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Cover: Landsat 7 image of southern Vancouver Island, showing the surface trace of the Leech River fault and its intersection with the population centers surrounding Victoria, British Columbia, Canada. See related article, p. 4–10.

27 Zealndia: Earth’s Hidden Continent
Nick Mortimer et al.

Inside Cover: The St. Bathans Range, Otago, New Zealand, shows three key elements of Zealandia. The bedrock is Mesozoic Haast Schist, a major geological unit that can be tracked across the continent. The flat top of the range is a diachronous Late Cretaceous to Oligocene marine planation surface that was cut as Zealandia subsided. Like the rest of the South Island of New Zealand, the 2000-m-high range was uplifted in the Neogene in response to intracontinental transpression across the Pacific-Australian plate boundary. Image credit Lloyd Homer/GNS Science. See related article, p. 27–35.

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Quaternary Rupture of a Crustal Fault beneath Victoria, British Columbia, Canada

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ABSTRACT

The seismic potential of crustal faults within the forearc of the northern Cascadia subduction zone in British Columbia has remained elusive, despite the recognition of recent seismic activity on nearby fault systems within the Juan de Fuca Strait. In this paper, we present the first evidence for earthquake surface ruptures along the Leech River fault, a prominent crustal fault near Victoria, British Columbia. We use LiDAR and field data to identify >60 steeply dipping, semi-continuous linear scarps, sags, and swales that cut across both bedrock and Quaternary deposits along the Leech River fault. These features are part of an ~1-km-wide and up to >60-km-long steeply dipping fault zone that accommodates active forearc transpression together with structures in the Juan de Fuca Strait and the U.S. mainland.

Reconstruction of fault slip across a deformed <15 ka colluvial surface near the center of the fault zone indicates ~6 m of vertical separation across the surface and ~4 m of vertical separation of channels incising the surface. These displacement data indicate that the Leech River fault has experienced at least two surface-rupturing earthquakes since the deglaciation following the last glacial maximum ca. 15 ka, and should therefore be incorporated as a distinct shallow seismic source in seismic hazard assessments for the region.

INTRODUCTION

Unlike plate boundary faults that often exhibit a strong seismic or geodetic expression (e.g., Rogers, 1988), active faults within the adjacent crust can have long recurrence intervals (e.g., 5–15 k.y.; Rockwell et al., 2000), and they may not be detectable by seismic or geodetic monitoring (e.g., Mosher et al., 2000; Balfour et al., 2011). This point was exemplified by the 2010 Mw 7.1 Darfield, New Zealand (Christchurch), earthquake and aftershocks that ruptured the previously unidentified Greendale fault (Gledhill et al., 2011). This crustal fault showed little seismic activity prior to 2010, but nonetheless produced a 30-km-long surface rupture, caused more than 180 casualties, and resulted in at least US$10 billion in damage (Quigley et al., 2012).

In the forearc of the Cascadia subduction zone (Fig. 1), where strain accrues due to the combined effects of northeast-directed subduction and the northward migration of the Oregon forearc block (McCaffrey et al., 2013), microseismicity data are sparse and do not clearly elucidate planar crustal faults (Cassidy et al., 2000; Balfour et al., 2011). But geomorphic,
trenching, and geophysical studies have proven successful at highlighting a network of oblique reverse forearc faults, both on- and offshore of Washington and Oregon, that can produce earthquakes up to 7.5 in magnitude (McCaffrey and Goldfinger, 1995; ten Brink et al., 2006; Blakely et al., 2014; Sherrod et al., 2016). In particular, LiDAR, seismic, and aeromagnetic data have been paramount in the recognition of the Seattle fault as a significant seismic hazard source within the greater Seattle region (SF, Fig. 1) (Johnson et al., 1999; Blakely et al., 2002; Kelsey et al., 2008; Nelson et al., 2014).

The potential Quaternary activity of the Leech River fault, an ~60-km-long terrane-bounding fault in the southern Vancouver Island forearc (Muller, 1977; MacLeod et al., 1977), has drawn significant attention in recent years because of the seismic hazard it may pose to the nearby population of Victoria, British Columbia (Figs. 1 and 2A) (see Cassidy et al., 2000; Mosher et al., 2000; Balfour et al., 2011). Several previous authors suggest that this fault, which places Jurassic-Cretaceous schists of the Leech River Complex to the north against Eocene basalts of the Metchosin Formation to the south (Fig. 2A) (Fairchild and Cowan, 1982; Rusmore and Cowan, 1985), was last active in the Eocene (MacLeod et al., 1977; Johnston and Acton, 2003). Yet, trenching, coring, and geophysical studies indicate multiple Quaternary ruptures of adjacent fault systems in Washington state, USA, including the Southern Whidbey Island fault, the Utsalady Point fault, and the Darrington–Devil’s Mountain fault (Fig. 1) (Johnson et al., 1996, 2001; Sherrod et al., 2008; Personius et al., 2014). Quaternary seismic activity is also recognized 10–20 km offshore of the Leech River fault along a structure in the Juan de Fuca Strait (Barrie and Greene, 2015) (Figs. 1 and 2A), but direct evidence for recent rupture onshore has remained ambiguous.

Here, we use a combination of techniques to delineate Quaternary fault-related features along the Leech River fault, including (1) mapping of fault scarps from hillshade and local slope images generated from a high resolution (~2 m horizontal by ~10 cm vertical) LiDAR digital elevation model (DEM) collected by Natural Resources Canada (James et al., 2010); (2) first-order bedrock and surficial field mapping; (3) collection of detailed structural and geomorphic data at key sites; and (4) compilation of our observations with data from previous studies (e.g., Fairchild and Cowan, 1982; Blyth and Rutter, 1993; Cassidy et al., 2000; Mosher et al., 2000; Balfour et al., 2011).
Massey et al., 2005). We identify several strands of the Leech River fault that displace post-glacial sediments and record at least two Mw > 6 earthquakes since the Cordilleran deglaciation ca. 15 ka (Clague and James, 2002). These data provide the first evidence for Quaternary surface rupture along a crustal fault that lies within close proximity of Victoria, British Columbia, and suggest that the Leech River fault is only one of a network of active faults that accommodate forearc deformation in southwestern Canada.

OBSERVATIONS

We mapped >60 topographic features along the Leech River fault that together extend >60 km in length and span ~1 km in width. Individual features range in length from hundreds of meters to >2.5 km, reach up to ~5 m in height, and form linear ridges, sags, and scarps with both north- and south-facing directions (Fig. 2). Along the eastern half of the fault, where we focused our analysis, these topographic features coincide with displaced geomorphic surfaces, steeply dipping brittle faults, and uphill-facing bedrock scarps.

In order to exclude topographic features that were produced by differential erosion along steeply dipping foliation planes, we mapped the position of lithologically distinct units and collected structural data on the occurrence and orientation of foliation and fault deformation fabrics. The topographic scarps we identified are roughly parallel to the previously mapped location of the Leech River fault (Fairchild and Cowan, 1982; Massey et al., 2005), but none of the identified fault scarps coincide exactly with the fault contact between the Leech River Complex and the Metchosin Formation (Fig. 2). Instead, individual topographic features occur both north and south of the lithologic fault boundary by as much as hundreds of meters. Where a discrete contact between the basalt and schist units is exposed at two locations in the area, the fault strikes parallel to regional foliation (300–310°) but dips more steeply (70–90° NE) than the foliation (~45° NE) (Figs. 2B and 2C, and GSA Data Repository1 Fig. DR1A). The westernmost of these sites contains a 10- to >200-m-wide mylonitic shear zone within both units, but exhibits no brittle deformation at the outcrop scale (Figs. 2B and 2C). Because the mapped features do not coincide with the lithologic terrane boundary, they cannot be explained by differential erosion across this strong lithologic contrast.

To further exclude topographic features produced by glacial processes, we determined local ice flow directions from bedrock striata and streamlined glacial deposits and collected geomorphic data designed to confirm a tectonic origin. The roughly east-west–oriented topographic features on the eastern half of the Leech River fault are nearly perpendicular to the southerly regional ice flow direction during the last glacial maximum. The LiDAR data delineate large (km-long) drumlinoid ridges with well-defined apices that are distinctively streamlined with steep up-ice (northern) margins and upper surfaces that gently slope in a southerly, down-ice direction (Figs. 2C and 2D). Our field work confirms that these ridges are mantled by glacial sediments (Fig. DR1E [see footnote 1]). South-directed ice flow is further supported by glacial striata data on bedrock near the drumlinoid ridges (Fig. 2C). The observation that the mapped scarps strike perpendicular to the ice flow direction rules out their formation by ice flow–parallel processes, including glacial scouring, grooving, molding, and streamlined.

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1 GSA Data Repository Item 2017046, supplementary figures, is online at http://www.geosociety.org/datarepository/2017/. If you have questions, please email gsatoday@geosociety.org.
FIELD EVIDENCE FOR TECTONIC SCARPS

We identify three key sites (Figs. 2C and 2D, sites A–C) where field and LiDAR data indicate tectonic displacement of bedrock and Quaternary deposits.

Site A

Near the center of the Leech River fault, the LiDAR data reveal a >200-m-long and up to ~3–6-m-high topographic scarp that faces uphill (southward) across a relatively steep (~20°), north-facing slope (Fig. 3A). Beneath an ~1-m-thick mantle of colluvium at the surface, the hillside consists of a dense, matrix-supported diamict with numerous erratics and striated clasts, interpreted as subglacial till. These field observations, the relatively smooth surface morphology, and the lack of a fan apex, indicate that this ~400-m-long by ~300-m-wide hillside is covered by an apron of colluvium. Several steep, linear channels littered with boulders incise this colluvial apron.

LiDAR and field data indicate that both the colluvial surface and the channels incising it are vertically displaced by several meters across the scarp (~3–6 m) (Figs. 3 and DR1B [see footnote 1]). We calculated vertical separations at 12 locations across the fault scarp by linear regression of LiDAR-derived topography and estimated regression uncertainties using a Monte Carlo routine (following Thompson et al., 2002) (Fig. DR2 [see footnote 1]). These data confirm that scarp height is systematically lower within the incised channels than on the colluvial surface. For example, at interfluve P1, the vertical separation across the scarp approaches ~6 m (5.7 ± 1.7 m) (Fig. 3B). At channel P2, however, the LiDAR profiles indicate only ~3 m (3.2 ± 1.2 m) of vertical separation. On average, the interfluves are vertically separated by 5.7 ± 1.3 m (n = 8) and the channels by 3.9 ± 0.9 m (n = 4) (1σ) (Fig. DR2). These estimates support our field observations of a differential amount of displacement across the scarp between channels versus interfluves (Fig. 3C).

