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RESULTS OF THE DOUGLAS BURDEN EXPEDITION TO THE ISLAND OF KOMODO

I.—NOTES ON *VARANUS KOMODOENSIS*^{1, 2}

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The following notes concerning the giant lizard of Komodo relate to the size attained, to the range, to its relationship to other living species, to its relationship to the various described varanid fossils, and to the problem presented by the known facts.

Varanus komodoensis was described by Ouwens in 1912. His material consisted of five specimens, all from Komodo, none of which were apparently sexed. The total length of these five measured 2.9 m., 2.35 m., 2.2 m., 1 m., 1 m., respectively. The largest may be taken as the type of the species; it is at present mounted in the Museum at Buitenzorg.

De Rooij described a specimen, sex not mentioned, from Labuan Badjo on the west coast of Flores, in 1915. This specimen measured 2.66 m.

The Duke of Mecklenburg in 1923 collected four specimens on Komodo. Of these, three are in the Museum at Buitenzorg and were seen by me, while the fourth is in the Berlin Museum. None of these has the data concerning the sex. The three in Buitenzorg are under 2.5 m. The Berlin specimen, according to the authorities in Buitenzorg, is under 3 m.

Horst (1926) shot a specimen on Rinja, which was just under 2 m.

While a member of the Douglas Burden Expedition to the Island of Komodo in 1926, I had the opportunity to take measurements and sex data on a number of individuals. I saw also a number whose lengths I am sure I did not underestimate. This material consisted of 17 whose sex I could determine, of 10 additional which I could measure, of 2 skeletons found in an abandoned native trap whose lengths I could

¹Contributions from the Department of Zoölogy, Smith College, No. 143.

²The Douglas Burden Expedition to the Island of Komodo obtained herpetological material from the islands of Pulo Weh, Java, Bali, Lombok, Sumbawa, Komodo, Padar, and Wetar. For the pleasure of accompanying the expedition as zoölogist I am indebted to the leader, Mr. Burden. The herpetological results will be published in four papers, dealing, respectively, with *Varanus komodoensis*, the snakes, the lizards, and the frogs.

estimate, and of 27 specimens seen in the field by me personally which are additional to those already mentioned. I took considerable pains to count the actual number seen by me and to make this number an underestimate. In this way, then, I can assert that I saw on Komodo, in the flesh, at least 54 specimens of *V. komodoensis*. Of these 54, the largest (a male) measured 2765 mm. in total length, the head and body 1380 mm.; the second largest, also a male, measured 2680 mm. in total length, the head and body 1380 mm.; the third largest, not sexed, with broken tail, measured head and body 1355 mm. The larger of the two skeletons had a lower jaw length of 250 mm. The two largest whole specimens had a lower jaw length of 255 mm. These were the four largest specimens to come under my observation.

Of the 17 specimens sexed, the 14 largest were males. Of the 3 females the largest was 6 feet, 6 inches, or under 2 m. One more specimen has been sexed, the larger of two taken to Bima by natives and later sent to Holland. This was a male. The lower jaw measurement given by de Jong (1927) is 210 mm., thus indicating an animal distinctly smaller than either of the two largest ones mentioned above.

Finally, 20 skins were sent in the early days of 1927 by native poachers from Komodo to Macassar. Some of these skins found their way to London where one came under the observation of Lord Rothschild (1927) and three of Mr. Burden. None of those seen were over 2.5 m.

This evidence based on 73 specimens gives no indication that *Varanus komodoensis* reaches a length of over three meters. In fact, the largest actual specimen on record is the type. It indicates that males alone reach great size.

The only evidence on a greater size is contained in the original description among information transmitted to Ouwens by Mr. J. K. van Steyn van Hensbroek. He says that Sergeant Beker shot one 4 m. long on Komodo, and that Messrs. Aldegon and Koch informed him that the former had shot some between six and seven meters in length on Komodo, when they first visited the island. There is absolutely no material evidence to support these statements.

