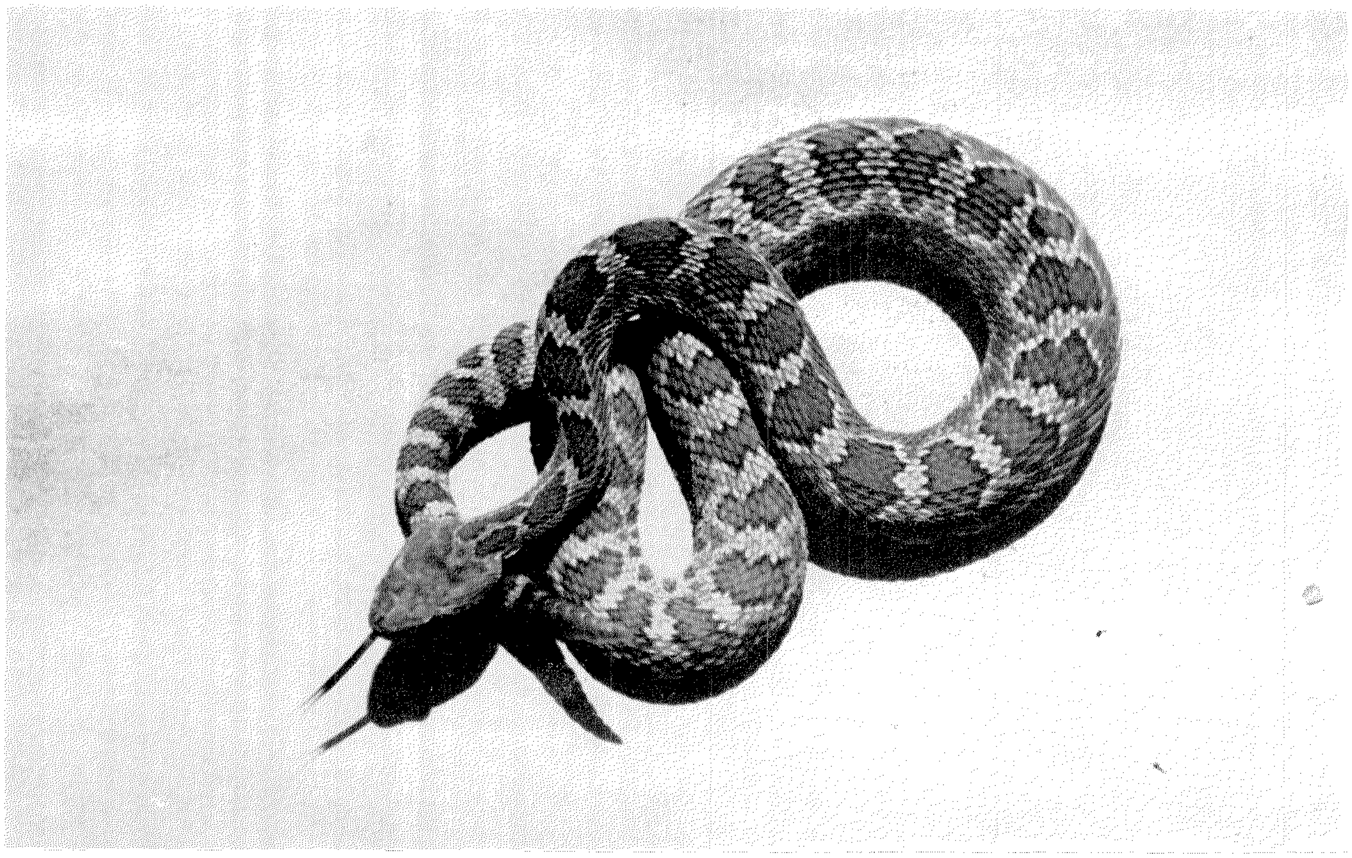

A modern Pacific rattlesnake, whose ancestors probably inhabited the tropical forests of Canada.

THE CLIMATE OF THE PAST

by BAYARD BRATTSTROM

CALTECH IS, OF COURSE, well known for its specialization in several fields of teaching and research. It is equally well known for the close relationships among the fields of research and the freedom from rigid boundaries between the academic divisions of the Institute (biology-biochemistry-chemistry, for example, or geology-geophysics-physics). It was surprising, therefore, to me to be repeatedly asked during my year at the Institute (as a research fellow in paleontology), "Just what is a biologist doing in a geology department?"

I am a herpetologist (one who studies reptiles and amphibians, such as snakes, lizards, turtles, frogs and salamanders). Two of my major interests are the ecology of modern reptiles and amphibians, especially their temperature requirements; and fossil reptiles and amphibians, especially those of more modern times (the Cenozoic, or the last 75 million years).

