EUROPA: ITS SURFACE FEATURES AND IMPLICATIONS FOR LIFE

Victoria Griffiths

Europa is a puzzle. It has been a source of interest to scientists since its discovery in 1610. Europa is one of Jupiter's large moons and is the sixth largest moon in the Solar System. It is of great interest as there is the possibility of a subsurface ocean of water and dissolved mineral salts, which could support primitive life. There is only one other planet in the Solar System where there are large amounts of water near a solid surface, Earth. This makes Europa very important in the search for extra terrestrial life.

Using the data that have been collected from the various probes scientists have been able determine more about the interior structure of Europa. Using data showing the gravitational fields of the moon it is possible to determine its interior structure and density. This showed that Europa has a metallic core and a layered internal structure similar to the Earth's beneath its icy lithosphere. The crust is thought to be a maximum of 15 km in thickness but this may not be constant all over Europa.

The debate about whether there is a liquid ocean or a layer of warmer ice beneath the icy crust continues. There is certainly a layer of less solid material beneath the crust, which allows the formation of chaotic terrain and the large ridges. This layer is thought to be approximately 100km deep. The current thinking suggests that there is an ocean of liquid water, which contains mineral salts, particularly magnesium sulphate in solution. These salts can be seen on the surface as brine rich areas and are associated with many of Europa's surface features.

There have been suggestions of experiments that can be carried out which can determine the existence of a liquid ocean. These experiments may be taken to Europa with the next space mission there. However it is uncertain whether NASA will continue to fund this mission.

There are many different types of surface feature on Europa, some of which are unique. These features have very little vertical relief. None of them are higher than a few kilometres making Europa one of the smoothest objects in the Solar System.

Using impact craters to date the moon's surface, it has been found that Europa's surface is only 30 million years old. Looking at the relative ages of the surface features it can be shown that Europa is far from dead. It is very active although there is no direct evidence of current activity.

The first spacecraft to image Jupiter were Pioneers 10 and 11. They were sent to Jupiter in the early 1970's. The images they sent back of Europa were dim and of poor quality. However they were very useful in planning the later missions to Jupiter and Europa.

The majority of the available data comes from the Voyager and Galileo probes. Voyager was launched in 1977. Voyager 1 showed a large number of intersecting linear features cutting through red and brown mottled terrain in pale icy plains. These images were at quite a low resolution, as the probe did not pass very close to Europa. Voyager 2 showed these lineations as having a very low relief.

Galileo was launched in 1989. There are 12 instruments on Galileo, which are designed to look at particular features on Jupiter and the Jovian moons. Only two of these instruments have been used on Europa. These are NIMS (Near Infra-red Mapping Spectrometer) and SSI (Solid State Imaging). NIMS is used to record the thermal and compositional nature of Europa. NIMS is a hyperspectral instrument which records data using 400 bands. The SSI is a 1550 mm telescopic camera using visible light. The sensor is a CCD of 800 by 800 pixels. The images produced by the SSI are 20 to 1000 times better than the images produced by Voyager. This is mainly because the probe is closer and the instruments are more sensitive.

The resolution of the images from Galileo is very good and some areas of Europa have been imaged at a resolution of 9m per pixel. This has allowed us to get a close up view of some of Europa's surface features. However Galileo has had some problems with its antenna array which reduced the amount of data which was sent back to Earth. As a result of this it was not possible to map the whole of Europa in great detail.

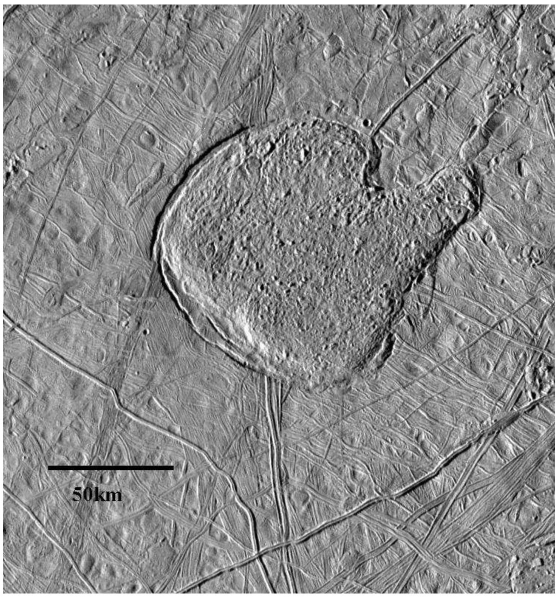
The passage of the Cassini probe through the Jovian system on its way to Saturn has allowed us another brief glimpse of Jupiter and its satellites.

