Jupiter has the largest magnetosphere in our Solar System, measuring from $100R_j$ (R_j = 71,400km) on the day side to 150-200R_j on the night side. It spans approximately 20 solar diameters wide and encompasses many of the orbiting Jovian moons [1]. Jupiter's magnetic field is compromised of three sections: the outer region (where the most variation occurs due to being bombarded with the solar wind and interplanetary material), the middle zone, which rotates with the magnetic field and shell of plasma that Jupiter produces, and the inner zone, the densest part of the magnetosphere, which can be found around and close to the surface [2]. The magnetic field present on Jupiter is generated by electrical currents in the outer core, composed of liquid metallic hydrogen, maintained by the rotational motion of the planet. This induces two magnetic models - open and closed. In a closed case, the magnetic field is induced due to the stress of the centrifugal forces, all happening on trapped low-energy plasma from large and rapid rotation. The open case is produced to make up for centrifugal plasma that radiates outward. This process produces a heliosphere from Jupiter, similar to the solar wind produced by the Sun. This can impose interesting effects on nearby objects, in particular, Ganymede [1].

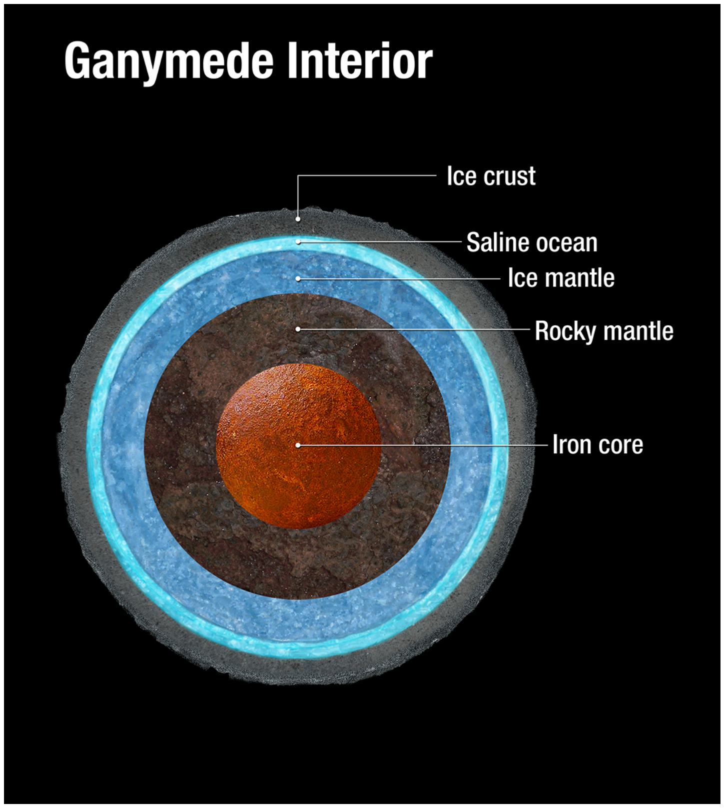

Figure 1: The figure shows the interior make-up of Ganymede, presenting the iron core, rocky mantle, icy mantle, saline underground ocean, and icy crust.
Source: NASA [3].

Ganymede is a unique moon, tidally locked to Jupiter, larger than Mercury and Pluto, and the ninth-largest object in the Solar System. It produces its own magnetic field, a characteristic never discovered on a moon, detected by the Galileo spacecraft [4], which exists due to the moon's molten iron core, within Jupiter's magnetosphere [5]. Magnetic fields occur due to radioactive decay and heat from the formation of matter, which transpire from collisions and compression of matter. After thousands of years, the core becomes so hot that it reaches the melting point of iron - hence why there is a molten iron core. This core is illustrated in figure 1. For Ganymede, the matter used to form the satellite was (most likely) an accretion of dust and gas from the creation of Jupiter. It was much quicker at forming than other Jovian moons as it was closer to the planet, where the dust and gas were denser [6]. Convection within the liquid iron core, influenced by Jupiter's tidal forces, induces the magnetic field.

