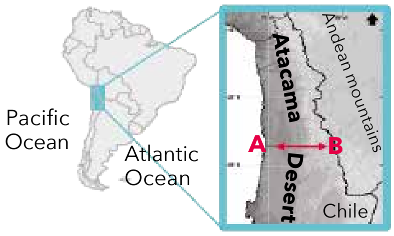
doi.org/10.22498/pages.horiz.1.44 Photo credit: Antonio Maldonado

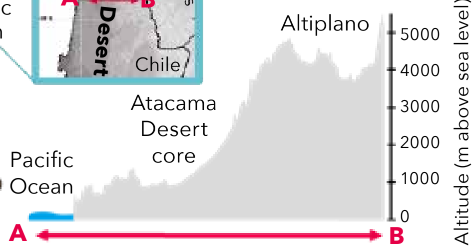
Humans and environments in the most arid place in the world: The Atacama Desert

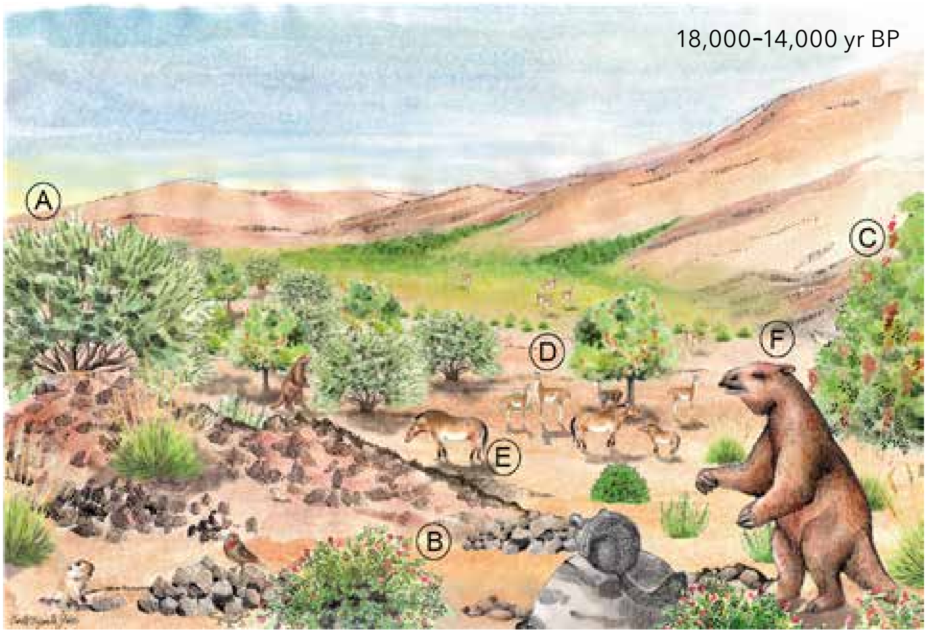
María Eugenia de Porras, Eugenia M. Gayó, Mauricio Uribe and Antonio Maldonado

The Atacama Desert lies between the Pacific coast and the Andes in northern Chile. It is the largest desert in South America and the driest on Earth. Here, annual precipitation is almost zero. The little water that is available depends on the summer rainfall that falls on the Andean mountains. It reaches the desert by runoff and is found within some canyons or by the emergence of groundwater.

The presence of life in this extreme environment may seem unimaginable today; however, fossil and archaeological records reveal that plants, animals, and even humans lived in this region during various periods over the last 18,000 years.







