# FLORIDA
# GEOLOGICAL SURVEY

REPORT OF INVESTIGATIONS

No. 14

STATE OF FLORIDA
STATE BOARD OF CONSERVATION
ERNEST MITTS, *Director*

FLORIDA GEOLOGICAL SURVEY
HERMAN GUNTER, *Director*

REPORT OF INVESTIGATIONS
No. 14

# THE AVIFAUNA OF THE BONE VALLEY FORMATION

By
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Gainesville, Florida

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Florida Geological Survey

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## LETTER OF TRANSMITTAL

# Florida Geological Survey

## Tallahassee

**August 20, 1955**

Mr. Ernest Mitts, *Director*
Florida State Board of Conservation
Tallahassee, Florida

Dear Mr. Mitts:

The Bone Valley formation is the source of most of the commercial phosphate in Florida. The stratigraphic relationship of the formation to older and younger formations is being determined through studies being conducted by the Atomic Energy Commission in cooperation with the United States Geological Survey. The determination of the age of the Bone Valley formation is important economically to the phosphate industry in that the time of formation of the phosphate can thus be determined and a possible lead to future prospecting and an expansion of the phosphate reserve may be obtained.

This paper, "The Avifauna of the Bone Valley Formation," by Dr. Pierce Brodkorb of The Department of Biology, University of Florida, Gainesville, contributes additional data on the age of the Bone Valley formation. The data will be welcomed by geologists, stratigraphers, and ornithologists of the State. We are pleased to publish this contribution to Florida stratigraphy as Report of Investigations No. 14.

Very truly yours,

Herman Gunter, *Director*

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# THE AVIFAUNA OF THE BONE VALLEY FORMATION

Pierce Brodkorb

## INTRODUCTION

Lying unconformably upon the lower Miocene Hawthorn formation and covered by Pleistocene terrace sands is the Bone Valley gravel, named by Matson and Clapp (1909: 138), to which the term Bone Valley formation was later applied by Cooke (1945: 203). In Polk and Hillsborough counties, in southwestern Florida, this formation is being exploited through extensive phosphate mining operations.

Remains of fossil vertebrates were first reported from the Bone Valley phosphate by Leidy (1889). Sellards (1915: 73) reported a new species of gavial, a large land tortoise, several large land mammals, cetaceans, and teeth of elasmobranchs. The pelagic mammals have been worked up by Allen (1921), Hay (1922), Kellogg (1924), Simpson (1932), and Case (1934). The land mammals, comprising a rather extensive fauna, were studied by Simpson (1930) and by White (1941, 1942).

The birds heretofore known from this deposit consist of four fragmentary bones of three species, preserved in the Museum of Comparative Zoology (Wetmore, 1943). Until the present study was undertaken they represented all that was known of the avifauna attributed to the Pliocene east of the Mississippi River.

In November 1951 George C. Elmore began to collect bird material from two localities near Brewster, Florida. Thanks to his interest and diligence, about 200 bird bones were assembled, so that the Bone Valley formation now has the largest known avifauna of Tertiary age in this country, both as to species and specimens. New species of grebe, flamingo, and gull in this collection have been described in previous papers (Brodkorb, 1953A, 1953B, 1953D). These forms, as well as Wetmore's records, are included in the present report in order to present a complete survey of the avifauna of the Bone Valley formation. About five specimens not identified generically are omitted. All holotypes are retained in the Brodkorb collection at the University of Florida.

*Acknowledgments.* Thanks are due George C. Elmore, who assembled the collection. Valuable advice was given by Dr. Robert O. Vernon and Herbert Winters, Florida Geological Survey; by E. C. Pirkle, Jr., Department of Geology, University of Florida; and by

John L. Rich, Department of Geology, University of Cincinnati. James B. Cathcart, United States Geological Survey, generously supplied stratigraphic sections of the two collecting localities. Drs. Loye Miller and Alden H. Miller kindly made a comparison of specimens with the type of *Limosa vanrossemi* at the University of California Museum of Paleontology.

For the loan of recent or fossil comparative material I am indebted to Drs. Herbert Friedmann and Alexander Wetmore, United States National Museum; Dr. Hildegarde Howard, Los Angeles County Museum; S. J. Olsen, Museum of Comparative Zoology; Dr. Frank A. Pitelka, Museum of Vertebrate Zoology, University of California; and Dr. Harrison B. Tordoff, Museum of Natural History, University of Kansas.

The drawings are the work of Miss Esther Coogle, of the University of Florida staff. The photographs of a bird rookery were supplied by Dr. Ernest H. Lund, Department of Geology, Florida State University.

*Location.* Bird fossils were collected at two localities on holdings of the American Agricultural Chemical Company, with headquarters at Pierce, Florida. Both localities lie somewhat south of the post office of Brewster, in southwestern Polk County, Florida.

Locality 1 is an area of about five acres in extent in the center of sec. 32, T. 31 S., R. 24 E., or about two and one-half miles east-southeast of Brewster; surface elevation about 145 feet above sea level.

Locality 2 is in the N ½ NE ¼ NW ¼, sec. 5, T. 32 S., R. 24 E., or about three miles southeast of Brewster; elevation about 145 feet.

I have not been able to ascertain the exact locality at which Dr. Theodore E. White collected the four bird specimens reported by Wetmore. They were said to have been collected near Pierce from screenings of the company, and may or may not have come from one of Elmore's localities. It is my understanding that some of Elmore's material was also obtained from screenings.

*Stratigraphy.* Stratigraphic sections taken by James B. Cathcart at the two Elmore localities are given in Tables 1 and 2. Bed 6 at Locality 1 is the equivalent of Beds 7 and 8 at Locality 2. It is in this lowest part of the Bone Valley formation that vertebrate fossils occur. They are white in color and are heavily mineralized.

In these sections the bottom of the Bone Valley lies at an altitude of about 102-104 feet above sea level, and the top of the formation lies at about 128-134 feet above sea level. If no actual movement of the land took place, sea level at the beginning of Bone Valley time must have been at least 104 feet higher and at the close of Bone Valley time at least 134 feet higher than at present.

*Table 1.*—SECTION AT LOCALITY 1: CENTER OF SEC. 32, T. 31 S., R. 24 E.; SURFACE ELEVATION ABOUT 145 FEET ABOVE SEA LEVEL.

| *Bed* | *Depths in Feet* | | |
|---|---|---|---|
| 1) | 0–5 | Sand, brown and black, slightly carbonaceous, loose | Surface soil, Recent or Pleistocene |
| 2) | 5–17 | Sand, brown and white, some iron-cemented lumps, slightly clayey | Pleistocene? terrace sands |
| | | *Lithologic break* | |
| 3) | 17–24 | Sand, gray-green and white, slightly clayey, but less clay than bed 2; minor aluminum phosphate as cement | Upper Bone Valley formation |
| 4) | 24–31 | Sand, gray-green, slightly clayey, with 10% calcium phosphate nodules, coarse sand to granule size | |
| | | *Base of the "Overburden" of the Company* | |
| 5) | 31–34 | Sand, gray, with thin interbeds of greenish clayey sand. Contains thin lens-like beds of highly phosphatic sand. Phosphate is about 15% of matrix | Lower Bone Valley formation |
| 6) | 34–41 | Sand, gray, loose, cross-bedded, with 45–50% of black and brown phosphate, sand to gravel size | |
| | | *Unconformity (Base of "Matrix")* | |
| 7) | 41–44½ | Sand, slightly clayey, blue-gray; contains abundant borings filled with material from bed 6. Some black and brown phosphate nodules. Phosphate is 15% of matrix | Miocene: Hawthorn formation |
| | | *Base of Exposure* | |

*Table 2.*—SECTION AT LOCALITY 2: N½ NE¼ NW¼ SEC. 5, T. 32 S., R. 24 E.; SURFACE ELEVATION ABOUT 145 FEET ABOVE SEA LEVEL.

| *Bed* | *Depths in Feet* | | |
|---|---|---|---|
| 1) | 0–8 | Sand, loose, white, quartz | Surface sand, possibly Recent or Pleistocene wind-blown sand |
| 2) | 8–11 | Sand, brown and white, loose, with non-cemented lumps | Pleistocene? terrace sands |
| | | *Lithologic Break* | |
| 3) | 11–13½ | Clay, sandy, to sand, clayey, blue-green, with minor tan and white phosphate nodules | |
| 4) | 13½–18½ | Sand, slightly clayey, light green, with trace of phosphate nodules | Upper Bone Valley formation |
| 5) | 18½–30½ | Sand, gray, mottled with light green, trace clay, trace black phosphate nodules—unit massive | |
| | | *Base of the "Overburden" of the Company* | |
| 6) | 30½–32 | Gravel, phosphatic, gray, contains abundant quartz sand but little or no clay | |
| 7) | 32–38 | Sand, white, strongly cross-bedded, very abundant black and brown phosphate nodules, from coarse sand to granule size | Lower Bone Valley formation |
| 8) | 38–43 | As above, except for abundant fossil bones | |
| | | *Unconformity (Base of "Matrix")* | |
| 9) | 43–? | Clay, greenish-gray, very sandy, with fine black phosphate nodules. Upper surface irregular and filled with borings. Exposed in base of pit | Miocene: Hawthorn formation |

## LIST OF SPECIES

### Order GAVIIFORMES

### Family GAVIIDAE

The loons have a Holarctic distribution and a time record from the upper Eocene to the Recent. There are four living and seven fossil species.

## Genus GAVIA Forster

### *Gavia palaeodytes* Wetmore

*Gavia palaeodytes* Wetmore, 1943: 64, figs. 1-2 (orig. descr.; Middle Pliocene, Pierce, Florida; type coracoid, M.C.Z. 2329).—Wetmore, 1951:65 (Middle Pliocene, Pierce, Florida).—Brodkorb, 1953C: 212, fig. 1C (near Brewster, Florida; descr. coracoid, humerus, femur).

*Material.* Six specimens, three individuals. Represented in White's locality by M.C.Z. 2329, in Elmore's Locality 1 by No. 88, and in Locality 2 by the remaining specimens.

Coracoid: left distal M.C.Z. 2329 (cast of type); right complete No. 132.

Humerus: right proximal No. 306; left distal Nos. 88, 524.

Femur: right complete No. 133.

All of the material listed except No. 524 has been described in my paper cited above. The measurements of the latter specimen are included in Table 3.

*Gavia palaeodytes* was a small species, about the size of the living red-throated loon, *G. stellata.* The latter has a Holarctic distribution, breeding in the far north and wintering south to the Gulf of Mexico and the Mediterranean. Thus far *G. palaeodytes* is known only from the Bone Valley.

### *Gavia concinna* Wetmore

*Gavia concinna* Wetmore, 1940: 25, figs. 1-4 (orig. descr.; lower Pliocene, Sweetwater Canyon, east of King City, California; type proximal portion of ulna, U.S.N.M.).—Brodkorb, 1953C: 211, fig. 1A (Bone Valley formation, near Brewster, Florida; descr. humerus, ulna, femur).

*Material.* Five specimens, two individuals. Represented in Locality 1 by Nos. 89, 90, and 593; in Locality 2 by Nos. 297, 298.

Humerus: left distal 90, 297; right proximal 593.

Ulna: right distal 89.

Femur: left complete 298.

The proximal humerus (593) was received since completion of my paper cited above. Its measurements are included in Table 3. This new material confirms the assignment of the Bone Valley specimens to *G. concinna.*

The present species was somewhat larger than *G. palaeodytes.* It had a continent-wide distribution. The type locality is in the Etchegoin formation, which Wood *et al.* (1941: 19) and Woodring, Stewart, and Richards (1940: 112, insert) consider middle Pliocene.

*Table 3.*—MEASUREMENTS (IN MILLIMETERS) OF HUMERUS IN *Gavia*.

| | *G. howardæ* (*3 distals*) | *G. palæodytes* (*2 distals, 1proximal*) | *G. concinna* (*2 distals, 2 proximals*) |
|---|---|---|---|
| Breadth through epicondyles | 12.0–14.4 | 14.3–14.7 | 15.5–16.7 |
| Breadth through condyles | 9.2–10.2 | 11.7–12.4 | 12.5–13.1 |
| Depth through internal condyle | 8.8– 9.3 | 10.1 | 10.5–11.6 |
| Depth through external condyle | 7.8– 8.4 | 9.1– 9.2 | 9.7–10.4 |
| Depth through brachial depression | 4.2– 4.7 | 5.1– 5.5 | 6.0– 6.1 |
| Depth above brachial depression | 4.7– 5.2 | 5.8– 6.1 | 6.5– 7.0 |
| Width above brachial depression | 6.2– 6.8 | 6.9– 7.1 | 8.4– 8.8 |
| Length of attachment for anterior ligament | 9.5–10.2 | 8.6– 8.7 | 10.2–10.7 |
| Length of internal condyle | 4.3– 4.8 | 5.2– 5.4 | 5.4– 5.5 |
| Diagonal length of external condyle | 6.8– 7.4 | 8.4– 8.8 | 9.2–10.5 |
| External tuberosity to capital groove | ..... | 16.6 | 18.5–18.8 |
| External tuberosity to internal tuberosity | ..... | 19.3 | 21.5–22.0 |
| Maximum depth of head | ..... | 9.5 | 10.1–10.2 |
| Depth through internal tuberosity | ..... | 6.4 | 7.4– 7.6 |
| Length of capital groove | ..... | 8.6 | 9.4– 9.5 |

## Order COLYMBIFORMES

### Family COLYMBIDAE

The record of this cosmopolitan family extends from the Oligocene to the Recent. Eighteen living and five extinct species of grebes are recognized.

### Genus PLIODYTES Brodkorb

#### *Pliodytes lanquisti* Brodkorb

*Pliodytes lanquisti* Brodkorb, 1953D (orig. descr.; Bone Valley formation, near Brewster, Florida; type coracoid).

*Material.* One specimen, one individual, Locality 2.

Corocoid: right complete, No. 299 (type).

This new genus combines some of the characters found in the genera *Colymbus* and *Podilymbus*, besides having some unique characters. It was about the size of the living pied-billed grebe, *Podilymbus podiceps*. *Colymbus pisanus* (Portis), of the upper Pliocene of Italy, is larger than the Bone Valley grebe (see Lambrecht, 1933: 262).

## Order PROCELLARIIFORMES

### Family DIOMEDEIDAE

The albatrosses, represented by 14 living species, frequent all oceans except the North Atlantic, where they are only of accidental occurrence. It is therefore of considerable interest that the only named fossil species, *Diomedea anglica,* has been recorded on both sides of the North Atlantic.

