The skull of Stephanorhinus kirchbergensis (Jager, 1839) (Mammalia, Rhinocerotidae) from Spinadesco (Cremona, Lombardia, Northern Italy): morphological analyses and taxonomical remarks e an opportunity for revising the three other skulls from the Po Valley

Quaternary Science Reviews 109 (2015) 28–37

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

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ARTICLE INFO

Article history:
Received 22 September 2014
Received in revised form
28 November 2014
Accepted 29 November 2014
Available online 19 December 2014

Keywords:
Stephanorhinus kirchbergensis
Spinadesco
Po river
Northern Italy
Quaternary

ABSTRACT

The exceptional discovery of a complete and extraordinary well-preserved skull of *Stephanorhinus kirchbergensis* (Jäger, 1839) on an alluvial bar of the Po river near Spinadesco (Cremona, Lombardia, Northern Italy) in July 2013 presented us with the opportunity for reporting on the specimen. The thorough morphometric and morphological analyses carried out on the specimen (dentition included) revealed typical characteristics of *S kirchbergensis* – also known as "Merck's rhinoceros". These peculiar tracts highlighted distinctive taxonomic characteristics which are useful for reassessing the classifications of the specimens found in adjacent areas up to now.

In this paper, the distinguishing characters are discussed privileging the morphological features rather than the metrical characteristics also if the dimensions of the skull are significative. The adopted criteria, employed for the first time by Loose (1975), were used also for comparing the skull from Spinadesco with other fossil rhinoceros skulls discovered in the Po Valley adjacent areas: the *Dicerorhinus hemitoechus falconeri* (Azzaroli, 1962) from Mezzana Rabattone (Zinasco, Pavia), the *Dicerorhinus hemitoechus aretinus* (Azzaroli, 1962) from San Colombano al Lambro (Milano), and the *Dicerorhinus hemitoechus intermedius* from the Torrente Stirone studied by Cigala-Fulgosi (1976).

Up to now, *S. kirchbergensis* appears to be a rather rare species on the vast Eurasian landmass as few fossils have been found in a relatively limited number of localities. Furthermore, there are generally not available chrono- or biostratigraphic data.

1. Introduction

An extraordinary well-preserved fossil rhinoceros skull was accidentally discovered in June 2013 on the alluvial bar of Spinadesco (Cremona, Northern Italy), on the right bank of the Po river downstream from its confluence with the Adda river on territory of Spinadesco (Fig. 1).

The area, which is well-known for its numerous palaeontological Quaternary discoveries, is composed of a long crescent-shaped meander bar (about 3 km), located along the northern side of Isola Serafini, just upstream from the confluence with the Adda river, towards the south-east, where the Po meets an artificial channel that flows into the meander becoming a single channel.

Ever since the seventies large fossils and palaeontological evidence have been discovered on this bar which do not show signs of having been transported by the river probably due to the intense erosion process generated by the natural morphology of the river, the hydrodynamic context generated by the confluence with the Adda river, the current generated by the functioning of the Isola Serafini hydroelectric power station and the possible presence of surface pleistocenic fossiliferous strata. In fact only the third left upper molar (M^3) is missing from the skull probably due to a post-mortem trauma.

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http://dx.doi.org/10.1016/j.quascirev.2014.11.022
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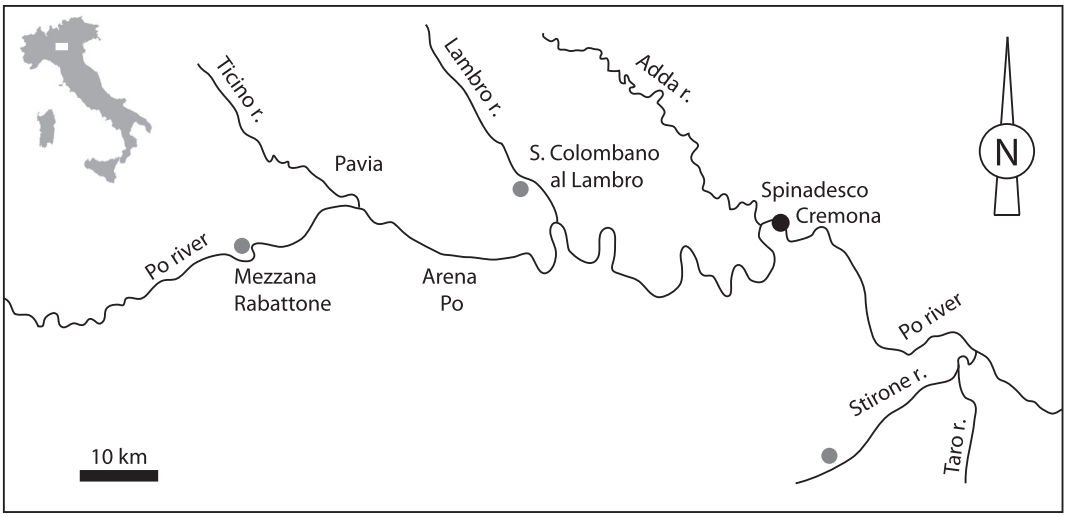


Fig. 1. Index maps of the central-eastern Po plain area and localization of the localities cited in this paper.

The fossil studied in this paper is comparable to three rhinoceros skulls discovered in neighbouring areas of the Po plain. They were found in various localities surrounding of the Po plain. The one found close to San Colombano al Lambro (Milano, Lombardia) was described as *Rhinoceros Merchianus Etruriae* by Caccia (1928) and was later re-documented by Cantaluppi (1969) as *Dicerorhinus hemitoechus aretinus*. Another one was discovered at Mezzana Rabattone (Pavia, Lombardia) by Anfossi and Cantaluppi (1987) who ascribed it to *Dicerorhinus hemitoechus falconeri*. The third one was found in the Torrente Stirone (Salsomaggiore, Parma, Emilia Romagna) by Cigala-Fulgosi (1976), assigned to *Dicerorhinus hemitoechus intermedius*.

As a genus name, *Stephanorhinus* was first introduced by Kretzoï (1942) in honour of Stephan I, the first King of Hungary. *Stephanorhinus* – as a still controversial genus in literature – is here in synonymy with *Dicerorhinus/Dihoplus*.

