summers of 1925 and 1926. There is the distinct probability that the narrow growth zones in the midlife of the bullsnake represent a crisis of some kind. A logical deduction is that the crisis was a shortage of animal food brought on by a combination of severe, drouthstricken summers which had a cumulative effect on the food supply in 1925 and especially in 1926. Also, excessive heat and aridity may have severely limited foraging activities of the usually *diurnal bullsnake. Thus a climatic crisis was brought to bear on the bullsnake primarily by affecting the food chain, specifically the rodent prey, e.g., *Microtus,* dependent upon summer vegetation, both wild and cultivated, and by affecting foraging activity. The combination of an unusually narrow, growth zone followed by a still narrower growth zone suggests that the possibility of disease or bodily injury might be considered, but the skeleton appears to have no abnormalities except for the evidence of the growth zones. It seems most likely that the deficiency in growth is a simple reflection of accumulative effects initiated by drouth conditions.

Clearly the annular zones seen in section do not lend themselves to discrete recordings of interrupted summer growth as do the growth zones appearing on the surface of the skull bones. Apparently the zones in section are too small and compact for reliable graphic illustration of interrupted summer growth, at least in the specimen at hand. Possibly a deficient growth period in the maxillary resulted in complete or nearly complete failure to form a new lamina of osteocytes. There seems to be no way to detect on such a small scale as the cross section of maxillary and dentary the growth record literally stretched out on flat bones of the skull. However, studies in progress indicate that the dentary of reptiles usually is the most consistent in preserving annual zones.

* Described by Smith (1950, p. 242) as a diurnal species. According to H. S. Fitch (personal communication) the species is largely crepuscular; therefore, the point made here is dubious.

It is concluded that the growth zones in the squamosal and ectopterygoid of the bullsnake are excellent indicators of age, and in this instance, also record faithfully a time of crisis in the life of the bullsnake occasioned probably by the severe drouth in Kansas in the summers of 1924, 1925 and 1926. Also there is the clear indication that annual growth zones may be developed in bones of the skeleton other than those exhibiting zones on the surface. These conclusions suggest interesting lines of study in the ecology of terrestrial poikilotherms, especially of the Great Plains. In this connection, discovery of annual zones in Pleistocene poikilotherms may be possible and highly informative. Current studies by myself reveal the occurrence of excellent annual zones in the dentaries of Australian lizards found in cave deposits of Pleistocene to Recent age.

Misses Hermine Newcombe and Madeline Peabody gave much appreciated assistance in the preparation of the manuscript and illustrations. Dr. Henry S. Fitch of the University of Kansas Natural History Reservation provided a helpful, critical reading of the manuscript.

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Pleistocene Lizards of the Cragin Quarry Fauna of Meade County, Kansas

Richard Etheridge

Many important contributions to our knowledge of Pleistocene paleoecology and zoogeography of the Great Plains have been made by studies of vertebrate faunas recovered in southwestern Kansas and northwestern Oklahoma. The recovery and analysis of these faunas are due largely to the efforts of Dr. Claude W. Hibbard and summer field parties of the University of Michigan Museum of Paleontology. Most of the faunas are predominantly mammalian. No lizard remains have yet been recovered from any of those faunas which have been tentatively correlated with glacial advances (e.g. Dixon, Cudahay, Berends, Butler Springs, Jones, etc.). On the other hand, those faunas that have been correlated with the last two interglacial ages all contain at least some lizard remains. The Borcherds fauna (Yarmouth) lizards have not yet been carefully studied but appear to be predominately or entirely of the family Scincidae. From the Jinglebob fauna (Sangamon), Tihen (1954) has recorded *Holbrookia*, *Sceloporus* and *Eumeces*. Lizards from the Cragin Quarry fauna discussed in this report represent the largest Pleistocene lizard fauna yet recovered from southwestern Kansas. This fauna contains the same number of species that occur in that area today.

