

David Tovar

María Angélica Leal *Editors*

Astrobiology and Planetary Sciences in Latin America

Research, Education, Public Outreach,
and its Potential for Near-Future
Investigations.



Springer

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Foreword

In recent decades, astrobiology has emerged as one of the most exciting and integrative fields in contemporary science. Arising at the intersection of biology, geology, astronomy, physics, and chemistry, this branch of knowledge dares to confront some of humanity's most profound questions: When, where, and how did life originate? Is life a phenomenon exclusive to our planet, or a possibility distributed throughout the universe? What conditions render a world habitable? How might we detect life beyond Earth?

Astrobiology is a profoundly multidisciplinary discipline that explores the origin, evolution, distribution, and potential destiny of life in the universe. Although there is still no unanimous definition of what exactly constitutes life, biology has identified its essential components—the building blocks of living systems—as well as the extraordinary variety of environments in which life can thrive. When the focus shifts to our immediate neighborhood—the planets and moons of the Solar System—astrobiology relies on planetary sciences. These disciplines, which take Earth as their primary reference point, enable the construction of atmospheric models, the performance of geodynamic simulations, the interpretation of imagery and chemical spectra, and the analysis of surface features, all with the aim of assessing whether a given environment could have once supported, or may still support, life on the surface or within the interior of a Solar System body. When astrobiology looks much farther afield—toward exoplanets or even regions of the interstellar medium—it turns to astrophysics and astrochemistry. These fields make it possible to investigate whether some of the thousands of planets discovered to date, or certain interstellar environments, might harbor forms of life similar to, or perhaps radically different from, those known on Earth.

What is perhaps most fascinating about astrobiology is not only the frontiers of knowledge it explores but also the profound effect it has on those who engage with it. It is a science that inspires, that awakens vocations, that opens the door to wonder—and leaves no one indifferent. Images of robotic vehicles traversing the Martian surface, spectacular photographs of distant bodies at the edge of our Solar System, the discovery of exoplanets in habitable zones, or the resilience of microbes in Earth's extreme environments are not merely technical and scientific

achievements; they are also visual and symbolic narratives that nourish the collective imagination and strengthen the bond between science and society.

In Latin America, astrobiology is taking root with increasing strength. Dedicated research groups have emerged, academic programs have been launched, regional meetings are being organized, and a growing number of institutions across the region are participating in international networks and missions. What is most striking is that much of this development has not relied on large budgets or centralized infrastructures. Rather, it has been the result of the sustained efforts of small, inspired, and enthusiastic groups with a deep scientific, educational, and social commitment. Public universities, research centers, planetariums, museums, citizen associations, and dedicated educators have all contributed to driving this momentum forward.

But this is not all—the continent’s geographical diversity offers an exceptional framework for studying life under extreme conditions and, by extension, for exploring its potential existence beyond Earth. The combination of inhospitable landscapes, unique ecosystems, and active geological processes makes this region a true natural laboratory, ideally suited for astrobiological and planetary research. Numerous sites closely replicate, with remarkable fidelity, environments that may be found on celestial bodies, such as Mars, Europa, or Enceladus.

In the Andes and the Southern Cone, numerous examples of such environments can be found. The Uyuni and Coipasa salt flats in Bolivia, rich in evaporites and exposed to intense ultraviolet radiation, have been studied as Martian analogs. In Chile, the Atacama Desert—the driest on Earth—serves as a privileged site for testing life-detection technologies and understanding the resilience of the most extreme ecosystems. Argentina adds to this landscape with arid northwestern regions, volcanic environments such as the Payunia field, and the hypersaline lagoons of the Puna, all of which offer conditions similar to those expected on Mars. In Brazil, the iron-rich outcrops of the Quadrilátero Ferrífero, together with the ecosystems of El Cerrado, have been used to investigate analogs from both a mineralogical and biological adaptation perspective in highly demanding environments. In Colombia, the Andean páramos and volcanoes such as Nevado del Ruíz provide opportunities to explore arid and hydrothermal settings and study endolithic organisms. Peru stands out for its retreating glaciers and high-altitude hypersaline lakes, which offer ideal conditions for investigating the cryospheres of other planetary bodies. Ecuador, with volcanoes such as Cotopaxi and Chimborazo, presents acidic and high-altitude conditions that facilitate the study of extreme geochemical processes. In Venezuela, the rock formations of the Guayana Shield and the Roraima tepuis—with their isolated ecosystems and unique biota—evoke truly extraterrestrial landscapes.

North and Central America also offer environments of high astrobiological value. In Mexico, the cenotes and caves of the Yucatán Peninsula, as well as the volcanoes of the Trans-Mexican Volcanic Belt, have served as key references for studying subsurface habitats and potential sheltered niches similar to those that may exist within lava tubes beneath the Martian surface. In Cuba, karst systems and low-light humid caves provide useful models for exploring radiation-protected environments. Costa Rica and Nicaragua, with active volcanoes such as Turrialba and Masaya,

allow for the analysis of interactions between geothermal activity, gases, and microbial life. In Panama, the isthmus offers transitional zones between marine and terrestrial environments that are valuable for studying biosignatures in ecological frontier settings. In Guatemala, volcanoes such as Pacaya and Fuego provide dynamic contexts with significant atmospheric variability. Honduras and El Salvador have begun documenting craters and geological structures that are generating interest within the astrobiological community. Meanwhile, in the Dominican Republic, saline lakes and coastal ecosystems offer valuable conditions for studying biological adaptation and hydrological fluctuations—phenomena that may have occurred, for example, on Mars.

And one key factor cannot be overlooked: many Latin American countries are signatories to the Antarctic Treaty, which grants them access to a completely different and scientifically invaluable environment. In Antarctica, research is conducted in fields, such as microbiology in extreme environments, glacier dynamics, and permafrost processes—studies that enhance our understanding of the interactions between climate, life, ice, water, and rock. These investigations are of tremendous value for modeling potential ecosystems on icy moons, such as Europa or Enceladus, or even on frozen regions like the surface of Mars.

All of this environmental richness should not be viewed solely as a natural heritage. It is, above all, a scientific opportunity of the highest order. To seize it requires careful stewardship, responsible study, and the transformation of these assets into a strategic platform from which researchers in Latin America can actively contribute to planetary exploration and the advancement of astrobiology.

In this context, the purpose of this book is clear: to highlight, connect, and project the efforts currently underway in the region in the fields of astrobiology and planetary sciences. The aim is not merely to compile scattered experiences, but to construct a strategic and referential document that reflects the diverse trajectories, major accomplishments, and shared challenges—ultimately contributing to the consolidation of a cohesive regional scientific community with its own distinct identity.

One of the central elements of this volume is the recognition of pioneering groups that, across different countries and often with very limited resources, have contributed to key areas, such as planetary geology, microbiology in extreme environments, scientific instrumentation, and public outreach. This book also underscores the transformative role these disciplines have played in education, not only within formal school and university settings but also in less conventional environments, such as planetariums, museums, and citizen associations.

