ARTHUR L. DAY MEDAL

Presented to Kenneth A. Farley

DAY MEDAL

Presented to T. Mark Harrison

T. Mark Harrison
University of California at Los Angeles

Citation by Frederick J. Ryerson

It is a great pleasure to present T. Mark Harrison as this year's recipient of the Arthur L. Day Medal. The Day Medal recognizes "outstanding distinction in contributing to geologic knowledge through the application of physics and chemistry to the solution of geologic problems" perfectly describing Harrison's career contributions. Central to all geologic problems and processes are the issues of timing and rate. For the past 3 decades, Mark Harrison has been one of the world's leaders in the application of thermochronology to geologic problems. Recognizing the thermal signature inherent in tectonic and plutonic processes Harrison developed and applied a variety of geochronologic tools to tectonic processes, leading to thermal histories of unprecedented detail. Harrison is a geochemist with relentless energy and vision, and his accomplishments are fully deserving of the prestigious award.

Over the course of his career he has developed a wide range of geochemical and geochronologic tools, combining field-based investigations, geochemical/geochronological analysis, thermal/tectonic modeling and fundamental laboratory experiments to constrain relevant kinetics and phase equilibria. His work comprises seminal contributions in the fields of thermochronology, the tectonic evolution of the Himalayan-Tibetan mountain system, crustal geochemistry, and isotopic microanalysis. Most recently he conceived and organized an international consortium to investigate the Hadean (>4.0 billion year old) zircons of Western Australia. Realizing the full potential of the geochemical information encapsulated in these Hadean samples required elevation of ion probe-based zircon geochronology to an almost industrial scale with over 100,000 zircons dated — a truly audacious undertaking.

Harrison's contributions have focused largely on the thermal and chemical evolution of the Earth's crust. As most geologic processes involve changes in crustal heat flow (e.g., thrusting, rifting, plumes, magmatism, etc.), understanding the thermal history of the lithosphere is essential. When Harrison began his career, there were relatively few strategies that permitted this information to be gleaned. The principal goal of geochronology was then seen as determining crystallization ages, and the K-Ar dating system was in disrepute relative to more robust systems like zircon geochronology. The idea that 'leaky' isotopic systems could be made useful was laid out in Dodson's classic 1973 paper. Its potential went largely unnoticed until Harrison picked up the thread in the late 1970's and, over the subsequent 30 years, has been its leading proponent.

Mark's initial approach empirically calibrated closure temperatures (T_c) for a variety of Ar-Ar mineral geochronometers and then obtained a thermal history by interpolating between the individual *T-t* data. A major advance, and Harrison's signature contribution to Ar-Ar thermochronology, was the development of K-feldspar multi-diffusion domain model (MDD). Developed in collaboration with Frank Richter and Oscar Lovera, Harrison showed that continuous, high-accuracy thermal histories could be extracted using intra-grain isotopic gradients. The enhanced sensitivity of the MDD model has permitted numerous advances in our understanding of continental tectonics. While the MDD model was initially the focus of considerable debate, Harrison and his colleagues have systematically evaluated the underlying assumptions over the past 20 years and the model has now achieved paradigm status. That his efforts to perfect Ar-Ar thermochronology is demonstrated by recent paper that applies and experimentally calibrated a multi-diffusion domain model to Ar outgassing in muscovite, adding an additional mineral to the Ar-Ar thermochronologic toolbox.

Harrison's development and application of geochemical and geochronologic tools extends well beyond the temperature range sampled by the Ar-Ar system. Although U-Pb dating of accessory minerals (e.g., zircon, monazite, apatite) had been widely used for determining crustal histories for over 40 years, the full potential of these systems could not be realized without characterizing their petrologic and geochemical behavior. In a series of novel papers in the early 1980s Mark and Bruce Watson experimentally documented the saturation behavior and dissolution kinetics of zircon and apatite in crustal magmas and began measurement of the diffusion properties of geochemically important species in these minerals and associated melts. This work formed the basis for what we now know as "accessory mineral thermometry," leading to the first quantitative understanding of the widespread phenomenon of zircon inheritance in terms of mineral-melt equilibria. Harrison also recognized the potential of monazite as a recorder of prograde pressure-temperature metamorphic histories, due of its unusual behavior during diagenesis (absent in pelitic sediments) and its unexpected Pb retentivity at lower crustal conditions. In 1997, he published the first *in situ* Th-Pb analysis of monazite inclusions in garnet allowing him to relate the age of monazite crystallization to the pressure-temperature conditions provided by compositional zoning in garnet.

