AGE DETERMINATION OF THE BLACK RHINOCEROS (*DICEROS BICORNIS* LINN.) IN ZULULAND

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ABSTRACT. — A description is given of age criteria for the black rhinoceros based on tooth eruption and attrition. Assignment of chronological ages to the classes has been made by reference to known-age animals and to numbers of cementum lines in tooth section. It is concluded that the most reliable estimate of chronological age can be obtained from the counts of cementum lines in the first permanent molar.

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ABSTRAK. — 'n Beskrywing word gegee van ouderdomkriteria vir die swartrenoster, gebaseer op tanddeurbraak en -slytasie. Toewysing van chronologiese ouderdomme aan die klasse berus op diere van bekende ouderdom, sowel as die aantal sementumlyne in snitte van tande. Die gevolgtrekking is dat die betroubaarste skatting van chronologiese ouderdom verkry word van die telling van sementumlyne in die eerste permanente molaartand.

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INTRODUCTION

During studies on the black rhinoceros *Diceros bicornis bicornis* Linn. in the Zululand game reserves between 1961 and 1973, it became necessary to develop methods of age determination when investigating aspects of the ecology of this species. Field age determination of immature animals has been described by various authors (Schenkel and Schenkel-Hulliger 1969, Hitchins 1970, Hitchins and Keep 1970). Anderson (1966) and Schuarte (1967) both determined the age, by tooth eruption, of the same sample of black rhinoceros skulls from Hluhluwe Game Reserve in 1963. Certain discrepancies were found in their results which necessitated updating and clarification of age determination techniques. By the time the ecological study in Zululand was completed, Goddard (1970) had published information on age determination of black rhinoceros by tooth eruption and tooth wear from the Tsavo National Park in Kenya.

Age determination based on tooth wear alone has various drawbacks (Morris 1972) and, in order to obtain a more accurate assessment of age, the usefulness of cementum lines was investigated. Foster (1965) sectioned molar teeth of black rhinoceros and discovered dark and light bands in the dentine but made no attempts at age determination using this information. Goddard (1970) reported bands in the dentine but could not correlate their observed numbers with the age of known-age specimens.

In this study, age criteria have been based on the conventional methods of tooth replacement and wear. The assignment of an absolute age to each class has been made by reference to a limited number of known-age animals and to incremental lines in the dental cement.

MATERIAL AND METHODS

From 1960 to 1972 all black rhino skulls found in Hluhluwe Game Reserve were brought into reserve headquarters as a matter of routine. Each skull was marked with a numbered metal tag and the following details were recorded: date, locality, sex and cause of death when known. Additional skulls were obtained from Umfolozi, Mkuzi and Ndumu Game Reserves. Information on sex, cause of death, etc., was available for only a small proportion of these skulls.

The entire collection (n = 148) was grouped into age classes based on characteristics of tooth eruption and tooth wear of both the maxillary and mandibular dentition. Each group was examined in detail for homogeneity.

An erupting tooth was defined as one protruding above the bone surface. The nomenclature given by Cooke (1946) was used to describe the physical features of the maxillary molariform teeth PM^2 - M^2 (Fig. 1). In the maxillary teeth attrition leads to the rapid disappearance of the crista, the crochet initially becomes rounded and the prefossette becomes isolated and eventually disappears. The postfossette is obliquely V-shaped, tending to U-shaped with wear, until ultimately it disappears.

A rapid technique was developed for sectioning the molariform teeth of the black rhinoceros for the examination of cementum lines. The equipment consisted of a rock-cutting saw bench fitted with a 6″ diamond lapidary blade driven by an electric motor. The cementum pad at the base of the tooth was cut transversely between the anterior and posterior roots. If necessary the two cut surfaces of cement were polished using various grades of wet carborundum paper. The cut surface was viewed under reflected light for growth lines after wetting the surface with alcohol.

Sections of the cementum pad were prepared from all the skulls that had M^1 fully erupted. In all the teeth examined, the first two or three lines had a fragmented appearance, each line being split into two to six accessory lines when viewed at the thickest part of the cementum pad. However, at the edge of the cementum pad the accessory lines coalesced to form a single line, and consequently this area of the cementum was used for counting.

Within the skull collection were skulls of three known age individuals, a male of 7,3 years, a male of 4,1 years and a female of 12,2 years.

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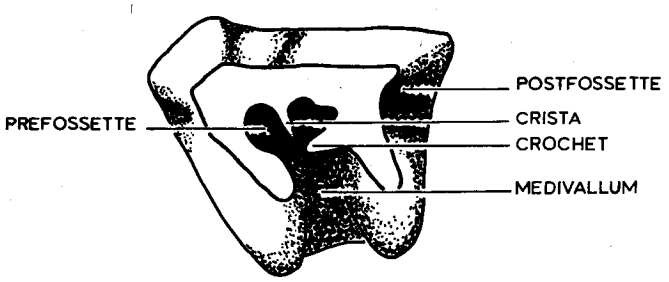

FIG. 1. Physical features of maxillary molariform teeth PM^2 - M^2 of black rhinoceros (after Cooke 1946).