The Cragin Quarry lizards were collected during the summers of 1954, 1955 and 1956 by the University of Michigan Museum of Paleontology field party under the direction of Dr. Claude W. Hibbard. About 16 tons of matrix from the Cragin Quarry and one third of a ton from Mount Scott (Cragin Quarry horizon) were washed, using the techniques described by Hibbard (1949). Nearly 100 fragments of fossil lizards were recovered.

Cragin Quarry is located on the Big Springs Ranch in the southwestern quarter of section 17, T. 32 S., R. 28 W., 4 miles southwest of Meade, Meade County, Kansas. Mount Scott is about one-half mile south-southwest of Cragin Quarry in the southeastern quarter of section 18, T. 32 S., R. 28 W. The single fossil reported here from Mount Scott is from the Cragin Quarry horizon of that exposure. The matrix consists of silty and sandy clays deposited by a late Pleistocene stream that flowed into the early Cimarron River. The Cragin Quarry fauna is considered as occurring in the upper part of the Kingsdown formation, referred to the Sangamon interglacial of the Pleistocene. A discussion of the stratigraphic position of these deposits, in relation to the stratigraphic terms used by other authors, together with a survey of the history of collecting at this site, has been presented by Hibbard (1955: 189–90).

Lizard remains from the Cragin Quarry include vertebrae, limb bones, pelves, scapulocoracoids, dentaries, maxillaries, frontals, squamosals and parietals. All specimens are in the University of Michigan Museum of Paleontology (UMMP). Identifications are based on comparisons of the fossil remains with skeletons of recent North American lizards. Skeletons representing 28 genera and 61 species were examined during this study. Also available were topotypes of the five extinct lizards described by Talyor (1941) from the Rexroad fauna (Upper Pliocene) of Kansas. The nomenclature used is that of Schmidt (1953).

I am indebted to Claude W. Hibbard of the University of Michigan Museum of Paleontology for the privilege of studying these fossils and for permission to offer this report for publication, Dr. Hibbard has generously made available other fossil lizard material from the Museum of Paleontology collections for comparison with the Cragin Quarry fossils, and has offered valuable suggestions during the course of this study. I am grateful to Norman E. Hartweg of the University of Michigan Museum of Zoology for permission to use the extensive collection of recent lizard skeletons in the Division of Herpetology, and for his assistance in the preparation of this work for publication. I also wish to thank John Legler of the University of Kansas Museum of Natural History for the loan of recent *Cnemidophorus* skeletons, Bayard H. Brattstrom of Adelphi College for providing me with information concerning a specimen in the United States National Museum, and Ralph Axtell of the University of Texas for his helpful correspondence concerning the comparative osteology of *Holbrookia* and *Uma*.

IGUANIDAE

Crotaphytus collaris Say

The modern genus *Crotaphytus* contains five species, of which two are known as Pleistocene fossils. *Gambelia wislizeni* (= *Crotaphytus wislizeni*) is known from the McKittrick Pits of Kern County, California (Brattstrom, 1953) and *Crotaphytus collaris* is known from Gypsum Cave of Clark County, Nevada (Brattstrom, 1954). Gilmore (1928) provisionally referred the median portion of a left dentary from the Pliocene Benson funa of Arizona to the genus *Crotaphytus*. The description and figure of this specimen given by Gilmore indicates that the fragment should not be referred to this genus or even to the family Iguanidae. The fragment was described as having 10 pleurodont teeth which are subcylindric with slightly compressed crowns, anterior teeth simple and sharply pointed; median teeth unequally bicuspid; teeth inclined slightly backward. Iguanid lizards never have a long series of bicuspid teeth, the anterior simple series being followed immediately by tricuspid or multicuspid teeth or occasionally with one or two bicuspid teeth between the two series. The specimen may well be referrable to the teiid genus *Cnemidophorus* in which many species have a long series of bicuspid teeth. Brattstrom (*in litt.*) has informed me that the specimen (USNM 10690) is labeled *Cnemidophorus* and that he agrees with this determination.

