

Bollettino della Società Paleontologica Italiana	40 (2), 2001	ISSN 0375-7633	249-256	—	Modena, Giugno 2001
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The fossil Rhinoceros found by Nesti on 1811 dated in the final Pliocene by magnetostratigraphy of the Upper Valdarno sequence

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KEY WORDS – Vertebrate collection dating, Magnetostratigraphy, Olduvai chron, Late Pliocene, Upper Valdarno, Northern Apennines, Italy.

ABSTRACT – A magnetostratigraphic calibration is provided, for an old fossil find of the Upper Valdarno (UV) vertebrates stored in the Palaeontological Museum of Florence, by the correlation established with the reference of the Faella section, which covers the nearly complete depositional sequence of the Montevarchi Succession. The latter yielded most of the UV fossil collections of late Villafranchian age. Nesti's rhinoceros was recovered at Poggio di Monte al Pero in the same sequence and is correlatable with its findings. From partial information in the catalogue and Nesti's description, the site level was determined quite high in the sequence, while from the paleomagnetic survey through the more than 50 m thick hill-side section it was contained within one magnetic zone of normal polarity. Magnetostratigraphy of this section correlates with that of the facing Faella section containing the composite of the entire Olduvai Chron (1.95–1.77 Ma). The level of the corresponding Nesti's site in the Faella reference section yields a date of 1.830 ± 0.015 Ma. Its high resolution is provided by the sharp constraints of the Olduvai magnetozone C2n recorded with the split short reversals dated in the stratotype of the Pliocene-Pleistocene boundary 1.815 Ma and lasting 1.785 Ma and 1.770 Ma, respectively. The approximation of 15 ky is taken to a cautionary value, having assumed an incertitude of 5 meters in the reconstructed site elevation and an average accumulation rate measured at Faella as nearly 300 mm/ky by the aforesaid time constraints.

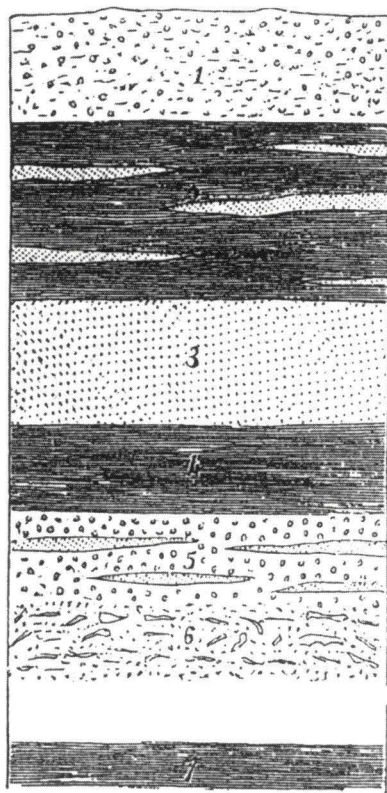
RIASSUNTO – [Il Rinoceronte fossile rinvenuto nel 1811 da Nesti e sua età misurata dalla magnetostratigrafia della serie del Valdarno Superiore] – Viene effettuata la prima applicazione di calibrazione magnetostratigrafica dell'antica collezione dei fossili del Valdarno Superiore nel Museo di Storia Naturale di Firenze con lo standard di Faella appena stabilito (Albianelli et al., in stampa) che racchiude quasi tutta l'estensione dei depositi della Successione di Montevarchi della serie del Valdarno Superiore (VS). Dalle notizie parziali del catalogo e dalla descrizione del ritrovamento del celebre esemplare di rinoceronte illustrato da Nesti nel 1811, la posizione stratigrafica di quest'ultimo è stata definita; inoltre, dall'analisi magnetocronologica questa corrisponde ad un livello della serie di Montevarchi databile in 1.830 ± 0.015 Ma, nell'intervallo che contiene il crono Olduvai.

