PERSPECTIVES: PALEONTOLOGY

Polar Dinosaurs

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In 1960, footprints from Spitzbergen showed that nonavian dinosaurs had once lived at polar latitudes (*1*). Initially, this intriguing find remained an essentially isolated discovery, but during the past 20 years, much information about polar dinosaurs has been unearthed (*2*). The late development of knowledge in this field was largely a matter of logistics: The fossil remains of most polar dinosaurs are to be found today at high latitudes and often in remote areas (see the third figure). Their discovery and collection are, therefore, more costly than is generally the case for comparable lower latitude fossils.

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Despite these drawbacks, the study of polar dinosaurs provides potentially unique insights into their physiological adaptations because they may have been exposed to extreme conditions not experienced elsewhere. These conditions cannot be assumed to have been the same as at comparable latitudes today, however. Establishing just what the climate was like in polar latitudes is critical for the accurate interpretation of polar dinosaur finds.

It has been proposed that the inclination of Earth's rotational axis may have been substantially different during the Mesozoic Era (248 to 65 million years ago) than it is today, resulting in warmer climates and more even day length through the year at high latitudes (*3*). In contrast, theoretical investigations suggest that except for the regular and well-understood variation by a few degrees that takes place on the scale of tens of thousands of years, the inclination of the Earth axis has remained much the same relative to the plane of the ecliptic (*4*). In the latter case, polar dinosaurs and their associated biota would have had to contend with the same extremes of day length through the year that characterize comparable latitudes today.

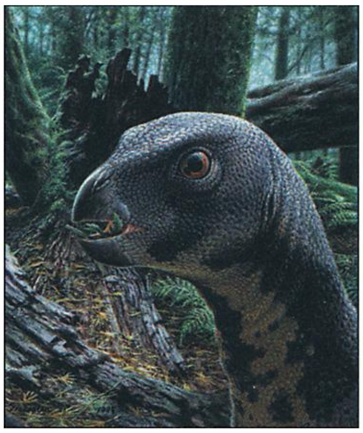
Mean annual temperature, on the other hand, may have been substantially different at a given polar location during the Mesozoic than at a comparable latitude today.

Corpse of *Leallynasaura amicagraphica* on an Early Cretaceous (110 million years ago) sand bar in southeastern Australia. The season is autumn, and ice has already began to encroach on a stream that would freeze over during the 3-month-long polar night.

Past mean annual temperatures have been estimated in two areas where polar dinosaurs from the Cretaceous (145 to 65 million years ago) have been found: southeastern Australia and the North Slope of Alaska.

For the North Slope, Parrish and Spicer have constructed a mean annual temperature curve spanning the last 35 million years of the Cretaceous based on the leaf shapes of flowering plants (*5*). They inferred a maximum temperature of 13°C and a minimum temperature of 2° to 8°C. For comparison, the mean annual temperature in Portland, Oregon, is 12°C, and that in Calgary, Alberta, is 4°C.

The dinosaurs on the North Slope closely resemble contemporaneous ones farther south in Alberta, Montana, and Wyoming, but there is a profound difference in the animals associated with them. On the North Slope, the remains of terrestrial, cold-blooded forms such as lizards and crocodilians are conspicuous by their absence. These missing components constitute a major part of the more southern faunas, supporting the idea that at least some nonavian dinosaurs were warm-blooded (*6*).



Qantassaurus intrepidus in an Early Cretaceous (115 million years ago) summer forest of southeastern Australia. The forest is composed of ginkgoes and conifers but lacks the variety of flowering plants found here today.

In southeastern Australia, evidence for the contemporaneous presence of permafrost, ice wedges, and hummocky ground in association with dinosaur-bearing deposits during the late Early Cretaceous (105 to 115 million years ago) has been found. This suggests that these animals lived there when mean annual temperatures ranged between –6°C and +3°C (*7*). Oxygen isotope studies give a mean annual temperature of −2° ± 5°C for the same deposits (*8*). For comparison, the modern mean annual temperature of Fairbanks is −2.9°C. However, the diversity of the late Early Cretaceous flora in southeastern Australia and the large size of some of its trees far exceed that found in such cold environments today. It is difficult to imagine how this community functioned if the temperatures were as low as the physical indicators suggest. No convincing explanation exists as yet for this apparent anomaly.

Hypsilophodontids—rare components of most dinosaur assemblages—make up half of the dinosaur taxa in southeastern Australia (see the first and second figure). Enlarged optic lobes on the only brain endocast (a cast of the inside of the cranium of a fossil skull) available in this family from Australia suggest that *Leaellynasaura* had more pronounced visual acuity than lower latitude hypsilophodontids with existing brain endocasts. Coupled with histological evidence that their bones were constantly growing and that they were thus active throughout the year, this observation suggests that this family of dinosaurs was well adapted to polar conditions (*7*).

It has been suggested that North American polar dinosaurs may have occupied high latitudes only at favorable times of the year (*10*). However, such an annual trek would have been unlikely in southeastern Australia, particularly in the case of small, terrestrial dinosaurs like hypsilophodontids, because seaways to the north blocked the passage to lower latitudes (*7*).

