



New materials of *Dinocrocuta* (Percrocutidae, Carnivora) from Lantian, Shaanxi Province, China, and remarks on Chinese Late Miocene biochronology

Nouveau matériel de *Dinocrocuta* (Percrocutidae, Carnivora) de Lantian, Province du Shaanxi, Chine, et remarques sur la biochronologie du Miocène supérieur de Chine

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Abstract

New materials from the middle part of the Bahe formation are described as *Dinocrocuta gigantea*. Review of the species reveals that it is derived in the evolutionary lineage of *Dinocrocuta*, and biochronologically later than Vallesian records from Turkey. The only possibly related Vallesian species from China is *Crocuta gigantea xizangensis* from Biru, Tibet, which may prove to be conspecific with *D. senyureki*. Based on the mammalian faunal sequence from Lantian, and with reference to Red Clay paleomagnetic data, the duration of *D. gigantea* in China should be later late Miocene, rather than the previously postulated early late Miocene (Vallesian equivalent) age.

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Résumé

Deux nouveaux spécimens provenant de la partie moyenne de la formation Bahe, un fragment de mandibule gauche portant p2–p4 et un fragment de maxillaire gauche portant P3–P4, sont décrits et attribués à *Dinocrocuta gigantea*. Une révision de cette espèce révèle sa position dérivée au sein de la lignée évolutive de *Dinocrocuta*; cette espèce est biochronologiquement postérieure au Vallésien de Turquie. La seule espèce vallésienne de Chine possiblement reliée est *Crocuta gigantea xizangensis* de Biru, Tibet, qui pourrait être conspécifique à *D. senyureki*. Sur la base de la séquence de faunes de mammifères de Lantian, et en référence aux données paléomagnétiques de la Red Clay, *D. gigantea* pourrait se maintenir, en Chine, jusqu'à la fin du Miocène supérieur, et non jusqu'au début du Miocène supérieur (équivalent au Vallésien), comme postulé jusqu'à présent.

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Keywords: Late Miocene; *Dinocrocuta*; Vallesian; Biochronology; Bahe formation

Mots clés : Miocène supérieur; *Dinocrocuta*; Vallésien; Biochronologie; Formation Bahe

1. Introduction

Many localities yield abundant mammal fossils in the Chinese Late Miocene, as indicated by the famous Lagrelius and

Frick collections, and collections in the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) and Tianjin Nature History Museum. However, subdivision of the Chinese Late Miocene has long been handicapped by a lack of stratigraphically controlled superposed faunas, and an absence of fossils that can be used as direct evidence for correlation

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with the western Eurasia due to strong endemism in Chinese forms.

Since the description of fragmentary materials from drug-stores by Schlosser in 1903, a few specimens of *Dinocrocota* have been found from Biru, Tibet (Zheng, 1980); Tianzhu (Zheng, 1982), Hezheng, Gansu Province (Qiu et al., 1988), Lantian, and Fugu, Shaanxi Province (Liu et al., 1978; Zhang and Xue, 1996). *Dinocrocota* has been regarded as one of the key elements indicating Vallesian equivalent faunas in the Chinese Late Miocene, and is used to sequence late Miocene faunas (Li et al., 1984; Qiu, 1990; Qiu and Qiu, 1995; Qiu et al., 1999).

During 1997–2001, the Sino–Finnish project in the Lantian area focused on the Late Miocene mammal fauna sequence. This project produced a large collection from different levels of the Bahe and Lantian formations, which provides strong biostratigraphic evidence for the subdivision of the Chinese Late Miocene (Zhang et al., 2002; Kaakinen and Lunkka, 2003). This paper briefly describes the new *Dinocrocota* materials collected from the middle Bahe formation, revises the known fossils of *Dinocrocota* from China, and discusses biochronological correlation with the western Eurasia.

Measurements of the length and width of the teeth are maximum dimensions, using Vernier calipers to the nearest 0.1 mm. The specimens described in this paper are housed in IVPP.

