Serpentinizing Systems Science

NASA Workshop Without Walls

1
00:00:04,150 --> 00:00:02,149
all right then uh uh good morning

2
00:00:05,430 --> 00:00:04,160
everyone and welcome back to the third

3
00:00:06,550 --> 00:00:05,440
day of this

4
00:00:19,429 --> 00:00:06,560
uh

5
00:00:22,550 --> 00:00:19,439
and then kick it over to steve vance who

6
00:00:24,630 --> 00:00:22,560
will be uh your host for the rest of the

7
00:00:26,310 --> 00:00:24,640
morning or afternoon or evening

8
00:00:28,310 --> 00:00:26,320
depending on your time zone

9
00:00:30,550 --> 00:00:28,320
anyway i just wanted to

10
00:00:32,310 --> 00:00:30,560
highlight a couple of lessons or things

11
00:00:34,790 --> 00:00:32,320
that seem to pop out

12
00:00:37,110 --> 00:00:34,800
me as what we learned from yesterday's

13
00:00:38,790 --> 00:00:37,120

session uh and i've listed those here in

14
00:00:41,350 --> 00:00:38,800
this slide and

15
00:00:43,430 --> 00:00:41,360
so one of the things that i think uh

16
00:00:46,069 --> 00:00:43,440
that is of particular relevance to

17
00:00:47,190 --> 00:00:46,079
astrobiology is the

18
00:00:48,549 --> 00:00:47,200
uh

19
00:00:50,310 --> 00:00:48,559
production of hydrogen during

20
00:00:52,950 --> 00:00:50,320
serpentinization and i think we saw

21
00:00:55,029 --> 00:00:52,960
reflected in yesterday's talk that

22
00:00:56,709 --> 00:00:55,039
kind of the rates of hydrogen generation

23
00:00:58,549 --> 00:00:56,719
are highly variable under different

24
00:00:59,750 --> 00:00:58,559
conditions and in different environments

25
00:01:03,110 --> 00:00:59,760
and uh

26
00:01:05,270 --> 00:01:03,120
but it's not really clear yet as what is

27
00:01:06,710 --> 00:01:05,280
underlying those variations and

28
00:01:08,950 --> 00:01:06,720
understanding why

29
00:01:11,190 --> 00:01:08,960
those variations occur and how it might

30
00:01:12,550 --> 00:01:11,200
translate into how much hydrogen might

31
00:01:13,670 --> 00:01:12,560
be applied in different kinds of

32
00:01:15,350 --> 00:01:13,680
environments

33
00:01:17,109 --> 00:01:15,360
it's something that really needs a lot

34
00:01:19,109 --> 00:01:17,119
more work to go on

35
00:01:20,550 --> 00:01:19,119
as we go forward

36
00:01:22,390 --> 00:01:20,560
uh very

37
00:01:25,030 --> 00:01:22,400
intimately key

38
00:01:26,950 --> 00:01:25,040

linked into that is the distribution of

39
00:01:28,870 --> 00:01:26,960
iron among the products which really

40
00:01:31,510 --> 00:01:28,880
controls the hydrogen production thank

41
00:01:34,069 --> 00:01:31,520
you and uh i think we've seen uh

42
00:01:35,910 --> 00:01:34,079
yesterday in a couple of talks that

43
00:01:37,990 --> 00:01:35,920
there really is a lot of heterogeneity

44
00:01:39,670 --> 00:01:38,000
and where that iron goes and reaction

45
00:01:42,149 --> 00:01:39,680
products and

46
00:01:43,910 --> 00:01:42,159
and uh how that gets reflected in the

47
00:01:45,990 --> 00:01:43,920
hydrogen production and again that's an

48
00:01:48,230 --> 00:01:46,000
area where i think we really need to

49
00:01:51,190 --> 00:01:48,240
uh have a lot more work to see

50
00:01:53,190 --> 00:01:51,200
uh to really look in samples and natural

51
00:01:56,230 --> 00:01:53,200
samples and see where it's going and do

52
00:01:57,670 --> 00:01:56,240
more uh modeling and theoretical work

53
00:01:59,910 --> 00:01:57,680
and experimental work to really

54
00:02:01,590 --> 00:01:59,920
understand what's controlling where that

55
00:02:04,870 --> 00:02:01,600
iron is going

56
00:02:07,109 --> 00:02:04,880
uh we saw yesterday from uh sanjoy and

57
00:02:09,029 --> 00:02:07,119
the previous day from everett shock

58
00:02:12,470 --> 00:02:09,039
that we're seeing the models are really

59
00:02:14,390 --> 00:02:12,480
uh progressing in order in and uh

60
00:02:16,550 --> 00:02:14,400
helping us understand

61
00:02:18,869 --> 00:02:16,560
our ability to map out

62
00:02:21,750 --> 00:02:18,879
uh where energy sources occur in these

63
00:02:23,670 --> 00:02:21,760

kind of environments and what conditions

64
00:02:24,949 --> 00:02:23,680
uh make it more favorable and less

65
00:02:27,670 --> 00:02:24,959
favorable

66
00:02:29,110 --> 00:02:27,680
to support life uh and i think going

67
00:02:31,110 --> 00:02:29,120
forward it's gonna be interesting to see

68
00:02:33,110 --> 00:02:31,120
how well those predictions

69
00:02:35,110 --> 00:02:33,120
uh compare with observations in the

70
00:02:36,790 --> 00:02:35,120
natural systems and and try and link

71
00:02:37,750 --> 00:02:36,800
those two together and see if we can

72
00:02:38,550 --> 00:02:37,760
come to

73
00:02:55,589 --> 00:02:38,560
a

74
00:02:57,670 --> 00:02:55,599
serpentinizing

75
00:02:59,750 --> 00:02:57,680
environment are continuing to evolve as

76
00:03:01,509 --> 00:02:59,760
we begin to know more

77
00:03:03,110 --> 00:03:01,519
about the systems and learn more about

78
00:03:05,830 --> 00:03:03,120
the chemistry and

79
00:03:08,470 --> 00:03:05,840
it goes on in those systems and uh

80
00:03:10,070 --> 00:03:08,480
a lot of this stuff is still really very

81
00:03:12,630 --> 00:03:10,080
much hypothetical

82
00:03:14,309 --> 00:03:12,640
and needs to be tested experimentally so

83
00:03:15,830 --> 00:03:14,319
i'm looking forward to

84
00:03:17,750 --> 00:03:15,840
more developments in terms of

85
00:03:19,509 --> 00:03:17,760
experimentally testing some of the ideas

86
00:03:22,149 --> 00:03:19,519
that mike and others have proposed in

87
00:03:24,470 --> 00:03:22,159
terms of what might have led to origins

88
00:03:27,430 --> 00:03:24,480

of life on earth and serpentinizing

89
00:03:29,910 --> 00:03:27,440
systems and what might be

90
00:03:32,390 --> 00:03:29,920
uh take place somewhere else in our

91
00:03:33,750 --> 00:03:32,400
solar system where we see serpentizing

92
00:03:36,550 --> 00:03:33,760
systems and whether that could have led

93
00:03:39,030 --> 00:03:36,560
to an another origin of life

94
00:03:40,789 --> 00:03:39,040
and lastly i just wanted to comment that

95
00:03:43,270 --> 00:03:40,799
you know we didn't really have time to

96
00:03:44,470 --> 00:03:43,280
even get into the abiotic carbon sources

97
00:03:45,990 --> 00:03:44,480
story

98
00:03:47,350 --> 00:03:46,000
so a lot of people are interested in the

99
00:03:48,229 --> 00:03:47,360
potential for

100
00:03:50,390 --> 00:03:48,239
uh

101
00:03:53,270 --> 00:03:50,400
circuit and serpentinizing systems to

102
00:03:55,429 --> 00:03:53,280
make methane making avionic methane

103
00:03:56,149 --> 00:03:55,439
uh both as a source for for

104
00:03:58,630 --> 00:03:56,159
uh

105
00:04:01,270 --> 00:03:58,640
microbial metabolism and also as a

106
00:04:03,429 --> 00:04:01,280
potential signature for looking

107
00:04:06,390 --> 00:04:03,439
to see if we can determine whether life

108
00:04:08,229 --> 00:04:06,400
exists on other planets uh but

109
00:04:09,990 --> 00:04:08,239
that's a that's an area that's really a

110
00:04:11,910 --> 00:04:10,000
lot of ongoing research and that's

111
00:04:14,229 --> 00:04:11,920
something that we didn't really even get

112
00:04:16,150 --> 00:04:14,239
to touch on yesterday but we we need to

113
00:04:17,990 --> 00:04:16,160

keep in mind

114
00:04:21,509 --> 00:04:18,000
and that's pretty much all i had to say

115
00:04:27,030 --> 00:04:21,519
so uh i'm going to kick it over to

116
00:04:27,040 --> 00:04:35,350
all right tom thanks so much

117
00:04:40,070 --> 00:04:37,189
yeah it's been an exciting couple days

118
00:04:45,110 --> 00:04:40,080
i've certainly learned a lot and uh

119
00:04:49,510 --> 00:04:47,030
today's session is about planetary

120
00:04:52,150 --> 00:04:49,520
serpentine is that

121
00:04:54,469 --> 00:04:52,160
i'm sorry it seems that the

122
00:04:56,469 --> 00:04:54,479
widescreen slide is a little bit cut off

123
00:04:57,830 --> 00:04:56,479
i think for most of my other slides this

124
00:05:01,110 --> 00:04:57,840
will not be

125
00:05:02,550 --> 00:05:01,120
uh too much of a problem

126
00:05:05,270 --> 00:05:02,560
i'll just say what i have to say and let

127
00:05:07,510 --> 00:05:05,280
the other speakers take over um so

128
00:05:08,950 --> 00:05:07,520
planetary servantization as you know

129
00:05:10,390 --> 00:05:08,960
thinking about serpentinization in the

130
00:05:13,510 --> 00:05:10,400
planetary context

131
00:05:15,110 --> 00:05:13,520
uh encourages us also to think about the

132
00:05:17,110 --> 00:05:15,120
earth planetary context of

133
00:05:17,990 --> 00:05:17,120
serpentinization

134
00:05:20,469 --> 00:05:18,000
so

135
00:05:23,510 --> 00:05:20,479
what we observe on earth comes about by

136
00:05:29,350 --> 00:05:26,469
the configuration of earth continents uh

137
00:05:31,990 --> 00:05:29,360
and the relation of earth's um

138
00:05:35,270 --> 00:05:32,000

surface layer to its deeper interior and

139
00:05:39,590 --> 00:05:37,749
similarly other worlds will have a

140
00:05:40,710 --> 00:05:39,600
similar set of conditions that influence

141
00:05:41,590 --> 00:05:40,720
what we observe

142
00:05:44,310 --> 00:05:41,600
and

143
00:05:46,550 --> 00:05:44,320
how do i advance my slide

144
00:05:49,029 --> 00:05:46,560
like that

145
00:05:49,909 --> 00:05:49,039
okay so the earth system again we are

146
00:05:51,909 --> 00:05:49,919
this

147
00:05:54,550 --> 00:05:51,919
little soup skin on top of the the

148
00:05:55,590 --> 00:05:54,560
mantle with the crust underneath uh our

149
00:05:58,870 --> 00:05:55,600
ocean

150
00:05:59,590 --> 00:05:58,880
and the continents uh interact um

151
00:06:05,189 --> 00:05:59,600
with

152
00:06:07,270 --> 00:06:05,199
the underlying rock

153
00:06:10,309 --> 00:06:07,280
just

154
00:06:12,070 --> 00:06:10,319
constrained depth um and the composition

155
00:06:14,870 --> 00:06:12,080
of those rocks determines the materials

156
00:06:15,830 --> 00:06:14,880
that come out um so

157
00:06:18,230 --> 00:06:15,840
um

158
00:06:19,749 --> 00:06:18,240
similarly planet understanding planetary

159
00:06:22,550 --> 00:06:19,759
serpentinization will be about

160
00:06:24,790 --> 00:06:22,560
understanding other system uh contexts

161
00:06:27,590 --> 00:06:24,800
and how that relates to habitability

162
00:06:28,950 --> 00:06:27,600
we want to understand um what we might

163
00:06:30,870 --> 00:06:28,960

be able to observe with upcoming

164
00:06:32,710 --> 00:06:30,880
missions here's the europa

165
00:06:35,430 --> 00:06:32,720
multiple flyby mission that's planned to

166
00:06:37,510 --> 00:06:35,440
arrive at europa in 2026 and we'll have

167
00:06:38,710 --> 00:06:37,520
a suite of instruments um to look at the

168
00:06:40,950 --> 00:06:38,720
surface and try to understand the

169
00:06:43,270 --> 00:06:40,960
composition of the ocean uh these are

170
00:06:46,309 --> 00:06:44,230
but

171
00:06:48,309 --> 00:06:46,319
there's a capable suite of remote

172
00:06:51,589 --> 00:06:48,319
sensing instruments to understand the

173
00:06:52,390 --> 00:06:51,599
surface composition and geology

174
00:06:54,309 --> 00:06:52,400
and

175
00:06:56,390 --> 00:06:54,319
instead of in situ instruments here

176
00:06:58,150 --> 00:06:56,400
shown in red that includes two mass

177
00:06:59,589 --> 00:06:58,160
spectrometers

178
00:07:01,830 --> 00:06:59,599
that could

179
00:07:05,029 --> 00:07:01,840
taste the ocean um if there are

180
00:07:06,070 --> 00:07:05,039
materials that are lofted from this

181
00:07:08,550 --> 00:07:06,080
from the

182
00:07:11,029 --> 00:07:08,560
from within the ice via um yet to be

183
00:07:13,510 --> 00:07:11,039
confirmed plumes um so there's some hope

184
00:07:15,510 --> 00:07:13,520
that we will be able to infer something

185
00:07:18,230 --> 00:07:15,520
about serpentinization what i'd really

186
00:07:20,629 --> 00:07:18,240
like to see from some of the experts

187
00:07:22,790 --> 00:07:20,639
who've been attending this meeting is

188
00:07:24,629 --> 00:07:22,800

some weighing in about

189
00:07:26,790 --> 00:07:24,639
uh the detailed signatures for example

190
00:07:28,550 --> 00:07:26,800
isotopic signatures or mineral

191
00:07:32,629 --> 00:07:28,560
signatures that we should really look

192
00:07:38,710 --> 00:07:35,909
some hints of the ocean composition

193
00:07:40,390 --> 00:07:38,720
similar story applies at

194
00:07:42,469 --> 00:07:40,400
other worlds like enceladus which we'll

195
00:07:45,029 --> 00:07:42,479
hear about later

196
00:07:47,189 --> 00:07:45,039
and the upcoming mars 2020 rover also

197
00:07:49,830 --> 00:07:47,199
has a capable set of instruments

198
00:07:52,309 --> 00:07:49,840
including uh

199
00:07:55,270 --> 00:07:52,319
spectrometers um we heard about some

200
00:07:57,350 --> 00:07:55,280
advanced uh techniques uh yesterday uh

201
00:07:59,670 --> 00:07:57,360
including the application of raman to

202
00:08:01,909 --> 00:07:59,680
understanding the detailed uh

203
00:08:03,670 --> 00:08:01,919
mineral progression

204
00:08:07,110 --> 00:08:03,680
that can tell us something about the

205
00:08:10,390 --> 00:08:08,869
system context let me just say a few

206
00:08:12,710 --> 00:08:10,400
things about

207
00:08:14,550 --> 00:08:12,720
europa as an example of the kinds of

208
00:08:16,390 --> 00:08:14,560
things that we want to understand in

209
00:08:18,950 --> 00:08:16,400
terms of the habitability context of

210
00:08:19,670 --> 00:08:18,960
serpentinization

211
00:08:22,790 --> 00:08:19,680
so

212
00:08:24,550 --> 00:08:22,800
well let me by to to get at that let me

213
00:08:26,469 --> 00:08:24,560

let me just emphasize that the earth

214
00:08:28,230 --> 00:08:26,479
system is complex

215
00:08:32,310 --> 00:08:28,240
there are a lot of different reservoirs

216
00:08:36,949 --> 00:08:34,550
habitable and um

217
00:08:38,949 --> 00:08:36,959
the context of serenitization then as

218
00:08:40,550 --> 00:08:38,959
illustrated in this figure from a paper

219
00:08:42,550 --> 00:08:40,560
by sherwood lawler is about

220
00:08:45,829 --> 00:08:42,560
understanding um

221
00:08:48,470 --> 00:08:45,839
what's the flux so what is the

222
00:08:49,990 --> 00:08:48,480
amount of material that's generated and

223
00:08:53,030 --> 00:08:50,000
how does that couple into the global

224
00:08:57,269 --> 00:08:54,550
that's that for a lot of different

225
00:08:58,310 --> 00:08:57,279
reservoirs um you know so these are the

226
00:08:59,670 --> 00:08:58,320
these are the

227
00:09:01,350 --> 00:08:59,680
um

228
00:09:02,790 --> 00:09:01,360
reservoirs that were examined in this

229
00:09:05,110 --> 00:09:02,800
paper the

230
00:09:07,590 --> 00:09:05,120
um alteration of the oceanic crust

231
00:09:09,269 --> 00:09:07,600
spreading ridges um

232
00:09:11,110 --> 00:09:09,279
and um

233
00:09:13,269 --> 00:09:11,120
periodize

234
00:09:15,350 --> 00:09:13,279
um so we can ask what are the what are

235
00:09:18,790 --> 00:09:15,360
the reservoirs on other worlds i want to

236
00:09:20,870 --> 00:09:18,800
emphasize that these reservoirs um can

237
00:09:22,949 --> 00:09:20,880
change with time earth's history is

238
00:09:24,550 --> 00:09:22,959

complex um

239
00:09:28,630 --> 00:09:24,560
this this group probably understands

240
00:09:32,949 --> 00:09:31,509
the evolution of redox fluxes on earth

241
00:09:34,470 --> 00:09:32,959
has changed through time and is

242
00:09:35,430 --> 00:09:34,480
intimately coupled with the evolution of

243
00:09:36,389 --> 00:09:35,440
life

244
00:09:37,350 --> 00:09:36,399
okay so

245
00:09:42,310 --> 00:09:37,360
thinking about planetary

246
00:09:43,990 --> 00:09:42,320
serpentinization um what is the flux um

247
00:09:45,590 --> 00:09:44,000
one question we ask we have to ask is

248
00:09:47,350 --> 00:09:45,600
what is the abundance of materials that

249
00:09:49,350 --> 00:09:47,360
may be serpentinized

250
00:09:52,230 --> 00:09:49,360
so this is something that mckinnon and

251
00:09:54,470 --> 00:09:52,240
zolensky asked in 2003

252
00:09:58,630 --> 00:09:54,480
and this is a question that's coupled to

253
00:10:02,150 --> 00:10:00,470
so this figure is showing the formation

254
00:10:03,590 --> 00:10:02,160
temperature of the object the average

255
00:10:04,389 --> 00:10:03,600
formation the bulk temperature of the

256
00:10:06,389 --> 00:10:04,399
object

257
00:10:08,150 --> 00:10:06,399
as a function of size and here i've

258
00:10:10,870 --> 00:10:08,160
indicated the sizes of enceladus and

259
00:10:12,870 --> 00:10:10,880
europa as vertical lines uh and i've set

260
00:10:14,630 --> 00:10:12,880
horizontal lines

261
00:10:16,470 --> 00:10:14,640
showing that the

262
00:10:18,630 --> 00:10:16,480
critical transitions from the stability

263
00:10:20,949 --> 00:10:18,640

of serpentine to olivine and the melting

264
00:10:22,949 --> 00:10:20,959
of four stripe and phallite

265
00:10:25,190 --> 00:10:22,959
h corresponds to

266
00:10:27,990 --> 00:10:25,200
the qualitative heat retention

267
00:10:33,190 --> 00:10:30,230
that is typically assumed to be between

268
00:10:36,470 --> 00:10:33,200
0.4 and 0.5 so what this is saying is

269
00:10:38,790 --> 00:10:36,480
that europa is just marginally

270
00:10:40,870 --> 00:10:38,800
based on the assumptions and this that

271
00:10:43,350 --> 00:10:40,880
were made in creating this figure just

272
00:10:45,990 --> 00:10:43,360
marginally at the transition of starting

273
00:10:48,150 --> 00:10:46,000
with an anhydrous interior

274
00:10:50,710 --> 00:10:48,160
now if we add tidal heating short-lived

275
00:10:52,389 --> 00:10:50,720
radionuclides um it's easier to imagine

276
00:10:54,550 --> 00:10:52,399
that it got hot

277
00:10:56,470 --> 00:10:54,560
the observation of

278
00:10:58,630 --> 00:10:56,480
signatures of a reduced ocean and

279
00:11:00,949 --> 00:10:58,640
enceladus indicate that

280
00:11:02,949 --> 00:11:00,959
something like surprisation has occurred

281
00:11:07,590 --> 00:11:02,959
um so there's more to this story but

282
00:11:12,870 --> 00:11:09,990
okay so the other question is how much

283
00:11:16,470 --> 00:11:12,880
material is accessible by water that is

284
00:11:18,790 --> 00:11:16,480
um if you have a peridotitic mantle um

285
00:11:22,150 --> 00:11:18,800
is all of it altered for earth that is

286
00:11:24,230 --> 00:11:22,160
probably not the case uh

287
00:11:27,269 --> 00:11:24,240
some detail in the last couple days and

288
00:11:28,630 --> 00:11:27,279

this figure is indicating in light brown

289
00:11:30,470 --> 00:11:28,640
the

290
00:11:31,990 --> 00:11:30,480
presumed

291
00:11:33,590 --> 00:11:32,000
depth of alteration this is on a

292
00:11:35,590 --> 00:11:33,600
relative scale

293
00:11:37,990 --> 00:11:35,600
this is from work that i did now 10

294
00:11:39,590 --> 00:11:38,000
years ago

295
00:11:42,550 --> 00:11:39,600
estimating the depth of fluid

296
00:11:44,630 --> 00:11:42,560
percolation in other objects so the

297
00:11:47,750 --> 00:11:44,640
assertion is that in a cooler mantle on

298
00:11:49,990 --> 00:11:47,760
mars fluids can percolate deeper um also

299
00:11:52,629 --> 00:11:50,000
that percol

300
00:11:54,949 --> 00:11:52,639
the object pools uh and so you should

301
00:11:57,910 --> 00:11:54,959
expect to have a greater reservoir of

302
00:12:00,150 --> 00:11:57,920
alterable material and at enceladus the

303
00:12:01,590 --> 00:12:00,160
entire material may be subject to water

304
00:12:04,550 --> 00:12:01,600
rock alteration

305
00:12:06,710 --> 00:12:04,560
um this is just a figure from a recent

306
00:12:08,310 --> 00:12:06,720
revisiting of that work

307
00:12:11,910 --> 00:12:08,320
that came out

308
00:12:13,509 --> 00:12:11,920
this last year 2016.

