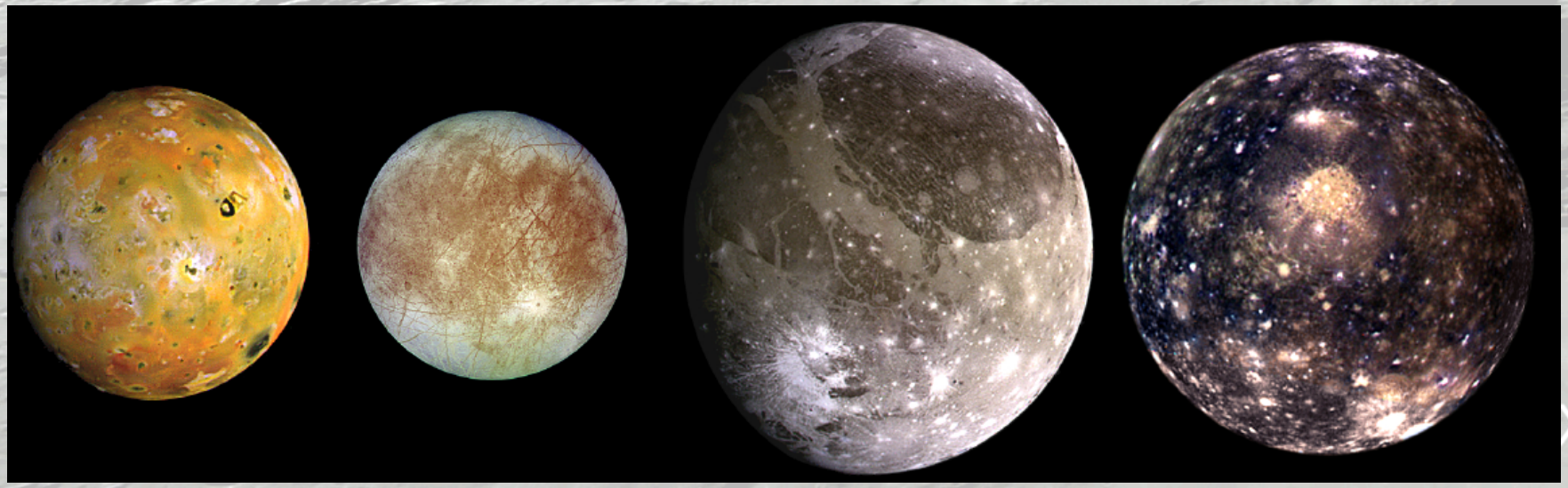
実験惑星学3：
ノンウオーターアイスの物性研究

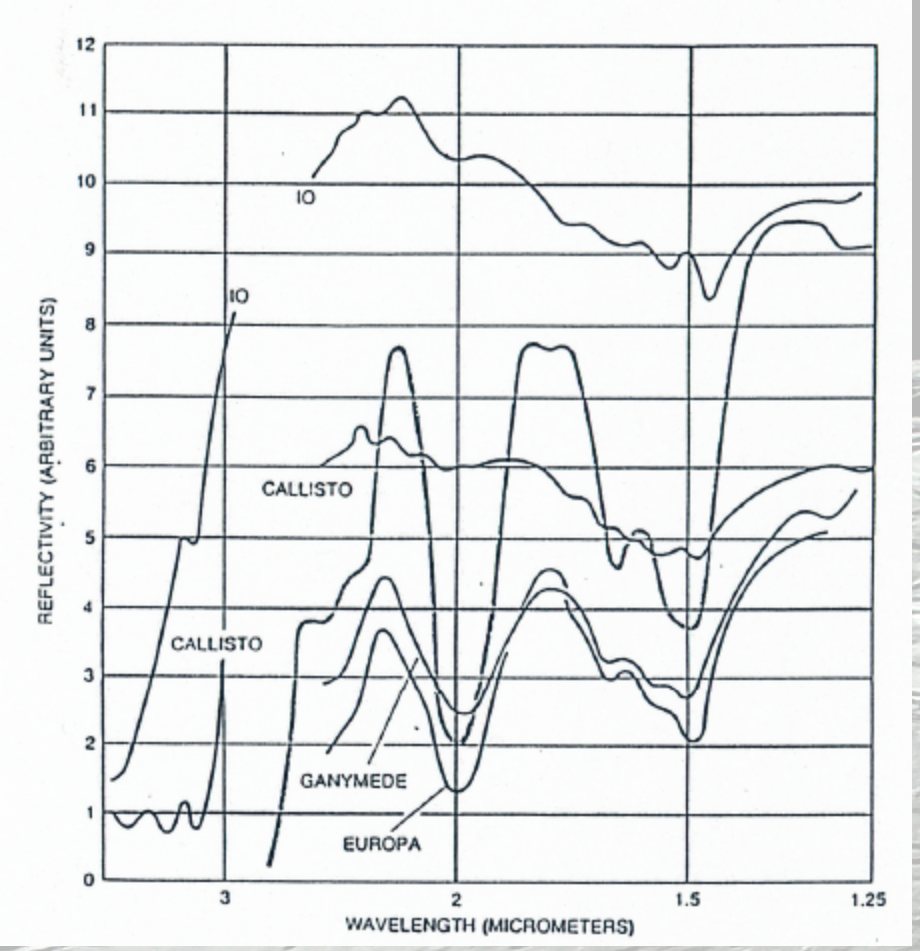
- 外惑星系に普遍的に存在する窒素、メタン、二酸化炭素の氷
- 作成法も未知のものが多い
- 音速や相図が何とか作られているが、確かめるべき
- クラスレート化合物も視野に入れる



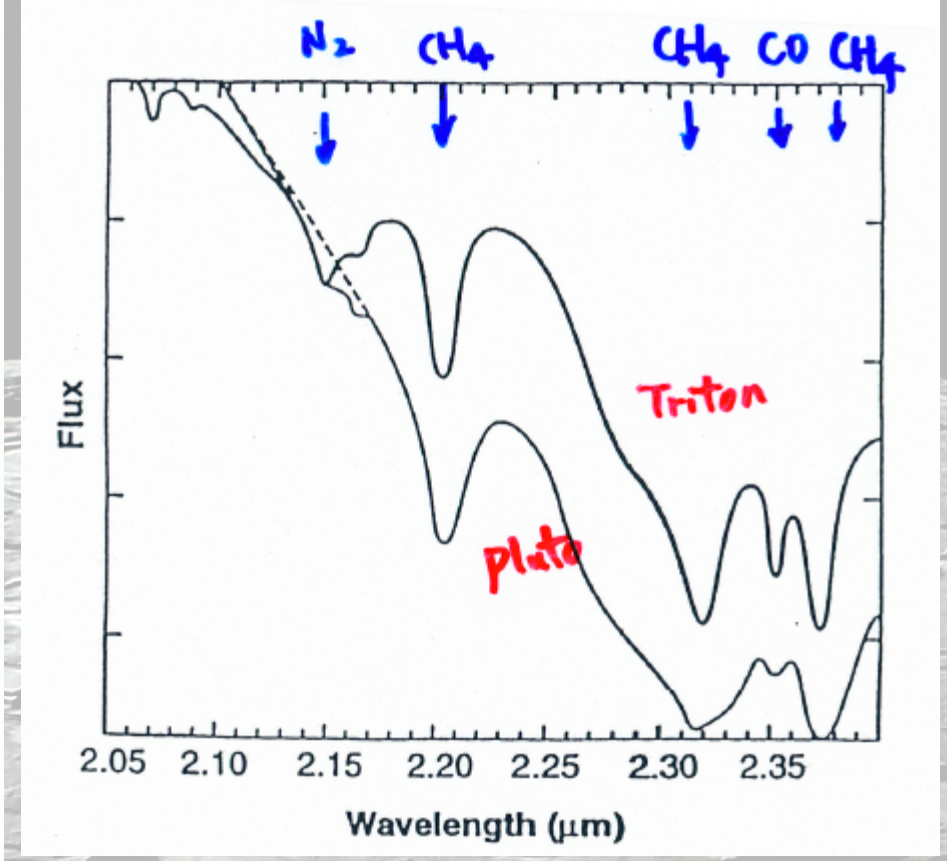
Ices in Solar System

Object	Radius(km)	Average density (g/cm^3)	Albedo	Varieries of ices identified or inferrerd
Io	1815	3.57	0.6	SO_2
Europa	1569	2.97	0.6	H_2O(I)
Ganymede	2631	1.94	0.4	H_2O(I,II,V,VI,VII,amorphous in polar caps ?)
Callisto	2400	1.86	0.2	H_2O(I,II,V,VI,VII)
Rings of Saturn			0.2 - 0.6	H_2O(I,amorphous?)
Mimas	197	1.17	0.77	H_2O(I)
Enceladus	251	1.24	1.04	H_2O(I,formerly amorphous?) clathrate hydrate ? ammonia hydrate ?
Tethys	524	1.26	0.80	H_2O(I)
Dione	559	1.44	0.55	H_2O(I)
Rhea	764	1.33	0.65	H_2O(I,II)
Titan	2575	1.881	0.2	H_2O(I,II,V,VI,VII) clathrate hydrate ?
Hyperion	175*120*100		0.25	H_2O(I)
Iapetus	718	1.21	0.5 / 0.04	H_2O(I)
s10 - s17	10 - 100		0.5 - 0.9	H_2O(I) ?
Rings of Uranus			- 0.03	H_2O(I) ? modified CH_4 ?
Miranda	235	1.35	0.22	H_2O(I) CH_4 ?
Ariel	580	1.66	0.38	H_2O(I)
Umbriel	585	1.51	0.16	H_2O(I)
Titania	790	1.68	0.23	H_2O(I)
Oberon	760	1.58	0.20	H_2O(I)
Triton	1350	2.075	0.6 - 0.9	CH_4 N_2 CO CO_2 H_2O(I) ? clathrate hydrate ?
Pluto	1145	1.84	0.612	CH_4 N_2 CO H_2O(I)? clathrate hydrate ?
Charon	642		0.424	H_2O(I)