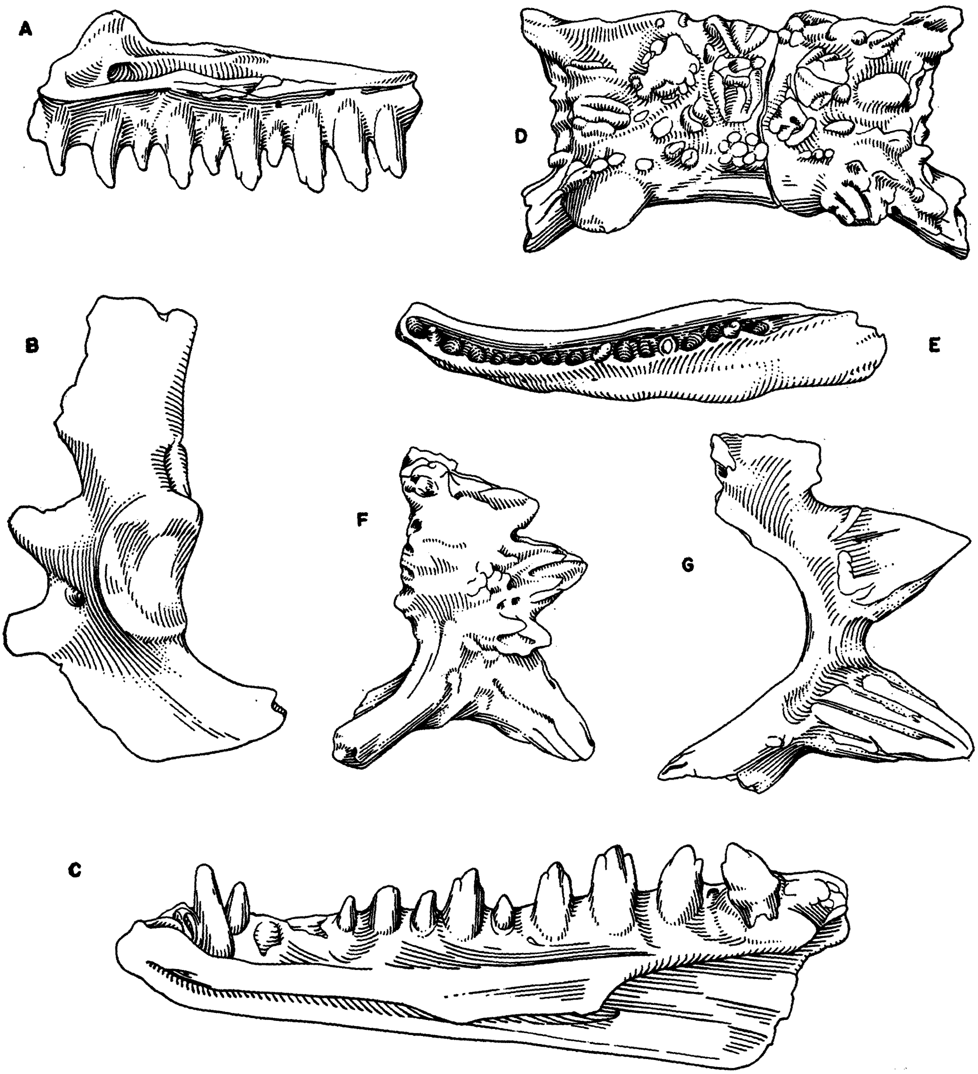

Fig. 1. Fossil remains of *Crotaphytus* and *Phrynosoma*. A, mesial view of a right maxillary of *Crotaphytus collaris* (UMMP No. 34132). B, right scapulacoracoid of *Crotaphytus collaris* (UMMP No. 33833). C, mesial view of right dentary of *Crotaphytus collaris* (UMMP No. 34138). D, dorsal view of parietal of *Phrynosoma modestum* (UMMP No. 33827). E, dorsal view of left dentary of *Phrynosoma modestum* (UMMP No. 34146). F, squamosal of *Phrynosoma modestum* (UMMP No. 34141). G, squamosal of *Phrynosoma cornutum* (UMMP No. 34126). A, C and E times 8; B, D, F and G times 12. Illustrations are by Mrs. Bonnie Hall.

