



Smithsonian Institution

Engineering the Inka Empire: A Symposium on Sustainability and Ancient Technologies

Thursday, November 14, 2013, 10:00 a.m. – 5:00 p.m.

**Rasmuson Theater
National Museum of the American Indian
4th Street and Independence Avenue, SW
Washington, D.C.**



One of civilization's most impressive engineering achievements, the Inka Road (or Qhapaq Ñan) traversed the Inka Empire, which encompassed large territories of present-day Peru, Bolivia, Ecuador, Colombia, Argentina, and Chile. The symposium explores new theories and discoveries about the construction of the Inka Road and how these ancient techniques can be applied by modern engineers and city planners. Insightful presentations by noted international engineers and scholars illuminate the planning, building, and sustainability of the magnificent Inka roads that five hundred years ago integrated the rugged, mountainous world of the Andes. Cosponsored by the National Museum of the American Indian and the Smithsonian Latino Center, this symposium was supported with internal Smithsonian funds from the Consortium for World Cultures.

Live webcast at: <http://nmai.si.edu/multimedia/webcasts>

Engineering the Inka Empire: A Symposium on Sustainability and Ancient Technologies

PROGRAM

- 10:00 am **Introduction** by Symposium Moderator José Barreiro, National Museum of the American Indian
- 10:10 am **Welcome** by Kevin Gover, Director, National Museum of the American Indian
- 10:20 am **Opening Remarks** by Wayne Clough, Secretary of the Smithsonian Institution
- 10:45 am **On Machu Picchu: Road Construction Technology and Water Management**
Kenneth Wright, Wright Water Engineers, Inc.
Ruth Wright, Wright Paleohydrological Institute
- 11:30 am **Visualizing Cusco: Archaeology of Architecture**
Crayla Alfaro Aucca, Architect and Project Manager, City of Cusco, Peru
José Alejandro Beltrán-Caballero, Universitat Rovira i Virgili, Tarragona, Spain
Ricardo Mar, Universitat Rovira i Virgili, Tarragona, Spain
- 12:15 pm **Lunch break** (on your own)
- 1:30 pm **Engineering in the Andes: Indigenous Suspension Bridge Technology**
John Ochsendorf, Massachusetts Institute of Technology
- 2:00 pm **Engineering a World with Strings Attached: The Place of the *Khipu* in Building the Inka Empire**
Gary Urton, Harvard University
- 2:30 pm **Break**
- 2:45 pm **Road Construction Technology in the High Cordillera**
Christine Fiori, Virginia Tech University
Clifford Schexnayder, Arizona State University (emeritus)
- 3:30 pm **The Inka Road through Ethnoarchaeology: Time and Space**
Ramiro Matos, National Museum of the American Indian
- 4:00 pm **Question & Answer Session**
- 4:30 pm **Closing Remarks** by Colin McEwan, Dumbarton Oaks

Engineering the Inka Empire: A Symposium on Sustainability and Ancient Technologies

SPEAKER ABSTRACTS AND BIOGRAPHIES

José Barreiro

Symposium Moderator

José Barreiro (Taíno) is Assistant Director for Research and Director, Office for Latin America, at the Smithsonian National Museum of the American Indian. Dr. Barreiro, one of the leading scholars of American Indian policy and the contemporary Native experience, is a pioneering figure in Native American journalism and publishing. He helped establish the American Indian Program at Cornell University, serving as associate director and editor-in-chief of Akwe:kon Press and the journal *Native Americas* throughout the 1980s and '90s. At Akwe:kon, he worked to develop communications networks among the indigenous peoples of North, Central, and South America, and the Caribbean. In 2002, he left Cornell to join the staff of *Indian Country Today* as Senior Editor. He continues to serve as a member of the editorial boards of *Kacike: The Journal of Caribbean Amerindian History and Anthropology* and of *Indian Country Today Media Network*.

Kevin Gover

Welcome

Kevin Gover (Pawnee) is director of the Smithsonian's National Museum of the American Indian. A former professor of law at the Sandra Day O'Connor College of Law at Arizona State University in Tempe, affiliate professor in the university's American Indian Studies Program, and co-executive director of its American Indian Policy Institute, Gover received his bachelor's degree in public and international affairs from Princeton University and his law degree from the University of New Mexico. Before joining the university faculty, Gover served as assistant secretary for Indian Affairs in the U.S. Department of the Interior from 1997 to 2000. A presidential appointee, he was responsible for policy and operational oversight of the Bureau of Indian Affairs, where he oversaw programs in Indian education, law enforcement, social services, treaty rights, and trust asset management. Gover also practiced law for more than 15 years in Albuquerque and Washington. He was awarded an honorary doctor of laws degree from Princeton in 2001.