Furthermore, this book aims to serve as a practical tool for fostering both regional and international collaboration by providing concrete examples that may be useful to science policymakers, academic administrators, and institutions interested in strengthening their networks. Above all, this book is an invitation—a motivation for others to join the growing field of astrobiological research and to contribute their experience to future editions.

The first part of the volume provides a global overview of the development of astrobiology, featuring contributions from internationally recognized researchers. It addresses key topics, such as institutional consolidation, the role of international

organizations like the IAU, and the impact of scientific events, networks, publications, and educational programs. The chapter dedicated to the Spanish Center for Astrobiology (CAB) illustrates how a single institution can successfully integrate research, training, participation in space missions, and international cooperation within a unified operational framework. Its experience offers a valuable model that may serve as inspiration for similar initiatives in Latin America.

The core of this book, however, is devoted to the national experiences of countries, such as Argentina, Brazil, Chile, Colombia, Cuba, Mexico, and Peru. These chapters showcase both well-established scientific trajectories and more recent initiatives. In all cases, particular emphasis is placed on the role that this discipline has played in higher education, science communication, and the cultivation of new scientific vocations—from amateur associations and school-based research projects to university programs focused on planetary sciences. These pages also document the emergence of collaborative networks, such as the Latin American Astrobiology Network, founded at the Second Latin American Congress in 2018, as well as national scientific societies that have helped to bring visibility to key actors, coordinate research agendas, and strengthen regional cooperation.

Although each country has followed its own path, the experiences gathered in this volume reveal common challenges across the region. The first is ensuring that public administrations recognize the strategic importance of astrobiology and planetary sciences, incorporating them into national science and technology agendas, allocating the necessary resources, and supporting the creation of networks, research centers, and programs that enable countries to position themselves internationally in the field of planetary exploration. The second major challenge is the consolidation of human capital. This involves improving both initial and continuing education for educators, creating joint postgraduate programs among institutions and countries, facilitating academic mobility, and ensuring stable working conditions with clear prospects for early-career researchers. The third challenge is strengthening scientific infrastructure—not only through the establishment of necessary laboratories, but also by providing the logistical means required for this kind of work. While the region possesses unique natural environments for such studies, it often lacks the technical resources and bureaucratic flexibility needed to explore them in depth, particularly in protected, remote, or hard-to-access areas.

But just as important as strengthening scientific capabilities is reinforcing the social dimension of this community. Science cannot be developed in isolation from society. Astrobiology—with its capacity to inspire wonder and its fundamental questions about life, the planet, and the future of the biosphere—holds immense potential to inspire, provoke reflection, and engage the public. The ultimate goal of science is not only to generate knowledge but also to share it and return it to society. This is not merely an ethical responsibility; it is an integral part of scientific work. Researchers funded by public resources have a duty to make their results accessible and to foster scientific literacy by equipping society with the tools needed to understand their environment, make informed decisions, and act responsibly—especially, in this case, with regard to our own planet and its biosphere.

This book is not merely a compilation of experiences; it is also a proposal and an invitation to all of Latin America. This invitation is extended to students, encouraging them to join with enthusiasm in this intellectual adventure of exploring both space and our own planet; to educators, urging them to renew their methodologies and connect with the curiosity of their students; to public administrators, calling on them to invest in knowledge as a driver of development; and to all citizens, inspiring them to take an interest in and claim ownership of scientific knowledge. In a world shaken by multiple crises—climatic, social, and health-related—astrobiology, with its focus on the origins of life and the possibility of its existence beyond Earth, reminds us that life on our planet is a rare and precious phenomenon, one that deserves to be understood and protected. As T. S. Eliot once wrote: “We shall not cease from exploration, and the end of all our exploring will be to arrive where we started and know the place for the first time.”

Bogotá, Colombia
April 30, 2025

Miguel Ángel de Pablo Hernández

Contents

1	Introduction	1
	María Angélica Leal and David Tovar	
2	State of Astrobiology in the World	5
	Sun Kwok, Masatoshi Ohishi, Muriel Gargaud, Nils G. Holm, Joseph A. Nuth, Jesus Martinez-Frias, and Sergio Pilling	
3	Centro de Astrobiología Over 20 Years of Research in Spain	13
	J. Miguel Mas-Hesse, Olga Prieto-Ballesteros, Francisco Najarro, Eduardo Sebastián, and Ricardo Amils	
4	Brief History of Astrobiology in Argentina	35
	Ximena C. Abrevaya	
5	Astrobiology and Planetary Sciences in Brazil	57
	Paulo Leme and Jorge Horvath	
6	Astrobiology and Planetary Sciences in Chile	77
	Giovanni Leone, Rómulo Oses, and Ricardo Cabrera	
7	Astrobiology and Planetary Sciences in Colombia	97
	David Tovar, María Angélica Leal, Jimena Sánchez, Rosa Reyes, Trinidad Ceferino, Argenis Bonilla, Nadejda Tchegliakova, María Camila Orozco, Luz Marina Melgarejo, Liliana Figueroa, Rosa Acevedo-Barrios, Walter Ocampo, Carlos Molina, Alejandro Guerrero-Caicedo, and Jonathan Pelegrin	
8	Astrobiology in Cuba	121
	Rolando Cardenas	
9	Sociedad Mexicana de Astrobiología	127
	Guadalupe Cordero-Tercero, Irma Lozada-Chávez, Hugo Beraldi-Campesi, Eduardo Piña, Sandra Ramírez Jiménez, Antígona Segura, and Roberto Vázquez	

10 Astrobiology in Peru: Early Achievements 147
Julio Valdivia-Silva

11 Latin American Astrobiology Network..... 167
María Angélica Leal, David Tovar, Ximena Abrevaya,
Jimena Sánchez, and Julio Valdivia-Silva

Chapter 7

Astrobiology and Planetary Sciences in Colombia



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Abstract This chapter presents a historical and contemporary review of the development of astrobiology and planetary sciences in Colombia, highlighting their origins, progress, and future projections. Beginning with the emblematic fall of the Santa Rosa de Viterbo meteorite in 1810—an event that symbolizes the country’s initial engagement with cosmic knowledge—the chapter traces the key milestones in research, education, outreach, and the formation of scientific communities. It examines the early initiatives in exobiology, the consolidation of research groups, the role of museums and planetariums, as well as strategies for the social appropriation of scientific knowledge. Furthermore, it explores major research

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lines in extreme environments and planetary analogs, alongside the development of educational programs and specialized scientific events. Finally, it outlines the perspectives that position Colombia as an emerging actor in the field of space sciences, leveraging its biodiversity, geodiversity, and the strengthening of interdisciplinary networks.