Several field observations suggest this scarp reflects north-side-up dip slip displacement along a steeply north-dipping (60–90°) fault. For instance, the interaction of the scarp with local topography suggests that the fault dips steeply to the north; the scarp trace is nearly linear in map view, but it deviates slightly northward into topographic lows (Fig. DR2A). Additionally, both the apparent north-side-up displacement and the spatial pattern of channel displacement indicate dip slip displacement with little to no lateral displacement. While northeast-trending channels show apparent right separation (white arrows, Fig. 3A), north-northwest–trending channels show apparent left separation (black arrows, Fig. 3A).

Together, these data indicate that both the colluvial surface and the channels have...
been vertically displaced by ~4–6 m due to slip on a steep, north-dipping reverse fault.

Site B

Five kilometers east along strike from site A, a prominent south-facing bedrock scarp extends for ~1.5 km and shows evidence for brittle deformation along its length (site B, Figs. 2 and 4). Near the center of this scarp, an abandoned rock quarry exposes two steeply north-dipping sub-parallel faults (dipping 85° to N40°E) cutting Metchosin Formation basalt (site B1, Figs. 4A and 4B). Both faults have a 1–2-mm-wide gouge zone and exhibit sub-horizontal slickenlines (05° toward 129°) consistent with strike-slip motion (Figs. 4B and DR1C [see footnote 1]). At the eastern end of site B, the scarp becomes ~4 m high and uphill facing (Fig. 4A).

Here, the northern (upthrown) side of the scarp consists of fractured and brittle deformed Metchosin Formation basalt, whereas the southern (downthrown) side of the scarp contains fine-grained sediment (P3, Fig. 4B). Similar to site A, the apparent north-side-up displacement across the scarp and the northward divergence of the scarp trace into topographic lows signifies dip displacement along a steeply north-dipping reverse fault (Figs. 4B and DR1D). Overall, these observations suggest an origin for this feature as a tectonic scarp.

Site C

Approximately 5 km east of site B, an ~1.5-km-long region contains >300-m-long ridges, linear sags, and swales up to ~2–5 m in height that cut across relatively smooth, gently sloping till-mantled hillslopes (Figs. 4C and DR1E). These topographic features display several differences from those at sites to the west. Whereas sites A and B exhibit discrete topographic scarps, features in this region are 10–15-m-wide elevated zones that sit more than ~5 m above the surrounding landscape. Moreover, while the scarps at sites A and B remain north-facing for hundreds of meters along strike, the facing direction of the features in site C transitions southeastward from south- to north-facing over a short (~200 m) distance (Figs. 2D and 4C).

These scarps have a nearly linear trace across topography, but they do not exhibit clear upthrown fault blocks or a marked increase in surface elevation. We interpret this en echelon arrangement of topographic ridges and the lateral juxtaposition of topographic highs and lows as pressure ridges, common in strike slip or oblique slip systems (e.g., Sylvester, 1988; Sherrod et al., 2008, 2016; Nelson et al., 2014).

QUATERNARY SLIP ON THE LEECH RIVER FAULT

The displaced geomorphic features, faulted bedrock, and prominent scarps collectively argue that several strands of the Leech River fault have been active since the late Pleistocene. Our observations support a tectonic genesis for the topographic features we identify for several reasons. First, several of the identified topographic features show evidence for extensive brittle faulting. For example, the fractured rock and gouge along the scarp at site B (Fig. 4B) require a tectonic origin and exclude formation by either ice plucking or the erosion of a bedrock foliation. Second, the observation that paleo–ice flow was directed to the south, at a high angle to the orientation of the topographic features (Fig. 2C), further rules out formation by glacial processes. Finally, it is unlikely that the topographic scarps in Quaternary deposits were produced by landside processes. Several of the scarps, including those at sites A and B (Figs. 2C and 2D), are uphill facing, nearly perfectly linear, and do not exhibit curvilinear head scarps that would be expected for landslides.

The most compelling evidence for a tectonic origin for these topographic features comes from site A, where both the hillslope surface and multiple channels are displaced vertically along an uphill facing scarp (Figs. 3A and 3B). The scarp at site A cannot represent the remnants of an abandoned logging road or placer mining excavation because the base of the scarp is not graded, and the upper and lower surfaces are vertically separated by ~4 m (Fig. 3B). Such displacement in hillslope elevation, and in particular the displaced channels, cannot be produced by any mechanism other than fault displacement. Because the colluvial apron at this site remains both in situ and intact, the tectonic scarps crosscutting the colluvial surface and inset channels must be no older than the deglaciation following the last glacial maximum (ca. 15 ka) (Clague and James, 2002).

We suggest that the identified scarps together compose an active fault system that is up to ~1 km wide and 30–60 km long (Fig. 2A). Although individual lineaments can be traced for only hundreds of meters along strike, meter-high fault scarps are not easily preserved in this wet climate, and the fault scarps are semi-continuous with one another along strike. Our recognition of topographic features along the western ~30 km of the fault similar to those on the eastern half (Fig. 2C) suggests that the active fault zone extends the entire 60-km length of the fault onshore (Fig. 2A). Scarp morphology, fault orientations, and fault kinematics suggest that the active strands of the Leech River fault accommodate strike and dip slip motion within a steeply dipping fault zone or flower structure. Within a zone up to 1 km wide, we observe near vertical faults, variable scarps facing directions, laterally discontinuous surface scarps, and field evidence for strike-slip and reverse faulting. These characteristics are typical of strike slip systems and are similar to features observed along active oblique-reverse faults in the adjacent Pacific Northwest (e.g., Johnson et al., 2001; Sherrod et al., 2008, 2016; Kelsey et al., 2012; Nelson et al., 2014; Personius et al., 2014; Blakely et al., 2014).

These new results challenge the prevailing view that the Leech River fault was primarily an Eocene structure (cf. MacLeod et al., 1977). This interpretation was partly based on the observation that relatively undeformed Oligocene sediments of the Carmanah Group (Sooke Fm.) lie unconformably above healed fractures and mylonitic fabrics close to the trace of the Leech River fault near Sombrio Point (Fig. 2A) (MacLeod et al., 1977). However, our results from the eastern half of the Leech River fault show that active fault strands occur within a zone as much as 1 km wide and these strands are not always co-located with observed fault-related fabrics. Therefore, the location of fault fabrics may not coincide with the surface trace of the active fault.

IMPLICATIONS FOR PALEOSEISMICITY

The displaced channels and colluvial surface at site A suggest this section of the Leech River fault has experienced at least two, and possibly three or more, large,
surface-rupturing earthquakes since the formation of the surface ca. 15 ka. For a 60–90° reverse fault, the displacements across the scarp require minimum dip displacements of 6.4 ± 1.5 m for interflues (n = 8) and 4.4 ± 1.1 m for channels (n = 4). The ~2 m difference in displacement between the channels and interflues implies multiple episodes of fault activity and suggests that at least one event with ~2 m displacement occurred after the formation of the colluvial apron but before channel incision. In addition to this early event, the ~4 m of displacement of the channels (Fig. 3B and DR2 [see footnote 1]) requires either one large event with ~4 m of slip, or multiple smaller events that together sum to ~4 m of slip. Global empirical relationships suggest that surface displacements on the order of meters correspond to earthquakes of Mw 6 or greater (e.g., Wells and Coppersmith, 1994).

IMPLICATIONS FOR REGIONAL SEISMOTECTONICS

Several observations indicate the active Leech River fault zone is part of a network of high-angle oblique faults that accommodate regional transpression across the Juan de Fuca Strait and Puget Sound region. Barrie and Greene (2015) trace the Devil’s Mountain fault of Washington state, USA, to within 10–20 km of the fault scarps on Fig. 2, and their bathymetric and seismic surveys reveal a steeply dipping oblique-slip fault zone similar to our observations of the Leech River fault zone. Both the Darrington–Devil’s Mountain fault and the Southern Whidbey Island fault systems of Washington state (Fig. 1) are likewise near-vertical fault zones with oblique slip histories (Sherrod et al., 2008; Personius et al., 2014) similar to many of the crustal fault systems throughout the Puget Sound region (e.g., McCaffrey and Goldfinger, 1995; ten Brink et al., 2006; Blakely et al., 2014; Nelson et al., 2014; Sherrod et al., 2016). Considering these similarities in orientation and slip sense, we suggest that the Leech River fault is part of this regional active forearc fault system. Although it remains possible that the timing of past ruptures along these fault systems was influenced by stress loading or release related to the last glaciation (e.g., Hetzel and Hampel, 2005), repeated earthquakes on crustal faults including the Leech River should be expected in order to accommodate ongoing tectonic strain in the forearc of the active Cascadia subduction zone.

IMPLICATIONS FOR SEISMIC HAZARD

The length of the active Leech River fault zone (30–60 km; Fig. 2A) and its history of multiple Quaternary ruptures suggest it is capable of producing earthquakes of Mw >6. This active fault zone lies within tens of kilometers of downtown Victoria and in close proximity to three local water dams. One of these dams is located within 2 km of the active fault zone and supports the region’s principal water supply reservoir (Fig. 2A). The other two dams lie within the active fault zone and support a hydroelectric power plant. Thus, our new identification of a significant shallow seismic source has considerable implications for the seismic risk exposure of this populated region.

Surface-rupturing earthquakes with shallow hypocenters can be highly destructive, and it is therefore important that the Leech River fault zone be incorporated into seismic hazard assessments of southwestern British Columbia and neighboring regions.

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We are excited to announce that the 2017 Cordilleran Section Meeting will be held at the stunning Hawai‘i Convention Center in Honolulu. The technical program includes 34 Topical Sessions and Symposia, complemented by six Science and Education Short Courses and Workshops, and 11 Field Trips on the islands of Hawai‘i, Maui, O‘ahu, and Kaua‘i. Short courses, workshops, and field trips will occur before and after the technical sessions.

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DEADLINES

- Exhibit space reservation deadline: 1 April
- Early registration deadline: 17 April
- Student travel application deadline: 17 April
- Student volunteer for registration waiver deadline: 17 April
- Registration cancellation deadline: 24 April
- Hotel reservation rate deadline: 1 May

REGISTRATION

Early registration deadline: 17 April
Cancellation deadline: 24 April
Register online at http://www.geosociety.org/GSA/Sections/cd/2017mtg/registration.aspx.