Wayne Clough

Opening Remarks

Dr. Wayne Clough is the 12th Secretary of the Smithsonian Institution, the world's largest museum and research complex. Since becoming Secretary in July 2008, Clough has taken the Smithsonian in new directions. A comprehensive strategic plan—the first of its kind for the Smithsonian—creates a new framework for goals, enterprises and operations. The Smithsonian now focuses on four grand challenges—Unlocking the Mysteries of the Universe, Understanding and Sustaining a Biodiverse Planet, Valuing World Cultures, and Understanding the American Experience. Since Clough became Secretary,

more than 300 exhibitions have opened across the Smithsonian. He has overseen the opening of major permanent exhibitions, including the Star-Spangled Banner at the National Museum of American History; the Hall of Human Origins at the National Museum of Natural History; and the new wing at the National Air and Space Museum's Udvar-Hazy Center. Previously, Clough was president of the Georgia Institute of Technology for 14 years. He received his bachelor's and master's degrees in civil engineering from Georgia Tech and a doctorate in civil engineering from the University of California, Berkeley. Clough was a member of the faculty at Duke University, Stanford University and Virginia Tech.

Kenneth Wright, Ruth Wright

Inka Trails near Machu Picchu

The Inka road system in the vicinity of Machu Picchu utilizes a wide variety of native technologies to meet enormous challenges and to achieve defined objectives. Slope stabilization, drainage, retaining walls, stairways, viewing stations, controlled access, guardhouses and platforms, rest stops and water supplies for the traveler all add up to a spectacular success by the ancient Inka road builders.

Kenneth Wright, a consulting engineer, is the founder of Wright Water Engineers of Denver, Colorado. His company is involved in paleohydrological research in Peru, Mesa Verde, Southern France, Pompeii, Olympia, Thailand, Cambodia, and China. In Peru he and his wife Ruth have focused on the hydrology and hydraulics of Machu Picchu, Tapon, Moray, and currently, Ollantaytambo. They have developed a deep appreciation for the skill and diligence of ancient Peruvian engineers and craftsmen. Ken has been awarded four honorary degrees from universities in Lima and Cusco, including an honorary doctorate from the Universidad Nacional de Ingenieria.

Ruth Wright is the vice president of Wright Paleohydrological Institute and is active in water resources policy and field research. As a former member of the Colorado House of Representatives (fourteen years total, six as House Minority Leader), Ruth Wright supported the wise use of resources. She was awarded honorary professorships in 2008 (Universidad Nacional San Antonio de Abad) and 2009 (Universidad Nacional de Ingenieria). Ruth Wright is a graduate of Marquette University and earned her JD from the University of Colorado School of Law.

Kenneth and Ruth Wright received the Order of Merit from Peru's President Alan Garcia and were honored in 2011 with a Joint Honorary Doctor of Science degree from the University of Wisconsin and the Explorer's Club's Lowell Thomas Award, all for their work in Peru.

Crayla Alfaro Auca, José Alejandro Beltrán-Caballero, Ricardo Mar

Cusco, Inka Capital: Planning and Construction

Cusco is crucial to the understanding of the Inka plan of imperial integration. The Inka Road, or Qhapaq Ñan, diverged out from Cusco to integrate the four corners of Tawantinsuyu, the Inka Empire. This interdisciplinary team discusses major new research on Inka urbanism to understand the cosmological and physical plan and construction of the imperial City of Cusco, systematically transformed and mostly destroyed after the Spanish arrival in 1533. New empirical and technical data clarify interpretations of how Inka engineers successfully solved actual construction problems, management of local, human, and natural resources, and how the application of "common sense" can evolve into engineering knowledge.

Crayla Alfaro Aucca is an architect with a graduate degree in Cultural Heritage Management. Her research focuses on the historical evolution of the City of Cusco. As manager of the historic section of the Provincial Municipality of Cusco, Alfaro promotes the development of research projects and dissemination of the cultural heritage of the historic City of Cusco. She has participated in the management and urban renewal of public spaces and housing in the historic section of Cusco. Alfaro is also responsible for the editorial direction of the Municipality. She has published the following books (in Spanish): *Cusco monumental: Ombligo del mundo*; *Machu Picchu santuario del cusco: Cien años para el mundo*; *Cusco monumental: Ombligo del mundo II*; *Antología quechua del Cusco: Qosqo Quechwasimipi Akllasqa Rimaykuna*; *Cusco: Identidad y desarrollo*, and *Cusco y la herencia del barroco andino*.

