On the Processing and Mounting of a Skeleton of a White Rhinoceros, *Ceratotherium sinum*

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(Received October 1, 2004; Accepted December 6, 2004)

Abstract. The skeletal remains of a white rhinoceros, *Ceratotherium sinum*, were recovered from the Leofoo Village Zoo in March, 2003. This white rhinoceros had been raised in the zoo for 30 years until its death, yet without any definite cause of death. Processing and mounting of the specimen is reported herein with a detailed characteristic description and morphological measurements. The profile length of the mounted skeleton is 348 cm and the shoulder height is 147.5 cm. According to the appearance of very heavy wear in the maxillary dentition with channel fully closed through to dentine and small patches of enamel left, this white rhinoceros was approximately an aged individual at the age of about 33-38 years old. The skeleton was supported by two main vertical metal pillars with four secondary pillars for limbs and connecting its skull, vertebrae and pelvis. Not only for educational exhibition, the restored whole skeleton of the white rhinoceros will also contribute the study of comparative anatomy with other extinct species from fragmentary fossils.

Key words: *Ceratotherium sinum*, rhinoceros, skeleton.

INTRODUCTION

White rhinoceros, *Ceratotherium sinum* may be called a great giant living genus of land mammals except for *Elephas*, *Loxodonta*, and perhaps *Hippopotamus*. The weight is about 1,400-1,700 kg in females and 2,000-3,600 kg in males (Nowak, 1991). *C. simum* inhabits widely regions of Africa, and can be recognized externally by its usually lighter coloration, squared upper lip with no trace of a proboscis, more sloping and less sharply defined forehead, shoulder hump, and less conspicuous skin folds on the body (Kingdon, 1979). *C. sinum* is classified as endangered by the IUCN (The World Conservation Union) and CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora). The populations have fluctuated in response to the alternating protection or exploitation of human, but the overall tendency of number has been destroying downward (Western and Vigne, 1985).

Since the wild rhinoceros is getting rare, the domestic ones in zoos will be more important, where bring the various aspects of scientific researches on their behavior, development and social interaction. Even the carcasses of animals which had been raised in zoos will be helpful in the study of anatomy, pathology and physiology. After a fine dissection and preparation of the skull and skeleton, the specimen can be mounted not only for public educational exhibition, but also for the study of comparative anatomy between modern species and extinct species which were based on fragmentary fossils.

We report here the processing and mounting of a skeleton of a white rhinoceros, *Ceratotherium sinum* obtained from the Leofoo Village Zoo (六福村野生動物園), with an attempt to record and discuss the relevant experiences and problems. The specimen of the white rhinoceros was examined in detailed character analyses and morphological measurements. The present report is made on the metric data of the modern rhinoceros sample for use in future studies. The specimen was numbered NMNS004017-F003822

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and preserved in the National Museum of Natural Science, Taichung, Taiwan.

MATERIALS AND METHODS

The material in this report is the skeleton remains of a male raised white rhinoceros (*Ceratotherium sinum*). It was named "Old Man" lived in the Leofoo Village Zoo until it died at the age of about more than 30 years without any definite cause of death. Prior to burial of the carcass, the horn was cut at the base of the skull (since there was no plan for recovery of the skeleton at that moment) and gone. The carcass was buried in red clay, which is characterized by high sticky clayed soil, low rate of infiltration and low concentrations of microfauna, around the zoo.

The first step of this project was to exhume the body of the white rhinoceros, and then carefully dismember and separate the skull and bones from skin and flesh. The final stage of this study was to study the morphologic characters of the white rhinoceros by detailed craniometry and osteometry. These measurements were taken with calipers (straight-line measurements) or with a flexible tape measure (curved measurements). The methodology of measurement referred to von den Driesch (1976).

RESULTS

The body of the rhinoceros was exhumed in March of 2003, nearly 3 months after the burial. Then the animal was carefully dismembered and the skull and bones were separated from skin and flesh. Chemicals like soluble-oil and petrol were tried to dissolve fat from the bone marrow. After repeated removal of fat and cleaning with water, the bones were dried in a room with a room temperature and good ventilation. Finally all bones were dipped in 10% hydrogen peroxide to bleach and remove the scars.

