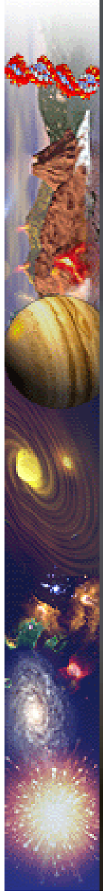
ASTROBIOLOGY OF EUROPA

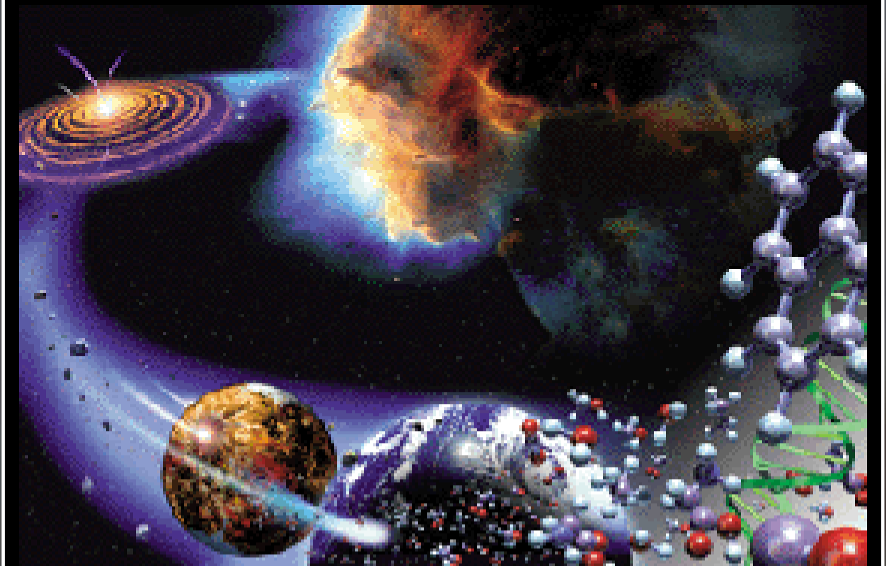
O. Prieto-Ballesteros, J.A. Rodriguez Manfredi, Felipe Gómez-Gómez.
Centro de Astrobiología-INTA-CSIC, Ctra. Ajalvir km. 4, 28850 Torrejón de Ardoz, Madrid, Spain. Contact: prietobo@inta.es

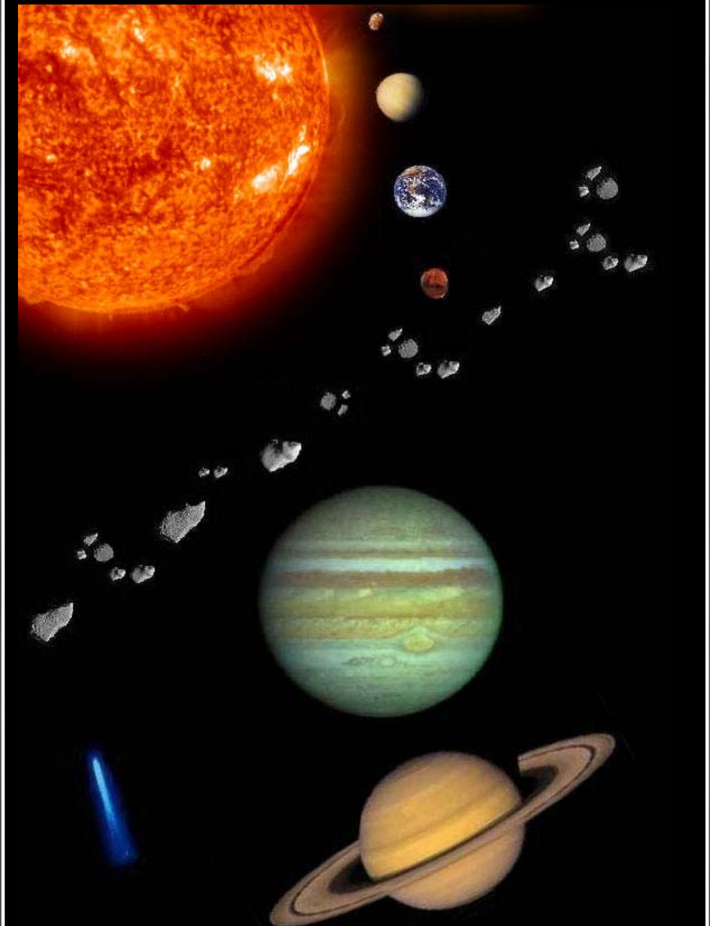
International Workshop Europa Lander: science goals and experiments

CENTRO DE ASTROBIOLOGÍA



Astrobiology: study of the origins, distribution and future of Life in the Universe





It includes the **searching of potential habitable planetary objects in our Solar System** as one of the main goals

CENTRO DE ASTROBIOLOGÍA

POTENTIAL HABITABILITY OF THE SOLAR SYSTEM

Mars has been traditionally the main target for astrobiological exploration.

Many missions to Mars

Evidences of a warmer and wetter past:
- flows
- hydrated minerals …

Lessons from the exploration:
- Planetary Protection
- Biological Experiments
- Technology challenges

FUTURE PLANETARY MISSIONS:
- ExoMars
- MSL
- AFL

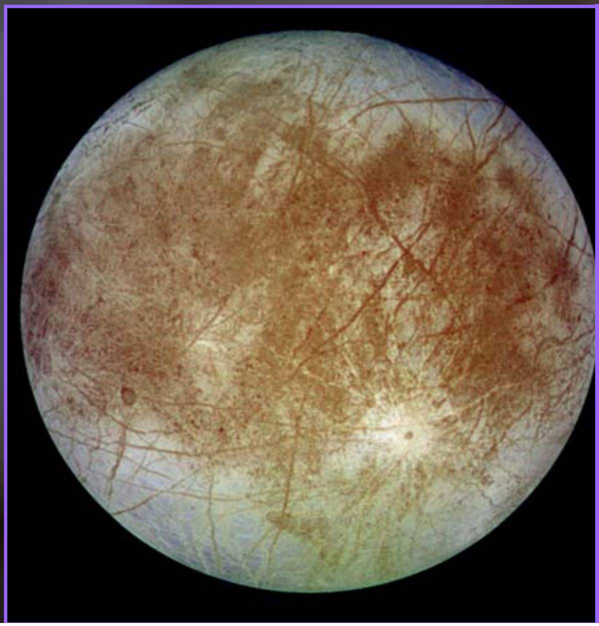
CENTRO DE ASTROBIOLOGÍA

STARTING THE ASTROBIOLOGICAL EXPLORATION OF THE OSS

1) Where do we look for life or answers about its origin? Potential habitable environments / Organic rich environments

2) What kind of life signals do we look for?. Extinct/extant life.