Non-Water Ices
in Triton, Pluto

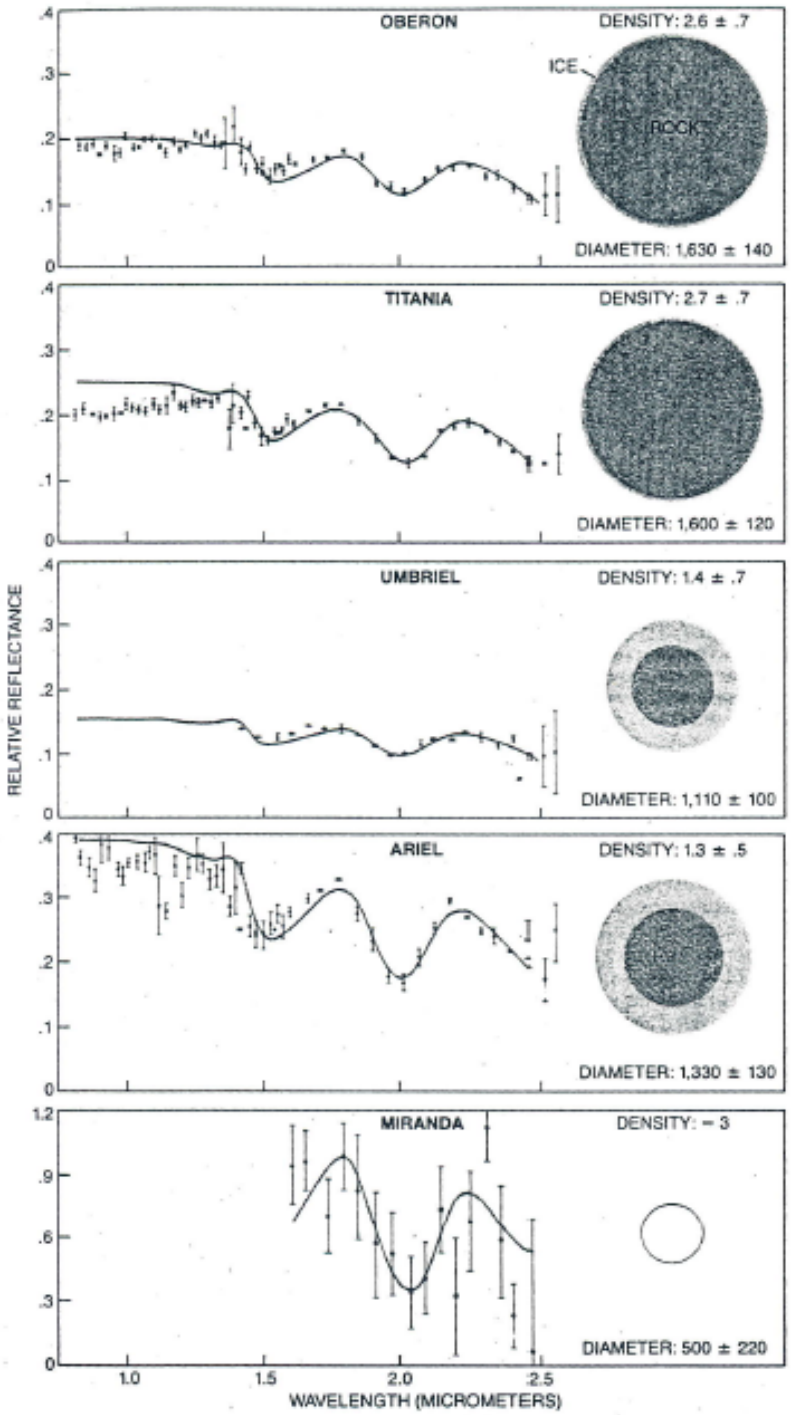


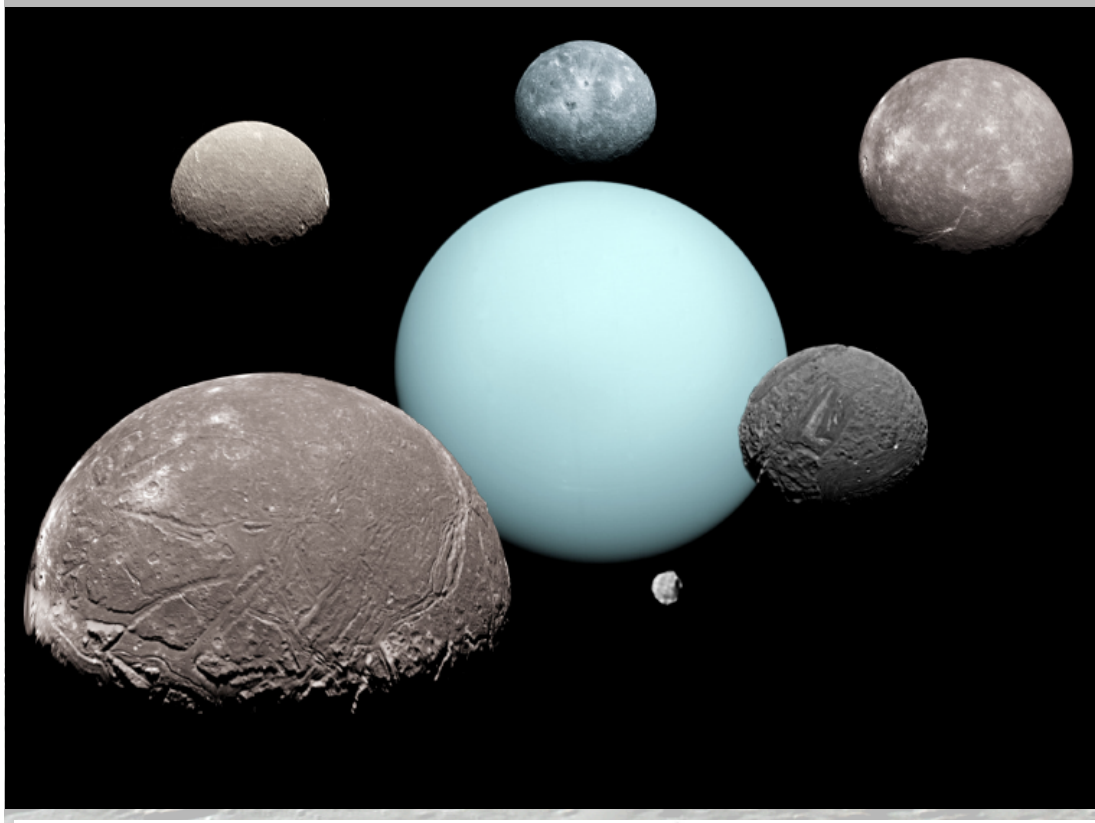
Galileo Satellites



	N_2	CH_4	CO	CO_2	H_2O
Triton	90%	0.1%	<0.1%	10%	-----
Pluto	>95%	2%	0.5%	-----	-----
Charon	-----	-----	-----	-----	>95%

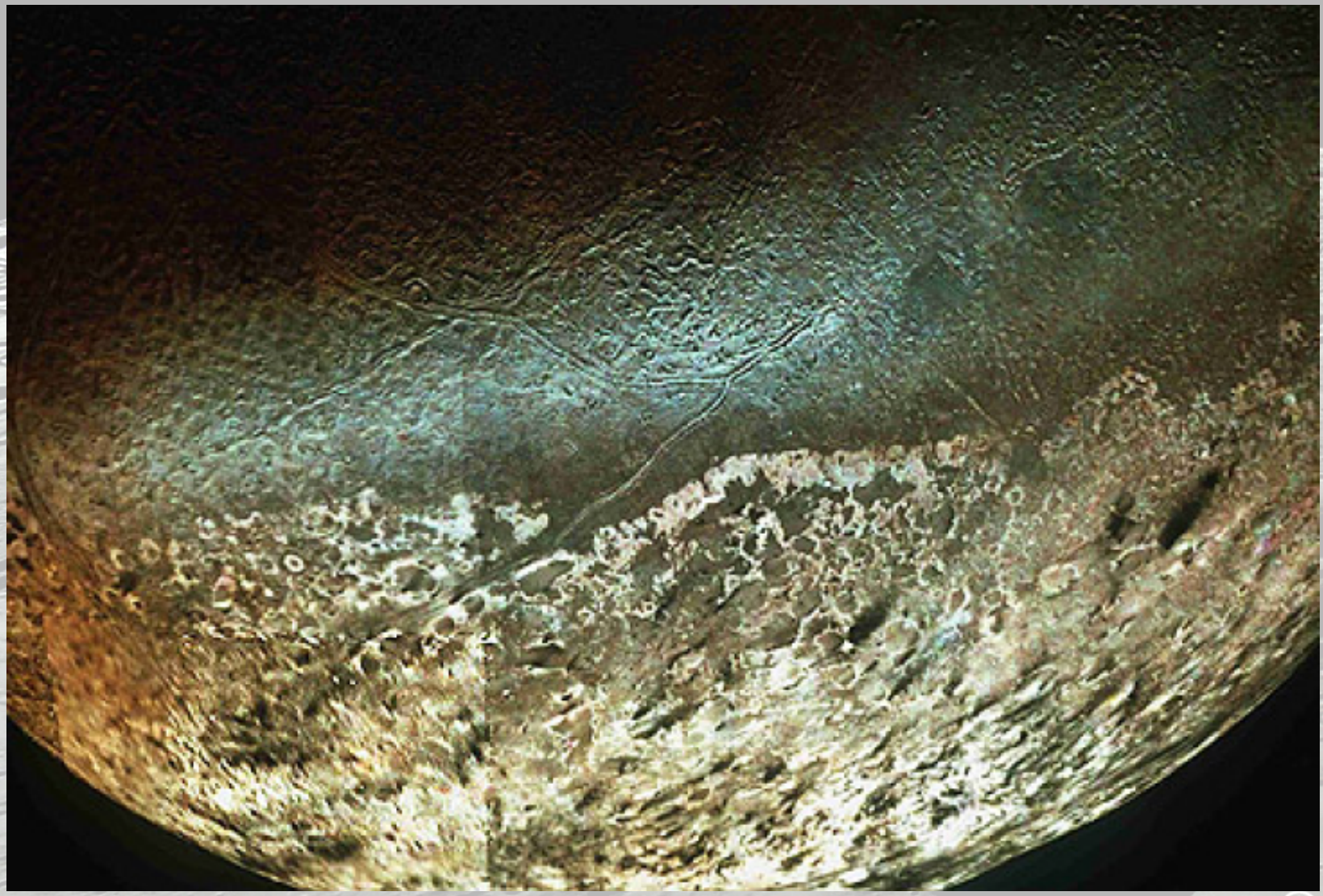
Reflective Spectrum of Uranian Satellites





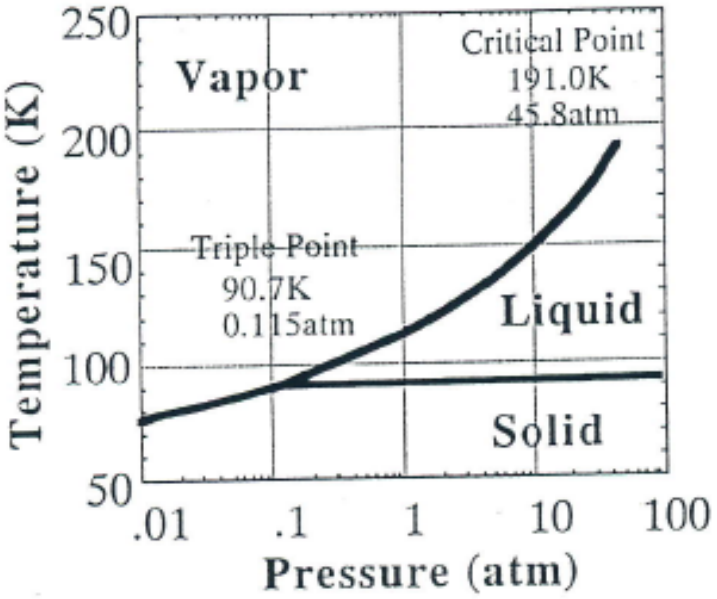
COMPOSITION OF URANIAN MOONS can be inferred from their near-infrared reflectance spectra and from their mean densities. The spectra of the four outer moons all have deep absorption bands at wavelengths of 1.5 and 2.0 micrometers, both of which are characteristic of water ice. The data for Miranda are crude (the vertical lines show the error range) but a strong absorption band is evident at 2.0 micrometers. The satellite spectra (*dots*) are matched closely by the spectra of two-component laboratory models (*lines*) consisting of water frost and charcoal. All the moons are thought to have an icy surface and a rocky core, but the differences in mean density (measured in grams per cubic centimeter) suggest that Ariel and Umbriel have thicker ice layers than Titania and Oberon. Miranda's density is too uncertain to allow a conclusion about its internal structure. The diameters are given in kilometers. In comparison, the earth's moon has a diameter of 3,480 kilometers.

