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Rhinocerotidae (Mammalia, Perissodactyla) from the latest Turolian localities (MN 13; Late Miocene) of central and northern Italy

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ABSTRACT - Latest Miocene (MN 13) rhinoceroses from central and northern Italian localities are here described and compared in detail. Rhinoceros specimens have been collected from four localities (Moncucco Torinese, Verduno, Baccinello V3 and Monticino Quarry) and consist of isolated teeth (upper and lower premolars and molars), an almost complete maxilla with I1 and P2-M3, a fragmentary mandible, a p2-p4, a scaphoid and a damaged tibia. A few specimens (isolated teeth from Verduno and Moncucco Torinese and a fragmentary tibia from Baccinello V3) have been generally referred to as Rhinocerotini indet. whilst other remains have been assigned to the species "Dihoplus" megarhinus *based on several morphological characters.* "D." megarhinus *has been considered a typical Pliocene species, nevertheless it has been recently recorded in several Late Miocene (MN 12 and MN 13) mammal assemblages of the Pannonian Basin. The occurrence of* "D." megarhinus *in the latest Turolian of Italy confirms the presence of this species during the Late Miocene in Europe and suggests a dispersal of eastern European taxa in western Europe and Italy during the MN 13 as also testified by other taxa such as* Hippotherium*,* Prolagus sorbinii *and* Hansdebruijnia *sp.*

RIASSUNTO - [Rhinocerotidae (Mammalia, Perissodactyla) dalle località del Turoliano terminale (MN 13; Miocene Superiore) dell'Italia centrale e settentrionale: implicazioni biocronologiche e paleobiogeografiche] - *Rispetto ad altre aree d'Europa, i resti di rinoceronti fossili miocenici in Italia sono piuttosto scarsi e poco conosciuti. In questo lavoro vengono descritti e comparati in dettaglio resti di rinoceronte rinvenuti in località del Miocene terminale (MN 13) dell'Italia centrale e settentrionale. I resti di rinoceronte provengono da quattro località: Moncucco Torinese (Piemonte), Verduno (Piemonte), Baccinello V3 (Toscana) e Cava Monticino (Emilia Romagna). Gli esemplari considerati in questo lavoro includono denti isolati (premolari e molari superiori e inferiori), un mascellare quasi completo con I1 e P2-M3, una mandibola frammentaria, p2-p4, uno scafoide ed una tibia danneggiata. Pochi esemplari (denti isolati da Verduno e Moncucco Torinese ed una tibia danneggiata da Baccinello V3) sono stati attribuiti come Rhinocerotini indet. poichè non mostrano caratteristiche mofologiche utili per una discriminazione a livello di genere o specie. Altri resti (ad esempio il mascellare di Baccinello V3 ed i denti superiori isolati di Cava Monticino) sono stati assegnati alla specie* "Dihoplus" megarhinus *sulla base di diversi caratteri morfologici. I denti di Cava Monticino mostrano alcuni caratteri più evoluti rispetto a quanto osservato negli esemplari di* "D." megarhinus *da Baccinello V3, Kávás e altre località mioceniche. Tali caratteri sono stati osservati in alcuni denti isolati rinvenuti nel sito di Montpellier, cronologicamente riferito al Pliocene Inferiore.* "D." megarhinus *era considerato un taxon tipico del Pliocene, ma la specie è stata recentemente segnalata nelle associazioni a mammiferi del Miocene terminale (MN 12 e MN 13) del Bacino Pannonico. La comparsa di* "D." megarhinus *nel Turoliano terminale in Italia conferma la presenza di questa specie in Europa nel corso del Miocene Superiore e suggerisce una dispersione di taxa dell'Europa Orientale verso Occidente e la Penisola Italiana durante la MN 13 così come testimoniato anche da altri elementi faunistici quali* Hippotherium*,* Prolagus sorbinii *e* Hansdebruijnia *sp.*

INTRODUCTION

Four Late Miocene species belonging to the tribe Rhinocerotini (sensu Heissig, 1999 = Rhinocerotina in Antoine, 2002) have been identified in Europe: *Dihoplus schleiermacheri* (Kaup, 1832), *Dihoplus pikermiensis* (Toula, 1906), "*Dihoplus*" *megarhinus* (de Christol, 1834) and *Ceratotherium neumayri* (Osborn, 1900). *D. schleiermacheri* occurs from MN 9 to MN 12 at several central and western European localities and it is the sole Rhinocerotini species in western Europe during the latest Miocene (Kaup, 1832; Guérin, 1980; Cerdeño, 1992; Heissig, 1996, 1999). *D. pikermiensis* occurs in the latest Vallesian and Turolian deposits (MN 10-MN 13) of the Balkan Peninsula and Turkey (Geraads, 1988; Heissig, 1999; Antoine & Saraç, 2005; Geraads & Spassov, 2009; Giaourtsakis, 2009; Koufos, 2016; Koufos et al., 2016). *C. neumayri* has been reported from several fossiliferous localities (MN 10-MN 13) of the Balkan Peninsula, Caucasus, Anatolia and Iran (Osborn, 1900; Geraads, 1988; Heissig, 1999; Geraads & Spassov, 2009; Giaourtsakis, 2009; Pandolfi, 2016). "*D.*" *megarhinus* has been recently reported from several latest (MN 12-MN 13) Miocene faunas of Hungary by Pandolfi et al. (2015a, 2016).

