

The Hemipenes of Chinese Species of *Deinagkistrodon* and *Gloydus* (Serpentes: Crotalinae)

PENG GUO¹, FU-JI ZHANG, AND YUE-YING CHEN

Chengdu Institute of Biology, the Chinese Academy of Sciences, Chengdu 610041, China

Abstract.— The hemipenes of eight species of two genera, *Gloydus* and *Deinagkistrodon* are described in detail and illustrated. The results indicate that (1) the structures of hemipenes of *Gloydus* markedly different from that of *Deinagkistrodon*, (2) more similarities are present among species of *Gloydus*. At the end of the paper, the taxonomic relationships among species revealed by hemipenial structures are discussed.

Key words.— Serpentes, Crotalinae, *Deinagkistrodon*, *Gloydus*, Hemipenes.

¹Present address: Sichuan Yibin Teachers College, Yibin, Sichuan 644007, China.

Introduction

Since Cope has firstly implied the characters of reptilian hemipenes to the classification in 1893, their important value in the classification and phylogeny was realized by more and more researchers around world (Pope, 1935; Smith, 1943; Dowling et al., 1960; Zhang et al., 1984; Zhang, 1986; Branch, 1988; Mao, 1989; Gloyd et al., 1990; Malnate, 1990). Although some of hemipenes of Chinese *Deinagkistrodon* and *Gloydus* were described (Pope, 1935; Smith, 1943; Mao, 1989; Gloyd et al., 1990; Malnate, 1990) previously, the authors didn't illustrate them except *Gloydus brevicaudus* and *Deinagkistrodon acutus*.

Prior to this paper, a comparative anatomy on skull of these two genera was done (in press.), we confirm that there are eight valid species of *Deinagkistrodon* and *Gloydus* in China. At the present work, the feathers of the hemipenes of these eight species will be described in detail, and the taxonomic relationships indicated by their structures will also be discussed, they will provide additional and further data for the classification and systematic of these species.

Material and Methods

The materials used in this study are based up formalin-preserved adult specimens; all of them are deposited in Chengdu Institute of Biology, the Chinese Academy of Sciences. The number and locality of examined and figured specimens are listed in Table 1.

In this paper, the descriptive terminology generally followed literature (Dowling et al., 1960; Zhang et al., 1984; Branch, 1986). In a majority of cases, the fully everted hemipenes were illustrated. In a few cases, the partly everted hemipenes were everted arti-

ficially. The drawings were done under the binocular-dissecting microscope.

Results

***Gloydus ussuriensis* (Emelianov).** The divided hemipenis (Fig. 1) extends to eighth subcaudal plate and is forked opposite the third. While the Russia (Kebrovka, Primorskiy Kray) specimens described by Gloyd et al. (1990) and Malnate (1990) extend to the eleventh subcaudal and are forked for eight subcaudals. It is spinous proximally, calyculate distally. The transition from spines to calyces is inconspicuous. The calyculate area is about equal to that of spinous one. The calyculate edges are spinous. Over sixty spines, they reduce in size distally and away from sulcus. Base of organ, proximal to the large spinous, is beset with very minute spines. Centripetal sulcus distinct, forking near the crotch which is about the second subcaudal, it ends at the tips of the organ. The lips of sulcus are spinous and calyculate in the respective areas of ornamentation.

The *M. retractor penis magnus* ends in the twenty-third to twenty-fifth subcaudal, it is forked at the level of the eleventh subcaudal before its insertion the dorsal organ. The dorsal lobe is one subcaudal longer than the ventral lobe (*in situ*).

***G. brevicaudus* (Stejneger).** The hemipenes (Fig. 2) of the specimens from Anhui and Zhejiang extend to the fifth to eighth subcaudal plate and are forked at the level of the third to fourth subcaudal. Base of the organ nude. The proximally half of the organ is spinous and the other half calyculate. The calyculate ridges bears tiny spines. Gloyd et al. (1990) also described the hemipenes from Anhui, they were sure that the lips of top calyces were smooth. The demar-

Table 1. Material used in this study.

