

# Chaos units in Argadnel Regio, Europa: Implications for timing of chaos formation



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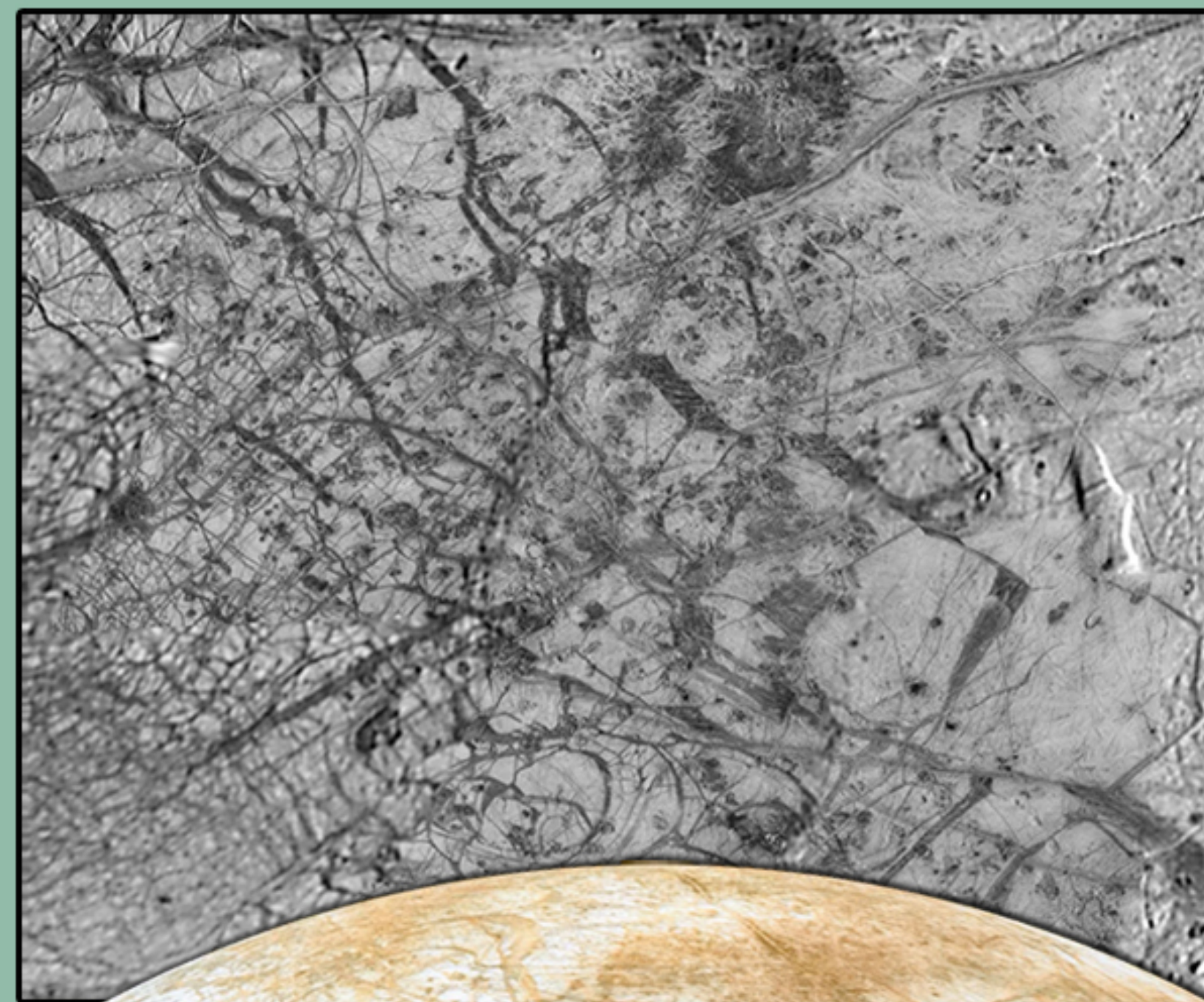
## Introduction

Chaos terrains are among the more prominent landforms of Europa, and are characterized by the disruption of the pre-existing crust, which is broken in plates of various sizes in a dark and rough matrix [1]. Chaos terrains are formed due to endogenic activity, most probably related to solid-state convection and thermal diapirism in the ice shell [2].