Triton by Voyager 2

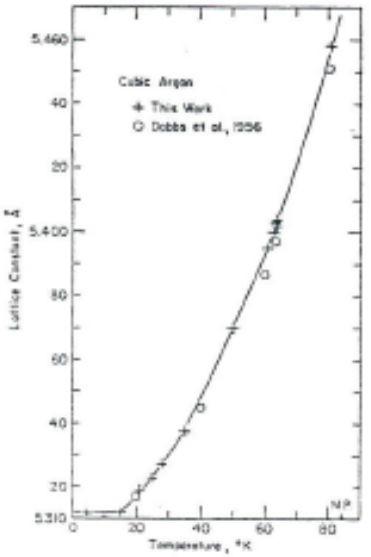


Cantaloup Terrain

Phase Diagrams of various Non-Water I*ces*

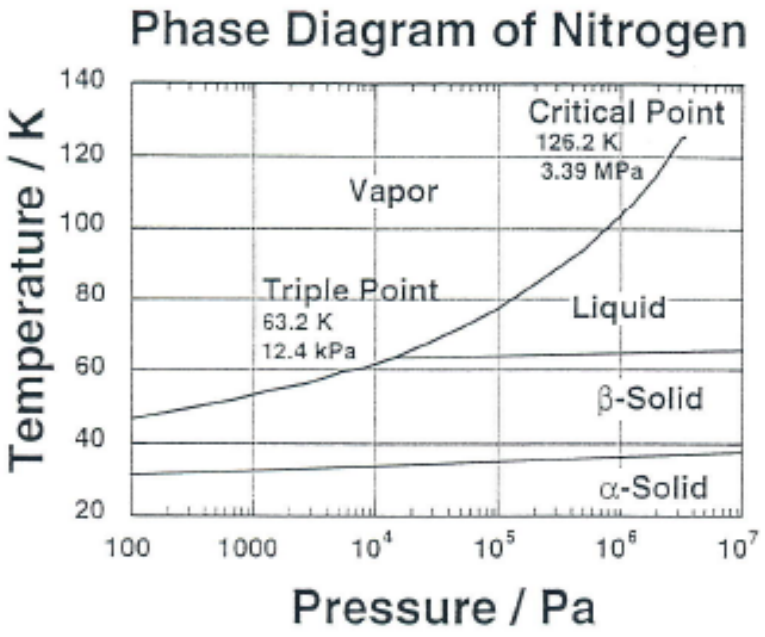


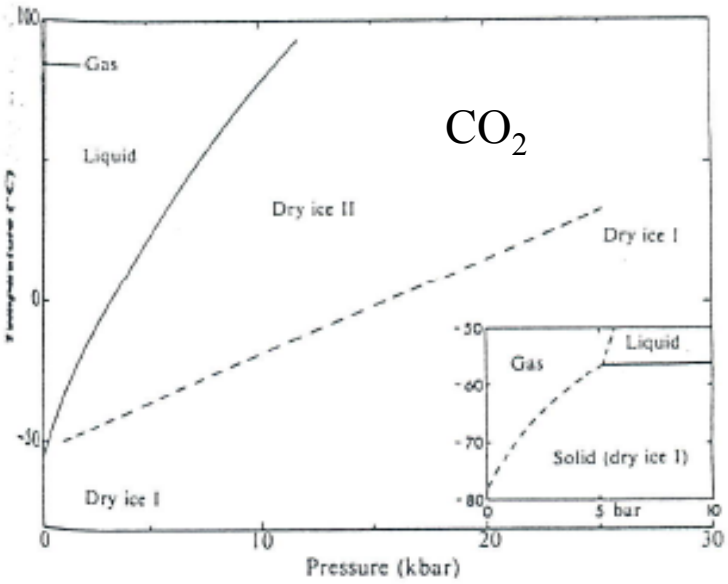
Phase diagram of CH_4



Ar

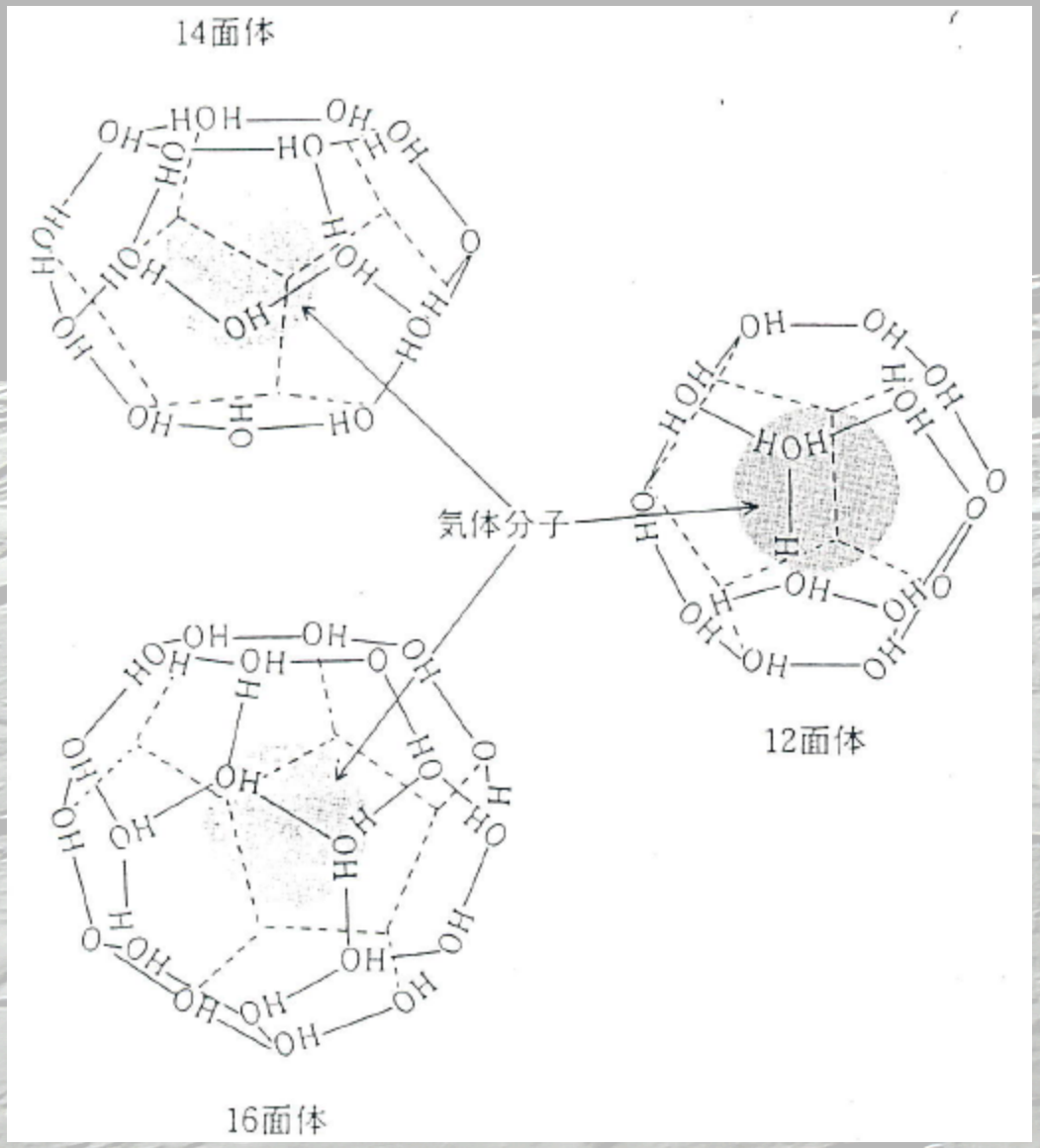
FIG. 1. Lattice constants for face-centered-cubic argon.





CO_2

Fig. 1 A tentative P–T phase diagram for CO_2 based on the results of this study and those reported in the literature[1,2,7,13]. The suggested small dT/dP slope for the phase boundary between dry ice II and dry ice I is consistent with the small density difference between the two phases observed in the present study.



Phase Diagrams of CH_4-N_2, NH_3-H_2O

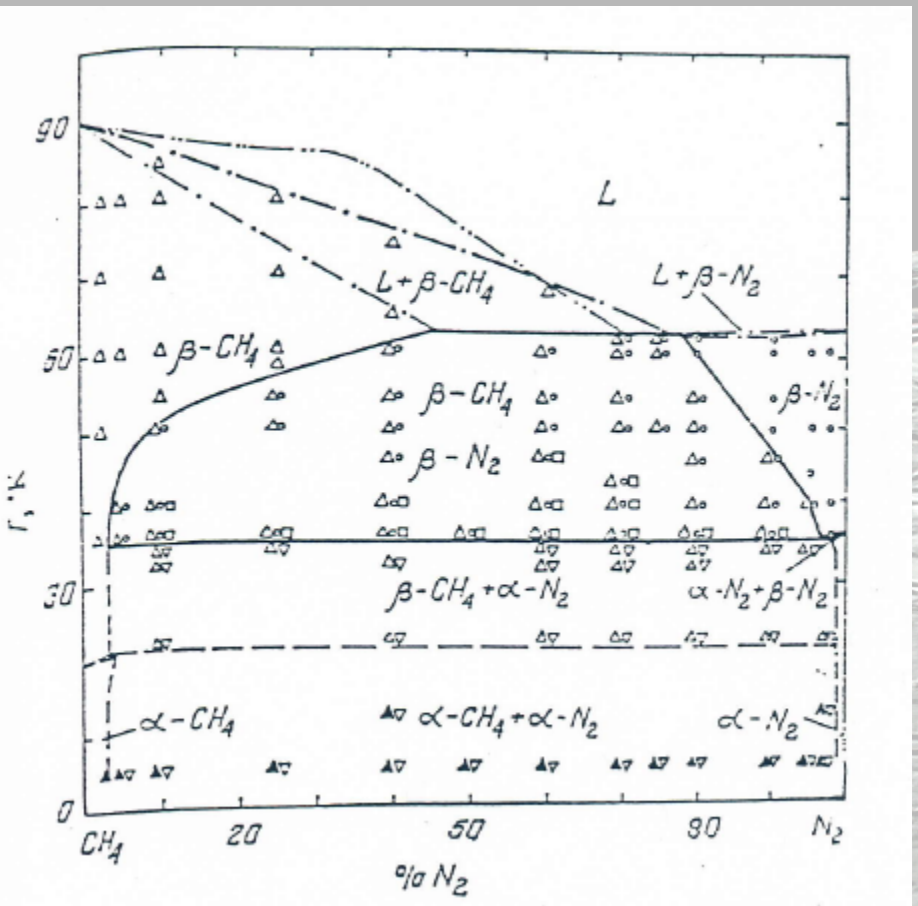


FIG. 1. Phase diagram of solid methane–nitrogen mixtures. The dashed-dotted line corresponds to the experimental data of Ref. 13 on the melting diagram; the dashed-double dotted line shows the data of Ref. 12 the solid lines are the phase boundaries of the solid mixture phase diagram determined in the present paper. The following are the structures of the phases observed: ▲, ▽) cubic phases of α-CH_4 and α-N_2; △, □) fcc lattice of β-CH_4 and of the orientationally disordered phase of N_2; ○) hcp lattice of β-N_2.