RESULTS AND DISCUSSION

Dental formula

The normal dental formula is :

Deciduous : $i \frac{0}{1 \text{ or } 2}$; $c \frac{0}{0}$; $pm \frac{4}{4}$

Permanent : $I \frac{0}{0}$; $C \frac{0}{0}$; $PM \frac{4}{3 \text{ or } 4}$ or rarely $\frac{3}{3}$; $M \frac{3}{3}$

Incisors. Flower (1876) recorded rudimentary incisors in both the upper and lower jaws of the black rhinoceros from Abyssinia. Gray (1876) and Sclater (1900) state that there were no incisors or canines in either jaw although Sclater mentions that indistinct marks of the sockets can be seen in the lower jaw. Roberts (1951) reports that there were sometimes two pairs of incisors above and below. Anderson (1966) and Schuarte (1967) both reported three specimens with two pairs of incisors and a further two with one pair in the lower jaws from Hluhluwe skulls. Goddard (1970) found that rudimentary incisors and canines did occur but were rare in his Tsavo National Park material.

In addition to Anderson's material, X-ray examination of a foetus showed two incisors on both sides of the mandible, and dissection of two foetuses also revealed two incisors on each side. In both cases no trace of upper incisors could be found. A further 15 mandibles had either one or two incisors on each side. Some of the incisors had fallen out whilst in others the incisor cavity was apparent only as a shallow depression. In all specimens where two incisors occurred on each side of the mandible, the outer was always the largest.

Premolars. The adult black rhinoceros normally has four premolars. Development, eruption and subsequent wear take place over approximately the same period in both mandible and maxilla, but the mandibular dentition usually develops slightly ahead of the maxillary dentition.

Foster (1965) states that the first premolar is apparently shed and replaced at a very early age. Anderson (1966) and Schuarte (1967) both working on Hluhluwe skulls, refer to a deciduous and 'first permanent premolar' and state that it erupts at about 18 months. Anderson's specimen H22 in which the 'permanent first premolar' was recorded as being in a state of eruption at 18 months was in fact the deciduous first premolar. X-ray examination of a foetus, dissection of two foetuses, and detailed examination of young skulls showed no evidence of the first premolar being replaced. Goddard (1970) confirms these observations while Laws (1968) reported the same condition in the hippopotamus *(Hippopotamus amphibius)* in which only the deciduous premolars 2-4 are replaced by permanent teeth.

From the skulls examined pm 1 is present from birth and is invariably permanently lost in the lower jaw at the age of 12 years, whilst in the upper jaw it is always present until the age of 14 years and thereafter it may or may not persist. Schuarte (1967) suggested that sometimes PM 2 develops so strongly that it holds back the development of pm 1 on one or both sides of the jaw. Furthermore he mentioned that PM 1 can suppress PM 2 so that the premolar sequence may be pm 1 PM 3 PM 4. The present study showed that PM 2 was suppressed and it is likely that Schuarte confused pm 1 and PM 2.

Description of age classes

Seventeen classes were recognized, based on the following stages of eruption and attrition (see Figs. 2-6)

Class 0 : Foetus : deciduous pm2 - pm4 present in both maxilla and mandible; all below bone surface.

I : pm^1 below bone level, deciduous pm^2 and pm^3 erupting, pm^2 having just pierced the gum; pm^4 level with bone surface, alveolus M^1 open.

II : pm^1 erupting above bone surface; pm^2 and pm^3 almost fully erupted; pm^4 almost level with bone surface.

III : pm^1 - pm^4 fully erupted; crests M^1 visible just below bone surface. Alveolus M^2 open.

IV : pm^1 with slight wear; deciduous pm^2 - pm^4 have marked wear. M^1 erupting, usually pierced gum. Alveolus M^2 open.

V : pm^1 - M^1 erupted. M^2 just below bone surface.

VI : M^2 erupting, occasionally piercing gum.

VII : Deciduous pm^2 not present, permanent tooth erupting, sometimes piercing gum; PM^3 sometimes having displaced its deciduous counterpart, below gum level. Deciduous pm^4 always present with the permanent tooth filling the alveolus below. M^2 just above gum level.

VIII : Permanent PM^2 and PM^3 fully erupted, permanent PM^4 erupting above gum line. M^2 partially or fully erupted. M^3 below bone surface. Maxilla : M^1 crista present, postfossette V-shaped. Mandible : M_1 exposed dentine between cusps not joined. M_2 marked constriction between cusps.

IX : pm^1 well worn; PM^2 - PM^4 lightly worn; M^3 usually below bone surface but sometimes just above. Maxilla: M^1 crista disappearing or disappeared. M^2 crista present. Mandible: M_1 exposed dentine between cusps not usually joined. M_2 anterior cusp with marked wear and posterior cusp with light wear.

X : M^3 erupting, sometimes through gum or almost fully erupted, not in wear. Maxilla: PM^2 crista absent, postfossette U-shaped. PM^3 crista disappearing or absent, postfossette U-shaped or sometimes isolated. PM^4 postfossette sometimes U-shaped. M^1 crista absent, postfossette V-shaped. M^2 crista disappearing, postfossette V-shaped. Mandible: PM_2 dentine between cusps joined. PM_3 dentine between cusps sometimes joined.