3) How could we detect them? Remote sensing vs. in situ measurements



International Workshop Europa Lander: science goals and experiments

1-WHERE) POTENTIAL HABITABLE ENVIRONMENTS

Planetary habitability is the measure of a planet's or a natural satellite's potential to develop and sustain life

LIFE on Earth

- Liquid water
- Chemical Building blocks. and appropriate environment for complex organics
- Energy sources (light, redox couples)

Evidences from previous missions

High priority on the exploration of EUROPA

(+)

- Harbor liquid water ocean
- Meteorites and other objects could have brought carbon (even organics)
- Active body with energy
- Interface water/rock: chemical disequilibria

(-)

- Radiations are too strong on surface
- Extreme conditions
  - pressure
  - pH
  - salinity
  - absence of light

EJSM is the first step in the exploration of habitability …

CENTRO DE ASTROBIOLOGÍA

Evidences supporting the liquid water in the interior of Europa.
CONFIRMATION OF THE PRESENCE AND CHARACTERIZATION ARE NEEDED

TECHNIQUE	IMPLICATIONS	CHALLENGE
Theoretical study of tidal deformation and heating	Predicts that an ocean will persist once formed	Rheology of ice is poorly known, especially at tidal frequencies, so predictions are uncertain
Observations of surface deformation, especially “chaotic” regions, rafting, cycloidal ridges, possible low viscosity surface flows	Suggests thin ice and highly mobilized ice, consistent with an underlying ocean	Might be explained by thin, cold, brittle ice “floating” on thick, warm, soft, easily deformed ice
NEAR Infrared spectroscopy suggesting salt deposits on surface	Salt could arise from sublimation of a salty water “eruption”	Even if water is implicated, it need not come from an ocean—there may be melting within the ice
Magnetic field evidence for an induction response	Requires a near surface, global conducting layer, most readily explained by a salty ocean	Is there any other possible conducting layer?
Altimetry and gravity field with sufficient resolution to determine tidal variation	Clear determination of whether there is an ocean; information on ice thickness	Requires Europa orbiter

Compiled by D. Stevenson (2000), Science 289, 1305-1307

Composition of the surface from spectral data.
CLUES CONCERNING THE INTERIOR ENVIRONMENTAL CHEMISTRY (NUTRIENTS) SHOULD BE SEARCHING

Water Ice I is dominant *(Pilcher et al. 1972, Clark and McCord, 1980, Clark 1981)*

Other identified materials:

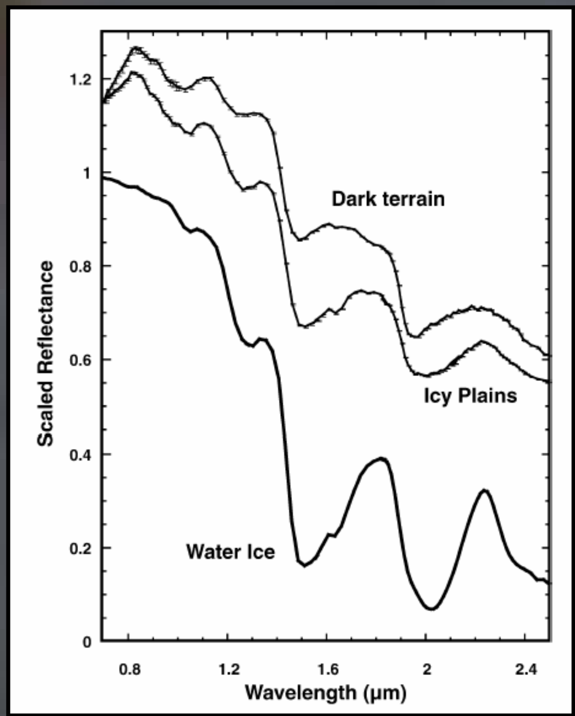
SO_2 *(Lane et al.,1981; Noll et al.,1995; Lane & Domingue,1997; Domingue & Lane,1998).*
CO_2, *(Smythe et al., 1998, Carlson 2001).*
H_2O_2,*(Carlson et al 1999a)*
Amorphous H_2O *(Hansen & McCord, 2001)*
O_2 *(Hall et al., 1995, 1998; Spencer & Calvin, 2002)*
Na, K ions *(Johnson et al., 2002)*

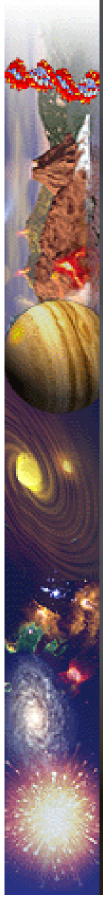
Hydrated species on the Dark terrains, distorted absorption features near 1.5 and 2.0 μm. Candidates:

Salt hydrates *(McCord et al. 1998, 1999: Kargel et. al. 2000, Dalton et al. 2005)*

Sulfuric acid hydrates *(Carlson et al. 1999b, 2002)*

Conducting solution if salts are dissolved in the water ocean





Some planetary environments may be envisioned .
Data sources: Spectroscopy, Geology/geophysics, Theoretical modeling

Environment	Physical-chemical characteristics	Energy sources	Terrestrial analog
Surface	Water ice contaminated by hydrated minerals (salts or/and sulfuric acid hydrates), organics (?) Cold. Low pressure. Liquid water deficiency	Extreme Radiation Oxidants	Polar ice surfaces
Subsurface	Water ice contaminated by hydrated minerals. Clathrates?. Organics (?) from surface. Cold. Cryospheric pressure.	Oxidants (?) from surface	Polar ice surfaces
Ocean or aqueous reservoir (speculative)	Saline. and organics (?) from the surface Dissolved gases? Thermally stratified or mixed. Pressure dependent of the crust thickness. pH?	Oxidants (?) from the surface Methanogenesis Chemolithotrophy	Subglacial Antarctic lakes Saline lakes
Seafloor or interface water/rock	Saline. Hydrothermal vents. Hot. High pressure. Rock-water interface. Salt deposits.	Methanogenesis Chemolithotrophy Thermal	Submarine hydrothermal vents Thermokarst?

CENTRO DE ASTROBIOLOGÍA

2-WHAT) ASTROBIOLOGICAL MEASUREMENTS (BEFORE A MISSION WHICH REACHS THE POTENTIAL HABITABLE ENVIRONMENT)

RADIATION ON THE SURFACE ALTERS DRAMATICALLY OR DESTROY THE MATERIALS!!