Species	Number	Locality	Date
<i>Gloydus ussuriensis</i>	4	Jiling	1979
<i>G. breviceaudus</i>	8	Anhui, Zhejiang, Liaoning	1972, 1974, 1979, 1991
<i>G. strauchii</i>	3	Sichuan	1975, 1978
<i>G. qinlingensis</i>	2	Shaanxi	1984
<i>G. intermedius</i>	5	Xinjiang	1976, 1977, 1980, 1987
<i>G. saxatilis</i>	3	Jiling, Liaoning	1978, 1979
<i>G. shedaoensis</i>	4	Liaoning	1965, 1979
<i>Deinagkistrodon acutus</i>	3	Jiangxi, Fujian	1964, 1979

cation between the two areas is inconspicuous. In the spinous area, there are about twenty-eight to thirty spines, they become larger away from the sulcus. Sulcus prominent, it is forked at the second subcaudal and ends at the tips of the organ. The lips of the sulcus are spinous in the spinous area and calyculate in the calyculate area. The *M. retractor penis magnus* originates at the level of the twenty-fifth to twenty-fourth subcaudal, and is forked for the length of two to four subcaudals before its insertion the organ dorsal.

In this paper, three specimens from Liaoning, which are dominated *brevicaudus* by Gloyd (1972), were also examined, they are different from the formers slightly. The calyce is restrict to the tips of the lob, its extent is about fourth of the spinous one. The *M. retractor penis magnus*, which is about ten to fourteen in length, is shorter than the former one, it is forked for the length of two subcaudals. The hemipenes of two specimens examined extend to the seventh or eighth subcaudal, and are forked at the level of the fourth subcaudal, but the other one is much longer, it extends to the twelfth subcaudal and is forked at the level of the seventh subcaudal. Our observation is consistent with Gloyd *et al.* (1990) and Malnate (1990).

***G. intermedius* (Strauch).** The hemipenis (Fig.3) is seven to eleven subcaudals in length, forked for the length of four to five subcaudals. It is spinous proximally half, and the distally half of the organ is calyculate. The line of changing from spines to calyces is inconspicuous. The calyces small adjacent to the sulcus but larger away from it, their lips bearing tiny spines. About sixty spines are present in the spinous area, they reduce in size distally and near the sulcus. One or two strongly enlarged spines adjacent to the

sulcus at the crotch level. Small spines are found in the base of the organ. The sulcus is forked at the level of the second to the fourth subcaudal, it continues to the tips of the lobes. The sulcus prominent, its lips are spinous or calyculate in the respective area of ornamentation. *M. retractor penis magnus* originates at the level of the twenty-seventh to twenty-ninth subcaudal, it is forked for the length of two to four subcaudals before its insertion at the organ tips.

***G. saxatilis* (Emelianov).** The hemipenis (Fig. 4) of this species extends to the ninth to the eleventh subcaudal plate, forked at the level of the third or fourth subcaudal. It is spinous proximally and calyculate distally. The spinous and calyculate areas are about equal in length, the demarcation between two areas is inconspicuous. There are about sixty to seventy spines near the crotch, including six much larger spines, four of them appearing on the surface near the crotch, while the other two are on the opposite side. The spines reduce in size distally on the organ lobes. The margins of the calyces are spinous. The base of the organ is covered with tiny spines. While Gloyd *et al.* (1990) previously described the specimens collected from Korea (near Seoul), the organ base nude, the lips of the distal cups are smooth. The sulcus is bifurcated at the level of the second subcaudal and extends to the tips of the organ, their lips are prominent, bearing a few spines in the spinous area and calyces in the calyculate area. The *M. retractor penis magnus* originates at the level of the twenty-fourth to twenty-fifth subcaudal, and is forked for the length of two to three subcaudals before its insertion at the organ tips.

***G. shedaoensis* (Zhao).** In this species, the hemipenis (Fig. 5) is eight to ten subcaudals in length, and forked for five to six subcaudals. The base of the

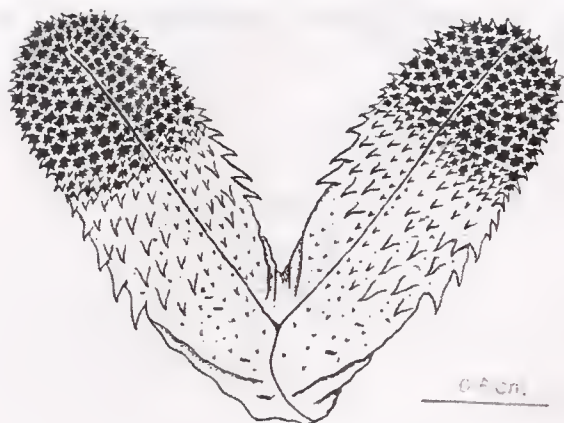


Figure 1. The right everted hemipenis of *G. ussuriensis* (CIB 785185, Panshi, Jilin)