Late Miocene Italian rhinoceroses are poorly documented and investigated with respect to other European areas. Rhinoceros remains are indeed known only at six latest Turolian (MN 13, Late Miocene, Messinian) Italian mammal faunas collected at: Moncucco Torinese (Piedmont), Verduno (Piedmont), Monticino Quarry (Emilia Romagna), Baccinello V3 (Tuscany), Cessaniti (Calabria) and Gravitelli (Sicily) (Fig. 1). The specimens collected at Gravitelli have been figured by Seguenza (1902, 1907) and were referred to as *Rhinoceros* (*Dihoplus*) *schleiermacheri*. Later, Hooijer (1946) attributed part of these remains to *Diceros* aff. *pachygnathus* (Wagner, 1848) (recte *Ceratotherium* aff. *neumayri*) whilst according to Guérin (2000) the material from Gravitelli clearly represents *Diceros*. In our opinion, the material is not sufficient for a certain specific identification but the overall characters of the specimens,

Fig. 1 - Location map of the Italian latest Turolian localities which yielded remains of rhinoceros. 1) Moncucco Torinese; 2) Verduno; 3) Monticino Quarry; 4) Baccinello V3; 5) Cessaniti; 6) Gravitelli.

deduced from the Seguenza's plates and measurements, suggest an affinity with *C. neumayri*. The material reported by Seguenza (1902, 1907) was destroyed during the 1911 Messina earthquake and direct observations of the specimens are impossible. The presence of the African genus *Diceros* has been also reported at Cessaniti (Marra et al., 2011). Nevertheless, the specimens collected from this locality need to be deeply revised and investigated in a separate paper, and are provisionally referred as Rhinocerotinae indet. Both the localities of Gravitelli and Cessaniti include taxa with African affinities suggesting a connection between the Calabro-Peloritan arch and North Africa (Seguenza, 1902, 1907; Hooijer, 1946; Kotsakis et al., 1997; Guérin, 2000; Ferretti et al., 2003; Rook et al., 2006; Marra et al., 2011). For completeness regarding the Late Miocene Italian rhinocerotid, a brief mention on the fragmentary mandible of *Acerorhinus* sp., recovered at Monte delle Piche (Rome), is necessary (Pandolfi et al., 2013, 2015b; Pandolfi & Marra, 2015). The specimen (together with some foraminifera included in a sample of sediment collected within the mandible; Pandolfi et al., 2013) represents a reworked Miocene element in Early Pleistocene deposits (Pandolfi & Marra, 2015).

The central and northern Italian latest Turolian localities which yielded rhinoceros remains (Moncucco Torinese, Verduno, Monticino Quarry and Baccinello V3) include taxa with clear European affinities and belong to a different paleobioprovince with respect to the southern Italian sites (Kotsakis et al., 1997; Rook et al., 2006; Angelone et al., 2011; Colombero et al., 2014). The material collected from these localities has been cited in several papers, but was never described, compared and figured in detail.

The aim of this paper is to provide a comprehensive description and updated overview on the latest Turolian rhinocerotids of central and northern Italy and to evaluate their paleobiogeographic implications.

MATERIAL AND METHODS

The material included in this study is currently housed in different institutions and museums and it has been collected from four localities: Verduno, Moncucco Torinese, Monticino Quarry and Baccinello V3. The scantly remains collected at Verduno (Piedmont) are housed at MCEA; they include a fragment of an upper tooth (MCEA P00944), a lower premolar (MCEA P00968) and a fragment of a lower molar (MCEA P00912) previously assigned as Rhinocerotidae gen. et sp. indet. (Colombero et al., 2014: p. 301, fig. 8.3-8.4). An isolated M3 from Moncucco Torinese (Piedmont), housed at MGPT (PU127004), was figured by Angelone et al. (2011) and assigned to *Stephanorhinus* sp. (Angelone et al., 2011: p. 95, fig. 5.7). The same specimen was also figured by Colombero et al. (2017: fig. 9.2) together with a much worn and badly preserved M2 (MGPT PU127005; Colombero et al., 2017: fig. 9.1); the two teeth were assigned to *Dihoplus schleiermacheri*. The specimens collected from Monticino Quarry (Emilia Romagna) are housed at MFS (isolated P4 MFS 115, isolated M2 MFS 116, a fragment of an upper tooth BRS1/15, an isolated m3 BRS1/14, a scaphoid BRS1/n.c.); they have been partially cited in some papers (Pandolfi, 2013; Pandolfi et al., 2015a, 2016) but lack a detailed description and comparison. Rhinoceros remains from Baccinello V3 (Tuscany) are currently housed at NMB and include a right maxilla with I1 and P2-M3 (BAC n.c.), an isolated P2 (BAC 1237), a fragment of the mandibular horizontal ramus (BAC 1240), a p2-p4 series (BAC 1241), an isolated p2 (BAC 1239), an isolated lower molar (BAC 1238), a cast of a damaged tibia (BAC n.c.). Part of the material has been cited in several paper (Hürzeler & Engesser, 1976; Guérin, 1980, 2003; Pandolfi, 2013; Pandolfi et al., 2015a, 2016), but it was never fully described and compared.

The studied specimens were morphologically compared with the rhinoceros material collected in several Miocene and Pliocene localities of Eurasia and North Africa and referred to as *Ceratotherium neumayri*, *Diceros douariensis* Guérin, 1966, *Dihoplus schleiermacheri*, *Dihoplus pikermiensis*, "*Dihoplus*" *megarhinus*, "*Stephanorhinus*" *miguelcrusafonti* (Guérin & Santafé-Llopis, 1978) and *Stephanorhinus jeanvireti* (Guérin, 1972). The comparisons were based on the material housed in several museums and institutions as well as on the specimens published by several authors (Appendix). Dental terminology and anatomical descriptions follow Guérin (1980) and Antoine (2002), whereas the protocol for measurements follows Guérin (1980).

Institutional abbreviations

BSPG, Bayerische Staatssammlung für Paläontologie und Geologie, Munich, Germany; HNHM, Hungarian Natural History Museum, Budapest, Hungary; IGF, Museo di Storia Naturale, sezione di Geologia e Paleontologia, Florence, Italy; IVPP, Institute of Vertebrate Paleontology

and Paleoanthropology, Chinese Academy of Sciences, Beijing, China; MCEA, Museo Civico "Federico Eusebio" di Alba, Cuneo, Italy; MFGI, Geological and Geophysical Institute of Hungary, Budapest, Hungary; MfN, Museum für Naturkunde, Berlin, Germany; MGGC, Museo di Geologia Giovanni Capellini, Bologna, Italy; MGPP, Museo di Geologia e Paleontologia, Padua, Italy; MNCN, Museo Nacional de Ciencias Naturales, Madrid, Spain; MNHN, Muséum National d'Histoire Naturelle, Paris, France; MFS, Museo Civico di Scienze Naturali, Faenza, Italy; MPP, Museo di Paleontologia, Università di Parma, Parma, Italy; MPPB, Museo di Palazzo Poggi, Bologna, Italy; MPUR, Museo di Paleontologia, Sapienza, Università di Roma, Rome, Italy; MSNAF, Museo di Storia Naturale, Accademia dei Fisiocritici, Siena, Italy; MGPT, Museo di Geologia e Paleontologia dell'Università di Torino, Turin, Italy; NHMUK, Natural History Museum, London, U.K.; NHMW, Naturhistorisches Museum, Wien, Austria; NMB, Naturhistorisches Museum, Basel, Switzerland; BAC, Baccinello collection at NMB; BRS, Monticino Quarry collection at MFS; n.c., no code.

