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93104R

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

Scholarship 2019
Earth and Space Science

9.30 a.m. Monday 2 December 2019

RESOURCE BOOKLET

Refer to this booklet to answer the questions for Scholarship Earth and Space Science 93104.

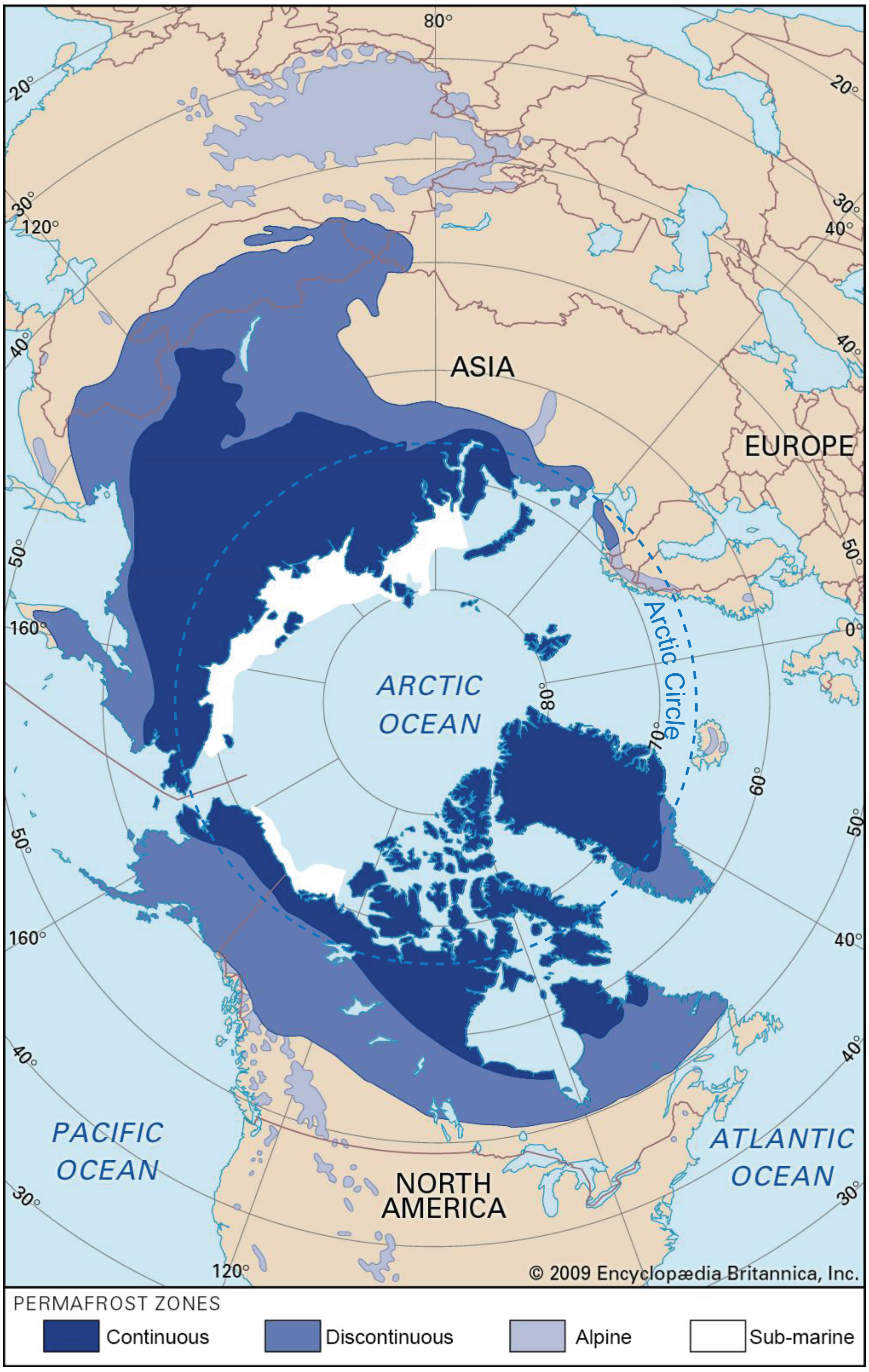
Check that this booklet has pages 2–7 in the correct order and that none of these pages is blank.

