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Improving and Facilitating Research on Collapse Calderas

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Roughly circular depressions known as calderas are distinctive features in volcanic areas (see Figure 1). Current views explain a caldera as the surface expression of a magma chamber's collapsed roof after magma drains elsewhere. Although not all calderas are associated with explosive activity, most major eruptions (i.e., those with a volcanic explosivity index of 5 or higher) develop such collapse calderas. Calderas are usually associated with magmatic systems that have endured for thousands of years at least. These systems undergo periods of unrest highlighted by ground displacement, seismicity, and gas emissions. As a consequence, calderas are some of the most studied volcanic features, particularly for their possible implications for hazard assessment and mitigation. In addition, calderas can be associated with geothermal and ore resources and can affect climate through the products they emit.

Calderas have been identified and investigated for decades, mainly through field analyses aimed at recognizing the nature and dispersion of the volcanic deposits associated with magma chamber evacuation. In recent years, more attention has been paid to understanding the nature and features of caldera unrest, structure, and development using a variety of geophysical, geodetic, and modeling techniques.

However, despite the many studies on calderas, major questions still remain poorly addressed. For example, what conditions can lead to caldera unrest? How does unrest evolve into an eruption? How may caldera structure and development influence volcanic activity? To help answer these and other questions related to calderas, in March 2008 the executive committee and the secretary general of the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) approved the creation of the new IAVCEI Commission on Collapse Calderas (CCC).

Current CCC Projects

The idea to file for the CCC emerged in 2005 during an IAVCEI workshop on caldera volcanism. The workshop spurred the creation of the Collapse Calderas Work Group, which later became the more solidly defined CCC. CCC includes a wide spectrum of disciplines, such as caldera geology, geophysics, mathematical and analogue modeling, subcaldera magma chamber processes, volcanic hazard and risk management, economic benefits, and environmental research. It promotes interdisciplinary action to help solve the many questions regarding the formation of collapse calderas, their evolution, and their effect on society.

In the past 3 years, CCC has promoted caldera-related activities with the support of IAVCEI officers including Secretary General Joan Martí; commissioners Gerardo Aguirre-Diaz and Adelina Geyer; and, from October 2010, new commissioner Valerio Acocella. These activities include creation of a Web site and a database, organization of workshops and courses, and the publication of IAVCEI-affiliated results in journals and books.

The Web site (http://www.gvb-csic.es/CCC.htm) contains the most important and up-to-date information on the scope and activities of CCC, which currently consists of more than 70 members worldwide. The Web site provides information about the most recent scientific results on calderas, key studies, a caldera reference list, and the activities of CCC.

A new collapse caldera database (CCDB; http://www.gvb-csic.es/CCDB.htm) is a significant component of the CCC Web site, which maintains a comprehensive catalog of information on all identified collapse calderas. Its aim is to update current field-based knowledge on calderas by merging previous databases and complementing them with existing studies. The availability of accurate and comprehensive statistics is vital to improving scientific understanding of these volcanic structures. This extensive data compilation is meant to be an accessible and useful tool for investigating caldera collapse processes.

Fig. 1. Hundreds of calderas dot the globe. Shown is a 4-kilometer-wide view of the youngest sector of the Las Cañadas caldera from the summit of the Tenerife Teide volcano. The eastern sector of the caldera wall is well exposed, and recent lavas from Teide and tephra products from an eruption 2000 years ago of the nearby Montaña Blanca form the top of the caldera fill sequence. In the foreground, the 300-year-old cinder cones are also visible. Careful examination of calderas such as Las Cañadas will help scientists understand local hazards, assess mineral resources, and evaluate how these features influence climate.

Workshops about calderas are organized on a regular basis (on average, every 2 years) and have been held at Tenerife, Canary Islands (2005); the Trans-Mexican Volcanic Belt, in Querétaro, Mexico (2008); and Réunion Island, in the Indian Ocean (2010). These workshops have allowed CCC members and other researchers to interact and exchange their multidisciplinary expertise on calderas through dedicated sessions and field excursions on different types of calderas. As part of the last workshop, held in Réunion, CCC started a new initiative, the International Course on Collapse Calderas. This course is open to undergraduate students, Ph.D. candidates, and postdocs. The next course and workshop are planned for late September 2012 in the Vulsini caldera district (Bolsena and Latera calderas), in Italy.

Scientific results have been inspired by or benefited from the multidisciplinary approach of these workshops, giving the scientific community the opportunity to discuss and focus on both specific and general aspects of calderas. Significant results among these are the publication of a book entitled *Caldera Volcanism: Analysis, Modelling and Response* [*Gottsmann and Martí,* 2008] and review studies on caldera formation, structure, and classification [e.g., *Acocella,* 2007; *Martí et al.,* 2009].