SYSTEMATIC PALAEONTOLOGY

Order Perissodactyla Owen, 1848
Family Rhinocerotidae Gray, 1821
Subfamily Rhinocerotinae Gray, 1821
Tribe Rhinocerotini Gray, 1821

Rhinocerotini indet.

Referred material - An ectoloph fragment of an upper tooth from Monticino Quarry (BRS 1/15); a much worn M2 from Moncucco Torinese (MGPT PU127005); a fragment of an upper tooth (MCEA P00944), a lower premolar (MCEA P00968) and a fragment of a lower molar (MCEA P00912) from Verduno; a damaged tibia from Baccinello V3 "locality 1" (NMB BAC n.c.).

Description - The ectoloph fragment from Monticino Quarry displays a rough enamel; in occlusal view, the posterior profile is concave and a faint mesostyle seems to be present.

The M2 from Moncucco Torinese is much worn and badly preserved. At this stage of wear, the crochet is single and short, the protocone is anteriorly constricted, the paracone fold is faint and the posterior part of the ectoloph is concave.

Among the scanty specimens from Verduno, a worn down lower premolar (probably p3 or p4) displays a well-developed external groove until the neck, a rounded trigonid and lacks the labial cingula.

The tibia from Baccinello V3 lacks the proximal epiphysis whereas the distal one is only slightly damaged. In distal view, the medial part of the articular surface for the astragalus is rectangular in shape with a slightly concave medial border and a convex anterior border. The margin in-between the medial and lateral parts of the articular surface for the astragalus is well marked on its anterior half. The lateral articular surface is elliptical, deeper and smaller than the medial one. In distal view, the posterior border of the distal epiphysis is slightly concave.

Comparison - The morphological characters of the described teeth are not useful for a precise taxonomic attribution being rather common among different taxa, in particular *Dihoplus* and *Stephanorhinus* (Guérin, 1980; Pandolfi, 2013; Pandolfi et al., 2015a).

Postcranial remains of Miocene rhinoceroses are poorly documented with respect to the dental material, the comparison of the tibia is therefore based on a few specimens. Compared with the studied specimen, the tibia of *C. neumayri* displays a wider lateral articular surface for the astragalus, in distal view, and a more squared-shaped and larger medial articular surface. The tibia from Baccinello V3 differs from that of *D. schleiermacheri* which displays a concave posterior border of the distal epiphysis in distal view, a less pronounced margin between the two distal articular surfaces for the astragalus, and a less oblique lateral surface with respect to the posterior border of the distal face. On the tibia of "*D.*" *megarhinus* from Montpellier, the distal margin between the articular surfaces is less antero-distally pronounced, and the medial articular surface is antero-posteriorly shorter than the distal epiphysis. Compared with the specimen from Baccinello V3, the tibia of *D. pikermiensis* displays a less developed margin in-between the distal articular surfaces for the astragalus, a more developed lateral articular surface, a rather concave posterior border of the distal epiphysis in distal view and a less squared medial articular surface. On *S. jeanvireti* the posterior border of the distal epiphysis, in distal view, is concave, the lateral articular surface is less oblique and larger with respect to that of the studied specimen. The tibia of "*S.*" *miguelcrusafonti* is currently unknown, whilst that of *D. douariensis* is represented only by a proximal epiphysis. Accordingly, a comparison with these species is impossible. The tibia from Baccinello V3 is provisionally attributed as Rhinocerotini indet. pending a detailed comparison with much more material.

Genus *Dihoplus* Brandt, 1878

Type species - *Rhinoceros schleiermacheri* Kaup, 1832 from the Late Miocene of Eppelsheim, Germany (Kaup, 1832: tab. X, fig. 1; Giaourtsakis and Heissig, 2004: fig. 1.4).

Other species - "*D.*" *megarhinus* (de Christol, 1834), *D. pikermiensis* (Toula, 1906). *D. ringstroemi* (Arambourg, 1959) is considered a junior synonym of "*D.*" *megarhinus* by Pandolfi et al. (2015a).

"*Dihoplus*" *megarhinus* (de Christol, 1834) (Figs 2-4)

Holotype - MNHN AC2683, skull with mandible described and figured by de Christol (1834: pl. I, figs 5-6, 9-10, 12-13, 18-19, 21, 25-27), and more recently by Guérin (1980: pls 10, 15).

Type locality and horizon - Montpellier (Hérault, France), Early Pliocene.

Referred material - A right maxilla with I1 and P2-M3, an isolated left P2, a fragmentary mandible, a p2-p4 series,