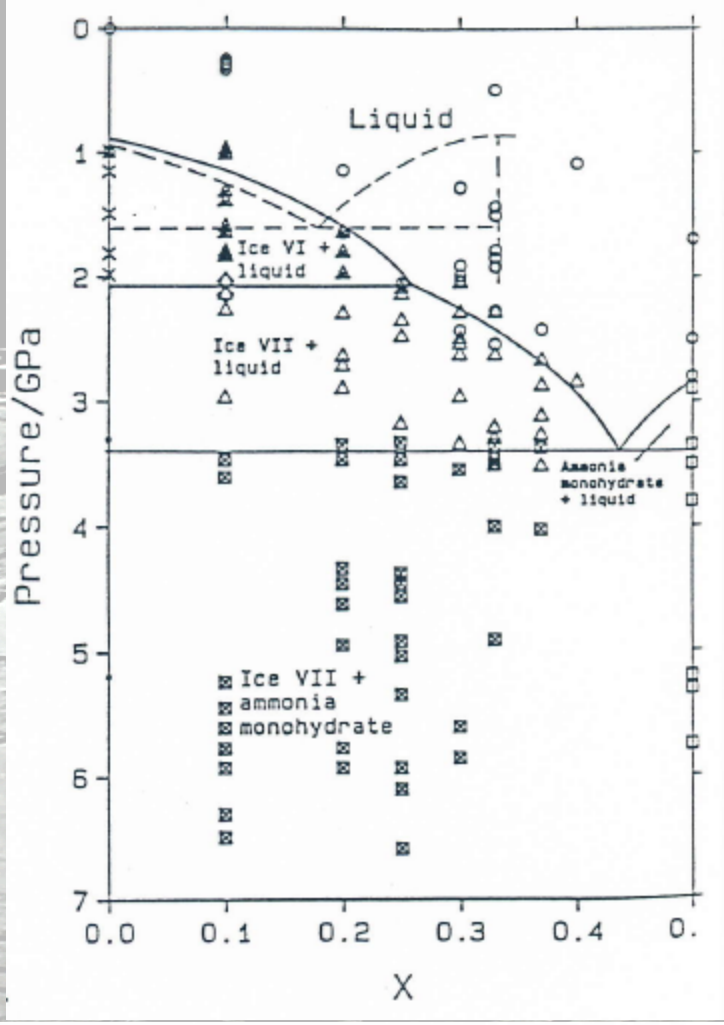
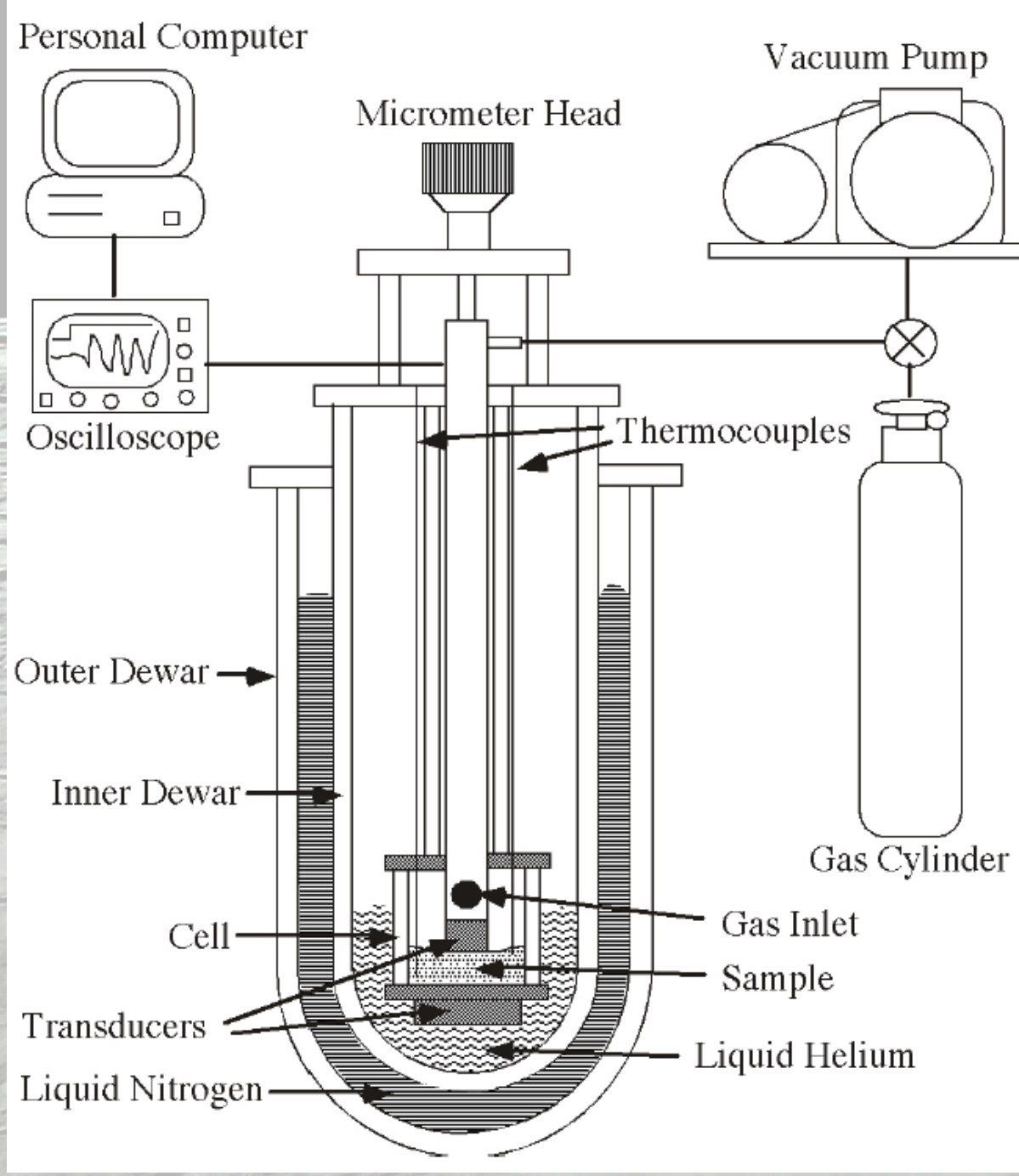
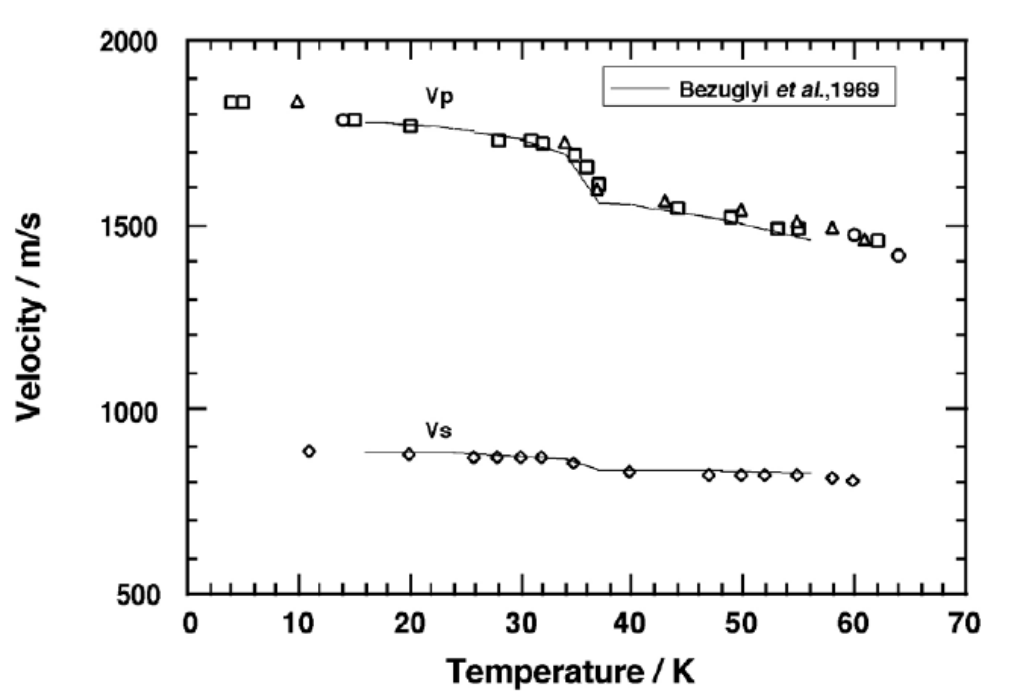


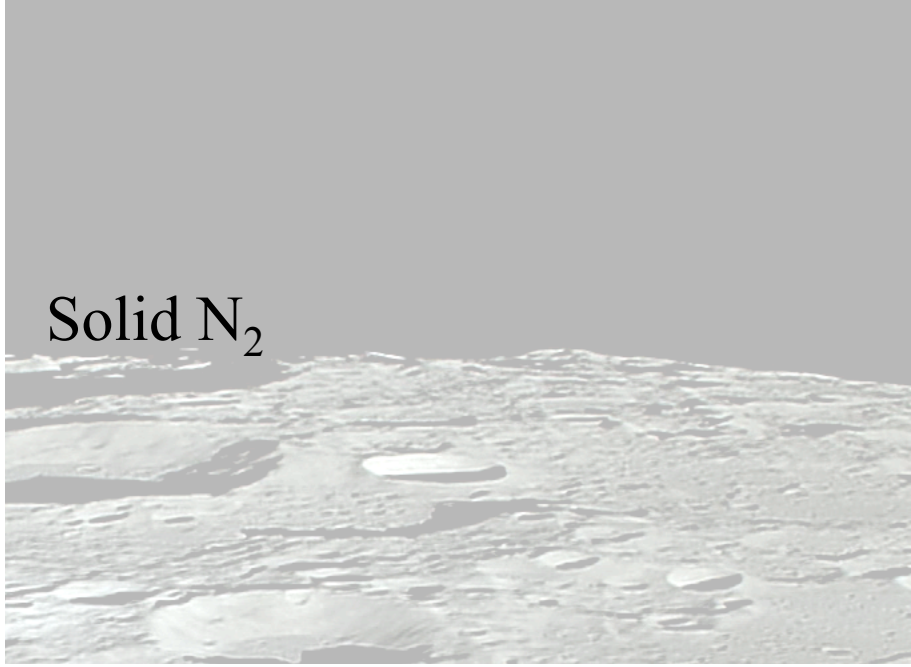
Fig. 1. Compositions, pressures, and phase assignments for $(NH_3)_x(H_2O)_{1-x}$ mixtures at 293 ± 3 K, and the isothermal phase diagram for the water-rich region derived from those data. Symbols represent individual data: circle, liquid; cross, Ice VI; dot, Ice VII; triangle, Ice VII + liquid; box, ammonia monohydrate; triangle with cross, Ice VI + liquid; box with cross, monohydrate + Ice VII. solid lines are phase boundaries assigned from these data. Dashed lines are phase boundaries reported by *Johnson and Nicol* (1987). The precision of the pressure measurement is approximately 0.2 GPa.

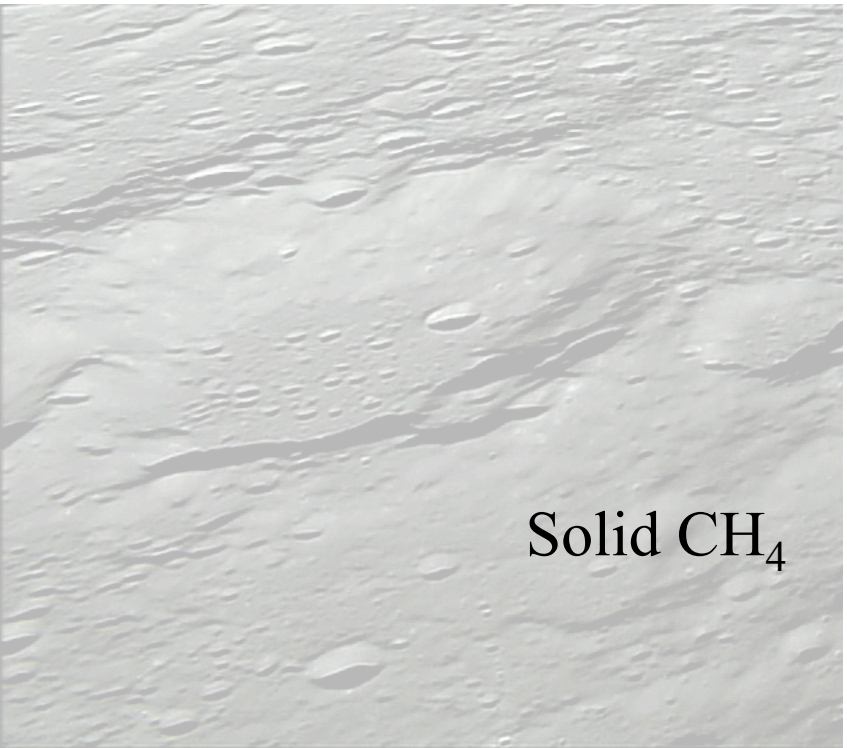
Sound Velocity Measurements of N_2 and CH_4 Ices

