil-fak.uni-koeln.de/6548.html),

(c) thirdly, the Neanderthal tooth recovered at the site is said to have come from the stalagmitic islet present in sectors 4-5 of the excavation, as indeed is also indicated in one the two versions of the field profile drawn by Veiga Ferreira at the end of the 1962 field season that we found in his personal archive (Fig. 2A); however, the excavation diary records the discovery as having taken place some two meters farther out — "between sector 2 and 3, against the wall and on top of a stone from the breccia that are [sic] loose and were [sic] placed there on purpose a human milk tooth was found" (Cardoso et al. 2002: 15) *[Entre o sector 2 e 3 do lado da parede e sobre uma pedra da*

brecha que estão soltas e foram colocadas ali de propósito foi encontrado um dente de leite humano]; the tooth was subsequently identified as the germ of a lower permanent molar (Ferembach 1964-65) but, more to the point, this diary entry is from August 27, and it is not until the afternoon of the following day that mention is made of sector 4 being under excavation, and not until August 30 that a complete profile is said to have been prepared for description and recording in that sector.

Whatever the reason underlying Veiga Ferreira's (1984) mis-presentation of the Hanover result, there can be no doubt nowadays that he was quite correct in rejecting it in his 1972 letter and quite wrong in accepting it for publication twelve years later. The Lagar Velho child burial making it clear that a modern human-associated Gravettian existed in central Portugal by ~24.9 ka ^{14}C BP (Zilhão & Trinkaus 2002), the KN-199/Hv-1350 result of ~22.4 ka ^{14}C BP for the Neanderthal-associated basal Mousterian of Gruta Nova is unquestionably an underestimation of its true age. But what caused the error?

As adequate pre-treatment techniques for bone samples had not yet been developed in the 1960s, one might speculate that the rejuvenation was caused by the mixed composition of the sample. However, according to the Hanover laboratory records, the Hv-1350 result was obtained on pure charcoal. This fact indicates that, prior to forwarding it for measurement, the Cologne laboratory had removed the bone component present in the field sample. Thus, Hanover would have been able to apply to the material received from Cologne the standard chemical pretreatment for charcoal (i.e. ABA or successive Acid-Base-Acid washings). This reconstruction of the events is supported by the δ^{13}C value of -25.6‰ associated with the Hanover date, which is a typical value for wood charcoal.

At the time, ages in excess of 40 ka ^{14}C BP were being obtained on such kinds of samples by many laboratories, so the explanation for the rejuvenated Gruta Nova result cannot be of a general nature, for instance technical shortcomings in the pretreatment or measurement procedures then current. Physical contamination of the sample with modern charcoal (e.g. introduced into the Mousterian deposits by undetected small mammal burrowing) is a possibility. However, not only did the sample come from the base of a sequence entirely of Mousterian age but this sequence was capped by a continuous stalagmitic crust. Therefore, although conceivable, the physical contamination hypothesis is weakly supported.

Site-specific chemistry issues may also have been in operation at Gruta Nova (e.g. the percolation of carbonates at the time of formation of the thick stalagmitic crust that seals the sequence). At first glance, the magnitude of the error makes it unlikely that such processes suffice to explain the result, but rejuvenations of the same magnitude affect the dates obtained for small charcoal samples from another Portuguese site, the Gruta da Oliveira (Almonda karstic system, Torres Novas). As at Gruta Nova, this site's Mousterian sequence is sealed under a continuous stalagmitic crust but the recently obtained AMS ^{14}C dates on charcoal from levels 12-14 form two disparate age clusters: two results from Gröningen and Oxford obtained on small samples yielded results in the 25-30 ka ^{14}C BP range, while three larger samples dated at the Beta Laboratory and at Gröningen yielded results ≥40 ka ^{14}C BP, i.e. within chronostratigraphic expectations (Angelucci & Zilhão 2009: Table I). In particular circumstances, the standard ABA pretreatment is insufficient to completely remove contaminants, as recently shown for the Italian site of Fumane (Higham et al. 2009). Therein must lie the explanation for the Oliveira anomalies as well as, conceivably, for the Gruta Nova Hanover result, even if the dated sample was in this latter case quite large.

Laboratory specific problems, either random or systematic (e.g. in sample preparation, or in β-radiation counting), would be the remaining option. Although we have no reason to assume such technical or chemical problems for the Hanover dates in general, they do appear to exist for some specific results obtained by this laboratory in the 1960s. For example, charcoal samples from Hungarian loess deposits gave ages of 25-30 ka ^{14}C BP whereas the true age of the sediments, established in the late 1990s by OSL, actually falls in the 60-70 ka calBP range (Manfred Frechen, personal communication, e-mail message to J. Zilhão dated February 27, 2003; Frechen et al. 1997; Novothny et al. 2002).

The Gif dates

As mentioned above, there are two Gif dates for the Gruta Nova: 26 400 ± 750 ^{14}C BP (Gif-2703) for level 16 and 28 900 ± 950 ^{14}C BP (Gif-2704) for level 20 (Fig. 3). From the information contained in the archive of the Gif laboratory we know that the samples were collected on November 16, 1972 and submitted alongside a letter signed by Roche dated December 27 of the same year, while the results were recorded on the dating forms on September 26 and September 28, 1973 (Michel Fontugne, personal communication, e-mail message to J. Zilhão dated December 17, 2002). Although the material dated at Gif was later described as "carbonaceous earth" (Delibrias et al. 1986), the laboratory forms identify the corresponding samples as "wood charcoal." The forms also record other important details, namely that the samples consisted of humid sediments (560 g from level 20 and 300 g from level 16) and that this material was treated according to the standard ABA protocol.

Considering that the amount of purified carbon necessary to fill the gas proportional counters in use at the time was in the order of a few grams, the recorded weight on combustion (130 g for one sample and 170 g for the other) indicates that the field samples must

have been rich in micro-sized charcoal particles indeed. However, these amounts also indicate that the combusted material cannot have been pure charcoal because the latter contains ~50% carbon, whereas the weights of the combusted samples, as given above, indicate that the samples would have contained an order of magnitude less of it.

Given the nature of the samples, this information confirms that the cautionary note associated with the publication of the results by the dating laboratory — that they should be treated as minimum ages only — was entirely justified. Although significantly older than the Hanover date (possibly due to more effective chemical pretreatment procedures yielding dates closer to the true age of the levels), the Gif results could still have been affected by the presence of residual contaminants in the combusted material.

