DEPARTMENT OF GEOLOGICAL SCIENCES
Jackson School of Geosciences

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Dear Members of the Faculty Search Committee, **October 28, 2020**

I am writing to express my interest in the Assistant Professor faculty position in Planetary Science within the Department of Earth, Atmospheric and Planetary Sciences (EAPS) at the Massachusetts Institute of Technology (MIT). I am currently a postdoctoral fellow in the Jackson School of Geosciences at the University of Texas (UT) at Austin, with the ultimate career goal of becoming a planetary-focused tenured faculty member at a world-leading research institution such as MIT. This position provides an exciting opportunity to continue MIT's long-lasting legacies on innovation, leadership, and equity and inclusion; I aim to advance these through expansion into novel research avenues, excellence in teaching and mentoring, and enhancing diversity and community support.

I work to understand the geomorphological processes that shape planetary surfaces. My research centers around answering the following questions: (i) how does landscape evolution vary as a function of time and space? and (ii) how can we quantify the primary driving forces which shape planetary surfaces? I tackle these problems by combining field studies (e.g., geologic, geomorphic, and stratigraphic mapping), laboratory techniques (e.g., geochronological dating, geochemical analyses), remote sensing (e.g., satellite and drone data), and theory (e.g., inverse and forward modeling of fluvial erosion). Whereas my doctoral work focused on detailed quantification of surface processes on Earth, I am using my postdoctoral fellowship to develop a robust foundation in planetary science and comparative planetology of terrestrial analogs. Going forward, I plan to use this groundwork to build an integrative research program that gravitates towards my expertise in quantitative geomorphic analyses, as well my comprehensive understanding of geologic, geodynamic, and climatic controlling processes, shedding light into landscape evolution across the Solar System.

My wide scope of research themes is exemplified by my five current publications (four as first author, with two more in preparation). My projects have ranged from extricating the history of mantle convection from the Icelandic plume using buried landscapes in the North Sea, to quantifying the amount of precipitation on ancient Mars using global lake geometries. I have won multiple fellowships and awards throughout various stages of my studies. More recently, I have begun to establish myself as an independent researcher capable of securing external funding. In particular, this year I developed a novel international project to investigate the evolution of the volcanic ocean islands of the Atlantic Ocean. This ambitious project spans multiple islands over three archipelagos, with collaborators across Europe, Africa, and North America, and has received funding from The American Philosophical Society / NASA Astrobiology Institute, the Royal Geographical Society, the Geological Society of London, and the British Society for Geomorphology. The results of this work will provide novel constraints on the life cycle of ocean islands, how they respond to external forcing, and will deepen their significance as natural laboratories for investigating planetary surfaces. In addition to my publication and funding record, I believe that I am an emerging leader within the field of planetary surface processes; I have served as a NASA panelist, reviewed planetary journal articles, and have been invited to speak at this year's early Mars geomorphology session at the Geological Society of America annual meeting.

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Aside from research, I am dedicated to teaching and mentoring. I have deeply enjoyed assisting with teaching in a wide spectrum of classes (10 total) at a variety of levels at Imperial, ranging between first year-level *Introduction to Field Geology*, higher-level undergraduate *Structural Geology 3*, to postgraduate-level *Seismic Techniques*. My interests and experience make me well-suited to teach several existing courses at MIT, and I could also bring several new courses to the curriculum. I have also enjoyed advising multiple students at UT and Imperial, working on projects ranging from fissure swarm formation in Icelandic transform zones to lahar hazards in Chilean volcanoes. Further, I am enthusiastic about disseminating science to the wider public, whether volunteering in local museums, writing popular science articles for the university magazine, or co-organizing *Pint of Science* talks at the local pub. Importantly, advancing MIT's current efforts towards embracing diversity, equity, and inclusion in the sciences is one of my key ambitions. I became a first-generation immigrant at 6 months old, when I left Brazil. I then emigrated to the UK at 17, and then again, a decade later, to advance my academic career in the US. Although these relocations come with small perks—such as being fluent in 5 languages—they are heavily outweighed by the challenges international people and historically marginalized people otherwise face. My familiarity with these hurdles and my wide-reaching scientific network make me an ideal candidate to tackle diversity issues both on campus and at a global-scale.

