METHANOGENS: A MODEL FOR LIFE ON MARS

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I am not a chemist.

I am not a physicist.

I am not a geologist.

I am not an astronomer.

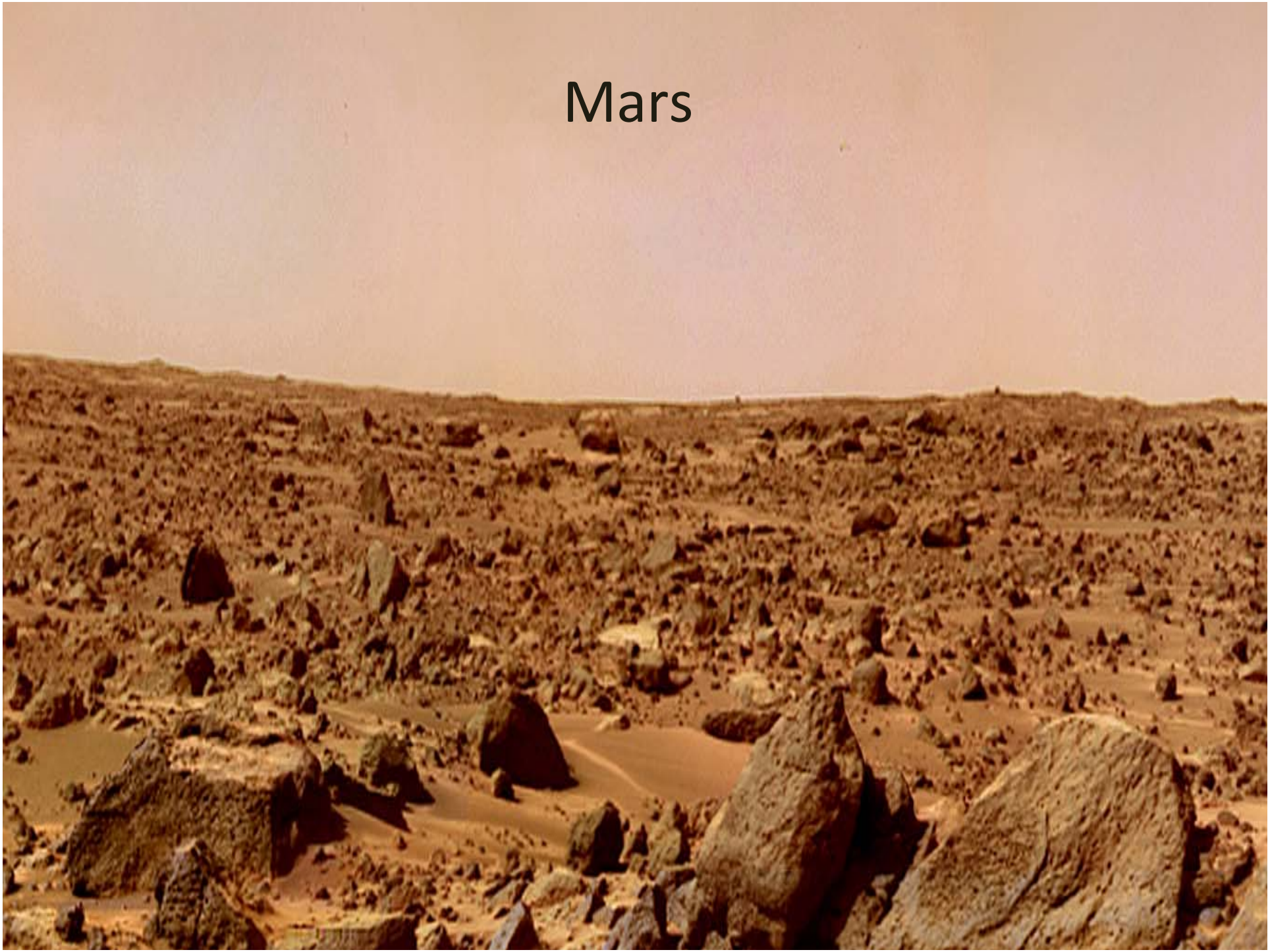
I am a microbiologist.

Which means that I know very little biology.

Outline

- Conditions on Mars
- Methanogens
- Low-Pressure Metabolism Experiments
- Perchlorate Experiments
- Carbonate Experiments
- Desiccation at 1 bar Experiments
- Desiccation at 6 mbar Experiments
- Conclusions

Mars



Conditions on the Surface of Mars

- Cold (-60^{o}C average)
- Dry (0.03% water vapor)
- Very Thin Atmosphere (6 mbar)
- No Detectable Organics
- Lethal Radiation
- Oxidants in the Soil

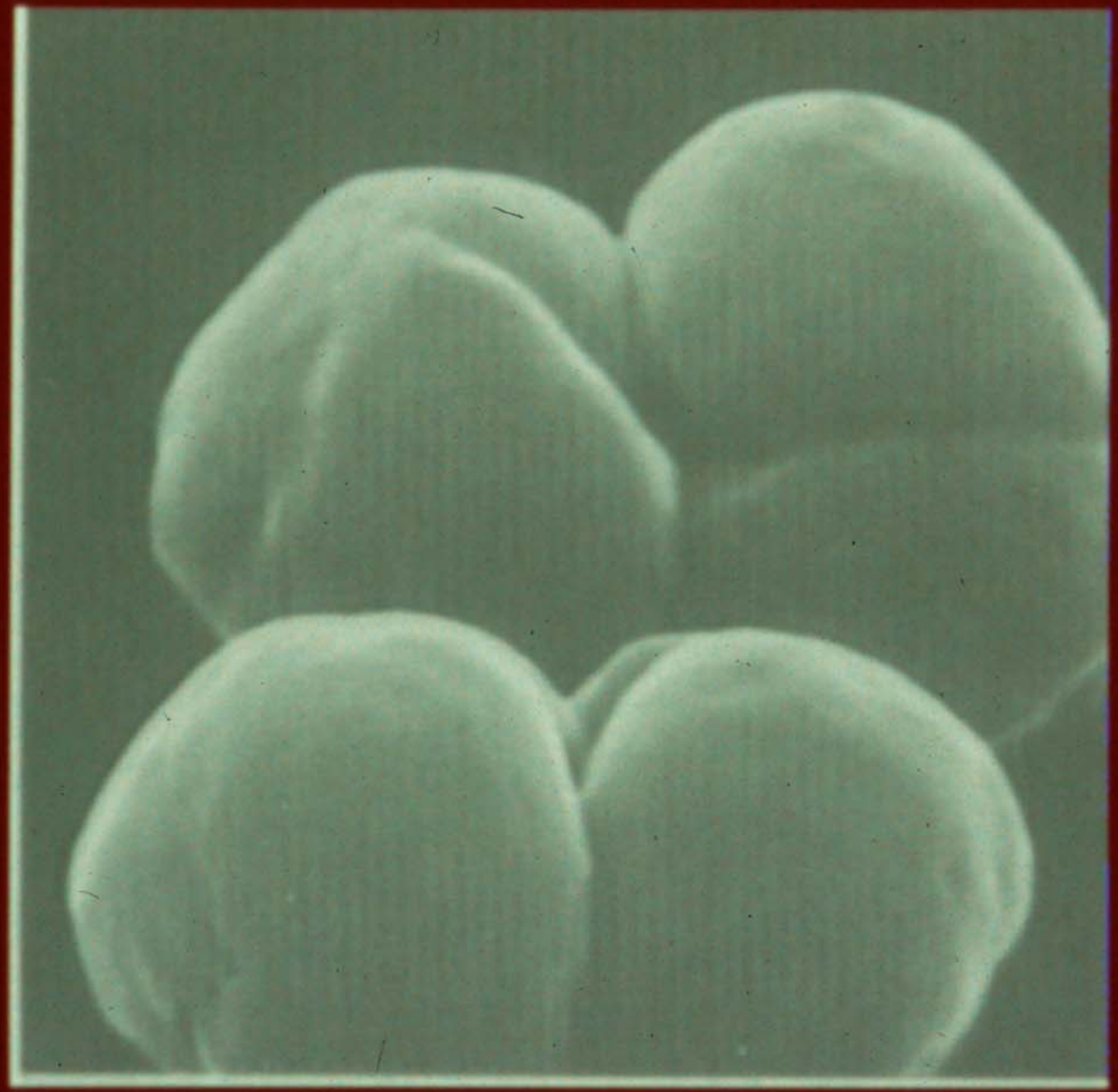
Do we believe that anything can grow or survive on the surface of Mars?