2. Systematic paleontology

CARNIVORA Bowdich, 1821

PERCROCUTIDAE Werdelin and Solounias, 1991

Dinocrocota Schmidt-Kittler, 1976

Dinocrocota gigantea (Schlosser, 1903)

Fig. 1 and Table 1

Synonym:

1903. *Hyaena gigantea* - Schlosser, p. 35–37, Taf. 3, Figs. 1–8.

1978. *Crocota* (*Percrocota*) *macrodongta* - Liu et al., p. 156, Text-fig. 52, Pl. 23, Fig. 6.

1982. *Percrocota* (*Dinocrocota*) *gigantea* - Zheng, p. 218, Pl. 1, Fig. 1

1988. *D. gigantea* - Qiu et al., p. 128–138, Pl. 1, 2.

1996. *D. gigantea* - Zhang and Xue, p. 18–26, Pl. 1–3.

Diagnosis: (Emended): Extremely large-sized percrocotid; lower premolars having distinct anterior and posterior cusplets; p2 strongly oriented lingually and close to the size of p3; p3 slightly shorter, but greater than or equal to p4 in width; P3 robustly built and widened anteriorly, due to the presence of anterolingual cusplet; P4 with extremely reduced protocone, but a strong root remains.

Materials from Lantian: A partial left mandible with p2–p4 (IVPP V 13789); a maxilla fragment with P3–P4 (V 13790).

Geological and geographical distribution: Later late Miocene of North China (Early–Middle Turolian? equivalent).

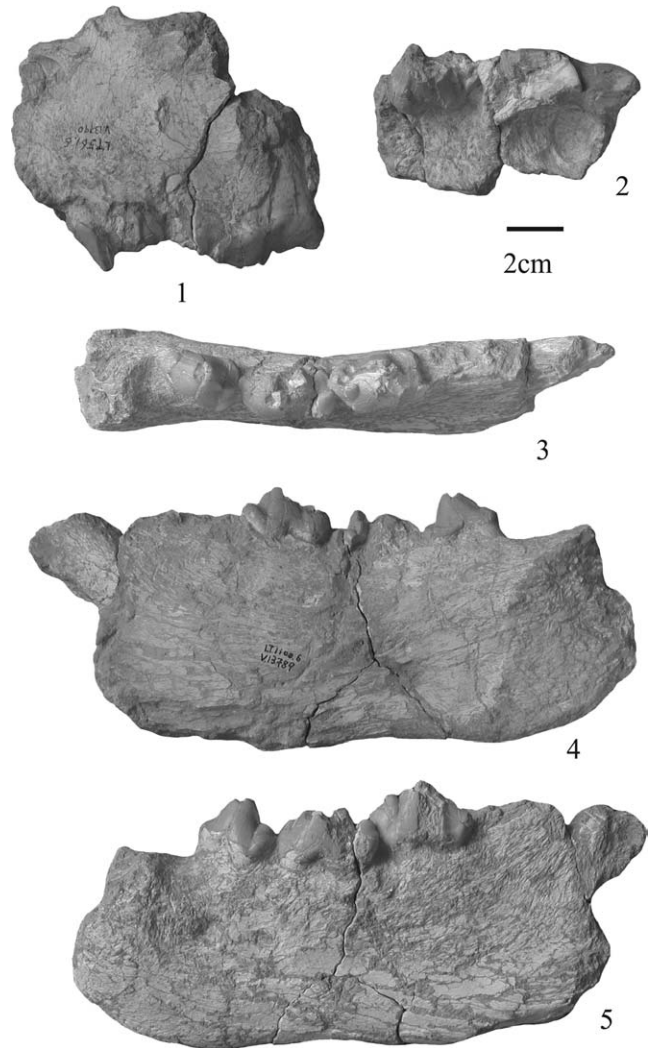


Fig. 1. *D. gigantea* from Loc. 6, Bahe formation, Lantian, Shaanxi Province. Left maxilla (V 13790): (1) lateral view, (2) ventral view; left mandible (V 13789): (3) occlusal view, (4) lingual view, (5) labial view.