Among the fossils from the Cragin Quarry are three maxillaries, seven dentaries, two scapulacoracoids, one vertebra and one pelvis of *Crotaphytus collaris* (Fig. 1). These fossils have been compared with modern skeletons of *C. wislizeni, C. collaris,* and *C. reticulatus.* The dentary of *C. wislizeni* differs from that of *C. collaris* in being generally more slender, having the mental foramina more widely separated, in having the last mental foramen below the 14th tooth, in lacking the terminal expansion of the anterior part of the element, and in having the Meckelian groove closed anterior to the splenial for a space of about seven teeth. The teeth of *C. wislizeni* are slenderer, longer and more widely separated at their tips and the tricuspid teeth are transversely compressed at their bases instead of being round as is *C. collaris.* The dentary of *C. reticulatus* is more like that of *C. collaris* but differs in having the Mackelian groove closed anterior to the splenial for a space of about four teeth and in having only three mental foramina. The maxillary of *C. collaris* differs from that of *C. wislizeni* in that the premaxillary process is longer and heavier, the anterior border of the nasal process rises at a more acute angle from the premaxillary process, the dorsal border of the posterior process is not as strongly concave, the labial foramina are closer together and the teeth are shorter, closer together, more robust and not so sharply pointed nor transversely compressed at their bases. The postcranial elements of the three species are nearly identical. In those skeletal elements which are different in the three species, the fossils are clearly referrable to *C. collaris.* In view of this and the fact that the ranges of *C. reticulatus* and *C. wislizeni* are far removed from the Cragin Quarry site, all of the fossil specimens of *Crotaphytus,* both cranial and postcranial elements, are referred to the species *C. collaris.*

Referred Material: dentaries UMMP 34129, 33831, 34138, 34135, 34137, 34134 and 34122; maxillaries UMMP 34133, 34130 and 34132; scapulacoracoids UMMP 33833 and 34129; pelvis UMMP 33828; dorsal vertebra UMMP 34139.

Phrynosoma modestum Girard

Three extant species of this genus have been reported as fossils. *Phrynosoma orbiculare* is known from the Late Pleistocene of San Josecito Cavern, Mexico (Brattstrom, 1955b); *P. platyrhinos* from the Pleistocene of Gypsum Cave, Nevada (Brattstrom, 1954); *P. cornutum* from the Upper Pliocene of the Rexroad fauna, Kansas (Oelrich, 1954) and from the Late Pleistocene of Newton County, Arkansas (Gilmore, 1928). A single extinct form has been described, *Phrynosoma josecitensis* from San Josecito Cavern (Brattstrom, 1955b).

The Cragin Quarry fossils referred to this species (Fig. 1.) have been compared with recent skeletons of *P. modestum, P. cornutum, P. douglassi, P. platyrinos and P. coronatum.* The number, position and size of the head spines and the sculpturing on the lower jaw is usually reflected by underlying elements of the skull so that most cranial elements may be identified to species. The dentary of *P. modestum* differs from those of the other forms examined in many respects, the most striking of which is the greatly expanded and scalloped ventrolateral margin. With respect to this character, as near as it is possible to tell from an examination of the external aspect of the lower jaw, *P. modestum* differs from all other species in the genus. The maxillary of *P. modestum* is distinguished by well developed rugosities at the base of the anterior border of the nasal process and by the relatively smaller size of the anterior inferior alveolar foramina. The squamosal of *P. modestum* may be readily distinguished from those of other species by the size and position of the temporal spines. These spines are small, wide at their bases and pointed. Those of *P. douglassi* are smaller, rounded and more widely spaced; those of *P. cornutum* are much longer and more sharply pointed. In *P. modestum* the anterior spine is smallest and laterally directed, the central spine is intermediate in size and posteriolaterally directed, and the posterior spine is largest and directed caudad. The parietal of *P. modestum* differs from that of *P. cornutum* in having dorsal rugosities that are more numerous, and less sharply pointed, in having much shorter parietal spines, and in having on the posterior border well developed recesses which receive the spinalis dorsi muscles. The parietal of *P. modestum* differs from that of *P. douglassi* in having dorsal rugosities and shorter, heavier posteriolateral processes.

