

# New and revised occurrences of *Dihoplus megarhinus* (Mammalia, Rhinocerotidae) in the Pliocene of Italy

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**Abstract** Several rhinoceros remains, collected in the Pliocene deposits of Northern Italy and usually ascribed to *Dicerorhinus* or *Rhinoceros megarhinus*, are revised; furthermore, unpublished Pliocene remains are also described. The material is compared with the respective anatomical elements of *Dihoplus megarhinus*, *Stephanorhinus jeanvireti* and *Stephanorhinus etruscus*. Based on morphological and morphometrical comparisons, the presence of *Dihoplus megarhinus* is confirmed in at least ten sites. In other Late Pliocene fossiliferous localities, the presence of *S. jeanvireti* and/or *S. etruscus* is recorded. *D. megarhinus* occurred in Italy at the beginning of the Early Pliocene. It was well represented in Val di Pugna (Tuscany) and in several Pliocene marine deposits near Bologna by fragmentary mandibles, some postcranial remains and few teeth. The species disappeared before the beginning of the Villafranchian (Late Pliocene) when *S. jeanvireti* and *S. etruscus* co-occurred both in the site of Villafranca d’Asti and Montopoli. *S. jeanvireti* disappeared in Italy at the Pliocene–Early Pleistocene transition whereas *S. etruscus* was widespread in Central and Southern Italy.

**Keywords** Rhinocerotidae · *Dihoplus* · *Stephanorhinus* · Pliocene · Italy

## Introduction

The taxonomy of the European Plio–Pleistocene rhinoceroses is still debated. Guérin (1980, 1982, 2004) assigned

them, with the exception of the species of the genera *Coelodonta* and *Elasmotherium*, to the genus *Dicerorhinus* (abbrev. *Di.*) and the species *Di. megarhinus* to the subgenus *Dicerorhinus*, the species *Di. miguelcrusafonti* to an indeterminate subgenus and the other species to the subgenus *Brandtorhinus*. Genus *Stephanorhinus* was ascribed by Fortelius et al. (1993) to the species *S. megarhinus*, *S. jeanvireti*, *S. etruscus*, *S. hundsheimensis* (partially identified to *Dicerorhinus etruscus brachycephalus* in Guérin 1980), *S. hemitoechus* and *S. kirchbergensis* (= *Dicerorhinus mercki* in Guérin 1980). Later, Cerdeño (1995) included the species *S. miguelcrusafonti* in this genus. Moreover, Heissig (1999) supposed a long European lineage from the Miocene *Dihoplus schleiermachersi* to the Pliocene *D. megarhinus* which was included in this genus also by Lacombat and Mörs (2008). Recently, Deng et al. (2011) ascribed the species *D. megarhinus* to the genus *Dihoplus*, together with the Miocene species *D. ringstromi* and *D. pikermiensis*; however, *D. schleiermachersi*, the type species of the genus, was not included in their analysis.

During the Pliocene, four species of rhinoceros were present in Europe: *D. megarhinus*, “*S.*” *miguelcrusafonti*, *S. jeanvireti* and *S. etruscus*.

*D. megarhinus* was named by De Christol (1834) and it is recorded from several Pliocene sites of Western Europe (Spain, France, Italy, Belgium and Germany), in Romania, Poland and Turkey (Guérin 1980; Guérin and Sen 1998). Recently, it was also reported in the Late Pliocene site of Udunga (Transbaikalia, Russia) (Fukuchi et al. 2009). “*S.*” *miguelcrusafonti* has a very restricted geographic and chronological distribution and it was recovered in few Spanish sites and in one French site (Guérin 1980; Cerdeño 1989). The latter species was described by Guérin and Santafé-Llopis (1978) based on few teeth, a fragmentary

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mandible and several postcranial remains. Unfortunately, skulls and complete mandibles are still unknown and the systematic position of the species appears problematic. Morphologically, the species appears to be close to *D. megarhinus* and the differences between them are minor. *S. jeanvireti* was a slender, medium-large-sized rhino with brachydont teeth (Guérin 1972, 1980). It is the oldest true species of the genus *Stephanorhinus* and it was present in Europe during the Late Pliocene. During this time, it co-occurs with the small *S. etruscus* (Guérin 1980; Lacombat and Mörs 2008). The morphological and morphometrical differences between *D. megarhinus* and *S. jeanvireti* are obvious in the skull but less in postcranial remains. On the contrary, *D. megarhinus* appears to be easily distinguishable from *S. etruscus*.

The aim of this paper is to provide a comprehensive updated overview of the knowledge of *Dihoplus megarhinus* in Italy with a revision of the Pliocene records and their palaeobiogeographic and biochronological implications.

## Materials and methods

The revised Quaternary time scale (Gibbard et al. 2010) for chronological references is used in this text; the Pliocene then spans approximately the period between 5.4 and 2.6 Ma.

This work is based on the fossil material stored in the following Institutions: Natural History Museum, Section of Geology and Paleontology, Florence (Florence) (MGPF), Museum of Geology G. Capellini (Bologna) (MGC), Natural History Museum Basel (Basel) (NMB), Natural History Museum, Fisiocritici Academy, Siena (Siena) (MSNAF) and Paleontological Museum, Sapienza University of Rome (Rome) (MPUR). The rhinoceros remains consist of isolated teeth, mandibles, a pelvis and several limb bones; a list of the revised remains is reported in Table 1. The majority of the studied specimens were described and partially figured by Cuvier (1822), De Christol (1834), Falconer (1868), Capellini (1894, 1913), Simonelli (1897, 1919), Sacco (1906), Cusani Politi (1963a, b, 1973, 1977) and Azzaroli (1962). Guérin (1980) included part of this material in his work and listed the fossiliferous Pliocene localities in which rhinoceros remains have been recovered. However, the specific attribution given by Guérin (1980) was not fully accepted in the literature (e.g. Fortelius et al. 1993; Bianucci et al. 2001).

The Pliocene sites in which the studied specimens have been recovered are located in Northern Italy (Northern Tuscany, near Bologna and Piacenza and in Piedmont) (Fig. 1). The remains have been usually found in marine deposits chronologically referred to the Early Pliocene (e.g.

Val di Pugna, referred to the European Neogene Mammal Fauna Zone 14; Bianucci et al. 2001) or in continental deposits chronologically related to the Late Pliocene/earliest Early Pleistocene (MN 15 and 16) (e.g. Montopoli, Barga Basin, Monte Tiffi) (Azzaroli 1973; Kotsakis 1986; Coltorti et al. 2008). Unfortunately, the fossiliferous levels in which several rhino remains have been collected are unknown or have an uncertain chronostratigraphic position. However, the Pliocene localities in which remains have been discovered are generally referred to the Early or early Late Pliocene (Ruscinian Mammal Age, MN14–15) (e.g. Montelungo, Colle della Casazza and other) (Kotsakis 1986 and references therein; Kotsakis et al. 1997).

For the morphological comparison of the fossil specimens, different remains from Pliocene and Early Pleistocene European sites are taken into account. In particular, the material of *D. megarhinus* from Montpellier and Lens-Lestang stored at NMB, of *S. jeanvireti* from Viale and Villafranca d'Asti stored at NMB and of *S. etruscus* from St. Vallier stored at NMB, from the Upper Valdarno stored at NMB and MGPF and from Capitone stored at MPUR have been considered. Furthermore, figures and descriptions reported by several authors are taken into account (in particular: De Christol 1834; Falconer 1868; Sacco 1895, 1906; Simonelli 1897; Guérin et al. 1969; Guérin and Santafé-Llopiés 1978; Guérin 1972, 1980).

The morphometric methodology is based on the work of Guérin (1980), Fortelius et al. (1993) and Lacombat (2005). Ratio diagrams are made using data on extant *Diceros bicornis* (data from Guérin 1980) as a reference.

## Systematic palaeontology

Order Perissodactyla OWEN, 1848

Family Rhinocerotidae GRAY, 1821

Genus *Dihoplus* Brandt, 1878

*Type species* *Rhinoceros schleiermacheri* Kaup, 1832 from Eppelsheim, Late Miocene.

*Other species* *Dihoplus megarhinus* (De Christol 1834), *Dihoplus pikermiensis* (Toula 1906), *Dihoplus ringstroemi* (Arambourg 1959).

*Diagnosis* (description from Brandt 1878; Geraads and Spassov 2009) Two-horned rhino. Occipital crest relatively high and large. Nasal bones relatively wide and thick. Posterior end of the nasal notch short and rounded. Post-glenoid apophysis close to the post-tympanic one. First upper premolar absent. Presence of second lower incisors.