#### Genus DIOMEDEA Linnaeus

#### *Diomedea anglica* Lydekker

*Diomedea anglica* Lydekker, 1891: 189, fig. 42 (orig. descr.; Red Crag, Foxhall, Suffolk, England; type tarsometatarsus and associated toe phalanx, Ipswich Mus.).—Lambrecht, 1933: 273 (type material assigned to middle Pliocene; ulna from Coralline Crag, Lower Pliocene).— Wetmore, 1943: 66, pl. 12, figs. 10-15 (middle Pliocene, near Pierce, Florida; descr. tibiotarsus).

*Material.* One specimen, one individual, White's locality.

Tibiotarsus: right distal, M.C.Z. 2328 (not examined by me).

It is unfortunate that the albatross was not represented among the material collected by Elmore. The reference of the Florida specimen to Lydekker's species was made simply on the basis of size, since the tibiotarsus is unknown in European collections. The two English localities are now considered to be of late Pliocene (Astian) and Middle Pliocene (Plaisancian) age.

## Order PELECANIFORMES

### Family SULIDAE

The family Sulidae, represented by nine living species, now has a cosmomarine distribution. The present material includes specimens of a gannet (*Morus*) and two boobies (*Sula*). The 15 fossil species are all from the Holarctic Region. The fossil record of the family is as follows:

| | |
|---|---|
| *Pleistocene:* | *Morus bassanus* (Linnaeus). Recent species recorded as fossil from Norway. |
| | *Morus reyanus* Howard. California. |
| *Middle Pliocene:* | *Miosula recentior* Howard. California. |
| *Bone Valley:* | *Morus peninsularis* Brodkorb. Florida. |
| | *Sula guano* Brodkorb. Florida. |
| | *Sula phosphata* Brodkorb. Florida. |

| | |
|---|---|
| *Upper Miocene:* | *Miosula media* L. Miller. California. |
| | *Morus lompocanus* (L. Miller). California. |
| | *Morus stocktoni* (L. Miller). California. |
| | *Morus vagabundus* Wetmore. California. |
| | *Sula willetti* L. Miller. California. |
| *Middle Miocene:* | *Sula pygmaea* Milne-Edwards. France. |
| *Lower Miocene:* | *Morus loxostyla* (Cope). Maryland, New Jersey. |
| | *Sula avita* Wetmore. Maryland. |
| *Upper Oligocene:* | *Sula arvernensis* Milne-Edwards. France. |
| *Lower Oligocene:* | *Sula ronzoni* (Gervais). France. |

Genus MORUS Vieillot

*Morus peninsularis* new species

Figs. 1, 4, 7

*Type.* No. 148, collection of Pierce Brodkorb; nearly complete left coracoid. Bone Valley formation, from Locality 2 near Brewster, Polk County, Florida. Collected in February 1952 by George C. Elmore.

*Diagnosis.* Agrees with *Morus* in having the lower anterior face of the coracoid broad and plane toward inner side, instead of being narrower and more rounded as in *Sula* (see Wetmore, 1926B).

Differs from *Morus reyanus* Howard (1936), from the Pleistocene of California, in having the head of the coracoid narrower and more pointed; length of bone somewhat shorter, but distance from head to procoracoid somewhat greater.

Differs from *Morus lompocanus* (L. Miller, 1925) and *Morus stocktoni* (L. Miller, 1935), both from the Miocene of California, in being considerably smaller. The coracoids of these species have not been described in detail nor well figured, so a further comparison is impractical. My assignment of *Sula stocktoni* to the genus *Morus* is made on the basis of the humerus exceeding the ulna in length, the reverse being the case in *Sula* (sensu stricto).

Differs from *Morus loxostyla* (Cope, 1870), from the Miocene of Maryland and New Jersey, in greater size and wider shaft. A further comparison with this species is likewise not possible at this time.

The coracoid of *Morus vagabundus* Wetmore (1930), from the Miocene of California, is unknown. This species is described as being of about the size of *Sula sula,* and thus the Florida gannet is a much larger bird.

The new species is smaller than the three living species of gannets, *Morus bassanus* (Linnaeus), *M. capensis* (Lichtenstein), and *M. serrator* (Gray). It has the anterior intermuscular line located relatively more posteriorly, and the head of the bone is more pointed.

In the Miocene and Pliocene genus *Miosula* the coracoid is larger than in *Morus* (see L. Miller, 1925).

*Referred material.* No. 613, nearly complete left coracoid (paratype), and No. 614, cervical vertebra, both from the type locality.

The cervical vertebra is about the size of that of *Morus serrator,* but the length through the zygapophyses (25.4 mm.) and the narrowest posterior width of the centrum (6.0) are less than in that species, whereas the length of the body of the vertebra (25.4) and the width through the prezygapophyses (16.6) are greater.

## Genus SULA Brisson

### *Sula guano* new species

Figs. 2, 5, 8

*Type.* No. 301, collection of Pierce Brodkorb; nearly complete left coracoid. Bone Valley formation, from Locality 2 near Brewster, Polk County, Florida. Collected in September 1952 by George C. Elmore.

*Diagnosis.* Agrees with *Sula* in having the lower anterior face of the coracoid narrower and more rounded than in *Morus.*

Compared with living species, the fossil is similar in size to *Sula sula* (Linnaeus), but the breadth of the head, breadth at level of scapular facet, and breadth of shaft are greater in the fossil, and the distance from head to procoracoid is somewhat greater. The new species is smaller than *S. nebouxii,* but the head of the bone and the internal sternal facet are both broader than in *nebouxii.* The fossil is likewise smaller than *S. dactylatra.*

The present species agrees with *Sula sula* in having the internal sternal facet shallow, with its medial margin passing gently toward the shaft in sternal aspect. It differs in having the external sternal

facet shorter and the internal sternal facet longer. The external facet makes a more pronounced shelf mediad, and the shaft above the shelf is more excavated. The anterior intermuscular line is situated more laterad than in *S. sula,* but swings farther mediad at its lower end as it meets the sternal facet, being parallel with the facet before joining it. A condition similar to that in the fossil occurs in *S. nebouxii* and *S. dactylatra,* whereas *S. leucogaster* resembles *S. sula* in that the line joins the facet without running parallel to it.

From the Oligocene forms of France, *Sula ronzoni* (Gervais, 1851) and *Sula arvernensis* Milne-Edwards (1868), it differs in being much smaller, since those species exceed *Morus bassanus* in size. Their retention here in *Sula* merely follows custom and is not necessarily a reflection of their true systematic position.

From the Miocene species, *Sula pygmaea* Milne-Edwards (1874) from France, *Sula willetti* L. Miller (1925) from California, and *Sula avita* Wetmore (1938) of Maryland, it differs in being much larger, since the Miocene forms were all smaller than any living booby.

*Referred material.* In addition to the coracoid there are two fragmentary right ulnae (Nos. 123, 529) and the distal end of a tibiotarsus (No. 309), all from the type locality.

The ulna of both fossil and living species of *Sula* differs from that of *Morus* in being more pneumatic in both the humeral and radial depressions. Compared with the living species of *Sula,* the proximal end of the ulna in the present species has the humeral depression more excavated, making the olecranon more pointed and hooked toward the inner side. There is a large pneumatic foramen in the humeral depression. This depression is non-pneumatic in *Sula sula* and *S. leucogaster* and shows only a slight pneumaticity in *S. nebouxii* and *S. dactylatra.* The two ulnar fragments indicate a species between *S. sula* and *S. nebouxii* in size.

The tibiotarsus of *Sula* differs from that of *Morus* in having the intercondylar fossa less excavated (i.e., shallower and wider), with the condyles less protruding. In *Sula* the external condyle is short, whereas in *Morus* it extends distad almost as far as the internal condyle. Further, in *Sula* the inner margin of the shaft, in anterior aspect, merges gradually into the internal condyle, so that the latter is located directly below the inner margin of the lower part of the shaft. In *Morus* the inner margin of the shaft swings abruptly mediad, so that the internal condyle is located more mediad than the inner

margin of the lower part of the shaft. The fossil tibiotarsus comes from a bird near *nebouxii* in size. The intercondylar fossa is wider; the internal condyle narrower; and the tibial bridge narrower and more elevated on the shaft than in *S. nebouxii.*

Because of the resemblance of these elements to those of *nebouxii* and because of the apparent affinity of *nebouxii* to *S. guano,* the ulnar and tibial fragments are referred to this species.

*Sula phosphata* new species
Figs. 3, 6, 9

*Type.* No. 302, collection of Pierce Brodkorb; right coracoid, lacking head and part of sternal end. Bone Valley formation, from Locality 2 near Brewster, Polk County, Florida. Collected in September 1952 by George C. Elmore.

*Diagnosis.* Differs from the Oligocene and Miocene species of *Sula* as described for *Sula guano.* From the latter species it differs in having the procoracoid process situated higher on the shaft; shaft slightly deeper; breadth at level of scapular facet somewhat less. In particular it differs from *S. guano* in having the external sternal facet longer and the internal facet shorter; the internal facet with its margin more arched in sternal aspect, and meeting the shaft at a more pronounced angle, as in *S. leucogaster.* The lower portion of the anterior intermuscular line swings farther forward in the present species than in *S. guano.*

Among living species it most closely resembles *S. leucogaster,* but differs in having the shaft deeper; breadth at level of scapular facet greater; and in having the internal sternal facet shorter. The lower portion of the anterior intermuscular line lies parallel to the sternal facet before joining it, which is not the case in *S. leucogaster.*

In both this species and the one just described, the coracoid is about the same size as in *Morus loxostyla,* although of a different form, as described above.

*Referred material.* No. 138, lower portion of left coracoid (paratype); Nos. 120 and 597, upper portions of left coracoids, all from the type locality.

Specimen No. 138 resembles the type of *S. phosphata.* The two specimens of the upper end of the bone agree among themselves and differ from the type of *S. guano;* they are therefore likewise referred to *S. phosphata.*

In *S. guano* the overhang of the lip of the brachial tuberosity at its upper end makes a rather clean sweep upward. In the two specimens of *S. phosphata* in which this region is preserved the lip is distinctly bifid at its upper end. Furthermore, in *S. phosphata* there is a more pronounced depression, in posterior view, between the medial margin of the head and the furcular facet. This is only weakly indicated in *S. guano.*

## Family PHALACROCORACIDAE

The abundant cormorant remains enable me to state that two species are represented in the Bone Valley, and further that the small form is not identical with the living double-crested species, as was thought by Wetmore, but rather represents a distinct species, closely allied and probably ancestral to the living bird.

The record of this cosmopolitan family, of which there are 30 Recent and 17 fossil species, extends back to the Oligocene.

### Genus PHALACROCORAX Brisson

### *Phalacrocorax wetmorei* new species

Figs. 10, 11

*Phalacrocorax auritus,* Wetmore, 1943: 68 (Middle Pliocene, near Pierce, Florida; two distal metatarsi).

*Type.* No. 530, collection of Pierce Brodkorb; nearly complete right coracoid. Bone Valley formation, from Locality 2 near Brewster, Polk County, Florida. Collected in December 1952 by George C. Elmore.

*Diagnosis.* Very similar to modern *Phalacrocorax auritus floridanus* (Audubon) but bones in general less robust.

Coracoid with anterior intermuscular line situated farther laterad. Humerus with head shallower, ligamental furrow relatively longer, pneumatic fossa narrower and deeper, and condyles averaging less deep. Ulna decidedly less robust. Carpometacarpus somewhat more delicate, but with first metacarpal more produced. Femur averaging longer and narrower. Tibiotarsus with both proximal and distal ends more slender, but with internal condyle relatively deeper. Tarsometatarsus averaging more slender, but shaft slightly deeper. The fragmentary specimens of synsacrum, scapula, and radius do not show differences from *P. auritus,* nor do the cervical vertebrae and digits.

*Table 4.*—MEASUREMENTS (MM.) OF CORACOID OF *Morus* AND *Sula*.

| | *Length along axial border* | *Length of external sternal facet* | *Length of internal sternal facet* | *Least depth of shaft* | *Head to procoracoid* | *Breadth of head* | *Breadth at level of scapular facet* |
|---|---|---|---|---|---|---|---|
| *M. peninsularis* | 54.0–55.6 | 14.2–14.5 | 8.6–10.8 | 7.0– 7.4 | 25.0–25.1 | 14.2 | 17.0–17.7 |
| *M. loxostyla* | 48.2–51.3 | 14.2 | ..... | 5.0– 5.8 | ..... | ..... | ..... |
| *M. reyanus* | 56.6 | ..... | ..... | ..... | 24.7 | 15.5 | 17.1 |
| *M. lompocanus* | 62.0 | ..... | ..... | ..... | ..... | ..... | ..... |
| *M. bassanus* | 58.6–61.3 | 17.4–20.8 | 13.8–14.3 | 7.4– 8.2 | 27.9–29.6 | 14.4–15.4 | 17.5–20.4 |
| *M. capensis* | 55.8 | 17.2 | 14.0 | 7.4 | 27.4 | 15.4 | 19.0 |
| *M. serrator* | 54.7 | 18.2 | 12.0 | 7.8 | 27.6 | 15.5 | 18.7 |
| *S. guano* | 50.0 | 10.7 | 10.3 | 5.6 | 21.0 | 13.4 | 14.7 |
| *S. phosphata* | ..... | 11.1–11.5 | 7.5– 7.7 | 5.7– 5.8 | 21.0 | 12.7–13.5 | 13.8–14.5 |
| *S. willetti* | 45.0 | ..... | ..... | ..... | ..... | ..... | ..... |
| *S. leucogaster* | 49.1 | 11.2 | 8.4 | 5.3 | 20.0 | 11.4 | 12.6 |
| *S. sula* | 48.7–50.5 | 11.5–12.1 | 9.4– 9.8 | 5.2– 5.5 | 20.5–20.7 | 11.0–11.6 | 13.5–13.8 |
| *S. nebouxii* | 55.2 | 12.2 | 10.0 | 5.8 | 23.5 | 12.5 | 14.8 |
| *S. dactylatra* | 58.2 | 14.7 | 12.0 | 5.8 | 25.0 | 13.8 | 15.6 |

*Material.* 135 specimens, at least 15 individuals. Represented in White's locality by two specimens, two individuals; Locality 1 by 48 specimens, 5 individuals; Locality 2, 85 specimens, 8 individuals.

