



The Geological Society of America Bulletin is a leading international journal for major scholarly research in all branches of the earth sciences. Published continuously since 1890.

T A B L E O F C O N T E N T S

PRECAMBRIAN GEOLOGY

- 259 **Hadean origins of Paleoproterozoic continental crust in the central Wyoming Province**
C.D. Frost, J.F. McLaughlin, B.R. Frost, C.M. Fanning, S.M. Swapp, S.C. Kruckenberg, and J. Gonzalez

GEOCHRONOLOGY

- 281 **Proterozoic–Mesozoic history of the Central Asian orogenic belt in the Tajik and southwestern Kyrgyz Tian Shan: U–Pb, ⁴⁰Ar/³⁹Ar, and fission-track geochronology and geochemistry of granitoids**
Alexandra Käbner, Lothar Ratschbacher, Jörg A. Pfänder, Bradley R. Hacker, George Zack, Benita-Lisette Sonntag, Jahanzeb Khan, Klaus P. Stanek, Mustafa Gadoev, and Ilhomjon Oimahmadov

SEISMOLOGY-SEISMOTECTONICS

- 304 **Holocene slip rate variability along the Pernicana fault system (Mt. Etna, Italy): Evidence from offset lava flows**
D. D'Amato, B. Pace, L. Di Nicola, F.M. Stuart, F. Visini, R. Azzaro, S. Branca, and D.N. Barfod

PALEOCLIMATOLOGY

- 318 **An Antarctic stratigraphic record of stepwise ice growth through the Eocene–Oligocene transition**
Sandra Passchier, Daniel J. Ciarletta, Triantafilo E. Miriagos, Peter K. Bijl, and Steven M. Bohaty

PALEONTOLOGY

- 331 **Theropod, avian, pterosaur, and arthropod tracks from the uppermost Cretaceous Las Encinas Formation, Coahuila, northeastern Mexico, and their significance for the end-Cretaceous mass extinction**
Wolfgang Stinnesbeck, Eberhard Frey, Belinda Espinoza-Chávez, Patrick Zell, José Flores-Ventura, Héctor E. Rivera-Sylva, Arturo H. González-González, José M. Padilla Gutierrez, and Francisco J. Vega

TECTONICS

- 349 **Stratigraphic and provenance variations in the early evolution of the Magallanes–Austral foreland basin: Implications for the role of longitudinal versus transverse sediment dispersal during arc-continent collision**
Matthew A. Malkowski, Theresa M. Schwartz, Glenn R. Sharman, Zachary T. Sickmann, and Stephan A. Graham

VOLCANOLOGY

- 372 **Emergence and evolution of Santa Maria Island (Azores)—The conundrum of uplifted islands revisited**
Ricardo S. Ramalho, George Helffrich, José Madeira, Michael Cosca, Christine Thomas, Rui Quartau, Ana Hipólito, Alessio Rovere, Paul J. Hearty, and Sérgio P. Avila

- 392 **Submarine deposits from pumiceous pyroclastic density currents traveling over water: An outstanding example from offshore Montserrat (IODP 340)**
M. Jutzeler, M. Manga, J.D.L. White, P.J. Talling, A.A. Proussevitch, S.F.L. Watt, M. Cassidy, R.N. Taylor, A. Le Friant, and O. Ishizuka

GEODYNAMICS

- 415 **Tracking ancient magmatism and Cenozoic topographic growth within the Northern Andes forearc: Constraints from detrital U–Pb zircon ages**
C. Witt, M. Rivadeneira, M. Poujol, D. Barba, D. Beida, G. Beseme, and G. Montenegro

PETROLOGY - IGNEOUS

- 429 **Regional and temporal variability of melts during a Cordilleran magma pulse: Age and chemical evolution of the Jurassic arc, eastern Mojave Desert, California**
A.P. Barth, J.L. Wooden, D.M. Miller, K.A. Howard, L.K. Fox, E.R. Schermer, and C.E. Jacobson

STRATIGRAPHY

- 449 **Paleosols and associated channel-belt sand bodies from a continuously subsiding late Quaternary system (Po Basin, Italy): New insights into continental sequence stratigraphy**
Alessandro Amorosi, Luigi Bruno, David M. Cleveland, Agnese Morelli, and Wan Hong

