TRAVELING FOR WORK – LESSONS FROM THE MARS CURIOSITY ROVER

Mt. Sharp, Mars, in white-balanced colors. NASA/JPL/MSSS

Most of us travel for work, but what about a trip to Mars? Recent headlines announced that a lucky couple is being sought for a trip to Mars orbit! In light of this buzz about Mars travel, it seemed appropriate to write an article about work travel, taking into account lessons from the Mars Science Laboratory (MSL) Curiosity rover's trip.

MAKING TRAVEL ARRANGEMENTS

Sending the Curiosity rover to Mars involved more than 8 years of preparation for the science team. The exciting descent of the rover into Gale Crater on Mars (Fig. 1) captivated many of us, but also required immense planning over many years by dedicated engineering and science teams.

Fortunately, work trips for geologists on Earth usually involve relatively simple logistics: we generally go on either research trips (to the field or a laboratory) or conference/meeting trips. In either case, transport needs to be arranged, accommodation has to be booked, and in some cases registration or access fees or training are required. When making your bookings, look out for "creeping costs" like parking fees, wireless fees, and bag transport or storage fees. Also, ensure that you have followed your workplace's protocols (see the "Questions to Ask" box).

PACKING FOR A WORK-RELATED TRIP

Of course, the Curiosity rover took all its work tools with it on its trip to Mars (http://msl-scicorner.jpl.nasa.gov/Instruments). Each tool was tested under many conditions, and there are backups of some of the important systems, which was important at the time of writing as the engineering team was fixing an error in one of the onboard computers.

For work trips, many of us depend on our computers for everything, and so it is important to have backup systems in case your laptop fails. One approach is to store electronic documents on the "cloud" where they are accessible through the Web. Another is to have documents backed up on a USB memory stick or backup drive.

Figure 1 An artist's concept of what the Curiosity rover looked like during the powered-descent portion of its trip into Gale Crater. NASA/JPL-Caltech, www.jpl.nasa.gov/msl

QUESTIONS TO ASK IN YOUR WORKPLACE BEFORE YOU LEAVE

- Will your institution arrange reimbursements and/or travel advances?
- Will you need receipts for all meals or is there a per diem?
- Are you expected to cover any of the costs yourself?
- Does your institution have a preferred rental-car supplier?
- Who pays for the rental-car insurance, and if your institution pays then what level do they recommend?
- Are you covered by health insurance (particularly if visiting another country)?
- Do you need to leave contact and trip details with your institution?
- Do you need to fill out any special forms (especially for field work)?
- Do you need a letter of invitation or special visa?
- Are there requirements for remote field work, such as frequent communication or particular forms (e.g. safety-evaluation forms)?
- Are separate arrangements needed for any personal travel during your trip

Many of us travel with rocks or waters in our luggage, and I have found it useful to include a letter to the airport safety officers with each box of samples. I write the letter on official letterhead paper and make sure to indicate the box contents (e.g. sample number, simple rock name) and the value of the samples (usually "no commercial value" or $5), and I also state whether the samples contain biological matter or soil (generally not). When I am carrying samples internationally, I include the Customs Tariff (Harmonized) Code for mineral samples for the country I am visiting. Sometimes, I send samples to my destination by courier because it is easier than having them accompany me.

ADJUSTING TO DIFFERENT TIME ZONES

To work effectively at the beginning of the mission, the MSL team worked on a Martian day (sol), which is ~24 hours and 40 minutes long. If work started at 10 pm one day, then the next day's shift would start at 10:40 pm. It was important for the team members to figure out the best times to sleep and eat each sol. One person was heard to say, "Breakfast tastes good at any time of day!"

Jet lag imposes similar strange time changes. People's body clocks respond differently to jet lag and so strategies vary. I usually stay awake until bedtime in the new time zone, and try to wake up and eat on a schedule similar to the new time zone. I also find that it is helpful to limit alcohol and caffeine, and instead drink water.

STAYING ON TOP OF COMMUNICATION

Each sol, Curiosity communicates with Earth through one of two satellites orbiting Mars: Mars Odyssey or Mars Reconnaissance Orbiter. This regular communication is necessary for both uplinking instructions to the rover and downlinking data. Both forms of communication are overseen by representatives from the instrument, science, and engineering teams and communicated within the entire team.

