



Obituary

FRANK REITH (11 June 1972–14 October 2019) The man with the gold bug

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Fig. 1. Frank Reith demonstrating gold panning near the historic Tomakin Park gold mine, New South Wales, Australia (photo 28/3/2007; Reith *et al.*, 2005, 2006).

Frank Reith's research legacy (Fig. 1) is the discovery that bacteria make a 'home' on gold grains and these microorganisms render gold mobile in the surrounding environment – belying the yellow metal's reputation for inertness and resistance to corrosion (Fig. 2). Frank was the first to integrate molecular characterisation with the 'classic' geochemical and morphological characterisation of placer gold grains, a radical step-change from the geological literature. His interdisciplinary approach to research integrated the latest cutting-edge techniques in chemical, spectroscopic, molecular and proteomic analysis. Frank had the gift of exciting people, of all walks of life, about his research. Throughout his career, he loved collaborative research and developed a vast and

diverse network of interdisciplinary collaborators (friends) across the globe. Although his academic career was relatively short, Frank published >75 scientific papers, listed in the Appendix. To the broader geoscience community, Frank was a world-leading geomicrobiologist, fascinated by gold and devoted to delineating the interactions between bacteria and precious metals. He described himself more simply as, "the man with the gold bug".

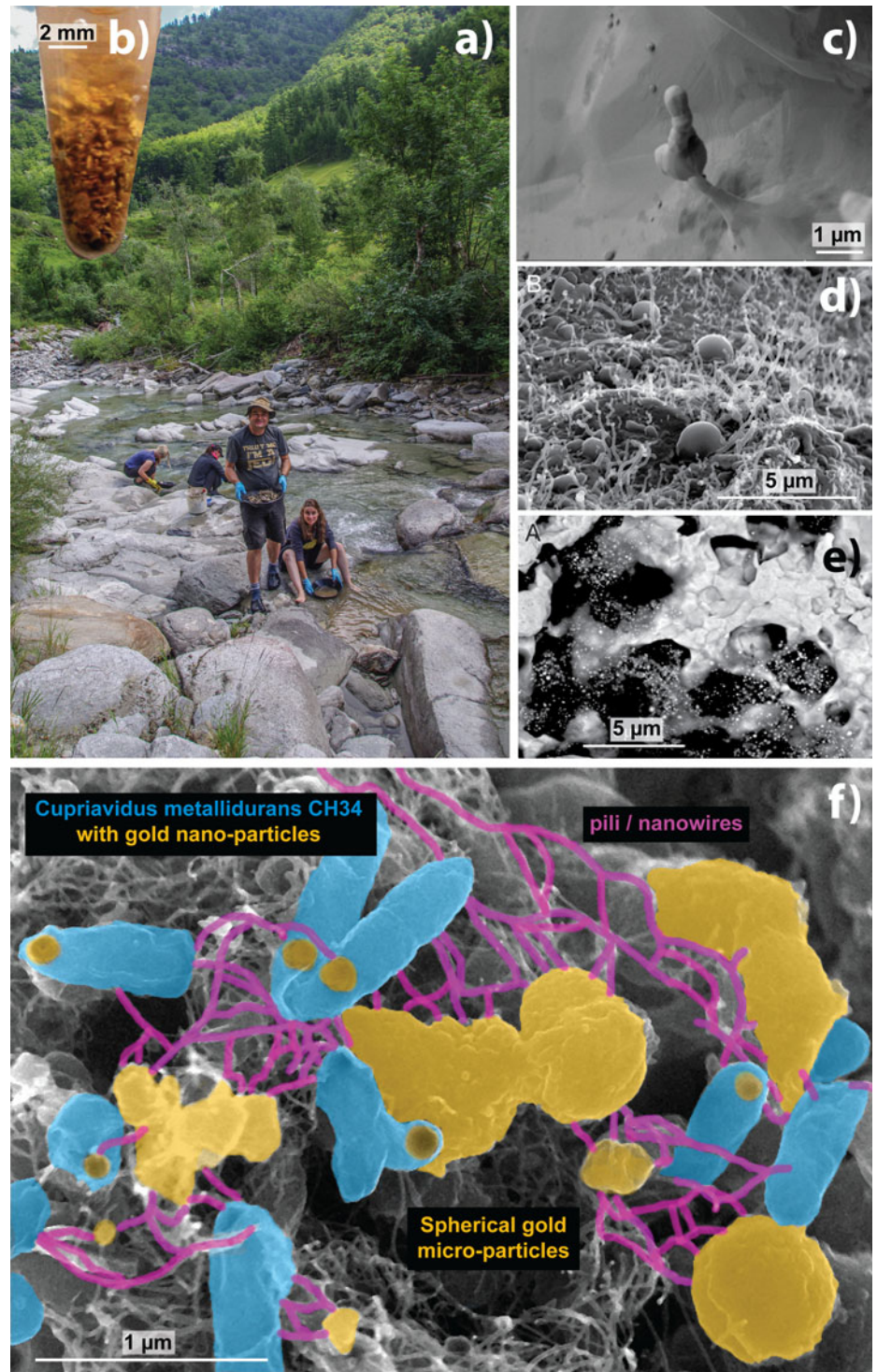
The man

Frank Reith, the elder of two children, was born on the 11th of June 1972 to Elke and Ernst-Wolfgang Reith, a family of wine makers in the Rhine–Hesse region, Germany. Frank grew up in the town of Woerrstadt and attended High School in Nieder-Olm. After fulfilling his civil service obligations as an ambulance driver, he attended the University of Bayreuth and graduated in 1999 with a Master's Degree in Ecological