Chaos terrains are located towards the top of the stratigraphical sequence of Europa, implying that those terrains are in general among the younger structures recorded in the surface. After the general stratigraphy of Greeley et al. [3], the oldest recognizable unit is the background ridges plains, which are characterized by other structures such as bands and large ridges, finally chaos terrains are cross-cutting all other units. However, there are regional examples of chaos terrains affected by younger landforms [4].

In this work, we analyze the crossing relations between chaos terrains and the other geologic structures, as well as between several units of chaos terrains. Our aim is placing the events of chaos formation into the general stratigraphic framework of this region of Europa and the implications for the local geological history of this jovian moon.

Argadnel Regio, with 1900 km, is located in the antijovian hemisphere of Europa characterized by crosscut wedged bands of very low albedo material. The image mosaic E14ESWEDGES01, obtained during the 14th Galileo orbit which has a mean resolution of 230 m ppx.

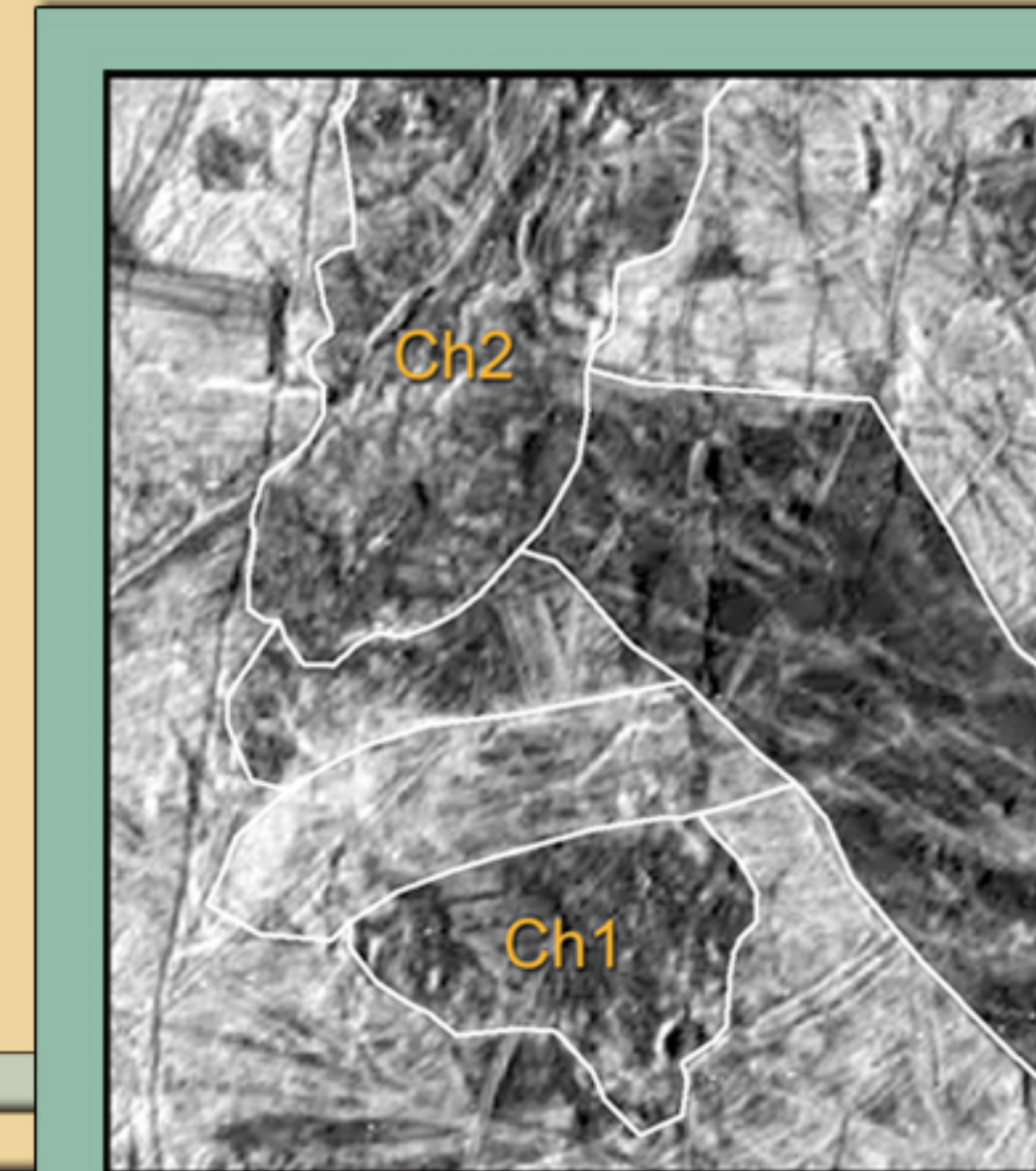


## Chaos Units

Chaos units can be distinguished by texture, morphology, matrix proportion, and relative position with respect to other structures. The two chaos events can be placed in different positions in the stratigraphic sequence, therefore being of different relative age.