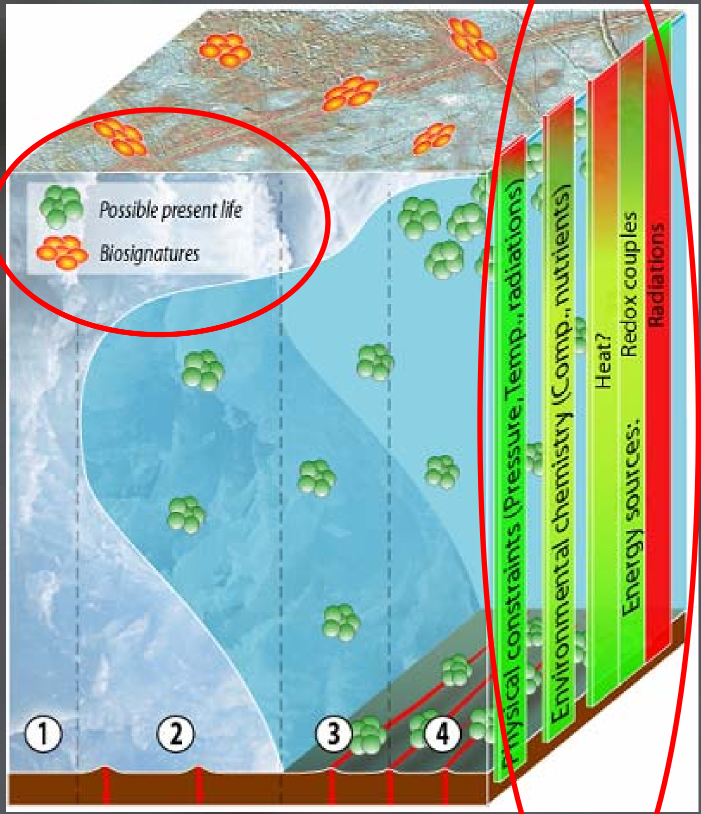
ONLY IF ANY BIOSIGNATURE IS ABUNDANT ON THE SURFACE, THEY CAN BE DETECTED REMOTELY

a) Key properties of the surface/ subsurface environment

b) Local composition and features. Potential biosignatures arisen from the interior. Extinct life/Extant life

Terrestrial analog studies

Simulation experiments



a) Properties of the surface/subsurface environment.

- Characterization of the landing site.
- Model the properties of the endogenous material

Comparison between surface/subsurface
Access to less altered materials (melting the ice, for instance)

Physical environmental constraints:
- pressure,
- temperature,
- radiation
- pH
- conductivity

Environmental chemistry: nutrients
- organics (endogenous, exogenous)
- minerals, elements, isotopes

Energy sources: heat flow,
- radiation

b) Detection of potential biosignatures

Structures. Size and shape may vary depending on environmental conditions (for instance starvation)

- Fossils
- Biominerals

Organic chemistry/Biochemistry

- Biopolymers
- Fatty acids
- Nucleic acids
- Proteins
- Hydrocarbons, hopanes
- Amino acids
- Chirality

Inorganic chemistry/ Isotopes

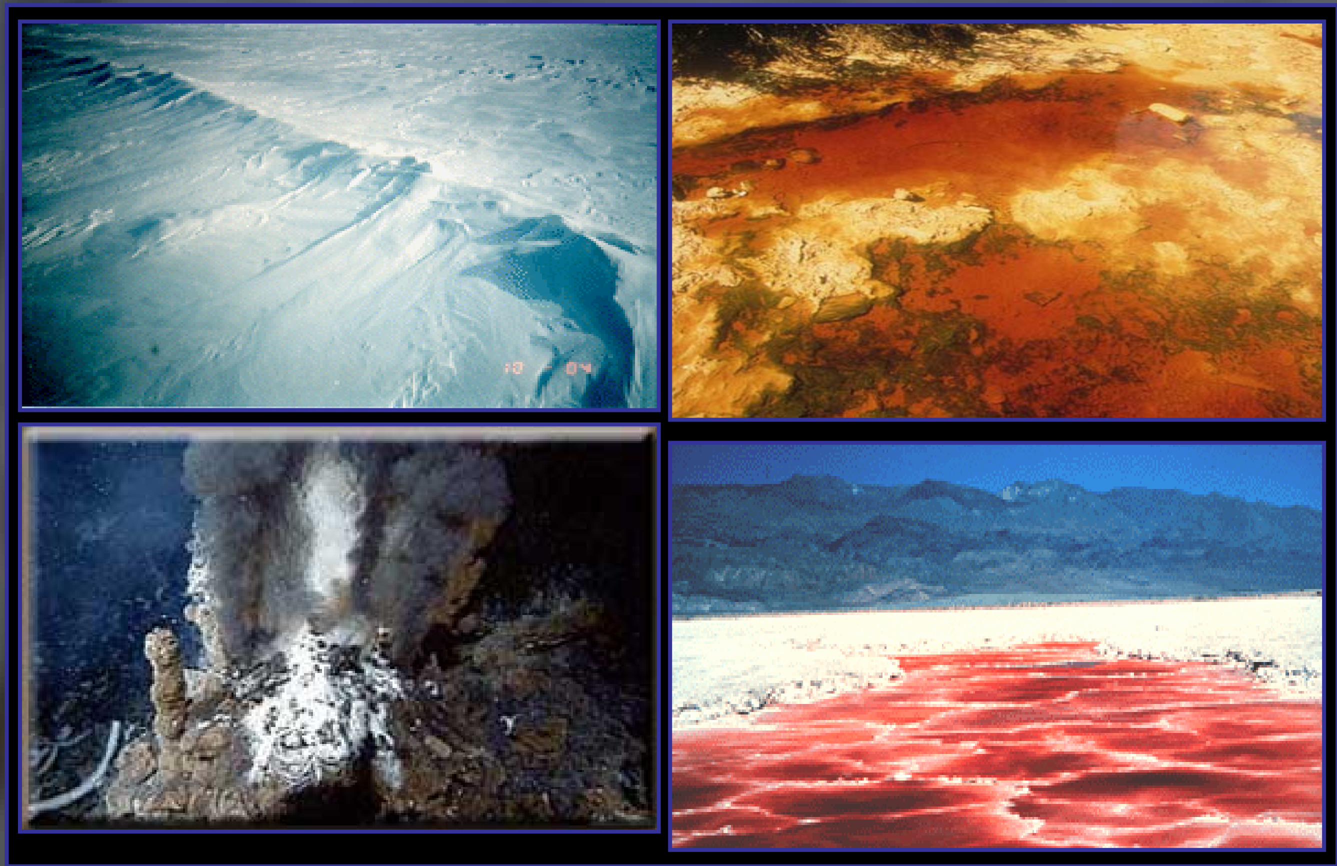
- Waste and metabolic products (silicates, carbonates)
- Environmental modifications induced by metabolic products

