The Oceans of Ancient Mars

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Class will meet 2-4 pm on Wednesdays October 30, November 6, 13, and 20, 2024,

Rubel Room at the University of Arizona's Poetry Center, 1508 E Helen St, Tucson, AZ,

Each class meeting will begin with an illustrated lecture of about 40-45 minutes. This will be followed by 15 to 20 minutes for Q&A and discussion. A second illustrated lecture of 40-45 minutes will then follow. The meeting will end with more Q&A plus discussion.

Syllabus and Reading List, as of August 2, 2024, subject to updating close to the start of the class. (Final versions will be either posted or linked.)

Overview:

This course will focus on how the geology of ancient Mars came to be understood from early astronomical observations to the most recent discoveries made from orbiting spacecraft and surface rover missions. It is now known that a few billion years ago the planet Mars was somewhat similar in its surface environmental condtions to the ice age Earth. At that time Mars had lakes, flowing rivers, glaciers, and even a kind of planetary ocean, the Oceanus Borealis. This relatively recent understanding of ancient Mars was partly achieved because of geological studies of the ice age floods that created the Channeled Scabland landscape of eastern Washington state. The course will incorporate the instructor's personal experiences with the relevant geological investigations and discoveries of the past 55 years. This will provide an inside view as to how geologists actually think about the natural world.

Week 1. October 30, 2024. Discovering Ancient Mars

During the favorable viewing conditions of 1877 and 1879 Giovanni Schiaparelli, Director of the Milan Observatory in Italy, made especially important telescopic observations of the planet Mars. He made detailed maps of bright areas on the surface of the planet, which he interpreted as land, and dark areas that he termed *mare* (Latin for "sea"). Schiaparelli also mapped the linear patterns on the surface that he mapped as *canali* (Italian for "channels"). Schiaparelli was initially guarded as to the origin of the canali, because he recognized that the relevant patterns were very difficult to see. Nevertheless, his mapping implied that the canali were natural, possibly water-filled channels that traversed from the mare through the various landmasses on Mars.

Starting in 1893–1894, after achieving popular fame with books on Japan, Korea, and their people, the prominent Bostonian, Percival Lowell, made use of his considerable personal fortune and his family and business connections to found and build an astronomical observatory at Flagstaff, Arizona. For the next 15 years Lowell focused his astronomical efforts primarily on observations of Mars, and specifically on his own interpretation of the canali, which he considered to be non-natural "canals" (a misunderstanding of Schiaparelli's interpretation). Lowell conceived a vision of Mars as an arid, dying planet, irrigated by a network of canals that had been constructed by an evolutionally advanced race of intelligent beings.

Lowell's ideas achieved much popular acclaim but little scientific recognition. Geologists, in particular, were highly critical, and Lowell developed a particular disdain for geologists and their science. Nevertheless, until the advent of spacecraft missions in the 1960s, Mars was viewed scientifically as possiblly having water and life, but not with any advanced civilizations. This view was dispelled when improved telescopic data and the early unmanned spacecraft from the U.S. and the former Soviet Union showed the current Martian surface to be exceeding dry and cold, with temperatures continously much below the freezing point of water. The surface atmospheric pressure was found to be so low that, even if water ice were present on the surface, it would easily sublimate away. What had once been viewed as Earth-like polar caps of water ice were reinterpreted as composed of carbon dioxide, which also comprised the very thin planeatary atmosphere.

Geologically, the early imagery from flyby spacecraft missions in the 1960s showed a heavily cratered Martian surface, apparently similar to that of the Moon, where the craters were billions of years old. The preservation of such ancient craters suggested that, unlike Earth, both the Moon and Mars never had flowing water needed to significantly erode their surfaces. The low gravitational acceleration and very thin atmosphere made it seem likely that any water present on the Martian surface would have been lost to space.

Then, in late 1972, there was a total surprise. Images from the Mariner 9 spacecraft revealed that portions of the Martian surface were dissected by networks of fluvial valleys and by immense flood-carved channels. Mars science became geological, and that perspective will be the focus of the lecture series, beginning this week.

Required Readings:

Baker, V.R., 2022, Mars, Paleo Ocean, in Gargaud, M. et al., editors, Encyclopedia of Astrobiology: Springer, Nature Heidelberg, p. 1811-1813. doi: 10.1007/978-3- - 27833-4_5599-1

Baker, V.R., 2015, Planetary geomorphology: Some historical/analytical perspectives: Geomorphology, v. 240, p. 8-17 (doi: 10.1016/j.geomorph.2014.07.016).

Baker, V.R., 2006, Geomorphological evidence for water on Mars: Elements (An International Magazine of Mineralogy, Geochemistry, and Petrology), v. 2, p. 139-143.

Baker, V.R., and Milton, D.J., 1974, Erosion by Catastrophic Floods on Mars and Earth: Icarus, v. 23, p. 27-41.

Optional Readings:

Baker, V.R., 1982, The channels of Mars: University of Texas Press, Austin, Texas, 198 p.