309
00:12:15,910 --> 00:12:13,519
envisioning the

310
00:12:18,629 --> 00:12:15,920
rocky interiors of these objects uh as a

311
00:12:19,990 --> 00:12:18,639
function of pressure and temper

312
00:12:22,389 --> 00:12:20,000
ocean depth

313
00:12:24,150 --> 00:12:22,399

so callisto and titan and ganymede start

314
00:12:25,910 --> 00:12:24,160
at very high depths or very high

315
00:12:28,069 --> 00:12:25,920
pressures rather because they have very

316
00:12:30,310 --> 00:12:28,079
deep oceans

317
00:12:31,750 --> 00:12:30,320
a result of that might be that in these

318
00:12:33,350 --> 00:12:31,760
larger worlds

319
00:12:36,150 --> 00:12:33,360
the extent of serpentinization may be

320
00:12:40,069 --> 00:12:38,360
confirmed by observation um

321
00:12:40,949 --> 00:12:40,079
[Music]

322
00:12:42,389 --> 00:12:40,959
so

323
00:12:44,470 --> 00:12:42,399
then we can ask what are the

324
00:12:45,230 --> 00:12:44,480
corresponding heat and reduction fluxes

325
00:12:50,230 --> 00:12:45,240
from

326
00:12:54,949 --> 00:12:53,030
now the serpentinization i will i will

327
00:12:56,550 --> 00:12:54,959
indicate from uh

328
00:12:58,949 --> 00:12:56,560
the figure from the same paper that came

329
00:13:02,550 --> 00:12:58,959
out last year um this is looking back in

330
00:13:04,230 --> 00:13:02,560
time um as the object uh in question

331
00:13:07,670 --> 00:13:04,240
cools um

332
00:13:08,389 --> 00:13:07,680
the um more materials exposed and so you

333
00:13:10,230 --> 00:13:08,399
can

334
00:13:12,790 --> 00:13:10,240
correlate that

335
00:13:14,790 --> 00:13:12,800
year per second uh amount of release of

336
00:13:16,470 --> 00:13:14,800
heat and hydrogen so just looking at the

337
00:13:17,750 --> 00:13:16,480
right of um

338
00:13:18,829 --> 00:13:17,760

the right side of the figure on the

339
00:13:21,350 --> 00:13:18,839
right at

340
00:13:23,590 --> 00:13:21,360
zero billion years ago that's the

341
00:13:26,150 --> 00:13:23,600
present day and i'm indicating uh the

342
00:13:29,750 --> 00:13:26,160
range of estimated fluxes of h2 for

343
00:13:31,509 --> 00:13:29,760
earth um to quite a broad range but it's

344
00:13:33,910 --> 00:13:31,519
less than the

345
00:13:37,110 --> 00:13:33,920
net oxygen production on earth as

346
00:13:38,710 --> 00:13:37,120
estimated as described in

347
00:13:39,990 --> 00:13:38,720
you know we can ask are there similar

348
00:13:41,990 --> 00:13:40,000
stories that we can construct for these

349
00:13:43,030 --> 00:13:42,000
other objects i did that for europa in

350
00:13:44,310 --> 00:13:43,040
this paper

351
00:13:46,150 --> 00:13:44,320
um

352
00:13:49,030 --> 00:13:46,160
but you know it's interesting to ask

353
00:13:51,590 --> 00:13:49,040
whether global serpentinization will

354
00:13:54,790 --> 00:13:51,600
be able to produce more hydrogen

355
00:13:56,949 --> 00:13:54,800
on mars europa enceladus series

356
00:13:58,550 --> 00:13:56,959
than is produced on earth

357
00:14:01,189 --> 00:13:58,560
the left side the left figure showing

358
00:14:03,030 --> 00:14:01,199
the serpentinization heat the the lower

359
00:14:05,990 --> 00:14:03,040
curves or the pentamization heat

360
00:14:07,590 --> 00:14:06,000
milliwatts per meter squared um

361
00:14:09,829 --> 00:14:07,600
the radiogenic heat

362
00:14:11,750 --> 00:14:09,839
is always much larger so that the amount

363
00:14:13,910 --> 00:14:11,760

of heat generated globally is not large

364
00:14:17,750 --> 00:14:13,920
perhaps it's nevertheless important for

365
00:14:22,389 --> 00:14:17,760
driving uh hydrothermal activity

366
00:14:25,990 --> 00:14:24,629
the other speaker's gonna have to uh and

367
00:14:28,550 --> 00:14:26,000
so yeah we've got some great talks lined

368
00:14:32,310 --> 00:14:28,560
up uh christoph zotan elena amador mark

369
00:14:34,470 --> 00:14:32,320
neva klein with some uh pop-up talks uh

370
00:14:36,310 --> 00:14:34,480
i believe at this point we have um

371
00:14:37,350 --> 00:14:36,320
uh julie castillo

372
00:14:40,389 --> 00:14:37,360
um

373
00:14:42,150 --> 00:14:40,399
brown

374
00:14:48,389 --> 00:14:42,160
uh and penny morill

375
00:14:54,470 --> 00:14:51,670
okay well i have to unmute first and i

376
00:14:55,430 --> 00:14:54,480
have you you told me 25 minutes is that

377
00:14:56,949 --> 00:14:55,440
correct

378
00:15:00,710 --> 00:14:56,959
yeah

379
00:15:03,750 --> 00:15:00,720
okay so i first need to share my my uh

380
00:15:06,150 --> 00:15:03,760
webcam i guess

381
00:15:09,990 --> 00:15:06,160
yep okay

382
00:15:16,629 --> 00:15:13,509
the webcam on my computer interesting

383
00:15:19,269 --> 00:15:16,639
and uh well so steve asked me to

384
00:15:22,470 --> 00:15:19,279
um give a talk more about the evidences

385
00:15:24,389 --> 00:15:22,480
for extraterrestrial hydrated silicates

386
00:15:28,230 --> 00:15:24,399
and at the beginning i thought it was

387
00:15:29,670 --> 00:15:28,240
only on on ocean worlds

388
00:15:31,509 --> 00:15:29,680

but

389
00:15:33,470 --> 00:15:31,519
then i decided to put something on mold

390
00:15:34,949 --> 00:15:33,480
because i did some more

391
00:15:36,949 --> 00:15:34,959
[Music]