Different paleoenvironmental records indicate that extensive wetlands, springs, shallow lakes, and several perennial rivers existed between 18,000 and 14,000 years ago in the core of the Atacama Desert. These landscape transformations are explained by higher precipitation over the Andes in the past (named the Central Andean Pluvial Event 1), that watered the core of the desert. This led to a flourishing of life, including several perennial native trees (*Prosopis tamarugo*[A], *Escallonia angustifolia*[B], *Schinus molle*[C]) growing along rivers (riparian areas) and close to wetland oases.[1]

Such a vegetated landscape also allowed many types of animals to live in this region, including rodents, birds, and South American camelids (guanacos[D]), as well as some larger, now extinct, South American animals (megafauna) such as small horses[E] and ground sloths.[F,2] This wetter phase ended abruptly about 14,000 years ago, leading to climatic and ecological conditions similar to today, which persisted over the following 1000 years.[1]

Name: **Zoë**

Type: Solar- powered autonomous robot

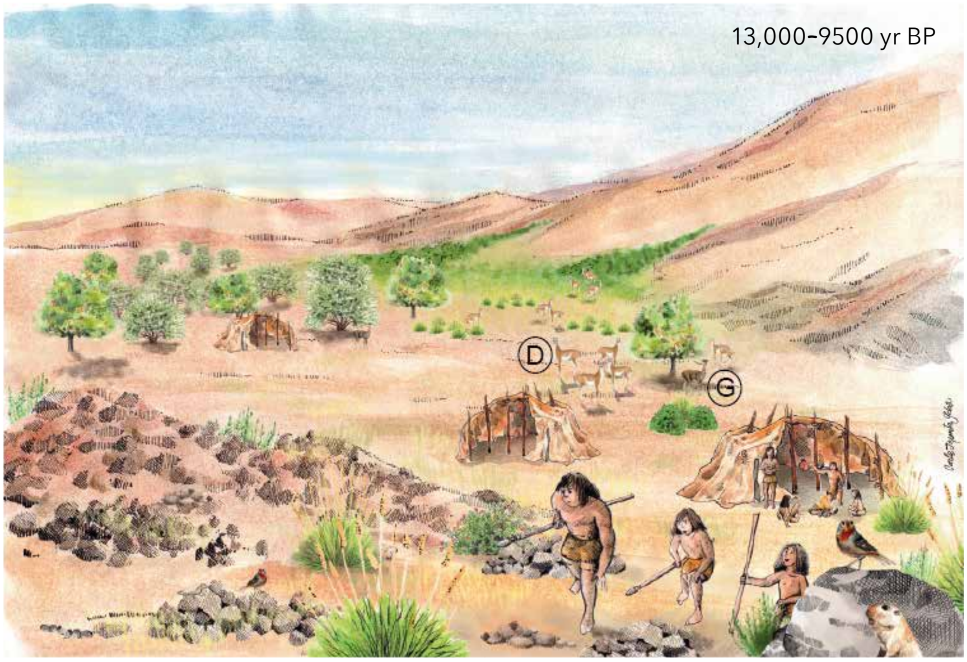
Mission: Detect microorganisms and map the distribution of life in the Atacama Desert; perform tasks that could be used in future exploration of Mars.

Name: **Gecko**

Scientific name: *Phyllodactylus gerrhopygus*

Where to find it: Northern Atacama Desert from the coast to the mountains up to 3500 m (11,500 ft) above sea level.

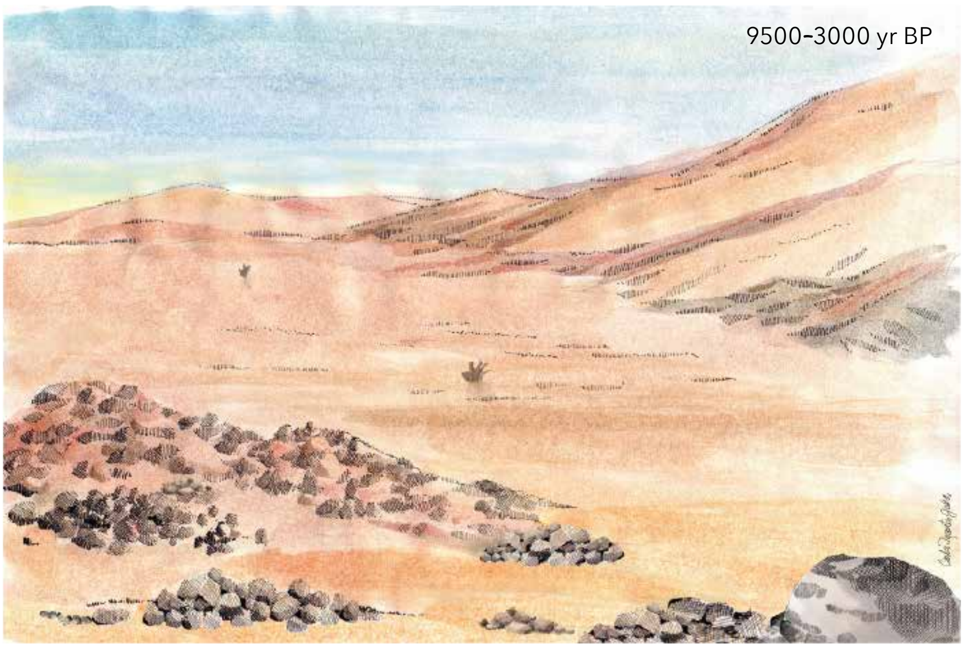
Fun fact: Each of its fingers has two touch pads and claws between them which allow Gecko to move on the hot surface of the desert.



