The Field Guide to Martian Landscapes

7.8° 27.8°

-16.3° 48.45°

-15.7° 0.87°

-22.6°

12.64°

-19.6°

44.38°

31.38° -2.05°

34.81°

8.98°

25.97° -5.07°

Galo Canizares/office ca

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All information contained here is derived from open source material. Original Digital Terrain Models are available to the public at https://www.uahirise.org//dtm/. Descriptions of landscape phenomena come from NASA's blog entries captioning each data set.

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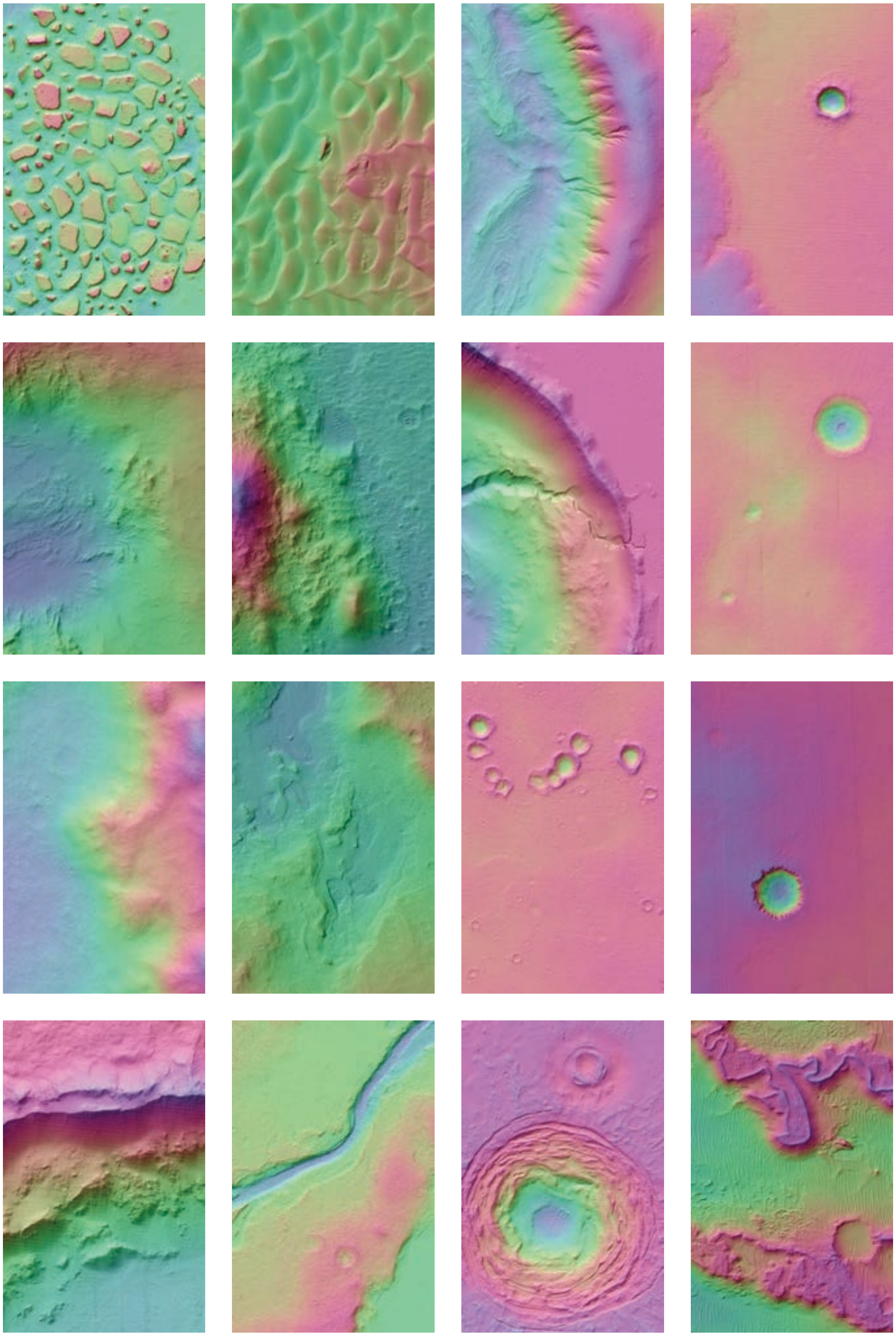
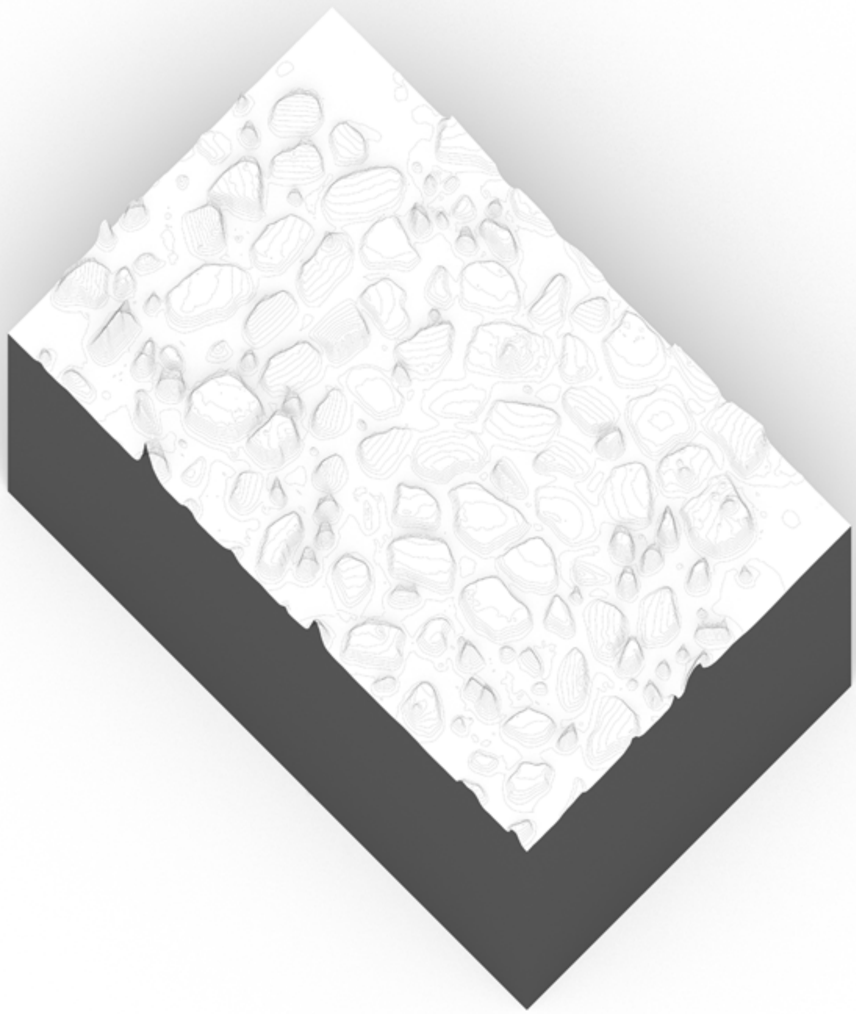
INTRODUCTION

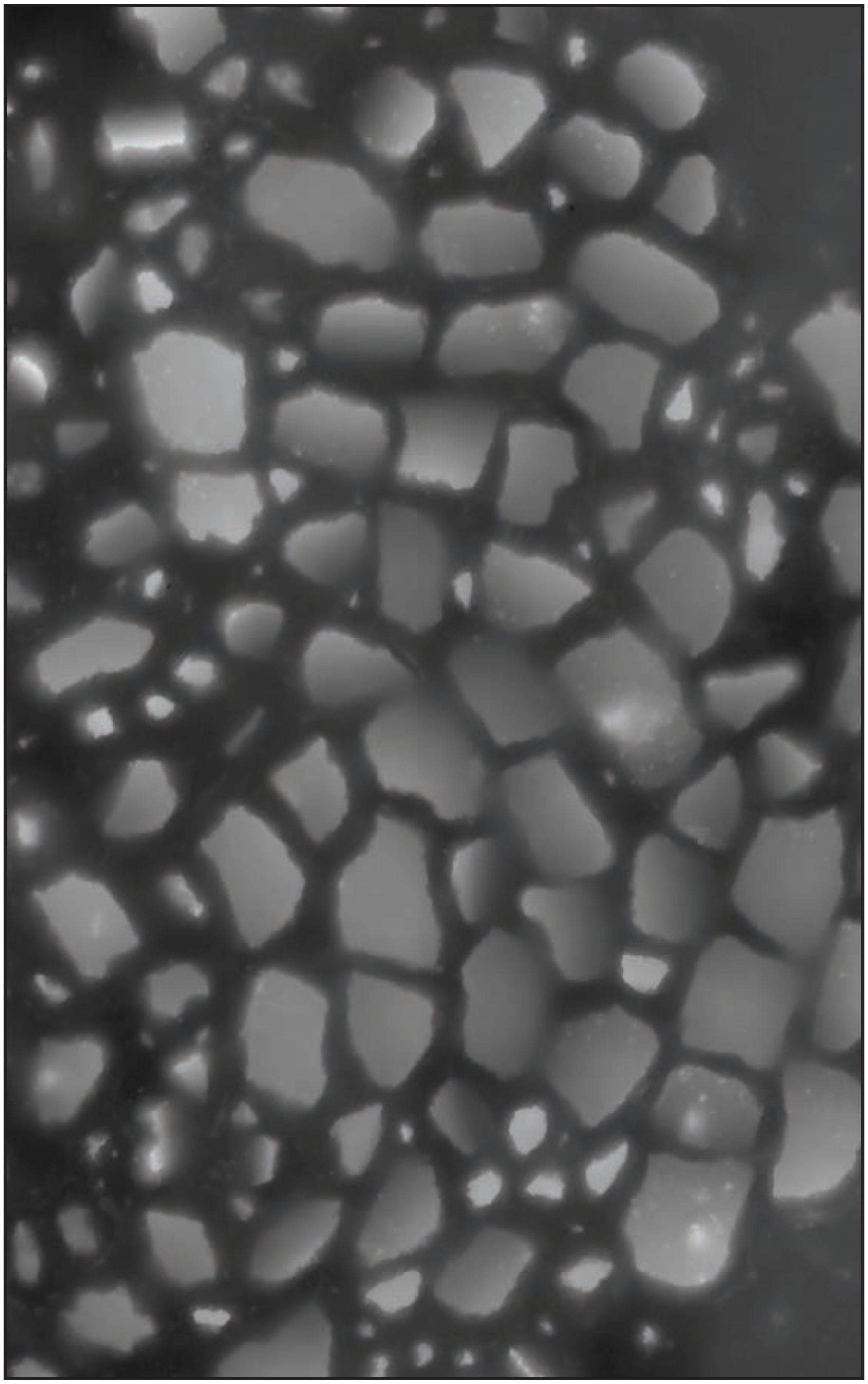
The Field Guide to Martian Landscapes is a taxonomy of landscape phenomena observed on Mars by the HiRISE (High Resoultion Imaging Science Experiment) Project at the University of Arizona in conjunction with NASA and the Jet Propulsion Laboratory. As it stands, there are over 382 publicly accessible data sets with resolutions of about 1m = 1px, making it the largest public database of high fidelity surface information on Mars. In order to make the information easier to read and usable for designers who may be interested in venturing to the red planet, this field guide has translated the data sets into a series of standardized graphics and three-dimensional models. While this list is hardly exhaustive, and not presented in any specific sequence, landscape typologies may emerge that will impact potential landing or colonization sites. We can identify some types as: dune fields, crater fields, large craters, riverbeds, chasms, montes, and dorsa. The goal is ultimately to introduce these landscapes as snippets or core samples of a new world awaiting our arrival.

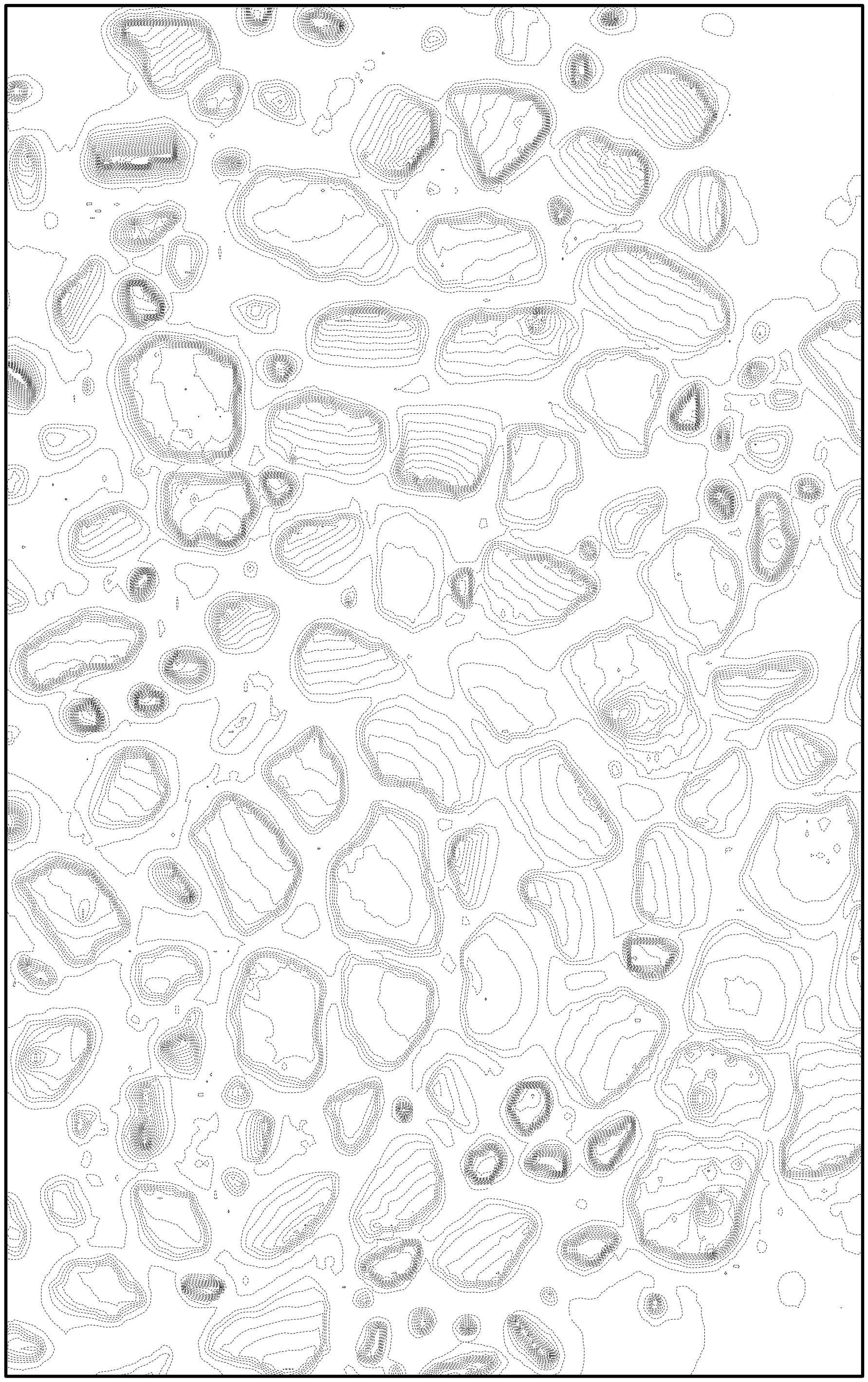


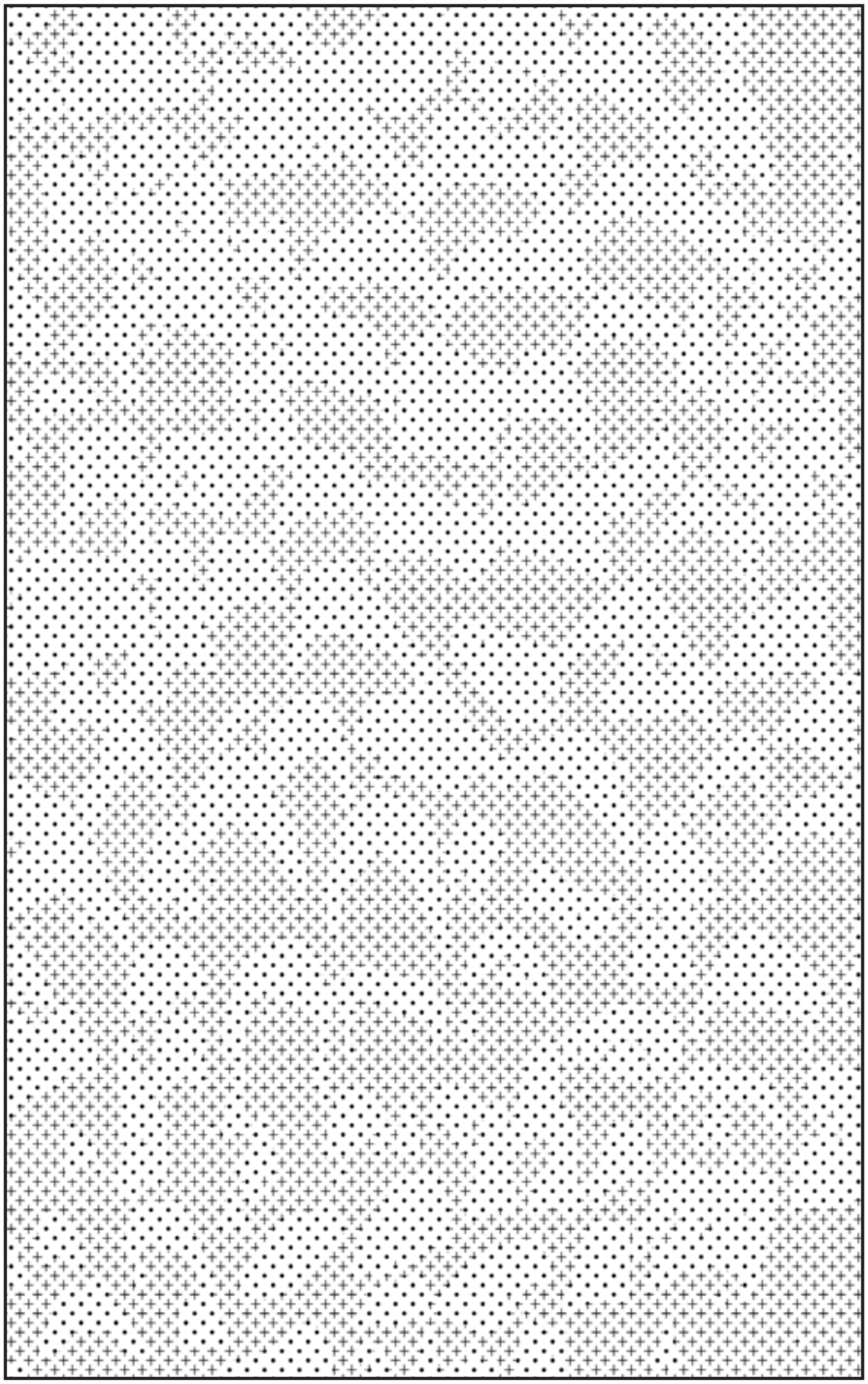
1. CERBERUS FOSSAE

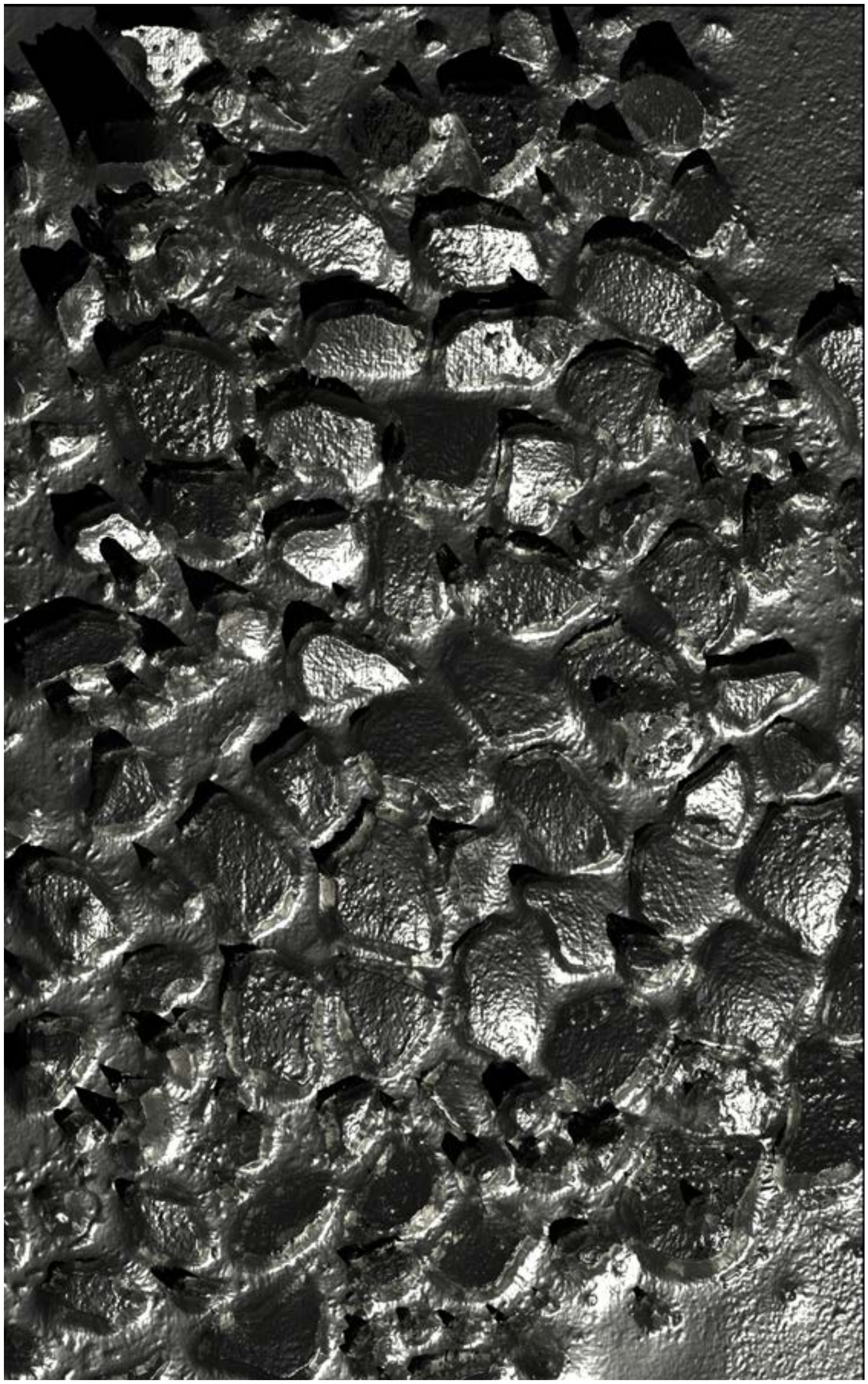
The Cerberus Fossae are a series of semi-parallel fissures on Mars formed by faults which pulled the crust apart in the Cerberus region. They are 1235 km across and centered at 11.28 °N and 166.37 °W. Their northernmost latitude is 16.16 °N and their southernmost latitude 6.23 °N. Their easternmost and westernmost longitudes are 174.72 °E and 154.43 °E, respectively. Ripples seen at the bottom of the faults are sand blown by the wind. The underlying cause for the faulting was magma pressure related to the formation of the Elysium volcanic field, located to the northwest. The faults pass through pre-existing features such as hills, indicating that it is a younger feature. The formation of the fossae is suspected to have released pressurized underground water, previously confined by the cryosphere, with flow rates up to 2 × 106 m3s–1, leading to the creation of the Athabasca Valles. Marte Vallis is another channel that was formed from water released from Cerberus Fossae.





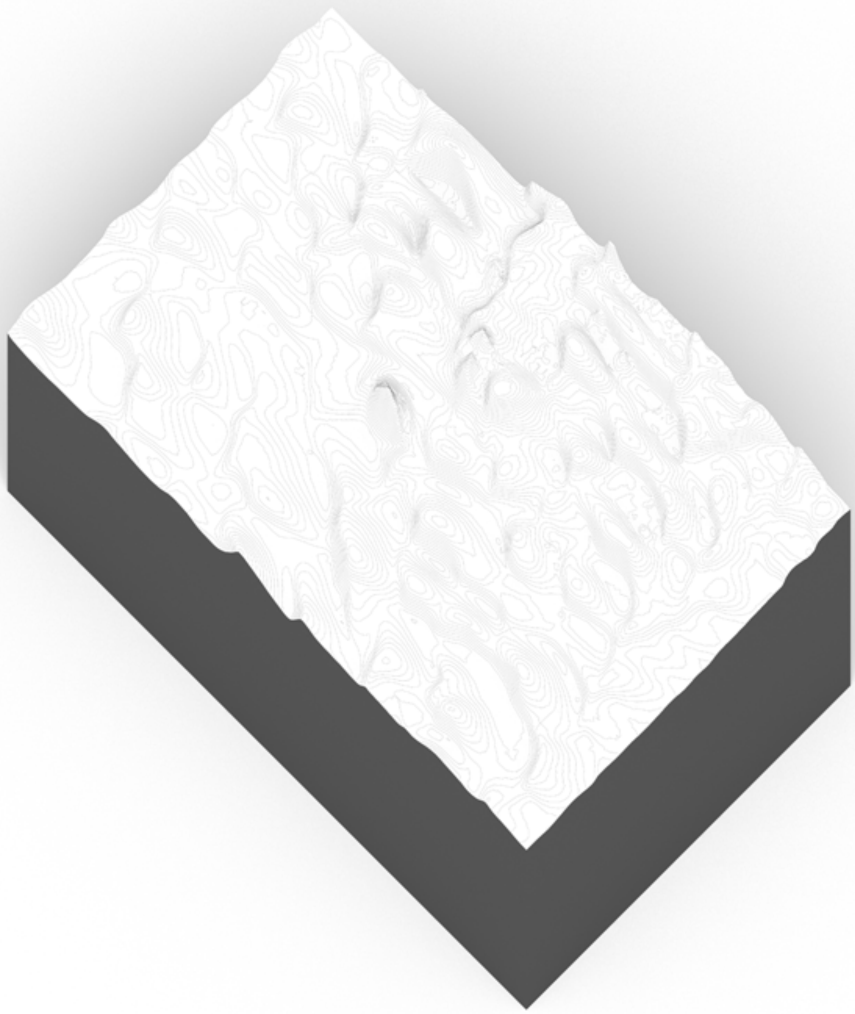


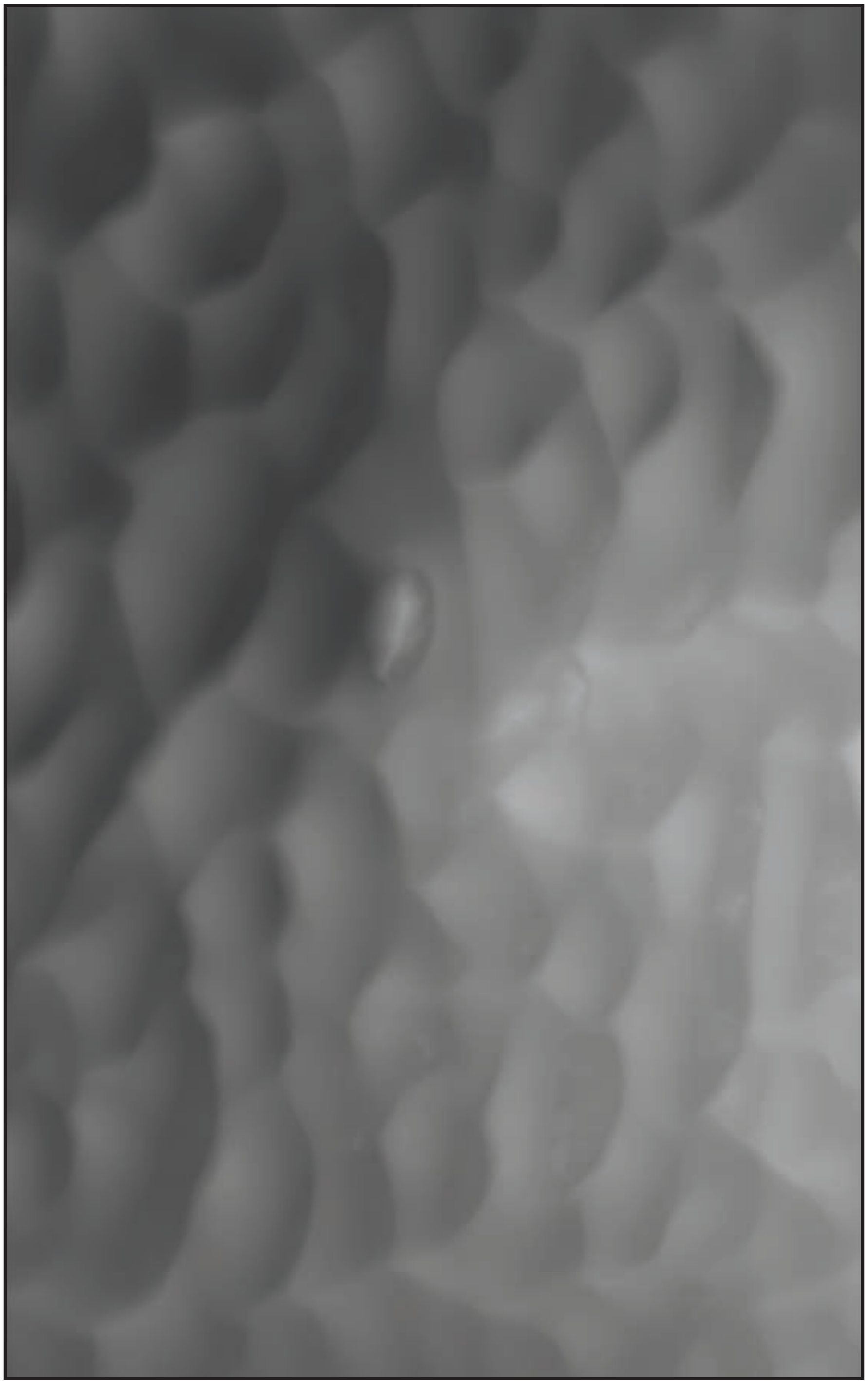


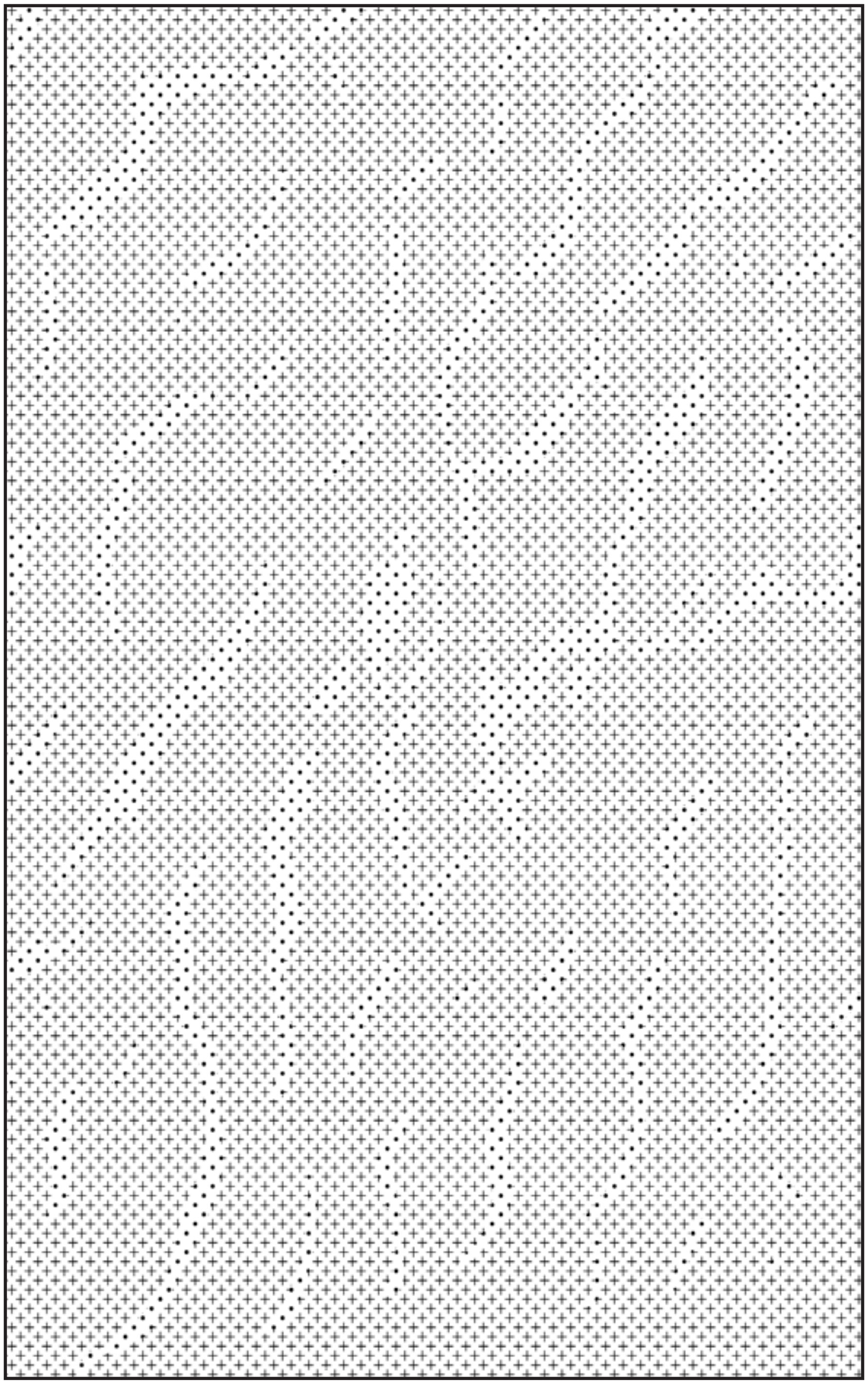


2. HERSCHEL CRATER DUNEFIELD

Herschel is a 304 kilometer impact basin in the Martian southern hemisphere, at 14.5°S, 130°E, located in the Mare Tyrrhenum region of Mars. The crater is jointly named after the seventeenth/eighteenth century father and son astronomers William Herschel and John Herschel. Mars Global Surveyor spacecraft originally photographed fields of dark sand dunes within Herschel. Images from the NASA Mars Reconnaissance Orbiter showed that sand dunes on the floor of the Herschel crater are not stationary (as previously believed), but moved over time. Images from photos taken by the Orbiter's High Resolution Imaging Science Experiment (HiRISE) on March 3, 2007 and December 1, 2010 show clear shifting of dunes and ripples. Research published in Icarus stated that the dunes in Hershel Crater moved 0.8 m in a time span of 3.7 Earth-years. Also, it was determined that dune ripple moved 1.1 m in that time period.



