GANYMEDE'S SURFACE INVESTIGATION IN SUPPORT OF THE RADAR FOR ICY MOON EXPLORATION (RIME) INSTRUMENT.

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JUICE (Jupiter Icy Moon Explorer)

- A mission by the European Space Agency and its patners.
- Scheduled launch in 2022 and arrival in the Jovian system in 2030.
- The first mission to the outer Solar System which includes instrumentation capable of performing direct subsurface measurements.

Fig.1. The three jovian satellites, objects of study. 2006 Pearson Education Inc., publishing as Addison-Wesley.

Aims

- Investigate the potentially habitable zones in the Galilean icy satellites.
- Characterise Ganymede as a planetary object and possible habitat.
- Explore Europa's recently active zones.
- Study Callisto as a remnant of the early Jovian system.

Instruments

The instruments particularly important and relevant to geological investigation of the icy moons are *Jovis, Amorum ac Natorum Undique Scrutator* (**JANUS**) camera system [1], *Ganymede Laser Altimeter* (**GALA**)[2], and Radar for Icy Moon Exploration (**RIME**) [3]

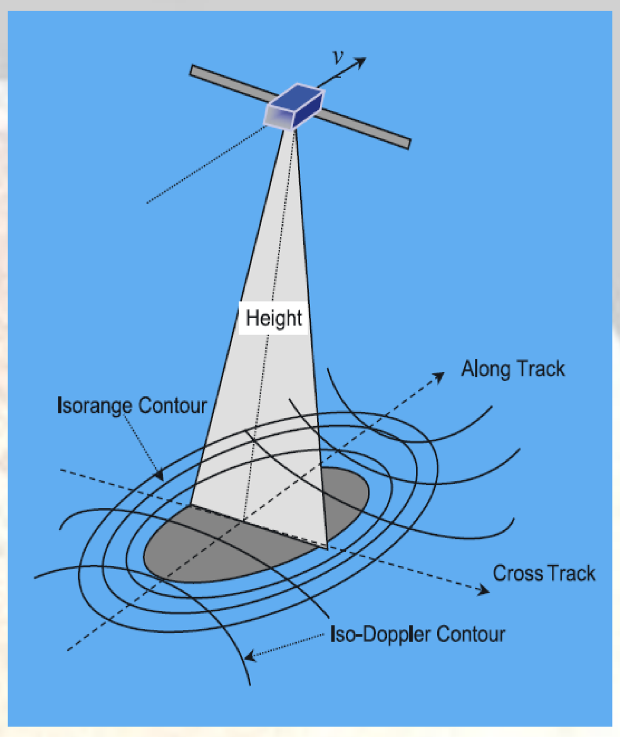

Fig.2. Orbital subsurface sounding by a radar. JUICE presentation by J.J. Plaut and L. Bruzzone (http://www.lpi.usra.edu/opag/jan2014/presentations/20_Plaut.pdf).

Main Instrument parameters	Parameter values
Transmitted central frequency (MHz)	9
Antenna type	Dipole
Optimal antenna length (m)	16 m
Peak radiated power (W)	10
Stand-by power with cont. (W)	13.3
Avg. power during sounding with cont. (W)	25.1
Penetration depth (km)	As deep as 9
Chirp length (μs)	50 - 100
Vertical resolution in ice (m)	30 - 90
Cross-track resolution (km)	2 - 10
Along-track resolution (km)	0.3 - 1.0
Circular Orbital Phase	
Orbit height (km)	200 - 500
Pulse repetition frequency (Hz)	200 - 400
Chirp bandwidth (MHz)	3, 1
Chirp length (μs)	50 - 100
Receiver window length (μs)	117 - 226
Data rate (kbps)	216 - 250
Flyby Phase	
Flyby distance (km)	< 1000
Pulse repetition frequency (Hz)	500
Chirp bandwidth (MHz)	3
Chirp length (μs)	100
Receiver window length (μs)	226
Data rate (kbps)	2400

Tab.1. Data sheet of the RIME instrument. RIME- Radar for Icy Moon Exploration, L. Bruzzone et al., IGARSS 2013

RIME (Radar for Icy Moon Exploration)

- Radar sounder, an ice penetrating radar,
- Optimized for the penetration of the Galielian icy moons, up to a depth of 9 km,
- To study the geology and the geophysics of the icy moons.