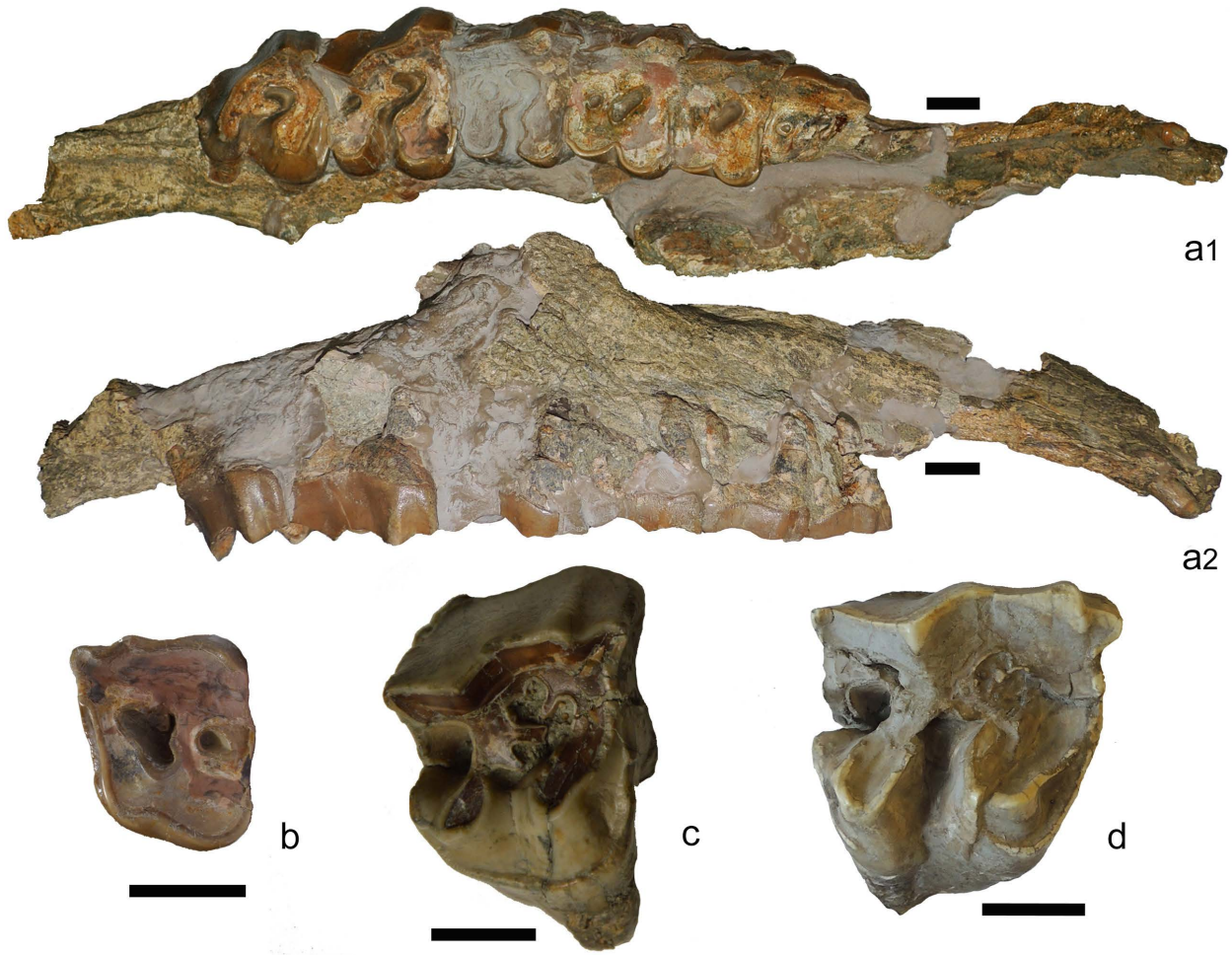

Fig. 2 - (Color online) Upper teeth of "*Dihoplus*" *megarhinus* from Baccinello V3 (a-b) and Monticino Quarry (c-d). a) Right upper maxilla (NMB BAC n.c.) in occlusal (a1) and vestibular (a2) views. b) Left P2 (NMB BAC 1237) in occlusal view. c) Right P4 (MSF 115) in occlusal view. d) Right M2 (cast of MSF 116) in occlusal view. Scale bar = 2 cm.

an isolated p2 and an isolated lower molar from Baccinello V3 locality Cinignano 11 (NMB BAC n.c., 1237, 1240, 1241, 1239, 1238), an isolated P4 and M2 from Monticino Quarry (MFS 115 and MFS 116), an isolated M3 from Moncucco Torinese (MGPT PU127004).

Upper teeth -

Description - The maxillary specimen NMB BAC n.c. from Baccinello V3 (Fig. 2a) retains almost the complete upper toothrow and a small and rounded I1. The P2 is antero-lingually damaged and the M1 is partially reconstructed by gypsum plaster. Labial and lingual cingula are absent on both premolars and molars; a very small lingual cingulum occurs at the base of the median valley on P4. The premolars are much worn down and the presence of metacone fold, crochet, antecrochet and crista cannot be observed. The occlusal profile of the ectoloph on P2 displays an evident paracone fold, the parastyle is large and short, the post-fossette is circular. At this stage of wear, the protocone and hypocone on P3 are lingually joined, as well as on P4. The profile of the ectoloph on P3 is rather straight, the paracone fold is weak and wide, the parastyle is short. The profile of the ectoloph on P4 displays a weak and very wide paracone fold, the parastyle is more developed than on P3. A weak protocone constriction is present on the molars. The M1 is much worn down and partially reconstructed by gypsum plaster. The profile of the ectoloph displays a weak paracone fold and a long parastyle. On M2 the paracone fold is strong and the parastyle is short. The occlusal profile of the ectoloph is wavy with an evident mesostyle and a concave posterior side. The protocone is more developed than the hypocone. A single crochet is present on M2 as well as on M3. The M3 has a triangular outline in occlusal view and displays a well-developed mesial and distal cingulum. The paracone fold is strong, the mesostyle is faint, the parastyle fold is marked and the parastyle is well developed. Crista and antecrochet are absent on both M2 and M3 at this stage of wear.

An isolated left P2 from Baccinello V3 (NMB BAC 1237; Fig. 2b) is morphological similar to that on the maxilla NMB BAC n.c. and probably belongs to the same individual. On this tooth, a mesial cingulum is present, the protocone is less developed than the hypocone, the protoloph is not constricted, a small crista and a very short crochet are present.

An isolated P4 from Monticino Quarry (MFS 115; Fig. 2c) has a rather straight ectoloph profile with a

weak paracone fold, a marked parastyle fold and a short parastyle. The labial cingulum is absent. A continuous mesial and lingual cingulum is present. The protoloph is straight and oblique. The metaloph is constricted, whereas the protocone and the hypocone are joined at their bases. The postfossette is circular. Two cristae and a double crochet are present.

An isolated M2 from Monticino Quarry (MFS 116; Fig. 2d) displays a small paracone fold and a large parastyle. The mestosyle is weak and the posterior profile of the ectoloph is concave. A mesial cingulum is present. The protoloph is slightly constricted, and the metaloph is short. A single crochet and a weak crista are present. The postfossette is elliptical in shape and the posterior cingulum is low and continuous.

