Dear Members of The Émile Argand Medal Selection Committee:

I am delighted to provide this nomination of **Dr. Thure Edward Cerling** for the Émile Argand Medal of the IUGS. Dr. Cerling is a Distinguished Professor of both Geology *and* Biology at the University of Utah, which is but one clue that he is a man of broad scientific interests and achievement. His research has had enormous impact at the intersection of these disciplines, including science foundational to our understanding of the geological history of atmospheric CO_2 and its multi-fold impacts on climate, plant, vertebrate and hominid evolution, and ecosystems. His work is remarkable for integrating concepts previously siloed in disparate disciplines, and in past and present time frames. The Émile Argand Medal is awarded *"for discoveries that have been strongly influential in the understanding of Earth System Science [and which] have contributed significantly to establishing basic principles or ground-breaking observations for understanding Earth System processes."* In fact, many of the most remarkable characteristics of Earth arise from the interactions of its geological and biological systems across time. In this letter, I hope to give you a fuller sense of Cerling's important insights and observations, and the rich mix of geological, chemical and biological elements he has woven together as he has defined the mechanisms by which a history of the environment is incorporated into and preserved in stable isotope proxies. His deep impact on the geoscience community and our understanding of Earth systems interactions was recognized in 2001 by his election to the U.S. National Academy of Sciences, the highest scientific recognition in our country.

In the late 1970s, Earth and soil scientists began to ponder the significance of the stable carbon and oxygen isotope compositions of carbonate nodules found in many soils and paleosols (fossil soils). They recognized that the isotopics *should* reflect the environmental conditions during formation, but lacked an adequate model to describe the isotope systematics. Cerling's breakthrough 1984 *EPSL* paper presented the answer: the concentration and carbon isotope composition of soil CO_2 can be described by a soil CO_2 diffusion-production equation. This model, which Cerling and many others have validated in the field and in multiple environmental settings, yielded several significant tools:

First, an important input to the diffusion-production equation is the concentration of atmospheric CO_2. Solving for that term, the model can be utilized as a *pCO_2 paleobarometer*— a proxy measure of past levels of atmospheric CO_2. Cerling fully developed this insight in his 1991 *Amer J Sci* paper, spawning a generation of paleosol work: >1000 papers by hundreds of authors, resulting in a proxy record of changes in atmospheric pCO_2 over the past 500 million years. Collectively, these studies have provided validation of long-term global carbon cycle models, such as Berner's GEOCARB models, that predict large changes in atmospheric CO_2 through the Phanerozoic. Additional pCO_2 and environmental proxies have subsequently been developed by

Cerling's research team based on carbon and oxygen isotopic compositions of fossil teeth and these have been key to our understanding of the very significant role of atmospheric CO_2 in driving major changes in climate and ecosystems. *These proxies define major periods of change on Earth*, including: a record of very high pCO_2 in the mid-Paleozoic, declining as vascular plants afforested the land surface, capturing carbon in terrestrial biomass and accelerating weathering rates; a CO_2 minimum during the Permian glaciation with low values unmatched until the Pleistocene glaciation, and periods of increased pCO_2 in the Triassic and in the Cretaceous. Higher resolution paleosol records capture periods of shorterterm global disturbance, such as the rapid, but very significant, Paleocene-Eocene Thermal Maximum. Cerling's work over two decades focused the attention of the community on these Earth system relationships, and gave us the tools to better understand them.

Second, Cerling's soil CO_2 model demonstrates the relationship between the carbon isotope composition of soil CO_2 and of soil vegetation, which is largely controlled by the photosynthetic pathway utilized by plants. For much of the Phanerozoic, plants utilizing the C3 photosynthetic pathway dominated terrestrial ecosystems (most trees, shrubs and cool season grasses). Cerling and his students published a series of papers using carbon isotope compositions of soil carbon and carbonates to identify for the first time a global expansion of C4 plant dominated ecosystems (savannah and prairie grasses) about 5-8 million years ago. The expansion of C4 photosynthetic ecosystems was one of the most significant shifts in the functioning of the world's terrestrial ecosystems since plants invaded land over 500 million years ago. *These studies moved extremely important knowledge of plant physiology, largely unknown to geologists, to an Earth systems context, exploring the interconnection of terrestrial ecosystems, atmospheric CO_2 and climate in the geologic record.* Over time, Cerling's team has developed sophisticated new proxy techniques for aridity and temperature, demonstrating that declining atmospheric CO_2 , coupled with increased aridity and higher temperatures, was a major selective force in the evolution and expansion of C4 dominated ecosystems. *These studies have proven especially important for defining the climatic and ecosystem context of hominid evolution in east Africa*.