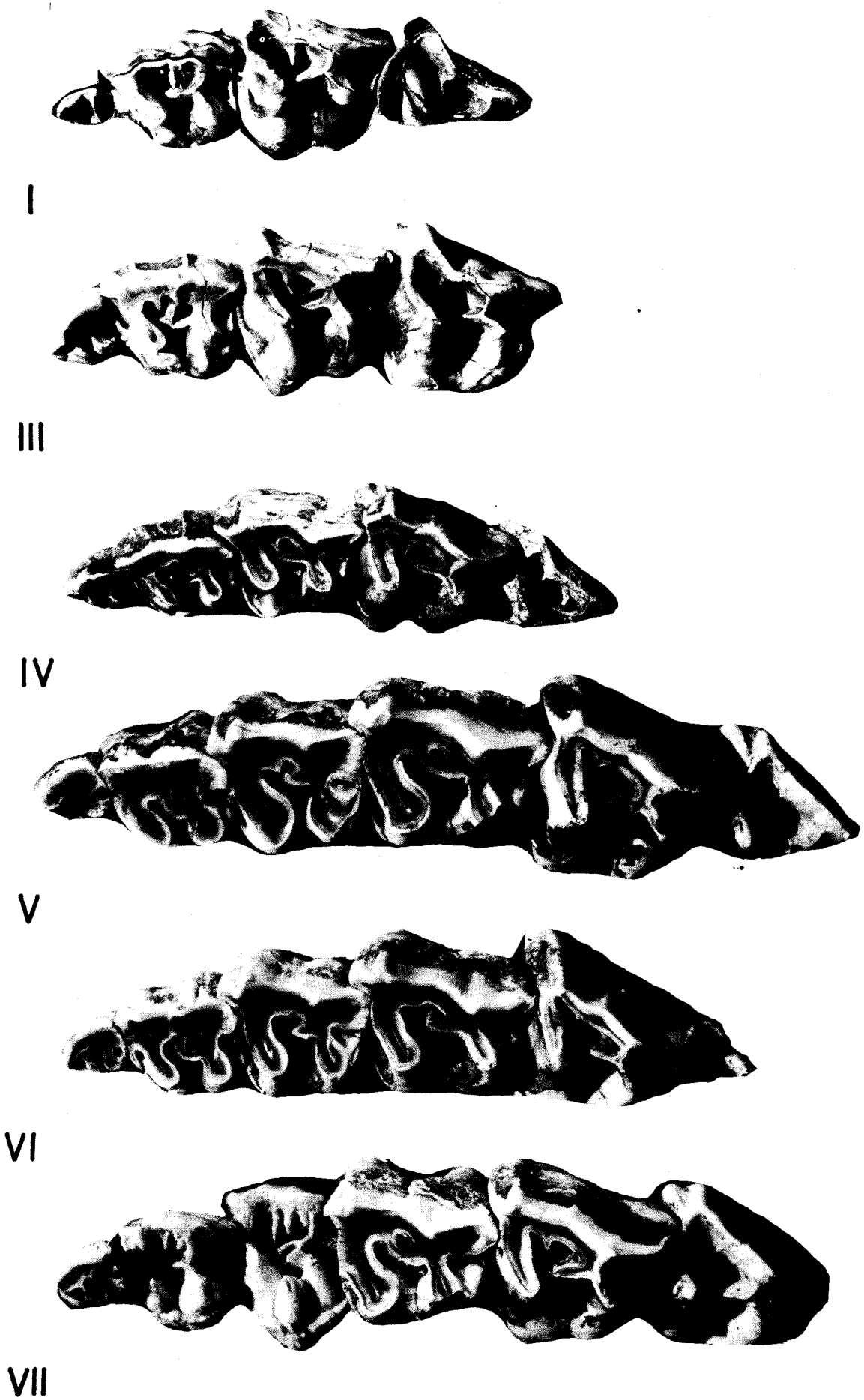

FIG. 2. Black rhinoceros maxillary dentition, age classes I - XII.