The new Cologne results

In order to test the inferences derived from the nature of the Gif samples, we requested and obtained permission to resample the extant profile, a task that we carried out on August 1, 2003. Two samples of ~2 kg of humid sediments each were collected, one from deposits equivalent to Roche's level 16 (sample A) and the other from deposits equivalent to his level 20 (sample B), both from the face of the 1986 trench that had cut back Roche's profile over an extension of about 1 m in the exact area that he had originally sampled (Figs. 4C & 5). The new samples were submitted to the Cologne laboratory in October 2003, and were pretreated with quite the same techniques used at Gif back in the 1970s — application of the ABA protocol to the bulk sediment submitted, and age measurement via β-radiation counting. Results were obtained two years later (the laboratory certificates were signed August 22, 2005), and were given as 18 000 ± 185 ^{14}C BP for sample A and 14 800 ± 120 ^{14}C BP for sample B. The δ^{13}C value was measured for sample A only and, at -25.47‰, was within the range to be expected for wood charcoal (Fig. 3).

The Cologne results show that carbon of Upper Palaeolithic (or more recent) age indeed exists in the deposits profiled by Roche. As such, those results are not consistent with the hypothesis that the Hanover and Gif dates simply reflect residual contamination of Mousterian charcoal by younger carbon percolating through the sediments from above. In fact, given the exponential decay of radiocarbon, such a hypothesis carries for the Cologne dates the implication that the putative "contaminant" would in fact be the predominant sample component (or at least a greatly abundant one). For instance, for a sample with a real age of 35 000 years to yield the radiocarbon age of about 15 000 years obtained for sample B, the weight of the younger component would have to be of 52% if that component were of early Holocene age (10 000 years old), and of 27% if it were of mid-Holocene age (5000 years old).

Such levels of contamination are unrealistic, but could the reverse hypothesis hold? Put another way, could it be that the formation of levels 16 and 20 dated indeed to the Tardiglacial, in which case the results obtained for them at both Gif and Cologne would be affected by the presence not of younger but of significant, albeit variable amounts of older carbon? Given that the Cologne results came out in inverted stratigraphic order, the hypothesis that the sampled deposits contain material in secondary position must indeed be entertained. In such a scenario, the black lenses rich in micro-charcoal particles could be a mix of material that (a) for the most part, derived from the erosion of the in situ Mousterian deposits excavated closer to the original entrance in 1962 and (b) to a lesser extent, consisted of environmental charcoal introduced around the time of redeposition. For instance, under a model of mixed sample composition and assuming that the displacement occurred 10 000 years ago, the Gif "age" of ~29 000 years for level 20 would be obtained if 37% of the sample was 10 000 year old carbon and the remaining 63% was 35 000 year old charcoal derived from the adjacent deposits of true Mousterian age. If such Mousterian charcoal was even older (e.g. 45 000 years old), the values for the inherited component and for the environmental carbon introduced at the time of redeposition would be of, respectively, 77% and 23%.

Clarification of these twin issues — the true age of the Gruta Nova Mousterian and the relation of the deposits excavated in 1962 with those extant at the back of the cave that were sampled in 1972 and 2003 — could come from the AMS dating of samples from the site's fauna, as the direct ^{14}C measurement of a single bone would circumvent the problems inherent to the potentially mixed carbon composition of bulk samples. Raposo & Cardoso (1998), however, reported that all bone samples from Veiga Ferreira's excavation that they submitted for AMS radiocarbon dating failed due to lack of collagen. This failure left unanswered the question of whether the samples were too old for the method or whether poor collagen preservation due to site-specific chemistry issues precluded the application of radiocarbon dating to the bones from the Gruta Nova. Additional U-series dating work was therefore the only path that remained open to further our knowledge of the chronology and stratigraphy of the site, and we thus turned to this technique.

The U-series age of a bone tool from level 8

In order to make sure that any results would be meaningfully and unambiguously related to the Mousterian occupation of the cave, we selected for this purpose the best of the small number of bone tools described by Barandiarán & Veiga Ferreira (1971: Fig. 3) and Veiga Ferreira (1984: Fig. 2). The object in question, classified by these authors as a "trihedral pick," is a thick diaphyseal fragment of a

rhinoceros tibia (*Dicerorhinus hemitoechus*), beveled by flaking to prepare a platform from whose periphery several removals were struck in order to sculpt the opposite side into a robust point (Fig. 6). All the breakage planes correspond to green bone fractures, and the scars left by preparation and retouch were also clearly