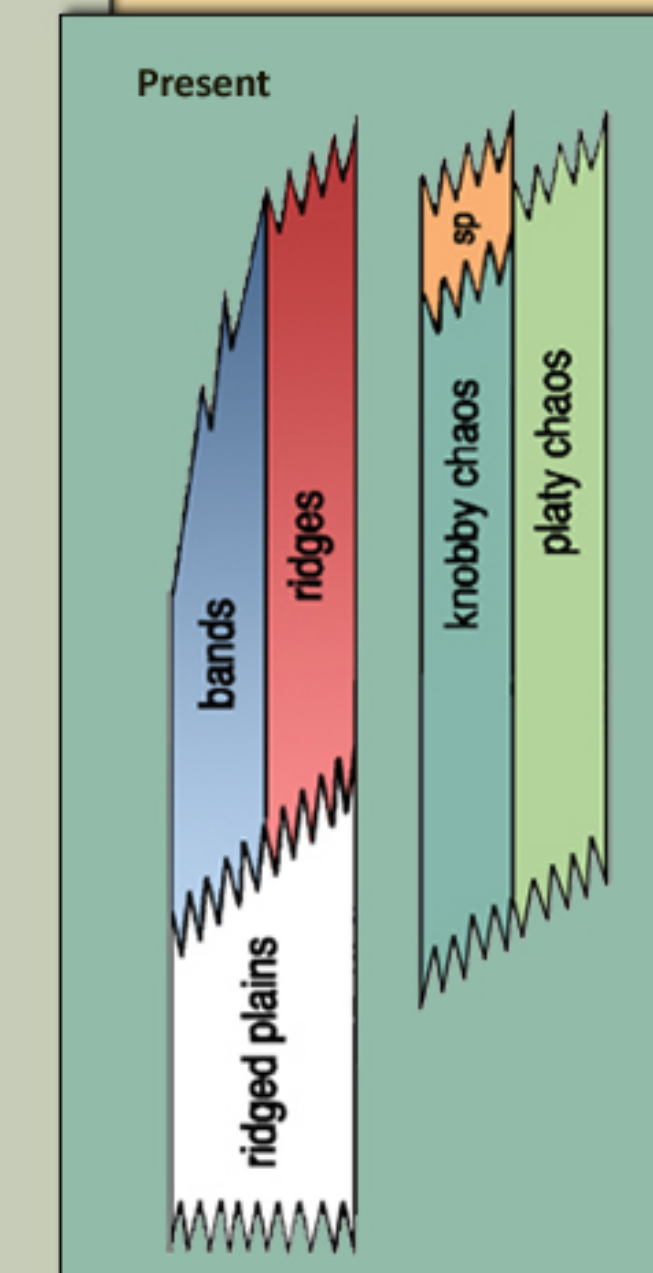
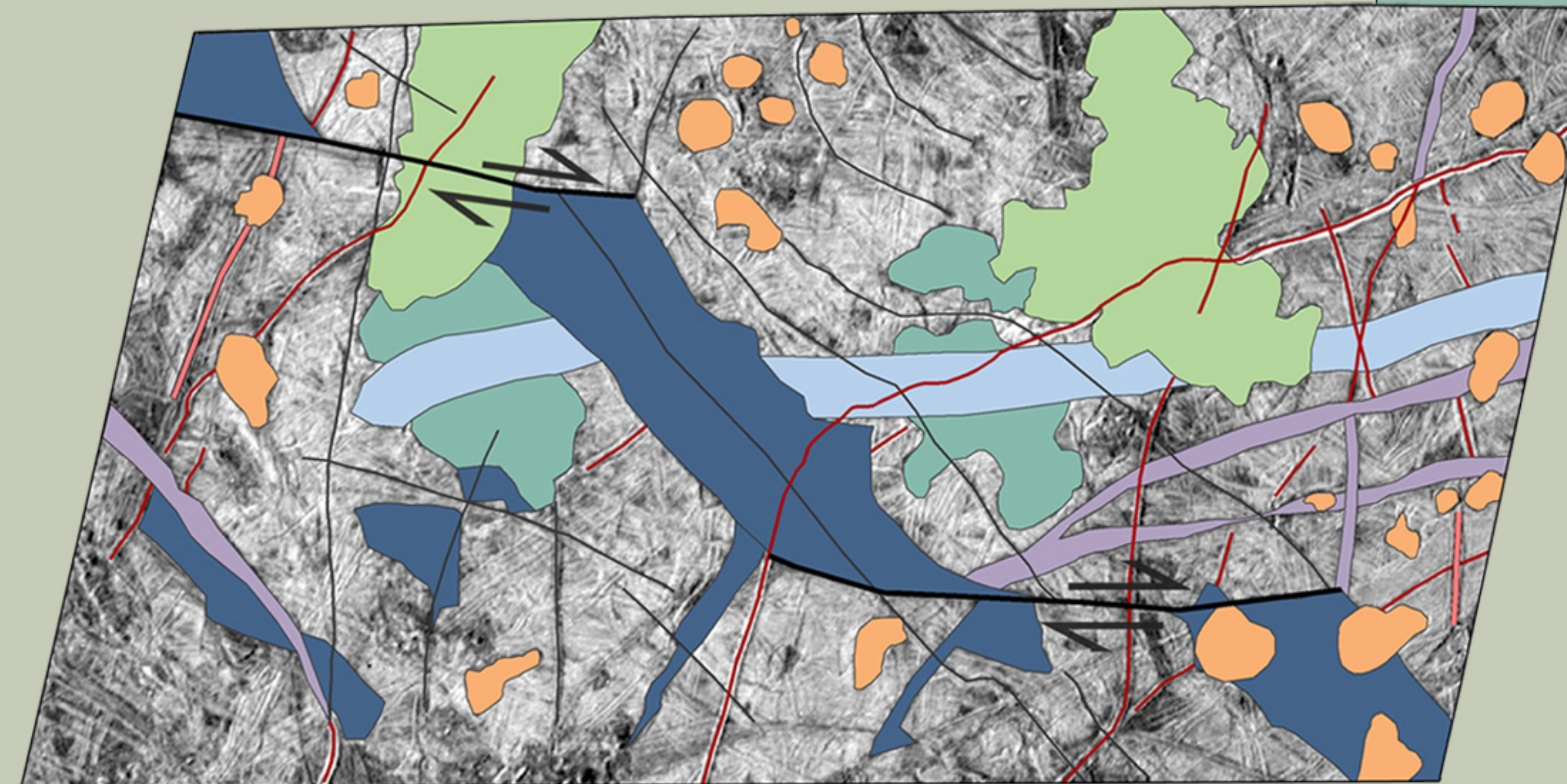
- Chaos Unit 1 presents an irregular morphology, with a relatively smooth matrix, and with scarce plates or blocks. The chaos boundaries are well defined because they are darker than the surrounding material. This chaos unit is crossed and affected by younger structures: a dark band, a complex band, and a different class of chaos terrain (second chaos unit).