CENTRO DE ASTROBIOLOGÍA

Some planetary environments may be envisioned .
Data sources: Spectroscopy, Geology/geophysics, Theoretical modeling

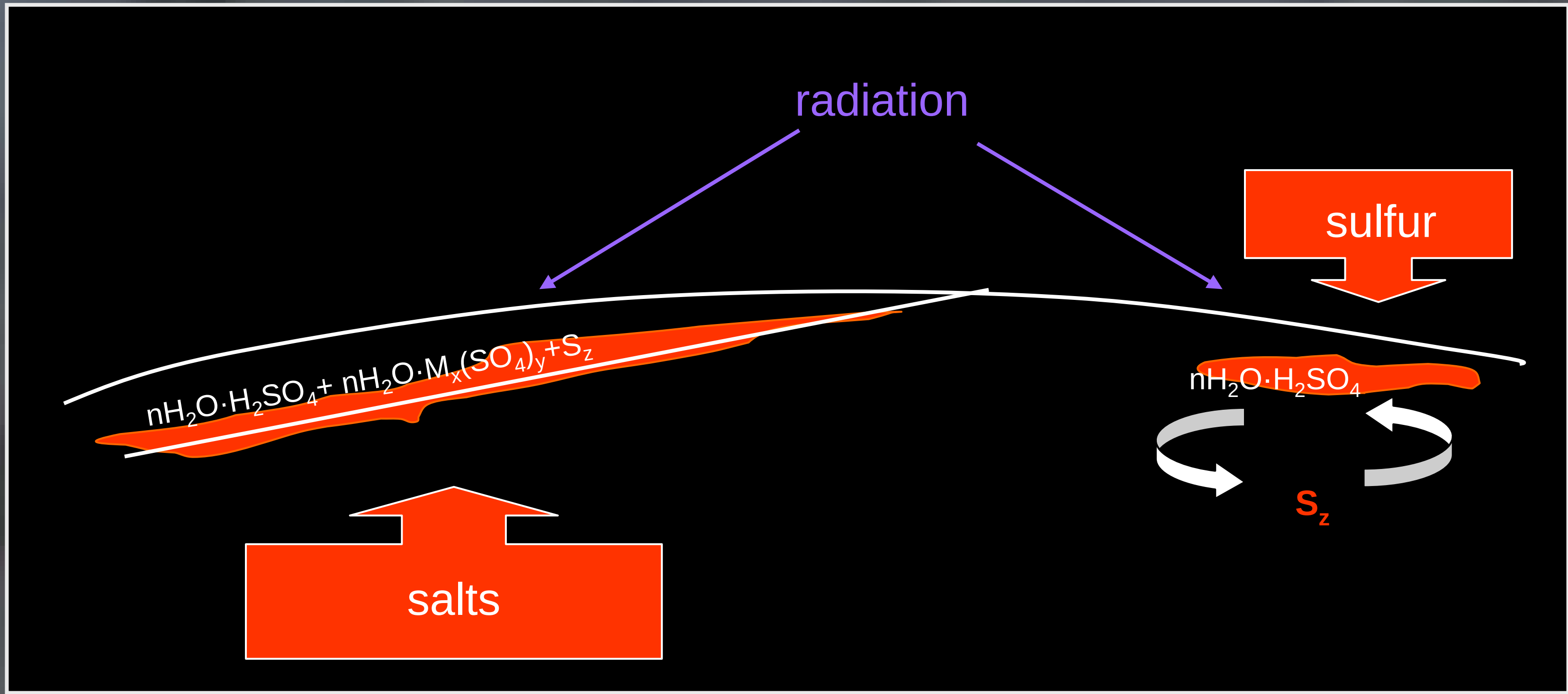
Environment	Physical-chemical characteristics	Energy sources	Terrestrial analog
Surface	Water ice contaminated by hydrated minerals (salts or/and sulfuric acid hydrates), organics (?) Cold. Low pressure. Liquid water deficiency	Extreme Radiation Oxidants	Polar ice surfaces
Subsurface	Water ice contaminated by hydrated minerals. Clathrates?. Organics (?) from surface.Cold. Cryospheric pressure.	Oxidants (?) from surface	Polar ice surfaces
Ocean	Saline. and organics (?) from the surface Dissolved gases? Thermally stratified or mixed. Pressure dependent of the crust thickness. pH?	Oxidants (?) from the surface Methanogenesis Chemolithotrophy	Subglacial Antarctic lakes Saline lakes
Seafloor	Saline. Hydrothermal vents. Hot. High pressure. Rock-water interface. Salt deposits.	Methanogenesis Chemolithotrophy Thermal	Submarine hydrothermal vents Thermokarst?

CENTRO DE ASTROBIOLOGÍA



We have learnt from the terrestrial analog studies that life can survive in very extreme conditions. Some terrestrial microbes resist to:

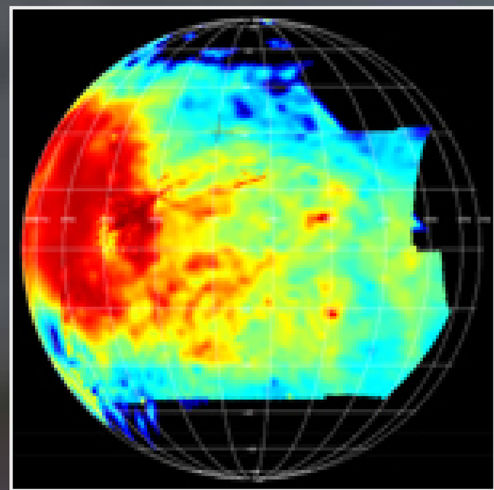
- Radiation fluxes
- Impacts 30 kGy
- Pressures up to 100 MPa
- Range of pH= 0.5 – 11
- Salinity
- Anoxic environments. Chemolithotrophy (H_2, S° or Fe^{++} as energy in the absence of O_2)



Terrestrial analogs also are useful for geochemical and cryopetrological modelling