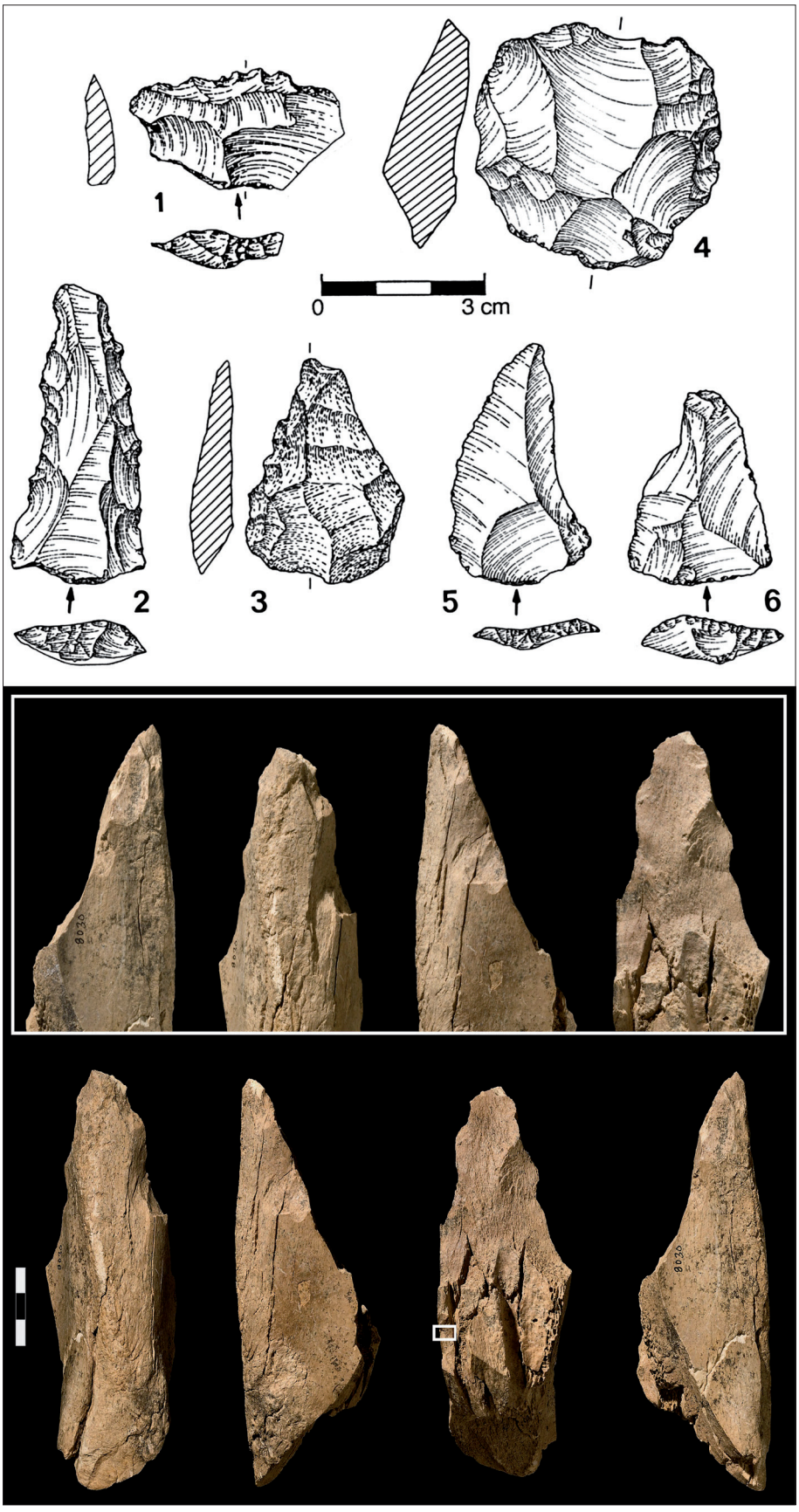

Fig. 6. Artefacts from level 8 of the 1962 excavations. Top: lithic artefacts (1-3: denticulated items; 4: core; 5-6: Levallois flakes; all flint, except no. 3, which is quartzite; reproduced from Cardoso 2006). Bottom: the U-series-dated bone tool, a robust trihedral point obtained by percussion flaking of a rhinoceros diaphyseal blank (four views of the whole object with indication of the area sampled for dating, and close-ups of the tip detailing the manner of its retouch; photos by José Paulo Ruas).

Abb. 6. *Artefakte aus Schicht 8 der Ausgrabungen von 1962. Oben: Steinartefakte (1-3: gezähnte Stücke; 4: Kern; 5-6: Levallois-Abschläge; alle aus Silex außer Nr. 3, aus Quarzit; aus Cardoso 2006). Unten: Durch U-Seriendatierung untersuchtes Knochenwerkzeug, eine robuste, durch Bearbeitung eines Diaphysenfragmentes eines Nashornknochens gewonnene dreieckige Spitze (vier Gesamtansichten mit Angabe der für die Datierung beprobten Fläche; Nahaufnahmen der Spitze, welche die Retuschiertechnik veranschaulichen; Fotos: José Paulo Ruas).*

made when the bone was fresh. According to Barandiarán & Veiga Ferreira, this item was recovered towards the bottom of sector 6 of the excavation, and such is indeed the only provenience indication given in the associated label. This information suggests that the tool came from either level 7 (the "brown soil") or level 8 (the "black earth"), the basal and richest units of the 1962 stratigraphy. In Veiga Ferreira (1984), the tool is specifically assigned to level 8, and this assignation finds corroboration in a September 2 entry to his excavation diary (Cardoso et al. 2002: 18): "Today we finished the excavation of the black earth in [sector] 6 and have delimited the ash feature, which is of oval shape. The material continues to be abundant and bones worked at the tip turned up for the first time" *[Hoje terminámos o corte em 6 da terra negra e delimitámos o cinzeiro que tem a forma oval. O material continua a aparecer em abundância e apareceram os primeiros ossos trabalhados na extremidade].*

Bone is an open system with respect to uranium and, therefore, the calculation of a U-series date from measured U-series isotopes requires a model of uranium uptake (or loss). We use the Diffusion-Adsorption (D-A) model (Millard & Hedges 1996), which predicts the spatial distributions ('profiles') of uranium and U-series isotopes across a bone section as uranium is taken up by the bone. It predicts that, under constant geochemical conditions, ∪-shaped uranium profiles will develop that gradually flatten over time as the bone equilibrates with the uranium in the groundwater of the burial environment. At equilibrium, the profile is uniform and uranium ceases to be incorporated into the bone. Under constant geochemical conditions, diffusion of uranium from the outer surfaces of the bone into the center leads to a ∪-shaped distribution of apparent dates, with the closed system date (i.e. the U-series date calculated assuming no uptake or loss of uranium) at the surfaces of the bone approximating the true age of the sample, and with underestimated apparent dates towards the centre. For bones where the profiles indicate uranium uptake has proceeded under relatively constant conditions, the D-A model can thus be used to calculate an open system date (Pike et al. 2002, 2004, 2005).