YOU MAY KEEP THIS BOOKLET AT THE END OF THE EXAMINATION.

Resource for
QUESTION ONE: TUNDRA – A MELTING LANDSCAPE

The tundra is a vast frozen plain, found in and around the Arctic Circle. It is characterised by both low summer and winter temperatures, which means that the soil below the surface is frozen. This is known as permafrost. Permafrost can be as deep as 1500 metres in some places, with a thin biologically active layer that thaws and refreezes every year. Globally, most permafrost was formed during the last ice age, which lasted for tens of thousands of years and ended about 10 000 years ago.

For more than the last 30 years, the Arctic region has been one of the fastest heating regions in the world, with average increases in air temperature of 3.5 degrees Celsius, compared with the global average increase of 0.9 degrees Celsius. This has resulted in the retreat of permafrost, and decreased surface snow and ice in tundra regions for longer periods of the year.



Distribution of permafrost in the Northern Hemisphere.

Adapted from T.L. Péwé, Arctic and Alpine Research, vol. 15 (1983), no. 2, p. 146
https://www.britannica.com/science/tundra/Environmental-conditions

Within the frozen layer, there are tens of thousands of years of deposits of dead animal and plant life. If layers of permafrost thaw, then microbes break down the organic matter in a wet, low-oxygen environment and produce methane as a waste product. The carbon stored in the permafrost is estimated at around 1400 gigatonnes (1 gigatonne = 1 billion tonnes), but with a large degree of uncertainty; this amount can be compared with the 850 gigatonnes of carbon in the atmosphere currently.

The first layer of clear ice on an Alaskan lake in winter captures methane. As permafrost melts, new lakes are forming all around the Arctic.

www.nationalgeographic.com/magazine/2012/12/methane/#/MM7908_101025_03526.jpg

Methane is bubbling from lakes all over the warming Arctic. Here a scientist ignites a large bubble that was trapped by the winter freeze – then freed by an ice pick.

www.nationalgeographic.com/magazine/2012/12/methane/#/MM7908_101026_04053.jpg

A large amount of this carbon could be released as methane. Methane is a greenhouse gas for which each molecule is 25 times more effective than carbon dioxide in warming the atmosphere. Gas seeps of methane large enough to be seen from passing planes, as well as large bubbles of methane trapped in ice, are common throughout the world's tundra regions, with some of this gas being diverted for use in homes for cooking and heating. The equation for the combustion of methane is as shown.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) + \text{energy}$$

Snowy reflective tundra, with an albedo close to 1 in winter compared with a much lower albedo, closer to zero, in the short summer growth period of up to 10 weeks.

https://northerncanadiantundra.weebly.com/meteorologistgeographer.html
www.trailfinders.com/cruises/hurtigruten

Resource for
QUESTION TWO: MASS EXTINCTION

There are five great mass extinctions known in the history of Earth. But probably none is more studied than the one that occurred 65 million years ago, wiping out 75% of the species living on this planet.

This event occurred at the Cretaceous-Tertiary boundary (also known as the K-T boundary or the K-Pg boundary) and there is a large amount of evidence that this mass extinction event was caused by an asteroid.

This mass extinction was significant, as it caused the extinction of dinosaurs, marine reptiles, ammonites, and many other marine and plant species around the world. There is evidence that more cool-climate species survived the impact than warm-climate species.

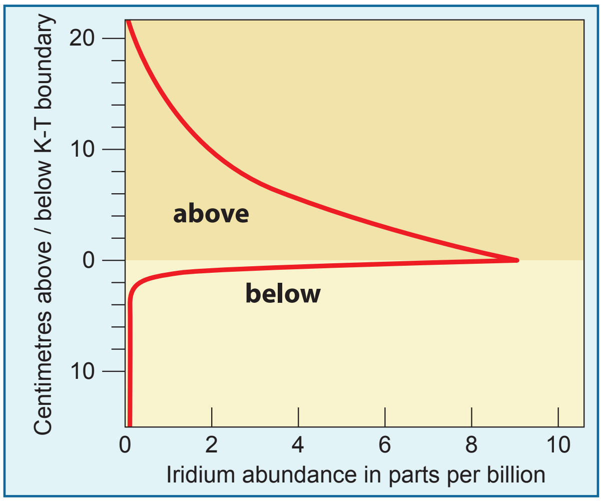
The asteroid is believed to have been 10 km in diameter, and its impact site is on the Yucatan Peninsula, Mexico. The impact site was mainly comprised of limestone and gypsum-rich rock, which also contained large amounts of sulfur and carbon. It is estimated that up to 100 billion tonnes of both sulfur and carbon were injected into the atmosphere by the impact.