Fees are shown in U.S. Dollars

<table>
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<tr>
<th></th>
<th>Early Full Meeting One day</th>
<th>Standard Full Meeting One day</th>
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<tr>
<td>Professional Member</td>
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<td>Professional Member (70+)</td>
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<td>$95</td>
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<td>Professional Non-Member</td>
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<td>$215</td>
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<td>Early Career Professional</td>
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<tr>
<td>K–12 Professional</td>
<td>$55</td>
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<tr>
<td>Guest or Spouse</td>
<td>$90</td>
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<tr>
<td>Field Trip/Workshop Only</td>
<td>$65</td>
<td>n/a</td>
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</table>

FIELD TRIPS

SPECIAL NOTICE: Costs shown below for field trips on the islands of Hawai‘i, Maui, and Kaua‘i do not include (1) airfare to and from those islands, (2) lodging while on those islands, and (3) breakfasts and dinners while on those islands. Please see the website for details on each trip. For additional information, please contact field trip co-chair Scott Rowland.

Pre-Meeting

1. Geology of East and West Maui. Cost: US$296. 8 a.m. Fri., 19 May, to 4 p.m. Sun., 21 May.
2. Eruptions, Structure, and History of the Kīlauea Summit Area, Island of Hawai‘i. Cost: US$169. 8 a.m. Sat., 20 May, to 4:30 p.m. Sun., 21 May.
3. Geologic Features of Hualalai Volcano, Island of Hawai‘i. Cost: US$228. 8 a.m. Sat., 20 May, to 4:30 p.m. Sun., 21 May.
5. **Structural Geology and Geothermal Energy of Kīlauea Volcano, Island of Hawai‘i.** US$242. 8 a.m. Sat., 20 May to 4:30 p.m. Sun., 21 May.

6. **Coastal Geology of Southern O‘ahu.** Cost: US$79. 8:30 a.m.–4 p.m. Mon., 22 May.

7. **Geology of Southeast Ko‘olau Volcano, Island of O‘ahu.** Cost: US$90. 8:30 a.m.–4 p.m. Mon., 22 May.

**Post-Meeting**

8. **Hydrology of O‘ahu.** Cost: US$68. 7:30 a.m.–3 p.m. Fri., 26 May.

9. **Geology of Wai‘anae Volcano, Island of O‘ahu.** Cost: US$92. 8:30 a.m.–4 p.m. Fri., 26 May.

10. **The Geology and Current Activity of Kīlauea Volcano, Island of Hawai‘i.** Cost: US$275. 7 a.m. Fri., 26 May, to 4 p.m. Sat., 27 May.

11. **Volcanic History and Coastal Processes of Kaua‘i.** Cost: US$208. 8 a.m. Fri., 26 May, to 4 p.m. Sat., 27 May.

**SHORT COURSES & WORKSHOPS**

**Pre-Meeting**

1. **Generic Mapping Tools for Geologists.** Mon., 22 May, 8:30 a.m.–4:30 p.m. US$10.

2. **Tsunami Awareness.** Mon., 22 May, 8:30 a.m.–4:30 p.m. US$5.

**During the Meeting**

3. **Hawaiian Volcanoes and Hazards Education Using Jigsaw Activities.** Tues., 23 May, 1:30–5 p.m. US$10. Principal Organizer: Andrew R. Greene, Hawai‘i Pacific Univ., agreene@hpu.edu. Co-Organizer: Michael O. Garcia, Univ. of Hawai‘i, mogarcia@hawaii.edu. This course will be held mid-meeting in conjunction with the Technical Sessions.

**Post-Meeting**

4. **Volcanic Crisis Awareness.** Fri., 26 May, 8:30 a.m.–4:30 p.m. US$5.

5. **Integrating Augmented Reality Grand Canyon Field Trips into Your High-Enrollment Introductory Geoscience Class.** Fri., 26 May, 8 a.m.–noon. US$10.

6. **Earth in Context: Resources for Integrating Earth Literacy with Societal Issues across the Curriculum.** Fri., 26 May, 1 p.m.–5 p.m. US$10.

**EXHIBITS**

Exhibit space reservation deadline: 1 April

Exhibition spaces are available on a first come first serve basis. Package descriptions, rates, exhibition hours, and a registration form are online at http://www.geosociety.org/documents/gsa/section/cd/2017/Sponsor_Exhibitor_Brochure.pdf. Please contact Garrett Ito at gito@hawaii.edu for additional information.
GeoCareers—2017 Section Meetings

GEOCAREERS

Geoscience Career Workshops

For more information, contact Jennifer Nocerino at jnocerino@geosociety.org.

Geoscience Career Workshop Part 1: Career Planning and Informational Interviewing. Your job-hunting process should begin with career planning, not when you apply for jobs. This workshop will help you begin this process and will introduce you to informational interviewing.

Geoscience Career Workshop Part 2: Geoscience Career Exploration. What do geologists in various sectors earn? What do they do? What are the pros and cons?

Geoscience Career Workshop Part 3: Cover Letters, Résumés, and CVs. How do you prepare a cover letter? Does your résumé need a good edit? Learn how to prepare the best résumé possible and avoid typical pitfalls.

Early Career Professional Focus Group (NE/NC and SC meetings only)

Have you graduated in the last five years and are either a working professional or still looking for a job? GSA would like to support you in pursuing your professional goals. During this 45-minute session, participants will be asked a series of questions regarding potential programming and activities that GSA could offer to help you reach your goals. For more information, contact Tahlia Bear at tbear@geosociety.org.

MENTOR PROGRAMS

Enjoy a free lunch while meeting with geoscience mentors working in the applied sector. The popularity of these programs means that space is limited, so plan to arrive early, because lunch is first-come, first-served. For further information, contact Jennifer Nocerino at jnocerino@geosociety.org.

South-Central Section Meeting
San Antonio, Texas, USA
Shlemon Mentor Luncheon Program: Mon., 13 March
Mann Mentors in Applied Hydrology Luncheon: Tues., 14 March

Northeastern/North-Central Joint Meeting
Pittsburgh, Pennsylvania, USA
Shlemon Mentor Luncheon Program: Mon., 20 March
Mann Mentors in Applied Hydrology Luncheon: Tues., 21 March

Southeastern Section Meeting
Richmond, Virginia, USA
Shlemon Mentor Luncheon Program: Thurs., 30 March
Mann Mentors in Applied Hydrology Luncheon: Fri., 31 March

Cordilleran Section Meeting
Honolulu, Hawaii, USA
Shlemon Mentor Luncheon Program: Tues., 23 May
Mann Mentors in Applied Hydrology Luncheon: Wed., 24 May

Rocky Mountain Section Meeting
Calgary, Alberta, Canada
Shlemon Mentor Luncheon Program: Fri., 9 June
Mann Mentors in Applied Hydrology Luncheon: Sat., 10 June

MENTORING OPPORTUNITIES

Professionals: Interested in sharing information about your applied geoscience career with students? Being a mentor is a rewarding experience. If you can volunteer to mentor at one of the GSA Section Meetings, please contact Jennifer Nocerino at jnocerino@geosociety.org. Early career professionals are encouraged to volunteer.
Conveners
Alessandro Montanari, Osservatorio Geologico di Coldigioco, I-62020 Frontale di Apiro (MC), Italy; sandro.coldigioco@gmail.com
Christian Koeberl, Dept. of Lithospheric Research, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria, and Natural History Museum, Burgring 7, A-1010 Vienna, Austria; christian.koeberl@univie.ac.at

Sponsors
GSA Foundation, Barringer Crater Company, and Associazione Le Montagne di San Francesco

Description and Objectives
Central Italy has been a cradle of geology for centuries. Since the beginning of the last century, the Triassic to Miocene carbonate succession exposed along the valleys of the Umbria and Marche Apennines of Italy has been a fertile playground for generations of earth scientists, particularly paleontologists, sedimentologists, stratigraphers, geophysicists, and structural geologists, from all over the world. It is in this geological theater that pioneering studies in the most disparate disciplines of the earth sciences have led to the understanding of novel principles and natural phenomena of the past, the development of new methodologies and experimental research approaches, and ultimately to discontinuities in scientific thinking, with the birth of such concepts as Event Stratigraphy, Integrated Stratigraphy, and Cyclostratigraphy applied to astronomical tuning, let alone Quaternary Geology, Neotectonics, and Speleogeology. The Umbria-Marche Apennines of northeastern Italy are a foreland fold-and-thrust belt, which was formed in the latest phase of the Alpine-Himalayan orogenesis. These mountains are entirely made of marine sedimentary rocks of the so-called Umbria-Marche Succession, which represents a continuous record of the geotectonic evolution of an epeiric sea from the Early Triassic to the Pleistocene. Studies of these rocks have promoted sensational discoveries, particularly about major events that have punctuated the history of Earth, such as the Cretaceous Oceanic Anoxic Events (OAE1 and OAE2), the Cretaceous-Paleogene (K-Pg) Boundary Event (with the global mass extinction caused by a catastrophic extraterrestrial impact), the events across the Eocene-Oligocene transition from a greenhouse to an icehouse world, and the Messinian Salinity Crisis of the Mediterranean, just to name the most famous ones.

The objective of this conference is to present an updated vision of 250 million years of earth history as recorded in the sedimentary succession of the northern Apennine orogeny in central Italy. At the conference, besides keynote review presentations, original research works will be presented covering specific subjects of Tectonics and Structural Geology, Integrated Stratigraphy and Astronomical Tuning, Extraterrestrial Event Stratigraphy, and Quaternary Geology and Geo-Bio Speleology. These research works are either still in progress or they were accomplished but never published before, all with the support of the Geological Observatory of Coldigioco, an independent research and educational center, which was founded in an abandoned medieval hamlet near Apiro in 1992 by Alessandro Montanari, Walter Alvarez, and David Bice.

Studies are now in progress about the recent tectono-seismic and structural history of the still active Umbria-Marche Apennines (as is exemplified by the recent seismic activity in 2016). More studies by international teams of stratigraphers are being conducted through long and continuous stretches of the Umbria-Marche sedimentary succession, focusing on the integration of bio-magneto-chemostratigraphy and radioisotopic geochronology with astronomical tuning via multiproxy cyclostratigraphic analysis.