My drive stems from a deep-seated curiosity to understand the dynamic landscapes and planetary phenomena that surround us, complemented by a passion for teaching, communicating, engaging, and inspiring others. I am confident I would be an excellent fit among MIT's distinguished faculty and diverse academic community, where I would form strong collaborations while seeking to answer outstanding questions on the past, present, and future of our Solar System. To better guide your decision, please find attached my curriculum vitae, a description of my teaching experience and philosophy, my research interests and future directions, and three professional references. Please feel free to contact me if there is anything else I can provide. Thank you for your consideration, and I look forward to hearing from you!

Sincerely,

Gaia Stucky de Quay

Statement of Research

Gaia Stucky de Quay *MIT EAPS | Faculty Application 2020*

General Research Interests

What drives landscape evolution? Are fluvial systems a reliable proxy for climate? Can we use the relationships we see on Earth to decipher the ancient Mars hydroclimate? Can we go a step further and shed light on enigmatic surface processes we see on moons such as Titan? These are some of the questions that have guided my research and I would aim to tackle as an Assistant Professor in the Department of Earth, Atmospheric & Planetary Sciences (EAPS) at the Massachusetts Institute of Technology (MIT). My work focuses on investigating topographic signals and landscape evolution, in order to both deconvolve and quantify primary driving forces such as tectonics, climate, and local geological processes across various planetary surfaces. My philosophy centers on finding compelling geological sites—either remotely or *in situ*—with significant potential to bridge knowledge gaps, and employing a wide variety of multi-disciplinary techniques to generate novel, impactful science results. Below are descriptions of major topics I am pursuing as I develop my research program, broadly divided into Earth and other Solar System bodies. Importantly, although I have listed these separately, my work would become increasingly integrative between different planetary systems, since a deeper understanding of Earth will help inform other planetary surface processes, and vice-versa. For example, understanding aqueous environments on Earth will shed light on potential habitability in extraterrestrial settings, while, on the other hand, constraining Mars' climate history may inform the fate of our own planet. My research topics all include stimulating projects that would make ideal building blocks for undergraduate or graduate theses, as well as intra- and inter-departmental collaborations at EAPS. As such, I plan to recruit a diverse team of students and work with a wide range of interdisciplinary faculty to continue to develop and expand on the research themes described below.

Terrestrial Surface Processes as Analogs

Past achievements. My first project during my PhD at Imperial was focused on using ancient, buried landscapes to constrain the geodynamic evolution of the North Sea. I combined three-dimensional seismic data, geophysical well logs, biostratigraphic records, and geochemical analyses of well cores to map the extent and age of a fluvial surface now preserved 1.5 km below the seabed (Stucky de Quay et al., 2017; see CV for Stucky de Quay references). I used these data to calibrate inverse numerical models for landscape evolution and discern the behavior of the Icelandic mantle plume, which was responsible for uplifting this region during its incipience. After studying Iceland's geodynamic origin and evolution, I became increasingly interested in its modern-day postglacial landscape. I investigated its largest canyon and waterfall system, Jökulsárgljúfur, by combining geomorphic mapping and volcanic stratigraphy to extract the relative chronology of the canyon. A combination of high-resolution Uncrewed Aerial Vehicles (UAV) mapping and cosmogenic Helium-3 techniques at Caltech was used to date the incised river terraces (Stucky de Quay et al., 2019a). Field observations and forward fluvial models suggested that the canyon was formed from gradual erosion during the Holocene, as opposed to catastrophic flood events. My extensive background in terrestrial surface dynamics make me an excellent candidate to tackle outstanding planetary problems using field, laboratory, remote sensing and theoretical analyses that have been *ground-truthed* on Earth.