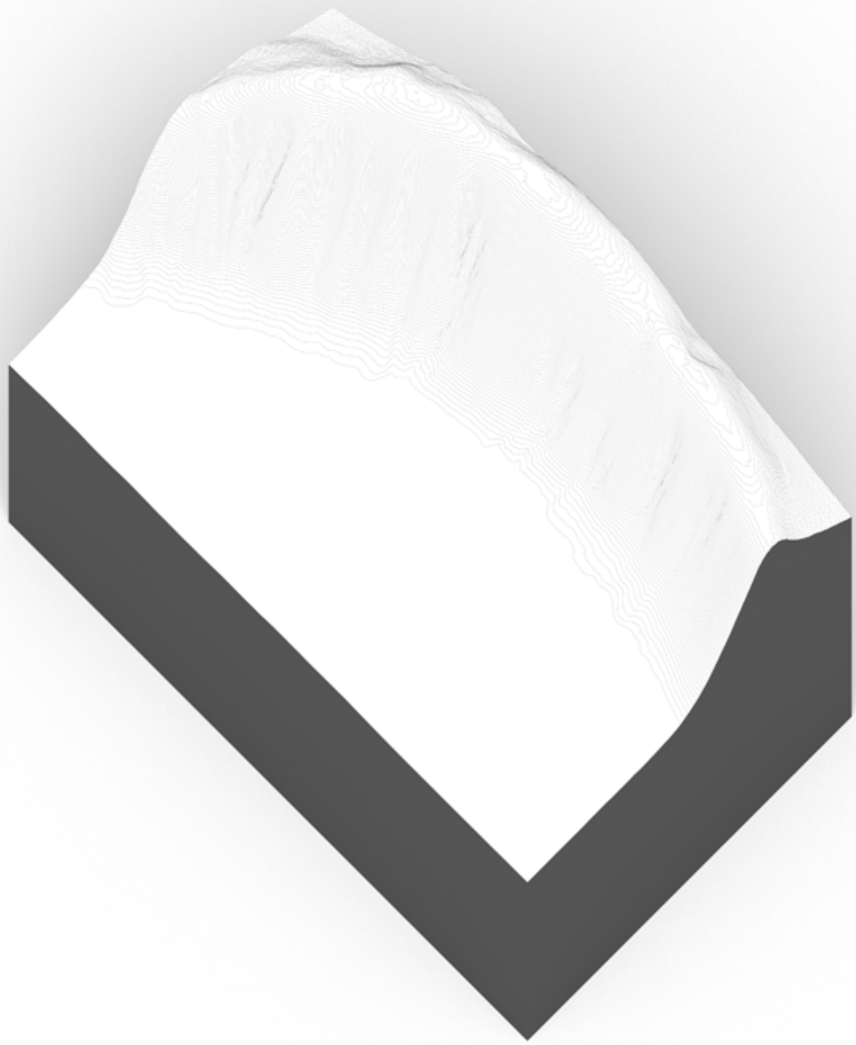


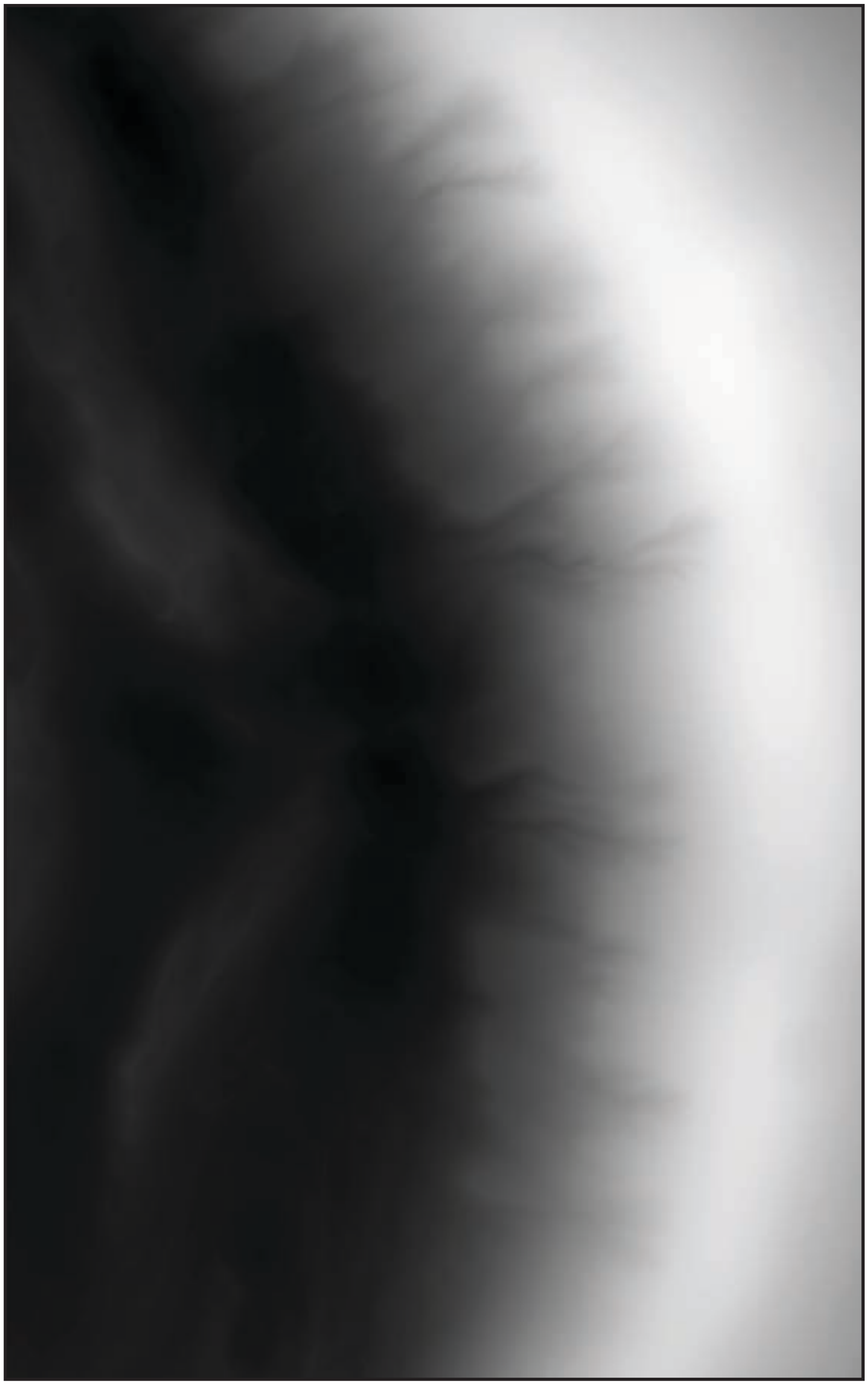


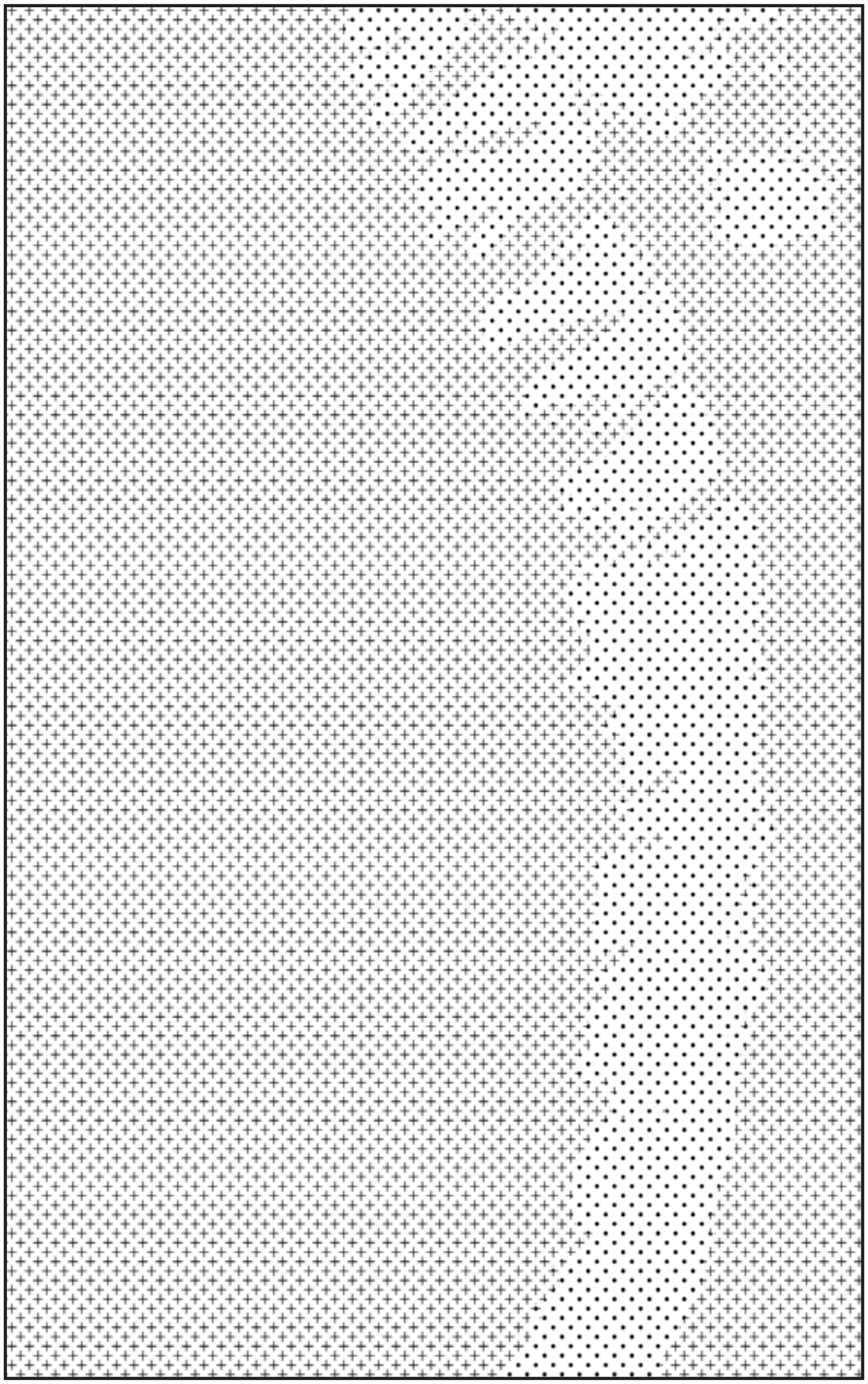
3. CRATER AT UTOPIA PLANITIA

Utopia Planitia is a large plain within Utopia, the largest recognized impact basin on Mars with an estimated diameter of 3,300 km, and is the Martian region where the Viking 2 lander touched down and began exploring on September 3, 1976. It is located at the antipode of Argyre Planitia, centered at 46.7°N 117.5°E. It is in the Casius quadrangle, Amenthes quadrangle, and the Cebrenia quadrangle of Mars. Many rocks at Utopia Planitia appear perched, as if wind removed much of the soil at their bases. A hard surface crust is formed by solutions of minerals moving up through soil and evaporating at the surface. Some areas of the surface exhibit what is called “scalloped topography”, a surface that seems to have been carved out by an ice cream scoop. This surface is thought to have formed by the degradation of an ice-rich permafrost.

On November 22, 2016, NASA reported finding a large amount of underground ice in the Utopia Planitia region of Mars. The volume of water detected has been estimated to be equivalent to the volume of water in Lake Superior.

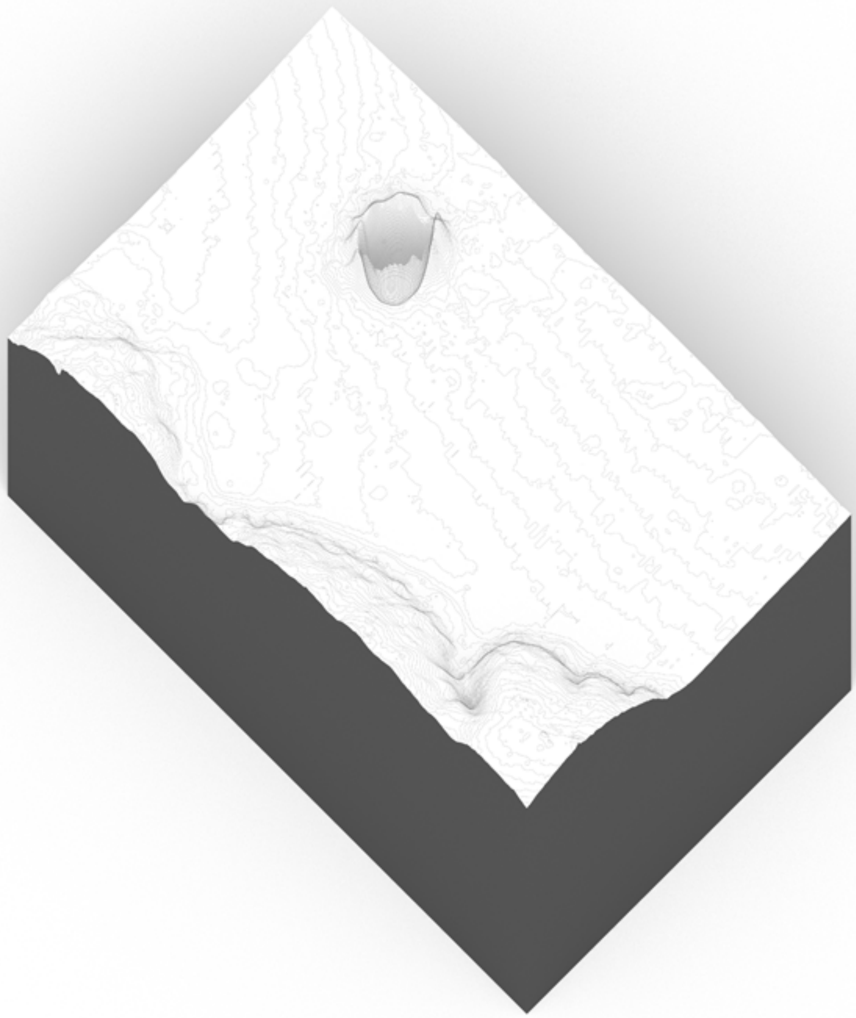


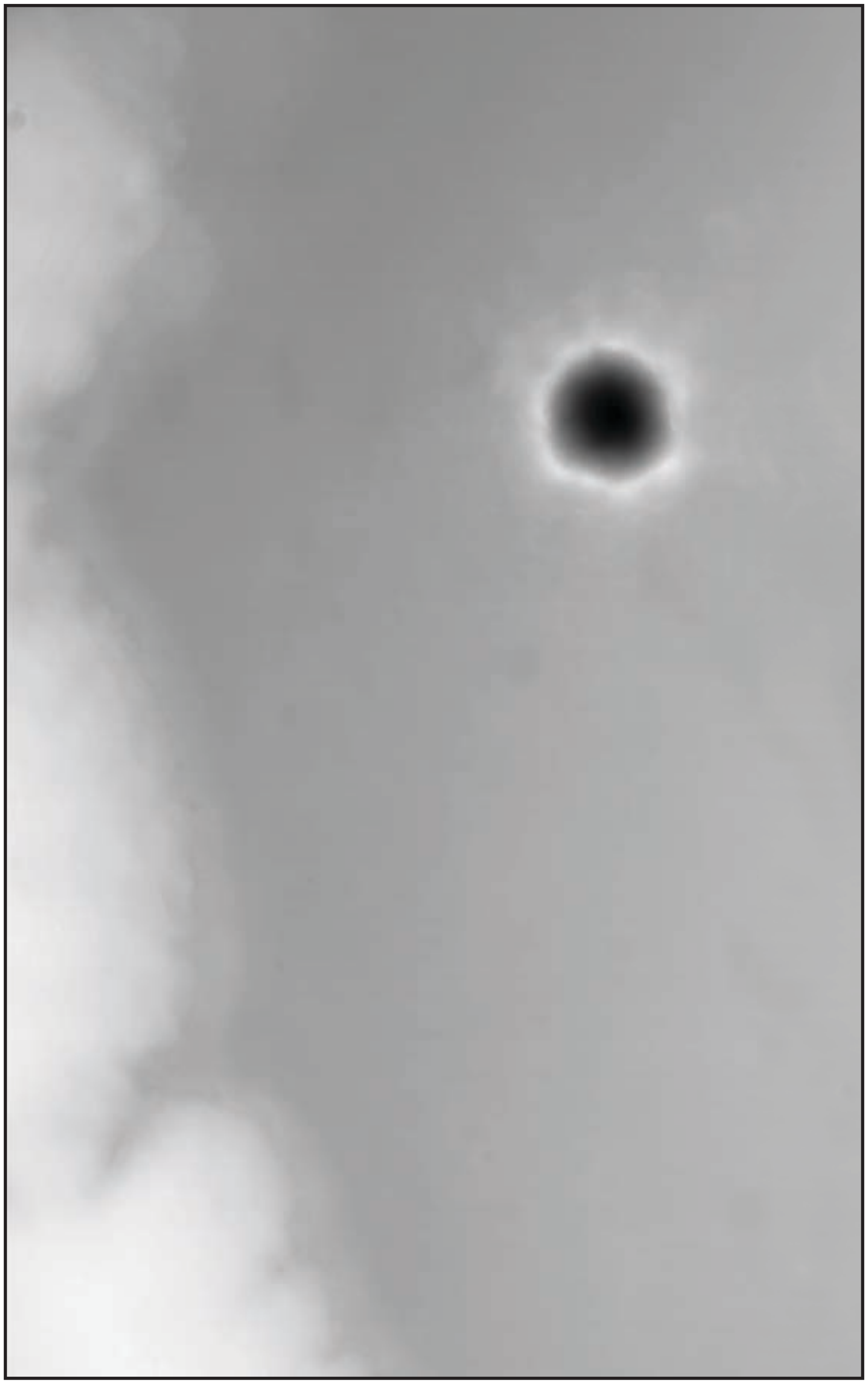


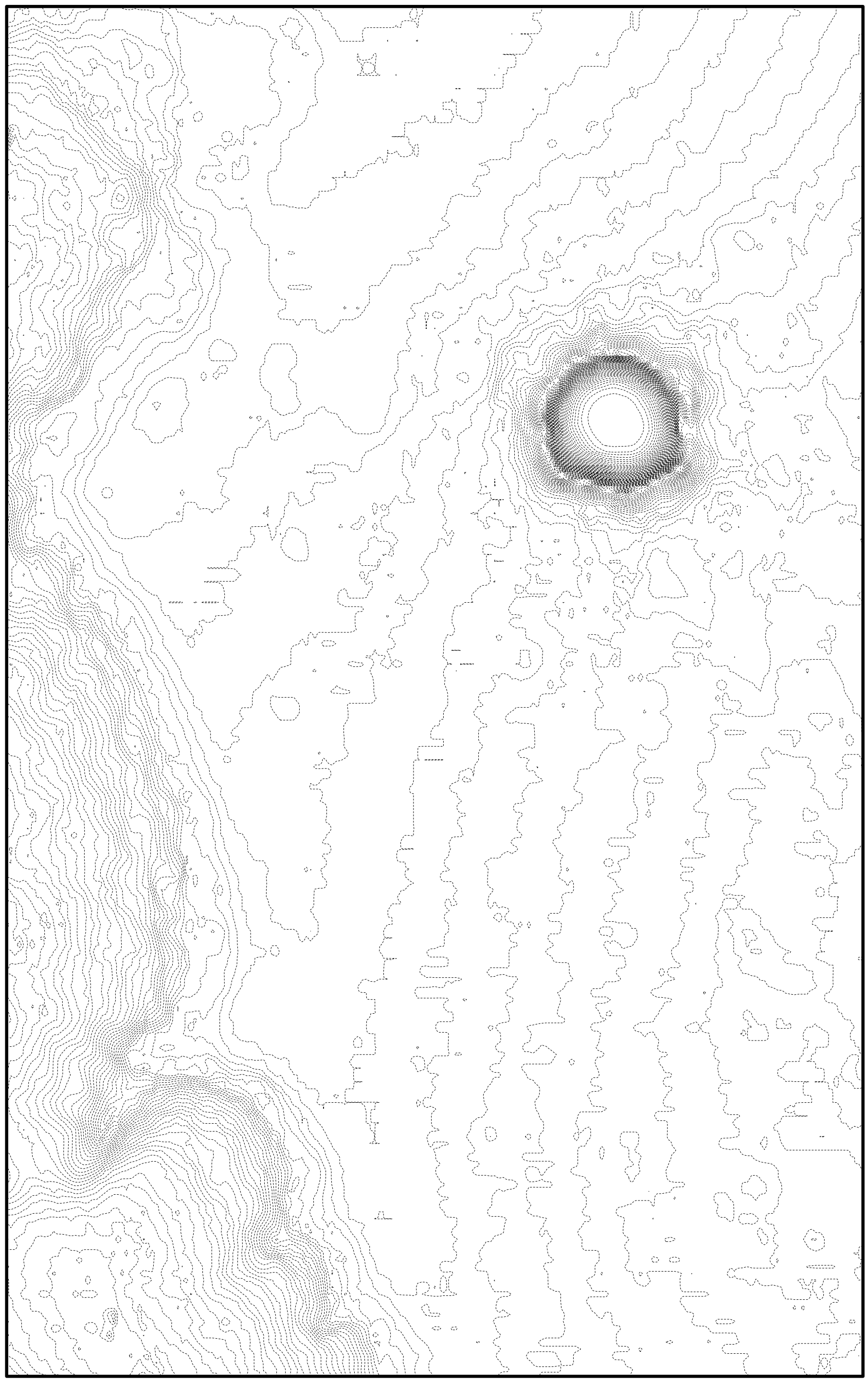


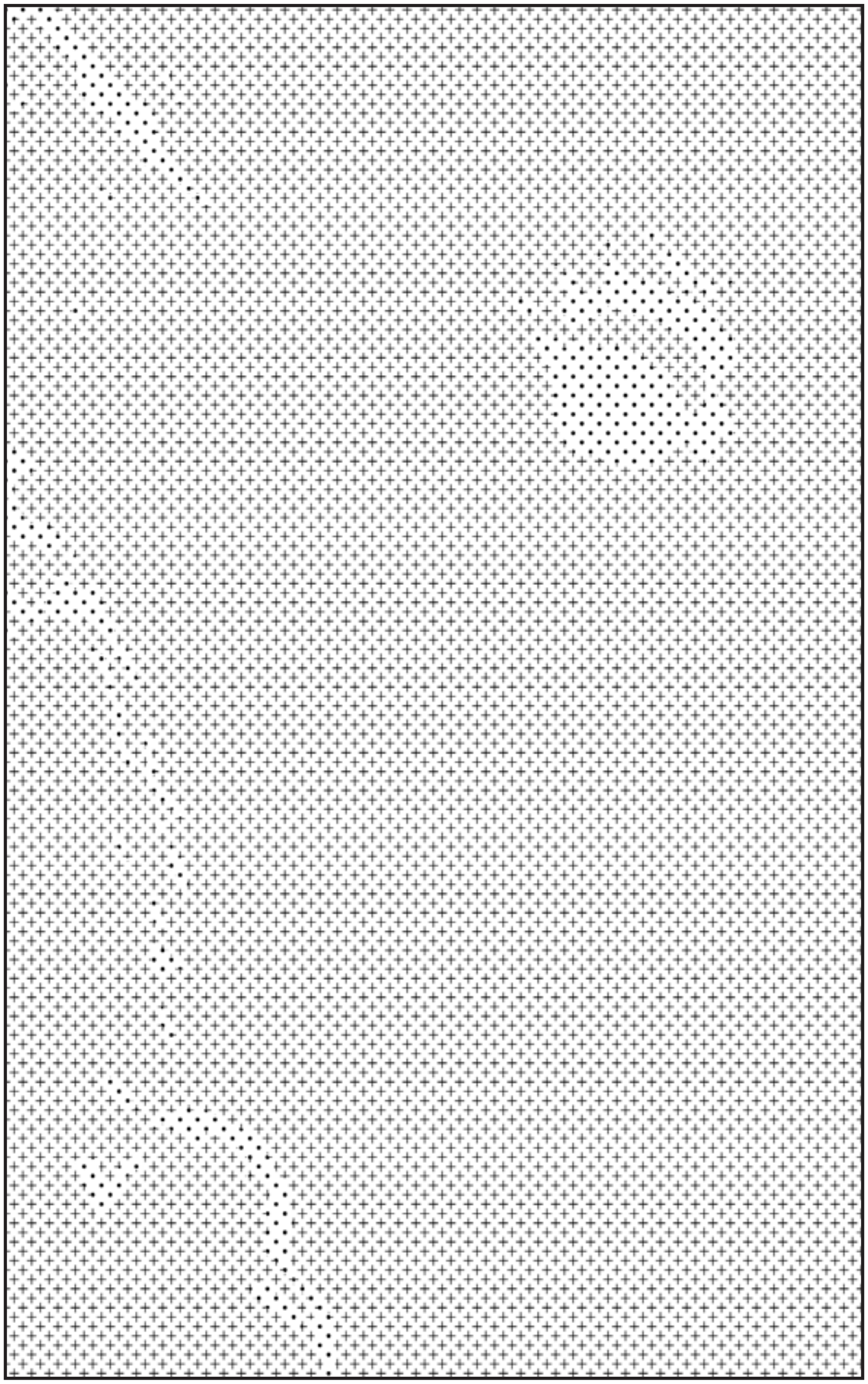
4. ELYSIUM PLANITIA

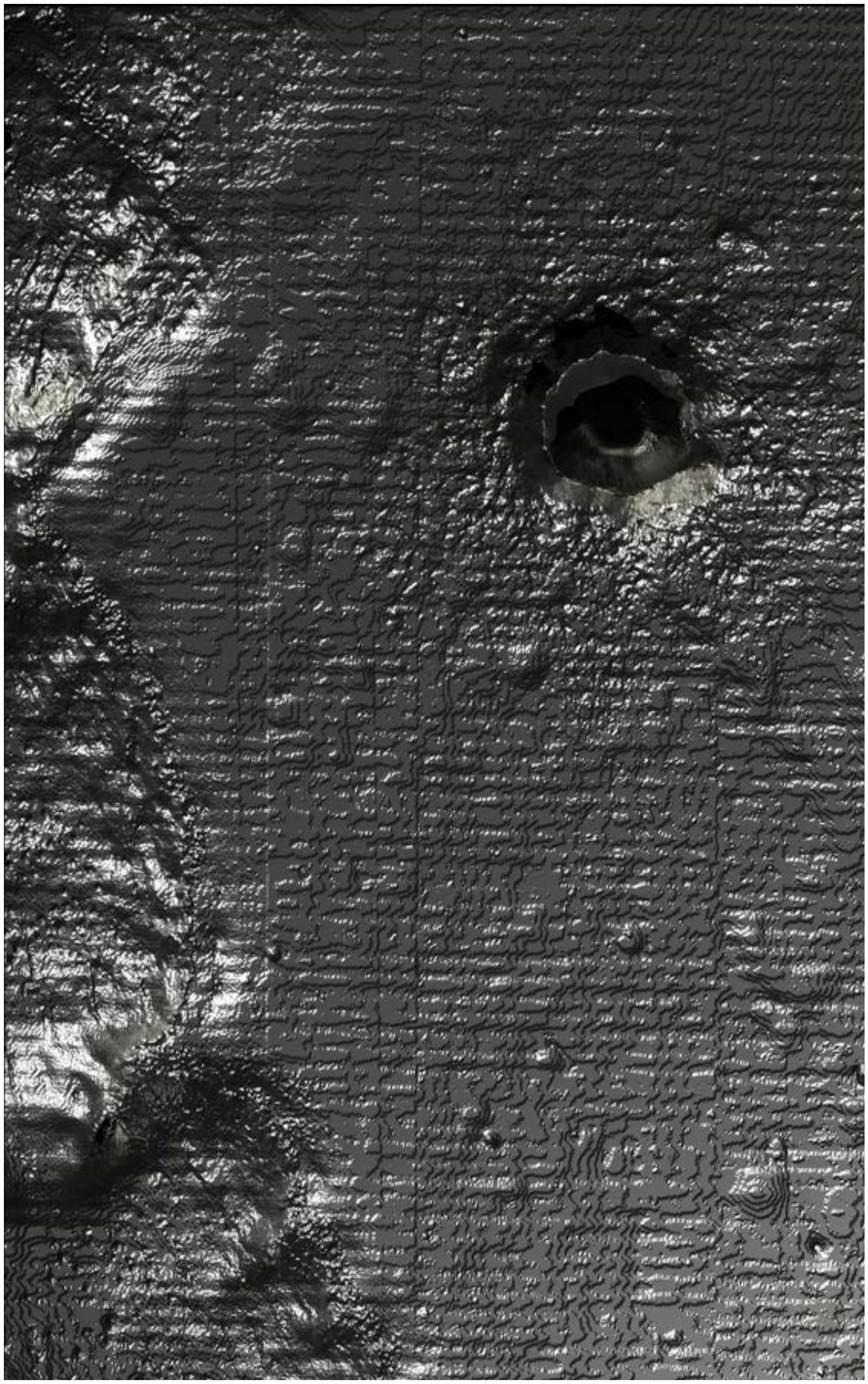
Elysium Planitia, located in the Elysium and Aeolis quadrangles, is a broad plain that straddles the equator of Mars, centered at 3.0°N 154.7°E. It lies to the south of the volcanic province of Elysium, the second largest volcanic region on the planet. The largest craters in this Elysium Planitia are Eddie, Lockyer, and Tombaugh. Elysium contains major volcanoes, Elysium Mons, Albor Tholus, and river valleys; one of which, Athabasca Valles, may be one of the youngest on Mars. A 2005 photo of a locale within Elysium Planitia at 5° N, 150° E by the Mars Express spacecraft shows what may be ash-covered water ice. The volume of ice is estimated to be 800 km by 900 km in size and 45 m deep, similar in size and depth to the North Sea. The ice is thought to be the remains of water floods from the Cerberus Fossae fissures about 2 to 10 million years ago. The surface of the area is broken into ‘plates’ like broken ice floating on a lake. Impact crater counts show that the plates are up to 1 million years older than the gap material, showing that the area solidified much too slowly for the material to be basaltic lava.