Mark's efforts in developing accessory mineral parameters and secondary ion microscopy collided in 2001 when his group co-discovered heavy oxygen isotopic compositions in >4.0 Ga zircons from the Jack Hills of Western Australia, a result that strongly suggested the presence of a liquid water hydrosphere on the earliest Earth. Harrison assembled an international consortium focusing on the systematic geochemical investigation of these samples and their implications for this most poorly sampled phase of Earth evolution. The accomplishments to date include vastly expanded databases of Hadean ages, oxygen and Lu-Hf and Sm-Nd isotope systems, as well as detection of fission-Xe related to the U/Pu ratio of the early Earth. With Bruce Watson he also developed and applied a novel Ti-in-zircon geothermometer to obtain crystallization temperatures from these detrital zircon grains, and continuing analysis of mineral inclusions is providing

P-T data to constrain a Hadean geotherm. Taken together, the results argue strongly for the existence of continents as early as 4.4 Ga (perhaps even 4.5 Ga), and crustal cycling and plate boundary interactions much like those of today.

Harrison's efforts to develop geochronologic and geochemical methods to interrogate crustal motions and granite petrogenesis came to fruition in his investigation of the ongoing evolution of the Himalayan-Tibetan mountain system. In the nearly 20 years that Mark has been investigating Indo-Asian tectonics, the view of its evolution has changed dramatically from a simple picture of uniform, distributed shortening to a specific, time- and spatially-dependent transfer of convergence among competing processes, often with multiple mechanisms operating simultaneously. He has been a significant agent in fostering this changing vision. Among his contributions are the establishment of the uplift history of the Himalaya and southern Tibet, application of *in situ* Th-Pb monazite dating directly leading to the discovery of the age paradox in the classic Himalayan inverted metamorphic sequences, and establishment of the temporal and kinematic connection between the tectonic extrusion of Indochina and the opening of the South China Sea.

Mark Harrison has successfully developed both the underlying theoretical framework and experimental realization of numerous geochemical and geochronologic approaches. He's always been motivated by fundamental issues concerning the evolution of the Earth's crust and his pursuit of these interests does not recognize boundaries between experimental petrology, analytical geochemistry and field-based investigations. One of Mark's colleagues has often described him as "the world's luckiest geochemist". Luck is not so persistent. Like previous recipients of the Day Medal, Mark has the ability to recognize important problems in the geological sciences, and the intellect, enthusiasm and persistence to bring novel new techniques to bear on their solution. It is my great honor to present T. Mark Harrison as this year's Arthur L. Day Medalist.

Response by T. Mark Harrison

Thanks Rick for your generous citation and to the Geological Society of America for selecting me the 2009 Arthur L. Day medalist. As honored as I am to receive this award for applying physics and chemistry to the solution of geologic problems, it pales in comparison to my astonishment given that I don't know much of either. Simply scanning the list of earlier generations of Day medalists gave my impostor complex a better feeding than it's had in years. But on closer inspection of that list, I sensed that my generation was presented with a unique opportunity that fortuitously fit well with what talents I do have. The first generation of awardees were largely pioneers of the geophysical and geochemical methods that we use today, but their approaches were unfortunately applied to a deeply flawed paradigm of how the Earth works. Many of the next generation of awardees were those that used the unifying theory of plate tectonics (and trips to the Moon and back) to discern the first order nature of planetary behavior. Thus when my generation came along, we encountered a field that could largely explain what had happened, but not how. The signature of the Day medalists over the past ten years or so has been their development of ways to see the Earth in a dynamic, rather than equilibrium, fashion. In that context, my contributions to the birth and growth of thermochronology provided useful information with which to understand the rates and mechanisms of geologic processes.

I arrived at UBC as something of an academic late-bloomer just as Dick Armstrong was getting established and a couple of years after publication of Dodson's largely unnoticed closure temperature paper. Dick's encouragement to come to grips with that theory coupled with Garry Clarke virtually adopting me gave me a giant head start in this new field that wouldn't have a name for another five years. The limitations of bulk closure theory drew me to 40Ar/39Ar and Ian McDougall's lab but it wasn't until collaborating with Frank Richter and Oscar Lovera that the method truly came of age. Together with students and colleagues, we took the new approaches out to the Himalaya for a test drive from which we've never really returned. I was fortunate while at ANU to watch the first SHRIMP instrument being built and saw immediately the thermochronological potential of a device that could resolve microscale gradients in other isotopic systems. This led to Kevin McKeegan and I conceiving of a new generation ion microprobe that helped usher in the development of prograde thermochronomety, which incorporated investigations of accessory mineral systematics begun years before with Bruce Watson. We've recently reunited in applying accessory mineral thermometers to the oldest known terrestrial minerals which led to a radically new view of earliest Earth.

I again thank the Geological Society of America for this great honor, my students, colleagues and mentors for sharing their great brainpower and friendship, and Susan, Matthew and Ainslie for your love and understanding of the pathological lifestyle of a research scientist.