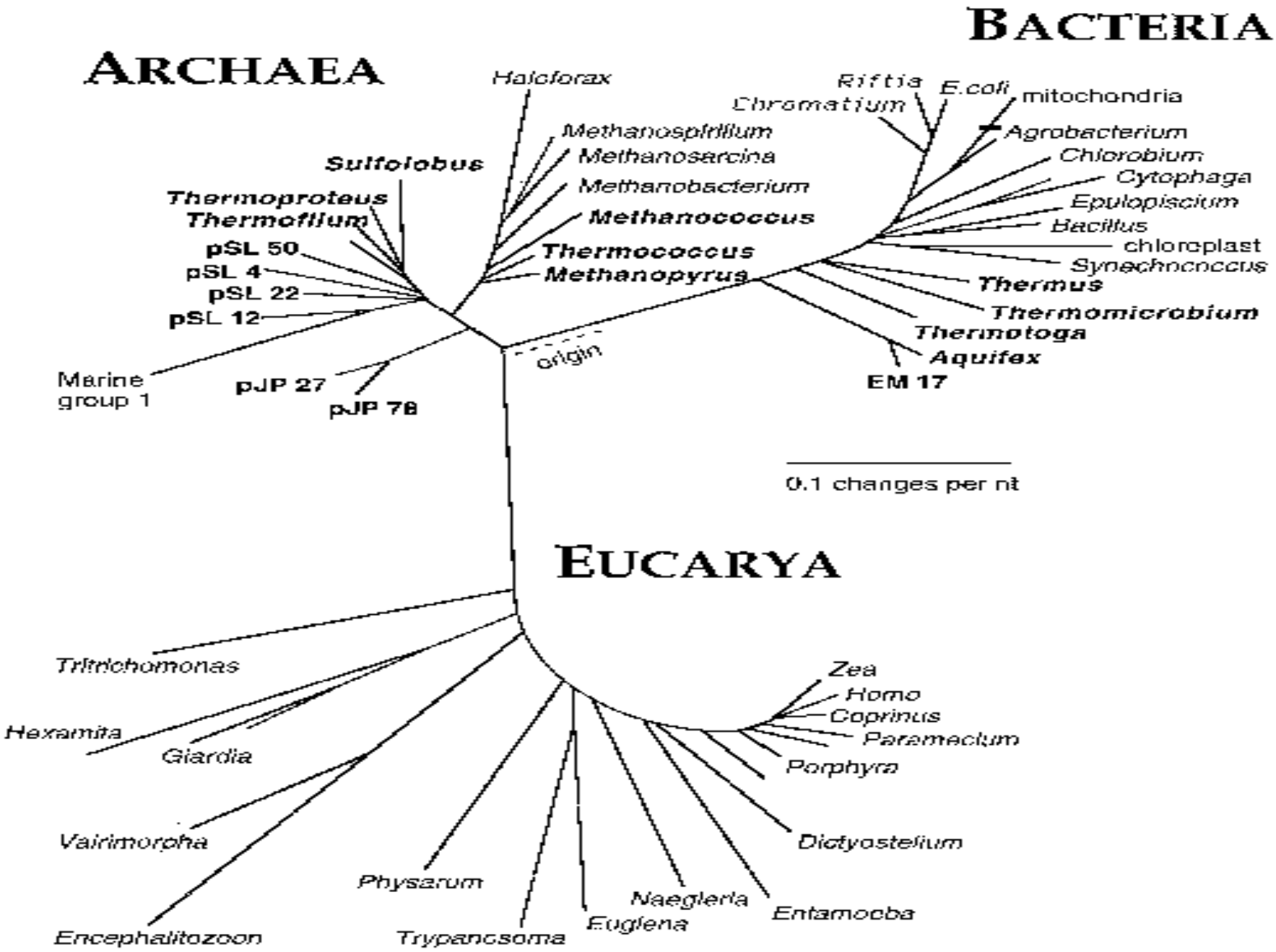
NO!

But the subsurface is a different matter.

Protected from radiation
Higher pressures
Possibly higher temperatures
Liquid water ?

Methanosarcina barkeri




BACTERIA
ARCHAEA
Halcforax
Riftia
E.coli
mitochondria
Chromatium
Methanospirillum
Agrobacterium
Methanosarcina
Chlorobium
Sulfolobus
Methanobacterium
Cytophaga
Thermoproteus
Methanococcus
Epulopiscium
Thermofilum
Bacillus
pSL 50
Thermococcus
chloroplast
pSL 4
Methanopyrus
Synechococcus
pSL 22
Thermus
pSL 12
Thermomicrobium
Thermotoga
origin
Marine
group 1
Aquifex
pJP 27
EM 17
pJP 78
0.1 changes per nt
EUCARYA
Trichomonas
Zea
Homo
Hexamita
Coprinus
Paramecium
Giardia
Porphyra
Vairimorpha
Dictyostelium
Physarum
Naegleria
Entamoeba
Euglena
Encephalitozoon
Trypanosoma

Methanogenesis

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

Why Methanogens?

- Not Photosynthetic
- Do Not Require Organics
- CO_2 in Martian Atmosphere
- H_2 Below the Surface?
- CO in Martian Atmosphere

- Methane in the Martian Atmosphere

Methanogens Used

- *Methanothermobacter wolfeii*
- *Methanosarcina barkeri*
- *Methanobacterium formicicum*
- *Methanococcus maripaludis*

Conditions on the Surface of Mars

- Cold (-55°C average)
- Dry (0.03% water vapor) ✓
- Very Thin Atmosphere (6 mbar) ✓
- No Detectable Organics ✓
- Lethal Radiation
- Oxidants in the Soil ✓