7.1 Introduction

1810 is remembered as the beginning of Colombia's independence process, a political and social milestone that profoundly transformed the destiny of the territory and its inhabitants (Pita Pico, 2021; Brungardt, 2000). However, that same year, an event of cosmic origin would silently and unexpectedly mark the course of Planetary Sciences in the country: the fall of the Santa Rosa de Viterbo meteorite, in the department of Boyacá. On the night of Holy Saturday, a shower of meteoritic masses culminated in the fall of a large metallic rock on the Tocavita hill, near the town of Santa Rosa de Viterbo. A young local resident, Cecilia Corredor, discovered a fragment of the celestial body, which was later moved to the town center (Rodríguez Prada, 2014). For years, the piece was used as an anvil by a local blacksmith, eventually becoming a symbol of the community and, ultimately, one of the foundational stones of scientific thought in the nascent Republic (Rodríguez Prada, 2014; Segura, 1995).

The so-called “aerolite of Santa Rosa de Viterbo,” now classified as an anomalous metallic meteorite (Bsdok et al., 2020), is undoubtedly one of the most emblematic objects in the history of Planetary Sciences in Colombia. Its story—marked by neglect, wonder, looting, and eventual vindication—paradigmatically reflects the country's relationship with scientific knowledge. It was not until 1822—more than a decade after its fall—that the object began to be examined from a scientific perspective, thanks to the arrival of two young naturalists: Mariano Eduardo de Rivero y Ustariz from Peru, and Jean-Baptiste Boussingault from France. Both were

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recruited in Paris by the diplomatic envoy Francisco Antonio Zea to join a scientific mission aimed at laying the foundations of natural knowledge in Colombia (Acevedo et al., 2014; Rodríguez Prada, 2010).

The contracts of Rivero and Boussingault outlined fundamental responsibilities: the establishment of a Museum of Natural Sciences, the design of a National School of Mines inspired by the Parisian model, and the systematic collection of geochemical, mineralogical, and astronomical observations (Ramírez, 1949, 1951; Ward, 1907). During their visit to Santa Rosa de Viterbo, these naturalists conducted a chemical analysis of the aerolite and communicated their findings to scientific institutions in Europe. Their observations were presented at the Academy of Sciences of the Institute of France by prominent figures such as Alexander von Humboldt and Georges Cuvier, and were soon published in scientific journals in Paris, London, and Leipzig (Ramírez, 1949).

In 1823, Rivero and Boussingault printed in Bogota: *Memoria sobre diferentes masas de hierro encontradas en la cordillera oriental de los Andes* (“Report on Various Masses of Iron Found in the Eastern Cordillera of the Andes”), in which they detailed their chemical analysis and described the aerolite, supported by lithographs produced in the most advanced printing workshop in the country at the time. This publication can be regarded as the first local geochemical study of a meteorite in Colombia and marked a transformation of the object—from an unknown natural mass to an item of scientific and cultural interest (Rodríguez Prada, 2014).

The symbolic and scientific value of the aerolite thus became embedded within a foundational moment for Colombian science. In 1823, with the institutional consolidation of the Republic under the vice presidency of Francisco de Paula Santander, Congress officially approved the establishment of the Museum of Natural Sciences—now the National Museum—and the School of Mines, both housed in the former Botanical House of José Celestino Mutis. The Museum was formally inaugurated in 1824, and among its first collections was a fragment of the iconic meteorite from Santa Rosa de Viterbo (Pulido Chaparro, 2015).

Subsequently, the aerolite became the object of desire for international collectors such as Henry A. Ward, who attempted to steal it in 1906 (Escallón, 2015). The incident triggered a national scandal that led to its recovery by order of President Rafael Reyes and its subsequent study at the National University of Colombia (Universidad Nacional de Colombia), marking a new chapter in the institutionalization of scientific knowledge concerning extraterrestrial objects in the country (Universidad Nacional de Colombia, n.d.). Years later, in 1949, Jesús Emilio Ramírez made the first Colombian contribution to the renowned journal *Contributions of the Meteoritical Society*, presenting the history and characterization of the Colombian aerolite (Ramírez, 1949). Finally, in 1992, the main fragment of the meteorite was reintegrated into the National Museum of Colombia (Museo Nacional de Colombia), where it is now preserved under catalog number 874 as part of the “Scientific Objects” collection (Paredes, 2016). Its placement at the center of the museum’s main exhibition hall is no coincidence: it represents the beginning of the national museological narrative, the birth of a scientific gaze toward the cosmos, and a point of convergence between natural history, geology, astronomy, and the very construction of the Colombian state.



Fig. 7.1 Santa Rosa de Viterbo Meteorite. Fragment on display at the National University of Colombia. (Source: Captured and provided by Miguel Ángel de Pablo, 2025)

Just as the history of the Santa Rosa de Viterbo aerolite (Fig. 7.1) is rooted in that singular event which occurred in the very same year the Colombian nation was born, perhaps, as a country, we should have understood that cosmic message not only in the context of our independence, but also as a call to recognize that planetary sciences—particularly planetary geology and astrobiology—can occupy a central role in the advancement and development of the nation’s space sciences. This is especially relevant considering that Colombia is not only one of the most biodiverse countries in the world, but also one of the most geodiverse (Tavera, 2015). Therefore, the present chapter seeks to highlight some of the progress Colombia has made in these fields.

7.2 First Steps

The term astrobiology was first introduced globally in 1953, when Soviet scientist Gavrill Adrianovich Tikhov published his book *Астробиология* (Astrobiology) (Tejfel, 2009). However, in the Americas, the term exobiology

gained greater popularity, largely due to the Soviet origin of the term astrobiology and the prevailing geopolitical context of the time. It was not until 1964 that George Gaylord Simpson emphasized the lack of a clearly defined object of study if life was considered solely as extraterrestrial in origin, and if the field referred only to life beyond our planet (Morange, 2007). The widely disseminated term exobiology remained in use for many years, until 1998, when NASA established the program that would later become the NASA Astrobiology Institute (NAI) (Leal et al., 2015).

It is thus under the framework of the term exobiology that this scientific field finds its origins in Colombia. In 1986, a group of individuals deeply motivated by astronomy and its related sciences—driven by a desire to study and explore various topics while also engaging others and disseminating knowledge—founded the Colombian Association for Astronomical Studies (Asociación Colombiana de Estudios Astronómicos, ACDA). Since its inception, one of ACDA's primary mechanisms has been the formation of study groups in diverse areas, such as astronautics, astrophysics, cosmology, the Solar System, the history of astronomy, and, notably, astrobiology. By the end of 1986, members of ACDA regularly visited libraries to consult the journal *Origins of Life*, which served as the inspiration for the establishment of the Exobiology Commission in 1987. This was the association's first study group and, as far as is known, the first in Colombia to formally address this subject. The group was initially composed of two physicians, a biologist, a microbiologist, and a chemist, who began by studying the biological experiments conducted during the Viking mission to Mars—experiments that, even then, were the subject of considerable debate. Over time, the members of the study group began organizing public outreach lectures, which would eventually become one of ACDA's foundational pillars: sharing and outreaching high-quality scientific knowledge for the broader public.