Coracoid: right complete 87 (paratype), 530 (type), right proximal 95, 312, 314, 315, 531; right distal 94, 179, 180, 181, 316, 532, 602; left complete 168 (paratype), left proximal 602; left distal 119, 313, 533.

Scapula: right proximal 97, 326; left proximal 96, 185, 607, 657.

Humerus: right proximal 99, 144; right shaft 319; right distal 102, 103, 183; left proximal 98, 182, 317; left shaft 100, 101; left distal 104, 121, 122, 184, 303, 608, 658.

Radius: right proximal 659; left distal 325, 534, 660.

Ulna: right proximal 105, 189, 190, 320, 321, 535, 536, 537, 603, 619, 620; right distal 186, 187, 621; left proximal 106, 124, 169, 188, 322, 538, 604; left distal 323, 324, 539, 540, 605.

Carpometacarpus; right proximal 541, 618; left proximal 125, 327, 617; left distal 328, 542, 606.

Alar digit: 117, 126.

Femur: right complete 662; right proximal 127, 193, 331; left complete 145, 543, 544; left proximal 191, 192, 661.

Tibiotarsus: right distal 108, 109; left proximal 107; left distal 110, 128, 170, 194, 195, 545, 609, 616.

Tarsometatarsus: right proximal 113, 114, 129, 198; right distal 131, 199, 334, 335, M.C.Z. 2326, M.C.Z. 2327; left proximal 111, 112, 115, 130; left distal 116, 196, 197, 332, 333.

Synsacrum: 118, 329, 615, 656.

Cervical vertebrae: 200, 201, 330, 546, 547, 599, 600.

## *Phalacrocorax idahensis* (Marsh)

Fig. 12

*Graculus idahensis* Marsh, 1870: 216 (orig. descr.; Pliocene: Castle Creek, Idaho; type fragmentary carpometacarpus, Yale Univ.)

*Referred material.* No. 311, proximal portion of left ulna, Locality 2.

This tremendous ulna came from a cormorant much larger than

any living species and differing from the mean of *P. wetmorei* by about six standard deviations. Its measurements are as follows: proximal width 13.7, depth through internal cotyla 12.8, maximum width of shaft 11.8 mm.

Two large fossil cormorants have been described from North America.

*Phalacrocorax macropus* (Cope, 1878) was based on material from the Pleistocene of Fossil Lake, Oregon. A number of the elements of the skeleton have been described (Howard, 1946) but these unfortunately do not include the ulna. However, the proximal portion of an ulna has been figured by Shufeldt (1913, pl. 21, fig. 269). Compared with the figure, the Bone Valley specimen is a trifle smaller, with the olecranon more pointed and deflected.

*Phalacrocorax idahensis* (Marsh, 1870) was described from a fragmentary carpometacarpus from the Pliocene of Castle Creek, Idaho. Later Wetmore (1933: 5) referred the distal portion of an ulna from the upper Pliocene Hagerman Lake beds to the same species. He stated that the ulna is not quite as heavy as in the extinct *Phalacrocorax perspicillatus* of Bering Island but gave no measurements. Comparison of the figures of the carpometacarpi of *P. macropus* (Shufeldt, 1913, pl. 21, fig. 262, 263) and *P. idahensis* (Shufeldt, 1915, pl. 6, fig. 44) shows the latter to be somewhat the smaller. As the Bone Valley specimen is also somewhat smaller than *P. macropus,* I refer it to *P. idahensis,* following the precedent of Wetmore in referring the Hagerman Lake specimen.

## Order CICONIIFORMES

### Family ARDEIDAE

The 66 living species of herons give this family a cosmopolitan distribution. The record of the family extends back to the Eocene, but it is unrecorded from the Pliocene epoch, except for two occurrences of *Ardea,* species uncertain, from the upper Pliocene of Europe (Lambrecht, 1933: 734). The heron described below, the seventeenth fossil species, thus helps fill in the chronology of the family.

*Table 5.*—MEASUREMENTS (MM.) OF *Phalacrocorax wetmorei*

| | *Mean* | *Range* | *Standard Deviation* | *Number* |
|---|---|---|---|---|
| Coracoid: | | | | |
| Length along medial side | 63.50 | 60.7–65.3 | ..... | 3 |
| Head to procoracoid | 21.44 ± .18 | 20.5–22.4 | .55 | 9 |
| Least width of shaft | 5.07 ± .09 | 4.4– 5.4 | .27 | 9 |
| Least width of blade | 3.12 ± .05 | 2.7– 3.4 | .19 | 13 |
| Anterior intermuscular line to medial end of sternal facet | 11.24 ± .42 | 9.4–13.6 | 1.39 | 11 |
| Width of head | 12.14 ± .13 | 11.2–12.7 | .40 | 9 |
| Humerus: | | | | |
| Proximal width | 22.22 | 20.7–23.8 | ..... | 3 |
| Depth of head | 7.10 | 7.0– 7.3 | ..... | 4 |
| Length of ligamental furrow | 14.07 | 13.6–14.6 | ..... | 3 |
| Width of shaft | 7.83 ± .18 | 7.0– 8.5 | .51 | 8 |
| Distal width | 15.77 ± .20 | 14.7–17.3 | .67 | 11 |
| Height of internal condyle | 6.17 ± .06 | 5.8– 6.5 | .22 | 11 |
| Height of external condyle | 10.52 ± .10 | 9.9–11.1 | .34 | 11 |
| Ulna: | | | | |
| Proximal width | 11.28 ± .10 | 10.1–11.8 | .42 | 18 |
| Depth through internal cotyla | 10.42 ± .08 | 9.9–10.8 | .34 | 17 |
| Maximum width of shaft | 9.08 ± .07 | 8.4– 9.5 | .29 | 18 |
| Maximum distal diameter | 10.75 ± .13 | 10.0–11.2 | .36 | 8 |
| Depth of external condyle | 8.16 ± .12 | 7.5– 8.4 | .35 | 8 |
| Distal depth of shaft | 5.51 ± .07 | 5.0– 5.7 | .19 | 8 |
| Least distal width of shaft | 5.26 ± .09 | 4.6– 5.5 | .26 | 8 |
| Carpometacarpus: | | | | |
| Length of metacarpal two | 54.0 | ..... | ..... | 1 |
| Width of shaft, metacarpal two | 4.60 ± .04 | 4.4– 4.8 | .12 | 8 |
| Height through metacarpal one | 13.80 | 13.6–14.2 | ..... | 5 |
| Width through trochleæ | 6.20 | 6.0– 6.3 | ..... | 5 |
| Width of distal end | 6.90 | 6.6– 7.1 | ..... | 3 |
| Femur: | | | | |
| Length | 58.18 | 57.0–61.0 | ..... | 4 |
| Width through condyles | 15.25 | 14.6–15.8 | ..... | 4 |
| Narrowest width of shaft | 6.14 ± .03 | 6.0– 6.3 | .10 | 9 |
| Depth of external condyle | 9.92 | 9.1–10.3 | ..... | 4 |
| Width through head | 13.46 ± .18 | 12.6–14.4 | .56 | 10 |
| Tibiotarsus: | | | | |
| Length of outer cnemial crest | 16.2 | ..... | ..... | 1 |
| Width of proximal end | 10.2 | ..... | ..... | 1 |
| Greatest width through fibular crest | 10.2 | ..... | ..... | 1 |
| Breadth through condyles | 11.67 ± .13 | 11.0–12.3 | .40 | 9 |
| Narrowest breadth of shaft | 6.64 ± .06 | 6.3– 7.0 | .16 | 8 |
| Narrowest depth of shaft | 4.45 ± .04 | 4.2– 4.7 | .14 | 10 |
| Depth of internal condyle | 10.92 ± .12 | 10.4–11.6 | .36 | 9 |
| Height of internal condyle | 9.07 ± .10 | 8.3– 9.7 | .31 | 9 |

| | *Mean* | *Range* | *Standard Deviation* | *Number* |
|---|---|---|---|---|
| Tarsometatarsus: | | | | |
| Depth through hypotarsus | 17.63 | 17.2–18.0 | ..... | 4 |
| Breadth of proximal end | 12.43 | 11.6–13.3 | ..... | 7 |
| Narrowest width of shaft | 5.97 ± .10 | 5.4– 6.5 | .32 | 11 |
| Breadth through trochleæ | 14.65 ± .17 | 13.4–15.5 | .58 | 11 |
| Narrowest depth of shaft | 4.41 ± .08 | 3.8– 4.8 | .27 | 11 |

## Genus ARDEA Linnaeus

### *Ardea polkensis* new species

Figs. 13, 14, 15

*Type.* No. 308, collection of Pierce Brodkorb; proximal portion of right tarsometatarsus. Bone Valley formation, from Locality 2, near Brewster, Polk County, Florida. Collected in September 1952 by George C. Elmore.

*Diagnosis.* Similar to living *Ardea herodias* Linnaeus of North America and *Ardea cocoi* Linnaeus of South America, but differs in smaller size; intercotylar knob more pointed and its outer edge more abruptly ascending; groove on inner side of intercotylar knob extending upward (as in *Ardea cinerea*) instead of being obliquely transverse; inner hypotarsal ridge relatively longer and continuing more proximad.

Differs from living *Ardea cinerea* Linnaeus of the Palearctic Region in larger size; more pointed intercotylar knob; longer inner hypotarsal ridge; relatively lower inner articular surface and rim.

Measurements of the type (compared in parentheses with those of *Ardea herodias, cocoi,* and *cinerea,* respectively) are as follows: proximal width 14.7 (16.4-16.6, 16.8, 14.2); proximal depth 15.0 (17.0-17.2, 16.8, 14.2); depth through middle of hypotarsus 13.7 (14.4-15.0, 16.2, 12.5), length of first hypotarsal ridge 13.0 (12.0-13.0, 11.4, 9.3), width of shaft below hypotarsus 7.6 (7.5-8.2, 9.6, 6.8 mm.).

The only other American fossil herons are *Botauroides parvus* Shufeldt (1915: 33) and *Eoceornis ardetta* Shufeldt (1915: 39), both from the Eocene of Wyoming and both considerably smaller forms. *Ardea paloccidentalis* Shufeldt (1892: 820), from the Pleistocene of

Oregon, has been synonymized by Howard (1946: 157) with the living American bittern, *Botaurus lentiginosus,* likewise a smaller bird.

### Family PHOENICOPTERIDAE

The six living species of flamingoes reach their northern limits in the West Indies and the Mediterranean area. The 14 fossil forms are entirely Holarctic in distribution, with a record going back to the upper Eocene.

### Genus PHOENICOPTERUS Linnaeus

### *Phoenicopterus floridanus* Brodkorb

*Phoenicopterus floridanus* Brodkorb, 1953A; 1, figs. 1-2 (orig. descr.; Bone Valley formation, near Brewster, Florida; type tibiotarsus, tarsometatarsus).

*Material.* Four bones, two individuals, Locality 2.

Tibiotarsus: right distal 147 (type); right shaft 202.

Tarsometatarsus: right distal 146, 300.

This is the first fossil flamingo material from eastern North America. Four species, referred to two genera, have been described from the west (South Dakota, Oregon, California, and Chihuahua) in the Miocene, Pliocene, and Pleistocene.

## Order ANSERIFORMES

### Family ANATIDAE

This large family, of 228 Recent species, has a cosmopolitan distribution. The fossil record goes back to the Cretaceous, and with the one described below there are now 84 species known.

### Genus BUCEPHALA Baird

### *Bucephala ossivallis* new species

Figs. 16, 17

*Type.* No. 172, collection of Pierce Brodkorb; proximal half of left coracoid. Bone Valley formation, from Locality 2 near Brewster, Polk County, Florida. Collected in April 1952 by George C. Elmore.

*Diagnosis.* Referable to the Subfamily Aythyinae on the basis of the head of the coracoid rising forward and upward from the anterior plane of the shaft.

Closely agrees with the living *Bucephala clangula* (Linnaeus)

in general appearance, particularly in the shape of the brachial tuberosity and the truncated upper margin of the head. Differs from *B. clangula* in much smaller size; more curved coraco-humeral groove; better developed procoracoid process; and more excavated triosseal canal.

Differs from living *Bucephala albeola* (Linnaeus) in larger size; less pronounced medial overhang of brachial tuberosity; relatively shallower head, which is more inclined from plane of shaft; stouter shaft; more curved coraco-humeral groove; better developed procoracoid process; more excavated triosseal canal.

Also resembles *Melanitta* in truncate head and decidedly curved coraco-humeral groove. Differs in much smaller size and in lacking the massiveness of the bone of that genus; more excavated triosseal canal; less overhanging medial end of lip of brachial tuberosity.

Differs more widely from *Aythya*, although resembling the smaller forms of that genus in size. *Aythya* has the head more rounded and less inclined forward from the plane of the shaft; less curved coraco-humeral groove; and shallower triosseal canal.

*Measurements.* Width of head 6.0; maximum depth of head 3.2; head to lower end of scapular facet 13.2; least width of shaft 4.2 mm.

## Order CHARADRIIFORMES

## Family HAEMATOPODIDAE

The oystercatchers are represented in the living fauna by a single genus with four species. The rather spotty distribution along the sea coasts of the world suggests some antiquity for the group. The only fossil heretofore described is *Paractiornis perpusillus* Wetmore (1930), from the Lower Miocene of Nebraska. The discovery of this family in the Florida phosphate is therefore a welcome addition to our scanty knowledge of the group.

### Genus PALOSTRALEGUS new genus

*Diagnosis.* Distal portion of tibiotarsus agrees with *Haematopus* in having the external ligamental prominence only moderately angular and situated well above condyle; groove for peroneus profundus moderately developed; internal condyle in distal aspect nearly perpendicular, that is slanting only slightly away from shaft; internal liga-

mental prominence situated high with relation to the condyle, that is at the anterior edge of the lower end of the shaft.

Differs from *Haematopus* in having the intercondylar sulcus more excavated; tibial bridge ossified; ligamental groove above bridge narrower; internal ligamental prominence slightly higher and slightly better developed.

Differs from the Scolopacidae, as exemplified by *Numenius,* in having the intercondylar sulcus more excavated and without raised medial portion; external ligamental prominence less angular and situated higher on shaft; groove for peroneus profundus less distinct; tibial bridge and its openings more oblique; ligamental groove above tibial bridge narrower; internal ligamental prominence better developed and located higher and more anteriorly; internal condyle in distal aspect nearly perpendicular, not slanting so abruptly away from shaft.