392
00:15:38,470 --> 00:15:36,959
work some time ago and we know that one

393
00:15:40,710 --> 00:15:38,480
more there are some hydrated tickets

394
00:15:42,230 --> 00:15:40,720
there

395
00:15:46,069 --> 00:15:42,240
so

396
00:15:47,590 --> 00:15:46,079
hydrated treats i guess uh

397
00:15:49,030 --> 00:15:47,600
we heard that yesterday and the day

398
00:15:51,030 --> 00:15:49,040
before

399
00:15:54,629 --> 00:15:51,040
it's about the emergence of life at

400
00:15:55,910 --> 00:15:54,639
places where water and rock can react

401
00:16:00,069 --> 00:15:55,920
and

402
00:16:02,389 --> 00:16:00,079
also there is this exploration of ocean

403
00:16:04,389 --> 00:16:02,399
worlds and to see places in these ocean

404
00:16:06,230 --> 00:16:04,399
worlds where we can have this

405
00:16:09,189 --> 00:16:06,240
interaction between

406
00:16:12,550 --> 00:16:09,199
water and rocks

407
00:16:15,110 --> 00:16:12,560
uh so i put together um the different

408
00:16:16,230 --> 00:16:15,120
places and the solar system where we can

409
00:16:18,150 --> 00:16:16,240
uh

410
00:16:21,269 --> 00:16:18,160
have this kind of interaction we know

411
00:16:23,670 --> 00:16:21,279
that on mars there was water from when

412
00:16:25,590 --> 00:16:23,680
mars was younger and

413
00:16:26,629 --> 00:16:25,600

i guess at the end of the night ken

414
00:16:28,310 --> 00:16:26,639
period

415
00:16:30,470 --> 00:16:28,320
people mentioned we know that there are

416
00:16:33,110 --> 00:16:30,480
river networks it's possible that there

417
00:16:34,829 --> 00:16:33,120
was an ocean on mars at some point

418
00:16:36,550 --> 00:16:34,839
of course the earth is our

419
00:16:37,990 --> 00:16:36,560
benchmark and

420
00:16:40,629 --> 00:16:38,000
then

421
00:16:41,670 --> 00:16:40,639
i mean on this on this line uh

422
00:16:48,629 --> 00:16:41,680
the

423
00:16:50,230 --> 00:16:48,639
it increases with atmospheric density at

424
00:16:51,990 --> 00:16:50,240
the surface and so that's why you have

425
00:16:54,310 --> 00:16:52,000
titan which is here

426
00:16:56,470 --> 00:16:54,320
on titans the pressure at the surface is

427
00:16:58,230 --> 00:16:56,480
1.5 bar but the density is about four

428
00:17:00,629 --> 00:16:58,240
times the density that we have on earth

429
00:17:03,110 --> 00:17:00,639
because the temperature is much smaller

430
00:17:04,949 --> 00:17:03,120
and i will come back on on titan later

431
00:17:07,590 --> 00:17:04,959
but uh you will see that from the

432
00:17:09,029 --> 00:17:07,600
gravity data that were acquired by the

433
00:17:11,669 --> 00:17:09,039
casino mission

434
00:17:14,150 --> 00:17:11,679
um we think that the interior of titan

435
00:17:15,429 --> 00:17:14,160
is made of hydrated silicate and so it's

436
00:17:18,549 --> 00:17:15,439
a huge

437
00:17:20,230 --> 00:17:18,559
actually

438
00:17:22,789 --> 00:17:20,240

and then we have venus so for venus we

439
00:17:25,189 --> 00:17:22,799
don't have any uh evidence for that an

440
00:17:27,829 --> 00:17:25,199
ocean existed in the past but venus had

441
00:17:29,350 --> 00:17:27,839
resurfacing about 500 million years ago

442
00:17:31,590 --> 00:17:29,360
or maybe one billion years ago and we

443
00:17:33,510 --> 00:17:31,600
don't know exactly what happened before

444
00:17:36,070 --> 00:17:33,520
then the vertical axis

445
00:17:37,830 --> 00:17:36,080
i put that as ocean rock exchange

446
00:17:40,710 --> 00:17:37,840
and so on the vertical axis i'm trying

447
00:17:48,870 --> 00:17:40,720
to get the green arrow for what do i

448
00:17:52,789 --> 00:17:50,630
oh yeah just um chris click on your

449
00:17:57,669 --> 00:17:52,799
slides where you want uh the arrow to go

450
00:18:01,909 --> 00:17:59,990
yeah so um if you have ganymede and

451
00:18:04,070 --> 00:18:01,919
ganymede is an interesting case and i

452
00:18:05,190 --> 00:18:04,080
will start with ganymede in my next

453
00:18:07,029 --> 00:18:05,200
slide

454
00:18:09,750 --> 00:18:07,039
uh then you have titan which is here

455
00:18:13,029 --> 00:18:09,760
where i just mentioned the iot kit

456
00:18:15,510 --> 00:18:13,039
uh i put europa and steve mentioned

457
00:18:18,230 --> 00:18:15,520
europa you can see the ocean on europa

458
00:18:21,029 --> 00:18:18,240
is much thinner than the ocean we can

459
00:18:22,870 --> 00:18:21,039
have on the ganymede or or titan and

460
00:18:24,789 --> 00:18:22,880
then there is answer and something we

461
00:18:26,230 --> 00:18:24,799
have to keep in mind is also the size of

462
00:18:29,350 --> 00:18:26,240
the different bodies so it's not

463
00:18:31,990 --> 00:18:29,360

respected here i'm sorry i couldn't

464
00:18:34,630 --> 00:18:32,000
make a nicer slide but anthrax is only

465
00:18:37,470 --> 00:18:34,640
250 kilometers in radius

466
00:18:40,710 --> 00:18:37,480
um titan is 22

467
00:18:42,870 --> 00:18:40,720
575 kilometers so it's about 10 times in

468
00:18:45,110 --> 00:18:42,880
the size of entreaders in terms of

469
00:18:47,590 --> 00:18:45,120
radius but of course the earth is more

470
00:18:50,070 --> 00:18:47,600
than 6000 kilometers in radius so it's

471
00:18:51,909 --> 00:18:50,080
uh twice as large as titan

472
00:18:53,990 --> 00:18:51,919
ganymede and titan are about the same

473
00:18:56,470 --> 00:18:54,000
size

474
00:18:57,270 --> 00:18:56,480
so the you know the questions we

475
00:18:59,350 --> 00:18:57,280
we

476
00:19:01,430 --> 00:18:59,360
want to ask and

477
00:19:03,750 --> 00:19:01,440
maybe several of them but uh what are

478
00:19:05,830 --> 00:19:03,760
the conditions uh which

479
00:19:08,470 --> 00:19:05,840
for example make titan and ganymede so

480
00:19:10,230 --> 00:19:08,480
different why ganymede you we don't

481
00:19:12,230 --> 00:19:10,240
think that there is a hydrated g case

482
00:19:14,310 --> 00:19:12,240
whereas on titan we

483
00:19:16,230 --> 00:19:14,320
it seems like we have identity but i

484
00:19:17,830 --> 00:19:16,240
just want to focus on

485
00:19:21,909 --> 00:19:17,840
on the evidences so i will start with

486
00:19:25,270 --> 00:19:23,990
i'm not using the right button okay here

487
00:19:27,830 --> 00:19:25,280
we are

488
00:19:29,990 --> 00:19:27,840

so on mars there were two infrared

489
00:19:32,789 --> 00:19:30,000
mapping spectrometers on north express

490
00:19:34,710 --> 00:19:32,799
we had the omega

491
00:19:36,950 --> 00:19:34,720
which uh

492
00:19:38,390 --> 00:19:36,960
which acquired the first uh i think it's

493
00:19:40,630 --> 00:19:38,400
it raised instruments that discovered

494
00:19:43,190 --> 00:19:40,640
the hydrated silicates on the

495
00:19:45,510 --> 00:19:43,200
on hydrated mirrors sorry let's see

496
00:19:47,510 --> 00:19:45,520
hydrated mirrors on the surface of mars

497
00:19:50,070 --> 00:19:47,520
and this is a map that was published in

498
00:19:52,310 --> 00:19:50,080
2007

499
00:19:54,230 --> 00:19:52,320
and eight by francois pulley and john

500
00:19:56,230 --> 00:19:54,240
mustard

501
00:19:58,470 --> 00:19:56,240
and so there are the different places

502
00:19:59,590 --> 00:19:58,480
where they identify the hydrated

503
00:20:01,430 --> 00:19:59,600
minerals

504
00:20:03,110 --> 00:20:01,440
and then chrisam

505
00:20:04,549 --> 00:20:03,120
had a much higher

506
00:20:07,990 --> 00:20:04,559
resolution

507
00:20:11,430 --> 00:20:08,000
and chrism found out something like uh

508
00:20:13,350 --> 00:20:11,440
1200 occurrences are hydrated kits these

509
00:20:16,070 --> 00:20:13,360
are the red points uh you can see so

510
00:20:18,310 --> 00:20:16,080
although most of the poles are located

511
00:20:20,470 --> 00:20:18,320
in the southern hemisphere of morse

512
00:20:22,310 --> 00:20:20,480
which is elevated you can see that there

513
00:20:24,149 --> 00:20:22,320

are a few places in the northern

514
00:20:26,710 --> 00:20:24,159
hemisphere where apparently you have

515
00:20:28,310 --> 00:20:26,720
also some hydrated silicates

516
00:20:30,950 --> 00:20:28,320
and there may be you know some

517
00:20:33,190 --> 00:20:30,960
difficulty in finding the hydrated

518
00:20:36,789 --> 00:20:33,200
minerals in the northern hemisphere

519
00:20:39,190 --> 00:20:36,799
because infrared the um infrared remote

520
00:20:41,190 --> 00:20:39,200
sensing can see only the few

521
00:20:42,549 --> 00:20:41,200
micrometers of the surface or maybe the

522
00:20:44,149 --> 00:20:42,559
you know the few millimeters of the

523
00:20:45,669 --> 00:20:44,159
surface and you have a lot of dust in

524
00:20:46,549 --> 00:20:45,679
the northern hemisphere so it's not

525
00:20:47,430 --> 00:20:46,559
clear

526
00:20:49,029 --> 00:20:47,440
that

527
00:20:51,590 --> 00:20:49,039
you don't have

528
00:20:55,669 --> 00:20:51,600
more hydrated minerals

529
00:20:59,430 --> 00:20:56,630
uh

530
00:21:01,110 --> 00:20:59,440
then you know all the information and

531
00:21:03,029 --> 00:21:01,120
i show that because

532
00:21:05,110 --> 00:21:03,039
a mars has a

533
00:21:08,149 --> 00:21:05,120
remnant magnetic field in the southern

534
00:21:09,909 --> 00:21:08,159
hemisphere and one way you can create a

535
00:21:12,390 --> 00:21:09,919
remnant magnetic field

536
00:21:16,230 --> 00:21:12,400
is by having some magnetite

537
00:21:18,070 --> 00:21:16,240
crystallizing uh into uh

538
00:21:20,149 --> 00:21:18,080

a magnetic field of mars and we believe

539
00:21:22,950 --> 00:21:20,159
that more sun must have had a magnetic

540
00:21:25,350 --> 00:21:22,960
field early on and of course magnetite

541
00:21:26,470 --> 00:21:25,360
can be formed if you hydrate the the

542
00:21:28,789 --> 00:21:26,480
minerals

543
00:21:31,590 --> 00:21:28,799
so it's interesting to see that most of

544
00:21:34,390 --> 00:21:31,600
the of the magnetic field is located in

545
00:21:35,909 --> 00:21:34,400
the south and hemisphere which is also

546
00:21:39,909 --> 00:21:35,919
more elevated

547
00:21:42,870 --> 00:21:39,919
and that's what triggered a study

548
00:21:45,350 --> 00:21:42,880
by johann canella

549
00:21:47,029 --> 00:21:45,360
in uh published in 2008 i think it was

550
00:21:49,430 --> 00:21:47,039
in epsilon

551
00:21:52,789 --> 00:21:49,440
and in this model we just compared the

552
00:21:54,710 --> 00:21:52,799
density of uh hydrated silicates which

553
00:21:56,830 --> 00:21:54,720
is lower than the density

554
00:21:59,110 --> 00:21:56,840
of both of the density of

555
00:22:01,590 --> 00:21:59,120
peridotite and we looked at the

556
00:22:03,110 --> 00:22:01,600
difference in elevation between the

557
00:22:05,430 --> 00:22:03,120
northern hemisphere and the south and

558
00:22:07,909 --> 00:22:05,440
hemisphere on on marsa

559
00:22:10,070 --> 00:22:07,919
and we determine some kind of values for

560
00:22:12,310 --> 00:22:10,080
how much hydrated silicates you would

561
00:22:13,350 --> 00:22:12,320
need in order to create these variations

562
00:22:15,590 --> 00:22:13,360
and that was

563
00:22:18,149 --> 00:22:15,600

also with the gravity data

564
00:22:20,149 --> 00:22:18,159
and then there were some thermal models

565
00:22:22,630 --> 00:22:20,159
where we plot the temperature as a

566
00:22:24,710 --> 00:22:22,640
function of pressure or

567
00:22:27,350 --> 00:22:24,720
here you have the depth

568
00:22:30,390 --> 00:22:27,360
so you have different uh

569
00:22:33,270 --> 00:22:30,400
thermal gradients from 20 kelvin per

570
00:22:35,990 --> 00:22:33,280
kilometer which would be the highest

571
00:22:37,510 --> 00:22:36,000
symbol gradient and here you have a 5 kv

572
00:22:39,190 --> 00:22:37,520
in per kilometer

573
00:22:40,630 --> 00:22:39,200
and of course the larger the the

574
00:22:42,070 --> 00:22:40,640
gradient

575
00:22:44,230 --> 00:22:42,080
the more

576
00:22:45,510 --> 00:22:44,240
the the larger the temperature increases

577
00:22:47,669 --> 00:22:45,520
with depth

578
00:22:49,990 --> 00:22:47,679
and then uh shallower depths you will

579
00:22:52,149 --> 00:22:50,000
get the transition from

580
00:22:55,510 --> 00:22:52,159
the hydrated minerals to

581
00:22:56,630 --> 00:22:55,520
dehydrated minerals so this is a one

582
00:22:59,270 --> 00:22:56,640
example

583
00:23:02,070 --> 00:22:59,280
uh where you have uh blue site and

584
00:23:04,230 --> 00:23:02,080
crystal which would be on top with a

585
00:23:06,230 --> 00:23:04,240
very low density that we can see here

586
00:23:08,390 --> 00:23:06,240
and if you have isostatic

587
00:23:10,549 --> 00:23:08,400
equilibrium then you create this

588
00:23:13,510 --> 00:23:10,559

difference in topography

589
00:23:17,110 --> 00:23:13,520
and of course you know another two

590
00:23:19,750 --> 00:23:17,120
um two explanations to explain the

591
00:23:21,669 --> 00:23:19,760
the difference in topography

592
00:23:22,950 --> 00:23:21,679
one is to say that the crystal thickness

593
00:23:24,870 --> 00:23:22,960
is different between the northern

594
00:23:26,549 --> 00:23:24,880
hemisphere and the south and hemisphere

595
00:23:27,909 --> 00:23:26,559
and because of the difference in cursor

596
00:23:29,909 --> 00:23:27,919
thickness and then you create a

597
00:23:31,510 --> 00:23:29,919
difference in topography

598
00:23:33,750 --> 00:23:31,520
but the other way is to say that you

599
00:23:35,510 --> 00:23:33,760
have lateral variations in density

600
00:23:37,590 --> 00:23:35,520
and the gravity data by themselves

601
00:23:38,710 --> 00:23:37,600
cannot distinguish between the the two

602
00:23:41,190 --> 00:23:38,720
models

603
00:23:43,909 --> 00:23:41,200
and it's possible that with insight with

604
00:23:45,110 --> 00:23:43,919
the seismometers on on insight

605
00:23:48,070 --> 00:23:45,120
then we will

606
00:23:51,350 --> 00:23:48,080
get information about the density of the

607
00:23:53,190 --> 00:23:51,360
motion crust and we will be able to see

608
00:23:55,430 --> 00:23:53,200
whether or not there is a density

609
00:23:57,350 --> 00:23:55,440
difference between the south and eastern

610
00:23:59,669 --> 00:23:57,360
the north and asia which of course would

611
00:24:04,390 --> 00:23:59,679
be great

612
00:24:05,909 --> 00:24:04,400
okay next so now we're going to move to

613
00:24:09,029 --> 00:24:05,919

i see

614
00:24:10,310 --> 00:24:09,039
moons ocean worlds

615
00:24:12,549 --> 00:24:10,320
this is a

616
00:24:14,230 --> 00:24:12,559
slide that i picked from killing and the

617
00:24:16,390 --> 00:24:14,240
earth in the middle so now we have the

618
00:24:18,470 --> 00:24:16,400
right size for the different uh icy

619
00:24:20,950 --> 00:24:18,480
worlds we have entered us here

620
00:24:22,870 --> 00:24:20,960
you have getting mad here and

621
00:24:26,149 --> 00:24:22,880
saitan is here you can see this about

622
00:24:28,310 --> 00:24:26,159
the same size and europa is uh is a

623
00:24:30,549 --> 00:24:28,320
planet here

624
00:24:33,350 --> 00:24:30,559
so we i start with uh genius just to

625
00:24:34,710 --> 00:24:33,360
explain how we get information about

626
00:24:37,590 --> 00:24:34,720
the density

627
00:24:39,510 --> 00:24:37,600
of the silicate core and

628
00:24:44,310 --> 00:24:39,520
steve led the study here which was

629
00:24:46,710 --> 00:24:45,190
and

630
00:24:50,549 --> 00:24:46,720
what we

631
00:24:52,549 --> 00:24:50,559
galileo mission

632
00:24:55,350 --> 00:24:52,559
and we have some ideas about what we

633
00:24:57,110 --> 00:24:55,360
call the gravity coefficient which is

634
00:25:00,310 --> 00:24:57,120
this value of

635
00:25:02,070 --> 00:25:00,320
c22 so this is what is measured and you

636
00:25:04,789 --> 00:25:02,080
can relate

637
00:25:07,830 --> 00:25:04,799
this gravity coefficient

638
00:25:11,029 --> 00:25:07,840

to a parameter which we call the love

639
00:25:13,669 --> 00:25:11,039
number kf which is here

640
00:25:16,070 --> 00:25:13,679
and the other parameters are well known

641
00:25:20,470 --> 00:25:16,080
that the spin rate at the radius

642
00:25:23,590 --> 00:25:20,480
but gm is the gravity constant times

643
00:25:25,830 --> 00:25:23,600
the mass so this part is known so from

644
00:25:27,110 --> 00:25:25,840
the gravity coefficient he knows this

645
00:25:30,870 --> 00:25:27,120
love number

646
00:25:33,110 --> 00:25:30,880
relationship between

647
00:25:36,310 --> 00:25:33,120
the moment of inertia from

648
00:25:39,269 --> 00:25:36,320
along the spin axis which is a c here

649
00:25:40,950 --> 00:25:39,279
and the love number kf which is here

650
00:25:44,470 --> 00:25:40,960
so from the gravity

651
00:25:46,710 --> 00:25:44,480
you know ks and from kf you can get the

652
00:25:48,390 --> 00:25:46,720
value of the moment of inertia and the

653
00:25:50,870 --> 00:25:48,400
moment of inertia

654
00:25:53,830 --> 00:25:50,880
is related to the distribution of the

655
00:25:55,830 --> 00:25:53,840
density here as a function of the radius

656
00:25:58,230 --> 00:25:55,840
and this is the expression of the moment

657
00:26:00,630 --> 00:25:58,240
of inertia so you can see the density

658
00:26:03,269 --> 00:26:00,640
here which depends on the radius

659
00:26:04,630 --> 00:26:03,279
and it's um you integrate and you have

660
00:26:07,990 --> 00:26:04,640
the

661
00:26:10,149 --> 00:26:08,000
to a power of four of course we also

662
00:26:11,190 --> 00:26:10,159
know the the mass and we know the radius

663
00:26:13,029 --> 00:26:11,200

or you have

664
00:26:15,029 --> 00:26:13,039
information about

665
00:26:16,390 --> 00:26:15,039
the total mass of the planet so when you

666
00:26:18,390 --> 00:26:16,400
you solve

667
00:26:19,510 --> 00:26:18,400
of course you have many more

668
00:26:20,390 --> 00:26:19,520
unknowns

669
00:26:25,269 --> 00:26:20,400
that

670
00:26:27,590 --> 00:26:25,279
start with the differentiate the

671
00:26:30,230 --> 00:26:27,600
gallimet and on ganymede we know that

672
00:26:32,390 --> 00:26:30,240
there is a liquid iron in the center

673
00:26:34,470 --> 00:26:32,400
because there is a dynamo form

674
00:26:37,029 --> 00:26:34,480
so you can build some thermal profile so

675
00:26:38,549 --> 00:26:37,039
you you would have in the center liquid

676
00:26:39,990 --> 00:26:38,559
iron

677
00:26:42,470 --> 00:26:40,000
the brown

678
00:26:44,789 --> 00:26:42,480
layer would be the silicates

679
00:26:46,950 --> 00:26:44,799
and then because we know the equation of

680
00:26:49,990 --> 00:26:46,960
state which is important

681
00:26:51,990 --> 00:26:50,000
then you would have high pressure ice

682
00:26:54,149 --> 00:26:52,000
we also know that there is an induced

683
00:26:56,470 --> 00:26:54,159
magnetic field which is best explained

684
00:27:00,310 --> 00:26:56,480
by the presence of an ocean on ganimela

685
00:27:04,149 --> 00:27:00,320
that could be the dark blue ear and

686
00:27:06,630 --> 00:27:04,159
at the surface you have the ice crust

687
00:27:09,510 --> 00:27:06,640
so if you take the phase diagram of

688
00:27:11,669 --> 00:27:09,520

water which is uh here

689
00:27:13,669 --> 00:27:11,679
the pressure from increases to the

690
00:27:15,830 --> 00:27:13,679
bottom so this is the depth and this is

691
00:27:18,389 --> 00:27:15,840
in steve's paper

692
00:27:20,710 --> 00:27:18,399
so you can see that the ice one which is

693
00:27:23,590 --> 00:27:20,720
a low pressure ice has a melting

694
00:27:25,190 --> 00:27:23,600
temperature that decreases with pressure

695
00:27:27,830 --> 00:27:25,200
and then at the pressure which

696
00:27:31,510 --> 00:27:27,840
corresponds to about 120 kilometers

697
00:27:33,430 --> 00:27:31,520
there from ganymede you you you change

698
00:27:35,190 --> 00:27:33,440
the low pressure ice into higher

699
00:27:38,549 --> 00:27:35,200
pressure species

700
00:27:41,750 --> 00:27:38,559
i3 i5 i6 some

701
00:27:42,630 --> 00:27:41,760
and so at some point when you plug the

702
00:27:44,310 --> 00:27:42,640
summer

703
00:27:46,789 --> 00:27:44,320
gradient uh

704
00:27:48,870 --> 00:27:46,799
profile speaking this curve here

705
00:27:51,350 --> 00:27:48,880
what happens is that uh

706
00:27:53,430 --> 00:27:51,360
the temperature increases with depth

707
00:27:55,350 --> 00:27:53,440
and we take equation of state of water

708
00:27:56,710 --> 00:27:55,360
and we assume that we have adiabatic

709
00:27:59,029 --> 00:27:56,720
transfer and you can see that the

710
00:28:00,630 --> 00:27:59,039
temperature increases but at some point

711
00:28:03,269 --> 00:28:00,640
you cross the freezing temperature

712
00:28:05,909 --> 00:28:03,279
between the water the liquid and the

713
00:28:08,230 --> 00:28:05,919

high pressure ice in that case that's i6

714
00:28:10,310 --> 00:28:08,240
and that's why you have this layer here

715
00:28:11,909 --> 00:28:10,320
so if you add equation of state and the

716
00:28:14,470 --> 00:28:11,919
phase diagram then you have some

717
00:28:16,389 --> 00:28:14,480
constraint about the the layer of ice

718
00:28:19,990 --> 00:28:16,399
and then you can determine what's the

719
00:28:22,470 --> 00:28:20,000
density of the silicates and the density

720
00:28:23,750 --> 00:28:22,480
of the iron core and for ganymede you

721
00:28:25,830 --> 00:28:23,760
find that you

722
00:28:28,710 --> 00:28:25,840
everything works really well with the

723
00:28:30,870 --> 00:28:28,720
density of dehydrated silicates you know

724
00:28:33,430 --> 00:28:30,880
you take peridotite and it gives a good

725
00:28:34,710 --> 00:28:33,440
value for the moment of inertia so for

726
00:28:37,190 --> 00:28:34,720
gandinez

727
00:28:39,029 --> 00:28:37,200
we think it's fully differentiated that

728
00:28:41,510 --> 00:28:39,039
the water

729
00:28:46,230 --> 00:28:41,520
the h2o layer is differentiated from

730
00:28:51,750 --> 00:28:49,350
okay so now we move to amsterdam because

731
00:28:55,029 --> 00:28:51,760
we have quite a lot of information from

732
00:28:57,430 --> 00:28:55,039
ansel adas with cassini here first we

733
00:28:59,190 --> 00:28:57,440
know so we have the mass

734
00:29:02,549 --> 00:28:59,200
we have the radius

735
00:29:05,029 --> 00:29:02,559
the moment of inertia for storage is to

736
00:29:07,350 --> 00:29:05,039
erase the values but moment of inertia

737
00:29:09,510 --> 00:29:07,360
is 0.335

738
00:29:11,430 --> 00:29:09,520

but if you take into account

739
00:29:12,389 --> 00:29:11,440
non-hydrostatic

740
00:29:15,590 --> 00:29:12,399
pressure

741
00:29:17,669 --> 00:29:15,600
on the south pole of antaradas that was

742
00:29:19,750 --> 00:29:17,679
a study by bill mckinnon and there was

743
00:29:21,990 --> 00:29:19,760
also a study by gail and stevenson in

744
00:29:24,870 --> 00:29:22,000
2013

745
00:29:29,190 --> 00:29:24,880
then you find out that you should take a

746
00:29:32,230 --> 00:29:29,200
value of 0.330 instead of 0.335 it

747
00:29:33,510 --> 00:29:32,240
doesn't change much the results but

748
00:29:35,190 --> 00:29:33,520
it's important

749
00:29:38,310 --> 00:29:35,200
then you take a model where you have

750
00:29:43,190 --> 00:29:41,669
then for dynamic uh considerations

751
00:29:45,590 --> 00:29:43,200
um you

752
00:29:48,310 --> 00:29:45,600
you can determine the thickness of the

753
00:29:51,830 --> 00:29:48,320
ice layer can vary from six kilometers

754
00:29:54,950 --> 00:29:51,840
at the south pole to about 20 to 40

755
00:29:57,110 --> 00:29:54,960
kilometers at the equator

756
00:30:00,230 --> 00:29:57,120
and these are studies by bill mckinnon

757
00:30:01,909 --> 00:30:00,240
again in 2015 but there was also for a

758
00:30:05,190 --> 00:30:01,919
more recent study by

759
00:30:06,870 --> 00:30:05,200
cadet in 2016

760
00:30:09,590 --> 00:30:06,880
and then we have also some information

761
00:30:11,430 --> 00:30:09,600
about the density of the ocean i forgot

762
00:30:14,389 --> 00:30:11,440
to mention that we know that there is an

763
00:30:17,510 --> 00:30:14,399

ocean on third a global ocean

764
00:30:19,750 --> 00:30:17,520
because the vibration of unsoldered

765
00:30:22,070 --> 00:30:19,760
demonstrates that you have a decoupling

766
00:30:24,950 --> 00:30:22,080
between the crust and the interior there

767
00:30:27,110 --> 00:30:24,960
is a global ocean on ontario

768
00:30:29,909 --> 00:30:27,120
um i want to precise that because i

769
00:30:31,990 --> 00:30:29,919
think in uh in the slides that steve

770
00:30:34,230 --> 00:30:32,000
mentioned before

771
00:30:35,590 --> 00:30:34,240
it was just a local ocean as a south

772
00:30:37,750 --> 00:30:35,600
pole but now we know that there is a

773
00:30:40,870 --> 00:30:37,760
global ocean

774
00:30:42,310 --> 00:30:40,880
and so the the density of ice um um

775
00:30:44,389 --> 00:30:42,320
[Music]