In order to assess the age of the Gruta Nova bone tool, we used laser ablation multicollector plasma mass spectrometry (LA-ICP-MS). A fragment of bone, approximately 8 x 4 x 3 mm, was removed from a pre-existing break using a diamond disc, ultrasonically cleaned, dried overnight in an oven, mounted in putty

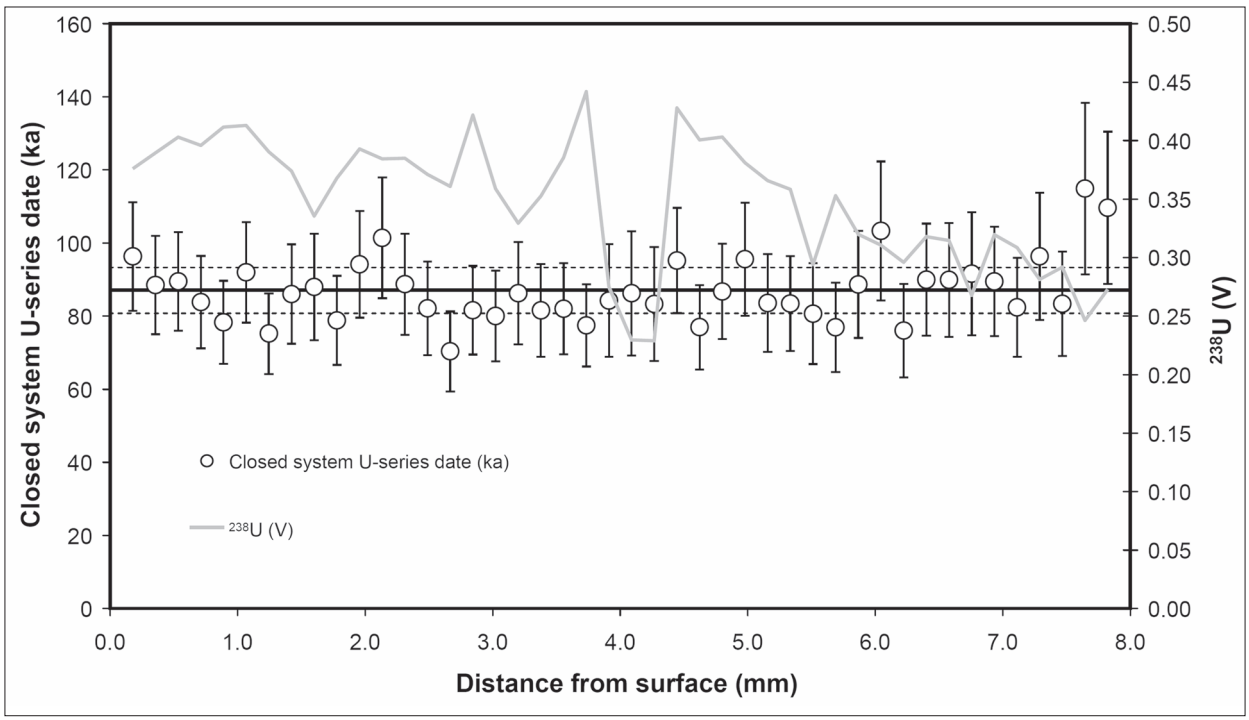

Fig. 7. U-series profile of a partial transverse section of the level 8 bone tool from the outer surface (0 mm) to 8 mm towards the center of the bone. The ^{238}U beam voltage is used as a proxy for U concentration, and is suggestive of a diffusive gradient as predicted by the D/A model. The homogeneous U-series dates (calculated as closed system dates) suggest U uptake has ceased, and the weighted average of 87.1 ± 6.3 ka gives our best age estimate for the tool. For all points, $^{230}Th/^{232}Th$ activity is >300, indicating insignificant detrital contamination. Errors are at one sigma.

Abb. 7. *U-Serien Profil eines Teilquerschnitts des aus Schicht 8 gefundenen Knochenwerkzeugs, von 0 mm an der Außenfläche bis auf 8 mm zur Knochenmitte hin. Die ^{238}U-Strahlstromspannung, die stellvertretend für die U-Konzentration verwendet wird, legt einen sich mit der D/A-Modellvorhersage deckenden Diffusionsgradient nahe. Die Gleichmäßigkeit der U-Serien Daten (als Daten eines geschlossenen Systems berechnet), legt nahe, dass die U-Aufnahme aufgehört hat, wobei der gewichtete Durchschnitt 87.1 ± 6.3 ka unseren besten Schätzwert für das Alter des Werkzeugs ergibt. Dass die $^{230}Th/^{232}Th$-Aktivität an allen Punkten >300 ist, lässt eine Kontaminierung durch Detritus unerheblich erscheinen. Standardabweichung: ein Sigma.*

on a Teflon disc and placed in the laser cell. U-series isotopes were measured on a Finnigan Neptune multi-collector ICP-MS with a 193 nm ArF Excimer laser. The laser spot size was 90 µm, and the sample traversed at 0.5 mm/min with a repetition rate of 20 Hz to ablate a track from the outer surface of the bone section. Bone sections with isotopes previously measured using TIMS were used as calibration standards.

The measured profiles are shown in Figure 7. The profiles are incomplete and only represent a small fraction of the total section of the bone, but it was considered too destructive to remove a complete section of this rare type of artefact. For an incomplete section, the distribution of uranium and uranium-series isotopes can be difficult to interpret, but we can make a number of observations that help constrain the age of the artefact. The beam voltage at mass 238 (as a proxy for ^{238}U) shows higher values towards the surface of the artefact. This may be a diffusive gradient, as predicted by the D/A model (Millard & Hedges 1996), and would reach a minimum in the center of the bone, rising again toward the lower surface. But, equally, this gradient could be a function of surface topography or porosity of the bone, and a complete section would be required to explain this distribution with any certainty. However, the "trough" at about 4 mm is a crack in the bone, and the enhanced concentration of uranium either side is suggestive of a diffusive mechanism being responsible for the uranium gradient.

The key feature of the profile is the homogeneous U-series dates. If the bone had been taking up uranium through diffusion, we would expect apparent U-series dates to be younger towards the center of the tool. But if the bone reaches an equilibrium with uranium in the environment, or ceases to take up uranium after an initial period of uptake, the U-series dates will tend towards the true age at all points in the bone. This looks the case for this sample, and, as such, the weighted mean of the dates across the section represents our best estimate of its age: 87.1 ± 6.3 ka (Fig. 7). This result is consistent with the stratigraphic position of the find — at the base of a thick Mousterian sequence — and confirms that the Hv-1350 bulk charcoal date of ~22.4 ka ^{14}C BP for the same level is indeed anomalous, as discussed above.

Roche's work

According to the account provided in the short description of the site that accompanied the 1972 submission to Gif, Roche first worked at Gruta Nova in 1970, and the archaeological heritage archive of the Portuguese Ministry of Culture contains a report on the 1973 field season that unambiguously describes as "excavation" (*campagnes de fouilles*) the research carried out at the site that year as well as in 1971 and 1972. At the end of this work, a profile with 23 different levels had been obtained (Roche 1973; Roche et al. 1986; Fig. 4A). A drawing of this profile was reproduced in a general work on the prehistory of Portugal (Farinha dos Santos 1972), but the associated descriptions remained unpublished.