2. Material and methods

The rhinoceros skull from Spinadesco (Plate 1) was taken to Museo Paleoantropologico del Po at San Daniele Po (Cremona) from June 2013. Prior to delivery, the skull had been washed by its discoverer, fortunately without causing any apparent damage, yet removing all the information regarding the sediment encasing the skull.

Therefore only a small sample of silt residue was found in the brain cavity and some residuals of peat that had remained between the folds of the tooth enamel with which it was possible to carry out a comparative analyses with sediments collected on site or on other fossils (Persico et al., 2012). The peat sample found in the folds of the tooth enamel only revealed the presence of compact organogenic sediment composed of plant residues. This sediment, considered to be primary, is characteristic of the sedimentary facies in which the bone fossilized.

These vegetal remains are of the great importance for the palaeoecological contextualization of the fossil skull, so that a future thorough investigation correlated to this article is absolutely suitable.

The morphometric study was performed using manual measuring instruments such as a manual gauge, an anatomical compass with curved branches, a level, and a yardstick. The fossil was fully photographed from every angle by using a digital camera Pentax WG-1 mounted on a stand. Angular measurements were obtained using a manual goniometer.

The data obtained were compiled in a table (Table 1) with the graphic description of the biometric parameters adopted which

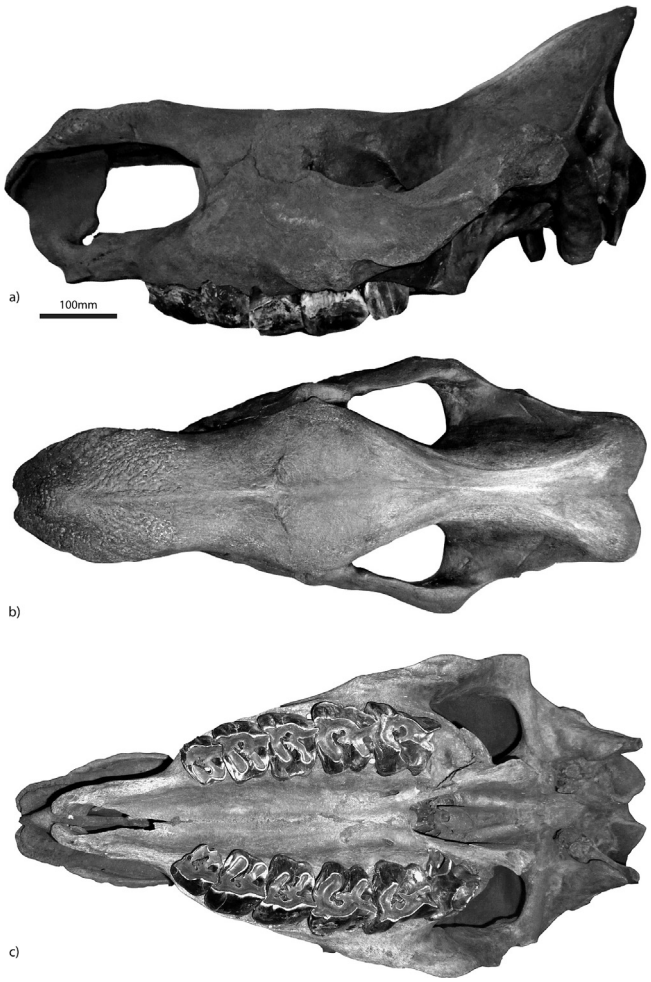


Plate 1. *Stephanorhinus kirchbergensis* (Jäger, 1839) from Spinadesco (Cremona, Lombardia, Norther Italy): a) lateral view; b) dorsal view; c) ventral view (scale bar = 100 mm).

Table 1
Synoptic table of the main and most significative absolute dimensions (in mm) and their ratio.

Biometric parameters	*D. etruscus* Valdarno superiore	*D. hemitoechus intermedius* T. Stirone	*D. hemitoechus falconeri* Bucine	*D. hemitoechus falconeri* Mezzana Rabattone	*D. hemitoechus aretinus* San Colombano	*D. hemitoechus aretinus* Ponte alla nave	*D. hemitoechus aretinus* Botro Maspino	*D. hemitoechus aretinus* Botro Maspino	*D. hemitoechus aretinus* (?) Ilford	*S. kirchbergensis* Spinadesco
L	630	710	700	710	704	725	700	725	787	776
LZ	315	(304)	320	359	325	328	330	310	364	406*
LF	217	(237)	224	228	253	250	249	248	–	238
LN	116	130	125	152	145	132	155	123	–	166
H	174	177	166	–	180	203	–	199	219	220
NO	278	358	328	364	341	354	356	358	354	383
LsD	218	263	249	–	258	260	–	245	271	310
tz	–	48.2	–	66.5	–	–	–	–	–	68.4
ac	–	–	–	–	–	–	–	–	–	131
gh	–	–	–	–	–	–	–	–	–	72.5
gb	–	–	–	–	–	–	–	–	–	422
af	–	–	–	–	–	–	–	–	–	250
LZ/L	0.50	(0.42)	0.46	0.50	0.46	0.45	0.47	0.43	0.46	0.52
LF/L	0.34	(0.33)	0.32	0.32	0.36	0.35	0.36	0.34	–	0.30
NO/L	0.44	0.50	0.47	0.51	0.48	0.49	0.51	0.49	0.45	0.49
gb/L	0.58	0.53	0.54	0.53	0.54	0.53	0.52	0.53	0.56	0.54
ac/L	(0.15)	0.19	0.14	0.15	0.15	0.13	0.13	0.14	–	0.16
af/L	0.29	0.36	0.35	0.33	0.36	0.36	0.35	0.36	0.35	0.32
af/NO	0.66	0.72	0.74	0.65	0.75	0.73	0.74	0.72	0.77	0.65
gh/H	0.40	0.42	0.41	–	0.40	0.33	–	0.30	0.34	0.32
LF/LZ	0.69	(0.77)	0.70	0.63	0.78	0.76	0.76	0.80	–	0.58
LN/LF	0.53	(0.54)	0.56	0.66	0.57	0.53	0.62	0.50	–	0.69
alfa	–	12°	–	9°	6.5°	–	–	–	–	8.5°

*Estimated measurement.

