

Comparative Osteology of Japanese Frogs and Toads
for Paleontological Studies (I): *Bufo*, *Hyla*,
Microhyla and *Bombina*

by

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Introduction

Fossil frogs found in cave or lake deposits in Japan have not been studied in detail. OKADA (1937) and SHIKAMA (1949) are the only scientists who reported on fossil frogs from Japan.

Dr. Y. HASEGAWA who has been studying fissure deposits collected a large number of fossil frog remains. Most of specimens are from Quarternary deposits. As the fossils are closely related to Recent species, a detail study of skeletons of Recent frogs became necessary for the investigation of fossil frogs.

There are few reports on the osteology of frogs of Japan and adjacent areas. OKADA (1930, 1966) briefly described cranial bones and pectoral girdle, and this have been the only available information on this subjects in Japan. In foreign countries, there are few works that report the osteology of Recent frogs. PROCTOR (1921) studied the scapula of *Aglossa* and *Arcifera*. CHANTEL (1968a; 1968b) studied the osteology of the family Hylidae. MARTIN (1972) described the cranial morphology of New World *Bufo*.

The author intended not only to investigate the skeletal morphology of frogs and toads in Japan and adjacent areas but also to study systematics of fossil frogs.

I present here the comparative osteology of Japanese frogs and toads. The author tried to use osteological characters for the classification of Recent frogs. Also osteological characters described here will be useful to identify the bones from archaeological sites.

The generic and specific characters are described following the classification of OKADA (1966) and NAKAMURA and UENO (1963). This paper was extracted from the thesis of Doctor of Science submitted to Nihon University.

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Material and Methods

Disarticulated bones were examined. The following skeletal elements are deposited in the collection of National Science Museum, Tokyo: Fronto-parietal, ethmoid, parasphenoid, maxilla, scapula, humerus, sacrum, ilium and femur.

All specimens were macerated in water. The outline of the cranial elements, shown in the figures, were drawn using Wild dissecting microscope with the drawing device. The outline of postcranial elements were drawn from the enlarged photographs. First the photographs were outlined by ink, then the photographs were washed off with the solution that was made by iodine and potassium iodide. Finally the drawing by ink was transferred to a sheet of paper by tracing.

The anatomical nomenclature follows that of CHANTEL (1968a). Where the proper nomenclature was not available in CHANTEL, nomenclature of ECKERS et al. (1956) was followed.

List of Species Examined

Order Salientia

Suborder Arcifera

Family Bufonidae

Bufo bufo japonicus SCHLEGEL, 1838

Bufo bufo gargarizans CANTOR, 1842

Bufo melanostictus SCHNEIDER, 1799

Family Discoglossidae

Bombina orientalis (BOULENGER, 1890)

Family Hylidae

Hyla arborea japonica G NTHER, 1858

Family Brevicipitidae

Subfamily Microhylinae

Microhyla ornata (DUMÉRIL et BIBRON, 1841)**Description**

Family Bufonidae

Genus *Bufo* LAURENTI 1768

Fronto-parietal (Fig. 1, 4–6): dermal ornamentation present on dorsal surface; supraorbital crest present; fused with prootics.

Ethmoid (Fig. 1, 12–17): slightly longer than its width; postero-dorsal edge wavy.

Parasphenoid (Fig. 1, 21–23): blade shorter than its width across alae; alae perpendicular to blade; a protuberance present on center of alae.

Maxilla (Fig. 1, 30–35): no teeth present; pterygoid process developed and projected postero-medially; dorsal process projected dorso-anteriorly.

Scapula (Fig. 2, 1–6): anterior margin of clavicular process convex; From dorsal view, large foramen present between clavicular and coracoid processes; ridge extends onto middle of dorsal surface of coracoid process.

Humerus (Fig. 3, 6–10): well developed medial flange present; spina tuberculi medialis well developed; fovea not clear; in female shaft more strongly arched laterally than in male; long axis of olecranon ball external to that of shaft.

Sacrum (Fig. 3, 11–13): anterior surface of centrum concave; diapophyses strongly expanded.

Ilium (Fig. 4, 1–3): no ilial crest present; dorsal protuberance well developed at base of ilium.

Femur (Fig. 4, 7): deltoid crest well developed.

Bufo bufo japonicus SCHLEGEL, 1838

Fronto-parietal (Fig. 1, 6): dorsal surface slightly ornamented; width slightly decreases towards its proximal end; width narrower than its length; occipital canal present but shallow; no postorbital crest present; supraorbital crest runs along lateral margin; in adult specimens, right and left bodies fuse with each along medial margins; fused with exoccipital along posterior margin of postorbital shelf; postorbital shelf small.

Ethmoid (Fig. 1, 16–17): length longer than its width; anterior projection developed; its width narrow; processus lateralis well developed and projects latero-anteriorly; distance between right and left distal end of processus lateralis almost equal to its length; a pair of pits present on dorso-lateral surface of body; flange weakly developed; posterior ventral edge wavy; posterior dorsal edge concave anteriorly; proximal end posterior to posterior corners of flange; in young specimen, no anterior projection present; posterior dorsal edge slightly concave.

Parasphenoid (Fig. 1, 21): blade shorter than its width across alae; anterior end of blade pointed; alae perpendicular to blade; both end of alae pointed; ridge

runs on ventral surface of alae along long axis of it; a protuberance present on center of alae; neck of blade not developed; posterior process well projected.

Maxilla (Fig. 1, 32–33): no teeth present; antero-dorsal corner of pars facialis convex anteriad; dorsal margin of pars facialis almost straight; dorsal process scarcely developed and projects dorso-anteriad; pterygoid process well developed and projects posteriad; lingual shelf well developed.

Scapula (Fig. 2, 5–6): anterior margin of clavicular process convex; From ventral view, large foramen present between clavicular and coracoid processes; ridge extends onto middle of dorsal surface of coracoid process; size of body the largest among three species.

Humerus (Fig. 3, 6–7): lateral flange weakly developed; in female medial flange smaller than in male; size of spina tuberculi medialis medium in size; in female shaft more strongly arched laterally than in male; long axis of olecranon ball external to that of shaft.

Sacrum (Fig. 3, 11): anterior surface of centrum concave; width of diapophyses increase their width towards ends; ridge lambdoid in shape and sharply developed; general shape of body resembles that of *B. b. gargarizans*.