In Cerling's creative mind, it was an obvious leap from grasslands to grazers. He saw the great potential of isotopic studies of fossil teeth and bones as new proxies for paleo-environment and paleodiets. Working on modern and experimental systems, Cerling developed a robust understanding of the transfer of environmental and dietary information to animal teeth and bones, with careful attention to animal physiology and complicating factors such as diagenesis or kinetic fractionations. He painstakingly determined the analytical methodology that allowed us to make sense of isotopic distributions in the complex, heterogeneous structure of teeth and bone. These discoveries revolutionized research using stable isotopes of vertebrate fossils, particularly over the past 65 million years, and profoundly affected our understanding of the linkages and interdependence of physiological ecology, ecosystem ecology and global changes in climate and atmospheric CO_2. **Thure Cerling's work has given us an *integrated* picture of the paleo-world in which terrestrial ecosystems emerged and evolved, responding to changes in atmospheric pCO_2 and climate. The impact of these studies reaches forward, as well, to help us understand Earth system responses to current and future environmental changes.**

Simply put, disparate ideas and disciplines have a way of coming together in Cerling's work. But his significant impact, across so many disciplines, is built on the *quality* of his work. In all of his studies, Cerling has taken the approach of first understanding chemical and isotopic behavior through fundamental principles and relationships, backed by experimental studies in modern systems, and ultimately applying his knowledge to understand geological history. For example, he was one of the first to use cosmogenic isotope dating of terrestrial geomorphic surfaces, and, true to form, began his work in Harmon Craig's lab, experimentally determining natural ^{3}He production rates. His work combines theoretical, field and laboratory studies and has taken him to all seven continents. His field experiments have had him studying CO_2 diffusion in deep snow, sampling carbonate in paleosols high in the Himalayan Mountains, studying teeth from grazers which codeveloped with hominids in the East African rift. He has been seen plucking tail hairs off elephants in the African savannah, and even collecting his beard hair daily as he traveled from the US to Mongolia— an early test of the forensic value of hair to constrain diet and geolocation and of isotopic turnover rates in mammals. (In order to describe his impact on Earth Science, I have no time here to develop his impact on modern isotope forensics!).

Finally, let me summarize Cerling's bibliographic metrics and professional recognition, to demonstrate how he meets the criteria of the Argand Medal as "an active senior geoscientist of high international recognition and outstanding scientific record". Thure Cerling is a Member of the U.S. National Academy of Sciences (2001), winner of the Geological Society of America (GSA) President's Medal (2017), the American Geophysical Union (AGU) Excellence in Earth and Space Science
Education Award (2017), and the Utah Governor's Medal for Science and Technology (2012). He is a
Fellow of AGU (2016), the International Association of Geochemistry and Cosmochemistry (2008), the
Association for the Advancement of Science (1997), and GSA (1994). He was a member, by Presidential appointment, of the U.S. Nuclear Waste Technical Review Board (2002–2011). Cerling has published nearly 300 highly cited papers earning him a Hirsch h index of 93 and more than 31,000 citations. Ten papers have been cited 600+ times and over 30 have been cited 250+ times— stellar metrics that reflect both the diversity and influence of his research contributions.

Thure Cerling is a “Renaissance man”, a global citizen, widely knowledgeable and endlessly curious. His ideas are at the foundation of our community’s understanding of “global change”, largely writ, and his selfless enthusiasm for science has inspired so many. For all of these reasons, I hope you will find he is most worthy of the Émile Argand Medal.

Respectfully,

Claudia I. Mora
Deputy Division Leader for Chemistry, Los Alamos National Laboratory,
Past President, Geological Society of America, and
Councilor, International Union of Geological Sciences