Radar sounders are nadir-looking active instruments which transmit radio waves. They penetrate deeply into the subsurface. When these radio waves travel through the subsurface, their reflected signal varies as they interact with subsurface horizons and structures with differing dielectric constants. These varying reflections are detected by the radar sounder and used to create a depth image of the subsurface.

Aims

- RIME will probe the icy shell of **Ganymede** for understanding the formation of surface features, searching for past and present activities, and constraining the global composition, distribution, and evolution of surface materials.
- On **Europa** RIME will permit to relate material composition and distribution to geological features and geological processes,
- RIME will do surface and subsurface exploration of the icy crust below **Callisto** determining the formation and characteristics of tectonic and impact landforms.

GEOLOGICAL STUDY IN SUPPORT OF THE INSTUMENT RIME

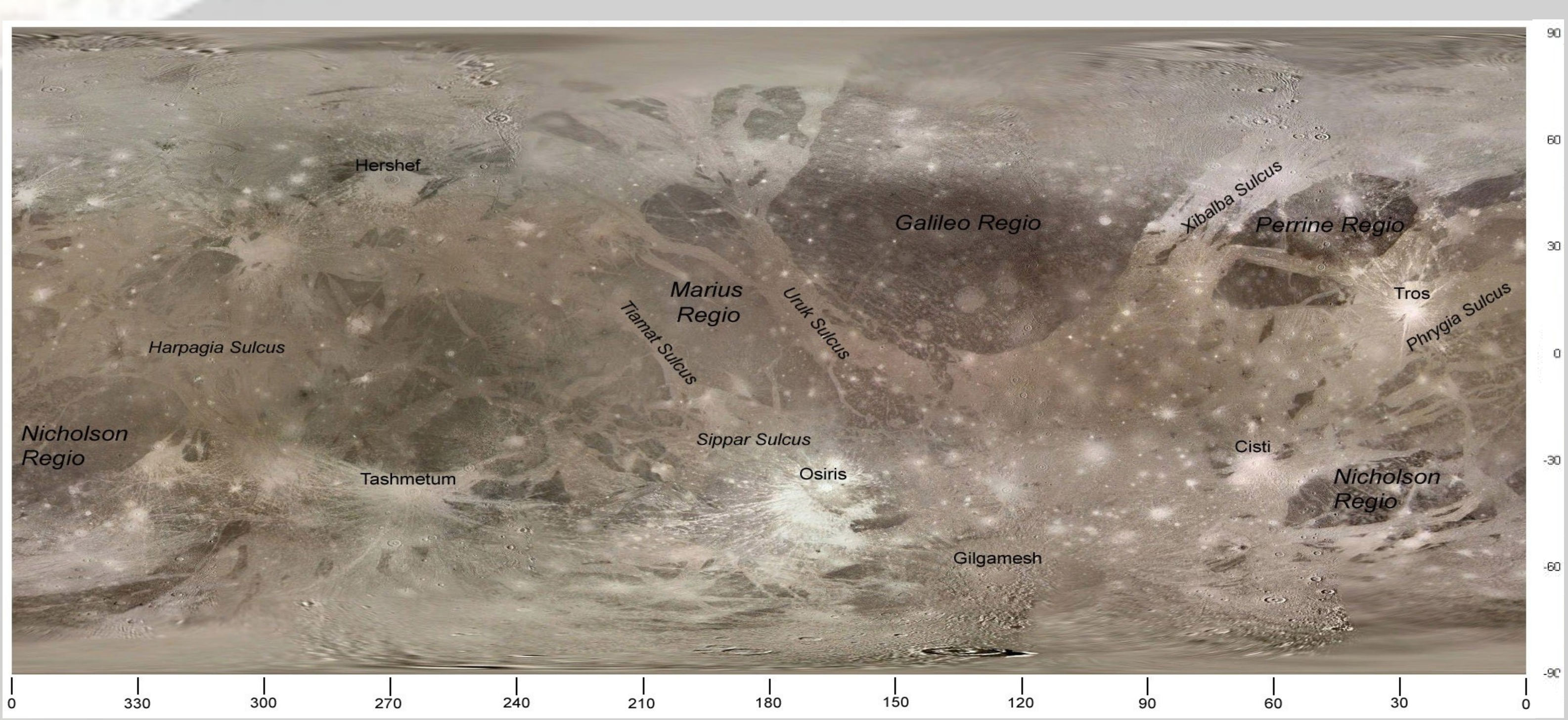

Fig.3. **Map of Ganymede** assembled by the *British Astronomical Society based on a basemap by Bjorn Jonsson*. Cylindrical projection. Centred on the antijovian point (L=180).