Traveling similarly exposes us to the need for multiple communication channels. We chat and network with colleagues and other scientists on

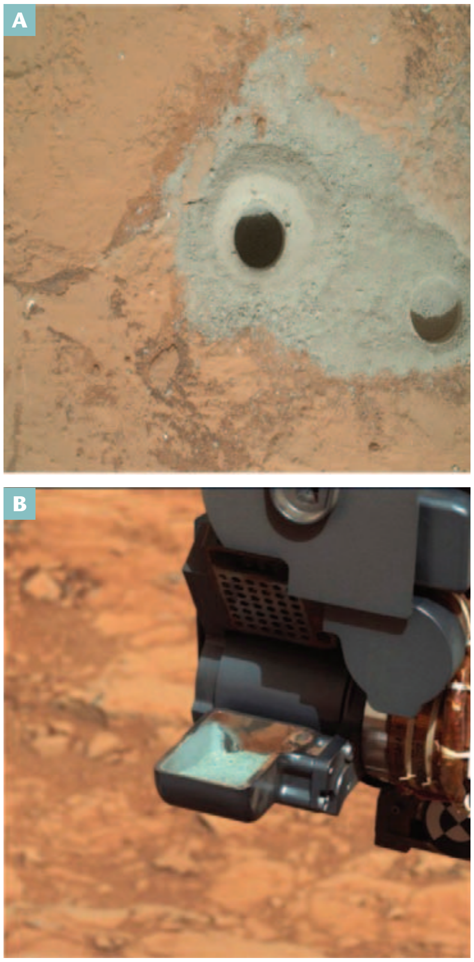
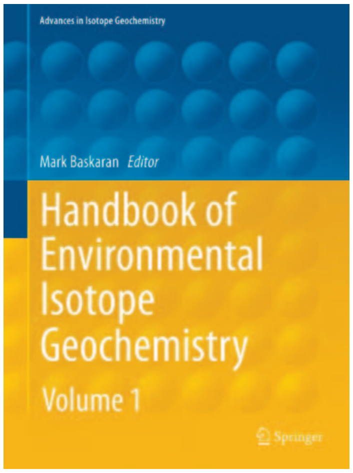


Figure 2 (**A**) Image taken when NASA's Curiosity rover used the Mars Hand Lens Imager (MAHLI) to show a drilled sample, on February 9, 2013, sol 182 of the Mars Science Laboratory mission. The diameter of the hole is 16 mm. (**B**) Image of the first sample of powdered rock extracted by the rover's drill; the image was taken after the sample was transferred from the drill to the rover's scoop. The scoop is 45 mm wide. The image was obtained by Curiosity's Mast Camera on February 20, or sol 193, Curiosity's 193rd Martian day of operations. Credit for images: NASA/JPL/MSSS

HANDBOOK OF ENVIRONMENTAL ISOTOPE GEOCHEMISTRY[1]



The *Handbook of Environmental Isotope Geochemistry* represents a massive undertaking. Running to 950 pages in two volumes, it covers an array of environmental isotopic methods and applications that is mind-boggling in breadth. In the introductory chapter the editor states, "The purpose of this volume is to bring together recent applications of a much larger number of radioactive and stable isotopes in earth and environmental sciences." This goal is certainly achieved, inasmuch as the *Handbook* must describe the systematics of at least 75 different nuclides.

The coverage of the volumes is so broad that it is very difficult to describe in a review of reasonable length. However, the contents are almost as notable for what they do *not* cover as for what they do. First, readers should not expect an updating of the classic 1986 two-volume work with the same title, edited by P. Fritz and J.-Ch. Fontes. That *Handbook* contained a relatively small number of chapters (24), each of which was a thorough, ~50-page review of a major field or technique in environmental isotope geochemistry. The present *Handbook* contains 40 chapters of about 20 pages each. The level of coverage varies widely. Many chapters consist of rather brief synopses of the systematics of the particular isotope considered, a short review of analytical methods, and a wide-ranging survey of recent applications. In contrast, others, such as the chapter on cosmogenic nuclides by D. Lal, contain a lengthy review of elementary systematics and no applications or recent developments.