Future directions. Since completing this work, I have developed a strong interest in fluvial-landscape interactions at a variety of spatio-temporal scales. Channel morphologies record a history of the competing processes of incision and deposition, alongside the system's response to regional and local driving forces. As a result, most geomorphic systems are inherently complex, containing a variety of unknown parameters. However, oceanic islands constitute one of the best natural laboratories to investigate the processes that govern fluvial systems. This is due to the broadly monolithological nature of the substrate (dominated by basaltic lava flows), the known initial topography (prominent shield volcano), and the well-constrained, homogeneous uplift history of post-constructional islands (Jefferson et al., 2014). Oceanic islands also benefit from the ubiquitous presence of datable surfaces which provide ample opportunities for geochronological dating methods, as well as dramatic topographic signals such as waterfalls, which may be analysed remotely and *in situ*. Despite their investigative potential, only a few of the larger islands are well studied (e.g., Hawaii, Iceland; Ferrier et al., 2013; Stucky de Quay et al., 2019a) due to most archipelagos' intrinsic remoteness and inaccessibility. At present, I have obtained various grants to undertake ambitious expeditions to three archipelagos: Azores, Madeira, and Cape Verde. Importantly, these sites populate a wide spectrum of climate zones, from humid to hyper-arid. Thus, when combined with existing climate data or new precipitation models, our field data will yield crucial quantitative insights into how climate variability is imprinted into fluvial morphologies. This project, which I would underake at MIT, would serve as a springboard for a longer-term, international research partnership focused on volcanic islands as terrestrial analogs, which could be supported through partnerships with the MIT Portugal program, Woods Hole Oceanographic Institution, or the Atlantic International Research Center. Future research avenues may comprise drainage initiation in new topographic surfaces, the role of faulting, volcanism, and landsliding in stream development, coupling of coastal geomorphology and sedimentation, and, crucially, deepening the use of volcanic island surfaces as terrestrial analogs for planetary systems. The plethora of potential data will allow for fruitful collaborations with MIT faculty in various fields beyond geomorphology, including geodynamics, geochronology, paleoclimatology, volcanology, remote sensing, and oceanography.

Early Mars Geomorphology & Beyond

Past achievements. The ubiquity of sedimentary and erosional landforms on Mars suggest it was subject to a very different climate in its past, with a rich history of surface processes similar to those on Earth today (Carr, 1987). During my MSci at UCL, I mapped and cataloged mass movements from the slopes of the Valles Marineris canyon. By classifying and quantifying their properties and drawing on comparisons to glacial deposits, I presented evidence that these may have been emplaced over icy substrate (Stucky de Quay et al., 2014, *LPSC* Abstract). Further, during my visiting studentship at UChicago I studied localized channels and alluvial fans found in crater basins (Stucky de Quay, et al., 2019b). I developed erosional relationships and used comparative studies between crater alcoves on Mars and rift escarpments on Earth to showcase their origin as advective bedrock valleys in an arid environment. I applied sediment transport relations to conclude that surface water must have been available in intermittent, but not short, periods (>100 year episodes), likely supplied by snowmelt. The relationships I developed were subsequently applied to paleochannels, which showed that Martian runoff was much greater, and occurred much later, than previously thought (Kite et al., 2019). I am also currently working on a project that uses open-source landscape evolution models to investigate Warrego Valles, one of the best examples for past surface runoff on Mars. Preliminary results show that it may have formed during the emplacement of the Tharsis plateau it is located on. This would suggest planet-wide volcanism and liquid water may have been synchronous, and thus very likely coupled in a direct feedback system.