One of the primary results that have been derived from the Umbria-Marche sedimentary succession in the past 25 years with the support of the Geological Observatory of Coldigioco has been the development of the subject of the role that extraterrestrial...
Ten million years of geologic history across the Cretaceous-Paleogene boundary in the Frontale quarry near Coldigioco (image credit: A. Montanari).
Is it “the earth” or Earth?

A.M. Celâl Şengör, İTÜ Maden Fakültesi, Jeoloji Bölümü, and Avrasya Yerbilimleri Enstitüsü, Ayazağa 34469 İstanbul, Turkey, sengor@itu.edu.tr

Student: But each word, I think, should harbour some idea

Mephistopheles: Yes, yes, indeed, but don’t torment yourself too much because precisely where no thought is present, a word appears in proper time.
Words are priceless in an argument, Words are building stones of Systems.
It’s splendid to believe in words: from words you cannot rob a single letter.
— J.W. von Goethe, Faust

As a non-English speaker I was taught that when referring to our planet, native speakers say and/or write “the earth.” I wondered why all other planets have capitalised names with no definite article preceding them, but not ours. Moreover, both our satellite and the star have definite articles in front of their names, although their names are capitalised: the Moon and the Sun.

Years later, in the Department of Geosciences in the University of Houston, where I had started my undergraduate education, my good friend Mrs. Irene “Cookie” Jones, a senior graduate student in the same department, asked me why all planet names are capitalised, but not ours. I had no idea. Cookie answered it for me: because all other planets carry proper names; they are names of Greek and Roman gods. Our planet also has a divine name, Gaia (Γαῖα), or simply Ge (Γ) in less poetical form in Greek and Tellus or Terra in Latin, but we do not use these names except as adjectives: telluric, terrestrial, terran…. Instead, we use for our planet what we also call the regolith and the soil of the land surface. So far, Cookie.

When we started calling our planet “earth,” we did not know that it was a planet in a solar system, let alone that it had also siblings. It was simply where we lived, later tilled it and grew our food in it and in places used it to make our dwellings. Something similar happened with the Sun and the Moon. The word Sun simply comes from the Indo-European root “to shine.” It was what shone to us and thereby enlightening and warming us. So we gave it a descriptive name. The name Moon has also an Indo-European root that it shares with meter (not metre; American English unfortunately confuses the unit, i.e., metre with the tool, i.e., meter), i.e., “measurer,” because our ancestors used its phases to measure time. So our satellite also has a descriptive name, not a divine one. Both the Sun (the enlightener) and the Moon (the measurer) also have divine names: Helios (Ἥλιος) in Greek, Helius in Latin for the Sun and Selene (Σελήνη) in Greek and Luna in Latin for the Moon.

Recently it has become fashion to write and speak of “Earth” without a definite article and to capitalise it. Using Earth as a planet name in the Solar System violates the time-honoured rules of how we name its planets. In addition, this new fashion has created the necessity of explaining what we are referring to. A plant may grow in the earth or on Earth. This context is not too unclear (but think of exclaiming “where on earth is this plant?”). The meaning is not so clear if we say we walked on the sacred earth or on Sacred Earth. What if Sacred Earth is the proper name of a sacred place and does not refer to our planet? Or just remember the famous phrase, often attributed to the English poet W.H. Auden, but actually first formulated by the British comedian John Foster Hall: “We are all here on earth to help others; what on earth the others are here for, I don’t know.” Which earth would you capitalise in this quote? Thus, in many instances, the whole e versus E distinction and the employment or non-employment of a definite article become useless to distinguish different concepts.

If we are so keen to have the name of our home planet capitalised and get rid of the definite article in front of it, we should simply call it Gaia. We have already done so when we named our science geology, Gaia + logos, and its parent science geography, Gaia + graphein. I personally never use earth without a definite article and never capitalise it in my publications. I respect the historical roots of our usage. But if people are unhappy about it, let us switch to Gaia.

However, there is a much weightier reason that we should continue calling our planet “the earth” and not “Earth”: it is our abode, not any old planet in the Solar System. If we called our planet Gaia, it would be just one of the eight siblings named according to a certain rule, i.e., giving it a divine name, which is fine. It would be one among equals. If we called it Earth, it would be similar. But “the earth” is not the equal of the others: it is where humanity arose to question its origins, its place and its meaning. The rise of humanity is dependent on the planet, its peculiar distance from the Sun, its ability to harbour water and develop soil, i.e., “earth” that feeds us and makes our life and thought possible. When we say and write “the earth” we mean both the planet and signify that it is our home.

Table 1. Names of the planets of the Solar System as gods and goddesses

<table>
<thead>
<tr>
<th>Names</th>
<th>Latin (dwarf planets are not listed)</th>
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<tbody>
<tr>
<td>Hermes</td>
<td>Mercury</td>
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<tr>
<td>Aphrodite</td>
<td>Venus</td>
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<tr>
<td>Gaia (or Ge)</td>
<td>Tellus or Terra</td>
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<tr>
<td>Ares</td>
<td>Mars</td>
</tr>
<tr>
<td>Zeus</td>
<td>Jupiter</td>
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<tr>
<td>Kronos</td>
<td>Saturn</td>
</tr>
<tr>
<td>Uranus</td>
<td>Uranus</td>
</tr>
<tr>
<td>Poseidon</td>
<td>Neptune</td>
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</tbody>
</table>

Left: Greek; right: Latin
I joined GSA as an undergraduate student more than 25 years ago and have remained a member since then. As a military geologist I typically move across the country (or overseas) to a new assignment every few years and am frequently the only geologist assigned to my organization. I am a hydrogeologist working primarily with environmental and public health professionals in a mix of academic and applied settings, so GSA is my professional home where I can interact with other geologists. I frequently attend the GSA Annual Meeting each fall and enjoy catching up with my friends and colleagues while also meeting new geoscientists.

Being a part of GSA gives me the opportunity to share my research and learn about a variety of relevant, high-impact geoscience research presented by others. The interdisciplinary nature of GSA’s Section and Annual Meeting technical sessions is appealing because my interests span a wide spectrum, including hydrogeology, geochemistry, geology and health, and military geology. In addition to giving research presentations at meetings, I have also published my research through GSA publications. The GSA short courses and field trips allow me to engage in lifelong learning and remain current in my field.

My GSA membership also allows me to give back to the profession in many ways. I have organized several technical sessions at meetings, served on GSA committees, participated in numerous mentoring programs, and recently was the Hydrogeology Division Technical Program Chair for GSA’s Annual Meeting. I find these volunteer opportunities to be both personally and professionally rewarding because they allow me to make a difference and broaden my network of colleagues. Why is GSA membership important to me? For all of the opportunities it provides to me and for the opportunity to help others through my service to the organization.

Christopher A. Gellasch
GSA member since 1991
CALL FOR GSA COMMITTEE SERVICE

Help Shape the Future of Geoscience
Serve on a GSA Committee

Deadline: 15 June 2017
Terms begin 1 July 2018 (unless otherwise indicated)

If you are looking for the opportunity to work toward a common goal, give back to GSA, network, and make a difference, then we invite you to self-nominate (or nominate a fellow GSA member) to serve on a Society committee or as a GSA representative to another organization.

Learn more and access the nomination form at www.geosociety.org/committees. Use the online form to make a nomination or self-nomination. GSA Headquarters Contact: Dominique Olvera, GSA, P.O. Box 9140, Boulder, CO 80301-9140, USA; fax: +1-303-357-1060; dolvera@geosociety.org.

Key: B—Meets in Boulder or elsewhere; E—Communicates by phone or electronically; M—Meets at the Annual Meeting; T—Extensive time commitment required during application review period.

ACADEMIC AND APPLIED GEOSCIENCE RELATIONS COMMITTEE
One member-at-large vacancy (industry-related; 3-year term) (E/M)

This committee is charged with strengthening and expanding relations between GSA Members in applied and academic geosciences. As such, it proactively coordinates the Society’s effort to facilitate greater cooperation between academia, industry, and government geoscientists. **Qualifications:** Committee members must work in academia, industry, or government and be committed to developing a better integration of applied and academic science in GSA meetings, publications, short courses, field trips, and education and outreach programs. **Professional Interest:** Environmental & Engineering Geology, Hydrogeology, Karst, Quaternary Geology & Geomorphology, Structural Geology & Tectonics, Sedimentary Geology. Members must also be active in one or more GSA Division.

ANNUAL PROGRAM COMMITTEE
Three member-at-large vacancies (4-year terms) (B/E/M)

This committee is charged with developing a plan for increasing the quality of the annual and other society-sponsored meetings in terms of science, education, and outreach; evaluating the technical and scientific programs annually to identify modifications necessary for accomplishing the Society’s long-range goals; conducting short and long-range planning for the society meetings as a whole, and developing a long-term logistical plan/strategy for the technical programs of all GSA meetings and other society-sponsored meetings. One member-at-large should have previous meeting experience.

ARTHUR L. DAY MEDAL AWARD
Two member-at-large vacancies (3-year terms) (E/T)

This committee selects candidates for the Arthur L. Day Medal. **Qualifications:** Members should have knowledge of those who have made “distinct contributions to geologic knowledge through the application of physics and chemistry to the solution of geologic problems.” All of the committee’s work will be accomplished during the months of February/March. All committee decisions must be made by 1 April.

DIVERSITY IN THE GEOSCIENCES COMMITTEE
Three member-at-large vacancies (3-year terms) (E/M)

This committee provides advice and support to GSA Council and initiates activities and programs that will increase opportunities for people of ethnic minority, women, and persons with disabilities and raise awareness in the geosciences community of the positive role these groups play within the geosciences. The committee is also charged with stimulating recruitment and promoting positive career development for these groups. **Qualifications:** Members of this committee must be familiar with the employment issues these groups face; expertise and leadership experience in such areas as human resources and education is also desired.

EDUCATION COMMITTEE
Three vacancies: One graduate educator and one informal science educator (museum, visitor center, interpretation officer, etc.) (4-year terms); and one undergraduate student representative (2-year term) (B/E/M)

This committee works with GSA members representing a wide range of education sectors to develop informal, pre-college (K–12), undergraduate, and graduate earth-science education and outreach objectives and initiatives. **Qualifications:** Members of this committee must have the ability to work with other interested scientific organizations and science teachers’ groups.

