Automated Feature Detection and Hydrocode Modeling of Impact-Related Structures on Mars

First Year Annual Report, Solid Earth Geophysics Focus
University Campus: U. C. Santa Cruz
Start Date: October 1, 2003
Second Year Start Date: October 1, 2004

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Abstract

We are studying large-scale impact structures on planets (Mars in particular), exploiting extended impact aftermaths (craters, ejecta, secondary crater fields, and rays) to better constrain target geologies and the detailed mechanics of planetary cratering. Our goals include forward modeling of impacts on Mars, with special attention devoted to the fate of ejecta (rampart ejecta, secondary craters, atmospheric contributions), together with remote sensing analysis of Mars image products.

In the first year we have achieved the significant milestone of completing much of the remote sensing application development and obtaining key results for rampart craters and secondaries. We have developed algorithms to rapidly and automatically extract a list of craters with center coordinates and radii from a satellite image. At this time we are in the final stages of testing the accuracy of these algorithms against peer-revued manual crater counts. We have also made great progress working with the SAGE hydrocode to verify the physical accuracy of the simulated results, and model impacts under realistic Martian conditions (CO2 atmosphere, multi-layered targets including layered ice-rich soils, etc.). We are now able to design and run simulations in one or two dimensions, with complicated and increasingly realistic simulated target and impactor geologies.

Summary of research results to-date

The first phase of the project is nearing completion. Two lines of research are being pursued, image processing, which involves the GENIE software, and impact modeling, which involves the SPH and SAGE software. We have made good progress along both lines, overcoming unforeseen obstacles, clarifying objectives, and producing good results.

On the image processing side, we are now able to process THEMIS (multispectral infrared), and Mars Orbiter Camera (high resolution grayscale) data, and use GENIE to develop algorithms for feature extraction in satellite imagery. Due to a clock error in the THEMIS instrument, it was not trivial to process the data into a useful form. The bands of each image, when processed according to the instrument team's instructions, were misaligned relative to each other by several pixels. Brumby and Plesko developed techniques to manually align the bands to within one pixel, which appears to be sufficient for the purposes of automated crater detection.

We have succeeded in evolving crater-finding algorithms that can detect craters with 95-97% accuracy. We then leverage the graphical results of the crater-finding algorithms through a filter for circularity (to further improve accuracy), and a script that calculates the crater centers and radii, which are then output to a database. This is the first automated crater counting effort not only to successfully detect the craters within an image, but also the first to succeed in translating detection into a human-readable database of crater sizes and locations. Initial results were presented at the American Geophysical Union's annual Fall Meeting in November 2003, and at the Lunar and Planetary Society's annual meeting in March.

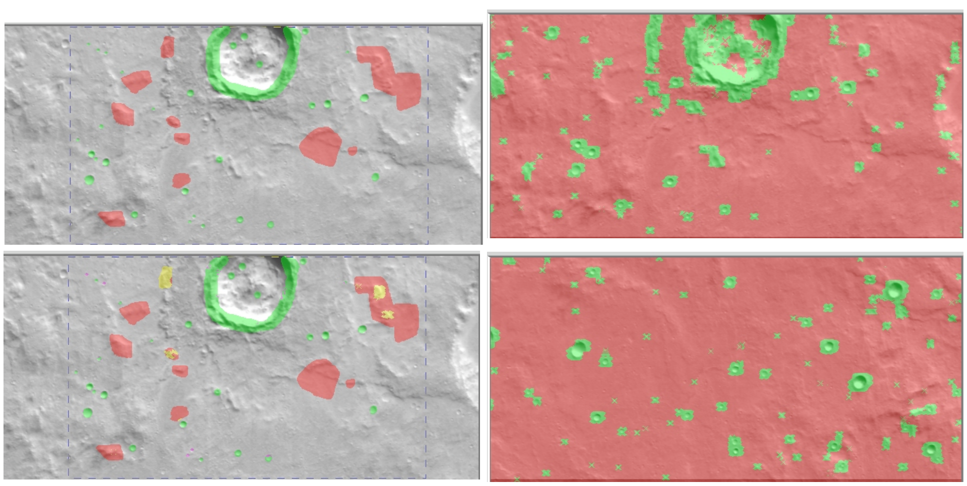

Fig. 1. (Top row) GENIE input file, results file, (bottom row) comparison of the two, result of algorithm on data not in the training sample.

The final stage of the crater detection phase is to compare the results of the crater counting algorithms against a peer-reviewed manual count. We are in the process of completing this stage, and will present our results at the American Astronomical Society's Department of Planetary Sciences Annual Meeting in November 2004 in preparation for a full publication of the results of this phase of our project in the Journal of Geophysical Research.