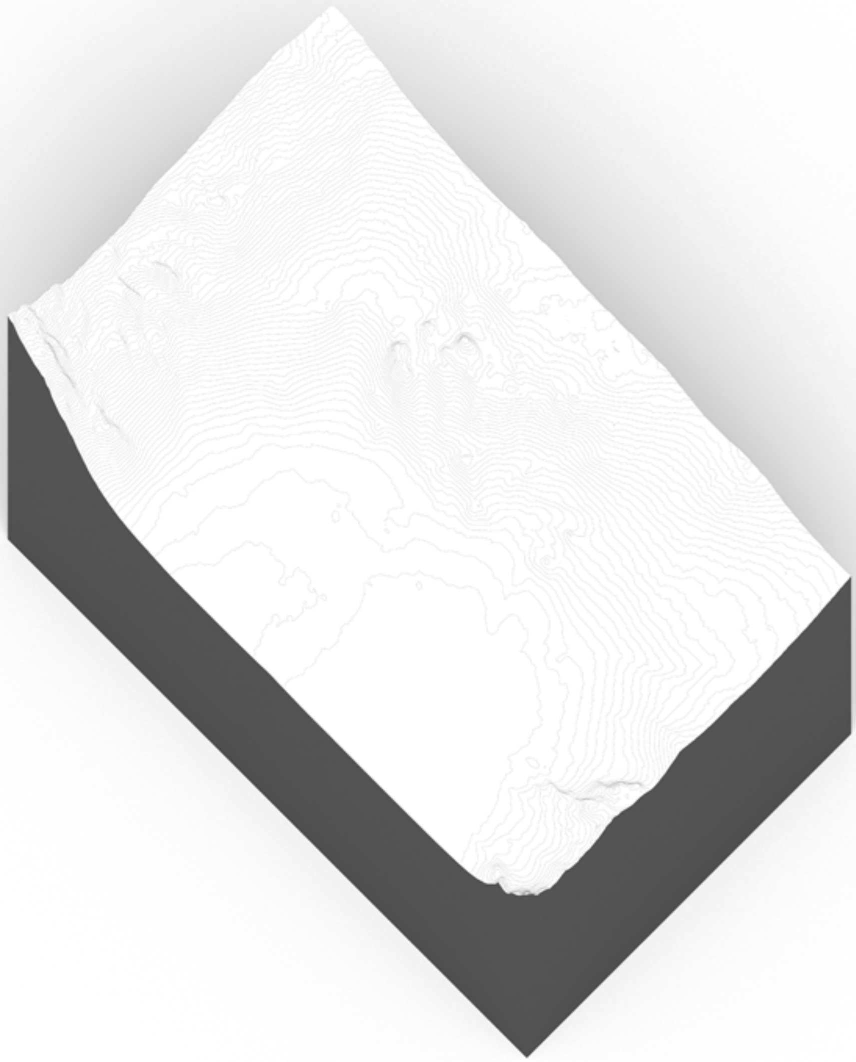


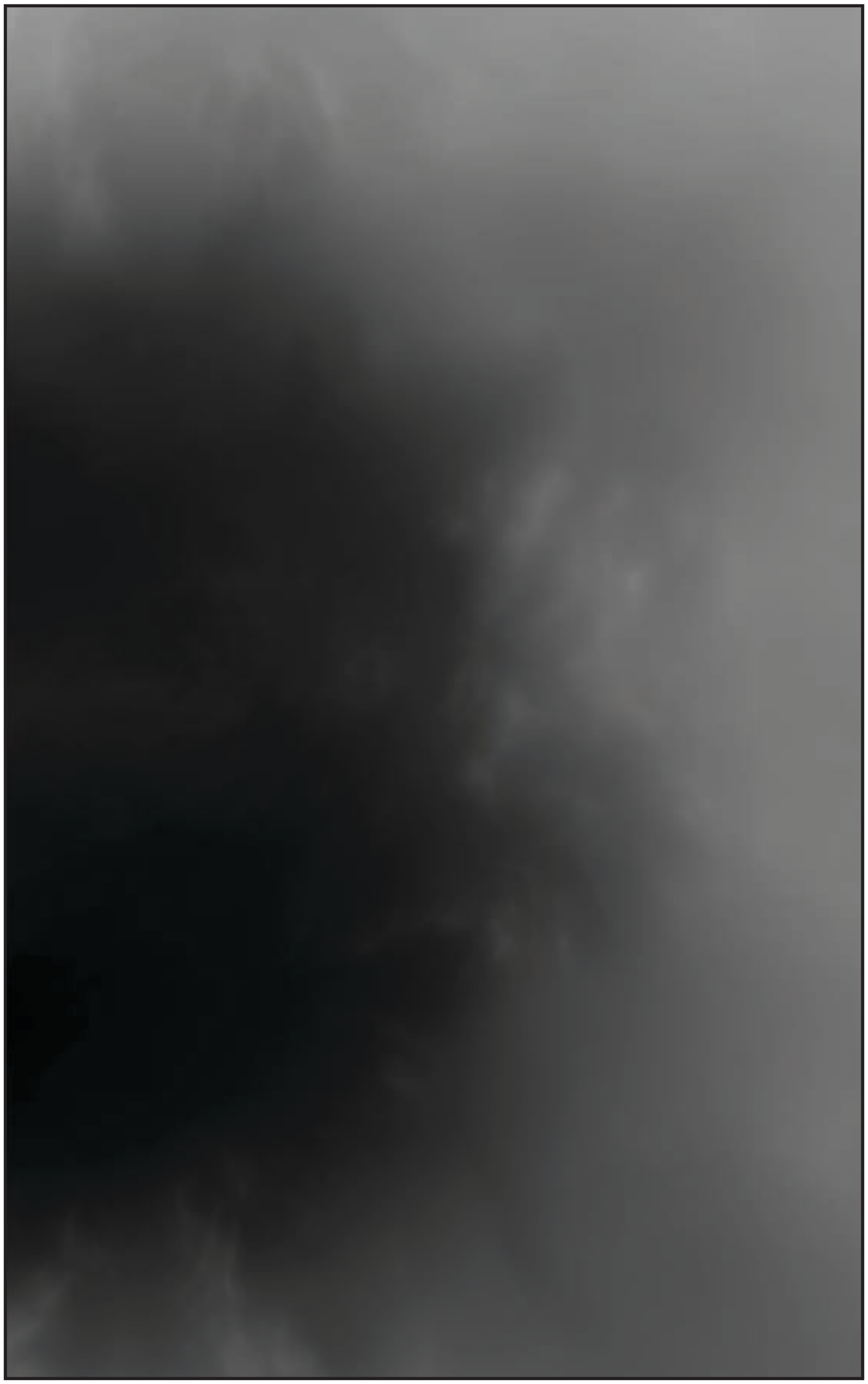


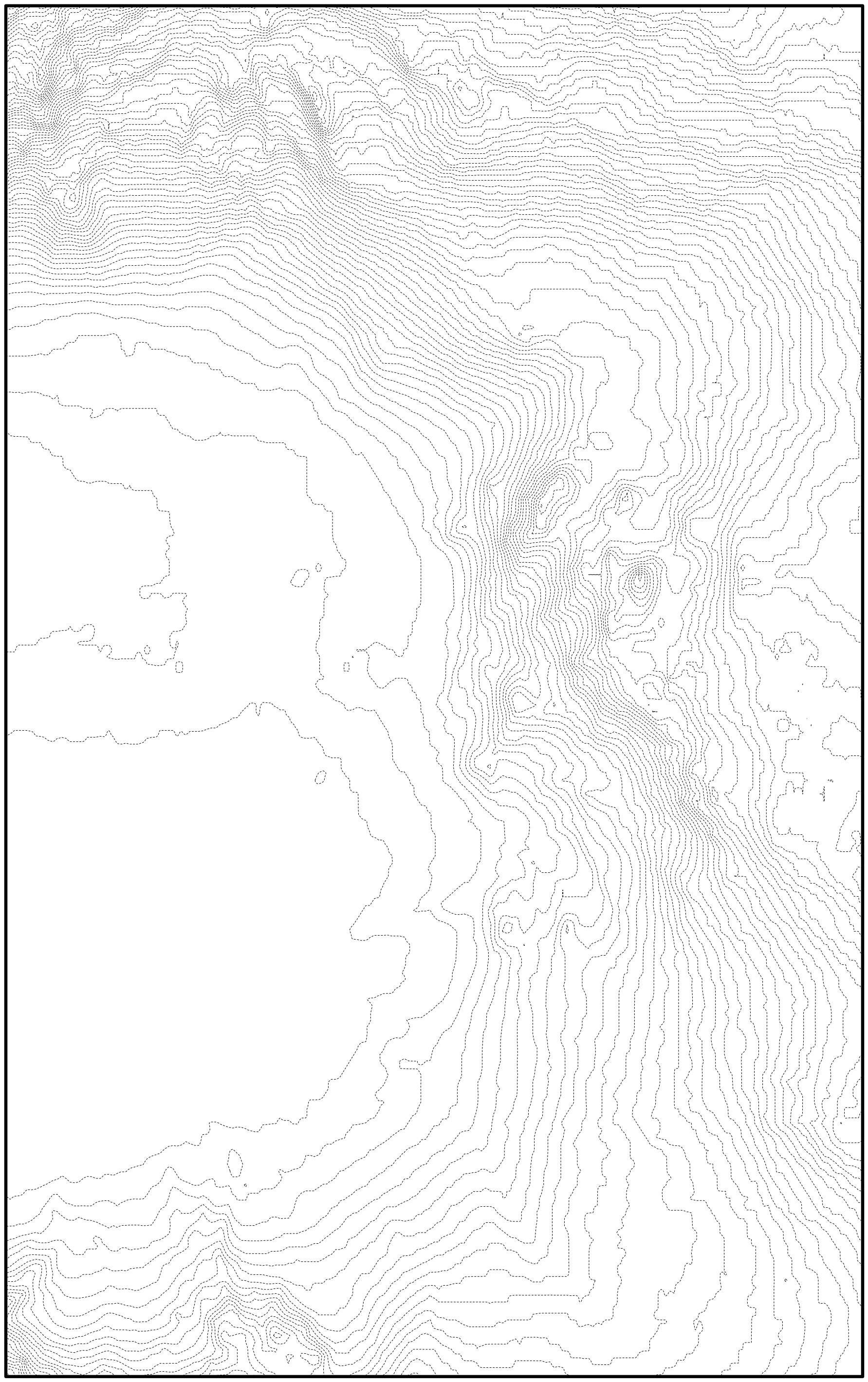


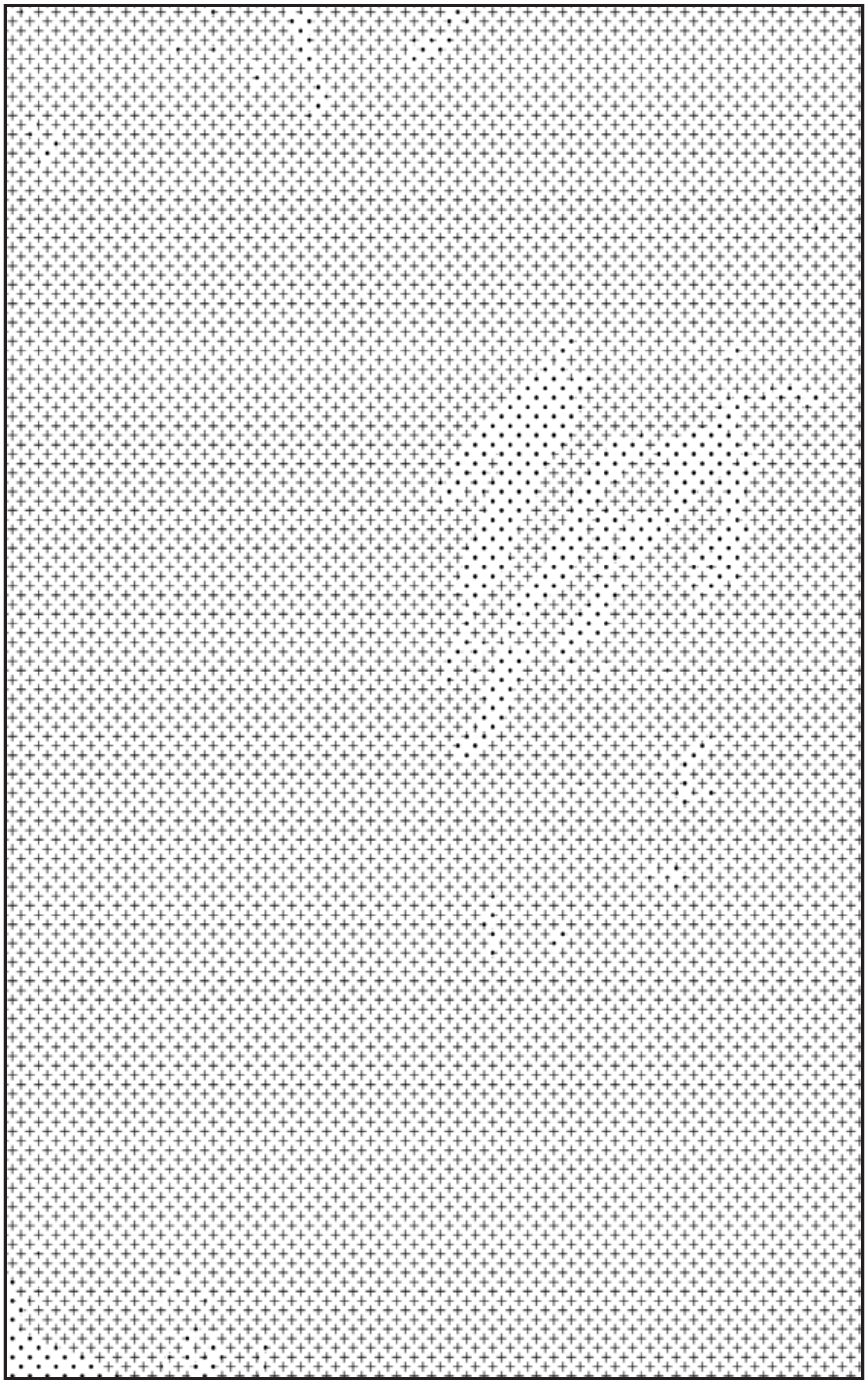
5. NECTARIS FOSSAE

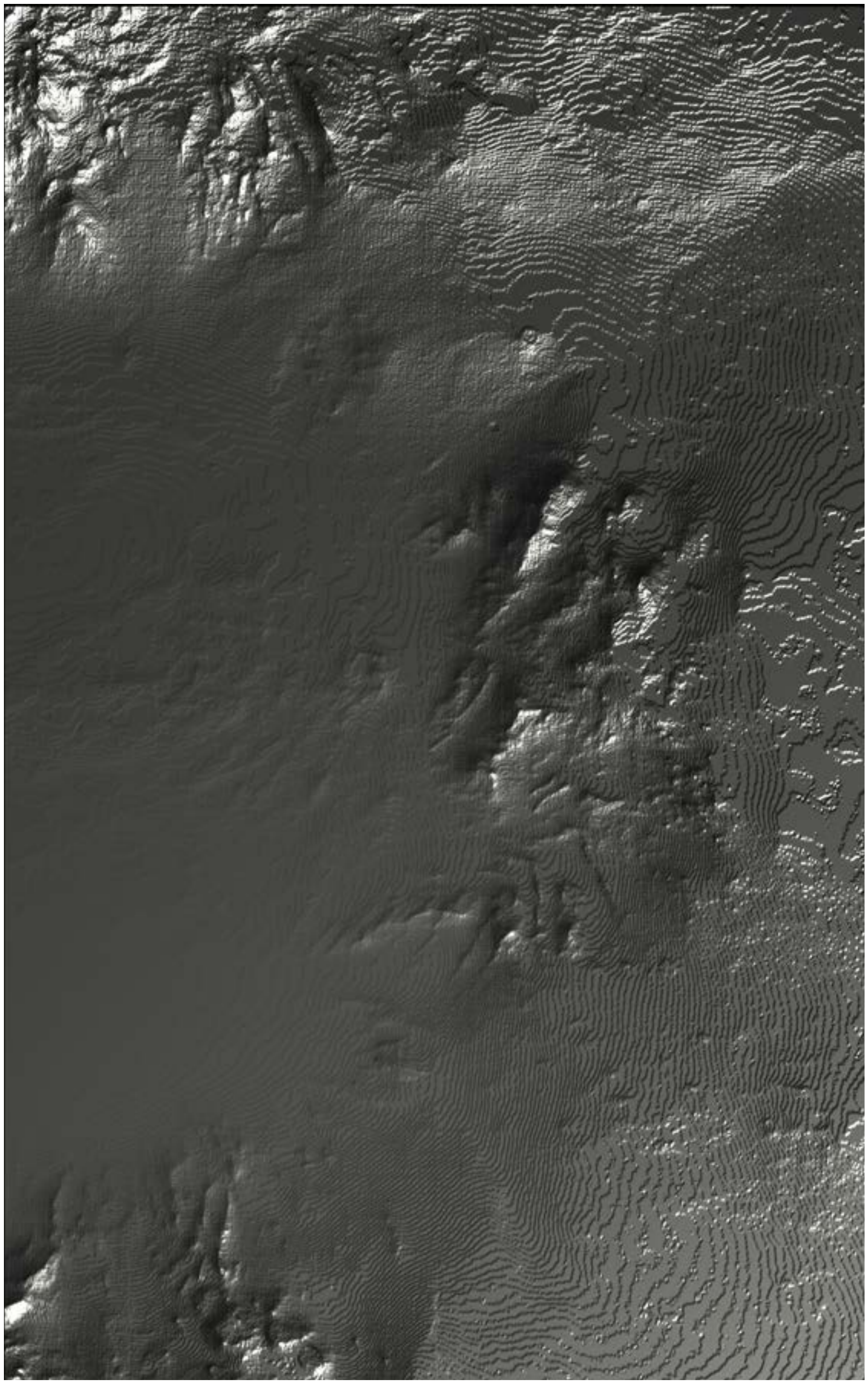
Nectaris Fossae is ancient floodplain featuring a smooth, sandy terrain. It contains sparse 100m wide dunes, small craters, and low hills. Some plains in the southern region are being actively considered for landing sites, as it has ample space and connects to Protva Valles, another potential landing site. The valley networks are thought to have been formed by flowing liquid water. It is a “Proposed Exploration Zone” because of its close proximity to a number of fluvial, volcanic, and impact features as well as sites for potential resource utilization.





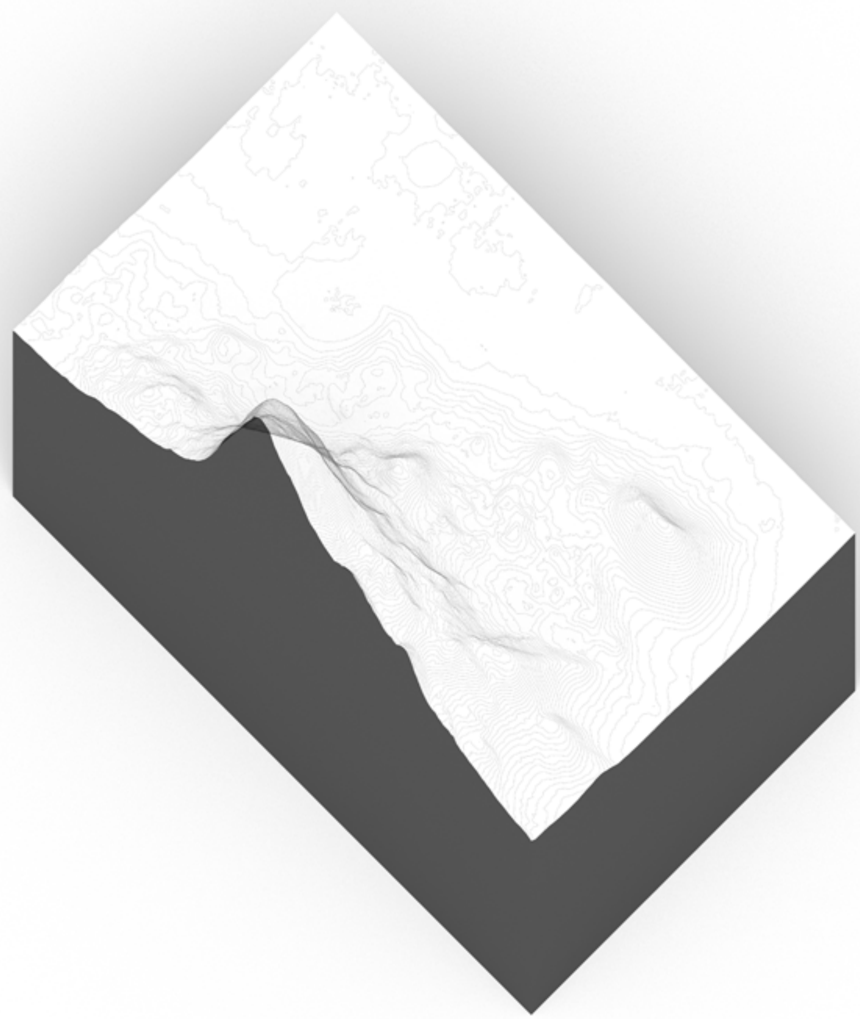


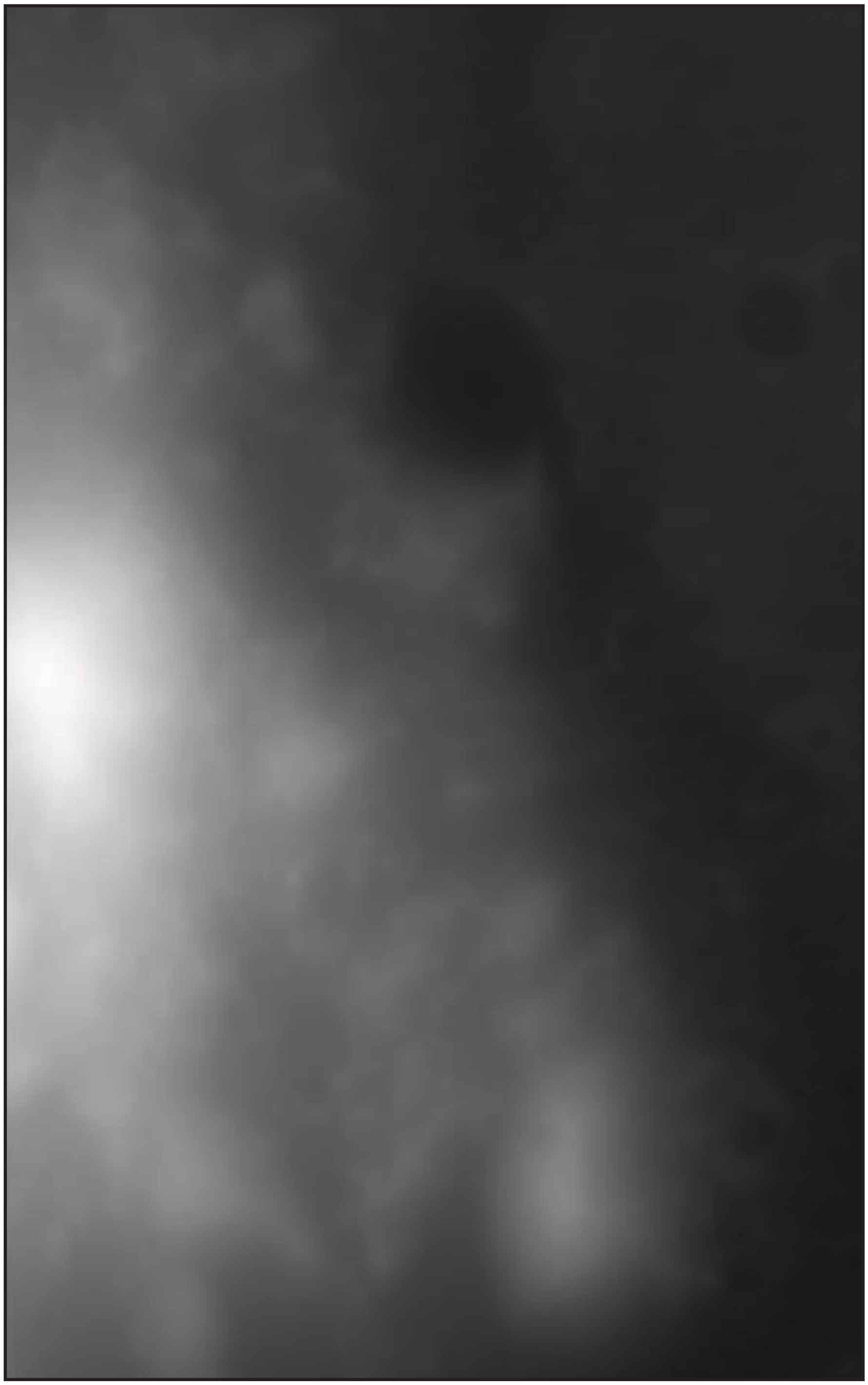


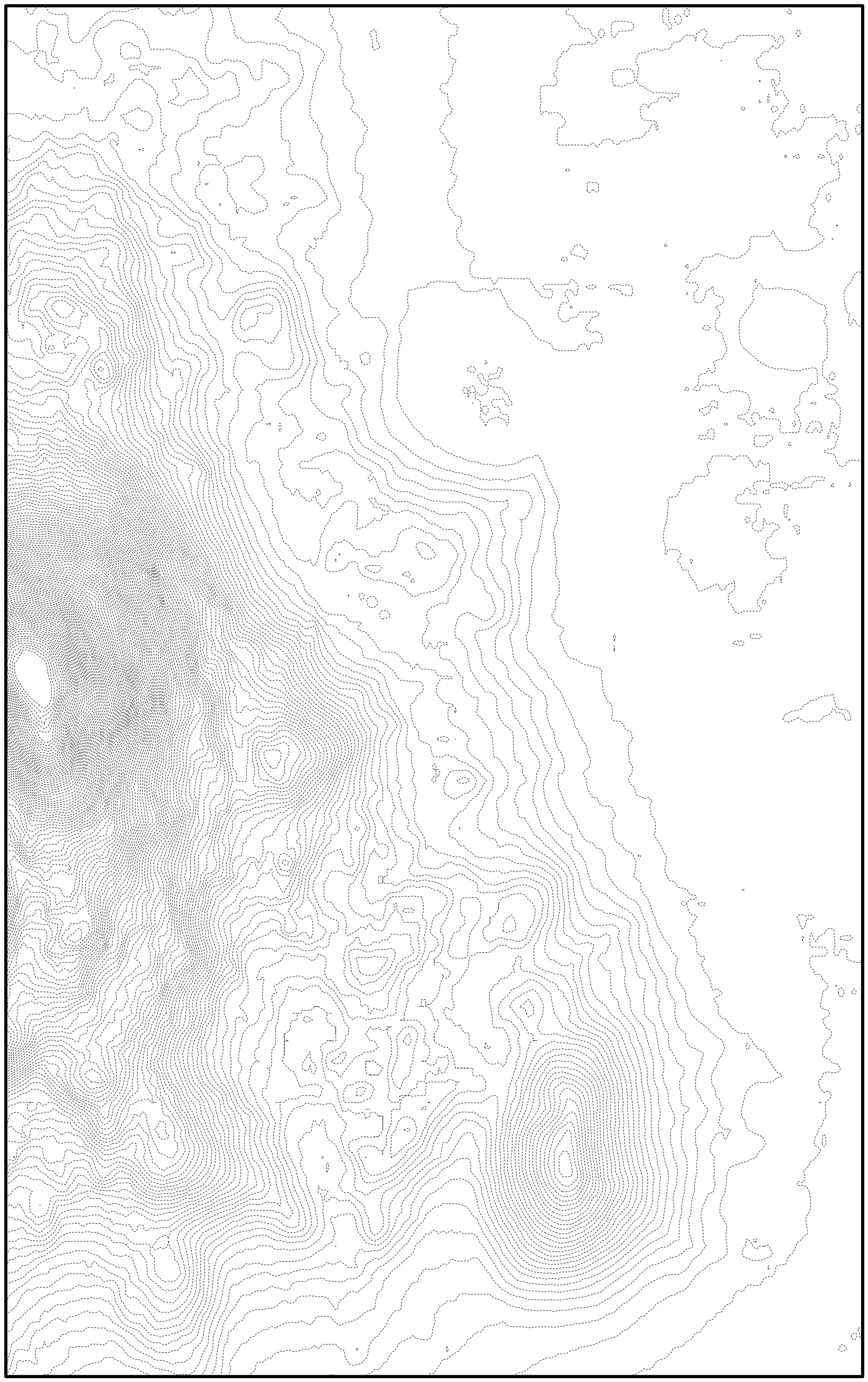


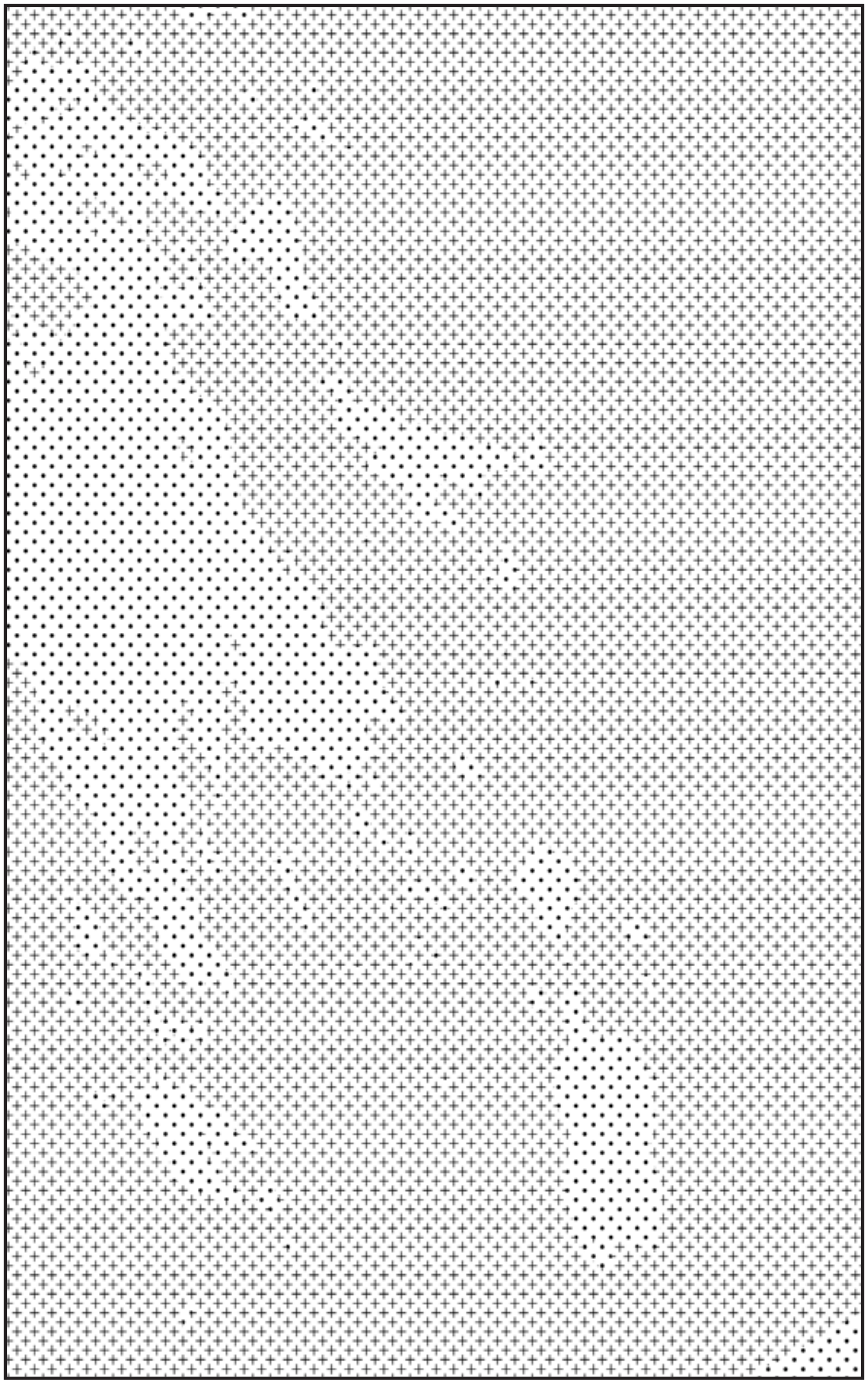
6. TYRRHENA TERRA

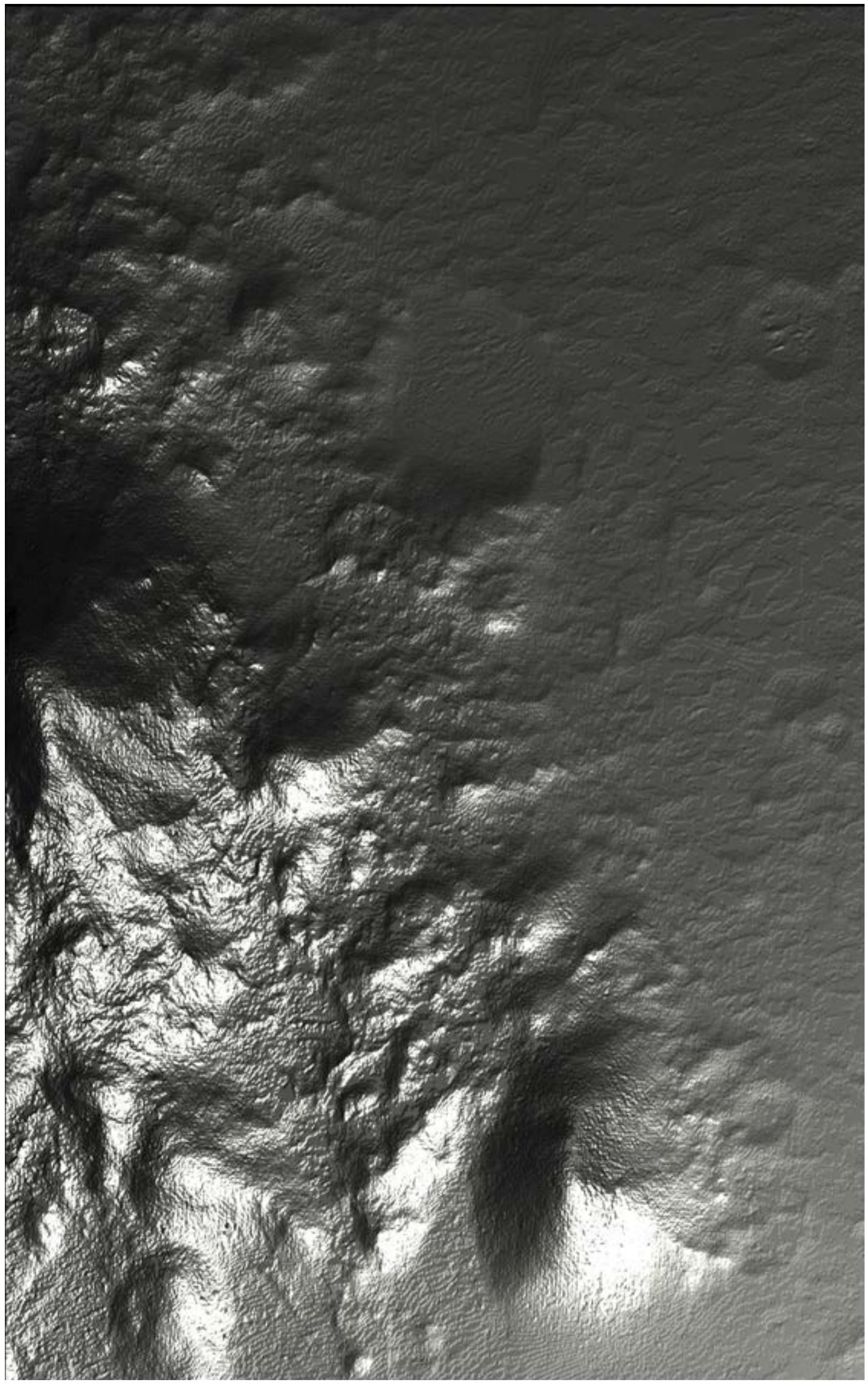
Tyrrhena Terra is a large area on Mars, centered south of the Martian equator and immediately northeast of the Hellas basin. Its coordinates are 14.8°S 90°E, and it covers 2300 km at its broadest extent. It was named for a classic albedo feature of the planet and is in the Mare Tyrrhenum quadrangle of Mars. Tyrrhena Terra is typical of the southern Martian terrae, with heavily cratered highlands and other rugged terrain. It contains the large volcano Tyrrhena Patera, one of the oldest volcanoes on Mars. Its largest crater is Herschel. Licus Vallis and the Ausonia Montes are other major features in the region.