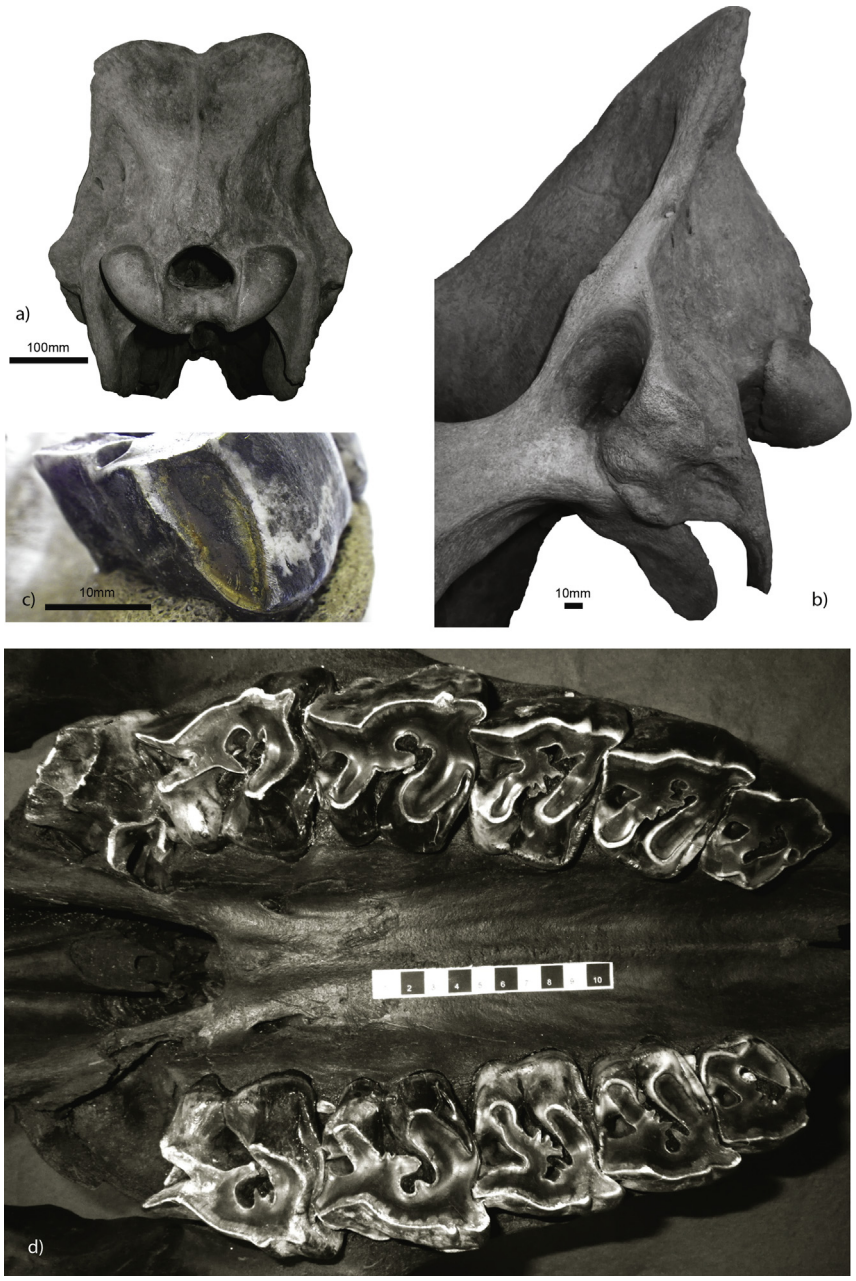


Plate 2. *Stephanorhinus kirchbergensis* (Jäger, 1839) from Spinadesco (Cremona, Lombardia, Norther Italy): details of the skull: a) occipital view; b) particulars of the nuchal crest and of the post-tympanic (ppt), paraoccipital (ppo), and post-glenoid (ppg) processes; c) particular of a recent fracture on a second upper left premolar (P^2); d) particular of the two dental ranges.

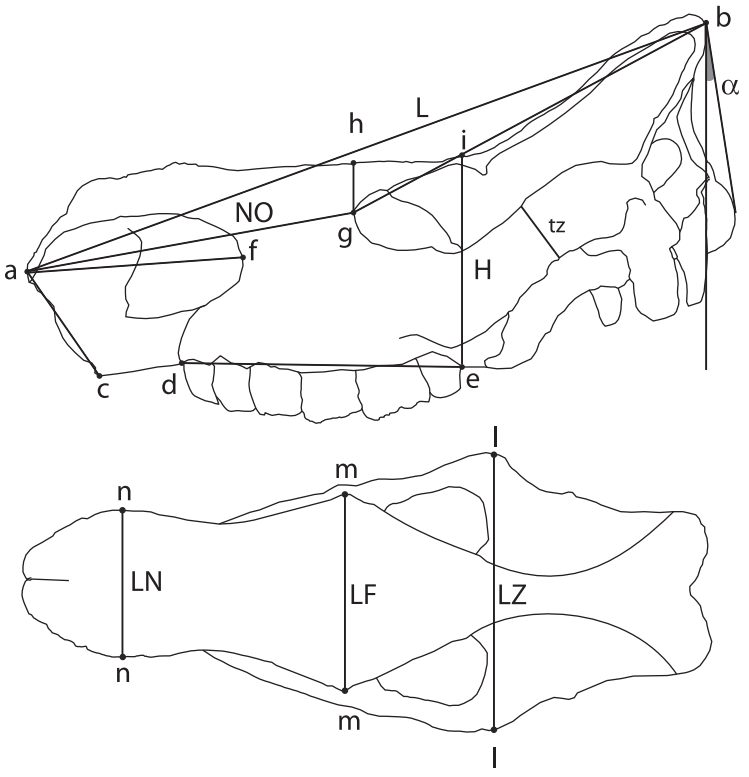
were then used in various comparative tables with the aim of validating the distinctive characteristics of the specimen, through dimensional ranges and ratios.