Low-pressure metabolism experiments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W.M. KECK LABORATORY FOR SPACE SIMULATION
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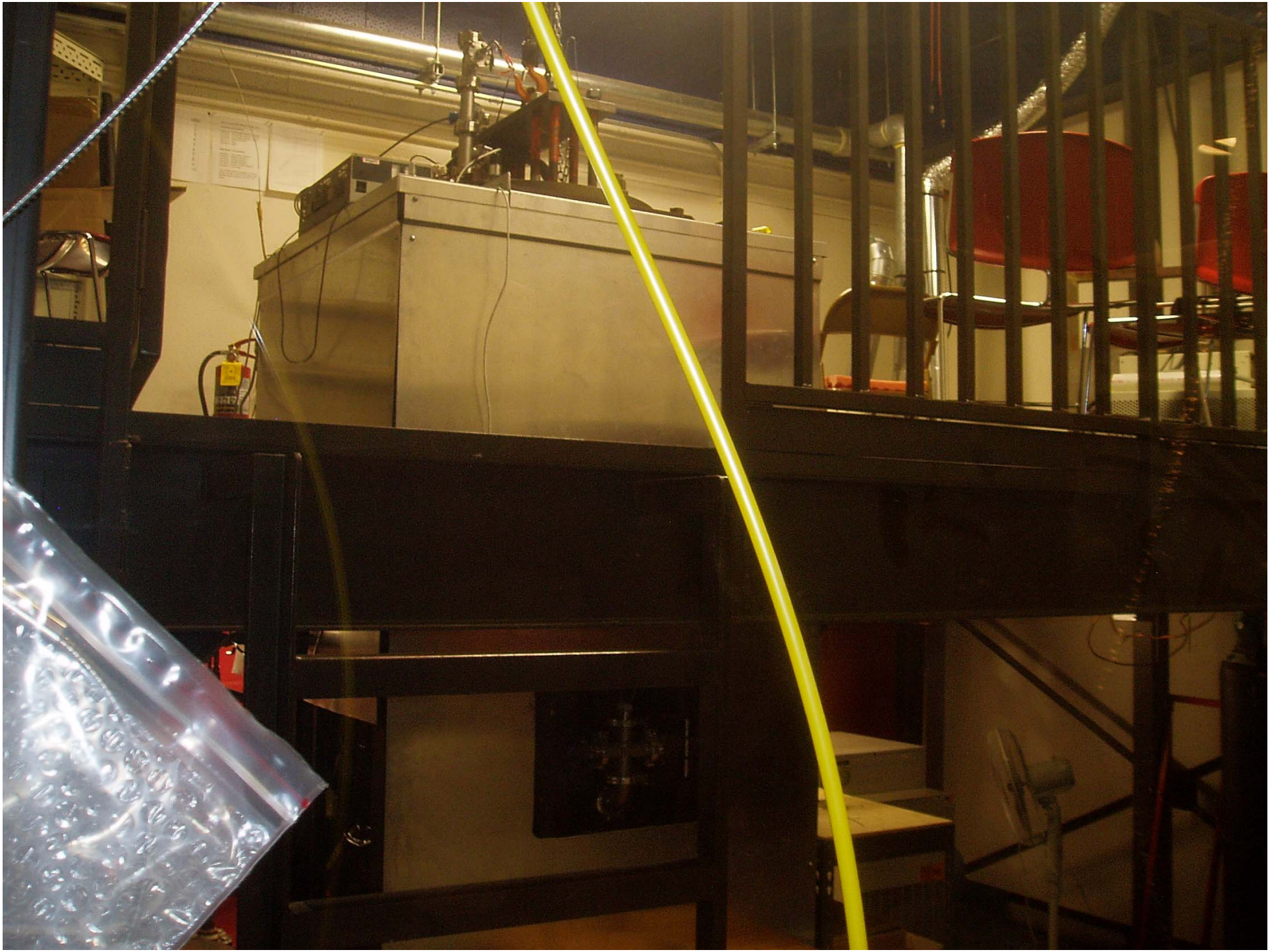
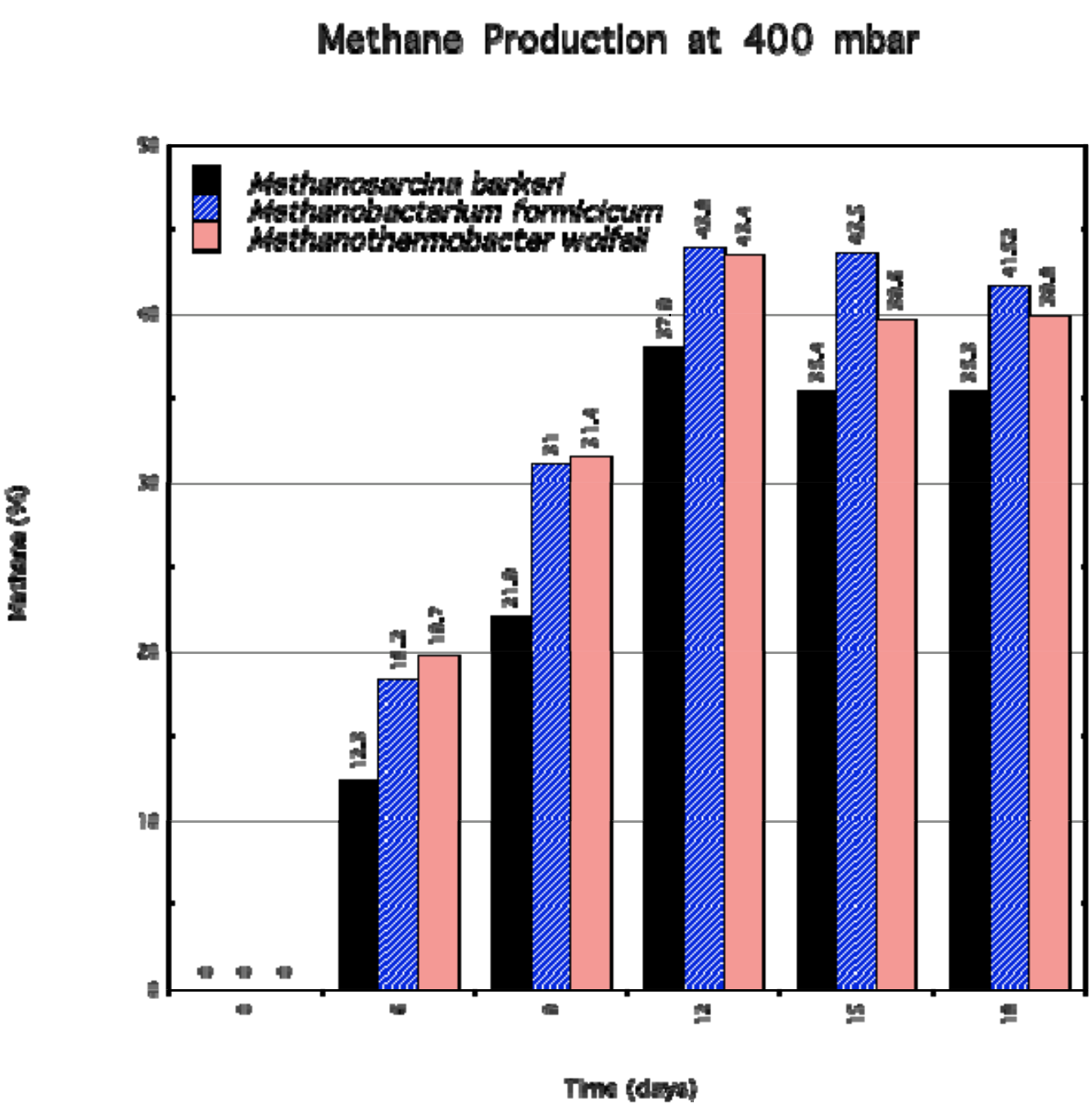
NO PARKING

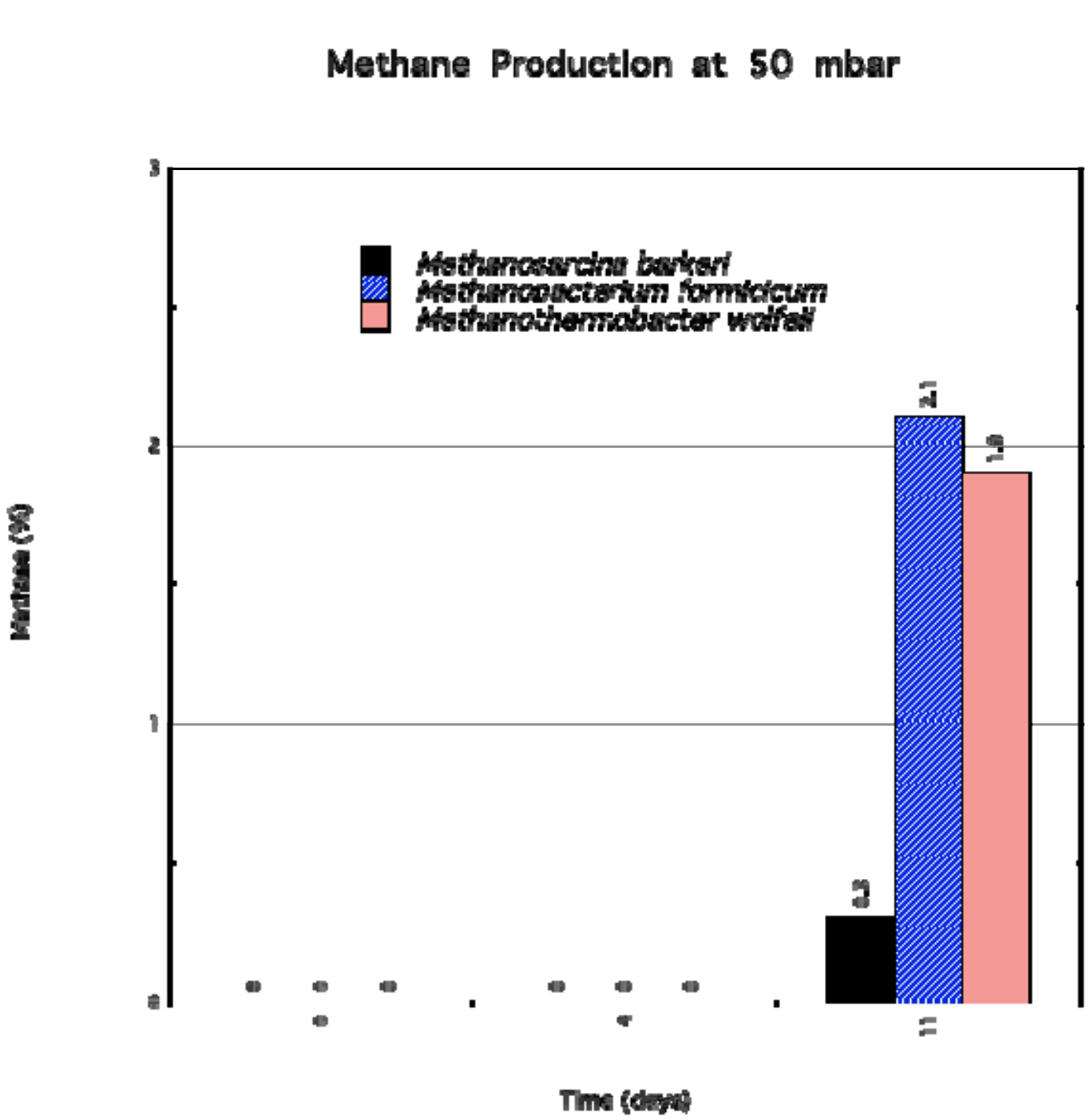



ATTENTION !