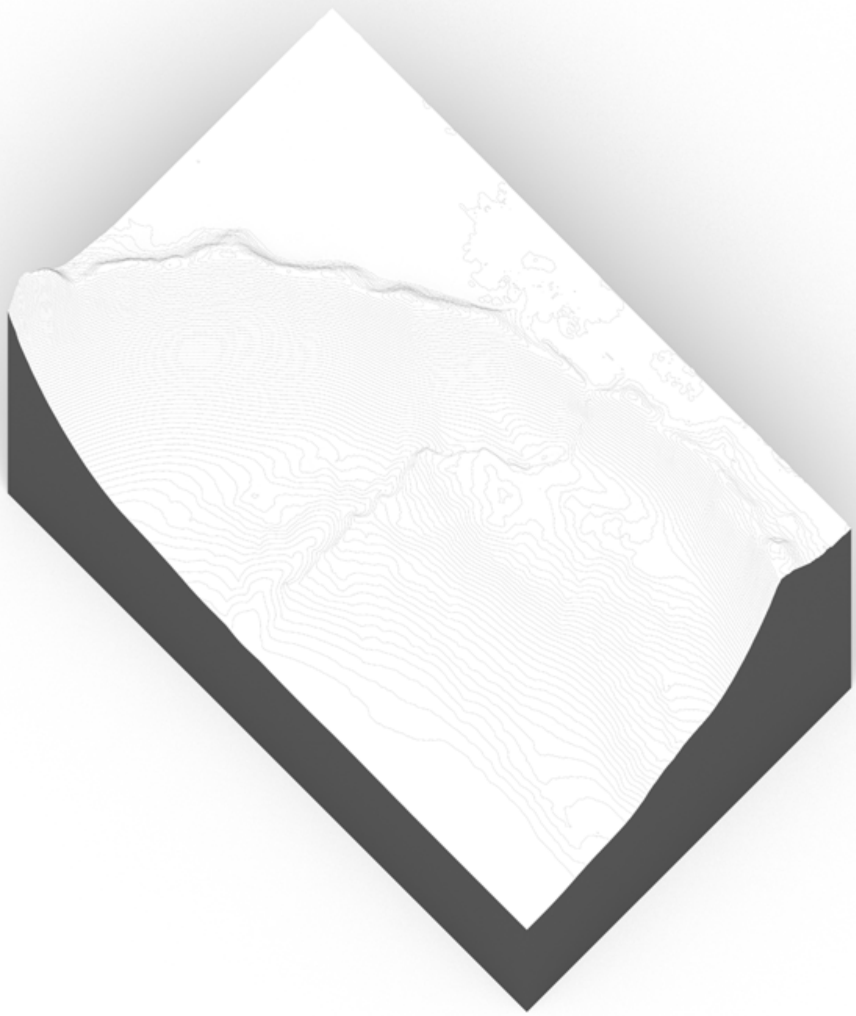


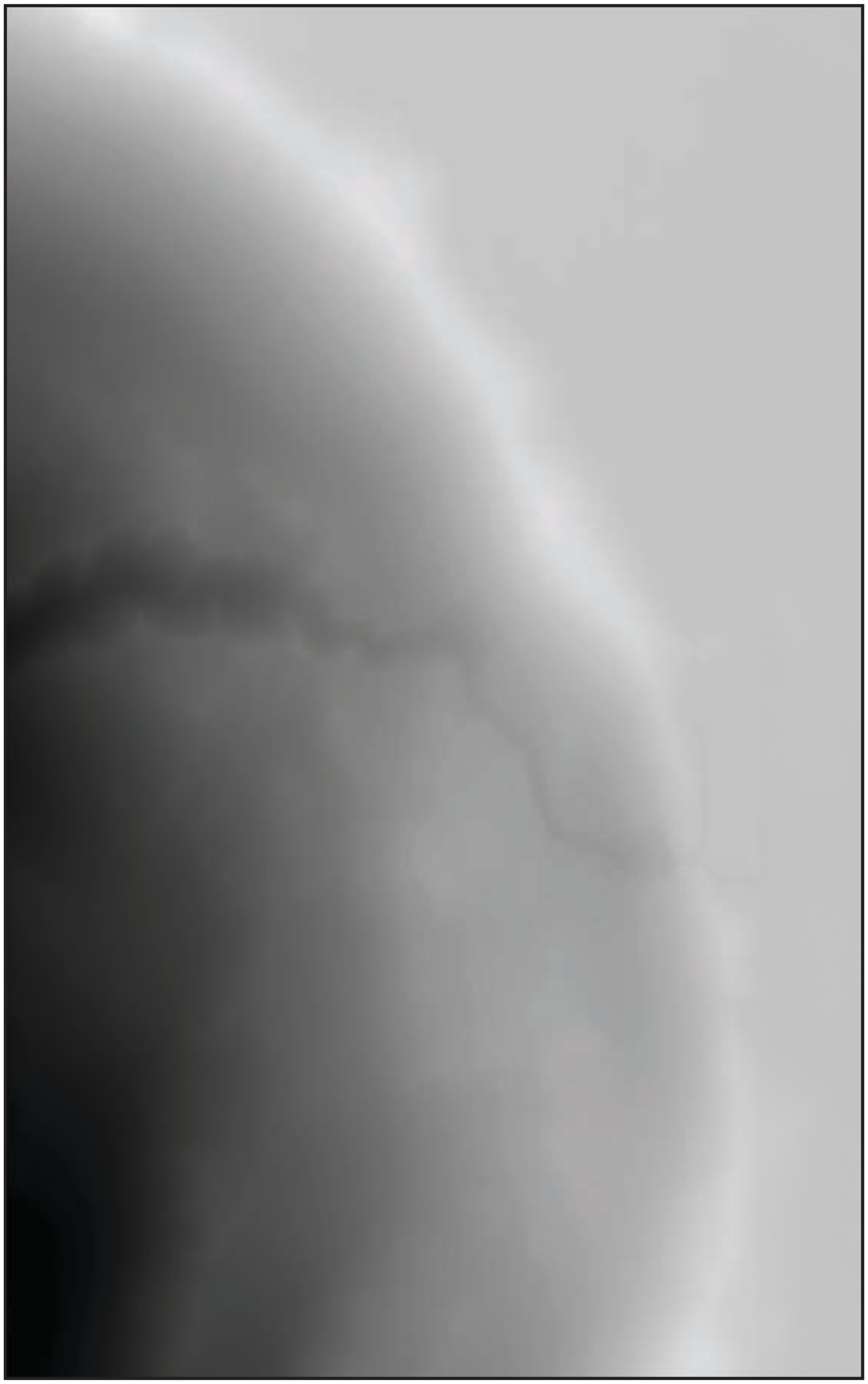


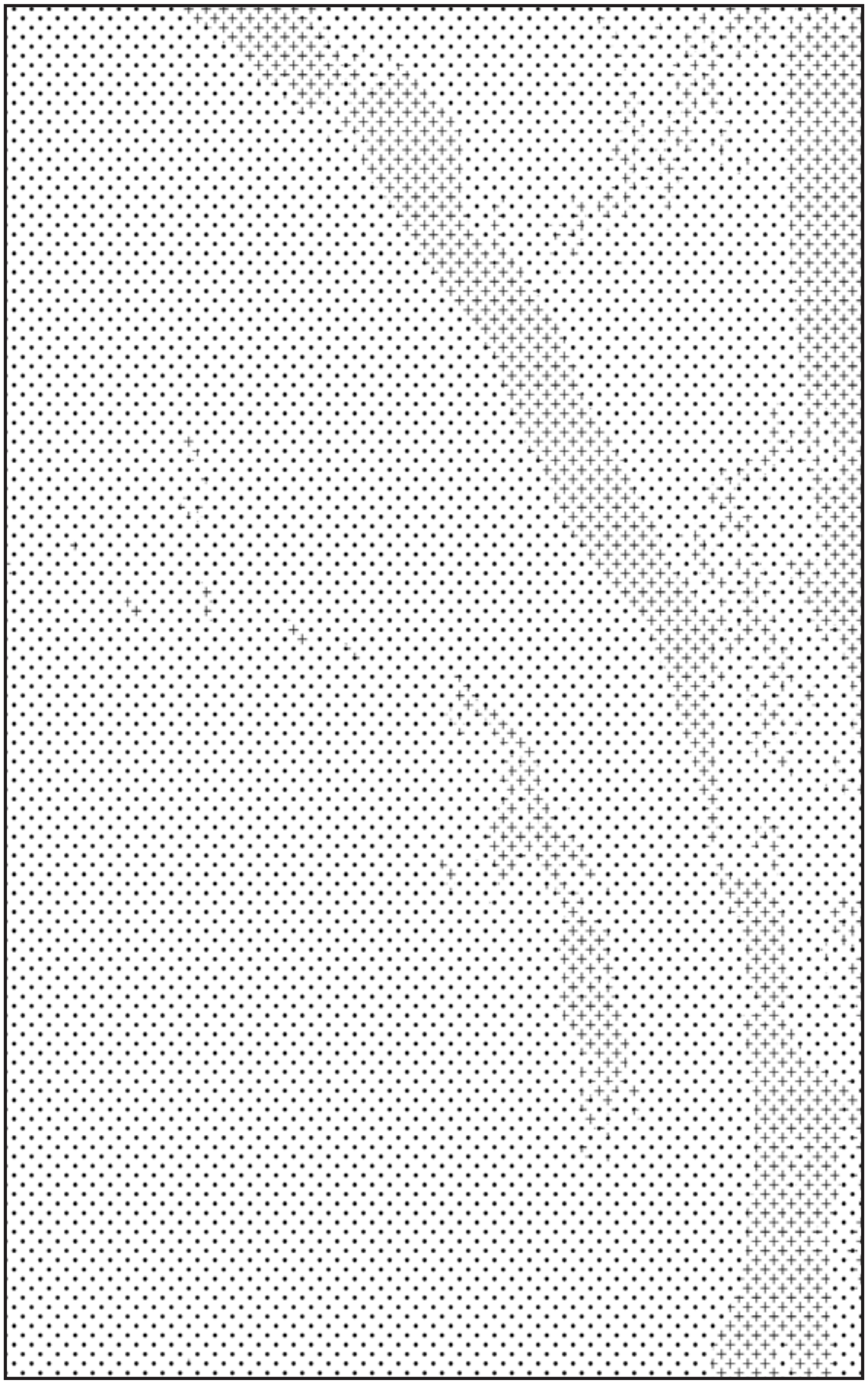


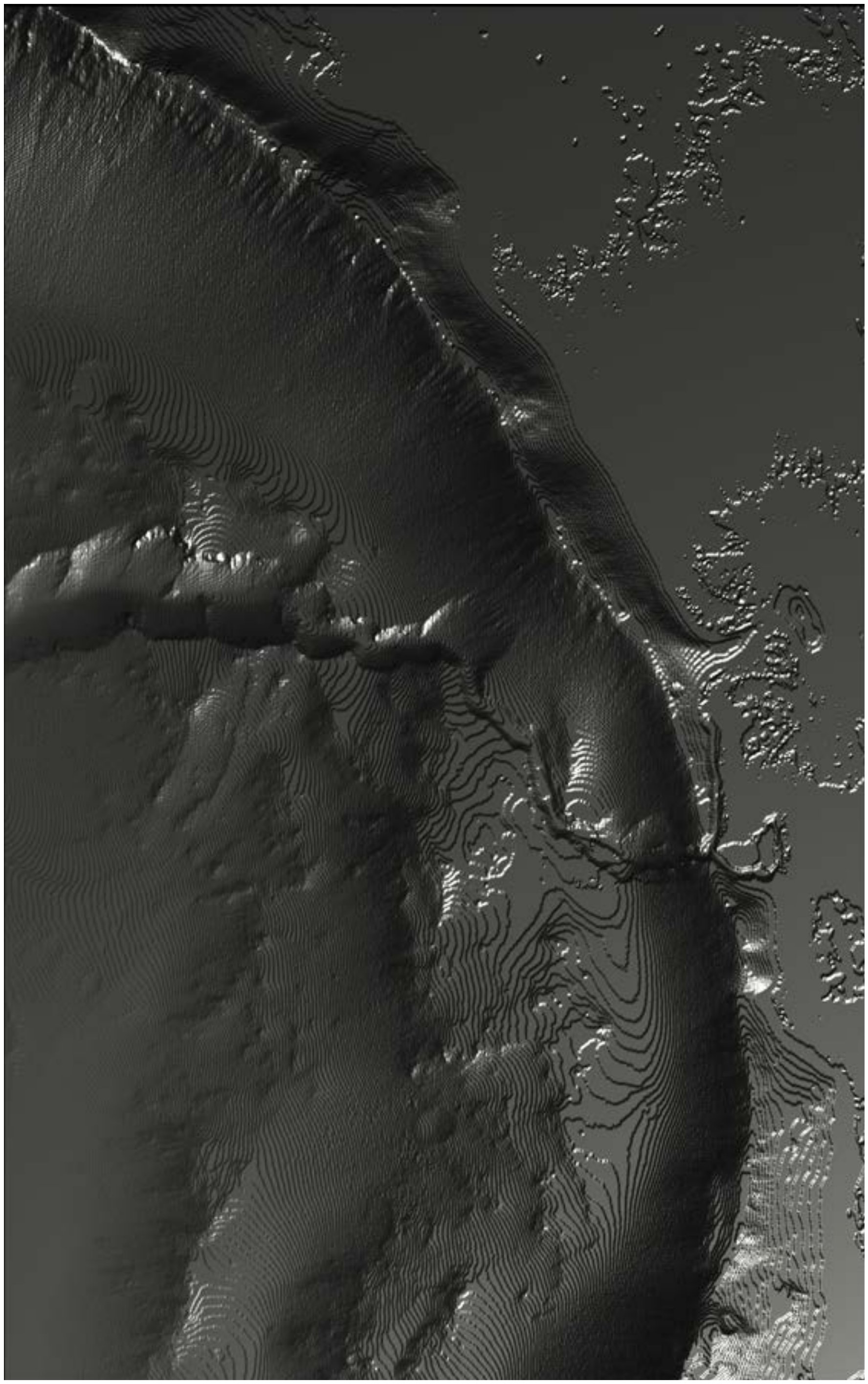
7. TOMBAUGH CRATER

Tombaugh Crater is an impact crater in the Elysium quadrangle of Mars, located at 3.5°N latitude and 198.2°W longitude. It is 60.3 km in diameter and was named after Clyde Tombaugh, American astronomer (1906–1997), and the name was approved in 2006 by the International Astronomical Union Working Group for Planetary System Nomenclature



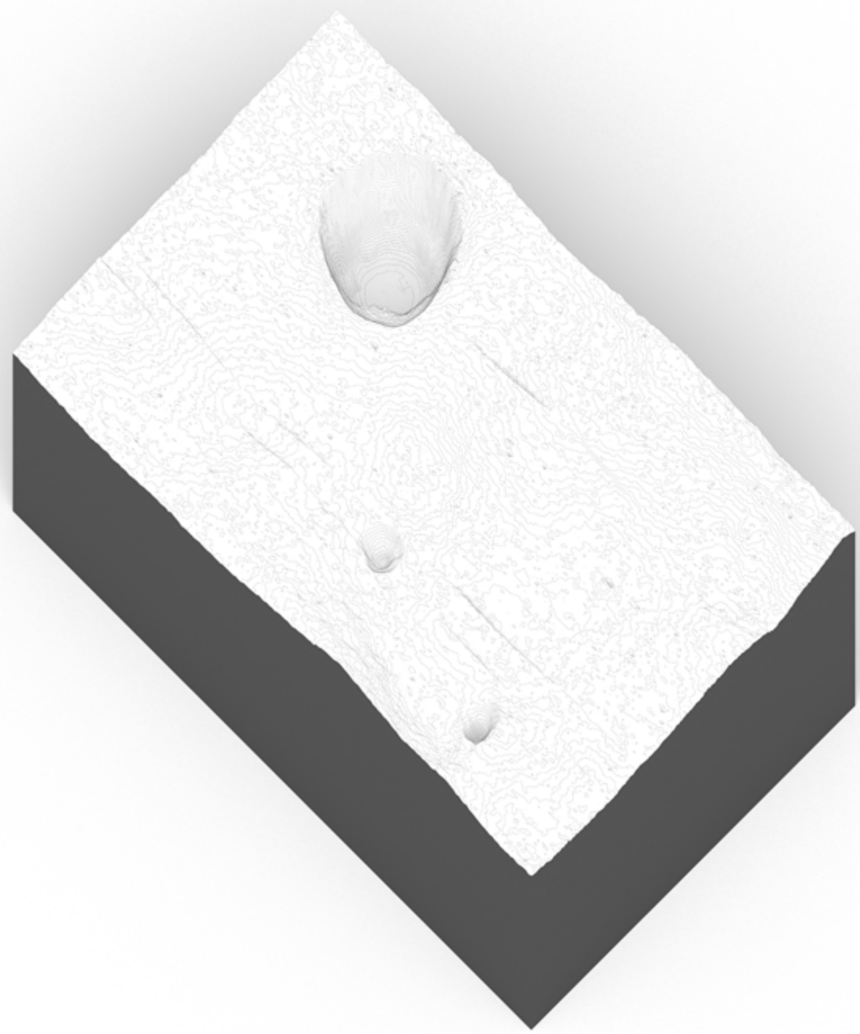


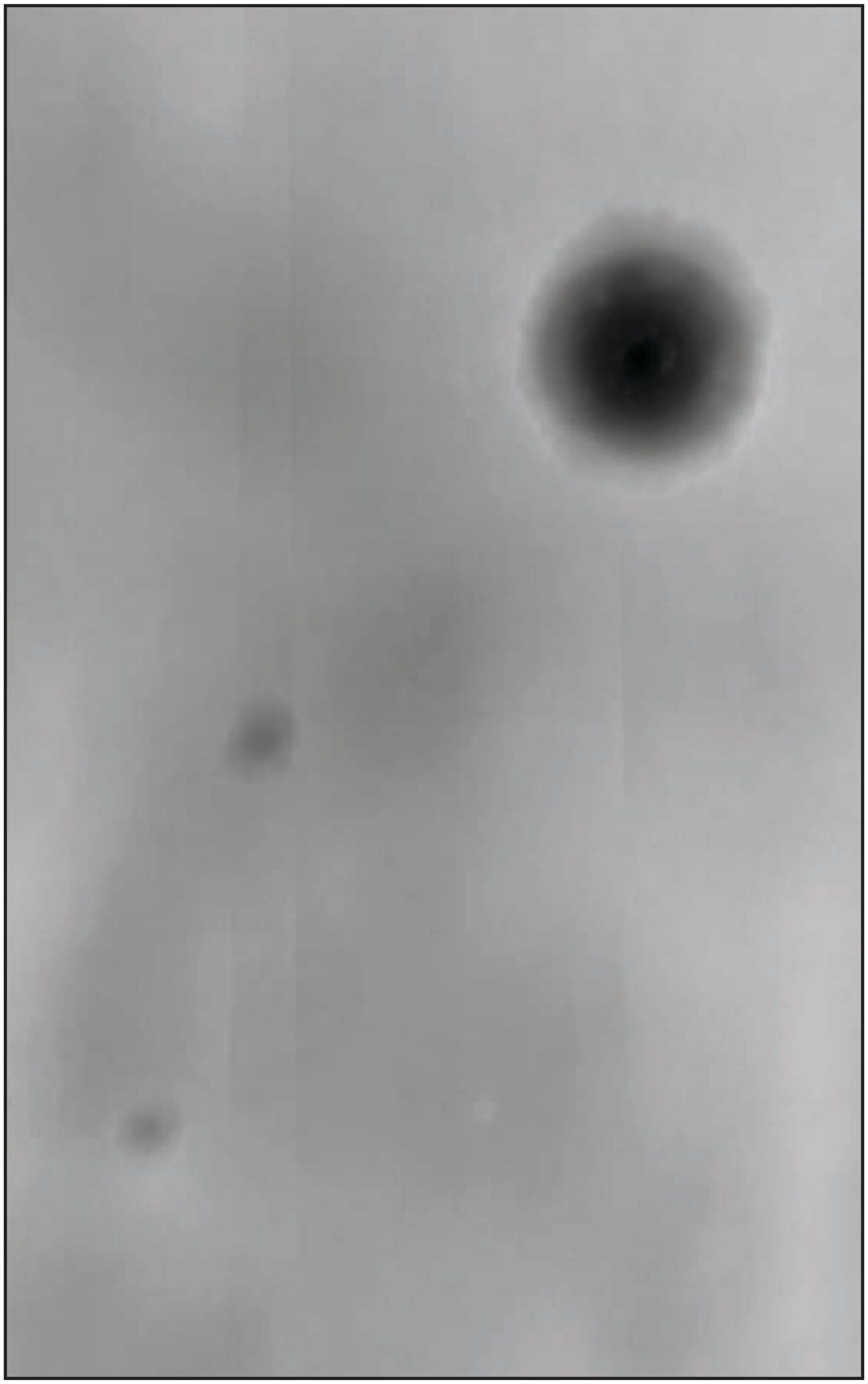


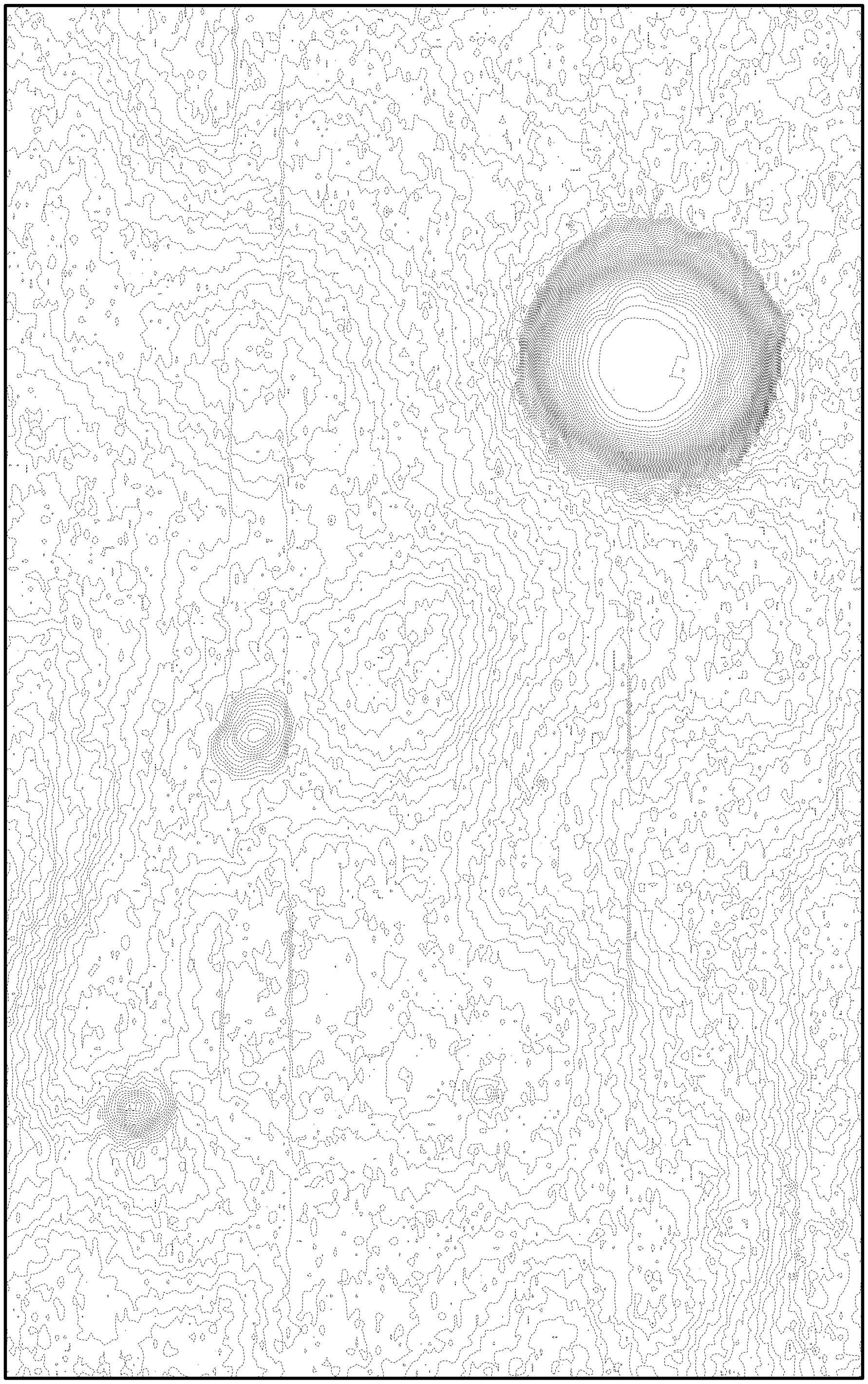


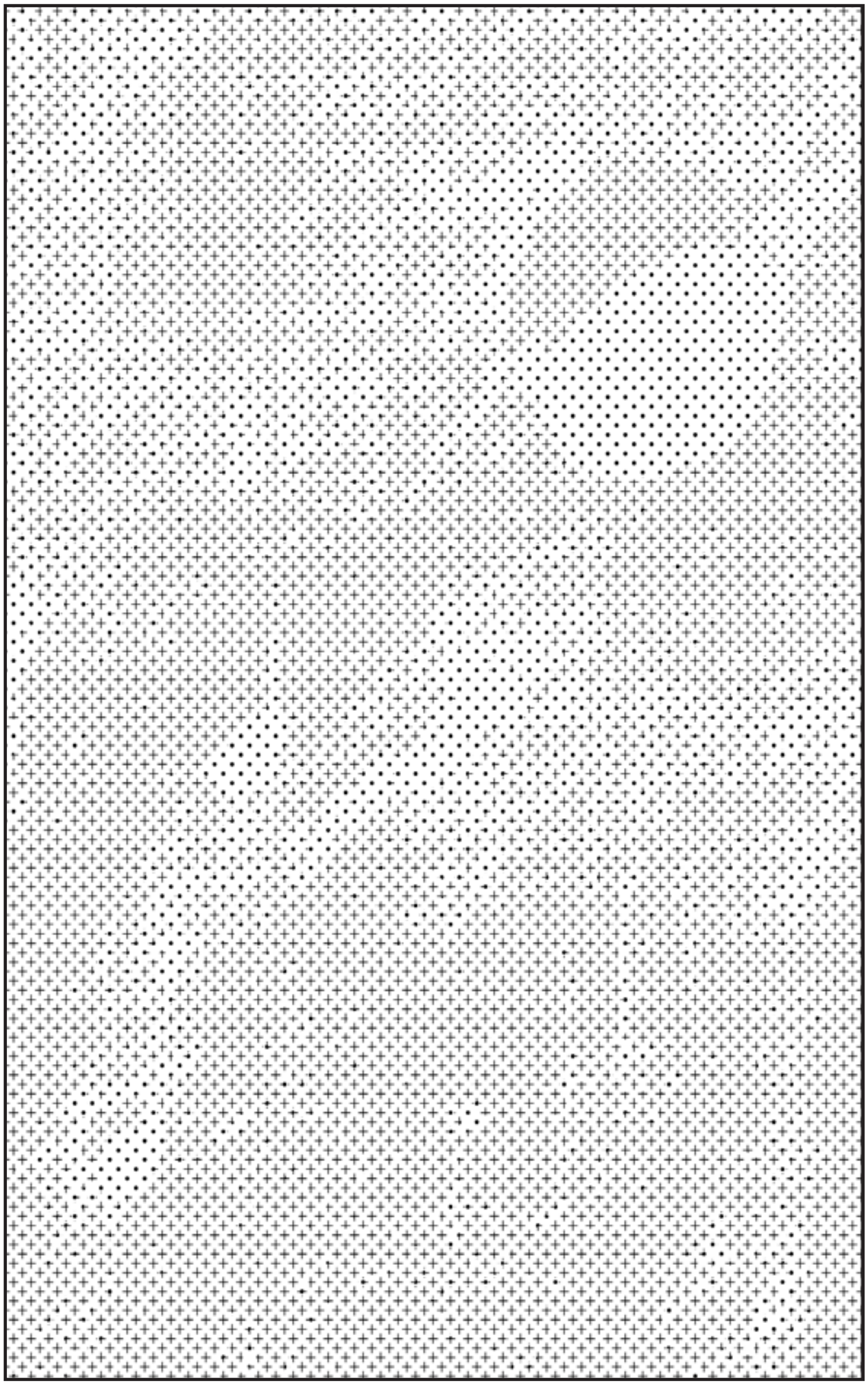
8. ARCADIA PLANITIA

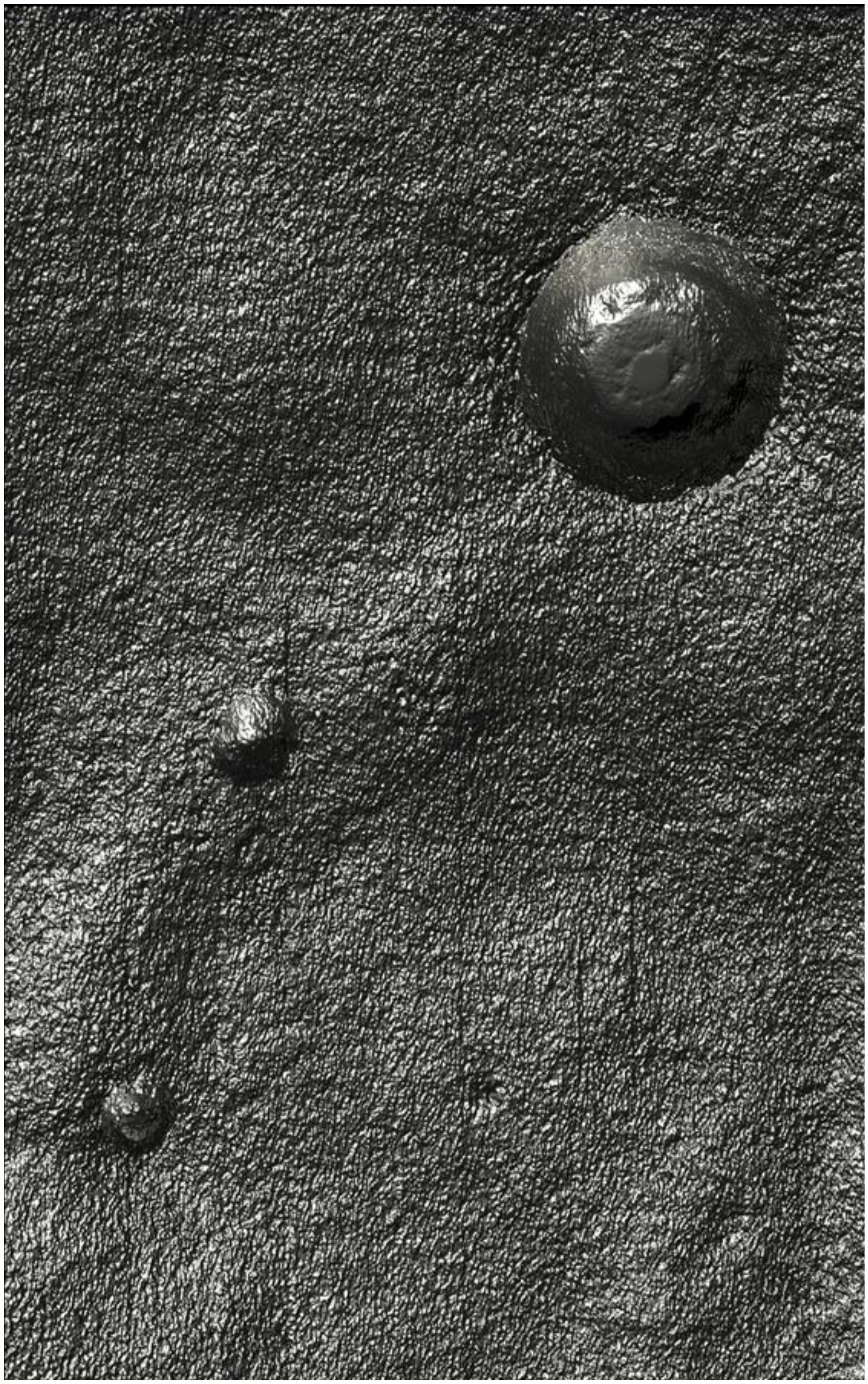
Arcadia Planitia is a smooth plain with fresh lava flows and Amazonian volcanic flows on Mars. It was named by Giovanni Schiaparelli in 1882 after the Arcadia region of ancient Greece. It includes a more recently developed large region of aeolian materials derived from periglacial processes. It is located northwest of the Tharsis region in the northern lowlands, spanning the region 40-60° North and 150-180° West in the Cebrenia quadrangle and centered at 47.2°N 184.3°E. Part of it is in the Diacria quadrangle. Arcadia marks a transition from the thinly cratered terrain to its north and the very old cratered terrain to the south. On its east it runs into the Alba Mons volcanoes. Its elevation relative to the geodetic datum varies between 0 and -3 km.
In a lot of the low areas, one finds grooves and sub-parallel ridges. These indicate movement of near surface materials and are similar to features on earth where near surface materials flow together very slowly as helped by the freezing and thawing of water located between ground layers.