*Species* *Dihoplus megarhinus* (De Christol 1834)

**Table 1** Revised list of rhinoceros specimens from the Pliocene of Italy

Institution	Specimen or reference	Anatomical element	Site	Age	Taxonomy
MSNAF	MSNAF4743	Fragmentary mandible	Val di Pugna, Fangonero-Bucca	Early Pliocene	<i>D. megarhinus</i>
MSNAF	MSNAF4747	Fragmentary mandible	Val di Pugna, Fangonero-Bucca	Early Pliocene	<i>D. megarhinus</i>
MSNAF	MSNAF4555	Fragmentary upper molar	Val di Pugna, Fangonero-Bucca	Early Pliocene	cf. <i>D. megarhinus</i>
MSNAF	MSNAF7100	Fragmentary humerus	Val di Pugna, Fangonero-Bucca	Early Pliocene	<i>D. megarhinus</i>
MSNAF	MSNAF7101	Fragmentary humerus	Val di Pugna, Fangonero-Bucca	Early Pliocene	<i>D. megarhinus</i>
MSNAF	MSNAF4754	Fragmentary radius	Val di Pugna, Fangonero-Bucca	Early Pliocene	cf. <i>D. megarhinus</i>
MGPF	IGF5957v	Fragmentary mandible	Pliocene of Siena	Early Pliocene	<i>D. megarhinus</i>
MSNAF	MSNAF4531	Calcaneum	Senese	Early Pliocene	<i>D. megarhinus</i>
MSNAF	MSNAF4761	Second and third lower premolars	Val di Pugna- Montarioso	Early Pliocene	<i>D. megarhinus</i>
MSNAF	MSNAF7000	First upper molar	Val di Pugna- Montarioso	Early Pliocene	<i>D. megarhinus</i>
MSNAF	MSNAF7100	First upper molar	Val di Pugna- Montarioso	Early Pliocene	<i>D. megarhinus</i>
MGC	MGC1870	Fragmentary humerus	Colle della Casazza	Early Pliocene	<i>D. megarhinus</i>
MGPT	Sacco 1906, Tav. I figs. 1 and 2	First and second molars and fourth premolar	Dusino-San Paolo, lower levels	Early Pliocene	<i>D. megarhinus</i>
MGC	MGC sn (cast)	Upper molar	Montelungo	Early Pliocene	<i>D. megarhinus</i>
MPPB	MPPB sn	Fragmentary mandible	Monte Biancano	Early Pliocene	<i>D. megarhinus</i>
MPP	Simonelli 1898, pp 91- 112, Tav. X, XI, XII, XII	Several bones, teeth and a fragmentary mandible	Monte Giogo	Early Pliocene	<i>D. megarhinus</i>
MGC and MGPF	MGC9352, IGF4684 (cast)	Fragmentary mandible	Monte Pulgasco	Pliocene	<i>S. jeanvireti</i>
	Cuvier 1823, Pl. 47, fig. 7; Falconer 1868, pp 381–390	Skull and mandible	Montezago	Early Pliocene	<i>D. megarhinus</i>
MGPF	IGF5566v	Nasal bone	Palaia	Early Pliocene	<i>D. megarhinus</i>
MGPF	IGF13091	Fragmentary mandible	Palaia	Early Pliocene	<i>D. megarhinus</i>
MGC	MGC sn	Astragalus	Pradalbino	Pliocene	<i>S. jeanvireti</i>
MGC	MGC9350	Fragmentary pelvis	Rio Secco	Early Pliocene	<i>D. megarhinus</i>
MSNP	Azzaroli 1962, Tav. VII fig. 3, tav. XI fig. 5	Fragmentary mandible	S. Regolo	Pliocene	cf. <i>D. megarhinus</i>
MGC	MGC7584	Lower molar	Barga Basin	Late Pliocene	Rhinocerotini indet.
MSNP	Ugolini 1918, Tav. XIII	Maxillae	Barga Basin	Late Pliocene	<i>S. etruscus</i>
MGC	MGC sn	Fragmentary nasal bones	Costa Marenga	Late Pliocene	<i>S. etruscus</i>
MGPF	IGF1450v	Fragmentary mandible	Lucardo (near Montopoli)	Late Pliocene	<i>Stephanorhinus</i> sp.
MGC	MGC sn	Proximal and distal epiphysis of humerus	Monte Pastore	Late Pliocene	<i>S. jeanvireti</i>
MGC	MGC9354	Mandible	Monte San Pietro	Late Pliocene	<i>S. jeanvireti</i>
MGPF	IGF1452v	Astragalus	Montopoli	Late Pliocene	<i>S. etruscus</i>
MGPF	IGF4688v	Fragmentary metatarsus	Montopoli	Late Pliocene	<i>S. cf. etruscus</i>
MGPF	IGF1075	Lower cheek teeth and four limbs.	Montopoli	Late Pliocene	<i>S. jeanvireti</i>
MGPF	IGF14869	Fragmentary skull	Montopoli	Late Pliocene	<i>S. jeanvireti</i>
MGPF	IGF1449v	Fragmentary mandible	Capannoli	Late Pliocene	<i>S. jeanvireti</i>

**Table 1** continued

Institution	Specimen or reference	Anatomical element	Site	Age	Taxonomy
MGC	MGC sn	Fragmentary astragalus	Monte Tiffi	Late Pliocene	<i>Stephanorhinus</i> sp.
MGC	MGC sn	Fourth lower premolar	Sarzanello	Late Pliocene	Rhinocerotini indet.

MSNAF, Natural History Museum, Fisiocritici Academy, Siena; MGPF Natural History Museum, section of Geology and Paleontology, Florence; MGC Museum of Geology G. Capellini, Bologna; MPPB Museum of Palazzo Poggi, Bologna; MPP Paleontological Museum, University of Parma; MSNP Natural History Museum, University of Pisa; MGPT Museum of Geology and Paleontology, University of Turin



**Fig. 1** Location of the Pliocene fossiliferous localities cited in the text: Dusino-San Paolo and Villafranca d'Asti (1); Montezago, Monte Giogo and Monte Pulgnasco (2); Costa Marenga (3); Colle della Casazza, Monte Bianco, Montelungo, Monte Pastore, Rio Secco, Pradalbino and Monte San Pietro (4); Monte Tiffi (5); Sarzanello (6); Barga Basin (7); Lower Valdarno (various localities including Montopoli, Palaia, Lucardo, S. Regolo and Capannoli) (8); Val di Pugna (9)

*Synonymy list* 1820 *Rhinoceros cuvieri*, Desmarest, 402, 546

1822 *Rhinoceros leptorhinus* Cuvier, 71–85, 88, 93, pl. IX, X, XI

1822 *Rhinoceros leptorhinus* Cuvier, 71–85, 88, 93, pl. IX, X, XI

1867 *Ceratorhinus monspellianus* Gray, 1023

1878 *Atelodus (Mesorhinoceros) leptorhinus* Brandt, 59

1894 *Rhinoceros megarhinus* Capellini, 8–13, pl. I, II see Guérin et al. (1969) for a more complete synonymy list.

*Type material* Skull with mandible (n° AC 2683) described and figured by De Christol (1834) stored at Natural History Museum Paris.

*Type horizon* Early Pliocene.

*Type locality* Montpellier (Hérault, France).

*Diagnosis* (following De Christol 1834; Guérin 1980) Large-sized two-horned rhino characterized by a massive skull with thick and long nasal bones, by the absence of a nasal septum, by a slightly vertical occipital face, and by a large occipital crest with a slight concavity in the middle. The mandible has a long symphysis and long horizontal ramus. The anterior border of the vertical ramus is inclined backwards. Non-functional but obvious lower incisors are present. Long bones are massive and large, third metapodials are long and flat.

*Remarks* *D. megarhinus* has generally been referred to the genus *Dicerorhinus*, represented by the extant species *Di. sumatrensis*. The latter species shows several primitive characteristics also recognized in the fossil species. However, *Di. sumatrensis* differs from *D. megarhinus* in its smaller size, shorter nasal bones, concave lower margin of the nasal bones, in a generally more posterior position of the upper tooth-row and consequently in a different position of the posterior border of the nasal notch, of the infra-orbital foramen and the anterior border of the orbital cavity, in the presence of a marked metacone style in the upper premolars, in the absence of crista and, generally, of the crochet in the upper premolars.

*Referred material* The material includes fragmentary mandibles and fragmentary post-cranial elements collected in several localities of Val di Pugna (MSNAF), isolated teeth from Dusino-San Paolo (MGPT) and Montelungo (MGC), fragmentary mandibles from Monte Bianco (MPPB), Palaia and S. Regolo (MGPF) and several other remains collected at Montezago, Rio Secco (MGC), Colle della Casazza (MGC), Monte Giogo (MPP) and Palaia (MGPF) (Table 1).

## Description and comparison

*Val di Pugna, Fangonero-Buca and Montarioso (Siena, Tuscany)*

Several remains of rhino have been recovered at Fangonero-Buca and other localities of Val di Pugna. The fossiliferous level was chronologically correlated to the Early Pliocene (MN14) and the rhinoceros remains were referred to *Rhinoceros* or *Dicerorhinus megarhinus* by Cuscani Politi (1963b, 1973, 1977) and Guérin (1980). Some of these specimens were referred to *S. jeanvireti* by Bianucci et al. (2001).

A fragmentary mandible with P4/, M1/ and M2/ (MSNAF4743; Figs. 2, 3; Tables 2, 3, 4) has a ventral profile slightly convex. P4/ has a V-shaped lingual valleys; mesial and slight buccal cingula are present; the difference in height between the bottoms of the valleys in this tooth is relatively important. M1/ and M2/ have a broad V-shaped lingual valleys, the differences in height between the bottoms of the valleys are relatively important. Slight lingual cingula occur below the bottoms of the lingual valleys in M2/. The vestibular syncline is deep in all the teeth. The dimensional values of the fragmentary mandible and of teeth are close to both *D. megarhinus* and *S. jeanvireti*. However, the morphology of the lingual valley and the presence of the cingula allow to refer the fragmentary mandible to *D. megarhinus*.