In the morphological description, we used the same biometric measurements and indexes adopted by Cantaluppi (1969), Cigala-Fulgosi (1976), and Anfossi and Cantaluppi (1987) in order to compare the Spinadesco skull with the published data concerning the three other skulls from Po Valley as well as the Krapina skull mould. The comparative approaches proposed by Loose (1975a,b) and Azzaroli (1962) were particularly useful. The integration of all these methodologies generated the overall picture outlined below.

The find of the *Stephanorhinuskirchbergensis* skull from Spinadesco strongly suggest a taxonomical revision of the skulls coming from San Colombano al Lambro and from the Torrente Stirone. This comparison has been made by using the *Stephanorhinushundsheimensis* skull from Pakefield (Breda et al., 2010, Fig. 10) and the mould of the skull (belonging to *S. hundsheimensis*) from Isernia-La Pineta (Molise, Central Italy), specimen faithfully reproduced and kept at the Museo di Paleontologia e Preistoria of the Ferrara University.

3. Description of the skull found in Spinadesco (Cremona, Northern Italy)

The fossil skull object of this paper is certainly one of the largest and best preserved finds unearthed in Western Europe (Plate 1).



Biometric parameters and measurements	
L	776 mm
LZ	406 mm*
LF	238 mm
LN	166 mm
H	220 mm
NO	383 mm
LsD	310 mm
tz	68.4mm
ac	131 mm
gh	72.5 mm
gb	422 mm
af	250 mm
LZ/L	0.52
LF/L	0.30
NO/L	0.49
gb/L	0.54
ac/L	0.16
af/L	0.32
af/NO	0.65
gh/H	0.32
LF/LZ	0.58
LN/LF	0.69
α	8.5°

Fig. 2. Adopted skull's biometric parameters and values.

The grey-brown colouring of the bones and the grey-black hue of the teeth is typical of the evidence found in the alluvial sediments of the Po river, namely partially mineralized fossil bones containing pyrite, limonite, haematite, manganese, and manganocalcite (Persico et al., 2012). These minerals, indicating an anoxic environment of fossilization characterised by abundant carbonificated organic plant matter, are clearly visible inside the teeth, especially in the internal areas brought to light by recent fractures (Plate 2, Fig. c).

There is no evidence of river transport (rafting) on the skull and the exceptional status of preservation reveals every diagnostic trait necessary for its specific classification.

3.1. General morphology

The skull is very large and exceptionally-preserved, except for a small, post-mortem surface fracture in the most prominent point of its right zygomatic arch.

The profile of the skull is very robust indicating that it does not belong to *Stephanorhinus etruscus* (Falconer, 1868), *S. hundsheimensis* (Toula, 1902), or *Stephanorhinus hemitoechus* (Falconer, 1868), which are generally much more slender. The thickness of the zygomatic bone (tz) (Fig. 2), for example, reaches a maximum measurement of 68.4 mm, far superior to any skull used as a comparison, but in line with the size of the specimens of the *S. kirchbergensis* species. A resin copy (faithfully reproduced and preserved in the collections kept at the Museo di Paleontologia e Preistoria of the Ferrara University) of the *S. kirchbergensis* skull (also known as *Rhinoceros Mercki* var. *Krapinensis*) found at Husnjakovo Brdo (Krapina, not far from Zagreb, Croatia) (Gorjanovich-Kramberger, 1913), also reported in Billia (2010, Plate 2), was used as direct biometric comparison, showing a maximum value of zygomatic thickness (tz = 62 mm), even if the bone is partially damaged.

The maximum occipital nose length (*L*) of 776 mm corresponds to relatively tight front and nasal bones. The maximum distance between the cheekbones (LZ) of 406 mm (estimated value due to a few missing cm of the right zygomatic bone), is superior to the values of any other specimen shown in the table as comparison. This fact is particularly evident in ventral view observation (Plate 1 Fig. c).

The dorsal profile, slightly concave from the occiput to the nose, is interrupted by a small and thin parietal crest and at the same level as the lacrimal bone, which forms the base of insertion for the posterior horn; this saddle continues with the nasal bones which bend decisively forward, converging with the septum nasal bone.

3.2. Nasal region

The nasal cavity is open, indicating that it does not belong to the closed-nostril *Coelodonta antiquitatis* (Blumenbach, 1799).

The nasal notch (f) is 250 mm long (Fig. 2). By referring to the comparative method adopted by Anfossi and Cantaluppi (1987), which compares the relationship between the length of incisura nasalis and occipital-nose length (L), it is observed that the value of the ratio in the fossil under examination (0.32) positions itself in the middle of the comparative values (0.33). Since the other specimens belong to at least three different species, the value of this ratio does not seem to be taxonomically discriminating. On the other hand, the ratio between the width of the incisura nasalis (af)

and the nose orbital distance (NO) (Table 1) appears to be more suggestive as with a value of 0.65, the fossil analysed corresponds to the morphological specimen found in the Po at Mezzana Rabattone and studied by Anfossi and Cantaluppi (1987).

From Table 1 it is clear that the rhinoceros skull from Mezzana Rabattone is the only Po Valley example with a value of af/NO is less than 0.7. In our opinion, this morphometric discrepancy calls for a taxonomic revision of the specimen.

By observing the side view of the skulls under examination, the caudal extremity of the nasal notches and the vertical lines passing through the third upper premolar (P^3) only correspond in the specimens belonging to *S. kirchbergensis* (e.g., Daxlanden [Karlsruhe, Baden-Württemberg] and Krapina [Croatia]). In all other species, the nasal notch is further back even as far as the vertical line passing through the first upper molar (M^1) (Loose, 1975a,b Pl-5 Fig. 1).

3.3. Otic and zygomatic regions

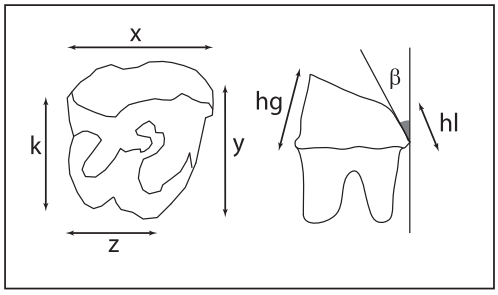
The external acoustic meatus is wide of a sub-elliptical shape, with a nuchal crest and a pronounced, protruding retro-articular process.