776
00:30:46,789 --> 00:30:44,399
because there are geysers on entourage

777
00:30:48,070 --> 00:30:46,799
so we know also that the geysers

778
00:30:50,549 --> 00:30:48,080
are

779
00:30:53,510 --> 00:30:50,559
chewing some water from uh

780
00:30:55,430 --> 00:30:53,520
from the ocean so we can get information

781
00:30:57,269 --> 00:30:55,440
about the density of the ocean and i

782
00:30:58,230 --> 00:30:57,279
guess chris is going to see more about

783
00:31:00,789 --> 00:30:58,240
that

784
00:31:02,549 --> 00:31:00,799
and then you solve for the mass and for

785
00:31:05,430 --> 00:31:02,559
the moment of inertia

786
00:31:08,549 --> 00:31:05,440
and you get the values which are on the

787
00:31:10,789 --> 00:31:08,559
on the right so for the cdk core

788
00:31:12,870 --> 00:31:10,799

the two unknowns would be the density of

789
00:31:14,950 --> 00:31:12,880
the silicate core and the radius of the

790
00:31:17,190 --> 00:31:14,960
silicate core and what you find out is

791
00:31:19,909 --> 00:31:17,200
that the density of the silicate core is

792
00:31:21,509 --> 00:31:19,919
something like 2450

793
00:31:23,269 --> 00:31:21,519
it can vary

794
00:31:25,110 --> 00:31:23,279
a little bit

795
00:31:28,630 --> 00:31:25,120
but it doesn't vary much you know it can

796
00:31:30,470 --> 00:31:28,640
be 2500 maybe or 2400

797
00:31:32,389 --> 00:31:30,480
and the radius can vary by a few

798
00:31:34,230 --> 00:31:32,399
kilometers but re if you take this

799
00:31:37,990 --> 00:31:34,240
equation it gives you very good

800
00:31:40,630 --> 00:31:38,000
constraints on the density of the core

801
00:31:43,750 --> 00:31:40,640
so in order to get this kind of density

802
00:31:47,990 --> 00:31:43,760
if you look at the density of minerals

803
00:31:50,470 --> 00:31:48,000
if you take uh antigo right which is uh

804
00:31:53,110 --> 00:31:50,480
if you take only the magnesium size of

805
00:31:55,950 --> 00:31:53,120
antigonita you find that the density is

806
00:31:59,509 --> 00:31:55,960
larger than that actually you have

807
00:32:00,470 --> 00:31:59,519
2580 yeah if you start adding

808
00:32:03,350 --> 00:32:00,480
iron

809
00:32:05,190 --> 00:32:03,360
then you have more than three thousand

810
00:32:07,590 --> 00:32:05,200
for the density but depending on the

811
00:32:10,549 --> 00:32:07,600
amount of iron you get density even

812
00:32:12,549 --> 00:32:10,559
larger of course if you take borosite uh

813
00:32:15,590 --> 00:32:12,559

the magnesium

814
00:32:18,230 --> 00:32:15,600
and for either lower than ct but uh if

815
00:32:20,470 --> 00:32:18,240
you include the the iron then it

816
00:32:23,110 --> 00:32:20,480
becomes much louder

817
00:32:27,350 --> 00:32:23,120
so the idea is that actually the the the

818
00:32:29,029 --> 00:32:27,360
for the core of ontario's is porous

819
00:32:31,190 --> 00:32:29,039
and so when you

820
00:32:33,269 --> 00:32:31,200
when you look at the porosity as a

821
00:32:35,710 --> 00:32:33,279
function of the iron number

822
00:32:39,110 --> 00:32:35,720
and if you take this value of

823
00:32:41,269 --> 00:32:39,120
2450 for the density of the core you

824
00:32:42,950 --> 00:32:41,279
find that even if there is no iron you

825
00:32:46,630 --> 00:32:42,960
have a density which is close to 10

826
00:32:49,269 --> 00:32:46,640
percent and if you add you know 30 iron

827
00:32:51,990 --> 00:32:49,279
or iron number which is iron divided by

828
00:32:52,870 --> 00:32:52,000
iron plus magnesium if you take a value

829
00:32:57,750 --> 00:32:52,880
of

830
00:32:59,669 --> 00:32:57,760
20

831
00:33:01,830 --> 00:32:59,679
and keeping in mind that the pressure in

832
00:33:04,710 --> 00:33:01,840
the core is very small it's we're

833
00:33:06,149 --> 00:33:04,720
talking about tenths of npa so as steve

834
00:33:09,029 --> 00:33:06,159
mentioned before

835
00:33:11,430 --> 00:33:09,039
um if we take uh what we know about the

836
00:33:14,389 --> 00:33:11,440
earth and the depths at which water can

837
00:33:18,630 --> 00:33:14,399
percolate and you find out that uh the

838
00:33:22,710 --> 00:33:20,310

and uh you know the next thing is that

839
00:33:24,630 --> 00:33:22,720
the porosity is very sensitive to

840
00:33:28,149 --> 00:33:24,640
the density of the core and of course to

841
00:33:32,310 --> 00:33:30,230
um so there have been some studies i i

842
00:33:34,630 --> 00:33:32,320
won't go into into the studies but about

843
00:33:35,830 --> 00:33:34,640
how much tiger dissipation can happen in

844
00:33:39,350 --> 00:33:35,840
the core

845
00:33:41,990 --> 00:33:39,360
and there is a paper from which is uh

846
00:33:44,389 --> 00:33:42,000
which has been submitted and

847
00:33:47,430 --> 00:33:44,399
about the amount of title eating and we

848
00:33:49,350 --> 00:33:47,440
get values which are just uh huge in

849
00:33:50,870 --> 00:33:49,360
terms of the amount of tidal eating in

850
00:33:53,909 --> 00:33:50,880
this kind of

851
00:33:56,789 --> 00:33:54,950
um

852
00:33:58,789 --> 00:33:56,799
the other thing that i think uh chris is

853
00:34:00,710 --> 00:33:58,799
going to mention that but we are

854
00:34:03,750 --> 00:34:00,720
hydrogen has been observed in the proof

855
00:34:06,149 --> 00:34:03,760
upon foreigners by the cassini ilms of

856
00:34:07,509 --> 00:34:06,159
course just to show that you can produce

857
00:34:09,829 --> 00:34:07,519
hydrogen

858
00:34:11,270 --> 00:34:09,839
from the hydration of energy that's

859
00:34:14,310 --> 00:34:11,280
olivine

860
00:34:16,470 --> 00:34:14,320
and if you transform the part of the sa2

861
00:34:17,829 --> 00:34:16,480
plus into ss3 process then you create

862
00:34:21,430 --> 00:34:17,839
the hydrogen but

863
00:34:25,190 --> 00:34:23,909

on this for this workshop so i won't go

864
00:34:27,109 --> 00:34:25,200
into the details but you know that's

865
00:34:29,990 --> 00:34:27,119
another evidence that this kind of

866
00:34:31,750 --> 00:34:30,000
reaction may actually happen inside on

867
00:34:34,389 --> 00:34:31,760
solidus

868
00:34:35,589 --> 00:34:34,399
and i just put all the information

869
00:34:39,030 --> 00:34:35,599
on uh

870
00:34:42,310 --> 00:34:39,040
on one plot uh comparing europa

871
00:34:44,389 --> 00:34:42,320
on solidus and the earth

872
00:34:47,669 --> 00:34:44,399
so let's see the pressure is the

873
00:34:49,750 --> 00:34:47,679
vertical axis it increases to the bottom

874
00:34:52,950 --> 00:34:49,760
as the temperature is the horizontal

875
00:34:54,230 --> 00:34:52,960
axis but it increases to the right

876
00:34:55,669 --> 00:34:54,240
in red

877
00:34:58,470 --> 00:34:55,679
you have a

878
00:35:00,390 --> 00:34:58,480
thermal profile for the earth

879
00:35:03,670 --> 00:35:00,400
so you go into the crust and then the

880
00:35:05,430 --> 00:35:03,680
temperature increases um and i forgot to

881
00:35:07,270 --> 00:35:05,440
mention that this is the phase diagram

882
00:35:09,750 --> 00:35:07,280
of water so you have the triple point of

883
00:35:11,109 --> 00:35:09,760
water which is here so you have the ice

884
00:35:13,670 --> 00:35:11,119
on the left

885
00:35:16,230 --> 00:35:13,680
you have the vapor on the right and you

886
00:35:19,670 --> 00:35:16,240
have the liquid inside this domain

887
00:35:21,910 --> 00:35:19,680
between the freezing temperature

888
00:35:23,430 --> 00:35:21,920

here by the way that's high pressure ice

889
00:35:26,470 --> 00:35:23,440
and here you have

890
00:35:30,870 --> 00:35:26,480
the critical point of water

891
00:35:32,630 --> 00:35:30,880
which is at 650 degrees that can be

892
00:35:34,710 --> 00:35:32,640
so if you look at the earth in the

893
00:35:36,710 --> 00:35:34,720
correct of the ursa if you don't take it

894
00:35:38,790 --> 00:35:36,720
to account i draw some more circulation

895
00:35:41,910 --> 00:35:38,800
what you find out is that

896
00:35:44,390 --> 00:35:41,920
the water is in the liquid phase

897
00:35:47,030 --> 00:35:44,400
if you look at europa uh

898
00:35:49,109 --> 00:35:47,040
the thermal profile is a green one

899
00:35:51,030 --> 00:35:49,119
so in the crust of europa

900
00:35:52,230 --> 00:35:51,040
you increase the temperature at this

901
00:35:53,829 --> 00:35:52,240
point here

902
00:35:56,550 --> 00:35:53,839
the temperature

903
00:35:57,430 --> 00:35:56,560
crosses the melting temperature so that

904
00:35:59,349 --> 00:35:57,440
would be

905
00:36:00,870 --> 00:35:59,359
the interface between the cross and the

906
00:36:02,870 --> 00:36:00,880
ocean

907
00:36:05,990 --> 00:36:02,880
and then uh

908
00:36:07,910 --> 00:36:06,000
here you are in the ocean so this uh

909
00:36:10,230 --> 00:36:07,920
domain on the green curve that's the

910
00:36:12,390 --> 00:36:10,240
domain of the ocean and on europa there

911
00:36:13,670 --> 00:36:12,400
is not much h2o so at some point you

912
00:36:15,030 --> 00:36:13,680
reach a

913
00:36:16,150 --> 00:36:15,040

secret

914
00:36:18,550 --> 00:36:16,160
core

915
00:36:20,310 --> 00:36:18,560
and this is this point here and then the

916
00:36:22,630 --> 00:36:20,320
temperature increases

917
00:36:25,030 --> 00:36:22,640
and what i find interesting is that you

918
00:36:27,589 --> 00:36:25,040
find out that the conditions of pressure

919
00:36:29,270 --> 00:36:27,599
and temperature on europa in the

920
00:36:30,390 --> 00:36:29,280
subsurface in the

921
00:36:31,510 --> 00:36:30,400
um

922
00:36:34,230 --> 00:36:31,520
in the

923
00:36:36,470 --> 00:36:34,240
delicate core of europa is very similar

924
00:36:38,310 --> 00:36:36,480
to what we have in the

925
00:36:40,870 --> 00:36:38,320
in the current of the earth

926
00:36:41,829 --> 00:36:40,880
now if you look at the answers so that's

927
00:37:41,030 --> 00:36:41,839
a

928
00:37:43,510 --> 00:37:41,040
so

929
00:37:45,990 --> 00:37:43,520
one major difference between uh titan

930
00:37:50,230 --> 00:37:46,000
and on solid oh sorry ganymede so for

931
00:37:54,390 --> 00:37:50,240
ganymede the moment of inertia is 0.310

932
00:37:56,390 --> 00:37:54,400
and for titan it's a 0.3414

933
00:37:58,069 --> 00:37:56,400
and the other five is the entirety on

934
00:38:00,310 --> 00:37:58,079
the last number here

935
00:38:02,870 --> 00:38:00,320
you can see the moment of inertia for

936
00:38:04,550 --> 00:38:02,880
titan is much larger than the moment of

937
00:38:06,390 --> 00:38:04,560
inertia for ganymede so it means that

938
00:38:10,470 --> 00:38:06,400

titan is much less

939
00:38:13,030 --> 00:38:10,480
differentiated than ganymede

940
00:38:14,710 --> 00:38:13,040
we have some additional information on

941
00:38:17,349 --> 00:38:14,720
titan

942
00:38:18,550 --> 00:38:17,359
we were able to guess the peridot number

943
00:38:22,950 --> 00:38:18,560
from

944
00:38:24,630 --> 00:38:22,960
it is a very large value

945
00:38:27,190 --> 00:38:24,640
and it works only if there is a

946
00:38:29,349 --> 00:38:27,200
decoupling between the crust of titan

947
00:38:32,230 --> 00:38:29,359
and the interior of titan

948
00:38:34,630 --> 00:38:32,240
so it's one way to demonstrate that

949
00:38:36,950 --> 00:38:34,640
there is a global ocean on titan and

950
00:38:38,790 --> 00:38:36,960
then when against um descended into

951
00:38:43,190 --> 00:38:38,800
python's

952
00:38:44,790 --> 00:38:43,200
atmosphere um it's uh recorded as the

953
00:38:47,750 --> 00:38:44,800
electric field

954
00:38:50,470 --> 00:38:47,760
and there is a paper by christian began

955
00:38:53,589 --> 00:38:50,480
ital in 2012 saying that the best

956
00:38:56,230 --> 00:38:53,599
explanation is by adding a conductor at

957
00:38:57,910 --> 00:38:56,240
about 65 kilometers depth and the

958
00:38:59,109 --> 00:38:57,920
conductor we are thinking of would be

959
00:38:59,829 --> 00:38:59,119
the ocean

960
00:39:02,150 --> 00:38:59,839
so

961
00:39:04,390 --> 00:39:02,160
the crust of titan may be on the order

962
00:39:07,190 --> 00:39:04,400
of 65 kilometers according to the

963
00:39:09,030 --> 00:39:07,200

interpretation of the human resonance by

964
00:39:11,750 --> 00:39:09,040
measured by the

965
00:39:14,470 --> 00:39:11,760
by the again program

966
00:39:17,990 --> 00:39:14,480
so now if you do the same same

967
00:39:20,150 --> 00:39:18,000
calculations and as the ones we i showed

968
00:39:24,150 --> 00:39:20,160
for gaining med what you find out is

969
00:39:26,710 --> 00:39:24,160
that titan score has a density of 2570

970
00:39:29,829 --> 00:39:26,720
kilograms per cubic meters and a radius

971
00:39:31,430 --> 00:39:29,839
of about two thousand and uh one hundred

972
00:39:34,069 --> 00:39:31,440
kilometers

973
00:39:35,829 --> 00:39:34,079
uh so it's uh the core is much larger

974
00:39:37,829 --> 00:39:35,839
than the core on ganymede and the

975
00:39:40,470 --> 00:39:37,839
density is much lower

976
00:39:42,230 --> 00:39:40,480
and to get such a density and the best

977
00:39:44,310 --> 00:39:42,240
explanation is to have hydrated

978
00:39:46,230 --> 00:39:44,320
silicates

979
00:39:47,430 --> 00:39:46,240
actually this was already mentioned by

980
00:39:48,150 --> 00:39:47,440
uh

981
00:39:52,150 --> 00:39:48,160
by

982
00:39:55,349 --> 00:39:52,160
julie castillo and jason renina um in uh

983
00:39:58,630 --> 00:39:55,359
in a paper from 2010

984
00:40:00,390 --> 00:39:58,640
um and julie can develop a model for

985
00:40:01,069 --> 00:40:00,400
thermal evolution you can see the value

986
00:40:04,230 --> 00:40:01,079
of

987
00:40:06,470 --> 00:40:04,240
2080 kilometers here for the

988
00:40:08,630 --> 00:40:06,480

for the silicate core

989
00:40:10,470 --> 00:40:08,640
and in the summer revolution what they

990
00:40:12,470 --> 00:40:10,480
have but they didn't know at that time

991
00:40:14,710 --> 00:40:12,480
what they have is that

992
00:40:17,030 --> 00:40:14,720
the water freezes completely here but at

993
00:40:20,390 --> 00:40:17,040
that time we didn't know that titan has

994
00:40:23,349 --> 00:40:20,400
an ocean so i say we have to now have

995
00:40:25,190 --> 00:40:23,359
models where we can still have an ocean

996
00:40:27,910 --> 00:40:25,200
on titan and there are ways that we can

997
00:40:29,990 --> 00:40:27,920
maintain an ocean during 4.5 billion

998
00:40:32,150 --> 00:40:30,000
years i won't go into the detail but if

999
00:40:34,069 --> 00:40:32,160
you put ammonia for example which should

1000
00:40:35,990 --> 00:40:34,079
be present because of the nitrogen and

1001
00:40:38,630 --> 00:40:36,000
titan's atmosphere then you can maintain

1002
00:40:41,109 --> 00:40:38,640
the ocean for billions of years

1003
00:40:42,309 --> 00:40:41,119
and at the end of their uh simulations

1004
00:40:47,349 --> 00:40:42,319
for

1005
00:40:48,950 --> 00:40:47,359
they find that you have uh some

1006
00:40:51,589 --> 00:40:48,960
transformation of the

1007
00:40:53,109 --> 00:40:51,599
from some dehydration of the sea kids

1008
00:40:54,309 --> 00:40:53,119
that the brown color that you find on

1009
00:40:56,710 --> 00:40:54,319
the right

1010
00:40:59,109 --> 00:40:56,720
so i will go to the to the conclusions

1011
00:41:00,870 --> 00:40:59,119
oh no sorry yeah yeah what i want to say

1012
00:41:03,190 --> 00:41:00,880
that something that steve mentioned

1013
00:41:04,069 --> 00:41:03,200

before is that actually the dehydration

1014
00:41:06,710 --> 00:41:04,079
curve

1015
00:41:08,950 --> 00:41:06,720
of the hydrated silicates put some very

1016
00:41:11,270 --> 00:41:08,960
strong constraints on the evolution of

1017
00:41:14,150 --> 00:41:11,280
the thermal revolution of titan because

1018
00:41:16,870 --> 00:41:14,160
you know around 900 degrees

1019
00:41:18,630 --> 00:41:16,880
then you should go back to much denser

1020
00:41:21,190 --> 00:41:18,640
minerals which

1021
00:41:25,190 --> 00:41:21,200
we don't observe on the outside

1022
00:41:26,630 --> 00:41:25,200
so the the conclusion is that on mars we

1023
00:41:27,829 --> 00:41:26,640
have some hydrated minerals at the

1024
00:41:29,910 --> 00:41:27,839
surface

1025
00:41:32,950 --> 00:41:29,920
and the question is whether

1026
00:41:34,390 --> 00:41:32,960
there is some hydrated silicates forming

1027
00:41:35,190 --> 00:41:34,400
the crust

1028
00:41:37,670 --> 00:41:35,200
um

1029
00:41:39,510 --> 00:41:37,680
the gravity data from cassini and from

1030
00:41:41,990 --> 00:41:39,520
galileo provides some constraints on the

1031
00:41:44,710 --> 00:41:42,000
density of the ck cores of the icy moons

1032
00:41:48,870 --> 00:41:44,720
and so i mentioned

1033
00:41:51,270 --> 00:41:48,880
ganymede titan and an others so

1034
00:41:53,430 --> 00:41:51,280
for amsterdams uh the silicate core

1035
00:41:55,670 --> 00:41:53,440
would be hydrated and would be porous

1036
00:41:57,190 --> 00:41:55,680
and that would allow for a lot of tiger

1037
00:41:59,990 --> 00:41:57,200
dissipation

1038
00:42:01,270 --> 00:42:00,000

for titan the core would be also

1039
00:42:03,349 --> 00:42:01,280
hydrated

1040
00:42:06,069 --> 00:42:03,359
and i guess we will get more information

1041
00:42:08,230 --> 00:42:06,079
on europa with the upcoming europa

1042
00:42:10,790 --> 00:42:08,240
multiply by missions which is also known

1043
00:42:13,750 --> 00:42:10,800
as clipper so that's what i

1044
00:42:15,030 --> 00:42:13,760
i wanted to present for uh for

1045
00:42:19,030 --> 00:42:15,040
you know for the presence of the

1046
00:42:21,349 --> 00:42:19,040
evidences of hydrated silicates on

1047
00:42:23,589 --> 00:42:21,359
mars and uh

1048
00:42:28,150 --> 00:42:23,599
thank you

1049
00:42:31,270 --> 00:42:29,670
do we have any any questions over the

1050
00:42:34,470 --> 00:42:31,280
phone otherwise there's there's a lot uh

1051
00:42:39,030 --> 00:42:36,390
oh yeah julie made a comment because

1052
00:42:41,030 --> 00:42:39,040
she's on the line it's true that in the

1053
00:42:42,870 --> 00:42:41,040
in the gerald papers they did not model

1054
00:42:44,309 --> 00:42:42,880
the summer revolution of the ic crest

1055
00:42:46,470 --> 00:42:44,319
they were only interested in the

1056
00:42:47,190 --> 00:42:46,480
evolution of the of the course so that's

1057
00:42:53,030 --> 00:42:47,200
why

1058
00:42:57,349 --> 00:42:55,510
so could you um

1059
00:42:59,190 --> 00:42:57,359
give your your take on what is the

1060
00:43:02,470 --> 00:42:59,200
appropriate thermal gradient for early

1061
00:43:07,910 --> 00:43:03,750
uh well i

1062
00:43:09,829 --> 00:43:07,920
there were some papers uh by baratheon i

1063
00:43:12,069 --> 00:43:09,839

think a few years ago

1064
00:43:14,150 --> 00:43:12,079
and they have a thermal gradient which

1065
00:43:16,630 --> 00:43:14,160
was larger

1066
00:43:19,190 --> 00:43:16,640
i think it was 20 kelvin per kilometer

1067
00:43:21,990 --> 00:43:19,200
but something we have to struggle with

1068
00:43:23,750 --> 00:43:22,000
is uh thermal conductivity of the crust

1069
00:43:26,069 --> 00:43:23,760
so i don't remember exactly what thermal

1070
00:43:27,190 --> 00:43:26,079
conductivity they took us for the summer

1071
00:43:29,589 --> 00:43:27,200
brilliant

1072
00:43:32,309 --> 00:43:29,599
christmas that's something that

1073
00:43:37,670 --> 00:43:32,319
sorry could you say the authors again

1074
00:43:37,680 --> 00:43:41,510
b-x

1075
00:43:44,790 --> 00:43:43,829
kristoff this is chris do you hear me

1076
00:43:46,309 --> 00:43:44,800
yes

1077
00:43:49,630 --> 00:43:46,319
yeah i had a quick question what is your

1078
00:43:52,069 --> 00:43:49,640
thoughts about the paper from 2014 by

1079
00:43:54,230 --> 00:43:52,079
bolondel where they're arguing for a

1080
00:43:56,710 --> 00:43:54,240
lower density i mean a higher density of

1081
00:43:59,510 --> 00:43:56,720
titan's core with a greater anhydrous

1082
00:44:02,470 --> 00:44:01,030
um

1083
00:44:04,150 --> 00:44:02,480
yeah because they take

1084
00:44:05,430 --> 00:44:04,160
what they look at the

1085
00:44:08,150 --> 00:44:05,440
librations

1086
00:44:09,910 --> 00:44:08,160
and how they can and also the the fact

1087
00:44:12,390 --> 00:44:09,920
that titan has an obliquity of zero or

1088
00:44:14,870 --> 00:44:12,400

three percent uh and so they try to

1089
00:44:16,630 --> 00:44:14,880
explain the density but i have discussed

1090
00:44:18,470 --> 00:44:16,640
with um

1091
00:44:20,230 --> 00:44:18,480
with the group

1092
00:44:22,550 --> 00:44:20,240
and it's not very well constrained

1093
00:44:23,910 --> 00:44:22,560
actually uh there are yeah

1094
00:44:26,630 --> 00:44:23,920
so i have discussed with them and

1095
00:44:27,349 --> 00:44:26,640
they're going back to a lower density

1096
00:44:30,950 --> 00:44:27,359
for

1097
00:44:32,710 --> 00:44:30,960
the gravity

1098
00:44:35,510 --> 00:44:32,720
data

1099
00:44:36,790 --> 00:44:35,520
can be inverted without making the

1100
00:44:39,109 --> 00:44:36,800
hypothesis

1101
00:44:41,270 --> 00:44:39,119
that you have hydrostatic equilibrium so

1102
00:44:44,309 --> 00:44:41,280
you get the value of j2 and the value of

1103
00:44:47,270 --> 00:44:44,319
c22 independently from each other

1104
00:44:49,510 --> 00:44:47,280
so even if you put some non-hydrostatic

1105
00:44:51,910 --> 00:44:49,520
forces on j2

1106
00:44:57,670 --> 00:44:51,920
you still have to explain the c22 and if

1107
00:45:01,750 --> 00:44:59,109
a love number

1108
00:45:05,190 --> 00:45:01,760
which then gives you a density for the

1109
00:45:09,750 --> 00:45:05,200
core which is uh much closer to the

1110
00:45:15,750 --> 00:45:10,470
so

1111
00:45:22,390 --> 00:45:16,829
thanks

1112
00:45:27,990 --> 00:45:23,910
what constraints there are on the iron

1113
00:45:29,910 --> 00:45:28,000

content of the interior of enceladus

1114
00:45:33,910 --> 00:45:29,920
well i guess that's the question for uh

1115
00:45:33,920 --> 00:45:36,470
yes

1116
00:45:40,950 --> 00:45:38,550
uh well i mean the simplest

1117
00:45:44,470 --> 00:45:40,960
model to start with is to assume a solar

1118
00:45:46,309 --> 00:45:44,480
composition or ci quadratic ratio of fe

1119
00:45:48,630 --> 00:45:46,319
to magnesium

1120
00:45:51,349 --> 00:45:48,640
and then we can

1121
00:45:52,710 --> 00:45:51,359
discuss possibilities where

1122
00:45:54,470 --> 00:45:52,720
you could consider

1123
00:45:56,470 --> 00:45:54,480
evolutionary processes in the formation

1124
00:45:59,190 --> 00:45:56,480
of enceladus or we could use

1125
00:46:01,030 --> 00:45:59,200
observations of things like hydrogen to

1126
00:46:03,109 --> 00:46:01,040
try to understand how much iron might be

1127
00:46:07,190 --> 00:46:03,119
reacting so

1128
00:46:11,510 --> 00:46:09,670
and something i i want to to mention too

1129
00:46:14,870 --> 00:46:11,520
is that there is this paper saying that

1130
00:46:16,390 --> 00:46:14,880
on threaders from very recently only 200

1131
00:46:18,230 --> 00:46:16,400
million years ago

1132
00:46:21,109 --> 00:46:18,240
so if it formed

1133
00:46:23,109 --> 00:46:21,119
you know in saturn's environment

1134
00:46:26,150 --> 00:46:23,119
it's possible that the amount of iron

1135
00:46:34,470 --> 00:46:26,160
would have been much less that what we

1136
00:46:40,829 --> 00:46:36,309
yeah that's an interesting point i

1137
00:46:46,230 --> 00:46:44,309
um so i i wanted to know uh do you know

1138
00:46:48,309 --> 00:46:46,240

offhand what is the um

1139
00:46:49,910 --> 00:46:48,319
amount of heat generated in the course

1140
00:46:51,430 --> 00:46:49,920
core the model that you refer to the

1141
00:46:53,829 --> 00:46:51,440
forthcoming paper

1142
00:46:54,710 --> 00:46:53,839
so it depends a lot on the viscosity you

1143
00:46:55,510 --> 00:46:54,720
take

1144
00:47:01,670 --> 00:46:55,520
for

1145
00:47:03,910 --> 00:47:01,680
porous material

1146
00:47:07,030 --> 00:47:03,920
but when you compare with similar

1147
00:47:09,510 --> 00:47:07,040
material on earth uh gabriel toby and

1148
00:47:13,430 --> 00:47:09,520
gail shoblesh is the other poster at the

1149
00:47:16,390 --> 00:47:13,440
last dps they find values uh up to 20

1150
00:47:19,589 --> 00:47:16,400
terawatt which is gigawatts which is

1151
00:47:21,990 --> 00:47:19,599
just huge for unparalleled

1152
00:47:23,510 --> 00:47:22,000
right okay but okay

1153
00:47:24,790 --> 00:47:23,520
um

1154
00:47:26,710 --> 00:47:24,800
there was a question about the

1155
00:47:28,390 --> 00:47:26,720
composition and salinity of the oceans

1156
00:47:29,670 --> 00:47:28,400
uh i will assert that we don't have

1157
00:47:31,510 --> 00:47:29,680
great constraints but i'd be interested

1158
00:47:36,230 --> 00:47:31,520
in christoph knowing what your

1159
00:47:40,549 --> 00:47:38,710
or in general any of the iso moons

1160
00:47:42,630 --> 00:47:40,559
well for anthrax i don't have the

1161
00:47:44,470 --> 00:47:42,640
numbers in mind but i guess chris can uh

1162
00:47:46,870 --> 00:47:44,480
can comment but we have some good ideas

1163
00:47:48,549 --> 00:47:46,880

about the amount of uh

1164
00:47:52,230 --> 00:47:48,559
what kind of source do you have in

1165
00:47:56,470 --> 00:47:54,069
yes that's correct so i'll go over that

1166
00:48:00,640 --> 00:47:56,480
in a couple slides of my presentation in

1167
00:48:04,309 --> 00:48:02,390
[Music]