The skeleton of the rhinoceros was planned to use metal supports and internal joints through which the weight from top portions of the body could be transferred to the two main vertical supporting pillars. The pillar was a 64 mm (2.5 inch) diameter metal pipe supporting the skeleton respectively at the skull and pelvic regions (Fig. 1). Further, it was planned to interconnect the

Fig. 1. Profile view of the mounted skeleton of the white rhinoceros showing the two main vertical supporting pillars.

main pillars at skull and hip-joint level through 21 mm (0.8 inch) diameter metal pipes, which were fabricated to bear the weight of the cranium and pelvis. Another thin metal pipes with 9 mm diameter, bent and formed a stand to the mandible (Fig. 2). A 16 mm diameter iron rod, prepared to the shape of the column, was passed through the neural canal and up to the occipital condyles (Fig. 3). Subsequently, individual vertebrae were glued together and ribs were glued at their articulation at the vertebral column with epoxy resins. The four limbs were placed in their natural position with reference to a living rhinoceros. The second supporting pillars for limbs, with 21 mm (0.8 inch) diameter metal pipes, were bolted and riveted to the big bones, like humerus, ulna and radius, to pass their weight down to the platform (Fig. 4). Other small bones, like carpals, metacarpals and phalanges, were arranged and glued together with cyanoacrylate and epoxy resins.

Fig. 2. Lateral view of the mounted skull and mandible.

Fig. 3. The vertical supporting pillar interconnected the skull and mandible. Abbreviation: C, carpus; Cv, cervical vertebrae; H, humerus; M, metacarpals; P, phalanges; R, radius; Ri, ribs; S, scapula; St, sternum; Tv, thoracic vertebrae; U, ulna.

The skeleton was mounted on a wooden platform measuring 320 cm long, 125 cm wide and 10 cm high. For the whole complete appearance of the skeleton, the casts of the two horns of white rhinoceros were made and glued to the skull. The profile length of the mounted skeleton is 348 cm. The shoulder height is 147.5 cm and the height at the tip of the sagittal crest of the skull is 183.9 cm. We were optimistically hoping to use the reconstructed skeleton of the white rhinoceros to provide an educational exhibit for the public at the museum in the near future.

The skull of the white rhinoceros is markedly dolichocranial with long backwardly extended occipital crest. It features shortened in front of eyes, with nasal, premaxillae and mandible symphysis all abruptly ending shortly in front of level of cheekteeth. Its nasal is broad and humped. The premaxillae are firmly fused with maxillae. The occiput is high, narrow, making dorsal outline of skull very concave. The posterior margin of

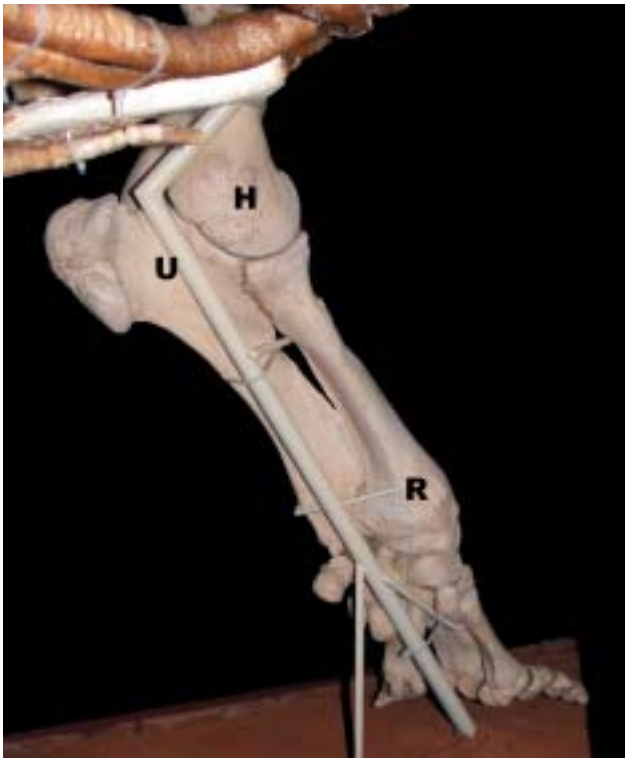

Fig. 4. Left forelimb showing the second supporting pillar. Abbreviation: H, humerus; R, radius; U, ulna.

palate is concave with a small median projection; basilar bones are narrow, pterygoid compressed; vomer is thick and united to pterygoids; mesopterygoid fossa is relatively narrow and deep. Measurements of skull and mandible are given in Table 1, Table 2, respectively.