STRUCTURAL GEOLOGY - FLUID FLOW

- 464 **Diagenetic controls on the evolution of fault-zone architecture and permeability structure: Implications for episodicity of fault-zone fluid transport in extensional basins**
Randolph T. Williams, Laurel B. Goodwin, and Peter S. Mozley

QUATERNARY GEOLOGY/GIOMORPHOLOGY

- 479 **Limited impact of Quaternary glaciations on denudation rates in Central Asia**
Nicolas Puchol, Julien Charreau, Pierre-Henri Blard, Jérôme Lavé, Stéphane Dominguez, Raphaël Pik, Dimitri Saint-Carlier, and ASTER Team
- 500 **Rapid fluvial incision of a late Holocene lava flow: Insights from LiDAR, alluvial stratigraphy, and numerical modeling**
Kristin E. Sweeney and Joshua J. Roering



THE
GEOLOGICAL
SOCIETY
OF AMERICA®

EDITORS

Aaron Cavosie

Curtin University
aaron.cavosie@curtin.edu.au

David Schofield

British Geological Survey
gsab@bgs.ac.uk

Brad S. Singer

University of Wisconsin–Madison
gsabull@geology.wisc.edu

GEOLOGICAL SOCIETY OF AMERICA

Executive Director

Vicki S. McConnell

President

Claudia I. Mora

Vice President

Isabel P. Montanez

Past President

Jonathan G. Price

Treasurer

Bruce R. Clark

Council

July 2013–June 2017

Elizabeth J. Catlos
John J. Clague
Neil Fishman

July 2014–June 2018

Timothy J. Bralower
Anke Friedrich
Stephen J. Pollock

July 2015–June 2019

Christopher M. Bailey
Mary J. Kraus
Frank J. Pazzaglia

July 2016–June 2020

F. Edwin “Ed” Harvey
Mark Little
Marjorie A. Chan

Committee on Publications

Julia A. Baldwin
John J. Clague
Richard A. Davis
Shanaka de Silva
Gerald Dickens
Lisa G. Dunn
David E. Fastovsky
John M. Holbrook
Craig H. Jones
Brian G. Katz
Brendan Murphy
David Schofield
Kurt Stüwe
Jennifer Thomson

The Geological Society of America Bulletin

(ISSN 0016-7606 USPS 216-300 CODEN BUGMA) is published bimonthly by The Geological Society of America, Inc. (GSA), with offices at 3300 Penrose Place, Boulder, Colorado. Mailing address is P.O. Box 9140, Boulder, CO 80301-9140, USA. Periodicals postage paid at Boulder, Colorado, and at additional mailing offices. Postmaster: Send address changes to *GSA Bulletin*, Sales & Service, P.O. Box 9140, Boulder, CO 80301-9140, USA, or e-mail to gsaservice@geosociety.org.

Copyright © 2017, The Geological Society of America, Inc. (GSA). All rights reserved. Copyright not claimed on content prepared wholly by U.S. government employees within the scope of their employment. Individual scientists are hereby granted permission, without fees or further requests to GSA, to use a single figure, a single table, and/or a brief paragraph of text in other subsequent works and to make unlimited photocopies of items in this journal for noncommercial use in classrooms to further education and science. In addition, an author has the right to use his or her article or a portion of the article in a thesis or dissertation without requesting permission from GSA, provided the bibliographic citation and the GSA copyright credit line are given on the appropriate pages. For any other form of capture, reproduction, and/or distribution of any item in this journal by any means, contact: Permissions, GSA, P.O. Box 9140, Boulder, CO 80301-9140, USA, fax +1-303-357-1073, editing@geosociety.org; reference *GSA Bulletin*, ISSN 0016-7606. Permission is granted to authors to post the abstracts only of their articles on their own or their organization's Web site providing the posting includes this reference: “The full paper was published in the *Geological Society of America Bulletin*, [include year, month, and page number, if known, where article appears or will appear].”