GEOLOGIC MAPPING AWARD COMMITTEE
One member-at-large vacancy (government; 3-year term) (E)

This purpose of this committee is to generate, receive, and evaluate candidates for the Geologic Mapping Award. This award acknowledges contributions in published, high-quality geologic mapping that led the recipient to publish significant new scientific or economic-resource discoveries, and to contribute greater understanding of fundamental geologic processes and concepts. The objective is to encourage training and support toward production of excellent, accurate, detailed, purposeful geologic maps and cross sections. With respect to size or scale, there are no restrictions on map products. GSA’s Geological Mapping Award will be made on an annual basis, leaving the option open for multiple awards to be given under unusual circumstances in any given year; or to make no award in any given year.

GEOLOGY AND PUBLIC POLICY COMMITTEE
Three vacancies: two members-at-large (3-year terms) and one student representative (2-year term) (B/E/M)

This committee provides advice on public policy matters to Council and GSA leadership by monitoring and assessing international, national, and regional science policy; formulating and recommending position statements; and sponsoring topical white papers.
papers. This committee also encourages active engagement in geoscience policy by GSA members. **Qualifications:** Members should have experience with public-policy issues involving the science of geology; ability to develop, disseminate, and translate information from the geologic sciences into useful forms for the general public and for GSA Members; and familiarity with appropriate techniques for the dissemination of information.

**GSA INTERNATIONAL**

Three vacancies: one member-at-large (International Associated Society), one member-at-large (North America), and one member-at-large (outside North America) (4-year terms) (E/M)

Serve as GSA's coordination and communication resource seeking to promote, create, and enhance opportunities for international cooperation related to the scientific, educational, and outreach missions shared by GSA and like-minded professional societies, educational institutions, and government agencies. Build collaborative relationships with Divisions and Associated Societies in International issues and serve as a channel for member-generated proposals for international themes.

**JOINT TECHNICAL PROGRAM COMMITTEE**

Two member-at-large vacancies: one paleoclimatology & paleoceanology and one Precambrian geology (2-year terms, 1 Dec. 2017–30 Nov. 2019) (B/E)

Members of this committee help finalize the technical program for GSA's annual meetings by participating in the Web-based selection and scheduling of abstracts, as well as topical session proposal review. **Qualifications:** Members must be familiar with computers and the Internet, be a specialist in one of the specified fields, and be available in late July through mid-August for the organization of the annual meeting technical program.

**MEMBERSHIP AND FELLOWSHIP COMMITTEE**

One member-at-large vacancy (government; 3-year term) (B)

This committee contributes to the growth of the GSA membership, enhances the member experience, and serves a vital role in the selection of Fellows, all with the goal of fostering a membership community as pertinent and global as our science. Committee members should understand what various segments of our members want from GSA and should be familiar with outstanding achievers in the geosciences who would be worthy of fellowship.

**NOMINATIONS COMMITTEE**

Two member-at-large vacancies (industry, government) (3-year terms) (B/E)

This committee recommends nominees to GSA Council for the positions of GSA Officers and Councilors, committee members, and Society representatives to other permanent groups. **Qualifications:** Members must be familiar with a broad range of well-known and highly respected geoscientists. Meets in Boulder in July or August.

**PENROSE CONFERENCES AND THOMPSON FIELD FORUMS COMMITTEE**

Two member-at-large vacancies (3-year terms) (E)

This committee reviews and approves Penrose Conference and Field Forum proposals and recommends and implements guidelines for the success of these meetings. **Qualifications:** Committee members must be past conveners of a Penrose Conference or Field Forum.

**PENROSE MEDAL AWARD COMMITTEE**

Two member-at-large vacancies (3-year terms) (E/T)

Members of this committee select candidates for the Penrose Medal Award. Emphasis is placed on “eminent research in pure geology, which marks a major advance in the science of geology.” **Qualifications:** Members should be familiar with outstanding achievers in the geosciences worthy of consideration for the honor. All of the committee’s work will be accomplished during the months of February/March. All committee decisions must be made by 1 April.

**PROFESSIONAL DEVELOPMENT COMMITTEE**

One member-at-large vacancy (3-year term) (E)

This committee directs, advises, and monitors GSA's professional development program; reviews and approves proposals; recommends and implements guideline changes; and monitors the scientific quality of courses offered. **Qualifications:** Members must be familiar with professional development programs or have adult education teaching experience.

**PUBLICATIONS COMMITTEE**

Two vacancies: one member-at-large and one young professional member-at-large (4-year terms) (B/E/M)

The primary responsibilities of the committee are: nomination of candidates for editors when positions become vacant; reviewing the quality and health of each Society publication; and reporting with an annual report to Council that shall include recommendations for changes in page charges, subsidies, or any other publishing matter on which Council must make a decision. To carry out this charge, GSA headquarters will provide the committee with all necessary financial information.

**RESEARCH GRANTS COMMITTEE**

Eleven member-at-large vacancies and one NSF delegate (3-year terms) (B/T)

The primary function of this committee is to evaluate the research grant applications received, by delegation of the Council's authority and within the limits of the research grants budget, to award specific grants to chosen recipients. The committee will also act on the distribution of funds derived from any other gifts or memorial or award funds that are to be administered by it. **Qualifications:** Members should have experience in directing research projects and in evaluating research grant applications. Extensive time commitment required 15 Feb.–15 April.

**RESEARCH GRANTS COMMITTEE—ALTERNATES**

Ten member-at-large vacancies (3-year terms; B/T)

This has the same functions/requirements as the research grants committee, but the positions are only used when necessary depending on the number of research grants received.

**YOUNG SCIENTIST AWARD (DONATH MEDAL) COMMITTEE**

One member-at-large vacancy (3-year term) (E/T)

Committee members investigate the achievements of young scientists who should be considered for this award and make recommendations to GSA Council. **Qualifications:** Members should have knowledge of young scientists with “outstanding
achievement(s) in contributing to geologic knowledge through original research which marks a major advance in the earth sciences.” All of the committee’s work will be accomplished during the months of February/March. All committee decisions must be made by 1 April.

GSA REPRESENTATIVES TO OTHER ORGANIZATIONS

GSA Representative to the AAAS Consortium of Affiliates for International Programs (CAIP)
One vacancy (3-year term, 1 Jan. 2018–1 Jan. 2021) (B/E):
CAIP encourages cooperation on projects with international aspects and facilitates networking in its member societies. Qualifications: Interest in the international area of his/her society, but no other specific qualifications.

GSA Representative to the AGI Environmental Geoscience Advisory Committee (EGAC)
One vacancy (3-year term, 1 Jan. 2018–1 Jan. 2021) (E/M):
Fosters communications within the community about issues related to serving the broader international community; helps identify and focus on the highest priority environmental informational needs and issues best addressed by the geoscience community. Qualifications: Well-acquainted with GSA programs in environmental geoscience.

North American Commission on Stratigraphic Nomenclature:
One vacancy (3-year term, Nov. 2018–Nov. 2021) (E/M):
This committee develops statements of stratigraphic principles, recommends procedures applicable to classification and nomenclature of stratigraphic and related units, reviews problems in classifying and naming stratigraphic and related units, and formulates expressions of judgment on these matters.

GSA Representative to the U.S. National Committee for Soil Science (USNC/SS): One vacancy (3-year term, 1 July 2018–30 June 2021) (B/E):
The mission of the USNC/SS is to promote the advancement of soil science in the United States and throughout the world in order to strengthen U.S. soil science as a contributor to the international scientific community and to inform the U.S. scientific community of soil science activities carried out elsewhere in the world.

Committee, Section, and Division Volunteers: Council Thanks You!

GSA Council acknowledges the many member-volunteers who, over the years, have contributed to the Society and to our science through involvement in the affairs of the GSA. Your time, talent, and expertise help build a solid and lasting Society.

Since 1975, Mountain Press’s Roadside Geology series has been providing geology enthusiasts with fascinating and accessible information for states and provinces in the United States and Canada.
IMPORTANT DATES

- Late March: Meeting room request system opens (non-technical, social, and business meeting room requests);
- Mid-May: Housing opens (Orchid Events is the official housing bureau for GSA 2017 Seattle);
- Early June: Registration and Travel Grant applications open;
- 6 June: Meeting room request deadline—fees increase after this date;
- Early August: Student volunteer program opens (new timing this year);
- 1 August: Abstracts deadline;
- 18 September: Early registration deadline;
- 18 September: GSA Sections travel grants deadline;
- 25 September: Registration and student volunteer cancellation deadline;
- 27 September: Housing deadline for discounted hotel rates.

With more than 50% of Washington wines scoring 90+ points in Wine Spectator, flying home with your perfect souvenir might take some pre-planning! Source: Washington State Wine Commission.

HOTEL INFORMATION

The official GSA Housing Bureau, Orchid Events, will open for reservations in mid-May. The Sheraton Seattle Hotel will serve as GSA headquarters, and it’s just half a block from the Washington State Convention Center. The GSA block includes 10 hotels offering rates from US$169 to US$219 single/double occupancy (per night, plus tax). All hotels are within walking distance of the Washington State Convention Center.

Protect yourself: As the number of online hotel bookings continues to increase, so does the rate of booking scams. According to the American Hotel & Lodging Association, fraudulent websites con 2.5 million North Americans out of US$220 million every year. Use only a trusted source to make your hotel reservation and beware of anyone contacting you directly via email, phone, or fax. If you have any questions, please contact the GSA Meetings Department at meetings@geosociety.org. We will post information to our website regarding hotel reservations in mid-May.

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Join more than 400 students who have received travel funding to attend a GSA Annual Meeting. On To the Future provides students from groups that are traditionally underrepresented travel funding and mentorship to their first GSA Annual Meeting, this year in Seattle, Washington, USA, on 22–25 October 2017. Awardees will be exposed to an array of geoscience research, career options, networking opportunities, and the opportunity to interact with GSA leadership. The deadline to apply is 26 May.

Check the OTF website for eligibility guidelines and application information: www.geosociety.org/GSA/OTF/Home.aspx. Questions? Contact Tahlia Bear at tbear@geosociety.org.
FALL/WINTER 2017–2018

The NPS GIP program places college students and early career professionals (18–35 years old) in National Park Service units for three months to one year to assist with geology and integrated science projects. This program is a partnership between the National Park Service, the Geological Society of America, and Environmental Stewards. Opportunities for fall/winter will be posted by GSA and open for application starting 1 May. The application deadline is 1 July.

GeoCorps™ America

FALL/WINTER 2017–2018

The next GeoCorps America fall/winter season runs from September 2017 through May 2018. All fall/winter GeoCorps positions will be posted on the GeoCorps website and be open for applications starting 1 May. The application deadline is 1 July.