The cheekteeth are hypsodont; protoloph and metaloph strong curved back, showing early fusion with wear. The ectoloph is relatively flat with little parastyle buttress. The paracone and protocone are separated by a fossa and the protocone is inclined backward. There is no incisor or canine. The dental formula is i 0/0, c 0/0, p 3/3, m 3/3. However, some molars in the white rhinoceros are eroded and broken down, with upper left P1 and P2 are missing in maxillary, and lower left m1, right p1, p2, and m1 are missing in dentary (Fig. 5). The appearance of maxillary dentition is very heavy wear with

Fig. 5. Skull and mandible of *Ceratotherium simum*, shown from top to bottom in dorsal view of occlusal surface of upper and lower molars. Abbreviation: P, upper premolar; M, upper molar; p, lower premolar; m, lower molar; Arabic numeral indicates its serial number. Bar scale equals 10 cm.

channel fully closed through to dentine and small patches of enamel left. According to the molars preserved and their wear on occlusal surfaces, this white rhinoceros therefore could be assigned to age class XV (Hillman-Smith *et al*., 1986), which is equivalent to 30-38 years old individual. Measurements of molars preserved are given in Table 3.

As a member of the Order Perissodactyla, the limbs of the white rhinoceros are unguligrade and mesaxonic. A large central digit carries the main axis of weight and smaller lateral digits are present. Both manual and pedal digits number three. The bones of limbs are massive. Total forelimb length is almost 100% of total hindlimb; the humerus is 67.2% of basal skull length; the radius length is 78.5% of humerus; the tibia length is 71.8% of femur; the humerus length is 90.0% of femur; the radius length is 98.1% of tibia; the metacarpal III length is 51.5% of radius. The ischial tuberosities are expanded and rounded. Metric data of scapula and pelvis, forelimb, and hindlimb are given in Table 4, Table 5, Table 6, respectively.

The vertebral formula of the white rhinoceros is C 7, T 18, L 3, S 3, Cd 16; i.e. seven cervical vertebrae; eighteen thoracic vertebrae; three lumbar vertebrae; three sacral vertebrae; sixteen caudal vertebrae. Spine of the first thoracic is long; length of spines are decreasing anteriorly to C 5, posteriorly to T 6; spines of T 15 to 17 are slightly raised; T 17 and T 18 are anticlinal. There is a very slight rise in lumbar spines. Each thoracic vertebra articulates with a pair of ribs. Each rib head is aligned with the junction of two vertebral bodies. The ribs are strongly expanded. Measurements of vertebrae are given in Table 7 and Table 8. Measurements of both right and left ribs are given in Table 9.

DISCUSSION

The carcass of the white rhinoceros was haphazardly buried in sticky red clay with a low infiltration rate. As a result, recovery was difficult, the carcass was still not decomposed and the bones were unduly stained. The thick skin and hard muscles of the pachyderm make the manual dissection and cleaning very cumbersome. Also, the chemical cleaning and enzyme treatment (Taylor, 1967) of them are very costly. Therefore, burial work appears to be inevitable. In order to facilitate the natural decay of a burial body and the

bleaching of bones, we suggest that the body should be buried in loose sandy soil, make deep incisions at various places on the body, and cut the skin at the abdomen and remove major portions of viscera. Regarding the duration of burial, approximate 10 months' time would be adequate provided the cartilaginous parts of the skeleton are spared for separate processing.

Permanent mounting of skeletal bones often limits the accessibility of the specimen for scientific study. In view of future study available, the removable arrangement of bones and external armature mounting with possible dismantling are require. For external armature, metal pipe is ideal. It can be bent to follow the contours of the bone and each piece can be adjusting the shape before welding them together. Moreover, due to the huge size and heavy weight of the white rhinoceros, special care should be taken on the weight could be transmitted to the ground. The pedestals, devised to distribute the weight of the skeleton evenly to the ground, enhance the stability and hence the living style of the mounted skeleton. The restoration skeleton of the white rhinoceros was constructed in an attempt to breathe life into the bone remains with dynamic, standing in a bit midstride. It is hoped to invite the visitor to imagine the living animal walking.