D. gigantea de la Loc. 6, Formation Bahe, Lantian, Province du Shanxi. Maxillaire gauche (V 13790): (1) vue latérale, (2) vue ventrale; mandibule gauche (V 13789): (3) vue occlusale, (4) vue linguale, (5) vue labiale.

Measurements: Table 1.

Description: The mandible (V13789, Fig. 1(3–5)) is massively built, with a deep horizontal ramus (72 mm below p2) and bulky labial surface at the root of the canine. The lower borderline of the horizontal ramus is slightly concave under p3. There are two mental foramina. The anterior one is larger and positioned between the two roots of p2, in the upper half of the ramus. The posterior one is about one centimeter posterior to the anterior one and much smaller in diameter. Below the premolar row the lingual surface of the mandible is arched superiorly, but straight-walled inferiorly. The position of m1 is much higher than the premolars.

There is no p1, and the diastema between the canine and p2 is concave on the labial side.

The p2 is basically oval, with a narrow anterior part and much wider posterior border. The longitudinal axis is about 40 degrees to the ramal axis. The anterior cusplet is small but

Table 1
Tooth measurements and comparison of *D. gigantea* from Lantian (in mm)
Mesures et comparaison des dents de *D. gigantea* de Lantian (en mm)

	p2		p3		p4		m1		P2	P3	P4	M1	
	L	W	L	W	L	W	L	W	L	L	W	L	
V 13789	30.4	20.7	32	21	36.1	20.7							
V 13790										35.5	23.9	59.6	6
V 3093 (59s2)									23.2	29	21.5	49.6	3.8
Fugu													
(Zhang and Xue, 1996)	27.6	18.1	30.5	19	34.5	19.4			29.7	30.5	24	54.6	
Schlosser (1903)	24	17.5			34	19			28	30	23.5	54	
Tianzhu (Zheng, 1982)	29.2	19.1	30.5	21.3	34.3	18.4							
Kurtén (1957)			28.3	19.5									
<i>D. grandis</i>	20.4				29.5		30			26		41	
<i>Dinocrocota senyureki</i> (Ozansoy, 1965)	22.4	14.8	28	15	32	16.8	32	15	25.6	32.3	22.5	50.5	
Biru, Tibet (Zheng, 1980)	25.5	16	25.5	17.5	30.5	17.5	31.5	15.5					

distinct, with a weak lingual cingulum. The main cusp is rather strongly built, with distinct anterior ridge and slightly larger posterior ridge. The posterior cusplet, bulky and ridge-like, is larger than the anterior cusplet, positioned labially, and connected with the posterior ridge of the main cusp. To the lingual side of the posterior cusplet is a wide shelf with a weak cingulum.

The p3 is taphonomically broken. The occlusal outline is rectangular. The anterior and posterior cusplets are larger than those of the p2, and the posterolingual cingulum is also more developed and distinct. The anterior cusplet is located lingually with respect to the main cusp and the posterior cusplet.

The p4 is also partly broken. The anterior cusplet is significantly larger and higher, about 30% of the total length. The posterior cusplet is partly missing, with a high and well-developed posterolingual shelf.

The maxilla (V13790, Fig. 1(1, 2)) is as strongly built as the mandible. The height from the lower border of the orbit to the alveolus of P3 is about 70 mm. The infraorbital foramen is anteriorly positioned, with the posterior border above the anterior end of P3. Anterior to the M1, the fossa embracing the lower carnassials is very deep. The P3 is rectangular in shape, with the anterior border wider than the posterior one due to expansion of the labial side and the lingually positioned anterior cusplet, which is small but distinct. The lingual border of the tooth is concave. The posterior cusplet is large and separated from the main cusp with a groove.

The P4 is also broken anteriorly, with the protocone and paracone not fully preserved. Judging from the remnants, the protocone is small and much lower positioned than the labial cusps, the anterior border of the root is about at the same level as that of the parastyle.

The M1 is very short and wide, in a diagonal position with respect to the metastyle of the P4. There are no distinct cusps on the occlusal surface. The labial part is much higher. There are only two roots on M1.