Preliminary modeling efforts have also been successful. GRA Plesko learned to use SPH and developed a model of the Shoemaker Regio impact on Eros, and demonstrated the possibility that the impact may have formed the nearby Rahe Dorsum fault. University PI Asphaug and GRA Plesko met with lab co-PI Gisler in August 2003 to train on the SAGE modeling software and associated equations of state. Preliminary modeling efforts to verify SAGE's accuracy and usefulness in planetary impact studies using well-documented events like the Scooter and Sedan explosions are nearing completion. GRA Plesko has begun learning about various equations of state, specifically ANEOS and SESAME. Elisabetta Pierazzo (U. Arizona) is working with PI Asphaug on a separate project (impact de-hydration of asteroids) so the PI has access to the latest developments of ANEOS for use with hydrated minerals such as serpentine, which may prove to be useful analogs for this proposed work. In the process of training and verification of software, it has been decided that SAGE will be more useful than SPH for half-space impacts, so future modeling efforts will probably exclusively use SAGE.

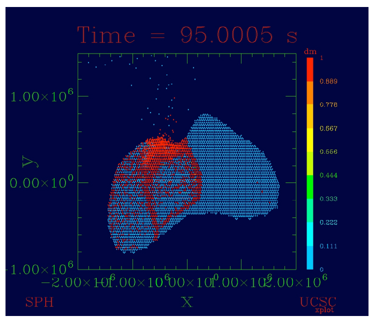

Fig. 2. SPH simulation of cracks in asteroid 433 Eros generated by an impact to the upper left lobe of the asteroid. Cracks and damaged area correspond accurately to observed fault and damaged regions.

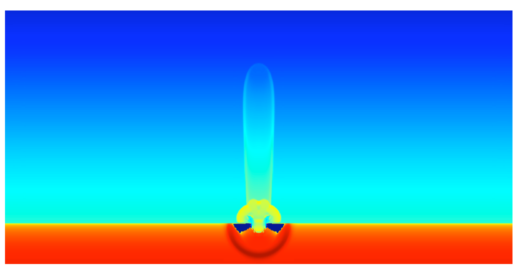

Fig. 3. SAGE preliminary test model of pressures during Bosumtwi crater impact, Ghana.

The main phase of the impact modeling line of research has begun. In this phase we are examining a variety of impacts in to the early Martian surface (circa 4 billion years ago). Our main questions are how subsurface water would respond to a primary impact into the surface, and to a prolonged rain of secondary impact debris over a much wider area. The way in which impacts and their ejecta affect the release of water and other volatiles into the early Martian atmosphere may have a profound impact on the early and potentially water-rich climate of the planet. We are currently running a model of a hypothetical primary impact, and will present our preliminary results at the American Geophysical Union's annual meeting in December of this year.

List of publications, including submissions

We have two papers under preparation, which we will submit for publication in early 2005.

List of Presentations

Brumby, S. P., C. S. Plesko, E. Asphaug, "Evolving Automated Feature Extraction Algorithms for Planetary Science" ISPRS Extraterrestrial Mapping Workshop, 2003.

Plesko, C. S., E. Asphaug, G. R. Gisler, J. A. Manion "Autodetection of Impact Crater Statistics and Crater Morphologies in Mars THEMIS Data" American Geophysical Union, Annual meeting, November 2003.

Plesko, C. S., S. P. Brumby, E. Asphaug, D. Chamberlain, T. Engel, "Automatic Crater Counts on Mars", Lunar and Planetary Science Conference, March 2004.

Plesko, C. S., S. P. Brumby, E. Asphaug, "A Comparison of Automated and Manual Crater Counting Techniques in Images of Elysium Planitia." American Astronomical Society Department of Planetary Sciences Annual Meeting, November 2004

Plesko, C. S., E. Asphaug, G. R. Gisler, "Ejecta Curtains and Ground Ice on Mars: Efficiencies of Volatile Release. American Geophysical Union Annual Meeting, December, 2004

Progress of the graduate student towards a PhD:
GSR Catherine Plesko has made good progress in defining her thesis proposal and assembling her thesis committee. She finished all department-required courses in Spring 04. In addition to the research progress described above, she has taken courses in Remote Sensing, Geology, Geomorphology, Fluid Dynamics and Modeling, Magnetohydrodynamics, Planetary Geology, Geodynamics, and Cratering Processes.

Visits and exchanges of personnel between the University and Laboratory:

Summer 03, Asphaug and Plesko to LANL
October 03, Brumby to UCSC
March 04, Plesko to LANL
May 04, Gisler to UCSC
July-August 04, Plesko to LANL

LANL and/or facilities used in the research

LANL ISIS/GENIE software (ISR-2), and collaboration with the ISIS software development team.

LANL SAGE software (X-2)
LANL Lambda/Theta, and QSC high performance computing resources. (For use with SAGE, which is restricted to LANL machines.)
UCSC SPH code as modified by Asphaug.
UCSC Excalibur high performance computing and other computing resources. (SPH only.)

Budget details

The budget has been spent, as proposed, only on the following: (1) academic GSR support for Catherine Plesko during the academic year at UCSC; (2) summer support for Catherine Plesko at Los Alamos National Laboratory, and (3) directly-related travel.

Efforts to secure further funding from other agencies.

GRA Plesko obtained a $500 travel grant from the UC Santa Cruz branch of the IGPP Center for Origin, Dynamics and Evolution of Planets (CODEP). The ongoing research is expected to grow into a Mars Fundamental Research proposal to study impact craters on Mars, which we intend to propose in the end of the second year or early in the third year of this award.