1168
00:48:05,430 --> 00:48:04,319
oh so there's a clarification about the

1169
00:48:08,870 --> 00:48:05,440
ocean temperatures that you've

1170
00:48:10,950 --> 00:48:08,880
considered uh pointing out that uh sue

1171
00:48:13,190 --> 00:48:10,960
at all uh infer that you have to have

1172
00:48:15,990 --> 00:48:13,200
temperatures as high and 90 degrees

1173
00:48:17,670 --> 00:48:16,000
somewhere in the interior i i think the

1174
00:48:18,870 --> 00:48:17,680
the um

1175
00:48:20,069 --> 00:48:18,880
the question is what you know what are

1176
00:48:25,030 --> 00:48:20,079
the uh

1177
00:48:29,430 --> 00:48:27,750
i have not done

1178
00:48:30,390 --> 00:48:29,440
okay maybe chris will touch on that a

1179
00:48:31,349 --> 00:48:30,400
little

1180
00:48:33,910 --> 00:48:31,359
um

1181
00:48:37,829 --> 00:48:33,920
well actually uh well if i go back to my

1182
00:48:40,870 --> 00:48:39,430
i mean on one side

1183
00:48:46,549 --> 00:48:40,880
the

1184
00:48:51,589 --> 00:48:46,559
i'm sorry

1185
00:48:54,630 --> 00:48:53,829
so

1186
00:48:56,950 --> 00:48:54,640
uh

1187
00:48:59,190 --> 00:48:56,960
yeah i guess that's what i i don't i

1188
00:49:01,430 --> 00:48:59,200

didn't put any uh

1189
00:49:03,670 --> 00:49:01,440
any

1190
00:49:05,589 --> 00:49:03,680
convective model so i haven't considered

1191
00:49:08,390 --> 00:49:05,599
in that case what could happen but if

1192
00:49:11,030 --> 00:49:08,400
you imagine that you have a convection

1193
00:49:12,870 --> 00:49:11,040
uh in in the in the core then the

1194
00:49:15,190 --> 00:49:12,880
temperature would uh remain in that

1195
00:49:17,910 --> 00:49:15,200
range and so gail choblay in his

1196
00:49:20,230 --> 00:49:17,920
simulations he has a 3d theory called

1197
00:49:22,950 --> 00:49:20,240
code and he gets temperature which are

1198
00:49:28,470 --> 00:49:22,960
consistent with this 100 degrees

1199
00:49:31,670 --> 00:49:29,990
christoph this is getting kind of really

1200
00:49:34,069 --> 00:49:31,680
speculative here but is there any sense

1201
00:49:36,710 --> 00:49:34,079
from gabriel toby's models

1202
00:49:37,750 --> 00:49:36,720
of the localization of tidal heating so

1203
00:49:40,470 --> 00:49:37,760
should it be

1204
00:49:42,950 --> 00:49:40,480
close to the ocean floor or

1205
00:49:46,150 --> 00:49:42,960
uniform throughout the rocky core or

1206
00:49:48,870 --> 00:49:46,160
any sense or ideas about that

1207
00:49:53,030 --> 00:49:51,349
well the the title

1208
00:49:55,349 --> 00:49:53,040
well it depends on the structure it

1209
00:49:57,270 --> 00:49:55,359
depends on how the porosity

1210
00:49:59,190 --> 00:49:57,280
varies with that so i think you know you

1211
00:50:02,309 --> 00:49:59,200
have a few nerves that you can turn in

1212
00:50:03,109 --> 00:50:02,319
order to modify your models

1213
00:50:04,549 --> 00:50:03,119

but

1214
00:50:07,510 --> 00:50:04,559
right now the

1215
00:50:09,750 --> 00:50:07,520
uh the density the sorry the amount of

1216
00:50:11,190 --> 00:50:09,760
heat of tidal eating

1217
00:50:17,190 --> 00:50:11,200
is uh

1218
00:50:22,549 --> 00:50:19,270
and there is more tidal eating at the

1219
00:50:25,190 --> 00:50:22,559
pores than the equator

1220
00:50:27,670 --> 00:50:25,200
but one question we can ask is why do we

1221
00:50:38,950 --> 00:50:27,680
see only the south pole with activity

1222
00:50:44,390 --> 00:50:41,349
mark niva clarifies that uh he thinks

1223
00:50:46,710 --> 00:50:44,400
that the 90 degree result uh was in the

1224
00:50:50,710 --> 00:50:46,720
core uh where the submentalization is

1225
00:50:50,720 --> 00:50:55,430
uh sorry i didn't get uh

1226
00:50:59,030 --> 00:50:57,190
there's no question he's just clarifying

1227
00:51:00,950 --> 00:50:59,040
about the sioux uh

1228
00:51:03,109 --> 00:51:00,960
uh result about the 90 degree

1229
00:51:04,390 --> 00:51:03,119
temperature uh the point being that yeah

1230
00:51:08,870 --> 00:51:04,400
you have high temperatures in the rock

1231
00:51:10,630 --> 00:51:08,880
but in the ocean those will kind of uh

1232
00:51:12,230 --> 00:51:10,640
i i should weigh in a little bit more

1233
00:51:14,390 --> 00:51:12,240
about the salinity because i

1234
00:51:17,030 --> 00:51:14,400
glibly stated that we don't have many

1235
00:51:18,710 --> 00:51:17,040
constraints but uh um and this is

1236
00:51:21,109 --> 00:51:18,720
relevant to serpentinization if you have

1237
00:51:22,470 --> 00:51:21,119
a uh high flux of reductants from

1238
00:51:24,630 --> 00:51:22,480

serpentinization that you're going to

1239
00:51:26,950 --> 00:51:24,640
drive the ph to a high value and you

1240
00:51:30,309 --> 00:51:26,960
would expect to have more dominance of

1241
00:51:32,309 --> 00:51:30,319
chlorides than sulfates for example

1242
00:51:34,630 --> 00:51:32,319
and we certainly have measurements from

1243
00:51:37,829 --> 00:51:34,640
enceladus plumes that might

1244
00:51:45,430 --> 00:51:37,839
tip us off about uh hydrocarbon

1245
00:51:45,440 --> 00:51:50,790
any other responses to kristoff's talk

1246
00:51:53,589 --> 00:51:51,910
all right well christoph thanks very

1247
00:51:56,470 --> 00:51:53,599
much you're able to congratulate the

1248
00:51:58,390 --> 00:51:56,480
discussion yeah and uh elena please uh

1249
00:52:02,950 --> 00:51:58,400
when you're ready

1250
00:52:04,870 --> 00:52:02,960
okay can you see me and hear me okay

1251
00:52:07,109 --> 00:52:04,880
yes it's loud and clear

1252
00:52:09,990 --> 00:52:07,119
okay great all right well thank you very

1253
00:52:11,589 --> 00:52:10,000
much for inviting me um to present this

1254
00:52:13,670 --> 00:52:11,599
morning i really appreciate it i'm

1255
00:52:16,549 --> 00:52:13,680
actually defending my phd tomorrow so

1256
00:52:19,190 --> 00:52:16,559
this is kind of a nice uh productive

1257
00:52:21,829 --> 00:52:19,200
distraction from that um

1258
00:52:23,990 --> 00:52:21,839
so steve asked me to

1259
00:52:26,710 --> 00:52:24,000
talk about evidence for serpentinization

1260
00:52:28,870 --> 00:52:26,720
on mars so my expertise is remote

1261
00:52:30,470 --> 00:52:28,880
sensing and and using near-infrared

1262
00:52:32,870 --> 00:52:30,480
orbiters to

1263
00:52:34,470 --> 00:52:32,880

describe surface characteristics of mars

1264
00:52:35,829 --> 00:52:34,480
and a lot of my focus has been looking

1265
00:52:37,270 --> 00:52:35,839
for evidence for

1266
00:52:38,950 --> 00:52:37,280
serpentine

1267
00:52:40,630 --> 00:52:38,960
and i think it's it's really important

1268
00:52:42,549 --> 00:52:40,640
because

1269
00:52:43,510 --> 00:52:42,559
it's one of these minerals that we can

1270
00:52:44,950 --> 00:52:43,520
use

1271
00:52:46,710 --> 00:52:44,960
to really indicate

1272
00:52:48,790 --> 00:52:46,720
hopefully a habitable environment and we

1273
00:52:50,309 --> 00:52:48,800
can detect it from orbit so it can help

1274
00:52:52,069 --> 00:52:50,319
constrain where we should be sending

1275
00:52:53,829 --> 00:52:52,079
more detailed

1276
00:52:56,549 --> 00:52:53,839
landers or rovers that have higher

1277
00:52:58,710 --> 00:52:56,559
resolution instrumentation

1278
00:53:01,430 --> 00:52:58,720
let's see

1279
00:53:03,910 --> 00:53:01,440
so we've all seen some version of of

1280
00:53:06,390 --> 00:53:03,920
this slide over the last few days

1281
00:53:09,510 --> 00:53:06,400
and um i don't think i i need to

1282
00:53:10,870 --> 00:53:09,520
convince anybody here of the compelling

1283
00:53:12,549 --> 00:53:10,880
why it's so compelling to look for

1284
00:53:13,910 --> 00:53:12,559
evidence of serpentinization on other

1285
00:53:16,470 --> 00:53:13,920
planets

1286
00:53:18,710 --> 00:53:16,480
but from my point of view the thing that

1287
00:53:21,349 --> 00:53:18,720
that makes the serpentinization reaction

1288
00:53:22,870 --> 00:53:21,359

so exciting as a remote sensor is that

1289
00:53:25,349 --> 00:53:22,880
serpentine

1290
00:53:27,750 --> 00:53:25,359
can act as an indicator mineral by

1291
00:53:29,190 --> 00:53:27,760
identifying this mineral you have a good

1292
00:53:31,030 --> 00:53:29,200
sense for

1293
00:53:33,190 --> 00:53:31,040
the fact that serpentinization occurred

1294
00:53:34,710 --> 00:53:33,200
and potentially this availability of

1295
00:53:39,270 --> 00:53:34,720
hydrogen

1296
00:53:43,910 --> 00:53:41,670
and it checks a lot of our boxes as far

1297
00:53:44,950 --> 00:53:43,920
as a habitable environment so for a long

1298
00:53:46,710 --> 00:53:44,960
time

1299
00:53:48,470 --> 00:53:46,720
mars exploration has been driven by

1300
00:53:50,230 --> 00:53:48,480
follow the water but now we can actually

1301
00:53:52,230 --> 00:53:50,240
say something like follow the energy and

1302
00:53:53,750 --> 00:53:52,240
follow the geochemical environment we

1303
00:53:56,309 --> 00:53:53,760
can say more than just whether or not a

1304
00:53:57,750 --> 00:53:56,319
surface was hydrated and serpent and

1305
00:54:00,870 --> 00:53:57,760
serpentine is one of these minerals that

1306
00:54:03,589 --> 00:54:01,990
so

1307
00:54:05,589 --> 00:54:03,599
and looking back at all the other

1308
00:54:08,230 --> 00:54:05,599
studies that have looked for evidence of

1309
00:54:09,910 --> 00:54:08,240
serpentine in the past as far as landers

1310
00:54:11,910 --> 00:54:09,920
and rovers are concerned there have been

1311
00:54:13,670 --> 00:54:11,920
no detections to date with with their

1312
00:54:15,910 --> 00:54:13,680
instrumentation

1313
00:54:19,349 --> 00:54:15,920

there have been observations of iron

1314
00:54:21,829 --> 00:54:19,359
serpentine and knock light meteorites

1315
00:54:23,430 --> 00:54:21,839
and this was probably an impact to do

1316
00:54:25,430 --> 00:54:23,440
induced

1317
00:54:27,109 --> 00:54:25,440
serpentinization

1318
00:54:28,710 --> 00:54:27,119
and then from the big picture global

1319
00:54:31,270 --> 00:54:28,720
scale there actually have been quite a

1320
00:54:33,190 --> 00:54:31,280
few uh orbital identifications with

1321
00:54:35,030 --> 00:54:33,200
near-infrared spectroscopy

1322
00:54:36,710 --> 00:54:35,040
uh there was a big search

1323
00:54:39,430 --> 00:54:36,720
a study in 2010 which kind of did a

1324
00:54:40,390 --> 00:54:39,440
global search for serpentine across the

1325
00:54:42,390 --> 00:54:40,400
planet

1326
00:54:45,109 --> 00:54:42,400
and by bethany allman

1327
00:54:46,710 --> 00:54:45,119
and we found that serpentine was

1328
00:54:48,549 --> 00:54:46,720
observed in a range of different

1329
00:54:51,109 --> 00:54:48,559
terrains

1330
00:54:53,430 --> 00:54:51,119
typically in melange kind of

1331
00:54:56,789 --> 00:54:53,440
rework terrains in southern highland

1332
00:54:58,630 --> 00:54:56,799
craters associated with ejecta or within

1333
00:55:00,470 --> 00:54:58,640
the walls of

1334
00:55:01,829 --> 00:55:00,480
crater rims

1335
00:55:03,589 --> 00:55:01,839
and then more recently there have been

1336
00:55:05,990 --> 00:55:03,599
more observations of serpentine along

1337
00:55:06,789 --> 00:55:06,000
tectonic boundaries by christina viviano

1338
00:55:09,270 --> 00:55:06,799

beck

1339
00:55:11,510 --> 00:55:09,280
just south of alice marineris

1340
00:55:13,829 --> 00:55:11,520
and then the really exciting one from an

1341
00:55:15,910 --> 00:55:13,839
astrobiological standpoint i think uh is

1342
00:55:19,349 --> 00:55:15,920
the observation of serpentine within a

1343
00:55:21,990 --> 00:55:19,359
nowakian bedrock in stratigraphy

1344
00:55:24,630 --> 00:55:22,000
so it appears to be found in situ where

1345
00:55:26,630 --> 00:55:24,640
it would have presumably formed which

1346
00:55:28,230 --> 00:55:26,640
from a habitability perspective is

1347
00:55:30,150 --> 00:55:28,240
really nice because you can actually go

1348
00:55:32,630 --> 00:55:30,160
to the place where these reactions were

1349
00:55:35,190 --> 00:55:32,640
occurring

1350
00:55:36,870 --> 00:55:35,200
so the way that we do this uh just for

1351
00:55:39,270 --> 00:55:36,880
people who aren't uh

1352
00:55:41,030 --> 00:55:39,280
used to thinking about uh defining

1353
00:55:43,430 --> 00:55:41,040
surface composition another planet is we

1354
00:55:45,430 --> 00:55:43,440
use near-infrared spectrometers or

1355
00:55:47,990 --> 00:55:45,440
thermal infrared spectrometers to get a

1356
00:55:50,630 --> 00:55:48,000
sense of what the top very top layer of

1357
00:55:51,589 --> 00:55:50,640
the surface is composed of

1358
00:55:56,069 --> 00:55:51,599
and

1359
00:55:58,549 --> 00:55:56,079
luckily for us serpentine is actually

1360
00:56:00,309 --> 00:55:58,559
uniquely identifiable in near-infrared

1361
00:56:01,510 --> 00:56:00,319
and thermal infrared

1362
00:56:04,150 --> 00:56:01,520
actual data

1363
00:56:05,589 --> 00:56:04,160

so it has these really if i can get my

1364
00:56:06,789 --> 00:56:05,599
pointer

1365
00:56:09,670 --> 00:56:06,799
there we go

1366
00:56:11,270 --> 00:56:09,680
it has these um

1367
00:56:13,670 --> 00:56:11,280
these absorptions

1368
00:56:16,150 --> 00:56:13,680
that are diagnostic if you find all of

1369
00:56:19,670 --> 00:56:16,160
them in the reflectant spectrum of its

1370
00:56:23,670 --> 00:56:21,910
and so we can use this to map out where

1371
00:56:25,829 --> 00:56:23,680
it exists and then

1372
00:56:26,710 --> 00:56:25,839
additionally there are other minerals

1373
00:56:29,190 --> 00:56:26,720
that

1374
00:56:31,030 --> 00:56:29,200
are often associated with serpentine and

1375
00:56:33,670 --> 00:56:31,040
serpentinizing environments on earth

1376
00:56:35,670 --> 00:56:33,680
that also have diagnostic spectral

1377
00:56:38,069 --> 00:56:35,680
absorption so you can kind of use all

1378
00:56:39,190 --> 00:56:38,079
these minerals as a suite and all

1379
00:56:41,270 --> 00:56:39,200
together

1380
00:56:42,829 --> 00:56:41,280
to look for where serpentinization might

1381
00:56:45,990 --> 00:56:42,839
have been

1382
00:56:47,990 --> 00:56:46,000
occurring so here's a map of of where

1383
00:56:48,870 --> 00:56:48,000
all the surface occurrences

1384
00:56:52,230 --> 00:56:48,880
of

1385
00:56:55,030 --> 00:56:52,240
um

1386
00:56:58,549 --> 00:56:55,040
for the most part they're they're found

1387
00:57:00,710 --> 00:56:58,559
in these isolated regions um

1388
00:57:02,870 --> 00:57:00,720

its detections have actually been quite

1389
00:57:05,109 --> 00:57:02,880
rare using just traditional

1390
00:57:07,670 --> 00:57:05,119
near-infrared analyses of the data

1391
00:57:09,510 --> 00:57:07,680
um there is not very much there are not

1392
00:57:11,750 --> 00:57:09,520
very many occurrences there actually are

1393
00:57:13,349 --> 00:57:11,760
a few more down between if this and

1394
00:57:14,950 --> 00:57:13,359
helispace and that i don't have maps

1395
00:57:17,349 --> 00:57:14,960
here but

1396
00:57:18,950 --> 00:57:17,359
it's still quite rare

1397
00:57:20,549 --> 00:57:18,960
so for the most part these occurrences

1398
00:57:23,670 --> 00:57:20,559
that i have mapped are these melange

1399
00:57:25,750 --> 00:57:23,680
trains these impact craters

1400
00:57:28,150 --> 00:57:25,760
not in stratigraphic sections the only

1401
00:57:31,349 --> 00:57:28,160
ones that we find within a complete

1402
00:57:34,630 --> 00:57:31,359
package are these ones here

1403
00:57:36,309 --> 00:57:34,640
and um in milli faucet see if i can do

1404
00:57:40,710 --> 00:57:36,319
this without

1405
00:57:42,470 --> 00:57:40,720
there we go so nelly phosphate um

1406
00:57:44,789 --> 00:57:42,480
has this really nice stratigraphic

1407
00:57:46,710 --> 00:57:44,799
section that i'll get to where we find

1408
00:57:48,950 --> 00:57:46,720
serpentine

1409
00:57:50,630 --> 00:57:48,960
so on the left i'm showing a thermal

1410
00:57:53,190 --> 00:57:50,640
infrared

1411
00:57:54,710 --> 00:57:53,200
multispectral image that is basically

1412
00:57:56,950 --> 00:57:54,720
showing you um

1413
00:57:59,670 --> 00:57:56,960

surface composition at the bulk level

1414
00:58:01,270 --> 00:57:59,680
and what we see at nelly fosse um here

1415
00:58:03,270 --> 00:58:01,280
are the fractures associated with noise

1416
00:58:04,950 --> 00:58:03,280
flossing he's um

1417
00:58:07,190 --> 00:58:04,960
you're not used to looking at

1418
00:58:08,549 --> 00:58:07,200
in this region but these these magenta

1419
00:58:10,390 --> 00:58:08,559
units that

1420
00:58:12,789 --> 00:58:10,400
um we see in the thermal infrared are

1421
00:58:14,630 --> 00:58:12,799
indicating these really um

1422
00:58:17,349 --> 00:58:14,640
olivine rich basalts that are quite

1423
00:58:20,390 --> 00:58:17,359
expansive um with about 48 percent

1424
00:58:21,910 --> 00:58:20,400
olivine and it's the chemistry of those

1425
00:58:24,230 --> 00:58:21,920
olivines are shifted towards more

1426
00:58:25,430 --> 00:58:24,240
magnesium-rich composition

1427
00:58:27,190 --> 00:58:25,440
so they're these really expensive

1428
00:58:29,030 --> 00:58:27,200
olivine rich basalts and here i've laid

1429
00:58:30,789 --> 00:58:29,040
out the um

1430
00:58:32,150 --> 00:58:30,799
just the compositional spatiography we

1431
00:58:33,589 --> 00:58:32,160
see in the region

1432
00:58:35,510 --> 00:58:33,599
and

1433
00:58:37,990 --> 00:58:35,520
on the bottom we have this olivine poor

1434
00:58:39,829 --> 00:58:38,000
basalt that has some phyllosilicates and

1435
00:58:41,510 --> 00:58:39,839
then on on top of that or where the

1436
00:58:42,710 --> 00:58:41,520
really interesting

1437
00:58:44,470 --> 00:58:42,720
is where the interesting unit with

1438
00:58:45,430 --> 00:58:44,480

respect to serpentinization has occurred

1439
00:58:47,990 --> 00:58:45,440
so

1440
00:58:50,069 --> 00:58:48,000
there's this olivine rich unit and it's

1441
00:58:53,430 --> 00:58:50,079
been variably altered to magnesium

1442
00:58:55,109 --> 00:58:53,440
carbonate serpentine talc saponite and

1443
00:58:56,630 --> 00:58:55,119
these have been identifications that

1444
00:58:57,349 --> 00:58:56,640
people have been making over the years

1445
00:59:00,470 --> 00:58:57,359
with

1446
00:59:01,510 --> 00:59:00,480
of the near infrared and the near

1447
00:59:02,789 --> 00:59:01,520
infrared

1448
00:59:05,430 --> 00:59:02,799
um

1449
00:59:07,910 --> 00:59:05,440
and let's see

1450
00:59:09,349 --> 00:59:07,920
and we can actually map them out and see

1451
00:59:10,789 --> 00:59:09,359
where they're actually occurring so what

1452
00:59:12,470 --> 00:59:10,799
i'm showing here is the deep

1453
00:59:15,109 --> 00:59:12,480
distribution of

1454
00:59:16,789 --> 00:59:15,119
magnesium carbonate serpentine

1455
00:59:19,510 --> 00:59:16,799
talc and saponite across the melee

1456
00:59:21,349 --> 00:59:19,520
fossae region and these are aggregated

1457
00:59:23,349 --> 00:59:21,359
from all the studies over the past few

1458
00:59:25,750 --> 00:59:23,359
years including my own

1459
00:59:28,309 --> 00:59:25,760
and what you find is that let's see the

1460
00:59:30,710 --> 00:59:28,319
green the green boxes are indicating

1461
00:59:32,950 --> 00:59:30,720
prism stamps where

1462
00:59:35,270 --> 00:59:32,960
where we see evidence for serpentine

1463
00:59:37,910 --> 00:59:35,280

so serpentine is still pretty rare in

1464
00:59:40,390 --> 00:59:37,920
melee fossa but it's found widespread

1465
00:59:42,309 --> 00:59:40,400
across the region in general there's a

1466
00:59:44,390 --> 00:59:42,319
lot of evidence for magnesium carbonate

1467
00:59:49,030 --> 00:59:44,400
and there's good evidence for talc

1468
00:59:53,349 --> 00:59:50,870
and the way that we identify these again

1469
00:59:55,829 --> 00:59:53,359
are with these

1470
00:59:58,789 --> 00:59:55,839
spectral responses in the near infrared

1471
01:00:00,630 --> 00:59:58,799
and on the left i have what the spectral

1472
01:00:03,270 --> 01:00:00,640
types look like in

1473
01:00:04,789 --> 01:00:03,280
melee fossae and then another study that

1474
01:00:06,789 --> 01:00:04,799
i've done in collaboration with billy

1475
01:00:08,549 --> 01:00:06,799
brazelton and deb kelly here at the

1476
01:00:11,030 --> 01:00:08,559
university of washington with taking

1477
01:00:13,030 --> 01:00:11,040
rocks from velocity hydrothermal field

1478
01:00:14,870 --> 01:00:13,040
um so an active serpentinizing system on

1479
01:00:16,390 --> 01:00:14,880
earth and trying to characterize those

1480
01:00:18,630 --> 01:00:16,400
rocks using the same types of

1481
01:00:20,950 --> 01:00:18,640
measurements we have for nellie fosse

1482
01:00:22,870 --> 01:00:20,960
um and and what we found is that we see

1483
01:00:24,549 --> 01:00:22,880
the same types of the same spectral

1484
01:00:26,789 --> 01:00:24,559
types in both regions and so you can

1485
01:00:31,670 --> 01:00:26,799
kind of use these these spectral

1486
01:00:34,630 --> 01:00:31,680
signatures as um a proxy or a key for a

1487
01:00:36,309 --> 01:00:34,640
potentially serpentinizing environment

1488
01:00:38,309 --> 01:00:36,319

so it's all these spectral types

1489
01:00:40,309 --> 01:00:38,319
together that kind of tell you oh we

1490
01:00:41,829 --> 01:00:40,319
probably had some sort of in-situ

1491
01:00:44,710 --> 01:00:41,839
serpentinization occurring in the

1492
01:00:46,309 --> 01:00:45,510
and

1493
01:00:48,309 --> 01:00:46,319
but

1494
01:00:50,470 --> 01:00:48,319
when we start looking for these um

1495
01:00:51,990 --> 01:00:50,480
absorption so if i go back to so this

1496
01:00:53,430 --> 01:00:52,000
green line

1497
01:00:55,349 --> 01:00:53,440
is the spectrum that indicates the

1498
01:00:57,349 --> 01:00:55,359
serpentine bearing surface

1499
01:01:00,150 --> 01:00:57,359
and the diagnostic absorption is this

1500
01:01:02,150 --> 01:01:00,160
little guy here at 2.12 which is really

1501
01:01:03,510 --> 01:01:02,160
weak and it's pretty hard to find and we

1502
01:01:04,950 --> 01:01:03,520
found that it was

1503
01:01:06,950 --> 01:01:04,960
pretty difficult to find it even in

1504
01:01:09,910 --> 01:01:06,960
places where other people

1505
01:01:11,589 --> 01:01:09,920
see it you still really have to um dig

1506
01:01:14,069 --> 01:01:11,599
around and and try and find those

1507
01:01:17,349 --> 01:01:14,079
absorptions and it was really quite rare

1508
01:01:19,910 --> 01:01:17,359
and so our question is um

1509
01:01:21,670 --> 01:01:19,920
is serpentine really so rare on mars or

1510
01:01:23,670 --> 01:01:21,680
are we just missing it in the spectral

1511
01:01:26,789 --> 01:01:23,680
data um

1512
01:01:28,870 --> 01:01:26,799
is it is it hard to find um or is the

1513
01:01:30,470 --> 01:01:28,880

pendulumization rare on a global scale

1514
01:01:32,069 --> 01:01:30,480
and really faucet

1515
01:01:34,069 --> 01:01:32,079
and then the other question is is mili

1516
01:01:35,829 --> 01:01:34,079
fossa unique you know are there other

1517
01:01:38,470 --> 01:01:35,839
places that show these spectral suites

1518
01:01:39,829 --> 01:01:38,480
that would indicate serpentinization um

1519
01:01:41,349 --> 01:01:39,839
how how

1520
01:01:44,309 --> 01:01:41,359
common were these locales or so

1521
01:01:46,150 --> 01:01:44,319
pentatonization was occurring on mars

1522
01:01:48,309 --> 01:01:46,160
and so if we go back to our original map

1523
01:01:50,150 --> 01:01:48,319
of where others have seen serpentine all

1524
01:01:52,870 --> 01:01:50,160
these detections were made using just

1525
01:01:54,549 --> 01:01:52,880
traditional prism analysis techniques

1526
01:01:57,109 --> 01:01:54,559
that again

1527
01:01:59,510 --> 01:01:57,119
um the spectral absorption that is

1528
01:02:01,670 --> 01:01:59,520
diagnostic of serpentine is really weak

1529
01:02:03,990 --> 01:02:01,680
and really hard to find and it's

1530
01:02:05,750 --> 01:02:04,000
very time consuming and

1531
01:02:06,710 --> 01:02:05,760
by hand analyses can take minutes to

1532
01:02:07,670 --> 01:02:06,720
hours

1533
01:02:12,950 --> 01:02:07,680
so

1534
01:02:13,990 --> 01:02:12,960
analysis techniques to the chrism data

1535
01:02:15,670 --> 01:02:14,000
set

1536
01:02:17,510 --> 01:02:15,680
using factor analysis and target

1537
01:02:19,270 --> 01:02:17,520