L'importanza che il Rinoceronte di Nesti assunse circa due secoli addietro risiedeva nell'essere, nel nuovo criterio di confronto osteologico delle faune fossili con quelle viventi, l'esemplare più completo. Ad essa ora si aggiunge l'importanza di rappresentare il prototipo degli esemplari provenienti da recuperi di antica data che possiede in catalogo la determinazione diretta dell'età numerica, espressa dal valore in anni misurato con i criteri geocronologici della stratigrafia magnetica. La risoluzione nella misura dell'età del livello stratigrafico della serie in cui fu rinvenuto il Rinoceronte di Nesti è data in così poche migliaia di anni in virtù della calibrazione con l'antistante sezione magnetostratigrafica tipo, per gli ultimi 200 ky del Pliocene del VS nella quale peraltro la risoluzione cronologica dei livelli fossiliferi individuati più di recente è di soli 2 ky. Risulta allora che quasi tutta la fauna del Villafranchiano superiore rinvenuta, se ubicata con precisione nell'ambito di detto intervallo, può essere di riferimento per gli altri reperti della serie poiché le unità litostratigrafiche in essa riconosciute sono state quasi completamente analizzate dal punto di vista paleomagnetico. Ciò è risultato utile per le associazioni costituenti le faune locali del VS che così possono essere definite fino a qualche ky di precisione, allo stesso modo degli esemplari individuali nelle collezioni del Museo che possono usufruire dei criteri applicati per ricostruire la posizione del Rinoceronte di Nesti nella serie litostratigrafica ora calibrata fino alle sabbie terminali. Rimane invece escluso dalla definizione ad alta risoluzione una quantità di ca. il 70% del patrimonio di vertebrati fossili del Museo che è privo di dati sulla posizione dei siti di provenienza degli esemplari. In tal modo manca per essi qualsiasi riferimento di età se non quello di appartenere all'intervallo della sedimentazione continentale del VS e pertanto un nuovo impegno è in atto nel reperire notizie più accurate dalle fonti antiche e non riportate in catalogo. In questa sede può essere dato l'annuncio che un importante risultato è stato già ottenuto con la datazione dei livelli dove fu recuperato da Azzaroli nel 1953 lo scheletro completo di elefante presso Montevarchi e datato con lo stesso criterio di questo esemplare di Nesti.

INTRODUCTION

The rhinoceros recovered by Nesti (1811) at Poggio (peak) di Monte al Pero is one of the most important records in the Vertebrate collection of the Natural History Museum of Firenze (NHMF) because it was cited in the “comparative” osteologic catalogue that was established by Cuvier (1824). An exceptional finding occurred in July 1999 on Poggio Rosso hill-top, only 500 meters from Monte al Pero, by the NHMF with the complete skeleton of a rhinoceros.

Its recovery immediately recalled the collection made two centuries ago, and the possibility that the magnetochronology just established for the Upper Valdarno (UV) sequence (Albianelli et al., 1997; in press; Napoleone & Albianelli, 1998) (Text-fig. 1) could be applied to both sites of Poggio Rosso and Poggio di Monte al Pero. In fact, while the paleomagnetic surveys carried out on their short sections recorded only one normal polarity that prevented a magnetic zonation for calibration, the correlation which was made available by the new magnetostratigraphic sec-



Text-fig. 3 - The section on the eastern foot of the Monte al Pero hill, drawn by Cocchi (1867) as 80 m high from the fossil site of Casenuove which was at 132 m, almost the same level as the recent finds in the Faella pit where are mostly located below the Olduvai magnetic zone. The site was reported in the topographic map of Text-fig. 2 as positioned from the old map and the description of the schematic lithostratigraphy is that by Cocchi: 1) Clay-sandy layer with sandy pebble and gravel; 2) Grey clay with thin interbedded sandy levels; 3) Yellow coarse sand; 4) Compacted clay; 5) Pebble and sand, seldom with iron oxides; 6) Sandy layer with bones (Drepanodon, Ursus, Felis, Cervus, Bos, Rhinoceros, etc.). Its lower boundary was not reached; 7) Lower bluish clay outcropping to some distance and at lower level towards the Arno.