An isolated M3 from Moncucco Torinese (MGPT PU127004, Angelone et al., 2011: fig. 5.7; Colombero et al., 2017: fig. 9.2) has a continuous and well-developed mesial cingulum and a distal cingulum. The paracone fold is weak and the parastyle is short. The protocone is slightly constricted. A single crochet is present and a very small antecrochet seems to be present. Considering the scale bar reported on figure 9.2 by Colombero et al. (2017), the anatomical length of the tooth is about 65 mm.

Comparison - The upper teeth of *C. neumayri* differ from the studied specimens by having backwardly bent protolophs, molariform upper premolars and a more wavy profile of the ectoloph in occlusal view (Geraads, 1988; Antoine & Saraç, 2005; Giaourtsakis, 2009; Pandolfi, 2016). The premolars of *D. douariensis* are molariform and have a strong and continuous lingual cingulum, whilst the M1 has a flat lingual side of the protocone which also displays a lingual groove on the type material from Douaria (Guérin, 1966: fig. 8; Giaourtsakis et al., 2009: fig. 14.2 A). In *D. schleiermacheri*, DP1 is present on the upper tooth row, a crista and a pronounced metacone fold occur on the upper premolars, P2 displays an isolated protocone during the early to middle stages of wear, the postfossete is posteriorly opened on P2-M2, and the M3 is relatively small (the anatomical length is between 44.5 and 52.5 mm; Guérin, 1980: tab. 47). A reduced lingual cingulum is usually present on the upper premolars of *D. pikermiensis*; in addition, the metacone fold on the upper premolars is marked and a protocone constriction is evident on M1-M2. The M2 of "*S.*" *miguelcrusafonti* displays a well-developed crochet and a crista and a rather pronounced mesostyle; the M1 has traces of a lingual cingulum, the protocone constriction is stronger than in "*D.*" *megarhinus*, and the posterior part of the ectoloph is markedly concave, whereas the P3 displays a separated protocone and hypocone, a lingual cingulum, double crochet, a crista with accessory folds and a wide post-fossette (Guérin & Santafé-Llopis, 1978). *S. jeanvireti* has protocone separated from the hypocone on P2 (Guérin, 1972, 1980; Guérin & Tsoukala, 2013: figs 5-7), the paracone fold is less developed and the profile of the ectoloph is less wavy than in the studied specimens. In "*D.*" *megarhinus* from China (Henan, Shanxi and Gansu provincies; Ringström, 1924; Deng, 2006; Pandolfi et al., 2015a) and Hungary (Kávás; Pandolfi et al., 2015a), as in the studied specimens, the lingual cingulum is absent on the upper premolars, P1 is absent and the protocone is less developed than the hypocone on P2 (Ringström, 1924: figs 1-2; Deng, 2006: fig. 3; Pandolfi et al., 2015a). In the cheek teeth from Lens Lestang (cast housed at NHMUK and NMB; Falconer, 1868), as well as in the studied material, the postfossette is small and rounded on the teeth, the protocone is less developed than the hypocone on P2, the P3 and P4 have a rather squared shape, and the protocone is weakly constricted on the molars. Nevertheless, in the skull from Lens Lestang a small crista occurs on the left M3 and a reduced lingual cingulum is evident on the upper premolars, whereas it occurs only on P4 of the maxilla from Baccinello V3. On the teeth from Saint-Laurent, the lingual cingulum is absent on the premolars (Guérin et al., 1969: p. 111). The upper teeth of the type skull of "*D.*" *megarhinus* from Montpellier are quite similar to those from Lens Lestang and Kávás but they also display some advanced features: the crochet on P3 is slightly more developed than on the Miocene specimens, a weak crista occurs on P3 and P4, the crochet is replaced by three weak enamel folds on P4 and a weak crista occurs on M2 (Guérin, 1980: pls 10, 15). Similar advanced features are evident on the isolated teeth from Monticino Quarry. The presence of the lingual cingulum on the upper premolars is a variable character on the specimens from Montpellier (Guérin et al., 1969: p. 112). Thirty-seven isolated teeth from Montpellier (Appendix) are morphologically similar to those from Lens Lestang, Kávás and Baccinello V3 (Appendix), but a few of them, as in the case of the specimens from Monticino Quarry, display some variation in other characters: a crista is present on two P3, a weak metacone fold is evident on one P4, a weak double crochet occurs on one M2, a weak crista occurs on three M2 and on two M3. The rudimentary I1 preserved on the specimen from Baccinello V3 is small and rounded, morphologically very similar to those observed in *D. pikermiensis* (Giaourtsakis et al., 2006; Giaourtsakis, 2009).

The dimensions of the upper teeth from Baccinello V3 and Monticino Quarry falls within the range values of the Pliocene "*D.*" *megarhinus* or are slightly smaller (Tab. 1).

Mandible -

Description - The fragment of the horizontal ramus from Baccinello V3 (Fig. 3a) preserves the alveoli of p4-m3. The height of the ramus gradually decreases below the premolars. The ventral border is rather straight and slightly curved upwards under p2-p3.

Comparison - The mandible of *C. neumayri* displays a slightly convex lower border of the horizontal ramus, which inclines abruptly upwards below the premolars, as well as in *D. douariensis* (Pandolfi et al., 2015a: fig. 5). In *D. schleiermacheri* the ventral border of the horizontal ramus is regularly straight and is influenced by the presence of well-developed lower incisors (Pandolfi et al., 2015a: fig. 5). In the studied mandible of *D. pikermiensis* the ventral border is regularly convex. *S. jeanvireti* has a relatively less high horizontal ramus beneath the molars with respect to the studied specimen. As in the specimen from Baccinello V3, the ventral border of the horizontal ramus of the mandible of "*D.*" *megarhinus* from Saint-Laurent is rather straight and the height of

Measurement	Baccinello V3 (NMB BAC n.c.)	Baccinello V3 (NMB BAC 1237)	Monticino Quarry (MFS 115)	Monticino Quarry (MFS 116)	Lens Lestang (NHMUK M40834)	western Europe
L P2-M3	(257)				264.74	255-274
L P2-P4	(115)				118.09	105.5-128
L M1-M3	(149)				156.1	142-162.5
P2 LxB		33.55x44.14				35-40x40-46
P3 LxB	38.9x47.9					39.5-48x48-59
P4 LxB	43.1x54.3		44.5x54.9			43-51x53-67
M1 LxB	(58x55)					49-64x55.5-70
M2 LxB	58.3			58.47x61.77		53.5-65.5x59.5-73
M3 LxB	58.6					57-65.5x56-66

Tab. 1 - Measurements (in mm) of the upper teeth of "*Dihoplus*" *megarhinus* from Baccinello V3 and Monticino Quarry (latest Miocene, Italy) compared with those of "*D.*" *megarhinus* from Lens Lestang (Pliocene, France), and from several Pliocene localities of western Europe (from Guérin, 1980). L = length; LxB = length and breadth.

the horizontal ramus decreases below the premolars (Guérin et al., 1969: p. 99, fig. 8, p. 107, fig. 13). The mandibles of "*D.*" *megarhinus* from Kávás (Pandolfi et al., 2015a: fig. 5), Montpellier (NHMUK M40805 and NMB various specimens) and from other Italian localities (e.g., Palaia: Pandolfi, 2013) have a straight ventral border of the horizontal ramus beneath the molars, which curves gradually under the premolars and towards the symphysis.