GSA BULLETIN BOARD OF ASSOCIATE EDITORS

2015–2017

Sandra Barr

Acadia University

Geological Survey of Canada

Peter Cawood

University of Western Australia

Fernando Corfu

University of Oslo

Henning Dypvik

University of Oslo

Peter Eichhubl

University of Texas–Austin

Richard Ernst

Ernst Geoscience Consultant,
Carleton University

Luca Ferrari

Universidad Nacional Autónoma
de México

Joan Florsheim

University of California–Davis

William L. Griffin

Macquarie University

Andrew Hynes

McGill University

Stephen T. Johnston

University of Victoria

Zheng-Xiang Li

Curtin University

Ken MacLeod

University of Missouri–Columbia

David R. Marchant

Boston University

Stefano Mazzoli

University of Naples ‘Federico II’

Brian McConnell

Geological Survey of Ireland

Jocelyn McPhie

University of Tasmania

Michael Ort

Northern Arizona University

Jon Pelletier

University of Arizona

Brian Pratt

University of Saskatchewan

Robert H. Rainbird

Geological Survey of Canada

Wolfe Uwe Reimold

Humboldt University

Steven C. Ruppel

University of Texas–Austin

Bradley S. Singer

University of Wisconsin–Madison

Enrico Tavarnelli

Università di Siena

Nicholas Timms

Curtin University

Cees R. van Staal

Geological Survey of Canada

Karl Wegmann

North Carolina State University

An Yin

University of California, Los Angeles

2016–2018

Ya-Ju Hsu

Institute of Earth Sciences,
Academia Sinica

Ganqing Jiang

University of Nevada–Las Vegas

Christian Koeberl

University of Vienna

J. Bruce H. Shyu

National Taiwan University

Hiroyuki Tsutsumi

Kyoto University

John Waldron

University of Alberta

Fu-Yuan Wu

Chinese Academy of Sciences

Wenjiao Xiao

Chinese Academy of Sciences

Haijiang Zhang

University of Science and
Technology of China

XiXi Zhao

State Key Laboratory of
Marine Geology

Haibo Zou

Auburn University

2017–2019

Barbara Carrapa

University of Arizona

Cinzia Cervato

Iowa State University

Bradley D. Cramer

University of Iowa

Bernhard Grasemann

University of Vienna

Daniel Clay Kelly

University of Wisconsin–Madison

Chris Kirkland

Curtin University

Ben Laabs

North Dakota State University

Massimo Mattei

University Roma TRE

Troy Rasbury

SUNY Stony Brook

Michael Elliot Smith

Northern Arizona University

GSA provides this and other forums for the presentation of diverse opinions and positions by scientists worldwide, regardless of their race, citizenship, gender, religion, sexual orientation, or political viewpoint. Opinions presented in this publication do not reflect official positions of the Society.

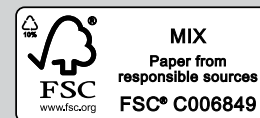
SUBSCRIPTIONS for 2017 calendar year. GSA Members and Fellows: \$89 (print + online), \$60 (online only). GSA Student, K–12 Teacher, and Early Career Professional Members: \$45 (print only; online included in membership). Nonmembers and institutions: \$1185 (print + online + archive). Details on subscription choices, formats, and pricing at: www.geosociety.org/pubs/. For orders, call GSA Sales & Service at +1.888.443.4472 or +1.303.357.1000, or e-mail gsaservice@geosociety.org. Claims for nonreceipt or damaged copies, please contact GSA Sales & Service. Claims are honored for one year; please allow sufficient delivery time (up to 8 weeks) for overseas copies.

Staff: Director of Publications, Jeanette Hammann; Managing Editor, Cary Cosper (ccosper@geosociety.org); Editorial Staff, Jennifer Olivarez; composition and covers, Eric Christensen.

GSA Bulletin Online: <http://www.gsapubs.org>.

Online Submission: <http://www.editorialmanager.com/gsbulletin/>.

GSA Online: <http://www.geosociety.org>.



ON THE COVER

Cover: Volcano-sedimentary sequence at Ponta da Malbusca (Santa Maria Island, Azores) comprising a staking of fossiliferous marine sediments, pillow lavas and hyaloclastites, mega-pillows, submarine sheet flows, and capping subaerial flows. The coastal cliffs of Santa Maria exhibit thick submarine volcano-sedimentary sequences, which serve as testimony to the island's recent uplift trend. See “Emergence and evolution of Santa Maria Island (Azores)—The conundrum of uplifted islands revisited” by Ramalho et al., p. 372–391.

Photo by: Ricardo A.S. Ramalho

Cover design by: Eric Christensen