The original description states that the animal is found on Komodo and on the west coast of Flores at Labuan Badjo. Horst (1926) mentions Mboera on the west coast of Flores and gives a definite record for Rinja, an island about the size of Komodo and between it and Flores. The only other island of any size nearby is Padar, between Komodo and Rinja. We saw tracks on the east coast of Padar which were indistinguishable from those seen on Komodo, and the natives of Komodo told us that the

lizards were found there. It is probable that these tracks were those of *komodoensis* and not *salvator* (the only other *Varanus* of the region) since apparently the two do not occur together, at least it is fairly certain that *salvator* does not occur on Komodo, although it is found on Sumbawa to the west and on Flores to the east. Whether the two are found together in Flores, or what the relationships between them when or if they meet, is an interesting question. Horst (1926) says of its range on Flores: "That its range on Flores may have been formerly more extensive (than 'a . . . strikingly small region of the extreme west') is very probable, although the animal is apparently restricted to a particular terrain, as may be deduced from the regions in which it maintains itself at present. This type of country consists of bare rocks and broken ground, grown up with *alang-alang* grass and bushes mingled with open woods and solitary *lontar* palms; although this country in the dry season presents a very barren aspect it is not lacking in game. Especially Komodo and Rinja . . . are rich in game in the form of deer and wild pig."

The relationships of *V. komodoensis* to the living fauna seem fairly simple. Using Boulenger's synopsis and characters (scalation, shape and position of nostril, and shape of tail) *komodoensis* comes nearest to *Varanus varius* of Australia. In scalation it differs from *varius* in having 80-97 ventrals as against 120-130 in *varius* and in having much more enlarged nuchal scales. The proportions are of course different, *varius* being a much slimmer beast with a longer tail, and the coloration, especially of the throat and belly, is different, the black ventral bars of *varius* being wholly absent.

Near also are *giganteus*, *gouldii*, and *boulengeri*, all Australian species. But both *giganteus* and *gouldii* have more ventrals than *varius*, and neither have the large scales on the snout which are so prominent in both *varius* and *komodoensis*. Neither *gouldii* nor *boulengeri* have the terminal nostril which is present in the other three. I have not seen *boulengeri* but the other four all agree in the possession of osteoderms which are commonly supposed to be absent in Varanidæ. These are present in the nuchal scales of both *varius* and *gouldii*, they seem to be all over *giganteus*, and in *komodoensis* there is not only one below each scale, but on the head they form a curious network of anastomosing little bones, more like the skeleton of a starfish than anything else. Perhaps other species of *Varanus* might, on examination, belong with this group, although they form a section in Boulenger's key, but none I have seen do so. While *varius* and *komodoensis* are nearly allied, there is no possibility of per-

forming a dichotomy on the genus, since *Varanus* consists of a rather homogeneous series separated only by minor technical characters, and occasional more peculiar forms, each obviously related to another more normal. Thus *varius* could not be separated from the mass on any pretext, and there is no character whereby *komodoensis* could be removed without taking *varius* with it, save only proportions, which will be discussed below.

Rothschild (1927), on the basis of one of the skins, makes the statement that *komodoensis* is allied to *albogularis* of West Africa, because the two have similar scales. I have not seen *albogularis* but, according to the literature, the two differ in every other character, while, as a matter of fact, the scales of *komodoensis* and *varius* are exactly alike.

The fossils allied to the living genus *Varanus* have been treated by Fejérváry (1918), by Gilmore (1922), and by Camp (1923). These authors allow at least three genera: *Varanus*, *Megalia*, and *Saniwa*. They furthermore allow the other two genera subfamily or family distinction from *Varanus*. Gilmore has found a sufficient difference between the skeleton of the American Eocene *Saniwa ensidens* and that of *Varanus salvator* to regard them as belonging to different genera of the family. In this opinion I am content to follow him, seeing no reason for the erection by Camp of a subfamily Saniwinæ.

The Old World fossils are considered by Fejérváry. He himself had access to little of the material, taking his information from descriptions and figures. I have access to none of it and am compelled to rely almost entirely on Fejérváry's paper. He regards the fossil material as representing two well-established species from Europe, the earlier *cayluxi*, and the later *marathonensis*: one from India, *sivalensis*; and three from Australia, *priscus* (*Megalia*), *dirus*, and *emeritus*. All the Australian fossils are late, probably Pleistocene. The Indian is Pliocene. The dates of the European ones are various, none known with certainty to be earlier than Miocene, the later perhaps persisting until the Neolithic.