These activities developed by ACDA led to its recognition in 1992 by the Administrative Department of Science, Technology, and Innovation, Colciencias, through its support program for scientific associations. As a result, ACDA was granted its own headquarters in the Camilo Torres Building at the Universidad Nacional de Colombia (National University of Colombia), where the association remained for several years (ACDA, 2022). These efforts began to generate interest and motivation among undergraduate students at the National University of Colombia, leading to the formation in 2004 of the group “Vida sin Fronteras” (“Life Without Borders”)—later renamed the Astrobiology Club at the Universidad Nacional de Colombia (UNASB)—which focused on outreach activities within the university community and in public spaces such as city libraries. Outreach efforts expanded further through ACDA, which initiated programs in science museums such as the Bogota Planetarium and Maloka. These initiatives were replicated across the country in other science museums, and in 2009, Parque Explora in Medellín city, in collaboration with professionals from the Universidad de Antioquia (University of Antioquia), launched an outreach activity called the Journal Club. This initiative became a space for discussion around astrobiology-related concepts and led to the creation of the Multidisciplinary Group for Studies in Biology and

Astrobiology (AMEBA), which brought together individuals interested in the field (Rodríguez, 2018).

It was not until 2009 that UNASB took a distinctive direction compared to other groups and associations, by incorporating not only outreach, but also research and education as core areas of work—thus establishing itself as a national reference (Grupo de Ciencias Planetarias y Astrobiología, 2017). One of the milestones of that year was the publication of the book: *The Ontogeny of Evolutionary Thought* (*La ontogenia del pensamiento evolutivo*) by one of the professors then leading the student club in astrobiology and theoretical biology. The book explores the relationship between evolutionary epistemology and biological evolution, serving as an academic foundation for the study of one of astrobiology's central questions: how life evolves (Andrade, 2009). Furthermore, in 2011, the article *Planet Earth as a Receptacle of Life: An Ordinary Planet or a Rarity in the Universe?* (*El planeta Tierra como un receptáculo de vida: ¿Un planeta corriente o una rareza en el universo?*) was published, contributing to philosophical and scientific reflection within the field of astrobiology (Portilla, 2011).

Planetary geology began to take its first steps in Colombia in 2012, with the development of an undergraduate thesis comparing the largest volcanic events on Earth with super-eruptions on Jupiter's moon Io (Tovar & Sánchez-Aguilar, 2012), at least as far as current records show. That same year, the Titan Planetary Sciences Club was consolidated, with the aim of conducting research, outreach, and education in the field. In 2013, collaborative efforts began between the Vida sin Fronteras Astrobiology Club and Titan, ultimately leading to the establishment of the Planetary Sciences and Astrobiology Group (GCPA). This group is currently endorsed by the Universidad Nacional de Colombia and the Laguna Scientific Corporation (Corporación Científica Laguna), recognized by the Colombian Ministry of Science, Technology, and Innovation (Minciencias), and serves as the Colombian node of the Latin American Astrobiology Network.

In the same year, 2013, a research line in astrobiology was established within the research group on Stress Physiology and Biodiversity in Plants and Microorganisms at the Universidad Nacional de Colombia—one of the highest-ranked research groups according to the Colombian Ministry of Science, Technology, and Innovation (MinCiencias). Likewise, the Physics and Computational Astrophysics Group (FACOM) at the Universidad de Antioquia incorporated an astrobiology research line. The consolidation of astrobiology and planetary geology within research groups recognized by the Ministry marked a milestone for the country, as these areas of study were now formally acknowledged by the national research system.

7.3 Science Outreach and Public Communication of Science

Outreach has been one of the fundamental pillars in the development of astrobiology and planetary geology in Colombia, particularly considering that the introduction of these fields in the country began through outreach activities, due to the

general lack of knowledge among both the public and even academic communities. One of the major challenges was the frequent confusion of these scientific disciplines with pseudoscience such as ufology. Therefore, in recognition of the origins of these sciences in the country and the persistent gaps in access to knowledge across various regions and socioeconomic sectors, efforts in the social appropriation of knowledge, scientific outreach, and public communication of science remain essential.

As previously mentioned, ACDA began offering outreach talks in a variety of venues, some of which have continued for over 28 years—such as the Saturday astronomy gatherings at the Bogotá Planetarium. These sessions regularly address topics related to Astrobiology and Planetary Sciences (Fig. 7.2) (Planetario de Bogotá, 2022). Additionally, ACDA's long-standing contributions include numerous lectures delivered at events such as the annual meeting of the Red de Astronomía de Colombia—RAC (Colombian Astronomy Network) and various astronomy and space science festivals held throughout the country.

One notable initiative within the framework of space science festivals is the Astrobiology Festival, developed by the Universidad de La Sabana (University La Sabana) and the Secretariat of Education of the Municipal Government of Cota. The first edition of the festival took place in 2020 and was conducted virtually, featuring activities such as workshops on extremophiles, impact craters, terrestrial analogs, and the origin of life, as well as lectures on a wide range of astrobiology topics. The Astrobiology Festival held its second edition in 2021 and a third in 2022 (Alcaldía Municipal de Cota, 2021). One of the most remarkable aspects of this festival was the participation of multiple institutions and, notably, the active involvement of students from local schools. These students were not only attendees, but also facilitators of activities and presenters of the various educational products developed in their academic seedbeds. This dynamic sparked interest and curiosity not only among the students themselves but also among the general public (Leal, 2024). Another festival organized by the University de La Sabana is the Astro-Sciences Festival, held in the municipality of Chía, Cundinamarca, which covered a wide range of topics (Fig. 7.3) (Universidad de La Sabana, 2023).

Among the strategies for the social appropriation of knowledge is the development of discussion spaces centered around science, where topics related to astrobiology and planetary sciences are addressed. One such space is *Café y Ciencia* (Coffee and Science), organized by the Planetary Sciences and Astrobiology Group (GCPA) since 2016. This initiative emerged as a means of disseminating astrobiology and planetary geology, adapting to the Colombian context the French strategy known as *Café Scientifique*. Under this format, every Tuesday from 6:00 p.m. to 8:00 p.m., a scientific topic is presented by an expert speaker, followed by an open discussion with the audience, all while enjoying coffee and cookies. With over 60 in-person sessions held since August 2016, and a subsequent transition to virtual meetings during the COVID-19 pandemic in 2020, the activity succeeded in gathering hundreds of attendees and dozens of speakers. It became a highly diverse and popular outreach platform to explore a wide range of scientific topics, enriched in each edition by current debates, valuable historical perspectives, and insights into

ACDA PROGRAMACIÓN OCTUBRE 2019
CICLO DE CONFERENCIAS LA TABLA PERIÓDICA Y LA ASTRONOMÍA
 DENTRO DE LA CELEBRACIÓN DEL AÑO INTERNACIONAL DE LA TABLA PERIÓDICA (IYPT-2019)