José Alejandro Beltrán Caballero holds a PhD in Architecture and is an Associate Researcher of the Seminar on Ancient Topography at the Universitat Rovira i Virgili. Specializing in Landscape Interpretation and Ancient Cities, Dr. Beltrán Caballero has collaborated on projects to virtually reconstruct archaeological sites in Europe (Tarragona and Rome) and in South America (Cusco).

Ricardo Mar is a Professor of Classical Archaeology at Universitat Rovira i Virgili in Tarragona, Spain. Holding graduate degrees in architecture (PhD, 1988), he specializes in ancient Roman urbanism, with major archaeological field experience in Rome and in Tarragona. He has been involved in restoration projects and patrimony assessments in Italy, France, Portugal, and Spain, including as director of the reconstruction project on Tarraco, the ancient Roman city beneath modern Tarragona.

John Ochsendorf

Engineering in the Andes: Indigenous Suspension Bridge Technology

The Inka Empire relied on an extensive network of roads and bridges to connect the various regions under Inka control. Though the Inka road system has been studied in some detail, scholars have largely neglected the role of bridges. These functional works enabled the expansion of the Inka Empire and often dictated the location of roads, tambos, and other Inka sites. The role of bridges in Andean history raises important questions and demands greater attention from historians of the built environment. Due to the detailed chronicles of the construction process, suspension bridges provide a unique opportunity for understanding the organization of construction in the Inka Empire. This presentation draws on primary source material from chroniclers' descriptions of the bridges to identify important Inka bridges, explore their origins, and pose questions for future research in Inka engineering.

John Ochsendorf has been on the faculty at the Massachusetts Institute of Technology since 2002, and is the Class of 1942 Professor of Architecture and Civil and Environmental Engineering. He earned his Bachelor of Science in structural engineering and archaeology from Cornell University, where his undergraduate thesis carried out the first technical study of Andean suspension bridges. Ochsendorf earned a Master of Science in Civil and Environmental Engineering from Princeton University and a PhD in structural engineering from the University of Cambridge. He is a founding partner of Ochsendorf DeJong and Block LLC, a consulting firm specializing in historical structures. He has won numerous awards for research in structural engineering and architecture, including a Graduate Research Fellowship from the National Science Foundation, a Fulbright Pre-Doctoral Scholarship from the J. William Fulbright Foundation, a Rome Prize from the American Academy in Rome, and a MacArthur Fellowship from the John D. and Catherine T. MacArthur Foundation.

Gary Urton

Engineering a World with Strings Attached: The Place of the Khipu in Building the Inka Empire

The knotted-string recording device known as the khipu (“knot”) was the principal device used for the storage of information by state agents and administrative officials in the Inka Empire of Pre-Columbian South America. This presentation examines the role of khipu record keeping in a variety of contexts relating to the building of state facilities in the empire—from roads to store houses to administrative centers. It is argued that the knotted string hierarchical arrangement of the khipu was important to the Inka not only as an instrument for record keeping but also as a structural paradigm for building the empire.

Gary Urton is the Dumbarton Oaks Professor of Pre-Columbian Studies and Chairman of the Department of Anthropology at Harvard University. His research focuses on a variety of topics in pre-Columbian and early colonial Andean intellectual history, drawing on materials and methods in archaeology, ethnohistory, and ethnology. He is the author of many articles and editor of several volumes on Andean/Quechua cultures and Inka civilization. His books include: *The History of a Myth* (1990), *The Social Life of Numbers* (1997), *Inca Myths* (1999), and *Signs of the Inka Khipu* (2003). A MacArthur Fellow (2001–2005), he is Founder/Director of the Harvard Khipu Database Project.

Christine Fiori, Cliff Schexnayder

Road Construction Technology in the High Cordillera

The engineers of the Inka Empire had a unique consciousness of nature, with construction skills founded in lessons learned from careful observation of the power of nature. The Inka Road demonstrates the superior Inka understanding of nature. Built without the use of iron, the wheel, or stock animals, it represents important milestones in the development of civil engineering knowledge. The road’s creators understood the fundamental laws of nature and employed impressive engineering strategies in response to the challenges presented by the aggressive physical geography of western South America.