Referred Material: dentaries UMMP 34146 and 34145; parietal UMMP 33827; maxillaries UMMP 34144 and 34143; squamosals UMMP 34140, 34141 and 34142.

Phrynosoma cornutum Harlan

A single right squamosal from the Cragin Quarry is referred to this species. The temporal spines are large, pointed and directed more or less laterally. The central spine is the longest.

Referred Material: squamosal UMMP 34126.

Several dorsal vertebrae and a single sacrum from Cragin Quarry belong to the genus *Phrynosoma*. These elements are so similar in the species examined that I am unable to determine the species to which they belong.

Holbrookia cf. texana Troschel

A single maxillary from the Jinglebob fauna of Kansas (Pleistocene, Sangamon interglacial) has been questionably referred to *Holbrookia* by Tihen (1954). There are no other records of this genus in fossil form.

Ten dentaries, three maxillaries, three frontals and two pelves from Cragin Quarry are referred to *Holbrookia* and tentatively to the species *texana* (Fig. 2). Dentaries and maxillaries of *Holbrookia* may be distinguished from most other North American iguanids by their teeth. These elements most nearly resemble those of *Uma and Sceloporus*. The posterior dorsolateral face of the dentary (where the adductor mandibularis is attached) of *Holbrookia* is convex but flat or slightly concave in *Sceloporus*. The maxillaries of these two genera differ in that the lateral face of the posterior process ascends more steeply from the alveo-