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Fig. 2. Frank's approach to precious metal microbiology. (a) Obtaining fresh samples under field sterile conditions means dropping the lab coat (gloves are required, though) and turning to the mining methods used by small scale miners and prospectors since times immemorial (Grosses Wasser river, Gondo, Switzerland; 8/8/2014; from front to back, Frank, Emilie Delpech, Barbara Etschmann and Tina Reith). (b) The gold and PGE grains are prepared carefully on-site to preserve DNA and/or delicate surface biofilms at their surface (Kilkivan, Queensland). (c) The surface of a washed alluvial gold grain from Kilkivan shows a typical bacteriomorph feature; do such features indicate biological cycling of gold? (d) Frank discovered that fresh, carefully prepared, alluvial gold samples are often covered by extensive biofilms, as in this example from Lively's Gold Find, Flinders Ranges, South Australia. Genetic analyses revealed that the microbial communities on the gold grains differ from those of the surrounding sediments and include a number of metallophilic. (e) The biofilms also commonly contain nanoparticulate Au particles, indicating that the biofilms contribute to the cycling of gold in the near surface by transforming 'solid gold' into mobile and reactive gold nanoparticles. Frank demonstrated that this happens in many different environments over four continents – highlighting similarities and well as the uniqueness of each environment (gold grain from the beach placer at Orepuki, New Zealand; Reith *et al.*, 2012b). (f) The identification of the microbial cycling occurring on the surface of natural gold grains inspired a diverse experimental program. Illustrated here is an SEM image of the results of column experiments spiked with soluble gold and selected organisms that were identified on the surface of natural gold grains. The coloured SEM image highlights the association between bacterial cells at the surface of quartz grains, secondary gold particles via a network of nanowires (Fairbrother *et al.*, 2013).



Microbiology and Geo-ecology as well as a degree in Marketing and Economics. As an avid *The Lord of the Rings* enthusiast, and an adventurer at heart, Frank then backpacked across the USA, Canada and Australia. Captivated by Australia's diverse landscapes, spectacular coastlines, and colourful history of gold mining, he chose to do his doctorate thesis, *The Microbiology of Gold*, at the Australian National University in Canberra under the supervision of Professor 'Bear' McPhail (Fig. 3).

