PALAIOS

An International Journal of SEPM
(Society for Sedimentary Geology)

VOL. 19, NO. 1 FEBRUARY, 2004

SPOTLIGHT

Déjà-Vu All Over Again: Deep Time (Climate) Is Here To Stay

The farther backward you can look, the farther forward you are likely to see.
—Winston Churchill (attributed)
This is like déjà vu all over again.
—Yogi Berra

Albeit likely expressed in different contexts, both Yogi and Winston were imploring all to recall that trite adage we already know: history repeats itself, so if we wish to divine our future, we must know our past. It's an adage that is no less true for the history of Earth as for the history of its people. And so, in this brief essay, I wish to make the single point that—with regard to Earth's climate system—Deep Time Is Here To Stay.

Geoscientists are no strangers to this adage. Indeed, our greatest challenge in crafting proposals, and educating undergraduates, is in concocting nouveau ways of expressing it. Our science IS important. Our science IS socially relevant. Nevertheless, those who study "Deep" (here used as "pre-Quaternary") time traditionally have shouldered an even greater burden in attempting to justify their pursuits. The Quaternary, after all, represents a high-resolution record of our nearest climatic relative—a time of glacial-interglacial variation, of geochronologic resolution within human comprehension; a time of tree rings, ice cores, and packrat middens.

Indeed, the Quaternary has revealed a treasure trove of lessons about Earth's climate system. Perhaps the most significant and surprising is that climate can change on a dime, even in the context of human time, and that its record can be preserved at incredibly high fidelity. Nevertheless, the Quaternary ultimately reveals a rather myopic view of our climatic past; a view that we must look beyond, because we are now entering an atmospheric composition the likes of which the Quaternary has never seen. The likes of which are represented only in Deep Time. Deep Time Is Here To Stay.

One could choose any of numerous justifications for studying Earth's Deep Time climate record. On first principles alone, there are bound to be some interesting tidbits to be learned from the first 99.96% of Earth history, if merely because Deep-Time studies enable us to break though our "temperate climate-interglacial-[glacial] chauvinism" (c.f., Pfefferkorn, 1995, p. 391). Nobly esoteric reasons aside, however, CO_2 is a particularly compelling reason, owing to its relevance to climate change on all timescales (Crowley and Berner, 2001; Royer et al., in press). The ice -core record, which has enabled reconstruction of atmospheric CO_2 at incredibly high resolution, shows that we are, today, at the highest level of CO_2 in the last 420,000 years and likely higher than any point in the last 20,000,000 yrs (IPCC, 2001). Using the example of CO_2 alone, we *must* study Deep Time, because we have already returned back to the future.

Yes, of course. . . but the details. . . what shall we use for the proxies; what shall we use for the dates?! Can we achieve the resolution, in terms of either the data or the dates? Can we rise to the challenge? Yes, we can! Indeed, we must, if we wish to continue to pursue socially relevant science.

Consider the issue of data. Granted, direct measurement of CO_2 from ice cores, for example, is a feat with which deep-time geologists cannot compete. Nevertheless, we are making significant progress in development of increasingly detailed and quantitative proxies that are enabling paleoclimatic reconstruction well beyond the generalized (but still useful) lithologic declarations of "evaporites mean dry and tills mean cold." Publications within the last few years,

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for example, have reconstructed, with increasing rigor, atmospheric CO_2 (e.g., Ekart et al., 1999; Royer et al., 2002) ocean temperatures (e.g., Huber et al., 2002), wind direction, speed, and seasonality (e.g., Loope et al., 2001; Soreghan et al., 2002), and even air temperatures (e.g., Benison and Goldstein, 1999) for various Deep-Time slices, to name a few examples. Many of the proxies used for such reconstructions have been or are being developed by specialists in subdisciplines such as isotope geochemistry and paleobotany; others represent novel applications of old, or perhaps traditionally Quaternary methods by non-specialized field sedimentologists. Most fruitful of course, are those that arise from the interdisciplinary collaboration of both. The admittedly disparate results from various deep-time CO_2 proxies does not signal defeat, but only underscore the dire need for intensified development of additional proxies and cross-calibration of existing proxies (see McElwain, 2002; Montañez, 2003). Equally key is interaction and communication with climate modelers, who rely on proxy data for input to their models, and whose results are particularly important for understanding feedbacks in Earth's climate system and for providing testable hypotheses for further field and analytical studies. For more on these topics, see the new Geoclimate website (http://geoclimate.ou.edu), established as a result of a recent NSF-funded workshop on Deep-Time Paleoclimatology (Soreghan et al., 2003).

OK, fine. . . so continued development and novel application of robust proxies are key and within reach, but do we nevertheless remain hamstrung by data preservation? Clearly, the Quaternary is blessed with an abundance of high-resolution data. In comparison, the pre-Quaternary seems almost ridiculously ill-endowed—no ice cores, no tree rings (of consequence), no packrat middens (Thank God!). For the pre-Jurassic, the landscape darkens further, with the loss of even the deep-sea record. For we poor souls destined to study Deep Time, the prospects are made seemingly even more hopeless by infamous geologic adages such as that comparing the stratigraphic record to a net (a lotta holes tied together with string).

Phooey! Perhaps the record has holes; but consider the richness in the string! High-resolution records DO exist in Deep Time. Yes, there are no ice cores, but there are plenty of aggradational systems with comparably long archives of high-resolution data. Lacustrine systems, loess deposits, epeiric sediments (to name a few) all have the potential for exceptional lithologic and paleobiologic preservation over durations at least rivaling the 0.04% of Earth history recorded in the Quaternary. Even systems deemed notoriously "gappy" (e.g., fluvial or, the epitome of gappy, paleosols) preserve surprisingly high-resolution data. It's just that these data exist as snippets suspended in time. Indeed, the Quaternary is such a snippet. It simply happens to be a very well-dated snippet during which humans largely evolved.