LA TABLA PERIÓDICA, PIEDRA ANGULAR DE LA QUÍMICA
 WALTER OCAMPO MOURE
 SOCIO ACDA
 OCTUBRE 5

EL ORIGEN ESTELAR DE LOS ELEMENTOS QUÍMICOS
 WALTER OCAMPO MOURE
 SOCIO ACDA
 OCTUBRE 12

EL VIAJE DEL ASTRÓNOMO A TRAVÉS DE LA TABLA PERIÓDICA POR MEDIO DE LA ESPECTROSCOPIA
 GABRIEL GONZALEZ
 SOCIO ACDA
 OCTUBRE 19

LA TABLA PERIÓDICA DEL GEÓLOGO PLANETARIO
 DAVID TOVAR RODRIGUEZ
 SOCIO ACDA
 OCTUBRE 26

LA TABLA PERIÓDICA DEL ASTROBIÓLOGO: LOS ELEMENTOS DE LA VIDA
 MARIA ANCELICA LEAL
 CONFERENCISTA INVITADA
 NOVIEMBRE 2

Sábados - 10:00 AM - 11:30 AM
 PLANETARIO DE BOGOTÁ
 Auditorio
 Entradas libre

ACDA PROGRAMACIÓN MAYO DE 2020

LA CRUZ DEL SUR EN LA COSMOVISIÓN ANDINA
 JULIO BONILLA ROMERO
 CONFERENCISTA INVITADO
 MAYO 2

¿ES LA VIDA UNA FORMA DE AUTO-ORGANIZACIÓN DEL UNIVERSO?
 ROSA ALEJANDRA REYES QUIÑONES
 CONFERENCISTA INVITADA GCPA
 MAYO 9

APOLLO 13: 50 AÑOS DE UNA ODISEA
 JOSÉ ANTONIO MESA REYES
 CONFERENCISTA ACDA
 MAYO 16

¿DÓNDE ESTÁ EL AGUA EN MARTE?
 DAVID TOVAR RODRIGUEZ
 CONFERENCISTA ACDA
 MAYO 23

EL COMETA C/2019 Y4 ATLAS
 PEDRO IGNACIO DEAZA RINCÓN
 CONFERENCISTA ACDA
 MAYO 30

Sábados - 10:00 AM 11:30 AM

ACDA GCPA IYPT 2019

ACDA PROGRAMACIÓN JUNIO DE 2021

ASTROBIOLOGÍA: LA VIDA EN LA TIERRA A TRAVÉS DEL TIEMPO
 FERNANDO YAACOV PEÑA
 CONFERENCISTA ACDA
 JUNIO 5

ASTROBIOLOGÍA: DE LAS MOLÉCULAS A LA CONSCIENCIA O LA AUTODESTRUCCIÓN
 FERNANDO YAACOV PEÑA
 CONFERENCISTA ACDA
 JUNIO 12

SERPENTINIZACIÓN: UNA PERSPECTIVA GEOLÓGICA Y ASTROBIOLÓGICA
 DAVID TOVAR RODRÍGUEZ
 CONFERENCISTA ACDA
 JUNIO 19

DÍA DEL ASTEROIDE 2021: EL MILAGRO DE FÁTIMA DESCIFRADO
 IGNACIO FERRIN
 CONFERENCISTA INVITADO
 JUNIO 26

Sábados - 10:00 AM 11:30 AM

ACDA

PROGRAMACIÓN AGOSTO DE 2024

LOS PLANETAS EXTRASOLARES: 30 AÑOS DE DESCRUBIMIENTOS
 WALTER OCAMPO MOURE
 CONFERENCISTA ACDA
 AGOSTO 3

PLANETAS SIMILARES A LA TIERRA
 WALTER OCAMPO MOURE
 CONFERENCISTA ACDA
 AGOSTO 10

PANORAMA GENERAL DE LOS EXOPLANETAS DENOMINADOS SUPERTIERRAS
 JORGE DUEÑAS SUATERNA
 CONFERENCISTA ACDA
 AGOSTO 17

TIERRAS Y SUPERTIERRAS POTENCIALMENTE HABITABLES ALREDEDOR DE ESTRELLAS ENANAS ROJAS
 GONZALO QUEVANA PARDO
 CONFERENCISTA ACDA
 AGOSTO 24

BIOSEÑALES Y TECNOSERÑALES
 FERNANDO YAACOV PEÑA
 CONFERENCISTA ACDA
 AGOSTO 31

SÁBADOS AGOSTO | 2024 | 10:00 A.M. (UTC-5)

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CICLO DE CONFERENCIAS
 POSIBILIDADES DE VIDA EN LOS PLANETAS EXTRASOLARES
 GRUPO DE ESTUDIO EN EXOBIOLOGÍA ACDA

Fig. 7.2 Selected ACDA lecture series on astrobiology and planetary sciences, held as part of the Saturday astronomy gatherings. (Source: ACDA archive)



Fig. 7.3 Promotional posters for the festivals held in the Sabana Centro region, organized by the University of La Sabana. (Source: GCPA archive)

future developments across multiple fields. The activity resumed in 2023 with a new schedule, hence its current name: *Café y Ciencia*. These discussions aim to encourage participation from a wide variety of audiences and guests, recognizing in age, cultural, gender, and epistemic diversity an opportunity to co-construct knowledge (Grupo de Ciencias Planetarias y Astrobiología, 2016).

In addition to these initiatives, several strategies have been successfully developed in the digital realm. One such example is the digital capsule series *Orígenes: Señales de la vida en el universo* (Origins: Signs of Life in the Universe), produced by the Bogotá Planetarium. This series explores various aspects related to life and living systems in the cosmos. The videos incorporate interactive elements and diverse methods of content presentation, making astrobiology topics fully accessible to all audiences. Some of the subjects covered in the series include Life on Earth (Planetario de Bogotá, 2021a), Natural Satellites (Planetario de Bogotá, 2021b),

Titan and Enceladus (Planetario de Bogotá, 2021c), and Exoplanets (Planetario de Bogotá, 2021d).

Other outreach strategies have included a variety of public events featuring lectures and workshops aimed at the general public. Notable examples include activities organized by the Astrobiology Seedbed of the National University of Colombia, such as the Astrobiology Workshop held at the Luis Ángel Arango Public Library in 2009; the lecture *Astrobiology: Life in the Cosmos from a Scientific Perspective* in 2013 at the Bogotá Planetarium; talks on extreme environments and the search for extrasolar planets during the 17th Astronomy Festival of Villa de Leyva in 2014; as well as lectures titled *Life in Extreme Environments and Prebiotic Chemistry and the Origin of Life*, presented at the San Agustín Cloister in 2014; and the webinar *Let's Talk About Astrobiology*, held in 2020 in collaboration with the Peruvian Scientific Society of Astrobiology.

In addition to these public activities, institutions such as the Medellín Planetarium have also contributed through their *Science on a Bicycle* program, which has featured talks on planetary sciences and astrobiology. One such lecture was *Living on Moons: Other Habitable Worlds*, presented in 2021. Similarly, in 2020, the museum and astronomical observatory of the Metropolitan Technological Institute of Medellín hosted events on topics such as *Extremophiles: A Mirror to Find Life on Other Planets* and *Fire and Ice Volcanoes in the Solar System*. Along the same lines, in 2020, the University of La Sabana launched a webinar series on astrobiology, addressing themes such as *Places in the Solar System to Search for Life and Extremophiles*.