Ilium (Fig. 4, 1): no ilial crest present; dorsal protuberance well developed at base of shaft; ilial shaft arches dorsally; ilial shaft angle about 110°.

Remarks: Large sized toad. For this study, 13 specimens are available. It is difficult to separate postcranial skeletons of the genus *Bufo* at the subspecific level. However, the cranial elements (fronto-parietal, ethmoid and parasphenoid) are separable. This species is the largest among three species in Japan. This species differs from other toads as follows: supraorbital crest runs along lateral margin of fronto-parietal; width of fronto-parietal almost constant; a pair of pits present on dorso-lateral surface of ethmoid; no projections on ventral anterior margin of ethmoid; ridge runs on ventral surface of long axis of alae of parasphenoid; pterygoid process of maxilla projects postero-medially.

Bufo bufo gargarizans CANTOR, 1842

Fronto-parietal (Fig. 1, 4): weak ornamentation present on dorsal surface; width decreases its width towards its proximal end; body narrow comparing with its length; lateral margin of body arches laterally; occipital canal deeply developed; no parietal crest present; supraorbital crest weakly developed; in adult specimens, body, prootics and exoccipital are fused.

Ethmoid (Fig. 1, 12–13): length longer than its width; anterior projection developed; there is a pair of projection on ventral anterior margin of body; anterior projection held on dorsal border by a pair of projection; processus lateralis developed and projects latero-anteriad; distance between right and left of distal ends of processus lateralis equal to its body length; weak ridge present at base of processus lateralis; flange developed; neck of posterior corner of flange well developed; posterior ventral edge wavy; posterior dorsal edge concave; anterior end of it same level as both posterior

corner of flange.

Parasphenoid (Fig. 1, 23): blade shorter than its width across alae; anterior end of blade pointed; a few grooves present on ventral surface of anterior part of blade; alae perpendicular to blade; both end of alae pointed; weak ridge runs along long axis of ventral surface of alae; a protuberance present on center of alae; width of alae almost constant; neck of blade not developed; distal end of posterior process slightly posterior to posterior ends of alae.

Maxilla (Fig. 1, 34–35): no teeth present; antero-dorsal end of pars facialis convex anteriad; dorsal process well developed and projects dorso-anteriad; pterygoid process well developed and projects posteriad; lingual shelf developed.

Scapula (Fig. 2, 1–2): anterior margin of clavicular process convex; From ventral view, narrow foramen present between clavicular and coracoid processes; size of body smaller than that of *B. b. japonicus*.

Humerus (Fig. 3, 9–10): lateral flange well developed; in male medial flange larger than in female; size of spina tuberculi medialis largest among three species; in female shaft more arched laterally than in male; long axis of olecranon ball external to that of shaft.

Sacrum (Fig. 3, 13): general shape of this species resemble that of *B.b. japonicus*; size of this bone smaller than that of *B. b. japonicus*.

Ilium (Fig. 4, 2): no ilial crest present; well developed dorsal protuberance at base of ilium; ilial shaft narrow and arches dorsally; ilial shaft angle about 80°.

Remarks: Small sized toad. This species resemble *B. b. japonicus* except their size. Four specimens are available for study. This toad differs from other frogs and toads as follows. Lateral margin of fronto-parietal arches laterally; a pair of projection on ventral anterior margin of ethmoid; flange of ethmoid developed; weak ridge runs along long axis of ventral surface of alae of ethmoid; dorsal process of maxilla projects dorso-anteriad.

Bufo melanostictus SCHNEIDER, 1799

Fronto-parietal (Fig. 1, 5): heavily ornamented on dorsal surface; width gradually decreases its width towards its proximal end; width broad comparing with its length; supraorbital crest runs along latero-dorsal margin of body; occipital canal present but can not be seen from above; postorbital shelf developed; in adult specimen, fused with prootics.

Ethmoid (Fig. 1, 14–15): longer than its width; width of body narrowest at posterior edge; faint ornamentation present on dorsal surface; anterior projection scarcely developed; there is a pair of projection which hold anterior projection from both side; this projection weaker than that of *B.b. gargarizans*; processus lateralis developed and projects anterolaterally; distance between right and left distal end of processus lateralis almost equal to its body length; no flange present; posterior ventral edge scarcely arches posteriad; posterior dorsal edge arches anteriad; anterior end of it far posterior to posterior corners of orbitonasal foramen.

Parasphenoid (Fig. 1, 22): blade shorter than its width across alae; width of blade narrow comparing with its length; anterior end of blade pointed; neck of blade not developed; posterior margin of alae arches posteriad; alae inclined slightly anteriad; distal end of alae pointed; articular for pterygoid present on ventral surface of distal part of alae; a protuberance present on center of alae; posterior process developed.

Maxilla (Fig. 1, 30–31): no teeth present; lateral surface sculptured; height of pars facialis low; dorsal process well developed and projects dorso-anteriorly; ridge runs along latero-dorsal margin of body; pterygoid process weakly developed.

Scapula (Fig. 2, 3, 4): anterior margin of clavicular process convex; From ventral view, large foramen present between clavicular and coracoid processes; neck of body well developed.

Humerus (Fig. 3, 8): in male medial flange not well developed; spina tuberculi medialis weakly present; long axis of olecranon ball external to that of shaft.

Sacrum (Fig. 3, 12): anterior surface of centrum concave; From ventral view, both condyle well developed and projects posterior to posterior margin of neural arch; width of diapophyses increase their width but width of it narrower than that of above mentioned two species; antero-postero length of distal end of diapophysis slightly longer than centrum length; ridge faintly developed and extends onto middle of diapophyses.

Ilium (Fig. 4, 3): no ilial crest present; dorsal protuberance well developed at base of ilial shaft; depth of ilial shaft long. ventral margin of ilial shaft not strongly arches dorsally; ilial shaft angle about 90°.

Remarks: Medium sized toad. Three specimens are available for study. This species differs from other *Bufo* as follows. Heavy ornamentation on dorsal surface of frontoparietal; width of fronto-parietal broad comparing with its length; faint ornamentation on dorsal surface of ethmoid; width of ethmoid narrowest at posterior edge; posterior dorsal edge of ethmoid arches anteriad; anterior end of blade of parasphenoid pointed; posterior margin of alae arches posteriad; alae of parasphenoid incline slightly anteriad; articular for pterygoid present on ventral surface of distal part of alae; heavy sculpture on lateral surface of maxilla; ridge runs along latero-dorsal margin of maxilla; spina tuberculi medialis of humerus weakly present; diapophyses of sacrum weakly expanded; ridge on sacrum faintly present and extends onto middle of diapophyses; depth of ilial shaft large.