Of all these fossils the best preserved portions are the dorsal vertebrae. These immediately range themselves into three classes: (1) those with small condyles and large neural canals; (2) those with larger condyles and narrower neural canals; and (3) those with extremely large condyles and extremely narrow neural canals. To the first category belong *cayluxi*, *sivalensis*, and most of the known modern species. To the second belong *marathonensis* and *komodoensis*. To the third belongs *priscus*. Thus the relationship between height of condyle and diameter of neural canal is $\frac{1}{4}$ in *cayluxi*, $\frac{1}{2}$ in *sivalensis*, $\frac{3}{4}$ in *griseus*, $\frac{5}{8}$ anteriorly

and $\frac{3}{4}$ posteriorly in small *komodoensis*, $\frac{1}{4}$ anteriorly and $\frac{3}{4}$ posteriorly in large *komodoensis*, about $\frac{3}{4}$ in *marathonensis*, and $\frac{1}{4}$ in *priscus*. These figures are an index of the weight and thickness of the osseous growth. They show, as do a number of similar measurements which might be given, that three species of the varanoid group are known to have attained a "chunkiness" or stoutness surpassing that of the ordinary, slim type as exemplified by *varius* or *salvator*. They possibly show relationship between these three species. But here a note of warning must be sounded. I have been able to compare a skeleton of *griseus*, a skull of *salvator*, a skull of *giganteus* (in the Smith College collection and apparently the only specimen of the species outside of Australia except the types in the British Museum), and excellent figures of skulls of *niloticus* and *exanthematicus* (Schmidt, 1919, Figs. 8-10) and there is no indication that weight and thickness of osseous growth is at all correlated with any other skeletal characters, for in practically all points save thickness the skull of *komodoensis* agrees with that of *giganteus*, and the two are opposed to the skulls of *salvator*, *griseus*, *niloticus*, and *exanthematicus*, although there is ample difference between all these forms. *Komodoensis* differs from all in the extreme length of the paroccipital processes, but *giganteus*, while nearer the rest in this respect, is intermediate. Correlated with this, the dentary portion of the lower jaw is only three-fourths the length of the angular portion in *komodoensis* and *giganteus*, while in the others examined the dentary part is as long or longer than the angular part. In the SHAPE of a great many bones, irrespective of their thickness, there is greater agreement between *komodoensis* and *giganteus*, such as the flange on the proötic process of the paroccipital, the parietal, the posterior end of the nasal, the anterior end of the frontal, the maxilla, the pterygoid, the palatine, the transverse, and all the bones of the lower jaw.

One is led to conclude from this that the thickness of the bones rather obscures than illuminates the true relationships and that shape rather than size should be considered.

Another way of considering the vertebræ is the relation of width to length. They are all wider than long, but the length is .7 per cent of the width in *cayluxi*, .71-.76 per cent in *griseus*, .531 per cent in *marathonensis*, .545-.578 per cent in old and .6 in young *komodoensis*, .54 per cent in *niloticus*, .487 per cent in *sivalensis*, and .3-.357 per cent in *priscus*, thus giving a totally different arrangement of the forms. But here both *cayluxi* and *sivalensis*, which are almost at the extremes, have nearly cylindrical centra with no obvious precondylar constriction and thus differ markedly from the majority of the species (resembling the Ameri-

can fossil *Saniwa ensidens*). The relative broadness of the vertebra of *sivalensis* is caused not by shortening of the centra but by the great development of the transverse processes, in which character it stands alone. A proper arrangement of these vertebræ would place *cayluxi* at the base of the series with *griseus* next. *Sivalensis* would appear as an aberrant offshoot, while *marathonensis*, *niloticus*, and *komodoensis* are more or less alike and stand between *griseus* and *priscus*. Adult *komodoensis* has rudimentary zygosphenes, thus approaching *priscus*. Other species lack them.

