Briny SLiMEs in the Subsurface of Earth and Mars.  

Tullis C Onstott1, Calvin Rusley1, Renxing Liang1, Zachary K. Garvin1, Devan M. Nisson1, Rachel Harris1, John Higgins1, Nicolas W. Slater1, Esterhuizen Van Heerden2, Brenda Freese2, Bennie Leibenberg2, Hiroshi Ogasawara2, Esta vanHeerden3, Errol Cason3, J-G Vermeulen2, Barbara Sherwood Lollar4, Tom Kieft5, Thomas Wiersberg5, Martin Zimmer5, and Joseph R. Michalski9

1Dept. of Geosciences, Princeton University, Princeton, NJ 08544, tullis@princeton.edu; crusley@princeton.edu, rliang@princeton.edu, zggarvin@exchange.Princeton.EDU, dnisson@princeton.edu, rlh6@princeton.edu, jahiggin@PRINCETON.EDU, ns12@exchange.Princeton.EDU. 2Moab Khotsong Gold Mine, Republic of South Africa, VHEsterhuizen@harmonymau.com, BFreese@harmonymau.com, benniesives@gmail.com. 3College of Science and Engineering Risø National Laboratory, 1-1-1 Noji Higashi, Kusatsu, Japan 525-8577, ogasawar@se.ritsumei.ac.jp. 4IWATER, Walter Sisulu 5, Bloemfontein 9300, Republic of South Africa, 5Microbial Biocatalysis and Food Biotechnology, Faculty of Natural and Agricultural Sciences, University of the Free State, PO Box 339, Bloemfontein 9300, Republic of South Africa, 6Department of Earth Sciences, 22 Russell St. University of Toronto, Toronto, ON, Canada M5S 3B1, bslollar@chem.utoronto.ca. 7Biological Dept., New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM 87801, Thomas.Kieft@nmt.edu. 8Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Telegrafenberg 14473, Potsdam, Germany, icdp.outreach@gfz-potsdam.de, weihei@gfz-potsdam.de. 9Department of Earth Sciences and Laboratory for Space Research, The University of Hong Kong, Pokfulam, Hong Kong, China, jmichal@hku.hk.

Introduction: Earth’s deep subsurface is perhaps the closest analogue available for the study of Martian habitability, owing to the hypothesized similarity of each planet’s subsurface geology and the relative irrelevance of atmospheric or radiative factors. As such, terrestrial subsurface lithoautotrophic microbial ecosystems (SLiMEs) are a promising area of abiological study. Hypersaline subsurface ecosystems are of special interest because of their likely occurrence on present day Mars [1]. During the formation of the cryosphere the fractional crystallization of ground water will form a residual brine. On Earth, salt-saturated brines are mostly associated with Phanerozoic salt deposits and saline ground waters and brines hosted in Precambrian crystalline rocks [2]. At Kidd Creek mine in Canada, brines were discovered in metavolcanic rocks isolated from the surface for billions of years [3] in a setting with a relatively low thermal history (< 100 degrees C) for the past 2 billion years. Such brines not only provide terrestrial analogues to the past and present Martian subsurface, but potentially provide clues as to whether subsurface abiotic organosynthesis reactions lead to the emergence of life [4].

In early 2018 we discovered a brine reservoir in the Archean Kaapvaal Craton of South Africa. Samples were collected of high temperature brine from 3.0 to 3.1 km underground in the Moab Khotsong gold mine, South Africa (26.98° S, 26.78° E). The host shale, quartzite, conglomerate, mixtures thereof, and amygdaloidal lava are collectively referred to as the West Rand Group (a part of the Witwatersrand Supergroup), and were deposited between 3.1 to 2.9 Ga and intruded by 2.7 Ga mafic sills. The brines are associated with the contact zones between the mafic intrusions and host rock and occur between 2.55 km to 3.4 km below ground. Brine temperatures range from 48 to 55°C and pressures are over 100 bars. One sample collected at 3 km depth exhibited high concentrations of CI (4.3 M), Na+ (1.3 M), and Ca2+ (1.5 M), with minor amounts of sulfate (0.8 mM), nitrate (14 µM), total Fe (2.8 mM), Mg (5.3 mM), acetate (30 µM), and formate (198 µM). Another sample at 3.1 kmbs contained high level of Cl− (4.2M), lower concentration of sulfate (0.2 mM), nitrate (7.4 µM), but much greater acetate (259 µM), and formate (684 µM) concentrations. A gas sample collected at 3.1 km was mainly CH4 (62 vol-%), followed by He (16 vol-%), N2 (15 vol-%), H2 (4.8 vol-%), Ar (1.6 vol-%), and higher hydrocarbon gases (volumes expressed after air correction). The carbon isotope signatures of CH4 and higher hydrocarbon gases suggest an abiotic gas source produced by water–rock reactions. Epifluorescence microscopy and SEM imaging reveal active microbial cells with an estimated total concentration of 104 cells/mL [5]. This is noteworthy given the energetic tax imposed by high salinity environments. The combination of high salinity and temperature appears to impose a habitability constraint on subsurface terrestrial life that has not been fully understood. Moab Khotsong is the only location where subsurface brines have been encountered in the Witwatersrand Basin. The composition of these brines suggests they have likely been isolated from the surface since the Proterozoic, providing a terrestrial analogue to the Martian subsurface. Furthermore, the discovery of living biomass from such hypersaline, deep, and presumably old water, extends the abiotic fringe and could provide clues to the limits of habitable subsurface environments on Mars.