Geological, Geochemical and Engineering considerations for choosing a landing site on the Jovian moon Europa.
M. R. El Maarry[1], H. Sierks[1] [1]MPI für Sonnensystemforschung, in 37191Katlenburg-Lindau, Germany, elmaarry@mps.mpg.de, sierks@mps.mpg.de

Introduction: The existence of an aqueous ocean, the interactions between the ice crust and liquid, chemical characterization of the surface, and search for biotraces of a pre, or still existing life are some of the important scientific objectives of the upcoming mission(s) to Europa. Many of these objectives maybe achieved through experiments performed in-situ on the surface. One of the most important aspects in planning a lander mission to meet these goals is the choice of a proper landing site that represents a balance between scientific interests and engineering concerns. This work aims at giving a short preliminary list of areas on Europa that not only can be of geological and biological significance, but are also meeting the basic engineering limitations on landing and mission operations.

Available datasets: The site candidates are chosen through the analysis of the high (less than 100m/pixel) and medium resolution (100-300 m/pixel) images of the Galileo solid state imager (SSI), and the near-infrared mapping spectrometer (NIMS). The aim of this approach is to combine the knowledge of the terrain geology and morphology [1] with spectral data of areas of chemical significance [cf. 2, 3]. Due to constraints on image resolution in high latitudes, all the site candidates are proposed in the mid latitudes, i.e. ±50 degrees from the equator.

Geological considerations: A thorough and detailed description of the various geologic units and history of Europa's geologic evolution has been done by various authors [cf. 1, 4, 5]. The relevant part to this work is that a candidate landing site should be chosen with the aim of analyzing material that has been ejected recently in geologic terms, i.e., mottled terrain and Chaos regions (more information on these units is available in the aforementioned references). Consequently, we have chosen sites that are mostly located in Chaos regions, pull-apart bands, and regions that show evidence of material ejected from the surface recently, ex., Fig. 1(c, d, h, i, and k). In addition, large impact craters with central peaks are targets of high scientific values regardless of their age. Large craters should contain material excavated by the impact process that otherwise would not be available for analyzing. For that reason, we included two prime targets to the candidate sites: Pwyll crater (fig. 1a) and an unnamed crater north of Manannán crater lying in old rough terrain (fig. 1b). Both craters are more than 25 km in diameter and display central peak features.

Geochemical considerations: Spectra of Europa were acquired by the NIMS instrument during the Galileo mission. The most interesting spectra collected were those for regions showing what came to be called "Non-icy" material which manifested itself through distorted and asymmetric adsorption features near 1.5 and 2 μm [6]. Many candidates were chosen to explain these features, but the two most prominent candidates have been hydrated salts [2], hydrated sulfuric acid [3], or a combination of both [7]. It is clear that one of the main objectives of any upcoming lander mission would be not only the in-situ analysis of ice, but also that of these "non-icy" materials. Consequently, we have taken into account spatial distribution of this material in choosing our candidate landing sites in order to maximize the scientific gains of the mission (Fig. 2). Consequently, most of the candidate sites fall in regions that show high concentrations of non-icy material as shown in fig. 2

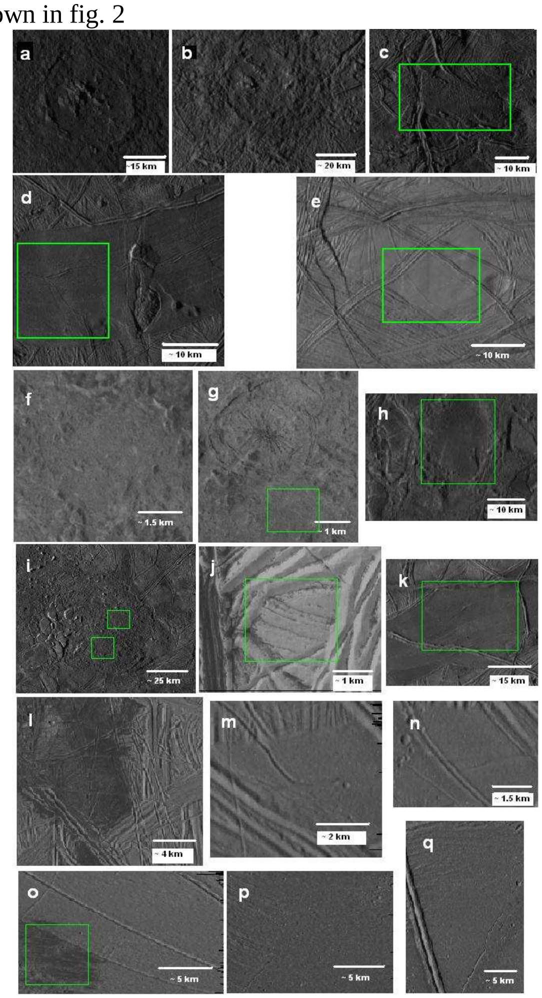

Fig. 1. Candidate landing sites; (a) Pwyll crater (image ID 11E0012); (b) Unnamed crater north of Ma-