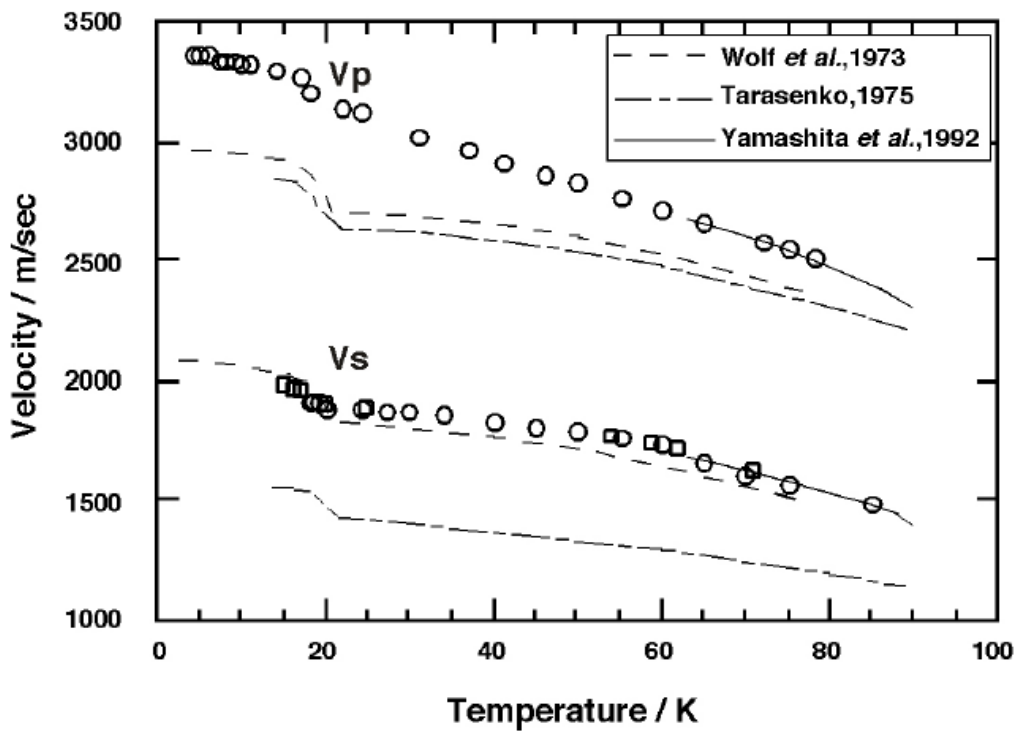


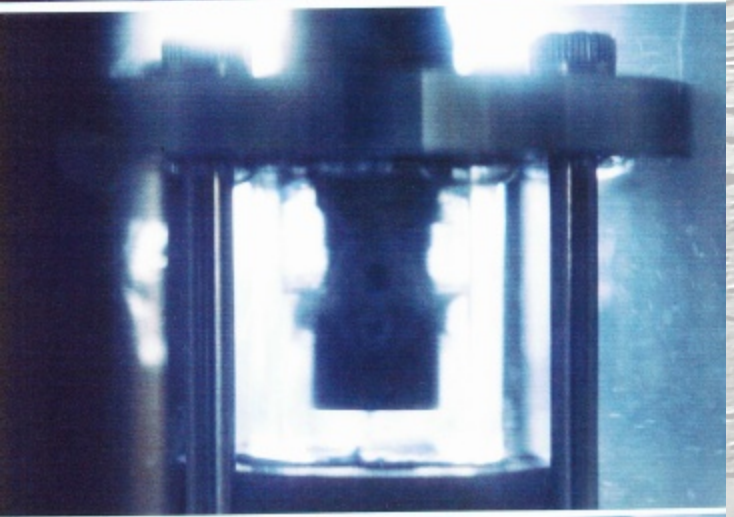
Yamashita et al., Icarus 207, 2010


Velocity / m/s
Temperature / K
Vp
Vs
Bezuglyi et al.,1969
2000
1500
1000
500
0
10
20
30
40
50
60
70


Solid N_2


Solid CH_4

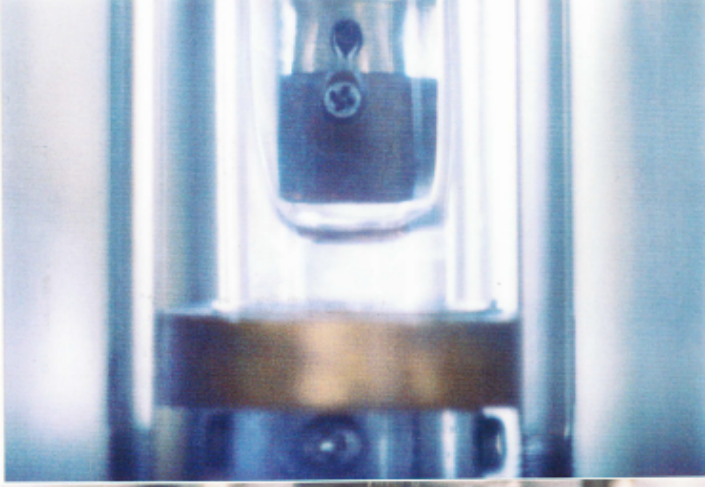

Velocity / m/sec
Temperature / K
Vp
Vs
Wolf et al.,1973
Tarasenko,1975
Yamashita et al.,1992
3500
3000
2500
2000
1500
1000
0
20
40
60
80
100

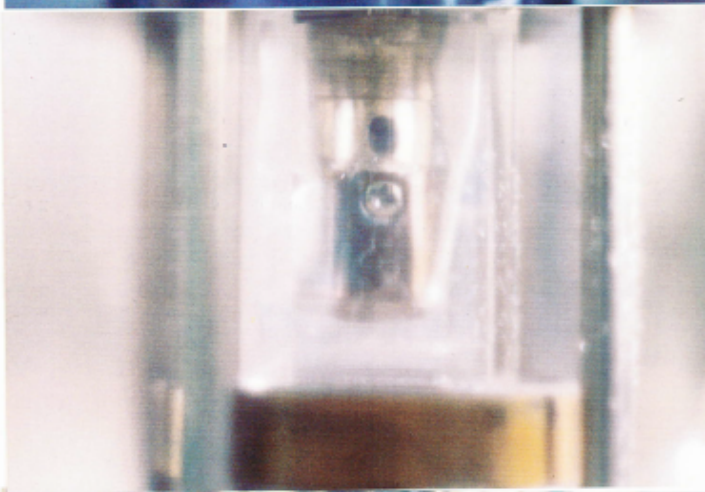


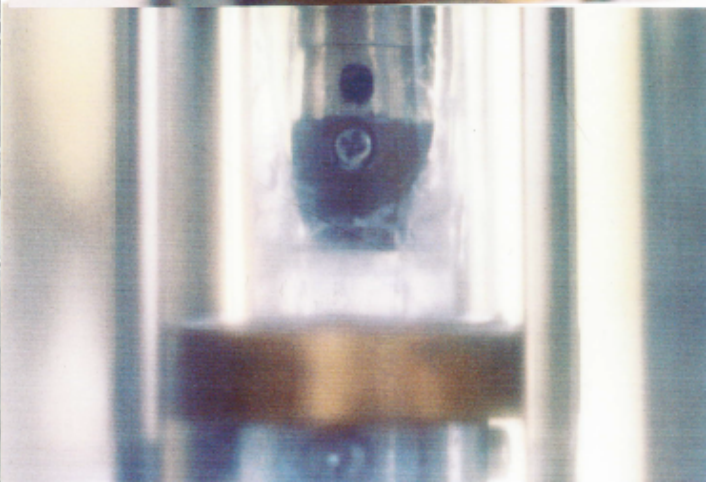
Deformation Experiments At Liquid N_2 Temperature