Differs from the Burninidae in having the intercondylar sulcus wider and without raised medial area; internal condyle with upper end more inclined toward shaft; internal ligamental prominence more angular and situated above condyle; groove for peroneus profundus less distinct; internal condyle in distal aspect much deeper than external condyle (only slightly so in *Burhinus*).

From the Recurvirostridae it differs more markedly. Its long internal condyle, stout shaft, and raised internal ligamental prominence remove it from that family immediately.

*Type. Palostralegus sulcatus* new species.

*Palostralegus sulcatus* new species

Fig. 18

Type. No. 177, collection of Pierce Brodkorb; distal third of right tibiotarsus. Bone Valley formation, at Locality 1 near Brewster, Polk County, Florida. Collected in May 1952 by George C. Elmore.

*Description.* Anterior face with surface of shaft flat with a ridge rising along distal portion of internal edge, its distal portion with a tendinal groove and with an anterior prominence; supratendinal bridge with its upper margin sloping medially, its lower margin more nearly straight; a pronounced external ligamental prominence above supratendinal bridge; a well-marked flattened knob for muscle attach-

ment between external ligamental prominence and supratendinal bridge; a groove for peroneus profundus between this and external ligamental prominence; distal opening under supratendinal bridge obliquely rounded, with lower end sloping toward medial edge; internal ligamental prominence angular, with its apex (slightly imperfect) below projected line from distal opening of supratendinal bridge, its anterior face concave; external condyle broad and upright; internal condyle narrower, sloping proximally toward supratendinal bridge, and extending somewhat farther distad than external condyle; intercondylar sulcus broadly rounded, with little division into lateral and median portions.

Internal face with internal condyle lengthened anteriorly, its surface concave and its edges distinctly raised; internal ligamental prominence located on anterior edge of bone, immediately above condyle; distal border of condyle slightly indented forward of midline of shaft projected.

Posterior face with shaft sloping toward medial edge; intercondylar sulcus broad, shallow, and practically undivided.

External face with shaft gently rounded toward rear; groove for peroneus profundus distinct; external condyle rounded, its surface concave, with prominent raised anterior margin, a papilla in center, and another above groove for peroneus profundus.

*Measurements.* Width through condyles 8.0; width through internal ligamental prominence 8.2; width of shaft 4.4; depth of external condyle 7.5; depth of internal condyle 9.4 approximately; depth of shaft 3.6; width of distal end of posterior intercondylar sulcus 6.0 mm.

*Characters.* Resembles modern *Haematopus palliatus* and *H. bachmani,* but width through condyles less; shaft more robust (wider and deeper); external ligamental prominence situated higher on shaft and more pronounced (rising more abruptly from shaft, both distally and proximally); internal ligamental prominence more angular and situated slightly higher on shaft; tendinal groove rather more pronounced; internal condyle deeper; intercondylar sulcus narrower and deeper; groove for peroneus profundus deeper; tibial bridge completely ossified.

*Paractiornis perpusillus* is known only from the tarsometatarsus. It is a tiny bird, about the size of a sanderling.

## Family SCOLOPACIDAE

Although 21 fossil species of sandpipers have been previously described, only one has heretofore been found in the Pliocene deposits of North America. This is *Micropalama hesternus* Wetmore (1924), from the Upper Pliocene of Arizona. The discovery of three species of scolopacids in the Bone Valley gravel is therefore of considerable interest.

### Genus CALIDRIS Merrem

### *Calidris pacis* new species

Figs. 19, 20

*Type.* No. 594, collection of Pierce Brodkorb; proximal half of left humerus, with internal tuberosity broken. Bone Valley formation, from Locality 2 near Brewster, Polk County, Florida. Collected January 18, 1953, by George C. Elmore.

*Characters.* Similar in general size and conformity to modern *Calidris canutus* (Linnaeus), but head of humerus more rounded, less elongate; capital groove shallower; coraco-humeral groove broader and deeper, the outer part of its proximal margin straight, and with more pronounced overhang proximally; medial bar lying more oblique to mid-line; capital-shaft ridge straighter, not deflected inwardly; surface of deltoid ridge slanted toward external edge of bone, instead of toward inner edge, the scar about the same width throughout, instead of tapering distally; bicipital groove shorter; bicipital furrow deeper.

*Measurements.* Proximal width 10.6; least width of shaft 3.2; least depth of shaft 2.8; depth of head 2.8; length from outer end of bicipital groove to end of caput humeri 8.8 mm.

*Comparisons.* Although its measurements are almost identical with those of *Calidris canutus,* this species may require generic separation when more specimens are collected.

*Micropalama hesternus* Wetmore is a smaller species with the proximal width of the humerus 7.7 mm., and the length of the bicipital groove 7.1 mm.

The humerus of *Calidris gracilis* (Milne-Edwards, 1868), from the upper Oligocene of France, is described as being much smaller than that of *C. canutus.* It may belong in the genus *Erolia* rather than *Calidris.*

*Totanus grivensis* Ennouchi (1930), from the upper Miocene of France, is larger than *C. pacis,* and *Tringa numenoides* (Serebrovsky, 1941), from the Pliocene of the Ukraine, is very much larger.

## Genus EROLIA Vieillot

### *Erolia penepusilla* new species

Fig. 21

*Type.* No. 611, collection of Pierce Brodkorb; left humerus, lacking the head. Bone Valley formation, from Locality 2 near Brewster, Polk County, Florida. Collected by George C. Elmore, March 10, 1953.

*Characters.* Agrees with the smaller living species of *Erolia* in having the external condyle relatively small and the internal condyle relatively large. Larger than the Asiatic *Erolia temminckii* (Leisler), the Palearctic *E. ruficollis* (Pallas), and the American *E. minutilla* (Vieillot). Smaller than the American species *Erolia bairdii* (Coues) and *E. fuscicollis* (Vieillot). Appears to be closest to *Erolia minutilla,* from which it differs in larger size and in having a higher internal condyle/external condyle ratio.

Larger also than the American genus *Ereunetes,* represented by the two living species, *E. pusillus* (Linnaeus) and *E. mauri* Cabanis. The humeri of *Erolia* and *Ereunetes* are very close, but differ in proportions of the condyles. In various species of *Erolia* the ratio internal condyle/external condyle is 36.00-50.00 per cent. In *Ereunetes* the ratio is 33.33-41.67 percent, reflecting the relatively large external condyle and the small internal condyle. The new species, with a ratio of 44.00 percent, falls within the range of *Erolia* and beyond that of *Ereunetes.*

The only fossil species of comparable size is *Totanus minor* Ennounchi (1930), described from the Miocene of France. Inspection of Ennounchi's plate shows that *penepusilla* differs in having the distal end of the bone more on a plane, with the internal condyle less deep as seen from below, and its shaft is narrower. Ennouchi's species appears to have little in common with the genus *Totanus,* now known as *Tringa.* Furthermore, the name *minor* is preoccupied in *Tringa* by *Tringa cinclus minor* Schlegel (1844).

Ennouchi's bird is very similar to the smaller species of *Erolia,* and probably should be referred to that genus. However, the name *minor* is also preoccupied in *Erolia* by *Tringa cinclus minor* Schlegel,

since the latter is a synonym of *Erolia alpina* (Linnaeus). In view of these circumstances, it is greatly to be desired that Dr. Ennouchi supply a new name for his *Totanus minor*.

*Measurements.* Length (estimated), about 26.1 mm.; length from bicipital crest 20.7; narrowest width of shaft 1.7; distal width 4.0; diagonal length of external condyle 2.5; height of internal condyle 1.1; upper base of spur to distal end 3.7; narrowest depth of shaft 1.5 mm.

## Genus LIMOSA Brisson

### *Limosa* sp.

Figs. 22, 23

*Material.* Two specimens, one individual.

Nos. 526, 527, distal and proximal portions of right tibiotarsus (Locality 2). There is a segment of about an inch of the shaft missing between the two pieces.

*Characters.* Differs from the living *Limosa lapponica* and *L. fedoa* in having smaller condyles and narrower posterior intercondylar sulcus, but with the shaft of about the same breadth and depth as in those species.

Because of the inadequate description of *Limosa vanrossemi* Miller (1925) from the Miocene of California, I am unable to differentiate my bird from that form, the only measurement of the tibiotarsus given by Miller being the length. The type is an impression of a skeleton, and it is not feasible to take accurate measurements. Dr. Miller kindly compared my material with his type but was unable to come to a conclusion. This is unfortunate, because the difference in age of the Florida bird makes it practically certain that it represents a new species.

*Measurements.* Width through condyles 6.3; narrowest width of shaft 3.2; depth of shaft 2.5; depth of external condyle 5.7; depth of internal condyle 6.5; width of posterior intercondylar sulcus 4.7; width of shaft above fibular crest 3.7; width of head 5.7 mm.

## Family LARIDAE

Gulls are relatively rare as fossils, there being 84 living and 14 fossil ones. The record goes back to the Oligocene.

## Genus LARUS Linnaeus

### *Larus elmorei* Brodkorb

*Larus elmorei* Brodkorb, 1953B: 94, fig. 1 (orig. descr.; Bone Valley formation, near Brewster, Florida; type distal portion of humerus; descr. coracoid, carpometacarpus).

*Material.* Six specimens, two individuals. Nos. 176 and 178 are from Locality 1, the others from Locality 2.

Coracoid: right proximal 134.

Humerus: right distal 140 (type); left distal 176.

Ulna: left proximal 307.

Carpometacarpus: left distal 178; left proximal 528.

Measurements. Two of the above specimens (Nos. 307 and 528) were received after the description of this species was published. Their measurements are given below.

Ulna: width through cotylae 11.0, depth of shaft 5.2 mm.

Carpometacarpus: width of metacarpal two 3.8, height of proximal end 11.7, width through trochleae 5.0.

*Remarks.* The phosphate species is closely related to the living ring-billed gull, *Larus delawarensis,* of which it was probably the direct ancestor.

## Family ALCIDAE

At the present time the Alcidae occur in Florida only as rare or accidental stragglers along the east coast. The dovekie (*Plautus alle*), a species subject to sporadic migrations, has been collected a few times in Florida, and two bones of the great auk (*Pinguinus impennis*) have been discovered in an Indian shell heap at Ormond (Hay, 1902). Considerable interest, therefore, is attached to alcid material in the phosphate deposits of the Gulf region. The Bone Valley specimens do not necessarily indicate a cooler climate, however, since several species breed at present in the Pacific as far south as Latitude 27° along the Mexican coast.

The family is entirely Holarctic. There are 23 Recent species and the Bone Valley auk is the tenth fossil species.

## Genus AUSTRALCA new genus

*Diagnosis.* Coracoid agrees with that of the Alcidae and differs from the Mancallidae in having the sternal facet with a broad mesial

flare. The brachial tuberosity and the sternal facet are elongated, as in *Pinguinus, Alca, Synthliboramphus, Uria,* and *Cepphus,* in contrast with the group typified by *Plautus, Fratercula, Lunda,* and *Cerorhinca,* in which these parts are reduced.

The proximal end of the bone is wide, with the ratio of the distance from head to brachial tuberosity greater than in any living form examined. The shaft is also relatively wide.

Differs from *Pinguinus* in narrower dorsal end, but relatively more produced brachial tuberosity; relatively greater depth of head; less elongate and straighter neck of the coracoid.

Differs from *Alca* in somewhat shorter relative distance from head to scapular facet; more produced brachial tuberosity; greater depth of head; wider sternal end.

Differs from *Synthliboramphus* in more produced and less deflected brachial tuberosity, and less rotated procoracoid.

Differs from *Uria* in more produced and less deflected brachial tuberosity, wider shaft, and deeper head.

Differs from *Cepphus* in more produced and less deflected brachial tuberosity, deeper shaft, wider sternal end, and in having a fenestrate, not notched, procoracoid.

*Type. Australca grandis,* new species.

*Relationships.* In general appearance the coracoid of this genus falls between that of *Pinguinus* on the one hand, and *Uria* and *Alca* on the other.

An index to the coracoid was obtained by summing four intramembral ratios. These were the percentage of the length of the bone involved in the distances of the head to scapular facet, glenoid facet to brachial tuberosity, depth of shaft, and sternal width, respectively. The indices thus computed for various alcids are as follows: *Pinguinus* 139, *Alca* 127, *Synthliboramphus* 122, *Australca* 121, *Uria* 117, *Cepphus* 116, *Plautus* 98, *Fratercula* 95, *Lunda* 92, and *Cerorhinca* 91 percent. The index of *Australca* confirms its intermediate position between *Pinguinus* and the *Uria-Alca* group.

*Australca grandis* new species

Figs. 24, 29

*Type.* No. 141, collection of Pierce Brodkorb; right coracoid, lacking the hyosternal facet. Bone Valley formation, from Locality 2, near Brewster, Polk County, Florida. Collected in February 1952 by George C. Elmore.

*Diagnosis.* General size of coracoid near that of *Lunda,* shorter than in *Pinguinus,* and larger than that of any other living alcid.

Length of bone to medial side 44.4, brachial tuberosity to sternal facet 44.2, head to procoracoid 17.0, glenoid facet to brachial tuberosity 14.1, head to brachial tuberosity 8.5, depth of shaft below glenoid facet 5.4, greatest depth of head 7.0, width of sternal facet 17.5 mm.

*Referred material.* The total alcid material consists of three specimens and one individual from Locality 1, and 15 specimens and four individuals from Locality 2.

Humerus: right proximal 137, 310; right distal 91, 304, 305, 595; left proximal 135, 136, 525; left distal 173.

Radius: left distal 93.
Ulna: right proximal 142; left distal 92, 596.
Carpometacarpus: right distal 143.
Tibiotarsus: left distal 612.

Humerus with capital lip but little overhanging capital groove surface, as in *Alca* and *Pinguinus,* less so than in *Uria,* much less so than in *Cepphus.* However, the medial bar is only faintly indicated, and in this respect the fossil more nearly resembles *Cepphus* and *Uria.* None of the humeri is complete, but two (Nos. 91 and 304) lack only the proximal end. These indicate that the humerus was similar in length to that of *Uria,* being decidedly longer than in *Alca* or *Cepphus.* The distal portion of the humerus has a very well developed ectepicondylar process, whose outer margin is parallel to the shaft, as in *Cepphus,* instead of being inclined toward the shaft proximally as *Uria* and *Alca.* The proximal margin of the ectepicondylar process is therefore wider and is also more truncate than in living genera. Possibly No. 525 may represent another species, since its shaft narrows abruptly distal to the middle of the bone. This character, however, shows some variation in living alcids.