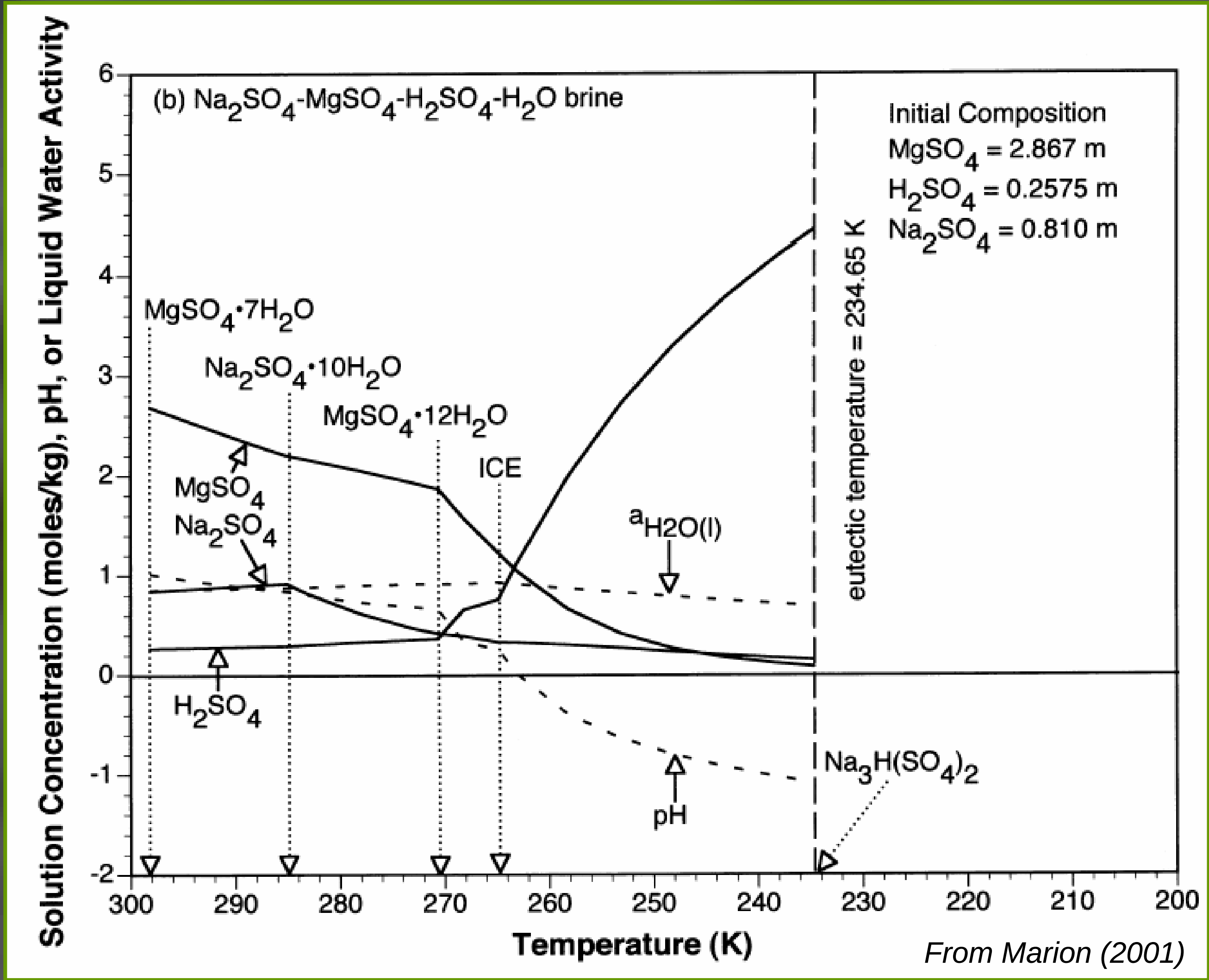
Endogenic origin of the salts is supported by:

- dark materials are related to fractures
- geochemical models



It is compatible the presence of both sulfuric acid hydrates and salt hydrates in the surface of Europa. Acidity is produced by radiolysis at low temperature from the salty materials, although endogenic acid brines should not be totally rejected.

Crystallization **of the Ocean brines** under equilibrium vs. Flash frozen brines



From Marion (2001)

Fractional crystallization ➡ mineral differentiation ➡ endogenous acid mineral assemblage on surface

Flash freezing ➡ endogenous acid to neutral mineral assemblages

CENTRO DE ASTROBIOLOGÍA

Possible geochemistry of the ocean

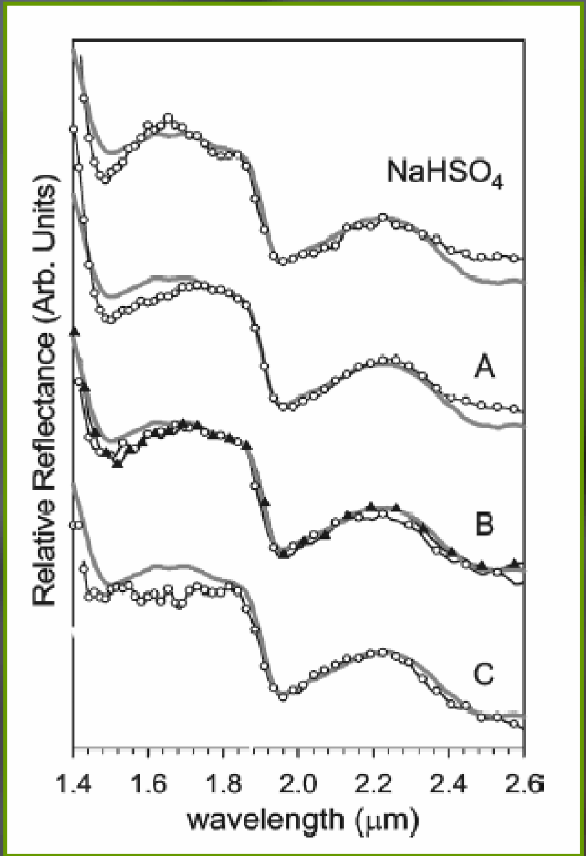
Assuming the dark terrain materials are partly endogenous. We take examples of brines with different acidic character to make experiments about cristallization of cryomagmas:

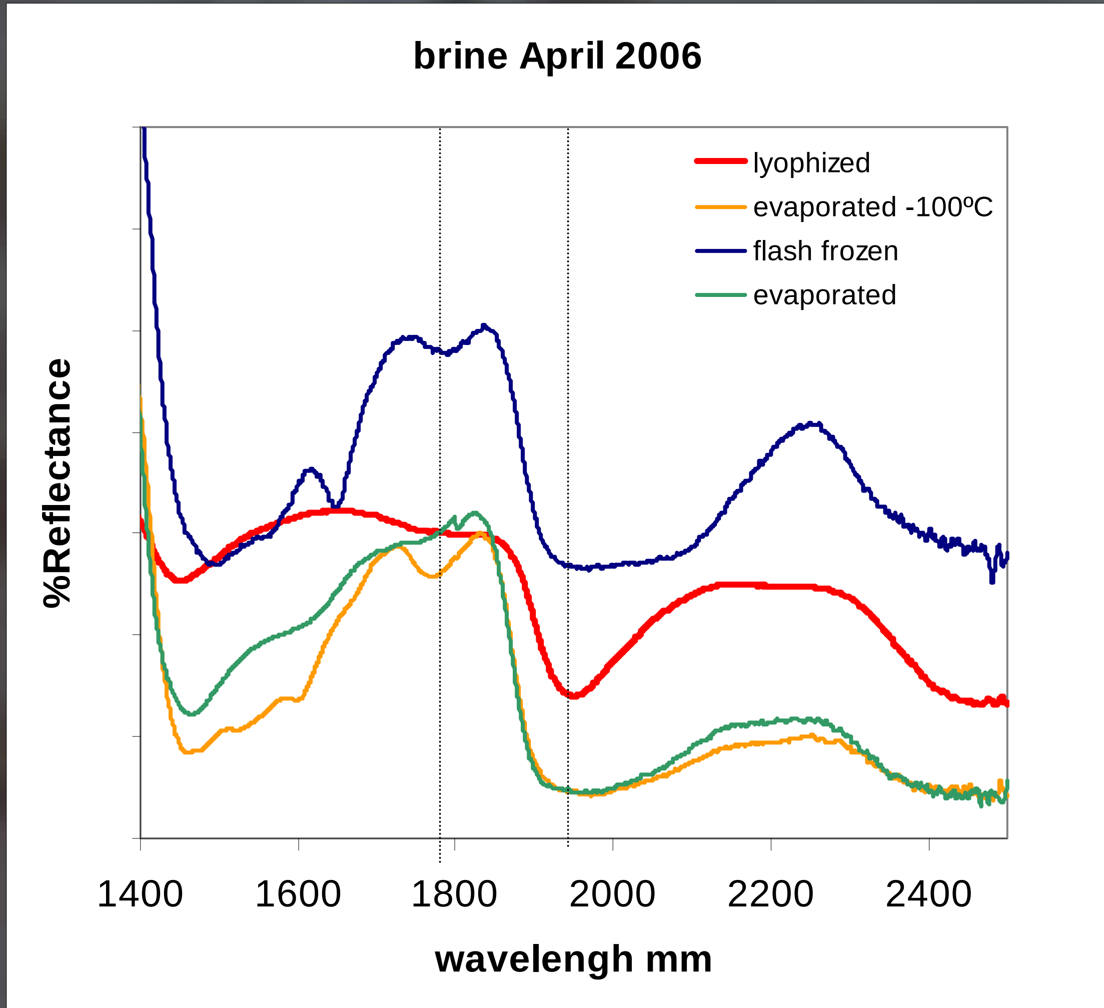
- Neutral. Example: Tirez lake

- Acidic. Example: Rio Tinto

XRD

Evaporated: hexahydrate + halite
Lyophized: bischofite + halite





Same brine, different crystallization path (T, ΔP), different spectra

CENTRO DE ASTROBIOLOGÍA

THE HIGH PRESSURE PLANETARY SIMULATION CHAMBER (HPPSC)

The equipment has two different chambers (both large volume cells):

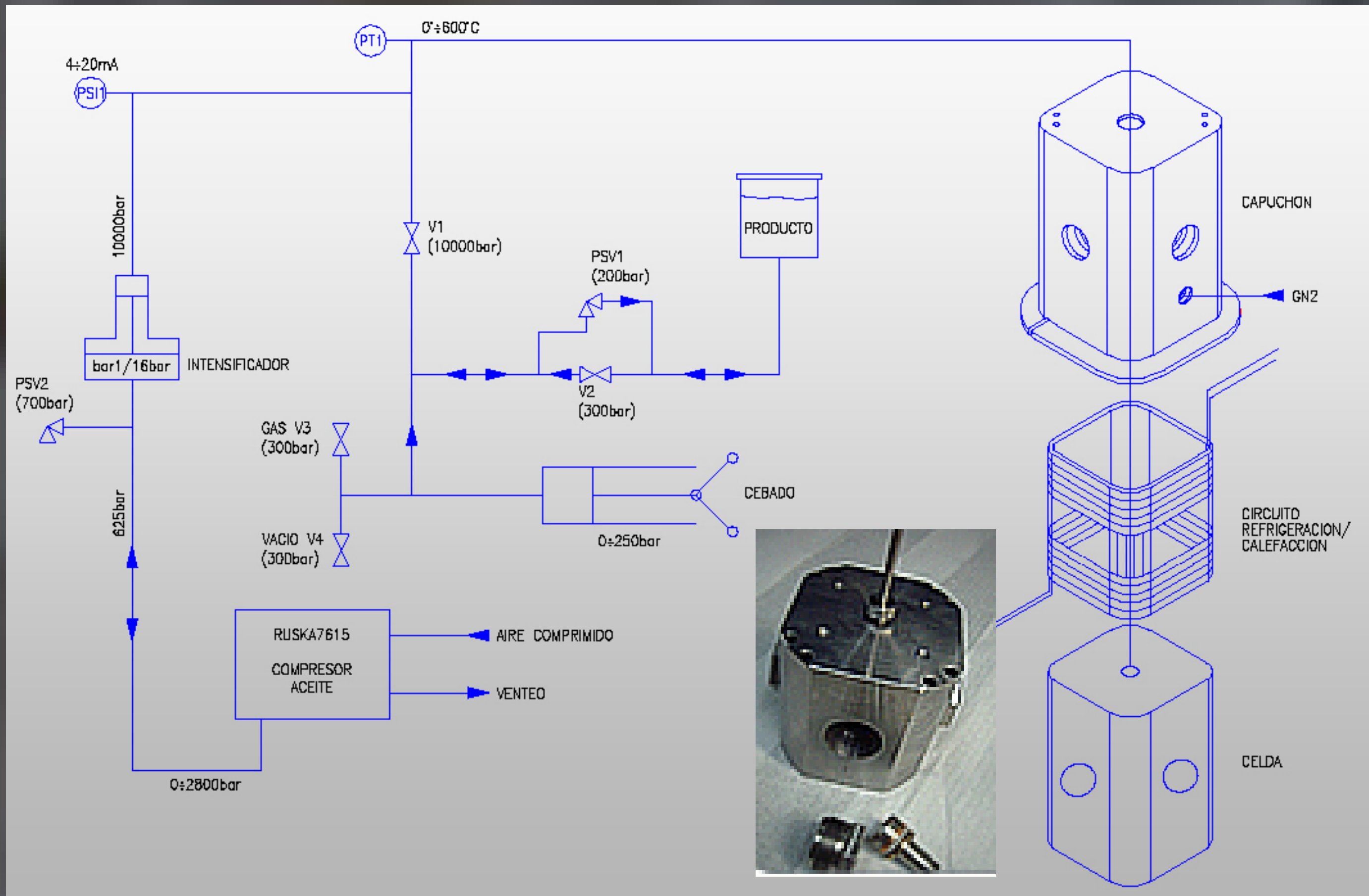
- MINchamber (2 cm^3), for physico-chemical studies which can reaches pressures up to 10000 bar
- BIOchamber (10 cm^3), for biological experiments which has higher volume and can reaches up to 3000 bar