Future directions. More recently, I have been increasingly fascinated by the 'early Mars paradox', wherein climate scientists and geomorphologists struggle to converge on the amount, nature, and timing of surface water up to 3.7 Ga (Wordsworth et al., 2018). To tackle these problems, I have written and will be submitting a proposal to the NASA Mars Data Analysis Program, which expands on our newly identified 'coupled lake systems' on Mars. These paleolake systems contain a hydrologically open- and a closed-basin lake simultaneously, which provides both upper and lower boundaries on local precipitation (Stucky de Quay et al., 2020). I plan to combine these with climate model runoff results to inform the absolute timescales of lake-filling, breaching, and overflow, as well as their variability across the martian surface. Combining these with further morphometric analyses will provide key quantitative constraints on the intensity, recurrence, and timing of the planetwide climate. An improved fundamental understanding of liquid water availability will be crucial in the search for habitable environments and will strongly influence the relative success of future missions such as NASA's Mars 2020 (Perseverance) rover. The Jezero crater paleolake system will be our next landing site; the future work outlined here would provide key predictions that may be directly tested through *in situ* geochemical, geologic, and geochronologic techniques, as well as eventual sample return. Lastly, these same questions may be posed on other planetary bodies, such as Titan, which contains a 'methanological' cycle analogous to our own water cycle (Hayes, 2016). Evidence of active erosion by rivers, and deposition into lakes and seas, suggest climate and tectonics are intricately linked to topography. The NASA Cassini Data Analysis Program (CDAP) would be an ideal future target for steering my research into the depths of the Solar System, applying the very same tools and expertise described above to further characterize the origin of Titan's uplifted labyrinth terrains, dendritic valley network geometries, polar lake distributions, and shoreline morphologies. These stimulating projects could foster collaborations outside of the planetary sciences, particularly with faculty involved in sedimentology, climate science, geochemistry, and geobiology.

Potential Collaborations & Scope at MIT

I would bring an exciting and complementary direction to the exceptional research in MIT EAPS, sparking many opportunities for productive collaborations. Importantly, my work would significantly augment EAPS's current scope by incorporating (i) novel geological sites (e.g., volcanic islands, subarctic regions, martian lakes) (ii) cutting-edge tools (e.g., geochronology, geochemistry, UAV), (iii) additional disciplines (e.g., sedimentology, volcanology, limnology), and (iv) key applications for coastal, landsliding, and volcanic hazards. Specifically, my research on topographic signals would provide opportunities for strong collaborations with Professor Taylor Perron, whose integrative approach to studying planetary bodies would provide stimulating links with my own work. Further, my drive to understand the habitability of early Mars surface environments would open the door for collaborations with Professors Tanja Bosak and Professor Benjamin Weiss, given their expertise in the formation, evolution, and history of ancient planetary landforms, and their involvement with scientific missions. Professor Kristin Bergmann's background in sedimentology and stratigraphy and Professor Leigh Royden's geophysical background would also provide an exciting opportunity to investigate the depositional and sub-surface aspects of landscape evolution, respectively. Finally, Professor Timothy Grove would provide invaluable expertise when characterizing volcanic terrains and extending their application to other planets. As my future research interests continue to expand through new projects and experiences, I also eagerly anticipate that additional collaborative opportunities will emerge given the strength, distinction, and diversity of the faculty and academic community at MIT.

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Statement of Teaching

Gaia Stucky de Quay *MIT EAPS | Faculty Application 2020*

Teaching Philosophy & Experience. The educational process is often described as a transmission of knowledge and skills to the subsequent generation. However, this simplification implies a misleading one-way process—a teacher cannot force knowledge and skills into a student's mind. Instead, a teacher must *create* a context in which students are both open and eager to be taught. What steps can be taken towards fostering such dynamics in MIT's classrooms? **[1]** Maintaining students engaged requires a healthy mixture of slideshows, 'blackboard'-style science, and interactive media. I would create a varied, stimulating program allowing students to focus on avenues that best fit their learning personalities (e.g., Brown, 2000). **[2]** I would instill different levels of interaction through team projects and paired exercises to increase collaboration and participation (e.g., creating a 'cohort'; Goodman et al., 1998). **[3]** Each student group is unique. I intend to loosely follow a class plan, but promote questions with prompts and breaks. I would ensure all voices are heard and not dominated by bolder individuals. This will create an inclusive environment for all, especially those hindered by language, cultural, or disability barriers. **[4]** Finally, I am a passionate speaker, with an infectious level of curiosity. I hope to impart my enthusiasm on them, cementing their engagement and satisfaction with my class. In the past few years, I have taught an extensive suite of courses in Earth and planetary sciences at Imperial. I was an assistant teacher for undergraduate and graduate courses: *Introduction to Field Geology*, *Structural Geology 3*, *Solar System Geoscience*, *Surface Processes*, *Sedimentary Geology*, *Geomorphology*, *Basin Analysis*, and *Seismic Techniques*. I gave a guest lecture for the senior-level course, *Field Geomorphology*, where I described erosional principles, deriving the stream power law, among others. This course, as well as *Field Geology 1*, contained a large field work portion for which I was a guide for several days in Wales and Spain, respectively.