The ulna is represented by two distal and one proximal portions. The entire bone seems to have been about the size of the ulna of *Uria,* and resembled that genus in its conformity, without the pronounced shortening which occurs in *Pinguinus.* The proximal end is a little smaller than in *Uria,* but wider than in *Alca.* The two distal ends differ considerably in size, No. 596 equaling the great auk in most measurements. The shaft in both distal specimens tapers gently distad, without any pronounced decrease near the condyles.

The fragmentary radius resembles that of *Alca* and *Uria,* without the great deepening and compression of *Pinguinus.* There is a pronounced neck just before the distal end, more so than in any other alcid examined.

The fragmentary carpometacarpus is relatively short compared with the other elements, and therefore shows a tendency toward the condition in *Pinguinus.* In size it comes closest to *Cepphus columba,* being smaller than the carpometacarpus of *Uria,* and also being smaller than *Alca* except in the length of the shaft of the second metacarpal, which is the same. It therefore may be said that the carpometacarpus resembles that of *Alca* in length, but its distal portion is narrower and less deep.

The distal portion of the tibiotarsus resembles that of *Uria.* The internal condyle extends far inward, as in *Uria,* more so than in *Alca* and *Cepphus.* The posterior intercondylar sulcus is broad as in *Uria* and *Pinguinus;* in *Alca* it is somewhat, and in *Cepphus* it is much narrower. The tibial bridge is incompletely ossified, as in *Pinguinus, Alca,* and some specimens of *Uria;* the bridge is ossified in *Cepphus.*

*Measurements.* Humerus: length to pectoral attachment (1), 66.0; proximal width (1), 18.3; depth of head (4), 6.1-6.7; least width of shaft (6), 5.5-6.6; depth of shaft (8), 3.3-3.8; distal width (5), 8.0-8.5.

Ulna: proximal width (1), 8.4; depth through external cotyla (1), 10.3; distal depth (2), 8.7-9.8.

Radius: distal width (1), 5.4.

Carpometacarpus: length of second metacarpal (1), 28.2; distal depth (1), 6.4.

Tibiotarsus: width through condyles (1), 7.1.

*Conclusions.* Considerable study was required before it was de-

termined that all the alcid material represented a single species. It gradually became apparent that the Bone Valley auk was a large bird with the wings reduced in size compared with the living members of the family. The reduction is especially evident in the distal elements of the wing.

All alcids use the wings in swimming under water (Bent, 1919: 206). *Cepphus, Uria,* and *Alca* are strong fliers. The recently extinct great auk, *Pinguinus impennis,* had lost the power of flight and had carried the reduction of the distal wing elements to a remarkable degree (see Table 6).

In *Australca* the reduction of the wings was about half-way between the condition in the flying alcids and *Pinguinus.* It was thus already well on the road to flightlessness, and because of other similarities it may even have been the ancestor of the great auk.

*Table 6.*—RATIOS (PERCENT) OF WING ELEMENTS TO LENGTH OF CORACOID

| | *Coracoid length* | *Humerus length to pectoral attachment* | *Ulna depth through external cotyla* | *Radius distal width* | *Second metacarpal length* |
|---|---|---|---|---|---|
| *Cepphus columba* | 100.00 | 181.61 | 27.42 | 16.13 | 88.71 |
| *Uria aalge* | 100.00 | 187.18 | 27.69 | 14.62 | 79.23 |
| *Uria lomvia* | 100.00 | 185.75 | 27.75 | 15.50 | 78.00 |
| *Alca torda* | 100.00 | 168.99 | 29.61 | 15.36 | 78.77 |
| *Australca grandis* | 100.00 | 149.22 | 23.20 | 12.22 | 63.80 |
| *Pinguinus impennis* | 100.00 | 134.62 | 21.79 | 9.77 | 43.22 |

## AGE OF THE DEPOSIT

Geological opinion differs as to the age of the Bone Valley formation. Cooke (1945: 207) considered it middle Pliocene (Hemphillian age). Cathcart (1950) allocated the formation to the lower part of the Pliocene. From a study of the Pleistocene shore lines MacNeil (1950: 106) concluded that there is a possibility that the Bone Valley gravel might be early Pleistocene (Aftonian), but he too accepted a Pliocene age. Currently (*in litt.,* January 18, 1954) he favors uppermost Miocene for the upper Bone Valley and middle Miocene (Hawthorn) for the lower Bone Valley. Vernon (1943: 156) first assigned the

Bone Valley to the Pleistocene but now believes it to be late and middle Miocene (Vernon, 1951: 195, 197).

The cetaceans were studied by Allen (1921), Kellogg (1924), and Case (1934). These mammals were thought to be of Miocene age, or more specifically late Miocene. It has been suggested that the cetaceans were redeposited secondarily from reworked upper Miocene rocks, but this is at variance with the finding of articulated specimens.

Those who have worked with the land vertebrates are in general agreement as to the Pliocene age of the fauna. Simpson (1930) placed the land mammals in the lower Pliocene and later stated that the relationships of the sirenians also supported this view (Simpson, 1932). White (1941A, 1941B) variously attributed certain land mammals to the lower or middle Pliocene. Wood *et al.* (1941: 15) considered the Bone Valley vertebrates to be of Hemphillian (middle Pliocene) age.

It is obvious from these accounts that the Miocene-Pliocene boundary in Florida is in need of further study, and the land vertebrate chronology may be a portion of an epoch ahead of the chronology based upon marine sediments. In other words, what is considered lower Pliocene by vertebrate paleontologists may be the equivalent of uppermost Miocene in the marine invertebrate chronology.

*Age of the Avifauna.* In determining the age of the avifauna the possibility of reworking must be considered. No articulated bird skeletons were discovered. This in itself cannot be taken as evidence of reworking, however, since skeletons of birds dying in the rookeries of the Everglades today are similarly disarticulated and scattered (see Figs. 30-32). Much of the Bone Valley bird material is in excellent condition. In nearly every specimen the muscle scars and processes are perfectly preserved with little or no abrasion. Extensive reworking is therefore out of the question, and the bird material must be contemporaneous with the sediments.

The age of the avifauna will be tested by the proportion of extinct and living species and by the presence of indicators of particular epochs on both generic and specific levels.

A comparison of the proportion of extinct species to those still living is given in Table 7 for the Bone Valley and other late Tertiary and Quaternary deposits in North America. As might be expected, all the Pleistocene localities have a relatively low proportion of ex-

tinct forms, with a mean of 20.3 percent (range 13.7-24.3). The upper Pliocene avifaunas of Blancan age are marked by a decided increase in the proportion of extinct species, with a mean of 72.3 percent (range 63.6-83.3). All the localities of middle Pliocene (Hemphillian) age or older are characterized by having their avifaunas composed entirely of extinct species. Since the Bone Valley avifauna is likewise composed wholly of extinct species, it must therefore be concluded to be of middle Pliocene (Hemphillian) age or older.

*Table 7.*—PROPORTION OF EXTINCT SPECIES IN QUATERNARY AND LATE TERTIARY AVIFAUNAS.

| *Age and Locality* | *Authority* | *Species* | *Percent Extinct* |
|---|---|---|---|
| PLEISTOCENE: | | | |
| Rancho La Brea, California | Miller and DeMay (1942) | 114 | 15.8 |
| McKittrick, California | Miller and DeMay (1942) | 73 | 13.7 |
| Carpinteria, California | Miller and DeMay (1942) | 58 | 17.2 |
| Fossil Lake, Oregon | Howard (1946) | 70 | 24.3 |
| San Josecito, Nuevo Leon | L. Miller (1943) | 39 | 30.5 |
| LATE PLIOCENE (Blancan age): | | | |
| Rexroad fauna, Kansas | Wetmore (1944) | 11 | 63.6 |
| Hagerman, Idaho | Wetmore (1933) | 10 | 70.0 |
| Benson, Arizona | Wetmore (1924) | 6 | 83.3 |
| MIDDLE PLIOCENE (Hemphillian age): | | | |
| San Diego, California | Howard (1949) | 8 | 100.0 |
| EARLY PLIOCENE (Clarendonian age): | | | |
| Snake Creek, Nebraska | Wetmore (1923) | 2 | 100.0 |
| AGE UNCERTAIN: | | | |
| Bone Valley, Florida | Brodkorb (1955) | 18 | 100.0 |
| LATE MIOCENE (Barstovian age): | | | |
| Snake Creek, Nebraska | Wetmore (1923) | 3 | 100.0 |
| MIDDLE MIOCENE (Hemingfordian age): | | | |
| Sheep Creek, Nebraska | Wetmore (1923, 1926A) | 3 | 100.0 |
| Calvert, Maryland | Wetmore (1940A) | 5 | 100.0 |
| Lompoc, California | Miller and DeMay (1942) | 6 | 100.0 |
| Sharktooth Hill, California | Miller and DeMay (1942) | 3 | 100.0 |
| EARLY MIOCENE (Arikareean age): | | | |
| Flint Hill, South Dakota | A. H. Miller (1944) | 9 | 100.0 |
| Lower Harrison, Nebraska | Wetmore (1933) | 9 | 100.0 |

Although fifteen genera of birds are present in the collection, most of them have a long time span. There are three extinct genera, *Pliodytes, Palostralegus,* and *Australca,* which are unknown from

other localities. The other genera are still living in the Recent fauna of Florida. One of the living genera, *Bucephala,* was previously reported from the upper Pliocene of Kansas (Wetmore, 1944). The remaining living genera have records extending back to the Miocene or Oligocene. In the absence of indicators of a particular epoch, the analysis of the genera merely limits the age of the deposit as being Oligocene or later. Since, however, the Bone Valley beds are underlain by the Hawthorn formation of middle Miocene (Hemingfordian) age, the oldest possibility for the Bone Valley must be late Miocene or younger.

Three species in the Bone Valley collection help to restrict further the age correlation of the avifauna, since they also occur in other deposits. These are *Gavia concinna, Diomedea anglica,* and *Phalacrocorax idahensis,* all reported from localities referred to the Pliocene.

*Gavia concinna* Wetmore (1940A) was described from the Etchegoin formation of California, referred by the describer to the lower Pliocene. According to Woodring, Stewart, and Richards (1940: 112, insert) and to Wood *et al.* (1941: 19), this formation is of middle Pliocene (Hemphillian) age. *G. concinna* is also reported from the San Diego formation in San Diego (Howard, 1949; Brodkorb, 1953C). The San Diego facies of this formation is usually assigned to the middle Pliocene, but Woodring, Stewart, and Richards (1940: 112) give it a late early Pliocene age.

*Diomedea anglica* Lydekker (1891: 189) was described from the upper Pliocene (Red Crag) of England. Lambrecht (1933: 273) lists this species from both Plaisancian and Astian ages, which Wood *et al.* (1940) correlate with the Hemphillian and Blancan, respectively, and therefore of middle and late Pliocene age. The Florida record is based on a tibiotarsus, an element unrepresented in the European material, and therefore its reference to the present species is somewhat open to question.

*Phalacrocorax idahensis* (Marsh, 1870) was described from a supposed Pliocene deposit of Idaho and has since been reported from the upper Pliocene near Hagerman (Wetmore, 1933). As the Bone Valley and Hagerman ulnas represent different ends of the element, the reference is likewise not absolutely certain.

On the basis of the above criteria, the age of the Bone Valley avifauna falls between the late Miocene and middle Pliocene, with some evidence in favor of an early or middle Pliocene age. While

this conclusion is in agreement with that reached by students of the land mammals, it does not preclude the possibility that the vertebrate chronology is not synchronous with the chronology based upon marine invertebrates and beach lines.

## PALEOECOLOGY

*Census.* A census of specimens and individuals for three Bone Valley localities is given in Table 8. The minimum number of individuals of each species was computed in the usual way, by counting the right or left members of the most abundant element of that species in the locality. In several cases the actual number of individuals was probably greater.

White's locality is represented by only four specimens and four individuals of three species. Locality 1 has 58 specimens and ten individuals of six species. Locality 2 is the most prolific with 133 specimens and 31 individuals of 16 species. The total material on which this report is based thus includes 195 specimens from at least 45 individuals and comprises a total of 18 species.

*Dominance of species.* The dominant species is the small cormorant *Phalacrocorax wetmorei,* represented by no less than 135 specimens. In Locality 1 83 percent of the specimens are of this species, and 64 percent of those in Locality 2.

The next species in point of abundance is the auk *Australca grandis,* with 18 specimens. Other relatively common forms are represented by from three to six specimens. These include the two loons (*Gavia palaeodytes* and *G. concinna*), the gannet (*Morus peninsularis*), the two boobies (*Sula guano* and *S. phosphata*), the flamingo (*Phoenicopterus floridanus*), and the gull (*Larus elmorei*). These eight species may all be classed as influent. They comprise 16 percent of the specimens at Locality 1 and 30 percent at Locality 2. Together the dominant and influent species make up 99 percent of the collection from Locality 1 and 94 percent at Locality 2.

The remaining nine species may be classed as subinfluent. They are represented by one or at most two specimens.

*Habitat requirements.* The entire avifauna of the Bone Valley presents a fairly homogeneous aspect. All of the species are aquatic. Further they are all representatives of groups which inhabit salt-water exclusively or else frequent both salt and fresh water. The six forms whose allies today are strictly confined to salt-water include

*Table 8.*—CENSUS OF BIRDS OF THE BONE VALLEY FORMATION.

| *Species* | LOCALITY 1 | | LOCALITY 2 | | WHITE'S LOCALITY | | TOTAL | |
|---|---|---|---|---|---|---|---|---|
| | *Specimens* | *Individuals* | *Specimens* | *Individuals* | *Specimens* | *Individuals* | *Specimens* | *Individuals* |
| *Gavia palæodytes* | 1 | 1 | 4 | 1 | 1 | 1 | 6 | 3 |
| *Gavia concinna* | 3 | 1 | 2 | 1 | 0 | 0 | 5 | 2 |
| *Pliodytes lanquisti* | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| *Diomedea anglica* | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| *Morus peninsularis* | 0 | 0 | 3 | 2 | 0 | 0 | 3 | 2 |
| *Sula guano* | 0 | 0 | 4 | 2 | 0 | 0 | 4 | 2 |
| *Sula phosphata* | 0 | 0 | 4 | 3 | 0 | 0 | 4 | 3 |
| *Phalacrocorax wetmorei* | 48 | 5 | 85 | 8 | 2 | 2 | 135 | 15 |
| *Phalacrocorax idahensis* | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| *Ardea polkensis* | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| *Phœnicopterus floridanus* | 0 | 0 | 4 | 2 | 0 | 0 | 4 | 2 |
| *Bucephala ossivallis* | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| *Palostralegus sulcatus* | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Calidris pacis* | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| *Erolia penepusilla* | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| *Limosa* sp. | 0 | 0 | 2 | 1 | 0 | 0 | 2 | 1 |
| *Larus elmorei* | 2 | 1 | 4 | 1 | 0 | 0 | 6 | 2 |
| *Australca grandis* | 3 | 1 | 15 | 4 | 0 | 0 | 18 | 5 |
| | 58 | 10 | 133 | 31 | 4 | 4 | 195 | 45 |

the halobionts *Diomedea, Morus, Sula guano, S. phosphata, Palostralegus,* and *Australca.* The remaining twelve forms are halocoles, as their present-day allies are tolerant of both fresh water and salt, although most of them are perhaps more numerous in the latter environment.