Family Hylidae

Genus *Hyla* LAURENTI 1768

Hyla arborea japonica GÜNTHER, 1858

Fronto-parietal (Fig. 1, 2): there is cartilage plate investing both right and left element fusing fronto-parietal into a single unit; no dermal ornamentation; width decreases its width towards its proximal end; width especially narrow comparing with its length; no occipital process present; no occipital canal present; no postorbital shelf present.

Ethmoid (Fig. 1, 8, 9): length shorter than its width; anterior margin of body arches anteriad; anterior projection not developed; processus lateralis projects latero-anteriorly; orbitonasal foramen can be seen from below; no flange present; posterior ventral edge weakly wavy; posterior dorsal edge well arches anteriad and proximal end of it same level as both posterior end of orbitonasal foramen.

Parasphenoid (Fig. 1, 19): blade longer than its width across alae; width of blade broad comparing with its length; proximal end of blade pointed; antero-postero length of alae narrow comparing with its width; posterior margin of alae nearly perpendicular to long axis of blade; both distal end of alae pointed; neck of blade not developed; there is one or two posterior process and distal end of it posterior to both posterior end of alae.

Maxilla (Fig. 1, 26–27): teeth present; anterior margin of pars facialis concave posteriad; dorsal margin of pars facialis almost straight; height of pars facialis high; dorsal process weakly projects dorsally; pterygoid process well developed; lingual shelf weakly developed; height of body gradually decreases its height towards its distal end.

Scapula (Fig. 2, 7, 8): anterior margin of clavicular process concave; foramen present between clavicular and coracoid processes; neck of body well developed; From ventral view, ridge weakly developed and extends onto middle of dorsal surface of coracoid process.

Humerus (Fig. 3, 1, 2): distal end of medial epicondyle same level as that of olecranon ball; intertubercular groove well developed; lateral margin of lateral epicondyle projects laterally; long axis of olecranon ball external to that of shaft; length of ventral crest about length of shaft; outline of olecranon scar not clear; proximal end of it not pointed and stands on long axis of shaft; in male medial flange well developed, and sexually dimorphic.

Sacrum (Fig. 3, 14): anterior surface of centrum concave; ridge extends onto dorsal surface of neural arch along posterior margin of it; this ridge $\cap$ or $+$ shaped; diapophyses strongly expanded antero-posteriad.

Ilium (Fig. 4, 5): no ilial crest present; dorsal protuberance well developed and projects dorso-laterally; anterior edge of acetabular fossa anterior by half length to dorsal protuberance; antero-postero length of ventral acetabular expansion broad; ilial shaft angle about 90° .

Femur (Fig. 4, 8): deltoid crest present.

Remarks: Tiny frog. Seven specimens are available for study. This species differs from other frogs and toads as follows. Width of fronto-parietal especially narrow comparing with its length; antero-postero length of alae of parasphenoid short comparing with its width; teeth present on maxilla; foramen present between clavicular and coracoid processes of scapula; length of ventral crest of humerus about half length of shaft; diapophyses of sacrum strongly expanded; no ilial crest of ilium present.

Family Brevicipitidae
Subfamily Microhylinae
Genus *Microhyla* TAXHUSI 1838
Microhyla ornata (DUMERIL et BIBRON, 1941)

Fronto-parietal (Fig. 1, 1): no dermal ornamentation; width especially decreases towards its proximal end; width narrow comparing with its length; no occipital process and occipital canal present; neck of medial posterior corner of orbital foramen not developed.

Ethmoid (Fig. 1, 7): body separates into right and left elements; there is cartilage plate investing both element fusing ethmoid into a single unit; longer than its width; no anterior projection developed; processus lateralis projects lateroanteriorly; no flange present.

Parasphenoid (Fig. 1, 18): blade longer than its width across alae; width of blade broad comparing with its length; proximal end of blade not pointed; neck of blade not developed; anterior margin of alae perpendicular to long axis of blade; width of alae narrower than that of blade; distal end of posterior process projects posteriad.

Maxilla (Fig. 1, 24, 25): no teeth present; pars facialis scarcely developed; anterior margin of pars facialis convex anteriorly; dorsal process delta in shape and projects dorsally; no pterygoid process present; anterior one third of lingual shelf developed; height of body decreases its height towards its distal end.

Scapula (Fig. 2, 11, 12): ridge runs along anterior margin of coracoid process from proximal end to anterior margin of body; this ridge well developed; antero-postero length of clavicular process long; no foramen present between clavicular and coracoid processes.

Humerus (Fig. 3, 3): distal end of medial epicondyle at same level as that of olecranon ball; no medial and lateral flanges present; it is hard to separate each sex; no intertubercular groove present; ventral fossa broad and shallow; length of ventral crest less than half length of shaft; outline of olecranon scar indistinct; proximal end not pointed and matches with long axis of shaft.

Sacrum (Fig. 3, 16): anterior surface of centrum convex; width of centrum narrower than that of neural canal; ridge extends onto dorsal surface of neural arch; this ridge well developed and + or lambda shaped; diapophyses expanded but weaker than that of *Bufo*.

Ilium (Fig. 4, 4): no ilial crest present; deltoid shaped dorsal protuberance present on dorsal edge of dorsal acetabular expansion; length at its base of dorsal protuberance shorter than its height; dorsal protuberance posterior to proximal end of acetabular fossa; antero-postero length of ventral acetabular expansion narrow; shallow groove runs along long axis of lateral surface of ilial shaft from base to half length of shaft; ilial shaft angle less than 40°.

Femur (Fig. 4, 9): no deltoid crest present.

Remarks: Tiny frog. Size of this species resemble that of *Hyla arborea japonica*.

Two specimens are available for study. This species differs from other frogs and toads as follows. Width of fronto-parietal especially decreases its width towards its proximal end; ethmoid separates into right and left elements; no teeth of maxilla present; no foramen of scapula present between clavicular and coracoid processes; no flanges of humerus present; long axis of olecranon ball on that of humerus; anterior surface of sacrum convex anteriad; deltoid shaped dorsal protuberance of ilium present; shallow groove runs along long axis of lateral surface of ilial shaft.