A fragmentary mandible with two horizontal rami (MSNAF4747; Figs. 2, 3; Tables 2, 3, 4) shows morphometric values close to the mean of *S. jeanvireti* and *S. etruscus* and to the minimal values of *D. megarhinus*. The premolars are slightly longer than in *S. jeanvireti* and *S. etruscus*. The dimensions of P/2 are very close to the values of *S. etruscus* and to the minimal values of *D. megarhinus*; they are larger than *S. jeanvireti*. P/3 is dimensionally close to the maximal values of *S. etruscus* and *S. jeanvireti* and to the mean values of *D. megarhinus*. P/4 and M/1 are dimensionally close to the maximal values of *S. etruscus*, *S. jeanvireti* and the mean of *D. megarhinus*. Incisor alveoli are relatively large (transverse diameter = 15.7 mm). P/3 and P/4 have buccal cingula; a mesial cingulum is present in M/1. Distal cingula are present in the premolars and a slight mesial cingulum occurs in P/2. The presence of large incisor alveoli allows to exclude an attribution to *S. jeanvireti* and *S. etruscus*. Furthermore, the ventral profile of the horizontal ramus of the mandible appears to be less convex below the molars than in *S. jeanvireti*, and the area of the diastema is more massive than in the samples from Vialette. The mandible from Fangonero is morphologically similar to *D. megarhinus* than to the other species.

The vestibular wall of an M1/ or M2/ (MSNAF4555) shows marked folds; moreover, the area of the metacone is

concave. These features are recognized in *D. megarhinus* but a clear specific attribution is problematic.

The fragmentary distal epiphysis of a humerus (MSNAF7100) is dimensionally close to the mean value of *D. megarhinus* and it is larger than *S. etruscus* (Table 5); moreover, the oleocranic fossa appears larger than in *S. jeanvireti* and the bone is more massive than in *S. jeanvireti* and *S. etruscus*.

The proximal epiphysis of a humerus (MSNAF7101; Fig. 4) has the proximal transverse diameter close to the maximal values of *D. megarhinus* and it is larger than *S. jeanvireti* and *S. etruscus* (Table 5). In proximal view, the articular surface appears slightly more rounded than in *S. jeanvireti* and the posterior groove is less marked than in *S. jeanvireti* and it is similar to that of *D. megarhinus*. Moreover, the intertuberal groove is regularly concave in *S. jeanvireti* while in the studied specimen and in *D. megarhinus* it appears more angular.

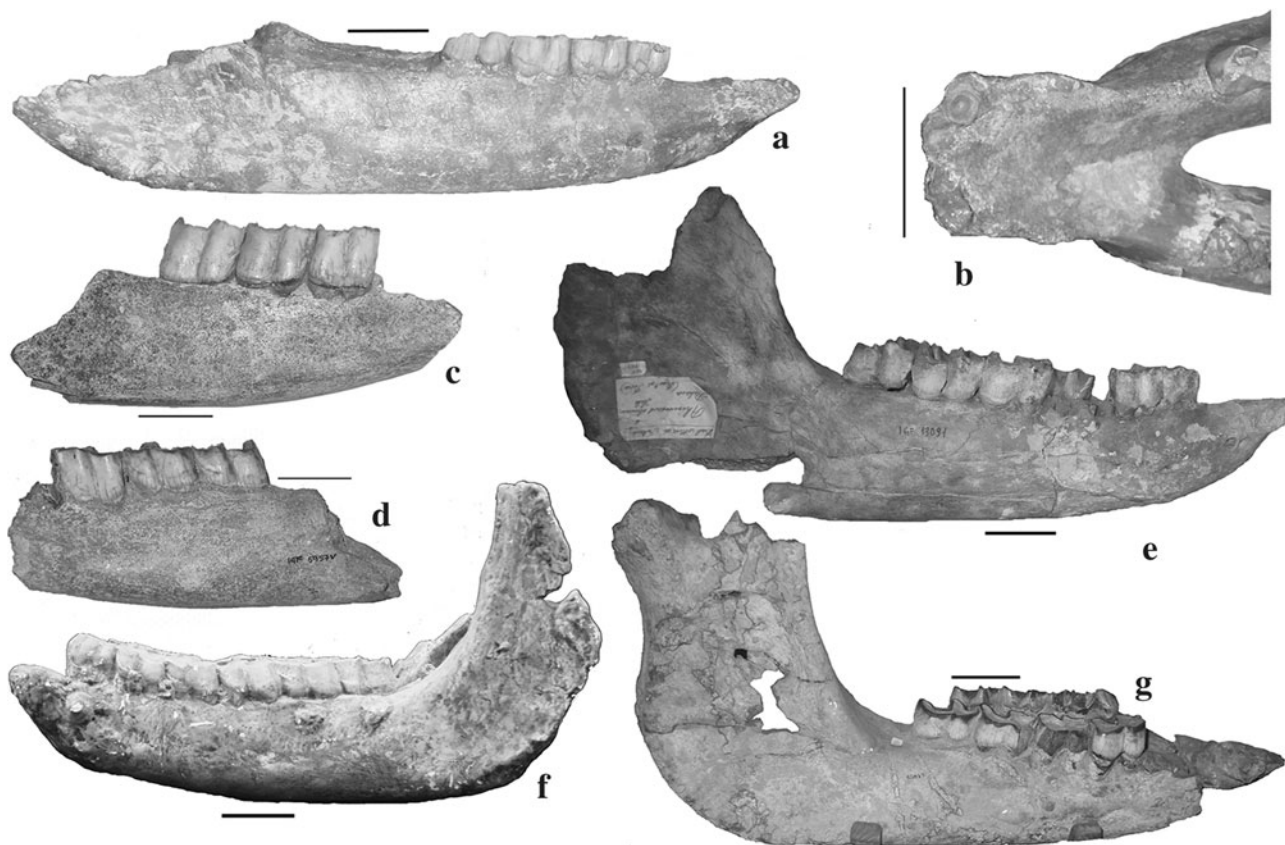
The distal half of a radius (MSNAF4754) is very damaged; in distal view, the external outline of the articular surface is linear while the posterior outline is slightly concave in its external half; the external tuberosity of the anterior face is rounded and large. These features are closer to *D. megarhinus* than to any other Pliocene species (cf. Guérin 1972).

Other rhino remains from Fangonero-Buca are very damaged and fragmented; a specific attribution of these remains appears impossible.

A fragmentary mandible (IGF5957v; Fig. 2) stored at MGPF shows the same fossilization status than the specimens recovered at Fangonero and its label reports the indication "Pliocene of Siena". The teeth (P/4, M/1 and M/2) have vestibular and mesial cingula; their dimensions fall into the range of *D. megarhinus* and are close to the maximal values of *S. jeanvireti* (Tables 2, 4).

A large-sized calcaneum (MSNAF4531) stored at the MSNAF has been collected from Senese, an undefined locality near Siena. The dimensions of this remain fall into the range of *D. megarhinus* and *S. jeanvireti* (Table 5) and it can be referred to *D. megarhinus* based on its morphological traits. In particular, in lateral view, the posterior border is slightly convex while in *S. jeanvireti* a concavity at the level of the beak is present; in posterior view, the tuber calcanei is more massive than in *S. jeanvireti*; furthermore, in the same view, the articular surface for the cuboid is obvious and its superior border is nearest to the sustentaculum tali than in *S. jeanvireti*. In articular view, the medio-distal articular surface for the astragalus is small, high and has a rectangular shape while in *S. jeanvireti* it is longer and elliptical in shape.

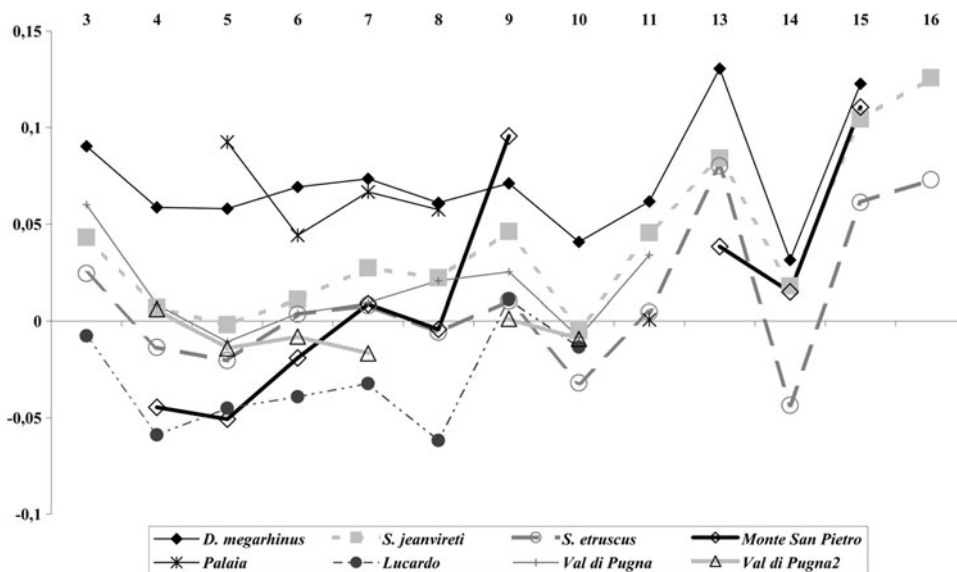
Finally from the locality of Montarioso, two lower premolars (P/2 and P/3; MSNAF4761), belonging to the same individual, and two upper molars (MSNAF7000 and



**Fig. 2** Rhinoceros mandibles from the Pliocene sites of Italy: fragmentary mandible MSNAF4747 from Val di Pugna, in buccal view (a), incisive corpus of the mandible MSNAF4747 from Val di Pugna in dorsal view (b), fragmentary mandible MSNAF4743 from Val di Pugna, in buccal view (c), fragmentary mandible IGF5957v

from the Pliocene of Siena, in buccal view (d), fragmentary mandible IGF5566v from Palaia, in buccal view (e); fragmentary mandible MGC9352 from Monte Pulgnasco, in buccal view (f); almost complete mandible MGC9354 from Monte San Pietro, in buccal view (g). Scale bar 5 cm

**Fig. 3** Ratio diagram for the mandibles from Monte San Pietro (MGC9354), Palaia (IGF13091), Lucardo (IGF1450v) and Val di Pugna (MSNAF4747 and MSNAF4743) (standard *Diceros bicornis*). The specimens are compared with the mean values of *D. megarhinus*, *S. jeanvireti* and *S. etruscus* (data from Guérin 1980). \*\*\*8Abbreviations in Table 2



MSNAF7100) have also been recovered. The lower teeth have vestibular and mesial cingula; the anterior and posterior lingual valleys in P/2 have a V-shaped morphology.