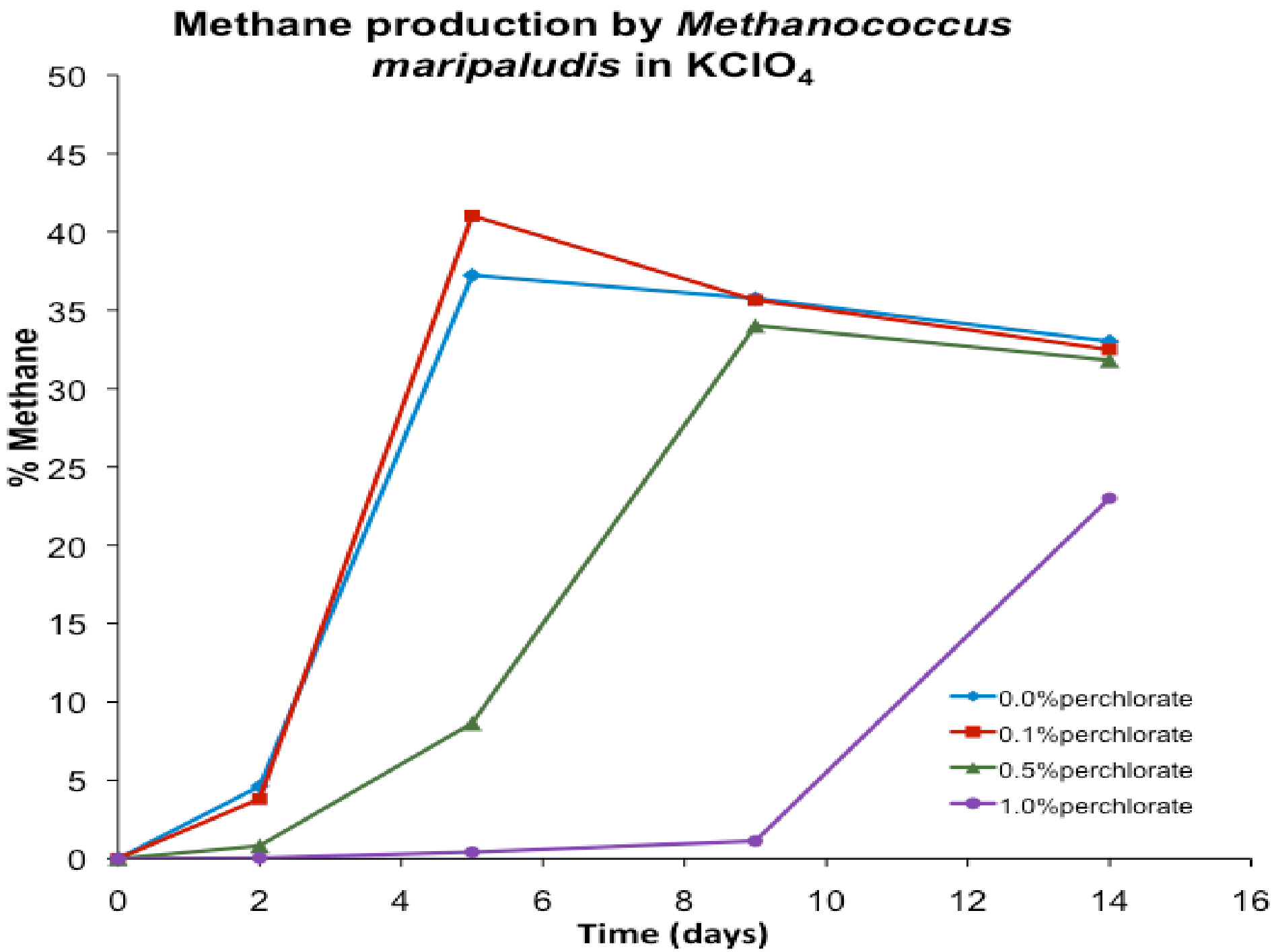
Chamber Conditions

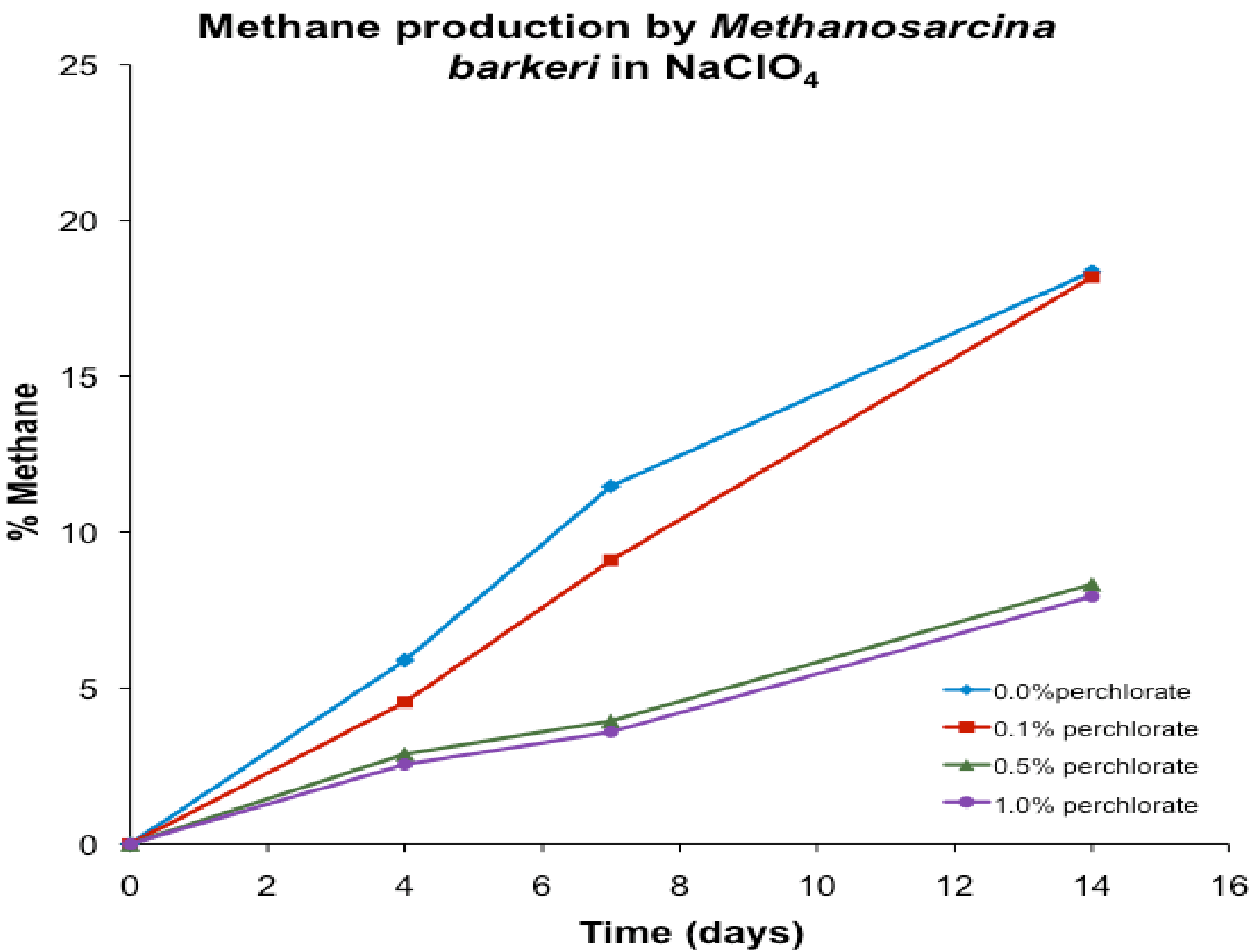
- Atmosphere: 50% Hydrogen
  50% Carbon Dioxide
- Temperature: 35°C
- Pressure: 400 mbar or 50 mbar