Iridium is an element not commonly found on Earth, and it enters our atmosphere as extraterrestrial dust, generally at a constant rate. Scientists have determined the iridium concentration in some rock layers after the impact to be 9 ppb (parts per billion), which far exceeds the concentration if it had been produced gradually over time.

ERA	PERIOD	EPOCH	AGE*	MAJOR EVENTS
CENOZOIC	Quaternary	Holocene	0.01	Earliest *Homo sapiens*
		Pleistocene	1.8	Earliest *hominids*
	Tertiary	Pliocene	5.3	
		Miocene	23.8	
		Oligocene	33.7	Dominance of mammals
		Eocene	55	
		Paleocene	65	Widespread extinctions
MESOZOIC	Cretaceous		145	First flowering plants
	Jurassic		200	Dinosaurs dominant
	Triassic		251	

* millions of years ago

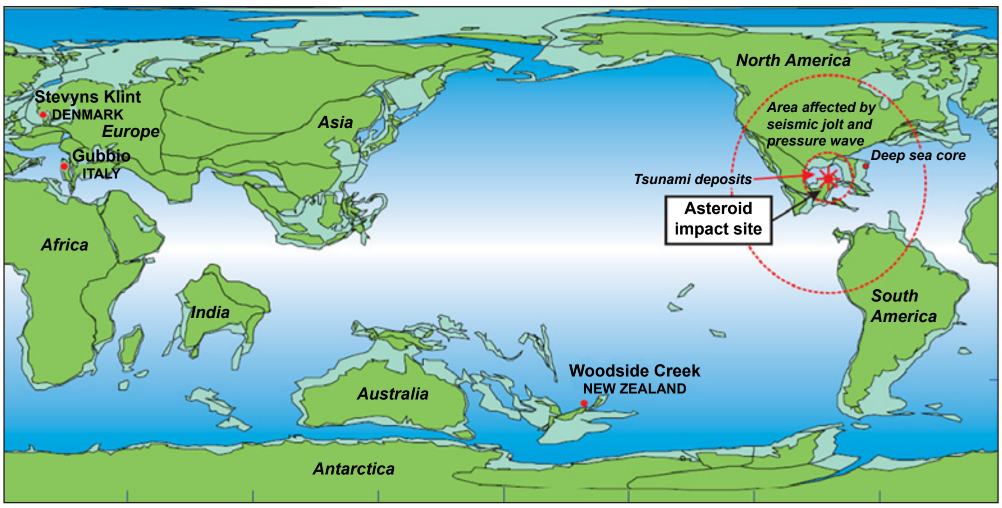
Adapted from: https://teara.govt.nz/en/diagram/8294/geological-time-scale



Iridium content across the K-T boundary in an Italian rock sample.

Source: https://undsci.berkeley.edu/article/0_0_0/alvarez_04

There are more than 100 sites all over the world where this iridium spike is observed, and eight of these are in New Zealand. The first New Zealand site recorded was Woodside Creek in eastern Marlborough. The five most complete K-T (Cretaceous/Tertiary) boundary sites in New Zealand are all located in the northern South Island. The Chancet Rocks, Woodside Creek, and Mead Stream sites are in deep marine limestone. The Waipara River site is in shallow marine

