ECOLOGY

Comment (2) on "Formation of the Isthmus of Panama" by O'Dea *et al.*

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O'Dea *et al*. challenged the inference that the Isthmus of Panama has been in place for the last 10 million years or more and from "an exhaustive review and reanalysis of geological, paleontological, and molecular records," they argued for a "formation of the Isthmus of Panama sensu stricto around 2.8 Ma." I review environmental changes since ~5 Ma throughout Earth, and I argue that environmental changes in the Central American-Caribbean region have been part of a concurrent, worldwide phenomenon that requires a global, not local, explanation. Accordingly, evidence of environmental change from the Central American-Caribbean region does not implicate the emergence of the Isthmus of Panama.

INTRODUCTION

Building on a pair of previous studies (*1*, *2*), Montes *et al.* (*3*) showed that zircons in fluvial sediment deposited in northern Colombia since at least 10 million years ago (Ma) bore an isotopic signature of granitic rock from Panama. Recognizing that rocks neither swim nor would likely be carried by ice to northern Colombia, they inferred that rivers not only deposited the sediment but also must have transported it from the granitic belt in Panama to the sites of deposition. Most investigators have placed the now-closed Central American Seaway, sometimes called the Bolivar Trough (*4*–*7*), Bolivar seaway (*8*), Bolivar Portal (*9*), Bolivar geosyncline (*10*), or Atrato Basin (*11*) in the region between the sediment and the granitic belt, although some had inferred previously that no connection between the Pacific and Atlantic lay there (*12*). Concurrent with the work of Montes *et al*., Bacon *et al.* (*13*) exploited molecular and fossil constraints on the timing of biotic interchange between North and South America to conclude that interchange was well underway before ~3 to 4 Ma, the commonly assumed time of closure of the Central American Seaway. Against these observations for a relatively old land bridge connecting North and South America, if not necessarily isolating the Caribbean Sea from the Pacific Ocean, O'Dea *et al.* (*14*) argued that much evidence does require a relatively young isthmus (~3 Ma). Although perhaps biased (*15*), I contend that even if the isthmus proves to be so young, the arguments of O'Dea *et al.* (*14*) ought to convince no one of such youth.

First, O'Dea *et al.* (*14*) addressed little of the evidence that bears on the possibility that the Isthmus was in place at 10 Ma. They stated, "In the 1970s, high-resolution paleoceanographic data available from deep-sea cores began to show that an isthmus…was in place only relatively recently, around 3 million years ago (Ma)," and they supported that claim by citing two papers (*16*, *17*). Readers of that sentence might not realize that those two papers presented data applicable to the periods since 4 and 6 Ma, respectively. Neither could address the possibility that the Central America Seaway closed at 10 Ma or earlier.

Second and more importantly, much evidence shows different regional climates across the globe before and after ~3 to 4 Ma. The Northern Hemisphere before 3 to 4 Ma was warmer than today by several degrees Celsius, as shown by environmental conditions in mid- and high-latitude regions on land in North America (*18*–*20*) and in Europe (*21*, *22*), along Atlantic coastal regions of North America (*23*–*25*), and by North Atlantic sea surface temperatures (SSTs) (*26*–*28*). The largest changes in SSTs come from regions of marked upwelling at lower latitudes, ~9°C off the coast of southern California (*29*) and ~4°C of the west coast of Africa in the North Atlantic (*30*), as well as in the South Atlantic, ~10°C off the southwest coast of Africa (*31*, *32*). Whether these regions, where cold, deep water upwells today, cooled because winds changed or because the thermocline shoaled (*33*) is not pertinent here, for with these changes in SSTs, winds must also have changed.

Marked changes in winds are virtually certain in the equatorial Pacific because the eastern Pacific has cooled by as much as 3° to 4°C since 4 to 5 Ma (*34*–*37*). Although some controversy continues, the western equatorial Pacific does not seem to have cooled since that time. Moreover, the thermocline in the eastern equatorial Pacific has shoaled since 4 Ma, as one would expect from strengthened easterly winds (*38*, *39*). This cooling of the eastern Pacific has transformed the SST distribution from one resembling that during occasional El Niño events to the present-day more La Niña–like normal state (*33*, *40*–*43*). Whereas most of the world was warmer in Early to Middle Pliocene time than today, one area that seems to have been cooler—the southeastern United States and the region surrounding the Gulf of Mexico (*23*–*25*, *41*, *42*)—is the only area that cools during El Niño events (*44*, *45*).