Family Discoglossidae

Genus *Bombina* OKEN 1816

Bombina orientalis (BOULENGER, 1890)

Fronto-parietal (Fig. 1, 3): no dermal ornamentation; width gradually decreases towards its proximal end; width narrow comparing with its length; no occipital process present; no postorbital shelf present; concavity present on half way of medial margin of body; it looks like fontanella; anterior one third of medial margin of both left and right bodies do not contact each other.

Ethmoid (Fig. 1, 10, 11): length almost equal to width; width narrowest at middle; anterior projection weakly developed; processus lateralis well developed and projects latero-anteriad; distance between both distal end of processus lateralis longer than its body length; no flange present; posterior ventral edge scarcely arches posteriad; posterior dorsal edge arches anteriad; anterior end of it same level as both posterior corner of orbitonasal foramen.

Parasphenoid (Fig. 1, 20): blade longer than its width across alae; width of blade broad comparing with its length; proximal end of blade not pointed; alae scarcely inclined posteriad; antero-postero length of alae almost constant; neck of blade not developed; posterior end of posterior process extends beyond both posterior end of alae.

Maxilla (Fig. 1, 28–29): teeth present; anterior margin of pars facialis almost straight; dorsal margin of pars facialis almost straight; height of pars facialis high; dorsal process biconvex dorsally; pterygoid process developed; lingual shelf well developed; height of body decreases its height towards its distal end.

Scapula (Fig. 2, 9–10): general body L in shape; length longer than its width; clavicular process weakly projects medio-anteriad; size of coracoid process larger than that of clavicular one; From dorsal view, ridge weakly developed and runs along center of coracoid process; distal part of body well developed; articular fossa almost contracted by coracoid process.

Humerus (Fig. 3, 4–5): spina tuberculi medialis present; distal end of medial epicondyle almost same level as that of olecranon ball; medial flange well developed in both sexes and length of it more than half length of shaft; in male lateral flange well developed; it can separate each sex; lateral epicondyle developed and convex laterally; long axis of olecranon ball external to that of shaft; ventral crest developed; length of it quarter length of shaft; posterior margin of shaft almost straight; From posterior

view, outline of olecranon scar seen clearly; lateral margin of olecranon scar does not contact with that of shaft.

Sacrum (Fig. 3, 15): anterior surface of centrum convex; there is mono-condyle behind centrum; strong expanded diapophyses present; antero-postero length of it more than three times longer than centrum length; no ridge present on diapophyses; prezygapophyses developed and contact with each other at medial margin of it.

Ilium (Fig. 4, 6): no ilial crest present; dorsal protuberance developed; ventral acetabular expansion scarcely developed; anterior end of acetabular fossa anterior by half length to base of dorsal protuberance; general shape of it resembles that of *Rha. buergeri*; ilial shaft angle nearly 90° .

Femur (Fig. 4, 10): deltoid crest present.

Remarks: Small sized frog. Four specimens are available for study. This species is very peculiar frog. It differs from other frogs and toads as follows. Concavity present on center of medial margin of fronto-parietal; both anterior one third of medial margin of fronto-parietal does not contact with each other; width of ethmoid narrow at middle; posterior dorsal edge of ethmoid arches anteriorly; width of blade of parasphenoid broad comparing with its length; maxilla teeth present; dorsal process of maxilla biconvex dorsally; lingual shelf of maxilla well developed; general shape of scapula L shaped; size of coracoid process larger than that of clavicular process of scapula; length of medial flange of humerus more than half length of shaft; no ridge of sacrum present on diapophyses; both prezygapophysis of sacrum developed and contact with each other at medial margin of it; no ilial crest of ilium present; ventral acetabular expansion of ilium scarcely developed.

Discussion and Conclusion

In the preceding section, the author described skeletons at the specific level. Here, I discuss about osteological problems of subspecies.

Only few books have been published as to the taxonomy of the Japanese frogs and toads.

According to NAKAMURA and UENO (1963), one genus two species and two subspecies of the family Bufonidae are distributed in Japan and adjacent area. There are clear osteological differences between *Bufo bufo* and *Bufo melanostictus*. Two subspecies of *Bufo bufo* can be separated only by cranial bones (fronto-parietal, ethmoid and parasphenoid). OKADA (1966) divided *Bufo bufo japonicus* of NAKAMURA and UENO (1963) into three subspecies: *Bufo bufo formosus*, *B. b. japonicus* and *B. b. montanus*. OKADA used markings of the body surface and the length of the hind limbs for the subspecific characters. I found no reflections of the subspecific characters on bones in these three subspecies.

MARTIN (1972) divided the form of the fronto-parietal of the genus *Bufo* into the broad line (lowland) and the narrow line (highland). Concerning the Japanese species of *Bufo*, the frontoparietal of two subspecies of *Bufo bufo* belong to the narrow

line and that of *B. melanostictus* to the broad line. Of these, *B. b. japonicus* is distributed from the lowland to the highland in Honshu. According to INGER (1972), *Bufo bufo* migrated from the Asian continent via Korean peninsula to Honshu. At the time when *Bufo bufo* was differentiated into *B. b. japonicus*, it probably obtained the ability to live in the areas different from the highland.

Osteologically, the genus *Bufo* is well differentiated from other genera of Japanese frogs. Diagnostic characters separating *Bufo* from other Japanese frogs and toads are recognizable on the following bones.

Fronto-parietal (Fig. 1, 4–6): dermal ornamentation present on dorsal surface; supraorbital crest present; fused with prootics. Ethmoid (Fig. 1, 12–17): slightly longer than width; posterior dorsal edge weakly W shaped.

Parasphenoid (Fig. 1, 21–23): blade shorter than its width across alae; alae well developed and almost perpendicular to blade.

Maxilla (Fig. 1, 30–35): no teeth present; pterygoid process developed and projected medioposteriorly; dorsal process projected anterodorsally.

Scapula (Fig. 2, 1–6): anterior margin of clavicular process convex; foramen present between clavicular and coracoid processes.

Humerus (Fig. 3, 6–10): medial flange well developed; spina tuberculi medialis well developed.

Sacrum (Fig. 3, 11–13): anterior surface of centrum concave; diapophyses expanded anteroposteriorly.

Ilium (Fig. 4, 1–3): no ilial crest present; dorsal protuberance well developed.

Femur (Fig. 4, 7): deltoid crest well developed.