CH_4

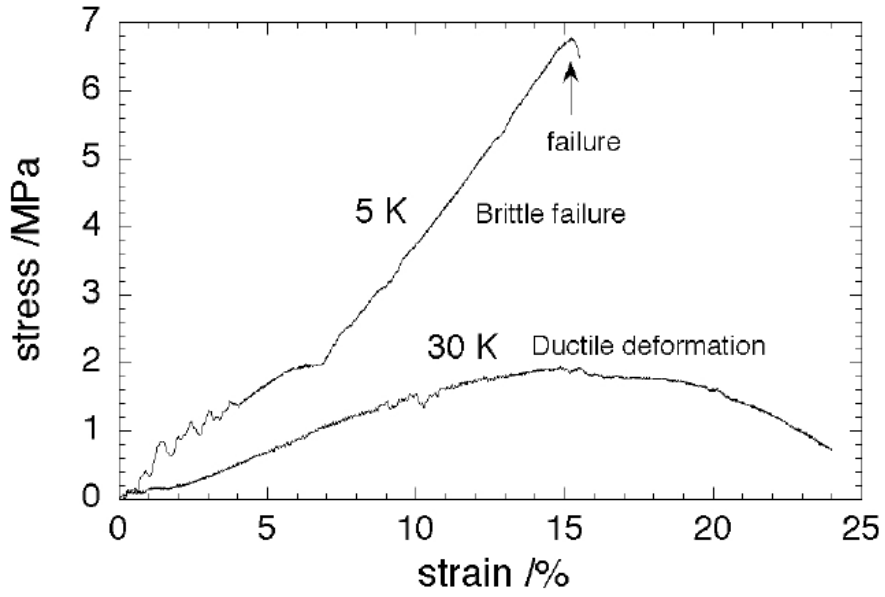
CO_2

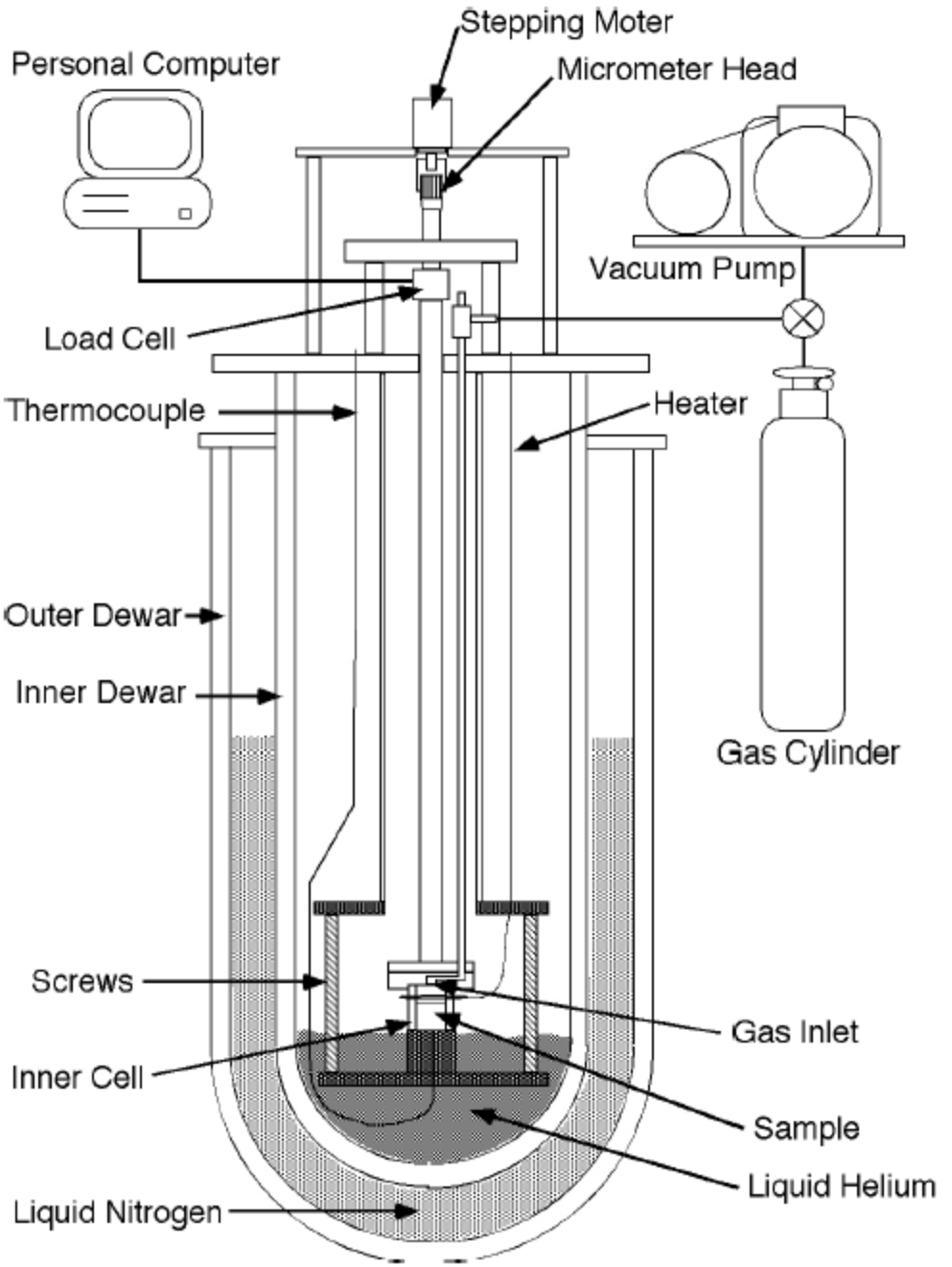




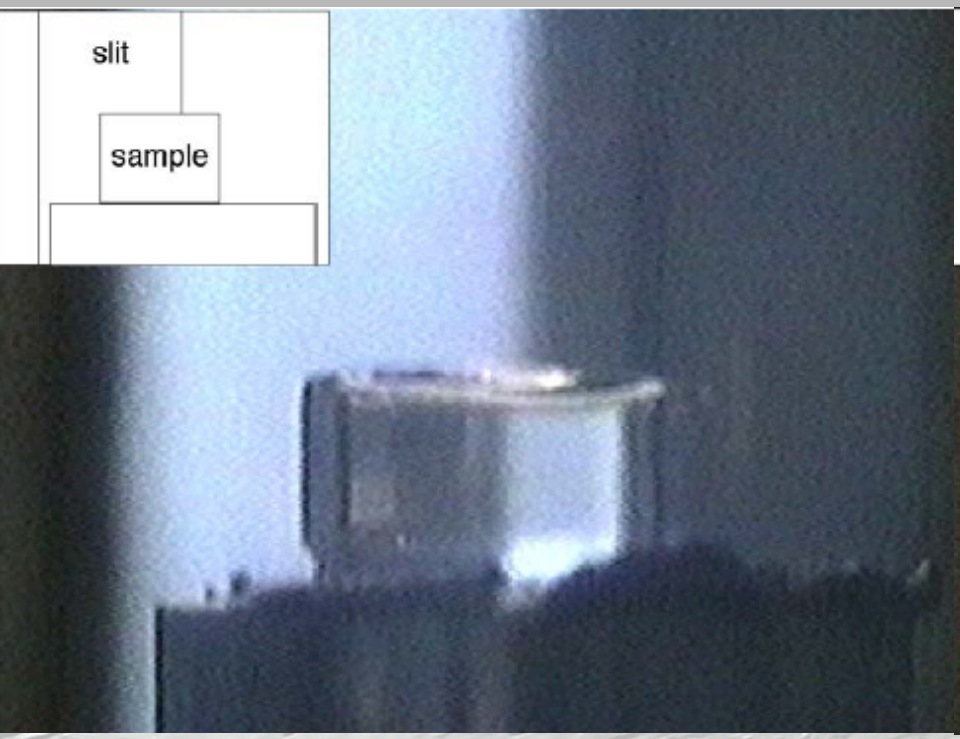


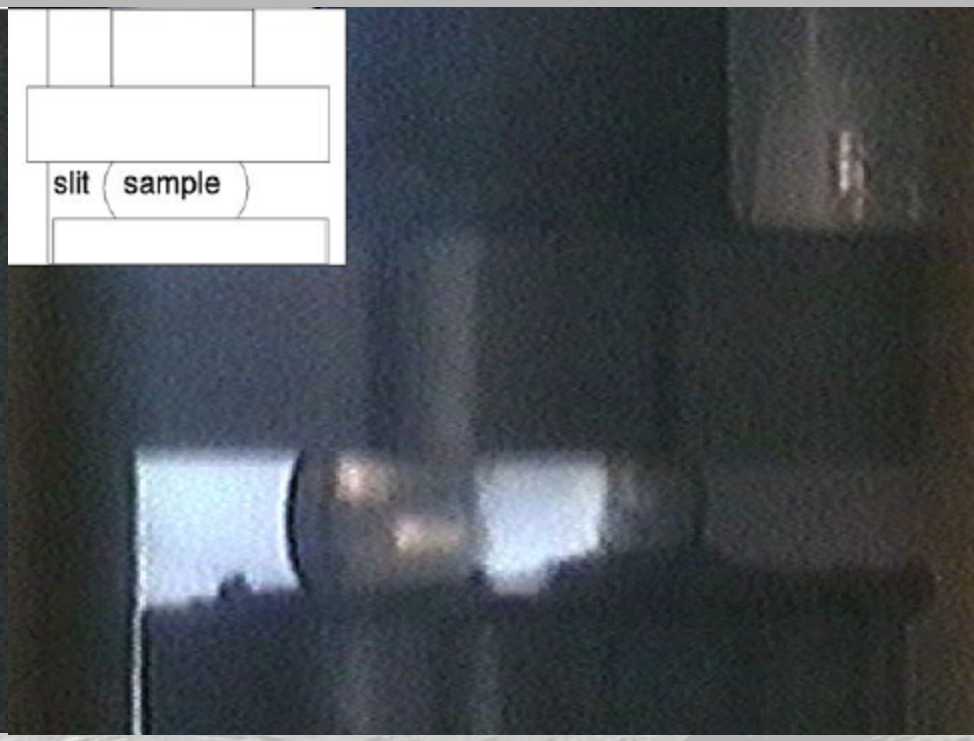
Uniaxial Deformation of N_2 and CH_4 Ices to 5 K