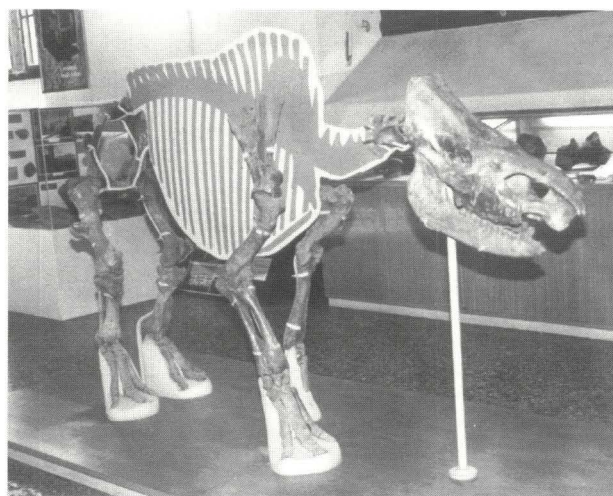
which were published: the fossil rhino was illustrated by Mr. Cuvier for the bones known until five years ago, and the comparative examination of the skull and dentition is one of the most interesting works of this kind". Finally, the finds: "As this year I undertook to enrich the Museum of fossil bones, I encouraged a farmer of the surroundings of Figline in Upper Valdarno, an able man on this kind of research [...] (This excavator is Giovan Battista Pieralli). He brought me first a complete femur of an elephant, several fragments of this animal, of ox, and of deer, and finally several bones of rhinoceros".

It is not known from the above whether the bones attributed to the Monte al Pero site were all from that site or were part of the previous collection of Mr. Pieralli (from various or multiple sites). Informations

on topography and taphonomy of the finding were given as follows: "It laid on a hill called Poggio di Monte al Pero, three miles from Figline on the right bank of the Arno, about 120 "braccia" above the level of this river, and at two thirds of the height of the hill. Only three anterior hooves had made appearance from the ground, which had here crumbled almost vertically [...]. In the surroundings there was some of what we call Fuoco lapito, in thin flakes, and which is carbonized, fragile wood, which occurs everywhere in the Valdarno, usually laying horizontally". After a digression on the layout of common findings, usually disarticulated, the site description goes on: "The earth on which the rhinoceros lays is of the sort farmers call Sansino, and is an arenaceous clayey deposit mixed with small and sometimes minute gravels, an earth by which farmers believe fossil bones to be accompanied, and therefore they call them earths of bones: but this is incorrect, because I saw on the ground, and have received bones which were included in clay, and also in a haematitic cement with small crystals of sulphured chalk. The rhinoceros bones are very well preserved and very hard, as are those which were buried at a certain depth and were not exposed to the action of waters, of cold and to the roots of plants". To conclude: "Here is [...] the description of these bones, of a Rhinoceros recently acquired by the Museum, many of which have not yet been published, the others are more complete than those hitherto described". A sample of Nesti's osteologic data is provided by one of his artistic plates (Text-fig. 5).

AGES FOR THE FOSSIL FAUNA OF THE MUSEUM COLLECTIONS

From Nesti's words emphasizing to investigate "on the causes which buried those bones" several steps were made to "say something more plausible" on the times in



Text-fig. 4 - Nesti's Rhinoceros on exhibition. Its description of 1811 did not include the cranium, which was found in the Lower Valdarno and added by Azzaroli in the 1970's, together with some other pieces.

which those bones were buried, and to determine a chronological order which gives account of the phases of their evolution. The most recent phases of such steps were the magnetostratigraphic asset of the UV sedimentary sequence and introduction of the automated catalogue for the paleontological collections of the NHMF. The GEF catalogue was established in order to facilitate a steadily more frequent use of information by a growing number of users (Cioppi *et al.*, 1996). One of these results consists of the chronological resolution which magnetostratigraphy of the exposed series in the UV (Albianelli *et al.*, 1997; 1999; in press) offers for the remains of the richest and longest succession in the Apennine continental basins (Azzaroli, 1977; 1983; 1986; 1995).