The overturned-Y-shaped nuchal crest (Plate 2, Fig. b), branches out outlining the external acoustic meatus according to the scheme reported by Loose (1975a,b, Fig. 5, p. 18), in reference to *S. kirchbergensis*. In this paper, the author also illustrates the morphology of the otic region of *S. etruscus*, *S. hemitoechus* and the present species with an extreme precision. The location of the post-tympanic (ppt), paraoccipital (ppo) and post-glenoid (ppg) processes are also fundamental for distinguishing the various species through the morphology of the otic region. In the skull from Spinadesco, these three processes are located below yet in contact with the external acoustic meatus (ppt); vertically below yet in a slightly caudal position (ppo) and below, but slightly shifted in a cranial position to the curved front end (ppg) (Plate 2, Fig. b). The morphology recognised in this fossil formally coincides with that proposed by Loose (1975a,b) for *S. kirchbergensis*.

Following a direct comparison, similar morphologies were observed in the specimens found at Mezzana Rabattone, for which a taxonomic revision is required in our opinion.

All the measurements of the Po valley skulls have been verified and additional measures have been taken and added in Table 1 as an integration of the older ones.

In the specimen from Spinadesco, the maximum interzigomatic width (WM = 406 mm) is much higher compared to that of all the other specimens analysed creating even more doubt concerning the correct measurement of the specimen. Following repeated checks it appeared to be a very large skull which seems very similar in size to the skulls found at Ilford (Essex, Great Britain) and at Mezzana Rabattone with at least 42–46 mm of variance.



	x	y	z	k	hl max	hg max	β
P2	34 mm	31	22	37	18	37	-
P3	42.5	58.5	30.3	51.8	22.6	51	-
P4	50.5	63	37	55.9	36.5	60.5	37.5°
M1	53.6	66.8	37.4	56.6	23	49	27.5°
M2	57.2	68.8	47.6	57.2	32.5	61.5	41°
M3	63.5	63	55	-	30.8	58.5	-

x= labial anteroposterior diameter
y= anterior transverse diameter
z= lingual anteroposterior diameter
k= posterior transverse diameter
β= angle between the vertical line and the lingual wall

Fig. 3. Adopted teeth's biometric parameters and values.

3.4. Occipital region

The posterior dorsal region is strongly upward and ends in an occipital crest with a sharp incision along the caudal margin (Plate 2 fig. a) (in our opinion, this character which is highly variable cannot be considered as a taxonomic evidence).

The posterior ridge is very short and the occipital condyles protrude caudally in respect to it. This prominence is highlighted by the value of the angle formed between the vertical line passing through the top of the caudal occipital crest and the segment passing between the top of the caudal occipital protuberance and the most prominent point of the occipital condyles (α) (Fig. 2). The caudal projection of the condyles in relation to the occipital crest is one of the most distinguishing features in *S. kirchbergensis* (Loose, 1975a,b).

3.5. Teeth

The skull from Spinadesco shows typically brachyodont teeth: both the vestibular and lingual walls of dental elements are strongly inclined compared to the vertical (e.g., in M^2 $\beta = 41°$). The same elements have truly remarkable dimensions (the length of the dental series is 319 mm). The protocones of the first and second molars (M^1 and M^2) show a remarkable bulbousity at their base, a typical trait of *S. kirchbergensis*.

The biometric parameters used for describing the teeth and the relative sizes of each singular tooth (right upper dental range) are listed in Fig. 3.

These features differentiate the teeth of this fossil with its counterparts of *S. hemitoechus* typically hypsodont and with sub-vertical lingual walls.

4. The skull from Spinadesco: diagnosis

In the description of the Spinadesco skull, cranial morphological criteria were preferred to biometric ones. This because in the past (even recently) only biometric parameters were used which later proved to be quite misleading when attributing a specific characteristic to a single skeletal fossil.

For this reason the morphological study of the fossil skull from Spinadesco made it possible to emphasize some diagnostic elements for classifying fossils.

By comparing the skull from Spinadesco to the one found at Krapina (Croatia) which is attributed to *S. kirchbergensis*, a remarkable correspondence can be observed even if they have different dimensions (the skull from Krapina (728 mm) is shorter) with the intertemporal ridges (already mentioned for the fossil in question) which proceed, spaced out, up to the occipital crest.

In the Krapina skull (Billia, 2010), these ridges are equally spaced, yet much more pronounced. The concretions of the nasal bone at the insertion of the nasal horn and the upper margins of the orbits are also more pronounced on the Krapina skull. This variability of characters can be attributed to the different ontogenetic stage, as well as some intraspecific variabilities or possible sexual dimorphism.

The zygomatic arch of the Spinadesco skull is very thick. The same thickness is also observed in the Krapina skull. The slightly recessed nasal fossa is also a common characteristic of both the skulls – which is also evident in the *S. kirchbergensis* skull reported by Loose (1975a,b) (Plate 5, Fig. 1).

1) – which never exceeds the caudal margin of the third upper premolar (P^3).

In short, the following specific taxonomic characters must be considered:

a) the maximum nose-occipital length exceeding 700 mm (the *S. kirchbergensis* skull studied by Loose (1975a,b), generally considered specimen of anomalous dimensions, represents an exception);
b) the nasal cavity open retracted posteriorly up in correspondence with the vertical through the third upper premolar (P^3);
c) the short occipital crest;
d) the occipital condyles aligned or caudally protruding to the occipital crest;
e) the remarkable thickness of the zygomatic;
f) the remarkable brachyodontia of the teeth, in particular that of the fourth upper premolar (P^4), the first and second upper molars (M^1 and M^2);
g) the accentuated bulbosity at the base of the protocones of the first and second upper molars (M^1 and M^2).

The above characteristics highlighted by the skull from Spinadesco represent characters absolutely typical of *S. kirchbergensis* (Jäger, 1839).