The dimensions of the teeth fall into the range of *D. megarhinus* and they are close to the maximal values of *S. jeanvireti* given by Guérin (1980) (Table 4). The presence

**Table 2** Dimensions (in mm) of the mandibles from Val di Pugna (MSNAF4747 and MSNAF4743), Monte San Pietro (MGC9354), Palaia (IGF13091), Lucardo (IGF1450v), Senese (IGF5957v), Capannoli (IGF1449v) and *D. megarhinus*, *S. jeanvireti* and *S. etruscus* (data from Guérin 1980)

Site	Specimen	3	4	5	6	7	8	9	10	11	13	14	15
Val di Pugna	MSNAF4747	71.99	75.66	77.96	82.85	86.13	96.5	50.02	51.71	117.93			
Val di Pugna	MSNAF4743		75.28	77.34	80.6	81.11		47.33	51.6				
Monte San Pietro	MGC9354		66.97	71.07	78.56	86	91.11	58.82	68.2		129.93	103.5	245.11
Palaia	IGF13091			87.94	90.88	98.28	105			109.24			
Lucardo	IGF1450v	61.6ca	64.8ca	72ca	75ca	78.24	79.8	48.43	51.1				
Senese	IGF5957v		74.88	83.07	86.28	85.37		53.14	53.8				
Capannoli	IGF1449v	59ca				90ca	90ca						
<i>D. megarhinus</i>	min–max	56–94	64–106	74–117	85–112	86.5–120	87–127	48–70	46–72	101–149	140–184	100–115	236–284
<i>S. jeanvireti</i>	min–max	61.5–77	70–82	74–85	71–92	77–99	90–105	45–60.5	43.5–69	114–133	135.5–163	92–115	220–270
<i>S. etruscus</i>	min–max	55.5–80	62.5–83.5	64–85.5	65–91	70–96.5	79–105	41–60	41–60	94–123	115–152	77.5–107	182–243

The measurement is taken according to the methodology exposed by Guérin (1980)

3–8 height of the horizontal ramus, respectively, at the level of P/2–P/3, P/3–P/4, P/4–M/1, M/1–M/2, M/2–M/3, rear of M/3; 9–10 width of the horizontal ramus, respectively, at the level of P/4–M/1 and M/2–M/3; 11 length of the symphysis; 13 antero-posterior diameter of the vertical ramus; 14 transverse diameter of the articular condyle; 15 height of the condyle

**Table 3** Dimensions (in mm) of the lower cheek teeth from Val di Pugna (MSNAF4747 and MSNAF4743), Monte Pulgnasco (MGC9352) (data from Simonelli 1897), Monte San Pietro (MGC9354), Palaia (IGF13091), Lucardo (IGF1450v), Capannoli (IGF1449v) and *D. megarhinus*, *S. jeanvireti* and *S. etruscus* (data from Guérin 1980)

Site	Specimen	Lbt	Llt	Lbm	Llm	Lbp	Llp	Lbp3-p4	Llp3-p4
Val di Pugna	MSNAF4747	244.65ca		139ca		110.17ca	106.63	78.43	75.57
Monte Pulgnasco	MGC9352	232		128		104		75ca	
Monte San Pietro	MGC9354			138.9	134				
Palaia	IGF13091	254.81	254.93	144.97	144.13	113.34ca		83ca	
Lucardo	IGF1450v			135.30ca					
Capannoli	IGF1449v	234.70ca		133.15	127.76	108ca		78.32ca	
<i>D. megarhinus</i>	min–max	228–293		134–165		101–136		71–91	
<i>S. jeanvireti</i>	min–max	234–242		127–138		98–106		69.5–77	
<i>S. etruscus</i>	min–max	210–251.5		121–143		87–108		63–80.5	

Lbt total buccal length of the tooth-row, Llt total lingual length of the tooth-row, Lbm buccal length of the molars, Llm lingual length of the molars, Lbp buccal length of the premolars, Llp lingual length of the premolars, Lbp3-p4 buccal length of the last two premolars; Llp3-p4 lingual length of the last two premolars

of the cingula and the length of the premolars allow to exclude an attribution to *S. jeanvireti*, while the presence of the anterior lingual valley in P/2 allows to exclude an attribution to *S. etruscus*. This last morphological feature can be recognized in some specimens of *D. megarhinus* (e.g. in the P/2 of the mandible from Palaia) as the presence of the above-mentioned cingula. Two upper molars can be referred to the same species. The latter teeth have a marked and large paracone fold, a wavy profile of the vestibular wall, crista and a slight lingual cingulum. In *S. jeanvireti*, the vestibular wall of the upper molars (in particular M1/) is less wavy than in *D. megarhinus* and has a slight paracone fold, while crista and cingula are generally absent (cf. Guérin 1980).

#### Colle della Casazza (Bologna, Emilia-Romagna)

A fragmentary proximal epiphysis of a humerus (MGC1870) has been collected from the Pliocene sands outcropping at Colle della Casazza (Capellini 1894). The proximal transverse diameter overlaps the maximal values of *S. jeanvireti* and *S. etruscus* and it is close to the mean values of *D. megarhinus* (Table 5); moreover, the articular surface appears more rounded than in *S. jeanvireti*.

#### Dusino-San Paolo (lower levels)

The teeth (first and second molars and fourth premolar; one isolated upper premolar) recovered in the lower levels at

**Table 4** Dimensions (in mm) of the teeth from Val di Pugna (MSNAF4747 and MSNAF4743), Senese (IGF5957v), Monte San Pietro (MGC9354), Monte Pulgnasco (MGC9352) (data from Simonelli 1897), Palaia (IGF13091) and *D. megarhinus*, *S. jeanvireti* and *S. etruscus* (data from Guérin 1980)

Site	Specimen	Tooth	Lmax	Dtmax	Lb	Ll	TDd	TDm	Hav	H <sub>pv</sub>
Val di Pugna	MSNAF4747	P/2	31.73	19.05	31.44	28.19	19.16	14.75		
Val di Pugna	MSNAF4747	P/3	40.05	25.83	38.42	35.12	25.5	21.25		
Val di Pugna	MSNAF4747	P/4	42.43	30.51	39.35	38.52	29	25.28		
Val di Pugna	MSNAF4747	M/1	48.85	29.60ca	42.13			26.20ca		
Val di Pugna	MSNAF4743	P/4	39.41	28.7	39.89	35.2	27.71	25.96	20.65	16.14
Val di Pugna	MSNAF4743	M/1	44.22	30.3	42	38.77	27	28.9	23.1	15.91
Val di Pugna	MSNAF4743	M/2	49.02	30.61	45.22	42.9	27.89	29.12	20.42	16.2
Val di Pugna	MSNAF4761	P/2	31.88	18.50						
Val di Pugna	MSNAF4761	P/3	37.60							
Senese	IGF5957v	P/4	41.16	30.17	39.77	38				
Senese	IGF5957v	M/1	47.33	32.2	43.76	44.11				
Senese	IGF5957v	M/2	49	32.73	44.71	44.05				
Monte San Pietro	MGC9354	P/4		29.37ca	42.33					
Monte San Pietro	MGC9354	M/1	44.4	33.61ca	42.64					
Monte San Pietro	MGC9354	M/2	48.63	32.69	46.87					
Monte San Pietro	MGC9354	M/3	54.97	33.37	49.6					
Monte Pulgnasco	MGC9352	P/2	29–28.4	19–19						
Monte Pulgnasco	MGC9352	P/3	36	30.3						
Monte Pulgnasco	MGC9352	P/4	38	29.3						
Monte Pulgnasco	MGC9352	M/1	42.3–42.5	32–32						
Monte Pulgnasco	MGC9352	M/2	44.7–44	31–32						
Monte Pulgnasco	MGC9352	M/3	43–41	29.4–29						
Palaia	IGF13091	P/2	28.6	17.92	28.41	27.95				
Palaia	IGF13091	P/3	39.42	24.6	35.95	33.52			19.95	14.42
Palaia	IGF13091	P/4	42.52	27.66	43.5	39.63			17.3	10.24
Palaia	IGF13091	M/1	48.65	31.16	47.39	44.94			19.23	12.77
Palaia	IGF13091	M/2	52.24	32	45.25	45.39			16	13.22
Palaia	IGF13091	M/3	49.12	35	44.45	45.36			14.91	13.61
<i>D. megarhinus</i>	min–max	P/2	29.5–43	16.5–25						
<i>D. megarhinus</i>	min–max	P/3	35–44	22.31,5						
<i>D. megarhinus</i>	min–max	P/4	37.5–48	27.5–38						
<i>D. megarhinus</i>	min–max	M/1	38.5–53	29–40						
<i>D. megarhinus</i>	min–max	M/2	43–57.5	31–39						
<i>D. megarhinus</i>	min–max	M/3	48–62	29.5–37						
<i>S. jeanvireti</i>	min–max	P/2	27–28.5	16.5–19						
<i>S. jeanvireti</i>	min–max	P/3	33–38	23–27						
<i>S. jeanvireti</i>	min–max	P/4	37–40.5	24–31						
<i>S. jeanvireti</i>	min–max	M/1	42–47	28–34						
<i>S. jeanvireti</i>	min–max	M/2	43–50	27–33						
<i>S. jeanvireti</i>	min–max	M/3	43.5–51	26–33						
<i>S. etruscus</i>	min–max	P/2	25–33	16–21.5						
<i>S. etruscus</i>	min–max	P/3	31.5–37	21.5–29						
<i>S. etruscus</i>	min–max	P/4	35–39.5	24–31						
<i>S. etruscus</i>	min–max	M/1	37–43	26.5–33						
<i>S. etruscus</i>	min–max	M/2	40.5–47.5	37–33.5						
<i>S. etruscus</i>	min–max	M/3	41–50	26–33						