Frank received his PhD in November of 2006 and his curiosity to discover more of the outback (and eventually the world) through field work and research never waned. Frank's journey continued when he moved to Adelaide, South Australia, to begin a postdoctoral position at the Commonwealth Scientific and Industrial Research Organization (CSIRO) on the Waite Campus. Having made a home in the scenic sea-side southern suburb of Marino, Frank enjoyed balancing research with sailing



Fig. 3. Joint field trip with Frank's PhD supervisor, D.C. 'Bear' McPhail, to the Northern Flinders Ranges in May 2011. Bear never visited Frank in the field during his PhD (2003–2006) – this was their first and only joint field trip. (a) Reaching Radium Ridge, the site of early mining for radium from 1910 to the mid-1930s (photo 18/5/2011). From left to right, Fred (Bear's PhD student), Yuan Mei, Bear, Joël Brugger and Frank. (b) The trip became memorable when we discovered that rain and thixotropy combined to make a dry river bed an efficient trap for vehicles. Spending an unplanned night in the wilderness revealed that Frank was best prepared, as the only person (of seven participants) with a sleeping bag and a pillow (temperature dropped to $\sim 5^{\circ}\text{C}$). On the next day, Frank is celebrating one of his favourite foods, Nutella, while waiting for the rescue party (21/5/2011). No situation is hopeless with Nutella!



Fig. 4. Good chemistry. Frank at Paul Shand's Spirit of Gondwana whiskey distillery in the Adelaide Hills together with Andreas Schmidt Mumm (on the right) and his wife Tina (the photographer; photo 16/5/2018).



Fig. 5. Frank and Tina taking a pause in the chase for PGE grains. Angra dos Rei, Brazil, 10/12/2012.

and discovering epicurean delights in the Barossa Valley, Clare Valley and McLaren Vale. Indeed, wine appreciation was in his blood and he sought to visit every cellar door in South Australia, often bringing family and friends on wine-tasting adventures to his favourite places. Frank was also a dedicated whiskey enthusiast (Fig. 4).

Frank was an avid fan of Dr. Who – the ultimate adventurer. Much like this famous doctor, Frank discovered he worked and travelled best with a ‘companion’. In 2010, Frank met his future wife, Tina Reitz, on a trip back to Germany. Tina, who was working as a social worker at the time, was seeking travel advice for a trip to Australia. With strong mutual attraction and a passion for travel, they soon became a long-distance couple. Two years later, Tina travelled to Australia and embarked on a ten week-long journey with Frank. They explored the East Coast up to the historic gold town of Gympie in Queensland before returning to Adelaide, which soon became the duo’s home base. Tina became Frank’s companion when they married on the 20th of September 2013 and together they lived happily, taking pleasure in walking the neighbour’s dog, Oscar, along the beach near their home base. For the next 5 years, the duo planned Frank’s extensive research-based travels to obtain ‘fresh’ samples of gold and other precious metals from around the world (Brazil, Finland, Sweden, Norway, Switzerland, Germany, France, UK, South

Africa, New Zealand, USA and Australia) to better understand bacteria–gold interactions. With their shared passion for photography, they documented each fieldtrip capturing the memories of shared experiences throughout their journey (Fig. 5).

The gold bug

Frank advocated that scientific research should be fun and novel discoveries come by embracing the challenge of uncertainty with friends (Fig. 3b). The need to obtain fresh gold samples – and grains of the much rarer Platinum Group Elements (PGE) – inspired many of Frank’s adventures. Frank also loved driving, listening to a range of music (from Scottish bagpiping to heavy metal) and, in Australia, enjoyed hours of cricket on the radio. Many field trips became amazing road trips, logging tens of thousands of kilometres through Australia, Europe, Brazil and South Africa (Fig. 6). Frank was in his element during field work, and these trips were thrilling because they combined exciting scientific discoveries with an endless curiosity for nature and people alike. Careful and extensive planning ensured that these trips achieved their scientific goals.

