YOUNG SCIENTIST AWARD (DONATH MEDAL)

Presented to Dana Royer

Dana Royer
Wesleyan University

Citation by Peter D. Wilf

Dana Royer is a brilliant, prolific, and highly visible geoscientist. I first met Dana as his TA when he was a Penn freshman in 1996, and subsequently worked with him as my field assistant in the Green River Basin of Wyoming. He later took his fascination with fossil plants and climates to Yale and completed a Ph.D. there in 2002 with resounding success, working with Leo Hickey and Robert Berner and also collaborating extensively with David Beerling at Sheffield. Dana then became my postdoc for three productive years at Penn State and has been a close colleague ever since. Dana is a true innovator who successfully tackles important questions in paleoclimatology and paleoecology, in part using paleobotanical proxies calibrated from a remarkable series of careful modern analog studies using growth chamber, greenhouse, and field experiments. His work lies at the poorly known intersection of plant paleoecology and ecophysiology, paleobotany, paleoclimatology, and environmental science. And he really writes the papers. Dana's very first article, in *Geology* (1999) and begun as an undergraduate, was already an important contribution because it dispelled the prevailing notion that depth to pedogenic carbonate is a reliable quantitative indicator of paleoprecipitation.

Dana is probably best known for quantifying pCO_2 through time from many proxies, including his own major line of research estimating paleo-pCO_2 from fossil plant cuticles. Dana's work on pCO_2 through time connects the deep-time record to the present day in societally relevant ways. In a striking set of papers, Dana demonstrated more convincingly than anyone that pCO_2 and temperature are well correlated on geologic time scales, and quantified the long-term sensitivity. His high-profile articles in Science and Nature are widely cited in the modern climate-change literature, including several IPCC and NRC reports. At a time when it was fashionable to generate paleo-pCO_2 estimates from tiny sample sizes of almost any fossil-plant cuticle, Dana kept the community aware of high interspecies variation and the need for replicate measurements, without which he showed that results are unreliable. He demonstrated the value of emphasizing as proxies species such as Ginkgo adiantoides and Metasequoia occidentalis that appear unchanged since the Late Cretaceous. Using this approach, based on carefully constrained observations of living analog plants, he made a provocative argument from fossil cuticle data that globally warm intervals of the Eocene and Miocene had low pCO_2, similar to today. This showed that we may still lack a credible explanation for some periods of past global warmth, and that raising pCO_2 alone may not be sufficient to bring typically "cold" paleoclimate models in line with geologic proxy data.

Dana used his paleoplant physiology approach to provide several other, startling new insights into ancient ecosystems and climates. Again using experiments on living analogs, he showed that high pCO_2 significantly lowers the freezing tolerance of frost-sensitive plants such as palms. Given the high-latitude distribution of these taxa during past warm intervals, this result implied that "paleofreeze lines" for paleoclimatic reconstructions need to be moved and further increased the ongoing disparity between proxy data from fossils and climate-model outputs. From a different set of long-term experiments on analog species, Dana led the first rigorous examination of carbon budgets in polar forests, a major paleo-biome that does not exist in today's icehouse world. This work showed for the first time that the carbon costs of respiration during dark polar winters, long considered to be the main selective force against evergreen trees that were rare in polar forests, were in fact not significant in comparison to other aspects of the carbon budget such as the leaf fall of deciduous species. These results opened up many new lines of inquiry into the paleoecology and selective regimes of polar forests, which may appear once again in a greenhouse future.

Dana has made important advances that link plant paleoecology to neoecology in exciting ways, for example the new proxy for leaf mass per area derived from easily accessible variables: petiole width and leaf area. Leaf mass per area is a critical variable for understanding ecosystem function that was previously inaccessible from fossils, and it has further implications for quantifying nutrient turnover in ancient forests. Recently, Dana has made breakthroughs in better understanding classic correlations of leaf-shape traits, such as having marginal teeth, with climate variables that are widely used to estimate ancient climates. Once more using an experimental approach, he demonstrated that leaf teeth in the Eastern Deciduous Forest perform significant carbon uptake early in the growing season relative to the rest of the leaf, and that this effect is magnified in colder climates. This was the first quantitative, experimental explanation for why leaf teeth might be evolutionarily advantageous at colder temperatures: in this biome, they help to jumpstart photosynthesis when both temperature and leaf size are limiting. Dana also quantified climate-related variation in leaf morphology within single species, generated massive extant and fossil data sets documenting how numerous leaf-shape variables vary with climate around the world, and showed that in an Australian rainforest the classic increased prevalence of toothed species near streams is correlable with a continuous topographic gradient, not binary as previously assumed.

There is no doubt that Dana Royer is a gifted scientist with abundant future potential, who has already achieved many notable breakthroughs. I can think only of very few who have made comparably high-impact contributions in geosciences at such an early career stage or with such diverse interests. Simply put, without Dana's contributions we would know much less about Earth's climate history and its great importance to today's world. I am immensely pleased to see Dana's achievements and potential recognized by the Geological Society of America and the Donath Family.

Response by Dana Royer

Thank you, Peter, for your kind words. We first met when I took Geology

101 my first semester at the University of Pennsylvania and Peter, a graduate student then, taught the lab section. This means that I have known Peter longer than any other scientist. Peter's broad vision, attention to detail, and emphatic love-of-life have been an inspiration and guiding force for me ever since. My three years as a post-doc with Peter at Penn State were some of my most fulfilling. At Penn (University of, that is), Art Johnson and Robert Giegengack planted the seeds of love for the earth sciences and of desire to pursue research. Art, in his subtle way, shepherded me to the door of unlimited possibilities. At Yale, where I pursued my PhD, Bob Berner and Leo Hickey were my co-advisors, and they were the ideal mix of knowledge and personality. Their histories of mentorship serve as a how-to template as I begin my own mentoring. And now that I am back in Connecticut, I continue to develop formal and informal collaborations with Yale faculty, for which I am grateful (note to students: never burn any bridges!). At Wesleyan, my current home, my colleagues feel like an extended family. An advantage to a modest-sized department is that, owing to the lack of multiple colleagues in a single subfield, I am regularly forced to think outside the confines of my regular teaching and research activities. The twin lights of research and teaching shine brightly at Wesleyan, and I am proud to participate in the tradition.

Ever since my undergraduate days, I have straddled the geology-biology divide. While this can pose challenges at times (e.g., funding, job hiring), the highs from unexpected discovery have been so worth it. As is often noted, the intersection between fields is dripping with opportunity. Peter mentioned my penchant for long-distance running. When you are running 50 or 100 miles, raw talent takes a back seat to desire and will. I quite like this aspect of the sport, and it carries over into my professional life. We all know to take one step at a time, but in ultra-running this is wrought literal. When I begin a project I usually don't know what the next phase is, but it always comes. And it's always fun.

I am forever indebted to my parents for enabling my love of the outdoors and of science. All of those visits to our awe-inspiring national parks and forests had a tangible outcome, after all. I thank Jenny, my wife, for being a prescient sounding board and for keeping me pointed in the right direction. Finally, I would be remiss not to thank Fred Donath and the Geological Society for supporting this award. It has been exhilarating, but humbling as well, looking at the list of past medalists. I have big shoes to fill. Where to next?