There are many different types of surface feature on Europa but three that have been studied extensively are chaotic terrain, impact craters and Agenor Linea. Chaotic terrain forms some of the youngest features on Europa. It is composed of plains and other pre-existing material, which have been severely disrupted. Chaotic terrain is characterised by blocks of icy material set in a fine hummocky matrix. The contact between the chaos and the plains can either be a sharp boundary or a more gradational contact. The type of contact depends upon the type of chaos. There are also differences in the morphology of the chaos types.

The chaotic terrain can be divided into two main types. The first type is a smaller type of chaos with a very sharp boundary with the plains material. Here the chaos is raised above the plains. Features like the Mitten typify this type of chaos. The second type of chaos is larger and has a gradational boundary with the surrounding plains. The chaos is not raised above the plain like the Mitten. The Connemara Chaos typifies this type of chaos and it is more typical of chaotic terrain on Europa.

The Mitten is quite a large surface feature approximately 100km by 75km. It's distinctive shape looks similar to a Mitten with a "hand" and a "thumb" shaped feature.

Sun direction



This feature has some vertical relief. It is raised higher than the surrounding plains material and has a flat top with a hummocky surface made up of pieces of material within the matrix of the structure. There is a ditch around some of the feature. This is mainly seen on the west side. It is obscured to the south and there are some smaller ditches in the south-east. These ditches are thought to be faults caused by the loading of the ice. The chaos material looks to be "spilling" out over the surface. However in the south-east corner of the Mitten the material appears to be pushing up through the plains material rather than resting on top of it.

The Mitten and other raised chaotic terrains are thought to be flows which are pushed up from below the icy crust onto the surface.

The Connemara Chaos *(see illustration)* has a very different appearance to the Mitten It does not appear to have a raised surface above the plains material like the Mitten. It is approximately 60km by 100km in size. It does not have as distinctive a shape as the Mitten. It is more archetypal of the chaotic terrain seen on Europa.

This chaotic terrain contains both matrix material and large platey pieces of the plains material. The matrix is at a lower level than the platey material. The ratio of platey material to matrix is approximately 60:40.

Sun Direction

The Connemara Chaos (8N 275 W)

The platey material pieces are polygonal in shape and they range from 2 to 15 km in size. There has been some lateral movement and rotation of the plates in the chaotic terrain but not all of the pieces have been moved or rotated. Some of the pieces have been tilted. At a first glance they appear to be breaking away from the edges like icebergs.

The Connemara Chaos was not caused by a flow but by some other process. The boundary of the chaos suggests a gradual break up of the ice rather than a sudden event. This could indicate an ongoing process. It is possible that the Connemara Chaos was formed by a gradual melt through process caused by tidal heating by Jupiter. This means that there are large thermal anomalies within the interior of Europa which could have strong implications for a liquid ocean beneath the icy lithosphere

Unlike many objects in the Solar System, there are very few large impact craters on the surface of Europa. This has been used to give an approximate age for the surface of the moon of 30 million years. This is very important as it indicates that there must be a resurfacing process going on in order to produce such a young surface.

