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Origins for Surface and Exospheric Composition of Ganymede

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Abstract

Ganymede's uniquely diverse surface terrain serves as a "Rosetta Stone" of the dynamical history of this largest moon of the solar system and its dominant place within the Jupiter system. Imbedded within and above this terrain, the global distribution of elemental and isotopic composition records hemispheric, regional, and more local history of sources and processes affecting composition. Bulk and some minor constituents of surface composition presumably arise early from primordial formation, interior differentiation, and subsequent heavy bombardment by cometary materials. Early bombardment would have also driven surface material exchange with the volcanic moon Io, the ocean moon Europa, and ancient battered Callisto via impact ejecta. History of interior dynamical evolution may also be recorded in present and temporal evolution of Ganymede's intrinsic magnetic field. Later thermal evolution of Ganymede in response to tidal heating may be recorded in surface emergence of subsurface oceanic materials, such as salts and carbonates.

The unique mini-magnetosphere of Ganymede in turn controls the exchange of trace components of surface composition with the Jupiter magnetosphere, mainly including the iogenic plasma from Io volcanism but also including sputtered components from Europa, already suggested to be a net source of sodium. High energy heavy ion measurements also indicate a distributed magnetospheric source of carbon, perhaps from the external solar wind but potentially also from moon surface and exospheric sputtering. Surface CO_2 has been detected on the three icy Galilean moons and with a trailing hemisphere enhancement on Callisto. The thin patina of material deposited by magnetospheric interaction, iogenic sulfur, may obscure the intrinsic sources of Ganymede surface composition but should also show hemispheric and latitudinal profiles characteristic of the interaction. Direct unfiltered implantation of magnetospheric ions would contribute to exogenic composition of the polar caps, while magnetic filtering would increasing affect exogenic ion input at lower latitudes. Since the incident fluxes vary strongly with energy and mass/charge, the magnetic filtering would enhance exogenic contributions of high m/q ions and heavier isotopes. Characteristic latitudinal variance of exogenic composition from magnetospheric input might be measured and subtracted to reveal the endogenic sources. Correlation to surface features at the polar cap boundary might also reveal the history of temporal variance in orientation and strength of the field. Complex molecular species deposited in the equatorial region of Ganymede from impact ejecta of Io and Europa, including any organics of astrobiological origin, would be relatively protected there from magnetospheric irradiation.

Unlike Europa with its major exospheric constituent being O_2 from surface sputtering, Ganymede is modelled with a variable exospheric composition. Oxygen is dominant at polar latitudes, as more globally on Europa from the same sputtering source, but water vapour is modelled as the main low-altitude component from thermal sublimation at the sub-solar equatorial surface. Any H_2O and associated trace species detected elsewhere could conceivably arise from active cryovolcanic processes, thus far found only at Triton and Enceladus, both located in comparable magnetospheric environments further from the Sun.

High resolution spatial and isotopic mapping of Ganymede surface and exospheric composition could reveal the rich history of this largest moon's interior and magnetic evolution, and its magnetospheric and chemical connections to the Jupiter system including other Galilean moons.