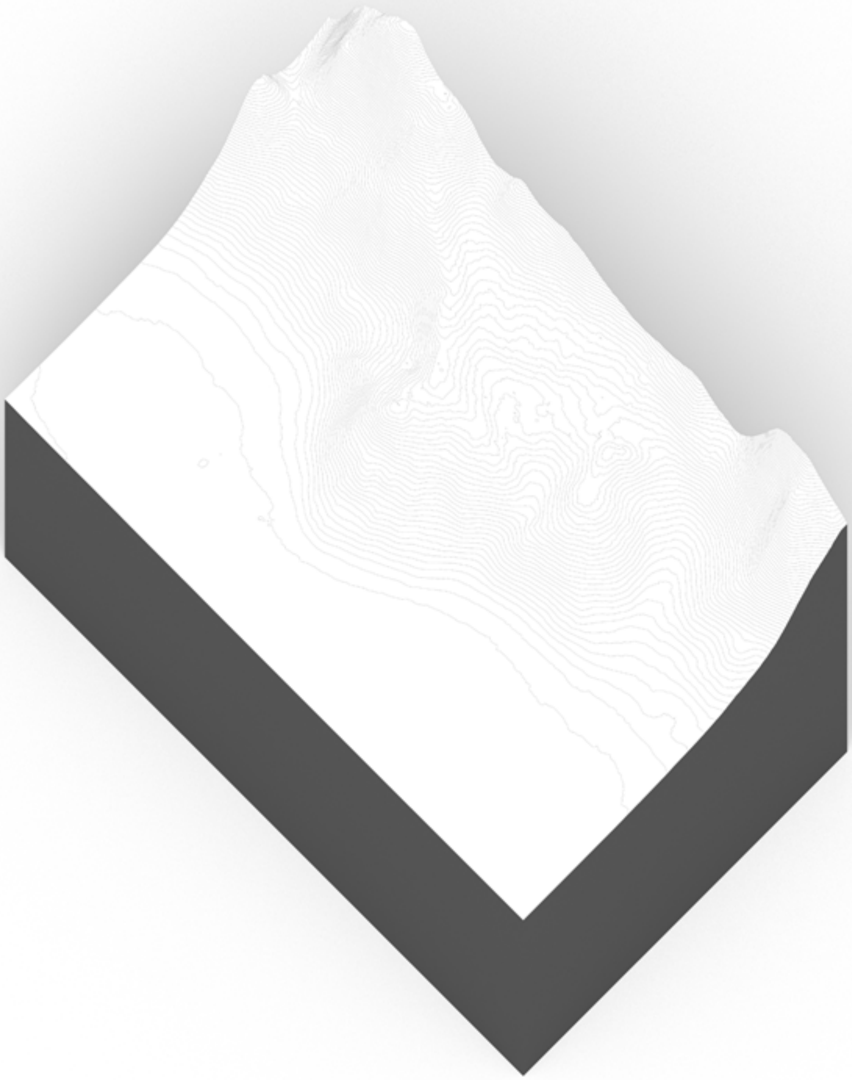


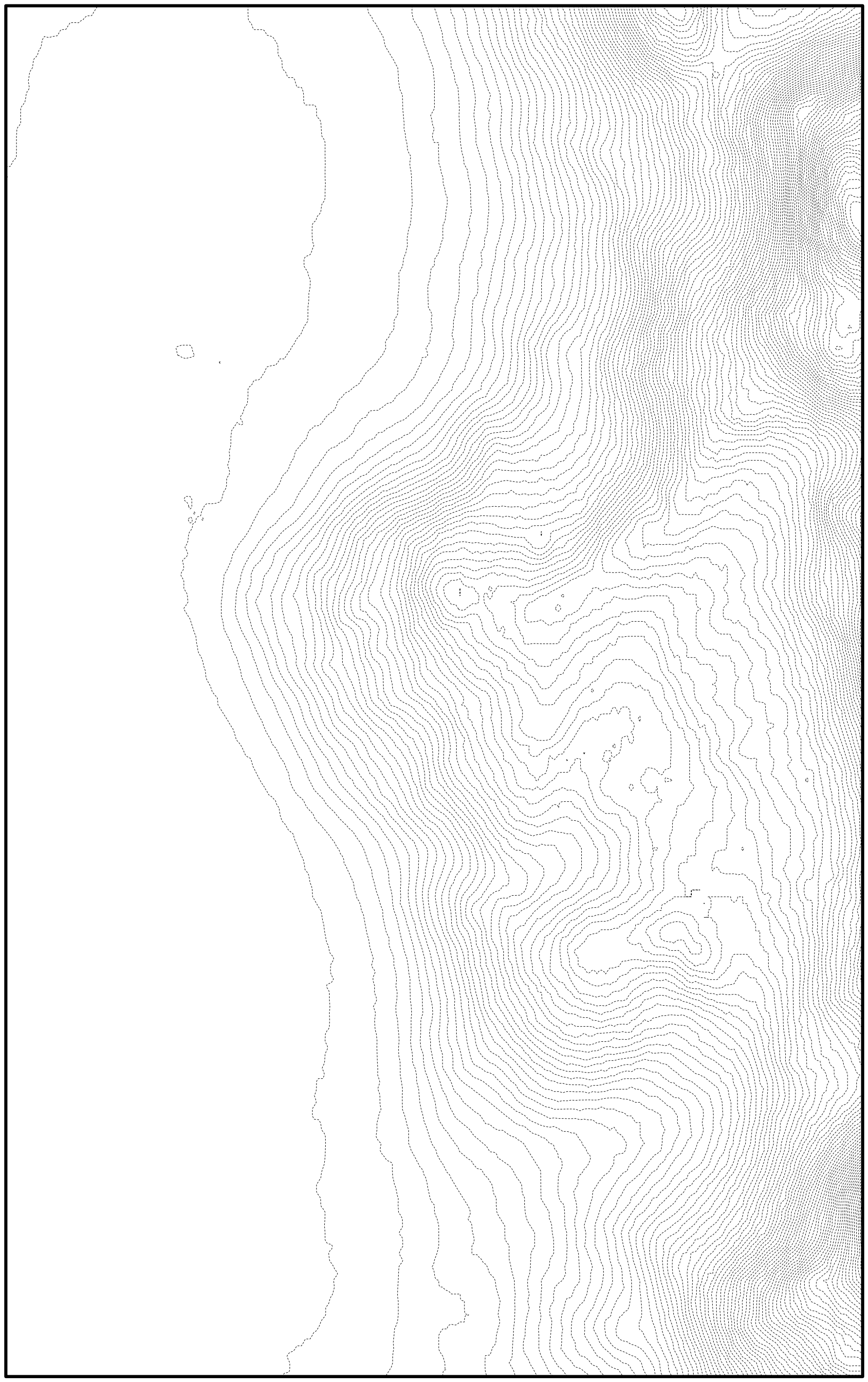


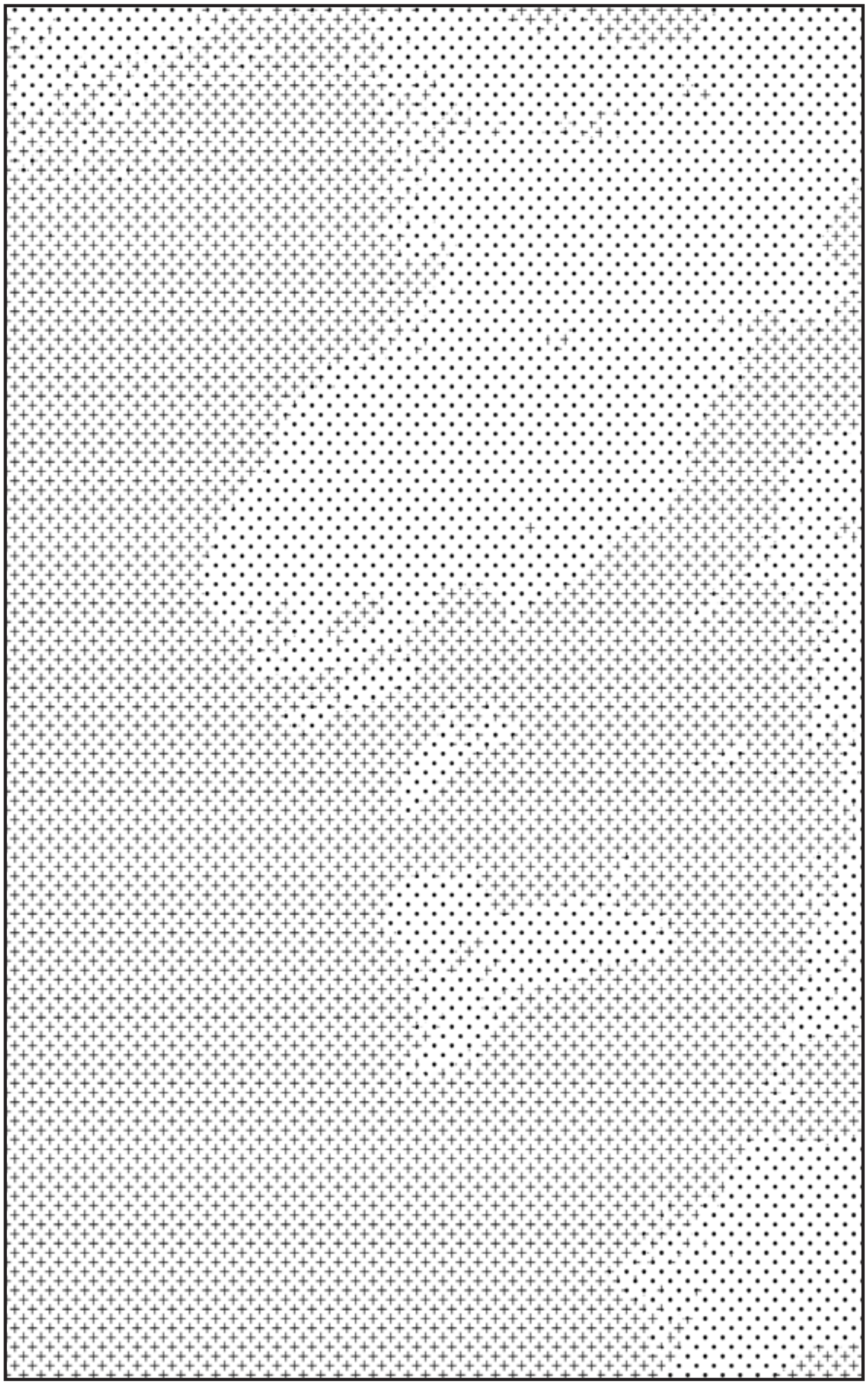


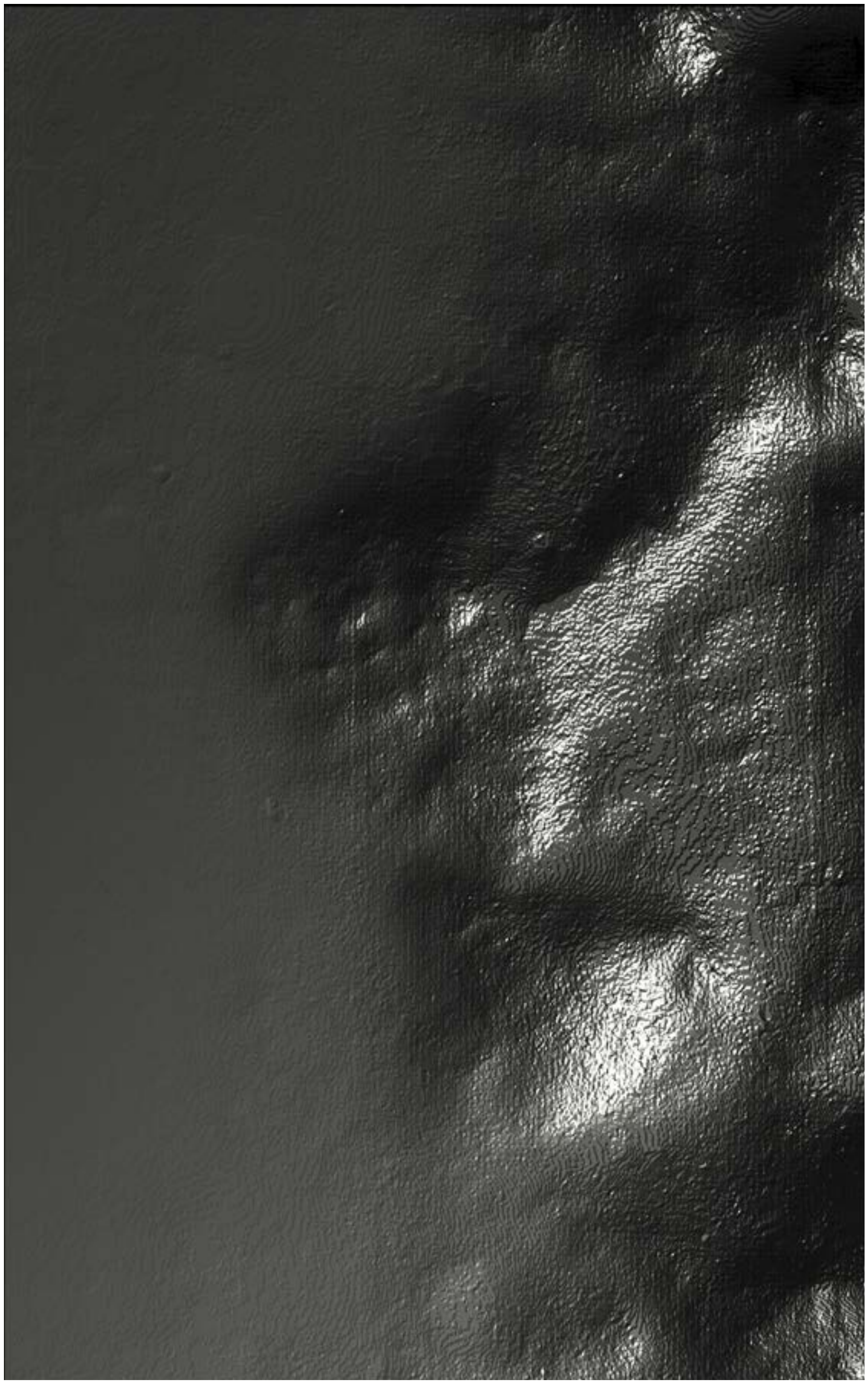
9. MARTH CRATER

Marth Crater is an impact crater in the Oxia Palus quadrangle on Mars at 13.0° N and 3.5° W. and is 98.4 km in diameter. Its name was approved in 1973, and it was named after Albert Marth. Light and dark markings on the surface are due to dust and sand blown around. Some of the dark sand has formed into dunes. The terrain is hummocky and rolling, punctuated by smaller impact craters and wind-blown drifts of sand or dust.



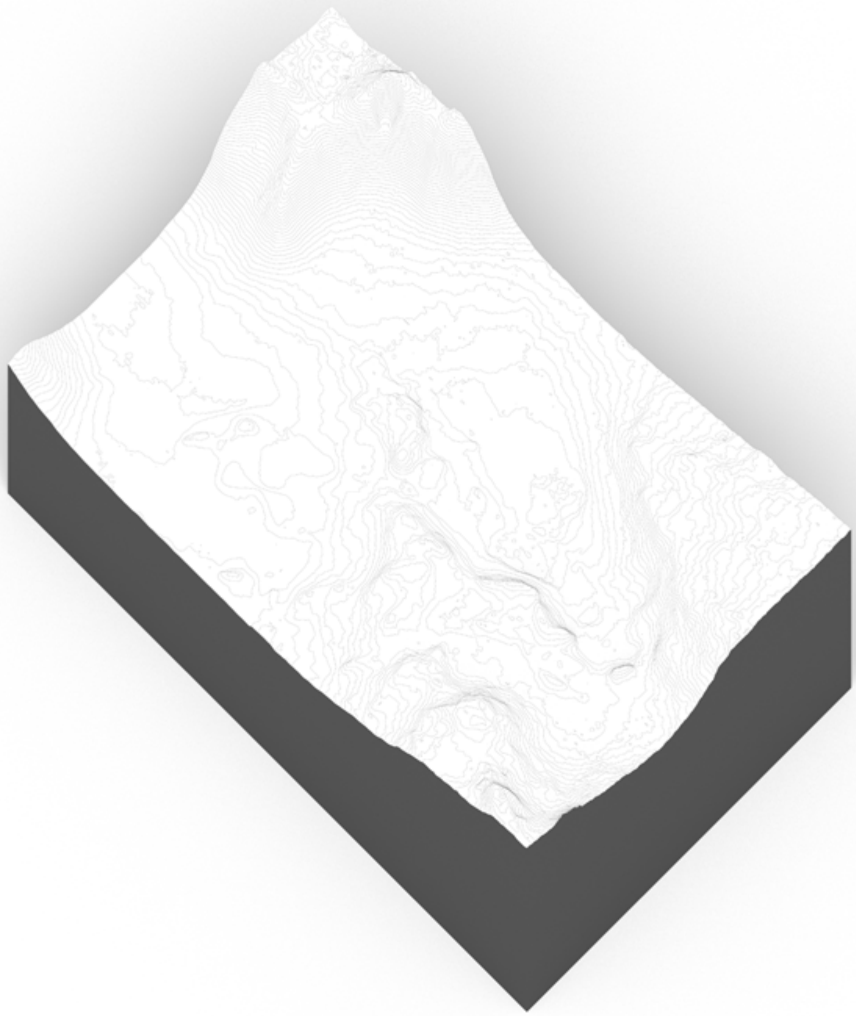


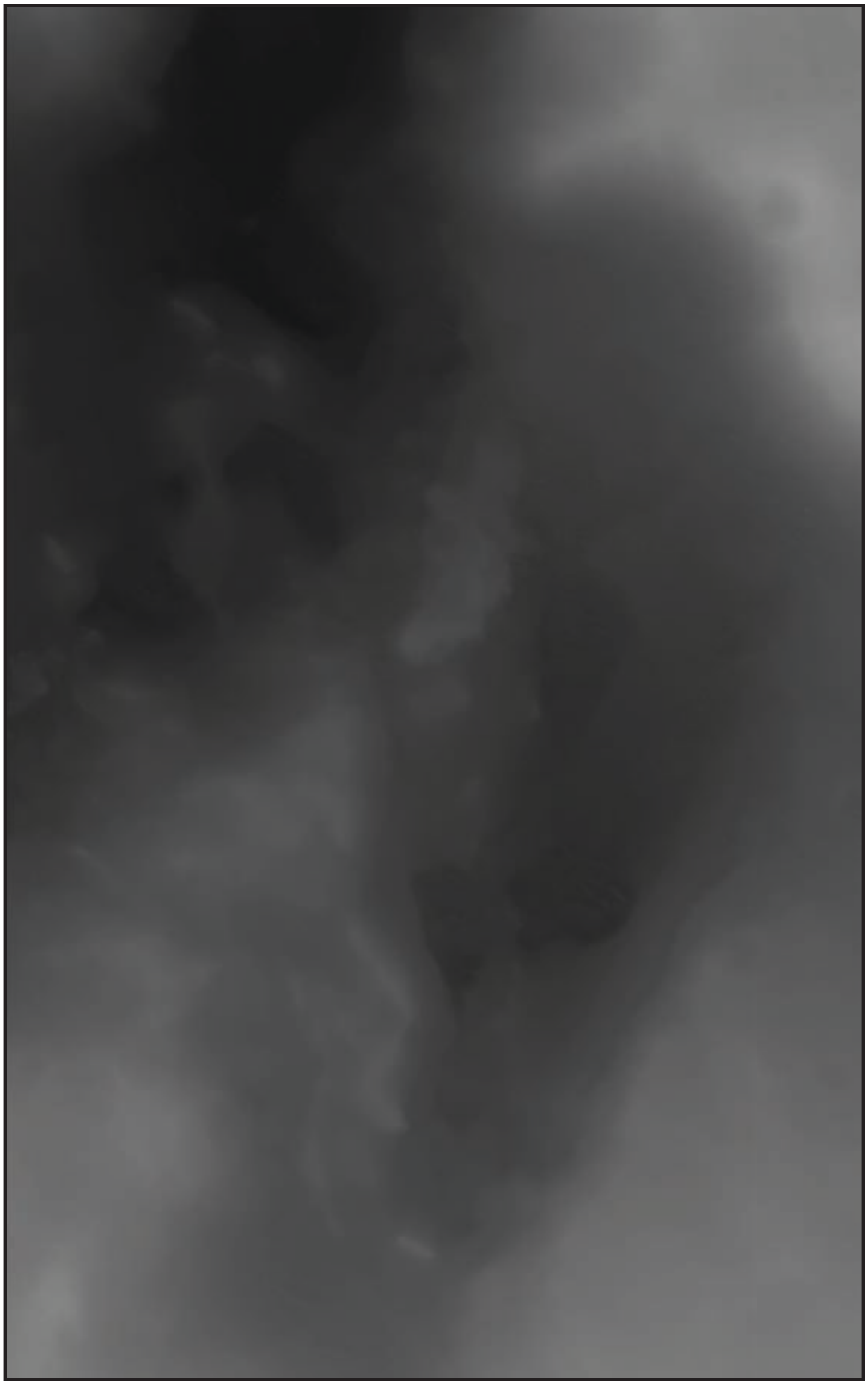


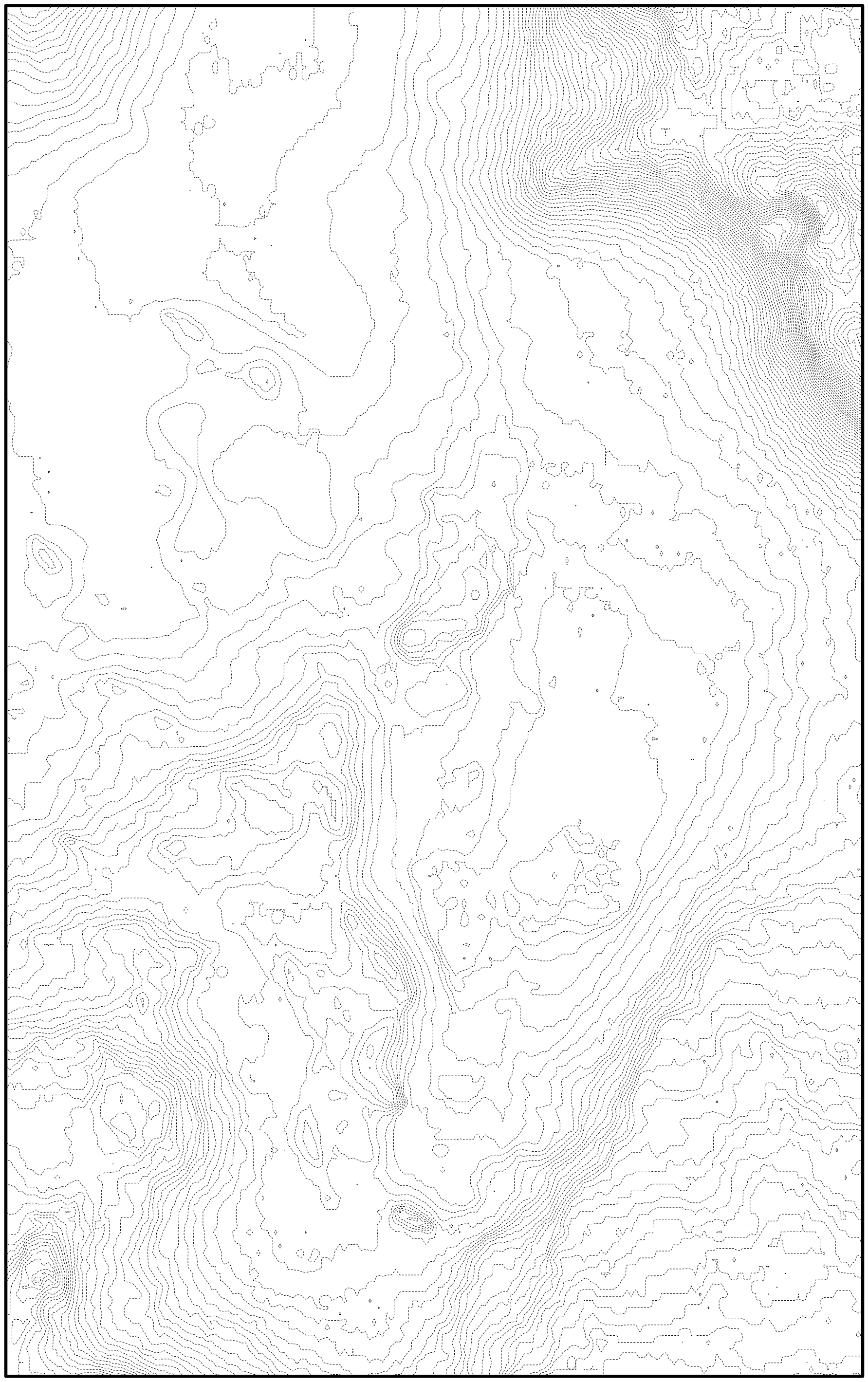


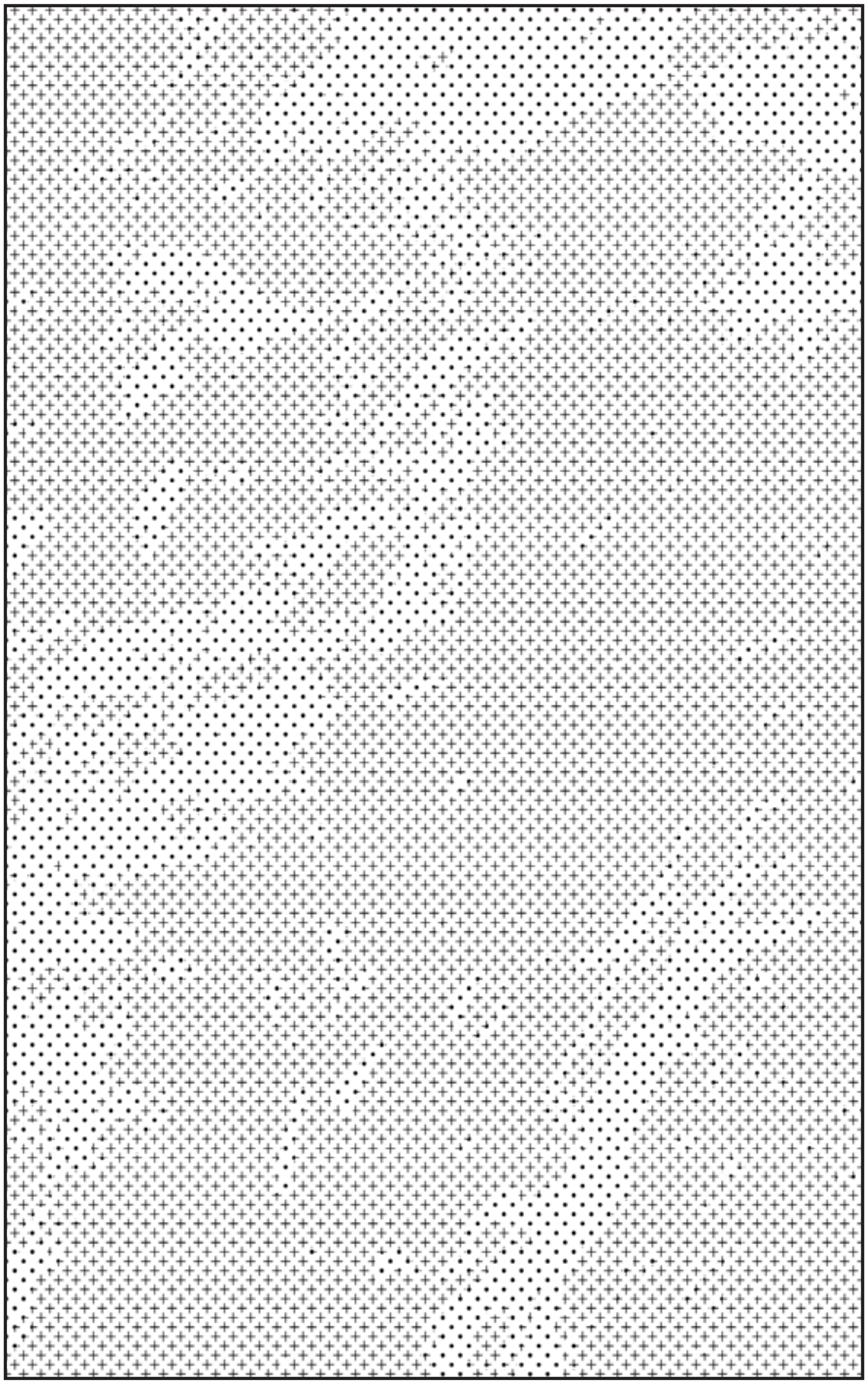
10. LADON VALLES

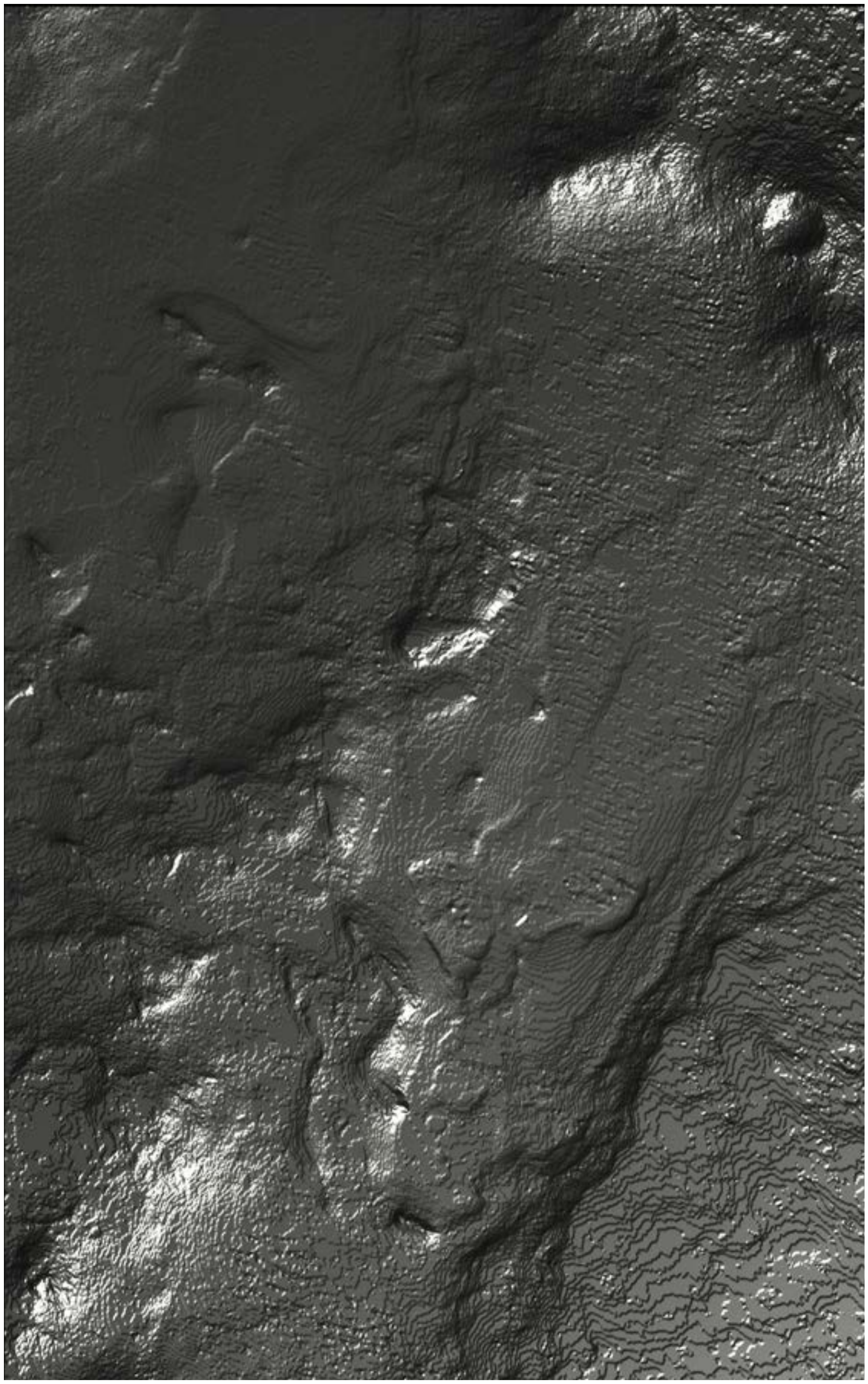
Ladon Valles is a river valley lying within the Margaritifer Sinus quadrangle region of the planet Mars located at 22.6° South and 28.7° West. It is 278 km long and was named after an ancient name for a Greek river. It has been argued that Uzboi, Ladon, Margaritifer and Ares Valles, although now separated by large craters, once comprised a single outflow channel flowing north into Chryse Planitia. The source of this outflow has been suggested as overflow from the Argyre crater, formerly filled to the brim as a lake by channels (Surius, Dzigai, and Palacopus Valles) draining down from the south pole. If real, the full length of this drainage system would be over 8000 km, the longest known drainage path in the solar system.