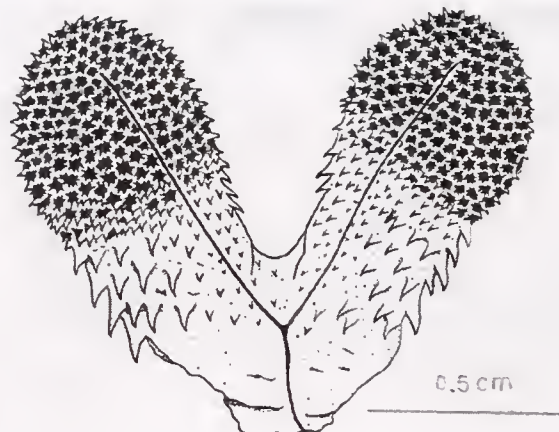


Figure 2. The right everted hemipenis of *G. brevicaudus* (CIB 726108, Taiping, Anhui)



Figure 3. The right everted hemipenis of *G. intermedius* (CIB 8010015, Xingyuan, Xinjiang)



Figure 4. The right everted hemipenis of *G. saxatilis* (CIB 7910090, R. Zhuang, Liaoning)

organ is covered with tiny spines. Spinose proximally, calyculate distally. The margins of calyces are tiny spines. The extent of calyces is about half of spines. Line of changing from spine to calyces is inconspicuous. There are ninety to one hundred spines in the spinous area, and six especially larger spines in each lobe. The sulcus prominent, forked at the level of the third subcaudal, and extends to the tips of the organ rami. Sulcus lips are spinous or calyculate in the respective areas of ornamentation. The *M. retractor penis magnus* originates at the level of the twenty-fourth to twenty-seventh subcaudal and is bifid for the length of two to three subcaudals before its insertion at the organ tips.

G. strauchii (Bedriaga). The hemipenis (Fig. 6) examined extends to the seventh to eleventh subcaudal and is forked for four to five subcaudals. It is spinous proximally half, and the distally half is calyculate. The line of changing from spines to calyces is inconspicuous. The calyces are small adjacent to the sulcus but larger away from it, their lips bearing tiny spines. About sixty spines are present in the spinous area, they reduced in size distally and near the sulcus. One or two strongly enlarged spines are adjacent to the sulcus at the crotch level. Small spines are present in the base of the organ. The sulcus forks at the level of the second to fifth subcaudal, and continues to the tips of the lobes. The lips of the sulcus prominent, they are spinous or calyculate in the respective areas of ornamentation. *M. retractor penis magnus* origi-

nates at the level of the twenty-seventh to twenty-

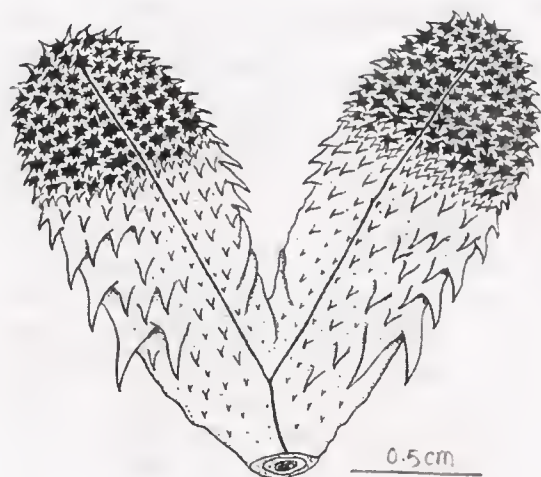


Figure 5. The right everted hemipenis of *G. shedaoensis* (CIB 79110006, Shedao, Liaoning)



Figure 6. The right everted hemipenis of *G. strauchii* (CIB 755127, Hongyuan, Sichuan)



Figure 7. The right everted hemipenis of *G. qinlingensis* (840050, Qinling, Shaanxi)