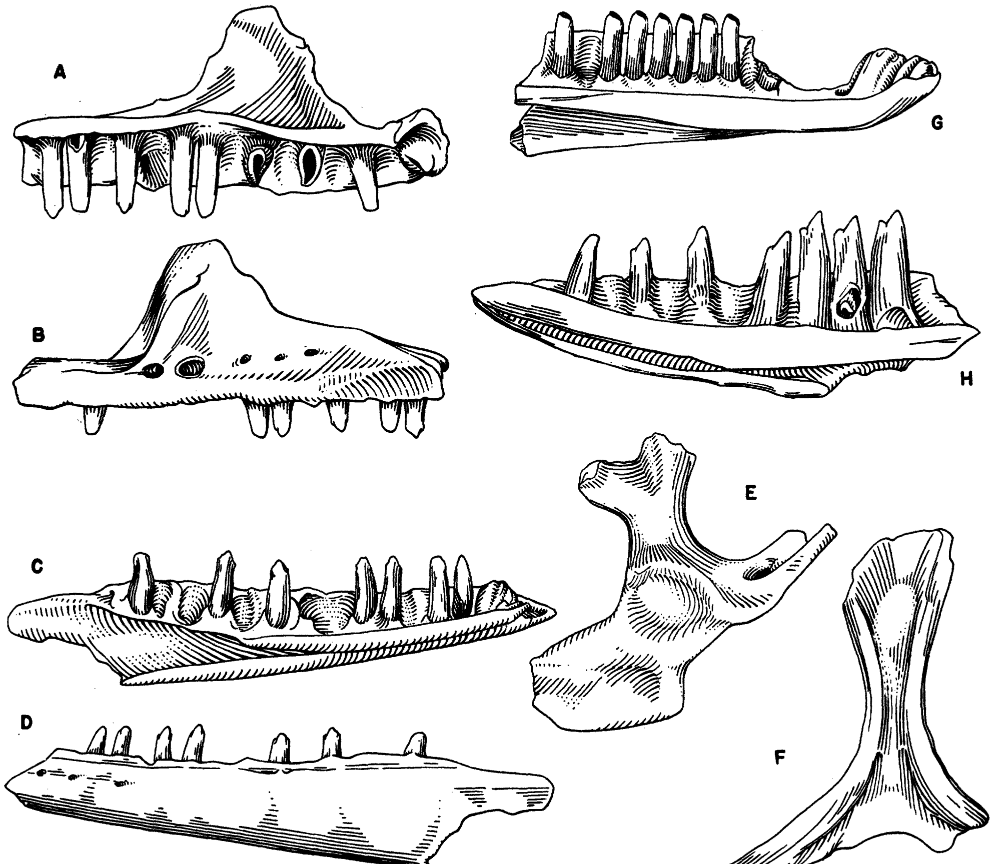

Fig. 2. Fossil remains of various Cragin Quarry lizards. A and B, mesial and lateral views of left maxillary of *Holbrookia cf. texana* (UMMP No. 34171). C and D, mesial and lateral views of left dentary of *Holbrookia cf. texana* (UMMP No. 34172). E, left half of a pelvis of *Holbrookia cf. texana* (UMMP No. 34165). F, ventral view of a frontal of *Holbrookia cf. texana* (UMMP No. 34556). G, mesial view of left dentary of *Eumeces obsoletus* (UMMP No. 34159). H, mesial view of a right dentary of *Cnemidophorus sexlineatus* (UMMP No. 34151). A, B, C, D, G and H times 12; E and F times 8.

lar margin in *Sceloporus* than in *Holbrookia*. Both maxillary and dentary differ from those of *Uma* in being smaller and in having fewer teeth. The pelvis of *Holbrookia* is similar to that of *Callisaurus, Uma* and *Crotaphytus* in that the preacetabular process is well developed but not produced anteriorly. The anterior and ventral borders of the process form a right-angle ridge bordering an excavation for the attachment of the M. iliotibialis. The pelvis of *Holbrookia* may be distinguished from that of *Uma, Callisaurus and Crotaphytus* by the absence of well marked sutures in the acetabulum.

Except by the larger adult size of *Holbrookia texana,* I am unable to distinguish recent skeletons of that species from those of *Holbrookia maculata.* Although *H. maculata* now occurs in southwestern Kansas and *H. texana* does not, the fossils of this genus are tentatively referred to the latter species because of their large size and the associated lizard fauna. Axtell (*in litt.*) has informed me that the caliche rubble substratum and associated lizard fauna indicate an environment characteristic of modern *Holbrookia texana* rather than of *H. maculata.*

Referred Material: dentaries UMMP 34167, 34175, 34174, 34173, 34172, 31678, 34170, 33375 and 34176: maxillaries UMMP 33832, 34171 and 34168; pelves 34167 and 34166; frontals UMMP 34451, 34452 and 34556.

Teiidae

Cnemidophorus sexlineatus Linneaeus

A nearly complete dentary and the anterior part of another are referred to this species (Fig. 2). The fossils have been compared with 13 species and subspecies representing all of the five species groups of this genus and with 11 topotypic specimens of the Kansas Pliocene form, *Cnemidophorus bilobatus* Taylor, 1941. The Cragin Quarry fossils are indistinguishable from *C. sexlineatus,* the only species of *Cnemidophorus* occurring in the region today.

According to Taylor (1941), *Cnemidophorus sexlineatus* differs from *C. bilobatus* in having more slender and somewhat more tapering, laterally compressed teeth with their bases closer together and the upper parts more widely separated. I may add that *C. bilobatus* also has a higher number of mental foramina, 9 to 10 in *C. bilobatus* and 5 to 7 in *C. sexlineatus.* Among the additional lizard fossils secured from the Rexroad fauna there are two nearly complete dentaries of *C. sexlineatus,* UMMP 34191 and 34192, as well as a number of other *C. bilobatus.*

Referred Material: dentaries UMMP 34152 and 34151.