Wynne-Edwards (1935: 240) has classified the ecological requirements of the oceanic birds of the North Atlantic, and Murphy (1936: 326) has made a similar classification for those of South America. The characteristic birds of the divisions of the ocean, based on the above-mentioned authors with additional data from Bent (1919 et seq.), are as follows:

1. Littoral (beaches and rocky foreshores): sandpipers, plovers, oystercatchers, herons, flamingoes.
2. Inshore (within sight of land): loons, grebes, some cormorants, sea-ducks, most gulls, skimmers.
3. Offshore (to edge of continental shelf): some diving petrels, gannets, boobies, some cormorants, pelicans, auks.
4. Pelagic (open ocean): penguins, petrels, shearwaters, albatrosses, tropic-birds, skuas, jaegers, phalaropes.

On the basis of this division there are present in the Bone Valley avifauna six littoral species, *Phoenicopterus, Ardea, Palostralegus, Calidris, Erolia,* and *Limosa.* Only the first of these is an influent species, the others being subinfluent.

The seven inshore forms are the two species of *Gavia, Pliodytes,* two species of *Phalacrocorax, Bucephala,* and *Larus.* This group includes all the dominant Bone Valley species, three influents, and three subinfluents.

The offshore group contains four birds, all influents. They are *Morus,* the two species of *Sula,* and *Australca.*

A single pelagic bird, *Diomedea,* is recorded from the Bone Valley. It is subinfluent.

The above classification is based on the feeding habits of the birds during the non-breeding season. It must be remembered that during the time of nesting they customarily feed farther inshore. Therefore the presence together in the Bone Valley of species from all four ecological divisions of the ocean may best be interpreted as a group-

ing of some of them at a coastal or insular breeding site. Furthermore, it is hardly possible to account for such large numbers of bones being accumulated in any other manner, particularly in the case of *Phalacrocorax wetmorei.* I believe that more specimens are known of this cormorant than of any other Tertiary bird.

*Effect of bird life on the production of phosphate.* With the exception of the two loons all of the dominant and influent species, as well as two of the subinfluents (*Diomedea* and *Phalacrocorax idahensis*) are social birds which nest in large colonies.

The presence of large numbers of sea-bird fossils in the phosphate beds immediately brings to mind the guano islands off the coast of Peru and other parts of the world. Large rookeries of birds as a source for the Florida phosphate were suggested long ago by Sellards (1913: 45), and more recently Vernon (1951: 195-198) has elaborated on this hypothesis.

The important guano-producing birds today are members of the order Sphenisciformes, *Diomedea* among the Procellariiformes, the order Pelecaniformes, and the families Laridae and Alcidae among the Charadriiformes (Hutchinson, 1950: 366). According to Murphy (1936: 293) the Pelecaniformes, in particular species of the genera *Phalacrocorax* and *Sula,* are the most important contributors to the formation of guano on the Peruvian islands today. Coker (1919) reports high concentrations of phosphoric acid in cormorant and pelican guano.

In both their past and present distribution the penguins (Sphenisciformes) are confined to the southern hemisphere and therefore do not enter into the picture here.

*Diomedea* is represented in the Bone Valley by one subinfluent species. The albatrosses today are limited to southern oceans and the North Pacific and are only of accidental occurence in the North Atlantic, but are recorded from three British localities of Pliocene and Pleistocene age (Lambrecht, 1933: 273, 732).

Five of the eighteen Bone Valley species are members of the Pelecaniformes. This order includes the dominant *Phalacrocorax wetmorei,* three of the influent species (*Morus peninsularis, Sula guano* and *S. phosphata*), and the subinfluent *Phalacrocorax idahensis.* It is noteworthy that the two genera which Murphy considers the most

important in the production of guano make up 83 percent of the collection from Locality 1 and 70 percent from Locality 2.

The Laridae and the Alcidae are each represented in the Bone Valley by an influent species, *Larus elmorei* and *Australca grandis.*

Thus all the dominant and influent species of the Bone Valley, except the two loons and the flamingo, are guano birds. The eight guano species comprise 44 percent of the avifauna and 88 percent of the specimens.

The loons today are not gregarious birds and they occur this far south only in the non-breeding season. There is no reason to believe that their habits during the Pliocene were markedly different from those of the present time.

The formation of guano has on several occasions been attributed to the flamingoes, but according to Hutchinson (1950: 36, 43, 336) the cases are not well authenticated. Flamingoes nest on tidal flats, and it seems probable that their excrement would become dissolved in the sea-water. Thus while not preserved as guano it would nevertheless help to raise the phosphorus content of the water.

Hutchinson states that marine deposits of phosphate are always intimately associated with a rich supply of phosphorus from the land. He continues (p. 373):

> "The result of a very large bird colony on a section of coast line or on an island, whenever climatic conditions and the form of the substrate permit guano to be returned to the ocean will be to steepen the nutrient gradient . . . The result will be increased littoral productivity . . . and a steady state condition will be set up."

Vernon (1951: 197) suggested that limestone islands with bird rookeries on them existed in Florida during the Miocene and younger epochs and formed a ready source of phosphoric acid. Now for the first time the data are at hand to support this hypothesis.

Whatever the original source of phosphorus in Florida waters may have been, it would increase the production of phytoplankton, and this in turn would increase the production of marine invertebrates and fish on which large bird populations might subsist. Excrement from the birds would return the phosphorus to the sea and complete the cycle, attaining an equilibrium.

The general picture derived from a study of the avifauna is of a guano island near the coast, probably rocky in character. Nesting on its shores were myriads of cormorants, similar in size to the

present-day species. The rookery was also populated by colonies of other sea-birds, including a gannet, two species of boobies, and a large auk, the last already on the road to flightlessness. A second giant species of cormorant was present in lesser numbers. Flocks of flamingoes occurred on the tidal flats, where an occasional large heron stalked its prey. A medium-sized gull was common and probably robbed the eggs of the other birds. Along the beach an oystercatcher and three species of sandpipers rested and fed. In the waters off-shore two species of loons were fairly common, and a grebe and a sea-duck also occurred in lesser numbers off-shore. From still farther distant an occasional albatross appeared, perhaps attracted by the teeming invertebrate life, which fed on the plankton fertilized by the droppings of the nesting birds.

## SUMMARY

Eighteen species of birds represented by nearly 200 specimens are recorded from the Bone Valley formation in Polk County, Florida, making this the largest North American Tertiary avifauna. The following species are described as new in the present paper: *Morus peninsularis, Sula guano, Sula phosphata, Phalacrocorax wetmorei, Ardea polkensis, Bucephala ossivallis, Palostralegus sulcatus* (new genus and species), *Calidris pacis, Erolia penepusilla,* and *Australca grandis* (new genus and species). Three other new species were described in preliminary papers.

Criteria used for the determination of the age of the Bone Valley avifauna are the proportion of extinct species, the maximum known age of the various genera, and the presence of index species. A comparison of the proportion of extinct versus living species in major Quaternary and late Tertiary avifaunas shows the Pleistocene with about 14-24 percent extinct species, the upper Pliocene with about 64-83 percent extinct, and the Bone Valley and all localities of middle Pliocene age and older composed entirely of extinct species. Thus the Bone Valley cannot be younger than middle Pliocene. The conclusion derived from study of the age of the genera and from the stratigraphy indicate that the avifauna cannot be older than late Miocene. Three species of Bone Valley birds are reported elsewhere from early, middle, or late Pliocene deposits. The avifauna, therefore, must be of late Miocene to middle Pliocene age, and the agreement is closest to other avifaunas recorded from the early or middle parts of the Pliocene. These conclusions are in agreement with the deduc-

tions of those who have studied the land mammals, but there is a possibility that the land vertebrate chronology is a portion of an epoch ahead of the chronology based upon marine invertebrates.

The avifauna is composed of one dominant, eight influent, and nine subinfluent species. Classified according to feeding habitat, there are six littoral species, seven inshore forms, four in the offshore group, and a single pelagic bird. The association of members of these four groups is explained as representing a breeding colony, and this further explains the presence of large numbers of individuals, one species being represented by 135 specimens.

Groups important today in the production of guano comprise 44 percent of the species and 88 percent of the specimens from the Bone Valley. Whatever the original source of the phosphorus in Florida waters may have been, the large colonies of sea-birds added materially to it and set up stable conditions which may have continued for a long time.

# PLATES

Explanation of Plate I

Figure 1. *Morus peninsularis* n. sp. No. 148, type. External view of coracoid.

Figure 2. *Sula guano* n. sp. No. 301, type. External view of coracoid.

Figure 3. *Sula phosphata* n. sp. No. 302, type. External view of coracoid.

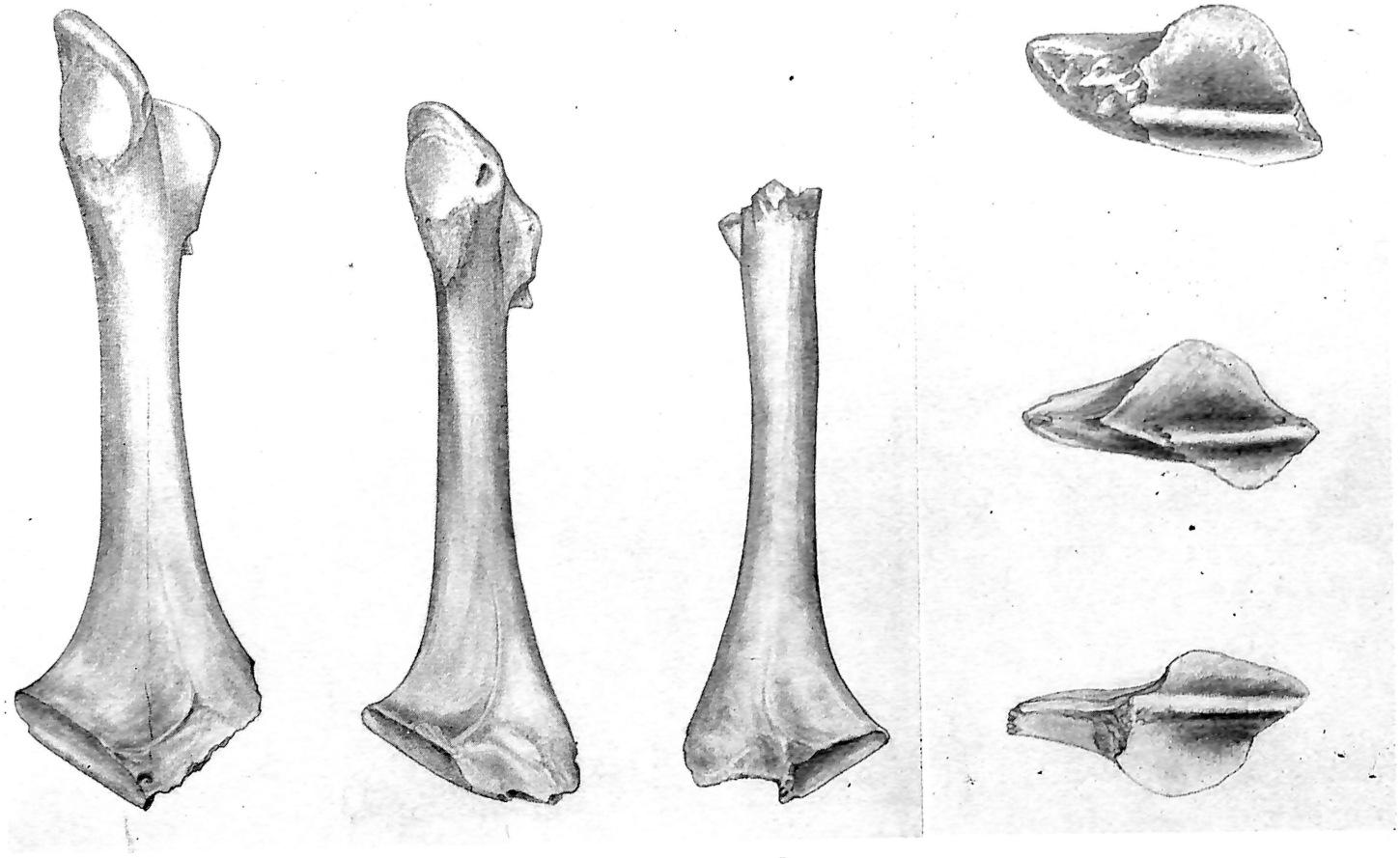
Figure 4. *Morus peninsularis* n. sp. No. 148, type. Distal view of coracoid.

Figure 5. *Sula guano* n. sp. No. 301, type. Distal view of coracoid.

Figure 6. *Sula phosphata* n. sp. No. 302, type. Distal view of coracoid.

All figure approximately X 1⅔.

