The Geology of Exoplanet Atmospheres

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Atmospheres are dynamic entities, formed from the volatile substances that accrete when a planet is formed and later in its history, cooked out in the hot-high pressure interior of the planet, and exchanging with the interior through crustal processes (for planets which have a solid surface) or mixing into the deep interior (for fluid planets). Loss of atmosphere to space is also a major mechanism whereby the chemical composition of entire planets evolve. There is thus no distinct boundary between the disciplines of planetary geology and planetary atmospheres, and the dawning age of exoplanet discovery has made it even more essential to think across the boundaries of the two disciplines. The likely characteristics of known exoplanets greatly expand the range of substances that have to be thought of as atmospheric components, with many things thought of as "rocks and minerals" on Earth being atmospheric or cloud forming substances. There are planets hot enough to have permanent magma oceans which may give rise to rock vapor atmospheres, and others where clouds may be formed of enstatite or even sapphire (or more prosaically, corundum). Some of these atmospheres are supersonic and local, others may be global and subsonic. There is also a host of new problems to be thought about in connection with "gas midgets," which are mostly fluid but small enough that they need not have a hydrogen dominated composition. In this lecture, I will provide a survey of the emerging field of integrated planetary science, and conclude with some thoughts on how to train the next generation of planetary scientists to deal with the leading-edge problems of the future.