Solid CH_4 at 45 K

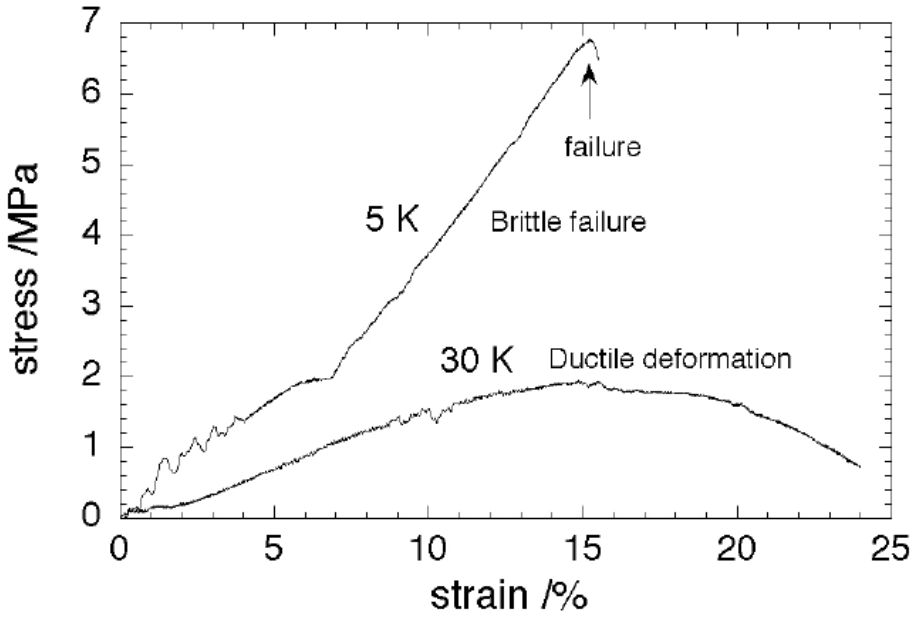




Before Compression

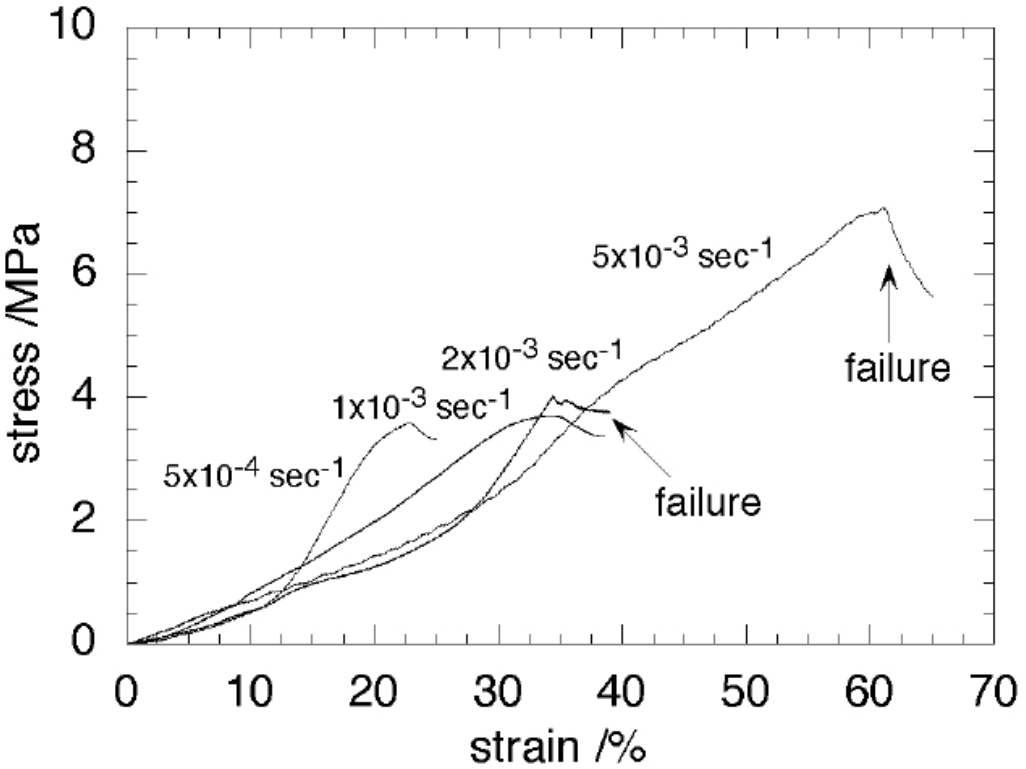
10 mm × 7 mm

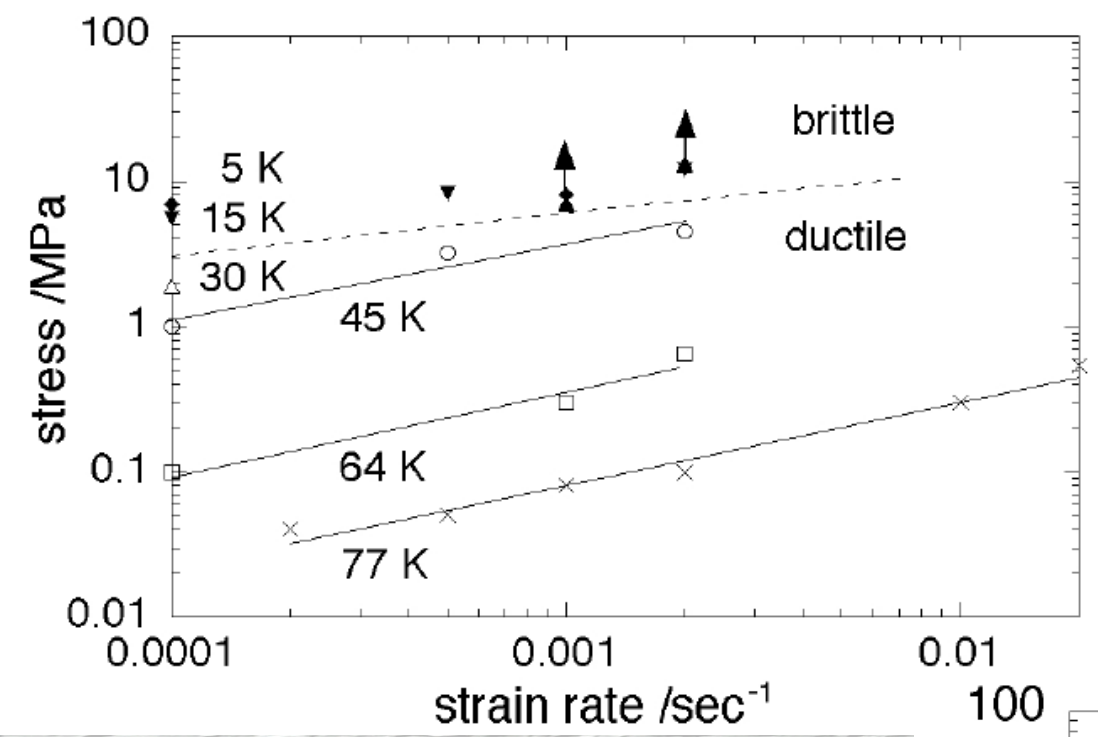
Under Compression
30 % Strain



Solid CH_4 Deformation with Strain Rate10^{-4}/s

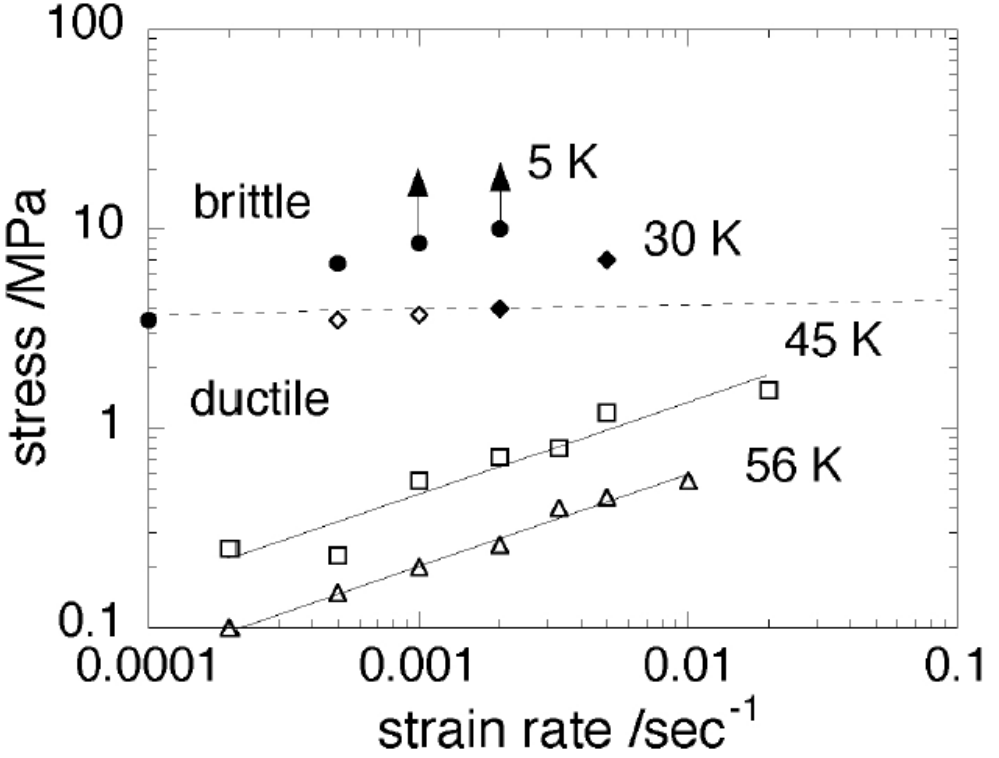
Solid N_2 at 30 K

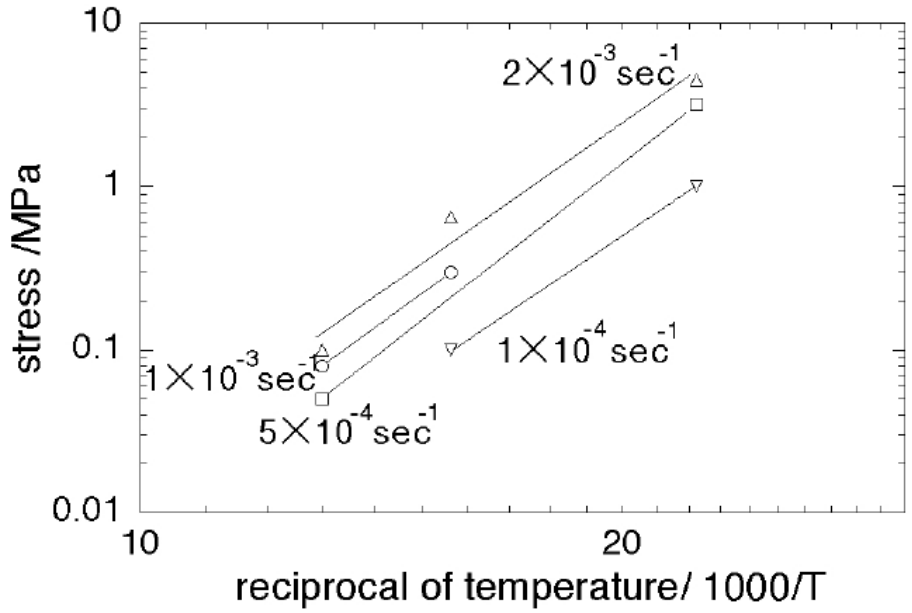


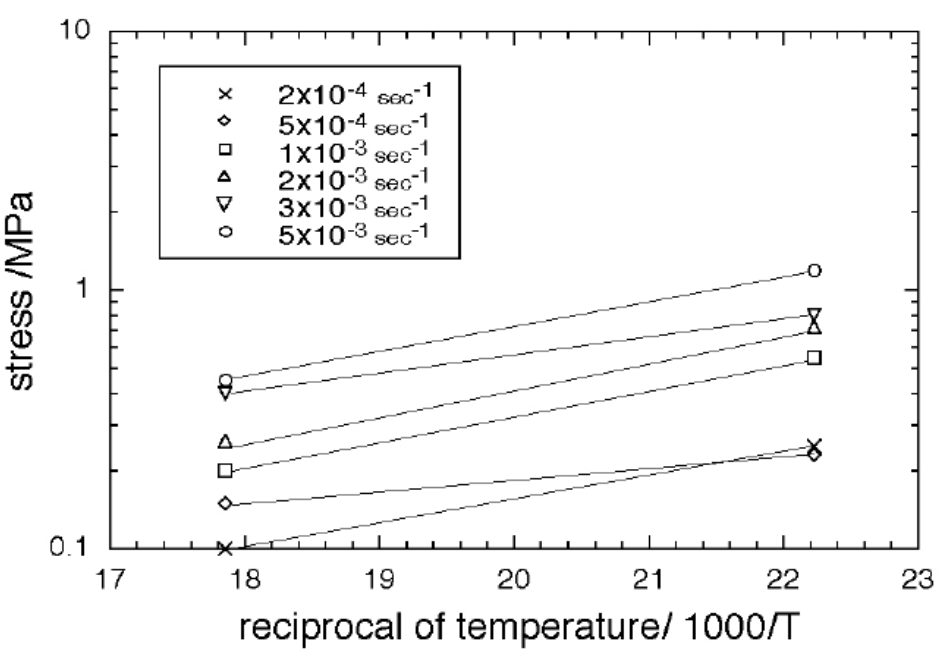


Solid CH_4: Maximum Stress and Strain Rates

Solid N_2: Maximum Stress and Strain Rates







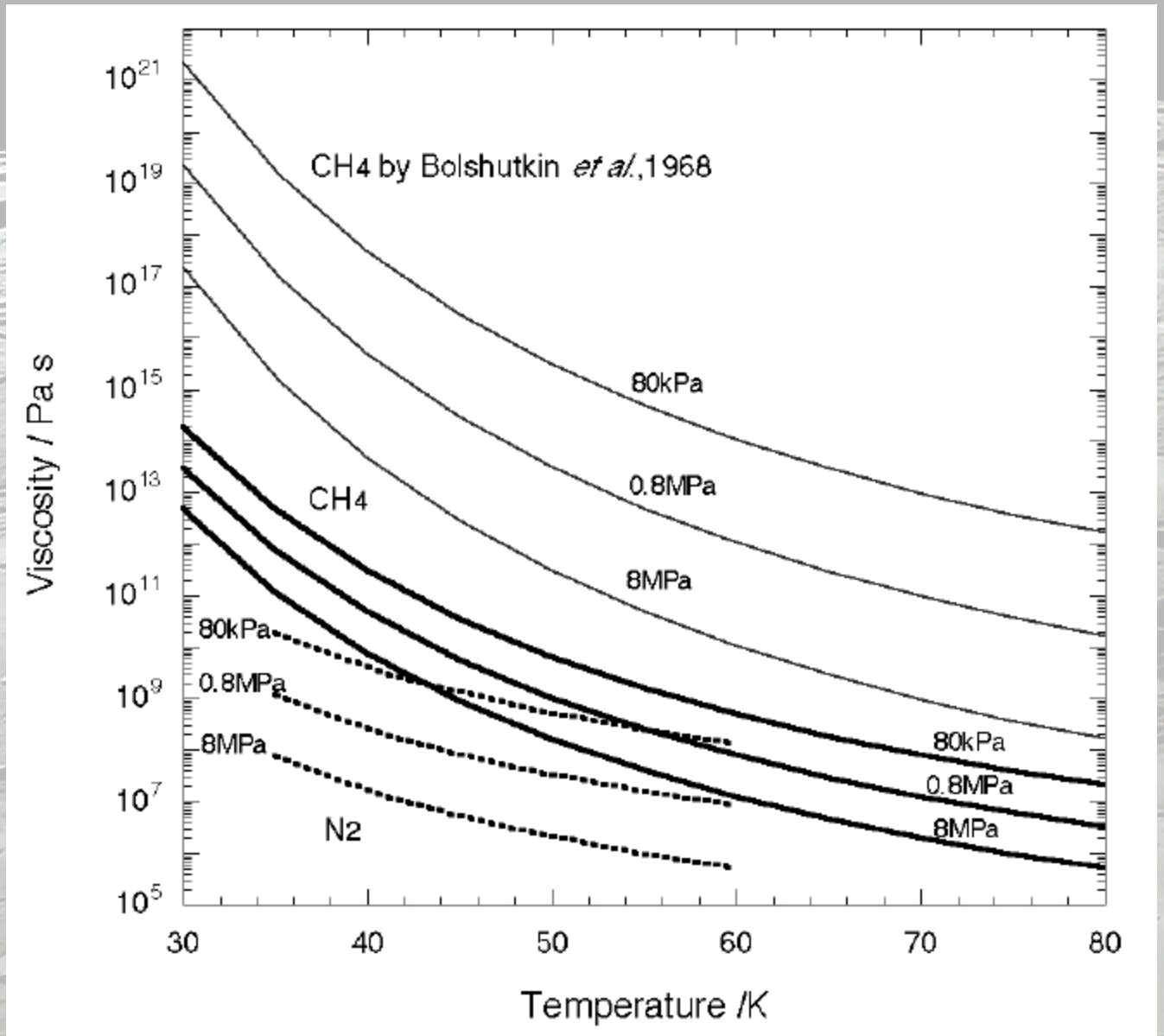
Solid CH_4: Maximum Stress and Reciprocal Temperature