In 2007, Frank was awarded a prestigious Australian Research Council (ARC) Postdoctoral Industrial Fellowship for his research project, ‘*Bacterial mechanisms of gold mobilisation and precipitation with applications to mineral processing and exploration*’. Frank held this fellowship through the University of Adelaide (UA) but remained at CSIRO because he integrated comfortably into that campus. The positive outcomes of this project enabled Frank to develop as an early career researcher and build an independent research programme. As his fellowship came to a close, Frank applied for a highly competitive ARC Australian Research Fellowship in 2010. For this application, endorsement from the School of Earth and Environmental Sciences (UA) was required; however, it received tepid support. Thanks to well established collaborations at Flinders University, in the south of Adelaide, Frank’s proposal received greater support and was awarded funding to explore interactions between platinum-group metals and bacteria. During this time, Frank formally joined the ‘Minerals Microbes and Solution’ group (formerly ‘Minerals Metals and Solutions’), a consortium of researchers from the South Australian Museum and the University of Adelaide. With Frank’s increasing grant success and a promising research profile, the University of Adelaide was anxious to retain his expertise. Frank relished in negotiating hard with UA authorities to not only move his fellowship to UA but to also provide him a continuing position with additional funding. During his fellowship, Frank led an ARC Linkage Project that involved the collaboration between UA, Newmont, Barrick Gold, the South Australian Museum, and a network of interdisciplinary colleagues across the globe. This collaboration successfully developed a live cell biosensor that could detect gold concentrations down to 1 ppb. While this applied research was not commercially viable for exploration, it did lead to a series of landmark papers.

In 2015, Frank was awarded a highly prestigious ARC Future Fellowship, one of only two fellowships granted to researchers based in South Australia that year. This fellowship enabled Frank to continue his research in gold geomicrobiology. In doing so, he recruited a postdoctoral fellow and another graduate student to join his research group, ‘*Microbes and Heavy Metal*’. In addition to leading his own research programme, Frank also contributed to the Biome of Australia Soil Environments (BASE) project (Bissett *et al.*, 2016). As part of his contribution, he led an epic >10,000 km field trip starting in Adelaide, travelling across the continent to