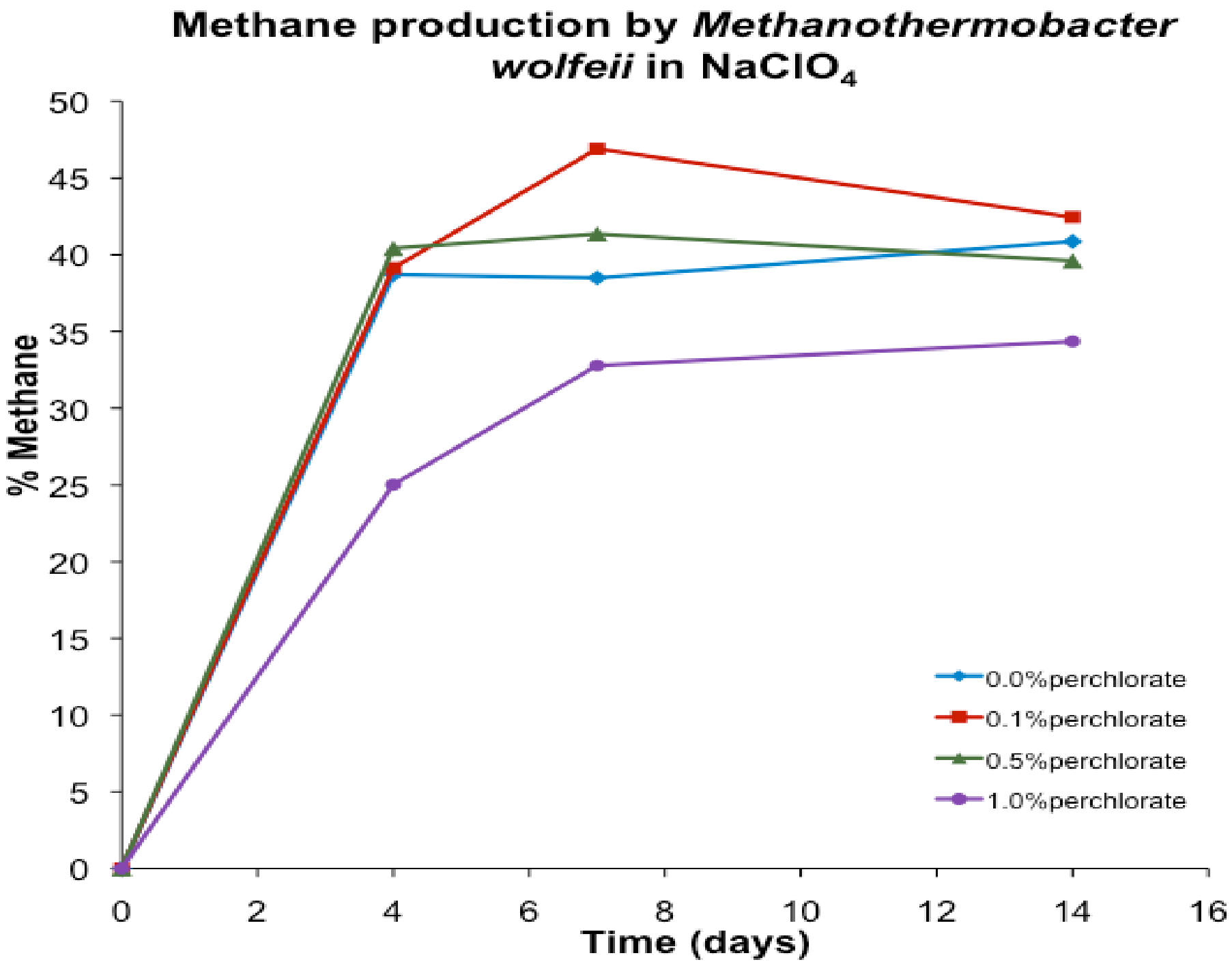

Methane Production at 400 mbar
Methanosarcina barkeri
Methanobacterium formicicum
Methanothermobacter wolfeii
Methane (%)
Time (days)

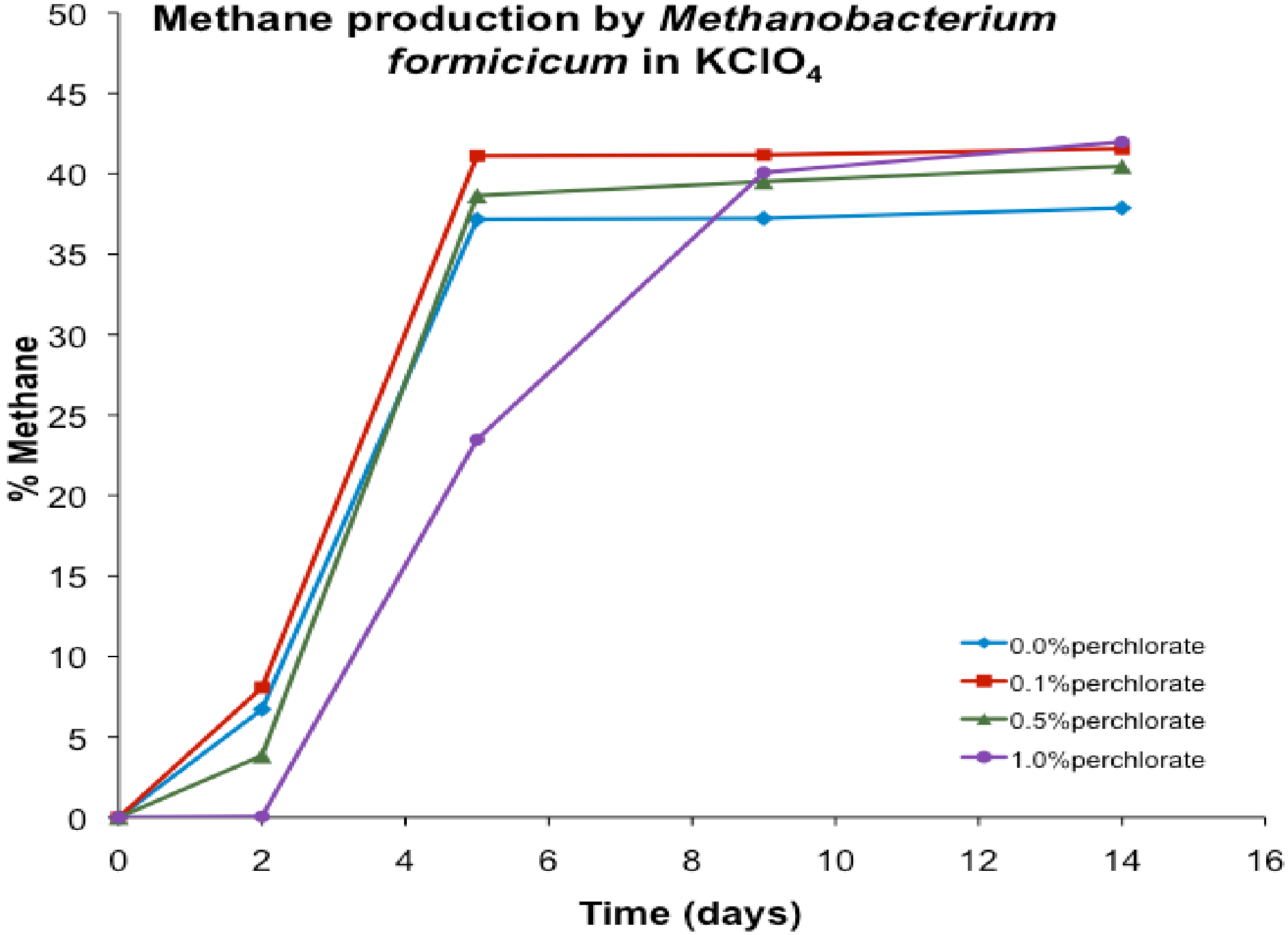

Methane Production at 50 mbar
Methanosarcina barkeri
Methanobacterium formicicum
Methanothermobacter wolfeii
Methane (%)
Time (days)