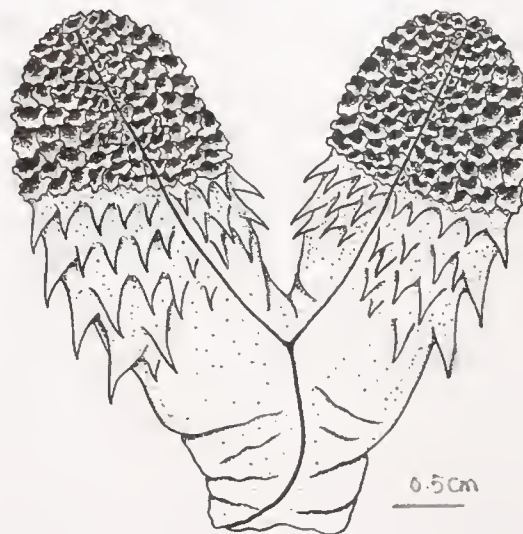


Figure 8. The right everted hemipenis of *D. acutus* (CIB 6416190, Fujian)

four subcaudals before its insertion at the organ tips.

***G. qinlingensis* (Song).** The hemipenis (Fig. 7) extends to the eleventh subcaudal plate in length and is forked at the level of the fifth subcaudal. Minute spines are present in the base of the organ. It is spinous proximally, calyculate distally, the spinous area is about twice to third times as the calyculate one. The line of demarcation between two areas is inconspicuous. The calyculate edges are spinous, there are approximately thirty to forty spines in the spinous region. The sulcus bifurcates the fourth to fifth subcaudal, terminates at the tips of the organ. Sulcus is distinct, bearing spines in spinous area and

calyces in the calyculate one. The length of *M. retractor penis magnus* extending is 14 subcaudals and it is forked for the length of two subcaudals before its insertion at the organ tips.

***Deinagkistrodon acutus* (Gunther).** The hemipenis (Fig. 8) extends to the eleventh to thirteenth subcaudal and is forked opposite the fourth subcaudal, base of organ nude. The proximally half of the organ is spinouse, the distally half calyculate, the demarcation between these two areas is distinct. The calyces with smooth margins reduce in size distally and near the sulcus. The spines are about sixth to seventy, they are larger on the lateral surface of each lobe than those

near the sulcus. The sulcus forks at the level of the fourth subcaudal, it extends to the tips of the each lobe. The lips of sulcus prominent, they bearing calyces in the calyculate region and smooth in the spinous area. *M. retractor penis magnus* originates at the level of the twenty-sixth subcaudal and is bifid for the length of two to four subcaudals before its insertion at the tips of the organ.

Discussion

The hemipenes are deeply forked in eight Chinese species of pitvipers, the shape of the everted hemipenes are "Y". It is spinous proximally and calyculate distally. The centripetal sulcus is consistently bifurcated on the basal part of the organ in all of the species examined, and it extends to the tips of the lobes. These similarities reveal the taxonomic relationships between genus *Gloydus* and *Deinagkistrodon*. The deeply forking of the hemipenis and the bifurcation of the sulcus in the basal region of the organ are exactly like those of the other pitvipers (Pope, 1935; Smith, 1943).

D. acutus can be characterized by presence of the following hemipenial structures: (1) the margins of the calyces are smooth; (2) transition from spines to calyces is abrupt and conspicuous; (3) the sulcus lips are smooth in the spinous area; (4) the base of the organ is naked. These conditions further confirmed the validity of the independent generic status of *Deinagkistrodon*.

The seven species of *Gloydus* exhibit rather conservative and stable hemipenial structures, the interspecific variation is only limited to: (1) the length of the hemipenes and the depth of their forking; (2) the extent of the calyculate area on the lobes; (3) the length of the retractor muscle and the depth of their forking; (4) the manner of insertion of the retractor muscle onto the organ; (5) the number of enlarge spines. The results above indicated that the differentiation of the hemipenial structures in *Gloydus* is little.

Acknowledgments

This project was supported by the Special Fund for Classification & Fauna, the Chinese Academy of Sciences (950633), and by Chengdu Diao Science Fund, the Chinese Academy of Sciences.

The authors express their grateful appreciation to Prof. E. M. Zhao, Chengdu Institute of Biology, the

Chinese Academy of Sciences, for providing literature and reviewing the manuscript. We also thank the following people for presenting with studying specimens: Prof. M. H. Huang, Zhejiang Medical University; Prof. M. T. Song, Shaanxi Institute of Zoology; Prof. Y. H. Zhou, Xinjiang Normal University; Prof. K. C. Huang, Dalian Museum of Natural History.

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