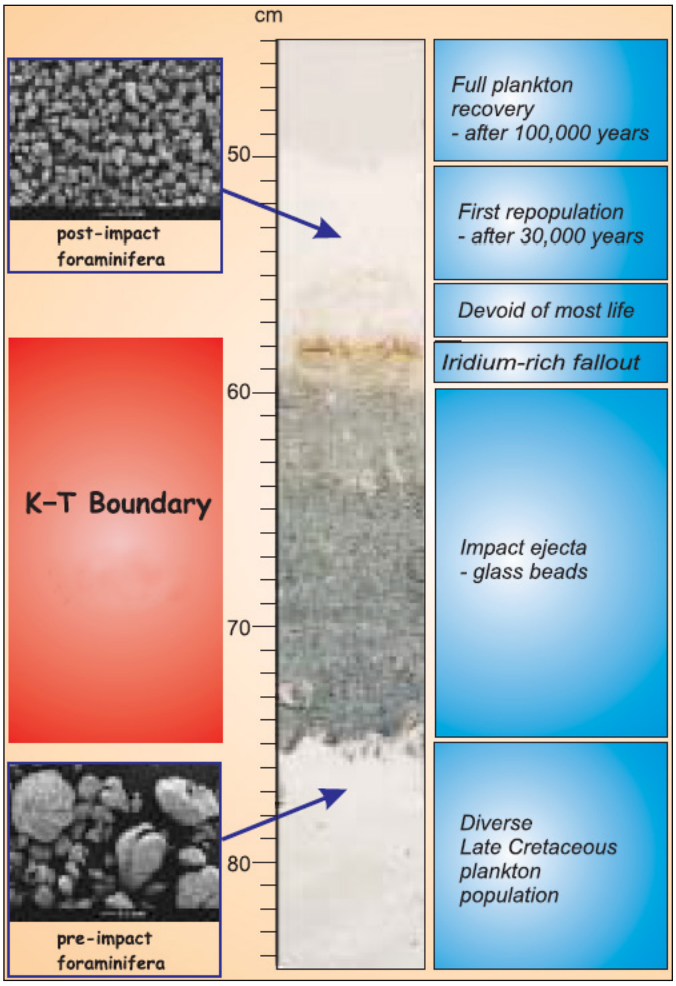


Map showing distribution of landmasses 65 million years ago, with the effects of continental drift removed, and the asteroid impact site on the Yucatan Peninsula, Mexico. Tsunami deposits are recorded throughout the Gulf of Mexico and the shock wave is predicted to have flattened forests over much of North America. Fallout from the impact is recorded as far away as Italy, Denmark, and New Zealand.

Source: Hollis, Christopher (2003). *Fatal impact: the asteroid that wiped out the dinosaurs*. Royal Society of New Zealand, Wellington limestone. The Moody Creek Mine site is the only record of the K-T boundary event in non-marine sediments (in this case coal and sandstone) in the Southern Hemisphere.

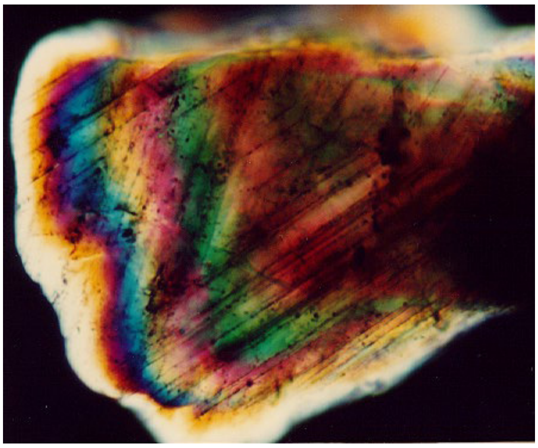
The New Zealand locations hold a very good account of what happened after the asteroid impact, and contain other pieces of evidence, such as shocked quartz and glass beads. Quartz is known to be shocked by pressure waves generated by volcanic eruptions, asteroid impacts, and nuclear bomb testing. If the quartz is shocked by volcanic eruptions, then it has linear fracture lines, and if the cause was asteroid or nuclear bomb testing, it displays crisscross fracture lines. Glass beads found in New Zealand are found widely in clay layers throughout the world and form in a similar fashion to hailstones, but rather than being made of water, they are formed from material ejected into the atmosphere from the asteroid impact.