GeoCorps provides paid geoscience opportunities in partnership with government agencies and other organizations committed to science and stewardship, including the U.S. Forest Service and the Bureau of Land Management (BLM). All levels of geoscientists—students, educators, professionals, retirees, and others—are encouraged to apply.
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Zealandia: Earth’s Hidden Continent
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ABSTRACT

A 4.9 Mkm² region of the southwest Pacific Ocean is made up of continental crust. The region has elevated bathymetry relative to surrounding oceanic crust, diverse and silica-rich rocks, and relatively thick and low-velocity crustal structure. Its isolation from Australia and large area support its definition as a continent—Zealandia. Zealandia was formerly part of Gondwana. Today it is 94% submerged, mainly as a result of widespread Late Cretaceous crustal thinning preceding supercontinent breakup and consequent isostatic balance. The identification of Zealandia as a geological continent, rather than a collection of continental islands, fragments, and slices, more correctly represents the geology of this part of Earth. Zealandia provides a fresh context in which to investigate processes of continental rifting, thinning, and breakup.

INTRODUCTION

Earth’s surface is divided into two types of crust, continental and oceanic, and into 14 major tectonic plates (Fig. 1; Holmes, 1965; Bird, 2003). In combination, these divisions provide a powerful descriptive framework in which to understand and investigate Earth’s history and processes. In the past 50 years there has been great emphasis and progress in measuring and modeling aspects of plate tectonics at various scales (e.g., Kearey et al., 2009). Simultaneously, there have been advances in our understanding of continental rifting, continent-ocean boundaries (COBs), and the discovery of a number of microcontinental fragments that were stranded in the ocean basins during supercontinent breakups (e.g., Buck, 1991; Lister et al., 1991; Gaina et al., 2003; Franke, 2013; Eagles et al., 2015). But what about the major continents (Fig. 1)? Continents are Earth’s largest surficial solid objects, and it seems unlikely that a new one could ever be proposed.

The Glossary of Geology defines a continent as “one of the Earth’s major land masses, including both dry land and continental shelves” (Neuendorf et al., 2005). It is generally agreed that continents have all the following attributes: (1) high elevation relative to regions floored by oceanic crust; (2) a broad range of siliceous igneous, metamorphic, and sedimentary rocks; (3) thicker crust and lower seismic velocity...
structure than oceanic crustal regions; and (4) well-defined limits around a large enough area to be considered a continent rather than a microcontinent or continental fragment. The first three points are defining elements of continental crust and are explained in many geoscience textbooks and reviews (e.g., Holmes, 1965; Christensen and Mooney, 1995; Levander et al., 2005; Kearey et al., 2009; Condie, 2015). To our knowledge, the last point—how “major” a piece of continental crust has to be to be called a continent—is almost never discussed, Cogley (1984) being an exception. Perhaps this is because it is assumed that the names of the six geological continents—Eurasia, Africa, North America, South America, Antarctica, and Australia—suffice to describe all major regions of continental crust.

The progressive accumulation of bathymetric, geological, and geophysical data since the nineteenth century has led many authors to apply the adjective continental to New Zealand and some of its nearby submarine plateaus and rises (e.g., Hector, 1895; Hayes, 1935; Thomson and Evison, 1962; Shor et al., 1971; Suggate et al., 1978). “New Zealand” was listed as a continent by Cogley (1984), but he noted that its continental limits were very sparsely mapped. The name Zealandia was first proposed by Luyendyk (1995) as a collective name for New Zealand, the Chatham Rise, Campbell Plateau, and Lord Howe Rise (Fig. 2). Implicit in Luyendyk’s paper was that this was a large region of continental crust, although this was only mentioned in passing and he did not characterize and define Zealandia as we do here.

In this paper we summarize and reassess a variety of geoscience data sets and show that a substantial part of the southwest Pacific Ocean consists of a continuous expanse of continental crust. Furthermore, the 4.9 Mkm² area of continental crust is large and separate enough to be considered not just as a continental fragment or a microcontinent, but as an actual continent—Zealandia. This is not a sudden discovery but a gradual realization; as recently as 10 years ago we would not have had the accumulated data or confidence in interpretation to write this paper. Since it was first proposed by Luyendyk (1995), the use of the name Zealandia for a southwest Pacific continent has had moderate uptake (e.g., Mortimer et al., 2006; Grobys et al., 2008; Segev et al., 2012; Mortimer and Campbell, 2014; Graham, 2015). However, it is still not well known to the broad international science community. A correct accounting of Earth’s continents is important for multiple fields of natural science; the purpose of this paper is to formally put forth the scientific case for the continent of Zealandia (Figs. 1 and 2) and explain why its identification is important.

**ZEALANDIA AS A CONTINENT**

New Zealand and New Caledonia are large, isolated islands in the southwest Pacific Ocean. They have never been regarded as part of the Australian continent, although the geographic term Australasia often is used for the collective land and islands of the southwest Pacific region. In the following sections, we summarize the four key attributes of continents and assess how Zealandia meets these criteria.

**Elevation**

Continents and their continental shelves vary in height but are always elevated relative to oceanic crust (Cogley, 1984). The elevation is a function of many features, fundamentally lithosphere density and
thickness, as well as plate tectonics (e.g., Kearney et al., 2009). The existence of positive bathymetric features north and south of New Zealand has been known for more than a century (Farquhar, 1906). The accuracy and precision of seafloor mapping have improved greatly over the past decades (Brodie, 1964; Smith and Sandwell, 1997; Stagpoole, 2002) and a deliberately chosen color ramp on a satellite gravity-derived bathymetry map provides an excellent visualization of the extent of continental crust (Fig. 2). The approximate edge of Zealandia can be placed where the oceanic abyssal plains meet the base of the continental slope, at water depths between 2500 and 4000 m below sea level. The precise position of the foot of the continental slope around Zealandia was established during numerous surveys in support of New Zealand’s Law of the Sea submission (Wood et al., 2003; UNCLOS, 2008).

Zealandia is everywhere substantially elevated above the surrounding oceanic crust. The main difference with other continents is that it has much wider and deeper continental shelves than is usually the case (Fig. 1). Zealandia has a modal elevation of ~1100 m (Cogley, 1984) and is ~94% submerged below current sea level. The highest point of Zealandia is Aoraki–Mount Cook at 3724 m.

**Geology**

By itself, relatively high elevation is not enough to establish that a piece of crust is continental. Oceanic large igneous provinces such as the Ontong Java Plateau (Fig. 1; Coffin and Eldholm, 1994) are elevated but not continental. Rocks of the modern oceanic crust typically comprise basalt and gabbro of Jurassic to Holocene age. In contrast, continents have diverse assemblages of Archean to Holocene igneous, metamorphic, and sedimentary rocks, such as granite, rhyolite, limestone, quartzite, greywacke, schist, and gneiss, arranged in orogenic belts and sedimentary basins.

Essential geological ground truth for Zealandia is provided by the many island outcrop, drill core, xenolith, and seabed dredge samples of Paleozoic and Mesozoic greywacke, schist, granite, and other siliceous continental rocks that have been found within its limits (Fig. 2). Many of these have been obtained from expeditions in the past 20 years (see Fig. 2, caption). Orogenic belts, of which the Median Batholith and Haast Schist are parts, can be tracked through onland New Zealand and across Zealandia (Fig. 2). Thus, there is a predictable regional coherency and continuity to the offshore basement geology.

Traditionally, continents have been subdivided into cratons, platforms, Phanerozoic orogenic belts, narrow rifts, and broad extensional provinces (Levander et al., 2005). Eurasia, Africa, North America, South America, Antarctica, and Australia all contain Precambrian cratons. The oldest known rocks in Zealandia are Middle Cambrian limestones of the Takaka Terrane and 490–505 Ma granites of the Jacquiery Suite (Mortimer et al., 2014). Precambrian cratonic rocks have not yet been discovered within Zealandia, but their existence has been postulated on the basis of Rodinian to Gondwanan age detrital zircon ratios (Adams and Griffin, 2012). Furthermore, some Zealandia mantle xenoliths give Re-Os ages as old as 2.7 Ga (Liu et al., 2015). Geologically, Zealandia comprises multiple Phanerozoic orogenic belts on which a broad extensional province and several narrow rift zones have been superimposed (Mortimer and Campbell, 2014).

Atop its geological basement rocks, Zealandia has a drape of at least two dozen spatially separate Late Cretaceous to Holocene sedimentary basins. These typically contain 2–10-km-thick sequences of terrigenous and calcareous strata (Zealandia Megasequence of Mortimer et al., 2014) and include a widespread continental breakup unconformity of ca. 84 Ma age (Bache et al., 2014). The Zealandia Megasequence provides a Zealandia-wide stratigraphic record of continental rifting, and marine transgression events, similar to that seen in formerly conjugate east Australian basins (Blewett, 2012).

**Crustal Structure**

Continental crust varies considerably in thickness and physical properties. Christensen and Mooney (1995) give an average P wave velocity of 6.5 km$^3$ and
mean density of 2830 kgm$^{-3}$ with an average thickness of 46 km for orogens and 30 km for extended crust. In contrast, oceanic crust is typically 7 km thick, and, in its lower part typically has a P wave velocity of 7.5 km$^{-1}$ (White et al., 1992).

From geophysical work, we know that Zealandia has a continental crust velocity structure, $V_p$, generally <7.0 km$^{-1}$, and a thickness typically ranging from 10 to 30 km throughout its entire extent to >40 km under parts of South Island (Shor et al., 1971; Klingelhoefer et al., 2007; Grobys et al., 2008; Eberhart-Phillips et al., 2010; Segev et al., 2012). Whereas most of Zealandia’s crust is thinner than the 30–46 km that is typical of most continents, the above studies show that it is everywhere thicker than the ~7-km-thick crust of the ocean basins. This result is visible in the global CRUST1.0 model of Laske et al. (2013) shown in Figure 3. Collectively, the crustal structure results show that the rock samples of Figure 2 are not from separate continental fragments or blocks now separated by oceanic crust, but are from a single continental mass.

The thinnest crust within Zealandia is in the 2200-km-long and 200–300-km-wide New Caledonia Trough, where the water depth varies from 1500 to 3500 m (Fig. 2). This raises the question as to whether the trough is floored by oceanic crust or is a failed continental rift. Two wide-angle seismic profiles across the trough near New Caledonia (Klingelhoefer et al., 2007) both show ~2–5 km of sedimentary cover over 8.5 km of crustal basement that has a velocity of ~7 km$^{-1}$ throughout much of its thickness. Klingelhoefer et al. (2007) noted these profiles as atypical of normal oceanic crust. Sutherland et al. (2010) and Hackney et al. (2012) interpreted the New Caledonia Trough as continental crust that was thinned in the Late Cretaceous and re-deepened in the Eocene due to lithospheric delamination.