Earliest human sites at present

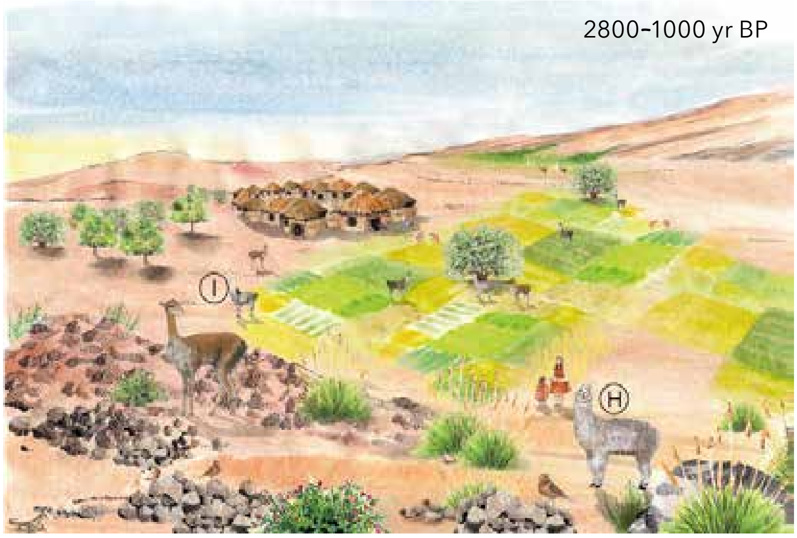
Projectile point

About 13,000 years ago, the desert once again became wet (Central Andean Pluvial Event 2), and freshwater oases with herbaceous vegetation and trees took root across the lowlands of the Atacama Desert.[1,3,4] The megafauna was no longer part of the story, but small rodents, birds, and camelids such as guanacos[D] and vicuñas[G] became commonplace in these ecosystems. Humans also entered the scene during this period: evidence indicates that the first settlers in the desert arrived about 12,800 years ago.[3,4] Attracted by the availability of biotic and water resources, these hunter-gatherers established camps around wetlands and riparian areas. However, such residential bases were only intermittently occupied as environmental and ecological conditions varied, making a nomadic lifestyle necessary during various periods in the extreme inland Atacama.[3,4]



The lack of paleoenvironmental and archaeological records dating between 9500 and 3000 years ago has led paleoecologists and archaeologists to infer that a huge 6000-year drought took place in the Atacama Desert core due to a decrease in rainfall over the Andes.[1,3,4] The heavy decrease in water availability was hard for hunter-gatherer groups, who disappeared from the landscape. In fact, the previous environment full of water and biotic resources vanished, leaving a harsh habitat resembling the modern desert.