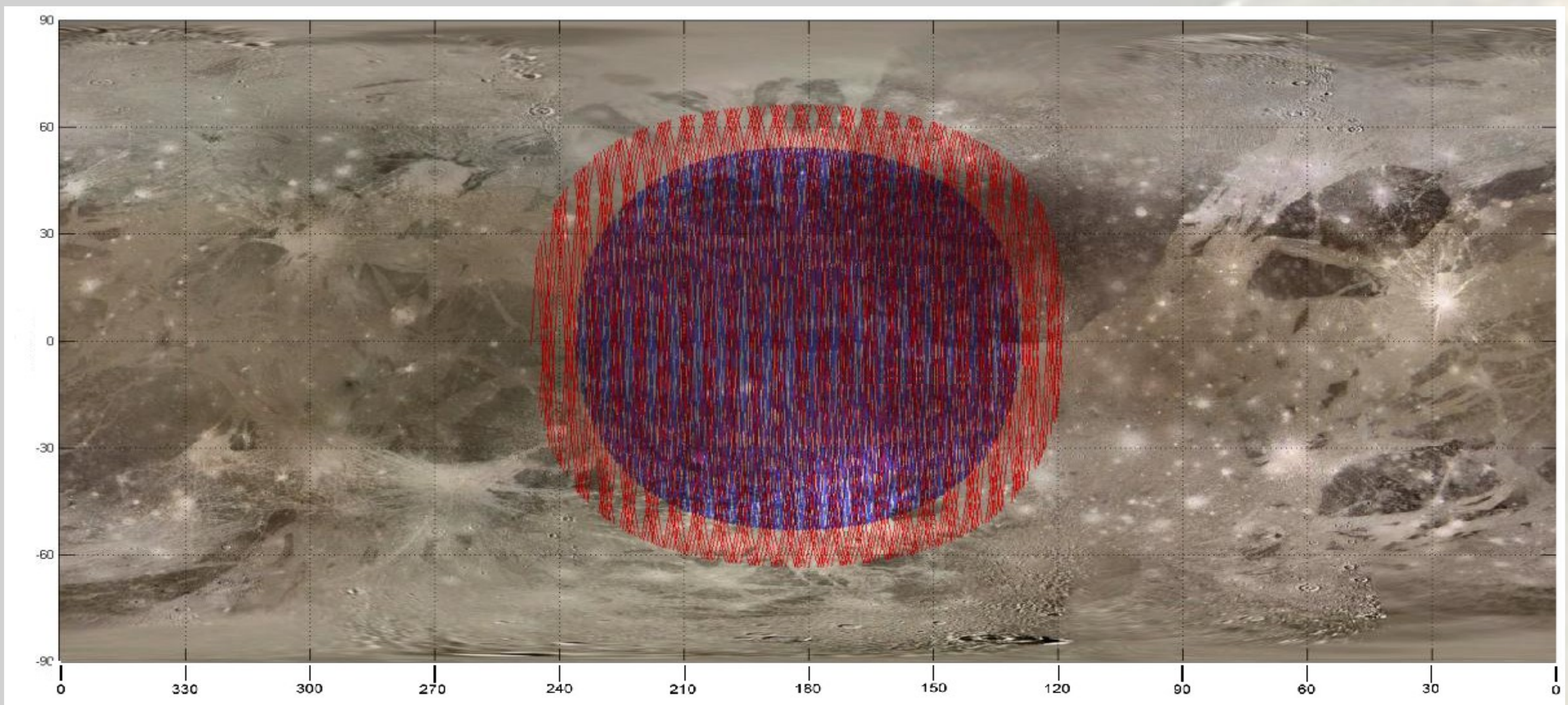

Fig. 4. Plot of the planned RIME **coverage on Ganymede**. The tracks show the area where the spacecraft is completely screened from Jovian radio emission. Ground tracks for the 500 km orbit phase are shown in blue, and those for the 200 km orbit are shown in red. *JUICE presentation by J.J, Plaut and L. Bruzzone (http://www.lpi.usra.edu/opag/jan2014/presentations/20_Plaut.pdf)*