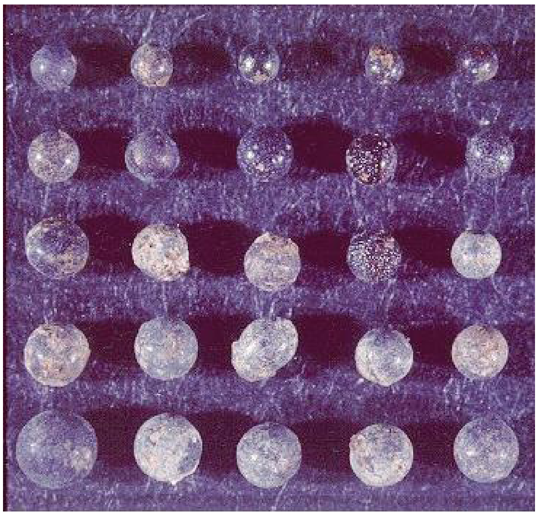
The New Zealand sites also have soot and complex carbon molecules called fullerenes, which provide evidence of huge forest fires. All of these pieces of evidence further support the asteroid impact hypothesis, as well as providing an idea of what happened subsequently. Other locations around the world show similar evidence to that found in New Zealand.



A deep-sea sediment core from offshore Florida, western Atlantic Ocean, shows remarkable evidence for the extinction among marine plankton – in this case fossil foraminifera – at the time of the asteroid impact. The impact is recorded by a 15 cm thick layer of glass beads, which are condensation droplets formed from the vaporised particles of meteorite and target rock, overlain by a thin layer of impact dust.

Source: Brian Huber, Smithsonian Institution





An impact-shocked quartz grain showing crisscross fracture lines (top) and glass beads (bottom) from the K-T boundary in Yucatan and Wyoming.

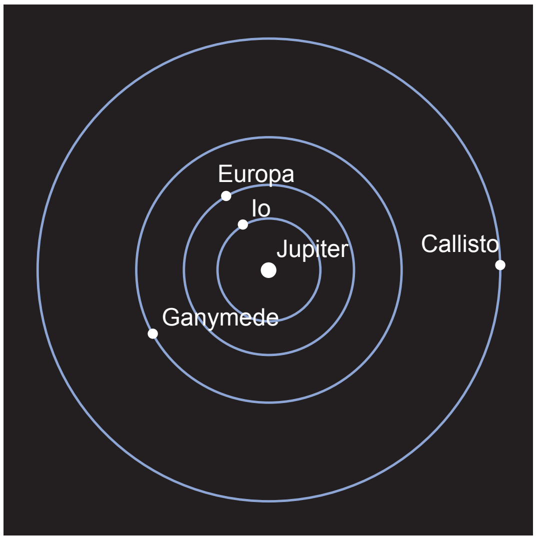
Source: www.uqac.ca/miac/chicxulub.htm

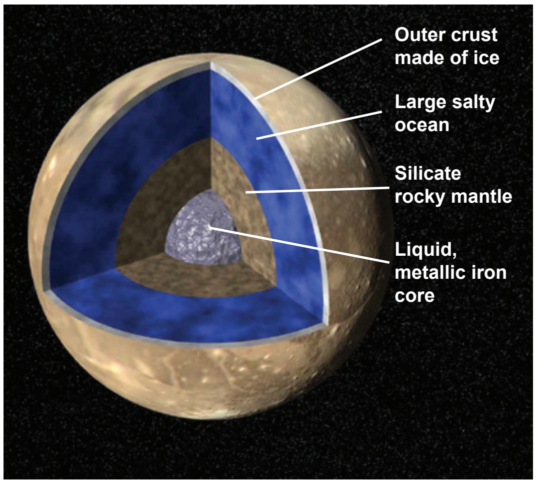
Resource for
QUESTION THREE: AURORAS ON GANYMEDE

Ganymede is the largest moon of Jupiter. It is thought to have a layered interior, with an iron core and a liquid ocean around it. Ganymede has light and dark regions on the surface, with the lighter regions being mostly areas of frozen water, and the darker regions having higher levels of materials such as clay. Ganymede's surface shows signs of strike-slip faulting and active tectonics due to tidal flexing and heating, gravitational interactions with Jupiter and the other Galilean moons, which some hypotheses suggest might have been much greater in the past.

Ganymede is of interest astronomically because it has a very strong magnetic field for a moon. Planets in the solar system have varied degrees of magnetic field. Earth has the strongest of the inner planets. Mars possibly had more significant magnetic fields in the past, but its magnetic field is now much smaller, although nearly 50 times stronger than the effect of Earth's oceans and tides, which form their own magnetic fields that minutely affect the Earth's auroras.