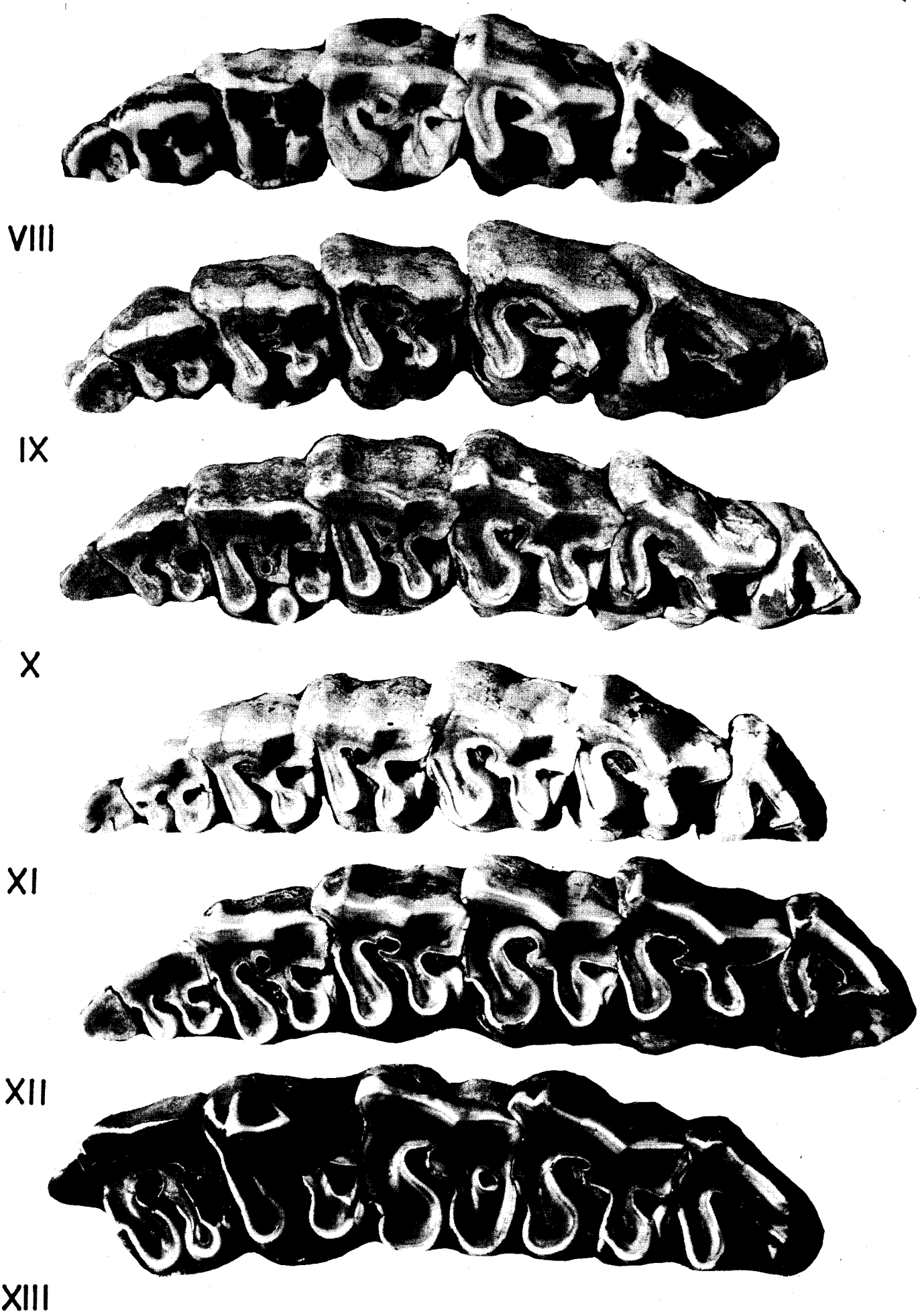

FIG. 3. Black rhinoceros maxillary dentition, age classes VIII - XIII.