Scincidae

Eumeces obsoletus Baird and Girard

Fragments of two maxillaries, four dentaries, two sacra, one cervical vertebra and two dorsal vertebrae from Cragin Quarry are referred to this species (Fig. 2). the fossils have been compared with recent skeletons of *E. obsoletus, E. septentrionalis* and *E. fasciatus.* Both dentaries and maxillaries are similar in the three species but may be distinguished by the shape of their teeth. The teeth of *E. obsoletus* are more strongly compressed transversely than in the other two species. In addition, the crown is somewhat expanded laterally in *E. fasciatus* and *E. septentrionalis* whereas in *E. obsoletus* the tooth tapers uniformly to the tip. The fossil dentaries have been compared with topotypes of the Kansas Pliocene form, *Eumeces striatulatus.* The differences noted by Taylor (1941: 172) between *E. obsoletus* and *E. striatulatus* apply as well to the differences between *E. striatulatus* and the Cragin Quarry fossils. Although the postcranial elements of the species examined differ very little, the fossil postcranial elements are also referred to this species because of their large size.

Paleoecological Implications of the Cragin Quarry Lizard Fauna

The Cragin Quarry lizard fauna is composed of species still living at the present time; thus, two types of data are available for paleoecological considerations, which are not normally available to the researcher working entirely or partially with extinct faunas. First, the extant ranges of the species under consideration are well known, and second, there is considerable information available concerning the habitats in which these species live and the environmental factors which control their distribution. By superimposing the extant ranges of the Cragin Quarry lizards, an area is delimited in which all forms except *C. sexlineatus* may be found today (Fig. 3). This area covers most of the desert plateau of northcentral México between the Sierra Madre Occidental and the western slopes of the Sierra Madre Oriental, as well as the semi-arid regions of southern New Mexico and Western Texas.

This area is entirely south of the present 50°F mean winter isotherm and for the most part within the present 90°F summer isotherm. This region has been characterized by Dice (1943) as being distinctly arid, with long, hot summers and short winters with only brief periods of below-freezing temperature. The spring and early summer are extremely dry and summer rains normally occur from July to October. Vegetation is composed of scrubby, thorny trees such as mesquite, creosote bush and yucca, with scattered short grass leaving wide areas of bare ground. The present climate of southwestern Kansas differs from the climate of

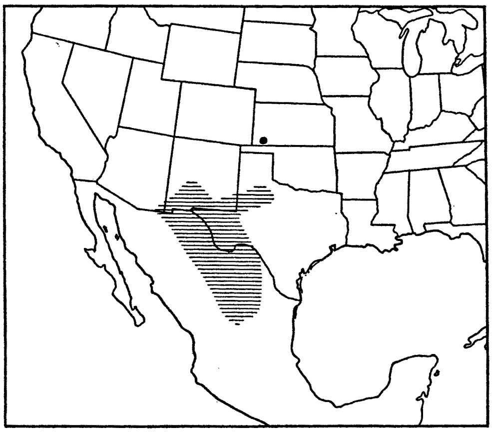

Fig. 3. Map showing the region where *Crotaphytus collaris, Holbrookia texana, Phrynosoma cornutum, Phrynosoma modestum* and *Eumeces obsoletus* now occur together (shaded area). The black dot in southwestern Kansas indicates the locality of the Cragin Quarry.

the area outlined in figure 1, in having a lower annual temperature, a lower winter minimum but not a higher summer maximum, and somewhat higher mean annual precipitation. If the lizard fauna of the Cragin Quarry is a true reflection of the enviornment existing at the time that horizon was formed, then the climate and vegetation of the area outlined in figure 1 and characterized above, may be considered approximately that of the Cragin Quarry horizon.

In addition to general climatic considerations, we may speculate on other aspects of Cragin Quarry local environment. For at least three of the lizard species, *Crotaphytus collaris, Holbrookia texana* and *Eumeces obsoletus,* exposed rocky outcrops and extensive areas of bare ground seem to be essential features of their habitat (Fitch, 1955, 1956 a and b; Jameson and Flury, 1949; Peters, 1951). Although *Phrynosoma,* especially *P. modestum,* is often found in rocky areas, exposed rock outcrops are probably not required. *Phrynosoma* does, however, share with the other three species a requirement for open areas with little or no vegetation. All of the lizards concerned spend considerable time basking in direct sunlight. None of the species is arboreal and extensive areas in which the ground is shaded most of the day, either by dense grass or close stands of trees or bushes, would be uninhabitable by any of the Cragin Quarry lizards.