1. INTRODUCING MAGNETOCHRONOLOGY FOR THE UPPER VALDARNO STRATIGRAPHY

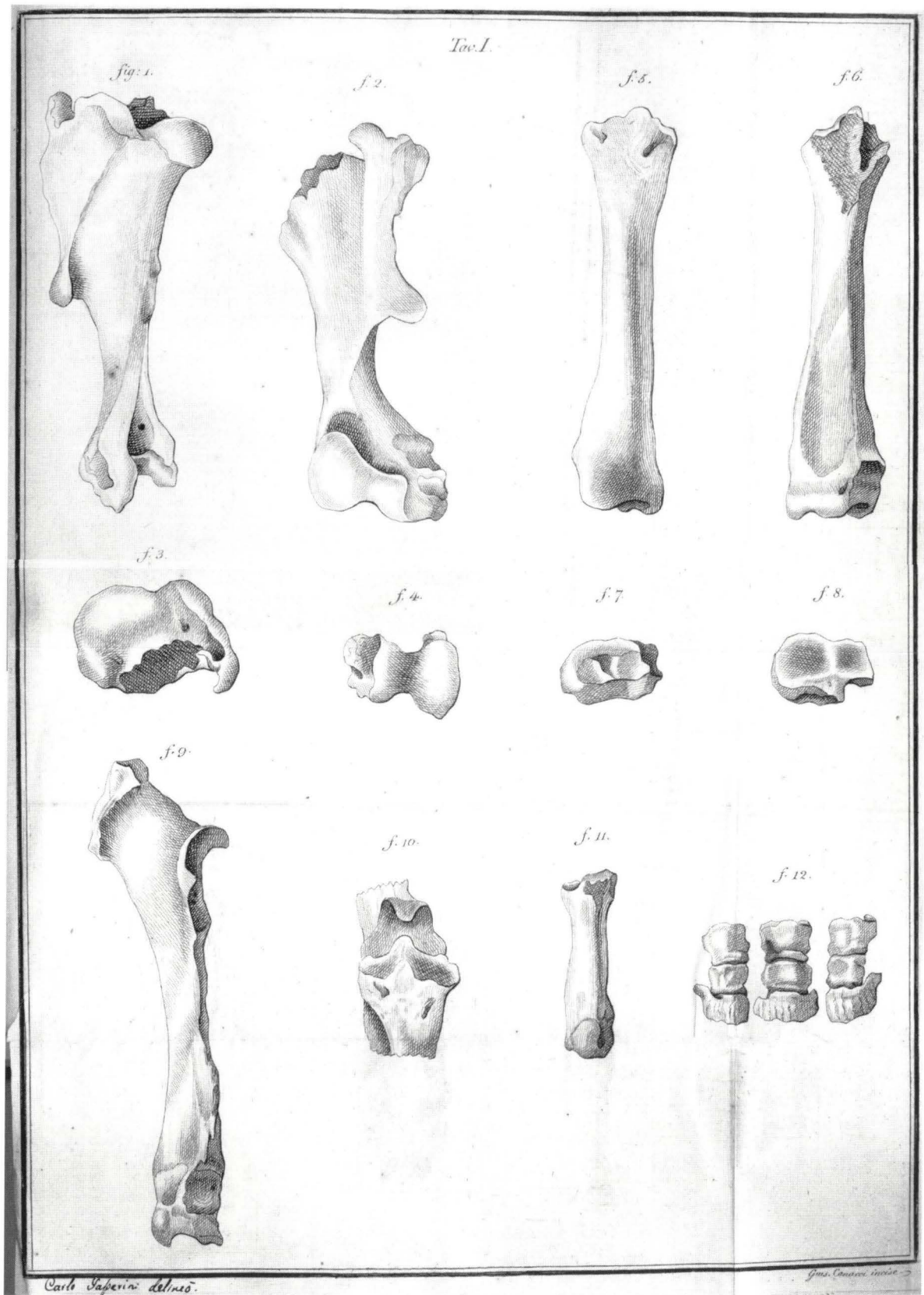
The use of magnetostratigraphy was brought into this Department a quarter of a century ago, with the calibration of exposed pelagic sediments and later to continental sediments. The fluvio-deltaic sediments of the Himalayan foothills were analyzed (Azzaroli & Napoleone, 1981), in order to refine the chronologic succession of important fossil collections in the London and Calcutta Museums, that were not datable otherwise. In recent years studies were undertaken in the UV (Torre *et al.*, 1993; Albianelli *et al.*, 1995; 1997; in press), the most recent ones concentrated on the area of Text-fig. 2, where Nesti's Rhinoceros site is located. It is noticeable that this began when magnetostratigraphy had become an important tool for geochronology. In addition, also the cyclostratigraphic concept was applied to the UV sequences by using the continuous variations of their magnetic signatures (Napoleone & Albianelli, 1998; Albianelli *et al.*, 1999), after having been developed for many years in the pelagic facies of Mesozoic-Palaeogene basins in the Northern Apennines (Ripepe, 1988; Napoleone & Ripepe, 1989). However, the development of magnetochronologic applications in the Apennine continental sequences near Firenze was restricted, until it was reactivated with the 1995 discovery of Poggio Rosso locality, the richest fossil site ever found in the UV (Mazzini *et al.*, 2000), and near that of Poggio di Monte al Pero. Therefore, the magnetochronologic applications used for dating recent finds of accurate stratigraphic position (Napoleone *et al.*, in press) was also used for dating the old "museum remains" harboured in the collections. As a consequence, on the one hand relevant sections for establishing a reference magnetostratigraphy were specifically surveyed, on the other hand more faunas stored in the Museum collections were seen as an effectively datable sequence to be stratigraphically ordered also in the GEF catalogue. The first attempt led Azzaroli & Napoleone (in manuscript) to reconsider the middle and late Villafranchian fauna of the Italian peninsula in the new magnetochronologic asset of the UV sequence.