transformation which essentially it's

1538
01:02:21,910 --> 01:02:19,280

similar to principal component analysis

1539
01:02:23,190 --> 01:02:21,920
that you can take your your chrism data

1540
01:02:25,510 --> 01:02:23,200
and really

1541
01:02:27,430 --> 01:02:25,520
take that complex spectral data set and

1542
01:02:29,589 --> 01:02:27,440
reduce it to the

1543
01:02:30,630 --> 01:02:29,599
significant spectral components of an

1544
01:02:32,069 --> 01:02:30,640
image

1545
01:02:33,510 --> 01:02:32,079
and in the past people have done this

1546
01:02:35,270 --> 01:02:33,520
and found that

1547
01:02:37,190 --> 01:02:35,280
it's very successful in finding these

1548
01:02:38,710 --> 01:02:37,200
weak diagnostic absorptions similar to

1549
01:02:41,190 --> 01:02:38,720
what we see um

1550
01:02:43,190 --> 01:02:41,200
in in milli fossa

1551
01:02:44,870 --> 01:02:43,200
so so we applied this technique to the

1552
01:02:47,589 --> 01:02:44,880
entire prism data set to see if we can

1553
01:02:49,910 --> 01:02:47,599
find new occurrences of serpentine and

1554
01:02:51,270 --> 01:02:49,920
what we found if we go back and forth is

1555
01:02:53,190 --> 01:02:51,280
we could corroborate the past

1556
01:02:54,150 --> 01:02:53,200
identifications of serpentine across the

1557
01:02:56,630 --> 01:02:54,160
globe

1558
01:02:59,430 --> 01:02:56,640
and then we found additional ones um

1559
01:03:00,150 --> 01:02:59,440
so for the most part um

1560
01:03:01,510 --> 01:03:00,160
they're

1561
01:03:03,670 --> 01:03:01,520
the serpentine is occurring in the

1562
01:03:04,950 --> 01:03:03,680
southern highlands as kristoff showed

1563
01:03:07,029 --> 01:03:04,960

that's where most of the hydrated

1564
01:03:09,589 --> 01:03:07,039
minerals are identified on mars

1565
01:03:11,190 --> 01:03:09,599
um just for

1566
01:03:13,510 --> 01:03:11,200
reasons of dust coverage and

1567
01:03:14,549 --> 01:03:13,520
observational issues

1568
01:03:16,630 --> 01:03:14,559
um

1569
01:03:18,390 --> 01:03:16,640
and so we find a serpentine across the

1570
01:03:20,309 --> 01:03:18,400
southern highlands and corroborate where

1571
01:03:23,190 --> 01:03:20,319
other people are seeing it

1572
01:03:24,950 --> 01:03:23,200
and um and then we also look for this

1573
01:03:26,549 --> 01:03:24,960
other spectral seats we look for places

1574
01:03:28,870 --> 01:03:26,559
with magnesium carbonate and

1575
01:03:30,710 --> 01:03:28,880
calciferonite phase in hopes of finding

1576
01:03:32,710 --> 01:03:30,720
other regions that showed this grouping

1577
01:03:35,109 --> 01:03:32,720
of minerals that might indicate um this

1578
01:03:38,309 --> 01:03:35,119
in-situ sepantonization and for the most

1579
01:03:39,990 --> 01:03:38,319
part we didn't find that talc magnesite

1580
01:03:41,910 --> 01:03:40,000
and serpentine

1581
01:03:43,670 --> 01:03:41,920
correlated very much spatially they were

1582
01:03:45,270 --> 01:03:43,680
found distributed across the southern

1583
01:03:46,870 --> 01:03:45,280
highlands but

1584
01:03:48,150 --> 01:03:46,880
they weren't all necessarily found

1585
01:03:50,069 --> 01:03:48,160
together

1586
01:03:52,309 --> 01:03:50,079
and the serpentine observations kind of

1587
01:03:54,549 --> 01:03:52,319
fell into these two categories

1588
01:03:56,470 --> 01:03:54,559

um they were either found in these kind

1589
01:03:59,910 --> 01:03:56,480
of isolated occurrences across the

1590
01:04:02,549 --> 01:03:59,920
southern highlands or or like with melee

1591
01:04:04,789 --> 01:04:02,559
phosphate here they were found together

1592
01:04:07,190 --> 01:04:04,799
um some other places like mars ballast

1593
01:04:09,589 --> 01:04:07,200
and um florida's rise also kind of

1594
01:04:10,829 --> 01:04:09,599
showed this interesting grouping of

1595
01:04:13,990 --> 01:04:10,839
of

1596
01:04:16,710 --> 01:04:14,000
detection so these isolated occurrences

1597
01:04:19,829 --> 01:04:16,720
although still quite rare across the

1598
01:04:22,069 --> 01:04:19,839
globe um were found across the southern

1599
01:04:24,150 --> 01:04:22,079
highlands they're well distributed

1600
01:04:26,470 --> 01:04:24,160
the target transformation fits so using

1601
01:04:28,230 --> 01:04:26,480
this new technique we're really clear in

1602
01:04:29,910 --> 01:04:28,240
their identification so we're confident

1603
01:04:31,990 --> 01:04:29,920
that it's there

1604
01:04:34,549 --> 01:04:32,000
they're typically associated with crater

1605
01:04:36,789 --> 01:04:34,559
ejecta or discontinuous layers so really

1606
01:04:38,789 --> 01:04:36,799
reworked terrain

1607
01:04:40,069 --> 01:04:38,799
so not necessarily found in situ and

1608
01:04:41,270 --> 01:04:40,079
they weren't necessarily found with

1609
01:04:42,470 --> 01:04:41,280
these other spectral types we were

1610
01:04:44,150 --> 01:04:42,480
interested in

1611
01:04:45,750 --> 01:04:44,160
and the target transformation detections

1612
01:04:47,910 --> 01:04:45,760
were really telling us that their the

1613
01:04:50,950 --> 01:04:47,920

serpentine is occurring at really

1614
01:04:52,549 --> 01:04:50,960
low concentrations

1615
01:04:53,510 --> 01:04:52,559
and then there were these other regions

1616
01:04:55,829 --> 01:04:53,520
where

1617
01:04:58,069 --> 01:04:55,839
the geologic and the mineralogical

1618
01:05:02,390 --> 01:04:58,079
context makes a lot more sense

1619
01:05:07,430 --> 01:05:04,789
that's not working but down um in this

1620
01:05:09,190 --> 01:05:07,440
so here's dallas marineris

1621
01:05:11,190 --> 01:05:09,200
there are these detections of serpentine

1622
01:05:13,589 --> 01:05:11,200
along the thaumasia highlands and what's

1623
01:05:16,230 --> 01:05:13,599
the thought is that this is an uplifted

1624
01:05:19,109 --> 01:05:16,240
tectonically controlled terrain

1625
01:05:20,549 --> 01:05:19,119
um so perhaps we're we're seeing a

1626
01:05:23,190 --> 01:05:20,559
serpentine brought up from the

1627
01:05:25,750 --> 01:05:23,200
subsurface and exposed here

1628
01:05:28,069 --> 01:05:25,760
it definitely tectonically

1629
01:05:32,150 --> 01:05:28,079
mediated

1630
01:05:33,589 --> 01:05:32,160
another interesting area was mark valas

1631
01:05:36,309 --> 01:05:33,599
there are quite a few kind of low

1632
01:05:37,670 --> 01:05:36,319
concentration detections of serpentine

1633
01:05:40,630 --> 01:05:37,680
associated with

1634
01:05:42,390 --> 01:05:40,640
carbonate and one detection of talc down

1635
01:05:44,309 --> 01:05:42,400
in the south i mean this is just

1636
01:05:45,670 --> 01:05:44,319
interesting because marthalist has some

1637
01:05:47,670 --> 01:05:45,680
of the highest abundances of

1638
01:05:49,670 --> 01:05:47,680

phytosilicate on the planet it's

1639
01:05:50,950 --> 01:05:49,680
observable both in the near infrared and

1640
01:05:52,069 --> 01:05:50,960
potentially in the thermal infrared

1641
01:05:53,510 --> 01:05:52,079
which tells you it's really high

1642
01:05:55,510 --> 01:05:53,520
concentration

1643
01:05:57,510 --> 01:05:55,520
so using this new technique does target

1644
01:05:58,950 --> 01:05:57,520
transformation and factor analysis we're

1645
01:06:00,870 --> 01:05:58,960
able to show that there's even

1646
01:06:03,990 --> 01:06:00,880
potentially serpentine there at these

1647
01:06:05,510 --> 01:06:04,000
low concentrations

1648
01:06:07,349 --> 01:06:05,520
and then the target transformation the

1649
01:06:08,470 --> 01:06:07,359
factor analysis this independent

1650
01:06:11,510 --> 01:06:08,480
technique

1651
01:06:14,230 --> 01:06:11,520
also found um abundant

1652
01:06:16,309 --> 01:06:14,240
serpentine again in nile phosphate

1653
01:06:18,870 --> 01:06:16,319
so if we go back to my first map that i

1654
01:06:20,549 --> 01:06:18,880
showed so these are the distributions of

1655
01:06:22,630 --> 01:06:20,559
serpentine

1656
01:06:26,549 --> 01:06:22,640
using just traditional prism analysis

1657
01:06:29,349 --> 01:06:27,990
previously

1658
01:06:31,349 --> 01:06:29,359
if we look at what the target

1659
01:06:33,190 --> 01:06:31,359
transformation and the factor analysis

1660
01:06:34,710 --> 01:06:33,200
find they corroborate those in those

1661
01:06:36,789 --> 01:06:34,720
initial um

1662
01:06:38,950 --> 01:06:36,799
three detections but then they find

1663
01:06:41,829 --> 01:06:38,960

um that serpentine is actually much more

1664
01:06:44,150 --> 01:06:41,839
pervasive across this region

1665
01:06:46,470 --> 01:06:44,160
and in particular it looks like it's

1666
01:06:47,910 --> 01:06:46,480
concentrated um in the eastern portion

1667
01:06:49,270 --> 01:06:47,920
of nelly fosse and this is where those

1668
01:06:50,789 --> 01:06:49,280
really um

1669
01:06:53,990 --> 01:06:50,799
high concentration all of the enriched

1670
01:06:57,190 --> 01:06:54,000
basalts are actually located

1671
01:07:00,630 --> 01:06:57,200
and so um a model put forth by christina

1672
01:07:01,910 --> 01:07:00,640
viviano in 2013 i think is still pretty

1673
01:07:04,150 --> 01:07:01,920
consistent with what we're observing

1674
01:07:06,549 --> 01:07:04,160
with both the target transformation um

1675
01:07:09,430 --> 01:07:06,559
and the previous analyses is that

1676
01:07:11,670 --> 01:07:09,440
you started with this initial uh

1677
01:07:13,670 --> 01:07:11,680
compositional stratigraphy of having

1678
01:07:15,910 --> 01:07:13,680
this this pre-weathered olivine rich

1679
01:07:17,910 --> 01:07:15,920
basalt and over time

1680
01:07:19,910 --> 01:07:17,920
this was likely hydrated and you you had

1681
01:07:22,470 --> 01:07:19,920
serpentinization forming

1682
01:07:25,029 --> 01:07:22,480
um serpentine but then now we have this

1683
01:07:27,029 --> 01:07:25,039
associated magnesite and talc

1684
01:07:31,270 --> 01:07:27,039
um which likely implies that you had

1685
01:07:35,589 --> 01:07:32,950
and so what about other olivine rich

1686
01:07:36,549 --> 01:07:35,599
regions why is nelly fosse so special

1687
01:07:39,190 --> 01:07:36,559
well

1688
01:07:41,109 --> 01:07:39,200

there are other abundant olivine rich

1689
01:07:43,190 --> 01:07:41,119
areas on the surface other ultramafic

1690
01:07:45,109 --> 01:07:43,200
regions mostly associated with these

1691
01:07:46,950 --> 01:07:45,119
large impact craters and the idea is

1692
01:07:48,549 --> 01:07:46,960
that you're you're potentially tapping

1693
01:07:50,390 --> 01:07:48,559
into the mantle when you have these huge

1694
01:07:52,309 --> 01:07:50,400
impacts and you brought all the enriched

1695
01:07:54,549 --> 01:07:52,319
material to the surface

1696
01:07:56,309 --> 01:07:54,559
but we didn't find all serpentine

1697
01:07:57,990 --> 01:07:56,319
necessarily associated with them so you

1698
01:07:59,910 --> 01:07:58,000
don't see serpentine down on the edges

1699
01:08:02,390 --> 01:07:59,920
of our gyre basin there's only a few

1700
01:08:04,069 --> 01:08:02,400
exposures here um

1701
01:08:05,430 --> 01:08:04,079
near helis basin

1702
01:08:06,630 --> 01:08:05,440
um so

1703
01:08:08,150 --> 01:08:06,640
there doesn't seem to be this

1704
01:08:09,910 --> 01:08:08,160
relationship between

1705
01:08:11,990 --> 01:08:09,920
the olivine rich basalt on a global

1706
01:08:13,349 --> 01:08:12,000
scale and serpentinization other than in

1707
01:08:15,349 --> 01:08:13,359
melee faucet

1708
01:08:17,990 --> 01:08:15,359
so perhaps melee phosphate is this

1709
01:08:21,910 --> 01:08:18,000
unique um setting

1710
01:08:23,269 --> 01:08:21,920
uh where you had this sustained kind of

1711
01:08:24,630 --> 01:08:23,279
surface

1712
01:08:26,709 --> 01:08:24,640
serpentinization and subsequent

1713
01:08:30,390 --> 01:08:26,719

carbonation

1714
01:08:32,149 --> 01:08:30,400
um so kind of the the overall

1715
01:08:34,950 --> 01:08:32,159
summary i'd say of this global search

1716
01:08:37,669 --> 01:08:34,960
for evidence of serpentine is that um

1717
01:08:39,829 --> 01:08:37,679
overall exposures

1718
01:08:41,990 --> 01:08:39,839
that are detectable from orbit

1719
01:08:43,749 --> 01:08:42,000
are quite rare on mars but they are

1720
01:08:45,110 --> 01:08:43,759
still found across the southern

1721
01:08:47,269 --> 01:08:45,120
highlands

1722
01:08:50,070 --> 01:08:47,279
most of those occurrences are in these

1723
01:08:52,070 --> 01:08:50,080
isolated rework terrains at really low

1724
01:08:53,990 --> 01:08:52,080
concentrations and maybe this is telling

1725
01:08:56,709 --> 01:08:54,000
us that there was an early

1726
01:08:58,229 --> 01:08:56,719
um global serpentinizational process

1727
01:09:00,870 --> 01:08:58,239
happening when mars was more

1728
01:09:02,390 --> 01:09:00,880
geologically active

1729
01:09:04,149 --> 01:09:02,400
and since they're not associated with

1730
01:09:06,309 --> 01:09:04,159
those other olivine rich regions perhaps

1731
01:09:09,349 --> 01:09:06,319
this was happening prior to those large

1732
01:09:11,349 --> 01:09:09,359
impact impact events so you know really

1733
01:09:12,950 --> 01:09:11,359
long time ago 4.1 billion years ago in

1734
01:09:14,309 --> 01:09:12,960
the pre-milwaukee

1735
01:09:16,149 --> 01:09:14,319
and so this is really interesting from a

1736
01:09:17,590 --> 01:09:16,159
planetary evolution perspective but it's

1737
01:09:20,229 --> 01:09:17,600
less satisfactory say from an

1738
01:09:21,669 --> 01:09:20,239

astrobiological um

1739
01:09:22,630 --> 01:09:21,679
perspective

1740
01:09:26,229 --> 01:09:22,640
and then

1741
01:09:27,910 --> 01:09:26,239
really point to the fact that nearly

1742
01:09:30,709 --> 01:09:27,920
fosse is this

1743
01:09:33,110 --> 01:09:30,719
uh unique site on mars and that having

1744
01:09:34,950 --> 01:09:33,120
this large-scale regional

1745
01:09:36,709 --> 01:09:34,960
serpentinizing system was probably

1746
01:09:38,229 --> 01:09:36,719
pretty rare

1747
01:09:40,229 --> 01:09:38,239
um at least for what from what we can

1748
01:09:43,030 --> 01:09:40,239
detect at present day

1749
01:09:44,709 --> 01:09:43,040
um and so i think from a habitability

1750
01:09:47,829 --> 01:09:44,719
standpoint this is a really intriguing

1751
01:09:50,630 --> 01:09:47,839
place to go study in more detail

1752
01:09:52,149 --> 01:09:50,640
certainly is is pretty rare so it

1753
01:09:54,149 --> 01:09:52,159
it seems like a very interesting place

1754
01:09:56,550 --> 01:09:54,159
to go look and regardless of whether or

1755
01:09:58,870 --> 01:09:56,560
not life formed there i think it has a

1756
01:10:02,229 --> 01:09:58,880
lot of implications for um

1757
01:10:04,550 --> 01:10:02,239
for planetary evolution on mars ours

1758
01:10:06,790 --> 01:10:04,560
so my my last kind of thoughts are there

1759
01:10:08,149 --> 01:10:06,800
quite a few um open-ended questions i

1760
01:10:09,750 --> 01:10:08,159
say with this study

1761
01:10:11,510 --> 01:10:09,760
from the data we have now it's really

1762
01:10:13,110 --> 01:10:11,520
hard to say whether or not any

1763
01:10:15,350 --> 01:10:13,120

serpentinization in the lyfosa was

1764
01:10:17,189 --> 01:10:15,360
sustained or episodic it's not clear if

1765
01:10:19,430 --> 01:10:17,199
it came and went for how long it lasted

1766
01:10:21,270 --> 01:10:19,440
there's still a lot of olivine left so

1767
01:10:22,709 --> 01:10:21,280
clearly you know all of it wasn't

1768
01:10:24,149 --> 01:10:22,719
serpentinized

1769
01:10:25,510 --> 01:10:24,159
it's hard to say what the mineral

1770
01:10:27,030 --> 01:10:25,520
abundances are

1771
01:10:27,990 --> 01:10:27,040
with the data we have so i think this

1772
01:10:30,550 --> 01:10:28,000
really

1773
01:10:32,470 --> 01:10:30,560
makes it an even a better case for going

1774
01:10:37,510 --> 01:10:32,480
there with a landed mission that has

1775
01:10:40,870 --> 01:10:39,030
better techniques for determining the

1776
01:10:42,870 --> 01:10:40,880
mineral abundances

1777
01:10:44,470 --> 01:10:42,880
and then it's still not clear how well

1778
01:10:47,590 --> 01:10:44,480
bio signatures are preserved in these

1779
01:10:49,189 --> 01:10:47,600
environments necessarily so um

1780
01:10:50,390 --> 01:10:49,199
as i you know the last few days

1781
01:10:51,990 --> 01:10:50,400
listening to everyone talk it sounds

1782
01:10:53,590 --> 01:10:52,000
like the most biologically productive

1783
01:10:54,470 --> 01:10:53,600
areas and these serpentinizing systems

1784
01:10:55,430 --> 01:10:54,480
are where

1785
01:10:56,630 --> 01:10:55,440
um

1786
01:10:58,630 --> 01:10:56,640
the

1787
01:11:00,310 --> 01:10:58,640
altered fluids are interacting with

1788
01:11:02,229 --> 01:11:00,320

fresh water or where you're getting

1789
01:11:03,910 --> 01:11:02,239
mixing so it's not clear where that's

1790
01:11:05,669 --> 01:11:03,920
exactly happening in milli fossa is that

1791
01:11:06,950 --> 01:11:05,679
actually happening in that olivine rich

1792
01:11:09,510 --> 01:11:06,960
layer or

1793
01:11:10,790 --> 01:11:09,520
do we need to look down watershed at

1794
01:11:12,790 --> 01:11:10,800
where these fluids would have been

1795
01:11:14,149 --> 01:11:12,800
coming out of the surface

1796
01:11:16,390 --> 01:11:14,159
and i think a lot of the research that

1797
01:11:17,990 --> 01:11:16,400
people are doing in oman and

1798
01:11:21,590 --> 01:11:18,000
velocity and actually drilling into the

1799
01:11:23,189 --> 01:11:21,600
bedrock will give us a better idea of

1800
01:11:25,510 --> 01:11:23,199
where we should be looking as far as

1801
01:11:26,870 --> 01:11:25,520
biosignatures from this environment

1802
01:11:29,350 --> 01:11:26,880
so i'll leave it with that i i think

1803
01:11:34,470 --> 01:11:29,360
there probably is a lot to discuss

1804
01:11:37,189 --> 01:11:36,470
thanks so much the questions are coming

1805
01:11:38,830 --> 01:11:37,199
in

1806
01:11:41,990 --> 01:11:38,840
um

1807
01:11:43,430 --> 01:11:42,000
so let me just uh start at the top

1808
01:11:44,709 --> 01:11:43,440
um

1809
01:11:47,750 --> 01:11:44,719
so there's a question from adrian brown

1810
01:11:48,950 --> 01:11:47,760
whether you've found anything um

1811
01:11:55,430 --> 01:11:48,960
uh

1812
01:11:56,470 --> 01:11:55,440
he thinks that the resolution was just

1813
01:11:58,790 --> 01:11:56,480

was uh

1814
01:12:00,470 --> 01:11:58,800
the outcomes were too small

1815
01:12:02,709 --> 01:12:00,480
yeah so

1816
01:12:04,470 --> 01:12:02,719
yeah that in the thermometer two thermal

1817
01:12:06,550 --> 01:12:04,480
infrared spectrometers

1818
01:12:07,990 --> 01:12:06,560
that have been to mars there's the test

1819
01:12:09,990 --> 01:12:08,000
instrument which actually is pretty high

1820
01:12:12,229 --> 01:12:10,000
resolution and would be able to observe

1821
01:12:14,470 --> 01:12:12,239
serpentine the spectral resolution but

1822
01:12:16,149 --> 01:12:14,480
unfortunately the spatial resolution is

1823
01:12:17,990 --> 01:12:16,159
kilometers in scale so there's no way

1824
01:12:19,750 --> 01:12:18,000
we'd be able to see um

1825
01:12:22,950 --> 01:12:19,760
those serpentine outcrops

1826
01:12:24,709 --> 01:12:22,960
and then the femus instrument has a

1827
01:12:27,350 --> 01:12:24,719
better spatial resolution it's still

1828
01:12:29,189 --> 01:12:27,360
about 200 meters per pixel but the

1829
01:12:30,790 --> 01:12:29,199
spectral resolution is so poor that you

1830
01:12:33,030 --> 01:12:30,800
wouldn't actually be able to say whether

1831
01:12:34,950 --> 01:12:33,040
or not there was serpentine um that's

1832
01:12:36,390 --> 01:12:34,960
better at telling you oak silica

1833
01:12:38,870 --> 01:12:36,400
abundances so unfortunately with the

1834
01:12:40,550 --> 01:12:38,880
data we have today for the instruments

1835
01:12:42,229 --> 01:12:40,560
we have available today in thermal bread

1836
01:12:43,030 --> 01:12:42,239
we don't see them

1837
01:12:44,870 --> 01:12:43,040
okay

1838
01:12:47,750 --> 01:12:44,880

i had a related question in the visible

1839
01:12:49,830 --> 01:12:47,760
spectrum uh there are large outcrops of

1840
01:12:52,070 --> 01:12:49,840
serpentine that i know of in california

1841
01:12:53,110 --> 01:12:52,080
i've often wondered about uh seeing

1842
01:12:55,590 --> 01:12:53,120
those in

1843
01:12:57,669 --> 01:12:55,600
spatial mapping wondering if um if

1844
01:13:00,390 --> 01:12:57,679
that's a reasonable thing to pursue and

1845
01:13:03,110 --> 01:13:00,400
if current instrumentation at mars is

1846
01:13:05,110 --> 01:13:03,120
not up to the task

1847
01:13:08,310 --> 01:13:05,120
yeah i i haven't looked for those

1848
01:13:11,030 --> 01:13:08,320
outcrops um in earth data

1849
01:13:12,870 --> 01:13:11,040
i imagine that um

1850
01:13:15,590 --> 01:13:12,880
you know for earth stuff you really

1851
01:13:16,870 --> 01:13:15,600
vegetation really gets in the way

1852
01:13:19,430 --> 01:13:16,880
and um

1853
01:13:20,870 --> 01:13:19,440
so i i would be worried that that you

1854
01:13:23,350 --> 01:13:20,880
would be flooding those spectral

1855
01:13:25,669 --> 01:13:23,360
absorptions with with other um

1856
01:13:28,390 --> 01:13:25,679
interfering factors but i think there

1857
01:13:30,550 --> 01:13:28,400
are uh folks in bethany allman's group

1858
01:13:32,790 --> 01:13:30,560
looking in oman about crops in oman and

1859
01:13:35,189 --> 01:13:32,800
trying to correlate um you know

1860
01:13:36,630 --> 01:13:35,199
spacecraft aerial spectral data to what

1861
01:13:39,030 --> 01:13:36,640
they actually see on the ground and

1862
01:13:40,790 --> 01:13:39,040
really trying to understand what you can

1863
01:13:42,550 --> 01:13:40,800

observe from orbit

1864
01:13:43,590 --> 01:13:42,560
and how that relates to what's actually

1865
01:13:52,550 --> 01:13:43,600
on the surface and that'll have

1866
01:13:57,830 --> 01:13:54,950
okay that's great um

1867
01:13:59,830 --> 01:13:57,840
tom clarifies that uh

1868
01:14:01,189 --> 01:13:59,840
serpentine is usually associated with

1869
01:14:03,270 --> 01:14:01,199
ultramafic rocks not all of the

1870
01:14:04,630 --> 01:14:03,280
enrichment assault um and you're just

1871
01:14:09,189 --> 01:14:04,640
wondering if there are instances where

1872
01:14:13,990 --> 01:14:12,070
well i i think

1873
01:14:16,390 --> 01:14:14,000
i i don't know off the top of my head of

1874
01:14:20,470 --> 01:14:16,400
serpentinization and in just the salt

1875
01:14:23,350 --> 01:14:20,480
but aren't ultramafic um but for mars 40

1876
01:14:25,350 --> 01:14:23,360
olivine uh in a basalt is pretty ultra

1877
01:14:27,910 --> 01:14:25,360
mafic and that's about as good as you

1878
01:14:29,510 --> 01:14:27,920
get on the surface of mars um and so i

1879
01:14:32,229 --> 01:14:29,520
think it's it's pretty intriguing that

1880
01:14:34,229 --> 01:14:32,239
we do see these spectral responses

1881
01:14:36,470 --> 01:14:34,239
for serpentine and they're diagnostics

1882
01:14:37,910 --> 01:14:36,480
and we know serpentine is there in

1883
01:14:40,830 --> 01:14:37,920
in some form we don't know the

1884
01:14:43,990 --> 01:14:40,840
concentration of it but it's it's

1885
01:14:45,350 --> 01:14:44,000
detectable um in 20 meter pixels from

1886
01:14:46,470 --> 01:14:45,360
prism

1887
01:14:49,590 --> 01:14:46,480
um

1888
01:14:53,030 --> 01:14:49,600

so it's a little unsatisfactory but

1889
01:14:54,830 --> 01:14:53,040
okay 40 percent ultra mars

1890
01:14:57,030 --> 01:14:54,840
okay so point of

1891
01:14:59,430 --> 01:14:57,040
clarification uh brian heineck was

1892
01:15:01,430 --> 01:14:59,440
asking uh in your survey it seemed like

1893
01:15:04,470 --> 01:15:01,440
there were some previous serpentine

1894
01:15:05,669 --> 01:15:04,480
detections um that weren't represented

1895
01:15:07,189 --> 01:15:05,679
in your map and

1896
01:15:09,270 --> 01:15:07,199
uh is that

1897
01:15:12,229 --> 01:15:09,280
so and if so why

1898
01:15:14,310 --> 01:15:12,239
yeah i didn't see those before a few

1899
01:15:17,830 --> 01:15:14,320
days ago so those will be absolutely

1900
01:15:19,030 --> 01:15:17,840
added to my to my map um and in looking

1901
01:15:21,590 --> 01:15:19,040
at where they are they kind of fall

1902
01:15:32,790 --> 01:15:21,600
between isidius and helispacen so those

1903
01:15:36,870 --> 01:15:34,630
wondering if the system is sub-aerial at

1904
01:15:39,750 --> 01:15:36,880
the time or uh or if it's subsurface

1905
01:15:41,430 --> 01:15:39,760
that was then exposed later

1906
01:15:43,990 --> 01:15:41,440
so i i believe that this is all

1907
01:15:46,310 --> 01:15:44,000
subsurface so the olivine rich basalt is

1908
01:15:48,470 --> 01:15:46,320
actually capped by another unit this

1909
01:15:50,229 --> 01:15:48,480
this capping unit of an olivine for

1910
01:15:52,310 --> 01:15:50,239
basalt and all of this would have been

1911
01:15:54,229 --> 01:15:52,320
covered at some time and now it's being

1912
01:15:55,270 --> 01:15:54,239
exposed to the surface so

1913
01:15:57,590 --> 01:15:55,280

um

1914
01:15:58,790 --> 01:15:57,600
this the olivine rich unit probably

1915
01:16:00,070 --> 01:15:58,800
wasn't

1916
01:16:03,270 --> 01:16:00,080
on the surface when it was

1917
01:16:07,270 --> 01:16:04,149
okay

1918
01:16:08,229 --> 01:16:07,280
uh cody lazar chimes in about clarifying

1919
01:16:09,189 --> 01:16:08,239
um

1920
01:16:11,669 --> 01:16:09,199
this question about all of the

1921
01:16:14,229 --> 01:16:11,679
enrichment assaults and states that uh

1922
01:16:15,510 --> 01:16:14,239
uh seen it some sometimes rarely in the

1923
01:16:17,430 --> 01:16:15,520
thin sections

1924
01:16:19,110 --> 01:16:17,440
uh

1925
01:16:21,030 --> 01:16:19,120
i'm not sure what surely in bulk process

1926
01:16:22,149 --> 01:16:21,040
equilibrium you're seeing this as well

1927
01:16:24,070 --> 01:16:22,159
um

1928
01:16:26,310 --> 01:16:24,080
the student just found uh serpentine

1929
01:16:28,950 --> 01:16:26,320
pseudomonas

1930
01:16:34,310 --> 01:16:28,960
in the san bernardino mountains

1931
01:16:36,630 --> 01:16:35,110
okay

1932
01:16:38,310 --> 01:16:36,640
um

1933
01:16:40,229 --> 01:16:38,320
let's see the

1934
01:16:41,830 --> 01:16:40,239
is it possible to define the minimum

1935
01:16:43,910 --> 01:16:41,840
aerial extent or degree of

1936
01:16:46,950 --> 01:16:43,920
serpentinization necessary for a

1937
01:16:49,910 --> 01:16:46,960
diagnostic special signature um

1938
01:16:53,270 --> 01:16:49,920

and any associated carbonates

1939
01:16:56,070 --> 01:16:53,280
yeah let's see um

1940
01:16:57,430 --> 01:16:56,080
it's that's really hard it's really hard

1941
01:16:59,910 --> 01:16:57,440
to get

1942
01:17:01,270 --> 01:16:59,920
uh concentrations in near-infrared data

1943
01:17:04,550 --> 01:17:01,280
because of scattering effects so the

1944
01:17:07,669 --> 01:17:04,560
best you can do is say okay this 20

1945
01:17:08,790 --> 01:17:07,679
meter pixel in chrism

1946
01:17:10,709 --> 01:17:08,800
um

1947
01:17:12,790 --> 01:17:10,719
has the spectral signature and then you

1948
01:17:14,790 --> 01:17:12,800
can hopefully go in with higher

1949
01:17:17,189 --> 01:17:14,800
resolution visual data

1950
01:17:20,149 --> 01:17:17,199
and try and piece out which outcrops

1951
01:17:22,149 --> 01:17:20,159
might actually be

1952
01:17:25,430 --> 01:17:22,159
producing that signature typically i

1953
01:17:27,270 --> 01:17:25,440
think what what people say is about 10

1954
01:17:29,910 --> 01:17:27,280
volume percent

1955
01:17:32,229 --> 01:17:29,920
phylosolocate is what you is the minimum

1956
01:17:33,590 --> 01:17:32,239
that you could probably see within these

1957
01:17:35,030 --> 01:17:33,600
um

1958
01:17:36,229 --> 01:17:35,040
spectral signatures

1959
01:17:38,790 --> 01:17:36,239
um

1960
01:17:41,430 --> 01:17:38,800
but it it it's hard to

1961
01:17:45,750 --> 01:17:41,440
to actually get an aerial extent without

1962
01:17:49,030 --> 01:17:45,760
knowing exactly where the outcrops are

1963
01:17:53,030 --> 01:17:50,950

obviously an important thing to consider

1964
01:17:53,910 --> 01:17:53,040
for the future seems like this is

1965
01:17:55,669 --> 01:17:53,920
something that we're going to keep

1966
01:17:57,590 --> 01:17:55,679
learning more about as

1967
01:17:59,430 --> 01:17:57,600
let's continue as mars exploration

1968
01:18:01,189 --> 01:17:59,440
continues um

1969
01:18:03,990 --> 01:18:01,199
so we just have a little bit of time for

1970
01:18:05,669 --> 01:18:04,000
the break uh adrian brown mentions that

1971
01:18:07,350 --> 01:18:05,679
there are some ground studies in

1972
01:18:11,590 --> 01:18:07,360
australia wondering if adrian if you

1973
01:18:15,430 --> 01:18:12,950
oh that uh

1974
01:18:17,590 --> 01:18:15,440
i i missed the question

1975
01:18:19,750 --> 01:18:17,600
uh well so i'm asking adrian to

1976
01:18:25,350 --> 01:18:19,760
elaborate i'm not sure what uh ground

1977
01:18:31,189 --> 01:18:27,750
oh and i'm just reading one of brian

1978
01:18:34,470 --> 01:18:31,199
ryan's questions about um

1979
01:18:37,910 --> 01:18:36,149
some of bethany and christina's

1980
01:18:38,950 --> 01:18:37,920
detections don't have detections in my

1981
01:18:41,830 --> 01:18:38,960
study so

1982
01:18:43,830 --> 01:18:41,840
um in bethany allman's 2010 paper she

1983
01:18:45,270 --> 01:18:43,840
had some probable detections she had her

1984
01:18:47,189 --> 01:18:45,280
confidence sections which were those

1985
01:18:49,830 --> 01:18:47,199
stars and then probable detections which

1986
01:18:51,430 --> 01:18:49,840
were squares and um

1987
01:18:53,750 --> 01:18:51,440
to me i think that

1988
01:18:55,350 --> 01:18:53,760

so that spectral spectral signature for

1989
01:18:57,270 --> 01:18:55,360
serpentine is so

1990
01:18:59,430 --> 01:18:57,280
um dubious

1991
01:19:00,470 --> 01:18:59,440
that it could just be that

1992
01:19:03,030 --> 01:19:00,480
those ones that she thought were

1993
01:19:04,950 --> 01:19:03,040
probable um

1994
01:19:06,070 --> 01:19:04,960
maybe weren't real

1995
01:19:07,510 --> 01:19:06,080
um

1996
01:19:09,030 --> 01:19:07,520
it's really hard to find it in the near

1997
01:19:11,270 --> 01:19:09,040
infrared so i think it says something

1998
01:19:13,270 --> 01:19:11,280
that the ones that she was confident in

1999
01:19:14,709 --> 01:19:13,280
we independently confirmed as well and

2000
01:19:16,149 --> 01:19:14,719
maybe that helps constrain whether or

2001
01:19:17,669 --> 01:19:16,159
not her probables were real and then

2002
01:19:20,709 --> 01:19:17,679
there are a few of christina viviana's

2003
01:19:24,149 --> 01:19:20,719
that we also didn't um corroborate

2004
01:19:25,750 --> 01:19:24,159
um and again i'm not i can't say why or

2005
01:19:27,750 --> 01:19:25,760
we did or we didn't it might just be

2006
01:19:31,669 --> 01:19:27,760
that those spectral signatures are a

2007
01:19:37,350 --> 01:19:34,870
okay uh we are into the break period but

2008
01:19:39,030 --> 01:19:37,360
i do want to just uh touch on the last

2009
01:19:40,790 --> 01:19:39,040
questions that just came up and then we

2010
01:19:43,110 --> 01:19:40,800
can continue receiving questions during

2011
01:19:44,709 --> 01:19:43,120
the break um there was a question about

2012
01:19:47,910 --> 01:19:44,719
the concurrent formation of the

2013
01:19:49,270 --> 01:19:47,920

carbonates with the serpentinization um

2014
01:19:51,990 --> 01:19:49,280
or whether they formed afterward and if

2015
01:19:53,189 --> 01:19:52,000
there's any way to really constrain that

2016
01:19:54,790 --> 01:19:53,199
yeah so

2017
01:19:56,630 --> 01:19:54,800
the carbonate can form under a few

2018
01:19:59,030 --> 01:19:56,640
different scenarios right like you could

2019
01:20:01,189 --> 01:19:59,040
actually just get the alteration of

2020
01:20:02,550 --> 01:20:01,199
olivine from surface water

2021
01:20:04,790 --> 01:20:02,560
um to

2022
01:20:06,950 --> 01:20:04,800
to produce the magnesium carbonate or

2023
01:20:09,110 --> 01:20:06,960
the carbonate again could form from the

2024
01:20:11,750 --> 01:20:09,120
subsequent alteration of serpentine to

2025
01:20:13,830 --> 01:20:11,760
form talc and magnesite and i think the

2026
01:20:16,550 --> 01:20:13,840
fact that we're seeing the talc with the

2027
01:20:18,390 --> 01:20:16,560
magnesite and the serpentine kind of put

2028
01:20:20,070 --> 01:20:18,400
everything together in this

2029
01:20:21,590 --> 01:20:20,080
nice little package that implies

2030
01:20:23,910 --> 01:20:21,600
carbonation

2031
01:20:26,149 --> 01:20:23,920
but it could be that there are multiple

2032
01:20:28,470 --> 01:20:26,159
mechanisms for forming that carbonate in

2033
01:20:30,390 --> 01:20:28,480
um in milli fossa there are other

2034
01:20:32,149 --> 01:20:30,400
exposures of magnesium carbonate across

2035
01:20:33,910 --> 01:20:32,159
mars that aren't necessarily associated

2036
01:20:34,629 --> 01:20:33,920
with um

2037
01:20:36,070 --> 01:20:34,639
so

2038
01:20:37,990 --> 01:20:36,080

i don't think we're we're not

2039
01:20:41,430 --> 01:20:38,000
necessarily only seeing one mechanism

2040
01:20:44,070 --> 01:20:42,790
yeah that makes sense so we shouldn't

2041
01:20:48,229 --> 01:20:44,080
necessarily be biased by our

2042
01:20:50,390 --> 01:20:48,239
expectations from earth um yeah

2043
01:20:53,110 --> 01:20:50,400
okay i i think cody's comment is a

2044
01:20:54,149 --> 01:20:53,120
clarification on uh

2045
01:20:55,669 --> 01:20:54,159
on

2046
01:20:57,270 --> 01:20:55,679
your uh

2047
01:20:59,350 --> 01:20:57,280
the earlier discussion about the

2048
01:21:01,590 --> 01:20:59,360
occurrence of the solid serpentine so

2049
01:21:03,750 --> 01:21:01,600
all right so let's go to our break um we

2050
01:21:06,629 --> 01:21:03,760
will reconvene just a minute or two

2051
01:21:09,270 --> 01:21:06,639
after 10 35 with uh mark nova

2052
01:21:11,669 --> 01:21:09,280
so thanks again

2053
01:21:12,870 --> 01:21:11,679
thanks for having me give this talk

2054
01:21:14,950 --> 01:21:12,880
so for those of you who don't know me

2055
01:21:17,110 --> 01:21:14,960
i'm a postdoc at arizona state

2056
01:21:23,270 --> 01:21:17,120
university and i'll try to give you a

2057
01:21:27,110 --> 01:21:25,910
and thanks for having me give this talk

2058
01:21:28,390 --> 01:21:27,120
so for those of you who don't know me

2059
01:21:30,709 --> 01:21:28,400
i'm a postdoc

2060
01:21:32,790 --> 01:21:30,719
at arizona state university and uh i'll

2061
01:21:35,110 --> 01:21:32,800
try to give you a brief overview of

2062
01:21:36,390 --> 01:21:35,120
serpentinity on small bodies from three

2063
01:21:38,950 --> 01:21:36,400

cent points

2064
01:21:40,229 --> 01:21:38,960
first what we know from meteorites

2065
01:21:43,510 --> 01:21:40,239
second

2066
01:21:45,990 --> 01:21:43,520
what we know from modeling works

2067
01:21:48,070 --> 01:21:46,000
and third the ground truth uh from the

2068
01:21:51,270 --> 01:21:48,080
exploration of series recently by the

2069
01:21:54,550 --> 01:21:53,110
so first we're very lucky with small

2070
01:21:56,149 --> 01:21:54,560
bodies because we have three return

2071
01:21:57,910 --> 01:21:56,159
samples

2072
01:22:00,070 --> 01:21:57,920
in the form of meteorites which are

2073
01:22:02,229 --> 01:22:00,080
basically fragments ejected

2074
01:22:03,590 --> 01:22:02,239
when these asteroids collide and they

2075
01:22:04,950 --> 01:22:03,600
fall down to earth

2076
01:22:06,709 --> 01:22:04,960
so the most primitive of these are

2077
01:22:11,669 --> 01:22:06,719
called contracts

2078
01:22:15,990 --> 01:22:13,830
show that you have this

2079
01:22:17,430 --> 01:22:16,000
dark matrix

2080
01:22:19,510 --> 01:22:17,440
essentially made of

2081
01:22:21,830 --> 01:22:19,520
anhydrous silicates

2082
01:22:23,910 --> 01:22:21,840
all living pyroxene

2083
01:22:26,950 --> 01:22:23,920
and you also see these interspersed

2084
01:22:29,430 --> 01:22:26,960
bright specks like this one here

2085
01:22:31,750 --> 01:22:29,440
uh which is metal and so essentially

2086
01:22:34,550 --> 01:22:31,760
these these mineralogies are quite

2087
01:22:36,310 --> 01:22:34,560
similar to ultramatic rocks uh plus the

2088
01:22:38,950 --> 01:22:36,320

metal which on earth

2089
01:22:40,229 --> 01:22:38,960
has sunk to the core

2090
01:22:42,149 --> 01:22:40,239
now there are other contracts called

2091
01:22:42,950 --> 01:22:42,159
carbonaceous contracts

2092
01:22:45,350 --> 01:22:42,960
um

2093
01:22:47,830 --> 01:22:45,360
whose mineralogy is quite different

2094
01:22:49,990 --> 01:22:47,840
much more hydrated

2095
01:22:51,189 --> 01:22:50,000
and you can see here a breakdown of the

2096
01:22:53,430 --> 01:22:51,199
mineralogy

2097
01:22:54,950 --> 01:22:53,440
of these uh cm contracts the class of

2098
01:22:58,070 --> 01:22:54,960
combinations contracts name after the

2099
01:23:00,149 --> 01:22:58,080
the mary meteorite

2100
01:23:01,430 --> 01:23:00,159
and and these are predominantly

2101
01:23:03,830 --> 01:23:01,440
serpentine

2102
01:23:08,790 --> 01:23:03,840
so magnesiums are present in green

2103
01:23:10,550 --> 01:23:08,800
and iron serpentine and black grayish

2104
01:23:13,750 --> 01:23:10,560
they still have about ten to thirty

2105
01:23:15,830 --> 01:23:13,760
percent of uh teroxin and olivine

2106
01:23:19,510 --> 01:23:15,840
but but their mineralogy is

2107
01:23:20,629 --> 01:23:19,520
substantially altered

2108
01:23:22,470 --> 01:23:20,639
so this is

2109
01:23:23,910 --> 01:23:22,480
evidence that we have from

2110
01:23:26,390 --> 01:23:23,920
immediate rights for

2111
01:23:29,350 --> 01:23:26,400
synchronization on small bodies

2112
01:23:32,310 --> 01:23:29,360
we also have direct evidence from

2113
01:23:34,310 --> 01:23:32,320

remote observations and this is as early

2114
01:23:35,189 --> 01:23:34,320
as the late 70s

2115
01:23:36,550 --> 01:23:35,199
um

2116
01:23:38,149 --> 01:23:36,560
showing a

2117
01:23:40,390 --> 01:23:38,159
data points

2118
01:23:41,750 --> 01:23:40,400
of an infrared spectrum of series so you

2119
01:23:43,189 --> 01:23:41,760
see the data points here and then the

2120
01:23:46,229 --> 01:23:43,199
lines

2121
01:23:47,669 --> 01:23:46,239
are carbonaceous contract spectra to try

2122
01:23:49,350 --> 01:23:47,679
to match

2123
01:23:51,270 --> 01:23:49,360
these data points

2124
01:23:52,550 --> 01:23:51,280
and there is a some absorption of three

2125
01:23:55,270 --> 01:23:52,560
microns

2126
01:23:56,790 --> 01:23:55,280
that's characteristic of

2127
01:23:59,270 --> 01:23:56,800
bounds oh

2128
01:24:02,470 --> 01:23:59,280
and so evidence of water for hydration

2129
01:24:05,030 --> 01:24:02,480
and since these first observations

2130
01:24:06,629 --> 01:24:05,040
this event has been seen on many other

2131
01:24:10,310 --> 01:24:06,639
asteroids between mars and jupiter

2132
01:24:14,790 --> 01:24:11,510
um so

2133
01:24:16,550 --> 01:24:14,800
quite early on even the the early 60s it

2134
01:24:19,430 --> 01:24:16,560
was established that

2135
01:24:21,270 --> 01:24:19,440
most likely these carbonaceous contracts

2136
01:24:22,790 --> 01:24:21,280
are the results of the aqueous

2137
01:24:27,990 --> 01:24:22,800
alteration

2138
01:24:30,950 --> 01:24:29,350

and so that the

2139
01:24:33,189 --> 01:24:30,960
the olivine the tyrex team the metal

2140
01:24:35,669 --> 01:24:33,199
gets turned uh into serpentine and

2141
01:24:36,550 --> 01:24:35,679
associated magnetite etc

2142
01:24:40,709 --> 01:24:36,560
um

2143
01:24:42,629 --> 01:24:40,719
developed and that's

2144
01:24:44,790 --> 01:24:42,639
pretty much still the same today

2145
01:24:46,470 --> 01:24:44,800
is that um

2146
01:24:49,189 --> 01:24:46,480
small bodies that i created ice and

2147
01:24:50,550 --> 01:24:49,199
anhydrous silicates um heated up either

2148
01:24:53,270 --> 01:24:50,560
via

2149
01:24:55,110 --> 01:24:53,280
endogenic processes due to rejective

2150
01:24:56,149 --> 01:24:55,120
decay

2151
01:24:59,030 --> 01:24:56,159
or

2152
01:25:01,030 --> 01:24:59,040
exogenic processes

2153
01:25:01,910 --> 01:25:01,040
due to impacts

2154
01:25:04,390 --> 01:25:01,920
um

2155
01:25:06,709 --> 01:25:04,400
and that this melted the ice uh the

2156
01:25:09,350 --> 01:25:06,719
resulting liquid water reacted within

2157
01:25:11,110 --> 01:25:09,360
hydrosilicates to hydrate them

2158
01:25:13,510 --> 01:25:11,120
and this is how we got the material that

2159
01:25:15,270 --> 01:25:13,520
we see in carbonaceous contracts

2160
01:25:16,149 --> 01:25:15,280
so essentially wherever there was liquid

2161
01:25:18,070 --> 01:25:16,159
water

2162
01:25:19,590 --> 01:25:18,080
in contact with contract material we

2163
01:25:25,030 --> 01:25:19,600

should expect

2164
01:25:28,870 --> 01:25:26,950
now different modes of aqueous

2165
01:25:30,709 --> 01:25:28,880
alterations have been postulated and the

2166
01:25:32,790 --> 01:25:30,719
reason for this is that we see

2167
01:25:34,870 --> 01:25:32,800
uh different classes

2168
01:25:36,310 --> 01:25:34,880
of combinations contracts uh the ci

2169
01:25:37,830 --> 01:25:36,320
chondrites for example named after the

2170
01:25:39,270 --> 01:25:37,840
ivuna meteorite

2171
01:25:41,350 --> 01:25:39,280
um

2172
01:25:43,350 --> 01:25:41,360
show and a bulk elemental composition

2173
01:25:46,070 --> 01:25:43,360
that's really close to that of the sun

2174
01:25:47,910 --> 01:25:46,080
and presumably the bulk solar system

2175
01:25:49,830 --> 01:25:47,920
uh and so it's inferred that the

2176
01:25:51,430 --> 01:25:49,840
alteration in the meteorite was

2177
01:25:53,669 --> 01:25:51,440
isochemical

2178
01:25:55,350 --> 01:25:53,679
and most likely that the fluid that that

2179
01:25:56,950 --> 01:25:55,360
altered

2180
01:25:59,910 --> 01:25:56,960
the anhydrous silicates didn't really

2181
01:26:03,030 --> 01:25:59,920
move everything stayed in place

2182
01:26:05,830 --> 01:26:03,040
whereas the cm contracts are

2183
01:26:07,510 --> 01:26:05,840
site diffractions in terms of elements

2184
01:26:09,510 --> 01:26:07,520
compared to the bulk sun

2185
01:26:10,950 --> 01:26:09,520
and so it's inferred that the fluids

2186
01:26:12,149 --> 01:26:10,960
that altered these

2187
01:26:13,590 --> 01:26:12,159
um

2188
01:26:16,149 --> 01:26:13,600

this material

2189
01:26:18,709 --> 01:26:16,159
moved with respect to it either in terms

2190
01:26:20,950 --> 01:26:18,719
of a single pass flow where

2191
01:26:23,350 --> 01:26:20,960
then the fluid vaporized space or

2192
01:26:25,350 --> 01:26:23,360
perhaps in a more in a closed system

2193
01:26:27,110 --> 01:26:25,360
where you had a multi-pass convection

2194
01:26:28,870 --> 01:26:27,120
kind of in a hydrothermal circulation

2195
01:26:31,510 --> 01:26:28,880
pattern

2196
01:26:33,110 --> 01:26:31,520
and more recently

2197
01:26:34,390 --> 01:26:33,120
there has been

2198
01:26:35,750 --> 01:26:34,400
new ways

2199
01:26:38,070 --> 01:26:35,760
new physical settings for alteration

2200
01:26:39,030 --> 01:26:38,080
phospholipids like like this one

2201
01:26:40,629 --> 01:26:39,040
um

2202
01:26:42,550 --> 01:26:40,639
the giant contacting meth balls of the

2203
01:26:44,709 --> 01:26:42,560
early solar system where instead of

2204
01:26:45,990 --> 01:26:44,719
having chunks of rocks the rock is

2205
01:26:48,310 --> 01:26:46,000
assumed to be

2206
01:26:49,189 --> 01:26:48,320
more like sand or mud in fine systemic

2207
01:26:51,030 --> 01:26:49,199
grains

2208
01:26:53,189 --> 01:26:51,040
that conflict with the fluid and so you

2209
01:26:54,629 --> 01:26:53,199
can have a pervasive alteration

2210
01:27:00,470 --> 01:26:54,639
throughout the body with the rough

2211
01:27:04,709 --> 01:27:02,310
so although we know that there has been

2212
01:27:07,110 --> 01:27:04,719
such a glitch alteration the remaining

2213
01:27:09,270 --> 01:27:07,120

alternative questions like where

2214
01:27:11,830 --> 01:27:09,280
is there was there liquid water

2215
01:27:13,910 --> 01:27:11,840
and how long does the water persist is

2216
01:27:16,470 --> 01:27:13,920
it just for a few millions of years

2217
01:27:19,030 --> 01:27:16,480
after the formation of the solar system

2218
01:27:20,950 --> 01:27:19,040
driven by short-lived activities

2219
01:27:25,510 --> 01:27:20,960
or did it persist for billions of years

2220
01:27:28,950 --> 01:27:26,870
um so

2221
01:27:30,709 --> 01:27:28,960
about where the water is

2222
01:27:32,550 --> 01:27:30,719
we can just look around in the solar

2223
01:27:34,390 --> 01:27:32,560
system i've put here

2224
01:27:36,870 --> 01:27:34,400
a number of bodies of astrological

2225
01:27:38,629 --> 01:27:36,880
significance plus uh series and pluto

2226
01:27:40,629 --> 01:27:38,639
which are probably electrobiological

2227
01:27:41,430 --> 01:27:40,639
significance too at this point

2228
01:27:44,229 --> 01:27:41,440
um

2229
01:27:45,830 --> 01:27:44,239
and the stressing feature here is that

2230
01:27:48,709 --> 01:27:45,840
once you go

2231
01:27:50,790 --> 01:27:48,719
beyond what's called the snow line um

2232
01:27:53,510 --> 01:27:50,800
they keep us the orbit of mars

2233
01:27:54,310 --> 01:27:53,520
uh water is able to condense

2234
01:27:56,709 --> 01:27:54,320
and

2235
01:27:59,750 --> 01:27:56,719
so these objects will create uh large

2236
01:28:02,070 --> 01:27:59,760
amounts of ice uh as evidence that there

2237
01:28:03,510 --> 01:28:02,080
are densities which are all around

2238
01:28:05,590 --> 01:28:03,520

three grams per cubic centimeters so

2239
01:28:07,110 --> 01:28:05,600
essentially they're half water and half

2240
01:28:08,070 --> 01:28:07,120
rock

2241
01:28:10,229 --> 01:28:08,080
um

2242
01:28:13,030 --> 01:28:10,239
so the the amounts of water are not

2243
01:28:15,110 --> 01:28:13,040
really the the issue the question is uh

2244
01:28:16,709 --> 01:28:15,120
where is there liquid water

2245
01:28:20,870 --> 01:28:16,719
and how long did the liquid water

2246
01:28:25,669 --> 01:28:23,750
so a very useful tool to help us

2247
01:28:26,709 --> 01:28:25,679
determine how long there was liquid

2248
01:28:28,950 --> 01:28:26,719
water

2249
01:28:30,390 --> 01:28:28,960
our thermal evolution models

2250
01:28:32,550 --> 01:28:30,400
essentially these are

2251
01:28:34,070 --> 01:28:32,560
numerical models that compute

2252
01:28:36,310 --> 01:28:34,080
the internal structure and the internal

2253
01:28:38,470 --> 01:28:36,320
temperatures uh inside these these

2254
01:28:42,629 --> 01:28:38,480
bodies over time and crystal gives you

2255
01:28:44,310 --> 01:28:42,639
an overview of this a little bit earlier

2256
01:28:45,270 --> 01:28:44,320
so let me go just very quick into how

2257
01:28:47,990 --> 01:28:45,280
these

2258
01:28:49,750 --> 01:28:48,000
uh work

2259
01:28:51,510 --> 01:28:49,760
essentially they compute

2260
01:28:53,350 --> 01:28:51,520
the production of heat

2261
01:28:54,830 --> 01:28:53,360
inside these objects would be the small

2262
01:28:57,750 --> 01:28:54,840
body

2263
01:29:00,629 --> 01:28:57,760

mars uh icy worlds and so on

2264
01:29:02,310 --> 01:29:00,639
um so a chief heat source for small body

2265
01:29:04,229 --> 01:29:02,320
is radioactive decay you don't really

2266
01:29:05,270 --> 01:29:04,239
have any tidal heating

2267
01:29:09,030 --> 01:29:05,280
um

2268
01:29:10,870 --> 01:29:09,040
this can drive uh heating in the rocks

2269
01:29:12,629 --> 01:29:10,880
potential differentiation between rock

2270
01:29:15,110 --> 01:29:12,639
and ice

2271
01:29:17,110 --> 01:29:15,120
if you melt the ice for example

2272
01:29:18,870 --> 01:29:17,120
they compute heat transfers in the rock

2273
01:29:20,550 --> 01:29:18,880
in the ice

2274
01:29:22,950 --> 01:29:20,560
melting and freezing

2275
01:29:24,790 --> 01:29:22,960
of water and their bounds

2276
01:29:26,950 --> 01:29:24,800
by a surface temperature

2277
01:29:29,189 --> 01:29:26,960
which is usually set up by the

2278
01:29:31,430 --> 01:29:29,199
the distance between the objects and the

2279
01:29:33,590 --> 01:29:31,440
sun

2280
01:29:34,709 --> 01:29:33,600
so this is a typical outcome of such a

2281
01:29:36,550 --> 01:29:34,719
model

2282
01:29:38,470 --> 01:29:36,560
from a paper by usually to you and some

2283
01:29:41,189 --> 01:29:38,480
accord 2010.