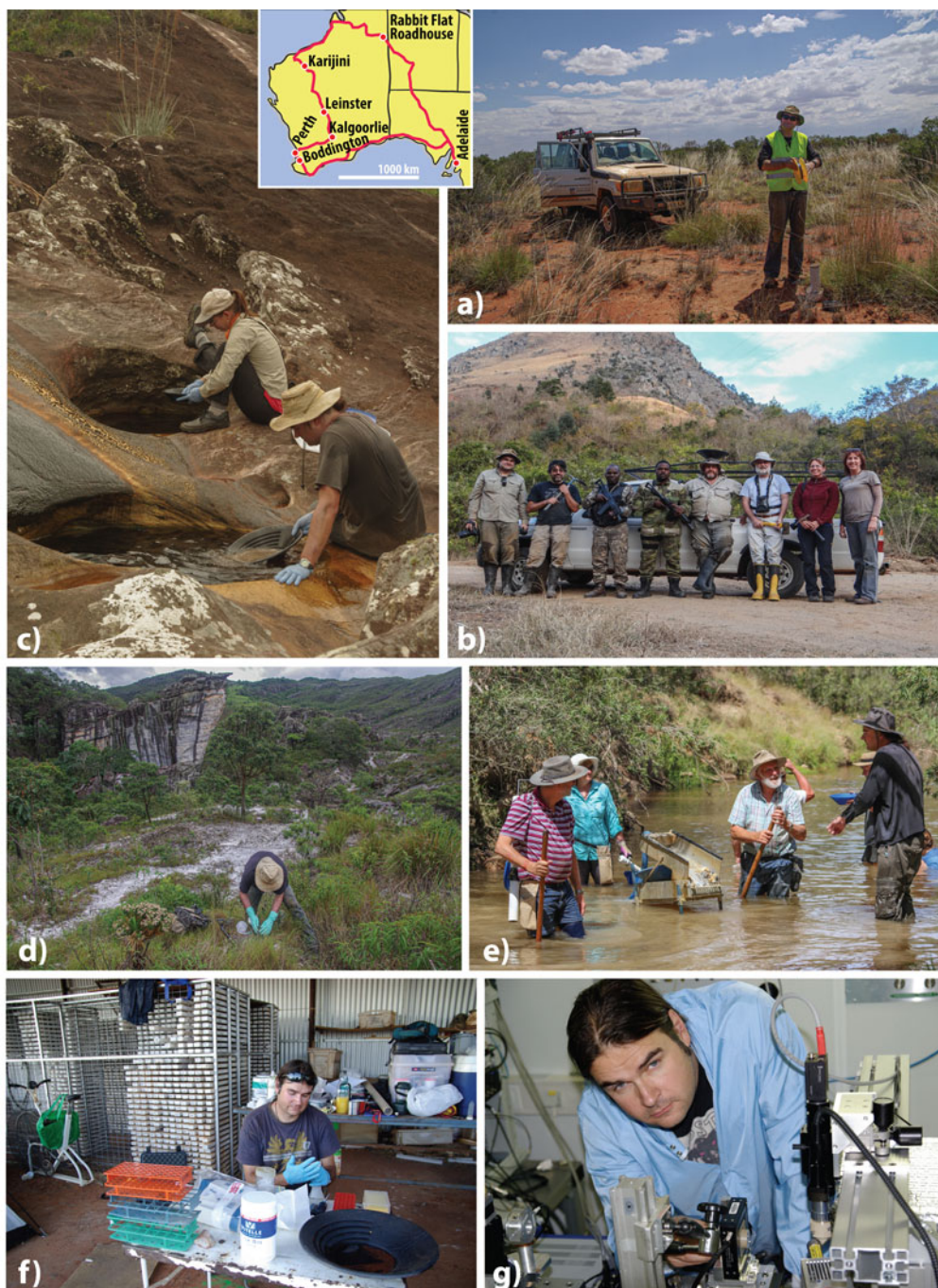


Fig. 6. Frank at work. (a) Despite the heat being Frank's greatest enemy in the field, he loved the beauty of the isolated wilderness. Sampling groundwater for Au content near the Rabbit Flat Roadhouse, Northern Territory, that claimed to be the most isolated roadhouse in Australia (photo 4/11/2011; Ta *et al.*, 2014). The insert map shows the full extent of this >10,000 km sampling trip; one soil sample was collected every 100 km to contribute to the biomes of Australian soil environments soil microbial diversity database (Bissett *et al.*, 2016). (b) The team at Concession Creek, Agnes Mine, Barberton gold fields, South Africa (16/8/2016; Sanyal *et al.*, 2020). This trip also delivered unexpected results. Several sites turned out to be heavily contaminated with mercury due to intense activity by illegal miners – which led to a study of the effect of heavy metals on Au cycling (Sanyal *et al.*, 2020). Some of the on-going illegal mining is conducted by rather unsavoury types, requiring a well-armed security escort. From left to right: Frank, Joël (Monash University), two security personnel from Agnes Mine, Jaco Delpont and Roger Dixon (University of Pretoria), Barbara Etschmann (Monash University) and our local guide, Andrea Botha. (c,d) Deciphering the geobiochemistry of palladium, gold and other platinum-group minerals at the type locality for the mineral palladium, Corrego Bom Sucesso in Brazil (Reith *et al.*, 2014; 2019); photo (c), panning for PGE, 25/11/2012; and photo (d), sampling local soils, 29/11/2012. The remarkable dendritic Pt-Pd rich nuggets from this locality were attributed a biological origin early on, but fresh samples were required to prove this hypothesis by demonstrating the existence of specific organisms on the surface of these grains. There were some tense moments when our guide declared the trip to be a failure following the strenuous walk to the remote site: local Garimpeiros had not worked the claim in a while (one died of old age; one broke his hip; and one took a 'real' job), and academics could not possibly have the stamina, muscles and skills to extract the rare minerals from local sediments. Four days of hard work provided the material to prove the biological cycling of PGE in tropical sediments (Reith *et al.*, 2014; 2019). (e) Sluicing at Eldorado gold fields near Wangaratta, Victoria, Australia (3/1/2018). (f) Field laboratory at the Titania prospect near The Granites gold mine, Northern Territory (2/1/2008). Day-time temperatures well in excess of 40°C and high humidity made a 2008 expedition to the Tanami desert one of the toughest field trips in Frank's career (Reith *et al.*, 2012a). (g) Frank changing a sample during a late-night shift at the ID22 beamline at the European Synchrotron Research Facility (ESRF), Grenoble, France (25/2/2008; Brugger *et al.*, 2013).