Infraspecifically, it is hard to separate subspecies of *Bufo* by postcranial skeletons.

Bufo bufo japonicus can be separated from *B. b. gargarizans* and *B. melanostictus* by following cranial elements.

Fronto-parietal (Fig. 1, 6): weak ornamentation present on dorsal surface; width narrow; lateral margin of both sides parallel with each other; only supraorbital crest present.

Ethmoid (Fig. 1, 16–17): a pair of projection absent on both sides of anterior projection; a pair of pit present on dorsolateral surface of body.

Parasphenoid (Fig. 1, 21): ridge present along long axis of alae; this ridge slightly inclined posteriad.

Maxilla (Fig. 1, 32–33): well developed pterygoid process projected postero-medially.

Skeletal characteristics present in *Hyla arborea japonica* are as follows.

Fronto-parietal (Fig. 1, 2): dermal ornamentation absent; width extremely narrow; no postorbital shelf present.

Ethmoid (Fig. 1, 8–9): width broader than length; no anterior projection present; posterior dorsal edge arches anteriorly and its proximal end present posterior to posterior corners of processus lateralis.

Parasphenoid (Fig. 1, 19): blade longer than its width across alae; antero-postero

length of alae very narrow and their distal ends pointed; alae perpendicular to blade; distal end of posterior process posterior to posterior ends of alae.

Maxilla (Fig. 1, 26–27): teeth present; dorsal process weakly developed; no pteryoid process present.

Scapula (Fig. 2, 7–8): foramen present between clavicular and coracoid processes; ridge indistinct.

Humerus (Fig. 3, 1–2): long axis of olecranon ball external to that of shaft; ventral crest well developed and its length about one half of shaft.

Sacrum (Fig. 3, 14): anterior surface of centrum concave; diapophyses expanded antero-posteriorly.

Ilium (Fig. 4, 5): no ilial crest present; anterior edge of acetabular fossa anterior by half length to dorsal protuberance.

Skeletal characteristics of *Microhyla ornata* are as follows.

Fronto-parietal (Fig. 1, 1): no ornamentation present; width broad; postorbital shelf present; no occipital process present.

Ethmoid (Fig. 1, 7): body separate into right and left elements; processus lateralis projected latero-anteriorly; no flange present.

Parasphenoid (Fig. 1, 18): blade longer than its width across alae; width of blade broad; posterior process well developed.

Maxilla (Fig. 1, 24–25): no teeth present; dorsal process well developed; no pteryoid process present.

Scapula (Fig. 2, 11–12): antero-postero length of clavicular process long; ridge runs along anterior margin of coracoid process to anterior margin of body.

Humerus (Fig. 3, 3): no flange present; length of ventral crest less than one half of shaft; long axis of olecranon ball matches with that of shaft.

Sacrum (Fig. 3, 16): anterior surface of centrum convex; diapophyses expanded antero-posteriorly.

Ilium (Fig. 4, 4): no ilial crest present; anterior end of acetabular fossa anterior to dorsal protuberance.

Skeletal characteristics of *Bombina orientalis* are as follows.

Fronto-parietal (Fig. 1, 3): no dermal ornamentation present; width narrow; no occipital process present; no ridge present.

Ethmoid (Fig. 1, 10–11): length almost equal to width; posterior ventral edge slightly arches posteriad; posterior dorsal edge wavy.

Parasphenoid (Fig. 1, 20): blade longer than its width across alae; width of blade broad; alae slightly inclined posteriad.

Maxilla (Fig. 1, 28–29): teeth present; pteryoid process well developed; lingual shelf developed; dorsal process biconvex.

Scapula (Fig. 2, 9–10): body L in shape; size of coracoid process larger than that of clavicular one.

Humerus (Fig. 3, 4–5): lateral condyle developed and projects laterally; long axis of olecranon ball external to that of shaft; ventral crest developed and length of

it about one fourth of shaft.

Sacrum (Fig. 3, 15): anterior surface of centrum convex; diapophyses well expanded antero-posteriorly; posterior surface of centrum convex; monocondyle.

Ilium (Fig. 4, 6): no ilial crest present; anterior end of acetabular fossa anterior by half length to base of dorsal protuberance; antero-postero length of ventral acetabular expansion not so wide.

Femur (Fig. 4, 10): deltoid crest present.

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Explanation of figures

Fig. 1. Right fronto-parietal (dorsal view). 1, *Microhyla ornata*, "Himeamagaeru", $\times 8.3$; 2, *Hyla arborea japonica*, "Amagaeru", $\times 8.3$; 3, *Bombina orientalis*, "Suzugaeru", $\times 4$; 4, *Bufo bufo gargarizans*, "Ajiahikigaeru", $\times 1.3$; 5, *Bufo melanostictus*, "Herigurohikigaeru", $\times 1.3$; 6, *Bufo bufo japonicus*, "Hikigaeru", $\times 1.3$. A scale indicates 1 mm.

Ethmoid (Odd number: ventral view; Even number: dorsal view). 7, *Microhyla ornata*, "Himeamagaeru", $\times 8.3$; 8, 9, *Hyla arborea japonica*, "Amagaeru", $\times 8.3$; 10, 11, *Bombina orientalis*, "Suzugaeru", $\times 4$; 12, 13, *Bufo bufo gargarizans*, "Ajiahikigaeru", $\times 1.3$; 14, 15, *Bufo melanostictus*, "Herigurohikigaeru", $\times 1.3$; 16, 17, *Bufo bufo japonicus*, "Hikigaeru", $\times 1.3$. A scale indicates 1 mm.

Parasphenoid (Ventral view). 18, *Microhyla ornata*, "Himeamagaeru", $\times 8.3$; 19, *Hyla arborea japonica*, "Amagaeru", $\times 8.3$; 20, *Bombina orientalis*, "Suzugaeru", $\times 4$; 21, *Bufo bufo japonicus*, "Hikigaeru", $\times 1.3$; 22, *Bufo melanostictus*, "Herigurohikigaeru", $\times 1.3$; 23, *Bufo bufo gargarizans*, "Ajiahikigaeru", $\times 1.3$. A scale indicates 2 mm.