Readers should be aware that in addition to the difference in treatment from the earlier *Handbook*, the topical coverage may be much different from what they are expecting. Most of the major areas of application of environmental isotopes are missing. For example, the volumes contain little or nothing on the isotopes of oxygen and hydrogen in the hydrological cycle, the interpretation of these isotopes in marine or ice cores, developments in carbon-14, stable isotopes in soil minerals, the application of stable isotopes to paleotemperature reconstruction, the applications to groundwater dating (except helium isotopes), and many other classical and widely employed environmental isotope applications. Instead, the new *Handbook* focuses on either less commonly used isotope systems (e.g. Li, Si, Ca, Cd, Cr, Se, Fe, Hg, Th, transuranic elements) or applications to fairly specialized problems (tracing phosphorus, perchlorate, nitrous oxide, polyhalogenated atmospheric compounds, oxyanions in ice cores, paleohuman diet). This makes the book a handy place to turn to for information on many fairly obscure topics and techniques, but not a resource to explain the systematics of the most commonly employed environmental isotopes.

The *Handbook* starts off with introductory chapters that nicely lay out the historical development of the environmental isotope field and present a systematic overview of nuclide physics, general isotope systematics, and measurement methods. These would be suitable reading for an upper-level undergraduate or graduate geochemistry course. The remainder of the book presents short chapters on tracers of continental and aquatic processes, atmospheric processes, environmental forensics, archeology and anthropology, and paleoclimate and paleoenvironments. In spite of the environmental-systems organization of the book's sections, most of the chapters are isotope-specific rather than presenting overviews of the methods that can be applied in particular settings.

The chapters on tracing perchlorate in the environment (by N. Sturchio and others), measuring soil erosion rates using natural and anthropogenic radionuclides (by G. Matisoff and P. J. Whiting), and isotope dendrochronology (by S. R. Managave and R. Ramesh) offer particularly thorough and readable coverage of their topics. The most entertaining chapter is that on light-element isotopes as tracers of fast-food meals in the American diet, by L. A. Chesson and others Cows turned into grocery-store ground beef eat more corn than those whose meat is sold at McDonald's, contrary to popular perception! The oxygen and hydrogen isotope compositions of ground beef, hamburger buns, and milk reflects the geographical location of production, but those of french fries cannot so easily be interpreted. Here is a frontier where more research is needed!

Given the cost of these volumes, they probably will not end up on the shelves of very many individual researchers, but they are an obvious recommendation for library purchase. The *Handbook* does not offer anything like a comprehensive coverage of the most important areas within the broad field of environmental isotope geochemistry, but it does bring together in a quite compact way all of the essential information on a very large number of isotopic specialties where reviews are not readily available. As such, most environmental isotope geochemists will want to at least have access to it.

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1 Baskaran M (ed) (2012) Handbook of Environmental Isotope Geochemistry. Springer, Heidelberg, ISBN 978-3-642-10637-8, two volumes, 951 pp, US$279, e-book US$219

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trips, while at the same time attempting to stay on top of e-mail and work communication and contact family and friends at home. Some travelers swear by setting up an "away from the office" return e-mail, while others find that taking time in the early morning or evening to deal with e-mail helps. I have become a fan of using Skype when traveling overseas for both business and family conversations. Wireless modems (on your phone) combined with free phone services (e.g. Google phone) are also another helpful option.

TAKING DETOURS AND ALLOCATING TIME FOR YOUR TRIP

Many research trips, including the Curiosity rover's trip, encounter the dilemma of whether it is best to travel long distances or spend time in one place. In fact, one of the first decisions of the Mars mission was to decide whether to detour to a fascinating area to the east when the ultimate goal was Mt. Sharp to the west. The team decided to go east, which has proven a good choice because rocks with high potential for habitability have been drilled and analyzed (Fig. 2; www.jpl.nasa.gov/news/news.php?release=2013-092).

To successfully complete research, it is important to ensure that adequate time has been assigned for the task at hand. Murphy's Law ("Anything that can go wrong will go wrong") seems to apply particularly in the cases of trips for analysis and field work. For such trips, it is always best to have the option of reanalyzing a sample or revisiting a location in the field, but this is not always feasible. My suggestion is to estimate how long a task might take and then multiply by three to five, depending on the uncertainties involved. If traveling by air, try to find a flexible ticket.

IN CLOSING

Traveling is one of the perks of being a geologist. It allows us to explore Earth and our Solar System and opens our eyes to new discoveries. Our thanks to the people who stay at home with the family when we are exploring! I thank Mary Hapel for her comments on this contribution.

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