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HAS LIFE EVER EXISTED ON MARS?

Gordon E. Brown, Jr.

This issue of *Elements* presents some of the remarkable scientific findings of the Martian rover Curiosity, which landed in Gale Crater on August 6, 2012. In preparing my editorial for the Mars issue, I felt compelled to reread the classic science fiction novel by H. G. Wells entitled *The War of the Worlds*. First published in 1898, this novel was about the invasion (Book One) and subjugation (Book Two) of Earth by extraterrestrials—in this case Martians—each of whom had two large dark eyes, a lipless mouth that "quivered and dropped saliva," tentacles, "oily brown skin," very large brains, and rounded bodies about 1.2 m in diameter (Wells 1898). Wells' sci-fi thriller was essentially a metaphor for some of the major social, scientific, and technological changes occurring in the late 19th century (Taglieri 2012). This tale was set in Victorian London and the nearby countryside, and had Martians landing near London in metal cylinders. The Martians had three-legged fighting vehicles (Fig. 1) armed with heat rays and proceeded to overcome all human resistance. Eventually, the invading Martians were killed, not by humans but by lowly microbial organisms on Earth.

Figure 1 Artist's depiction of three-legged fighting machines constructed by invading Martians in H. G. Wells' *War of the Worlds* (from http://www.waroftheworldsgame.com/images/thames-wallpaper.jpg). Ironically, the heat rays on these machines resemble the lasers used by Curiosity's ChemCam instrument to determine the elemental composition of Martian rocks.

Wells' novel was one of the first to raise the question of possible life on Mars. This possibility has become one of the major scientific drivers for NASA to send numerous orbiters, landers, and rovers to Mars. This issue of *Elements* focuses on the rover Curiosity, whose primary mission is to determine if Mars ever had environments that could support life.

The question of life on Mars has fueled the imagination of many earthlings since Wells' novel, but answering it has not been straightforward or without controversy. For example, in 1907 A. R. Wallace published the book *Is Mars Habitable?* (Wallace 1907), which criticized Lowell's 1906 claims of canals on Mars built by intelligent beings; Wallace concluded that complex life on Mars was impossible. More recently, the 1976 Viking missions to Mars were thought to have produced evidence of microbial life on the Red Planet based on the detection of key organics. However, many scientists think the results were inconclusive (e.g. Navarro-González et al. 2006). Twenty years later, David McKay of the Johnson Space Center led a team of scientists who claimed to have found evidence for fossil life forms in a Martian meteorite known as Allan Hills 84001, recovered from Antarctica. The resulting paper (McKay et al. 1996) concluded that "the PAHs, the carbonate globules, and their associated secondary mineral phases and textures could thus be fossil remains of past martian biota," referring to their analyses of ALH84001. On August 7, 1996, NASA announced these findings, and on the same day President Bill Clinton held a press conference at the White House and cautiously praised the effort, stating, "If this discovery is confirmed, it will surely be one of the most stunning insights into our universe that science has ever uncovered. Its implications are as far-reaching and awe-inspiring as can be imagined." Following this provocative study, there was negative reaction to it by the scientific community; for example, it was suggested that the objects thought to represent fossil nanobacteria were too small to support metabolism and did not contain the amount of DNA, ribosomes, enzymes, lipids, etc. needed to support life as we know it (Maniloff et al. 1997), and that ALH84001 was contaminated by terrestrial organic material following its landing on Earth (Jull et al. 1998). More recently, Martian meteorite Yamato 000593 was found to contain carbonaceous matter and microtubular features similar to those formed by bioerosion in terrestrial basalts (White et al. 2014). So, the quest for past life on Mars continues, as it should.

This issue of *Elements* contains six articles that report the latest results from the Mars Science Laboratory (MSL) following 2+ years of exploration by the rover Curiosity. This is an amazing mobile laboratory equipped with a variety of high-resolution cameras and four major analytical instruments capable of determining the minerals in Martian rocks via X-ray diffraction as well as the elements, isotopes, organics, and volatiles present in Martian rocks, soils, and atmosphere via various types of spectrometry. Sedimentary rocks dominate the samples examined by Curiosity, and clear evidence was found for hydrous minerals (e.g. phyllosilicates and hydrated sulfates), alteration of primary minerals by circumneutral pH solutions, a warm past climate (i.e. above 0°C), and lakes and rivers in Gale Crater. Most importantly, the evidence gathered by Curiosity and interpreted by MSL Chief

Cont'd on page 4

THIS ISSUE

Curiosity and her sister rovers (Sojourner, Spirit, and Opportunity) have captured our imagination since Sojourner safely landed on Mars in 1997. Although Sojourner and Spirit are no longer active, Opportunity continues to gather data and, in July 2014, NASA announced that she had set a new "off-world" distance record by having traveled over 40 km since her landing in 2004. Curiosity is the most recent NASA rover to explore Mars. As you will read in this issue, Curiosity is providing a wealth of petrological, geochemical, and mineralogical data that excite scientists and nonscientists alike.

