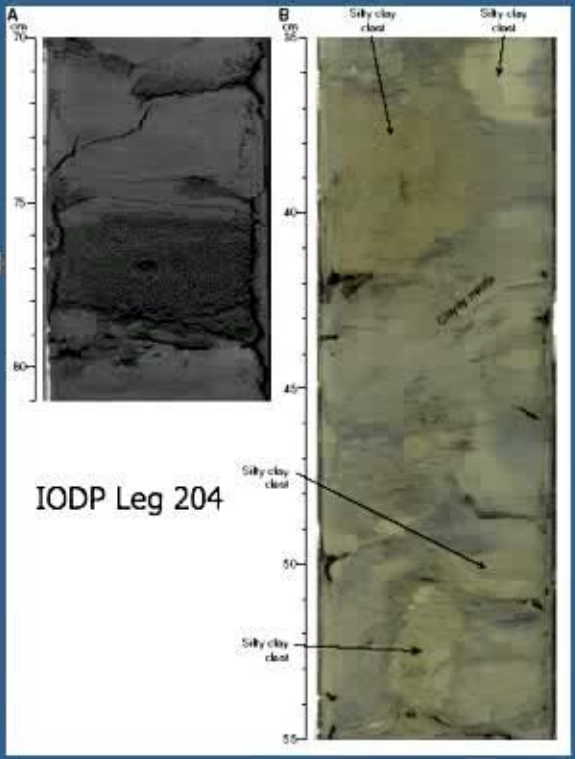
Geologic Controls on Hydrate Accumulation & Dissociation

- Effects of sediment heterogeneity on hydrate accumulation and dissociation pathways
- Sediment stability during hydrate accumulation, dissociation, and cycling (i.e. frost heaving)



1
00:00:07,460 --> 00:00:04,880
today we have the another candidate for

2
00:00:09,379 --> 00:00:07,470
our destro biology faculty position that

3
00:00:13,759 --> 00:00:09,389
she would sit in person space sciences

4
00:00:17,810 --> 00:00:13,769
if she were to come here Megan Elwood

5
00:00:20,990 --> 00:00:17,820
Madden got her PhD at Virginia Tech just

6
00:00:23,330 --> 00:00:21,000
two years ago in in 05 and she now has a

7
00:00:27,040 --> 00:00:23,340
postdoc at the Oak Ridge National

8
00:00:29,689 --> 00:00:27,050
Laboratory her work has to do with the

9
00:00:32,780 --> 00:00:29,699
flat rates and hydrates and so forth and

10
00:00:34,580 --> 00:00:32,790
various solar system bodies and before

11
00:00:36,229 --> 00:00:34,590
we get to today's talk let me just tell

12
00:00:39,950 --> 00:00:36,239
you the tomorrow morning at ten-thirty

13
00:00:42,530 --> 00:00:39,960

in Johnson 026 she's going to be giving

14
00:00:44,869 --> 00:00:42,540
a seminar directed more at the Earth and

15
00:00:47,060 --> 00:00:44,879
Space Sciences Department entitled where

16
00:00:48,950 --> 00:00:47,070
has all the water gone exploring the

17
00:00:52,400 --> 00:00:48,960
effects of time temperature pressure and

18
00:00:54,529 --> 00:00:52,410
Composition on planetary fluids that'll

19
00:00:56,990 --> 00:00:54,539
be a little more chila geologically

20
00:00:59,479 --> 00:00:57,000
oriented talk today she's going to talk

21
00:01:02,110 --> 00:00:59,489
about gas hydrates as planetary scale

22
00:01:05,690 --> 00:01:02,120
water and greenhouse gas reservoirs

23
00:01:07,340 --> 00:01:05,700
implications for astrobiology and also

24
00:01:08,810 --> 00:01:07,350
there's going to dinner tonight to Mike

25
00:01:11,660 --> 00:01:08,820
Brown right here is in charge if you

26
00:01:16,609 --> 00:01:11,670
want to join Mike in a small group see

27
00:01:19,000 --> 00:01:16,619
him after the after the talk thank you

28
00:01:21,040 --> 00:01:19,010
very much for inviting me here today

29
00:01:24,340 --> 00:01:21,050
have to be here I've never actually

30
00:01:28,450 --> 00:01:24,350
talked to screens bit before so we'll

31
00:01:29,560 --> 00:01:28,460
see how my point your skills become so

32
00:01:31,330 --> 00:01:29,570
make sure they're going to be talking a

33
00:01:33,790 --> 00:01:31,340
little bit about gas hydrates today I

34
00:01:35,020 --> 00:01:33,800
work at a national lab that's funded by

35
00:01:37,000 --> 00:01:35,030
the Department of Energy and the

36
00:01:38,200 --> 00:01:37,010
Department of Energy's course interested

37
00:01:40,540 --> 00:01:38,210
in gas hydrates from an energy

38
00:01:41,650 --> 00:01:40,550

perspective as a natural resource I'm

39
00:01:43,930 --> 00:01:41,660
going to talk a little bit about that

40
00:01:45,760 --> 00:01:43,940
today in terms of gas hydrates in a

41
00:01:47,890 --> 00:01:45,770
terrestrial perspective that one of

42
00:01:50,110 --> 00:01:47,900
those aspects is as an energy resource

43
00:01:52,840 --> 00:01:50,120
but also in terms of climate change and

44
00:01:54,370 --> 00:01:52,850
also some some safety issues involved

45
00:01:56,530 --> 00:01:54,380
and then I'll move on and talk about s

46
00:01:59,140 --> 00:01:56,540
hydrates from a planetary perspective

47
00:02:01,540 --> 00:01:59,150
yes materials as well and the

48
00:02:06,550 --> 00:02:01,550
implications of those for astrobiology

49
00:02:08,200 --> 00:02:06,560
oh so just to sort of highlight sponsors

50
00:02:09,669 --> 00:02:08,210
again the department of US Department of

51
00:02:12,190 --> 00:02:09,679
Energy and I've been working with

52
00:02:14,980 --> 00:02:12,200
collaborators at the Indian at Princeton

53
00:02:17,080 --> 00:02:14,990
Tennessee astrobiology institute as well

54
00:02:20,309 --> 00:02:17,090
but I haven't gotten any direct NASA

55
00:02:20,319 --> 00:02:24,400
so

56
00:02:24,410 --> 00:02:28,809
get the street

57
00:02:28,819 --> 00:02:31,650
hear me

58
00:02:31,660 --> 00:02:41,390
me

59
00:02:48,140 --> 00:02:46,220
Syria so what are gas hydrates I'm using

60
00:02:51,440 --> 00:02:48,150
the term gas hydrates because that's

61
00:02:54,110 --> 00:02:51,450
traditionally was used in geosciences

62
00:02:56,479 --> 00:02:54,120
community let the chemists and

63
00:02:58,250 --> 00:02:56,489

physicists making of gas hydrates as

64
00:03:00,470 --> 00:02:58,260
clap three materials class right

65
00:03:03,080 --> 00:03:00,480
materials basically describes this

66
00:03:05,630 --> 00:03:03,090
cage-like structure that forms in water

67
00:03:08,479 --> 00:03:05,640
ice that traps a gas molecule within the

68
00:03:11,990 --> 00:03:08,489
cage and this is a class rate structure

69
00:03:14,839 --> 00:03:12,000
gas hydrates are basically the natural

70
00:03:17,629 --> 00:03:14,849
occurring materials of the form given

71
00:03:19,670 --> 00:03:17,639
pump permafrost as well as steep where

72
00:03:24,289 --> 00:03:19,680
sediments probably throughout the solar

73
00:03:26,149 --> 00:03:24,299
system as ice like phases that trap gas

74
00:03:29,559 --> 00:03:26,159
molecules within this cage-like

75
00:03:32,990 --> 00:03:29,569
structure that forms within the ice oh

76
00:03:34,970 --> 00:03:33,000
so typically when we think of gas

77
00:03:36,800 --> 00:03:34,980
hydrates in a terrestrial contacts

78
00:03:38,660 --> 00:03:36,810
between of methane hydrate for methane

79
00:03:40,940 --> 00:03:38,670
gets trapped within this cage-like

80
00:03:43,610 --> 00:03:40,950
structure we also have naturally

81
00:03:46,460 --> 00:03:43,620
occurring ethane and propane hydrates

82
00:03:48,890 --> 00:03:46,470
that form the seafloor sediments as well

83
00:03:51,170 --> 00:03:48,900
as in permafrost in terms of the

84
00:03:53,750 --> 00:03:51,180
planetary perspective also interested in

85
00:03:55,430 --> 00:03:53,760
co2 hydrates particularly this is the

86
00:03:57,379 --> 00:03:55,440
phase diagram over here that shows the

87
00:03:59,659 --> 00:03:57,389
co2 hydrate stability to be looking

88
00:04:02,300 --> 00:03:59,669

green versus the methane hydrate

89
00:04:05,119 --> 00:04:02,310
stability field here in red you can see

90
00:04:07,729 --> 00:04:05,129
that methane hydrates of our stable at

91
00:04:09,409 --> 00:04:07,739
higher pressures and temperature at

92
00:04:13,159 --> 00:04:09,419
higher pressures and lower temperatures

93
00:04:16,250 --> 00:04:13,169
the water ice here in the blue field

94
00:04:18,439 --> 00:04:16,260
however co2 hydrate forms at higher

95
00:04:22,559 --> 00:04:18,449
temperatures and lower pressures than

96
00:04:25,870 --> 00:04:22,569
solid co2 so these random

97
00:04:27,460 --> 00:04:25,880
stability fields but produces some

98
00:04:29,110 --> 00:04:27,470
interesting effects when they look at

99
00:04:32,800 --> 00:04:29,120
this encryption for geologic context

100
00:04:34,659 --> 00:04:32,810
I'll on earnings we fighting the first

101
00:04:36,430 --> 00:04:34,669
occurrences of hydrate to be observed

102
00:04:38,920 --> 00:04:36,440
for in seafloor sediments this is an

103
00:04:41,439 --> 00:04:38,930
outcropping of gas hydrate Harold on the

104
00:04:43,870 --> 00:04:41,449
surface of the Senate water interface

105
00:04:45,430 --> 00:04:43,880
you can see this weight material here

106
00:04:48,309 --> 00:04:45,440
and then it has a dusting of sediment

107
00:04:49,749 --> 00:04:48,319
out of it it appears basically just like

108
00:04:51,909 --> 00:04:49,759
ice on the sea floor that's what it

109
00:04:53,529 --> 00:04:51,919
looks like however you bring this up to

110
00:04:56,110 --> 00:04:53,539
the surface it starts to decompose

111
00:04:58,360 --> 00:04:56,120
rapidly because as you can see at

112
00:05:00,490 --> 00:04:58,370
surface conditions were outside of the

113
00:05:03,129 --> 00:05:00,500

hydrate stability field so the hydrate

114
00:05:04,600 --> 00:05:03,139
starts to dissociate it releases the gas

115
00:05:06,490 --> 00:05:04,610
molecules that are trapped within the

116
00:05:09,249 --> 00:05:06,500
occasional X structure and in most cases

117
00:05:11,469 --> 00:05:09,259
triple sequences would be nothing of

118
00:05:13,870 --> 00:05:11,479
course methane is flammable gas so you

119
00:05:16,240 --> 00:05:13,880
can have ice that's actually burning at

120
00:05:19,270 --> 00:05:16,250
room temperature pressure conditions so

121
00:05:21,909 --> 00:05:19,280
this is the cover of science in 1996

122
00:05:23,710 --> 00:05:21,919
from Stern at all this really guarded a

123
00:05:26,649 --> 00:05:23,720
lot of extension in terms of hydration

124
00:05:29,260 --> 00:05:26,659
in a geologic context hydrates head

125
00:05:31,749 --> 00:05:29,270
person hypothesize and the first thought

126
00:05:34,629 --> 00:05:31,759
and in the Tyrolean community as a

127
00:05:37,209 --> 00:05:34,639
hazard so as you're pumping natural gas

128
00:05:40,089 --> 00:05:37,219
out of the ground Alaska and you're

129
00:05:41,830 --> 00:05:40,099
pumping out message as well as some

130
00:05:43,270 --> 00:05:41,840
produced water and if you get to the

131
00:05:45,640 --> 00:05:43,280
surface here in these pressurized

132
00:05:47,200 --> 00:05:45,650
pipelines you've got gas and water

133
00:05:49,240 --> 00:05:47,210
that's mixing at low temperature

134
00:05:50,320 --> 00:05:49,250
conditions pressurized you may form

135
00:05:52,390 --> 00:05:50,330
hydrates with

136
00:05:54,670 --> 00:05:52,400
which could cause clogs and then build

137
00:05:56,409 --> 00:05:54,680
up pressure leading to explosions so

138
00:05:59,350 --> 00:05:56,419

hydrogen first items they are ready

139
00:06:01,059 --> 00:05:59,360
clean controlling community as a problem

140
00:06:03,010 --> 00:06:01,069
and then once people start looking at

141
00:06:04,510 --> 00:06:03,020
the phase diagram for hydrates they

142
00:06:07,089 --> 00:06:04,520
realize that titers were likely to form

143
00:06:09,040 --> 00:06:07,099
under permafrost conditions and at

144
00:06:09,999 --> 00:06:09,050
seafloor sediments conditions as well so

145
00:06:13,390 --> 00:06:10,009
they started to go out and look for

146
00:06:15,309 --> 00:06:13,400
these things in the mid-1990s is one the

147
00:06:17,770 --> 00:06:15,319
interest in hydrates really took off in

148
00:06:19,390 --> 00:06:17,780
terms of an energy resource as well as

149
00:06:21,610 --> 00:06:19,400
the climatic effects that they may have

150
00:06:23,740 --> 00:06:21,620
a terrestrial system so even more

151
00:06:26,290 --> 00:06:23,750
recently really that there's been full

152
00:06:28,600 --> 00:06:26,300
monetization hydrates in terms of your

153
00:06:32,020 --> 00:06:28,610
platelets various contexts and this is

154
00:06:33,550 --> 00:06:32,030
just a sample in the laboratory this can

155
00:06:36,459 --> 00:06:33,560
be stored at liquid nitrogen content

156
00:06:38,230 --> 00:06:36,469
conditions at room pressure on so you

157
00:06:41,230 --> 00:06:38,240
can store these things in the laboratory

158
00:06:48,270 --> 00:06:41,240
that look at the under gluten nitrogen

159
00:06:56,850 --> 00:06:51,660
okay so just to kind of give you a brief

160
00:06:58,920 --> 00:06:56,860
overview like or closer chief in

161
00:07:00,750 --> 00:06:58,930
terrestrial systems mention both

162
00:07:04,020 --> 00:07:00,760
permafrost and sea floor sediment

163
00:07:06,270 --> 00:07:04,030

environments this is a diagram that was

164
00:07:08,340 --> 00:07:06,280
created by a Woods Hole in ocean at

165
00:07:10,530 --> 00:07:08,350
graphic Institute that shows basically

166
00:07:12,450 --> 00:07:10,540
three different ways that that hydrates

167
00:07:14,190 --> 00:07:12,460
typically form under sea floor

168
00:07:16,620 --> 00:07:14,200
conditions you have mud volcanoes that

169
00:07:18,840 --> 00:07:16,630
are releasing methane into the ocean

170
00:07:20,550 --> 00:07:18,850
when you uniform gas hydrate bubbles as

171
00:07:24,090 --> 00:07:20,560
well as free gas bubbles around these

172
00:07:27,420 --> 00:07:24,100
mud volcanoes can also have kind of a

173
00:07:31,170 --> 00:07:27,430
and near surface gas reservoir that's

174
00:07:33,000 --> 00:07:31,180
producing methane and that percolates up

175
00:07:35,100 --> 00:07:33,010
through the sediment and then you form a

176
00:07:36,990 --> 00:07:35,110
gas hydrate cap here where the where the

177
00:07:40,500 --> 00:07:37,000
methane intersects with the ocean and

178
00:07:43,260 --> 00:07:40,510
this probably also extends down beneath

179
00:07:46,350 --> 00:07:43,270
the sea floor to some some depth as well

180
00:07:48,120 --> 00:07:46,360
you can also have fracked hydrate

181
00:07:50,820 --> 00:07:48,130
forming and fractures and cracks and

182
00:07:54,540 --> 00:07:50,830
this could be a thermogenic gas source

183
00:07:57,330 --> 00:07:54,550
or a biological gas source so gas

184
00:07:59,760 --> 00:07:57,340
hydrate forms both in kind of void space

185
00:08:01,740 --> 00:07:59,770
within seafloor sediments and cracks and

186
00:08:03,960 --> 00:08:01,750
fractures as well as disseminated

187
00:08:05,490 --> 00:08:03,970
throughout the sediment in the terms of

188
00:08:07,380 --> 00:08:05,500

this diffuse gas source that's

189
00:08:09,480 --> 00:08:07,390
percolating up through the sediment in

190
00:08:11,430 --> 00:08:09,490
permafrost areas it's a little bit less

191
00:08:14,300 --> 00:08:11,440
clear how the hydrate is forming it

192
00:08:18,240 --> 00:08:14,310
could be that you have basically a

193
00:08:20,850 --> 00:08:18,250
natural gas reservoir that as it cools

194
00:08:23,130 --> 00:08:20,860
down you form hydrate where the natural

195
00:08:26,640 --> 00:08:23,140
gas is mixing with the water rich

196
00:08:29,070 --> 00:08:26,650
aquifer or it may be again a biogenic or

197
00:08:31,620 --> 00:08:29,080
thermogenic source where the methane is

198
00:08:33,719 --> 00:08:31,630
percolating up is moving up through the

199
00:08:36,089 --> 00:08:33,729
sediment and as it reaches the water

200
00:08:38,399 --> 00:08:36,099
table you're forming gas hydrates there

201
00:08:39,990 --> 00:08:38,409
as well it's it's not very clear yet how

202
00:08:43,370 --> 00:08:40,000
the hydrate is actually forming in the

203
00:08:46,550 --> 00:08:43,380
permafrost but as you can see this is

204
00:08:48,380 --> 00:08:46,560
a map that was created by the National

205
00:08:51,680 --> 00:08:48,390
Energy and Technology Laboratory in

206
00:08:54,410 --> 00:08:51,690
Pittsburgh do a lab where they're

207
00:08:56,420 --> 00:08:54,420
looking at different oil fields here on

208
00:08:58,310 --> 00:08:56,430
the North Slope of Alaska this is the

209
00:09:00,170 --> 00:08:58,320
range of free gas and they're quite

210
00:09:01,880 --> 00:09:00,180
quite a large area where they expect

211
00:09:04,130 --> 00:09:01,890
that there's significant volumes of gas

212
00:09:06,320 --> 00:09:04,140
hydrate beneath the surface as well so

213
00:09:08,960 --> 00:09:06,330

as they're producing this free gas zone

214
00:09:11,330 --> 00:09:08,970
they may also be dissociated rates from

215
00:09:12,830 --> 00:09:11,340
below that free gas zone and partially

216
00:09:14,660 --> 00:09:12,840
producing from the hydrate deposit

217
00:09:16,820 --> 00:09:14,670
there's also a test world that's

218
00:09:18,500 --> 00:09:16,830
actually under operation right now I

219
00:09:20,030 --> 00:09:18,510
believe it's in this area right here

220
00:09:21,290 --> 00:09:20,040
where they're actually drilling into the

221
00:09:23,180 --> 00:09:21,300
gas hydrates and trying to produce

222
00:09:25,610 --> 00:09:23,190
solely from those gas hydrates as kind

223
00:09:29,510 --> 00:09:25,620
of a demonstration of gas hydrates as a

224
00:09:31,940 --> 00:09:29,520
natural resource commodity in terms of

225
00:09:35,360 --> 00:09:31,950
gas hydrates as an energy resource this

226
00:09:37,040 --> 00:09:35,370
pie chart here shows the total methane

227
00:09:40,520 --> 00:09:37,050
resources that have been estimated for

228
00:09:42,650 --> 00:09:40,530
the United States this yellow piece of

229
00:09:44,660 --> 00:09:42,660
the pie right here is the methane that

230
00:09:47,240 --> 00:09:44,670
has been produced to date in terms of

231
00:09:49,820 --> 00:09:47,250
natural gas resources the orange piece

232
00:09:53,030 --> 00:09:49,830
is the remaining recoverable natural gas

233
00:09:58,520 --> 00:09:53,040
that we think of in a traditional gas

234
00:10:00,620 --> 00:09:58,530
play this right here is that there were

235
00:10:02,180 --> 00:10:00,630
all remaining non hydrate gas hydrate

236
00:10:04,280 --> 00:10:02,190
reservoirs so these aren't necessarily

237
00:10:06,770 --> 00:10:04,290
economic participa that this is natural

238
00:10:08,960 --> 00:10:06,780

gas that would be available this blue

239
00:10:11,450 --> 00:10:08,970
portion here that far outweighs these

240
00:10:13,670 --> 00:10:11,460
other is what's been estimated as the US

241
00:10:16,430 --> 00:10:13,680
natural gas resource in the form of gas

242
00:10:19,550 --> 00:10:16,440
hydrates now this does not separate this

243
00:10:21,170 --> 00:10:19,560
into recover world versus reservoir

244
00:10:23,270 --> 00:10:21,180
capacity and much of this is probably

245
00:10:25,430 --> 00:10:23,280
unrecoverable and just disseminated

246
00:10:27,950 --> 00:10:25,440
within sea floor sediment but this just

247
00:10:29,930 --> 00:10:27,960
shows you the vast volume of methane

248
00:10:33,500 --> 00:10:29,940
hydrates that may be available both in

249
00:10:38,510 --> 00:10:33,510
permafrost and as continental shelf

250
00:10:40,610 --> 00:10:38,520
sediment filling resource so do ii is

251
00:10:43,380 --> 00:10:40,620
particularly interested in gas hydrates

252
00:10:47,910 --> 00:10:43,390
from a natural resource point of view

253
00:10:49,710 --> 00:10:47,920
I've been looking at that as well as gas

254
00:10:53,580 --> 00:10:49,720
hydrates from a planetary point of view

255
00:10:55,800 --> 00:10:53,590
so we think of basically conditions in

256
00:10:58,200 --> 00:10:55,810
the solar system gas hydrates form at

257
00:10:59,790 --> 00:10:58,210
high pressures and low temperatures if

258
00:11:02,430 --> 00:10:59,800
we think of the outer solar system in

259
00:11:05,580 --> 00:11:02,440
particular beyond the frost line we have

260
00:11:07,920 --> 00:11:05,590
lots of hydrogen compounds in organics

261
00:11:10,380 --> 00:11:07,930
co2 this these are conditions that are

262
00:11:12,480 --> 00:11:10,390
right for hydrate formation so we know

263
00:11:15,500 --> 00:11:12,490

that we find gas hydrates on earth both

264
00:11:19,020 --> 00:11:15,510
in oceanic systems and in permafrost

265
00:11:20,760 --> 00:11:19,030
there's there's some evidence for

266
00:11:22,920 --> 00:11:20,770
hydrates on Mars as well although it's

267
00:11:25,410 --> 00:11:22,930
kind of a mixed bag there's no direct

268
00:11:27,750 --> 00:11:25,420
evidence for hydrates on Mars but

269
00:11:30,390 --> 00:11:27,760
conditions are favorable for hydrate

270
00:11:32,190 --> 00:11:30,400
formation and I'll show you at the end

271
00:11:34,050 --> 00:11:32,200
of the talk some work that we've been

272
00:11:35,460 --> 00:11:34,060
looking at the hydrate stability field

273
00:11:39,650 --> 00:11:35,470
on Mars and how that changes with

274
00:11:42,360 --> 00:11:39,660
salinity the same is true for Europa

275
00:11:44,750 --> 00:11:42,370
conditions are ripe on Europa for

276
00:11:49,170 --> 00:11:44,760
hydrate formation both co2 and methane

277
00:11:50,700 --> 00:11:49,180
hydrates and comets there's quite a bit

278
00:11:53,220 --> 00:11:50,710
of discussion about whether you could

279
00:11:57,930 --> 00:11:53,230
have methanol hydrates hydrogen sulfide

280
00:11:59,580 --> 00:11:57,940
hydrates hydrogen hydrates in comets and

281
00:12:02,430 --> 00:11:59,590
then on Titan we know we have lots of

282
00:12:04,800 --> 00:12:02,440
organics methane ethane this may be a

283
00:12:06,540 --> 00:12:04,810
water limited system where those gases

284
00:12:09,750 --> 00:12:06,550
basically suck up all the water into a

285
00:12:11,760 --> 00:12:09,760
hydrate typeface whereas on earth we're

286
00:12:13,890 --> 00:12:11,770
often limited by the amount of methane

287
00:12:16,200 --> 00:12:13,900
ER that's available in order to form

288
00:12:17,700 --> 00:12:16,210

hydrates on Titan we may be limited by

289
00:12:20,490 --> 00:12:17,710
the amount of water that's available to

290
00:12:23,190 --> 00:12:20,500
form hydrants so within the outer solar

291
00:12:25,170 --> 00:12:23,200
system there's hydrates could be

292
00:12:28,620 --> 00:12:25,180
significant reservoirs for both water

293
00:12:30,360 --> 00:12:28,630
and greenhouse gases and have

294
00:12:33,480 --> 00:12:30,370
significant implications for planetary

295
00:12:36,150 --> 00:12:33,490
climate change they also have an impact

296
00:12:39,660 --> 00:12:36,160
on surface features in terms of changing

297
00:12:42,310 --> 00:12:39,670
the properties of regolith and sediments

298
00:12:44,320 --> 00:12:42,320
as well as as they dissociate there

299
00:12:46,540 --> 00:12:44,330
releasing quite a bit of energy how does

300
00:12:48,010 --> 00:12:46,550
that affect erosion what types of

301
00:12:51,280 --> 00:12:48,020
surface features might be formed during

302
00:12:55,900 --> 00:12:51,290
gas hydrate dissociation or in that case

303
00:12:57,580 --> 00:12:55,910
formation as well so this will give you

304
00:12:58,660 --> 00:12:57,590
a brief outline here what we're going to

305
00:13:00,520 --> 00:12:58,670
talk about i'm just going to touch

306
00:13:02,830 --> 00:13:00,530
briefly on physical property

307
00:13:05,080 --> 00:13:02,840
measurements that we've been doing it at

308
00:13:07,030 --> 00:13:05,090
oak ridge national laboratory to look at

309
00:13:09,310 --> 00:13:07,040
the thermal expansion and

310
00:13:14,020 --> 00:13:09,320
compressibility of gas hydrates as well

311
00:13:16,600 --> 00:13:14,030
as determining the nature of natural

312
00:13:18,760 --> 00:13:16,610
samples what are the gas molecules that

313
00:13:20,620 --> 00:13:18,770

are filling those cages and and what

314
00:13:23,380 --> 00:13:20,630
proportions are those in natural samples

315
00:13:25,360 --> 00:13:23,390
then we'll I'll touch briefly on

316
00:13:27,250 --> 00:13:25,370
terrestrial systems looking at the

317
00:13:29,110 --> 00:13:27,260
environmental effects of gas hydrates as

318
00:13:30,880 --> 00:13:29,120
well as safety issues and then I'll

319
00:13:32,350 --> 00:13:30,890
share some results of experiments that

320
00:13:34,120 --> 00:13:32,360
we've been doing looking at geologic

321
00:13:37,090 --> 00:13:34,130
controls on hydrate accumulation and

322
00:13:39,280 --> 00:13:37,100
dissociation what in the sediment

323
00:13:41,590 --> 00:13:39,290
controls where hydrate forums and where

324
00:13:43,150 --> 00:13:41,600
it doesn't when hydrate is dissociated

325
00:13:45,250 --> 00:13:43,160
how does that affect the sediment column

326
00:13:47,020 --> 00:13:45,260
and then we'll take a look at some

327
00:13:50,260 --> 00:13:47,030
planetary systems talk briefly about

328
00:13:53,440 --> 00:13:50,270
Titan in Europa and then co2 hydrates on

329
00:13:56,250 --> 00:13:53,450
Mars and then finally I'll show you some

330
00:13:59,980 --> 00:13:56,260
data that recently been submitted

331
00:14:02,650 --> 00:13:59,990
looking at the effect of salinity on

332
00:14:04,210 --> 00:14:02,660
methane hydrate stability on Mars okay

333
00:14:06,550 --> 00:14:04,220
and this is a picture of the drill rig

334
00:14:09,570 --> 00:14:06,560
on the north slope that's currently

335
00:14:12,760 --> 00:14:09,580
active during this this test production

336
00:14:15,070 --> 00:14:12,770
experiments this is being funded by BP

337
00:14:19,070 --> 00:14:15,080
as well as the Department of Energy with

338
00:14:24,870 --> 00:14:22,260

okay so physical property measurements

339
00:14:27,030 --> 00:14:24,880
so again this is what gas hydrates look

340
00:14:28,920 --> 00:14:27,040
like from a molecular point of view

341
00:14:32,640 --> 00:14:28,930
these cage-like structures with the gas

342
00:14:33,960 --> 00:14:32,650
molecule trapped inside there are two

343
00:14:36,300 --> 00:14:33,970
main different structures of gas

344
00:14:38,370 --> 00:14:36,310
hydrates structure 1 and structure two

345
00:14:41,010 --> 00:14:38,380
so these are two crystallographic

346
00:14:43,110 --> 00:14:41,020
structures that can be formed based on

347
00:14:45,480 --> 00:14:43,120
the size of the molecule that's filling

348
00:14:47,700 --> 00:14:45,490
these cages basically and in mixtures of

349
00:14:50,010 --> 00:14:47,710
gas molecules structure one hydrates

350
00:14:52,710 --> 00:14:50,020
these are pure methane hydrates or pure

351
00:14:54,420 --> 00:14:52,720
co2 hydrates structure q hydrates are

352
00:14:57,120 --> 00:14:54,430
often in systems where you have methane

353
00:15:00,570 --> 00:14:57,130
and ethane perhaps propane hydrated as

354
00:15:03,570 --> 00:15:00,580
well or mixed um methane and co2

355
00:15:06,450 --> 00:15:03,580
hydrates we look at these thermal

356
00:15:09,420 --> 00:15:06,460
expansion data for all these different

357
00:15:11,820 --> 00:15:09,430
hydrates phases this is great here the

358
00:15:13,560 --> 00:15:11,830
thermal expansion of ice these are

359
00:15:14,970 --> 00:15:13,570
neutron diffraction experiments so much

360
00:15:16,740 --> 00:15:14,980
of this has been done with deuterated

361
00:15:18,810 --> 00:15:16,750
ice because neutron diffraction works

362
00:15:20,550 --> 00:15:18,820
much better I'm deuterated compounds

363
00:15:21,840 --> 00:15:20,560

than hydrogen rich compounds and I won't

364
00:15:24,329 --> 00:15:21,850
go into the details of that but that's

365
00:15:26,880 --> 00:15:24,339
why it says d 20 instead of h2o the

366
00:15:30,300 --> 00:15:26,890
properties are very similar first d 20

367
00:15:32,040 --> 00:15:30,310
verses h2o but you can see the thermal

368
00:15:34,260 --> 00:15:32,050
expansion properties of hydrates are

369
00:15:36,090 --> 00:15:34,270
very similar to the thermal expansion

370
00:15:38,220 --> 00:15:36,100
properties of ice so these cage-like

371
00:15:40,710 --> 00:15:38,230
structures are fairly rigid and they

372
00:15:42,449 --> 00:15:40,720
behave much like ice however the thermal

373
00:15:45,060 --> 00:15:42,459
properties of gas hydrates their

374
00:15:49,260 --> 00:15:45,070
insulating properties are much closer to

375
00:15:51,120 --> 00:15:49,270
the gas filling to the guests molecule

376
00:15:53,220 --> 00:15:51,130
properties them to the ice so gas

377
00:15:55,860 --> 00:15:53,230
hydrates are much better insulators than

378
00:15:57,900 --> 00:15:55,870
traditional your basic ice and this

379
00:16:00,570 --> 00:15:57,910
makes sense if you think saira foam

380
00:16:02,340 --> 00:16:00,580
versus plastic styrofoam is a much

381
00:16:04,079 --> 00:16:02,350
better insulator than plastic you've got

382
00:16:07,600 --> 00:16:04,089
these void spaces that are filled with

383
00:16:11,900 --> 00:16:07,610
gas attacked as insulators oh

384
00:16:14,210 --> 00:16:11,910
we've recently started clicking at hired

385
00:16:16,880 --> 00:16:14,220
of client high-energy x-ray diffraction

386
00:16:19,160 --> 00:16:16,890
to natural samples as well to determine

387
00:16:21,560 --> 00:16:19,170
whether we have structure 1 or structure

388
00:16:23,240 --> 00:16:21,570

to hydrates and natural samples what are

389
00:16:25,550 --> 00:16:23,250
the gas filling molecules how much

390
00:16:28,010 --> 00:16:25,560
methane is there versus ethane how much

391
00:16:30,079 --> 00:16:28,020
methane is there versus propane this is

392
00:16:31,970 --> 00:16:30,089
important both from a natural resource

393
00:16:34,100 --> 00:16:31,980
point of view and also from a climatic

394
00:16:35,690 --> 00:16:34,110
point of view because structure one in

395
00:16:37,430 --> 00:16:35,700
structure to hydrates have different

396
00:16:39,470 --> 00:16:37,440
stability fields so therefore as the

397
00:16:42,260 --> 00:16:39,480
temperature conditions within the ocean

398
00:16:43,670 --> 00:16:42,270
change structure one hydrates are going

399
00:16:45,350 --> 00:16:43,680
to be stable over slightly different

400
00:16:47,120 --> 00:16:45,360
pressure temperature conditions than

401
00:16:50,870 --> 00:16:47,130
structure too and they may be released

402
00:16:52,730 --> 00:16:50,880
at different seafloor conditions based

403
00:16:55,280 --> 00:16:52,740
on temperature changes and we can also

404
00:16:56,540 --> 00:16:55,290
look at cage occupancy so how much how

405
00:16:58,490 --> 00:16:56,550
many of these cages are actually

406
00:17:00,829 --> 00:16:58,500
occupied we can have empty cages within

407
00:17:03,380 --> 00:17:00,839
the hydrate structure some of it can be

408
00:17:05,000 --> 00:17:03,390
not fully filled so in terms of total

409
00:17:07,010 --> 00:17:05,010
carbon budget it's important to know

410
00:17:09,050 --> 00:17:07,020
what percentage of these cages are

411
00:17:12,220 --> 00:17:09,060
actually filled and what type of organic

412
00:17:15,110 --> 00:17:12,230
molecule is actually filling those cages

413
00:17:16,910 --> 00:17:15,120

again we've been doing a lot of we've

414
00:17:18,949 --> 00:17:16,920
been planning on doing lots of neutron

415
00:17:20,840 --> 00:17:18,959
scattering experiments at the new

416
00:17:24,740 --> 00:17:20,850
spallation neutron source at oakridge

417
00:17:28,100 --> 00:17:24,750
this is a 10 billion dollar facility and

418
00:17:29,780 --> 00:17:28,110
it's being built too and it will be the

419
00:17:32,390 --> 00:17:29,790
world's state-of-the-art neutron

420
00:17:36,140 --> 00:17:32,400
diffraction facility neutrons are

421
00:17:39,020 --> 00:17:36,150
particularly good at looking at hydrogen

422
00:17:41,990 --> 00:17:39,030
oxygen carbon things that we find lots

423
00:17:44,360 --> 00:17:42,000
of in in hydrate compounds so we'll be

424
00:17:46,700 --> 00:17:44,370
looking at thermal expansion at elevated

425
00:17:48,590 --> 00:17:46,710
temperature and pressure basically

426
00:17:50,240 --> 00:17:48,600
looking at the thermal expansion of

427
00:17:52,430 --> 00:17:50,250
hydrates at sea floor or permafrost

428
00:17:54,350 --> 00:17:52,440
conditions not just at liquid nitrogen

429
00:17:56,510 --> 00:17:54,360
conditions as well as time-resolved

430
00:17:58,310 --> 00:17:56,520
quantitative phase identification so

431
00:18:01,910 --> 00:17:58,320
what's actually happening is the hydrate

432
00:18:03,980 --> 00:18:01,920
accumulates and associates are

433
00:18:07,070 --> 00:18:03,990
k just filled first and then other pages

434
00:18:09,110 --> 00:18:07,080
filled later how how does that I'll work

435
00:18:12,740 --> 00:18:09,120
and then also some low angle neutron

436
00:18:15,110 --> 00:18:12,750
diffraction looking at crystallite size

437
00:18:17,360 --> 00:18:15,120
and things like that as high grade is

438
00:18:19,910 --> 00:18:17,370

forming and dissociating we have a built

439
00:18:22,310 --> 00:18:19,920
a special sapphire cell here this is a

440
00:18:25,070 --> 00:18:22,320
10 centimeter long single crystal of

441
00:18:28,280 --> 00:18:25,080
sapphire that we can use as a pressure

442
00:18:30,760 --> 00:18:28,290
vessel performing hydrates institute on

443
00:18:32,930 --> 00:18:30,770
the beam line and look at those hydrate

444
00:18:36,020 --> 00:18:32,940
accumulation and diffraction and

445
00:18:38,120 --> 00:18:36,030
association in real time so that's just

446
00:18:39,890 --> 00:18:38,130
to give you a taste of some of the

447
00:18:44,480 --> 00:18:39,900
physical property measurements as I've

448
00:18:47,720 --> 00:18:44,490
been involved in um we're also working

449
00:18:49,790 --> 00:18:47,730
on what are the environmental effects of

450
00:18:51,530 --> 00:18:49,800
gas hydrates within it within a

451
00:18:53,840 --> 00:18:51,540
terrestrial system so just like that

452
00:18:56,270 --> 00:18:53,850
natural resource pie graph that I showed

453
00:18:58,880 --> 00:18:56,280
you earlier for for natural gas

454
00:19:02,600 --> 00:18:58,890
reservoirs within the United States this

455
00:19:04,340 --> 00:19:02,610
is a global picture of total carbon you

456
00:19:06,290 --> 00:19:04,350
can see this white area here is the

457
00:19:09,560 --> 00:19:06,300
total carbon that's an estimated by

458
00:19:11,570 --> 00:19:09,570
cibola nat all within gas hydrate

459
00:19:14,300 --> 00:19:11,580
deposits compared to all other carbon

460
00:19:16,820 --> 00:19:14,310
sources on the surface of the earth so

461
00:19:19,400 --> 00:19:16,830
the striped area here is recoverable and

462
00:19:23,060 --> 00:19:19,410
non recoverable fossil fuels coal gas

463
00:19:25,160 --> 00:19:23,070

oil who got the carbon the sequestered

464
00:19:28,250 --> 00:19:25,170
in soil dissolved organic matter and

465
00:19:30,080 --> 00:19:28,260
biota heat and then detrital a ganic

466
00:19:31,910 --> 00:19:30,090
matter and then finally the atmosphere

467
00:19:34,070 --> 00:19:31,920
which you can't even really see up there

468
00:19:36,530 --> 00:19:34,080
so gas hydrates based on their

469
00:19:39,350 --> 00:19:36,540
estimation contribute more than half of

470
00:19:42,230 --> 00:19:39,360
the global carbon budget these estimates

471
00:19:43,550 --> 00:19:42,240
are controversial that can range in the

472
00:19:46,130 --> 00:19:43,560
literature by over an order of magnitude

473
00:19:48,380 --> 00:19:46,140
but no matter what the estimate is gas

474
00:19:52,920 --> 00:19:48,390
hydrates still contribute a significant

475
00:19:56,010 --> 00:19:52,930
chunk to the global carbon reservoir so

476
00:19:57,900 --> 00:19:56,020
these gas hydrates are sensitive to

477
00:19:59,550 --> 00:19:57,910
changes in pressure as well as

478
00:20:02,850 --> 00:19:59,560
temperature and salinity so if we think

479
00:20:06,750 --> 00:20:02,860
of changes in ocean dynamics and ocean

480
00:20:09,060 --> 00:20:06,760
temperature as well as ocean depth we

481
00:20:11,790 --> 00:20:09,070
could be dissociating and accumulating

482
00:20:14,090 --> 00:20:11,800
gas hydrates on a planetary scale which

483
00:20:16,830 --> 00:20:14,100
can have huge impacts on global climate

484
00:20:19,370 --> 00:20:16,840
gas hydrates are also important seafloor

485
00:20:21,990 --> 00:20:19,380
nutrient sources this is a picture of a

486
00:20:23,670 --> 00:20:22,000
hydrate outcrop with a bunch of two

487
00:20:25,770 --> 00:20:23,680
burns those are these pink things right

488
00:20:27,240 --> 00:20:25,780

here that are living in it they use the

489
00:20:29,250 --> 00:20:27,250
methane that's being released as

490
00:20:31,530 --> 00:20:29,260
hydrates associates as a nutrient source

491
00:20:33,270 --> 00:20:31,540
and then of course other animals come on

492
00:20:35,100 --> 00:20:33,280
and eat those two words and we have a

493
00:20:37,200 --> 00:20:35,110
whole ecological system that's developed

494
00:20:40,470 --> 00:20:37,210
at these these methane hydrate deposits

495
00:20:42,480 --> 00:20:40,480
on the sea floor there are also some

496
00:20:44,400 --> 00:20:42,490
important engineering applications for

497
00:20:46,830 --> 00:20:44,410
gas hydrates from an environmental

498
00:20:48,240 --> 00:20:46,840
context gas hydrates has have been

499
00:20:50,910 --> 00:20:48,250
proposed as a form of carbon

500
00:20:52,590 --> 00:20:50,920
sequestration if we take co2 injected

501
00:20:56,490 --> 00:20:52,600
into the deep ocean we formed hydrates

502
00:20:58,560 --> 00:20:56,500
hi the co2 hydrate is more dense than

503
00:21:00,060 --> 00:20:58,570
water so it sinks effectively

504
00:21:02,130 --> 00:21:00,070
sequestering the hydrate at the bottom

505
00:21:04,290 --> 00:21:02,140
of the ocean at the co2 at the bottom of

506
00:21:08,010 --> 00:21:04,300
the ocean and hydrates have also been

507
00:21:10,830 --> 00:21:08,020
used in test desalination projects so as

508
00:21:13,920 --> 00:21:10,840
you form gas hydrates that they exclude

509
00:21:16,110 --> 00:21:13,930
all salts so you could form gas hydrates

510
00:21:18,360 --> 00:21:16,120
separate the hydrates from your salty

511
00:21:20,190 --> 00:21:18,370
brine that's remaining milk dissociate

512
00:21:23,160 --> 00:21:20,200
your hydrates again and you're left with

513
00:21:24,840 --> 00:21:23,170

pure water basically so there are some

514
00:21:26,330 --> 00:21:24,850
important engineering applications as

515
00:21:28,279 --> 00:21:26,340
well

516
00:21:29,840 --> 00:21:28,289
and then finally there are safety issues

517
00:21:33,560 --> 00:21:29,850
as I mentioned before these rig and

518
00:21:34,970 --> 00:21:33,570
pipeline explosions people that work on

519
00:21:36,740 --> 00:21:34,980
drill rigs out in the middle of the

520
00:21:38,899 --> 00:21:36,750
ocean don't like to talk about gas

521
00:21:40,700 --> 00:21:38,909
hydrates in a positive way because they

522
00:21:42,289 --> 00:21:40,710
think of it as exploding and basically

523
00:21:44,480 --> 00:21:42,299
killing multiple people on their drill

524
00:21:46,070 --> 00:21:44,490
rig if you drill into a gas hydrate

525
00:21:48,950 --> 00:21:46,080
deposit you're releasing crush the

526
00:21:50,510 --> 00:21:48,960
pressure deposit you have basically a

527
00:21:53,600 --> 00:21:50,520
huge amount of gas that's released and

528
00:21:55,669 --> 00:21:53,610
can lead to a significant explosion in

529
00:21:58,909 --> 00:21:55,679
terms of seafloor stability gas hydrates

530
00:22:01,370 --> 00:21:58,919
are an important player as well we think

531
00:22:04,039 --> 00:22:01,380
of gas hydrates forming a layer slightly

532
00:22:06,320 --> 00:22:04,049
beneath the sediment surface or renamed

533
00:22:08,330 --> 00:22:06,330
the sediment as perhaps you have a

534
00:22:10,370 --> 00:22:08,340
change in sea level or change in ocean

535
00:22:13,610 --> 00:22:10,380
temperatures gas hydrates made associate

536
00:22:15,409 --> 00:22:13,620
and releasing large amount of gas as

537
00:22:17,090 --> 00:22:15,419
well as producing liquid water within

538
00:22:18,950 --> 00:22:17,100

that gas hydrate stability field so

539
00:22:21,110 --> 00:22:18,960
you're going from a solid to a mixed

540
00:22:22,370 --> 00:22:21,120
liquid and gas system sediment is no

541
00:22:23,960 --> 00:22:22,380
longer going to be stable if you're on

542
00:22:26,570 --> 00:22:23,970
any sort of slope and you're going to

543
00:22:29,000 --> 00:22:26,580
have significant mass wasting here so

544
00:22:31,310 --> 00:22:29,010
there's a significant safety issue here

545
00:22:34,430 --> 00:22:31,320
is Walter involved as well not only from

546
00:22:35,899 --> 00:22:34,440
climate change aspect but also from a

547
00:22:38,269 --> 00:22:35,909
drilling aspect so if you drill into

548
00:22:41,720 --> 00:22:38,279
these hydrates same similar process

549
00:22:45,830 --> 00:22:41,730
could occur if you're not careful okay

550
00:22:47,840 --> 00:22:45,840
so gas hydrates are in seafloor

551
00:22:49,220 --> 00:22:47,850
sediments they're also in permafrost but

552
00:22:50,780 --> 00:22:49,230
how do they form there what's

553
00:22:52,490 --> 00:22:50,790
controlling where hydrate forms and

554
00:22:54,530 --> 00:22:52,500
where they don't well the number one

555
00:22:56,630 --> 00:22:54,540
control is probably is is methane

556
00:22:58,790 --> 00:22:56,640
concentration is their ample methane

557
00:23:01,430 --> 00:22:58,800
available for hydrates to form or not

558
00:23:03,140 --> 00:23:01,440
the second control is probably what's

559
00:23:05,540 --> 00:23:03,150
happening with the sediment is there

560
00:23:07,070 --> 00:23:05,550
space for hydrates before me and what's

561
00:23:08,690 --> 00:23:07,080
controlling the pathway of methane

562
00:23:10,720 --> 00:23:08,700
through those sediments so we've been

563
00:23:12,860 --> 00:23:10,730

doing a series of large-scale

564
00:23:14,360 --> 00:23:12,870
experiments in the laboratory to look at

565
00:23:16,820 --> 00:23:14,370
the effects of sediment heterogeneity

566
00:23:18,920 --> 00:23:16,830
and methane flow path on high-grade

567
00:23:22,000 --> 00:23:18,930
accumulation and dissociation pathways

568
00:23:24,500 --> 00:23:22,010
and this also eventually leads to as

569
00:23:25,940 --> 00:23:24,510
some work on sediment stability during

570
00:23:28,880 --> 00:23:25,950
hydrate accumulation as well as

571
00:23:31,010 --> 00:23:28,890
dissociation and cycling so do we have a

572
00:23:34,160 --> 00:23:31,020
frost heaving effect in sediment that we

573
00:23:35,900 --> 00:23:34,170
see in permafrost do cycling of

574
00:23:37,700 --> 00:23:35,910
temperatures with ice formation and

575
00:23:39,800 --> 00:23:37,710
melting we get a similar effect from

576
00:23:41,570 --> 00:23:39,810
hydrate formation and dissociation or is

577
00:23:44,510 --> 00:23:41,580
it even more pronounced than than with

578
00:23:47,960 --> 00:23:44,520
ice so this just gives you an example of

579
00:23:50,330 --> 00:23:47,970
a sentiment Cora Corman I OBP leg which

580
00:23:52,610 --> 00:23:50,340
has hydrate in it at one point you can

581
00:23:55,760 --> 00:23:52,620
see that it's a fairly heterogeneous you

582
00:23:57,920 --> 00:23:55,770
have clay layers silty layers silt and

583
00:24:00,050 --> 00:23:57,930
clay and here you can see a sandy layer

584
00:24:02,120 --> 00:24:00,060
in the midst of some play layers here

585
00:24:03,620 --> 00:24:02,130
one thing that's not very clear is where

586
00:24:05,630 --> 00:24:03,630
is the hydrate actually forming within

587
00:24:07,760 --> 00:24:05,640
the sediment column what's controlling

588
00:24:10,220 --> 00:24:07,770

that which is high-grade prefer to form

589
00:24:12,470 --> 00:24:10,230
in the clay or in this in the sand where

590
00:24:14,060 --> 00:24:12,480
are we more likely to see it if we look

591
00:24:15,860 --> 00:24:14,070
at natural samples that are pulled up to

592
00:24:18,710 --> 00:24:15,870
the surface a lot of times we see

593
00:24:21,290 --> 00:24:18,720
hydrate mainly in the void spaces large

594
00:24:23,870 --> 00:24:21,300
class of hydrate that are forming in the

595
00:24:26,720 --> 00:24:23,880
coarser grain material as well as within

596
00:24:28,250 --> 00:24:26,730
basically fractures or cracks but is

597
00:24:29,630 --> 00:24:28,260
that actually the only place at the

598
00:24:30,010 --> 00:24:29,640
hydrate is forming or is that the only

599
00:24:31,660 --> 00:24:30,020
place

600
00:24:33,340 --> 00:24:31,670
the hydrate is preserved once you get it

601
00:24:35,770 --> 00:24:33,350
up to this ship it's the finer grained

602
00:24:37,150 --> 00:24:35,780
hydrate associating it as you pull it

603
00:24:38,320 --> 00:24:37,160
out so you don't have any record of that

604
00:24:41,290 --> 00:24:38,330
so we're trying to look at that in the

605
00:24:43,390 --> 00:24:41,300
laboratory um we have a very unique

606
00:24:45,010 --> 00:24:43,400
pressure vessel this is the sea floor

607
00:24:47,950 --> 00:24:45,020
process simulator that's what they call

608
00:24:51,760 --> 00:24:47,960
it it's a 72 leader pressure vessel it's

609
00:24:53,320 --> 00:24:51,770
basically a meter from end to end um we

610
00:24:55,420 --> 00:24:53,330
have a postdoc in our laboratory who

611
00:24:57,880 --> 00:24:55,430
could can fit inside of it if she

612
00:24:59,110 --> 00:24:57,890
scrunches down really small she's quite

613
00:25:02,740 --> 00:24:59,120

a petite woman but it's still pretty

614
00:25:05,080 --> 00:25:02,750
impressive um this has various

615
00:25:06,400 --> 00:25:05,090
observation ports sapphire windows so

616
00:25:09,550 --> 00:25:06,410
that we can actually see what's going on

617
00:25:11,550 --> 00:25:09,560
within the vessel we have ports where we

618
00:25:15,240 --> 00:25:11,560
can put in various instrumentation

619
00:25:17,320 --> 00:25:15,250
thermocouples pressure transducers

620
00:25:19,480 --> 00:25:17,330
conductivity meters all sorts of things

621
00:25:20,830 --> 00:25:19,490
we can use the vessel basically as an

622
00:25:22,840 --> 00:25:20,840
environmental chamber and set up

623
00:25:25,030 --> 00:25:22,850
experiments within the vessel like this

624
00:25:27,550 --> 00:25:25,040
one that's shown here or we can use that

625
00:25:29,890 --> 00:25:27,560
entire seventy two liters Ezard as our

626
00:25:31,690 --> 00:25:29,900
experimental chamber and fill it up

627
00:25:34,000 --> 00:25:31,700
completely with sediment and look at

628
00:25:35,590 --> 00:25:34,010
sediment processes at the we like to

629
00:25:37,570 --> 00:25:35,600
call it the meso scale so it's somewhere

630
00:25:39,400 --> 00:25:37,580
between a lab skit a traditional lab

631
00:25:42,280 --> 00:25:39,410
scale experiment which might be half a

632
00:25:46,360 --> 00:25:42,290
liter at the most to a field production

633
00:25:48,400 --> 00:25:46,370
experiment we're talking about seventy

634
00:25:51,250 --> 00:25:48,410
two liters of sediment here over a metre

635
00:25:54,220 --> 00:25:51,260
scale so it's a significant experimental

636
00:25:56,290 --> 00:25:54,230
procedure we recently acquired a

637
00:25:58,090 --> 00:25:56,300
distributed sensing system which is a

638
00:25:59,890 --> 00:25:58,100

fiber optic network that we can put

639
00:26:01,930 --> 00:25:59,900
within a sediment volume and measure

640
00:26:04,660 --> 00:26:01,940
temperature and strain at one centimetre

641
00:26:06,580 --> 00:26:04,670
intervals so that we can basically tell

642
00:26:12,290 --> 00:26:06,590
the temperature and strain conditions

643
00:26:14,630 --> 00:26:12,300
within an entire volume of sediment how

644
00:26:17,000 --> 00:26:14,640
the first experiments that I did when I

645
00:26:19,550 --> 00:26:17,010
when it came to Oak Ridge were hydrate

646
00:26:21,380 --> 00:26:19,560
accumulation experiments looking at how

647
00:26:25,100 --> 00:26:21,390
hydrate accumulates when it's in a free

648
00:26:27,620 --> 00:26:25,110
gas state versus a dissolved system so

649
00:26:29,960 --> 00:26:27,630
if you have free methane gas basically

650
00:26:31,700 --> 00:26:29,970
gas bubbles in the system do we do

651
00:26:33,470 --> 00:26:31,710
accumulate hydrate differently than if

652
00:26:36,080 --> 00:26:33,480
we have gas that's dissolved completely

653
00:26:38,720 --> 00:26:36,090
into the water so we set up this

654
00:26:41,120 --> 00:26:38,730
experiment where we had a column here

655
00:26:43,940 --> 00:26:41,130
which has glass beads and then sediment

656
00:26:46,310 --> 00:26:43,950
with a diffuser in here to put a free

657
00:26:49,790 --> 00:26:46,320
gas phase into the system or we can

658
00:26:52,310 --> 00:26:49,800
circulate water through the system from

659
00:26:53,900 --> 00:26:52,320
the bottom of this this pressure vessel

660
00:26:56,510 --> 00:26:53,910
so we have methane dissolved in the

661
00:26:58,190 --> 00:26:56,520
water but no free gas and then move that

662
00:27:00,860 --> 00:26:58,200
through the sediment column so we have

663
00:27:02,930 --> 00:27:00,870

either a free gas phase or a dissolved

664
00:27:06,170 --> 00:27:02,940
phase when we did this in both natural

665
00:27:08,630 --> 00:27:06,180
sentiment samples from from a permafrost

666
00:27:10,700 --> 00:27:08,640
environment as well as Ottawa sand and

667
00:27:12,320 --> 00:27:10,710
so some blacks and we use the blacks and

668
00:27:13,580 --> 00:27:12,330
just for optical contrast so that we

669
00:27:15,950 --> 00:27:13,590
could better see where the hydrate was

670
00:27:18,740 --> 00:27:15,960
forming unfortunately under the lab

671
00:27:20,840 --> 00:27:18,750
scale the laboratory conditions it's

672
00:27:24,260 --> 00:27:20,850
very difficult to form hydrate from a

673
00:27:27,140 --> 00:27:24,270
dissolved gas phase a dissolved methane

674
00:27:28,520 --> 00:27:27,150
phase we there's been groups in Germany

675
00:27:30,320 --> 00:27:28,530
they've run experiments for several

676
00:27:32,090 --> 00:27:30,330
months and never formed hydrate from a

677
00:27:35,060 --> 00:27:32,100
dissolved gas from a dissolved methane

678
00:27:39,770 --> 00:27:35,070
state it's much more it's much easier to

679
00:27:41,930 --> 00:27:39,780
form hydrate from a free gas phase so we

680
00:27:43,460 --> 00:27:41,940
ran lots of experiments both ways we

681
00:27:45,920 --> 00:27:43,470
never got hydrate to form from the

682
00:27:48,200 --> 00:27:45,930
dissolved gas phase part of that was

683
00:27:50,150 --> 00:27:48,210
because of safety considerations we were

684
00:27:53,120 --> 00:27:50,160
only allowed to run experiments over an

685
00:27:54,020 --> 00:27:53,130
eight hour shift basically so we could

686
00:27:57,680 --> 00:27:54,030
never get to those month-long

687
00:28:00,050 --> 00:27:57,690
experiments but we had some interesting

688
00:28:02,480 --> 00:28:00,060

data from the free gas experiment here's

689
00:28:03,980 --> 00:28:02,490
a sediment column with permafrost

690
00:28:05,270 --> 00:28:03,990
sediments you can see that there's some

691
00:28:07,100 --> 00:28:05,280
void space here that occurred just

692
00:28:09,920 --> 00:28:07,110
basically as we were packing the column

693
00:28:11,800 --> 00:28:09,930
there's bubbles of of methane that

694
00:28:13,930 --> 00:28:11,810
accumulate in those void spaces and they

695
00:28:15,400 --> 00:28:13,940
here is hydrate it's the methane hydrate

696
00:28:18,160 --> 00:28:15,410
forms you can see that that void space

697
00:28:19,330 --> 00:28:18,170
has filled with hydrate here as well as

698
00:28:20,980 --> 00:28:19,340
down here where there's another void

699
00:28:22,960 --> 00:28:20,990
space and at the top of the sediment

700
00:28:24,910 --> 00:28:22,970
column where there's born space this was

701
00:28:27,160 --> 00:28:24,920
where we first saw hydrate accumulation

702
00:28:29,170 --> 00:28:27,170
and as the hydrate first formed in that

703
00:28:30,940 --> 00:28:29,180
that board space event spread out from

704
00:28:33,310 --> 00:28:30,950
that void space into the surrounding

705
00:28:35,530 --> 00:28:33,320
make sediment matrix we saw the exact

706
00:28:38,710 --> 00:28:35,540
same thing with the blacks and we have

707
00:28:39,970 --> 00:28:38,720
some some void space here at the bottom

708
00:28:42,610 --> 00:28:39,980
of the column and as well as in the

709
00:28:44,530 --> 00:28:42,620
glass beads as we ran the experiment

710
00:28:46,930 --> 00:28:44,540
these were the first places for hydrates

711
00:28:49,390 --> 00:28:46,940
to form as gas bubbles were accumulating

712
00:28:50,770 --> 00:28:49,400
in that void space so it seems quite

713
00:28:52,720 --> 00:28:50,780

likely that when we have a free gas

714
00:28:54,490 --> 00:28:52,730
system where we have methane bubbles

715
00:28:55,900 --> 00:28:54,500
percolating through sediment it's going

716
00:28:57,490 --> 00:28:55,910
to be in those boy spaces and those

717
00:28:59,260 --> 00:28:57,500
fractures and cracks where hydrate is

718
00:29:02,340 --> 00:28:59,270
going to form first which makes sense

719
00:29:04,900 --> 00:29:02,350
because around those gas bubbles we have

720
00:29:06,730 --> 00:29:04,910
hydrate methane that's diffusing into

721
00:29:08,500 --> 00:29:06,740
the water that's where that the water is

722
00:29:10,390 --> 00:29:08,510
going to be most highly saturated in

723
00:29:12,640 --> 00:29:10,400
methane and that's probably where hybrid

724
00:29:14,980 --> 00:29:12,650
nucleation is first going to occur once

725
00:29:16,360 --> 00:29:14,990
we have hydrate nucleated it's then

726
00:29:22,300 --> 00:29:16,370
going to grow out from that initial

727
00:29:26,470 --> 00:29:22,310
nucleation point we've moved on to

728
00:29:30,550 --> 00:29:26,480
looking at large sediment volumes from

729
00:29:32,050 --> 00:29:30,560
30 to 70 liters sediment experiments

730
00:29:34,840 --> 00:29:32,060
trying to do some interlaboratory

731
00:29:36,850 --> 00:29:34,850
comparison of hydrate accumulation and

732
00:29:38,740 --> 00:29:36,860
dissociation processes in a standard

733
00:29:41,380 --> 00:29:38,750
sediment matrix basically a homogeneous

734
00:29:43,360 --> 00:29:41,390
system and doing some numerical product

735
00:29:44,950 --> 00:29:43,370
testing some numerical production models

736
00:29:47,320 --> 00:29:44,960
to see if they're valid in these

737
00:29:49,300 --> 00:29:47,330
laboratory conditions we're also hoping

738
00:29:51,670 --> 00:29:49,310

to look at the effects of sediment

739
00:29:53,530 --> 00:29:51,680
heterogeneity looking at Clay versus

740
00:29:55,360 --> 00:29:53,540
sand layers as well as fractures and

741
00:29:56,950 --> 00:29:55,370
void space on how hydrate is

742
00:29:58,770 --> 00:29:56,960
accumulating and associating in the

743
00:30:01,060 --> 00:29:58,780
system

744
00:30:03,250 --> 00:30:01,070
as I mentioned before we recently

745
00:30:05,440 --> 00:30:03,260
acquired this distributed sensing system

746
00:30:07,240 --> 00:30:05,450
where we can look at temperature and

747
00:30:10,090 --> 00:30:07,250
strain changes over a centimeter scale

748
00:30:12,310 --> 00:30:10,100
this is a system of a brad fiber

749
00:30:15,160 --> 00:30:12,320
gratings along a fiber optic cable and

750
00:30:16,750 --> 00:30:15,170
as those Bragg fittings bride gradings

751
00:30:18,580 --> 00:30:16,760
expand and contract with temperature

752
00:30:20,350 --> 00:30:18,590
strange changes we get a different

753
00:30:22,060 --> 00:30:20,360
optical signal which then can be

754
00:30:27,880 --> 00:30:22,070
interpreted in terms of temperature and

755
00:30:30,190 --> 00:30:27,890
strain so constructed a sediment column

756
00:30:32,710 --> 00:30:30,200
where we have layers of these fiber

757
00:30:35,410 --> 00:30:32,720
optic sensor planes within the sediment

758
00:30:38,290 --> 00:30:35,420
this is one of these planes here you can

759
00:30:41,890 --> 00:30:38,300
see it's a spiral that goes out here so

760
00:30:45,820 --> 00:30:41,900
there's this whole thing is 12 inches in

761
00:30:48,340 --> 00:30:45,830
diameter so there are 200 censored

762
00:30:50,710 --> 00:30:48,350
gradings along this two-meter fiber

763
00:30:52,720 --> 00:30:50,720

that's been coiled up onto this 12-inch

764
00:30:55,390 --> 00:30:52,730
diameter plane and then placed within a

765
00:30:57,070 --> 00:30:55,400
sediment column and we can see hydrate

766
00:30:59,800 --> 00:30:57,080
formation here in terms of this up

767
00:31:02,590 --> 00:30:59,810
ticket in the temperature data hydrate

768
00:31:04,360 --> 00:31:02,600
formation is exothermic exothermic so as

769
00:31:07,060 --> 00:31:04,370
hydrate forms we see an increase in

770
00:31:10,330 --> 00:31:07,070
temperature and we can see this here at

771
00:31:13,840 --> 00:31:10,340
individual gratings along along that

772
00:31:15,820 --> 00:31:13,850
fiber as we dissociate hydrate at the

773
00:31:18,370 --> 00:31:15,830
end of the experiment hydrate

774
00:31:20,050 --> 00:31:18,380
dissociation is again endothermic we see

775
00:31:23,380 --> 00:31:20,060
a localized temperature decrease and

776
00:31:25,420 --> 00:31:23,390
again we see to this downtick in in the

777
00:31:26,770 --> 00:31:25,430
temperature data right here this was all

778
00:31:29,190 --> 00:31:26,780
data that was collected within the last

779
00:31:31,720 --> 00:31:29,200
month and I apologize that I haven't

780
00:31:33,370 --> 00:31:31,730
penalized it further we have lots of

781
00:31:34,510 --> 00:31:33,380
interesting strain events that are

782
00:31:35,860 --> 00:31:34,520
happening throughout the course of the

783
00:31:37,000 --> 00:31:35,870
experiment but I'm not really sure what

784
00:31:38,350 --> 00:31:37,010
those mean yet it's going to take a

785
00:31:40,810 --> 00:31:38,360
little bit more time to work all those

786
00:31:43,540 --> 00:31:40,820
out but this is just demonstrating that

787
00:31:45,040 --> 00:31:43,550
within that sediment column you can see

788
00:31:46,840 --> 00:31:45,050

that at different points within that

789
00:31:49,180 --> 00:31:46,850
fiber hydrate is dissociating at

790
00:31:52,000 --> 00:31:49,190
different times at different places

791
00:31:54,490 --> 00:31:52,010
within that large volume of sediment so

792
00:31:56,710 --> 00:31:54,500
we do have some heterogeneity even in a

793
00:31:58,000 --> 00:31:56,720
homogeneous system it will be really

794
00:31:59,500 --> 00:31:58,010
interesting to look at this in a more

795
00:32:01,710 --> 00:31:59,510
heterogeneous system to see where

796
00:32:03,690 --> 00:32:01,720
hydrate is accumulating and associating

797
00:32:06,300 --> 00:32:03,700
and how that's affecting the strain the

798
00:32:10,410 --> 00:32:06,310
strain within that huge sediment column

799
00:32:15,780 --> 00:32:10,420
in terms of deformation of the sediment

800
00:32:18,390 --> 00:32:15,790
as well as production issues so moving

801
00:32:20,610 --> 00:32:18,400
on to things that are a little bit more

802
00:32:23,010 --> 00:32:20,620
relevant to astrobiology gas hydrates as

803
00:32:25,290 --> 00:32:23,020
as planetary materials we've seen from

804
00:32:27,930 --> 00:32:25,300
the terrestrial examples that hydrates

805
00:32:30,600 --> 00:32:27,940
are low temperature materials and that

806
00:32:32,790 --> 00:32:30,610
their global scale they can be global

807
00:32:34,740 --> 00:32:32,800
scale gas and water resour reservoirs

808
00:32:38,100 --> 00:32:34,750
and they have a huge effect on sediment

809
00:32:40,460 --> 00:32:38,110
stability as well so these are important

810
00:32:43,320 --> 00:32:40,470
players in in terms of terrestrial

811
00:32:45,270 --> 00:32:43,330
global climate change as natural

812
00:32:47,340 --> 00:32:45,280
resources that they're also likely to be

813
00:32:54,120 --> 00:32:47,350

important throughout the solar system as

814
00:32:56,790 --> 00:32:54,130
well um we take a look at Titan um this

815
00:32:59,880 --> 00:32:56,800
is a picture from the the horns probe

816
00:33:03,540 --> 00:32:59,890
you can see these cobbles here which may

817
00:33:05,850 --> 00:33:03,550
be ice or methane ethane hydrate here we

818
00:33:08,340 --> 00:33:05,860
see these food wheel systems as well

819
00:33:11,610 --> 00:33:08,350
this is one model that's been developed

820
00:33:14,970 --> 00:33:11,620
for for titan where we have an ice or i

821
00:33:17,130 --> 00:33:14,980
would say possibly hydroton mixed ice

822
00:33:19,470 --> 00:33:17,140
and hydrate layer here at the surface

823
00:33:21,750 --> 00:33:19,480
with a liquid layer so slightly below

824
00:33:24,360 --> 00:33:21,760
and then high pressure ice and I would

825
00:33:27,540 --> 00:33:24,370
argue hi great phases as well at greater

826
00:33:29,730 --> 00:33:27,550
depth on Titan we're probably looking at

827
00:33:32,640 --> 00:33:29,740
methane and ethane hydrates as well as

828
00:33:34,500 --> 00:33:32,650
ammonia and again it's probably going to

829
00:33:36,420 --> 00:33:34,510
be water limited water is probably the

830
00:33:39,570 --> 00:33:36,430
limiting factor for how much hydrate we

831
00:33:41,310 --> 00:33:39,580
could form I'm tighten the hydrate the

832
00:33:43,850 --> 00:33:41,320
the gases may actually be sucking up the

833
00:33:45,870 --> 00:33:43,860
the water and see frustrating

834
00:33:49,470 --> 00:33:45,880
sequestering it in a hydrate phase

835
00:33:56,890 --> 00:33:54,100
if we look at your ropa um again we may

836
00:33:59,920 --> 00:33:56,900
have co2 or methane hydrates in the icy

837
00:34:03,490 --> 00:33:59,930
shell um it's interesting to think of

838
00:34:05,200 --> 00:34:03,500

Europa in terms of this this deep ocean

839
00:34:08,770 --> 00:34:05,210
environment where we may have gas

840
00:34:10,810 --> 00:34:08,780
venting at a rock or fluid interface and

841
00:34:12,670 --> 00:34:10,820
it may be similar to terrestrial

842
00:34:15,160 --> 00:34:12,680
seafloor environments where again you

843
00:34:17,710 --> 00:34:15,170
might have these methane seeps forming

844
00:34:22,030 --> 00:34:17,720
gas hydrates both at the bottom of that

845
00:34:24,220 --> 00:34:22,040
gas the potion rock interface as well as

846
00:34:27,010 --> 00:34:24,230
at the top was happening at that water

847
00:34:29,650 --> 00:34:27,020
ice interface do we have hydrates

848
00:34:33,160 --> 00:34:29,660
forming there as well so this is just

849
00:34:37,480 --> 00:34:33,170
two examples of hydrates in the outer

850
00:34:39,880 --> 00:34:37,490
solar system of in terms of Mars there's

851
00:34:42,610 --> 00:34:39,890
been quite a bit of discussion over the

852
00:34:46,770 --> 00:34:42,620
past ten years about co2 hydrates on

853
00:34:49,840 --> 00:34:46,780
Mars in terms of surface processes and

854
00:34:51,850 --> 00:34:49,850
erosional effects so we have co2

855
00:34:54,790 --> 00:34:51,860
hydrates the that are stable within

856
00:34:57,460 --> 00:34:54,800
perhaps the within ten to a hundred

857
00:34:59,770 --> 00:34:57,470
meters of the Martian surface if those

858
00:35:01,150 --> 00:34:59,780
hydrates dissociate what's going to

859
00:35:04,570 --> 00:35:01,160
happen to the surface how does that

860
00:35:06,280 --> 00:35:04,580
affect the surface morphology and what

861
00:35:10,960 --> 00:35:06,290
kind of features might we expect to form

862
00:35:14,010 --> 00:35:10,970
so in two thousand Hoffman published

863
00:35:16,660 --> 00:35:14,020

this paper called white white Mars um

864
00:35:18,520 --> 00:35:16,670
which lifted this in quite a bit of

865
00:35:22,000 --> 00:35:18,530
detail and he suggested that there's a

866
00:35:24,160 --> 00:35:22,010
cryosphere of class right and dry ice or

867
00:35:26,350 --> 00:35:24,170
class right and normalized depending on

868
00:35:29,170 --> 00:35:26,360
your relative proportions of co2 and

869
00:35:32,500 --> 00:35:29,180
water within the Martian subsurface and

870
00:35:34,930 --> 00:35:32,510
then these form co2 hydrates that then

871
00:35:37,300 --> 00:35:34,940
dissociate and form these large outflow

872
00:35:38,890 --> 00:35:37,310
channels and perhaps are also

873
00:35:40,420 --> 00:35:38,900
responsible for some of this chaotic

874
00:35:43,090 --> 00:35:40,430
terrain there's been quite a bit of

875
00:35:45,490 --> 00:35:43,100
controversy about this and

876
00:35:47,410 --> 00:35:45,500
there's still some ongoing discussion

877
00:35:52,270 --> 00:35:47,420
who's also suggested that these recent

878
00:35:54,670 --> 00:35:52,280
meter scale erosion along crater slopes

879
00:35:57,160 --> 00:35:54,680
may also be the result of hydrates

880
00:35:59,560 --> 00:35:57,170
Association and again that's that's

881
00:36:01,720 --> 00:35:59,570
controversial but most of the hydrate

882
00:36:03,490 --> 00:36:01,730
discussion for Mars has focused on co2

883
00:36:06,280 --> 00:36:03,500
hydrates basically there's so much co2

884
00:36:09,040 --> 00:36:06,290
in the Martian atmosphere but the recent

885
00:36:11,770 --> 00:36:09,050
detection of methane within the Martian

886
00:36:13,810 --> 00:36:11,780
atmosphere has also kind of spurred a

887
00:36:15,430 --> 00:36:13,820
lot of discussion about methane hydrates

888
00:36:18,670 --> 00:36:15,440

within the context of Mars and that's

889
00:36:21,670 --> 00:36:18,680
what I I really want to focus on so

890
00:36:23,970 --> 00:36:21,680
there's been there was detection of

891
00:36:26,440 --> 00:36:23,980
methane within the Martian atmosphere

892
00:36:29,830 --> 00:36:26,450
however methane has a very short

893
00:36:31,420 --> 00:36:29,840
lifetime in terms of how long it can be

894
00:36:33,100 --> 00:36:31,430
stable within within the Martian

895
00:36:34,810 --> 00:36:33,110
atmosphere on the order for the

896
00:36:37,840 --> 00:36:34,820
concentrations that were detected

897
00:36:39,490 --> 00:36:37,850
perhaps 300 to 400 years so what's the

898
00:36:41,440 --> 00:36:39,500
source of this very recent methane

899
00:36:44,020 --> 00:36:41,450
that's that's been detected in the

900
00:36:46,570 --> 00:36:44,030
atmosphere of course it's been suggested

901
00:36:48,460 --> 00:36:46,580
it's a biogenic source or perhaps the

902
00:36:50,920 --> 00:36:48,470
result of water rock interactions at

903
00:36:56,560 --> 00:36:50,930
depth or even comet impacts where you

904
00:36:58,090 --> 00:36:56,570
have a extra planetary source of methane

905
00:36:59,440 --> 00:36:58,100
where the methane is actually coming in

906
00:37:02,260 --> 00:36:59,450
on the comment and then being

907
00:37:04,210 --> 00:37:02,270
disseminated into the atmosphere what

908
00:37:05,950 --> 00:37:04,220
really caught my attention was that it's

909
00:37:08,050 --> 00:37:05,960
been suggested that the methane is

910
00:37:10,200 --> 00:37:08,060
coming from the dissociation of methane

911
00:37:12,700 --> 00:37:10,210
hydrate reservoirs this has been

912
00:37:14,650 --> 00:37:12,710
discussed a little bit and it was kind

913
00:37:16,630 --> 00:37:14,660

of played down because there's been no

914
00:37:19,210 --> 00:37:16,640
thermal anomalies that have been

915
00:37:22,480 --> 00:37:19,220
associated that can be found that you

916
00:37:24,160 --> 00:37:22,490
would expect to see in terms of some

917
00:37:26,320 --> 00:37:24,170
sort of heating event that would

918
00:37:27,680 --> 00:37:26,330
dissociate gas hydrates and again

919
00:37:30,950 --> 00:37:27,690
there's no recent

920
00:37:33,170 --> 00:37:30,960
unloading events perhaps an impact or a

921
00:37:36,650 --> 00:37:33,180
landslide that could have destabilized

922
00:37:38,569 --> 00:37:36,660
gas hydrates either so at first this

923
00:37:41,510 --> 00:37:38,579
this hypothesis was kind of played down

924
00:37:43,040 --> 00:37:41,520
and that makes sense we usually think of

925
00:37:44,780 --> 00:37:43,050
pressuring temperature controls on

926
00:37:46,760 --> 00:37:44,790
hydrate stability so you'd expect this

927
00:37:49,250 --> 00:37:46,770
to be either a thermal anomaly or a

928
00:37:51,319 --> 00:37:49,260
change in pressure in order to stabilize

929
00:37:52,760 --> 00:37:51,329
those hydrates so basically you'd expect

930
00:37:55,309 --> 00:37:52,770
to see a thermal anomaly at the surface

931
00:37:57,140 --> 00:37:55,319
or some sort of unloading event but

932
00:38:02,829 --> 00:37:57,150
there's there's two other things that

933
00:38:08,000 --> 00:38:06,230
you got pressure temperature guests gasp

934
00:38:10,190 --> 00:38:08,010
concentration so is there enough methane

935
00:38:12,050 --> 00:38:10,200
there to form hydrates to begin with

936
00:38:14,900 --> 00:38:12,060
well that doesn't really cause hydrates

937
00:38:17,300 --> 00:38:14,910
to destabilize you can't take away the

938
00:38:19,280 --> 00:38:17,310

methane without basically decomposing it

939
00:38:21,950 --> 00:38:19,290
to begin with so that that can't really

940
00:38:25,700 --> 00:38:21,960
be the driving force here however

941
00:38:27,290 --> 00:38:25,710
there's a fourth control here as well

942
00:38:30,710 --> 00:38:27,300
and that's the activity of water in the

943
00:38:32,750 --> 00:38:30,720
system okay so if you think of ice that

944
00:38:34,849 --> 00:38:32,760
forms on your road the way you get the

945
00:38:37,849 --> 00:38:34,859
ice to melt is you put salt down on the

946
00:38:40,400 --> 00:38:37,859
road okay so inhibits ice formation so

947
00:38:42,710 --> 00:38:40,410
also inhibits hydrate formation see if

948
00:38:44,660 --> 00:38:42,720
it if you have a hydrate deposit you

949
00:38:46,490 --> 00:38:44,670
inject a salty brine you're going to

950
00:38:48,589 --> 00:38:46,500
dissociate hydrate you've changed the

951
00:38:50,089 --> 00:38:48,599
activity of water in the system and

952
00:38:51,950 --> 00:38:50,099
you've changed the hydrate stability

953
00:38:55,099 --> 00:38:51,960
field so what I wanted to look at was

954
00:38:57,950 --> 00:38:55,109
whether we could D suit destabilize

955
00:39:00,230 --> 00:38:57,960
hydrate simply by by increasing the

956
00:39:02,150 --> 00:39:00,240
salinity of the system without changing

957
00:39:04,010 --> 00:39:02,160
the pressure the temperature so without

958
00:39:05,900 --> 00:39:04,020
having these thermal anomalies or

959
00:39:09,609 --> 00:39:05,910
without these unloading events could we

960
00:39:11,780 --> 00:39:09,619
have just slight increases in salinity

961
00:39:15,200 --> 00:39:11,790
basically resulting in hydrate

962
00:39:18,330 --> 00:39:15,210
dissociation um

963
00:39:20,820 --> 00:39:18,340

and it turns out that you can you can do

964
00:39:23,190 --> 00:39:20,830
this very simply simply by adding a

965
00:39:25,650 --> 00:39:23,200
variety of any basically any type of

966
00:39:27,420 --> 00:39:25,660
salt to the system different salts have

967
00:39:29,010 --> 00:39:27,430
different effects on the freezing point

968
00:39:30,660 --> 00:39:29,020
of water they also have different

969
00:39:32,580 --> 00:39:30,670
effects on hydrate stability and it's

970
00:39:34,950 --> 00:39:32,590
closely tied to that freezing point

971
00:39:37,380 --> 00:39:34,960
depression in water so sulfate salts

972
00:39:38,760 --> 00:39:37,390
have a slight effect on freezing point

973
00:39:40,860 --> 00:39:38,770
depression in water they also have a

974
00:39:44,460 --> 00:39:40,870
slight effect in inhibiting hydrate

975
00:39:47,490 --> 00:39:44,470
formation it's really the chloride salts

976
00:39:49,470 --> 00:39:47,500
and especially the debate went colorants

977
00:39:51,090 --> 00:39:49,480
that have the most effect on both ice

978
00:39:55,230 --> 00:39:51,100
freezing point as well as hydrate

979
00:39:59,280 --> 00:39:55,240
stability so I decided to look at the

980
00:40:03,470 --> 00:39:59,290
effect of NaCl salinity as well as

981
00:40:06,780 --> 00:40:03,480
calcium chloride salinity on unhi great

982
00:40:08,760 --> 00:40:06,790
stability fields and then magic taking

983
00:40:10,710 --> 00:40:08,770
that data set and putting and comparing

984
00:40:11,820 --> 00:40:10,720
it to the Mars geotherm to see what

985
00:40:13,590 --> 00:40:11,830
effect that's going to have on the

986
00:40:15,360 --> 00:40:13,600
thickness of the hydrate stability zone

987
00:40:21,090 --> 00:40:15,370
that we'd expect to see in the Martian

988
00:40:25,080 --> 00:40:21,100

subsurface so here I'm taking the

989
00:40:27,720 --> 00:40:25,090
geothermal gradient from mellon at all

990
00:40:30,090 --> 00:40:27,730
and this goes from the equator to the

991
00:40:32,070 --> 00:40:30,100
poles so this is equatorial geothermal

992
00:40:34,560 --> 00:40:32,080
gradient here this is the geothermal

993
00:40:37,140 --> 00:40:34,570
gradient at the poles and it's in this

994
00:40:39,140 --> 00:40:37,150
light gray field here we have increasing

995
00:40:41,910 --> 00:40:39,150
pressure here along the y axis

996
00:40:44,790 --> 00:40:41,920
increasing temperature here along the x

997
00:40:47,850 --> 00:40:44,800
axis and I've overlaid on this the

998
00:40:49,380 --> 00:40:47,860
methane hydrate stability field and this

999
00:40:53,040 --> 00:40:49,390
is the methane hydrate stability field

1000
00:40:54,600 --> 00:40:53,050
here for pure water system okay you can

1001
00:40:57,270 --> 00:40:54,610
see that the hydrate stability field

1002
00:40:59,880 --> 00:40:57,280
would be expected to be down to a depth

1003
00:41:02,190 --> 00:40:59,890
of about five point five kilometers for

1004
00:41:05,160 --> 00:41:02,200
pure water system however is you add

1005
00:41:07,050 --> 00:41:05,170
salt to the system the hydrate stability

1006
00:41:10,950 --> 00:41:07,060
field is going to shrink and speakin of

1007
00:41:12,740 --> 00:41:10,960
hub become less thick for a sodium

1008
00:41:14,660 --> 00:41:12,750
chloride eutectic brine

1009
00:41:16,340 --> 00:41:14,670
the base of the hydrate stability zone

1010
00:41:18,290 --> 00:41:16,350
is now at three point nine kilometers

1011
00:41:20,150 --> 00:41:18,300
and for a calcium chloride eutectic

1012
00:41:22,430 --> 00:41:20,160
brine the the base of the hydrates

1013
00:41:23,810 --> 00:41:22,440

ability fields is basically down to one

1014
00:41:25,880 --> 00:41:23,820
point seven kilometers so we have a

1015
00:41:27,530 --> 00:41:25,890
decrease in almost four kilometers of

1016
00:41:29,720 --> 00:41:27,540
the thickness of that hydrate stability

1017
00:41:31,640 --> 00:41:29,730
zone simply by adding salt to the system

1018
00:41:34,100 --> 00:41:31,650
now I'm not suggesting that we have to

1019
00:41:36,640 --> 00:41:34,110
have a calcium chloride Bryan or sodium

1020
00:41:41,030 --> 00:41:36,650
chloride brine in the system in order to

1021
00:41:42,800 --> 00:41:41,040
for it to dissociate hydrate as we add

1022
00:41:46,160 --> 00:41:42,810
just a small amount of salt to the

1023
00:41:48,890 --> 00:41:46,170
system this stability field is going to

1024
00:41:51,320 --> 00:41:48,900
move slightly to the left here in fact

1025
00:41:53,450 --> 00:41:51,330
de so seeing hydrates from the bottom of

1026
00:41:55,100 --> 00:41:53,460
the hydrate stability field so this can

1027
00:41:57,080 --> 00:41:55,110
happen with even small changes in

1028
00:41:59,270 --> 00:41:57,090
salinity perhaps the effect of

1029
00:42:01,190 --> 00:41:59,280
dewatering reactions that are occurring

1030
00:42:03,920 --> 00:42:01,200
at depth where you have fluids that are

1031
00:42:05,480 --> 00:42:03,930
reacting with the bedrock and hydrating

1032
00:42:09,830 --> 00:42:05,490
the bedrock therefore increasing the

1033
00:42:11,750 --> 00:42:09,840
salinity of the fluids um so this is

1034
00:42:13,700 --> 00:42:11,760
this is the picture for for methane

1035
00:42:15,920 --> 00:42:13,710
hydrate I wanted to compare that to to

1036
00:42:17,660 --> 00:42:15,930
the stability field of co2 hydrate as

1037
00:42:20,150 --> 00:42:17,670
well if we're dissociating methane

1038
00:42:22,310 --> 00:42:20,160

hydrates at depths within Mars perhaps

1039
00:42:24,560 --> 00:42:22,320
would be dissociating co2 hydrates as

1040
00:42:27,050 --> 00:42:24,570
well I just wanted to get some idea of a

1041
00:42:29,240 --> 00:42:27,060
comparison here so again this is the

1042
00:42:32,210 --> 00:42:29,250
same figure on the previous side here

1043
00:42:35,360 --> 00:42:32,220
for for methane hydrates on the right

1044
00:42:37,760 --> 00:42:35,370
here's is basically a similar figure for

1045
00:42:40,220 --> 00:42:37,770
co2 hydrates you can see that the effect

1046
00:42:42,260 --> 00:42:40,230
on co2 hydrate stability is a little bit

1047
00:42:44,480 --> 00:42:42,270
less than the effect on methane hydrate

1048
00:42:46,640 --> 00:42:44,490
stability salinity has a greater control

1049
00:42:49,820 --> 00:42:46,650
on methane hydrate stability than on co2

1050
00:42:52,220 --> 00:42:49,830
hydrate stability so the base of the co2

1051
00:42:53,900 --> 00:42:52,230
hydrate stability zone basically four

1052
00:42:55,940 --> 00:42:53,910
point six kilometers and pure water

1053
00:42:59,060 --> 00:42:55,950
systems moves up to three point three

1054
00:43:01,730 --> 00:42:59,070
kilometers for sodium chloride and the

1055
00:43:05,270 --> 00:43:01,740
2.1 kilometers for calcium chloride

1056
00:43:06,859 --> 00:43:05,280
oh so basically if we look at this in

1057
00:43:09,620 --> 00:43:06,869
terms of a depth profile in

1058
00:43:11,870 --> 00:43:09,630
cross-section if you will we've got zero

1059
00:43:13,910 --> 00:43:11,880
degrees latitude here at 90 degrees at

1060
00:43:16,730 --> 00:43:13,920
either end here we've got co2 hydrate

1061
00:43:18,290 --> 00:43:16,740
cross-section here methane hydrate here

1062
00:43:20,870 --> 00:43:18,300
this is the base of the hydrate

1063
00:43:23,270 --> 00:43:20,880

stability zone for pure water NaCl brine

1064
00:43:24,859 --> 00:43:23,280
calcium chloride brine you can see that

1065
00:43:27,470 --> 00:43:24,869
the effect is much greater in the in the

1066
00:43:28,790 --> 00:43:27,480
methane system than in the co2 system so

1067
00:43:30,800 --> 00:43:28,800
we could be dissociating methane

1068
00:43:32,990 --> 00:43:30,810
hydrates without ever affecting co2

1069
00:43:35,450 --> 00:43:33,000
hydrates basically because the effect of

1070
00:43:37,130 --> 00:43:35,460
salinity is so much greater so we could

1071
00:43:39,380 --> 00:43:37,140
be releasing methane into the atmosphere

1072
00:43:41,240 --> 00:43:39,390
without additional release of co2

1073
00:43:43,220 --> 00:43:41,250
basically if we have a mixed system

1074
00:43:46,460 --> 00:43:43,230
where we have both methane hydrates and

1075
00:43:49,220 --> 00:43:46,470
co2 hydrates of depth so what does this

1076
00:43:52,790 --> 00:43:49,230
mean in terms of the recent observations

1077
00:43:55,370 --> 00:43:52,800
of methane in the atmosphere well what I

1078
00:43:57,109 --> 00:43:55,380
would suggest is that we could have let

1079
00:43:59,000 --> 00:43:57,119
me hydrate deposits at depths that are

1080
00:44:01,970 --> 00:43:59,010
simply being dissociated by slight

1081
00:44:04,040 --> 00:44:01,980
increases in salinity do too um

1082
00:44:06,410 --> 00:44:04,050
basically injection of a high salinity

1083
00:44:09,380 --> 00:44:06,420
brine into the region or dewatering

1084
00:44:11,990 --> 00:44:09,390
reactions with the bedrock so slight

1085
00:44:14,270 --> 00:44:12,000
increases in salinity dissociating

1086
00:44:16,280 --> 00:44:14,280
hydrate from the bottom up or we could

1087
00:44:20,300 --> 00:44:16,290
have basically injection of a high

1088
00:44:22,690 --> 00:44:20,310

fluidity brine into basically a low

1089
00:44:26,570 --> 00:44:22,700
salinity aquifer therefore also

1090
00:44:29,150 --> 00:44:26,580
increasing the bulk the total salinity

1091
00:44:32,599 --> 00:44:29,160
of the system and therefore dissociating

1092
00:44:34,220 --> 00:44:32,609
hydrates and then that as hydrates

1093
00:44:37,580 --> 00:44:34,230
dissociate we then have dissolved

1094
00:44:39,170 --> 00:44:37,590
methane within these fluids that then

1095
00:44:41,960 --> 00:44:39,180
gets released up to the surface through

1096
00:44:44,150 --> 00:44:41,970
a series of fractures this could be a

1097
00:44:46,609 --> 00:44:44,160
very small percentage of a large

1098
00:44:48,710 --> 00:44:46,619
reservoir being dissociated or perhaps

1099
00:44:51,650 --> 00:44:48,720
just a single small reservoir that's

1100
00:44:54,950 --> 00:44:51,660
been dissociated by a single fluid event

1101
00:44:57,080 --> 00:44:54,960
either one could could

1102
00:44:58,910 --> 00:44:57,090
basically accomplish the same thing and

1103
00:45:00,580 --> 00:44:58,920
result in the small amount of methane

1104
00:45:03,500 --> 00:45:00,590
that we see in the Martian atmosphere

1105
00:45:05,750 --> 00:45:03,510
now you've noticed I've been careful to

1106
00:45:08,030 --> 00:45:05,760
say not to say where this methane came

1107
00:45:10,490 --> 00:45:08,040
from in the first place this methane

1108
00:45:14,240 --> 00:45:10,500
could be thermogenic it could be

1109
00:45:16,430 --> 00:45:14,250
biogenic we don't know but what I'm

1110
00:45:19,450 --> 00:45:16,440
proposing here is that the recent source

1111
00:45:22,250 --> 00:45:19,460
of methane in the atmosphere could be

1112
00:45:23,810 --> 00:45:22,260
from methane hydrate dissociation how

1113
00:45:26,090 --> 00:45:23,820

that methane hydrate formed in the first

1114
00:45:27,560 --> 00:45:26,100
place I don't know and where that

1115
00:45:31,070 --> 00:45:27,570
methane came from in the first place I

1116
00:45:34,040 --> 00:45:31,080
don't know however we could look into

1117
00:45:36,830 --> 00:45:34,050
doing some ice a topic work on the

1118
00:45:38,990 --> 00:45:36,840
methane and get some idea of what the

1119
00:45:41,660 --> 00:45:39,000
source of that methane was but no matter

1120
00:45:43,810 --> 00:45:41,670
whether it's thermogenic or biogenic

1121
00:45:47,060 --> 00:45:43,820
it's an interesting question because

1122
00:45:49,550 --> 00:45:47,070
methane hydrates on earth are both

1123
00:45:52,220 --> 00:45:49,560
nutrient sources as well as reservoirs

1124
00:45:54,380 --> 00:45:52,230
for biogenic they produce gases so

1125
00:45:56,300 --> 00:45:54,390
either way whether you're producing

1126
00:45:57,860 --> 00:45:56,310
methane from methane hydrates or whether

1127
00:46:00,110 --> 00:45:57,870
you're trapping methane and methane

1128
00:46:02,180 --> 00:46:00,120
hydrates they both have very important

1129
00:46:04,999 --> 00:46:02,190
implications in terms of astrobiology on

1130
00:46:11,819 --> 00:46:08,659
okay and then just when one final note

1131
00:46:13,679 --> 00:46:11,829
the the previous data that i was showing

1132
00:46:15,359 --> 00:46:13,689
those two data sets those were both data

1133
00:46:17,519 --> 00:46:15,369
from the literature we're also looking

1134
00:46:19,949 --> 00:46:17,529
at measuring hydrate stability in the

1135
00:46:23,129 --> 00:46:19,959
presence of a variety of salts including

1136
00:46:25,349 --> 00:46:23,139
some sodium sulfate in terms of both

1137
00:46:27,869 --> 00:46:25,359
Marsh Martian system as well as Europa

1138
00:46:30,239 --> 00:46:27,879

and other planetary systems and we do

1139
00:46:32,879 --> 00:46:30,249
this in a small pack leader pressure

1140
00:46:36,689 --> 00:46:32,889
vessel where we basically fill filled

1141
00:46:39,059 --> 00:46:36,699
the the vessel up with with hydrate but

1142
00:46:42,089 --> 00:46:39,069
by injecting gas into a pure water

1143
00:46:44,459 --> 00:46:42,099
system and then once reformed the

1144
00:46:46,859 --> 00:46:44,469
hydrate we then inject the the sailing

1145
00:46:49,139 --> 00:46:46,869
Brian into the system and looking at the

1146
00:46:51,419 --> 00:46:49,149
pressure temperature curve again hydrate

1147
00:46:53,429 --> 00:46:51,429
dissociation is endothermic so we get

1148
00:46:55,319 --> 00:46:53,439
this plateau is as the hydrate is

1149
00:46:57,299 --> 00:46:55,329
dissociating and then this break and

1150
00:46:59,489 --> 00:46:57,309
slope here is basically the last of the

1151
00:47:02,639 --> 00:46:59,499
hydrate dissociating and we can take a

1152
00:47:04,319 --> 00:47:02,649
temperature pressure reading right here

1153
00:47:07,469 --> 00:47:04,329
and that's our pressure temperature

1154
00:47:09,179 --> 00:47:07,479
point in our stability field all so so

1155
00:47:10,679 --> 00:47:09,189
we are collecting data on these systems

1156
00:47:13,020 --> 00:47:10,689
as well that we hope to add to the

1157
00:47:20,770 --> 00:47:18,250
um quietly in summary um like e to think

1158
00:47:22,990 --> 00:47:20,780
about gas hydrates not only a large

1159
00:47:26,050 --> 00:47:23,000
energy resource and carbon sink on earth

1160
00:47:28,300 --> 00:47:26,060
but also as climatic controls and

1161
00:47:30,070 --> 00:47:28,310
planetary materials both on earth and

1162
00:47:32,710 --> 00:47:30,080
throughout the solar system so gas

1163
00:47:35,530 --> 00:47:32,720

hydrates are probably large players in

1164
00:47:37,960 --> 00:47:35,540
the climate controls on earth in terms

1165
00:47:41,320 --> 00:47:37,970
of global carbon cycle these are

1166
00:47:43,540 --> 00:47:41,330
planetary planetary scale reservoirs for

1167
00:47:48,490 --> 00:47:43,550
both water and greenhouse gases on earth

1168
00:47:50,230 --> 00:47:48,500
and likely on other planets as well talk

1169
00:47:52,390 --> 00:47:50,240
a little bit about geologic controls on

1170
00:47:53,440 --> 00:47:52,400
hydrate accumulation this is something

1171
00:47:55,770 --> 00:47:53,450
that hasn't been looked at before

1172
00:47:58,350 --> 00:47:55,780
there's been field studies looking at

1173
00:48:00,640 --> 00:47:58,360
collecting samples and basically

1174
00:48:03,040 --> 00:48:00,650
describing those samples there have been

1175
00:48:05,050 --> 00:48:03,050
laboratory studies and pure hydrate

1176
00:48:06,970 --> 00:48:05,060
systems basically looking at gas and

1177
00:48:10,150 --> 00:48:06,980
water systems but there haven't been

1178
00:48:12,310 --> 00:48:10,160
much work looking at gas hydrates in a

1179
00:48:14,109 --> 00:48:12,320
controlled sediment system how does the

1180
00:48:16,960 --> 00:48:14,119
hydrate forming in that sediment and how

1181
00:48:19,650 --> 00:48:16,970
is it's associating also salinity

1182
00:48:22,450 --> 00:48:19,660
induced Association mechanism for

1183
00:48:25,750 --> 00:48:22,460
methane hydrate methane release on Mars

1184
00:48:28,270 --> 00:48:25,760
I think they just have a lot of

1185
00:48:30,550 --> 00:48:28,280
potential simply because we don't need

1186
00:48:32,560 --> 00:48:30,560
to have some old nominees anomalies or

1187
00:48:34,540 --> 00:48:32,570
removal overburden you could simply have

1188
00:48:38,200 --> 00:48:34,550

these someone any changes at depth that

1189
00:48:41,140 --> 00:48:38,210
that would then be releasing methane

1190
00:48:43,120 --> 00:48:41,150
from these potentially small methane

1191
00:48:45,520 --> 00:48:43,130
hydrate reservoirs in terms of

1192
00:48:47,560 --> 00:48:45,530
implications for astrobiology these are

1193
00:48:50,790 --> 00:48:47,570
again important reservoirs for water and

1194
00:48:52,650 --> 00:48:50,800
carbon think probably going to be

1195
00:48:55,359 --> 00:48:52,660
important climate change drivers

1196
00:48:57,980 --> 00:48:55,369
nutrient sources as well as traps for

1197
00:49:01,270 --> 00:48:57,990
biologically produce gases and in

1198
00:49:03,710 --> 00:49:01,280
gas hydrates are likely to influence

1199
00:49:08,810 --> 00:49:03,720
planetary geomorphology and near surface

1200
00:49:10,880 --> 00:49:08,820
processes as well then finally I'd like

1201
00:49:13,160 --> 00:49:10,890
to acknowledge sources of support the

1202
00:49:15,590 --> 00:49:13,170
Oak Ridge National Laboratories vignette

1203
00:49:17,870 --> 00:49:15,600
fellowship program the Department of

1204
00:49:19,940 --> 00:49:17,880
Energy and Indiana Princeton Tennessee

1205
00:49:22,930 --> 00:49:19,950
astrobiology institute and these are my

1206
00:49:25,700 --> 00:49:22,940
collaborate collaborators at Oak Ridge

1207
00:49:26,960 --> 00:49:25,710
Princeton and then these four people

1208
00:49:28,520 --> 00:49:26,970
here are all students that are working

1209
00:49:30,640 --> 00:49:28,530
in our laboratory currently helping me

1210
00:49:33,440 --> 00:49:30,650
run the experiments and costas to source

1211
00:49:35,359 --> 00:49:33,450
who's an engineer who's been working on

1212
00:49:37,580 --> 00:49:35,369
those carbon sequestration and

1213
00:49:46,840 --> 00:49:37,590

desalination projects as well thank you

1214
00:49:57,830 --> 00:49:56,330
questions yes he's a tiny carpets let me

1215
00:50:01,600 --> 00:49:57,840
know what we mostly hear about us

1216
00:50:05,840 --> 00:50:01,610
there's a positive feedback service

1217
00:50:08,210 --> 00:50:05,850
Virginia church across the notes or of

1218
00:50:10,730 --> 00:50:08,220
these gases go into the atmosphere you

1219
00:50:12,320 --> 00:50:10,740
not possible you pointed to a second one

1220
00:50:14,510 --> 00:50:12,330
is to think you know in terms of the D

1221
00:50:18,859 --> 00:50:14,520
salad as a part of the salinity effect

1222
00:50:20,210 --> 00:50:18,869
that water melts I guess that interacts

1223
00:50:22,670 --> 00:50:20,220
with the rocks divert to change the

1224
00:50:24,590 --> 00:50:22,680
salinity around the environment so the

1225
00:50:27,430 --> 00:50:24,600
salinity effect is actually a negative

1226
00:50:30,980 --> 00:50:27,440
feedback loop okay okay so as you're

1227
00:50:33,290 --> 00:50:30,990
discussing gas hydrates you're releasing

1228
00:50:35,960 --> 00:50:33,300
quite a bit of fresh water into the

1229
00:50:38,330 --> 00:50:35,970
system so you're actually decreasing the

1230
00:50:40,340 --> 00:50:38,340
salinity in the localized environment

1231
00:50:43,550 --> 00:50:40,350
and that's actually going to inhibit

1232
00:50:45,320 --> 00:50:43,560
further hydrate dissociation so because

1233
00:50:48,349 --> 00:50:45,330
as you you're dissociating the hydrates

1234
00:50:50,750 --> 00:50:48,359
you're creating fresh water you may

1235
00:50:52,460 --> 00:50:50,760
actually slow down that runaway

1236
00:50:54,830 --> 00:50:52,470
greenhouse effect that lots of people

1237
00:50:57,050 --> 00:50:54,840
have talked about now I think that the

1238
00:50:58,250 --> 00:50:57,060

temperature climate change driver on

1239
00:51:01,130 --> 00:50:58,260
that is probably going to be greater

1240
00:51:03,590 --> 00:51:01,140
than the salinity effect that you see in

1241
00:51:06,109 --> 00:51:03,600
dissociating the hydrates but it's

1242
00:51:10,820 --> 00:51:06,119
interesting to think about it in terms

1243
00:51:14,300 --> 00:51:10,830
of the effects of salinity haven't been

1244
00:51:17,490 --> 00:51:14,310
well measured and inspect especially the

1245
00:51:20,340 --> 00:51:17,500
rates of those changes

1246
00:51:23,430 --> 00:51:20,350
in terms of natural systems haven't been

1247
00:51:24,690 --> 00:51:23,440
measured so that negative versus

1248
00:51:26,070 --> 00:51:24,700
positive feedback loop it would be

1249
00:51:32,340 --> 00:51:26,080
interesting to look at that in terms of

1250
00:51:34,830 --> 00:51:32,350
a global climate issue this is the

1251
00:51:36,560 --> 00:51:34,840
hydrate formation is essential in water

1252
00:51:39,990 --> 00:51:36,570
limited and them in the formation

1253
00:51:42,150 --> 00:51:40,000
essentially sequester to water is good I

1254
00:51:43,950 --> 00:51:42,160
could you comment on that process be

1255
00:51:45,810 --> 00:51:43,960
happening at Mars and form of co2

1256
00:51:49,050 --> 00:51:45,820
hydrate and that this would be a

1257
00:51:51,510 --> 00:51:49,060
reservoir for water it was right if we

1258
00:51:55,140 --> 00:51:51,520
have fresh water if we have liquid water

1259
00:51:57,120 --> 00:51:55,150
excuse me liquid water that's in contact

1260
00:51:59,460 --> 00:51:57,130
with significant amounts of co2 like you

1261
00:52:02,460 --> 00:51:59,470
have on Mars at the correct pressure and

1262
00:52:05,010 --> 00:52:02,470
temperature conditions you're going to

1263
00:52:07,410 --> 00:52:05,020

form hydrate and that hydrate is going

1264
00:52:09,180 --> 00:52:07,420
to sequester water in a solid phase it's

1265
00:52:11,580 --> 00:52:09,190
no longer going to be liquid the

1266
00:52:14,250 --> 00:52:11,590
question becomes whether you're more

1267
00:52:16,680 --> 00:52:14,260
likely to form co2 hydrate or whether

1268
00:52:18,390 --> 00:52:16,690
you're more likely to form co2 ice at

1269
00:52:21,930 --> 00:52:18,400
those pressure temperature conditions

1270
00:52:24,540 --> 00:52:21,940
and that's still an ongoing debate I'll

1271
00:52:26,610 --> 00:52:24,550
as to which in there some kinetic

1272
00:52:29,940 --> 00:52:26,620
effects there too which one is more more

1273
00:52:31,800 --> 00:52:29,950
likely to form I'm not a geologist if

1274
00:52:34,290 --> 00:52:31,810
you if you make these high grease

1275
00:52:35,880 --> 00:52:34,300
release the methane at depths name is it

1276
00:52:38,130 --> 00:52:35,890
inevitable that there's gonna be cracks

1277
00:52:40,860 --> 00:52:38,140
I mean is that converse at all you'll

1278
00:52:45,170 --> 00:52:40,870
get out oh it's definitely going to get

1279
00:52:46,710 --> 00:52:45,180
out um as you release the methane in ac4

1280
00:52:48,900 --> 00:52:46,720
it

1281
00:52:50,760 --> 00:52:48,910
in a sea floor sediment system if you're

1282
00:52:52,530 --> 00:52:50,770
releasing the methane eat in some cases

1283
00:52:55,349 --> 00:52:52,540
you actually see distinct bubbles that

1284
00:52:58,770 --> 00:52:55,359
then migrate don't our load bars Oh in

1285
00:53:01,700 --> 00:52:58,780
terms of Mars you could have basically a

1286
00:53:05,160 --> 00:53:01,710
closed aquifer system where you have an

1287
00:53:07,560 --> 00:53:05,170
eyesore methane cap on the system and

1288
00:53:11,339 --> 00:53:07,570

you have increasing hydrogen methane

1289
00:53:14,910 --> 00:53:11,349
pressure beneath as that pressure builds

1290
00:53:18,450 --> 00:53:14,920
may result in basically so cracking and

1291
00:53:20,550 --> 00:53:18,460
Henry's is probably going to burp at

1292
00:53:23,700 --> 00:53:20,560
some point of you can also have

1293
00:53:25,890 --> 00:53:23,710
diffusion of methane through the methane

1294
00:53:27,420 --> 00:53:25,900
hydrate as long as as the hydrate is

1295
00:53:28,859 --> 00:53:27,430
methane sidetracks in other words this

1296
00:53:30,660 --> 00:53:28,869
is not controversial to come in here

1297
00:53:35,700 --> 00:53:30,670
you're essentially positing these cracks

1298
00:53:38,280 --> 00:53:35,710
and Lars right um if we have methane at

1299
00:53:42,510 --> 00:53:38,290
pressure at depth eventually it's

1300
00:53:44,640 --> 00:53:42,520
probably going to want to get out yes if

1301
00:53:47,040 --> 00:53:44,650
we have well because they assume that

1302
00:53:50,760 --> 00:53:47,050
there's methane clathrates on Mars it

1303
00:53:52,530 --> 00:53:50,770
would be your best idea about where that

1304
00:53:55,710 --> 00:53:52,540
mapping originally came from and

1305
00:53:57,140 --> 00:53:55,720
secondly could those processes still be

1306
00:54:01,970 --> 00:53:57,150
function

1307
00:54:03,410 --> 00:54:01,980
I don't want to comment on the source

1308
00:54:05,180 --> 00:54:03,420
the methane because I don't think that

1309
00:54:07,490 --> 00:54:05,190
there's enough data out there to say

1310
00:54:09,289 --> 00:54:07,500
what the source of the methane is that

1311
00:54:14,839 --> 00:54:09,299
might be trapped in those methane

1312
00:54:17,480 --> 00:54:14,849
hydrates there are viable arguments for

1313
00:54:19,760 --> 00:54:17,490

water rock interactions as the source of

1314
00:54:21,019 --> 00:54:19,770
methane as well as biological activity I

1315
00:54:23,029 --> 00:54:21,029
don't know what the source of the

1316
00:54:25,609 --> 00:54:23,039
methane is that's in the hydrates I

1317
00:54:30,289 --> 00:54:25,619
think we should be taking a closer look

1318
00:54:33,140 --> 00:54:30,299
at isotopic work on the methane in the

1319
00:54:35,539 --> 00:54:33,150
atmosphere and potentially looking for

1320
00:54:37,700 --> 00:54:35,549
these methane seeps on the surface of

1321
00:54:40,430 --> 00:54:37,710
Mars whether that's through a methane

1322
00:54:45,920 --> 00:54:40,440
sniffing aircraft or or something else

1323
00:54:48,140 --> 00:54:45,930
or close um high-resolution spectroscopy

1324
00:54:50,150 --> 00:54:48,150
at the surface i'm not i'm not sure what

1325
00:54:51,769 --> 00:54:50,160
the best way to do that is but i think

1326
00:54:54,260 --> 00:54:51,779
probably determining where the source of

1327
00:54:56,299 --> 00:54:54,270
that methane is coming from and then

1328
00:54:57,890 --> 00:54:56,309
going to the source and trying to do

1329
00:55:02,299 --> 00:54:57,900
some isotopic work it's probably the

1330
00:55:05,420 --> 00:55:02,309
best way to determine that but yeah just

1331
00:55:10,280 --> 00:55:05,430
design an experiment on Mars too

1332
00:55:14,210 --> 00:55:10,290
distinguish between the say clathrate

1333
00:55:18,589 --> 00:55:14,220
but there's co2 and I think in classic

1334
00:55:21,710 --> 00:55:18,599
vs illicit sex co2 cloud in a hybrid

1335
00:55:24,380 --> 00:55:21,720
versus just frozen co2 mm-hmm say on

1336
00:55:26,780 --> 00:55:24,390
Rovers mm-hmm what would how would you

1337
00:55:30,549 --> 00:55:26,790
decide that and what would be the

1338
00:55:34,870 --> 00:55:30,559

implications of it or take your choice

1339
00:55:38,089 --> 00:55:34,880
climate on Mars or the source of the co2

1340
00:55:40,040 --> 00:55:38,099
so so you have an experiment where you

1341
00:55:41,809 --> 00:55:40,050
actually have access to a solid material

1342
00:55:43,510 --> 00:55:41,819
all right we have to do this remote

1343
00:55:47,480 --> 00:55:43,520
nexus of unix rovers in the land of them

1344
00:55:49,700 --> 00:55:47,490
all right you can do a simple melting

1345
00:55:53,270 --> 00:55:49,710
experiment basically look at the melting

1346
00:55:55,160 --> 00:55:53,280
point um the stability field of co2

1347
00:55:56,839 --> 00:55:55,170
hydrate and students you ice is

1348
00:55:59,059 --> 00:55:56,849
significantly different that you could

1349
00:55:59,839 --> 00:55:59,069
just measure basically the melting point

1350
00:56:02,930 --> 00:55:59,849
and you could tell the difference

1351
00:56:06,200 --> 00:56:02,940
between the two in terms of the

1352
00:56:10,700 --> 00:56:06,210
implications I think number one it would

1353
00:56:12,710 --> 00:56:10,710
be there's there's a huge difference in

1354
00:56:15,970 --> 00:56:12,720
the volume of co2 that's that's

1355
00:56:21,260 --> 00:56:15,980
contained within co2 ice & Co to hydrate

1356
00:56:24,289 --> 00:56:21,270
just in terms of Mars total co2 count

1357
00:56:26,359 --> 00:56:24,299
basically how much co2 is there and

1358
00:56:29,240 --> 00:56:26,369
again the differences in the stability

1359
00:56:31,670 --> 00:56:29,250
fields have a void effect on potentially

1360
00:56:33,440 --> 00:56:31,680
climate change on Mars you know how far

1361
00:56:38,150 --> 00:56:33,450
do you have to push the climate in order

1362
00:56:42,859 --> 00:56:41,569
yes really I'm perf there are microbes

1363
00:56:45,230 --> 00:56:42,869

that directly associated with the

1364
00:56:46,760 --> 00:56:45,240
methane clathrates so on Mars do you

1365
00:56:48,589 --> 00:56:46,770
think there would be severe physical

1366
00:56:50,779 --> 00:56:48,599
constraints of microbial community

1367
00:56:53,960 --> 00:56:50,789
developing around it I three this model

1368
00:56:57,710 --> 00:56:53,970
are deep in the bedrock um there have

1369
00:56:59,150 --> 00:56:57,720
been microbes that have been pulled for

1370
00:57:02,690 --> 00:56:59,160
more than a kilometer deep in earth

1371
00:57:05,000 --> 00:57:02,700
rocks so I don't see why it's out of the

1372
00:57:06,920 --> 00:57:05,010
realm of possibility on Mars as well I

1373
00:57:08,900 --> 00:57:06,930
think that's that's one of the most

1374
00:57:12,770 --> 00:57:08,910
interesting things about thinking about

1375
00:57:14,930 --> 00:57:12,780
methane hydrates on Mars is you know at

1376
00:57:16,549 --> 00:57:14,940
the base of the hydrate what's going on

1377
00:57:18,260 --> 00:57:16,559
at the top of the hydrate what's going

1378
00:57:20,329 --> 00:57:18,270
on where the methane might be released

1379
00:57:22,970 --> 00:57:20,339
to the surface at the base where you're

1380
00:57:25,670 --> 00:57:22,980
actually potentially perhaps forming

1381
00:57:26,960 --> 00:57:25,680
methane in scituate depth what's the

1382
00:57:28,460 --> 00:57:26,970
source of the methane and then what's

1383
00:57:30,410 --> 00:57:28,470
happening to the methane that may be

1384
00:57:33,200 --> 00:57:30,420
associated at the top our critters

1385
00:57:35,569 --> 00:57:33,210
eating it I don't know but I think it's

1386
00:57:38,809 --> 00:57:35,579
it's definitely an interesting system to

1387
00:57:41,420 --> 00:57:38,819
be looking at in terms of astrobiology

1388
00:57:44,059 --> 00:57:41,430

as well as geo microbiology on earth to

1389
00:57:47,990 --> 00:57:44,069
understand that global carbon cycle and

1390
00:57:49,609 --> 00:57:48,000
those ecological systems brother how

1391
00:57:51,650 --> 00:57:49,619
would you distinguish between methane

1392
00:57:55,849 --> 00:57:51,660
good understand part of its life trapped

1393
00:57:58,220 --> 00:57:55,859
in Martian fat right website from behind

1394
00:57:59,930 --> 00:57:58,230
that's being synthesized right now on

1395
00:58:04,339 --> 00:57:59,940
being linked directly from to the

1396
00:58:08,329 --> 00:58:04,349
atmosphere from us I'm not sure how one

1397
00:58:09,900 --> 00:58:08,339
would actually tie that down you could

1398
00:58:14,430 --> 00:58:09,910
do carbon dating

1399
00:58:16,319 --> 00:58:14,440
on the methane you they have done carbon

1400
00:58:19,339 --> 00:58:16,329
dating on methane hydrates but that

1401
00:58:21,960 --> 00:58:19,349
tells you the age of the carbon source

1402
00:58:25,829 --> 00:58:21,970
not the age of the hydrate deposit

1403
00:58:29,190 --> 00:58:25,839
itself so consumed carbonate methane

1404
00:58:31,500 --> 00:58:29,200
hydrate deposit may migrate deposit

1405
00:58:33,240 --> 00:58:31,510
itself maybe 10,000 years old but that

1406
00:58:35,279 --> 00:58:33,250
original methane source may be 10

1407
00:58:37,829 --> 00:58:35,289
million years old and you'd be getting

1408
00:58:40,829 --> 00:58:37,839
an age for the cart for the for that

1409
00:58:43,500 --> 00:58:40,839
original carbon source so I'm not sure

1410
00:58:49,289 --> 00:58:43,510
how you would necessarily dishes of

1411
00:58:53,270 --> 00:58:49,299
carbon dating on Mars know if you

1412
00:58:59,839 --> 00:58:56,670
from methane hydrate yes for co2 hydrate

1413
00:59:01,500 --> 00:58:59,849

it depends on your depth within the

1414
00:59:04,770 --> 00:59:01,510
depends on the pressure temperature

1415
00:59:07,920 --> 00:59:04,780
conditions so is it and it's lower

1416
00:59:13,250 --> 00:59:07,930
thermal activity then regular yes ice

1417
00:59:18,390 --> 00:59:16,560
it doesn't create any instabilities in

1418
00:59:20,550 --> 00:59:18,400
the sea floor like if it's less dense or

1419
00:59:25,470 --> 00:59:20,560
lower thermal conductivity than the

1420
00:59:27,120 --> 00:59:25,480
surrounding what's more dense wait or do

1421
00:59:30,500 --> 00:59:27,130
you die here isn't with these hydrates

1422
00:59:33,330 --> 00:59:30,510
it's interesting they there haven't been

1423
00:59:35,700 --> 00:59:33,340
much talk about diet pyramid hydrates

1424
00:59:37,530 --> 00:59:35,710
because it's mostly assumed that these

1425
00:59:39,090 --> 00:59:37,540
hydrate deposits in the sea floor or in

1426
00:59:41,040 --> 00:59:39,100
constant flux they're basically

1427
00:59:44,700 --> 00:59:41,050
constantly being formed from the bottom

1428
00:59:46,950 --> 00:59:44,710
and eroded from the top versus in in

1429
00:59:49,380 --> 00:59:46,960
terms of dissociation so at the top

1430
00:59:51,510 --> 00:59:49,390
there barely an equilibrium with the sea

1431
00:59:53,010 --> 00:59:51,520
floor and they're basically constantly

1432
00:59:55,440 --> 00:59:53,020
dissociating at the bottom they're

1433
00:59:58,770 --> 00:59:55,450
constantly being recharged by more

1434
01:00:02,640 --> 00:59:58,780
methane coming into the system so i'm

1435
01:00:04,260 --> 01:00:02,650
not sure that really die peers and think

1436
01:00:05,700 --> 01:00:04,270
of that more in terms of something

1437
01:00:08,610 --> 01:00:05,710
that's been there for a while and has

1438
01:00:11,880 --> 01:00:08,620

time to flow and and move upward i'm not

1439
01:00:14,760 --> 01:00:11,890
sure that that's but you do see these

1440
01:00:17,970 --> 01:00:14,770
cracks at form i don't know if you've

1441
01:00:20,910 --> 01:00:17,980
seen that the the pictures of the sea

1442
01:00:23,160 --> 01:00:20,920
floor in the North Sea where there's

1443
01:00:25,500 --> 01:00:23,170
kind of these pockmarked type things

1444
01:00:27,870 --> 01:00:25,510
that have been suggested that those are

1445
01:00:31,110 --> 01:00:27,880
evidence of hydrate dissociation that's

1446
01:00:33,480 --> 01:00:31,120
happening within the sediment there's

1447
01:00:35,940 --> 01:00:33,490
all sorts of sedimentary structures that

1448
01:00:37,650 --> 01:00:35,950
have been suggested that they're

1449
01:00:40,290 --> 01:00:37,660
associated with with methane hydrate

1450
01:00:42,510 --> 01:00:40,300
dissociation and we're trying to do some

1451
01:00:44,460 --> 01:00:42,520
of those those large-scale laboratory

1452
01:00:48,180 --> 01:00:44,470
experiments to show whether we actually

1453
01:00:50,010 --> 01:00:48,190
see sediment deformation within our 72

1454
01:00:51,180 --> 01:00:50,020
liter vessel as as the hydrate is

1455
01:00:52,740 --> 01:00:51,190
dissociating there haven't really been

1456
01:00:55,470 --> 01:00:52,750
any controlled studies of that that I

1457
01:00:58,260 --> 01:00:55,480
know what okay well I think we

1458
01:00:59,370 --> 01:00:58,270
two tremendous end up there and you can

1459
01:01:02,609 --> 01:00:59,380
ask Megan if you still have questions

1460
01:01:04,830 --> 01:01:02,619
remind you 1030 tomorrow in Johnson 26

1461
01:01:08,340 --> 01:01:04,840
if you would like to hear another talk

1462
01:01:10,320 --> 01:01:08,350
about planetary fluids and properties of

1463
01:01:13,170 --> 01:01:10,330

their properties and tonight if you want

1464
01:01:15,420 --> 01:01:13,180
to join my crown here's is hosting they