2. THE FAELLA TYPE SECTION FOR CALIBRATION OF THE MONTEVARCHI SUCCESSION

The Cava Faella clay pit provides a useful magnetostratigraphic reference, for its age includes the Olduvai chron (lasting 1.95-1.77 Ma) on the present geomagnetic polarity time scale (GPTS) reported by Berggren *et al.* (1995) and updated in Van Couvering (1997). This standard was needed for correlation in the UV, as it solves the basic question of timing the sequence of geological events hitherto reconstructed on biochronology. The main events may be recalled from all the previously quoted literature: The earliest continental sedimentation in the UV dated ca. 3.3 Ma, while the oldest fossil record (the Castelnuovo dei Sabbioni fauna, equivalent to the Triversa Faunal Unit by Azzaroli, 1977) dated ca. 3.1 Ma. The Castelnuovo dei Sabbioni Succession of lacustrine clays was interrupted by tectonic activity 60 ky before the end of the Gauss chron (C2An.1n, fixed at 2.58 Ma in the GPTS, and marking the middle-late Pliocene boundary), as determined by the cyclostratigraphic processing of the magnetic signal in 500 ky continuous series of clay beds forming the Meleto unit. The unconformably overlying lacustrine and palustrine sedimentary cycle of Montevarchi deposited after a gap of 600 ky of the tectonic phase, until its lower silty unit dated (so far in the Faella creek) 1.99 Ma. From thereafter the onset of the Olduvai magnetochron at 1.95 was recorded in the Faella section.

Given such time constraints, the fossil record distributed along the Faella section (Text-fig. 7) gave the ages for each specimen in stratigraphic series and their resolution with increasing accuracies for the more recent finds. The sample at the Faella creek level, dated 1.990 ± 0.002 Ma with a definition better than 1 m from the level of the Olduvai onset; the sample immediately above it in the abandoned quarry 1.980 ± 0.002 ; two more levels were defined before the sample just passed the Olduvai base and dated 1.945 ± 0.002 Ma. Specimens higher in the series and with lesser defined position were dated 1.875 ± 0.030 Ma and 1.870 ± 0.015 Ma, up to the oldest ones of the first collection which were not referred and Azzaroli considered as collected in the upper cover of the Montevarchi Succession exposed in the Faella area; they were therefore tentatively dated 1.820 ± 0.050 Ma.

The lowermost specimens of the Faella section dated 1.980 and 1.990 ± 0.002 Ma were the most recent finds, but also the oldest ones in the Montevarchi Succession and provided in the UV the record of the new faunal age after the revolution which took place in Europe with the "wolf event" (Lindsay *et al.*, 1980; Azzaroli, 1983). The remaining specimens enclose the full excursus of events up to last Pliocene phases, for a time span of ca. 200 ky.