CENTRO DE ASTROBIOLOGÍA

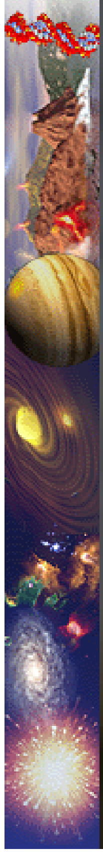
TECHNICAL CHARACTERISTICS OF HPPSC

The heating/cooling system is an integrated circuit of liquid nitrogen and electrical resistances. Both chambers can work in the temperature interval from 90 to 600 K.

The whole system can be controlled automatically, being the pressure, the temperature and the rest of parameters registered while the experiment is running.

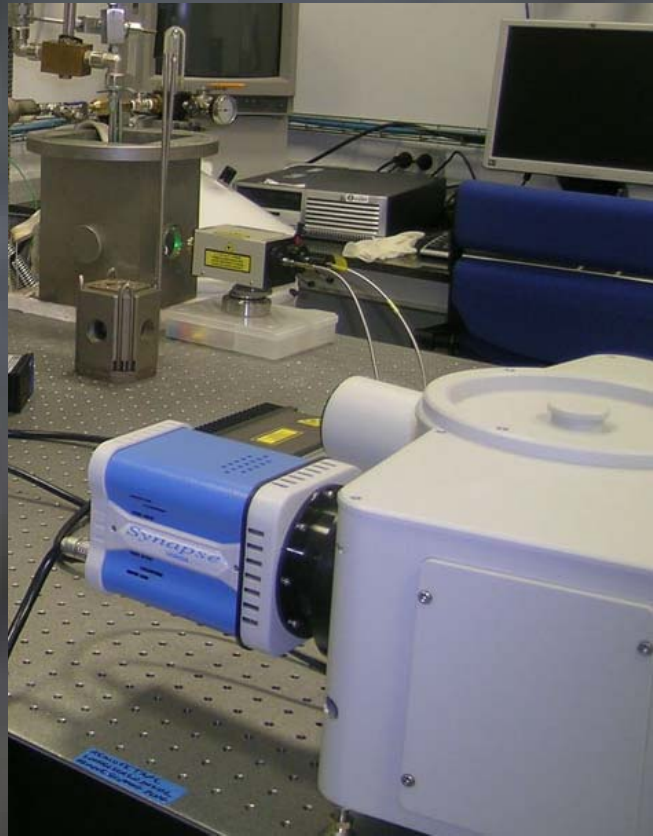


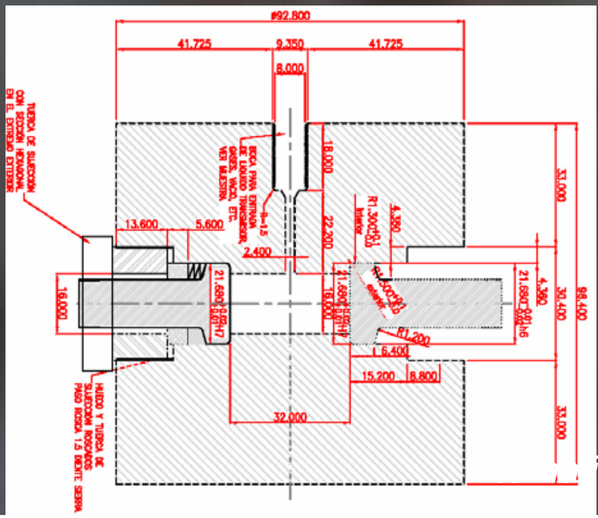
CENTRO DE ASTROBIOLOGÍA



TECHNICAL CHARACTERISTICS OF HPPSC

Each chamber has four different ports to incorporate several sensors. They are used for making in situ analysis and to be able to monotorize the processes occurring during the changes of pressure and temperature. Currently, a raman spectrometer, and a video camera are installed on two ports using sapphire windows. Other sensors able to be incorporated for specific studies are those to measure magnetic susceptibility, electrical resistivity, and mass spectrometry.





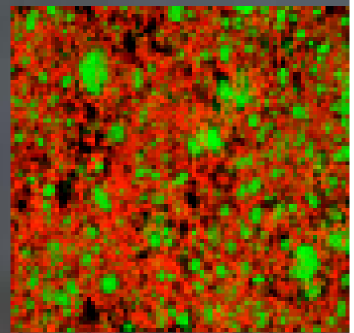
CENTRO DE ASTROBIOLOGÍA

EXAMPLES OF EXPERIMENTS RUNNING (BIOCHAMBER):
Survival of microorganisms and preservation of biosignatures

The potential habitable environments in the interior of icy satellites are characterized by some extreme conditions. Microorganisms adapted to the deep interior habitats of icy satellites should be, at least, baro-tolerant and non-fotosynthetic.