5. The other Eurasian *S. kirchbergensis* skulls

Excluding China, up to now the Spinadesco skull would be the eight *S. kirchbergensis* skull found on Eurasian territory. Three of them were discovered in Germany:

- the only complete German skull (LNK Op/650) was found at Daxlanden (Karlsruhe, Baden-Württemberg) in 1802 and has been studied by several authors over the last two centuries;
- the skull (NMM 1956/962) from the Rhine at Mosbach ("Mosbach-II") (Heilbronn, Baden-Württemberg), which was severely damaged in the front, is the oldest *S. kirchbergensis* skull found in Western Europe (a MOIS 13 – ca 500 kys BP – has been proposed for Mosbach-II [vide autem in Billia, 2010, pp. 20–21]) and has also been studied by numerous authors;
- the amply restored SMN 16275 skull found along the Murr at Steinheim an der Murr (north of Stuttgart, Baden-Württemberg) was studied by Staesche (1941, Pl. 11-figs 1, 3) and several other authors.

A detailed excursus storicus on the three above mentioned *S. kirchbergensis* German skulls may be found in Billia (2011, pp. 20–21).

The three other Eurasian skulls come from: Husnjakovo Brdo at Krapina (Croatia) (Gorjanovic-Kramberger, 1913, above cited in this text), from Warsaw (Poland) (MZ VIII Vm-450) (Borsuk-Bialynicka and Jakubowski, 1972), and from the "Irkutsk region" (southwest Eastern Siberia) (ZIN 10718) (Chersky, 1874; Brandt, 1877; Billia, 2008, 2010).

In accordance with the present revision (just as in this article), the skull from Mezzana Rabattone – previously attributed by Anfossi and Cantaluppi (1987) to *D. hemitoechus* – must be added to this list.

Another well-known rhinoceros skull was found in "Bessarabia". It has been referred to *Rhinoceros mercki* by Simionescu ("Nach den oben angeführter Einzelangaben glaube ich, dass der beschriebene Schädel mehr an *Rh. mercki* erinnert" [Simionescu, 1939–40, p. 430, figured in Pl. I–p. 432]). Nevertheless, by observing some of its morphological characters, in our opinion it may belong to *Coelodonta antiquitatis* (Blumenbach, 1799). However, the specimen – found in an unknown locality in Bucovina (now Ukraine) and previously preserved in the collections of the Palaeontological Institute of the University of Bucharest – is unfortunately unavailable at present (V.A. Codrea, personal communication).

Finally, according to Lanser (1997) "Bei Grabungsarbeiten in einem östlichen Seitengang der Dechenhöhle bei Iserlohn-Letmathe (nördliche Sauerland), wurde im Frühjahr 1993 ein Rhinozerosschädel entdeckt. Die Grabungen wurden außerhalb des Schauhöhlenbereichs durchgeführt, der seinerzeit als Bodendenkmal eingetragen war". This skull would be identified by Lanser as *S. kirchbergensis*.

Let us now focus on the Chinese skulls. In the past, most of the Southern Chinese Pleistocene rhinoceros material was attributed to *Rhinoceros sinensis* Owen, 1870 (= *Rhinoceros sinensis* Osborn, 1898). Furthermore, *Rhinoceros choukoutiensis* Wang, 1931 (recte *Dicerorhinus choukoutienensis* [Wang, 1931]) was considered to be a synonym of *S. kirchbergensis* by some authors (Teilhard de Chardin, 1936; Teilhard de Chardin and Leroy, 1942; Xu, 1986; Tong and Wu, 2010).

By assuming that *Rhinoceros sinensis* Owen, 1870 and *Dicerorhinus choukoutienensis* (Wang, 1931) are synonyms of *S. kirchbergensis* (Tong and Wu, 2010; inter alios), the four other skulls found on Chinese territory should also be ascribed to *S. kirchbergensis*. Two of them (VM 555 and V2682) – formerly ascribed to *R.* cf. *sinensis* and later to *D. choukoutienensis* – come from the well-known locality of Choukoutien (= Zhoukoudjan) (CKT-1 and CKT-20) (Beijing province) (Wang, 1931; Chow, 1963, Pl. I; Chow, 1979, Pl. I, inter alios). Nowadays, the juvenile VM 555 skull is unavailable. The third (damaged juvenile LA 7701-x) skull was found at Anping (Liaoning province) (Xu, 1986; the skull is not shown in the Xu paper). The last (H36 fragmentary juvenile) skull – previously referred to *R. sinensis* by Wu (1998) – comes from Xiniudong (Hubei Province) (Tong and Wu, 2010, Fig. 1).

However, up to now – according to the amount of fossil evidence found – *S. kirchbergensis* appears to be quite a rare species on the vast Eurasian landmass there have been few discoveries in relatively limited number of localities (Billia, 2011, 2014). Moreover, there is often no available chrono- or bio-stratigraphic data.

6. Taxonomic revision on the three other rhinoceros skulls found in adjacent areas in the Po plain

The same criteria and distinctive taxonomic characters used for the first time by Loose (1975a,b) were employed here for classifying the skull from Spinadesco comparing it to other fossil remains discovered in the Po Valley adjacent areas. These characters revealed the taxonomic discrepancies listed below. In particular, significant similarities between the *S. kirchbergensis* from Spinadesco and the fossil skulls found in the Po at Mezzana Rabattone (Zinasco, Pavia) (Anfossi and Cantaluppi (1987) and at San Colombano al Lambro (Milano) (Caccia, 1928; Cantaluppi, 1969) as

well as the *D. hemitoechus intermedius* found and studied by Cigala-Fulgosi (1976) have been observed.