nannán crater lying in old rough terrain (image ID E6E0031) ; (c) Small dark area south of Belus linea, highly indicative of recent material that has been injected into the surface disrupting the previous terrain (image ID 11E0014); (d) Dark pull-apart band south of (c) of material that has cut through and separated the older ridges on either side of the band (image ID 11E0016); (e) A remarkably "smooth" inter-banded region between several small ridges lying in region full of small unnamed lineae between Cadmus Linea in the north and Belus linea in the south (image ID 15E0007); (f) A rather smooth region within the Dyfed Regio east of Manannán crater (image ID 14E0006); (g) A smooth region just south of Manannán crater which appears in the upper part of the image (image ID 14E0007); (h) A smooth plain in a chaotic terrain south of Belus Linea (image ID 11E0011); (i) A chaotic-like terrain southeast of Manannán crater, similar in appearance and mode of formation to (c) but on a larger scale. No higher resolution images exist for this region to asses it fully in terms of its suitability for a lander (image ID 11E0013); (j) One of the highly resolved sites on the eastern edge of Yelland Linea in Argadnel Regio (image ID 12E0067); (k) A pull-apart dark band similar to (d) west of Castalia Macula in the Argadnel Regio (image ID 11E0015); (l) A highly resolved area in the Thrace Macula. Note the contrast between the Macula and the surrounding terrains in terms of color and texture (image ID 17E0056); (m) and (n) Both taken from the same high resolution image for terrain around Thrace Macula. Should prove as excellent targets for "older" terrains (image ID 17E0057); (o) Another site in the terrain around Thrace Macula which seems to show a transition between the darker and lighter colored terrains (appears more clearly in the parent image) (image ID 17E0058); (p) and (q) High-latitude targets around an unnamed Macula-like terrain around Libya Linea (image ID 17E0059 and 17E0060). The area shows features similar to the pull-apart bands of (d) and (k).

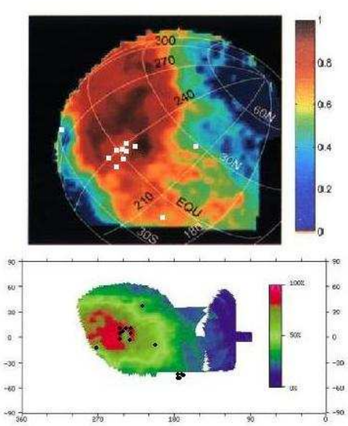

Fig. 2. Global distribution of "non ice-mixtures" as measured by NIMS onboard Galileo. White squares (upper panel)and black dots (lower panel) represent approximates locations of the candidate landing sites; **(a)** Spatial distribution of what McCord et al., assumed to be hydrated salts; **(b)** Similar distribution fractions reported by Carlson et al., assuming the non-ice mixtures to be those of hydrated sulfuric acid mixtures.

Engineering considerations: Due to the lack of enough information to make a definite choice of a landing site. It is assumed that the lander will be separated from a mother orbiter when the orbiter has arrived, maintained a closed orbit (circular or otherwise), and has collected more data that can help in constraining a candidate site. Consequently, this removes any restrictions on having definite landing ellipses that would, in that case, be dependent on a hyperbolic trajectory of a direct interplanetary arrival [8]. This makes the orbiter's orbit around Europa the defining factor, which is outside the scope of this work. However, a near equatorial site should be favored due to the differences in average temperatures between the poles and the equator. The energy from solar irradiance (~50 W/m2 on average) , will most probably be inefficient in powering all the lander's subsystems, rendering the reliance on other sources of energy (ex. radioactive substances) necessary, which means that putting the lander in an environment with the highest possible ambient temperatures is of prime importance for the mission's energy budget.

Summary: These candidate sites should only act as preliminary targets for further investigation. More information is needed to constrain the optimum site. While the sites suggested here are all in the mid-latitudes, this should not rule out the possibility of a near polar site if indeed, future observations show it to be of a higher scientific value. Rather, it is hoped that these sites can act as primary targets of interest from which a suitable site can be finally chosen.

References: [1] Papalardo R. T., et al., (1999), JGR, 104, 24,015-24055. [2] McCord, T.B., et al., (1999), JGR, 104, 11827-11,851. [3] Carlson R. W., et al, (2005), Icarus, 177, 461-471. [4] Carr, M.H., et al., (1998) Nature, 391, 363-365. [5] Procketer L. M., et al., (1999), JGR, 104, 16,531-16540. [6] Dalton J. B., et al., (2005), Icarus, 177, 472-490. [7] Orlando T.M. et al., (2005), Icarus, 177, 528-533. [8] Ball A. J, Garry R. C., Lorenz R. D., and Kerzhanovich V. V., (2007), Planetary Landers and Entry Probes, ISBN 978.5218200028, Cambridge University Press.