Wet phases returned to the area about 3000 years ago, but these were only moderate in comparison to what had occurred before. Paleoenvironmental evidence indicates that two wet periods at 2500–2000 and 1600–1100 years ago led to increased runoff and local water-table levels across the Atacama Desert core. However, these were not enough to activate springs or wetlands, and the vegetation cover of native herbaceous and woody plants was scarce and mostly restricted to ravines.[3,4] Humans re-occupied the low-elevation desert around 2800 years ago.[5] Since then, people gradually adapted their traditional hunting and gathering system to an agricultural lifestyle, despite still foraging some wild resources (plants and animals). Population sizes increased when largely dispersed but concentrated villages with monumental public spaces (squares) and cemeteries were built, incorporating new forms of social organization with different economic and ritual activities. Local communities developed sophisticated technologies to manage surface water, including dams and irrigation canals for maintaining large and well-drained cultivation plots on what are now arid floodplains. Domestic South American camelids (alpacas[H] and llamas[I]) usually hung around and herded around these fields where quinoa, gourd, and maize were cultivated, as well as algarrobos or mesquite trees (*Prosopis*).[3,4,5]

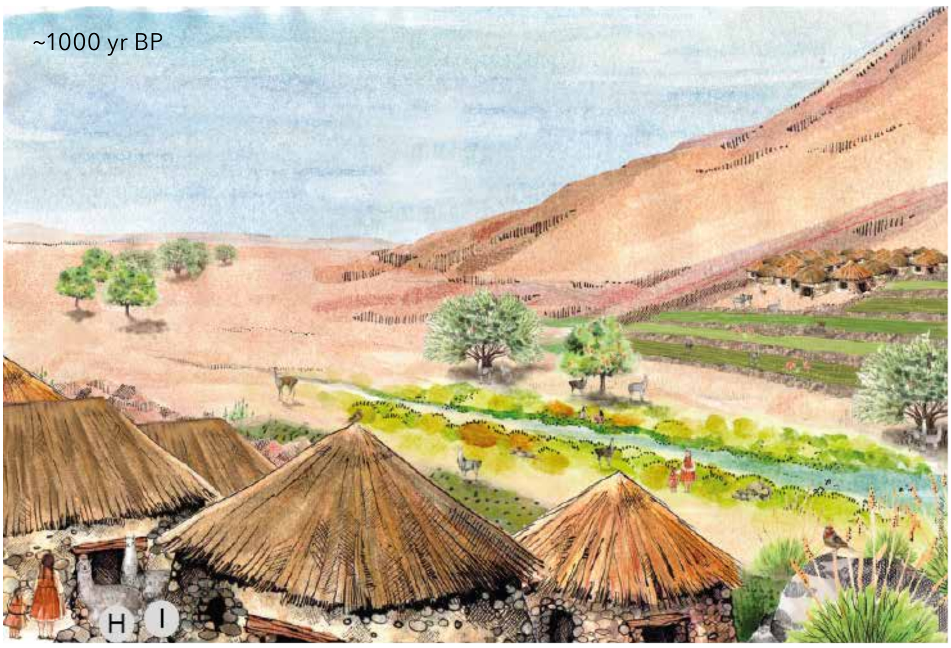


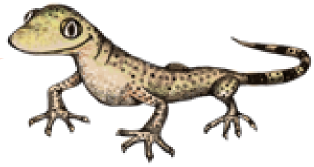
Abandoned village with circular-shaped buildings