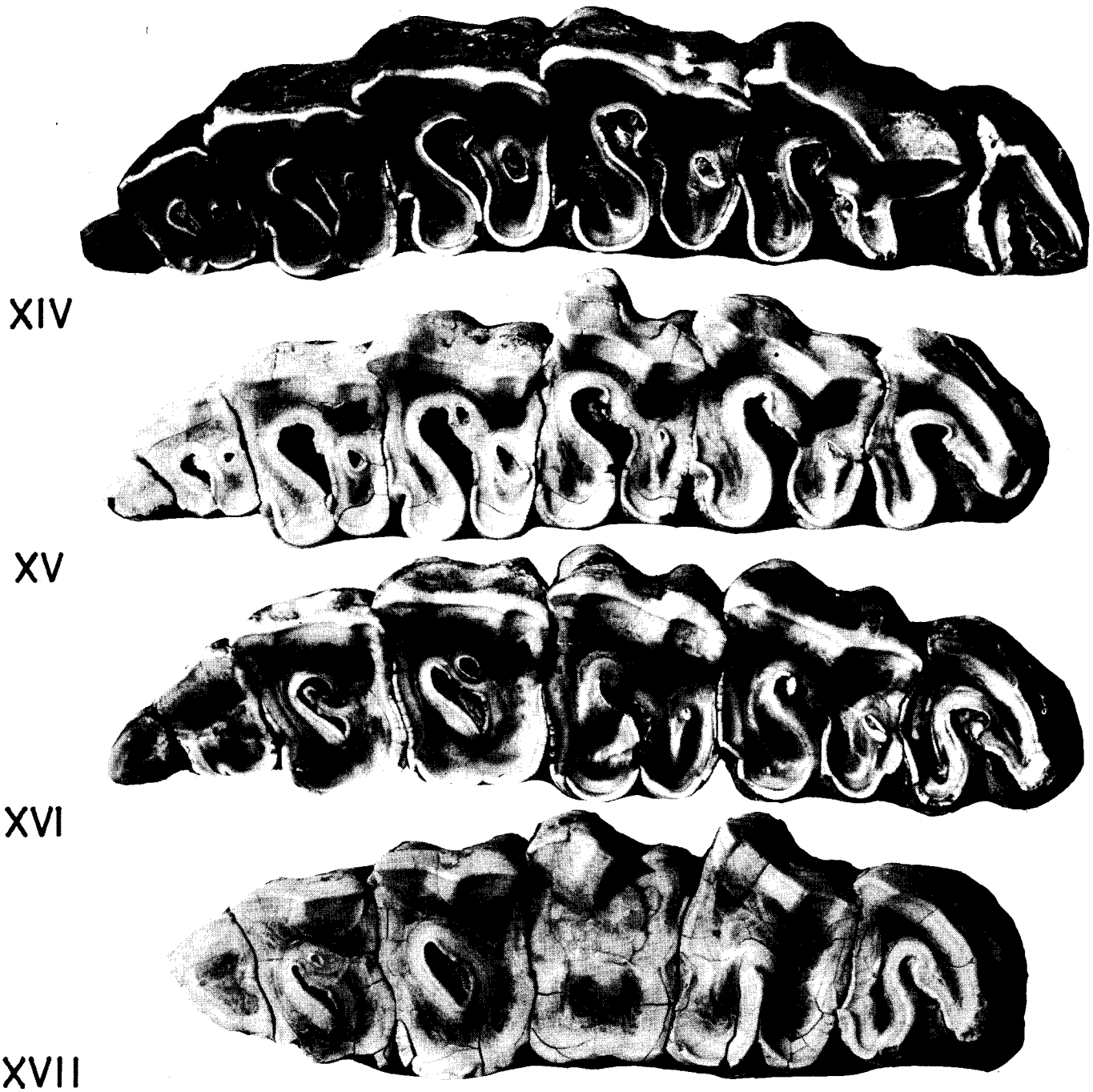

FIG. 4. Black rhinoceros maxillary dentition, age classes XIV - XVII.

PM_4 dentine between cusps sometimes joined. M_1 dentine between cusps joined. M_2 dentine between cusps sometimes joined. M_3 fully erupted with light wear.

XI : Maxilla: PM^2 prefossette almost isolated, postfossette U-shaped or almost isolated. PM^3 crista disappearing or absent, postfossette U-shaped or almost isolated. PM^4 postfossette V- or U-shaped. M^1 postfossette U-shaped. M^2 crista absent, postfossette V-shaped.

Mandible: PM_3 exposed dentine between cusps always joined. PM_4 exposed dentine between cusps sometimes joined. M_2 exposed dentine between cusps sometimes joined. M_3 light wear on anterior cusp only, marked constriction between cusps.

XII : Maxilla: PM_3 postfossette sometimes isolated. PM^4 crista absent, postfossette U-shaped. M^1 postfossette sometimes isolated. M^3 light to moderate wear. Mandible: M_1 anterior lingual infundibulum completely worn away. M_3 light wear on anterior cusp only or moderate wear on both, marked constriction between cusps.

XIII : Maxilla: PM^2 prefossette sometimes isolated, postfossette always isolated. PM^3 prefossette sometimes isolated, postfossette nearly always isolated. PM^4 postfossette sometimes isolated. M^2 postfossette sometimes U-shaped. M^3 moderate wear.

Mandible: M_1 posterior lingual infundibulum almost worn away. M_2 anterior lingual infundibulum worn away. M_3 exposed dentine between cusps sometimes joined, marked constriction between cusps.

XIV : Maxilla: PM^4 postfossette isolated, sometimes disappeared. M^2 postfossette U-shaped or isolated. Mandible: PM_3 and PM_4 anterior