## Plate 1



1

2

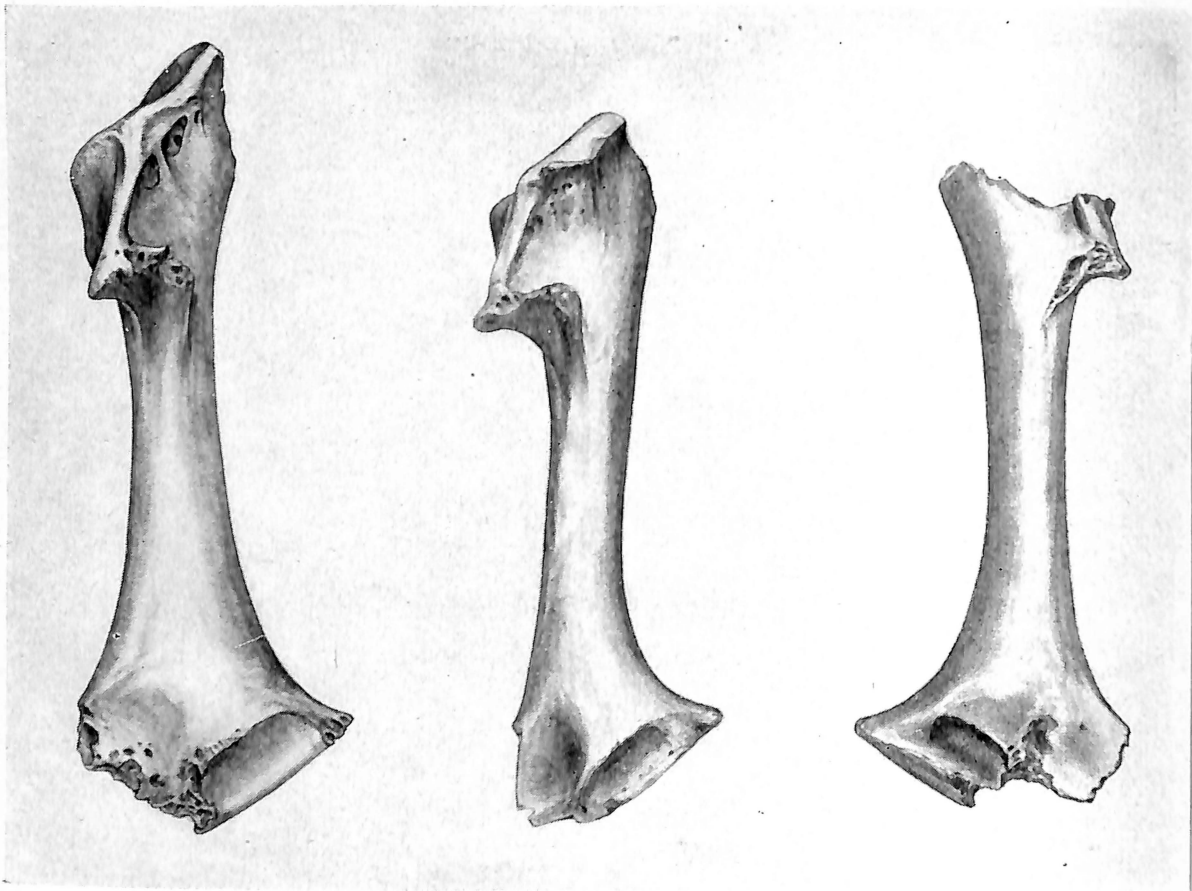
3

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## Plate 2



7 8 9

Explanation of Plate 2

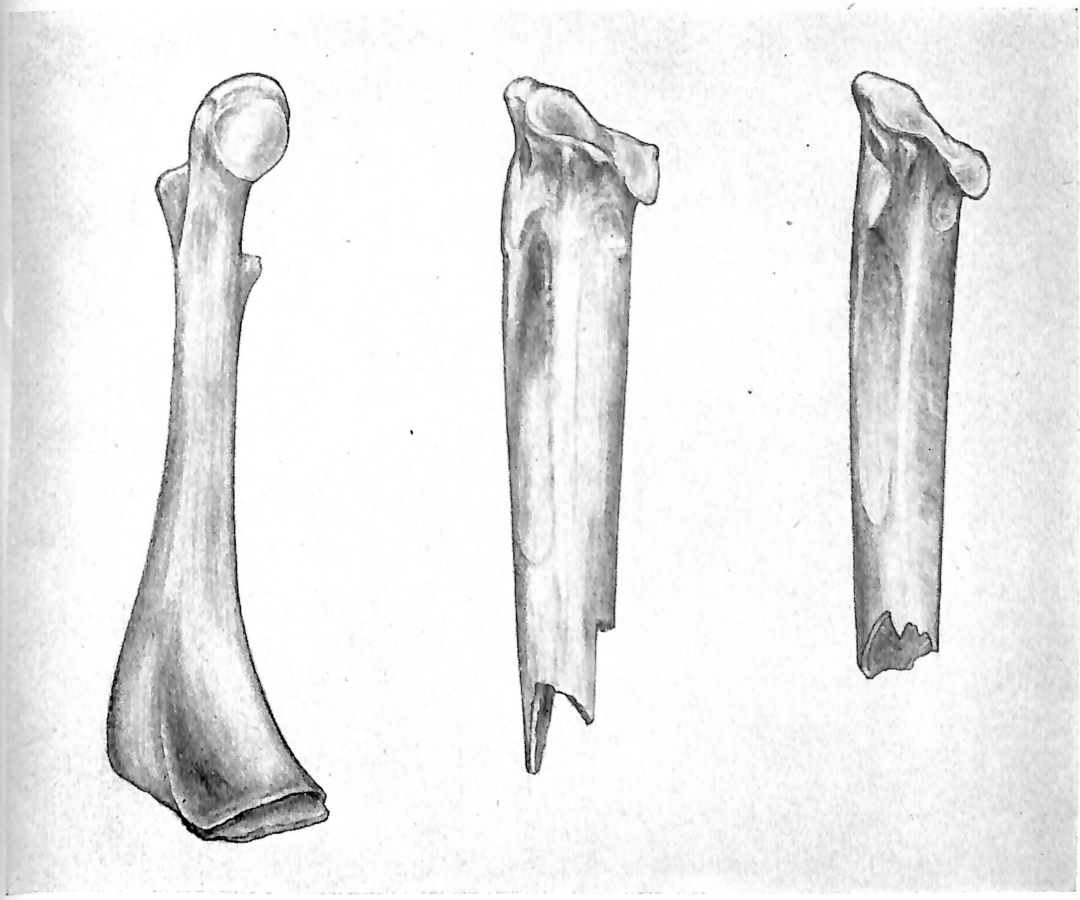
Figure 7. *Morus peninsularis* n. sp. No. 148, type. Internal view of coracoid.

Figure 8. *Sula guano* n. sp. No. 301, type. Internal view of coracoid.

Figure 9. *Sula phosphata* n. sp. No. 302, type. Internal view of coracoid.

All figures approximately X 1⅔.

## Plate 3

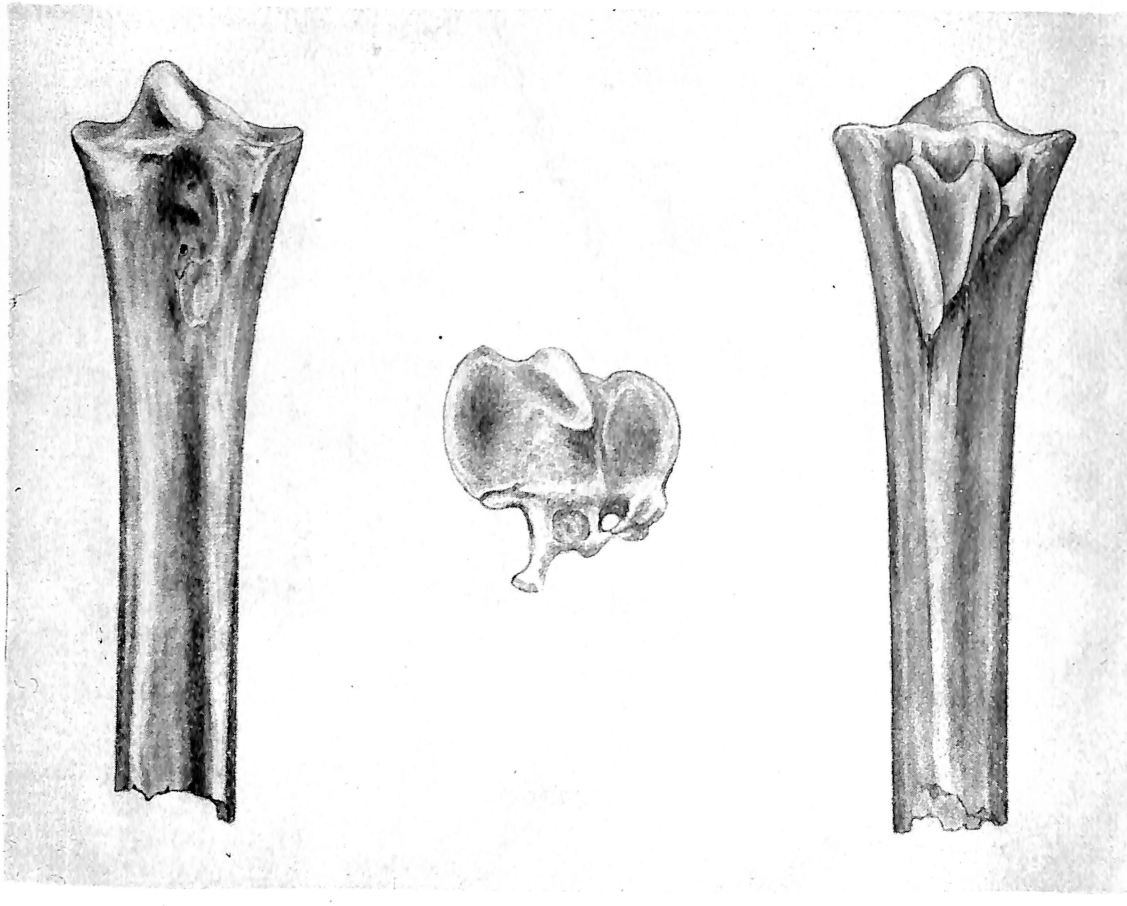


10 12 11

Explanation of Plate 3

Figure 10. *Phalacrocorax wetmorei* n. sp. No. 530, type. Coracoid.
Figure 11. *Phalacrocorax wetmorei* n. sp. No. 124. Ulna.
Figure 12. *Phalacrocorax idahensis* (Marsh). No. 311. Ulna.
All figures approximately X 1½.

## Plate 4



13 14 15

Explanation of Plate 4

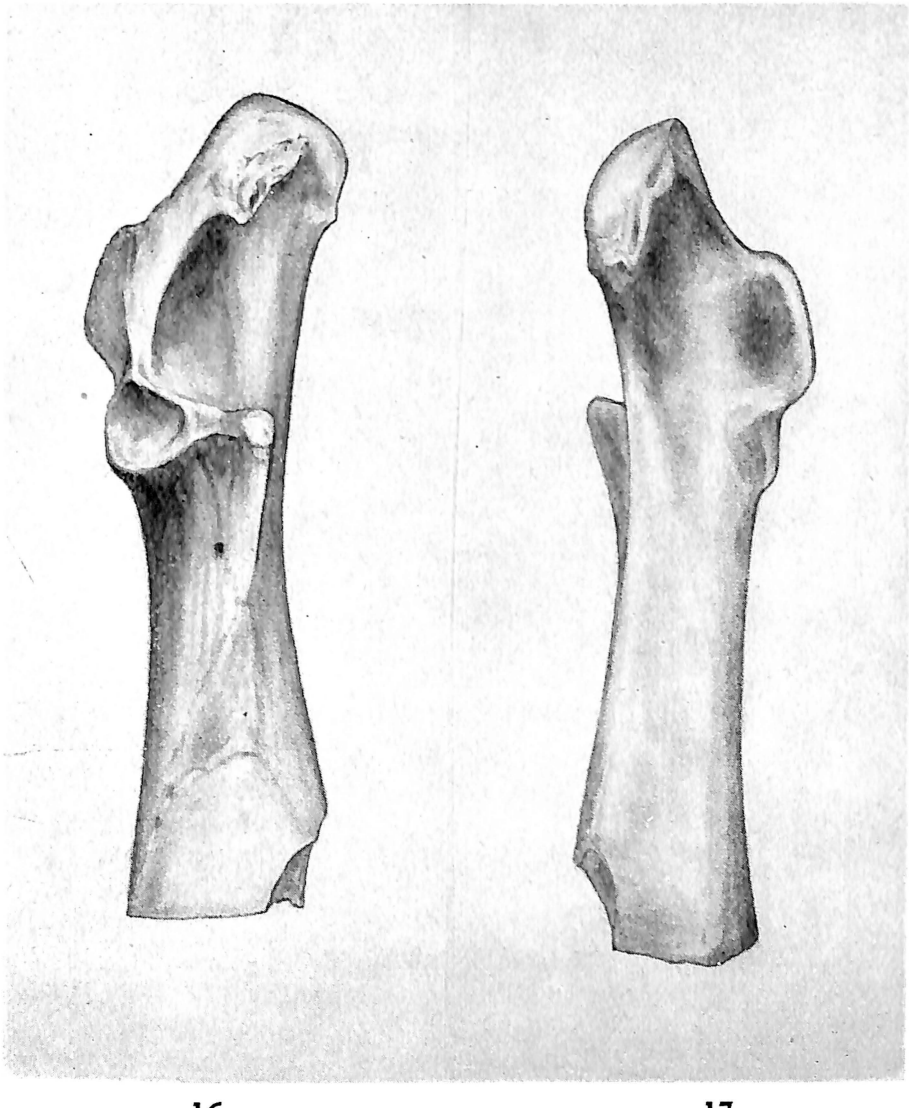
Figure 13. *Ardea polkensis* n. sp. No. 308, type. Anterior view of tarsometatarsus.

Figure 14. *Ardea polkensis* n. sp. No. 308, type. Proximal view of tarsometatarsus.

Figure 15. *Ardea polkensis* n. sp. No. 308, type. Posterior view of tarsometatarsus.

All figures approximately X 2.