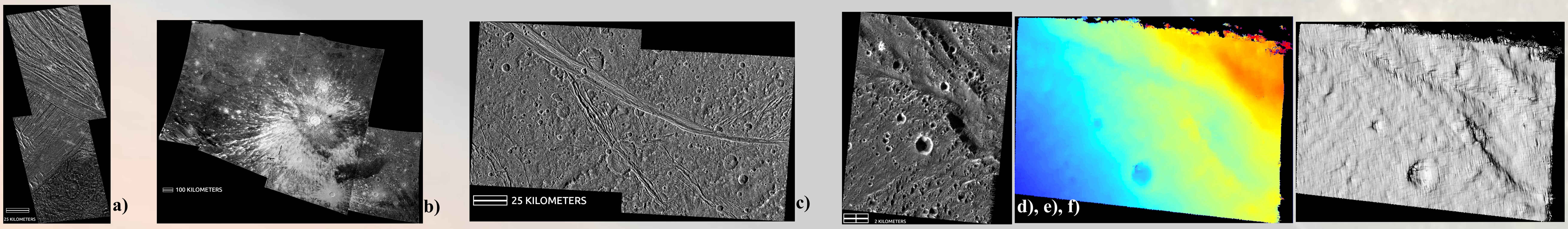

Fig. 5. Representative geological features of Ganymede. The RIME instrument will examine these types of features during the mission. We intend to understand the type of subsurface structures existing underneath these features in preparation for the mission. **a)** Grooved terrain and the difference between light and dark terrains centered near (lat 47°, lon 156°), **b)** Osiris Crater, an impact crater with far-reaching ejecta deposits, crater centered near (lat –37°, lon174°), **c)** dark terrain of Marius Regio centered near (lat 12°, lon 169°), craters divided by tectonism. In addition, in order to understand the structures better, we also use Digital Terrain Models (DTMs): **d)** image of Harpagia Sulcus centered near (lat -16°, lon 310°), **e)** DEM, **f)** hrad-shaded