Right maxilla (Odd number: lateral view; Even number: medial view). 24, 25, *Microhyla ornata*, "Himeamagaeru", $\times 8.3$; 26, 27, *Hyla arborea japonica*, "Amagaeru", $\times 8.3$; 28, 29, *Bombina orientalis*, "Suzugaeru", $\times 4$; 30, 31, *Bufo melanostictus*, "Herigurohikigaeru", $\times 1.3$; 32, 33, *Bufo bufo japonicus*, "Hikigaeru", $\times 1.3$; 34, 35, *Bufo bufo gargarizans*, "Ajiahikigaeru", $\times 1.3$. A scale indicates 2 mm.

Fig. 2. Right scapula (Odd number: dorsal view; Even number: ventral view). 1, 2, *Bufo bufo gargarizans*, "Ajiahikigaeru", $\times 4$; 3, 4, *Bufo melanostictus*, "Herigurohikigaeru", $\times 4$; 5, 6, *Bufo bufo japonicus*, "Hikigaeru", $\times 4$; 7, 8, *Hyla arborea japonica*, "Amagaeru", $\times 8$; 9, 10, *Bombina orientalis*, "Suzugaeru", $\times 4$; 11, 12, *Microhyla ornata*, "Himeamagaeru", $\times 8$. A scale indicates 1 mm.

Fig. 3. Right humerus (Anterior view). 1, *Hyla arborea japonica*, "Amagaeru", male, $\times 2.7$; 2, ditto, female; 3, *Microhyla ornata*, "Himeamagaeru", male, $\times 2.7$; 4, *Bombina orientalis*, "Suzugaeru", male, $\times 2$; 5, ditto, female; 6, *Bufo bufo japonicus*, "Hikigaeru", male, $\times 1.3$; 7, ditto; 8, *Bufo melanostictus*, "Herigurohikigaeru", male, $\times 1.3$; 9, *Bufo bufo gargarizans*, "Ajiahikigaeru", male, $\times 1.3$; 10, ditto, female. A scale indicates 1 mm.

Sacrum (Dorsal view). 11, *Bufo bufo japonicus*, "Hikigaeru", $\times 2$; 12, *Bufo melanostictus*, "Herigurohikigaeru", $\times 2$; 13, *Bufo bufo gargarizans*, "Ajiahikigaeru", $\times 2$; 14, *Hyla arborea japonica*, "Amagaeru", $\times 8$; 15, *Bombina orientalis*, "Suzugaeru", $\times 4$; 16, *Microhyla ornata*, "Himeamagaeru", $\times 8$. A scale indicates 2 mm.

Fig. 4. Right ilium (Lateral view). 1, *Bufo bufo japonicus*, "Hikigaeru", $\times 1.3$; 2, *Bufo bufo gargarizans*, "Ajiahikigaeru", $\times 1.3$; 3, *Bufo melanostictus*, "Herigurohikigaeru", $\times 1.3$; 4, *Microhyla ornata*, "Himeamagaeru", $\times 2.7$; 5, *Hyla arborea japonica*, "Amagaeru", $\times 2.7$; 6, *Bombina orientalis*, "Suzugaeru", $\times 2$. A scale indicates 3 mm.

Right femur (Anterior view). 7, *Bufo*, "Hikigaeru", $\times 2$; 8, *Hyla arborea japonica*, "Amagaeru", $\times 4$; 9, *Microhyla ornata*, "Himeamagaeru", $\times 4$; 10, *Bombina orientalis*, "Suzugaeru", $\times 4$. A scale indicates 2 mm.

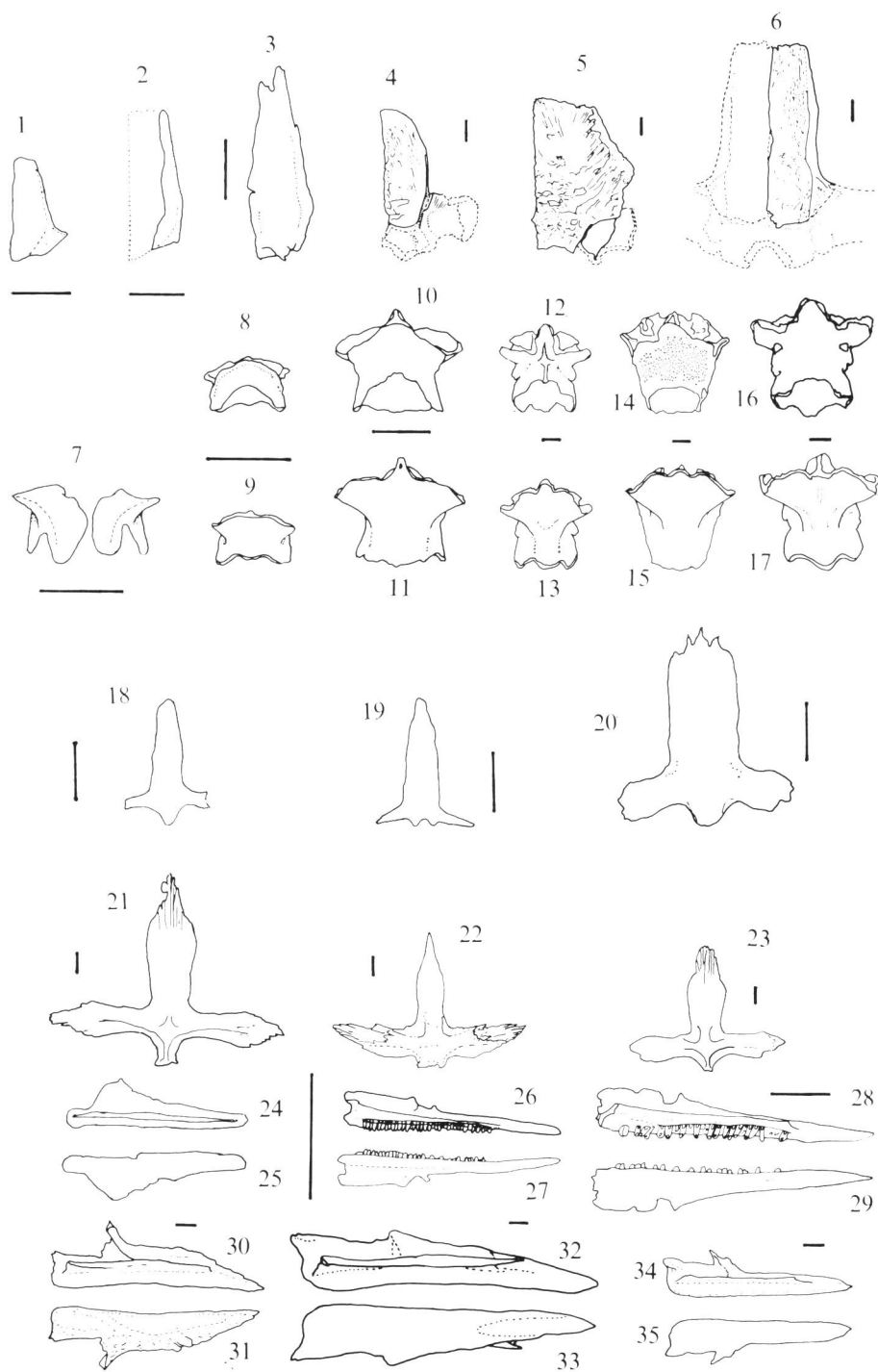


Fig. 1. Right fronto-parietal, Ethmoid, Parasphenoid, and Right maxilla.