CCC has strongly encouraged the use of new methodologies, mainly using mathematical and analogue models, as well as fundamental field volcanology to understand caldera collapse. These models have provided a robust scientific foundation for further understanding of caldera structure, development, and eruptive behavior.

Future Challenges

Future challenges for CCC include ensuring open access of scientific results as they are acquired by the caldera research community and facilitating discussion on key facets of calderas that remain poorly understood. These include the role of regional tectonics and preexisting discontinuities in eruptive behavior, how resurgence is triggered, and the nature of eruptive patterns as a function of the stress state and processes within the chamber.

Additionally, CCC aims to present acquired knowledge for easy use by those conducting hazard assessments and to provide background information on the economic benefits of caldera systems. Paramount issues that CCC plans to tackle include proposing a systematic classification of calderas; understanding the root causes and triggers of caldera unrest; uncovering how periods of unrest lead to eruptions; quantifying the climate effects of caldera-forming eruptions; and revealing the interconnections among caldera structures, geothermal energy, and hydrothermal ore deposits.

The accomplishment of these goals will not only help scientists to significantly increase their knowledge on collapse calderas but will also help them to better characterize the natural resources linked to calderas and to assess hazards and their mitigation during times of caldera unrest.

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New High-Resolution Images of Summer Arctic Sea Ice

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In 1995 a group of government and academic scientists were appointed by the vice president of the United States to review and advise on acquisitions of imagery obtained by classified intelligence satellites (National Technical Means) and to recommend the declassification of certain data sets for the benefit of science. The group is called MEDEA and was first described by *Richelson* [1998]. MEDEA disbanded in 2000 but reassembled in 2008.

On 15 June 2009, under the auspices of MEDEA, the U.S. Geological Survey (USGS) released to the public as Literal Image Derived Products (LIDPs) numerous images with 1-meter resolution acquired since 1999 at six locations in the Arctic Basin (Beaufort Sea, Canadian Arctic, Fram Strait, East Siberian Sea, Chukchi Sea, and Point Barrow). These locations are named "fiducial sites" to suggest that the collected imagery establishes a baseline data set for understanding recent and future changes. Data in the Global Fiducials Library (GFL) can be accessed via http://gfl.usgs.gov/. This data repository is updated by USGS as additional data become available.

As described in the *National Research Council* [2009] report "Scientific value of Arctic Sea ice imagery derived products," which was published at the same time as the data release in 2009, these LIDPs are valuable for understanding changes in the Arctic Ocean sea ice cover. Individual LIDPs are 1-meter-resolution, geocoded panchromatic images that cover an area of approximately 15 × 15 kilometers of Arctic sea ice. Since Arctic stratus clouds frequently obstruct imaging of the surface during summer, repeated acquisitions are typically required to obtain a single cloud-free scene of the surface.

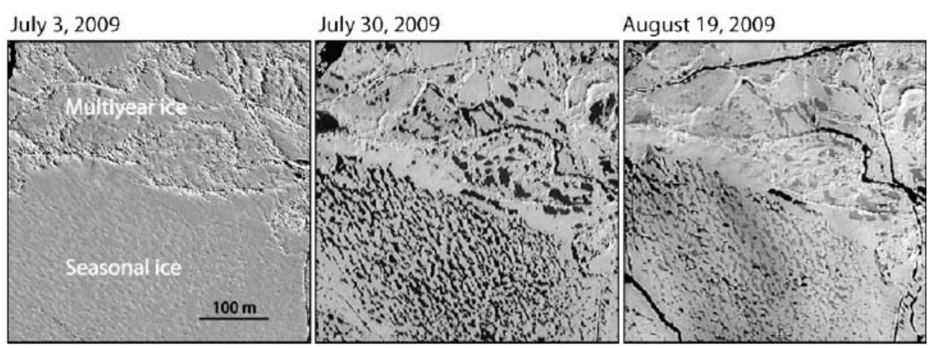

Fig. 1. High-resolution (1-meter) Image Derived Products (IDP) imagery captures the development of melt ponds on drifting sea ice: (left) prior to the onset of melt on 3 July 2009, (middle) melt pond coverage on 30 July 2009, and (right) partial freeze-up on 19 August 2009. Differences in the coverage and geometry of melt ponds over seasonal and multiyear ice can clearly be seen. Acquisitions of the imagery of these drifting ice parcels are guided by the locations of drifting buoys. The ensemble drifted a net distance of approximately 220 kilometers from 86.1°N, 3.3°E to 84.1°N, 2.4°W over the period of about 46 days. Each image covers an area of 400 × 400 meters.