## Plate 5



16 17

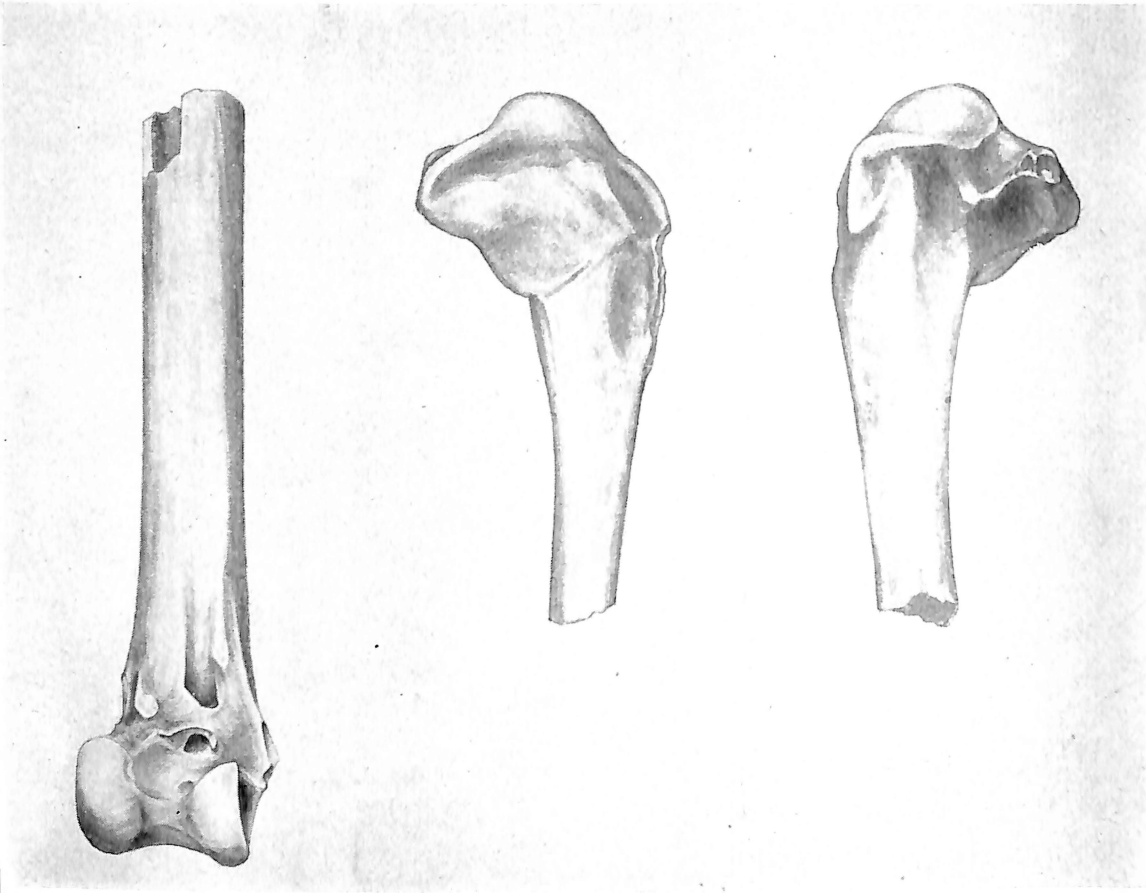
Explanation of Plate 5

Figure 16. *Bucephala ossivallis* n. sp. No. 172, type. Internal view of coracoid.

Figure 17. *Bucephala ossivallis* n. sp. No. 172, type. External view of coracoid.

All figures approximately X 4.

## Plate 6



18 19 20

Explanation of Plate 6

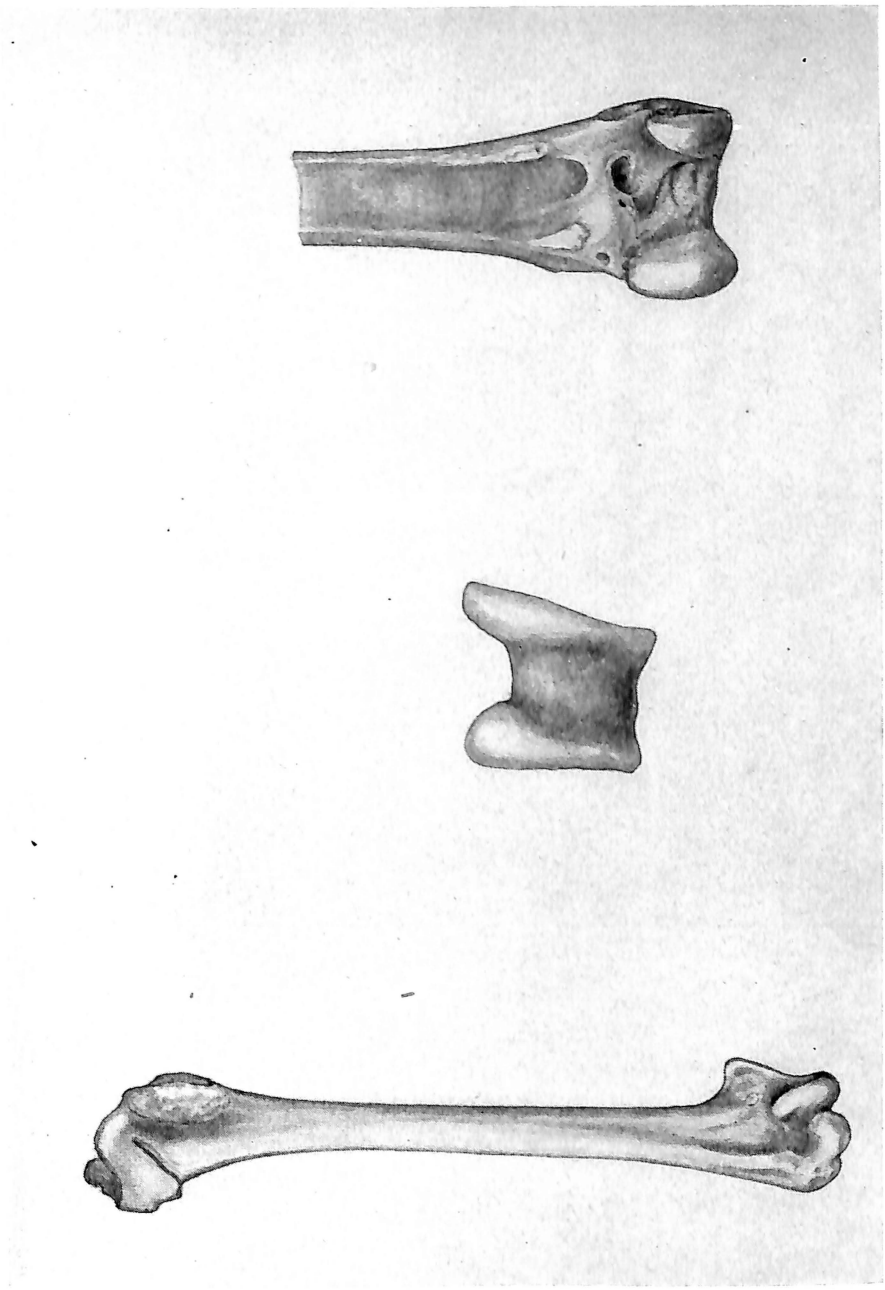
Figure 18. *Palostralegus sulcatus* n. g. et sp. No. 177, type. Tibiotarsus.

Figure 19. *Calidris pacis* n. sp. No. 594, type. Palmar view of humerus.

Figure 20. *Calidris pacis* n. sp. No. 594, type. Anconal view of humerus.

All figures approximately X 3.

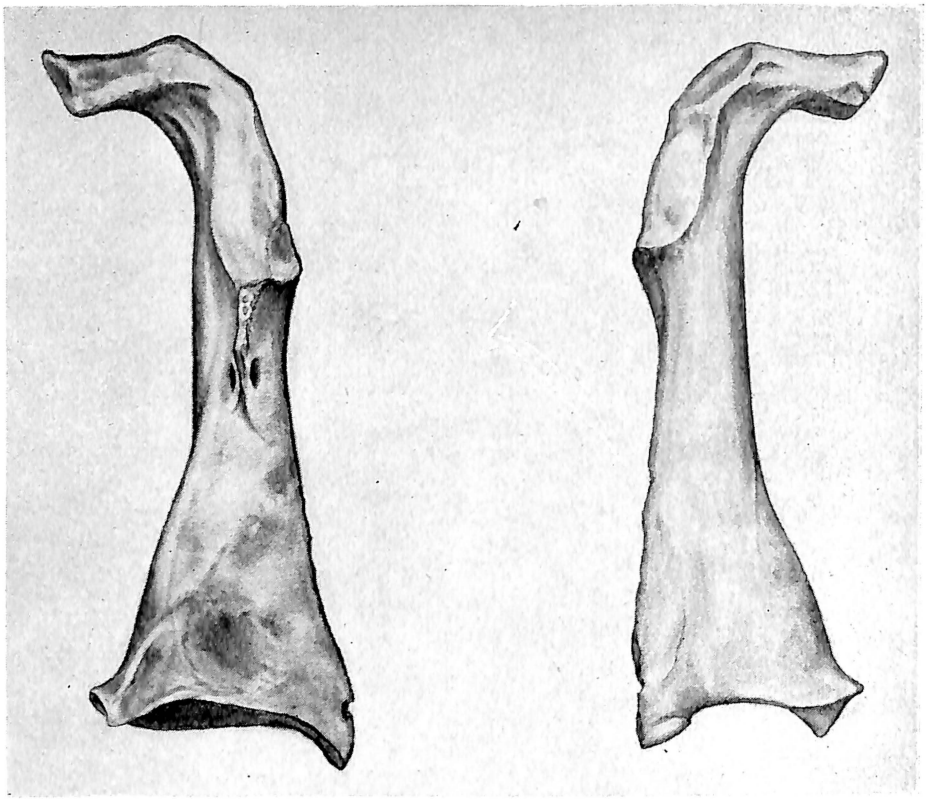
Plate 7




Explanation of Plate 7

Figure 21. *Erolia penepusilla* n. sp. No. 611, type. Humerus.
Figure 22. *Limosa* sp. No. 526. Distal view of tibiotarsus.
Figure 23. *Limosa* sp. No. 526. Anterior view of tibiotarsus.
All figures approximately X 4.

## Plate 8



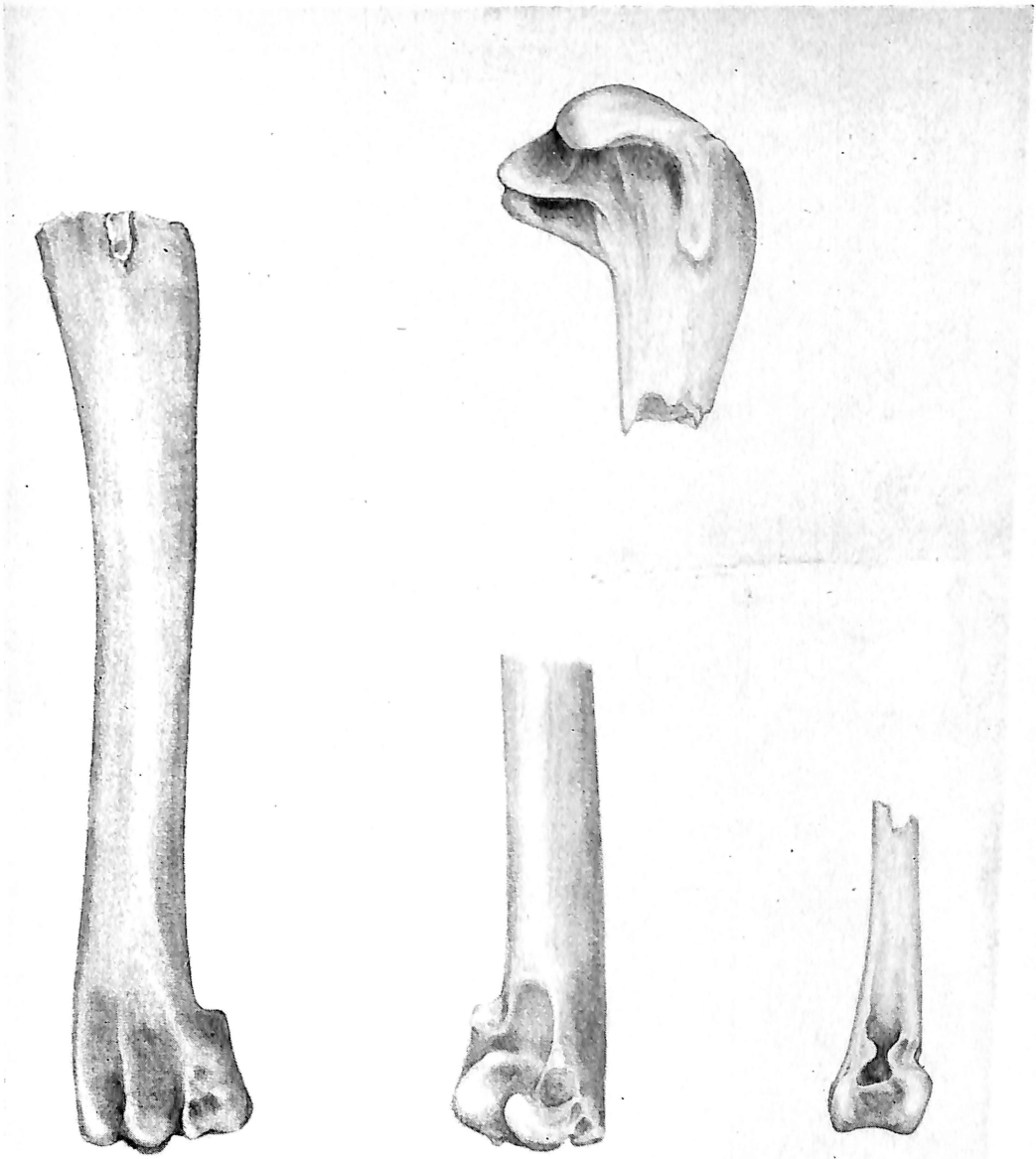
24 25

Explanation of Plate 8

Figure 24. *Australca grandis* n. g. et sp. No. 141, type. Internal view of coracoid.

Figure 25 *Australca grandis* n. g. et sp. No. 141, type. External view of coracoid.

All figures approximately X 2.



27 26 28 29

Explanation of Plate 9

Figure 26. *Australca grandis* n. g. et sp. No. 310. Anconal view of humerus.

Figure 27. *Australca grandis* n. g. et sp. No. 304. Anconal view of humerus.

Figure 28. *Australca grandis* n. g. et sp. No. 304. Palmar view of humerus.

Figure 29. *Australca grandis* n. g. et sp. No. 612. Tibiotarsus.

All figures approximately X 2.

## Plate 10



Explanation of Plate 10

Figures 30-31. Bird bones in rookery key, Cuthbert Lake, Everglades National Park. Figure 30 is at the top.

## Plate 11



Explanation of Plate 11

Figure 32. Bird bones in rookery key, Cuthbert Lake, Everglades National Park.

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