THE BREADTH AND DEPTH OF EUROPA GEOLOGY: PLANS FOR OBSERVING DIVERSE LANDFORMS WITH EUROPA CLIPPER. G. C. Collins[1], J. A. Rathbun[2], J. R. Spencer[3], K. Craft[4], R. T. Pappalardo[5], D. A. Senske[5], H. Korth[4], B. Buffington[5], L. M. Prockter[6], R. L. Klima[4], C. B. Phillips[5], G. W. Patterson[4], L. C. Quick[7], C. M. Ernst[4], J. M. Soderblom[8], E. P. Turtle[4], A. S. McEwen[9], J. M. Moore[10], D. A. Young[11], C. A. Hibbitts[4], A. G. Davies[5], S. L. Murchie[4], B. E. Schmidt[12], and I. J. Daubar[5]. [1]Wheaton College, Norton MA; gcollins@wheatoncollege.edu, [2]Planetary Science Inst., Tucson AZ, [3]Southwest Res. Inst., Boulder CO, [4]Johns Hopkins Applied Physics Lab, Laurel MD, [5]Jet Propulsion Lab, California Inst. Tech., Pasadena CA, [6]Lunar and Planetary Inst., Houston TX, [7]Smithsonian NASM, Washington DC, [8]MIT, Cambridge MA, [9]Univ. Arizona, Tucson AZ, [10]NASA-Ames Res. Ctr., Moffett Field CA, [11]Univ. Texas, Austin TX, [12]Georgia Inst. Tech., Atlanta GA.

Introduction: The Europa Clipper mission is planned to launch in 2022, with the current trajectory making 46 close flybys of Jupiter's moon Europa. One of the three main goals of the mission is to understand the formation of surface features on Europa, including sites of recent or current activity. Because the mission is designed around a multiple-flyby architecture instead of a circular mapping orbit, there will be considerable variability in the closest approach distance between the spacecraft and any particular point of interest on the surface of Europa. Therefore, we must work to ensure that the full breadth and diversity of Europa's geology will be properly represented in the mission dataset. It should be noted that our understanding of the diversity and classification of Europa's landforms is likely to change over the course of the mission, but we use our current best knowledge for planning purposes. Figure 1 shows the geologic map of Europa [1] with the planned Europa Clipper ground tracks below 1000 km altitude overlaid in red. The locations of close-approach ground tracks are important for assessing multi-instrument coverage because the remote sensing instruments are nadir-pointed (with the exception of the EIS narrow angle camera, which is on a gimbal), and will obtain their highest resolution data along the ground tracks. Some instruments that need to be close to Europa for peak operation, like ice-penetrating radar (REASON) and the *in situ* chemistry instruments (SUDA, MASPEX) will obtain their best data along the central portions of the ground tracks (see [2] for a description of Clipper instruments).

Representative landforms: There are seven main types of landforms that are important to cover in order to understand geological processes on Europa.

Ridges. Double ridges less than ~4 km in width are ubiquitous on the surface of Europa, and yet their formation mechanism remains unsolved. Other subtypes in the ridge category include complex ridges, single narrow troughs, cycloidal ridges, and ridged plains. Only the most prominent ridge structures are shown as light blue lines in the geologic map in Figure 1. Because ridges are so widespread, the Europa Clipper ground tracks will cover many ridges of all different types, without need for special targeting.

Bands. Smooth and lineated bands a few km to tens of km across (shown in purple on Fig. 1) are common in certain regions of Europa, notably in the equatorial antijovian region. Tectonic reconstructions show that the smooth and lineated bands are sites of crustal spreading and exposure of new material from below the surface [3]. Irregular bands do not have parallel edges, do not reconstruct as spreading centers, and may be sites of convergence and crustal subsumption [4]. Bright bands, such as Agenor Linea, have unusually high albedo and may be a sub-category of irregular bands. Irregular and bright bands are much more rarely sampled in the *Galileo* imaging dataset than smooth and lineated bands. The intensive ground-track coverage over the antijovian region ensures that smooth and lineated bands will be extensively covered, whereas currently known irregular and bright bands have at least a few ground tracks that intersect them.

Impact features. There are very few primary impact craters known on the surface of Europa. Because craters are the only type of geological feature on Europa for which we are absolutely certain about the mode of formation, it is important to include as many known large craters as possible under the ground tracks so that they may be used as probes of the ice shell. The simple to complex crater transition occurs at ~6 km diameter on Europa, and the ground tracks cover complex structures such as Tegid and Taliesin, as well as Cilix, which is also compositionally interesting for its dark ejecta halo. The fresh complex crater Pwyll is a target of high interest, but its position on Europa makes it inaccessible to the Europa Clipper trajectory at low altitude. Deeper probes of the ice shell are provided by the multi-ring basins Tyre and Callanish, and three ground tracks offer nadir viewing opportunities over the central regions of these structures.