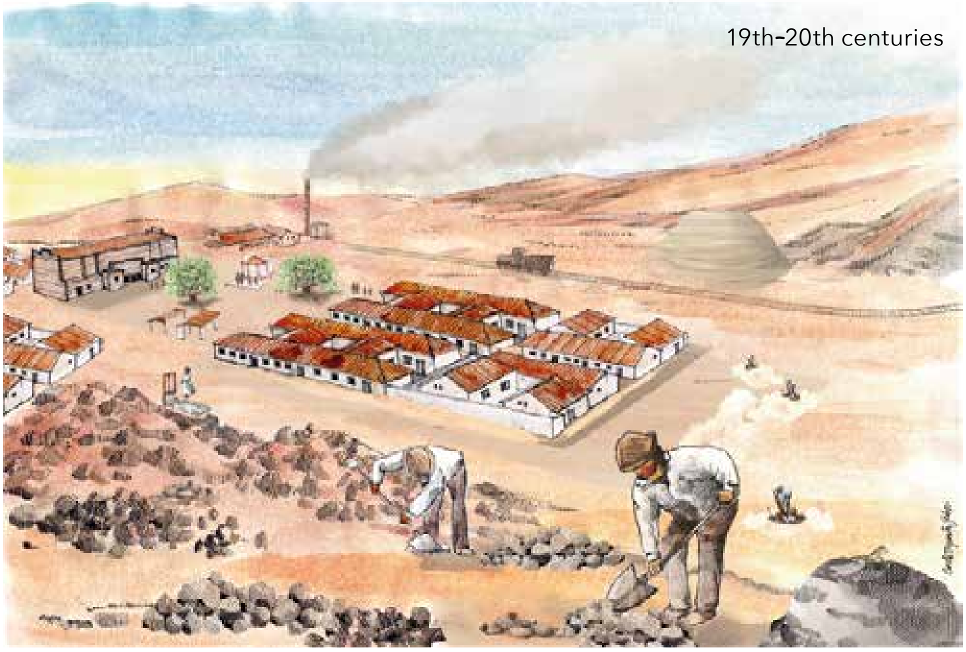
Ancient cultivation plots in the desert

Cob associated with a cultivation plot

Arid conditions set into the area 1000 years ago.[3,4] In order to face this scenario, people moved from the desert core to the Pacific coast or higher elevations (above 2400 m/7900 ft above sea level), where water was much more abundant. That is, villages were now built following a vertical arrangement at upstream oases (canyons, wetlands) or in the Altiplano.[6] Public spaces were separated from residential areas, located within or outside the villages. New systems of agriculture (arranged as terraced fields), defensive infrastructures (locally known as Pukaras) and land-use patterns emerged. Since this phase, the number of villages and the population density started to increase, and local communities intensified agricultural activities and the husbandry of alpacas[H] and llamas[I] within these circumscribed territories at high elevations.[6] The Atacama lowlands become a space that served as a place for communication and exchange between people from Andean highlands and the Pacific coast (an internodal territory). Still, archaeologists have suggested that this landscape was used opportunistically by farmers after flashflood episodes that temporarily inundated the Atacama Desert core.







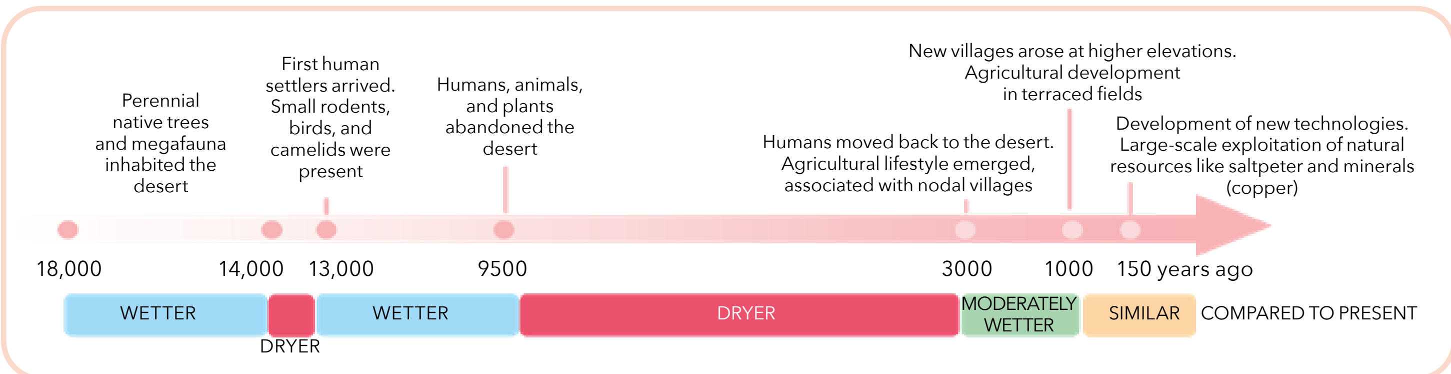
During the last 700 years, climate has remained similar to present, even during very short (but decade-long) wet pulses.[3,4] Despite this hostile environment, humans have continuously inhabited the core of the Atacama Desert since the European colonization (starting in 1533 CE).[3,4,7] This has been achieved by a flexible lifestyle that involves the incorporation of new technologies and the large-scale exploitation of non-renewable natural resources. For example, modern urban centers have relied heavily on the groundwater stored within underground aquifers (fossil water) during past wet phases.[3,4,7] The first profitable mining industry conducted between the 19th and 20th centuries in the Atacama Desert depended not only on the extraction of saltpeter but also on the use of logs of trees that grew in the core of the desert during both Central Andean Pluvial Events. Today, the Atacama Desert is the world's top producer of copper, which is a key raw material to manufacture a diverse array of devices that are part of our day-to-day life (e.g. computers, batteries, pipes, clothes, cars, electrical wires, and coins). Nevertheless, such extensive copper extraction to supply global technological needs will soon consume either the entire mineral reserve or a large volume of fossil water.