How did the 1971-73 excavations relate, spatially, to those carried out in 1962? Veiga Ferreira proceeded through transversal slices and the recording of successive profiles perpendicular to the axis of the cave (e.g. the stratigraphic schemes reproduced in Fig. 14 of Cardoso et al. 2002; cf. also Fig. 1). One of his drawings of the overall longitudinal profile of the excavated deposits ends at a straight line, indicating the presence of a right angle at that spot (Fig. 2A). From this evidence, we can infer the following: (a) the 1962 excavation stopped at about the point of the gallery indicated by that line; (b) an unrecorded transversal profile corresponding approximately to the back face of sector 13 (the innermost sector mentioned in the diaries; Cardoso et al. 2002: 23) must therefore have remained at the site after the 1962 work had ended; (c) Roche's 1971-73 work (Fig. 4B) consisted of the excavation of the deposits filling the cave behind that last transversal profile and resulted in a longitudinal profile representing a prolongation of Veiga Ferreira's toward the interior of the cave.

Assuming the above and knowing (a) that, in Veiga Ferreira's procedure (as used at, e.g. the cave site of Salemas, which he excavated between 1959 and 1961; Roche et al. 1961, 1962; Zbyszewski et al. 1961; Roche & Veiga Ferreira 1970), each sector was one meter wide, and (b) that another field version of the longitudinal profile indicates that this procedure was indeed followed at Gruta Nova (Fig. 2B), we could transfer the approximate limits of the different sectors and of the areas excavated at the site in 1962 and in 1971-73 onto Roche et al.'s (1986) site plan (Fig. 2D). Using the common features of the different documents to control for the accuracy of the operation, we could then merge them to obtain the composite reproduced in Figure 8. To provide additional detail, we also included in this figure short textural descriptions of the different levels derived from Veiga Ferreira (1984), Roche (1973) and Roche et al. (1986).

The different nature of the deposits excavated at both ends of the sequence became immediately apparent as soon as such a complete picture could be put together. While the Mousterian fill excavated by Veiga Ferreira was a sandy cave earth heavily indurated in the upper part and significantly altered by human activity in the lower part (cf. Fig. 1C), the deposits excavated by Roche consisted of clay with interspersed black lenses and intercalated eboulis levels (cf. Figs. 4B & 5). Moreover, in the area excavated by Roche in 1971-73 and in 1986, the massive carbonate cementation that had forced Veiga Ferreira's team to systematically rely on explosives to be able to advance through the deposits did not exist. This absence is all the more conspicuous considering that, with no hidden frustration, the chores associated with the removal of

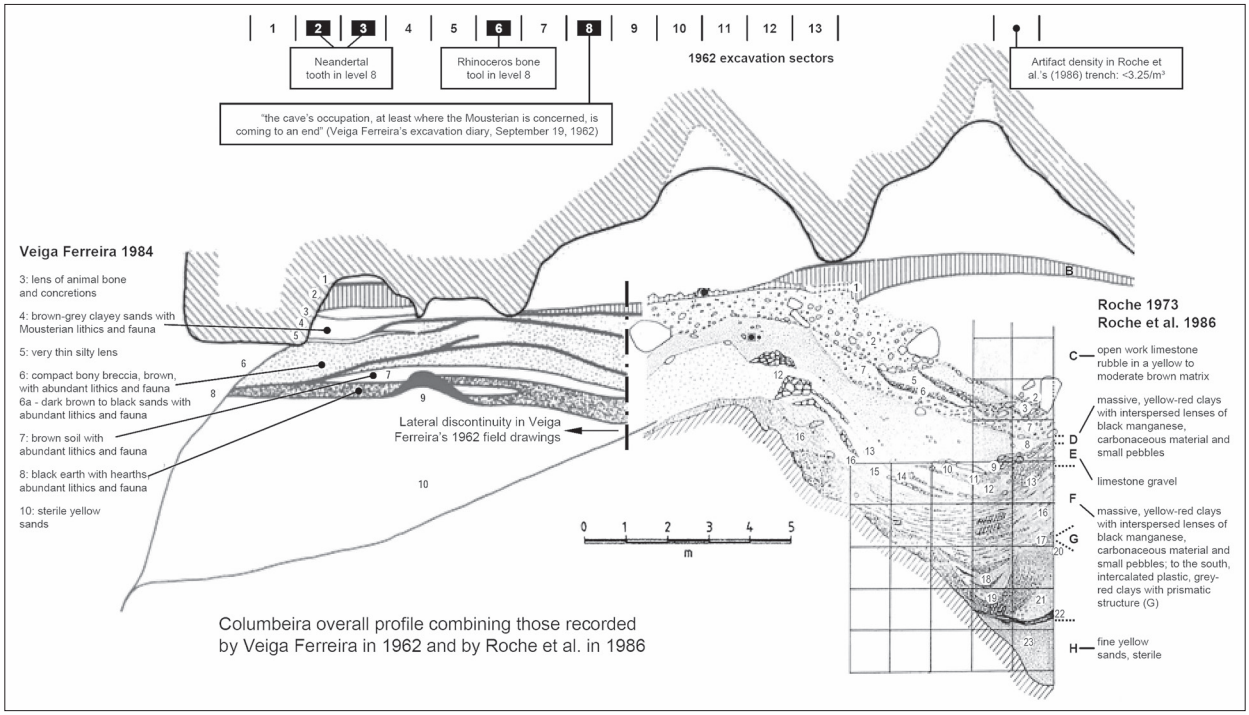

Fig. 8. Composite longitudinal stratigraphic profile assembled from the documents reproduced in Figures 2 & 4 and associated with a summary description of the deposits, based on Cardoso et al. (2002) and Roche et al. (2006). The spatial positioning of key finds and features, and of the areas where stratigraphically relevant field observations were made, are based on the 1962 excavation diary published by Cardoso et al. (2002). The equivalence between the stratigraphic designations used, respectively, by Roche (1973) and Roche et al. (1986), is as follows: level 1 = unit B; levels 2-7 = unit C; level 8 = unit D; levels 9-15 = unit E; levels 16-22 = unit F; level 23 = unit H.