Solid N_2

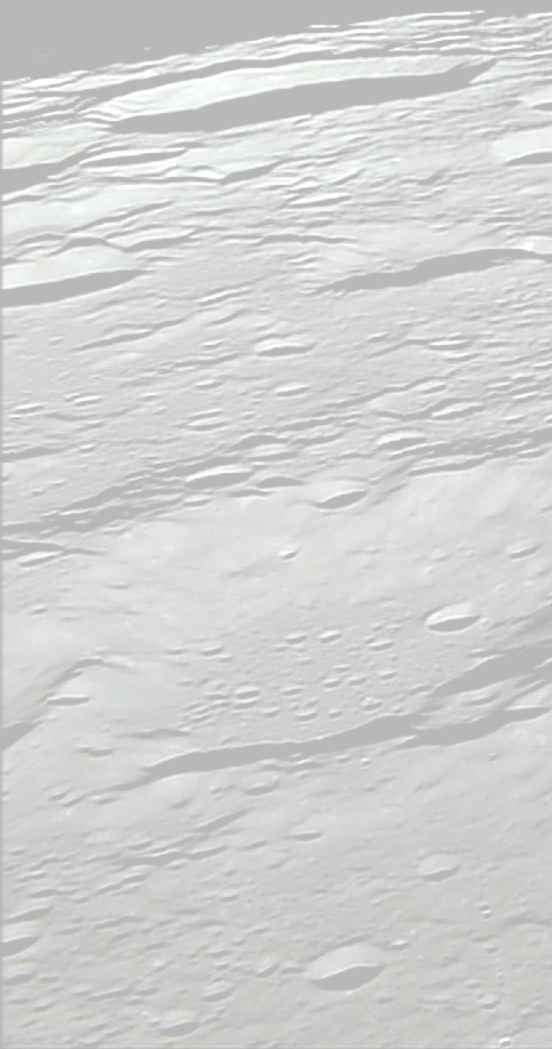
Flow low parameters for solid nitrogen and methane

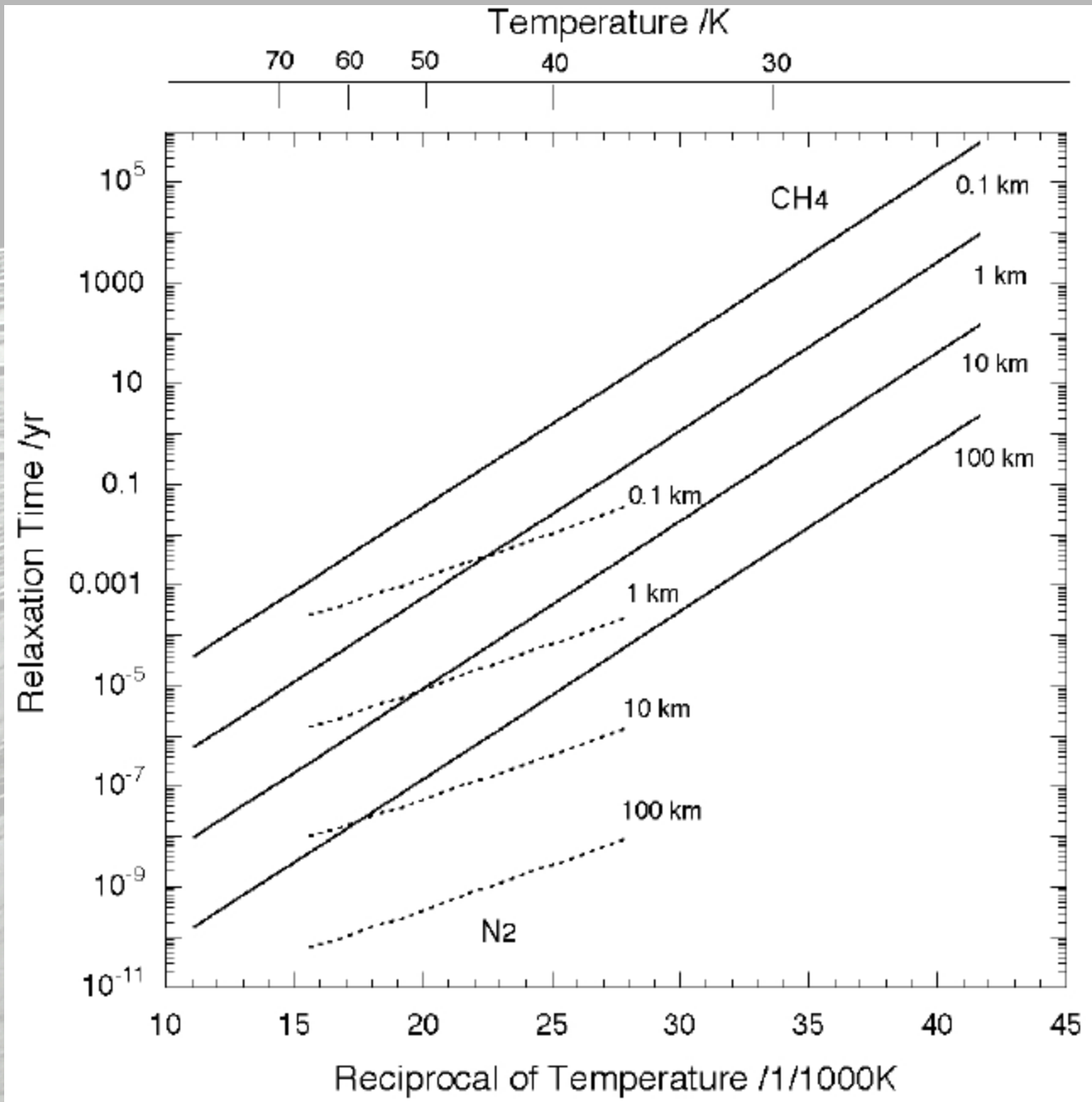
	$\log_{10}A$ ($MPa^{-n}s^{-1}$)	n	Q (kJ/mol)
N_2	3.3±0.4	2.2±0.2	3.5±0.3
CH_4	1.8±0.4	1.8±0.2	6.4±04

Effective Viscosity and Temperature

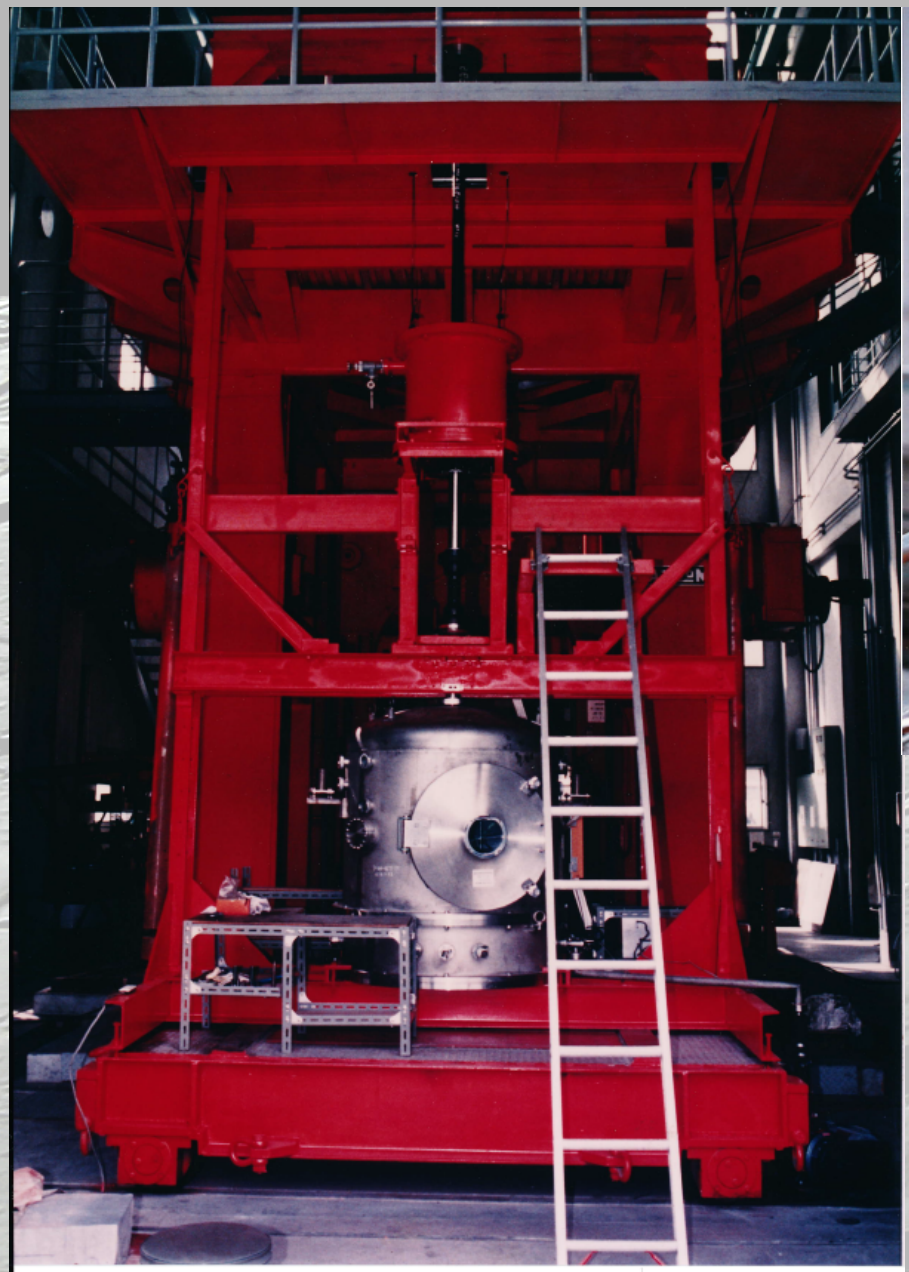


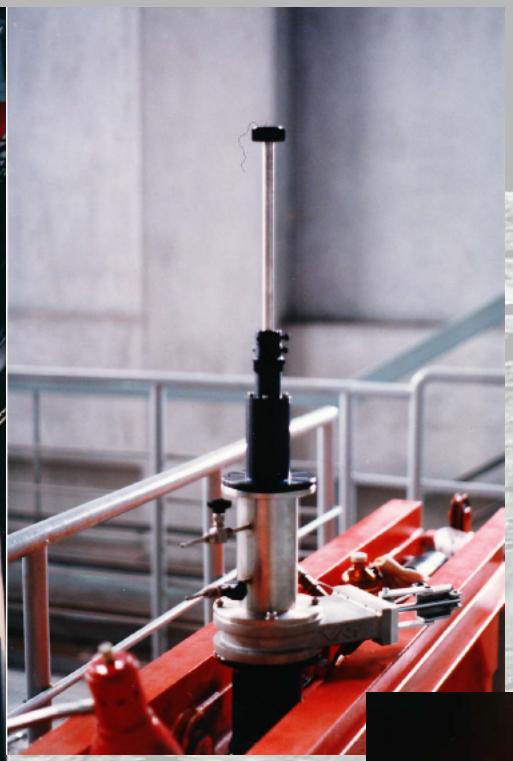
Relaxation Times of Craters on Triton Surface





実験惑星学4： Ice Impact Experiments





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