The El Niño–like SST distribution bears on an observation that O'Dea *et al.* (*14*) used to infer a closing of the Central American Seaway since 3 to 4 Ma; since that time, salinity in the Caribbean has increased (*46*–*51*), while the easternmost Pacific freshened (*35*). O'Dea *et al.* (*14*) attributed this increased difference in salinity to the isolating of the Caribbean from the Pacific by the emergence of the Isthmus of Panama. A change from El Niño–like conditions and its effect on moisture transport by the atmosphere offer another possible explanation (*52*). Virtually, all moisture exported from the Atlantic Ocean leaves the Caribbean and crosses Central America to the Pacific (*53*). Today, less moisture is transported across Central America during El Niño events than under normal conditions (*52*, *54*). The scatter in data is too large to demonstrate that the El Niño–like eastern Pacific SST conditions made moisture transport at 3 to 4 Ma sufficiently small to account for the change in salinity contrast (*52*), but the El Niño–like SST distribution at 3 to 4 Ma offers a possible explanation for the smaller salinity contrast at that time than today, a possibility that O'Dea *et al.* (*14*) ignored.

O'Dea *et al.* (*14*) attributed another difference between the Caribbean and the Pacific to the emergence of Panama. Today, the annual range of shallow-ocean temperature is only ~2°C on the Caribbean side but ~6°C on the Pacific side. From variations in zooid sizes in fossil bryozoan colonies in the Caribbean and the Pacific, O'Dea *et al.* (*55*) inferred

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a change of ~5°C in the mean annual ranges of temperature (MART) since 3 to 4 Ma. O'Dea *et al.* (*14*) assigned uncertainties of ~2.5°C for MART in the Caribbean and ~1°C for the Pacific. McClelland *et al.* (*56*) had assessed the statistics of these data, however, and had written: "The revised equation…has a large margin of error (±4°C) and is therefore useful only for comparing environments with a difference in MART greater than 4°C." With uncertainties of 4°C, the inferred ~5°C difference in MART can, at best, be only barely resolved, and given the other global changes at the same time, these inferred differences in MART do not provide a strong argument for the emergence of the isthmus since 4 Ma.

Changes in regional climates since 3 to 4 Ma characterize more than temperatures, winds, and salinity. Many regions became more arid, such as East Africa (*57*, *58*), Chad (*59*, *60*), West Africa (*61*), the Namib Desert in southwest Africa (*62*), the western United States (*63*, *64*), and Australia (*65*–*67*). Loess deposition increased in China (*68*), as did dust transport to the North Pacific (*69*, *70*) and to the Southern Ocean (*71*). High dust accumulation rates indicate arid source regions (*72*). As with temperature, however, at least one change of opposite sense seems to have occurred; Hovan (*73*) inferred that dust transport from South America to the eastern Pacific decreased and that northern South America has become wetter.

Finally, although also controversial (*74*), abundant evidence suggests that both erosion rates (*75*, *76*) and sedimentation accumulation rates (*77*–*79*) increased since ~3 to 4 Ma. In particular, studies of either sediment mass accumulation rates or cooling of rock as it has been exhumed show accelerated erosion since ~3 to 4 Ma in diverse settings: the Mississippi River drainage basin (*80*, *81*), the Colorado Plateau (*82*), Alaska (*83*, *84*), the Alps (*85*), the Tien Shan (*86*), and, in at least, parts of the Himalayas (*87*–*89*). Moreover, accelerated deposition of sediment could have affected nutrients positively or negatively, with corresponding changes in productivity.

Readers should see that I do not focus on the veracity or applicability of evidence suggesting that the Isthmus of Panama was in place by 10 Ma, nor do I pretend to show that an emergence of the Isthmus did not occur at 3 to 4 Ma. Rather, I contend that O'Dea *et al.* (*14*) have ignored abundant evidence showing that much happened throughout Earth at the suggested time when the Isthmus of Panama emerged. The most parsimonious interpretation of these global observations is that the evidence for environmental change in the Central America region is part of that global process and does not require a local cause. Some might argue that the closing of the Central America Region at ~3 Ma not only explains the data that O'Dea *et al.* (*14*) discussed but also caused the global changes noted above. I addressed that idea elsewhere and found little support for it (*15*). In summary, I would rewrite the final sentence of their abstract with the words "an older isthmus" changed to "a 3-Ma," "before" changed to "only since," and "we" to "I" so that it reads: "The evidence used to support" a 3-Ma "isthmus is inconclusive, and" I "caution against the uncritical acceptance of an isthmus" only since "the Pliocene."

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