Methane production in the presence of perchlorate salts

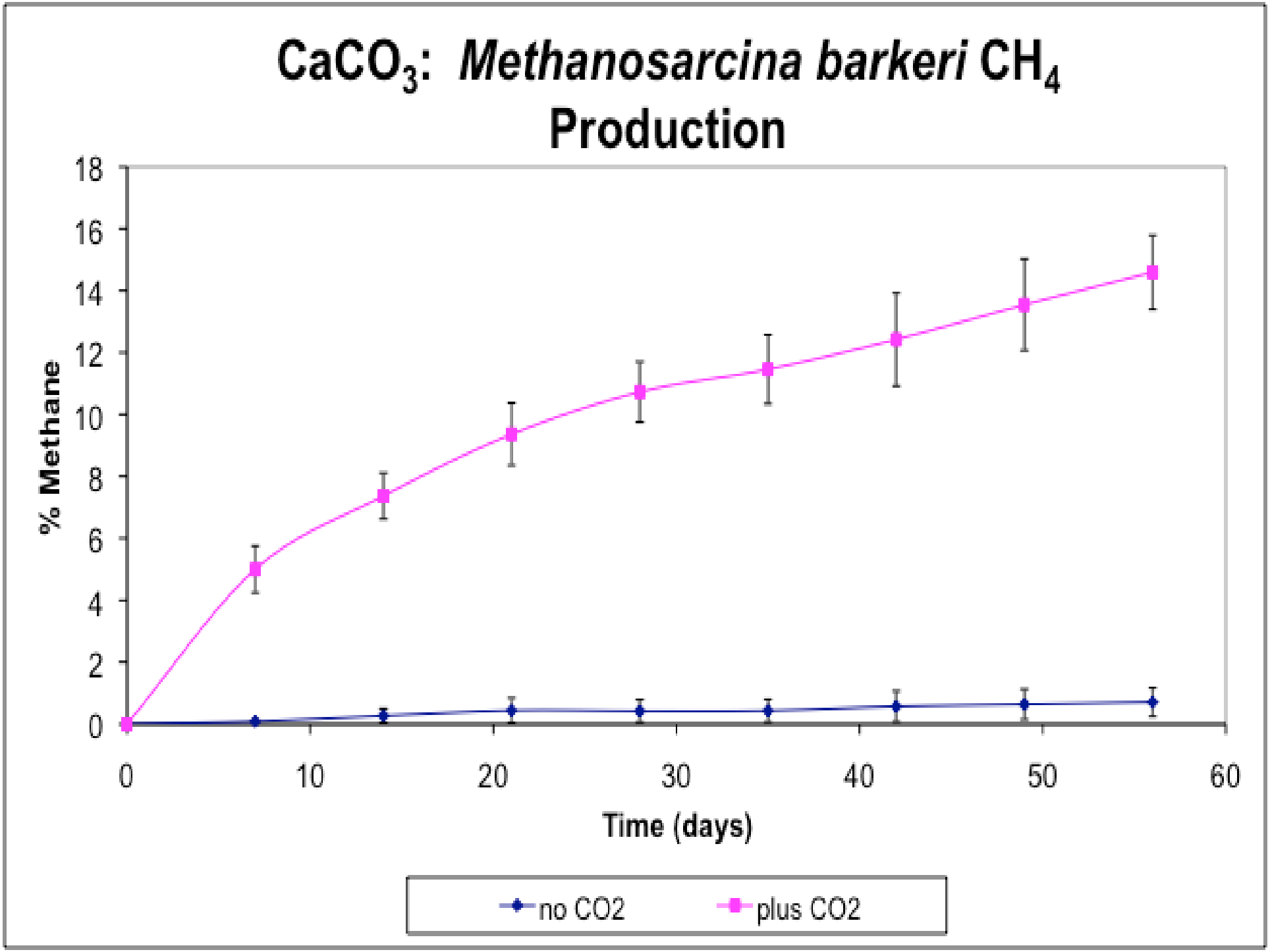

Methane production by Methanococcus maripaludis in KClO4
% Methane
Time (days)
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10
12
14
16
0.0%perchlorate
0.1%perchlorate
0.5%perchlorate
1.0%perchlorate

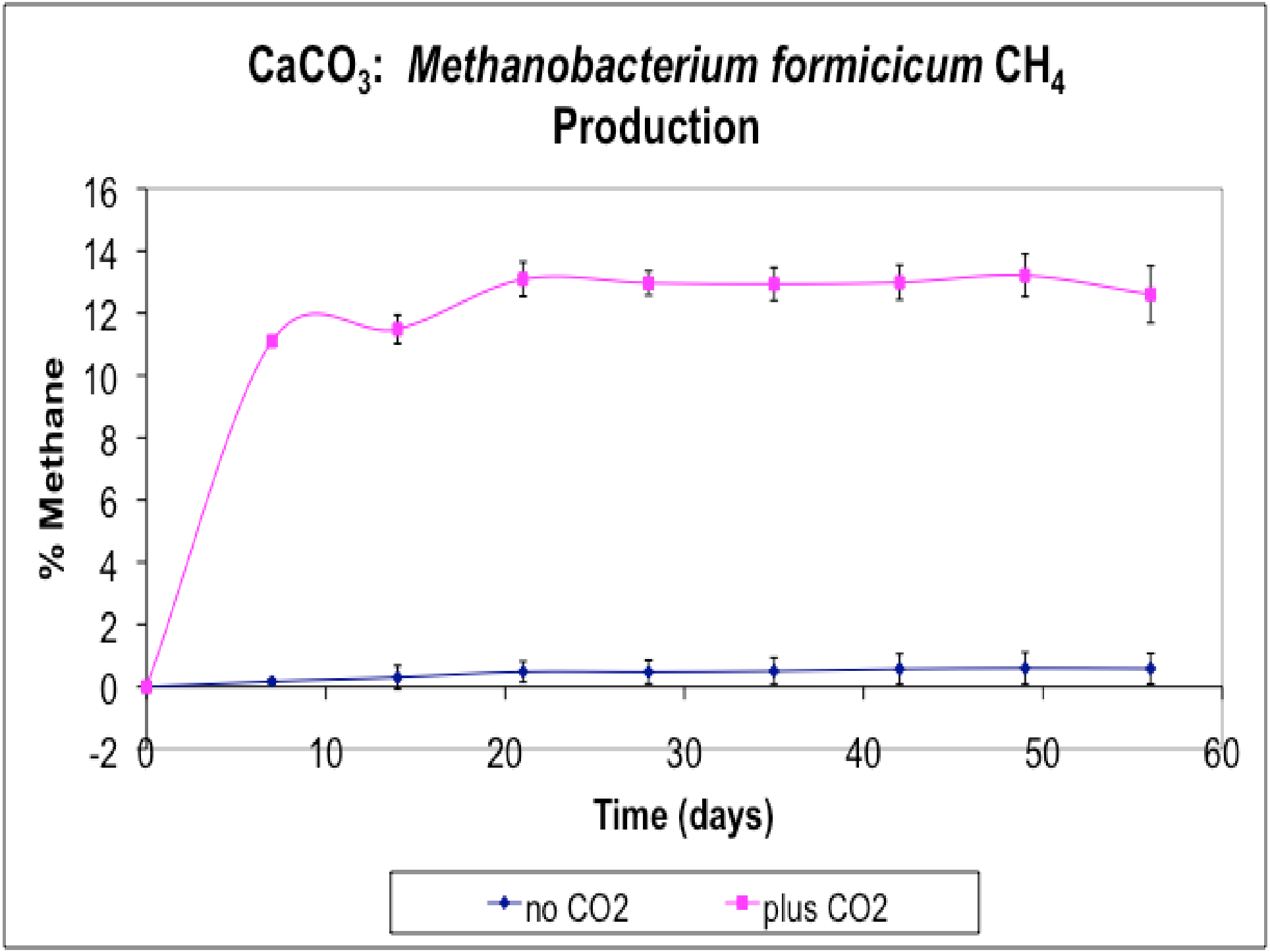

Methane production by Methanosarcina barkeri in NaClO4
% Methane
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
Time (days)
0.0%perchlorate
0.1% perchlorate
0.5% perchlorate
1.0% perchlorate