In other skeletal features material is scantier and even less conclusive. The femur of *cayluxi* offers no characters which I can use. The limb bones in general offer fewer characters in *komodoensis* which can be disassociated from size and thickness than do the skull and the vertebræ. The maxilla of *marathonensis* seems to have more vertical sides and thus approaches *griseus* rather than *komodoensis*. The humerus of *sivalensis* is smaller than that of large *komodoensis* (distal end 60 mm. wide as against 70 mm. in *komodoensis*). The width of the combined ulnar and radial condyles is much greater in *komodoensis* (45 mm. as against 31 in *sivalensis*). The figure, however, gives the impression that the humerus of *sivalensis* is a longer and slimmer bone, and does not have the hourglass shape seen in *komodoensis* and present to an even greater extent in *priscus*. Thus a humerus of *priscus* measures 170 mm. in length, breadth at distal end 106 mm., breadth of shaft 32 mm. The same measurements in *komodoensis* are 150 mm., 70 mm., and 20 mm., so that the humerus of *komodoensis* measures seven times the least breadth of the shaft and that of *priscus* five times. *Priscus* is said to have a humerus three times as long and 4.5 times as broad as that of *varius*. *Komodoensis* would then have a humerus 2.6 times as long and 3 times as broad as *varius*, and would be intermediate between the two. The humerus of *sivalensis* would probably have been nearer that of *varius*, and might have measured on that basis 146 mm. and thus nearly as long as that of *komodoensis*. The ulnar condyle is about twice as wide as the radial condyle in *komodoensis* and is quite flat, thus differing from that of *sivalensis*, where the radial condyle is nearly as wide as the ulnar and distinctly rounded. De Vis (1889) says of the humerus of *emeritus*: "affinities with *V. varius* in the prominence and length of its supinator ridge, but with *gouldii*, *punctatus*, etc., in the distinct rotundity of its ulnar condyle and relatively increased prominence of the radial." In both these characters *komodoensis* agrees with *varius* as against *sivalensis*, *emeritus*, *gouldii*, and *punctatus*.

De Vis further describes a tibia of *emeritus* as having certain characters of *varius* and others of *gouldii*. The *varius* characters are quite noticeable in the tibia of *komodoensis*, but not the *gouldii* characters.

The ulna of *priscus* is described and figured by de Vis. The length was 258 mm., and the breadth at the proximal end was 72 mm. The same measurements in a large *komodoensis* are 163 mm. and 30 mm. As in the humerus the relation of length to breadth is less in *priscus* (3.58) than in *komodoensis* (5.4). *Varius* has an ulna almost like *komodoensis*, as the same relationship in it is 5.37. Furthermore, de Vis mentions several features in which the ulnas of *priscus* and *varius* resemble each other, and all these features are found in *komodoensis*. Finally, there are the skull fragments attributed to *priscus* and to *dirus*.

Dirus was based on a single tooth whose figure resembles that of *komodoensis* very accurately. It seems to have had fewer ribs and to have been flatter. It is somewhat larger, 17×8 mm., while a tooth of a large *komodoensis* measures 14×7 mm. This tooth of *dirus* was three times the size of a tooth of a five-foot four-inch *V. varius*, and hence the animal was assumed by de Vis to have been 16 feet long, but the *komodoensis* was certainly not over nine feet in length, and if *dirus* had similar proportions it would have been under eleven feet long.

A jaw, referred to *dirus* by de Vis and somewhat questioned by Fejérváry, has teeth which show a more sigmoid flexure than obtains in either the first type tooth of *dirus* or in the teeth of *komodoensis*. It shows a character in the maxilla which I have seen elsewhere only in *komodoensis*, and this is the development of a wide alveolar surface. The prefrontal process is much more developed, however, and the two are certainly not conspecific. The teeth are proportionally much larger (one-third again as large in a jaw of the same size) but *komodoensis* has much larger teeth than *giganteus* of similar size.

The dentary fragment of *priscus* is from the anterior region and differs markedly from *komodoensis* in its very narrow alveolar surface. It presents the remarkable combination of teeth nearly twice the size (15 mm. in width at the base, 9 mm. in *komodoensis*) in a dentary which is indeed thicker but of no greater height, so that the bone seems too weak to have borne such teeth. This is the most puzzling feature presented by the remains of *priscus*.

The base of the skull of *priscus* offers a few characters for comparison: there is a strong ascending process on the supraoccipital, which is much more nearly approached by *giganteus* and by *komodoensis* than by *salvator*; the condyle of *priscus* is much wider than the foramen magnum,

and this condition is somewhat present in *komodoensis*; the foramen width enters the condyle width 1.78 times in *priscus*, 1.5 times in large and 1.3 times in small *komodoensis*, 1.05 times in *salvator*, and 1.02 times in *giganteus*. This again is a matter of the weight and thickness of ossification, and, as in the relation of condyle to nearal canal, *komodoensis* is intermediate between normal forms of the genus and the very heavily built *priscus*.

An illustration of the way in which this weight of bone increases in *komodoensis* with age is seen in the frontal. Here in small specimens the height of the nerve canal is 3.5 mm., and the thickness of the overlying bone is 4 mm. In large ones the canal measures 4 mm., and the bony roof is 9.5 mm. thick.