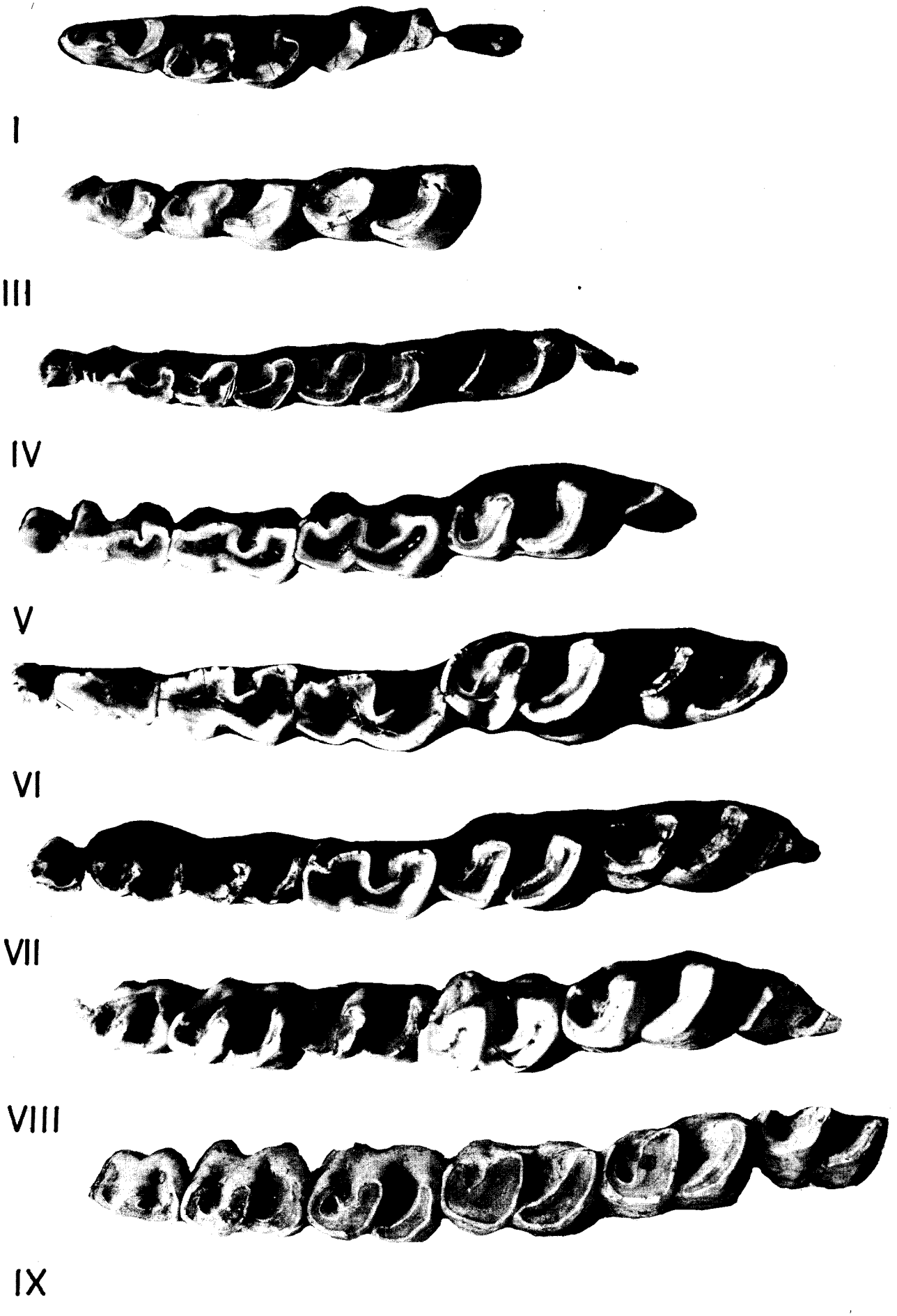

FIG. 5. Black rhinoceros mandibular dentition, age classes I - IX.