In the standing posture, the highest point in the white rhinoceros skeleton would be the tip of the sagittal crest of the skull. This was confirmed by having a few live domestic rhinoceroses in zoo standing in a normal position. However, in some museum specimens (e.g., the American Museum of Natural History), the skull is placed slightly degraded and the height of the rhinoceros is measured at the tip of the 2nd thoracic vertebra. Whereas the shoulder height of the rhinoceros is

Table 1. Measurements of the skull of *Ceratotherium sinum* (in mm).

Profile length	779
Condylobasal length	692
Basicranial axis	145
Basifacial axis	450
Facial length	543
Most oral point of the facial crest on the side	303
Short lateral facial length	304
Length of braincase	323
Lateral facial length	382
Median palatal length	197
Palatal length	191
Dental length	309
Lateral length of the premaxilla	119
Length of the diastema	86
Length of the cheektooth row	236
Length of the molar row	154
Length of the premolar row	125
Greatest inner length of the orbit	125
Greatest inner height of the orbit	94
Greatest mastoid breadth	63
Greatest breadth of the occipital condyles	164
Greatest breadth of the foramen magnum	21
Height of the foramen magnum	55
Greatest neurocranium breadth	243
Least frontal breadth	168
Least breadth between the supraorbital foramina	157
Greatest breadth of skull	310
Least breadth between the orbits	203
Facial breadth between the infraorbital foramina	181
Greatest breadth on the curvature of the premaxillae	104
Greatest palatal breadth	257
Facial height	256

considered as the standard for the height of a rhinoceroses, in a situation where the skull or 2nd thoracic vertebra is higher than natural on a mounted skeleton, the shoulder height can be obtained by reaching the tip of the scapulae. The shoulder height of the white rhinoceros is 147.5 cm and the height at the tip of skull is 183.9 cm.

Foster (1960) listed the measurements of four adult white rhinoceroses, sex not stated, as followed: head and body length 3.35 to 3.77 m; height 1.71 to 1.85 m; weight about 3200 to 3600 kg. The specimen we obtained was a mature male and its length and height are 3.48 m and 1.84 m, respectively, within the ranges of Foster's measurements. The potential longevity of white rhinoceros is 40-50 years and males may mature in 3 years (Groves, 1972). According to the molars preserved and their wear on occlusal surfaces, this white rhinoceros could be assigned to age class XV, which is equivalent to 30-38 years old. Moreover, the white rhinoceros had been raised in the zoo for over 30 years, after the import from the foreign zoo. We can therefore infer that this white rhinoceros would be a middle-aged animal with the age about 33-38 years old. Since mammals have approximately limited growth in skeleton until sexual maturity, the specimen we obtained would be taken as a representative individual of sexual maturity. Its skull and bones are available as criteria for further comparative study in anatomy with other fossil remains of extinct species of the Rhinocerotidae.

There are two main mammalian faunas in Taiwan during the Pleistocene. One is the "Cho-chen" fauna, which lived between 0.9 and 0.45, and the other is "Penghu" fauna, which considered

Table 2. Measurements of the mandible of *Ceratotherium sinum* (in mm).

Mandible (left side)	
Length from the angle	535
Length from the condyle	553
Length of the horizontal ramus	293
Length of the cheektooth row	245
Length of the diastema	56
Aboral height of the vertical ramus	258
Middle height of the vertical ramus	212
Oral height of the vertical ramus	319
Height of the mandible behind m3 from the most aboral point of the alveolus	126
Height of the mandible in front of m1	116

Table 3. Measurements of the cheekteeth of *Ceratotherium sinum* (in mm).

Upper maxillary teeth	Right		Left	
	Length	Breadth	Length	Breadth
P1	36	34	-	-
P2	47	45	-	-
P3	49	60	57	58
M1	36	67	37	69
M2	37	72	46	74
M3	76	63	71	54
Lower dentary teeth				
p1	-	-	42	24
p2	-	-	-	-
p3	-	-	39	31
m1	-	-	-	-
m2	42	31	47	33
m3	59	34	61	41

Abbreviation: P, upper premolar; M, upper molar; p, lower premolar; m, lower molar; Arabic numeral indicates its serial number.

to be of the Late Pleistocene (Chang, 1996). However, remains of the Rhinocerotidae are rare in the fossil assemblages. Only an upper molar M2 had been recovered in the "Cho-chen" fauna and a metacarpal bone had been found in "Penghu" fauna. The characteristic analysis of fossil remains and their comparative studies with extant specimens remain investigation. The present report encourages future studies of vertebrate paleontology on Rhinocerotid fossils.