Venus is unusual in not having a strong magnetic field despite some aspects of the planetology being very similar to Earth. Gas giants have much larger magnetic fields than the rocky inner planets. Jupiter's magnetic field is both much stronger and larger than that of the Earth. It extends in a tear-drop shape three million kilometres towards the Sun, and more than a billion kilometres behind it. This large volume of space rotates with the planet and sweeps up particles that have an electric charge. Near the planet, the magnetic field traps swarms of charged particles and accelerates them to very high energies. Earth's Moon has interesting fluctuations within its magnetic field as it interacts with the much stronger field of Earth.





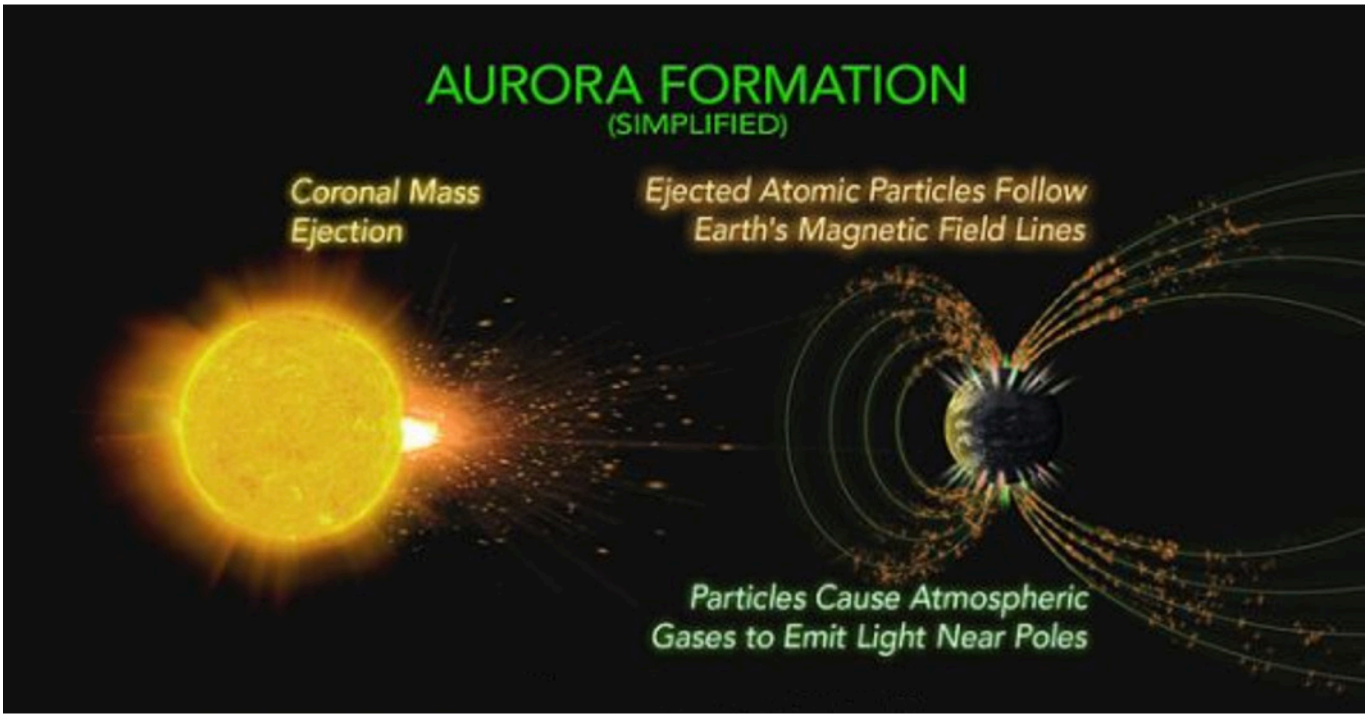
Hypothetical interior of Ganymede

www.jpl.nasa.gov/spaceimages/details.php?id=PIA00519

Planet / moon	**Mass (10^{24} kg)**	**Radius (km)**	**Density (10^3 kg m^{-3})**	**Average surface magnetic field $\|B_t\|$ (μT)**
Venus	4.87	6052	5.2	-
Earth	5.97	6371	5.5	38
Earth's Moon	0.07	1738	3.3	0.005
Mars	0.64	3390	3.9	$\leq$0.1
Jupiter	1900	69 911	1.3	550
Io	0.09	1821	3.5	-
Europa	0.05	1565	3.0	-
Ganymede	0.15	2634	1.9	0.91
Callisto	0.11	2403	1.9	-