Abb. 8. *Rekonstruiertes Profil aus den verschiedenen Grabungsdokumentationen nach den Beschreibungen von Cardoso et al. (2002) und Roche et al. (2006). Die räumliche Positionsbestimmung der Hauptfunde und -merkmale sowie der Stellen, an denen stratigrafisch relevante Feldbeobachtungen gemacht wurden, gehen auf das von Cardoso et al. (2002) veröffentlichte Ausgrabungstagebuch zur Kampagne aus 1962 zurück. Die von Roche (1973) bzw. Roche et al. (1986) verwendeten stratigrafischen Bezeichnungen sind folgendermaßen zuzuordnen: Schicht 1 = Einheit B; Schichten 2-7 = Einheit C; Schicht 8 = Einheit D; Schicht 9-15 = Einheit E; Schichten 16-22 = Einheit F; Schicht 23 = Einheit H.*

such cemented deposits are the 1962 excavation diary's most recurrent theme.

These textural and structural differences hint at some quite distinct depositional histories, as is further supported by the following observations:

- The Mousterian deposits excavated by Veiga Ferreira in 1962 were extremely rich in both faunal remains and stone tools. Despite the losses inevitably entailed by the heavy use of explosives, Cardoso et al.'s (2002: 47) inventory counts 5835 lithic artefacts. The same tally, however, records only 39 objects from the 1971 work, while Roche et al.'s 1986 trench yielded no more than 13, all of them recovered between 2.34 and 3.42 m below datum in units F (11 pieces), G (1 piece) and H (1 piece). Since the volume excavated by Roche et al. in 1986 was of some 4 m^3, the 13 artefacts they recovered amount to about one every 300 litres of deposit, or the approximate equivalent of one artefact for every 20 buckets of excavated sediment. Coupled with the vertical scatter of the finds, such an exceedingly small artefact density makes it clear that Roche et al.'s finds do not relate to in situ human occupation of the part of the cave from where they were recovered.
- In Roche et al.'s 1986 trench, units F-H yielded no large mammal bones at all, only microfauna, although scattered bone fragments were present in overlying units C, D and E (José Meireles, personal communication, e-mail message to J. Zilhão dated February 17, 2003).
- Lacking a proper archaeological context, the bedded black lenses in unit F are surely not in situ fire features. Moreover, despite the well defined boundaries of these features, no thermal alteration of the underlying clay sediments is reported by Roche et al. (1986). Given their association with scarce but diagnostic Middle Palaeolithic material, their clayey envelope, and the consistent presence of manganese concretions in the deposits making up the unit, these carbonaceous lenses must correspond instead to successive episodes of downslope redeposition in a temporary water-logged environment of material derived from the erosion of the adjacent ash- and charcoal-rich Mousterian deposits.
- The overall geometry of the fill suggests that it is composed of two different bodies, with the apex of the outermost one being located in the area of sector 6, and the apex of the innermost one being

located in the area of sector 12. The base of both bodies, however, corresponds to the same fine, sterile yellow sand described by Veiga Ferreira in 1962. This fact excludes explanations of the markedly inward slope of the external cone as an erosional surface and allows us to conclude that such a slope was not created by resumption of hydric circulation inside the gallery (for instance, as a result of karstic reactivation processes leading to the removal — via currently unknown, cluttered-up outlets — of sediments accumulated coevally with those located toward the entrance).

- If the inward talus of the more external sediment body corresponds to the natural surface extant at the end of the corresponding formation process, and if it was upon such a surface that the sediments forming the internal sediment body unconformably accumulated, then this accumulation must have been accompanied by the incorporation of significant amounts of inherited material displaced by gravity-aided run-off. In all likelihood, this progradation and build-up processes were triggered by the opening of the chimneys that connect the interior chamber to the ground surface above, and occurred at a time when the entrance area of the site was already completely filled-up. In this framework, the basin-shaped disposition of the carbonaceous lenses found in the more interiorly located sediment body can be explained as a by-product of the subsequent operation of subsidence-induced deformation mechanisms (e.g. suffosion; Gutiérrez et al. 2008) caused by the occurrence of bedrock collapses in deeper reaches of the karstic network.

The U-series evidence indicates that the levels excavated by Veiga Ferreira in 1962 are of "normal" Mousterian age, and the new Cologne results corroborate the existence of unexpectedly "young" carbon in the deposits excavated by Roche in 1971-73. This chronometric evidence can be reconciled with the overall site stratigraphy only if we accept that the deposits excavated by Roche at the back of the cave in 1971-73 and 1986 (a) were formed in post-LGM times (b) contain a (very small) Mousterian artefact component in secondary position, and (c) incorporate significant amounts of inherited charcoal (derived from the Mousterian hearth features located upslope, toward the cave's entrance, that were excavated in 1962). With current information, this is the parsimonious explanation for the Early Upper Palaeolithic "ages" obtained for the Gif-dated sediment samples.

Discussion

The geoarchaeological context, in combination with the radiometric data, can now be used to reconstruct the history of the site along the lines suggested in Figure 9. We note here that Roche (1973) had already suspected that the accumulation of his levels 1-15 could well have taken place in Upper Palaeolithic or even post-Palaeolithic times. The principal difference between his chronostratigraphic model and ours is, therefore, that we believe that the archaeological material in levels 16-22 (= unit F of Roche et al. 1986) is in derived position — although featuring a scarce and scattered Mousterian artefactual component, these deposits are not of Mousterian age.

A possible objection to our model lies in the lack of stratigraphic consistency of the Cologne dates for unit F (= levels 16-22 of Roche 1973). One could argue (a) that, due to this inconsistency, the Cologne dates should simply be disregarded and (b) that only the results obtained for those levels by the Gif laboratory should be retained. However, no technical grounds exist that might justify such a stand. Moreover, from a logical point of view, accepting the Gif results and rejecting the Cologne ones simply because the former fit a priori notions that a Mousterian of such young age should exist in Portugal and the latter do not would be a simple case of the fallacy of affirming the consequent.