Over time, as numerous professionals in fields such as science, engineering, and health sciences had already participated in outreach-oriented events, new initiatives began to emerge in Colombia to promote the circulation of specialized knowledge. Some of these were led by the Planetary Sciences and Astrobiology Group (GCPA), including *Astrogeology Day* in 2014; the *Planetary Sciences and Astrobiology Seedbed Meeting* in 2019; and the *Colombian Meeting on Women and Girls in Science*, which began in 2019 and has since held seven editions. This event consistently features a dedicated space for discussing the role of women in astrobiology and planetary sciences, with its third edition entirely devoted to Mars. Another specialized event is *Asteroid Day Colombia*, first held in 2019, which has now completed seven editions. Additionally, the *Workshop on Planetary Sciences and Astrobiology* held its first edition in 2024 and its second in May 2025 (Corporación Científica Laguna, 2025a).

Other events have also emerged in various regions of the country, such as the *International Congress of Astrobiology*, which has held six editions and has been organized by institutions including Colegio Vermont (Universidad Nacional de Colombia, 2010), Parque Explora and the Medellín Planetarium, the University of Antioquia, the Colombian Institute of Astrobiology Corporation (Corporación Instituto de Astrobiología de Colombia) (Planetario de Medellín, 2012), the University of Manizales, the University of Atlántico, and the Cooperative University of Colombia. Another notable event was the *First District Meeting on Astronomy and Astrobiology*, organized by the Francisco José de Caldas District University in



Fig. 7.4 Covers of the five issues of *Vida sin Fronteras* published to date. (Source: GCPA archive)

Bogotá in 2023, which facilitated the engagement of biology, physics, and chemistry students with these topics (Universidad Distrital Francisco José de Caldas, 2023a). More recently, in April 2025, the Workshop on Astrochemistry and Astrobiology was held by the University of Valle (Universidad del Valle, 2025).

In the realm of public communication of science, the Planetary Sciences and Astrobiology Group (GCPA) has undertaken efforts to develop a strategy that ensures written dissemination. The objective has been to provide astrobiologists and planetary scientists with a platform to read and share their work in their native language. This led to the creation of the journal *Vida sin Fronteras* (Life Without Borders) in 2011, which has published five issues to date (Fig. 7.4) (Corporación Científica Laguna, 2025b). The journal is currently undergoing a redesign aimed at enabling publication in both Spanish and English, thereby ensuring broader accessibility of these academic contributions to the international scientific community. Another notable initiative in written science outreach was a series of columns published in the national newspaper *El Tiempo* under the title *Wonders of the Solar System*, which explored various aspects of planetary geology (Tovar, 2019). It is also important to highlight the publication of outreach books such as *Astrobiología: Un universo de vida* (Astrobiology: A Universe of Life) (Bueno & Moreno, 2011) and *La Incertidumbre de la Vida en el Cosmos* (The Uncertainty of Life in the Cosmos), published by the Asociación de Estudios Astronómicos ACDA. The latter was the result of decades of discussions held by the association's astrobiology group (Comisión Colombiana de Exobiología ACDA, 2018).

Another important avenue for astrobiology and planetary science outreach includes dedicated museum spaces, particularly interactive exhibition halls. One such space is the Astrobiology Hall at the Medellín Planetarium, inaugurated just over a decade ago (Planetario de Medellín, n.d.). Likewise, the interactive halls of the Bogotá Planetarium offer a narrative centered on life and living systems in the cosmos. These halls, renovated in 2022, together constitute the only museum in Latin America exclusively dedicated to exploring astrobiology and planetary sciences.

The first hall, titled *We Are the Universe*, addresses the scales of the cosmos and how humanity has interpreted its origins. The second, *Understanding Life*, explores multiple human approaches to comprehending the physical, geological, chemical, and biological processes that have made Earth a habitable planet. Finally, the third

hall, *The Future of Life*, invites visitors to consider the possibility that life is an emergent property of matter that may have arisen in various places and times throughout the universe (Regalías Bogotá, 2024).

To activate the Bogotá Planetarium's interactive halls, the experience *Living Universe* was designed. Through full-dome projections and guided visits to exhibition devices—such as those explaining the Drake Equation, extremophiles, the origin of life, and geological time, among others—visitors are introduced to key concepts of astrobiology (Instituto Distrital de las Artes, 2022).

7.4 Education

From an educational perspective, various efforts have been made in Colombia to foster new scientific vocations in the field of planetary sciences and astrobiology. One of the earliest approaches has focused on engaging children, teenagers, and young students in basic education. Since 2015, the Bogotá Planetarium, in collaboration with the District Secretariat of Education, has implemented the Centers of Interest in Astronomy project. Beginning in 2021, astrobiology was adopted as a transversal and transdisciplinary theme within this initiative.

Astrobiology was chosen as a focal topic for early-age education because it enables the integration of concepts related to life and its implications, facilitates an understanding of our environment, and promotes reflection on how we interact with and study the world around us. Furthermore, these topics allow children to engage in meaningful discussions and connect with their own socio-environmental contexts (Secretaría de Educación del Distrito, 2023a).

To implement astrobiology as a central theme within the Centers of Interest in Astronomy, classroom discussions are framed within a school-based scientific inquiry process, developed according to the inquiry-based methodology and the pedagogical model of the Bogotá Planetarium (Leal et al., 2023a). In 2021, a total of 5323 students in Bogotá engaged with astrobiology-related topics (Secretaría de Educación del Distrito, 2021); in 2022, that number rose to 16,463 (Secretaría de educación del Distrito, 2021, 2022); in 2023, it reached 19,942 (Secretaría de educación del Distrito, 2022, 2023b); and in 2024, 6857 students participated in the program (Secretaría de Educación del Distrito, 2024). By 2025, the initiative aims to reach 12,000 students with content centered on astrobiology (Secretaría de Educación del Distrito, 2025).

Through these astrobiology-based processes, students develop essential scientific skills such as observation, inquiry, hypothesis formulation, critical thinking, and argumentation. As a result of the integration of astrobiology into the Centers of Interest in Astronomy, the Bogotá Planetarium has published four open-access educational booklets, which can be freely used by teachers and students across the Spanish-speaking world (Instituto Distrital de las Artes, 2021a, 2021b, 2021c, 2021d).

However, the Bogotá Planetarium's approach to astrobiology goes far beyond the aforementioned activities with basic education students. Since 2021, astrobiology

has been incorporated as a transversal thematic axis across all of its pedagogical initiatives, a framework that will be maintained through at least 2026 and may be extended depending on the outcomes (Leal et al., 2023a, 2023b).