*Lmax* maximal length, *Dtmax* maximal transverse diameter, *Lb* buccal length, *Ll* lingual length, *TDd* distal transverse diameter, *TDm* mesial transverse diameter, *Hav* height of the anterior lingual valley, *Hpv* height of the posterior lingual valley



**Table 5** Dimensions (in mm) of the humeri from Val di Pugna (MSNAF7100 and MSNAF7101), Monte Pastore (MGC sn), Colle della Casazza (MGC sn) and *D. megarhinus*, *S. jeanvireti* and *S. etruscus* (data from Guérin 1980 and from Fortelius et al. 1993)

Site	Specimen	PTD	PAPD	PTDa	PAPDa	TDM	APDM	DTD	DAPDm	DAPI	DTDa	TDfo
Val di Pugna	MSNAF7100					69.5	75		>110			
Val di Pugna	MSNAF7101	192.04	>146	102.2	94							
Monte Pastore	MGC sn	>163										
Monte Pastore	MGC sn	182ca		102.5	97.2		146.25		112.75	104.87	103.62	44.5
Colle della Casazza	MGC sn	150–190	170–206	100.96	89.94–90.2	61–78	64.5–87	144–166	100–135	103.94–119.3	98.61–126.43	43.65–55.76
<i>D. megarhinus</i>	min-max	151–175	164–184	96.35–97.17	89.9–96.82	62–70	69–77	142–152	117–126	84.18–109.33	90.06–108.89	35.56–36.79
<i>S. jeanvireti</i>	min-max	125–160.5	117–155	78–91	74.8–77	45.5–67.5	54–72	110–137	83.5–114		77–89	32–48
<i>S. etruscus</i>	min-max											

The range values of PTDa, PAPDa, DAPI, DTDa and TDfo for the humeri of *D. megarhinus* ( $N = 3$ ) and *S. jeanvireti* ( $N = 4$ ) are based on the material studied at NMB. The range values of PTDa, PAPDa, DAPI, DTDa and TDfo for the humeri of *S. etruscus* are from Fortelius et al. (1993)

PTD proximal transverse diameter, PAPD proximal antero-posterior diameter, PTDa transverse diameter of the proximal articular surface, PAPDa antero-posterior diameter of the proximal articular surface, PTDa transverse diameter of the diaphysis, DTD distal transverse diameter, DAPDm distal antero-posterior diameter of the medial side, DAPI distal antero-posterior diameter of the lateral side, DTDa distal transverse diameter of the olecranic fossa

Dusino-San Paolo have been described and figured by Sacco (1906; Tav. 1, Figs. 1 and 2). Guérin (1980) ascribed these remains to *D. megarhinus*. The teeth of the upper tooth-row are brachydont, with a wavy vestibular wall and a large paracone fold; an attribution to *D. megarhinus* can be confirmed. The isolated upper premolar is very worn and a specific attribution of this remain appears problematic.

#### Montelungo (Bologna, Emilia-Romagna)

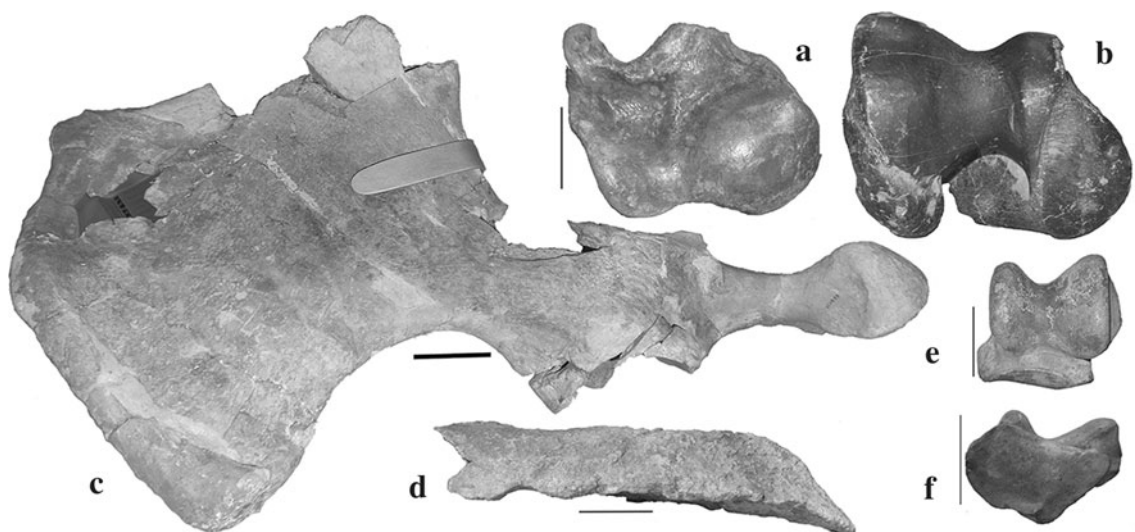
The upper molar (MGC sn) figured by Capellini (1894) shows morphological characteristics close to *D. megarhinus*. In particular, the tooth is brachydont with a well-developed mesial cingulum and a single crista.

#### Monte Bianco (Bologna, Emilia-Romagna)

The fragmentary mandible from Monte Bianco, stored at the Museum of Palazzo Poggi (Bologna) has been figured and described by several authors, including Cuvier (1822), De Christol (1834) and Capellini (1894). The remain has four incisor alveoli and a relatively long symphysis; in agreement with the above-mentioned authors and Guérin (1980), the remain can be referred to *D. megarhinus*.

#### Monte Giogo (Piacenza, Emilia-Romagna)

A partial skeleton of a large-sized rhinoceros has been recovered at Monte Giogo and it is stored at the Museum of Paleontology, University of Parma. The remains were extensively described by Simonelli (1897) and they were referred to *Rhinoceros megarhinus*. The morphology of the upper teeth is very close to the specimens from Montpelier, the nasal bones lack of the nasal septum and the postcranial remains are morphologically similar to the typical specimens of *D. megarhinus*. The upper teeth are brachydont with a relatively wavy vestibular wall; crista and crochet are present. P4/ has a multiple crochet while P2/ has a close mediofossette. The horizontal ramus of the fragmentary mandible is relatively high with an inflexion at the level of the P/3. The humerus has a marked antero-posterior crest in the lateral side of the distal epiphysis; the olecranic fossa appears large and the epicondyles are massive. The metapodials are relatively long and the astragalus has a high and massive medial tuberosity, the central depression below the trochlear trough is marked and the anterior border of the distal articular surface, in distal view, is linear. The dimensions of the remains are close to the mean values of *D. megarhinus* given by Guérin (1980).



**Fig. 4** Selected rhinoceros remains from the Pliocene sites of Italy: proximal epiphysis of humerus (MSNAF7100) from Val di Pugna in proximal view (a), distal epiphysis of humerus from Monte Pastore (MGC sn) in distal view (b), pelvis (MGC9350) from Rio Secco in

dorsal view (c), nasal bones (IGF5566v) from Palaia in lateral view (d), astragalus (MGC sn) from Pradalbino in anterior (e) and distal view (f). Scale bar 5 cm

#### *Montezago (Piacenza, Emilia-Romagna)*

The rhino from Montezago was described first by Cortesi (1819) and later by Cuvier (1822) and Falconer (1868). Unfortunately, the specimen was destroyed in 1944. In the skull figured by Cuvier (1822; Pl. 47, Fig. 7) and described by Falconer (1868; p. 381) “there is not the slightest indication of a dividing nasal septum” (Falconer 1868; p. 388), the occipital crest is not much projected backwards, “the occipital face inclines a little forwards as it ascends from the occiput upwards”, “the orbits are placed immediately over the sixth tooth”, the complex crochet in the fourth upper premolar is present, the enamel of the teeth is smooth. All these characteristics allow to refer the specimen to *D. megarhinus*. Guérin (1980) ascribed, with reserve, a cast of a fore limb stored at the Museum of Geology G. Capellini to the rhino from Montezago. However, no indications are reported on the cast and the specimen is not mentioned by Capellini (1894) in the list of the rhino remains stored at the MGC. Due to the impossibility to know the original site and to study some morphological traits (the elements of the cast are glued), the cast is not considered in this work.