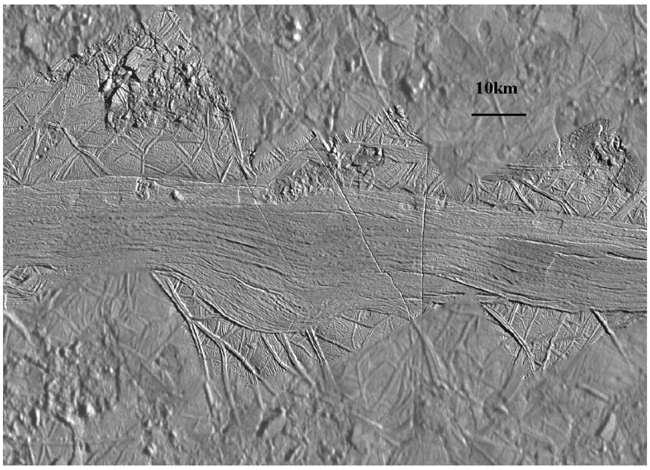
There are many small pits all over the surface of Europa. They are all between 0.5 and 1km in size. There are four simple craters with ejecta blankets and central peaks. They are all approximately 20km in diameter. The best preserved of all these craters is Pwyll Crater. There is one large multi-ring crater, Tyre.

Impactors of different sizes excavate to different depths, hence these sudden events give instantaneous information about the vertical structure of the ice.

The morphology of the craters and the compositional NIMS data show that there is a vertical change in the composition of the ice ranging from water rich ice at the surface to a brine rich ice at depth.

Agenor Linea is a large fault, which runs across the southern hemisphere of Europa. It is 1500km in length and up to 20km across. It is a strike slip fault which has some extensional movement. As it is such a long structure it has not been imaged in great detail all along its length.

It is thought that Agenor Linea was formed by the tidal effect of Jupiter. It mirrors the shape of the large triple bands that run along great circles on Europa. These triple bands are thought to be controlled by Jupiter's tides. They open and close with the tides and bring up material from the ocean below the lithosphere.



Part of Agenor Linea

Agenor Linea is a strike slip fault showing approximately 10km of displacement to the left. There is also approximately 10km of extension across the linea. Using high-resolution images it is possible match up ridges on either side of the Linea. The strike slip movement is thought to have occurred after the extension as the area of extension contains features, which are similar to those formed by strike slip faults on Earth. It is quite a young feature but it is being destroyed in places by chaotic terrain. This shows that Europa is not an inactive, dead moon but that there are ongoing dynamic processes affecting its surface.

There has been much speculation about the presence of primitive life on Europa. Scientists suggest that there is a liquid ocean beneath the lithosphere. There are also large thermal anomalies in this layer. The presence of liquid water containing salts, a source of heat energy and a solid surface are very important for life. Life exists in similar conditions at the bottom of the ocean on Earth. It is quite possible that life may have developed at the bottom of the ocean on the rocky surface.

For more information on Europa and links to other Europa sites and NASA missions try the following websites.

G.E.M. HOMEPAGE.
http://galileo.jpl.nasa.gov/galileo/europa

NASA'S PLANETARY PHOTOJOURNAL.
http://galileo.jpl.nasa.gov

MAKING MOUNTAINS- the building of Tibet and its consequences for global climate

- extract from an article in G.A. Magazine, Vol. 3, No 2, 2004

Nigel Harris

Over the past 50 million years global climate has been characterised by a strong cooling trend, suggesting a depletion of CO_2 in the atmosphere. One of the most powerful mechanisms for reducing atmospheric CO_2 is the weathering of continental, silicate-rich sediments. The linkage between Tibetan uplift and global climate is as follows. Uplift of the Tibetan Plateau provides a source of summer heating in the lower atmosphere that draws humid air masses northwards from the Indian Ocean. The resulting airflow is forced to rise steeply over the Himalaya, leading to the summer monsoon on their southern slopes and on eastern Tibet. The great Asian rivers that rise in Tibet and descend over 5 km before reaching the sea are a consequence of the monsoon, and these rivers contribute a quarter of all the dissolved matter influxed to the oceans by global rivers, despite the fact that the Tibetan Plateau comprises less than 5% of the continental surface area. Geochemists are currently studying the Ganges and Brahmaputra river systems to develop proxies for silicate weathering rates, and to determine the impact of the India/Asia collision on global climate.