Within this context, the Planetarium began offering the Astrobiology for Enthusiasts course in 2019, in collaboration with the Planetary Sciences and Astrobiology Group (GCPA) (Grupo de Ciencias Planetarias y Astrobiología, 2019; Secretaría de Cultura, Recreación y Deporte, 2019). This course has since been offered annually in 2020, 2021, 2023, 2024, and 2025 (Planetario de Bogotá, 2020a, 2020b, 2021e, 2023a, 2024a, 2025).

In addition to this, the Planetarium has developed courses on various planetary science topics, including the Solar System and Exoplanets and Planetary Geology (Planetario de Bogotá, 2021f, 2023b, 2024b). Similarly, the Medellín Planetarium also offers astrobiology courses for both adults and children (Parque Explora, 2024).

In addition to the public courses previously mentioned, university-level courses have also emerged. One example is the elective course in Astrobiology offered by the Biology Program at the Francisco José de Caldas District University. This course is open to students across the university and covers key astrobiological concepts, including practical sessions designed to explore core topics in the field. As part of this academic track, an elective course in Geobiology has also been developed, offering a complementary and in-depth framework for students interested in astrobiology (Universidad Distrital Francisco José de Caldas, 2023b).

Moreover, the same university has offered short courses in planetary geology, such as the 2023 workshop *Terrestrial Analogs and Their Relevance in Planetary Geology and Astrobiology*, providing foundational training in this area.

It is important to highlight that this is not the only university offering courses in these fields of knowledge. In 2016, the National University of Colombia hosted the Alumni Lecture Series in Planetary Sciences and Astrobiology, where undergraduate students and alumni received foundational training in these disciplines. Additionally, in June 2019, as part of Research Month, the same university offered the course *Research Methodology: Its Application in Planetary Sciences and Astrobiology* in the city of Leticia.

Meanwhile, the Environmental Engineering Program at Universidad El Bosque offers the elective course *Mars: New Challenges in Planetary Exploration*. The course aims to promote the development of transversal skills and strengthen competencies such as critical thinking, creativity, and teamwork. It is structured around questions such as, “What is your proposal for adapting and developing your potential adaptability on Mars?”—placing university students from various academic disciplines in a scenario that simulates the possible arrival of humans on the Red Planet.

Additionally, the University of Antioquia has begun promoting a publicly accessible astrobiology course, and in 2024, the University of the Andes offered a course titled *Astrobiology*, open to the general public (Universidad de los Andes, 2024). This course is distinct from the elective course of the same name that has been part of the university’s Physics Program since 2013. University of Valle has offered, since 2024, an elective course within its Chemistry Program titled *Introduction to Astrochemistry*. Similarly, in 2023, the University of Santiago de Cali offered a

diploma course on Space Sciences and the Earth System, organized by its Faculty of Education.

As part of the academic training of university students, the development of student research seedbeds has become evident. The oldest of these is affiliated with the Planetary Sciences and Astrobiology Group (GCPA), whose origins date back to 2004—well before the official establishment of the research group itself. Over the years, students from diverse disciplines including biology, geology, physics, engineering, health sciences, and education have participated in this initiative.

More recently, other astrobiology, astrochemistry, and astronomy clubs have emerged, such as AstroLuca, a student research group in astrochemistry and astrobiology established in 2020 under the leadership of institutions including Universidad Libre (Cali campus), Universidad Santiago de Cali, Universidad del Valle, and the Cali School of Astronomy (EAC). This initiative was launched in response to the growing interest among faculty and students from fields such as basic sciences, education, health, and engineering, particularly given that, until then, these areas of knowledge had not been formally developed in the city of Cali. Additionally, the University of Antioquia, in collaboration with the Medellín Planetarium, continues to offer activities through the Multidisciplinary Group for Studies in Biology and Astrobiology (AMEBA).

7.5 Scientific Research

One of the most prominent research lines in astrobiology at the global level is the study of extreme environments, as these allow scientists to understand how life adapts to adverse conditions—insights that, in turn, help to develop models for the search for life elsewhere in the universe (Leal et al., 2015). Colombia has not been an exception in this research line, particularly considering that it is one of the most biodiverse countries in the world (Arbeláez-Cortés, 2013), as well as country rich in geodiversity (Gerstner et al., 2024). Colombia is home to a wide variety of environments, including thermal springs (Alfaro et al., 2021), tropical dry forests (Golley et al., 1969), snow-capped mountains (Ruiz et al., 2008), and glaciated volcanoes (Huggel et al., 2017), among others.

As a result of the aforementioned developments, several research projects have been carried out in Colombia. One such project is Characterization of Functional Groups of Thermophilic Microorganisms Present in Thermal Springs of the Machín-Cerro Bravo Volcanic Complex (Colombia) (Sánchez, 2024a, 2024b). This project, funded by the Administrative Department of Science, Technology, and Innovation (Colciencias), now the Ministry of Science, Technology, and Innovation (MinCiencias), aimed to characterize microorganisms that could serve as models for understanding the early stages of life, whether on primitive Earth or under ancient, warmer conditions on rocky planets such as Mars.

Another noteworthy research initiative is the project titled Characterization of Natural and Human-Altered Extreme Environments in Colombia with Potential for

Astrobiology, Planetary Sciences, and Microbial Ecology (Sánchez, 2019). This initiative has been linked to seedbed projects funded through the Project Management Program, such as Preliminary Identification of Extremophilic Microorganisms Associated with Xerophytic Environments in the Municipality of Villavieja, which explored xerophilic microorganisms in the Tatacoa Desert, Colombia (Bolívar et al., 2021), as well as studies involving cave environments (Buitrago et al., 2023).

However, Colombian research on extreme environments with implications for astrobiology and planetary sciences is not limited to locations within the country. Within the framework of international collaborations established through the Colombian Antarctic Program, scientific investigations are also being carried out in Antarctica—one of the most suitable regions on Earth for research in these fields. Research projects such as (1) Characterization of Functional Groups of Psychrophilic Microorganisms Present in Frozen Sediments of the Antarctic Peninsula, and (2) Antarctica as a Model for the Development of Astrobiology in the Nevado del Ruíz (Colombia) and the Return of Its Advances to Antarctic Science, researchers have been able to explore various types of microorganisms of astrobiological interest in both Antarctic environments and Colombian sites that share environmental similarities with Antarctica (Leal et al., 2025a; Acevedo-Barrios & Olivero-Verbel, 2021; Acevedo-Barrios et al., 2022a, 2022b, 2023, 2024a, 2024b, 2025; Bolaños et al., 2023).

Another line of research developed in Colombia focuses on the study of extreme environments from a planetary perspective, considering them as potential planetary analogs for rocky bodies such as Mars or the Moon. Notably, within the framework of previously mentioned projects, Deception Island has been evaluated as a potential multifunctional Martian analog. Similarly, the research project titled Assessment of the Ecological, Geological, Geochemical, and Climatological Characteristics of Gorgona Island and the Nevado del Ruíz Volcano as Terrestrial Analogs of Mars and Their Potential for Habitability and Analog Mission Development explores how these Colombian sites could be considered planetary analogs (Tovar et al., 2024) (Figs. 7.5 and 7.6). Such evaluations have also been carried out in Antarctic locations, including Deception Island (Leal et al., 2025). In the field of planetary geology, research has been conducted on rocky bodies such as Mercury (Ceferino, 2019), Europa (Lozada, 2018), Mars (Torres & Gutiérrez, 2024; Tovar et al., 2024), and Io (Tovar & Sánchez-Aguilar, 2012).