#### *Palaia (Lower Valdarno, Tuscany)*

Azzaroli (1962) and Guérin (1980) recorded the occurrence of *D. megarhinus* at Palaia (Lower Valdarno). A fragmentary nasal bone without the presence of a nasal septum (IGF5566v) can be referred to this species together with an almost complete mandible (IGF13091) (Figs. 3, 4). In the

latter specimen, the ventral profile of the horizontal ramus is slightly convex below the premolars. The symphysis is long, its rear border is at the level of P/3 and, in the anterior border, four incisor alveoli are present. The lower cheek tooth-row is slightly longer than in *S. jeanvireti* and *S. etruscus*, while the high of the horizontal ramus is close to the mean values of *D. megarhinus* and the maximal values of *S. etruscus* and *S. jeanvireti* (Tables 2, 3, 4).

#### *Rio Secco (Bologna, Emilia-Romagna)*

An almost complete pelvis (MGC9350) has been recovered from the Pliocene sands at Rio Secco (Capellini 1894) (Fig. 4). An attribution to *S. etruscus* can be ruled out because of the large size of the specimen and the presence of some morphological differences. Moreover, the acetabulum is elliptical in shape as in *D. megarhinus*, while it appears more rounded in *S. jeanvireti*.

#### *Regolo (Lower Valdarno, Tuscany)*

The hemimandible from S. Regolo has a very large dimensions (Azzaroli 1962; Tav. VII, Fig. 3, Tav. XI, Fig. 5). The ventral profile of the horizontal ramus is slightly convex with an inflexion at the level of M/1–P/4; the molars and the two last premolars are longer than in *S. jeanvireti*. According to Guérin (1980), the specimen can be referred to an evolutionary stage of the *D. megarhinus*.

Genus *Stephanorhinus* Kretzoi, 1942

*Type species* *Rhinoceros etruscus* Falconer 1868 from the Upper Valdarno, Early Pleistocene.

*Other species* *Stephanorhinus jeanvireti* (Guérin 1972), *Stephanorhinus hundsheimensis* (Toula 1902), *Stephanorhinus hemitoechus* (Falconer 1859), *Stephanorhinus kirchbergensis* (Jäger 1839) and maybe “*S.*” *miguelcrusafonti* (Guérin and Santafé-Llopis 1978). Recently Tong (2012) included in this genus the species *S. yunchuchenensis* (Chow 1963) and *S. lantianensis* (Hu and Qi 1978).

*Diagnosis* Two-horned rhinos. Presence of a partially ossified nasal septum. Molarised premolars. No functional incisors. According to Fortelius et al. (1993), the genus *Brandtorhinus* Guérin 1980 is identical to *Stephanorhinus* Kretzoi, 1942 and the latter name “is preferable to Guérin’s because it has priority and has been used quite extensively in literatures”.

*Referred material* To *Stephanorhinus* sp. are referred a fragmentary mandible from Lucardo (MGPF) and fragmentary material from Monte Tiffi (MGC).

#### Description and comparison

*Lucardo (near Montopoli, Lower Valdarno, Tuscany)*

A fragmentary mandible (IGF1450v) was ascribed to *Rhinoceros megarhinus* by Azzaroli (1962). The teeth (M2/ , M1/ and P3/) are very wear and the mandible is poorly preserved. The ventral profile of the mandible below the premolars is slightly convex. The length of the molars, approximately of 135 mm, is close to the minimal values of *D. megarhinus* and falls into the range of *S. jeanvireti* and *S. etruscus* (Tables 2, 3). The mandible is less high and less thick than in *D. megarhinus*. Moreover, the relative proportions and dimensions of the mandible are close to *S. jeanvireti* and *S. etruscus* (Fig. 3). However, due to the conservation status of the remain, a specific attribution appears very difficult.

*Monte Tiffi (Forlì-Cesena, Emilia-Romagna)*

Two fragmentary teeth, one distal epiphysis of a second metacarpal and the external half of one astragalus (MGC sn), have been collected from a lignite bed at Monte Tiffi (Simonelli 1919). The talus is dimensionally close to the values of *S. jeanvireti* and it is larger than *S. etruscus* (Table 6). Morphologically, it shows some similarities with *S. jeanvireti* but a sure specific attribution appears uncertain.

*Species* *Stephanorhinus jeanvireti* (Guérin 1972)

*Synonymy list* 1828 *Rhinoceros elatus* Croizet and Jobert, 144–165, pl. I fig. 7, pl. IV figs. 3–7, pl. V figs. 1–4, pl. VI fig. 1, pl. XI figs. 1–6, pl. XII figs. 1–2, 8

1895 *Rhinoceros etruscus* var. *astensis* Sacco, 1–31, pl. I–IV

see Guérin (1972) for a more complete synonymy list.

*Type material* Skull and mandible (n° Vt 627) described and figured by Guérin (1972), stored at Natural History Museum Basel.

*Type horizon* Late Pliocene

*Type locality* Vialette (Haute-Loire, France).

*Diagnosis* (mostly translated from Guérin 1972, 1980) Large-sized rhino. Nasal septum ossified anteriorly. Post-orbital, sus-orbital and pre-orbital apophyses well marked. Occipital face slightly vertical. Occipital crest large and with a marked transverse concavity. Post-glenoid apophysis strong and forwards. Paraoccipital apophysis more developed than the post-tympanic one. Mandible with long symphysis, horizontal ramus relatively long. Absence of anterior teeth.

*Referred material* Fragmentary mandibles from Monte Pulgnasco (MGC and MGPF cast), Capannoli (MGPF) and Monte San Pietro (MGC), astragalus from Pradalbino (MGC), fragmentary humerus from Monte Pastore (MGC),

**Table 6** Dimensions (in mm) of the astragali from Pradalbino (MGC sn), Monte Tiffi (MGC sn) and *D. megarhinus*, *S. jeanvireti* and *S. etruscus* (data from Guérin 1980 and Fortelius et al. 1993)

Site	Specimen	Hmax	Hm	HI	Dtmax	DTD	DTDa	DAPm	DAPI
Pradalbino	MGC sn	89.02	79.21	82.03	96.06	75.89	73.73	61.33	45.65
Monte Tiffi	MGC sn			83.35					41.16
<i>D. megarhinus</i>	min–max	88–110	81.42–97.6	84.53–96.79	92.5–113	78–99	71–91	59–76	46.72–51.51
<i>S. jeanvireti</i>	min–max	87–104	80.81–96.57	83.55–97.92	92–107.5	77–94	70–85	60–72	42.96–53.97
<i>S. etruscus</i>	min–max	71–84	65–74	70–74	73–88	60–78	57–75	47–58	

The range values of Hm, HI and DAPI for the astragali of *D. megarhinus* ( $N = 7$ ) and *S. jeanvireti* ( $N = 6$ ) are based on the material studied at NMB. The range values of Hm and HI for the astragali of *S. etruscus* are from Fortelius et al. (1993)

*Hmax* maximal height, *Hm* medial height, *HI* lateral height, *Dtmax* maximal transverse diameter, *DTD* distal transverse diameter, *DTDa* distal articular transverse diameter, *DAPm* medial antero-posterior diameter, *DAPI* lateral antero-posterior diameter

several post-cranial bones, fragmentary skull and teeth from Montopoli (MGPF) (Table 1).

#### Description and comparison

##### *Monte Pulgnasco (Piacenza, Emilia-Romagna)*

The original mandible from Monte Pulgnasco was destroyed during the 1862 and was discussed and figured by Simonelli (cf. Simonelli 1897). However, a cast of the original remain is preserved at the MGC (MGC9352) and at the MGPF (IGF4684) (Fig. 2); the latter was figured by Simonelli (1897; Tav. XIV, figs 1–3). The mandible is damaged in the posterior margin of the vertical ramus and the incisive corpus is abraded; thus, the symphysis and the diastema appear relatively shorter than in *D. megarhinus* and *S. jeanvireti*. The dimensions of the teeth and of the horizontal rami fall into the range variations of *D. megarhinus*, *S. jeanvireti* and *S. etruscus* (Tables 3, 4). Finally, the total length of the molars is shorter than in *D. megarhinus*. The ventral profile of the mandible is convex and the anterior border of the vertical ramus is slightly vertical; the ratio between the length of P/3–P/4 and the length of the molars is relatively high. These last characteristics appear distinctive of *S. jeanvireti*.

##### *Pradalbino (Bologna, Emilia-Romagna)*

A well-preserved astragalus (MGC sn) from Pradalbino has been discussed by Capellini (1894) (Fig. 4) which referred the specimen to *Rhinoceros megarhinus*. The astragalus shows dimensional values close to the minimal values of *D. megarhinus* and those of *S. jeanvireti* (Table 6). Nevertheless, morphological characteristics allow to refer the remain to *S. jeanvireti*. In particular, in anterior view, in the astragalus from Pradalbino the trochlear trough is less developed than in *D. megarhinus* and the central depression under the trochlear trough, obvious in *D. megarhinus*, is absent. In addition, in posterior view, the medio-distal articular surface with the calcaneum appears more elliptical in shape than in *D. megarhinus*. In distal view, the articular surface for the cuboid is slightly elongated anteriorly than that for the navicular; in medial view, the posterior border of the trochlea is generally less developed posteriorly than in *D. megarhinus*.