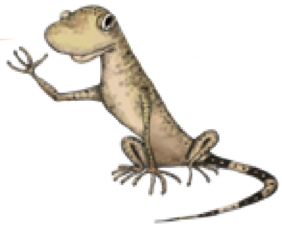
Old shovel used for saltpeter and fossil wood extraction

Ancient saltpeter/"caliche" processing plant

Saltpeter village ruins at present

Major paleontological, archaeological, and environmental changes recorded in the Atacama Desert over the last 18,000 years





As you see, my dear Zoë, the Atacama Desert has a fascinating environmental history, and people have maintained a delicate balance for over 12,000 years, but the modern lifestyle has affected the balanced relationship that native societies used to have with the fragile Atacama Desert ecosystem ...

Absolutely! Now I feel a little bit ashamed since my circuits are made with Chilean copper ... building me consumed a lot of fossil water! Now I understand that the Atacama Desert is not a barren landscape ... its present ecosystems and archaeological heritage deserve to be protected and the extraction of fossil resources needs to be managed sustainably. I hope it is not too late ...

GLOSSARY

Extraction of saltpeter: Ancient, extensive economic activity performed during the 19th and 20th centuries to extract potassium nitrate (saltpeter/caliche) from the surface of the Atacama Desert to be used to cure meat and to produce fireworks, fertilizers, and toothpastes.

Ground sloth: Extinct large mammal directly related to modern sloths. It was an herbivore that lived in and around the riparian and wetland oases of the Atacama Desert.

Oases: Isolated areas in the desert where water is available.

Paleoenvironmental: Related to a certain environment of the geologic past.

Perennial rivers: Streams where water is found throughout the year.

Water-table level: Shallowest depth of the groundwater below the Earth's surface. This depth can change through time.

Wetlands: Areas in the desert where water reaches the surface most of the year, allowing plants to grow there or in the surrounding areas.

Exposed fossil wood and plant material

Miebach (pp. 38-40)

1. Litt et al. (2012) Quat Sci Rev 49: 95-105
2. Video: Tired of reading? Take a look at this short video about pollen
3. Video: Want to know more about pollen analysis? Here's an informative video
4. Video: Some nice images from the Dead Sea

De Porras et al. (pp. 44-48)

1. Workman TR et al. (2020) Quat Sci Rev 243: 106502
2. Villavicencio NA et al. (2019) In: Cartes L et al. (Eds) Avances en Paleontología Chilena. Instituto Antárctico Chileno, pp. 296-298
3. Maldonado A et al. (2016) PAGES Mag 24: 56-57
4. Santoro CM et al. (2017) J Anthropol Archaeol 46: 28-39
5. Uribe M et al. (2020) Lat Am Antiq 1: 81-102
6. Uribe M (2006) Estudios atacameños 31: 91-114
7. Gayo EM et al. (2019) Elem Sci Anth 7: 15

Olatoyan (pp. 49-51)