Another line of approach to astrobiological research stems from the field of chemistry, through studies that seek to understand environmental pollutants present in potentially analogous sites and their implications for planetary bodies such as Mars (Acevedo-Barrios et al., 2025). This line of inquiry also includes investigations into the relevance of astrochemistry for estimating the possibility of life in the universe (Pelegrín & Guerrero-Cañedo, 2023) and the perception of astrochemical knowledge in Colombia (García et al., 2023). These chemical relationships are directly linked to biology, either through the study of microorganisms tolerant to environmental pollutants (Acevedo-Barrios et al., 2024b) or through the

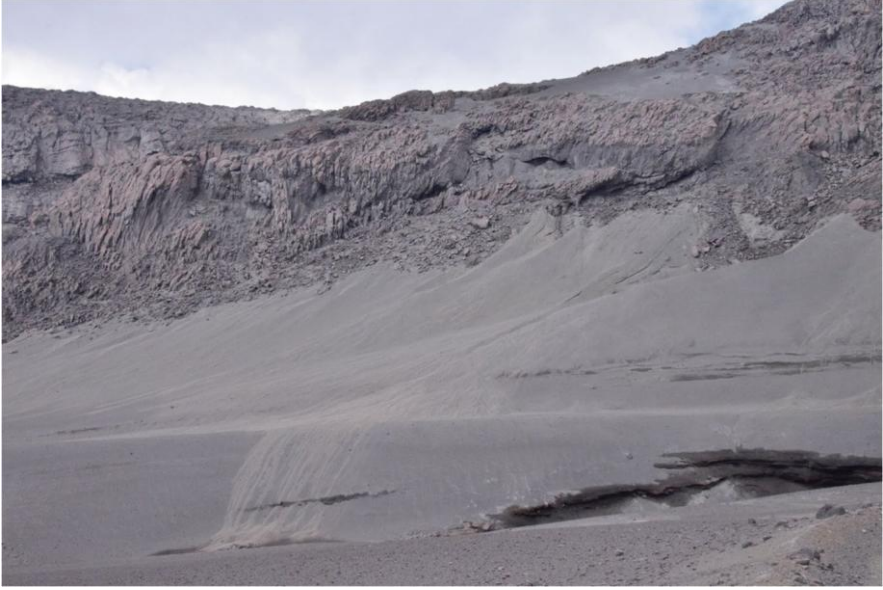


Fig. 7.5 Fieldwork at the Nevado del Ruíz Volcano. This site has been evaluated as one of the two terrestrial analogs studied to date in Colombia. Geomorphology and Geochemistry display similarities with Acidalia Planitia on Martian surface. (Credit: David Tovar, 2024)



Fig. 7.6 Fieldwork on Gorgona Island, located in the Pacific Ocean. This island is characterized by the presence of mafic and ultramafic rocks, with komatiites (above) being of particular interest in its evaluation as Colombia's second terrestrial analog site (Geochemical analog to Syrtis Major, Mars). (Credit: David Tovar, 2024)

understanding of biogeochemical processes associated with the origin of life (Reyes et al., 2024).

Another extensively studied area in the country relates to education in astrobiology and planetary sciences. Research in this field has been conducted at various school levels as well as in non-formal learning environments, demonstrating that these topics can support the integration and appropriation of scientific concepts while also inspiring children and young people to pursue science and develop scientific skills (Gil et al., 2023; Muñoz, 2020). Beyond these educational dimensions, other human-centered aspects have also been addressed, particularly with regard to the potential for human habitability on Mars. These include considerations of food systems, infrastructure design, and socio-political factors (Leal et al., 2021).

Additionally, one of the first milestones recorded in the field of Astrobiology research was the publication of one of the earliest research books in Spanish: *Temas selectos en astrobiología* (Selected Topics in Astrobiology). This book underwent a thorough peer-review process for each of the most relevant subjects in the field. It marked a significant departure from previously published works, as its target audience was scientists and scientists in training (Leal et al., 2015).

Finally, it is important to acknowledge that the studies presented here represent only a portion of the efforts currently underway in the country; other relevant work may have been conducted or may still be in progress.

7.6 Perspectives

As demonstrated throughout this chapter, the development of astrobiology and planetary sciences in Colombia has shown significant growth over the past decades, establishing itself as a multidisciplinary field that integrates research, education, public outreach, and international cooperation. Nevertheless, future projections call for the strengthening of various strategic areas to position the country as a regional leader in these disciplines.

One of the main priorities lies in reinforcing international collaborative networks, such as the Latin American Astrobiology Network, in which Colombia is represented by the Planetary Sciences and Astrobiology Group (GCPA). Another important step is the potential creation of advanced academic programs in these fields within the region, aimed at ensuring the training of highly qualified human capital capable of leading research initiatives and actively participating in global scientific missions.

It is also essential to strengthen specialized scientific infrastructure. Although the National University of Colombia hosts the Laboratory of Astrobiology, Planetary Sciences, and Microbial Ecology, and the University of Atlántico houses its own Astrobiology Laboratory, further investment is needed to support the appropriation of advanced technologies for planetary analog studies, the simulation of extreme environments, and the development of technologies for space exploration. Such facilities would not only enhance the country's research capabilities but also create

opportunities for participation in international projects, including future exploration missions to Mars, the Moon, or other bodies within the solar system.

In the realm of education and the social appropriation of knowledge, it is crucial to sustain and expand initiatives that bring astrobiology and planetary sciences closer to diverse audiences, particularly in remote areas and communities that have traditionally been excluded from access to scientific knowledge. Integrating these topics into school and university curricula, alongside the use of digital technologies and innovative pedagogical strategies, will help to inspire new scientific vocations and foster a more informed and engaged citizenry committed to space exploration and development. Colombia also holds a comparative advantage due to its geodiversity, which provides unique settings for the study of planetary analogs and extreme environments. The systematic exploration of these environments, in synergy with public policies that recognize the strategic importance of space sciences, could position the country as a natural laboratory for astrobiology and planetary geology.

For this reason, the strengthening of science and technology policy oriented toward the space sector is an urgent necessity. The creation of specific national programs, the promotion of funding for interdisciplinary projects, and the establishment of a dedicated research agenda in planetary sciences and astrobiology will not only advance fundamental scientific knowledge but also enable the development of technologies with impact across sectors such as health, agriculture, environmental management, and industrial innovation. Supporting such decision-making processes will require continued research that demonstrates the need to develop this scientific ecosystem.

Declarations

Competing Interests The authors declare no competing interests.

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