Impact cratering and disruption on Icy bodies and landscapes

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1. Introduction

The icy moons of Saturn and Jupiter are large and many are theorised to have a subsurface ocean beneath the surface layer of ice such as Europa [1] and Enceladus [2]. This makes these bodies prime targets for possible habitability with the ocean providing the medium which support the organic molecule needed for life to form. However, icy bodies are just as likely as other bodies to suffer impacts and though this may bring in the energy required for life to form [3], impacts can also cause major disruption to body, but the results of impacts also provide information about the icy moon structure which can help understand where life could develop due to variation in the size, shape and depth of the crater.

2. Aims of Project

This abstract is a summary of two major projects being undertaken by the Kent Impact Group at the University of Kent in order to discover more about the structure of icy moons and the scenarios under which catastrophic disruption would occur and what occurs on the surface during large scale impacts.

For project one impact experiments were undertaken with targets of ice over a sub-surface material of water, basalt or sand. For each sub-surface material, different thickness of the ice was laid above to recreate a planetary surface with an icy crust [4].

Project two investigated large impacts into whole ice spheres. Three types of ice spheres have been impacted: 1. Solid ice spheres, 2. Hollow ice spheres filled with water, 3. Hollow ice spheres filled with water and a solid core. Similar to the first project impact experiments were undertaking changing the thickness of the ice crust to understand the impact features that form on the surface including the impact crater and resulting fractures and disruption.

3. Methods

3.1 Layered Ice Targets

Each target was prepared so that the required ice thickness would be completely frozen with few blemishes and no cracks to act as weakened areas of the target. The ice formed downwards from the open top surface of a cylindrical flask of water, and the thickness required for each investigation was determined by varying the time interval the target remained within a -23 ^{O}C environment. Once placed in the target chamber a metal ring cooled to -140 ^{O}C was placed on the target to prevent the edge of the target melting and the water inside escaping. Impacts into water ice targets have been extensively researched [5 and 6 etc.] which provided a method for producing clear unblemished ice targets that were then modified for this study.

3.2 Ice Spheres

The ice spheres were formed using a similar method freezing from the outside inwards allowing different thicknesses to form as required. A balloon was used to form the correct shape and a core was placed within the balloon during the freezing process.

3.3 Impact Experiments

The impacts were produced using the two stage light gas gun facility at the University of Kent [7]. Table 1 shows the impact parameters used for each project.

Project	Impactor	Impact velocities used	Ice thickness
Layered Ice Targets	1.5 Al sphere	1 – 5 km s^{-1}	5 – 210 mm
Water filled Sphere	1.5 Glass sphere	1 – 5 km s^{-1}	25 mm
Water filled Sphere with Core	1.5 Glass sphere	1 – 3 km s^{-1}	7 – 40 mm

Table 1: Impact parameters for each Icy Moons project

4. Results and Discussion

4.1 Depth of Ice

There is a positive correlation between the thickness of the ice layer and the size of the crater. However, it was found that once the ice thickness was >15.5 times the diameter of the projectile there are no changes to the size or depth of the crater, meaning that at this thickness the ice layer is semi-infinite. When the ice thickness is less than this value there is a 4% reduction in the crater diameter for every projectile diameter reduction in ice thickness [4]. At an ice thickness of < 7 times the projectile diameter, penetration of the ice layer occurs forming deep shallow craters with an H/D (crater depth/diameter) of around 0.65. Between 7 and 15.5 times projectile diameter, there is a positive correlation between the ice thickness and the crater size meaning that within a limited threshold dependent of the projectile size the thickness of the ice can be determined. The density of the subsurface material also has an effect on the crater produced when the impacts were penetrative with all three target types producing different crater morphologies [4].

4.2 The Production of Fissures

The results of project two are still ongoing but the initial results show that during an impact fractures can from across the breadth of the body and open up. In the laboratory, this results in fragments of the target falling away but on a planetary scale, this would probably result in the opening of fissures allowing the escape of gasses and liquids from the sub -surface ocean which would then refreeze over time.

4.3 Disruption

Disruption of a target is when the target is completely broken up due to a single impact. It was concluded from the initial experiments using a constant thickness of 25 mm and a range of impact speeds, (see table 1) that below energy density of 13 J kg $^{-1}$ a non-penetrative crater is produced, 13 – 15 J kg $^{-1}$ a penetrative impact is produced and 15 -18 J kg $^{-1}$ disruption of the target occurs. In addition to the water filled target impact were also undertaken into solid ice bodies for a comparison between a homogeneous and a heterogeneous target. It was found that for a solid ice sphere at an energy density greater than 18 J kg^{-1} complete disruption of the target occurs.

5. Conclusions and ongoing work

This work is ongoing and is attempting to aid in our understanding of icy moons from remote sensing analyses alone. This work has shown that impact crater morphology can be used to gain an idea of the thickness of the ice layer and so the location where the ice is a suitable thickness to allow life to develop with enough light reaching the ocean. This work will continue to investigate impacts into these whole bodies including the more detailed study into the effects a solid core may have on the products produced by an large impact cratering event.

6. References

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Short Summary

Impact craters onto icy bodies can aid in our understanding of the internal mechanics and structures of those bodies. We present the results of a series of impact experiments into icy moon analogues in order to discover more about the possible habitability of these bodies.