As already mentioned, numerous studies have been focused on the morphometric comparison of different specimens in relation to biometric data which – over the time – have been linked to interspecific variation and are therefore not taxonomically diagnostic. One example is the trend of inter-temporal ridges which are spaced out in the skull from Spinadesco. This character – together with others – was used by Azzaroli (1962) for dividing the *Dicerorhunus hemitoechus* species into two subspecies: *D. hemitoechus falconeri* and *D. hemitoechus aretinus*. In the *D. hemitoechus aretinus* subspecies, to which the skulls from San Colombano al Lambro (Milano), Ponte alla Nave (Arezzo) (Azzaroli, 1962) and Botrio Maspino (Arezzo) (Azzaroli, 1962) belong, the skull is massive with ridges that converge with almost supratemporal bones and then join in the median sagittal plane, accenting the widening of the front. On the other hand, the *D. hemitoechus falconeri* subspecies includes the skulls found at Pogi near Bucine (Valdarno superiore, Arezzo) (Azzaroli, 1962) and Mezzana Rabattone (Zinasco, Pavia) (Anfossi and Cantaluppi (1987) which date back to the Late Pleistocene (Ambrosetti, 1972), while those found at Clacton-on-Sea (Essex, England) (Falconer, 1868) and Mosbach (Heilbronn, Baden-Württemberg, Germany) are commonly deemed to be from the Middle Pleistocene.

A thick zygomatic arch is a common characteristic of the skull from Mezzana Rabattone and those found at Spinadesco and Krapina. Nevertheless, the backward caudal tendency of the occipital condyles, in respect to the external occipital protuberance, suggests that a revision concerning the relevant category of the fossil which was attributed *S. hemitoechus* by Anfossi and Cantaluppi (1987) is required. The reduced thickness of the zygomatic bone specimens from Bucine (Azzaroli, 1962), Ponte alla Nave (Azzaroli, 1962), Botrio Maspino (Azzaroli, 1962), Torrente Stirone (Cigala Fulgosi, 1976) and San Colombano al Lambro (Caccia, 1928; Cantaluppi, 1969) indicates a morphological tenuity which enables us to exclude these specimens from *S. kirchbergensis*.

The skulls found at Mezzana Rabattone (Anfossi and Cantaluppi (1987) and Bucine (Azzaroli, 1962) show an occipital region with an outline and a shape of the crest similar to the Spinadesco skull, which is also the case regarding the temporal region of the Spinadesco, Mezzana Rabattone and Bucine skulls which are morphologically characterized by a generally, sub-elliptical external acoustic meatus, with a pronounced and protruding nuchal crest and back-articular process. In these three specimens, the nuchal crest branches out surrounding the external acoustic meatus as well as in the skull from the Torrente Stirone (Cigala-Fulgosi, 1976).

Although *S. kirchbergensis* has often been diagnostically misidentified with other rhinoceros species, we must also consider that for a long time several palaeontologists believed that *S. kirchbergensis* was a synonym of *S. hemitoechus* (Billia, 2008, 2011).

6.1. The skull from Mezzana Rabattone (Zinasco, Pavia) (Anfossi and Cantaluppi (1987)

The specimen – which was classified by Anfossi and Cantaluppi (1987) as belonging to *Dicerorhinus hemitoechus* – is morphologically compatible with the skull from Spinadesco. The skull from Mezzana Rabattone is poorly preserved, with no teeth, but with an almost completely intact left zygomatic bone and undamaged open nasal cavity and optic and occipital regions. Thanks to their preservation status and the morphometric analysis carried out by the authors, it was possible to identify some key taxonomic characters which would exclude the Mezzana Rabattone specimen from *S. hemitoechus*. In fact, in the side view picture proposed by Anfossi and Cantaluppi (1987, Fig. 1, Table 1) the optic region is characterized by a subelliptic acoustic meatus with three processes: post-tympanic (ppt), paraoccipitale (ppo) and post-glenoid (ppg) arranged according to the morphological scheme proposed by Loose (1975a,b Fig 5, p. 18), coincident with the sample under study. The occipital condyles are more prominent than the occipital ridge forming an angle of about 9°, which is comparable to the value of the same angle measured on the Spinadesco skull (8.5°) and non-negative as it should be considering the greater backward tendency of the occipital crest in *S. hemitoechus*. The zygomatic bone is very thick (66.5 mm), while due to the absence of the teeth and jaw bones, it is not possible to determine if the vertical line through the posterior margin of the incisura nasalis falls on the P^3.

These features, as well as the biometric measurements ($L = 710$) comparable to those of *S. kirchbergensis* from Spinadesco (Table 1), call for a taxonomic revision of the Mezzana Rabattone specimen in order to re-attribute the same to *S. kirchbergensis*.

6.2. The skull from San Colombano al Lambro (Milano) (Caccia, 1928; Cantaluppi, 1969)

The San Colombano al Lambro fossil is in excellent condition. The tenuity of the zygomatic is easily perceptible. The nasal incision is open and backward to the fourth upper premolar (P^4) and the lateral profile is characterized by a rather pronounced nasal protuberance. The occipital crest is short and the occipital condyles protrude slightly compared to its extreme posterior margin. The value of the alfa angle ($\alpha = 6.5°$) was measured between the vertical line passing through the caudal end of the occipital crest and a line passing through the same point and the rear of the condyles. The measured angle is lower than in *S. kirchbergensis* and much lower than in *S. hemitoechus* (Loose, 1975a,b; Guérin, 1980).

The skull is 704 mm long, the dental series measures 258 mm. The relationship between the orbito-frontal occipital distance and the maximum length of the skull is 0.54, which is identical to the same value of the *S. kirchbergensis* skull from Spinadesco. In both cases, the equivalence of the report highlights the shortness of the occipital crest, which differs greatly to the cranial morphology of *S. hemitoechus*. The comparison between the skull from San Colombano al Lambro and the *S. hemitoechus* reported by Loose (1975a,b, Pl. 5, Fig. 2) emphasizes the difference between the length of the two occipital ridges, markedly highlighting the relative position of the condyles, which are slightly protruding compared to the occipital protuberance of the skull found at San Colombano al Lambro and slant decisevely inwards in the skull of *S. hemitoechus* described by Loose (1975a,b) ($\alpha = -4.5°$). In addition, we outlined the slightly concave caudal outline of the occipital crest when observed in dorsal view, outline which is slightly convex in *S. hemitoechus* (Guérin, 1980: 631; Loose, 1975a,b: pls. 4 and 6).