Lower teeth -

Description - On the specimen from Baccinello V3, the lower toothrow is represented by p2-p4 (Fig. 3b). Labial and lingual cingula are absent on all the teeth, as well as any external rugosities. On p3-p4, the external groove is wide, U-shaped and developed until the neck and the paralophid reaches the lingual rim. The metaconid and the entoconid are not constricted at this stage of wear. The morphology of the lingual valleys cannot be observed because the teeth are worn down. On p2, the paralophid is straight, without constriction, and the paraconid is developed.

The isolated p2 (NMB BAC 1239) displays the same characters described for the previous specimen.

The isolated lower molar (probably m1; Fig. 3c) lacks lingual and labial cingula; the external groove is V-shaped and developed until the neck; the trigonid is angular; the metaconid and the entoconid are not constricted, the anterior and posterior lingual valleys are V-shaped and the difference in height between the bottoms of the valleys is relatively high. A small distal cingulum is also present.

The isolated m3 from Monticino Quarry (MSF BSR1/14; Fig. 3d), in occlusal view, has an angular trigonid; the external groove is developed and reaches the neck. The mesial cingulum reaches the anterior labial side of the trigonid. A small distal cingulum is also present. The posterior lingual valley has a broad V-shape.

Comparison - The morphology of the lower teeth is quite conservative in Late Miocene and Pliocene Rhinocerotini (Pandolfi et al., 2015a). Nevertheless, the lower teeth of *C. neumayri* are rather hypsodont with respect to those of the studied material. The presence of p1 is reported on the unique know mandible of *D. douariensis* (Guérin, 1966) and the external groove is less deep on the lower teeth with respect to that of the studied specimens. The lower teeth of "*D.*" *megarhinus* from Montpellier display the same characters described for the studied specimens. Lingual and labial cingula are absent on the lower premolars of *D. schleiermacheri* and of *D. pikermiensis* (NHMUK). On *D. schleiermacheri* the external groove is narrower and less deep at the base of the premolars with respect to the specimens from Baccinello V3. Compared with the tooth from Monticino Quarry, the m3s of *D. schleiermacheri* display a more rounded trigonid and a less oblique occlusal surface of the talonid; the latter character can be also observed on *D. pikermiensis*. The external grooves on the premolars of *D. pikermiensis* are narrower and less deep than in the studied specimens and the entoconid is smaller and slightly constricted. The lower teeth of "*S.*" *miguelcrusafonti* lacks of labial and lingual cingula. An isolated lower molar (probably m1) from Layna (MNCN) displays a similar stage of wear with the specimen from Baccinello V3 but differs from it by having a short and slightly constricted paralophid, broader lingual valleys and by lacking the distal cingulum. On *S. jeanvireti* from Monte San Pietro (MGGC) and Capannoli (IGF) the occlusal surface of m3 displays a more rounded talonid and a more oblique ectolophid with respect to that from Monticino Quarry. In addition, the premolars of *S. jeanvireti* from Monte San Pietro, as well as those from Monte Pulgnasco (MGGC), have a narrower external groove with respect to the specimens from Baccinello V3. On the lower teeth of *S. jeanvireti* from Montopoli (IGF) the external groove is also narrow and does not reach the base of the crown.

The dimensions of the lower teeth from Baccinello V3 and Monticino Quarry fall within the range values of the Pliocene "*D.*" *megarhinus* (Tab. 2).

Scaphoid -

Description - The anterior side of the scaphoid from Monticino Quarry (MSF BRS1/n.c.; Fig. 4) is partially damaged. In medial view, the posterior border of the bone is rather undulated, whereas the anterior one appears convex in its proximal half. The anterior tuberosity is well developed and its distal border is placed far from the anterior border of the distal articular surface. The postero-proximal tuberosity is well developed. In medial view,