Text-fig. 5 - Reproduction of a Table from the osteologic reconstructions done by Nesti. The example is reported also for comparison with the sample found in 1999, as it will be illustrated after restoration and osteologic reconstruction.

3. CORRELATION OF MONTE AL PERO WITH THE FAELLA SECTION

Nesti's Rhinoceros associates perfectly with the Faella fauna, and the Poggio di Monte al Pero sequence correlates in detail with the reference section of Faella (Magi, personal communication). Also the Poggio Rosso short section and its fauna will be dated by correlation with the same sequence of Faella. Among the annotations fixed after Nesti's description, let us recall the height reported as 120 "braccia" above the Arno level, corresponding to 70 m (the unit is ca. 58 cm), from 115-120 m above sea level of the latter near Figline: with good approximation, the two thirds of the hill height reported by Nesti may be referred to the almost 75 m difference between the base and top of it. The first may be fixed from the topographic map at 130-140 m, the second is labelled at 215 m in Text-fig. 2. The level of the fossil site was at 180-190 m. Also Nesti's remark on the occurrence of "*carbonized wood in the surroundings*" and "*which is found in all the Valdarno in an ordinarily horizontal position*" was confirmed by the 1999 find (Text-fig. 6) and the surveyed sections of Cava Faella, Tasso tunnel, Poggio Rosso, and others, to lie at the same elevation (within 5 m of incertitude).

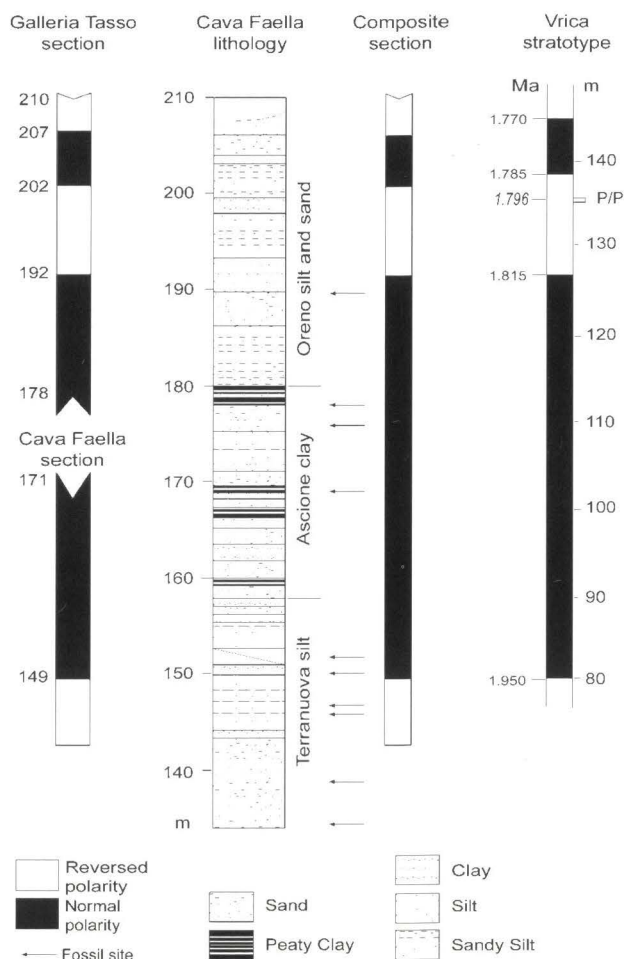
So, it offers a sufficiently close correlation with the site of Poggio al Pero. Also the one polarity magnetic signature yielded by the palaeomagnetic survey of the Monte al Pero section can be calibrated by the polarity sequence reconstructed in the Faella sequence that will be used for all sections in the Montevarchi series as the magnetostratigraphic standard section.