Curiosity landed at Gale Crater on August 6, 2012, and is currently at the foot of a 5.5 km high mountain dubbed Aeolis Mons (popularly known as Mt. Sharp). The Mars Science Lab mission scientists chose Mt. Sharp as their primary target because it contains sedimentary rocks deposited over billions of years, potentially holding clues to Mars' environmental past. Curiosity's first mission, however, was to explore Yellowknife Bay, including drilling the first holes by a robot on another planet. Eleven months after landing, Curiosity pulled anchor on July 4, 2013, and began her year-long trek to Mt. Sharp, arriving in September 2014. Along the way, she mapped broad plains, rocky ridges, and sandy valleys, and sampled outcrops to search for compositional and mineralogical patterns. But, the route was not without hazards, including abundant sharp rocks that damaged the wheels (see front cover), thereby slowing the pace of exploration. On Mars, there are no emergency roadside services, and the nearest spare wheel is millions of kilometers away. Mission scientists, therefore, learned to avoid the damaging rocky ridges and to drive through the safer sandy valleys instead. Scenic overviews were traded for spectacular panoramas of layered bedrock that revealed the geologic history of the Gale Crater plains. Curiosity may not match Opportunity's distance record, but she will definitely continue to satisfy our scientific curiosity.

Not only are Curiosity and Opportunity studying Mars' geologic past, they are also busy documenting present-day environmental conditions. Ultimately, these robotic explorers are paving the way for manned missions to Mars; it is NASA's goal to send humans to Mars in the 2030s. Curiosity has sent several incredible "selfies" back to Earth over her 2-year mission (see front and back cover images). It is exciting to think that in 20+ years we might see "selfies" from human geoscientists on Mars instead!

CHANGING OF THE GUARD

The *Elements* editorial team is in the midst of transition. Pierrette Tremblay has "officially" retired after 10 years at the helm of *Elements*. Tom Clark, our faithful copy editor, is retiring. So, we thought it appropriate to ask Pierrette and Tom to write this issue's Parting Shots article. Dolores Durant, our dedicated proofreader, will also be retiring after this issue. We extend a huge THANK-YOU to them for 10 years of dedicated service to *Elements*. In anticipation of Tom's retirement, we posted an ad for a copy editor in August 2014. To our delight, we received almost 20 applications, all from qualified candidates. We are excited to announce that Patrick Roycroft joined our editorial team in January 2015. He is a PhD geologist, a talented copy editor, and an avid reader of *Elements*. Welcome Patrick!

The *Elements* editorial office has moved west and across the Canada–US border going from Québec City (Quebec) to Richland (Washington). The contact information for our new editorial office can be found on page 3. Even if you never have the opportunity to visit our office, you are invited to visit our website, www.elementsmagazine.org, and to explore our Facebook and LinkedIn pages!

INTRODUCING BERNIE WOOD, PRINCIPAL EDITOR 2015–2017

With the start of 2015, Bernard J. (Bernie) Wood joins the *Elements* team as a principal editor. Bernie is currently a professor of mineralogy in the Department of Earth Sciences, University of Oxford (UK). He previously held positions at Northwestern University (USA), the University of Manchester (UK), and the University of Bristol (UK).

By combining high-pressure, high-temperature experimental petrology with physicochemical theory, Bernie has made wide-ranging contributions towards understanding the relationships between melts and solids in the Earth. During his career he has applied experiments to problems such as the thermodynamic properties of minerals, geobarometry and geothermometry, the nature of the seismic discontinuities in the mantle, and the factors controlling crystal–melt partitioning of trace elements. Currently his principal interest is the accretion and differentiation of the Earth.

The significance of his contributions to the fields of mineralogy, geochemistry, and petrology is evidenced not only by the 15,000+ citations of his work but also by the long list of honors and awards that Bernie has received over his distinguished career. He has Fellow status with several of *Elements* sponsoring societies as well as the American Geophysical Union, the Geological Society of America, and the Royal Society. He has also received many awards, most recently the Harry H. Hess Medal (2013) from the American Geophysical Union and the Roebling Medal (2014) from the Mineralogical Society of America. We are delighted to have Bernie join the editorial team. Bernie will be responsible for the petrology content of *Elements*. He is already hard at work handling the October 2015 issue on supergene deposits.

John Valley, Trish Dove, Gordon Brown, Bernie Wood, Pierrette Tremblay, and Jodi Rosso

EDITORIAL *Cont'd from page 3*

Scientist John Grotzinger and his team of experts indicates that habitable environments were present on Mars. To date, however, there is no clear evidence of current or fossil life forms in Martian minerals and rocks. A special section on the MSL mission was published in the *New York Times* on December 9, 2014, that addresses some of these findings. A major unanswered question is: did these environments exist long enough for life to evolve? Although it may be disappointing to some that Curiosity did not find Martians similar to those described by Wells, or even lowly bacteria, NASA's latest mission to Mars is a spectacular technological and scientific success that provides humankind with definitive new information on our sister planet and new insights into the geological processes that have shaped its surface.

Gordon E. Brown, Jr.
Principal Editor

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