ACKNOWLEDGMENTS

We would like to express our gratitude to the Leofoo Village Zoo (六福村野生動物園) for donating the white rhinoceros to the National Museum of Natural Science, Taiwan. Our special thanks must go to Mr. Y.C. Yeh, Mr. K.M. Chuang, and Ms. H.Y. Shan for preparation of the white rhinoceros as a specimen of collection of the museum. We thank Mr. K.A. Tung for producing the photographs of skeletal elements. We also thank very much anonymous reviewers for helping us to improve this manuscript.

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Table 4. Measurements of scapula and pelvis of *Ceratotherium sinum* (in mm).

Scapula	Right	Left
Height	511	512
Diagonal height	450	459
Greatest dorsal length	271	279
Smallest length of the Collum scapulae	129	128
Greatest length of the Processus articularis	162	164
Length of the glenoid cavity	113	101
Breadth of the glenoid cavity	100	95
Pelvis		
Greatest length of one half		1597
Length of the acetabulum including the lip		117
Length of the acetabulum on the rim		106
Length of the symphysis		239
Smallest height of the shaft of ilium		102
Smallest breadth of the shaft of ilium		62
Smallest circumference of the shaft of ilium		250
Inner length of the foramen obturatum		102
Greatest breadth across the tubera coxarum		1878
Greatest breadth across the acetabula		430
Greatest breadth across the tubera coxarum		290
Smallest breadth across the bodies of the ischia		239

Table 5. Measurements of forelimb bones of *Ceratotherium sinum* (in mm).

Humerus	Right	Left
Greatest length of the lateral part	465	449
Greatest length from caput	385	373
Greatest breadth of the proximal end	120	115
Depth of the proximal end	183	186
Smallest breadth of diaphysis	87	78
Greatest breadth of the distal end	166	183
Greatest breadth of the trochlea	120	129
Radius		
Greatest length	365	392
Length of the lateral part	345	332
Greatest breadth of the proximal end	125	122
Greatest breadth of the facies articularis proximalis	108	111
Greatest breadth of the distal end	118	117
Greatest breadth of the facies articularis distalis	91	88
Ulna		
Greatest length	485	475
Length of the olecranon	178	150
Greatest breadth across the coronoid process	114	119

Metatarsus	Right			Left		
	II	III	IV	II	III	IV
Greatest length	130	188	153	165	192	142
Greatest breadth of the proximal end	53	76	54	49	75	54
Smallest breadth of the diaphysis	40	54	41	39	56	41
Smallest circumference of the diaphysis	111	138	108	115	140	110
Greatest breadth of the distal end	63	78	58	52	79	61

Table 6. Measurements of hindlimb bones of *Ceratotherium sinum* (in mm).

Femur	R	L
Greatest length	518	512
Greatest length from caput femoris	503	509
Greatest breadth of the proximal end	219	217
Smallest breadth of diaphysis	80	84
Smallest circumference of diaphysis	231	235
Greatest breadth of the distal end	145	143
Fibula		
Greatest length	303	303
Tibia		
Greatest length	372	371
Lateral length on the outer side	340	324
Greatest breadth of the proximal end	139	136
Smallest breadth of the diaphysis	64	65
Smallest circumference of the diaphysis	214	214
Greatest breadth of the distal end	112	102
Greatest depth of the distal end	87	83

Table 6. (Continued)

Patella						
Greatest length				102		100
Greatest breadth				81		75
Metatarsus	Right			Left		
	II	III	IV	II	III	IV
Greatest length	134	168	157	146	161	139
Greatest breadth of the proximal end	43	59	39	29	61	46
Smallest breadth of the diaphysis	31	47	31	33	49	33
Smallest circumference of the diaphysis	98	127	91	94	125	97
Greatest breadth of the distal end	50	72	50	46	73	52

Table 7. Measurements of atlas, axis, and sacrum of *Ceratotherium sinum* (in mm).

Atlas	
Greatest breadth over the wings	356
Greatest breadth of the facies articularis cranialis	163
Greatest breadth of the facies articularis caudalis	153
Greatest length from the facies articularis to the facies articularis caudalis	144
Length of the arcus dorsalis, median	98
Height	176
Axis	
Greatest length in the region of the corpus including the dens	96
Greatest breadth across the processus articulares	68
Greatest breadth of the facies articularis cranialis	153
Greatest breadth across the processus transverse	258
Smallest breadth of the vertebra	56
Greatest breadth of the facies terminalis	90
Greatest height	215
Sacrum	
Physiological length	190
Greatest length on the ventral side	220
Greatest breadth	213
Greatest breadth of the facies terminalis cranialis	51
Greatest height of the facies terminalis cranialis	28

Table 8. Measurements of other vertebrae of *Ceratotherium sinum* (in mm).