Baker, V.R., 2014, Terrestrial analogs, planetary geology, and the nature of geological reasoning: Planetary and Space Science, v. 95, p. 5-10.

Week 2. November 6, 2024. Megafloods

The Mariner 9 discovery of immense channels on Mars led to a controversy over their origin. The prevailing explanation for the Martian channels derived from understanding of a landscape on Earth. That landscape, the Channeled Scabland region of eastern Washington state, had been proposed, 50 years earlier, to have formed by cataclysmic flooding during the last ice age about 20,000 years ago. The controversy that arose over this "outrageous geological hypothesis" was resolved just before I began my own investigations of the region in the late 1960s, and the Mariner 9 discoveries followed shortly thereafter. The lectures this week will explore these developments and more besides.

Required Readings:

Baker, V.R., 1978, The Spokane Flood controversy and the Martian outflow channels: Science, v. 202, p. 1249-1256.

Baker, V.R., 2002, The study of superfloods: Science, v. 295, p. 2379-2380.

Baker, V.R., 2009, The Channeled Scabland—A retrospective: Annual Reviews of Earth and Planetary Sciences, v. 37, p. 6.1-6.19.

Baker, V.R., 2022, J Harlen Bretz (1882-1981): Outrageous geological hypothesizer: GSA Today, v, 32, no. 5, p. 50-51.

Optional Readings:

Baker, V.R. (editor), 1981, Catastrophic flooding: the origin of the Channeled Scabland: Hutchinson Ross, Stroudsburg, Penn., 360 p.

Baker, V.R., 2008, The Spokane Flood debates: Historical background and philosophical perspective, *in* Grapes, R., Oldroyd, D., and Grigelis, A., editors, History of Geomorphology and Quaternary Geology: Geological Society of London Special Publication 301, p. 33-50.

Baker, V.R., 2020, Global megaflood paleohydrology, in Herget, J. and Fontana, A., editors, Palaeohydrology. Geography of the Physical Environment: Springer, Heidelberg, p. 3-28.

Baker, V.R., Hamilton, C.W., Burr, D.M., Gulick, V., Komatsu, G., Luo, W., Rice, J.W., Jr., and Rodriguez, J.A.P., 2015, Fluvial geomorphology on earth-like planetary surfaces: A review: Geomorphology, v. 245, p. 149-182.

Video - "Mystery of the Megaflood"

https://video.search.yahoo.com/yhs/search?fr=yhs-iba-3&ei=UTF-8&hsimp=yhs-3&hspart=iba&p=ice+age+floodscapes&type=teff_10019_FFW_ZZ#id=2&vid=a0956ad9e48c707daee7036bd7f17f0c

Week 3. November 13, 2024. The Mars Oceans Controversy

It was clear from the global pattern of the Martian channels that the responsible huge flood flows had been directed toward an immense lowland area on the northern portion of the planet, the Vastitas Borealis. Moreover, these lowland plains had a surrouding margin that appeared to mark the ancient shores of a great sea (Parker et al., 1989, 1993). The overall association of the channels with huge water bodies, combined with other ancient Mars features, led to the hypothesizing of episodic inundations of the Vastitas Borealis that were associated with short-term periods of Earth-like, global hydrological cycling (Baker et al., 1991). This overall concept became an outrageous geological hypothesis (Kerr, 1993) that met with much opposition in the planetary science community. Much of the opposition to the ancient Mars ocean hypothesis arose because theoretical work on the early Martian atmosphere predicted that the warming conditions implied by active hydrological cycling on the planet could not be achieved by reasonable levels of greenhouse gases (e.g., Wordsworth, 2016). This week will focus on the early Mars ocean controversy and related issues involving the early Mars climate.

Required Readings:

Baker, V.R., Strom, R.G., Gulick, V.C., Kargel, J.S., Komatsu, G., and Kale, V.S., 1991, Ancient oceans, ice sheets and the hydrological cycle on Mars: Nature, v. 352, no. 6336, p. 589-594.

Baker, V.R., 2023, The Oceanus Borealis of ancient Mars: National Science Review. v. 10, issue 9, nwad 146, https://doi.org/10.1093/nsr/nwad146

Kerr, 1983, An 'Outrageous Hypothsis' for Mars: Episodic Oceans: Science, v. 259, p. 910-911.

Wordsworth, R.F., 2016, The climate of early Mars: Annual Reviews of Earth and Planetary Sciences, v. 44, p. 381-408.

Optional Readings:

Baker, V.R., 2001, Water and the Martian landscape: Nature, v. 412, p. 228-236.

Fairén, A.G., Dohm, J. M., Baker, V.R., de Pablo, M.A., Ruiz, J., Ferris, J.C., and Anderson, R.C., 2003, Episodic flood inundations of the northern plains of Mars: Icarus, v. 165, p. 53-67.