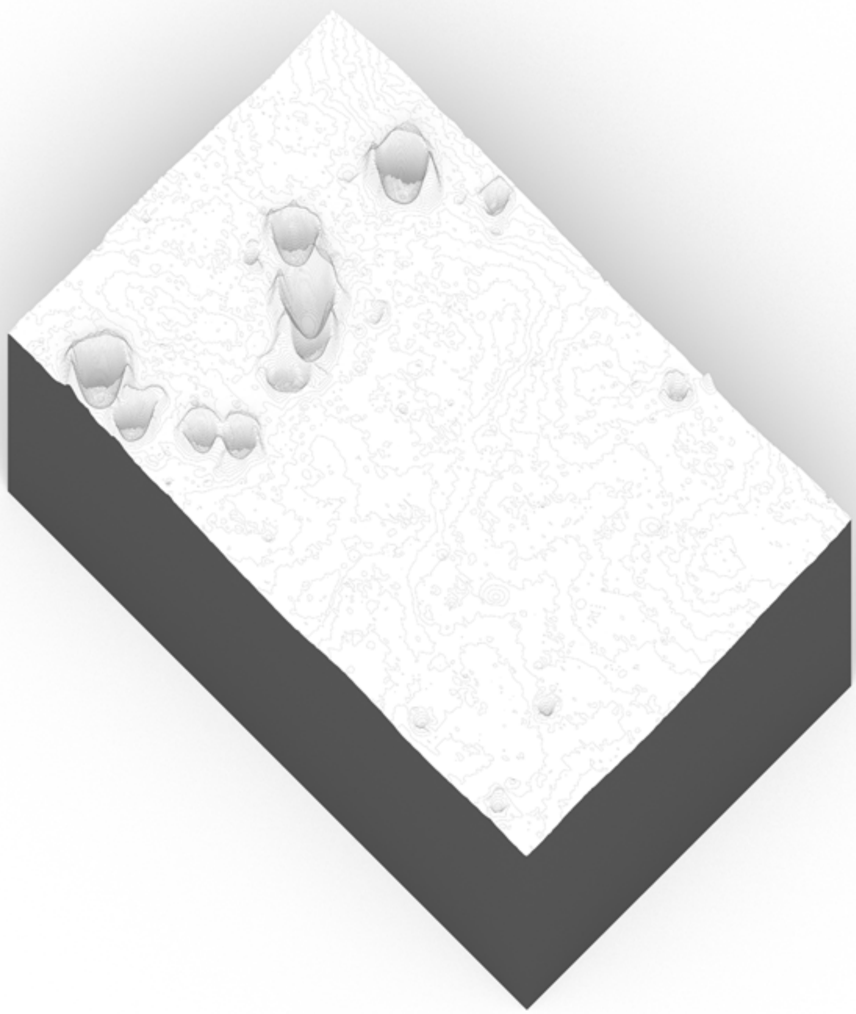


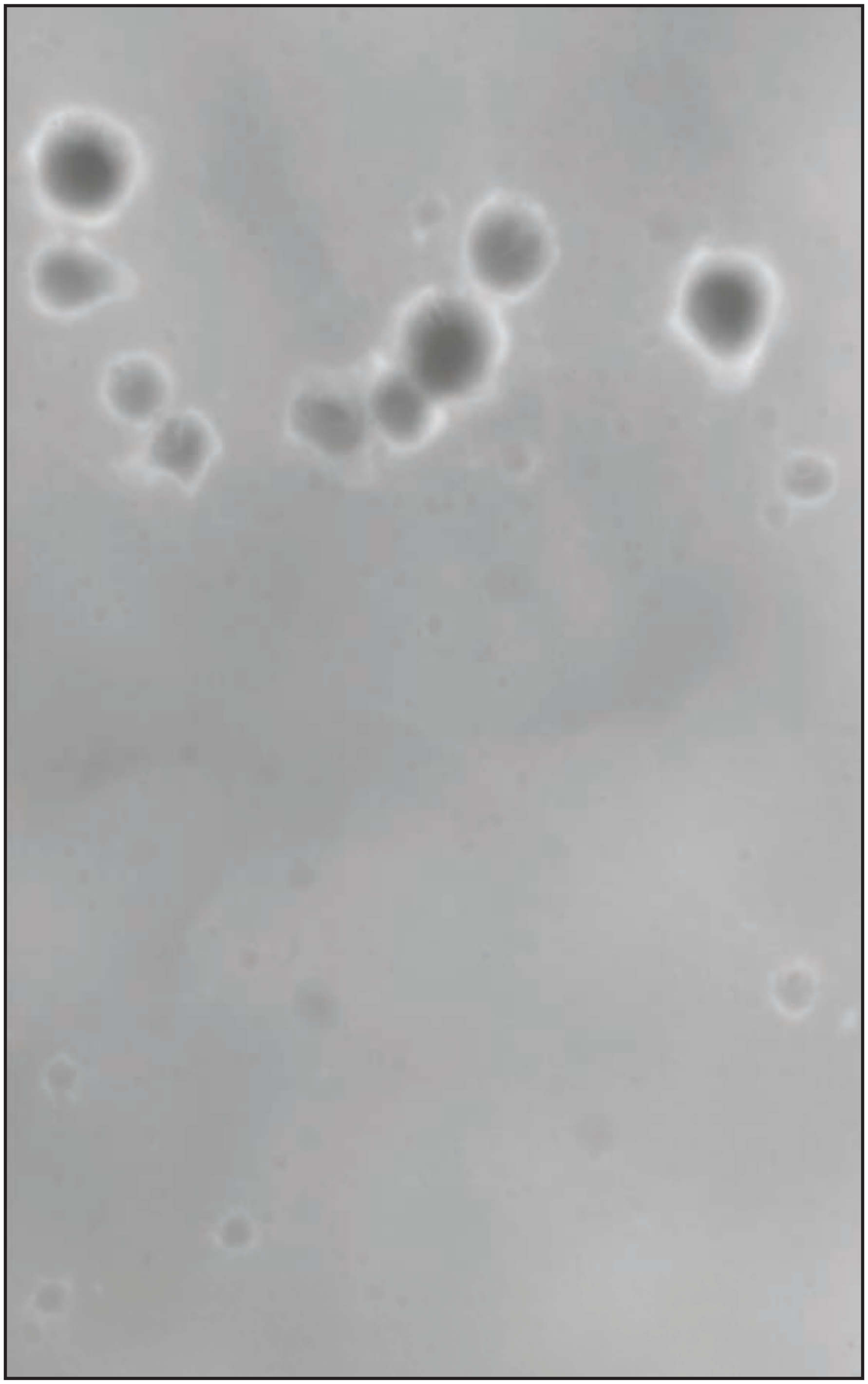


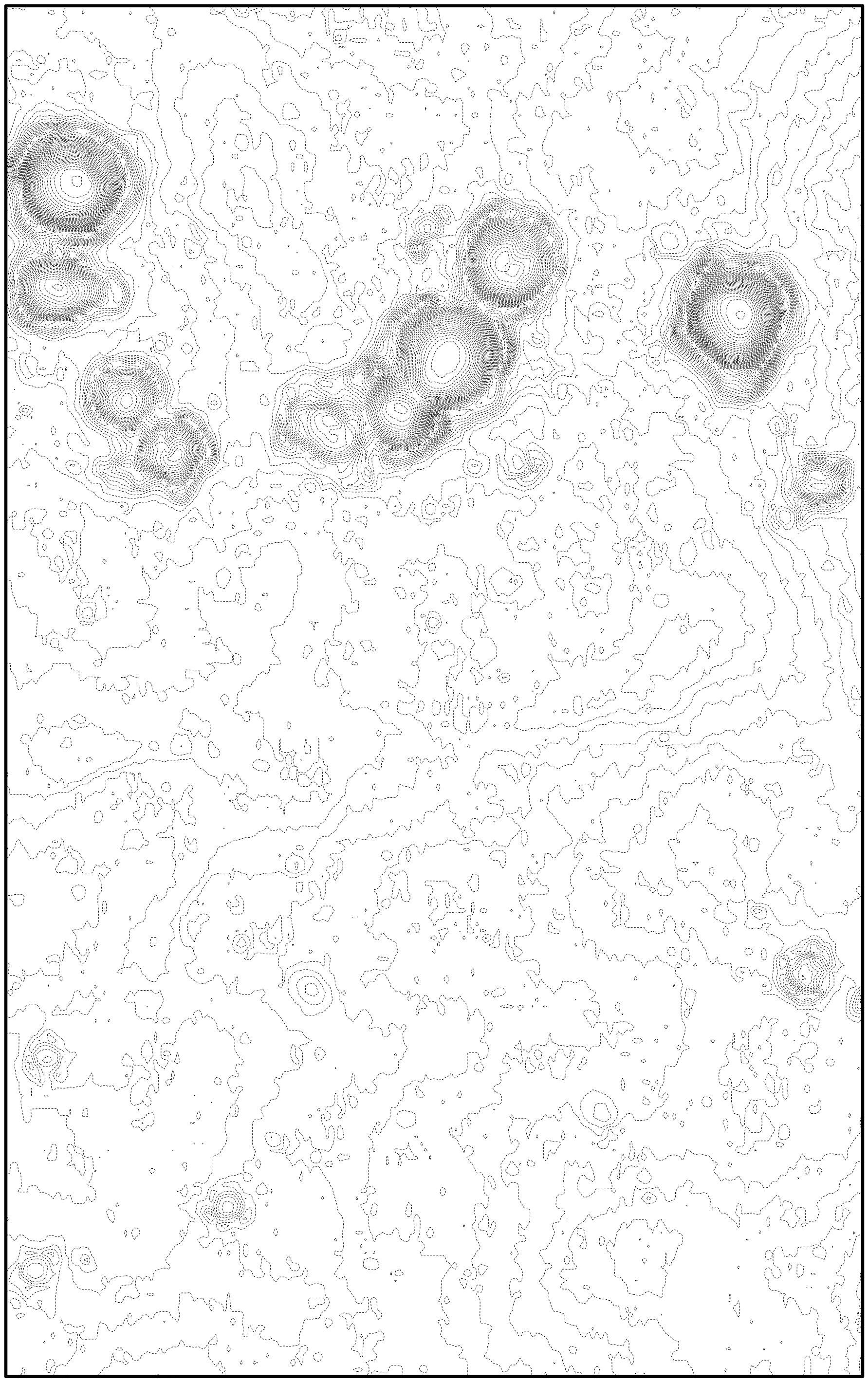
11. ACIDALIA PLANITIA

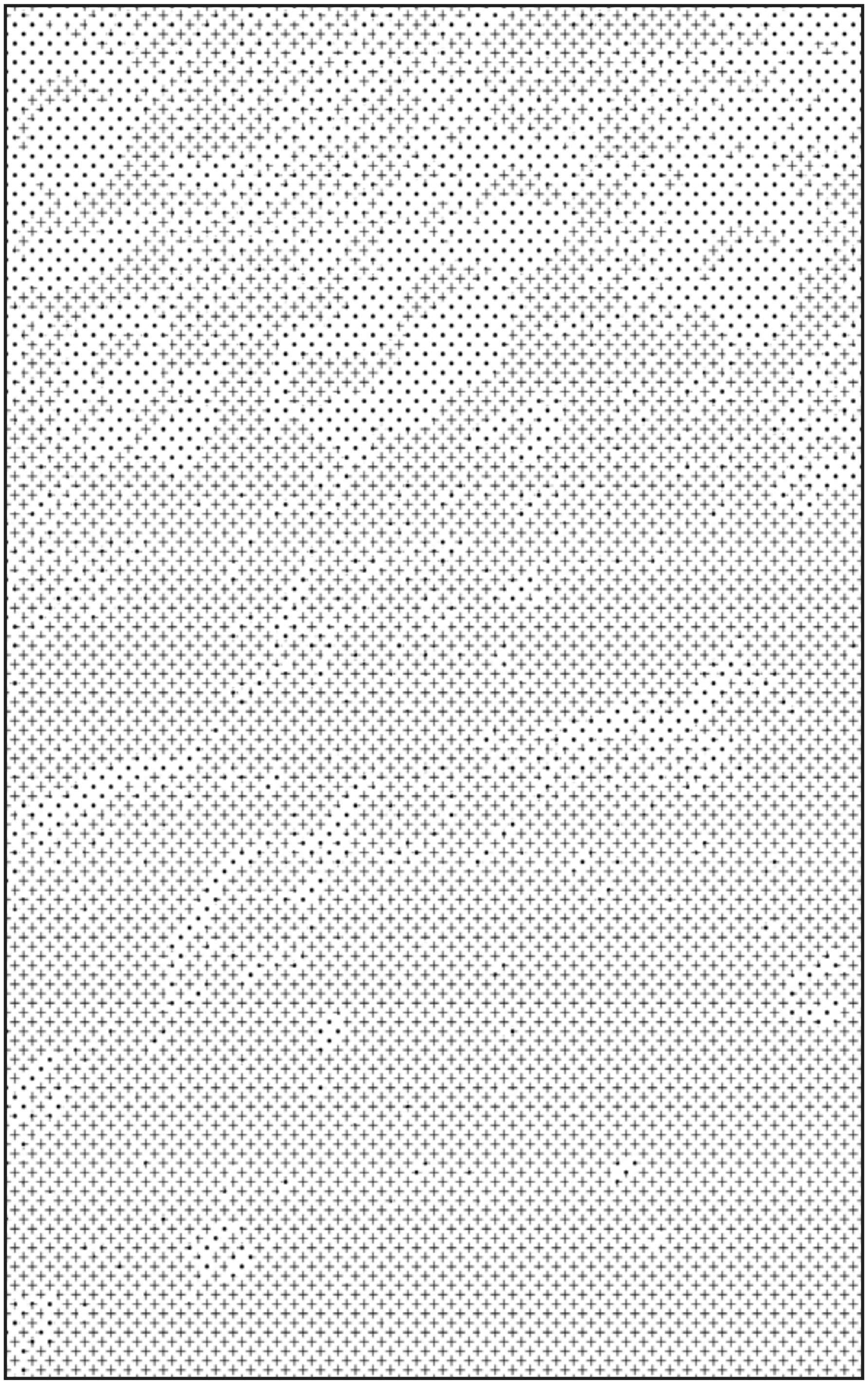
Acidalia Planitia is a plain on Mars. It is located between the Tharsis volcanic province and Arabia Terra to the north of Valles Marineris, centered at 49.8°N 339.3°E. Most of this region is found in the Mare Acidalium quadrangle, but a small part is in the Ismenius Lacus quadrangle. The plain contains the famous Cydonia region at the contact with the heavily cratered highland terrain. The plain is named after a corresponding albedo feature on a map by Giovanni Schiaparelli, which was in turn named after the mythological fountain of Acidalia. Some places in Acidalia Planitia show cones. Some researchers have suggested that these are mud volcanoes.

This area is featured in the novel and movie, The Martian, as the landing site of a crewed mission named Ares 3. For the story's central character, Acidalia Planitia is within driving distance from where NASA's Mars Pathfinder, with its Sojourner rover, landed in 1997.



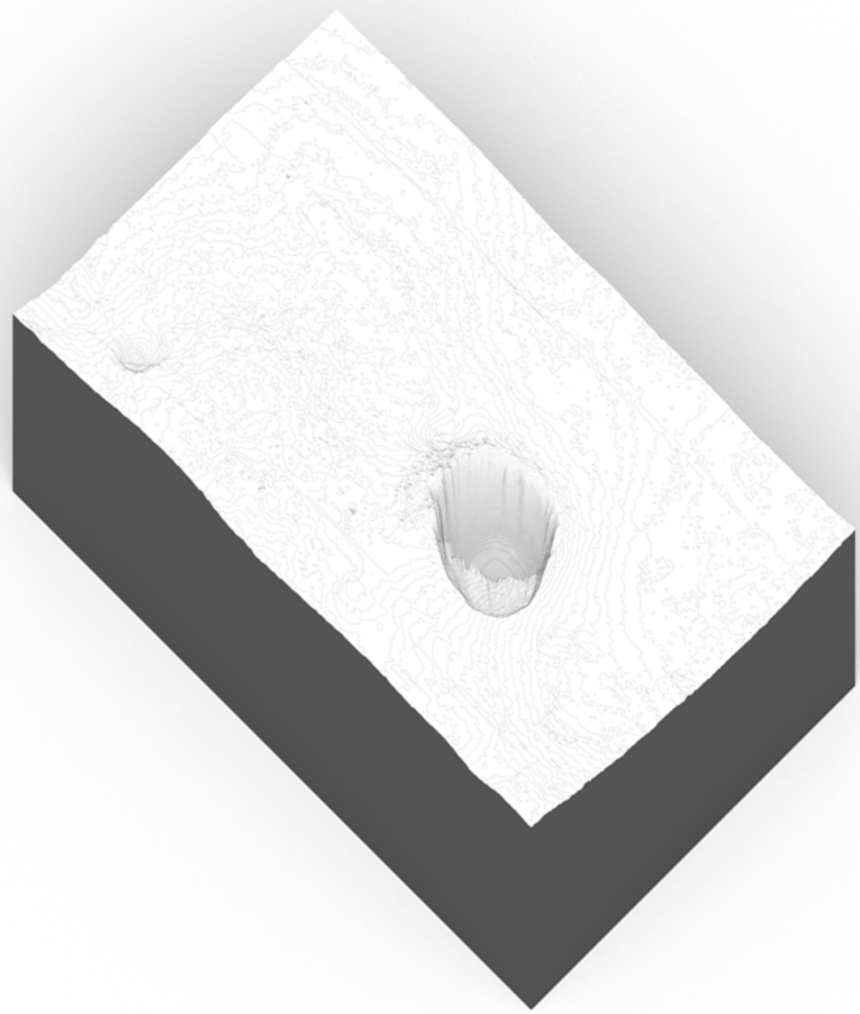


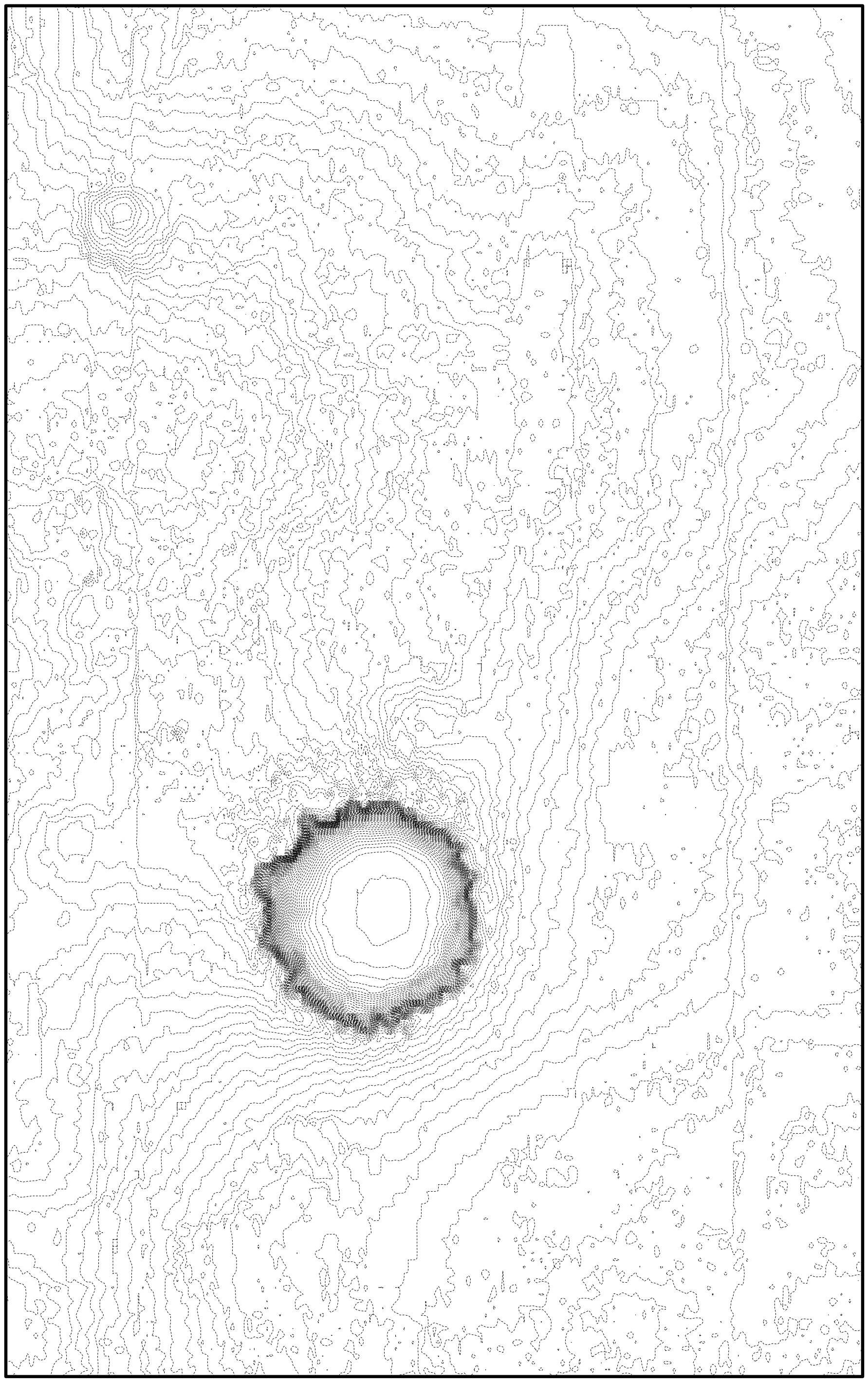


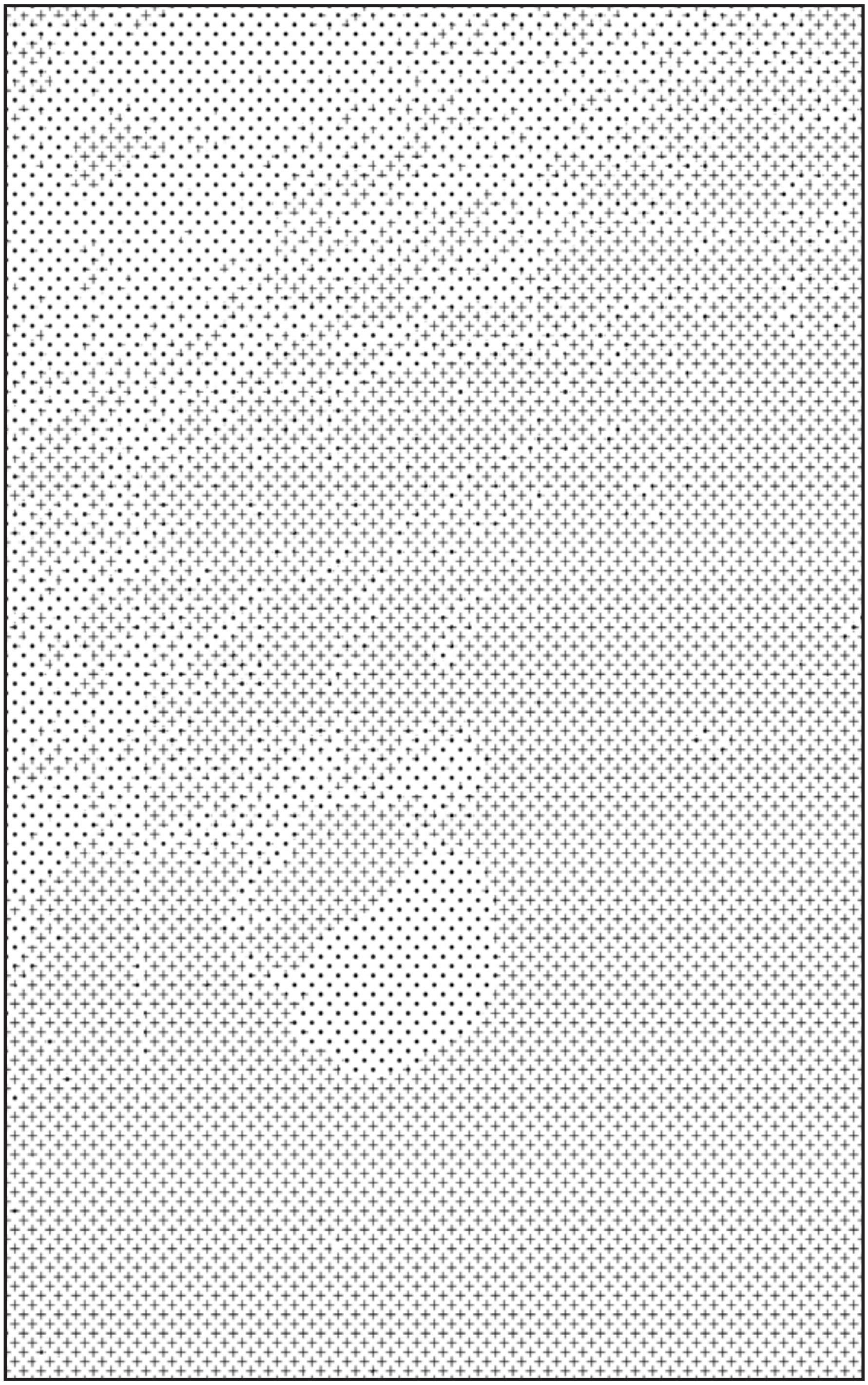


12. VICTORIA CRATER

Victoria is an impact crater on Mars located at 2.05°S, 5.50°W in the Meridiani Planum extraterrestrial plain, lying situated within the Margaritifer Sinus quadrangle region of the planet Mars. This crater was first visited by the Mars Exploration Rover Opportunity. It is roughly 730 meters wide, nearly eight times the size of the crater Endurance, visited by Opportunity from sols 951 to 1630. It is formally named after Victoria, Seychelles. Along the edges of the crater are many outcrops within recessed alcoves and promontories, named for bays and capes that Magellan discovered. Opportunity traveled for 21 months to Victoria before finally reaching its edge on 9-6-06 (sol 951), at the newly named “Duck Bay.” Around the rover were features dubbed “No Name”, “Duck Crater”, “Emma Dean”, “Maid of the Canyon”, and “Kitty Clyde’s Sister”. It also imaged several nearby alcoves, informally named “Cape Verde” and “Cabo Frio”, and a small bright crater the size of Beagle on the opposite end of Victoria.