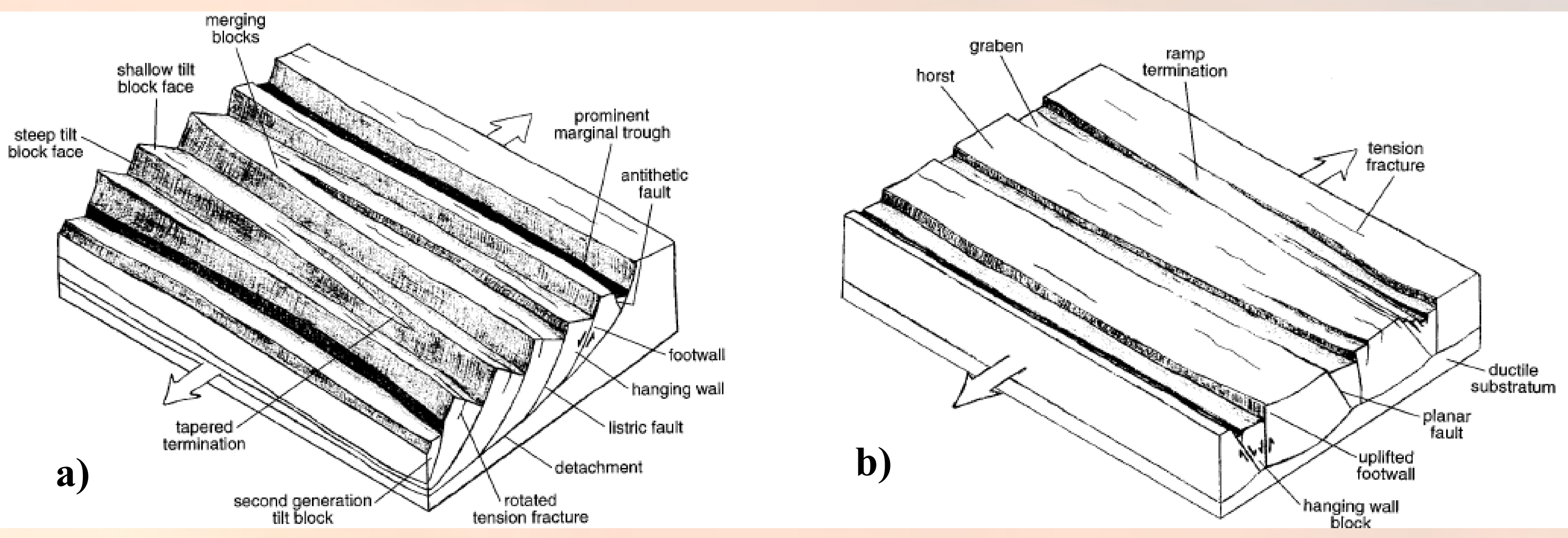

Fig. 6. Typical interpretation of fault geometry of parallel ridged terrain,on Ganymede. In this example the area of Uruk Sulcus is hipothesized: **a)** Idealized predictions of tilt-block-style normal faulting. **b)** Idealized morphological predictions of horst-and-graben-style normal faulting. Pappalardo et al. (1998). Understanding fault geometry is important for RIME exploration and we are assessing the hypotheses.

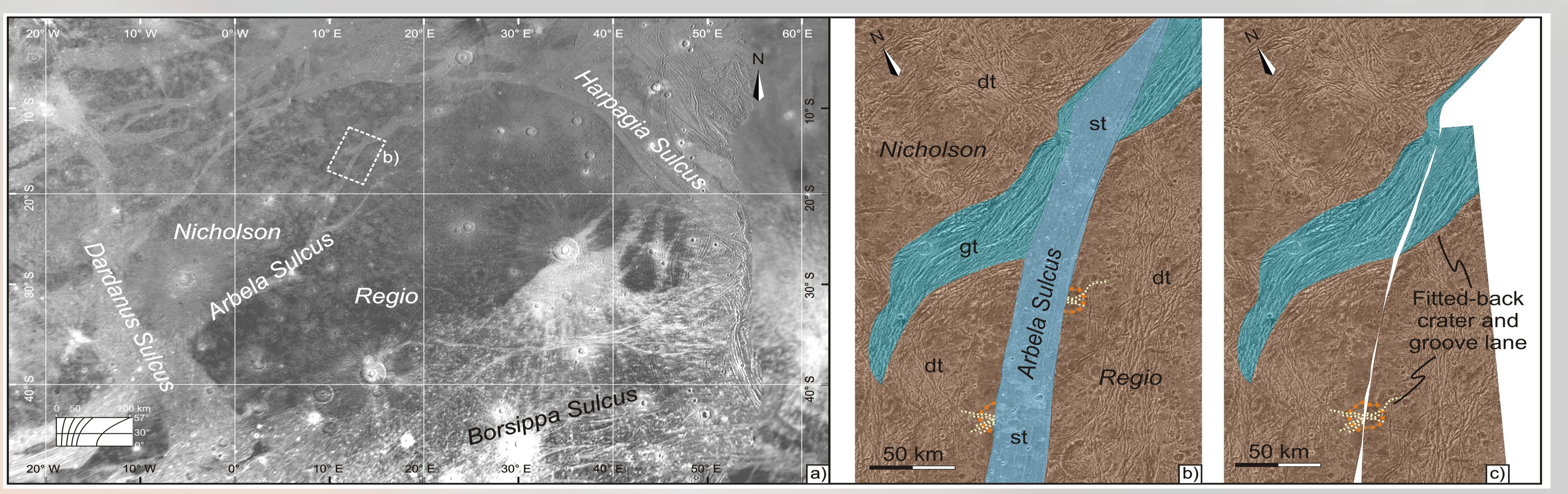

Fig. 7. An example of analysis we have been conducting for the evaluation of various hypotheses. a) Dark terrains at Nicholson Regio affected by both NNW-SSE- and NE-SW-trending sulci. Dashed rectangle indicates the area in Fig. b) Close-up of Arbela Sulcus. Smooth terrains (st) fill the Arbela Sulcus crosscutting both grooved (gt) and dark (dt) terrains. Dashed orange and white lines indicate crater and major fractures affecting the crater, respectively, offsetted by Arbela Sulcus c) Closing the Sulcus by making some relative movements among the involved blocks the groove lane and the two portions of a crater affecting the dark terrain can be fitted-back together (from Head et al., 2002). We are evaluating the previous interpretations such as the one presented by Head et al. (2002).

[1] Palumbo P. et al. (2014) LPS 45th, Abstract #2094. [2] Lingenauber K. et al. (2013) EPSC 2013, Abstract #428. [3] Bruzzone L. et al. (2013) IGARSS, IEEE, 3907–3910. [4] Pappalardo R.T. et al. (1998) Icarus, 135, 276–302. [5] Head et al. (2002) Geophysical Research Letters, 29, 24, 2151.
Background figure by NASA.