These discrepancies suggested to compare the morphology of the skull from San Colombano al Lambro with that ascribed to *S. hundsheimensis* from Pakefield (Breda et al., 2010, Fig. 10) and the mould of the skull from Isernia La Pineta (faithfully reproduced and kept at the Museo di Paleontologia e Preistoria of the Ferrara University). This comparison shows some taxonomical characteristics common with *S. hundsheimensis*. In particular, the relative position of the posterior edge of the nasal incision in relation with the P4 position, and of the anterior edge of the orbit with respect to the tooth row (Guérin, 1980); the degree of posterior elongation of the occipital crest (Guérin, 1980: 629; Loose, 1975a,b: pls. 3 and 5); in lateral view, the dorsal outline of the skull with a small but clear insertion for the posterior horn (Guérin, 1980: 629; Loose, 1975a,b: pls. 3 and 5): barely visible in S. hemitoechus, very visible in *S. kirchbergensis* and compatible with *S. hundsheimensis*. These data

is added to a morphology of the teeth absolutely compatible with that reported in Fig. 4 by Ballatore and Breda (2013).

Overall, the comparison of the characters listed above requires a revision concerning the classification of the San Colombano al Lambro specimen in order to reassign it to *S. hundsheimensis*, which was a common species between the end of the lower Early Pleistocene and the Middle Pleistocene.

6.3. The skull from the Torrente Stirone (Salsomaggiore, Parma, Emilia Romagna) (Cigala-Fulgosi, 1976)

A consequence of the revision of the skull from San Colombano al Lambro is the new taxonomical attribution to the fossil skull from the Torrente Stirone. Except for a diagenetic deformation, the skull is intact and preserves every specific character required for its classification. The fossil shows characteristics very close to those of the San Colombano al Lambro specimen, with a well-marked tenuity in the thin zygomatic (48.2 mm) and the reduced interzygomatic width (304 mm). The nasal cavity is open and slants backwards at the height of the fourth premolar (P^4), the nasal protuberance is pronounced.

As observed for the San Colombano al Lambro fossil which was attributed to *D. hemitoechus aretinus* by Cantaluppi (1969), the specimen found in the Torrente Stirone has a short occipital crest exemplified by the relationship between the orbito-frontal occipital distance and the total length of the skull (gb:L = 0:53). There is a positive angle between the vertical line passing through the caudal end of the occipital crest, a line passing through the same point and the rear end of the occipital condyles. It actually has a larger angle ($\alpha = 12^\circ$) than the San Colombano al Lambro and the Spinadesco skulls. This character is very different from the morphology of *S. hemitoechus* (Loose, 1975a,b; Guérin, 1980), to which the skull was originally assigned (Cigala-Fulgosi, 1976).

The length of the dental series (263 mm) is comparable to the San Colombano al Lambro specimen, and significantly lower if compared to *S. kirchbergensis* on which this study is focused (310 mm). However, this character is of a little importance if we consider the small specimen found in Daxlanden (Germany), deemed to belong to *S. kirchbergensis* by Loose (1975a,b) and previously attributed to *Dicerorhinus etruscus brachycephalus* by Guérin (1980). Moreover, the relative sizes of the fourth upper premolar (P^4), the first upper molar (M^1), and second upper molar (M^2) are similar to the other one, indicating that it probably belongs to *S. hundsheimensis* (in Bona, 2011).

7. Conclusions

The discovery of a remarkably well-preserved rhinoceros skull at Spinadesco (Cremona) and the consequential taxonomic revision of the fossil skull from Mezzana Rabattone enhances our knowledge concerning *S. kirchbergensis* on the Po plain.

The taxonomic revision of the skulls from San Colombano al Lambro and from the Torrente Stirone put better in evidence the *S. hundsheimensis* distribution, a species always neglected in this area throughout the time.

The exceptional status of preservation of the skull from Spinadesco reveals every diagnostic trait for its specific classification, the complete dental series and the presence of some peat residuals that had been found between the folds of the tooth. These vegetal remains are characteristic of the sedimentary facies in which the bone fossilised and they are of the great importance for future palaeoecological investigations.

During the late Middle Pleistocene and Late Pleistocene glacial stages, this area included Veneto, Carso, Istria and Dalmatia due to the fact that the Upper Adriatic had surfaced.

Up to now, the studies on the rhinoceros fossils discovered in this area have been carried out on the three skulls found in the Torrente Stirone (Parma), San Colombano al Lambro (Milano), and Mezzana Rabattone (Pavia).

In addition to the above-mentioned skulls, other minor skeletal remains have been found along the Po such as two teeth and two radii (Bona and Corbetta, 2009). A premolar tooth, found in Torricella di Sissa (Parma), was referred to *Stephanorhinus* sp. (Persico, 2004), while it was only possible to determine the family for the other tooth and the two radii due to their poor preservation status and the strong resemblance of the post-cranial skeleton to the various forms belonging to the Rhinocerotidae family (Bona and Corbetta, 2009).

As is it well-known, *Stephanorhinus* was undoubtedly the most important European Plio-Pleistocene rhinoceros genus. It occurs with five species: *Stephanorhinus jeanvireti* (= *Stephanorhinus elatus* Croizet and Jobert, 1828), *S. etruscus*, *S. hundsheimensis*, *S. hemitoechus* and *S. kirchbergensis*.

In the middle Villafranchian the most widespread species was *S. etruscus* which became extinct at the end of the Upper Villafranchian. During the Early Pleistocene, preceded by a small form present in most parts of Western Europe (Mazza et al., 1993), *S. hundsheimensis* also appeared in large numbers yet died out at the end of the Upper Galerian. *S. kirchbergensis* and *S. hemitoechus* were also widespread in the Galerian, the latter which was used to the cold palaeoecological conditions became widespread in the post-Galerian and was the last representative of the genus to become extinct in the Late Pleistocene (Bona and Corbetta, 2009).

Acknowledgments

We are greatly indebted to the anonymous Reviewers for their constructive comments to improve the manuscript. We are also very grateful to the palaeontological staff of the University of Pavia – Miriam Cobianchi, Giuseppe Santi and Claudia Lupi – for having kindly put the skull from Mezzana Rabattone at our disposal.Finally, special thanks are due to the Museo Paleoantropologico del Po of San Daniele Po (Cremona) and to the Soprintendenza Archeologica della Lombardia for allowing this research.

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