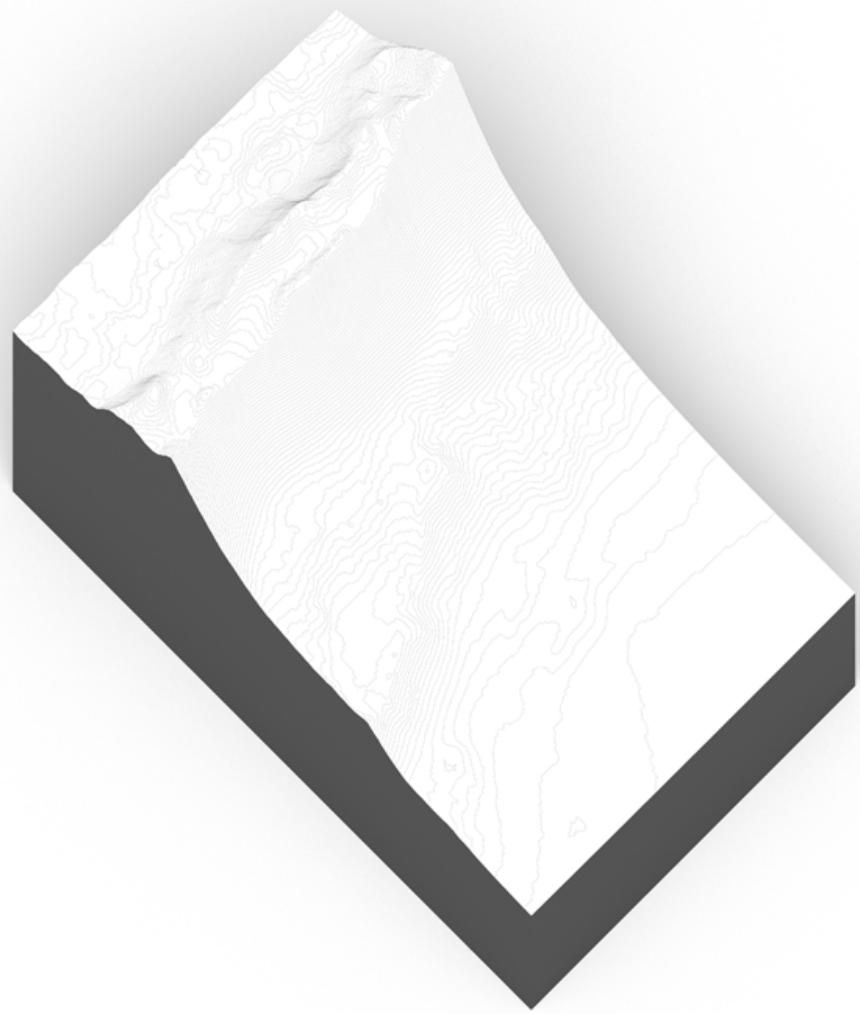


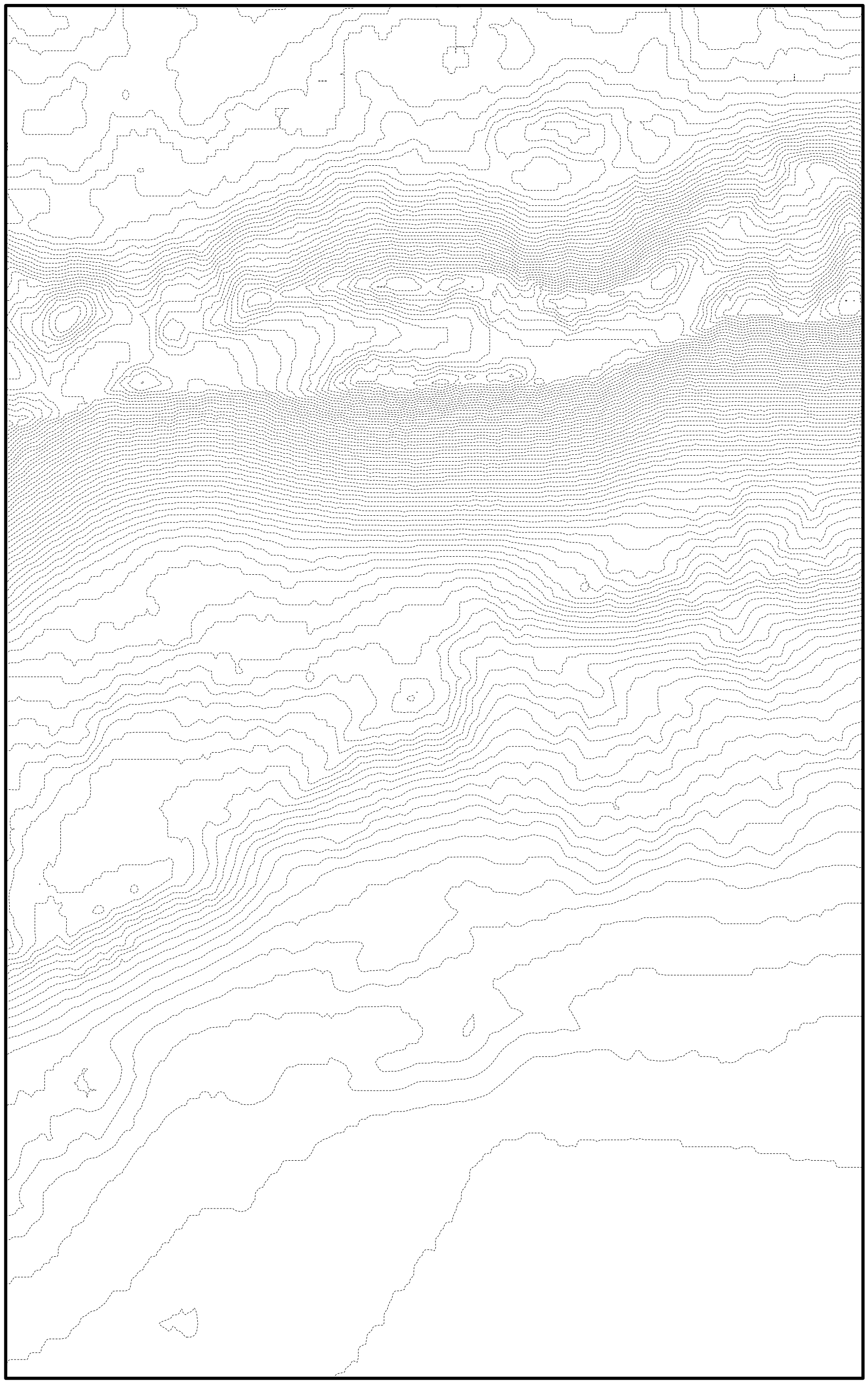


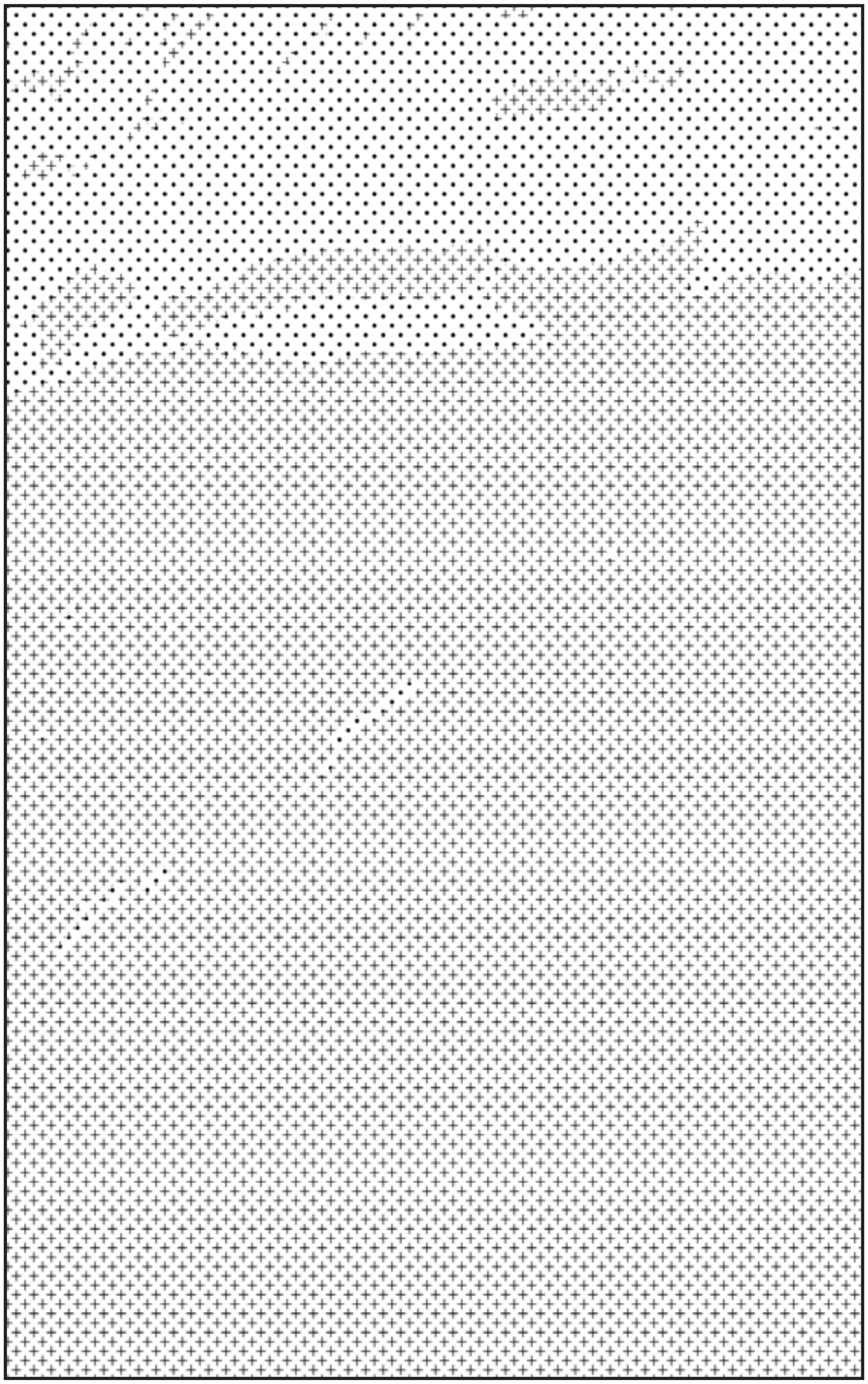


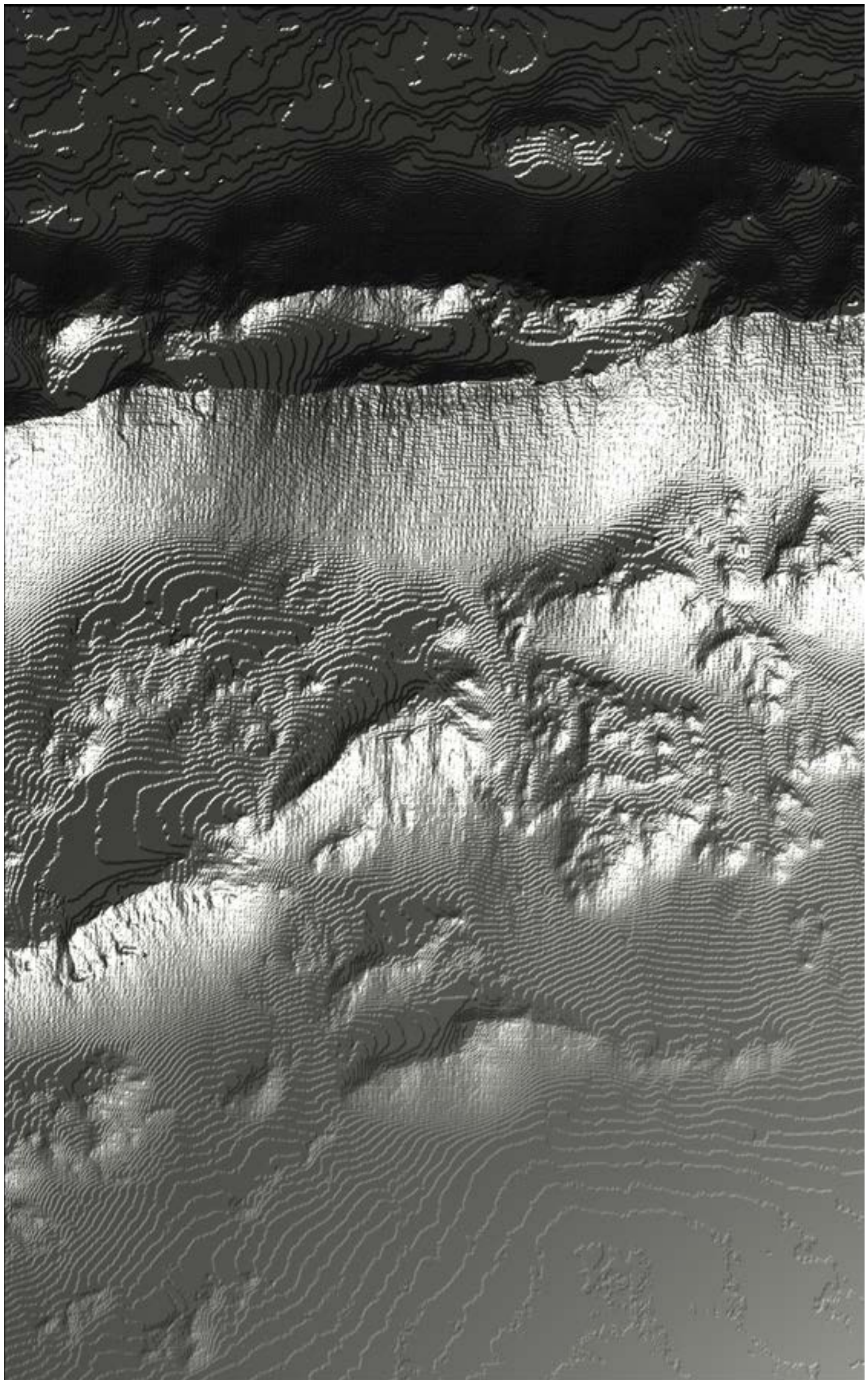
13. HYPANIS VALLIS

Hypanis Vallis is a 270 km valley in Xanthe Terra on Mars at 11° N, 314° E. It appears to have been carved by long-lived flowing water, and a significant river delta exists at its outlet into the lowlands.
Hypanis Vallis was one of the sites proposed as a landing site for the Curiosity rover of the Mars Science Laboratory mission to assess the past habitability potential of that zone. However, it did not make the final cut. Hypanis Vallis is also one of the four semifinalist candidate landing sites for the ExoMars rover mission, due to launch in 2018. The goal of ExoMars is search for signs of any past or present life on Mars. The rover would land on the distal deposits adjacent to the Hypanis river delta and the nearby Sabrina delta. These deposits are likely to be composed of fine grained sediment, having been laid down in a low energy environment, where any potential biosignatures could be preserved.



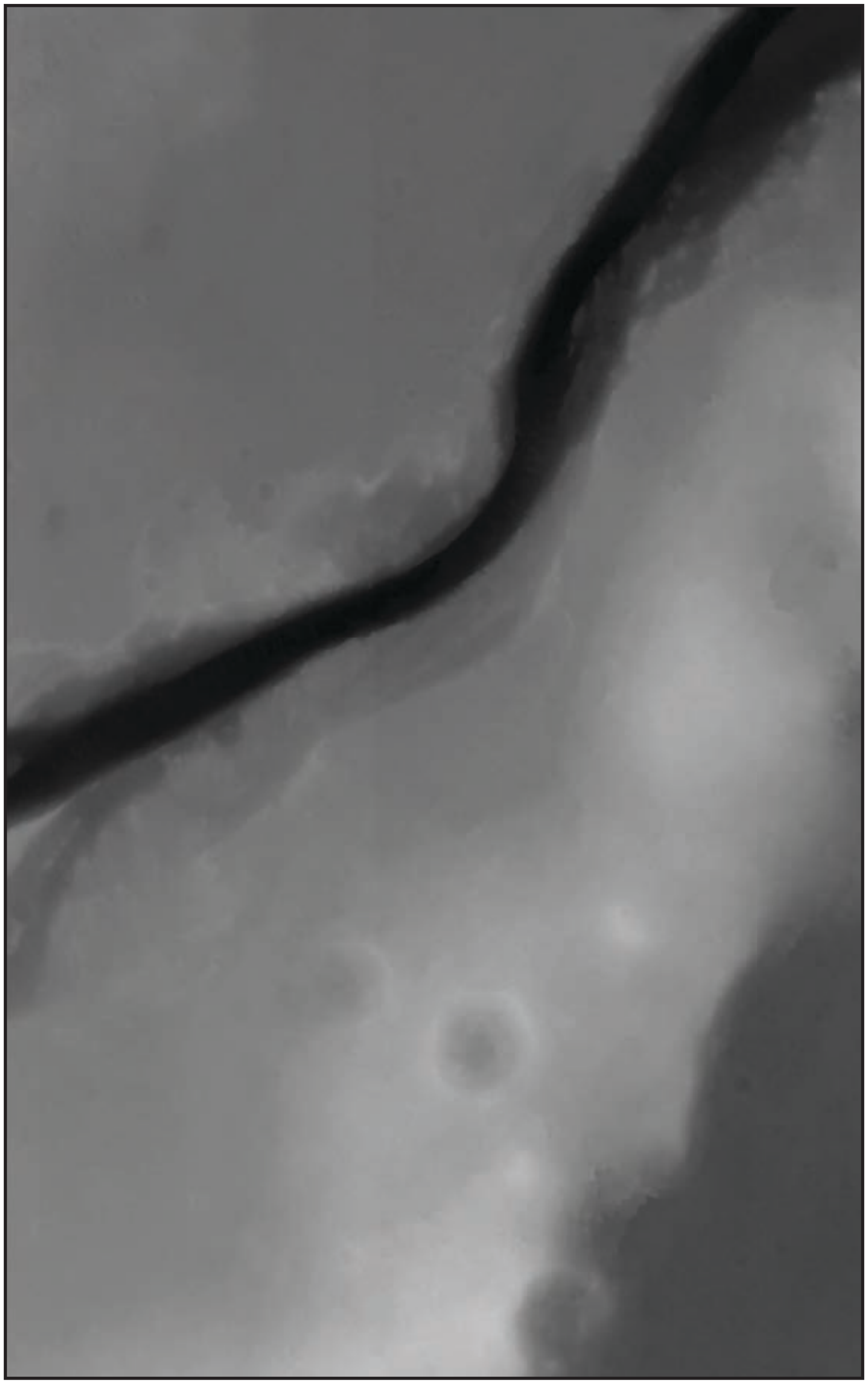


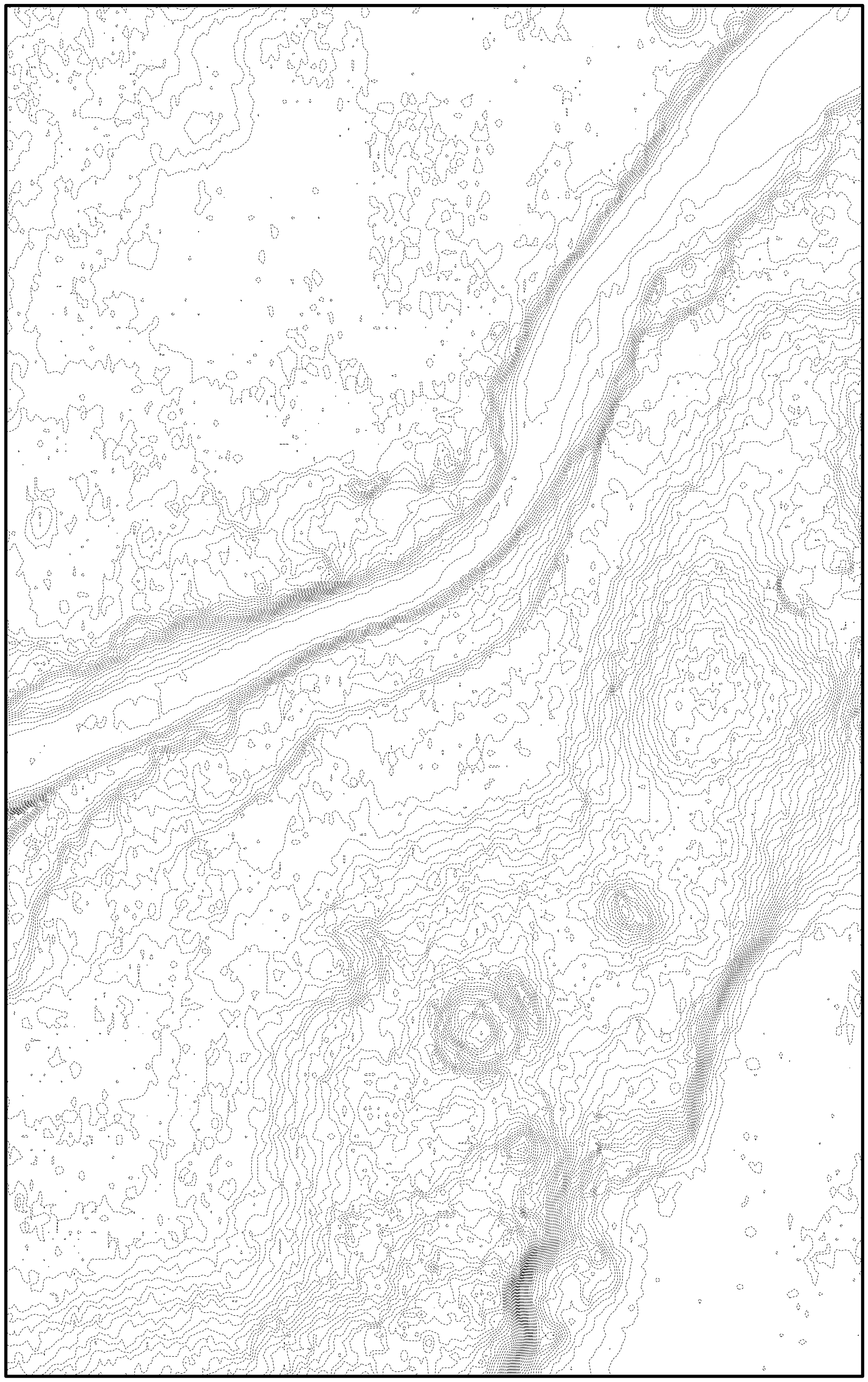


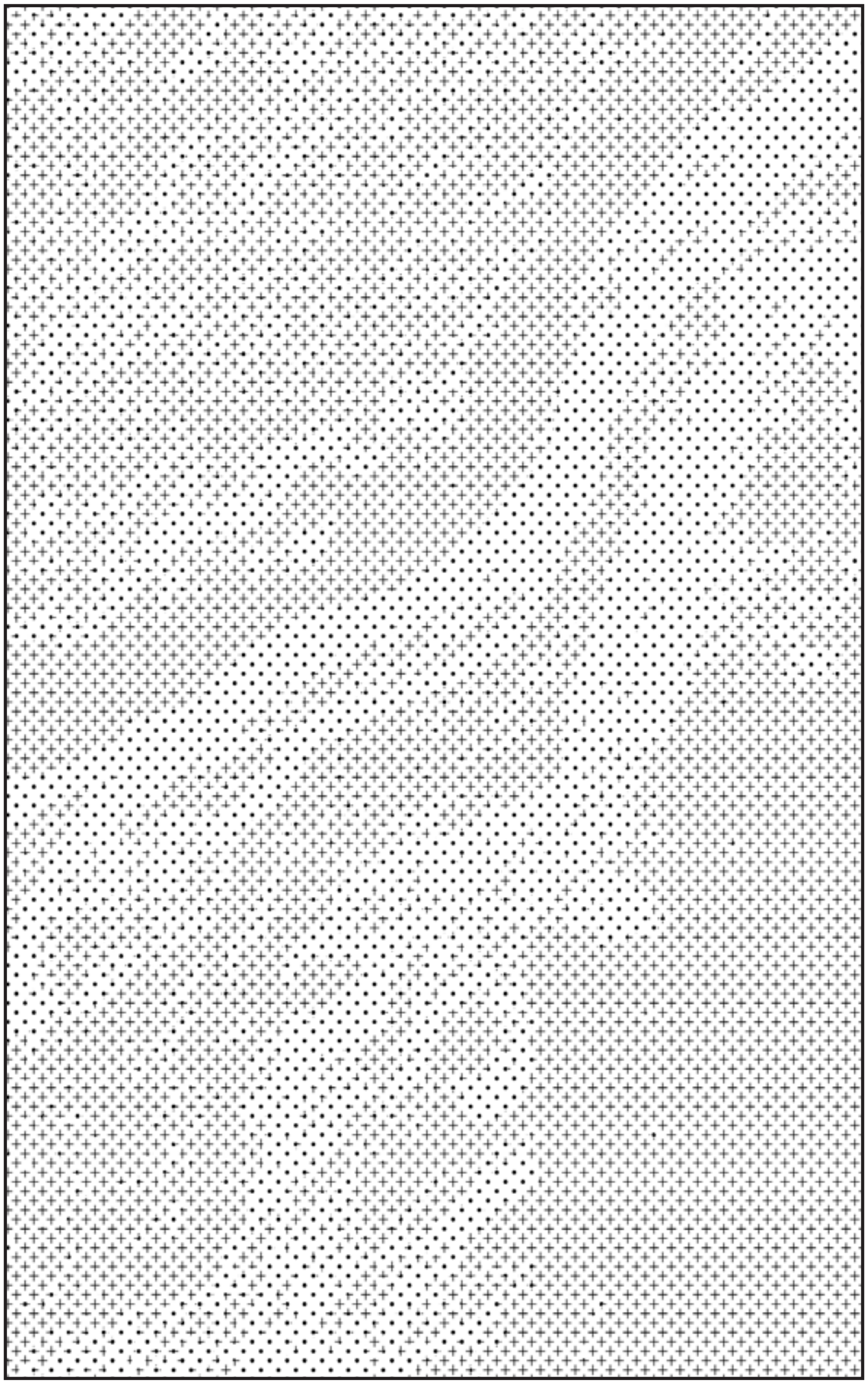


14. TARTARUS COLLES

Tartarus Colles are a group of hills in the Diacria quadrangle of Mars. They run from 8° to 33° north latitude and 170° to 200° west longitude. They were named after a classic albedo feature. The name was officially approved by the IAU in 1985. It was originally thought that slope streaks might be locations of surface water wetting and darkening soil, but it is now commonly believed that slope streaks are mini-avalanches of dust. Slope streaks fade over time as wind erosion blends them in with their surroundings.

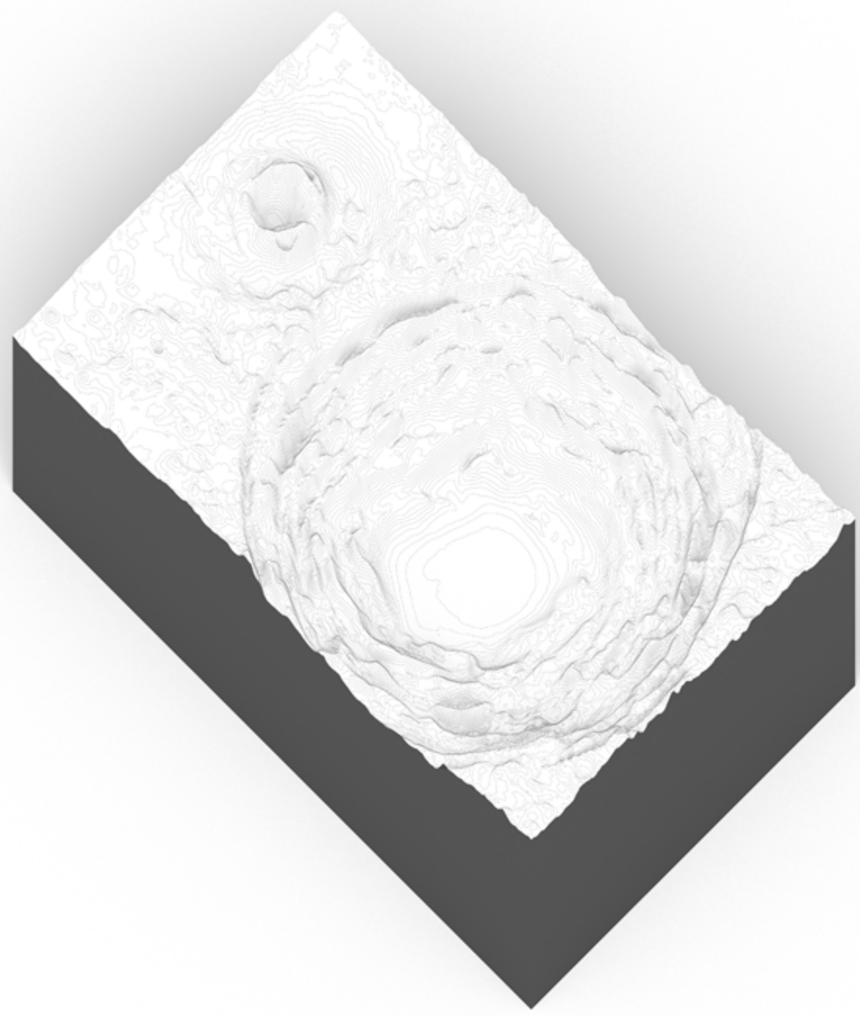


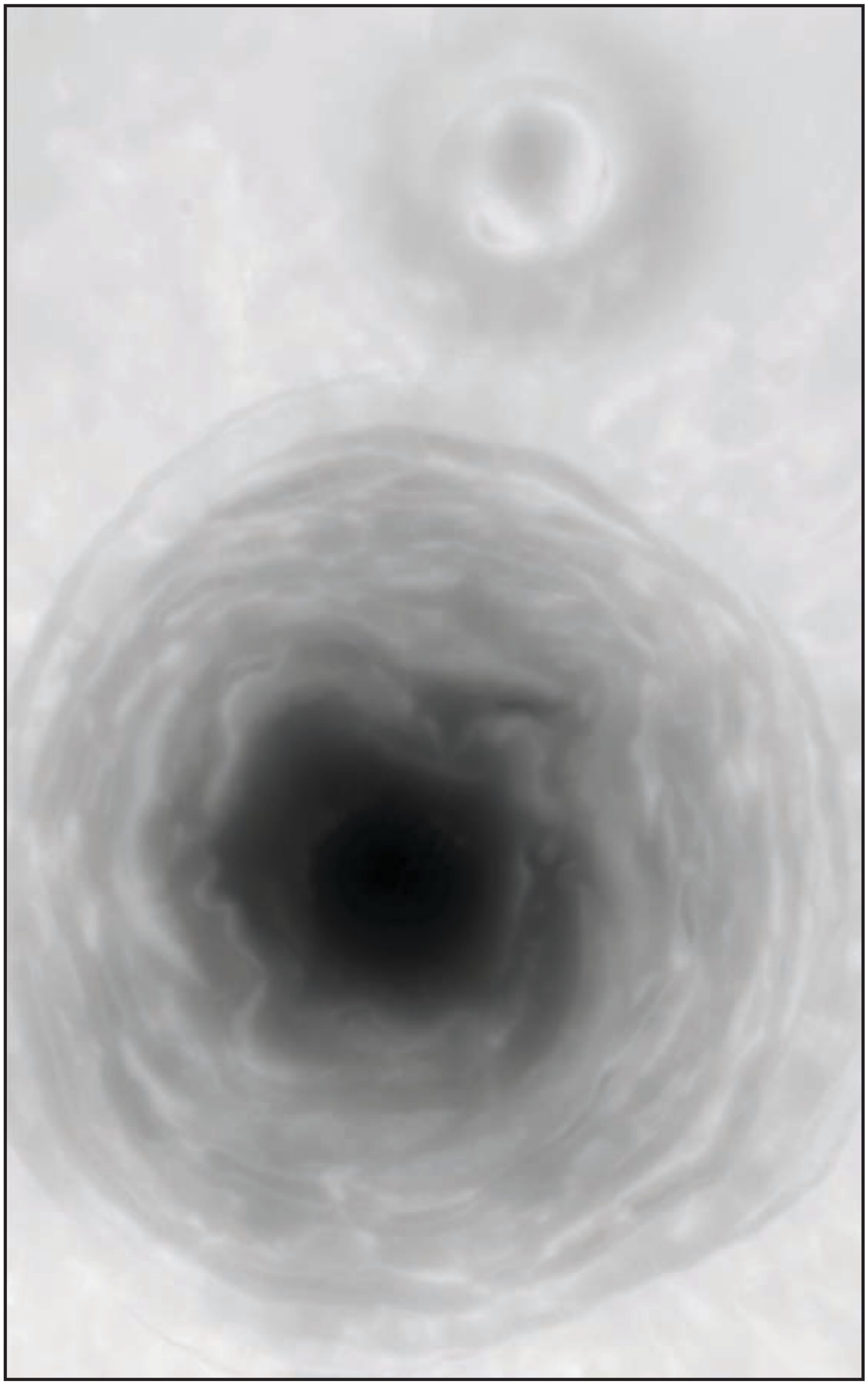


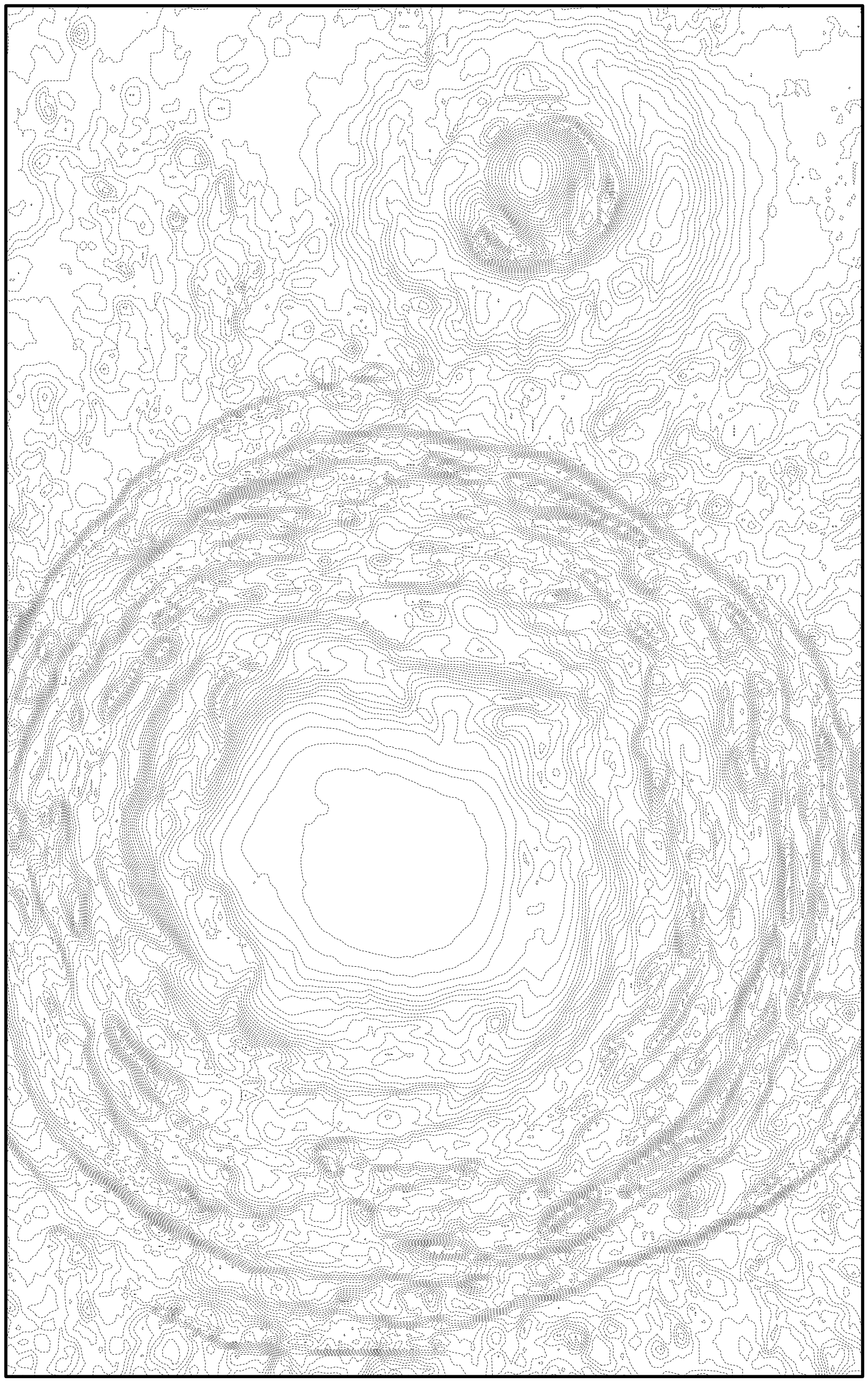


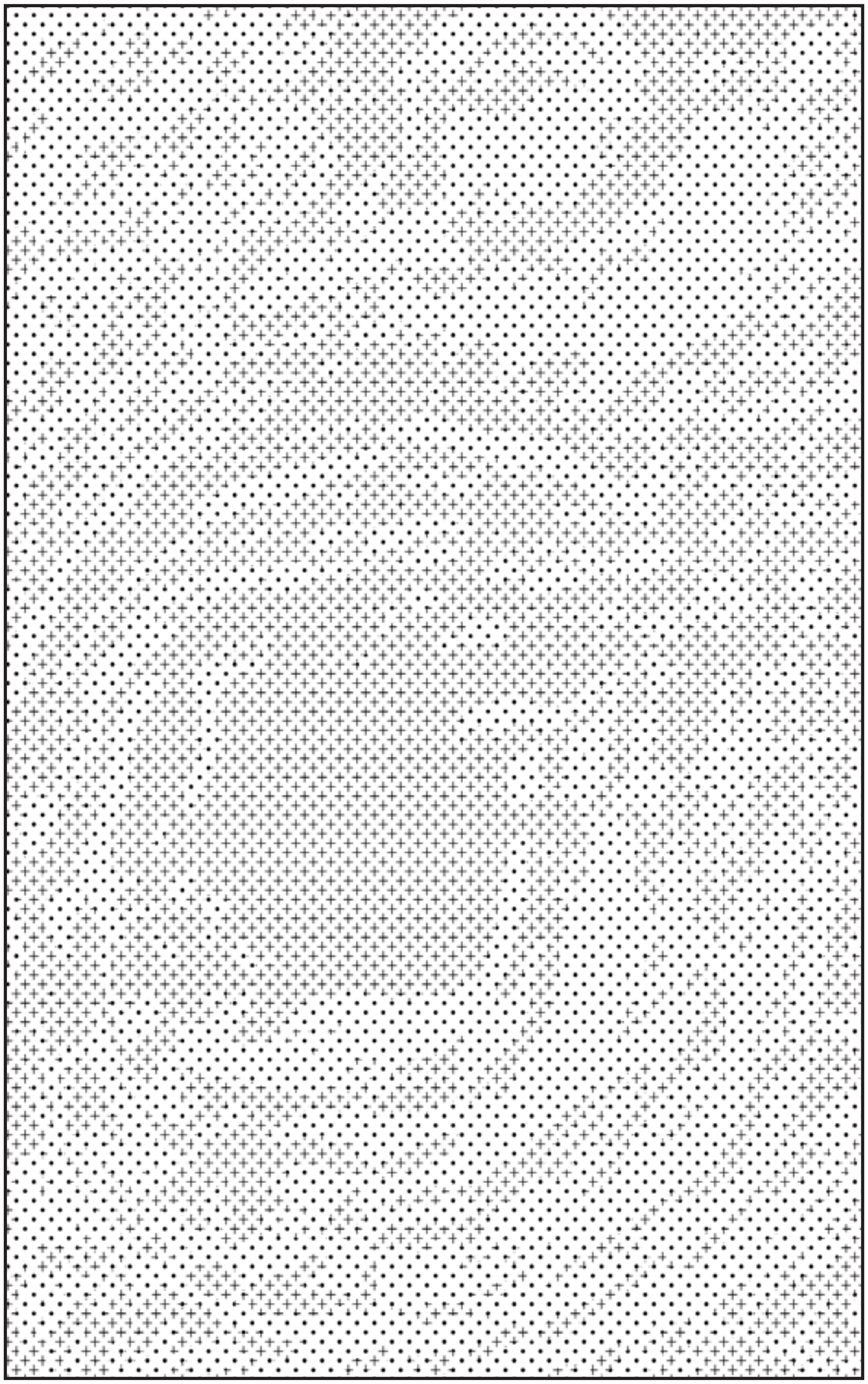
15. EAST ELYSIUM MONS

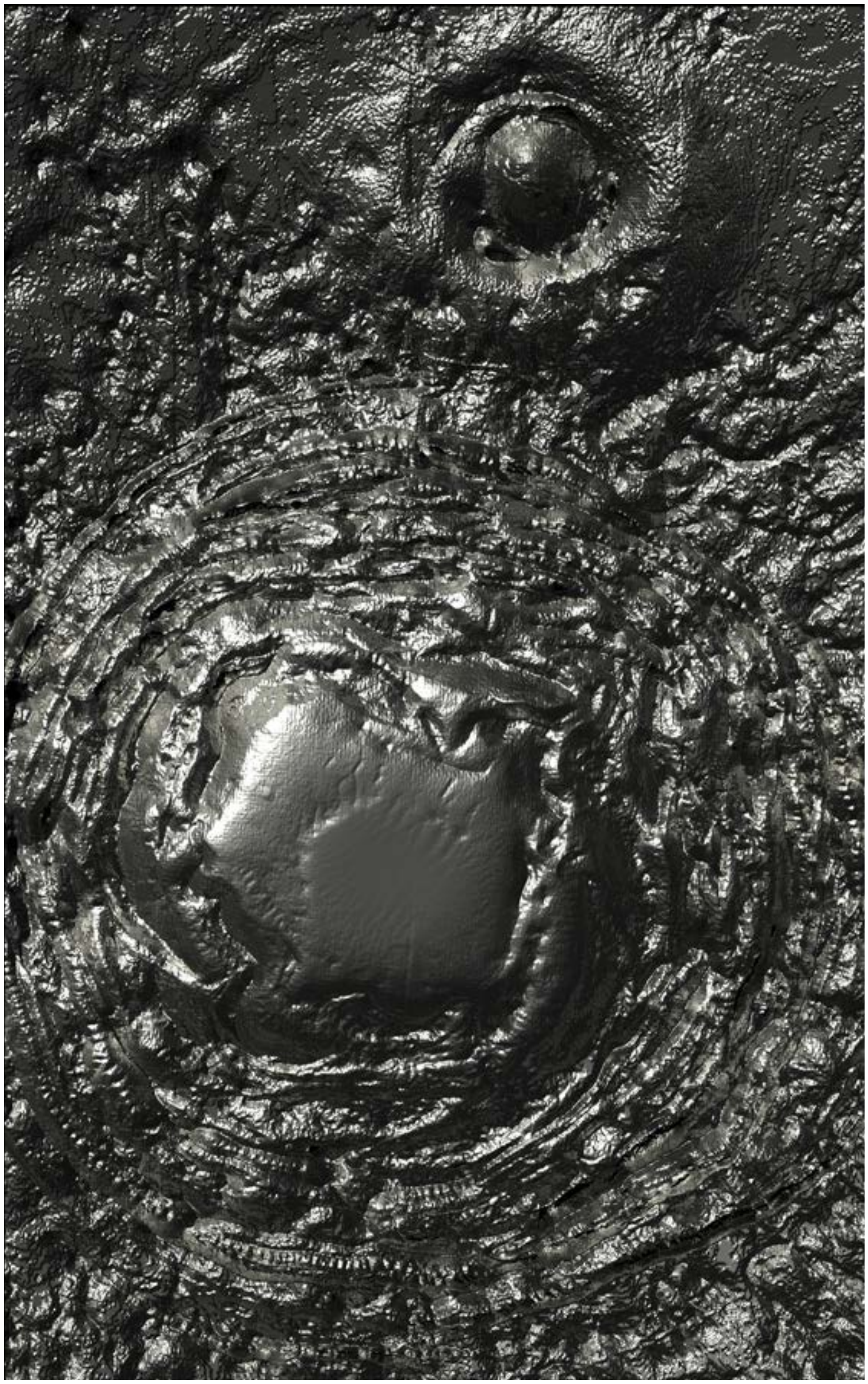
Elysium Mons is a volcano on Mars located in the volcanic province Elysium, at 25.02°N 147.21°E, in the Martian eastern hemisphere. It stands about 13.9 km (46,000 ft) above the surrounding lava plains, and about 16 km (52,000 ft) above the Martian datum. Its diameter is about 240 km (150 mi), with a summit caldera about 14 km (8.7 mi) across. It is flanked by the smaller volcanoes Hecates Tholus to the northeast, and Albor Tholus to the southeast. Elysium Mons was discovered in 1972 in images returned by the Mariner 9 orbiter. The terrestrial volcano Emi Koussi (in Chad) has been studied as an analog of Elysium Mons. The two shield volcanoes have summit calderas of similar size, but Elysium Mons is 3.5 times larger in diameter and 6 times higher than its counterpart on Earth.