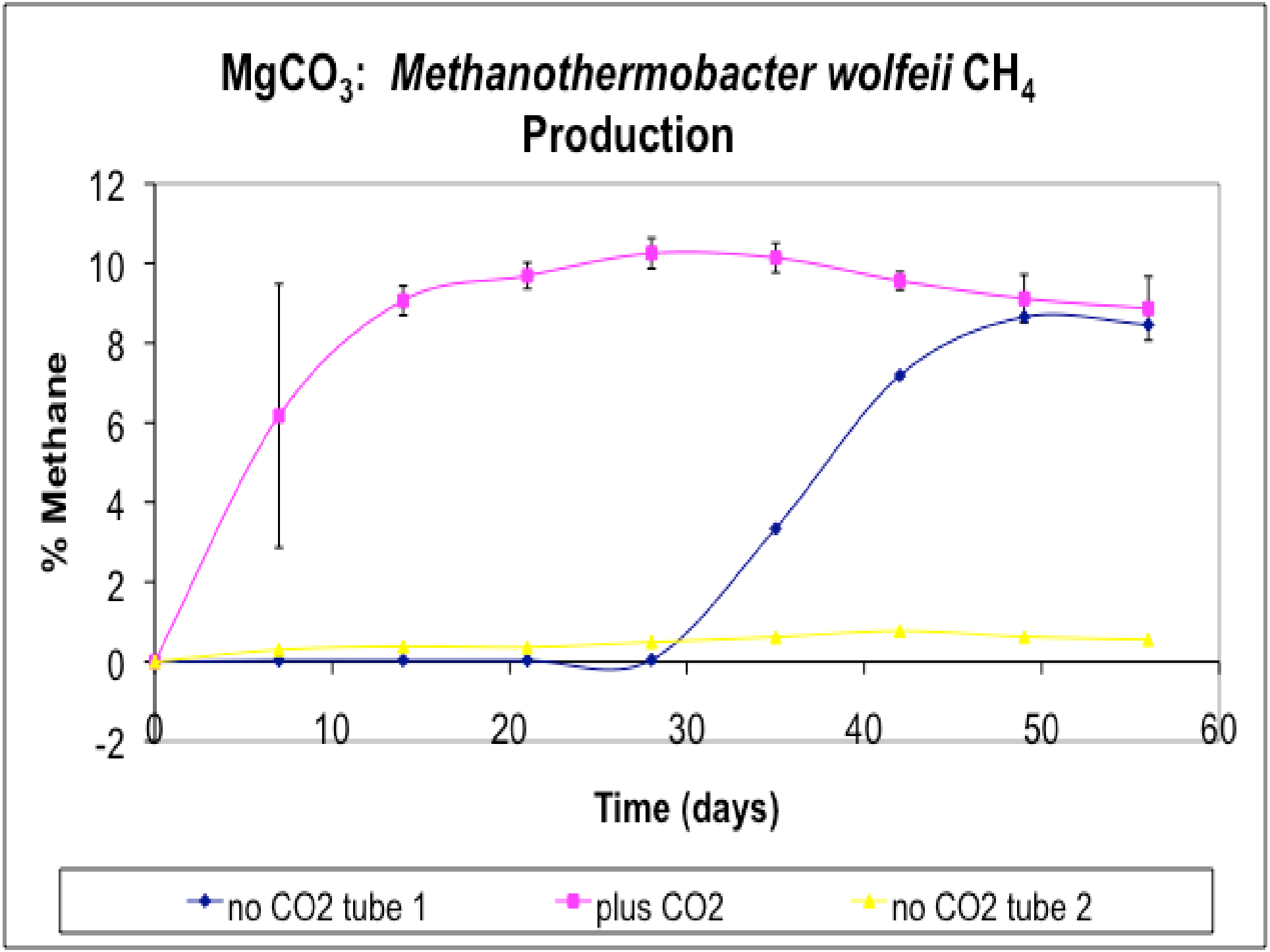

Methane production by Methanothermobacter wolfeii in NaClO4
% Methane
Time (days)
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10
12
14
16
0.0%perchlorate
0.1%perchlorate
0.5%perchlorate
1.0%perchlorate


Methane production by Methanobacterium formicicum in KClO4
% Methane
Time (days)
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10
12
14
16
0.0%perchlorate
0.1%perchlorate
0.5%perchlorate
1.0%perchlorate

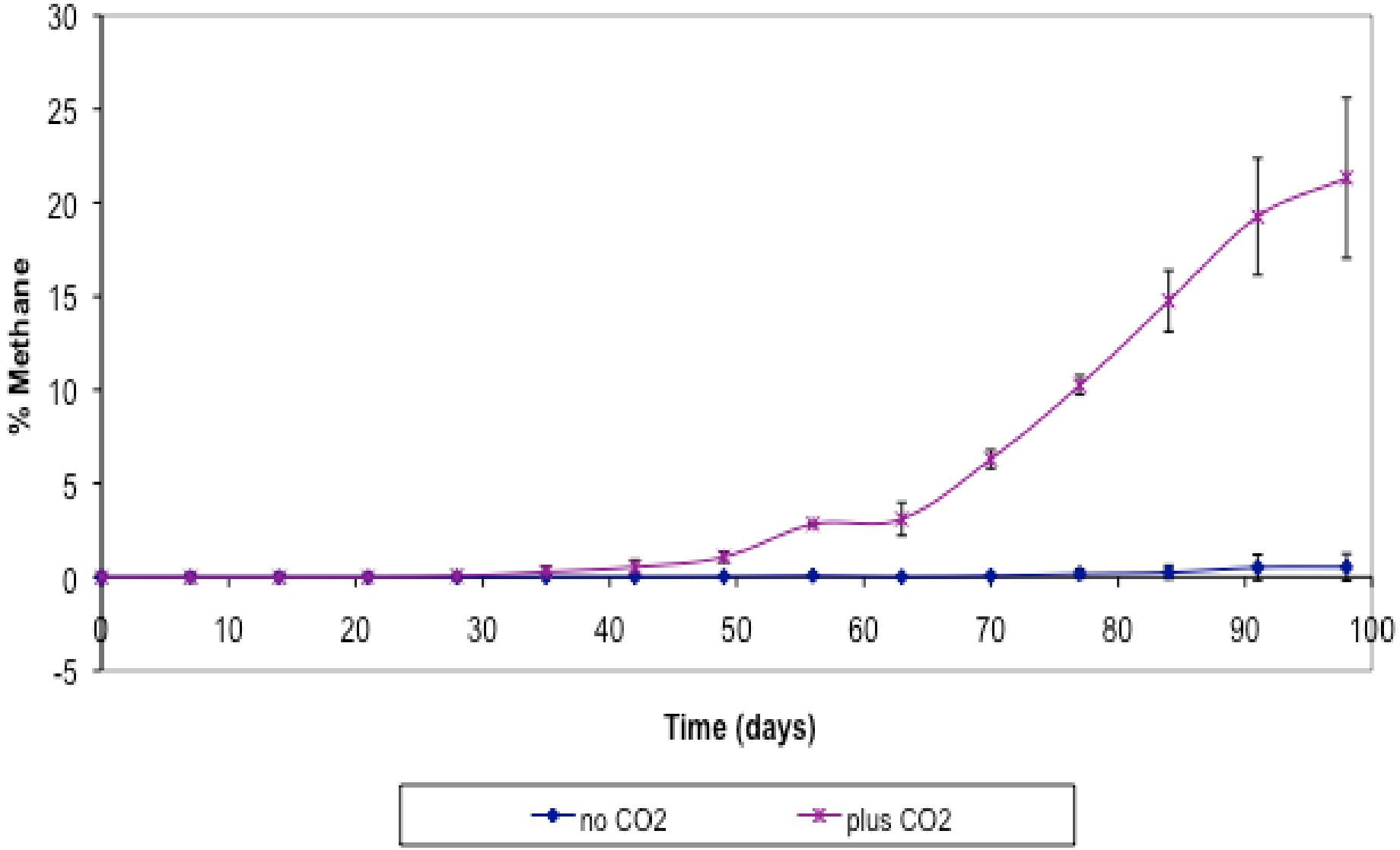
Methane production using carbonate as the sole carbon source


CaCO3: Methanosarcina barkeri CH4 Production
% Methane
0
2
4
6
8
10
12
14
16
18
0
10
20
30
40
50
60
Time (days)
no CO2
plus CO2


CaCO3: Methanobacterium formicicum CH4 Production
% Methane
16
14
12
10
8
6
4
2
0
-2
0
10
20
30
40
50
60
Time (days)
no CO2
plus CO2