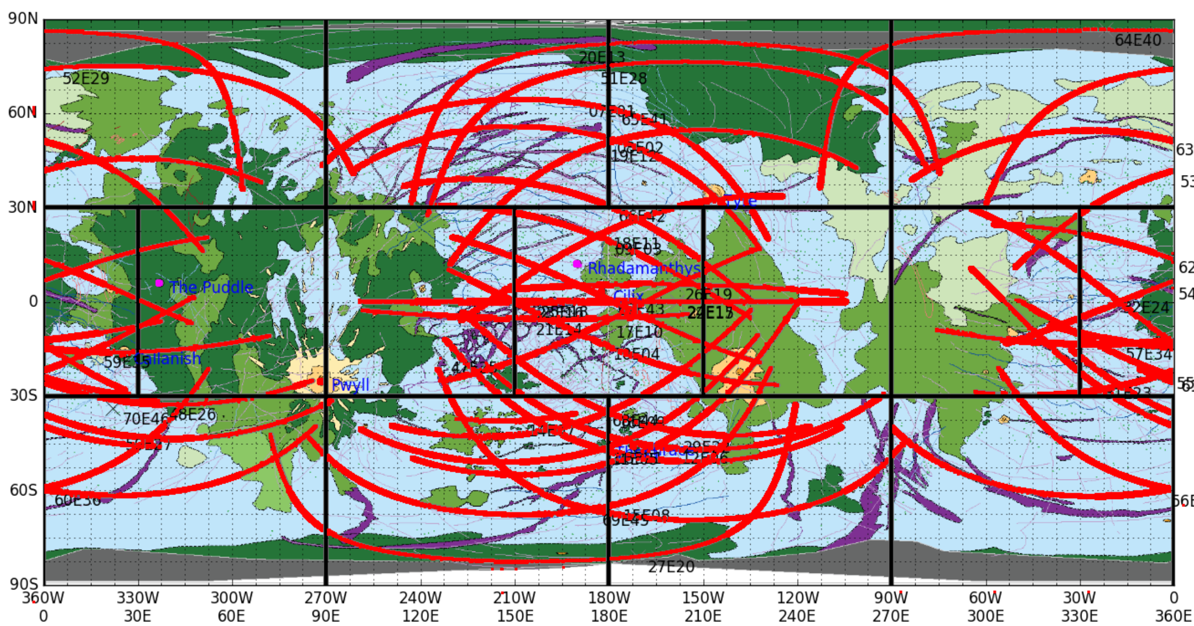
Chaos terrain. In chaos regions, Europa's surface has broken down into small mobile plates surrounded by rough matrix material, apparently through some type of endogenic process. Although small areas of chaos are found in almost every region of Europa, chaos is most heavily concentrated in the areas marked in green on Figure 1. Europa Clipper ground tracks cover many chaos areas, including passes directly over Thera

Macula, posited to be currently active [5]. The mechanics of orbiting Jupiter precludes ground tracks from closely approaching the leading and trailing points of Europa, preventing tracks over Conamara Chaos and Murias Chaos, two areas made famous during analysis of *Galileo* data. However, several similar features seen thus far only at lower resolution will be covered by Europa Clipper ground tracks, enabling completion of this mission objective.

Domes, pits, dark plains. The last three types of features are commonly found in association with each other and with chaos terrain. Domes and pits ~10 km in diameter warp the existing surface up or down, and dark plains appear to fill low areas with smooth, darker material. Dark plains (sometimes called "spots") are usually similar in size to domes and pits, but larger examples like Castalia Macula were also observed in the *Galileo* data. Many of these features occur within (or in close proximity to) the green areas on Figure 1, and Castalia (near the equator at 225°W) is well covered by Europa Clipper ground tracks. Another subtype of pits is the elongated "small circle depressions" [6] found ~40° of arc away from centers near the equator at 120° and 300°W. Several ground tracks cross these depressions, especially the western sides of both small circles.

In Summary: The planned Europa Clipper ground tracks offer a robust and diverse selection of terrain for understanding Europa geology (as we understand it today). Though a few notable features famous from *Galileo* data cannot be covered by direct close-range nadir observations, they can be covered by more distant remote sensing observations on approach and departure. By the end of the mission, most of Europa will be covered by passive remote sensing from the UV to the thermal infrared. Features located in the central sections of the ground tracks will have the highest resolution remote sensing coverage, as well as active radar sounding and *in situ* observations of dust particles and gas emissions from the surface.

References: [1] Leonard et al., LPSC XLVIII #2357, 2017; Senske et al., this meeting; [2] Pappalardo et al., LPSC XLVIII #2732, 2017; [3] Sullivan et al., Nature 1998; [4] Kattenhorn & Prockter, Nat. Geosci. 2014; [5] Schmidt et al., Nature 2011; [6] Schenk et al., Nature 2008.



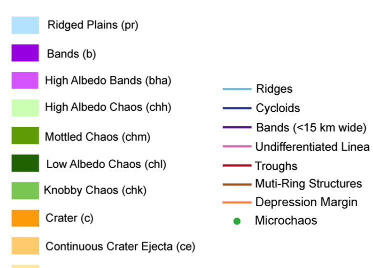


Figure 1: Geologic map of Europa (from [1]) overlaid in red by planned Europa Clipper ground tracks at <1000 km altitude. Blue areas are dominated by ridges. Purple areas are bands. Orange and yellow colors are associated with impact features. Chaos, pits, domes, and dark plains are most strongly concentrated in the green areas, but small examples are also found outside these regions. Along the highlighted ground tracks, the remote sensing instruments [2] will obtain pixel scales of: UVS <1 km, EIS-NAC <10 m, EIS-WAC <220 m, MISE <250 m, and E-THEMIS <280 m. REASON obtains along-track profile spacing of <10 km on these ground tracks.