So, we arrive at the final challenge—Time (more specifically, dates; the bane of young adults and geoscientists alike). We HAVE the high-resolution records (the strings), we continue to develop the paleoclimatic proxies and models, we simply need the dates. Without them, we are stuck with rocks floating in time. . . high-resolution records of precipitation/evaporation, or temperature, or atmospheric composition, or circulation. . . but no hard dates, so no hard rates either. Even qualitative lithologic proxies (evaporites, tills) assume renewed significance in the light of better age constraints. We know that climate can turn on a dime. But, we don't necessarily know *why.* We know that orbital and solar effects on climate can operate on timescales well within human comprehension and relevance. But we don't necessarily know *how.* We know that Earth's Deep-Time rock record can preserve great detail. But we don't yet know all the details. And, we know that our current climate is entering a state previously known only from Deep Time. Deep Time Is Here To Stay. . . it IS socially relevant. But can we access the record?

Yes, we can. Geochronologic barriers are not insurmountable, and their imminent demise simply needs a little hastening in order to elevate our science to the relevance it merits. Further, their imminent demise is linked to the demise of subdisciplinary silos. Soft-rock geologists and geochronologists maintain a relationship akin to that between those who model paleoclimate, and those who reconstruct it—wherein n'er the two e'er mix. Geochronology traditionally has been the purview of hard-rock geologists interested in igneous, metamorphic, structural, and tectonic questions, just as climate modeling has been the purview of climatologists and atmospheric scientists, none of whom necessarily read *PALAIOS* or *JSR.* Just as geologists and climate modelers need one another, geochronologists need soft-rock geologists and paleobiologists to enlighten them on the kinds of paleoclimatic and paleobiologic issues that can be addressed in the context of improved dating and correlation. Analogously, soft-rock geologists and paleobiologists need "geochronologic counseling" in order to comprehend the opportunities, limitations, and sheer work involved in radio-isotopic dating. Such exchange is beginning to happen, and systems for high-resolution radio-isotopic dating of sedimentary materials are on the horizon (e.g., Rasbury, 2000; Montanez, 2003; see also the EarthTime website, http://eaps.mit.edu/earthtime/).

We are poised to make great leaps in our understanding of long-perplexing processes in Earth's climate system, and its coupling with other (e.g., tectonic, biologic) systems, by studying—at Shallow-Time resolution—the Deep-Time record. We need to continue to develop better proxies, better models, better dating, and better collaboration. Perhaps most of all, we need to forge ahead with confidence in our relevance.

Yogi and Winston said it best. . . Deep-Time Is Here To Stay.

—GERILYN S. SOREGHAN

ACKNOWLEDGEMENTS

The opinions expressed here were shaped largely by my participation in recent NSF workshops on Deep-Time Paleoclimatology (Soreghan et al., 2003) and Geologic Time (October 2003). Reports for these workshops are available on the web (http://geoclimate.ou.edu; http://eaps.mit.edu/earthtime/), where you can (and should) also provide your feedback on future directions in these subdisciplines.

REFERENCES

Benison, K.C., and Goldstein, R.H., 1999, Permian paleoclimate data from fluid inclusions in halite: Chemical Geology, v. 154, p. 113–132.

Crowley, J.C., and Berner, R.A., 2001, CO_2 and climate changes: Science, v. 292, p. 870–872.

Ekart, D.D., Cerling, T.E., Montañez, I.P., and Tabor, N.J., 1999, A 400 million year carbon isotope record of pedogenic carbonate: implications for paleoatmospheric carbon dioxide: American Journal of Science, v. 299, p. 805–827.

Huber, B.T., Norris, R.D., MacLeod, K.G., 2002, Deep-sea paleotemperature record of extreme warmth during the Cretaceous: Geology, v. 30, p. 123–126.

IPCC, 2001, Climate Change 2001, The Scientific Basis: Cambridge University Press, Cambridge, 881 p.

Loope, D.B., Rowe, C.M., and Joeckel, R.M., 2001, Annual monsoon rains recorded in Jurassic dunes: Nature, v. 412, p. 64–66.

McElwain, J., 2002, Is the greenhouse theory a fallacy? A paleontological paradox: PALAIOS, v. 17, p. 1–2.

Montañez, I.P., 2003, It's all about dating: from Nexters to climate change: PALAIOS, v. 18, p. 299–301.

Pfefferkorn, H., 1995, We are temperate climate chauvinists: PALAIOS, v. 10, p. 389–391.

Rasbury, E.T., Meyers, W.J., Hanson, G.N., Goldstein, R.H., and Saller, A.H., 2000, Relationship of uranium to petrography of caliche paleosols with application to precisely dating the time of sedimentation: Journal of Sedimentary Research, v. 70, p. 604–618.

Royer, D.L., Berner, R.A., Montañez, I.P., Tabor, N.J., and Beerling, D.J., in press, CO_2 as a primary driver of Phanerozoic climate: GSA Today.

Soreghan, G.S., Parrish, J.T., and Maples, C.G., 2003, Workshop report—Geoclimate: the study of Earth's Deep-Time climate: Eos, v. p. 471–472.

Soreghan, M.J., Soreghan, G.S., and Hamilton, M.A., 2002, Paleowinds inferred from detrital-zircon geochronology of upper Paleozoic loessite, western equatorial Pangea: Geology, v. 30, p. 695–698.