Gulick, V.C., and Baker, V.R., 1989, Fluvial valleys and Martian paleoclimates: Nature, v. 341, no. 6242, p. 514- 5

Rodríguez, J. A. P., Fairén, A.G., Tanaka, K.L., Zarroca, M., Linares, R., Platz, T., Komatsu,G., Miyamoto, H., Kargel, J., Yan, J., Gulick, V., Higuchi, K. **Baker**, V.R., Glines, N., 2016, Tsunami waves extensively resurfaced the shorelines of a receding, early Martian ocean: Scientific Reports, v. 6, no. 25106. doi: 10:1038/srep25106

Rodriguez, J.A.P., Robertson, D.K., Kargel, J.S., **Baker, V.R.**, Berman, D.C., Cohen, J., Costard, F. Komatsu, G., Lopez, A., Miyamoto, H., and Zarroca, M., 2022, Evidence of an oceanic impact and mega-tsunami sedimentation in Chryse PlanitiaMars: Scientific Reports, v. 12, no. 19689, https://doi.org/10.1038/s41598-022-18082-2

Week 4. November 20, 2024. Implications: Life, Earth, and Future Exploration

The megafloods that formed the Martian outflow channels had maximum discharges comparable to those of ocean currents and the thermohaline circulation on Earth. For both Earth and Mars, the abrupt and episodic operations of these megascale processes have been closely associated with global environmental change. Moreover, the ancient Mars oceans seem to have occurred when environmental conditions on that planet were similar to those prevailing on the ancient Earth. For Earth these were the conditions under which life arose and evolved. If such conditions also led to the origin of life on Mars, then the subsequent co-evolution of life and the environment on that planet may have led to the sequestation of living organisms into habitable locations that persist to the present day. Thus, the present-day program of searching for signs of life on Mars may be closely tied to the geological history of water on that planet, including that of its ancient oceans. These and other questions will be explored in the final lectures of the series.

Required Readings:

Baker, V.R., 2006, Water and the evolutionary geological history of Mars: Bolletino Della Societa Geologica Italiana, v. 125, no. 3, p. 357-369.

Fink, W., Dohm, J.M., Tarbell, M.A., Hare, T.M., Baker, V.R., Schulze-Makuch, D., Fufaro, R., Fairen, A.G., Ferre, T.P.A., Miyamoto, H., Komatsu, G., and Mahaney, W.C., 2007, Tier-scalable Reconnaissance Missions for the Autonomous Exploration of Planetary Bodies, *in* IEEE Aerospace Conference Proceedings, Paper Number 1199. DOI: 10.1109/AERO.2007.352715

Optional Readings:

Baker, V.R., Maruyama, S., and Dohm, J.M., 2007, Tharis superplume and the geological evolution of early Mars, chapter 16, *in* Yuen, D.A., Maruyama, S., Karato, S.I., and Windley, B.F., editors, Superplume: Beyond Plate Tectonics: Springer, Heidelberg, p. 507-522.

Baker, V.R., 2009, Megafloods and global paleoenvironmental change on Mar and Earth, in Chapman, M.G., and Kesthelyi, L., editors, Preservation of Random Mega-scale Events on Mars and Earth: Influence on Geologic History: The Geological Society of America Special Paper 453, p. 23-36.

Instructor Bio: Victor R. Baker is Regents Professor of Hydrology and Atmospheric Sciences, Geosciences, and Planetary Sciences, University of Arizona. He was on the faculty of the University of Texas at Austin from 1971-1981, advancing to the rank of Full Professor. In 1981 he moved to the Departments of Geosciences and Planetary Sciences, University of Arizona, first a Full Professor, and then in 1988 as one of the first Regents Professors. From 1996-2004 he was the Department Head of the Department of Hydrology and Water Resources, which is now Hydrology and Atmospheric Sciences. Baker has authored or co-authored more than 1200 scientific contributions, including 20 books, 450 research articles and chapters, and 570 abstracts and short research reports. His research concerns paleoflood hydrology (a field of study that he defined in the 1970s and 1980s); flood geomorphology; channels, valleys, and geomorphic features on Mars and Venus; catastrophic Pleistocene megaflooding in the northwestern U.S. and central Asia; history/philosophy of Earth and planetary sciences; and the interface of environmental science with public policy. Professor Baker was the 1998-99 President of the Geological Society of America (1998). Among his honors are Foreign Membership in the Polish Academy of Sciences (1994); Honorary Fellowship in the European Union of Geosciences (1999); the David Linton Award of the British Society for Geomorphology (1995); the Distinguished Scientist Award (2002) and Distinguished Career Award (2010), both from The Geological Society of America. He has professional society Fellowships respectively in the American Geophysical Union, the American Association for the Advancement of Science, The Geological Society of America, and the British Society for Geomorphology. He has supervised the degree progams for 72 graduate students, including 31 for the Ph.D. His research work has been featured in more than a dozen television documentaries for PBS, BBC, and the National Geographic, Discovery, and History Channels, including the 2005 PBS NOVA production “Mystery of the Megaflood,” the 2017 NOVA production “Volatile Earth” episode on “Killer Floods,” and the 2023 Silverback Films production of “Life on Our Planet” series for Netflix.