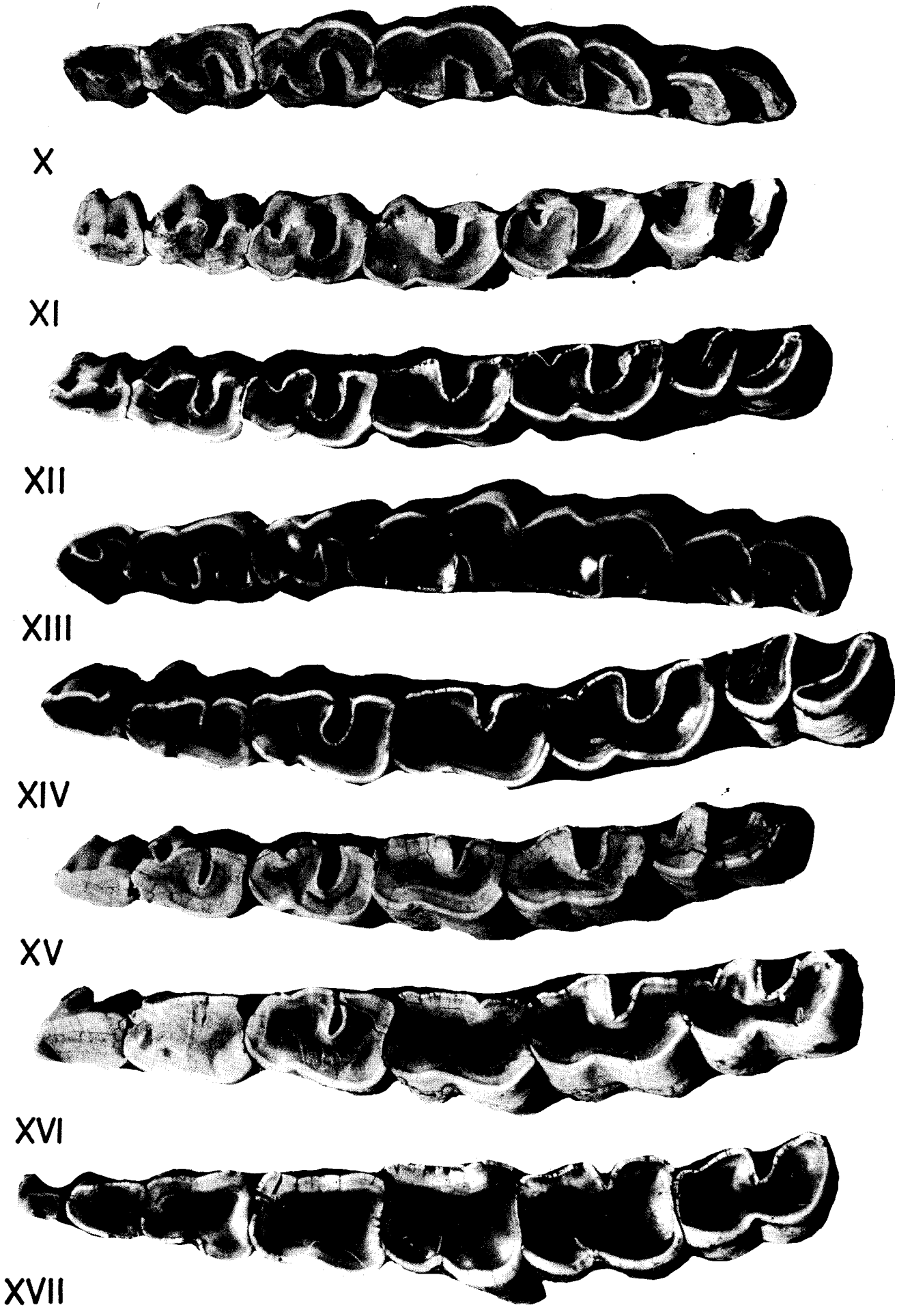

FIG. 6. Black rhinoceros mandibular dentition, age classes X - XVII.

lingual infundibulum worn away. M_1 posterior lingual infundibulum worn away. M_3 exposed dentine between cusps invariably joined, anterior lingual infundibulum sometimes worn away.

XV : Maxilla: PM^2 prefossette isolated. PM^3 prefossette and postfossette isolated. PM^4 prefossette almost isolated, medivallum disappearing, postfossette isolated. M^1 prefossette almost isolated, postfossette absent. M^2 prefossette almost isolated, postfossette U-shaped, isolated or absent. M^3 heavy wear. Mandible: PM_2 anterior lingual infundibulum worn away, posterior lingual infundibulum invariably worn away. PM_3 anterior and posterior lingual infundibulum worn away. PM_4 - M_2 anterior lingual infundibulum worn away, posterior lingual infundibulum almost worn away. M_3 anterior lingual infundibulum worn away.

XVI : Maxilla: PM^2 pre- and postfossette and medivallum invariably absent. PM^3 postfossette and medivallum invariably absent. PM^4 - M^1 postfossette invariably absent, medivallum still present. M^2 prefossette almost isolated, postfossette isolated or absent. Mandible: PM_2 - M_1 anterior and posterior infundibulum absent. M_2 and M_3 anterior lingual infundibulum absent.

XVII : Maxilla: PM^3 prefossette isolated, postfossette and medivallum absent. PM^4 prefossette isolated, postfossette and medivallum absent. M^1 pre- and postfossette and medivallum absent, dentine continuous over the entire occlusal surface. M^2 prefossette almost disappeared, postfossette absent. Mandible: M_2 posterior lingual infundibulum still present.

Cementum layers

Initial investigation of the cement pad revealed very clear lines when it was viewed under a dissecting microscope using reflected light (see Fig. 7). Further investigation showed that the number of lines increased with the estimated ages based on tooth wear using the method of Goddard (1970). Examination of cementum lines in PM^2 - M^3 in both upper and lower jaws of thirty skulls showed that a tooth in the process of erupting had no cementum lines, but a line became apparent once the tooth was fully erupted, and consisted of two bands, one broad and transparent and the other narrow and opaque.

The total number of cementum lines in the same teeth from both upper and lower jaws from the same skull was always identical, but those in the upper jaw were always clearer and easier to count. Cementum lines in the deciduous premolars were present but extremely difficult to count. In the permanent premolars the lines were clear in the less worn classes but with age the lines became faint and were not clearly differentiated from the surrounding cementum. M^1, when fully erupted, showed clearly defined lines in both young and old animals, although some of the lines did tend to become fainter in the older animals.

The three known-age animals provided a valuable confirmation of the use of the cementum lines for age determination. M^1 erupts at about 3 years of age (Goddard 1970), and in the 4,1 year old male M^1 was fully erupted and one cementum line was present. In the 7,3 year old male, four cementum lines were present, and nine lines were present in the 12,2 year old female. Consequently, M^1 was selected as the most suitable tooth for age estimation purposes, the calculated age in years being obtained by adding 3 to the number of cementum lines in M^1.

The relationship between the calculated age and the age classes based on tooth eruption and attrition is shown in Table 1, which illustrates the obvious discrepancies between the two techniques. This was confirmed by the fact that two of the known-age animals, the male of 7,3 years and the female of 12,2 years, had an identical pattern of tooth eruption, placing them both in age class X, but differed by a total of 5

TABLE 1. *Relationship between calculated age and age classes in the upper jaw of the black rhinoceros*

Age class		No of cementum lines in M^1		Calculated age* (years)	
	n	Range	Mean	Range	Mean
I	2				
II	2				
III	2		No cementum lines present		
IV	11				
V	5	1	1,0	4	4,0
VI	7	1-2	1,7	4-5	4,7
VII	4	3-4	3,5	6-7	6,5
VIII	10	3-4	3,4	6-7	6,4
IX	11	4-7	5,4	7-10	8,4
X	12	5-9	7,2	8-12	10,2
XI	2	7	7,0	10	10,0
XII	6	8-9	8,3	11-12	11,3
XIII	13	11-15	13,3	14-18	16,3
XIV	11	17-20	18,0	20-23	21,0
XV	20	19-28	23,7	22-31	26,7
XVI	2	30-31	30,5	33-34	33,5
XVII	1	34	34,0	37	37,0

* Calculated age : mean number of cementum lines in M^1 + 3 years.