Of the fossil species *sivalensis* has such different proportions from *komodoensis* that Lydekker's comparison with *salvator* and estimation of eleven feet may be accepted as correct. *Emeritus* seems to have been slim like *varius*, but half again as long. This might make a lizard ten to twelve feet in length. The maxilla referred to *dirus* is decidedly smaller than that of adult *komodoensis*, although the type tooth is larger. The maxilla is no longer than that of a six-foot six-inch *komodoensis*, but the teeth are about one-third again as large, thus forming an intermediate in this respect between *komodoensis* and *priscus*, and leading one to suppose that *dirus* was not as large as *komodoensis*. A *komodoensis* maxilla the same length as that of *giganteus* has much larger teeth.

On the basis of the vertebræ and assuming similar proportions, *marathonensis* was two-thirds the size of *komodoensis*. *Priscus*, on the other hand, was one-third or two-fifths larger, and on the basis of the vertebræ would have been 15 feet long. On the basis of the ulna, the longest preserved limb bone of *priscus*, that animal would have been fourteen and a half feet long. It was much more heavily built and must have been almost *Phrynosoma*-like in proportions.

CONCLUSIONS.

1. *Varanus komodoensis* is not known to reach a greater length than three meters.
2. Since only males are known to reach over two meters, the chances of a greater length than three meters being attained are small.
3. Of living species, *Varanus varius* of Australia is the most similar.
4. Among the Old World Miocene-Pleistocene fossils, there is similarity in one or another character with *marathonensis*, *dirus*, *emeritus*, and *priscus*. Described and figured remains indicate that *komodoensis* is conspecific with none of these, and definite similarity in characters other than those of weight of vertebræ is only indicated with the last three.

5. Of the fossils, the slimmer *sivalensis* and *emeritus* may have been ten to twelve feet in length. *Dirus* was probably smaller than *komodoensis*; *marathonensis* was about six feet long; *priscus*, which compared to *salvator*, has an estimated length of thirty feet, has, when the more proper comparison to *komodoensis* is made, a length of not more than fifteen feet.

6. Since, in regard to relative tooth size *komodoensis* forms a transition between the normal *giganteus* and the large-toothed *dirus* and *priscus*, and in regard to relative size of neural canal it and *marathonensis* form a transition between the normal type and the very heavy *priscus*, I am disinclined to regard *priscus* as having characters which necessitate generic and much less family distinction. Since the characters on which Camp considers *Saniwa* as of a different subfamily are vertebral and are solely proportional, I prefer to consider it merely generically distinct from *Varanus* on the basis of the characters pointed out by Gilmore.

7. I regard the osseous development of *marathonensis*, *komodoensis*, and *priscus* as extremely possible of independent origin. I therefore place no stress on a possible relationship to *marathonensis* where there are no other similar characters. This does not hold true for *priscus* nor for *dirus*. I regard *komodoensis* as definitely an Australian type derived from an animal much like *varius* and intermediate between it and the two Australian fossil forms.

8. The significance of the preceding conclusions may be expressed as follows: from an ordinary varanoid stock either larger and similar or larger and heavier forms may be produced under certain circumstances. These circumstances obtained in the Pleistocene in Australia. *Varanus komodoensis*, a modern offshoot from an Australian stock, now exists in a certain restricted region in the Lesser Sunda Islands. The Australian element in this region seems to be a reëntrant from the Australian center of evolution (cf. *Cuscus*, a Diprotodont Marsupial, and hence probably a reëntrant, for if a relict from the movement of the early Marsupials into Australia were left in the Lesser Sundas, it would be one of the more primitive Polyprotodonts). Whether *komodoensis* arrived in Komodo in its present state of development and by what route it arrived at its present range are two unanswerable questions. The picture of evolution which presents itself to my own mind is one of ordinary lizards, in arid country, and free from competition from the higher mammals (Australia in the pre-*Homo sapiens*, pre-*Canis dingo* days), becoming large carnivores or perhaps carrion feeders. One of these, or one of the yet undifferentiated members of the same stock possessing the same potentialities of development, arrived by unknown means in the Lesser Sundas and met the vanguard of the Placentals (Herbivores, as yet, and still, unaccompanied by the higher and larger Carnivores, and as yet unfollowed by man). Here, these Australian emigrants persisted or developed, and here, in the same or in a latterly more restricted range, they can still be found.

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