##### *Monte Pastore (Bologna, Emilia-Romagna)*

Two remains of rhinoceros, probably belong to the same individual, have been collected at Monte Pastore; a distal epiphysis and a very damaged proximal epiphysis of

humerus (MGC sn) (Fig. 4; Table 5). The proximal epiphysis does not shows useful morphological or morphometrical characteristics. In the distal epiphysis, in distal view, the medial epicondyle is rounded and massive; in the lateral side, the tuberosity is large, rounded and well developed as in *S. jeanvireti*. Finally, the transverse diameter of the distal trochlea is close to the values of *S. jeanvireti* from Vialette and it is generally smaller than the values of *D. megarhinus*.

##### *Monte San Pietro (Bologna, Emilia-Romagna)*

An almost complete mandible (MGC9354) has been recovered at Monte San Pietro and it was published by Capellini (1920) as *Rhinoceros megarhinus* (Fig. 2). Really, several dimensional values of the mandible and teeth are close to the minimal values of *D. megarhinus* and to the maximal values of *S. jeanvireti* (Tables 2, 3, 4). Moreover, the proportions of the mandible are more similar to *S. jeanvireti* than to *D. megarhinus* (Fig. 3). In addition, the high of the horizontal ramus below the premolars is shorter and the anterior border of the ascending ramus is more vertical than in *D. megarhinus*.

##### *Montopoli (Lower Valdarno, Tuscany)*

Azzaroli (1962) ascribed to *Di. megarhinus* two almost complete fore limbs, two almost complete rear limbs, two incomplete lower cheek teeth, a fragmentary skull of a young individual, a talus and a metatarsal. Guérin (1980) referred to *S. etruscus* the isolated talus and to *S. jeanvireti* the limbs, the skull and the teeth. The four almost complete limbs and the two cheek teeth (IGF1075) probably belong to the same individual and they have been recovered during the Paleontological excavations of Forsyth Major in the 1880. Based on the morphological characteristics of the specimens, the attribution to *S. jeanvireti* can be confirmed. Indeed, in the scaphoid, in anterior view, the medial profile is convex, while the lateral one is concave in the proximal half and slightly convex in the distal half; furthermore, the medial side of the bone is higher than the lateral one. In the second metacarpal, the posterior tuberosity is slightly developed and the proximal articular surface is rounded. In the third metacarpal, the anterior border of the proximal articular surface is slightly convex, the lateral articular surfaces are higher than the specimens from Montpellier and the posterior one has a sub-triangular shape. In the second metatarsal, the anterior border of the proximal articular surface extends less anteriorly than the anterior border of the epiphysis; the anterior and posterior lateral articular surfaces are similar in size but the posterior one is divided into two parts by a slight edge. In the astragalus, the medial tuberosity is massive and rounded and it is near

the distal border of the medial face. The fragmentary skull (IGF14869), referred to *S. jeanvireti*, belongs to a young individual and it is crushed and damaged. All the upper deciduous and two erupting M1/ are present. D1/ has a very small crista, a reduced protolophe and a convex profile of the vestibular wall. D2/ has a mesial cingulum and a wavy profile of the vestibular wall. D3/ has a mesial cingulum, a protocone constriction and a wavy profile of the vestibular wall with a marked paracone fold as in D4/.

#### Capannoli (Lower Valdarno, Tuscany)

Azzaroli (1962) ascribed a fragmentary mandible from Capannoli (Lower Valdarno) to *Di. megarhinus*. According to Guérin (1980), these specimens can be really referred to *S. jeanvireti*. The dimensions of the fragmentary mandible from Capannoli (IGF1449v) fall into the range of the three Pliocene species of rhinoceros; they are close to the minimal values of *D. megarhinus* and to the mean values of *S. jeanvireti* and *S. etruscus* (Tables 2, 3). The incisive corpus is abraded and the posterior border of the symphysis is at the level of P/2–P/3. The ventral profile of the horizontal ramus is convex and its height decreases abruptly in the premolar portion; unfortunately, the ventral side of the ramus below M/2 and P/4 has been partially reconstructed. The horizontal ramus appears proportionally thinner than in *D. megarhinus*. Buccal and mesial cingula occur in the molars and in the P/4; furthermore, lingual cuspules occur in the anterior lophe of the P/4, M/2 and M/3. The lingual valleys of the teeth have a V-shaped morphology. The ratio between the estimated length of the two last premolars (only the roots of P/3 are present) and the length of the molars is relatively high. Based on its morphological characteristics, the specimen can be referred to *S. jeanvireti*.

Species *Stephanorhinus etruscus* (Falconer 1868)

*Synonymy list* 1868 *Rhinoceros etruscus* Dawkins, 207–218, pl. VII–VIII

1921 *Rhinoceros etruscus* Ugolini, 1–4

1963 *Rhinoceros (Dicerorhinus) etruscus* Cusani Politi, 25–57 pl. I–III

1971 *Dicerorhinus etruscus* Guérin and Heintz, 13–22

1972 *Dicerorhinus etruscus* Ambrosetti, 177–198, pl. I–VII

(this is a selected list, see Guérin 1980).

*Type material* Skull (IGF 756) figured and described by Falconer (1868), stored at Natural History Museum, Section of Geology and Paleontology, Florence.

*Type horizon* Early Pleistocene

*Type locality* Upper Valdarno Basin (Tuscany, Italy).

*Diagnosis* (mostly translated from Guérin 1980) Small to medium-sized rhino. Nasal septum ossified anteriorly. Post-orbital and sus-orbital apophyses are marked. Occipital face slightly inclined posteriorly and downwards. Occipital crest large and with a marked transverse concavity. Post-glenoid apophysis strong and slightly forwards. Paraoccipital apophysis less developed than the post-tympanic one. Mandible with long symphysis, horizontal ramus relatively short and high. Absence of anterior teeth.

*Referred material* Maxillae from Barga Basin (MSNP), nasal bones from Costa Marenga (MGC), astragalus and fragmentary metatarsus from Montopoli (MGPF) (Table 1).

#### Description and comparison

##### Montopoli (Lower Valdarno, Tuscany)

A small-sized astragalus (IGF1452v) shows a lower and less developed medial tuberosity than in *D. megarhinus* and *S. jeanvireti*; moreover, the anterior border of the distal articular surface has a concavity in the lateral side and the articular surface for the cuboid extends more anteriorly than that for the navicular. Finally the lateral lip of the trochlea is less developed than in *D. megarhinus* and *S. jeanvireti*. In agreement with Guérin (1980), the remain can be referred to *S. etruscus*. A fragmentary small metatarsal (IGF4688v) has also been recovered at Montopoli. The specimen lacks the distal epiphysis and it is damaged in the proximal one; it can be referred to *S. cf. etruscus* based on its small dimensions.

##### Barga Basin (Lucca, Tuscany)

Coltorti et al. (2008) ascribed to *Stephanorhinus* sp. a large-sized fragment of metapodial diaphysis. Two complete maxillae were extensively described by Ugolini (1918) and they have been recovered at Castelnuovo di Garfagnana. The maxillae, the premolars and the molars are shorter than those of *S. jeanvireti* and *D. megarhinus* and they are close to the values of *S. etruscus*. Moreover, the vestibular walls of the teeth are relatively flat with a slightly marked paracone folds.

##### Costa Marenga (Salsomaggiore, Emilia-Romagna)

The nasal bones (MGC sn) from Costa Marenga show the presence of a partial nasal septum (Simonelli 1919). This morphology allows to exclude an attribution to *D. megarhinus*. The rugosity on the dorsal side of the nasal bones is

well developed and the rhinion is more inclined than in *S. jeanvireti* and it is similar to those of *S. etruscus*.

Rhinocerotini indet.

Few teeth collected at Sarzanello (Ponzano di Magra, Tuscany; Capellini 1913) (MGC sn) and Barga (MGC7584) show common characteristics belonging to both *D. megarhinus* and *S. jeanvireti*. They are ascribed to Rhinocerotini indet.

## Discussion and conclusions

The morphological and morphometrical revision of the occurrences of *Dihoplus megarhinus* in Italy allows to record the species in at least ten Pliocene localities: Val di Pugna, Colle della Casazza, Rio Secco, Montelungo, Monte Biancano, Monte Giogo, Montezago, Palaia, S. Regolo and Dusino-San Paolo (lower levels). The records of the species in other Pliocene localities are unfounded and they can be really referred to *S. jeanvireti* (Monte San Pietro, Monte Pastore, Montopoli, Pradalbino, Monte Pulgnasco) or *S. etruscus* (Costa Marenga, Montopoli). *D. megarhinus* appears to be easily distinguishable from *S. etruscus*, in particular, due to the large size of its remains. In the mandibles, the two species differ in the development of the diastema and the symphysis (longer in *D. megarhinus* than in *S. etruscus*) and additionally in the presence, in *D. megarhinus*, of obvious, but non-functional incisors. Other differences are clear in the vertical ramus of the mandible and in the height and thickness of the horizontal ramus. Moreover, the differences between the mandibles of *D. megarhinus* and *S. jeanvireti* are relatively scarce and are particularly apparent in the orientation of the anterior border of the vertical ramus and partially in the morphology of the ventral border of the horizontal ramus. In addition, the two species appear to differ in the morphology of the incisive corpus, but this area is usually poorly preserved in fossil specimens. The postcranial remains of *D. megarhinus* are more easily distinguished from those of *S. jeanvireti* and *S. etruscus* than the mandibles. The limb bones of *D. megarhinus* are generally larger than those of the two *Stephanorhinus* species and show peculiar morphological characteristics. The morphological differences between the humeri, astragali and calcanei of *D. megarhinus* and *S. jeanvireti* listed by Guérin (1972, 1980) are confirmed by the results of this study. However, in the astragalus, the position and development of the medial tuberosity appear to be variable in *D. megarhinus* and *S. jeanvireti*, and this morphological feature is not very useful in distinguishing the two species. Unfortunately, the scarce remains of *D. megarhinus* collected from the

Italian sites do not allow an extensive morphometrical investigation for analyzing evolutionary trends or variability in the populations. Several morphometric values of the remains from Val di Pugna are closer to the minimal values of *D. megarhinus* given by Guérin (1980) but they are also included in the range of morphometrical variability of the remains from Montpellier (see Guérin et al. 1969).