Mentoring Philosophy & Experience. Mentoring is a fundamental aspect of advancing research into a future beyond our own lifetimes. It is also at least as much about developing academic prowess as it is about cultivating creativity, resourcefulness, reflectiveness, and character. What actions should an MIT mentor take to form productive academic partnerships? **[1]** I believe that an open-door policy is indispensable. I intend to be readily available to provide academic and personal guidance at all times (Lee et al., 2007). **[2]** A research group can double as its own support network. I would aim to create a symbiotic (as opposed to hierarchical) group dynamic, by promoting data sharing, collaborations, and further mentoring among themselves. **[3]** The effectiveness of weekly group meetings has been widely contested (Mroz et al., 2018). To increase their effectiveness, I will make them 'crowd-sourced', ranging from workshops to personal development sessions, among others. **[4]** I am committed to having a diverse group, and will actively widen my hiring search, facilitated by my own international background. I will assist them with forming their own unique collaborations, with the ultimate goal of creating opportunities for historically marginalized groups, while also sparking innovative science. Overall, mentoring has been one of the most rewarding aspects of my career. I have been fortunate enough to have mentored 8 students at both undergraduate and graduate levels. I have enjoyed being involved with their research at every stage, starting from the initial hypothesis conception all the way to thesis submission. With all mentees I have striven to consistently provide positive yet constructive feedback on their work in order to preserve their motivation while helping them achieve their maximum potential. I have also led workshops on drone piloting, expeditions with my own students (Iceland, Texas), and am compiling a Generic Mapping Tools workshop next semester. Helping students has always come naturally to me and I would continue this legacy at MIT.

Specific Course Ideas. I have developed six ideas for classes at MIT; they are not the only classes I could teach, but are examples of courses I could offer on arrival. These would be distinct—but complementary—to courses already offered.

- ***Surface Processes/Advanced Surface Processes.*** We would investigate the ways in which Earth surface systems, materials, and processes interact to alter the land surface. Advanced approaches would comprise dynamic equilibrium in landscapes, tectonic geomorphology, remote sensing, and simple numerical models (Burbank and Anderson, 2011).
- ***Solar System Geoscience & Exploration.*** This course would explore the formation and evolution of the Solar System, from iron meteorites to icy moons. Astrobiological processes and terrestrial analogs (gullies, glaciation, etc.) would be taught (with a focus on habitability), as well as past and future rover/human planetary exploration (McSween et al., 2019).
- ***Advanced Remote Sensing and GIS.*** This course would teach quantitative analysis of remote sensing data in a GIS framework (using ArcGIS, ENVI), with focus on geospatial datasets of topography (LiDAR and stereogrammetry) and infrared spectroscopy. This could comprise a local, hands-on field outing using GPS and drone tools (Weng, 2010).
- ***Geodynamics & Global Tectonics.*** We would investigate plate boundaries, along with the unique geological and geophysical observations that characterize them. Students would learn about Earth's energy balance and how it relates to convective flow, stress/strain, and deformation, using numerical skills and software (Unix, GMT, Python) (Fowler, 1990).
- ***Basin Analysis.*** This course would outline basin types in a plate tectonic framework, and provide the basic principles underpinning basin formation. We would explore the relationships between e.g., extension of the lithosphere, subsidence and sedimentation, and evaluate tectonically controlled sedimentation (Allen and Allen, 2013).
- I am also qualified to teach current MIT courses: *Introduction to Geology*, *Introduction to Geophysics and Planetary Science*, *Sedimentary Environments*, *Sedimentology in the Field*, *Structural Geology*, *Field Geology*, *Geomorphology*, *Essentials of Geology*, *Essentials of Planetary Science*, and *Physical Principles of Remote Sensing*, among others.

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