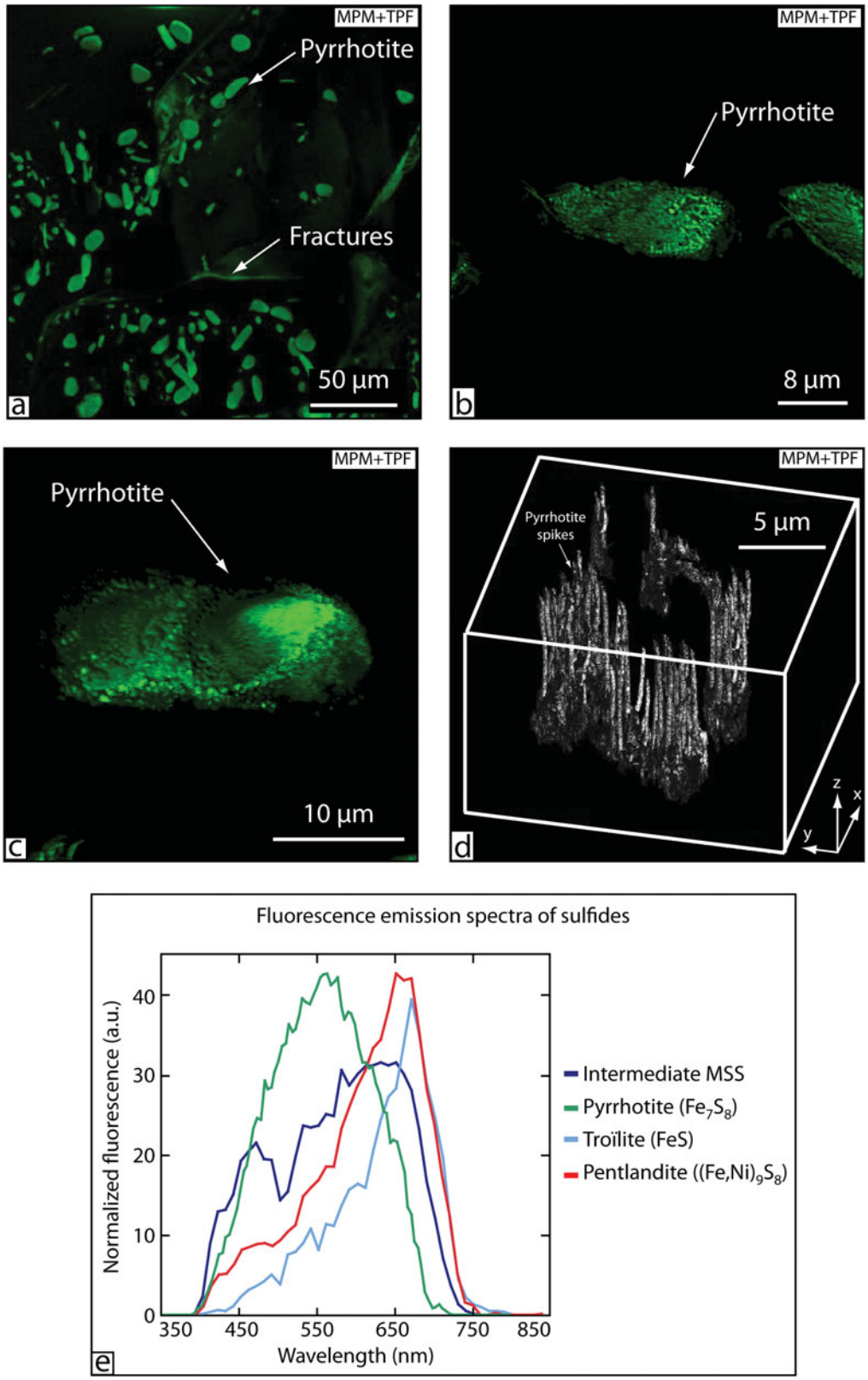

Supplementary Figure 1. (**a–c**) Projections of image stacks and (**d**) a 3D reconstruction of pyrrhotite in an orthopyroxene-rich vein cutting a peridotite xenolith from the Avacha volcano with MPM, and (**e**) representative TPF emission spectra of different natural sulfide species. **a:** A large-scale projection of image stacks of marginal and central parts of the vein. Voxel size (μm): $x = 0.46$, $y = 0.46$, $z = 0.50$, z-step size is 0.49 μm between two images and oil-immersion objective ($\times$63) was used at a zoom of 1. **b:** A projection of image stacks of pyrrhotite from a vein margin. Voxel size (μm): $x = 0.09$, $y = 0.09$, $z = 0.09$, z-step size is 0.09 μm between two images and oil-immersion objectives ($\times$63) was used at a zoom of 5. **c:** A projection of image stacks of pyrrhotite from a vein margin. Voxel size (μm): $x = 0.06$, $y = 0.06$, $z = 0.49$, z-step size is 0.47 μm between two images and oil-immersion objective ($\times$63) was used at a zoom of 7. **d:** A high-resolution 3D reconstruction of spikes on pyrrhotite surface. Voxel size (μm): $x = 0.07$, $y = 0.07$, $z = 0.09$. The z-step size between two images is 0.09 μm. An oil-immersion objective ($\times$63) was used at a zoom of 7. **e:** TPF emission spectra of different types of sulfides.