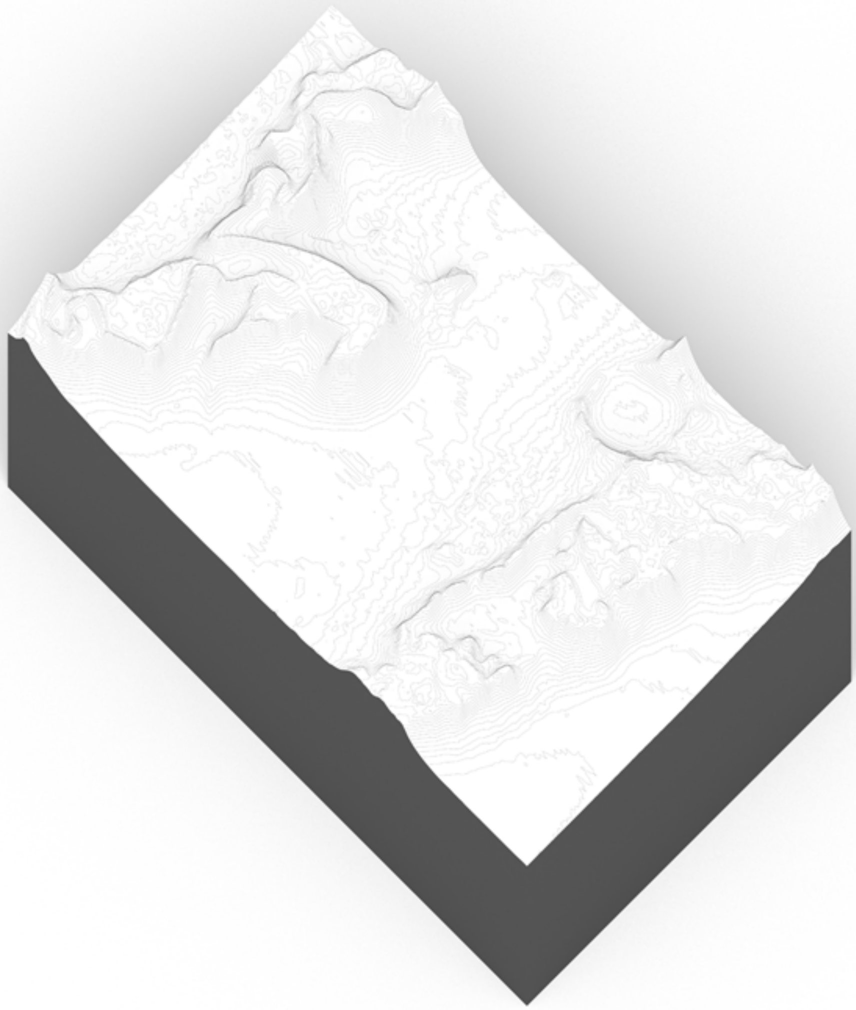


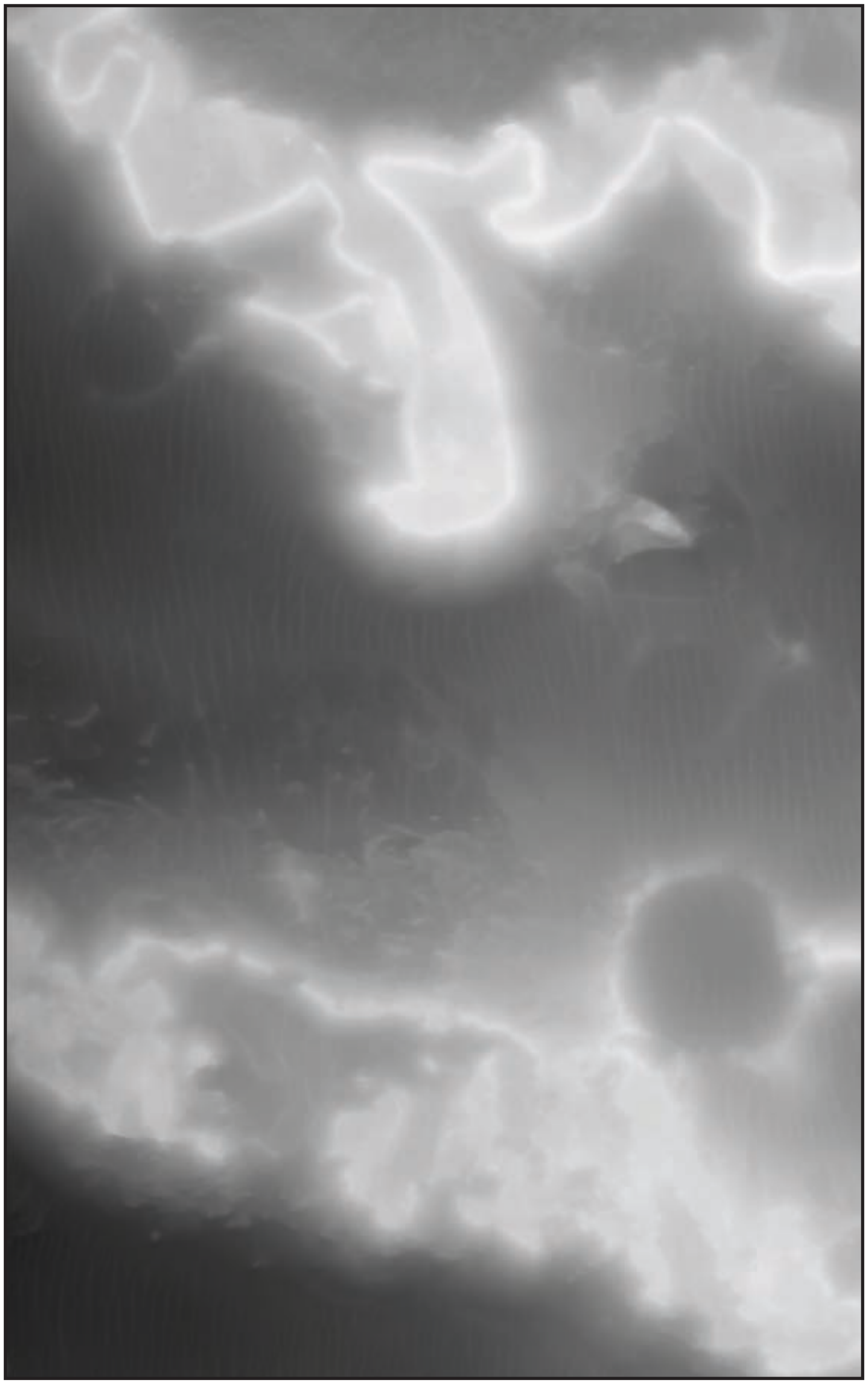


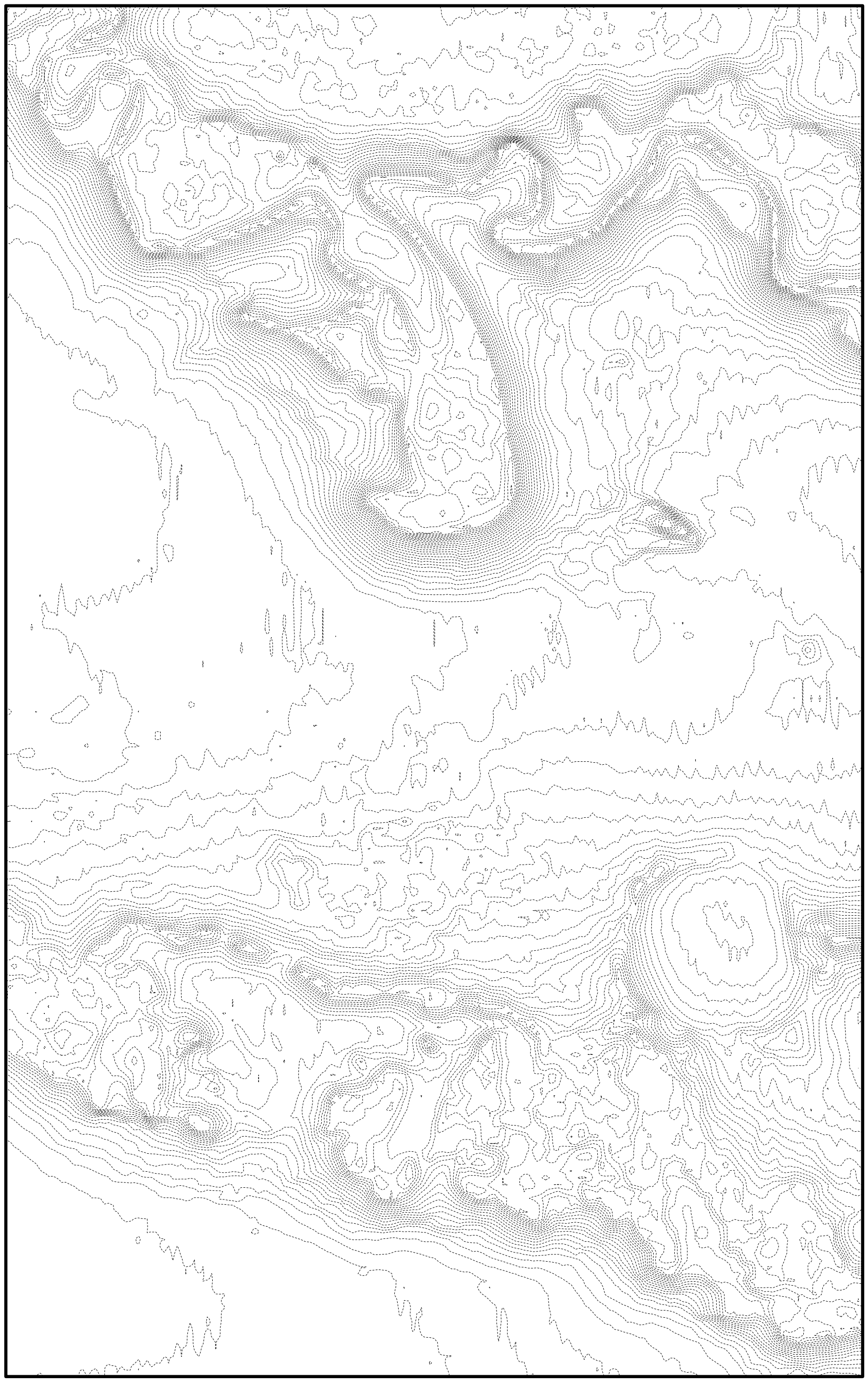


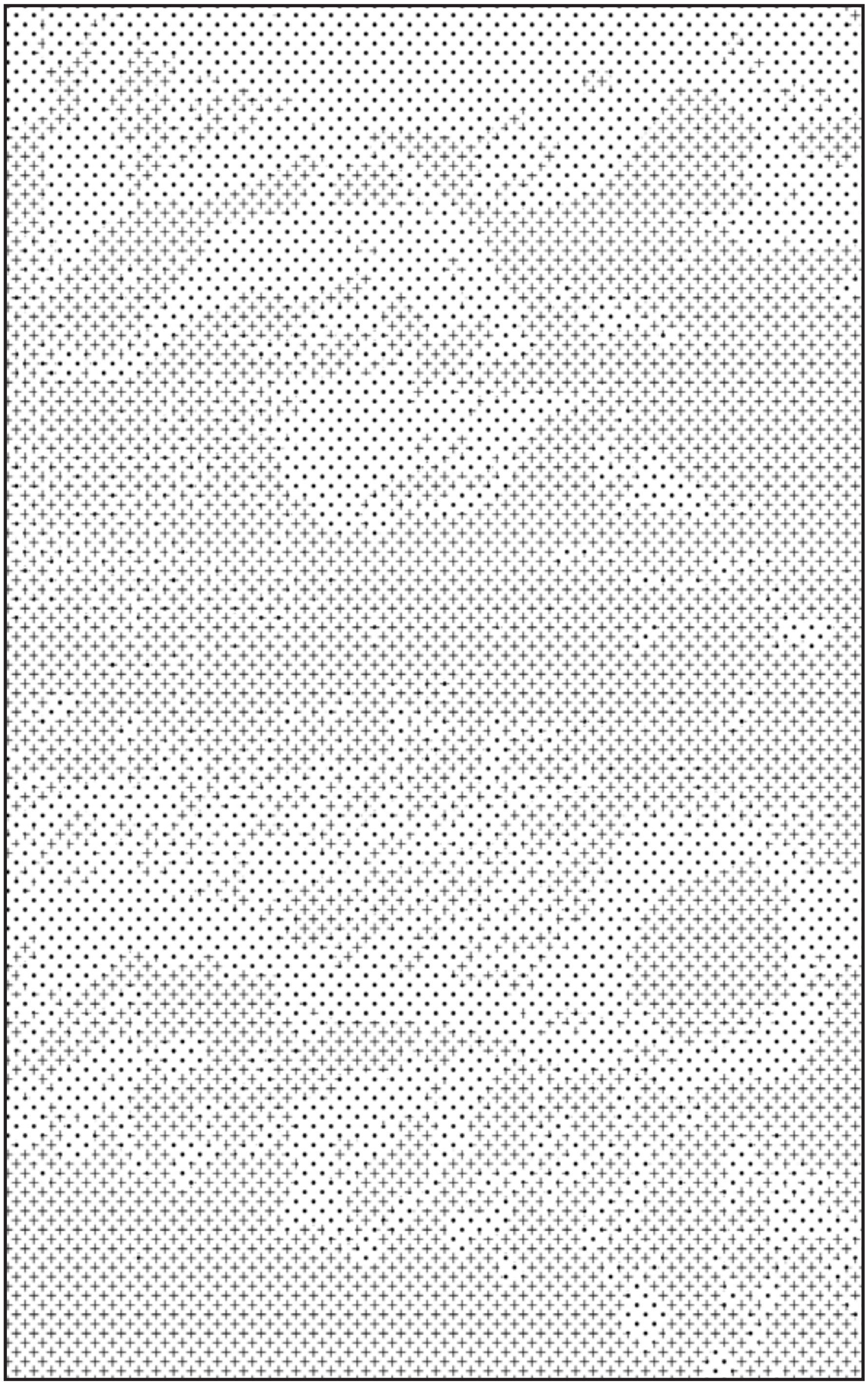
16. ZEPHYRIA PLANUM

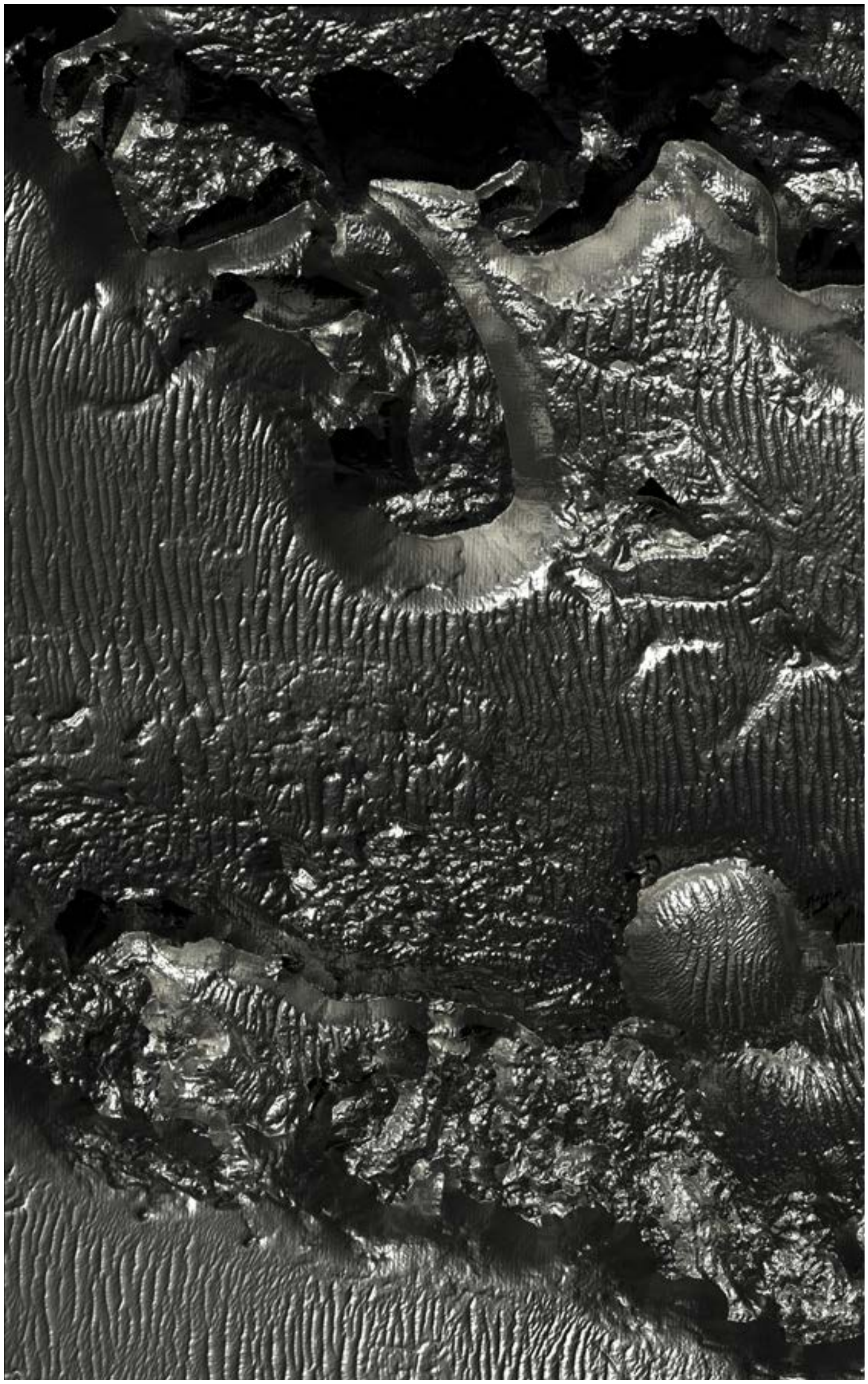
Zephyria Planum is an elevated flat extent (planum) extending on either side of the Martian equator. Eroded by countless years of wind action, the material in this region of Zephyria Planum is being sculpted into yardangs - long, thin hills separated by narrow valleys.











Lost in Translations (from Drawing to Building)

"[Digital technologies] are no longer the tools for making: they are primarily tools for thinking."

Mario Carpo, *The Alternative Science of Computation*[1]

"The theme of this article is translation... There are all those other identically prefixed nouns too: transfiguration, transformation, transition, transmigration, transfer, transmission, transmogrification, transmutation, transposition, transubstantiation, transcendence, any of which would sit happily over the blind spot between the drawing and its object, because we can never be quite certain, before the event, how things will travel and will happen to them on the way."

Robin Evans, *Translations from Drawing to Building*[2]

If Robin Evans' ceaselessly regurgitated *Translations from Drawing to Building* was to signify anything other than a debunking of the common architectural myths associated with notions of drawing buildings and building drawings, it would be the emergence of a renewed interest in the intellectual value of scrutinizing the very media in which we work. Writing in 1986, Evans is admittedly responding to various cultural dialogues concerning, on one hand, the fabled autonomy of the drawing, and on the other, architecture's abstract disciplinary knowledge.[3] We've heard this countless times before, and we all know how the story goes. Yet, it is thirty-one years later, and here we are, still discussing how to translate between a drawing and a building. But it seems that our current preoccupations address a different kind of translation; one not necessarily concerned with whether the drawing itself exists as "the real repository of architectural art."

Before diving in, let's make two assumptions. (1) That we live in the world of ubiquitous software; and (2) that the architectural drawing (at least the kind that dreams of becoming a building) is primarily a digital artifact. Putting aside any nostalgic opprobrium this might incite, "drawing" in the case of this essay will neither refer to the intellectual act of disegno, nor to the drafting of lines, whether digital or analog, projective or perspectival. Instead, “drawing” should be understood as a placeholder for a variety of digital file formats that are readily used in contemporary architectural practice (eg. DWG, PDF, JPG). Therefore, given our previous assumptions, we can situate the architect as a figure whose principal task is not only to translate between drawing and building, but also to translate across a vast, ever-updating landscape of standardized file-types and graphical user interfaces. While this may appear obvious, perhaps even remedial, a critical discourse surrounding these processes has not surfaced until recently. An understanding of design software has been stifled by a desire to marginalize it as a utility with the humanist paradigm that prioritizes design intellect’s hegemony over mechanical tools. But the analogy of the digital as a tool for the realization of some architectural a priori is just the myth Evans debunks.[4] In other words, software is no longer a simple vehicle for communicating that which we blindly create in our heads, but rather contributes to the formulation of that very thought from the first time we are in contact with digital media.

It is this reformulation of our relationship to the digital—what some are calling the second digital turn—that I wish to discuss.[5] From Autodesk Revit coordination to the management of plug-in applications to optimizing PDF files for printing, an ever-growing repertoire of software knowledge is crucial to the dissemination of a design project at all scales. Put differently, “we know that as soon as communications leave our lips or fingertips they are immediately diced and rearranged into information packets better suited for streaming digital compression.”[6] However, despite the ubiquity of the digital, I am not suggesting that architects should become programmers, nor that computation be conflated with design. Instead, my point is that, because it is so pervasive there needs to be a deeper understanding of the critical and cultural role that software plays in design processes from education to practice. As Lev Manovich argues in *Software Takes Command*, “[i]t is, therefore, the right moment to start thinking theoretically about how software is shaping our culture, and how it is shaped by culture in turn.”[7]

Manovich has widely been regarded as the progenitor of these thoughts within the humanities, having been one of the earliest thinkers to synthesize—and historicize—the development of “cultural software:” a loose umbrella term referring to computer applications involved in the creation of cultural artifacts, interactive services, aesthetic content, online social interactions, and interactive cultural experiences.[8] Each discipline, of course, has its own catalog of go-to software, which relies largely on a combination of specified workflows, licensing costs, and industry standards. For us architects, we know the usual suspects: Adobe Photoshop/Illustrator/InDesign, Autodesk AutoCAD/Revit/3d Studio Max/Maya, Rhino 3d, to name a few. Yet while students and professionals use these programs on a daily basis, Manovich’s theses posit that most discussions rarely touch on their impact on cultural conventions or their historical development.

But for now, let us return to the issue of translation (from drawing to building). If a major task of the contemporary architect is to manage the collection and transmission of various file-types through networks both local and international, then one would expect architectural curricula to address the fundamentals of navigating this digital landscape.[9] To a certain extent, design education teaches technical skills for successfully outputting a desired object from a piece of software, in some cases even covering best practices for compression, optimization, or conversion. These techniques, codified during the early 2000s (a.k.a. the first digital turn), were the results of students tinkering with early modeling software.[10] At the time, important themes began to surface, such as the basic discrepancies between OBJ meshes and IGES B-splines or those between raster and vector images. It should be noted, of course, that this knowledge was shared at the discretion of those early adopters of digital tools who saw the medium as a limitless playground for novel architectural forms. This emphasis on software as a means to an end remains the dominant pedagogical approach. Students now enter the professional field with a vast technical understanding and ability to translate two-dimensional drawings into three-dimensional models, and output results in a variety of media. If this has been working well for the better half of the 2010s, what is the value of a deeper immersion into the annals of software's history and socio-cultural impact?

For one, I would suggest that the presumption of software as a simple tool subservient to our architectural whims is an outdated pedagogical model. A few years back, the assertion that a designed product is only as good as the designer would yield nods of agreement from most in the field, a sentiment derived perhaps from the skeuomorphic qualities of CAD's "paperspace" digitizing drafting tables. As Building Information Modeling software spreads its reach, there are fewer analogies left. If drafting in CAD is akin to drafting by hand, then BIM is like building the building, before you build the building: a simulated act. Not only is it a digital simulation, but it is also dependent on data management. Thus, the process of translating from drawing to building today depends less on one's ability to form an apt analogy of what a "drawing" is or what it represents, and more on one's expertise in navigating information management systems, and coordinating between file-types from Navisworks, Revit, AutoCAD, Revit MEP, RISA 3D, etc. But what if instead of learning the actions to perform in each program, there was such a thing as design software theory; a course in which software interfaces, workflows, and file-types are dissected to relate to our shared experiences with other cultural media as a whole. This new addition of an architectural curriculum, dedicated to a broader discussion of design software, might tease out new analogies for translating from drawing to building.

Apropos of the above, let's look at a

hypothetical scenario. Take a simple topographical survey; a set of information common to both architects and landscape architects. A traditional approach to modeling such a survey is to extract contour lines at specific intervals, which results in an abstract, stepped representation of the specific topography. To represent the surface as a smoother continuous surface, one would have to interpolate between these lines using common B-spline modifiers, either “lofting” or “draping” complex doubly-curved surfaces over the contour splines as formwork. The result would be an approximation of a more realistic terrain. However, let’s say that the designer had taken a course in the history of computer graphics. She would have most likely covered early attempts at representing complex textures using displacement mapping algorithms, such as ones used by Pixar’s RenderMan engine. In this process, surfaces are subdivided into triangular meshes whose vertices’ height coordinate correspond to a specific distance from an origin managed by a greyscale “heightmap.” In other words, instead of interpolating offset contour lines, a displacement map on a mesh surface recreates a topography based on a series of points dictated by pixel grayscale value. On a typical 8-bit RGB image, this allows for up to 256 different height values, resulting in a high-fidelity, realistic terrain.

Now, the curious part about this hypothetical scenario is that the concepts remain software-independent. Most modeling software today will facilitate both methods (contouring and displacement) to some extent. However, disciplinary bias separates these ways of working. Architectural design favors the former, contour-based model, and video game/VFX design favors the latter. Tracing the historical lineage of these biases, we will find that displacement methods were much more computationally demanding, and thus were reserved for industries with large budgets. Architects, using relatively low-cost software in the early days of CAD such as Form*Z and Rhino 3D, would naturally gravitate towards a simpler, faster, and more abstract method for representing topographies. Indeed, many of our disciplinary proclivities for certain methods trickle down from an era where computation was a precious resource to be conserved. Nevertheless, as Mario Carpo has recently noted, the second digital turn is a shift from the formal vocabulary of calculus to that of infinite datasets. This suggests that if calculus is a compression tool used to express a complex geometrical order in a simple way, this compression is no longer necessary when processors can add up a large dataset to represent the same figure.[11] The landscape scenario exists as another analogy for this shift: why represent a landscape through approximate curves, when you can recreate topography with a pixel-to-polygon level of resolution?

There are obviously more complex translations at play in the execution of displacing bitmaps into three-dimensional landscapes. For instance, heightmaps are only produced in two ways: (1) by compositing satellite imagery at different points in time to calculate elevation data, or (2) by randomly generating grayscale fields with various bitmap algorithms, such as Perlin noise.[12] Both call for interactions with software outside the canon of Adobe and Autodesk; a daunting task for most students I've taught. Such an endeavor would require one to be fluent in the kinds of file-formats available and be able to translate from one to another with minimal loss of information. But more importantly, our hypothetical student would have to choose between which software would yield the faster and desired results, instead of forcing a method into a program better suited for another technique.

When I introduce students to Autodesk 3d

Studio Max, I usually begin by retelling a short history of modeling software. Typically, this involves an explanation of the OBJ, FBX, DXF/DWG file standards, a short anecdote about early visual effects technologies, a brief mention of Form*Z's influence, and, if we're willing to get political, Autodesk's relentless monopolization of the field. After understanding the program's background, we start to familiarize ourselves with the user interface and tools. Most of the observations outlined above stem from my experience attempting to teach not only software as a tool, but software as an extension of our everyday interactions with interfaces. While some of these thoughts may still be in their infancy, I have an increasing suspicion that themes from software and internet studies will find their way into design curricula. The need for tutorial-based, step-by-step sequencing of interactions will therefore dwindle in favor of a more expansive approach where students experiment across a variety of differing media, testing the limits of file-formats, discovering new workflows, and translating their concepts across platforms seamlessly.

NOTES

1 Mario Carpo, "The Alternative Science of Computation," *e-flux Architecture* (June 2017) accessed June 30, 2017. http://www.e-flux.com/architecture/artificial-labor/142274/the-alternative-science-of-computation/

2 Robin Evans, "Translations from Drawing to Building," *AA Files*, no. 12. (London: Architecture Association Press, 1986).

3 Ibid.

4 Curtis Roth has described how Evans' thesis suggests a paradox of the origins of architectural thought. See "On Our Dark Products" in *Some Dark Products: A Travelogue of Nine Instruments for Architecture* (Stuttgart: Edition Solitude Press, 2017).

5 Mario Carpo, "ACADIA 2016 Keynote," Vimeo video, 55:29. Posted [March 2017], https://vimeo.com/210622365

6 Keller Easterling, "Another Part of Speech," in *Dispute Plan to Prevent Future Luxury Constitution*, ed. Benjamin H. Bratton (Berlin: Sternberg Press, 2015).

7 Lev Manovich provides a rudimentary list of this category, but claims it will continue to evolve. See, "Introduction," in *Software Takes Command* (London: Bloomsbury Academic, 2013), 20.

8 Ibid. 23.

9 Roth has developed a syllabus for introducing some of these themes in architecture school. See "A Syllabus for Yung Distance," in *Some Dark Products*

10 An excellent example would be the development of Form*Z at The Ohio State University, where architects and educators worked together to develop a comprehensive 3d modeling program. See Pierluigi Serraino, *History of Form*Z* (Basel: Birkhauser, 2002), 23.

11 Carpo, "ACADIA 2016 Keynote."

12 Michelle Chang has recently covered a quick history of the Perlin noise algorithm, suggesting that some architectural scholars are starting to historicize these moments. See "Turning a Banana Inside Out," in *PLAT 6.0 Absence*, ed. Melis Ugurlu (Houston: Rice School of Architecture, 2017).