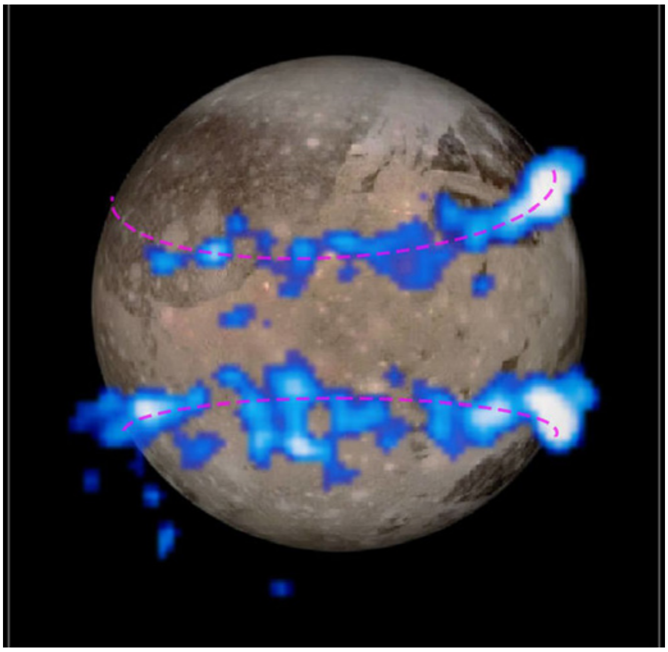
Data table of planets and moons including their average surface magnetic field measured in microtesla (μT).

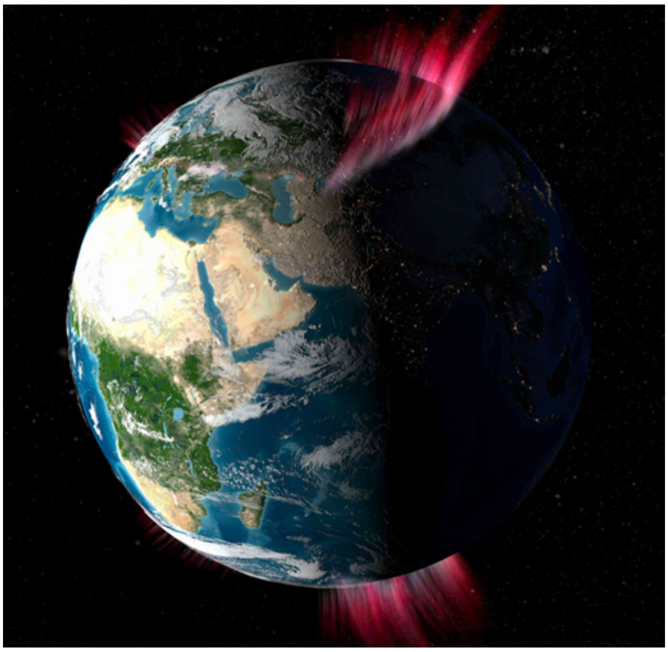
http://www.maths.gla.ac.uk/~rs/res/B/PlanetDyn/Schubert2011.pdf
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2009GL041721



www.accuweather.com/en/weather-news/northern-lights-viewing-condit/33834457

The auroras on Earth occur in a much straighter line around the poles than on Ganymede. Scientists predict the auroras should wobble around the poles on Ganymede by about 6 degrees as Jupiter spins. However, after hours of observations using the Hubble telescope, they suggest that the auroras were not rocking as much as they should be and were wobbling by only about 2 degrees. This decreased wobble implies that something in the moon's composition has affected the placement and movement of the auroras on Ganymede.





The projected auroras, of Ganymede and the Earth.

www.popsci.com/ganymede-has-electrically-conducting-ocean#page-2
www.newscientist.com/article/dn14400-magnetic-slingshot-creates-aurora-on-earth/

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