Fig. 7. Communicating science and mentoring. (a) Working closely with artisanal miners is the secret to getting access to exceptional gold samples and test sites. Frank and John Parsons from the Prophet Gold Mine in Kilkivan, Australia. (b) Interviewing together with Jeremiah Shuster for Scope TV (10play.com.au; 02/03/2018) at the Waite CSIRO laboratories. (c) Guiding a field trip to the Barossa gold fields for the Waterhouse Club, a support group of the South Australian Museum (15/9/2007). (d) Graduation ceremony of Dr Maria Angelica D. Rea (29/4/2019).

Broome, the Pilbara, Kalgoorlie, Perth and the Boddington gold mine, and back to Adelaide via the Nullarbor (Fig. 6a). Although not a golfer, Frank took great delight in playing the Nullarbor golf links, an 18-hole par 72 course that spans 1365 km on the Nullarbor plain. Aside from collecting numerous gold grains and associated samples (sediments and groundwaters), this trip produced >100 soil samples that contributed to the BASE project.

Frank's passion for science, his love of wine – and whiskey (Fig. 4) – and his engaging personality were key in opening doors with a variety of people from different backgrounds (Fig. 7). Through his adventures, he developed many strong friendships with local small-scale miners who appreciated his adaptability in the field. Through these friendships, Frank gained access to exciting and rare sampling locations – the ultimate adventurous journey of sharing what he found fascinating about the world around him.

“All that is gold does not glitter, Not all those who wander are lost....” J.R.R. Tolkien

One of Frank's long-time dreams was to retrace the tracks of North American gold-rush miners. As with any adventure, however, the path can take the traveller on a sudden and unexpected direction with no option to turn back. During a field excursion in

California, Frank's health declined rapidly and Frank and Tina were advised to return immediately to Adelaide. Frank was diagnosed with pancreatic cancer and underwent a series of major operations. With the tireless support of Tina, Frank received all



Fig. 8. Frank and Tina in Middle Earth, May 2019.

possible treatment over the next 18 months in hopes to prolong his adventures – he wanted to continue a life well lived. In doing so, Frank shared scientific discoveries by assisting his graduate students to complete their research (e.g. Fig. 7d); he visited family in Germany and hosted many friends in Adelaide when physically possible; he delivered an emotional plenary presentation at the International Mineralogical Association (IMA) 2018 Conference in Melbourne (Mills and Missen, 2018) as well as an invited talk to commemorate the passing of his PhD mentor, ‘Bear’ McPhail; he made his last adventure to Middle Earth (New Zealand; Fig. 8). With his companion by his side and surrounded by the mementos of his adventures in their home base, Frank’s life journey ended peacefully on the 14th of October 2019. Frank had a great gift in communicating the excitement and novelty of his research with people from all walks of life. His passion for sharing the joy of science, discovery, and his life lessons will be cherished in the memories of his wide circle of friends and colleagues.

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