1. Ferrar AA, Lötter MC (2007) Mpumalanga biodiversity conservation plan handbook. Mpumalanga Tourism & Parks Agency, pp 9-12
2. Huffman TN (2007) Handbook to the Iron Age: the archaeology of pre-colonial farming communities in southern Africa, pp 331
3. Manning K et al. (2011) J Archaeol Sci 38: 312-322
4. Crowther A et al. (2018) Quat Int 489: 101-120
5. Humphris JE (2010) An Archaeometallurgical Investigation of Iron Smelting Traditions in Southern Rwanda. PhD thesis, pp. 37-43
6. MIME/ADB (1996) Cambodian Energy Statistics; Sources of Energy Data and Methods of Estimation. United Nations, 69 pp
7. Food and Agriculture Organization (FAO) (2010) Forestry Paper, Ch. 2
8. Shi N et al. (1998) Veg Hist Archaeobot 7: 127-140
9. Willis KJ (2019) Tribulus terrestris (85.4.1 - 1). Digitized palynological slide. Obtained from: Martin AC, Harvey WJ (2017)
10. Widgren M et al. (2016) J Afr Archaeol 14: 33-53

Glossary (pp. 54-55)

1. Age models: On this website, under "Software and animations", you can see an animation of how fast sediments deposit and how the depth-age model is therefore built.
2. Radiocarbon: Here's an interesting article in *The Conversation* about how radiocarbon dating works

ACKNOWLEDGMENTS

The editors extend their sincere gratitude to Clara Aguilar, Yassine Ait Brahim, Stella Alexandroff, María Andrés, Asfawossen Asrat, Mindy Bell, Stephanie Borg, Ed Brook, Daniel Bruno, Emilie Capron, Cristiano M. Chiessi, Elisabeth Dietze, Mike Evans, Fátima Franco, Eva Fuentes, Carmen Galián-Barrueco, Eduardo García Prieto, Lindsey Gillson, Dai Grady, Alaia Herranz Franco, Darrell Kaufman, Christophe Le Gall, Quentin Lepiller, Nick Marriner, Erin Martin-Jones, Neil Roberts, Enrique Royuela, Deirdre Ryan, Willy Tinner, and Blas Valero-Garcés for lending their expertise in reviewing the articles in this issue.

Boris Vannière is supported by the Centre National de la Recherche Scientifique (CNRS) and the Maison des Sciences de l'Homme et de l'Environnement (MSHE), France.

Graciela Gil-Romera is supported by the Philipps-Märburg University, Germany, and the Spanish Research and Science Council (CSIC), Spain.

Sefton and Tan (pp. 16-19)

Symbols are attributed to Biorender, Canva and ian.umces.edu. Styling attributed to Canva.

Frisia et al. (pp. 30-33)

We are indebted to the Australian Research Council (ARC-DP160101058) and the Australia Synchrotron for support. Thanks to Mohammadali Faraji who provided the Sr image for Fig. 5 and Andrea Borsato for the data used in Fig. 4 and 5.

De Porras et al. (pp. 44-48)

The authors are very thankful to Carla Infanta Gabor (Instagram: @carla_ilustraciones) for her dedication during the illustration process, and Delfina España and Zoë Fleming for their help with the design and language style, respectively. Project FONDECYT #1181829 financially supported this publication.

PAGES PAST GLOBAL CHANGES CELEBRATING 30 YEARS

PAGES International Project Office
Hochschulstrasse 4
CH-3012 Bern, Switzerland

Series Editors
Sarah Eggleston, Boris Vannière, Graciela Gil-Romera, Marie-France Loutre

Text Editing
Angela Wade

Layout
Sarah Eggleston

Design
sujata.design

Printed on recycled paper by
Läderach AG, Bern, Switzerland

Telephone +41 31 631 56 11
Email pages@pages.unibe.ch
Website pastglobalchanges.org
Twitter @PAGES_IPO
Facebook PastGlobalChanges
Find out more about PAGES Horizons at
pastglobalchanges.org/products/pages-horizons

Parent program
PAGES is a Global Research Project of Future Earth.

Supporters
The PAGES International Project Office and its publications are supported by the Swiss Academy of Sciences (SCNAT), the Chinese Academy of Sciences (CAS), and the University of Bern, Switzerland.

doi.org/10.22498/pages.horiz.1