DISCUSSION ON DATING THE SPECIMEN IN THE COLLECTION

Nesti's description of the specimen became famous because it was the first skeleton found almost complete, shortly after the new criterion of "comparative" classification of fossil vertebrates was introduced in the earliest 18 hundred by Cuvier (1824). Nowadays, while the sample was reviewed for palaeontological correlations (Mazza, 1988), here it is dated by comparison with the Faella type section for the whole Montevarchi Succession. All specimens representing the 10 species of the Faella collection were located in the Faella magnetostratigraphic series, and therefore dated with a detail ranging from 2 ky to 50 ky (Text-fig. 7). The rhinoceros illustrated by Nesti was buried in the hill representing the external southern slope of the Matassino and Poggio Rosso pit, along the road to the Faella hamlet which runs through the quarry close to it. In all sections outcropping in the area of Text-fig. 2, the sedimentologic and stratigraphic characters given by the presence of the "*sansino*" pebbly sand and "*carbonized wood*" are both well visible and allow a fine correlation through the basin, within a resolution of few meters. Therefore the stratigraphic observations can be used by faunas of the collections also for dating single specimens from the collections. In the present case the dating of the Poggio di Monte al Pero site may be obtained by taking the base of the hill at the altitude of the plain crossed by the main road, at 134 m, and the beginning of the Olduvai chron (1.95 Ma) in proximity of its base. In addition, a section through the accessible exposure of Monte al Pero (from shortly above the inhabited level, at 150-160 m altitude, up to the hill-



Text-fig. 6 - View of the site where the complete skeleton of a rhinoceros was recovered at Poggio Rosso on the 8th of July, 1999. It was removed from the sansino sand, of the same kind described by Nesti for Poggio di Monte al Pero: "*an arenaceous clayey deposit mixed with small and sometimes minute gravels*", and contained also the "*carbonized*" wood, well prominent in the extreme right-hand side, which often occurs in extended levels either in the clay or in the sand, as it was remarked also by Nesti.



Text-fig. 7 - The magnetostratigraphic reference section of Faella as reconstructed in the composite made by the lower portion already measured in the Faella clay pit section (modified from Torre *et al.*, 1993) and the Tasso tunnel section. The simplified lithologic log is for the Faella pit and fits exactly the Tasso log (modified from Albanielli *et al.*, in press). The composite is correlated with the magnetic zonation of the stratotype sequence, which reports the calibrated ages (modified from Van Couvering, 1997).

top 215 m, and in the direction of the Matassino clay pit) was investigated palaeomagnetically and yielded a uniform magnetization of normal polarity.

Therefore, it can be assumed that the beginning of the Olduvai lays in its unsampled base, the area of the little hamlet of Monte al Pero, and at a comparable level with the Faella section. Then also the two thirds altitude of the Poggio, from which the fossil came, may be referred directly to its position in the Olduvai interval of the Faella section, and the incertitude in the topographic correlation may be of the order of 10 m, or probably less. The longer normal portion into which the Olduvai is subdivided in the Faella magnetostratigraphic composite series is calibrated at 1.815 Ma at its end from the stratotype of the Plio-

Pleistocene boundary, and placed at 191.6 m in the corresponding section of the Tasso tunnel which crops out further to the south within the basin. Again, the ages may be assigned with an incertitude inherent in a thickness of less than 10 m, which gives an approximation very close to ± 0.015 my, and therefore an upper boundary age is plausible at 1.830 Ma.

All this is based on an accumulation rate of the Montevarchi Succession, which for the Monte al Pero and Matassino area should be not far from that of Faella, the sedimentological and paleomagnetic facies being very close for both sequences. When possible, i.e. in sections sufficiently long to contain a time series adequate to the spectral analysis of periods of tens of ky, the refinement by the successive order (units of ky) is given by direct analysis of magneto-cyclic stratigraphy: it had been restated for the Argille di Meleto series (in the underlying Castelnovo Succession) and applied with a better approximation in the Faella section. As a result, the magnetostratigraphic numerical date of Nesti's Rhinoceros within the Olduvai implies to refine the age value reported in the catalogue card by updating also the biostratigraphic age. After the boundary stratotype was defined at Vrica "just below the end of the Olduvai chron", also the reported date of early Pleistocene has to be changed into the calibrated value of latest Pliocene.

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(manuscript received November 27, 2000
accepted February 2, 2001)

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