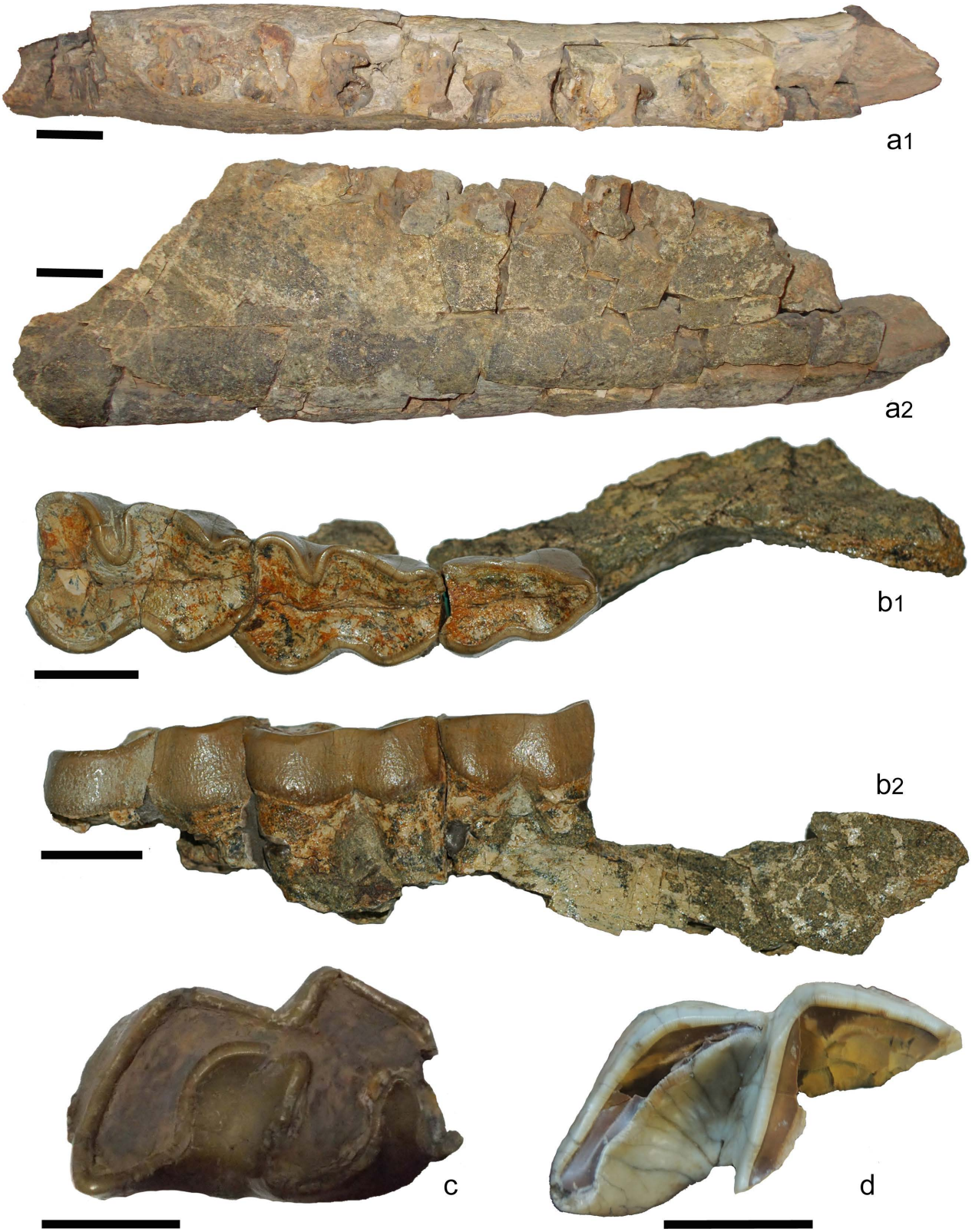

Fig. 3 - (Color online) Mandible and lower teeth of "*Dihoplus*" *megarhinus* from Baccinello V3 (a-c) and Monticino Quarry (d). a) Right fragmentary horizontal ramus (NMB BAC 1240) in dorsal (a1) and lateral (a2) views. b) Right p2-p4 (NMB BAC 1241) in occlusal (b1) and vestibular (b2) views. c) Left lower molar (NMB BAC 1238) in occlusal view. d) Left m3 (MSF BSR1/14) in occlusal view. Scale bar = 2 cm.

the proximal articular surface for the radius is regularly concave; in dorsal view, it is trapezoidal in shape and transversally covers the proximal face of the bone.

Comparison - The schapoid of *C. neumayri* (NHMW) is shorter compared to the studied material; the anterior tuberosity is regularly convex and the posterior half of the

Measurement	Baccinello V3 (NMB BAC 1241)	Baccinello V3 (NMB BAC 1239)	Baccinello V3 (NMB BAC 1238)	Monticino Quarry (BSR1/14)	Val di Pugna and Palaia	Montpellier (NHMUK M40805)	Montpellier (NMB MP1031)	western Europe
L p2-p4	105.43				106.63	118.14	(116)	101-136
p2 LxB	31.37x19.65	31.52x20.30			28.6-31.88x17.92-19.05			29.5-43x16.5-25
p3 LxB	42x30				37.6-40.05x24.6-25.83			35-44x22-31.5
p4 LxB	47x33.8				39.41-42.52x28.7-30.51			37.5-48x27.5-38
m1 LxB			(?)x34.2		44.22-48.85xca. 29.6-32.2			38.5-53x29-40
m3 LxB				54.92x28.94	49.12x35			48-62x29.5-37

Tab. 2 - Measurements (in mm) of lower teeth of "*Dihoplus*" *megarhinus* from Baccinello V3 and Monticino Quarry (latest Miocene, Italy), compared with those of "*D.*" *megarhinus* from Val di Pugna and Palaia (Early Pliocene, Italy: from Pandolfi, 2013), Montpellier (Early Pliocene, France), and from several Pliocene localities of western Europe (from Guérin, 1980). L = length; LxB = length and breadth.

bone, in medial view, is less massive. The scaphoid of *D. schleiermacheri* from Eppelsheim (NHMUK 1281) differs from the studied specimen in being shorter and smaller, in having, in medial view, a less developed anterior tuberosity. The scaphoid of "*S.*" *miguelcrusafonti* differs from that of Monticino Quarry in having, in medial view, a larger and higher distal articular surface, a less concave proximal articular surface and the anterior tuberosity very close to the anterior border of the distal articular surface (Guérin, 1980: fig. 63B). The scaphoid of *S. jeanvireti* resembles that from Monticino Quarry, but it displays a regularly convex anterior border in medial view, a less developed postero-proximal tuberosity and a less developed proximal articular surface transversally. The scaphoid from Monticino Quarry resembles those of "*D.*" *megarhinus* from Montpellier (NMB) in the morphology of the anterior tuberosity, of the proximal articular surface and in the development of the distal articular surface.

Fig. 4 - (Color online) Scaphoid (MSF BRS1/n.c.) of "*Dihoplus*" *megarhinus* from Monticino Quarry in dorsal (a) and medial (b) views. Scale bar = 2 cm.