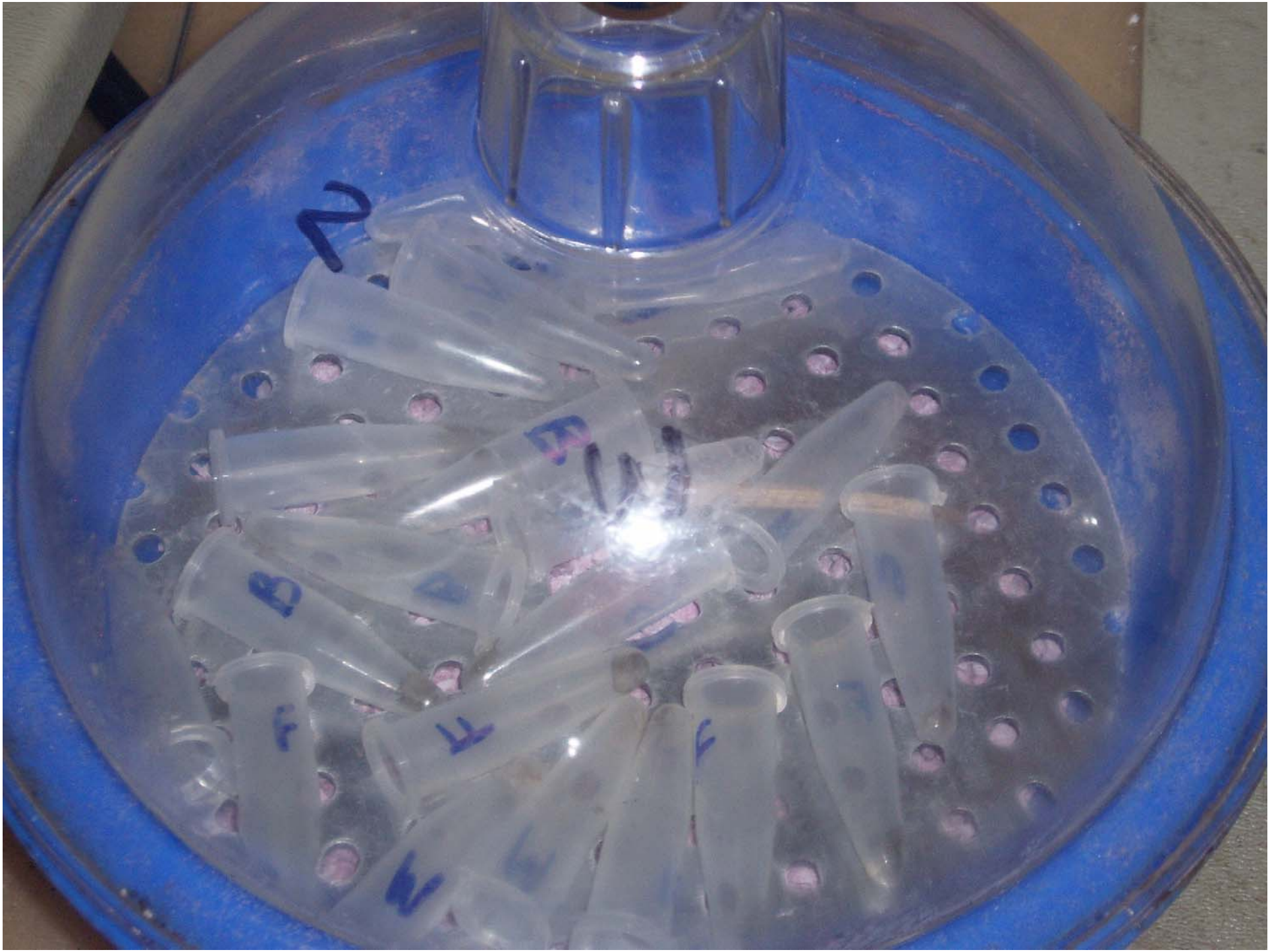

MgCO3: Methanothermobacter wolfeii CH4 Production
% Methane
12
10
8
6
4
2
0
-2
0
10
20
30
40
50
60
Time (days)
no CO2 tube 1
plus CO2
no CO2 tube 2

$MgCO_3$: *Methanococcus maripaludis* CH_4 Production



Desiccation at 1 bar

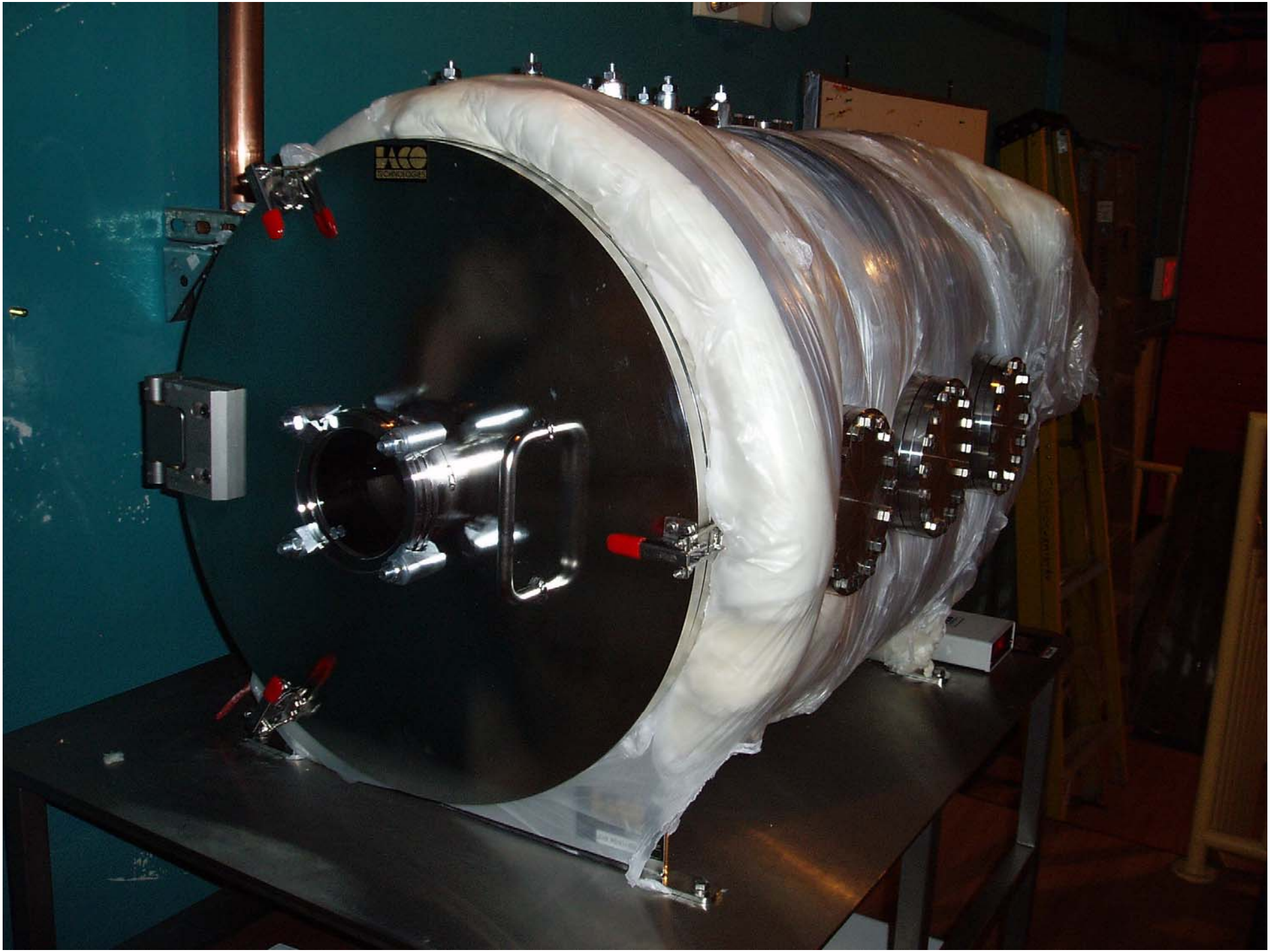

POWER
STATUS
CYCLE



Desiccation at 1 bar

M. barkeri	330 days (so far)
M. wolfeii	180 days
M. formicicum	120 days

Desiccation at 6 mbar



90 Days, 6 mbar, Desiccation

	Glass	Substrate*	Glass→Substrate	Substrate→Medium
M. wolfeii	+++	-	+ (SS & Basalt)	+ (Clay & Basalt)
M. barkeri	+++	++ (SS & Clay)	+ (Clay & Basalt)	++ (SS & Clay)
M. formicicum	++	-	-	-
M. maripaludis	-	-	-	-

*JSC Mars-1 (SS)
Clay (Montmorillonite)
Basalt

120 Days, 6 mbar, Desiccation

	Glass Beads	Ch. Basalt	Gr. Basalt	Ch. Jarosite	Gr. Jarosite
M. wolfeii	+++	-	-	-	-
M. barkeri	+++	++	++	++	-
M. formicicum	++	-	-	++	-
M. maripaludis	-	-	-	-	-

Ch. = Chunk
Gr. = Ground

Conclusions

- Methane production occurs at reduced pressures
- Methane production occurs in the presence of 1% perchlorate
- Methane production occurs when carbonate serves as sole carbon source
- Methanogens survive desiccation at 1 bar and 6 mbar for extended periods of time, relatively speaking

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