In Italy, *D. megarhinus* was also reported in other fossiliferous localities of lower significance and usually these records are related to nomenclatural misidentifications with other species. In particular, *D. megarhinus* was reported at Mulazzano (Parma, Emilia-Romagna) by Simonelli (1897), but the third upper molar recovered in this site can be referred to *S. etruscus* (Guérin 1980). Guérin (1980) ascribed a mandible from Alta Valle del Serchio (Lucca, Tuscany) to *D. megarhinus*; however, stratigraphic or chronological information about the site is not available. Isolated teeth probably belonging to the same individual have been collected from a lignite bed at Borgo San Lorenzo (near Florence, Tuscany) and they were ascribed to *Rhinoceros* cf. *leptorhinus* (the attribution has to be considered as *D. megarhinus*) by Leonardi (1947). The teeth are dimensionally smaller than *D. megarhinus* and *S. jeanvireti* and the morphology is similar to that of *S. etruscus*. In agreement with Guérin (1980), the above-mentioned remains can be referred to the Etruscan rhino. Moreover, Falconer (1868) and Guérin (1980) ascribed an upper cheek tooth-row from Imola (Bologna, Emilia-Romagna) to *D. megarhinus*; however, it shows morphological and morphometric characteristics similar to the Etruscan rhino from Capitone (Terni, Umbria) and it was referred to *S. etruscus* by Pandolfi and Petronio (2011). *D. megarhinus* was also reported in some Pleistocene sites by Falconer (1868) based on the remains collected from the Tiber River terraces (Rome, Latium). These records were really unfounded and the above-mentioned remains were ascribed to *S. hundsheimensis*, *S. hemitoechus* or *S. kirchbergensis* (see Guérin 1980; Di Stefano et al. 1998; Pandolfi et al. 2013 and references therein). Thus, in Italy, as in Western Europe, *D. megarhinus* characterized the Early and early Late Pliocene localities only. However, Breda et al. (2010) recently ascribed to *Stephanorhinus* cf. *megarhinus* some rhino remains recovered at the early Middle Pleistocene site of Boxgrove (England). These remains consist of teeth (M82482-97) and a fragmentary skull (M82542) (Breda et al. 2010; p. 140–144, Figs 6 and 7). According to the writer, the morphology of the fragmentary skull from Boxgrove partially resembles that of *S. etruscus*. In particular, in occipital view, the above-mentioned skull shows a linear outline of the occipital crest; in dorsal view, the occipital crest has a V-shaped concavity and, in lateral view, is poorly projected over the

occipital face; the latter is slightly inclined forwards. All these characteristics are clear in the Lectotype of *S. etruscus* (IGF756) from Upper Valdarno. However, the specimen from Boxgrove is dimensionally larger than the Upper Valdarno specimens but is close to the maximal values of *S. etruscus* given by Guérin (1980) except for measures 23 (occipital face height) and 32 (occipital condyles external width). The values of the latter are higher than those reported by Guérin (1980); indeed, the occipital face appears slightly higher in the Boxgrove specimen than in *S. etruscus*. Furthermore, several morphological characteristics of the teeth from Boxgrove can be recognized in some specimens of *S. etruscus* from Upper Valdarno (e.g., in the maxillae of skull IGF889) and Capitone (MPUR1500), in particular: the isolated protocone of P2/, multiple and complicated crochet in P4/ and P3/ with small additional spurs, a slight protocone constriction in M1/, the presence of a continuous lingual and mesial cingulum in the premolars, a constriction in the hypocone of P3/ and P4/, an open mediofossette and a single crochet in M3/. However, in the above-mentioned specimens, the paracone folds appear less marked than in the specimens from Boxgrove. An attribution of these remains to *D. megarhinus* can be excluded, but new investigations and new remains are needed to identify them.

The rhinoceros remains from Meyrargues (France), previously ascribed to *Dicerorhinus mercki*, can be referred to *D. megarhinus* (Bonifay 1961; Guérin 1980). These deposits were usually referred to the Pleistocene; however, according to Bonifay (1961), “L’origine de ces éléments reste assez obscure”, but “...ils portent encore des traces du sédiment qui les contenait, un sable calcaire de couleur rouille plus ou moins consolidé en grès.” (Bonifay 1961; p. 1, line 16). This calcareous sand can be readily correlated with the ancient depositional series outcropping at Meyrargues, chronologically related to the Pliocene (cf. Ollivier 2011; p. 9).

Finally, von Koenigswald (1988, 1991) reported the occurrence of *Dicerorhinus* cf. *megarhinus* in the Pleistocene deposits at Gross-Rohrheim (Germany). The morphology of the teeth figured by von Koenigswald (1988, 1991) is quite similar to that of the specimens from Boxgrove. However, the vestibular wall of the premolars from Gross-Rohrheim appears to have less marked paracone folds. The records in Late Pleistocene sites of rhinoceros remains morphologically similar to the Pliocene species are, according to Fortelius et al. (1993), “based on stratigraphic misinterpretation or aberrant individuals improbable, but their significance is unclear”.

According to Hürzeler and Engesser (1976) and Guérin (1980), a rhino dimensionally close to *D. megarhinus* has been recovered in Italy in the faunal assemblage of Baccinello V3 (latest Miocene; Tuscany). Recently, Guérin

(2008) ascribed the remain from Baccinello V3 to *Diceros douariensis*. This specimen, a fragmentary tibia (NMB sn), is quite different from those of *D. megarhinus*, but new discoveries and a detailed analysis are needed. Furthermore, two upper teeth ascribed to *Dicerorhinus* cf. *megarhinus* have been recovered in the latest Miocene deposits of Monticino Quarry (Brisighella, Emilia-Romagna) (De Giuli 1989; Engesser 1989; Rook et al. 1991, 1999). The teeth have a series of common characteristics with *D. megarhinus*. However, due to the records of African genera in Italy during the latest Miocene, a detailed revision of these specimens is needed. Thus, the earliest certain occurrence of *D. megarhinus* in Italy is at the beginning of the Pliocene in the sites of Val di Pugna. Moreover, in Italy, the records of *D. megarhinus* are limited to the northern area, in particular, in marine deposits of Northern Tuscany (Val di Pugna) and Emilia-Romagna (some localities between Bologna and Piacenza). The last occurrence of the species can be related to the first occurrence of *S. jeanvireti*. The latter rhino has never been recorded together with *D. megarhinus*, and it is probable that the Italian sites in which *S. jeanvireti* has been reported are younger than the Early Pliocene. Indeed, *S. jeanvireti* is present during the Late Pliocene (MN16), and, as *D. megarhinus*, it is frequent in the Northern Italian fossiliferous localities (Piedmont, Emilia-Romagna and northern Tuscany). Rare specimens of the small *S. etruscus* are recorded in the Pliocene sites of Villafranca d’Asti and Montopoli together with the more abundant *S. jeanvireti*. Indeed, the Etruscan rhino is represented only by one talus (IGF1452V) and a fragmentary metatarsal (IGF4688V) in the site of Montopoli (see the description in the previous chapter) and by a distal epiphysis of a humerus (NMB sn) in the site of Villafranca d’Asti. Mazza (1988) considered this record to be too poorly documented and gave scant credit to it. However, *S. etruscus* is also recorded in Late Pliocene deposits of Castelnuovo di Baradenga Scalo (Cusani Politi 1963a, 1971) and Città delle Pieve (Fortelius et al. 1993). Moreover, the association *S. jeanvireti*–*S. etruscus* is also recorded in other European sites in France, Spain and Romania (Guérin 1980; Mazo 1995; Radulescu and Samson 2001), and it appears to be exclusive of the MN16. At the end of the Late Pliocene, *S. jeanvireti* disappeared, whereas the Etruscan rhino was widespread in Central (Castel San Pietro, Tiberino Basin, L’Aquila Basin) and Southern Italy (Pirro Nord) (Pandolfi and Petronio 2011).

The records of *D. megarhinus* in Italy, and generally in Western Europe, are an important biochronological tool to correlate the European faunal assemblages of the Pliocene. The species appears to be present at first in Southern Europe during the Early Pliocene and later widespread in Asia during the Late Pliocene. These data suggest a

probable European origin of *D. megarhinus*, but a careful investigation of the phylogenetic relationships between the Late Miocene and Pliocene taxa is needed to verify this hypothesis.

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