In fact, the stratigraphic inversion apparent in the Cologne results can be perfectly explained from within our deposition model. Since we propose that the dated bulk samples contain a mix of quite distinct chronological components, it follows that the radiocarbon "dates" obtained for them are not measurements of any specific "age." Although misleadingly related to the radiocarbon time scale, they are instead to be interpreted as numerical expressions of the widely differing amounts of older (Mousterian) and younger (post-LGM) charcoal present in such mixed samples. And, although the results appear to span a significant time range (from ~15 to ~29 ka ^{14}C BP), the deposit whence come the dated samples is quite likely to have accumulated over a shorter period of time. How much shorter is something we can only guess, but in all probability within only a few millennia. Whatever the case, the "older" ^{14}C ages simply represent "more of" the old charcoal and the "younger" ones "less of" it. In this framework, the lack of consistency between ^{14}C age and depth is caused by the largely random distribution across the two meter thickness of unit F of the charcoal particles derived from the adjacent, upslope Mousterian deposits.

Another possible objection is that the version of Veiga Ferreira's profile that features in his 1984 paper extends to the back end of the cave a line marking the lower boundary of his level 6 (cf. Fig. 2C). The continuity between both parts of the site implied by this graphical convention is in contradiction with the stratigraphy presented in both field versions of that same profile. The difference may reflect subsequent reinterpretation, perhaps in the wake of observations made in the context of Roche's later work. More likely, it simply represents yet another factual error to be added to those mentioned above, which we

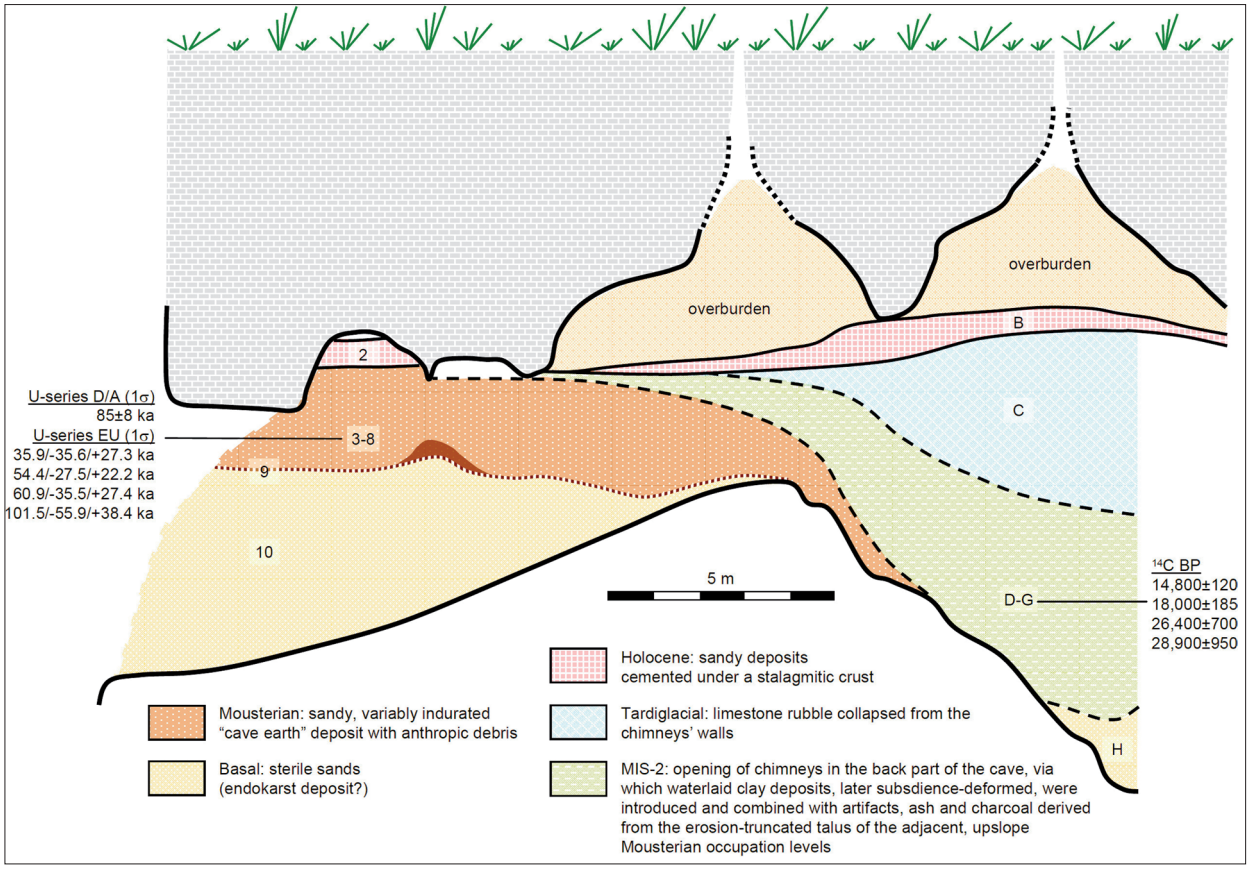

Fig. 9. Chronostratigraphy and site formation model, based on the archaeological, stratigraphic and dating information presently available. The ground surface was positioned 10 m above level 8 following the information given in the submission forms of sample KN-199/Hv-1350. The "overburden" loose deposits filling the inner chamber are not represented in the original field profiles but are described in the excavation diary published by Cardoso et al. (2002).

Abb. 9. *Modell der Schichtbildung aufgrund der vorhandenen archäologischen, stratigrafischen und absolutchronologischen Information. Die natürliche Oberfläche wurde aufgrund der im Einreichungsformular zu Probe KN-199/Hv-1350 enthaltenen Angaben 10 m über Schicht 8 positioniert. Die von oben eingedrungenen „Füllsedimente" werden in den ursprünglichen Profilen zwar nicht dargestellt, sind im Grabungstagebuch von Cardoso et al. (2002) jedoch beschrieben.*

hypothesized might be due to Veiga Ferreira's 1984 paper having been written a long time after the fact and without the field documents at hand. The 1962 drawings are clearly much more reliable, even if, given how the excavation proceeded, they are also schematic renderings, assembled from field notes and the observation of remnants — no such longitudinal profile was physically extant at the end of the dig, when the excavation diary records "I finished the profile and made the topographic plan of the cave" *[Terminei o corte e fiz o levantamento da planta da gruta]* (October 31, 1962, the last day of the field season; Cardoso et al. 2002: 25). Still, the 1962 versions carry over the 1984 one the advantage that they were drafted on spot and within immediate memory of the work. We therefore find it extremely significant that both field originals (cf. Figs. 2A & 2B) (a) feature a convention unambiguously indicative of the existence of a lateral stratigraphic discontinuity in the area of sector 9, and (b) accordingly, use different graphic fills to code for "level 6" on opposite sides of the divide.

