

How far did dinosaurs really migrate, and how hot do elephants really get?

Some points presented in the paper by Rowe et al. (Rowe et al., 2013) require discussion.

Rowe and colleagues presume that multitonne Late Cretaceous high latitude hadrosaurs migrated thousands of straightline kilometers each year to avoid severe arctic winter conditions. However, movements over such extreme distances are limited to marine and aerial creatures in the contemporary world, with many traveling many degrees of latitude to experience warm weather year round. This is practical for fliers and especially swimmers because their transport costs per unit distance traveled are modest. In contrast the longest ranged living land migrators, such as gnu and even caribou, do not move a straightline distance of more than a few hundred kilometers (Fancy et al., 1989), seasonal movements are always subregional efforts to find optimal conditions at a given time and place in the general area, and no modern land walker migrates north-south far enough to evade winter climates. This is probably because animal land locomotion is so energy inefficient that continent-spanning movements are too arduous and cost too much to be worth any gain, are excessively dangerous, would involve problems with feeding, and are hindered by geographic obstacles (Paul, 1988; Paul, 1994; Paul, 2012).

Specific to arctic hadrosaurs, most of the high latitude remains are those of juveniles too small to keep up with adults on long trips (Fiorillo, 2004). The taphonomic evidence indicates that most of the fossils were formed as the result of late winter/early spring riverine floods from mountain snowmelts (Fiorillo et al., 2010). If so, then the herds were already near or on the Alaskan North Slope as the winter ended, and lacked the time to have moved up far from the south. This is verified by Alaskan hadrosaur bone histology showing they were perennial residents that tolerated the winters, and were a distinct population from more southerly hadrosaurs whose bone microstructure is markedly different (Chinsamy et al., 2012). It is therefore well established that polar hadrosaurs were year-round residents (Paul, 1998; Paul, 1994; Paul, 2012; Fiorillo, 2004; Fiorillo et al., 2010; Chinsamy et al., 2012). It is similarly known that some giant polar southern hemisphere dinosaurs had to tolerate winter and cold and dark because there was no land to the north to migrate on (Bell and Snively, 2008; Paul, 2012). The possibility that polar hadrosaurs, or any other land animals, migrated thousands of kilometers must be ranked as very low and probably impossible, so such fictional creatures should no longer be modeled as plausible unless supporting fossil evidence is produced.

Presuming the polar hadrosaurs were permanent residents, then they rarely or never experienced warm conditions even in the summers, which were cool and cloudy (Spicer and Herman, 2010). However, giant hadrosaurs lived at all latitudes during a global warm period, so modeling their thermoregulation under high heat loads is valid. Rowe and colleagues (Rowe et al., 2013) logically used the largest, low

latitude land animals available, elephants, to help understand the thermal performance of similar-sized and probably tachyenergetic dinosaurs that experienced high ambient temperatures. What is not clear is whether the captive *Elephas maximus* they utilized experienced the extreme heat loads that may be tolerated by *Loxodonta africana* living in their most hyperthermally acute habitats. Elephant herds of the coastal Namib Desert have been documented crossing expansive, shade-baren flats in daytime when air temperatures were probably above their body temperatures; their daily range can exceed 100 km and they can go without water for days (Viljoen, 1992; Bartlett and Bartlett, 1992) (D. Bartlett, personal communication). It is possible that these elephants of the arid Skeleton Coast are adapted to remain active under higher daytime heat loads than data on captive forest elephants and modeling may suggest is feasible. But they have never been sufficiently studied to determine exactly what they experience, and how they cope with intense heat. To fully understand the thermoregulation of gigantic, tachyenergetic animals will require detailed field observation of the biggest living land animals residing in the hottest habitats to discover how they do it. That, of course, will be a difficult and expensive experiment to conduct.

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Gregory S. Paul

gsp1954@aol.com