Closed field lines can be seen at a region 30^{o} below latitude, in which charged particles are trapped, creating a radiation belt - a region surrounding the moon where charged particles accumulate due to the magnetic field - composed of electrons, ions and energetic particles. We can observe and analyze the magnetic field produced by Ganymede and how this field alters the moon's interactions with Jupiter [7]. By studying public data retrieved by spacecraft that have flown by Ganymede, such as Voyager 1/2, Galileo, New Horizons, Pioneer 10/11, and Juno, we can examine trends, and explain results present on Ganymede, such as surface weathering.

Weathering can be observed on Ganymede, as the surface is very asymmetric, this is due to Jupiter's magnetosphere plasma being directed along the closed magnetic field lines to Ganymede, bombarding and colliding with the poles. Hence the poles appear to be bright, and the equatorial planes to not be as affected. Ice affected by radiating particles - due to the moon's magnetic field - is why the poles are so bright. Spacecraft such as Pioneer 10 and 11, Voyager 1 and 2, New Horizons, Galileo, and Juno spacecrafts all completed at least one flyby of Ganymede and collected data on the surface features - along with many other features. Ganymede's surface is composed of equal parts of rocky material and water ice and has two types of terrain - dark regions, which are old and full of impact craters, and young, light regions, where the terrain is molded due to tectonic-plate movement from tidal heating - repeated deformation of a body due to gravitational waves of another body - due to the Jovian moon being situated so close to Jupiter [8]. The light terrain has cross-cutting lanes and a grooved surface. These light and dark terrains are visible through the satellite's thin polar caps.

Dark terrain makes up for around $\frac{1}{3}$ of Ganymede's surface and based on measured crater densities, of which there are many in the dark sections of Ganymede, the terrain is estimated to be over 4 billion years old [9]. This is nearly the same age as Jupiter, and as Ganymede is thought to have been created at around the same time as Jupiter, the dark terrain, therefore, holds information for the processes that have affected the moon since it was created.

Light terrain is believed to be tectonic in nature, takes up $\frac{2}{3}$ of Ganymede's surface, and is a result of tidal heating events, because of Jupiter. Tidal heating could have exhausted the lithosphere (the solid, outer part of the moon), causing cracks and deforming the once-dark terrain. High-resolution images, taken from the Galileo spacecraft, prove the existence of the tectonic grooved light terrain [10]. Another cause for the light terrain may be cryovolcanoes - a volcano that erupts with ice, water, and other materials instead of molten rock and ash - erupting water onto the surface.

Ganymede also hosts its own atmosphere, which is oxygen-rich - abundant in O, O_2, and O_3 [6]. The Jovian moon's atmosphere is theorized to be due to ultraviolet radiation, causing molecules on the icy surface of the moon to split into hydrogen and oxygen, where the oxygen is trapped in the atmosphere and hydrogen is expelled into space [11]. There is an ionosphere - a layer containing a high concentration of ions and free electrons - within the atmosphere. It is believed that the ionosphere on Ganymede is composed of molecular oxygen at the polar regions of the moon, and atomic oxygen ions at low latitudes. Theories suggest the ionosphere should exist, as oxygen molecules are ionized by the impacts of the energetic electrons arising from the magnetosphere, and by ultraviolet rays radiated from the Sun. Protons are absent in all regions of Ganymede's ionosphere [12]. The presence of Ganymede's atmosphere causes an effect called 'air glow', where there is a faint emission of light as a result of the interaction between atomic oxygen and energetic particles. Air glow causes bright spots to appear on the polar regions, called polar auroras, and are due to the magnetic field present on Ganymede.

All of these characteristics of Ganymede are observable. Firstly, we will investigate the magnetic field of Ganymede, focusing on how it interacts with Jupiter's magnetic field, by finding available data, plotting graphs as shown in (Section of data), and producing a magnetic pole simulation between Ganymede and Jupiter (Section of coding). Then, we will explore similarities between Ganymede's magnetic field and surface weathering patterns, to find a correlation between the phenomena. Our research will explain why Ganymede looks the way it does, and allow us to gain a deeper understanding into the interactions that take place between Ganymede and Jupiter.

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