The existence of such a discontinuity is further corroborated by the entries of the diary that concern the excavation of this part of the cave, dated September 17-19 (Cardoso et al. 2002: 21; cf. Fig. 8): "Today in profile 7 the entire front is almost breccia. The thickness of the levels decreases (…) the breccia plunges to the left side of the cave [i.e. eastwards] and the dip increases significantly. It is my impression that the archaeological level is coming to an end or at least decreases significantly. (…) on the right side of the cave [i.e. westwards] we have already progressed beyond profile 8 (…) the archaeological levels decrease significantly. (…) unlike so far, the breccia is now becoming very sterile. This seems to suggest that the cave's occupation, at least where the Mousterian is concerned, is coming to an end." *[Hoje no perfil 7 toda a frente é quase brecha. As espessuras das camadas diminuem (…) a brecha mergulha para o lado esquerda da gruta e a inclinação aumenta muito. Tenho a impressão que o nível arqueológico vai acabar ou pelo menos diminui muito. (…) ultrapassámos já o perfil 8 do lado direito da gruta (…) os níveis*

arqueológicos diminuem muito. (…) a brecha começa a ser muito estéril ao contrário do que sucedia antes. Isto parece indicar que o nível de ocupação da gruta, pelo menos no mustierense, parece acabar].

The following days of the excavation were principally occupied with removing the overburden accumulated on top of the Pleistocene deposits in this inner chamber. The farthest inside the cave that mention is made of a much impoverished level 8 having been recognized and excavated down to bedrock is in sector 8 (October 2 entry to the excavation diary; Cardoso et al. 2002: 23). No description of what happened over the following two weeks is available because, while work continued in his absence, Veiga Ferreira had to stay away from the site during that period due to other Geological Survey commitments. Such a fateful development must explain to a significant extent why this critical aspect of the Gruta Nova stratigraphy — the discontinuity between the deposits located at the entrance and those found at the back of the cave — passed unnoticed for so long.

As Roche was not present in 1962 and no stratigraphic baulks remained outward of sector 13, it is understandable that he assumed the black deposits identified at the bottom of the 1973 profile to represent the continuation towards the back of the site of Veiga Ferreira's Mousterian hearth levels. Why Veiga Ferreira failed to convey his observations concerning the marked change in the nature of the deposits occurring inward of sector 8, or why, if he did, did Roche then fail to pay due attention to such an important fact, is something we probably will never know. It certainly did not help that the flow of information between the two seems to have been weak, if at all existent. This is highlighted by the contents of an internal report to the director of the Geological Survey, dated June 27, 1977, where the delay in publishing the results of the 1962 work is justified by Veiga Ferreira on the grounds that the delay was due to the "negligence" of Roche, who at a certain point would have asked for collaborative work to be initiated with the Geological Survey scientists but, according to Veiga Ferreira, would actually have never acted in agreement with such a request (Cardoso et al. 2002: 30) *[o atraso desse estudo d eve-se à negligência do Abade Jean Roche que numa dada altura pediu para colaborar com os técnicos dos Serviços Geológicos trabalho esse que nunca fez].*

Conclusion

We believe that the site formation model presented here comes as close to the actual situation as can possibly be reconstructed from the available evidence. Many details remain obscure, but when the overall picture is considered there can be little question that the Gruta Nova da Columbeira can no longer be used to further the notion that a Neanderthal-associated Mousterian persisted in southwestern Iberia beyond the time horizon indicated by the dates obtained at Cueva Antón, Gorham's Cave and Gruta da Oliveira, i.e. beyond ~37 ka calBP. By the same token, the putative persistence of the Middle Palaeolithic beyond ~37 ka calBP seemingly indicated by the Gif dates for Gruta Nova can no longer be used as an argument to counter the notion that, in southern and western Iberia, the 37-35 ka calBP time slot is occupied by the Late Aurignacian (II and III-IV).

The surviving excavation documents clearly corroborate the excavator's contention that the basal levels of the Gruta Nova sequence did preserve an extremely rich record of the use of the site by Neanderthals. In hindsight, we must regret that the heavy cementation of significant portions of the cave fill precluded an adequate exploration of that record, and that its salvage excavation over a very short field season, although carried out with expert attention to stratigraphy, failed to appropriately document the habitation features and the overall spatial structure of the human occupations. Even if they date to the later part of MIS-5 instead of being of the young age that made their fame, the Mousterian levels of Gruta Nova clearly represented one of the few Iberian localities containing a detailed record of what a southern European Neanderthal residential cave site would have looked like archaeologically. These levels deserve further attention in the future under the light of the results presented here.

Acknowledgments: Through their work in the post-war years of the 20th century, Octávio da Veiga Ferreira (1917-1997) and Jean Roche (1913-2008) pioneered the study of Portuguese Middle and Upper Palaeolithic cave sites, a field where they represented the dominating figures for more than a quarter of a century. We dedicate this paper to their memory. João Pedro Cunha-Ribeiro, University of Lisbon, assisted with the 2003 sampling and Miguel Ramalho, curator of the collections of the Museu Geológico, kindly gave us permission to sample the level 8 bone tool for U-series dating. Michel Fontugne (Gif laboratory), Manfred Frechen (Leibniz Institute for Applied Geophysics), José Meireles (University of Minho) and Jean-Pierre Texier (University of Bordeaux) provided unpublished documents and were always available to supply information upon request. Jean-Philip Brugal (CNRS, Aix-en-Provence) helped with the classification and analysis of the rhinoceros bone tool. Nuno F. Bicho (University of the Algarve) provided unpublished details concerning the U-series results obtained at SMU in the late 1990s. Diego Angelucci (University of Trento), Thierry Aubry (Côa Valley Archaeological Park), António M. Monge Soares (Technological and Nuclear Institute, Sacavém) and Luís Raposo (National Museum of Archaeology, Lisbon) read preliminary versions of this paper and contributed useful comments. To all we are grateful. As usual, any errors or omissions are our own.

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