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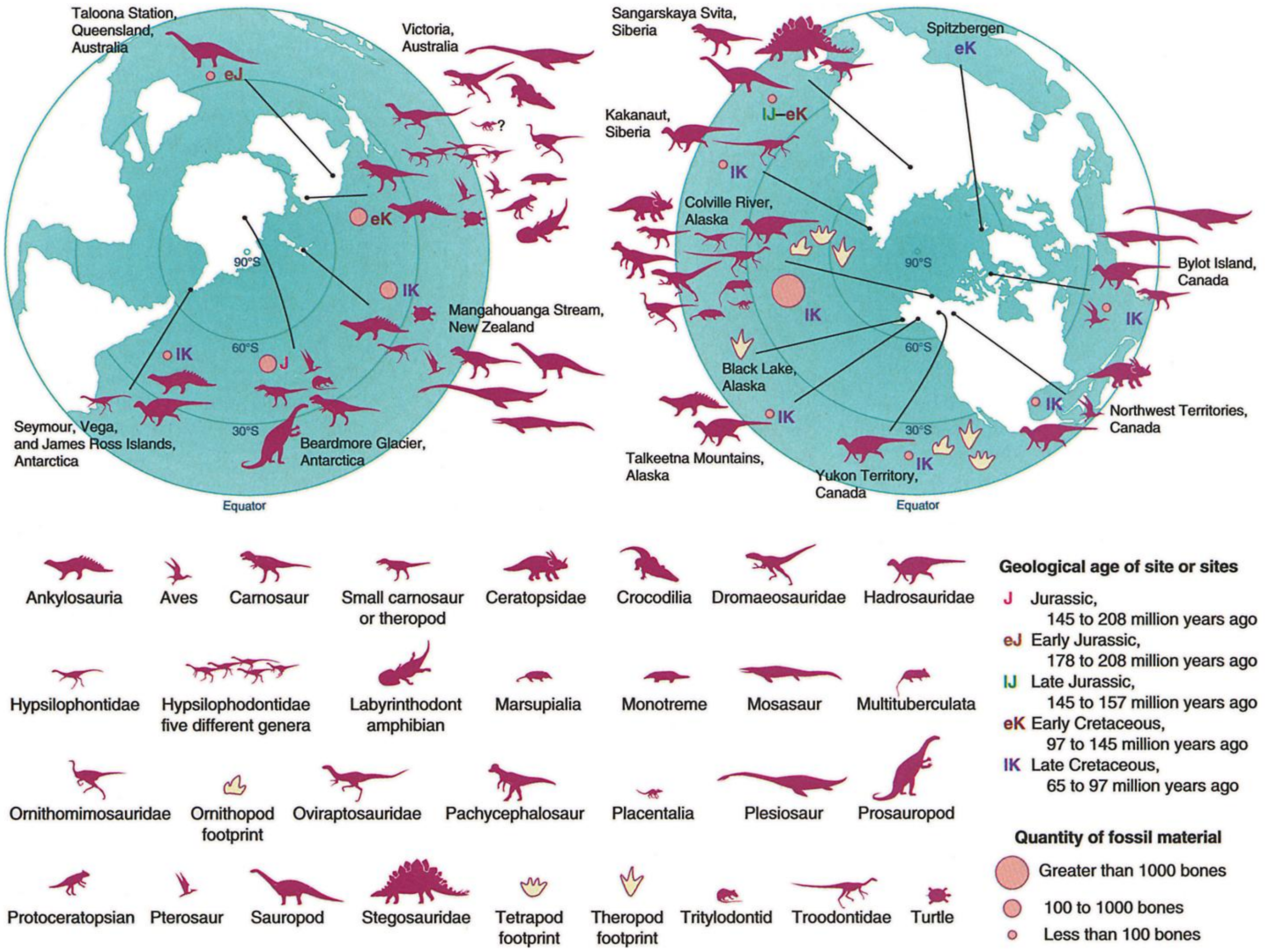

Sites of Jurassic (208 million to 145 million years ago) and Cretaceous (145 million to 65 million years ago) polar tetrapod finds. The base map shows the continental configuration in the late Early Cretaceous (100 million years ago). Modified from (*7*).

SOURCE: DRAGA GELT

During the Early Cretaceous, southeastern Australia was both a nursery and a refugium for terrestrial vertebrates. Early, if not the earliest, records of protoceratopsians, dromaeosaurids, ornithomimosaurs, and oviraptorosaurs have been found there (*7*). On the other hand, allosaurids, which elsewhere became extinct 30 million years before, survived here along with "labyrinthodont" amphibians. The survival of the labyrinthodonts long after they became extinct elsewhere has been explained by the greater tolerance of amphibians than crocodilians to cold water. Labyrinthodonts were superficially crocodile-like and may have been finally displaced by them when temperatures rose in southeastern Australia in the Early Cretaceous (*11*). The other chronological anomalies cannot be similarly explained by a polar habitat.

These studies in southeastern Australia and the North Slope of Alaska have yielded tantalizing glimpses of polar dinosaurs and their habitat. Elsewhere, studies of polar dinosaurs have focused on establishing what is there: Siberia; Bylot Island, the Yukon, and Northwest Territories, Canada; Talkeetna Mountains, Alaska; Beardmore Glacier, Antarctica; Antarctic Peninsula; New Zealand; and Queensland, Australia (*2*, *12–15*). New genera have been named, but no major groups restricted to high latitudes have been recognized.

One location is particularly promising for future investigations (*2*, *7*, *16*). A well-exposed sequence of rocks running more than 100 km along the left bank of the Colville River on Alaska's North Slope spans the last 40 million years that nonavian dinosaurs existed. Exploration of this site will be facilitated when collecting techniques, in particular tunneling (*7*), are tailored to take advantage of the fact that these fossils are entombed in permafrost. It is there that the greatest known potential exists for recovering the most extensive record of polar dinosaurs, one that is not restricted to a single, brief period of time.

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