Some 60 million years ago, in Eocene times, tropical forests extended northward almost to the Arctic Circle, and plants like breadfruit, fig and magnolia were found as far north as southern Alaska.

From that time to this, the tropics have receded southward; and as they have fallen back they have become diversified into such types as deciduous forest, coniferous forest, grasslands, chaparral and so on. The deserts of the southwestern United States did not come into existence until about one million years ago.

All this we learn from the fossil plants we find and from what we know of the climatic needs of modern plants that resemble these ancient ones.

This science of the relation of ancient plants to their environment is now being joined by the study of ancient animals and their environmental relationship. The general field of research is called paleo-ecology.

Reptiles and amphibians are "ectotherms"—which means that they obtain all their body heat from external sources, absorbing heat from the ground, water, or sun. This is in contrast to the "endotherms," or birds

In the restricted lives of reptiles and amphibians, scientists now find clues to the climatic conditions of the past.

and animals which produce their own internal heat by metabolism. Reptiles and amphibians have relatively limited ranges of temperatures that they can tolerate. They also have definite "preferred temperatures" that they keep their body at by their behavior.

For example, a lizard crawls on a rock and absorbs heat from the rock and from the sun. When its body temperature reaches a certain level, it leaves its "basking rock" and begins eating, reproducing, and so on. In doing so, it may crawl in the shade for a while and, as a result, lose heat to the environment. The lizard will then return to the rock to bring its body temperature back to the "preferred" level.

The ranges and preferences differ for the various species or families of reptiles and amphibians. For this reason reptiles and amphibians should be useful for the determination of past climates.

A review of the temperature requirements of reptiles and amphibians, based on a number of different studies and research projects, has just been completed. We now have a fair idea as to the requirements of modern reptiles and amphibians, both in regard to the temperature requirements of individual species and families (as determined by field and laboratory studies) and in regard to the heat-gain and heat-loss problems in relation to body size. For example, the more northern reptiles and amphibians are all small. Only a small ectotherm can absorb enough solar radiation in the more northerly latitudes to get its body temperature up to the levels required for digestion, reproduction, or escape from enemies. Large reptiles, such as boas, pythons and monitor lizards, are found only in the more equable climates of the tropics.

Reptiles and amphibians do not wander about like some of the large mammals, such as horses and bison, nor do they fly like birds, and only a few of them swim as do fish. Most reptiles and amphibians have "home ranges" or "territories" and hence live in a relatively small area; in fact, they probably never move out of an area of about 500 yards in diameter during their entire life. Reptiles and amphibians are, in addition, relatively restricted to certain habitats or plant associations. Such factors as these aid in making reptiles and amphibians useful for the determination of past climates.

The study of fossil reptiles and amphibians is becoming increasingly enriched through modern techniques of paleontology. In the past, usually only the large bones in a fossil deposit were found or saved. Modern techniques of washing, sifting, and sorting reveal that deposits previously considered barren have large faunas of small vertebrates. For example, a series of fossil reptiles and amphibians presently under study comes from many sites in Kansas that represent a time span from Middle Pliocene to the Recent (a span of about 5 million years). These collections include several thousand individuals of snakes, lizards, frogs, turtles, or salamanders.

A technique for the determination of past climates has recently been devised by the writer, based on the distribution and temperature requirements of modern reptiles and amphibians and the herpetological composition of a fossil deposit. With this technique such items as rainfall, temperature, or snowfall can be determined. Thus far the paleoclimatic data resulting from this technique conform with the paleobotanical picture. For example, the past distribution of alligators in North America conforms with the changing climates as determined by the paleobotanist. In the Eocene (60 million years ago) alligators occurred in southern Canada and Montana, as did the tropical and subtropical forests. About 15 or 20 million years ago, the range of alligators had slowly become restricted southward to Nebraska, along with the tropical and subtropical forests and swamps. The alligator of today occurs only in the warm subtropical region of the southeastern United States.

The climate for several fossil sites has been determined by this technique. For example, during the "heyday" of the La Brea tar pits (*i.e.*, after the mammoths and mastodons had become extinct, but when the dire wolves, sloths and saber-toothed tigers were still abundant) the Los Angeles basin had an average of 20 inches of rain a year (in contrast to its present annual average of 14.8 inches) and average winter and summer temperatures were some 5°F. warmer than today. It has also been determined by this technique that the San Pedro Valley of southeastern Arizona a million years ago was not a desert—as it is today—but an area with some 20-30 inches of rain a year (the rainfall there today averages 11.2 inches a year) and a temperature that was slightly warmer than that of the present.

The paleoclimatic technique based on the reptiles and amphibians is helping to supplement and refine the climatic picture presented by the fossil plants and it provides an independent check on the climates as deduced from the fossil plants. When the two differ for any one time and area, the basic assumptions and data of the two fields can be re-examined in order to arrive at a more accurate estimate of the climate of the past.