Comparison and discussion: *Dinocrocota* was first named by Schmidt-Kittler (1976) as a subgenus of *Percrocota*. Qiu

et al., (1988) raised it to the generic level, based mainly on skull characters. However, the type species *Dinocrocota algeriensis* from Oued el Hamman, Algeria (Arambourg, 1959), is evidently smaller in size and has a prominent protocone on P4. Whether the Chinese *gigantea* is congeneric with the *algeriensis* remains to be verified by more complete material (Qiu et al., 1988). Before systematic study on this group, the species name *D. gigantea* is adopted herein.

The diagnosis of *Crocota* (*Percrocota*) *gigantea* given by Kurtén (1957) includes: Extremely large-size, very robust teeth; carnassials relatively short; m1 with a small and bicuspid talonid; P4 with the protocone adjacent to the base of paracone and very much reduced.

The fossils from Hezheng, Fugu, Tianzhu, and Lantian all correspond in size to *D. gigantea* as cited by Schlosser, (1903: Table 1), and should be included in the species. The size variations are very small as shown in Table 1. There are some characters that unite these materials as one species: extremely large-size; lower premolars having distinct anterior and posterior cusplets; p2 strongly oriented lingually, and close to the size of p3; p3 slightly smaller in length than p4, and equal or wider; P3 robust, with widened anterior part due to the development of anterolingual cusplet; P4 with the protocone having no distinct enamel cusp, but a strong root retained. Nevertheless, there are some variations: The outline of p2 is oval-shaped in the Lantian specimens, with widened posterolingual shelf. There are two cusplets in the m1 specimens figured by Kurtén (1957), while only one weak cusplet on the specimen figured by Schlosser as is the case on specimens from Fugu. The position of the P4 protocone is figured more posteriorly by Schlosser, as is the case at Fugu, while it is anterior to the lingual side of the parastyle in the Lantian specimens. On the specimens from Fugu, the M1 is proportionally larger, with the posterior cusp visible, and has three roots; whereas there are only two roots in the specimen from Loc. 6, Lantian, and no posterior cusp, but the size still remains large. Of the specimen from 59s2, the M1 is very reduced, and much smaller, with only one cusp present. The infraorbital foramen lies above the anterior half of the P3, and the

anterior margin of the orbit lies at the level of the anterior border of the P4 on the specimens from Hezheng and Fugu, while on the specimens from Lantian, the infraorbital foramen lies anterior to the P3, and the anterior orbital rim is at the mid-line of P3. For the paucity of materials, it is not possible to detect if there existed any sexual dimorphism. The above differences are tentatively regarded to represent intraspecific individual variation.

Koufos (1995) described a mandible and two canines from Macedonia, Greece. Except the low horizontal mandibular ramus (because of the young age of the individual), the lower cheek teeth are very close in size to those of the *D. gigantea* from China, respectively.

Comparing with *D. senyureki* from middle Sinap (Ozansoy, 1965) and Loc. 12, 108 of Sinap Formation (Viranta and Werdelin, 2003), *D. gigantea* is much larger in size, has proportionally larger p2/P2, and the P4 protocone is more reduced.

The specimens from Biru, Tibet, are very interesting both systematically and biogeographically. Zhang and Xue (1996) listed differences from the Fugu materials, which hold true for the other *D. gigantea* specimens. Howell and Petter (1985) considered the Biru specimens to represent *Dinocrocota grandis* based mainly on size. However, the p2/p3 ratio of the Tibetan specimen is about 100%, whereas *grandis* has a reduced p2. Morphologically, the Tibetan form is much more primitive than those from central China (Hezheng, Tianzhu, Fugu, and Lantian). It is smaller in size, the premolars have almost no prestyles, and they are much less robust. It is closer to *D. senyureki* than *D. gigantea*, though *D. senyureki* has an even shorter p2 based on the observations of Ozansoy (1965) and confirmed by the recent findings from Sinap Formation (Viranta and Werdelin, 2003). The Tibetan form is closest to *D. senyureki* from Middle Sinap, Turkey, and the species may be the direct ancestor of *D. gigantea*, which species spread throughout the east at a later time. *D. gigantea*, as Kurtén (1957) indicated, should be the last representative of a lineage that showed continued size increase.

