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Presentation of the 2012 Roebling Medal of the Mineralogical Society of America to Harry W. Green II

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Mr. President, Colleagues, and Guests:

It is with great pleasure that I introduce Harry W. Green II, as recipient of the Mineralogical Society of America's highest honor, the Roebling Medal. The Roebling Medal is awarded "for outstanding original research in mineralogy...defined broadly"—a description that completely fits Harry Green's distinguished scientific career. Harry's research activities have focused on the rheology of geological materials in mantle conditions, and how stress and deformation interact with metamorphism and phase transformations. Now, Harry calls this direction "Mineralogy in Action," that is, indeed, a bridge between "Phase Transformations and Earth's Dynamics." Throughout his career of more than 40 years, Harry has made seminal advances in mineralogy-based disciplines using the physical properties of minerals, mineral reactions, and their connections with the microstructures of minerals and rocks. All of his numerous publications are done in provocative and creative ways, and Harry remains today on the scene as one of the most influential, world-leading scientists in high-pressure rheology and mineralogy. He has done so through innovative high-pressure experiments and exhaustive interrogation of natural minerals and their experimental counterparts down to the smallest scales by electron microscopy.

Before putting in context Harry's main achievements, I would like to highlight "Where Harry was first at the beginning of his career?" His first major impacts in the 1960s to the 1980s included research on understanding extreme preferred orientation of quartz caused by annealing; on deformation microstructures in mantle xenoliths connected to generation of kimberlite magmas; and his first pioneering application of transmission electron microscopy to the minerals deformed in the laboratory.

The rheology theme has been present throughout Harry's career. On the theoretical side, he has pursued the theory of nonhydrostatic thermodynamics and its relevance to phase transformations under stress. On the experimental side, he elaborated the dislocation flow mechanisms in olivine and the pressure dependence of flow in olivine as a component of mantle convection. In the 1980s, Harry developed new Griggs apparatus to extend the pressure range available for quantitative laboratory deformation experiments to 3 GPa (more recently to 4+ GPa) and invented a "molten-salt cell" in which the encapsulated specimen is surrounded by a low-viscosity fluid during deformation. As a result, the precision of stress measurement at high pressure was increased by nearly two orders of magnitude. This cell has become the standard for high-quality rheological studies at high pressure. Later, Harry and his students have measured the rheology of both dry and wet eclogite and recaptured in the laboratory the microstructures and fabrics of natural eclogites while obtaining high-quality rheological data for extrapolation to natural conditions and resolving several long-standing arguments in the literature.

While Harry's impact on experimental rheology has been profound, I would like to point out that he has similar stature in the field of subduction zone earthquakes. This theme of Harry's career is perhaps the one for which he is most widely known. Harry made two seminal discoveries in his research during the latter part of the 1980s—demonstration of two independent mechanisms for the olivine–spinel phase transformation and discovery of high-pressure faulting associated with that transformation. Based on those discoveries, the anticrack theory of deep-focus earthquakes was formulated. The faulting/earthquake discovery was shortly followed by confirmation of the anticrack faulting mechanism to 14 GPa during the olivine–wadsleyite transformation in mantle olivine. Acoustic emission detection during experimentally produced faulting demonstrated that the "working fluid" of the mechanism is the superplastic nanocrystalline contents of the anticracks, and that the anticrack mechanism cannot operate during endothermic or decomposition reactions. This work could provide an inherent explanation for the increase in earthquake frequency in subduction zones at the top of the mantle transition zone (400 km) and complete termination of earthquakes at the base of that zone (~680 km). However, it took more than another decade for seismology to catch up with the experimental work and demonstrate that the metastable olivine necessary for this mechanism to work does, indeed, exist in subduction zones. Strong seismic evidence has now been reported from 4 different deep subduction zones (Tonga, Izo-Bonin, Marianas, and Japan). These discoveries, combined with the distribution of earthquakes in subduction zones now combine to indicate that not only is this mechanism very likely responsible for the deepest earthquakes but also that subducting slabs are essentially dry below 400 km.

Harry's constant interest in mineral reactions and his extensive knowledge of microstructures and their geodynamic sense led him in the 1990s to an interest in ultrahigh-pressure metamorphism (UHPM). It was at this time that Harry and I became colleagues. Not long after my arrival Harry told me that he had a hunch that the Alpe Arami peridodite in the Swiss Alps had a very deep history. Together we examined rocks he had collected 20 years before and we startled the world of petrology by demonstrating that the abundance of

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$FeTiO_3$ and chromite precipitates in olivine of that peridotite suggest a minimum depth of its origin of 300 km. At that time, the report met with extreme resistance from metamorphic petrologists and was seriously challenged as in error. However, later additional microstructural evidence, experiments, and numerous follow-up studies in both Alps and other territories, demonstrated that the original report and its implications are real. This work triggered new microstructure-based studies of UHPM rocks and minerals in both field and experiments that have led to even more startling results and understanding depths from which lithosphere has been exhumed after subduction. Finally, a few years ago Jingsui Yang asked for our help in understanding presence of coesite in a highly reduced environment in massive chromite, implying great depth. The coesite had a strange crystal form and Harry suggested that it probably had been stishovite that inverted later to coesite. Using EBSD analyses we determined that his idea was probably right and subsequently together with Richard Wirth we found the high-pressure form of TiO_2 in the same rock (along with native titanium and boron nitride), confirming origin in the stishovite stability field. Such rocks clearly provide a new window into mantle convection, e.g., into mantle upwelling. It is possible that these minerals are residue of material that has been through at least one previous Wilson cycle. At about the same time, Harry and other colleagues published evidence of former stishovite in subducted sediments, demonstrating subduction to and return from ~350 km.

Harry's work is an extraordinary example of the roles of mineralogy in the solving of first-order dynamic Earth problems through detailed analytical and microstructural studies on natural rocks and similar experimental studies in his laboratory. Accumulation of all his contributions together has made a major impact on fundamental concepts involved in problems rooted in mineralogy/petrology and has opened new avenues: one to earthquake physics and a second to deep subduction zone processes, both are major components of global plate tectonics.

Throughout his academic career Harry has repeatedly produced surprises by demonstrating how things at the very finest scale may trigger large challenges to understanding of the Earth's system. Today, we are witnessing an unprecedented surge of information and only scientists whose minds are truly "open" are capable to push the complexities of human knowledge to the frontier of big science. Harry Green is such a scientist.

Congratulations, Harry, on winning the Roebling Medal.