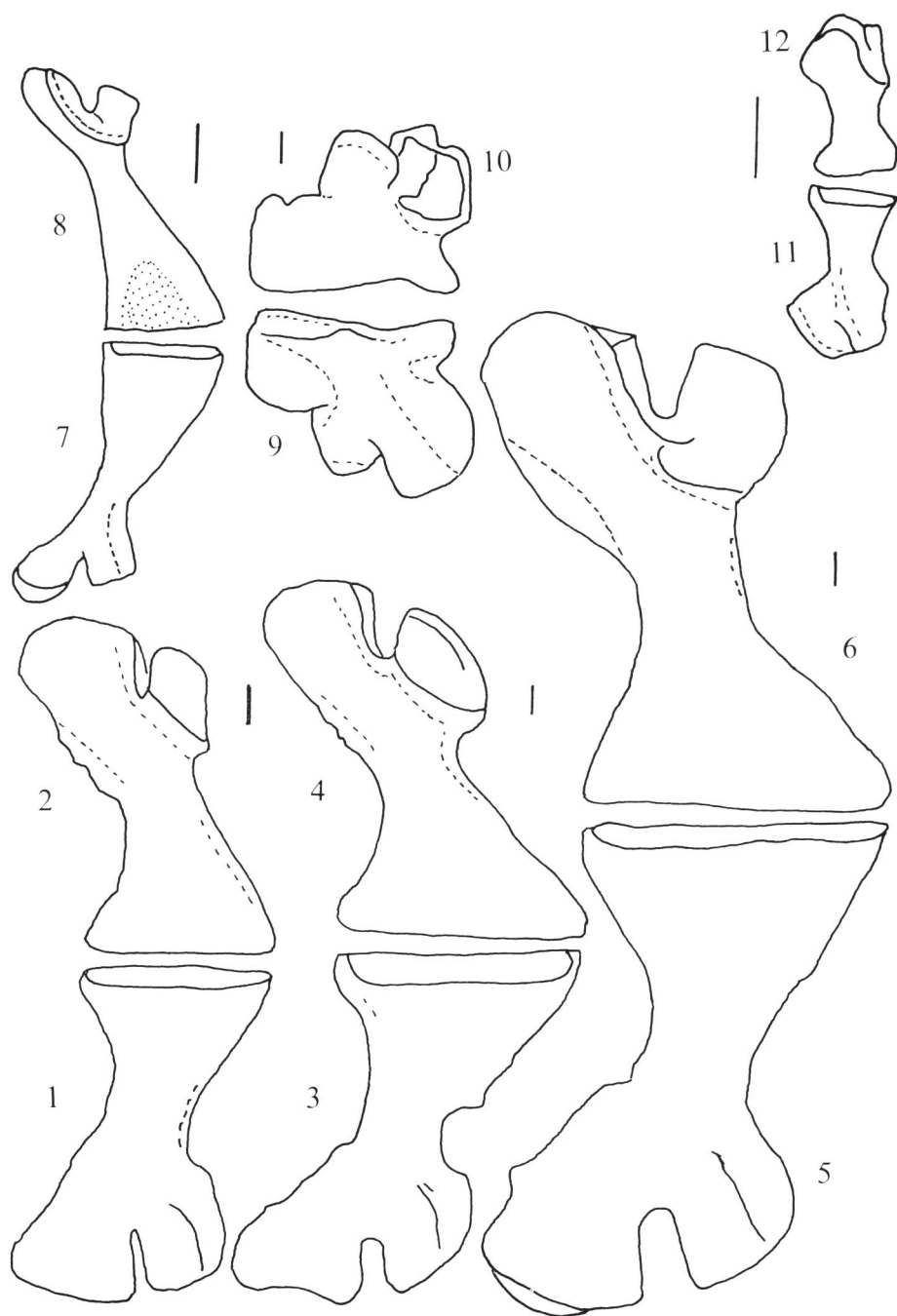


Fig. 2. Right scapula.