The allocation of *Hyaena salonicae* (Andrews, 1918) was discussed by Beaumont (1979). It was thought to be a synonym of *D. gigantea* by Soria (1980) based on the anterior-positioned orbit and infraorbital foramen, a distinct species of *Dinocrocota* by Koufos (1995). However, this character proves to be variable in the species. Given the small-sized P2, less laterally expanded P3 and the large distinct P4 protocone, this specimen from Salonica most probably belongs to *Pachycrocota* as Beaumont argued.

3. Biochronology

The geological age of *D. gigantea* has long been uncertain because the specimens were bought from drugstores (Schlosser, 1903). Considering the large-size and non-existence of any specimens of *D. gigantea* in the Lagrelius collection, Kurtén (1957) postulated a post-Pontian stage, up

to middle or later Pliocene. Koufos (1995) suggested a Vallesian to middle Turolian age. However, this suggestion is largely based on Chinese data.

Li et al. (1984) named the Bahean stage, comparing it with the European Vallesian, based on the findings of *Dinocrocota* from Bahe Formation, a geologically older position than the typical Baodean faunas. Qiu et al. (1988, 1999); Qiu (1990); Qiu and Qiu (1995) reconfirmed the significance of *Dinocrocota* as an indicator of the Vallesian equivalent in China. However, the paleomagnetic data of the Fugu section, which produced materials of *D. gigantea*, contradicts this possibility (Xue et al., 1995; Zhang and Xue, 1996).

From lower parts of the Bahe Formation, there are some new levels, e.g. loc. 12, 19, yielding *Progonomys* and other small mammals, which can be compared with western Eurasian Vallesian faunas (Zhang et al., 2002; Qiu et al., 2004). All these fossil records fit the preliminary result of the paleomagnetic dating (C5n.2n = 10–11 Ma, W Gose, person. comm.). From the middle part of the Bahe Formation, the faunas changed. The murid fossils, though scarce, show some derived characters (Qiu et al., 2004). *Gazella lydekkeri* recorded from the Siwalik Dhok Pathan Formation (ca. 8 Ma) was found from Loc. 6 and 33, in the middle part of the Bahe Formation, and together with *D. gigantea*, *Hipparion chiai* and *H. weihoensis*, became the typical of this interval. These elements are found also in the lower levels of the Red Clays of Fugu (Xue et al., 1995). Though the paleomagnetic data of the Bahe Formation still remains unpublished, the paleomagnetic data of the Red Clays from the Loess Plateau confirmed the biochronologic correlation (Sun et al., 1998; Ding et al., 1999; Qiang et al., 2001; Zhang et al., 1995). The earliest Red Clays from Loess Plateau, wherein many *Hipparion* faunas are discovered, are about 8 Ma. By the larger size and derived characters of *D. gigantea*, the fossil levels would be inferred to be younger than Turkish localities of middle Sinap (MN9, Sen, 1991; 10.1–9.6 Ma, Kappelman et al., 2003). The original contents of the Bahe fauna of Li et al. (1984) as representative of the Bahe age and NMU 9 of Qiu et al. (1999), were all from the middle and upper Bahe Formation, and the lowest Loess Plateau Red Clays, and can most probably be correlated with the early Turolian in west Eurasia.

The Bulong fauna from Biru is probably the only one in eastern Asia yielding *Dinocrocota* of Vallesian or early Turolian age. The Vallesian equivalence of the Biru fauna was proposed previously by the primitiveness of its *Hipparion* (Zheng, 1980; Qiu, 1987).

It is highly possible that primitive *Dinocrocota* originated in western Eurasia and migrated to central China via Tibet in early Late Miocene time, before the great uplift of the Tibetan Plateau, and the onset of the East Asian Monsoon then evolved into *D. gigantea*, which died out during later late Miocene.

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