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What Are Mineral Inclusions Really Telling Us about High-pressure Rocks?

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In his work, especially on the Alpe Arami peridotite, Harry Green established that while chemical signatures may be over-written in rocks, the microstructures may still preserve evidence of earlier history. Therefore he focused much of his research on inclusion minerals trapped and protected within robust host minerals. The ilmenite rods he found in olivine, and the clinoenstatite lamellae he found in diopside, are fully coherent with their hosts. When inclusions are precipitated coherently within the lattice of their host, they may be formed under significant deviatoric stress. Coherent or not, the subsequent changes in P and T upon exhumation will, because of the contrast in the elastic properties of the host and inclusion minerals, always lead to significant deviatoric stress in the host, and a stress state in the inclusion that is different from the external pressure. In the case of anisotropic inclusion crystals, or cubic inclusions in an anisotropic host mineral, the stress in the inclusion is also deviatoric. For 25 years or more Harry was concerned about the influence of these deviatoric stresses on mineral equilibrium. For example, he asked whether clino-enstatite can be stabilised relative to opx by shear stress? Or whether the high-clino to low-clino inversion in enstatite, inferred to have occurred in Alpe Arami from the observation of anti-phase domains, is also stress dependent.

It is only in the past decade that tools and theory have been developed that can probe the stress state of inclusions at the fine scales required and allow us to interpret the stress state in isotropic inclusions in isotropic host minerals. These developments, and the future prospects for developing methods and theory needed to measure and interpret the stress state in anisotropic minerals, will be reviewed. The scientific legacy of Harry Green is that he provoked us with many profound and intriguing questions over length scales from the atom to the mantle, and over many fields from thermodynamics to structural geology and geophysics, that will motivate research for decades to come.

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