The only species in the fauna that is characteristically found on sandy rather than rough, rocky ground, is *Cnemidophorus sexlineatus.* Although this species ranges widely over southeastern United States, it is restricted to localized areas of sparse vegetation and sandy soil where high precipitation is rendered less effective and more semiarid local conditions result. *Holbrookia maculata,* a species absent from the Cragin Quarry fauna but present in Meade County today, is found almost entirely on sandy soils. In contrast, *Holbrookia texana* is seldom found in sandy areas. The absence of *H. maculata* is difficult to explain, since the Cragin Quarry is located well within its present day range. Both *Holbrookia maculata* and *Cnemidophorus sexlineatus* characteristically show high population density wherever they occur, much higher than any of the other species except possibly *Holbrookia texana,* yet only two fragments of *C. sexlineatus* were recovered and none at all of *H. maculata.* Perhaps *Holbrookia maculata* did occur in southwestern Kansas at that time but local conditions were such that bare sandy areas on which *Holbrookia maculata* and *Cnemidophorus sexlineatus* occurred were too restricted or too distant to contribute much to the Cragin Quarry beds. From these considerations I would postulate that the Cragin Quarry local habitat was one of extensive areas of bare, rocky ground with occasional rocky outcrops, perhaps small, scattered patches of sand, and vegetation consisting of scattered clumps of short grass and low xerophilous shrubs.

The remaining species to be considered, conspicuous by its absence from the fauna, is the fence lizard, *Sceloporus undulatus,* common in southwestern Kansas and the immediate vicinity of the Cragin Quarry today. The local habitat constructed so far, from a consideration of the requirements of the other species, is quite in agreement with the requirements of this lizard with one obvious exception, the presence of trees or bushes. Trees and bushes, if they are scattered, may occur within the habitats of the other species but are not essential features of their environment. On the other hand, *Sceloporus undulatus* is primarily an arboreal lizard, and since it is the only arboreal lizard expected but not found in the fauna, the absence of trees or bushes is implied.

Speculations concerning the paleoecological conditions of the Cragin Quarry have required that a number of assumptions be made for which there is little or no direct evidence, e.g., that populations of lizards in the Sangamon of southwestern Kansas were influenced by environmental factors in the same way as are contemporary populations of the same species today, that the absence of a lizard species in the fossils from the Cragin Quarry precludes the occurrence of that species in the Sangamon fauna and that the absence of a species from the fauna was a result of the same excluding factors that influence the species today. The paleoecological considerations presented here have been drawn from an analysis of the lizard fauna alone. A large number of vertebrate and molluscan remains have been recovered from the Cragin Quarry and as the study of these other faunal elements proceeds, a better picture of the Cragin Quarry local environment is to be expected.

Summary

About 100 fragments of fossil lizards have been recovered from the Cragin Quarry horizon of the upper part of the Kingsdown formation, referred to the Pleistocene, Sangamon interglacial, of Meade County, Kansas. Six extant species of lizards are identified: *Crotaphytus collaris, Holbrookia cf. texana, Phrynosoma cornutum, Phrynosoma modestum, Cnemidophorus sexlineatus* and *Eumeces obsoletus. Phrynosoma modestum* is here reported as a fossil for the first time. The fauna includes no extinct species of lizards. *Holbrookia texana* and *Phrynosoma modestum* do not now occur in southwestern Kansas but range to the south and west. *Sceloporus undulatus* and *Holbrookia maculata* occur in the area today but where not found as fossils.

An analysis of the lizard fauna, from the standpoints of present species distribution and habitat requirements suggests the local environment was somewhat different than that found in southwestern Kansas today, with a climate of less extreme winter temperatures and generally more arid conditions. The local habitat suggested is one of extensive areas of bare, rocky ground with occasional rock outcrops and perhaps small, widely scattered patches of sand. The vegetations possibly consisted of scattered clumps of short grass and low xerophilous shrubs.

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