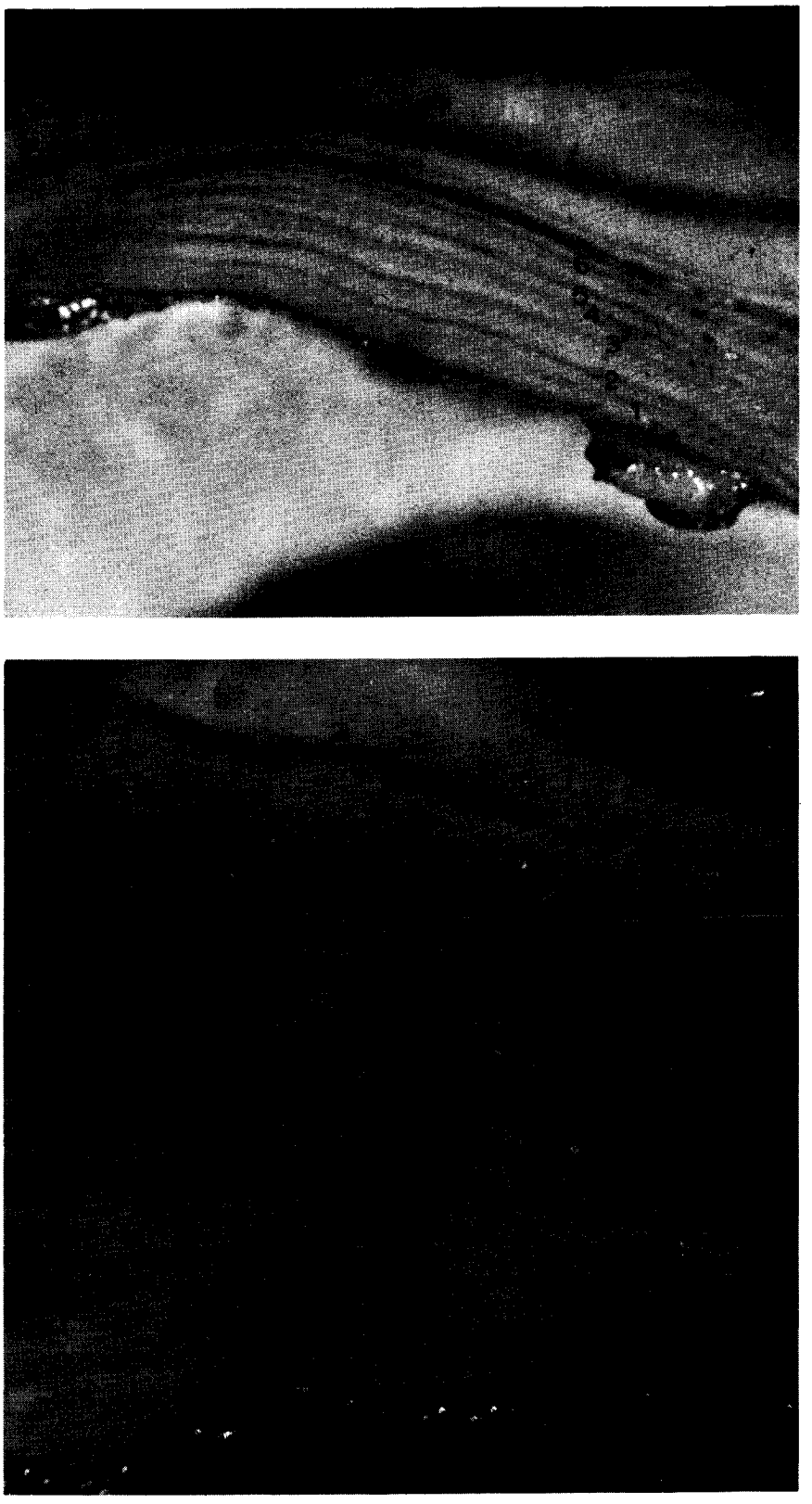

FIG. 7. Longitudinal section of M^1 showing clearly defined cementum lines under reflected light.

TABLE 2. *Chronological ages (based on cementum lines) allocated to the relative age classes of black rhinoceros*

Age class	Probable range (years)	Age class	Probable range (years)
I	-	X	9 ± 3
II	-	XI	10 ± 3
III	-	XII	12 ± 3
IV	-	XIII	16 ± 3
V	4 ± 0,5	XIV	21 ± 3
VI	5 ± 1	XV	27 ± 4
VII	6 ± 1	XVI	33 ± 4
VIII	7 ± 1	XVII	37 ± 4
IX	8 ± 2		

cementum lines, which corresponded exactly with their chronological ages.

The probable range of chronological ages in relation to the age classes based on tooth eruption and attrition is shown in Table 2. Although the 17 designated age classes do give a good indication of chronological age, there remains a considerable overlap between successive classes. A more reliable estimate of age can be obtained from the use of cementum lines.

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