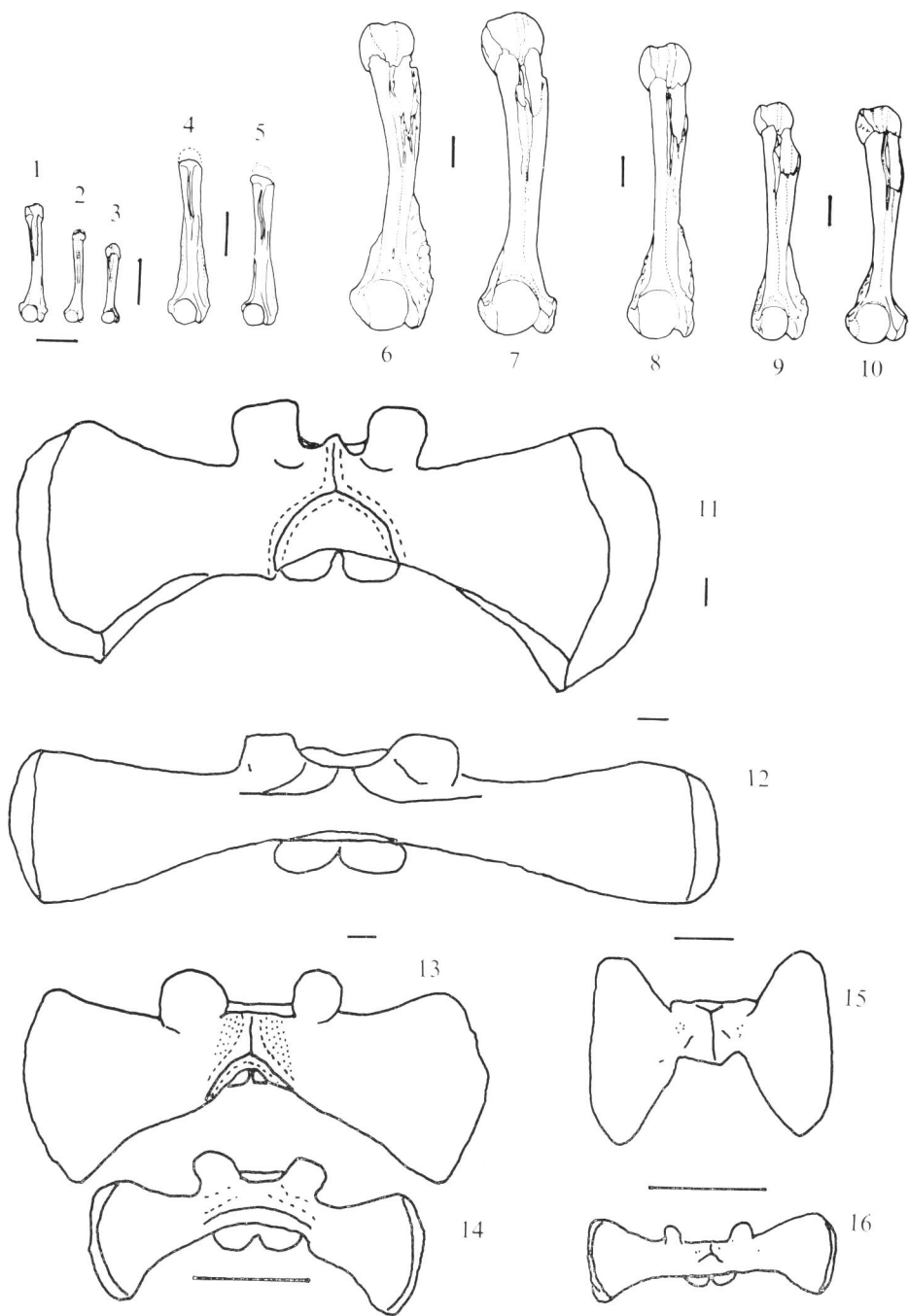


Fig. 3. Right humerus and Scapum.

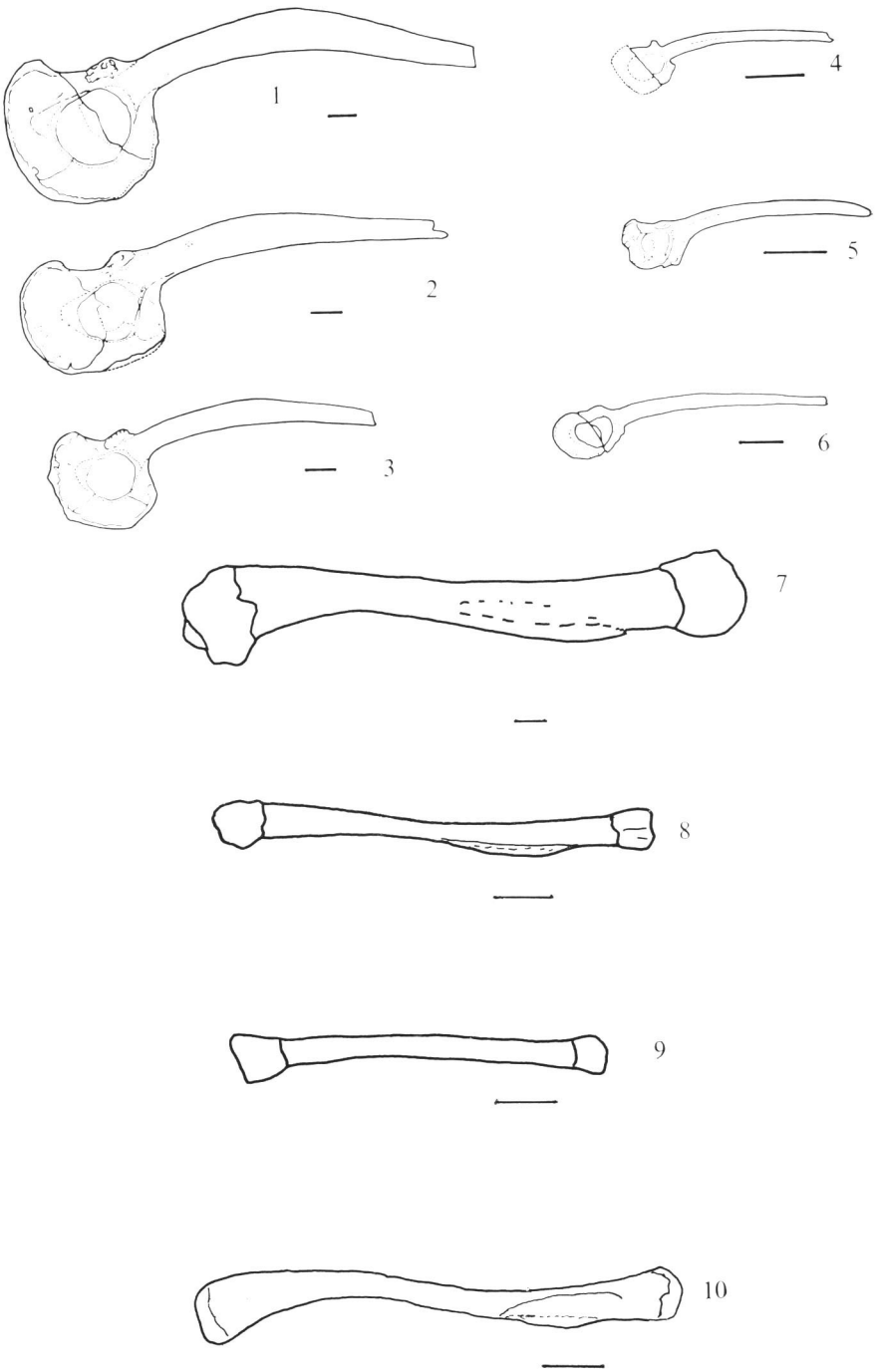


Fig. 4. Right ilium and Right femur.