**Limits and Area**

Where oceanic crust abuts continental crust, various kinds of continent-ocean boundaries (COBs) define natural edges to continents (Fig. 1; Eagles et al., 2015). Despite its large area, Greenland is uncontroversially and correctly regarded as part of North America (Figs. 1 and 4). This is because, despite oceanic crust intervening between southern Greenland and Labrador and Baffin Island, North American continental geology is continuous across Nares Strait between northernmost Greenland and Ellesmere Island (Pulvertaft and Dawes, 2011). Tectonic plate boundaries, with or without intervening oceanic crust, provide the basis for continent-continent boundaries between Africa and Eurasia, and North and South America (Fig. 1). Large area is an inherent part of the definition of a continent *sensu stricto* (Neuendorf et al., 2005). Cogley (1984) defined Central America (1.3 Mkm$^2$), Arabia (4.6 Mkm$^2$), and greater India (4.8 Mkm$^2$) as modern-day continents. This schema has not been generally adopted, probably because Central America (the Chortis block) is a piece of displaced North America, and Arabia and India are transferring to, and are now contiguous with, Eurasia and have clearly defined COBs in the Red Sea and Indian Ocean (Fig. 1). The six commonly recognized geological continents (Africa, Eurasia, North America, South America, Antarctica, and Australia) are thus not only large but they are also spatially isolated by geologic and/or bathymetric features.

At the other end of the size spectrum, a number of continental crust fragments in the world’s oceans are referred to as microcontinents. Examples include the Madagascar, East Tasman, Jan Mayen, Mauritia, and Gulden Draak microcontinents (Gaina et al., 2003; Torsvik et al., 2013; Whittaker et al., 2016). Discriminating between what is a continent and what is a microcontinent may be considered an arbitrary exercise. Nonetheless, maps like Figure 1 need labels. Therefore, following Cogley (1984) and the vagaries of general conventional usage, we propose that the name continent be applied to regions of continental crust that are >1 Mkm$^2$ in area and are bounded by well-defined geologic limits. By this definition India, prior to its collision with Eurasia, would be termed a continent.

The edges of Australia and Zealandia continental crust approach to within 25 km across the Cato Trough (Fig. 2). The Cato Trough is 3600 m deep and floored by oceanic crust (Gaina et al., 1998; Exon et al., 2006). The Australian and Zealandian COBs here coincide with, and have been created by, the Cato Fracture Zone along which there has been ~150 km of dextral strike slip movement, linking Paleogene spreading centers in the Tasman and Coral seas (Fig. 2; Gaina et al., 1998). This spatial and tectonic separation, along with intervening oceanic crust, means that the Zealandia continental crust is physically separate from that of Australia. If the Cato Trough did not exist, then the content of this
paper would be describing the scientific advance that the Australian continent was 4.9 Mkm² larger than previously thought. Being >1 Mkm² in area, and bounded by well-defined geologic and geographic limits, Zealandia is, by our definition, large enough to be termed a continent. At 4.9 Mkm², Zealandia is substantially bigger than any features termed microcontinents and continental fragments, ~12 × the area of Mauritia and ~6 × the area of Madagascar (Fig. 4). It is also substantially larger than the area of the largest intraoceanic large igneous province, the Ontong Java Plateau (1.9 Mkm²). Zealandia is about the same area as greater India (Figs. 1 and 4). Figure 4 makes a case for a natural twofold grouping of continents and microcontinents.

**DISCUSSION AND IMPLICATIONS**

**Recognition**

Satellite gravity-derived bathymetry maps (e.g., Fig. 2) have been of immense use in visualizing Zealandia, clarifying its limits, focusing attention on intra-Zealandia structures, and planning research voyages. If the elevation of Earth’s solid surface had first been mapped in the same way as those of Mars and Venus (which lack the arbitrary datums of opaque liquid oceans), we contend that Zealandia would, much earlier, have been investigated and identified as one of Earth’s continents. Even relatively recently, some papers refer to the offshore ridges and plateaus of Zealandia as an amalgam of continental fragments and slivers (e.g., Gaina et al., 2003; Blewett, 2012; Higgins et al., 2015) with the explicit or implicit notion that oceanic crust intervenes between the continental fragments. The way in which Zealandia has been divided into blocks to make it amenable to rigid plate reconstructions and the way in which coastlines and outlines have been drafted as “floating” in the Pacific Ocean (e.g., Gaina et al., 1998, 2003; Lisker and Läufer, 2013; Higgins et al., 2015) has probably sustained this false impression of remote and discombobulated tectonic allochthony and poorly defined COBs. In contrast, we view Zealandia as a coherent, albeit thinned and stretched, continent with interconnected and throughgoing geological provinces (Figs. 2 and 5; Mortimer et al., 2006; Grobys et al., 2008; Tulloch et al., 2009; Adams and Griffin, 2012; Bache et al., 2014; Graham, 2015). Like parts of North America and Eurasia, Zealandia has undergone active deformation in a zone between two essentially rigid plates—in Zealandia’s case, the Pacific and Australian (Fig. 2).

Several elevated bathymetric features north of Zealandia are possible candidates for Zealandia prolongations or separate microcontinents (Fig. 2). These include the Three Kings, Lau-Colville, and Tonga-Kermadec ridges and Fiji, which are known Cenozoic volcanic arcs (Graham, 2015), and the Mellish Rise and Louisiade and West Torres plateaus. However, no continental basement rocks have yet been sampled from any of these features, so their continental nature remains unproven.

**Development and Submergence**

As shown in Figure 4, ~94% of the area of Zealandia currently is submerged. It is not unique in this regard: an ice-free, isostatically corrected West Antarctica would also largely be submerged (Figs. 3 and 4; Jamieson et al., 2014). Zealandia and West Antarctica were formerly adjacent to each other along the southeast Gondwana margin and, prior to thinning and breakup, the orogenic belts, Cordilleran batholiths, and normal continental crustal thickness of eastern Australia would have projected along strike into these areas (Figs. 3 and 5).
Several continental metamorphic core complexes (Lister and Davis, 1989) of Late Cretaceous age have been identified in Zealandia and West Antarctica, but not in Australia or East Antarctica (Figs. 3 and 5; Kula et al., 2007). These have been explained by Lister et al. (1991) and Kula et al. (2007) in terms of an asymmetric continent-scale detachment fault model in which Zealandia and West Antarctica are highly extended, lower-plate passive continental margins, and Australia and East Antarctica are relatively unstretched upper plate margins. There is also abundant supporting sedimentary basin evidence that Zealandia experienced widespread Late Cretaceous (ca. 105–85 Ma) extension prior to Gondwana supercontinent breakup (e.g., Luyendyk, 1995; Klingelhofer et al., 2007; Bache et al., 2014; Mortimer et al., 2014; Higgins et al., 2015). The situation of Zealandia’s Phanerozoic orogen overlying Precambrian mantle (Liu et al., 2015) possibly suggests major tectonic detachments along the Moho.

Thermal relaxation and isostatic balance of the thinned continental crust of Zealandia and West Antarctica ultimately led to their submergence. Despite the pervasive thinning, the only part of Zealandia that might qualify as a hyper-extended zone (i.e., stretched by a factor of 3–4 with crustal thinning to 8 km or less; Doré and Lundin, 2015) is the New Caledonia Trough. Zealandia and West Antarctica seemingly record a mode of continental crust deformation in which extension, although substantial, is more distributed and less focused than in most examples of continental breakup. Zealandia has a widespread synrift Late Cretaceous volcanic record (Tulloch et al., 2009; Mortimer et al., 2014); thus, processes that operate at volcanic rifted margins (Menzies et al., 2002) may be applicable to the broad area of Zealandia.

**Significance**

Zealandia once made up ~5% of the area of Gondwana. It contains the principal geological record of the Mesozoic convergent margin of southeast Gondwana (Mortimer et al., 2014) and, until the Late Cretaceous, lay Pacificward of half of West Antarctica and all of eastern Australia (Figs. 3 and 5). Thus, depictions of the Paleozoic-Mesozoic geology of Gondwana, eastern Australia, and West Antarctica are both incomplete and misleading if they omit Zealandia.

The importance of Zealandia is not so much that there is now a case for a formerly little-known continent, but that, by virtue of its being thinned and subducted, but not shredded into microcontinents, it is a new and useful continental end member. Zealandia started to separate from Gondwana in the Late Cretaceous as an ~4000-km-long ribbon continent (Fig. 5) but has since undergone substantial intracrustal deformation, to end up in its present shape and position (Figs. 1–3). To date, Zealandia is little-mentioned and/or entirely overlooked in comparative studies of continental rifting and of COBs (e.g., Buck, 1991; Menzies et al., 2002; Franke, 2013). By including Zealandia in investigations, we can discover more about the rheology, cohesion, and extensional deformation of continental crust and lithosphere.

Gondwana breakup along the paleo-Pacific margin resulted in continents with wide, thinned shelves, such as Zealandia and West Antarctica (Figs. 1 and 3). In contrast, breakup of Gondwana’s core resulted in continents with narrow shelves, such as Africa and its neighbors (Fig. 1). Various lithospheric versus mantle controls on styles of continental rifting and breakup are still debated (Ebbing and van Wijk, 2014; Whittaker et al., 2016). The broad spatial association of stretched continental crust with a pre-softened, Mesozoic, paleo-Pacific convergent margin from the Falkland Plateau, through West Antarctica and Zealandia to the Marion Plateau (Fig. 3), is possibly no coincidence (cf. Rey and Müller, 2010). Other proposed controls on the localization of Zealandia-Gondwana breakup include a mantle plume (Weaver et al., 1994), plate capture (Luyendyk, 1995), and/or impingement of an oceanic spreading ridge (Mortimer et al., 2006). Gaina et al. (2003) proposed that microcontinents are created by plume-controlled ridge jumps during the early stages of supercontinent breakup. The general cohesion of continental crust in extension is attested to by the contrast in size between Zealandia and its neighboring continental fragments of East Tasman, Gilbert, and Bollons seamounts (Figs. 2 and 4). Condie (2015) postulated that ancient and modern continent-continent collisions were a leading cause of continental elevation. The geological history of Zealandia would support this hypothesis: The Paleozoic and Mesozoic orogens of Zealandia are non-collisional (Mortimer et al., 2014, and there is only incipient collision between northern and southern Zealandia across the present-day Pacific-Australian plate boundary. Ironically, for a continent so thoroughly shaped by extensional processes and subsidence, it is the more widely recognized and better-studied convergence across the Cenozoic Pacific-Australian plate boundary that has resulted in any of Zealandia being above the sea.