Scientific Questions

- Adaptation of live organisms under pressure
- Identify key factors determining piezoresistance in extremofile archea and eubacteriae, especially the piezoresistant proteins and the related genes
- Influence of the previous factors on the origin of life



Specific Goals

- Study the processes of lipidic oxidation in cell membranes under pressure
- Study cell membrane integrity and functionality under pressure
-Modeling of the cell membrane behavior under pressure as liposomes of known and simple composition
- Identification of proteins responsible for piezoresistance and the related genes

CENTRO DE ASTROBIOLOGÍA

EXAMPLES OF EXPERIMENTS RUNNING:
Survival of microorganisms and preservation of biosignatures

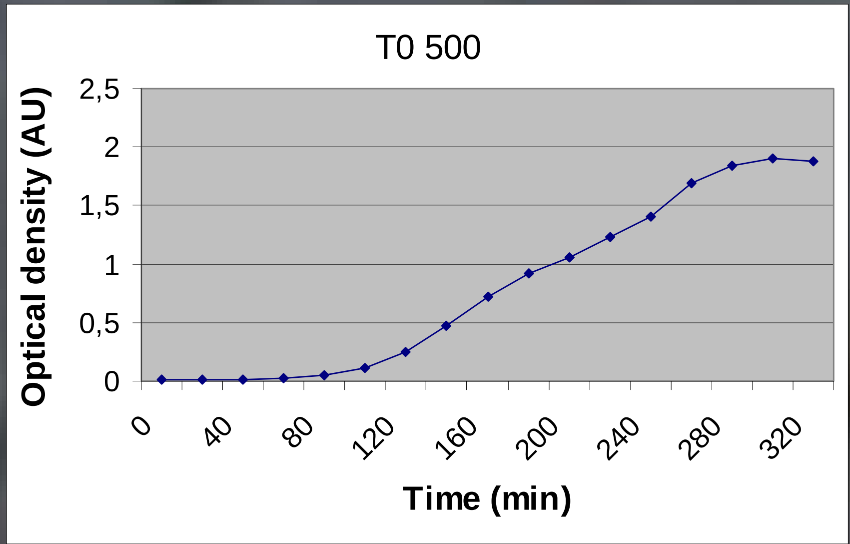
We have started using *Escherichia coli* for testing as a heterotrophic microorganism.

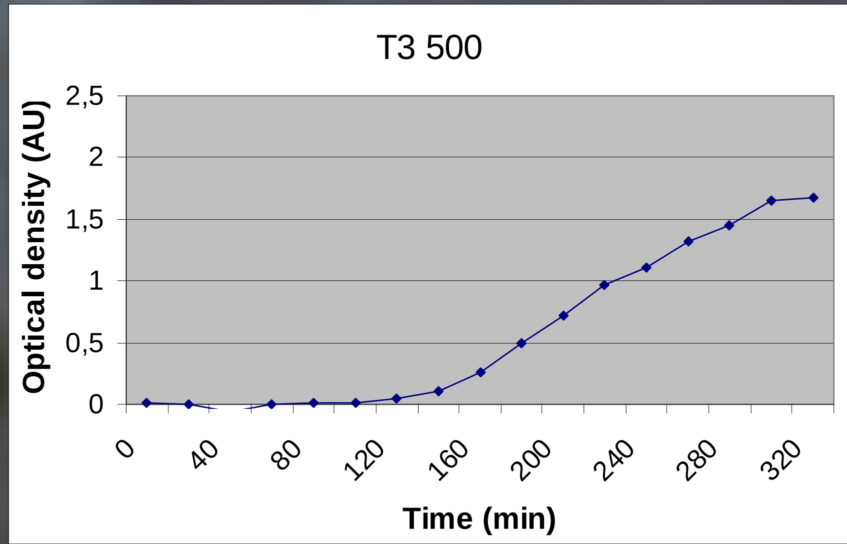
This model was used for pressure resistance studies. Fresh media re-inoculation techniques were used for survival capacity studies.

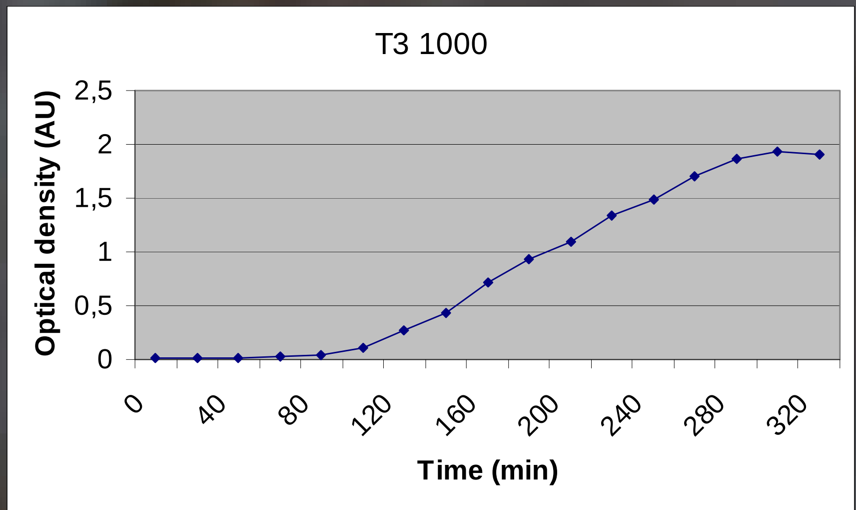
This microorganism was subject to high pressure conditions (500, 1000 and 1800 bar). After high pressure conditions fresh media were inoculated for microorganism viability studies. Optical density was used for following the bacterial growth. Optic microscopy was used (see figures) for microbial counting.

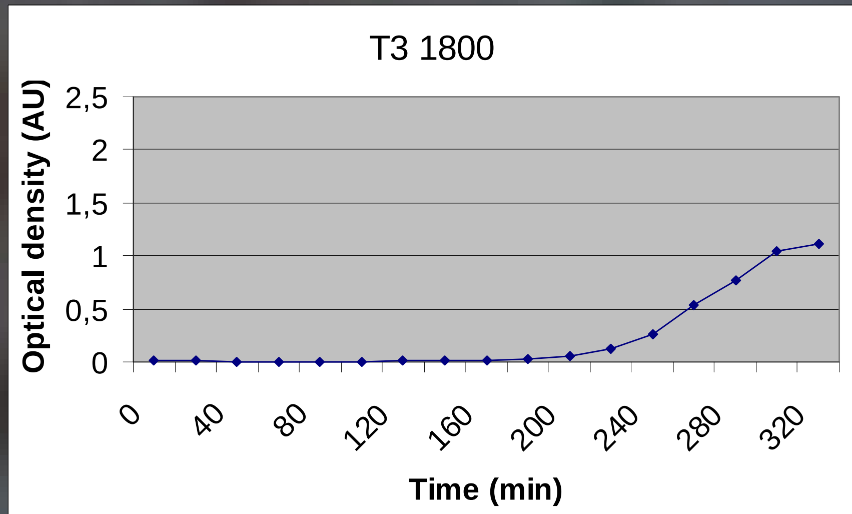
CENTRO DE ASTROBIOLOGÍA

EXAMPLES OF EXPERIMENTS RUNNING:
Survival of microorganisms and preservation of biosignatures









Microorganisms from the 3 runs grow after exposure at high pressure, but less at 1800 bar

CENTRO DE ASTROBIOLOGÍA

3-HOW) IN SITU MEASUREMENTS

Suggested instruments for surface element: