ELSEVIER

Journal of Structural Geology 28 (2006) 2121–2122

JOURNAL OF STRUCTURAL GEOLOGY

www.elsevier.com/locate/jsg

Editorial

Introduction to the Special Issue on faulting and fault-related processes on planetary surfaces

Abstract

Faults have been documented on nearly every solid surface in the solar system, from asteroids to moons to planets, and they provide a remarkable suite of data sets and critical problems for investigation and analysis by structural geologists. The lack of significant atmospheres on Mercury, the Moon, and most outer planet satellites, along with slow erosion rates and a lack of crustal recycling and Earth-like plate tectonics on most planetary bodies, allows for excellent preservation of fault scarp morphologies for study of fault populations and developmental sequences.

Keywords: Faulting; Planets

This Special Issue consists of 10 papers that represent some of the exciting work that is currently being done in planetary structural geology. The methods that are used in these papers are diverse, including field study of Earth-based faults, mapping of fault patterns from digital images of planetary surfaces acquired by spacecraft imaging or radar, mechanical modeling of fault-related topography, and calculation of potential causative stress fields for planetary structures. Most papers combine two or more of these approaches to arrive at the best interpretation within the constraints of the available data. As a result, the study of planetary structures is inherently a multidisciplinary one that exploits multiple data sets and approaches. The need for a detailed understanding of the uncertainties of planetary data sets and successful cryptography of the jargon of planetology may hinder access to, or an appreciation of, the high-quality research being accomplished in the field. Publication of a set of these papers for the first time in the Journal of Structural Geology demonstrates the rigor of contemporary research in planetary faulting and presents a feast for anyone interested in faults and fault-related processes.

Although the Special Issue focuses on processes, the papers are arranged geographically, first with our home planet and then through the solar system, as is customary in planetary science. The first five papers present work regarding bodies of the inner solar system, specifically Earth, Venus, and Mars. The next five papers present results for structures on Europa, one of the icy satellites of Jupiter in the cold outer solar system. An enormous volume of fine work is available in the literature, beyond this Special Issue, for fault systems on Mercury, the Moon, asteriods, and the satellites of the outer solar system. The papers collected here may provide an invitation, and a portal, into the structural geology, tectonics, volcanology, petrology, and geophysics of the full set of geologically interesting planetary bodies in our solar system.

Martel and Langley (2006) begin the Special Issue with a detailed geological and mechanical study of normal fault scarps of the Koae fault system on Kilauea volcano in Hawaii, with results that are important to the tectonics and hydrology of planetary grabens. They show that the collection of locally breached monoclines underlain by prominent cavities, deep gaping fissures on the footwall, small fissures on the hanging wall, and buckles at the scarp base forms as a normal fault propagates up towards the surface rather than down from it.

Kiefer and Swafford (2006) analyze the topography and growth of the Devana Chasma rift on Venus. Their work reveals that the rift topography results from both mechanical (flexural uplift) and thermal origins, and that the segments propagated into an interacting echelon geometry related to upwelling in the underlying mantle plumes.

Buczkowski (2006) investigates the origin and timing of ridges radial to the Irnini Mons volcano on Venus, based on calculations of the stress changes around a hole in a plate. She finds that regional north–south compression that caused the east–west trending wrinkle ridges was still active during the formation of Irnini Mons.

Okubo and Schultz (2006) investigate the origin of a set of intersecting fractures in the Tharsis area of Mars. They

0191-8141/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jsg.2006.09.005

demonstrate from topography and imaging data that the structures are strike-slip faults and evaluate several possible tectonic models for their formation. Based on calculations of mechanical interaction and observed cross-cutting relations, seismic stress triggering (Marsquakes) is inferred as the most likely mechanism for the development of the fault array.

Schultz, Okubo, and Wilkins (2006) compile and interpret measured values of maximum displacement (offset) and map length of normal and thrust faults on Mercury and Mars. Using a fracture mechanics model, they show that the displacement–length ratios of faults scale primarily with planetary gravity, with the rock type and pore-water conditions also being important. This work provides a physical basis for the observation that faults on planets and satellites in the solar system that are smaller than those on the Earth develop smaller values of displacement along faults of the same length.

Nimmo and Schenk (2006) identify two probable normal faults on the icy surface of Jupiter's moon Europa. They derive topography from a combination of stereo imaging and photoclinometry (shape-from-shading), determine the effective elastic thickness from flexural modeling, and find fault displacement–length ratios similar to faults on rocky planets. Additionally, they derive a shear modulus for Europa that is very low, implying significant near-surface fracturing or porosity.

Kattenhorn and Marshall (2006) identify a pattern of deformation at the terminations of large, crustal-scale strike-slip faults on Europa that indicates shearing, sometimes accompanied by opening, along the master faults. The near-tip cracks and anticracks identified by the authors demonstrate the importance of strike-slip faulting of the satellite's icy lithosphere in generating regional-scale structures such as normal fault arrays and cycloidal ridges.

Aydin (2006) maps and reinterprets the enigmatic ridge structures on Europa. Based on similarities with terrestrial structures formed in higher porosity materials such as sandstone, Aydin suggests that many of the earliest identifiable structures on Europa are dilational, compactional, and/or shear deformation bands; later structures interpreted as cracks and faulted cracks imply a change in conditions within the satellite's icy lithosphere that may have promoted more channelized fluid transport.

Patterson, Head, and Pappalardo (2006) develop a method to find the pole of rotation of rigid plates on Europa, applying it to plates defined by a set of prominent ridges in the Castalia Macula region. By using this technique combined with morphological analyses, they find that the prominent ridges may have accommodated contraction, but that the inferred lithospheric plates behaved non-rigidly.

Dombard and McKinnon (2006) test a hypothesis of widespread folding of Europa's lithosphere from observations and modeling. They conclude that folding may have been possible in the northern latitudes only, implying that the magnitude and distribution of folds on the satellite were insufficient to balance the more pervasive extension and shearing of the icy lithosphere.

This Special Issue would not have been possible without the 23 reviewers who generously lent their time and expertise. We also thank the Elsevier and Journal staff, and, most important, the authors themselves who invested the substantial time and energy that eventually led to this Special Issue.

Richard Schultz*
Department of Geological Sciences and Engineering, MS 172,
Mackay School of Earth Sciences and Engineering,
University of Nevada, Reno, NV 89557-0138, USA
*Corresponding author.
E-mail address: schultz@mines.unr.edu

Robert T. Pappalardo
Jet Propulsion Laboratory, Mail Stop 183-301,
Pasadena, CA 91109, USA
E-mail address: robert.pappalardo@jpl.nasa.gov

David A. Ferrill
Department of Earth, Material, and Planetary Sciences,
Southwest Research Institute, 6220 Culebra Road,
San Antonio, TX 78238-5166, USA
E-mail address: dferrill@swri.org

Received 28 August 2006