**CONCLUSIONS**

Zealandia illustrates that the large and the obvious in natural science can be overlooked. Based on various lines of geological and geophysical evidence, particularly those accumulated in the last two decades, we argue that Zealandia is not a collection of partly submerged continental fragments but is a coherent 4.9 Mkm$^2$ continent (Fig. 1). Currently used conventions and definitions of continental crust, continents, and microcontinents require no modification to accommodate Zealandia.

Satellite gravity data sets, New Zealand's UNCLOS program, and marine geological expeditions have been major influences in promoting the big picture view necessary to define and recognize Zealandia (Fig. 2). Zealandia is approximately the area of greater India and, like India, Australia, Antarctica, Africa, and South America, was a former part of the Gondwana supercontinent (Figs. 3 and 5). As well as being the seventh largest geological continent (Fig. 1), Zealandia is the youngest, thinnest, and most submerged (Fig. 4). The scientific value of classifying Zealandia as a continent is much more than just an extra name on a list. That a continent can be so submerged yet unfragmented makes it a useful and thought-provoking geodynamic end member in exploring the cohesion and breakup of continental crust.

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**REFERENCES CITED**


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The National Ground Water Association (NGWA) seeks a collaborative, forward-thinking Chief Executive Officer to lead the organization in partnership with the Board of Directors. NGWA is a hybrid international trade association and scientific professional society working together to advance groundwater knowledge and the success of members through education and outreach; advocacy; cooperation and information exchange; and enhancement of professional practices. NGWA’s vision is to be the leading groundwater association advocating the responsible development, management, and use of groundwater. NGWA also operates a charitable foundation, the NGWA Foundation, focused on education, research and charitable activities related to broader public understanding of groundwater.

The current CEO will retire at the end of 2017. The next CEO must be a talented leader who recognizes successes of the past and charts a course for future impact and growth. NGWA has four membership sections—contractors, scientists and engineers, manufacturers, and suppliers. The national board has 19 voting members and each membership section has an oversight board. The CEO manages a staff of 29 and a budget of $5.5 Million, and serves roughly 10,500 members.

In close partnership with the Board of Directors and staff, the CEO provides strategic vision and leadership to steward the future of NGWA and cultivates relationships with key policymakers, stakeholders, the media, and partners to advance NGWA’s goals. The CEO has a strong external presence and the ability to engage stakeholders.

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- Be highly knowledgeable about, attuned to, and effective in researching member needs and industry issues.
- Identify and foster opportunities to diversify and grow the organization’s revenue through new partnerships and services.
- Manage and nurture an exceptional staff.
- Possess a high level of business and financial acumen along with experience improving operational efficiencies.
- Have excellent communication skills, media experience, and the ability to positively influence others.
- Seek opportunities to strengthen cross-organizational collaboration.
- Effectively influence public policy and regulatory issues affecting members.
- Work to secure legislation and grants from federal government to better our industry and members.
- Represent NGWA regionally, nationally and internationally to achieve NGWA goals. Regular travel and public speaking engagements are an important part of this position.
- The ideal candidate will be a seasoned executive leader with a strong track record of successfully leading and developing teams, working with an engaged Board, diversifying revenue streams, leading strategic planning, and cultivating relationships with a wide spectrum of stakeholders, vendors, and partners.

This describes the general nature of the CEO position. A full position description will be provided to candidates.

To Apply: NGWA has retained Nancy Rummel of Nancy Rummel & Associates to assist in this search. Candidates should submit a letter of interest with salary requirement and resume to: Nancy@nancyrummel.com. Deadline for application is March 31, 2017. Salary package is commensurate with experience. The National Ground Water Association headquarters is located in Westerville, Ohio. To learn more about NGWA, visit: www.ngwa.org.

**GEOLOGY: SOLID EARTH GEOLOGY, GUSTAVUS ADOLPHUS COLLEGE**

Starting September 2017

Gustavus Adolphus College seeks a full-time one-year position of visiting assistant professor to begin September 1, 2017. We seek candidates with a PhD or ABD and demonstrated excellence in undergraduate teaching. Assignments include courses in earth materials/mineralogy, structural geology, petrology, introductory geology, a January Term experiential course, and senior thesis supervision. The strongest candidates will articulate their intersections with emerging employment opportunities in the geosciences, and complement our existing department strengths. Visit http://gustavus.edu/jobs for application instructions. Application review will begin immediately, and continue until the position is filled.

Gustavus Adolphus College is an EOE Employer/Disabled/Vet employer.

**DIRECTOR, KANSAS GEOLOGICAL SURVEY  
THE UNIVERSITY OF KANSAS, LAWRENCE**

Full-time position serving as the Director of the Kansas Geological Survey (KGS) and State Geologist. Must develop and articulate a vision of KGS programs, understand the concept of serving Kansas through high-quality research in the applied geosciences, and embrace a collegial leadership style. Requires doctorate in the geosciences with 10 years professional experience, prior administrative and/or leadership experience, national recognition in geoscience research, excellent communication skills, knowledge of natural resources and the environmental aspects of their use, and demonstrated ability to deal with natural-resource policy issues. Will have the opportunity to jointly hold a tenured faculty position in an academic department at the University of Kansas (KU).

The KGS is a research and service division of KU. Created in 1889, the KGS studies the geology of Kansas, develops new techniques for exploring and analyzing geologic data, and produces and disseminates maps, reports, and scientific papers. Among the premier earth-science research and service institutions in the U.S., the KGS has an annual state budget of $5.8 million, a fiscal year 2016 grant and contract budget of $4.6 million, and employs more than 112 researchers, support staff, and students engaged in a variety of disciplines. Staff collaborate extensively with faculty and students in academic departments at KU.


**Opportunities for students**

Ph.D. position in Sedimentology and Paleolimnology, Missouri University of Science and Technology. We seek a qualified Ph.D. candidate to investigate the sedimentology of modern lacustrine environments. The objective of the project is to better understand processes controlling sedimentation in an evolving lacustrine basin within an active tectonic setting. Full financial support is available for at least three years at a competitive rate through research and teaching assistantships. Candidates with a strong background and interest in sedimentology, paleolimnology, and palaeoclimate are strongly encouraged to apply. Starting date, August 2017.

If interested, please submit C.V. and one page summary of research interests to Dr. Jonathan Obrist at obristj@mst.edu.

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**Check out the Job Board for the latest recruitment postings.**
From Field Camp to Profession: One Step in the Career Path for Emerging Geoscientists

One of the pillars of GSA’s mission is advancement of the geosciences profession, and as geologists from all disciplines, we know how important fieldwork is to our careers. Opportunities to experience fieldwork are dwindling, and so GSA’s efforts to help provide this opportunity, with partner support, are important for our student members.

Starting in 2009, the GSA/ExxonMobil Bighorn Basin Field Camp awarded 20 undergraduate and/or graduate students and five faculty members participation in a high-quality seven-day field seminar for seven consecutive years. Run in the Bighorn Basin of north central Wyoming, USA, participants had costs covered for transportation, meals, and living expenses. The camp was taught by ExxonMobil professionals with specific skills in tectonics, geochemistry, structure, sequence stratigraphy, sedimentology, paleontology, hydrocarbon systems analysis, and integrated play analysis. GSA’s Committee on Professional Development selected participants based on grades, cover letters, and letters of recommendation.

Kimberly Gloersen was an undergraduate student at Clemson University when she attended the Bighorn Basin Field Camp in 2014. After the field camp, she was offered an internship as a production geologist. At the conclusion of the internship, Kim was offered a full-time position with ExxonMobil Exploration Company beginning in early 2016 and is now working with the Gulf of Mexico team.

As an undergraduate student with little to no prior experience in the oil and gas industry, it was initially quite intimidating to be in the field with and presenting to company and industry experts. I soon realized our mentors shared the same passion and curiosity for the geological sciences as I did, and it inspired me to pursue a career in industry.

Kim’s success is encouraging to all of us at GSA, at the GSA Foundation, at companies like ExxonMobil and others who have hired alumni of the Bighorn Basin Field Camp, and to students following in her footsteps. If you feel as strongly as we do about the vital component of field experience for students moving toward careers in the geosciences, please join us in support of our future geoscientists at https://www.gsafweb.org/donate/#fund=field-camp-opportunities. To discuss support of field camp opportunities like this one, please contact Debbie Marcinkowski at +1 303 357-1047 or dmarcinkowski@geosociety.org.
Tour the Chesapeake Bay with Free GSA Field Guides

The largest estuary in the United States, the Chesapeake Bay stretches from Havre de Grace, Maryland, to Virginia Beach, Virginia, covering ~4,400 square miles. Whether you start your trek from the Fall Zone in Washington, D.C., or on one of Virginia’s barrier islands, our field guides will help you explore the region’s diverse geology. Get free digital access to the following GSA field guides now through the end of April:

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  2015, v. 40, p. 171–229

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Location: San Antonio, Texas, USA
Dates: 13–14 March
Meeting Chair: Benjamin Surpless, bsurples@trinity.edu
www.geosociety.org/sc-mtg

Northeastern Section
(Joint with North-Central Section)
Location: Pittsburgh, Pennsylvania, USA
Dates: 19–21 March
Meeting Chair: Patrick Burkhart, patrick.burkhart@sru.edu
www.geosociety.org/ne-mtg

North-Central Section
(Joint with Northeastern Section)
Location: Pittsburgh, Pennsylvania, USA
Dates: 19–21 March
Meeting Chair: Timothy G. Fisher, timothy.fisher@utoledo.edu
www.geosociety.org/nc-mtg

Southeastern Section
Location: Richmond, Virginia, USA
Dates: 30–31 March
Meeting Co-Chairs: David Spears, david.spears@dmme.virginia.gov; Karen Layou, klayou@reynolds.edu
www.geosociety.org/se-mtg

Cordilleran Section
Location: Honolulu, Hawaii, USA
Dates: 23–25 May
Meeting Chair: Craig R. Glenn, glenn@soest.hawaii.edu
www.geosociety.org/cd-mtg

Rocky Mountain Section
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