Vertebra	NO	GL[a]	GB[b]	H[c]	PL[d]	BF[e]	HF[f]
cervical	3	-	241	181	83	85	89
	4	-	256	193	84	84	86
	5	-	202	286	86	84	86
	6	-	184	359	82	70	77
	7	-	166	495	75	105	72
thoracic	1	94	180	521	76	113	74
	2	81	162	500	74	113	85
	3	80	130	471	68	126	75
	4	77	133	418	69	94	78
	5	85	138	339	70	78	78
	6	78	126	289	74	78	86
	7	76	117	241	76	80	89
	8	73	118	208	76	76	90
	9	65	112	198	79	76	87
	10	79	107	199	79	73	82
	11	90	104	200	79	72	82
	12	79	106	222	83	76	77
	13	76	104	238	76	71	80
	14	74	100	232	79	73	79
	15	81	91	226	74	72	83
	16	73	92	221	73	83	73
	17	88	85	212	77	90	66
	18	88	92	206	80	87	64
lumbar	1	89	298	190	84	90	63
	2	86	283	180	74	95	59
	3	79	227	174	73	95	45
caudal	1	62	66	104	45	44	35
	2	61	68	83	48	42	34
	3	52	65	42	43	41	32
	4	62	64	50	47	39	38
	5	41	64	40	47	39	33
	6	40	39	40	45	38	33
	7	39	37	43	45	29	33
	8	37	28	36	40	29	29
	9	36	28	34	37	27	29
	10	37	24	33	35	26	22
	11	34	-	30	35	23	23
	12	34	-	25	36	19	22
	13	32	-	25	32	19	23
	14	30	-	23	30	17	18
	15	28	-	18	28	18	17
	16	27	-	16	28	17	14

[a] greatest length from the processes articulares craniales to the processus articulares caudales; [b] greatest breadth across the processus transverse; [c] greatest height; [d] physiological length of the body; [e] greatest breadth of the facies terminalis caudalis; [f] greatest height of the facies terminalis caudalis

Table 9. Measurements of the ribs of *Ceratotherium sinum* (in mm).

No. of ribs	A		B		C	
	Right	Left	Right	Left	Right	Left
1	52	56	432	435	441	415
2	60	55	573	575	541	531
3	61	65	645	655	620	616
4	61	69	751	735	652	649
5	60	63	745	830	688	692
6	59	61	875	920	722	720
7	70	66	920	940	741	743
8	60	65	945	952	755	764
9	58	64	945	965	755	762
10	56	61	943	957	750	760
11	50	57	915	960	749	750
12	50	56	895	920	727	738
13	48	49	887	894	705	713
14	42	43	825	870	676	684
15	37	38	817	846	642	661
16	37	34	780	807	600	631
17	29	29	650	752	516	565
18	16	24	605	632	460	484

A, arch length; B, width at middle; C, distance between proximal and distal ends

白犀牛（*Ceratotherium sinum*）骨骼標本製作與裝架之探討

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本文記錄於2003年3月挖掘埋藏於六福村野生動物園之現生白犀牛，描述白犀牛骨骼標本之製作與裝架過程，並詳細記錄形態與骨骼之特徵，以及各項形態測量資料。該白犀牛為雄性成熟年長個體，已經飼養三十年，死亡原因不明。裝架完成的骨架全長為348 公分，肩高為147.5 公分。該白犀牛的上顎臼齒齒質呈環狀且琺瑯質片段化，顯示臼齒磨蝕劇烈，推測為一近趨老年的個體。該骨骼標本之裝架以二金屬圓管為垂直主支幹，輔以四肢骨之外走金屬次支幹，以為支撐骨架之重量，並連結頭骨、脊椎骨與髖骨部位。裝架完成的立姿骨架，除具有展示教育之功能之外，各部位骨骼標本亦提供對犀牛化石之鑑別分析與研究之基礎比對材料。

關鍵詞：*Ceratotherium sinum*，白犀牛，骨架。