- The younger Chaos Unit 2 is characterized by a more heterogeneous matrix, in which plates (showing the pre-existing surface) and smaller blocks are best preserved. This unit is disrupting dark band material and the first chaos unit.



In our study area, can be characterized at least two chaos formation events, Chaos unit 1 (Ch1) and Chaos Unit 2 (Ch2).

Geological map of Europa with the different chaos units (green toned) and their relations with other geologic units.

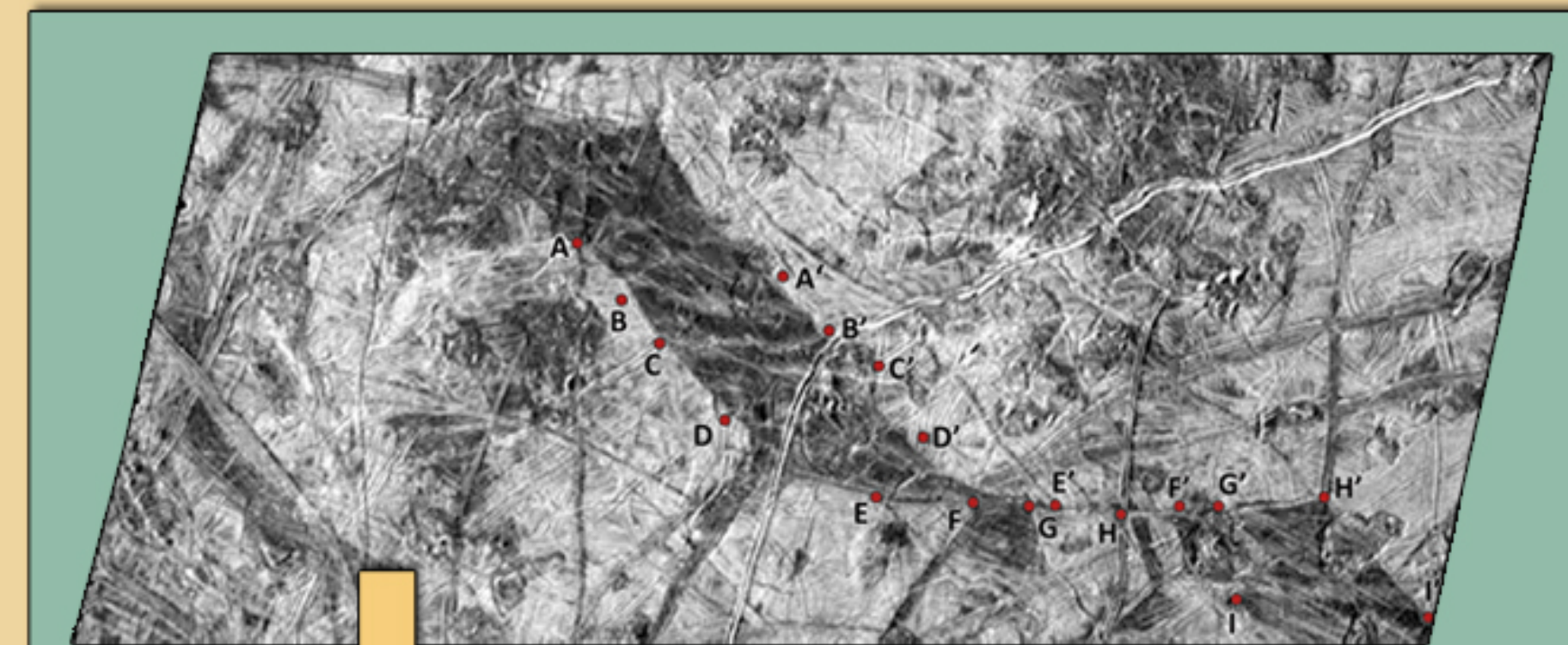


Stratigraphic column of the mapped area in Argadnel Regio. Modified from [3]