The Inka Road, or Qhapaq Ñan, in scale alone is one of man’s monumental engineering achievements. This engineering masterpiece rests on careful attention to the power of water, the energy expended by the users of the road (man and llama), and the energy required to construct the road. Keeping these concepts in mind, with the support of the University of Piura, Peru, and the assistance of Professor Luis Gerardo Chang Recavarren, the researchers investigated the construction techniques employed by the Inkas in the building of the road. Ground penetrating radar technology was employed to assess the subsurface structure of the road, slopes were measured, and grade and width were verified to understand the construction methods utilized. The investigation of the various methods to control water and erosion helped in developing an understanding of why the road has endured for centuries.

Christine Fiori is the Associate Director of the Myers-Lawson School of Construction at Virginia Tech. She received her PhD in Civil Engineering with a concentration in Geotechnical Engineering from Drexel University in 1997. Her interest in ancient construction led to a National Science Foundation grant to explore the construction techniques of the Inka, specifically the Inka road throughout Peru. Fiori leads the Construction Engineering and Management program and also facilitates the service learning programs for the Myers-Lawson School of Construction. She has led diverse groups of student teams to Vietnam, Kenya, Belize, Haiti, and Guatemala to complete construction projects and community engagement programs. Currently her work is focused in Haiti and Belize.

Cliff Schexnayder (Choctaw) is the Emeritus Eminent Scholar, Del E. Webb School of Construction, Arizona State University. He holds Civil Engineering BS and MS degrees from Georgia Institute of Technology and a PhD from Purdue University. Before entering academia he worked with major heavy/highway construction contractors as field engineer, estimator, and corporate Chief Engineer. In South America he has taught construction engineering at the Universidad de Piura and Ricardo Palma Universidad in Peru. Schexnayder is a member of the National Academy of Construction, the Academia Panamericana de Ingeniería, and is a Distinguished Member of the American Society of Civil Engineers (ASCE). He served as chairman of the ASCE's Construction Division and the Transportation Research Board's Construction Section.

Ramiro Matos

The Inka Road through Ethnoarchaeology: Time and Space

Contemporary Quechua and Aymara oral history is a part of the multidisciplinary research for the National Museum of the American Indian's Qhapaq Ñan exhibition project that utilizes various academic disciplines and methodologies, such as archaeology, history, and ethnology. Along with scientific knowledge, the museum attends to the community's memory, oral history, and ethnographic observation. In other words, we try to understand the Andean process, particularly Inka archaeology, from the voice and perspective of their contemporary heirs, without neglecting the very important archaeological and historical data. This approach allows us to understand the Andean road system from its origins in the first millennium of the Christian era to its contemporary relevance, as well as to comprehend it geographically—from Cusco as a center of Inka power and order to the peripheries in Colombia, Chile, and Argentina.

Ramiro Matos (Quechua) is an archaeologist and Associate Curator for Latin America at the Smithsonian National Museum of the American Indian. He is the lead curator for the forthcoming NMAI exhibition, *Qhapaq Ñan: Road of the Inka*. Matos is Emeritus Professor at the National University of San Marcos, Lima, Peru, and the author of numerous publications on Inka archaeology, including essays and books.

Colin McEwan

Closing Remarks

Colin McEwan is Director of Pre-Columbian Studies at Dumbarton Oaks Research Library and Collection, Washington, DC. Dr. McEwan specializes in the art and archaeology of the pre-Columbian Americas and has carried out fieldwork in diverse settings ranging from the Peruvian Highlands, Upper Amazon, coastal Ecuador, and Patagonia. From 1979–1991, he directed the Agua Blanca Archaeological Project focused on a major Manteño settlement in the Machalilla National Park, coastal Ecuador. He was formerly Head of the Americas Section at the British Museum, London, where he authored or co-edited numerous exhibition publications, including *Pre-Columbian Gold: Technology, Style and Iconography* (2000), *Unknown Amazon: Culture in Nature in Ancient Brazil* (2001), *Turquoise Mosaics from Mexico* (2006), *El Caribe Pre-Colombino* (2008); *Ancient American Art in Detail* (2009) and *Moctezuma: Aztec Ruler* (2009). He is particularly interested in reconstructing and interpreting the roles that objects play in prehistoric cultural landscapes.