CONCLUSIONS

The occurrence of "*D.*" *megarhinus* is reported from three latest Turolian (MN 13) localities of Italy, Moncucco Torinese, Baccinello V3 and Monticino Quarry, supporting the presence of this taxon during the latest Miocene in Europe. The possible occurrence of "*D.*" *megarhinus* at Baccinello V3 was firstly discussed by Hürzeler & Engesser (1976) based on a fragmentary tibia, but the latter specimen was later referred to the African species *D.* cf. *douariensis* by Guérin (2003). Nevertheless, the tibia from Baccinello V3 lacks the proximal epiphysis and a comparison with that of *D. douariensis* from Douaria (only a proximal epiphysis is preserved) is not possible. Following Pandolfi (2013), the tibia from Baccinello V3 is quite different from those of "*D.*" *megarhinus* from Montpellier and therefore is here referred to as Rhinocerotini indet. The presence of "*D.*" *megarhinus* at Baccinello V3 is however documented by several dental specimens. The teeth from Monticino Quarry share several morphological features with "*D.*" *megarhinus*, but also display some advanced characters that are not observed in the latest Turolian specimens from Baccinello V3, Kávás and other localities. These characters (e.g., presence of crista, double crochet on P4) are instead reported in a few teeth from the Early Pliocene locality of Montpellier. The variation in these characters may represent the expected morphological variability of the taxon, or they could indicate a different evolutionary stage within the same species. Nevertheless, further material would be required to investigate this issue.

The occurrence of "*D.*" *megarhinus* at Baccinello V3, as well as that of other taxa, marks the disappearance of the endemic faunal complex in the Baccinello-Cinigiano Basin, the definitive connection of the area with Europe and the diffusion of several non-endemic species

(Rook, 2016). At Moncucco Torinese, "*D.*" *megarhinus* is accompanied by taxa of clearly eastern European origin such as *Prolagus sorbinii* and *Hansdebruijnia* sp. (Angelone et al., 2011), whilst at Baccinello V3 and Monticino Quarry the rhinoceros is accompanied by the genus *Hippotherium* (Bernor et al., 2011; Rook & Bernor, 2013), which probably spread in Italy from the Pannonian Basin. Based on the currently known record of "*D.*" *megarhinus*, a dispersal pattern from the Pannonian Basin towards the Italian Peninsula during MN 13 can be hypothesized. The species is indeed recorded from Hungarian Late Miocene localities, at Baltavár (MN 12), at Kávás (around 7 Ma; MN 12-MN 13 transition) and probably at Polgárdi (MN 12 or 13) (Pandolfi et al., 2015a, 2016), which are slightly older than the Italian localities mentioned in this work (referred to MN 13). During the Pliocene (MN 14 and MN 15) "*D.*" *megarhinus* occured in several Italian (e.g., Val di Pugna, Monte Giogo, Monte Biancano; Pandolfi, 2013) and Hungarian localities (e.g., Gödöllö, Mogyoród; Pandolfi & Gasparik, unpubl. data) as well as elsewhere in Europe, including France (e.g., Montpellier; MN 14) and Turkey (e.g., Çalta; MN 15) (Guérin, 1980; Guérin & Sen, 1998). The presence of "*D.*" *megarhinus* in the Iberian Peninsula has been recorded only from the Girona Province (at Maia de Montcal, Cornellà de Terri y Sords and Molins de Rei; Guérin, 1980; García Fernández, 2000), but it needs to be confirmed by a careful revision and by further and diagnostic material. The species is not reported among the Spanish Neogene rhinoceroses listed by Cerdeño (1992), who suggested that "*S.*" *miguelcrusafonti* could possibly become a subspecies of "*D.*" *megarhinus* or could be confirmed as a different species pending the discovery of more specimens. "*Stephanorhinus*" *miguelcrusafonti*, which is provisionally retained within the genus *Stephanorhinus* although cranial remains of this species are unknown and its systematic position appears questionable, has been defined on a few postcranial remains and isolated teeth collected from the Pliocene Spanish locality of Layna (Guérin & Santafé-Llopis, 1978) and it has been also recognized at La Calera (Spain; Cerdeño, 1992), Alcalá del Júcar (Spain; Mazo, 1997) and at Perpignan (France; Guérin & Santafé-Llopis, 1978). A careful revision of these specimens would be helpful to clarify the paleobiogeographic setting and the rhinoceros distributions in Europe at the beginning of the Pliocene.

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APPENDIX

Source for comparison rhinoceros material

Taxon	Direct Observation	Locality	References
"*Dihoplus*" *megarhinus*	NHMUK, NMB	Lens Lestang, Millas, Montpellier, Saint-Laurens (France)	Gervais, 1851; Falconer, 1868; Maurette, 1910; Guérin et al., 1969; Guérin, 1980
"*Dihoplus*" *megarhinus*	IGF, MGGC, MPP, MPPB, MSNAF, NMB	Baccinello, Monte Giogo, Monte Zago, Rio Secco, Val di Pugna-Fangonero, Valdarno Inferiore (Italy)	Azzaroli, 1962; Guérin, 1980; Pandolfi, 2013
"*Dihoplus*" *megarhinus*	BSPG, IVPP	Honnan, Linxia (China)	Ringström, 1924; Deng, 2006; Pandolfi et al., 2015
"*Stephanorhinus*" *miguelcrusafonti*	MNCN	Layna (Spain)	Guérin & Santafé-Llopis, 1978; Guérin, 1980
Stephanorhinus jeanvireti	NMB	Perrier-Les Étouaires, Vialette (France)	Guérin, 1972, 1980
Stephanorhinus jeanvireti	IGF, MGGC, NMB	Dusino, Monte Pastore, Monte Pugnalsco, Monte San Pietro, Montopoli, Pradalbino, Villafranca d'Asti (Italy)	Guérin, 1972, 1980; Pandolfi, 2013
Dihoplus schleiermacheri	HNHM, MFGI, MfN, MNCN, NHMUK, NHMW, NMB	Eppelsheim (Germany), Pannonian Basin (Hungary, various localities), Vienna Basin (Austria, various localities), Venta del Moro (Spain)	Guérin, 1980; Cerdeño, 1992
Dihoplus pikermiensis	NHMUK, NHMW	Pikermi, Samos, Kerassia (Greece)	Geraads, 1988; Giaourtsakis, 2003, 2009; Giaourtsakis et al., 2006
Ceratotherium neumayri	NHMUK, NHMW	Pikermi, Samos, Kerassia (Greece)	Guérin, 1980; Geraads, 1988, 2005; Giaourtsakis et al., 2006; Giaourtsakis, 2009;
Ceratotherium neumayri	NHMW	Anatolia (Turkey, various localities), Maragha (Iran)	Geraads, 1988, 1994; Antoine & Saraç, 2005
Diceros douariensis		Douaria (Tunisia), Middle Awash (Ethiopia)	Guérin, 1966; Giaourtsakis et al., 2009