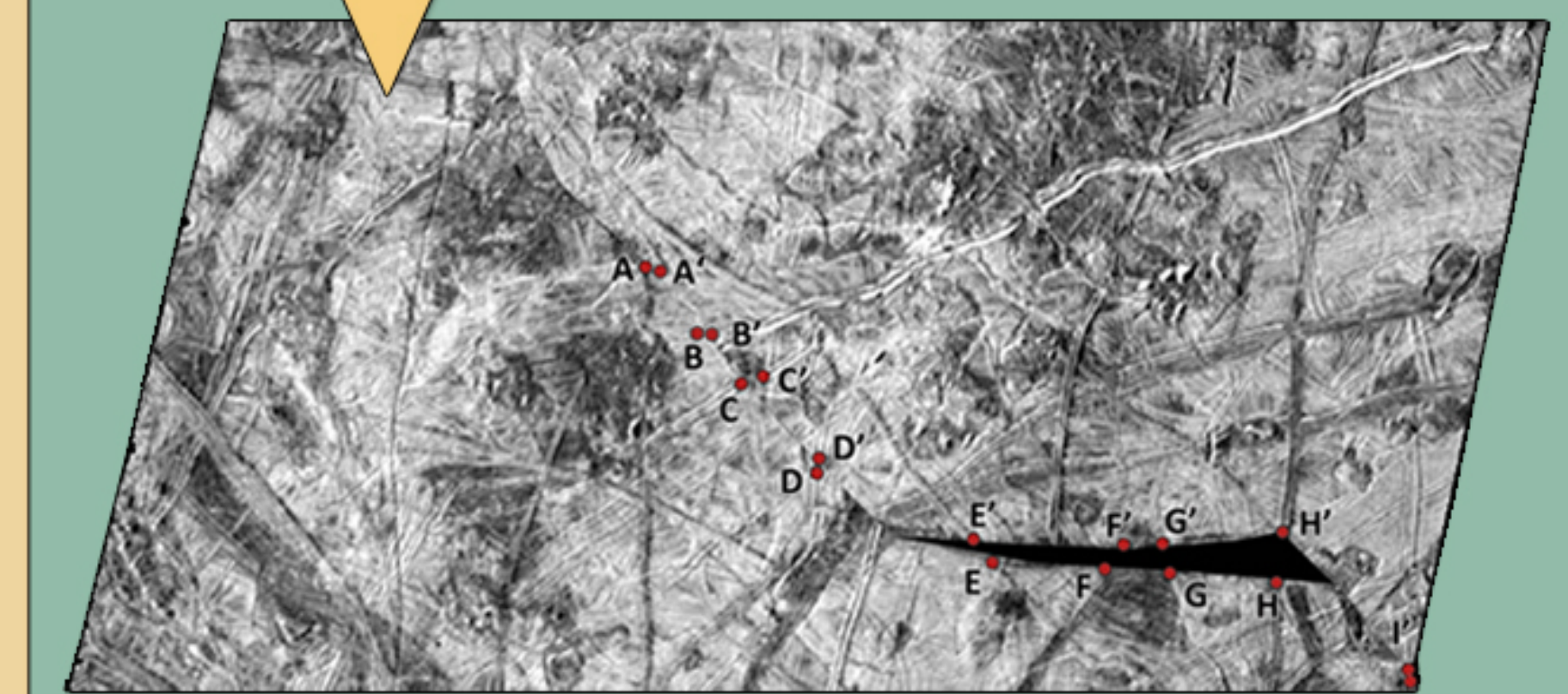
## Relationship of units

In this area the dark band (dark blue) oriented NW-SE is a prominent dark band, formed by three segments separated by dextral strike-slip faults. It's a dilational band formed by extension and separation away of the pre-existing crust. The complex band (light blue) exhibits a complex internal structure, characterized by ridges and lineaments. Other narrower bands (lavendar) of intermediate albedo correspond to those usually referred to as "gray bands" [5].

The determination of relative age relation between both bands permits us to define the relationship between the two units of chaos terrain and the other geological units in the study area.



Reconstruction



The dark band can be closed by eliminating the dark material filling the gap created by the opening process. This figure show piercing points for structures that can be clearly joined when the dark material is removed. The complex band is well-restored (piercing points A-A' and B-B'), and their internal lineaments are perfectly joined.

The complex band completely transects one of the areas of Ch1; therefore, this chaos unit must be older than the complex band. Hence, it is clear that this chaos terrain is also older than the dark band.

Chaos Unit 1 is crossed to the NE by the dark band. Older lineaments of the background plains are visible in this part of the chaos terrain, and those lineaments are well reconstructed by closing the dark band. This suggests that this part of the ridged plains are covered by dark cryomagnetic materials, rather than being disrupted.

Chaos Unit 1 does not seem to cross-cut terrains other than the ridged background plains, which reinforces our interpretation of that this unit formed early in the stratigraphic sequence of Argadnel Regio. On the other hand, Chaos Unit 2 is cross-cutting other geologic terrains, specifically the dark band and Chaos Unit 1.

## Conclusions

The geological history generally applicable for Europa, is not strictly the case in Argadnel Regio, considering our observations of two stages of chaos formation, where one of the chaos units clearly predates band formation. These chaos units show different levels of surface disruption, have a different surface texture, and the boundary between them is well demarcated.

The following stages in the geological history of this region are: (1) emplacement of bright ridges plains; (2) formation of Chaos Unit 1 affecting and disrupting the plains; (3) formation of the complex band by in-situ generation of parallel ridges; (4) dilation of the crust and formation of the dark band; and finally, (5) formation of Chaos Unit 2, which disrupts both the dark band and Chaos Unit 1.

This region of Europa records a complex geologic history.

## References

[1] Carr M. H. et al. (1998) Nature, 391, 363-365. [2] Pappalardo R. T. et al. (1998) Nature, 391, 365-368. [3] Greeley R. et al. (2000) JGR 105, 22559-22598. [4] Greenberg R. et al. (1999) Icarus, 141, 263-286. [5] Prockter L. M. et al. (1999) JGR 104, 16531-16540.