2284
01:29:43,669 --> 01:29:41,199
um this is a model for series series is

2285
01:29:47,030 --> 01:29:43,679
an object that's about 500 kilometers in

2286
01:29:49,750 --> 01:29:47,040
diameter with a density of about 2.1 2.2

2287
01:29:51,669 --> 01:29:49,760
grams per cubic centimeter

2288
01:29:54,229 --> 01:29:51,679

and so what you're seeing here is the

2289
01:29:55,830 --> 01:29:54,239
map of color map of temperatures uh nut

2290
01:29:57,030 --> 01:29:55,840
composition composition is thrown to the

2291
01:30:00,470 --> 01:29:57,040
right

2292
01:30:02,390 --> 01:30:00,480
uh with the core in the shell

2293
01:30:03,669 --> 01:30:02,400
and the so the temperature are not

2294
01:30:07,189 --> 01:30:03,679
according to the

2295
01:30:09,750 --> 01:30:07,199
scale bar at the bottom and

2296
01:30:11,270 --> 01:30:09,760
these temperatures change from formation

2297
01:30:12,550 --> 01:30:11,280
on the left to the present day on the

2298
01:30:14,550 --> 01:30:12,560
right

2299
01:30:16,870 --> 01:30:14,560
and on the y axis from the center to the

2300
01:30:19,669 --> 01:30:16,880
surface

2301
01:30:22,310 --> 01:30:19,679
so a general feature of these outcomes

2302
01:30:24,709 --> 01:30:22,320
is that first the temperatures increase

2303
01:30:27,270 --> 01:30:24,719
over time and this is because

2304
01:30:29,750 --> 01:30:27,280
reductive decay exceeds

2305
01:30:31,430 --> 01:30:29,760
the loss of heat by transport throughout

2306
01:30:33,110 --> 01:30:31,440
the body transport here is mostly by

2307
01:30:36,070 --> 01:30:33,120
conduction

2308
01:30:38,149 --> 01:30:36,080
um but then at some point after a

2309
01:30:40,390 --> 01:30:38,159
billion years or so this is a log scale

2310
01:30:43,910 --> 01:30:40,400
on the x-axis

2311
01:30:45,110 --> 01:30:43,920
the inside a series cools

2312
01:30:47,350 --> 01:30:45,120
because

2313
01:30:49,189 --> 01:30:47,360

radio rejective heating

2314
01:30:51,990 --> 01:30:49,199
is not powerful enough it decreases over

2315
01:30:53,350 --> 01:30:52,000
time and so transport starts

2316
01:30:55,750 --> 01:30:53,360
becoming dominant

2317
01:30:57,350 --> 01:30:55,760
which way you have cooling

2318
01:30:59,189 --> 01:30:57,360
now the point of interest here with

2319
01:31:00,470 --> 01:30:59,199
these models is to see what happens in

2320
01:31:03,030 --> 01:31:00,480
the shell

2321
01:31:06,550 --> 01:31:03,040
sufficient

2322
01:31:09,270 --> 01:31:06,560
to melt ice and have liquid water

2323
01:31:11,270 --> 01:31:09,280
and with this uh color scale here this

2324
01:31:13,110 --> 01:31:11,280
happens when you transition from the the

2325
01:31:14,950 --> 01:31:13,120
green to the orange and so you can see

2326
01:31:17,430 --> 01:31:14,960
there's a little bit of liquid water

2327
01:31:20,229 --> 01:31:17,440
early on it starts maybe after about 10

2328
01:31:22,310 --> 01:31:20,239
million years in this particular model

2329
01:31:24,229 --> 01:31:22,320
so these are a tool to tell us

2330
01:31:27,189 --> 01:31:24,239
if we have water

2331
01:31:29,189 --> 01:31:27,199
for aqueous alteration

2332
01:31:31,669 --> 01:31:29,199
um

2333
01:31:33,350 --> 01:31:31,679
switch here

2334
01:31:34,950 --> 01:31:33,360
this is a simulation that we did a

2335
01:31:36,950 --> 01:31:34,960
couple years ago with the same

2336
01:31:39,110 --> 01:31:36,960
assumptions for series but the model

2337
01:31:40,629 --> 01:31:39,120
that's completely independent just to

2338
01:31:44,870 --> 01:31:40,639

show you that

2339
01:31:46,709 --> 01:31:44,880
these are pretty robust results

2340
01:31:48,870 --> 01:31:46,719
what about smaller bodies series was

2341
01:31:51,430 --> 01:31:48,880
about 500 kilometers in diameter this is

2342
01:31:53,030 --> 01:31:51,440
an object that's only 50 kilometers

2343
01:31:54,390 --> 01:31:53,040
45

2344
01:31:56,709 --> 01:31:54,400
in radius

2345
01:31:59,990 --> 01:31:58,229
what you can see here is the colorful

2346
01:32:03,110 --> 01:32:00,000
regions have a temperature that's

2347
01:32:07,669 --> 01:32:03,120
sufficient to melt water so everything

2348
01:32:08,790 --> 01:32:07,679
in blue yellow red is above 273 kelvin

2349
01:32:10,229 --> 01:32:08,800
um

2350
01:32:12,470 --> 01:32:10,239
and so you're seeing the same object

2351
01:32:13,830 --> 01:32:12,480
over time evolving

2352
01:32:17,189 --> 01:32:13,840
and just

2353
01:32:18,950 --> 01:32:17,199
about after about 10 million years or so

2354
01:32:21,270 --> 01:32:18,960
the zone where

2355
01:32:23,110 --> 01:32:21,280
water can be liquid almost disappears

2356
01:32:24,390 --> 01:32:23,120
and so the time during which you can

2357
01:32:26,950 --> 01:32:24,400
have liquid water is actually pretty

2358
01:32:30,070 --> 01:32:26,960
short here again just about 10 millions

2359
01:32:33,990 --> 01:32:31,510
what about further out in the solar

2360
01:32:36,790 --> 01:32:34,000
system this is a simulation for pluto's

2361
01:32:38,950 --> 01:32:36,800
moon sharon assurance fairly big

2362
01:32:41,270 --> 01:32:38,960
compared to what we've seen about 600

2363
01:32:42,629 --> 01:32:41,280

kilometers in radius

2364
01:32:44,229 --> 01:32:42,639
and this is another way of showing the

2365
01:32:45,750 --> 01:32:44,239
results uh

2366
01:32:47,189 --> 01:32:45,760
you're looking at temperatures as a

2367
01:32:49,270 --> 01:32:47,199
function of radius

2368
01:32:51,510 --> 01:32:49,280
at different times but the outcome is

2369
01:32:53,110 --> 01:32:51,520
again pretty much the same you have

2370
01:32:54,550 --> 01:32:53,120
heating

2371
01:32:57,669 --> 01:32:54,560
between

2372
01:33:00,470 --> 01:32:57,679
zero one two billion years

2373
01:33:01,750 --> 01:33:00,480
and then cooling afterwards

2374
01:33:03,430 --> 01:33:01,760
um

2375
01:33:04,629 --> 01:33:03,440
so what's important to notice here is

2376
01:33:06,229 --> 01:33:04,639
that

2377
01:33:08,229 --> 01:33:06,239
at the base of the ice

2378
01:33:10,149 --> 01:33:08,239
there is always a region here where

2379
01:33:12,390 --> 01:33:10,159
temperatures are sufficient

2380
01:33:13,669 --> 01:33:12,400
to have liquid water

2381
01:33:15,910 --> 01:33:13,679
and

2382
01:33:17,510 --> 01:33:15,920
here is a diagram of how much liquid

2383
01:33:20,310 --> 01:33:17,520
water you have over time

2384
01:33:21,590 --> 01:33:20,320
in terms of earth oceans

2385
01:33:22,470 --> 01:33:21,600
and essentially you have about one

2386
01:33:25,350 --> 01:33:22,480
percent

2387
01:33:27,669 --> 01:33:25,360
worth of portions persists uh pretty

2388
01:33:29,350 --> 01:33:27,679

much until the present day

2389
01:33:30,390 --> 01:33:29,360
so of course these assessments change a

2390
01:33:31,590 --> 01:33:30,400
little bit depending on model

2391
01:33:32,470 --> 01:33:31,600
assumptions

2392
01:33:34,470 --> 01:33:32,480
um

2393
01:33:36,550 --> 01:33:34,480
but the bottom line here is that you can

2394
01:33:38,390 --> 01:33:36,560
have uh liquid water depending on the

2395
01:33:39,510 --> 01:33:38,400
size of the objects the distance from

2396
01:33:42,310 --> 01:33:39,520
the sun

2397
01:33:43,910 --> 01:33:42,320
uh the the rock content meaning the the

2398
01:33:46,229 --> 01:33:43,920
the amount of radioactivity

2399
01:33:47,510 --> 01:33:46,239
uh anywhere between a few millions of

2400
01:33:52,390 --> 01:33:47,520
years

2401
01:33:57,189 --> 01:33:55,430
so um this is important because

2402
01:34:00,149 --> 01:33:57,199
these models even though they predict

2403
01:34:02,470 --> 01:34:00,159
equip water they didn't really take into

2404
01:34:04,550 --> 01:34:02,480
account what that means in terms of the

2405
01:34:06,870 --> 01:34:04,560
geophysical evolution of these objects

2406
01:34:08,470 --> 01:34:06,880
once you have liquid water

2407
01:34:09,590 --> 01:34:08,480
presumably it starts interacting with

2408
01:34:12,709 --> 01:34:09,600
the rock

2409
01:34:15,110 --> 01:34:12,719
uh especially if there are fractures in

2410
01:34:17,030 --> 01:34:15,120
the core so that the water can percolate

2411
01:34:20,390 --> 01:34:17,040
down

2412
01:34:21,750 --> 01:34:20,400
so potentially it could get heated and

2413
01:34:24,790 --> 01:34:21,760

flows back up

2414
01:34:26,390 --> 01:34:24,800
in hydrothermal circulation patterns

2415
01:34:29,590 --> 01:34:26,400
and of course you have water rough

2416
01:34:31,750 --> 01:34:29,600
reactions which can produce or consume

2417
01:34:34,070 --> 01:34:31,760
antifreezes

2418
01:34:36,390 --> 01:34:34,080
and so all of a sudden you see all these

2419
01:34:37,350 --> 01:34:36,400
feedback arrows pop up in these loops

2420
01:34:39,030 --> 01:34:37,360
that

2421
01:34:41,189 --> 01:34:39,040
aren't really taken into account unless

2422
01:34:42,629 --> 01:34:41,199
you model this explicitly

2423
01:34:45,990 --> 01:34:42,639
and just to show you

2424
01:34:47,510 --> 01:34:46,000
this can really profoundly model the the

2425
01:34:49,030 --> 01:34:47,520
temperature evolution and the structural

2426
01:34:51,030 --> 01:34:49,040
evolution

2427
01:34:52,950 --> 01:34:51,040
of small bodies

2428
01:34:55,910 --> 01:34:52,960
so on the top here is the same

2429
01:34:57,750 --> 01:34:55,920
simulation i showed you before of series

2430
01:35:00,470 --> 01:34:57,760
so with the smooth

2431
01:35:02,550 --> 01:35:00,480
heating and then smooth cooling and at

2432
01:35:04,629 --> 01:35:02,560
the bottom this is uh with the same

2433
01:35:06,470 --> 01:35:04,639
assumptions except that you have

2434
01:35:08,229 --> 01:35:06,480
fracturing in the core and hydrothermal

2435
01:35:09,830 --> 01:35:08,239
circulation

2436
01:35:13,030 --> 01:35:09,840
so it starts off

2437
01:35:15,189 --> 01:35:13,040
uh serious starts off by heating again

2438
01:35:18,470 --> 01:35:15,199

but as soon as you reach the melting

2439
01:35:19,910 --> 01:35:18,480
point of water in the shell

2440
01:35:23,109 --> 01:35:19,920
the model has the water percolate

2441
01:35:24,070 --> 01:35:23,119
through the core and circulates down

2442
01:35:26,229 --> 01:35:24,080
and

2443
01:35:29,350 --> 01:35:26,239
this hydrothermal cooling of the core

2444
01:35:31,270 --> 01:35:29,360
really very efficiently transports heat

2445
01:35:32,709 --> 01:35:31,280
back up into the shell

2446
01:35:34,310 --> 01:35:32,719
where this heat completely melts the

2447
01:35:35,990 --> 01:35:34,320
shell so it's kind of a runaway

2448
01:35:37,350 --> 01:35:36,000
production of liquid

2449
01:35:38,550 --> 01:35:37,360
so you have very

2450
01:35:40,950 --> 01:35:38,560
pervasive

2451
01:35:42,310 --> 01:35:40,960
aqueous alteration here

2452
01:35:43,990 --> 01:35:42,320
and so the the model compute

2453
01:35:45,270 --> 01:35:44,000
serpentization

2454
01:35:47,189 --> 01:35:45,280
uh the

2455
01:35:48,070 --> 01:35:47,199
the thing is that the radioactive

2456
01:35:50,629 --> 01:35:48,080
heating

2457
01:35:52,790 --> 01:35:50,639
cannot really keep up uh with this very

2458
01:35:55,430 --> 01:35:52,800
vigorous cooling by convection in the

2459
01:35:57,910 --> 01:35:55,440
core and then in the ocean

2460
01:36:00,310 --> 01:35:57,920
and so the ocean ends up freezing after

2461
01:36:01,590 --> 01:36:00,320
maybe only 50 million years 100 million

2462
01:36:03,270 --> 01:36:01,600
years or so

2463
01:36:05,189 --> 01:36:03,280

and so you're back

2464
01:36:07,270 --> 01:36:05,199
into the initial state

2465
01:36:10,310 --> 01:36:07,280
where the ocean is frozen

2466
01:36:12,950 --> 01:36:10,320
um there is no more circulation and so

2467
01:36:14,950 --> 01:36:12,960
all the heat transfer is conducted again

2468
01:36:16,310 --> 01:36:14,960
because the heat transfer is not so

2469
01:36:18,229 --> 01:36:16,320
efficient

2470
01:36:19,590 --> 01:36:18,239
series heats up again because of

2471
01:36:21,669 --> 01:36:19,600
radioactivity

2472
01:36:24,149 --> 01:36:21,679
until you reach the point of melting

2473
01:36:25,430 --> 01:36:24,159
water and the same cycle starts again

2474
01:36:27,910 --> 01:36:25,440
now the peak

2475
01:36:29,669 --> 01:36:27,920
of activity here looks very narrow

2476
01:36:31,590 --> 01:36:29,679
this is just because of the love scale

2477
01:36:32,470 --> 01:36:31,600
these periods are always about

2478
01:36:35,030 --> 01:36:32,480
um

2479
01:36:37,590 --> 01:36:35,040
50 to 100 million years in length

2480
01:36:38,950 --> 01:36:37,600
and you have these alternating cycles of

2481
01:36:41,109 --> 01:36:38,960
a cool

2482
01:36:43,910 --> 01:36:41,119
frozen series that's heating

2483
01:36:45,510 --> 01:36:43,920
and then a molten

2484
01:36:48,390 --> 01:36:45,520
water layer that's conducting and

2485
01:36:50,390 --> 01:36:48,400
hydrothermally circulating

2486
01:36:52,629 --> 01:36:50,400
and very efficiently cooling and this

2487
01:36:55,030 --> 01:36:52,639
continues until uh reductive decay just

2488
01:36:58,070 --> 01:36:55,040

becomes too weak uh to

2489
01:36:59,830 --> 01:36:58,080
to ever melt liquid again

2490
01:37:01,990 --> 01:36:59,840
um so notice that the structures are

2491
01:37:04,790 --> 01:37:02,000
very different here the the interior is

2492
01:37:07,109 --> 01:37:04,800
provided pervasively serpentine

2493
01:37:09,510 --> 01:37:07,119
whereas here the core is mostly made of

2494
01:37:11,030 --> 01:37:09,520
dry silicates

2495
01:37:12,709 --> 01:37:11,040
uh in addition

2496
01:37:14,950 --> 01:37:12,719
in the model that accounts for uh

2497
01:37:16,390 --> 01:37:14,960
circulation you can have liquid water

2498
01:37:18,470 --> 01:37:16,400
intermittently for much longer time

2499
01:37:20,550 --> 01:37:18,480
scales billions of years as opposed to

2500
01:37:23,430 --> 01:37:20,560
only in the very early history

2501
01:37:28,070 --> 01:37:25,669
okay so this is what models predict what

2502
01:37:30,950 --> 01:37:28,080
about the ground truth

2503
01:37:32,149 --> 01:37:30,960
so in the past year a series has been

2504
01:37:35,030 --> 01:37:32,159
explored

2505
01:37:37,189 --> 01:37:35,040
by the dom mission

2506
01:37:39,430 --> 01:37:37,199
uh which returned

2507
01:37:41,910 --> 01:37:39,440
great images like this one uh so showing

2508
01:37:44,310 --> 01:37:41,920
a very dark surface very cratered

2509
01:37:46,629 --> 01:37:44,320
but with these very intriguing prominent

2510
01:37:48,870 --> 01:37:46,639
bright spots here

2511
01:37:51,510 --> 01:37:48,880
so don carried this infrared

2512
01:37:53,669 --> 01:37:51,520
spectrometer that acquired spectra in

2513
01:37:55,270 --> 01:37:53,679

the near infrared

2514
01:37:56,550 --> 01:37:55,280
with several features

2515
01:37:58,310 --> 01:37:56,560
this is

2516
01:37:59,990 --> 01:37:58,320
a spectrum of the average

2517
01:38:02,950 --> 01:38:00,000
surface of series it's very uniform

2518
01:38:04,790 --> 01:38:02,960
throughout except for the bright spots

2519
01:38:07,270 --> 01:38:04,800
very little variation

2520
01:38:09,350 --> 01:38:07,280
but the spectrum can be interpreted

2521
01:38:11,590 --> 01:38:09,360
as a mixture of serpentines ammonium

2522
01:38:13,750 --> 01:38:11,600
bearing clays and carbonates which is

2523
01:38:14,950 --> 01:38:13,760
quite unique

2524
01:38:17,669 --> 01:38:14,960
in the source system especially for the

2525
01:38:20,070 --> 01:38:17,679
ammonium bearing clays

2526
01:38:22,310 --> 01:38:20,080
and series very low you know only three

2527
01:38:24,149 --> 01:38:22,320
percent in the infrared can be explained

2528
01:38:26,390 --> 01:38:24,159
by the presence of a dark absorber which

2529
01:38:29,350 --> 01:38:26,400
is still unidentified but it could be

2530
01:38:31,669 --> 01:38:29,360
organics magnetite perhaps sulfides or

2531
01:38:33,990 --> 01:38:31,679
maybe a mixture of all that

2532
01:38:35,109 --> 01:38:34,000
so this is

2533
01:38:37,510 --> 01:38:35,119
showing that

2534
01:38:39,830 --> 01:38:37,520
series is blanketed by products of

2535
01:38:41,669 --> 01:38:39,840
circularization

2536
01:38:44,390 --> 01:38:41,679
what about the bright spots

2537
01:38:45,990 --> 01:38:44,400
the spectra are quite different showing

2538
01:38:47,669 --> 01:38:46,000

features

2539
01:38:48,629 --> 01:38:47,679
that are characteristic of carbonate

2540
01:38:51,270 --> 01:38:48,639
salts

2541
01:38:53,910 --> 01:38:51,280
so here sodium carbonate

2542
01:38:56,070 --> 01:38:53,920
as well as

2543
01:38:58,390 --> 01:38:56,080
ammonium bicarbonates or amino chloride

2544
01:38:59,830 --> 01:38:58,400
perhaps

2545
01:39:02,470 --> 01:38:59,840
and so the question is where did all

2546
01:39:05,350 --> 01:39:02,480
this come from this is this looks like

2547
01:39:07,189 --> 01:39:05,360
a fluid salt left from a fluid that

2548
01:39:09,109 --> 01:39:07,199
vaporized or froze

2549
01:39:12,629 --> 01:39:09,119
and only the

2550
01:39:14,149 --> 01:39:12,639
the solutes are left over

2551
01:39:16,149 --> 01:39:14,159
so to find out

2552
01:39:18,629 --> 01:39:16,159
i did some geochemical modeling trying

2553
01:39:20,470 --> 01:39:18,639
to react different starting compositions

2554
01:39:22,870 --> 01:39:20,480
of conjugate rock either ordinary

2555
01:39:25,030 --> 01:39:22,880
chondrites or cm chondrites

2556
01:39:27,590 --> 01:39:25,040
reacting with fluids

2557
01:39:30,149 --> 01:39:27,600
either pure water or cometary water like

2558
01:39:32,149 --> 01:39:30,159
cometary i mean um

2559
01:39:34,229 --> 01:39:32,159
water with a little bit of carbon and

2560
01:39:36,790 --> 01:39:34,239
nitrogen and sulfur compounds

2561
01:39:38,070 --> 01:39:36,800
that are seen in comic gases

2562
01:39:38,830 --> 01:39:38,080
and so i did this modeling with the

2563
01:39:41,430 --> 01:39:38,840

freak

2564
01:39:43,030 --> 01:39:41,440
software trying to

2565
01:39:45,030 --> 01:39:43,040
see at equilibrium what happens to these

2566
01:39:47,990 --> 01:39:45,040
mixtures at different temperatures

2567
01:39:49,270 --> 01:39:48,000
pressures and oil to rock ratios

2568
01:39:51,430 --> 01:39:49,280
so i'll just show you a couple of

2569
01:39:53,430 --> 01:39:51,440
results here

2570
01:39:56,629 --> 01:39:53,440
so first we're looking at an average

2571
01:39:59,750 --> 01:39:56,639
spectrum of series dark surface

2572
01:40:02,550 --> 01:39:59,760
and these little pie charts here are the

2573
01:40:04,870 --> 01:40:02,560
equilibrium mineral assemblages

2574
01:40:06,310 --> 01:40:04,880
for different pressures spanning the

2575
01:40:08,310 --> 01:40:06,320
interior series

2576
01:40:11,910 --> 01:40:08,320
to be halfway through the interior and

2577
01:40:13,830 --> 01:40:11,920
temperatures from zero to 200 kelvin

2578
01:40:16,229 --> 01:40:13,840
celsius

2579
01:40:17,030 --> 01:40:16,239
and the colors match the labels to the

2580
01:40:18,149 --> 01:40:17,040
right

2581
01:40:20,390 --> 01:40:18,159
so this

2582
01:40:22,390 --> 01:40:20,400
light blue here is serpentine

2583
01:40:24,310 --> 01:40:22,400
and you can see that

2584
01:40:26,390 --> 01:40:24,320
especially at cold conditions we

2585
01:40:27,990 --> 01:40:26,400
reproduce pretty well what's being

2586
01:40:30,310 --> 01:40:28,000
observed

2587
01:40:32,629 --> 01:40:30,320
by dawn at least qualitatively

2588
01:40:35,030 --> 01:40:32,639

the serpentines

2589
01:40:36,629 --> 01:40:35,040
the ammonium bearing clays which we see

2590
01:40:37,750 --> 01:40:36,639
only at low temperatures that seem to be

2591
01:40:40,709 --> 01:40:37,760
the result

2592
01:40:43,270 --> 01:40:40,719
of the substitution of potassium ions

2593
01:40:45,270 --> 01:40:43,280
which are leached into the fluid

2594
01:40:47,350 --> 01:40:45,280
and substituted for by

2595
01:40:48,709 --> 01:40:47,360
ammonium which either comes from the

2596
01:40:50,390 --> 01:40:48,719
fluid in

2597
01:40:52,229 --> 01:40:50,400
if the fluid is cometary and has

2598
01:40:55,510 --> 01:40:52,239
nitrogen at the beginning

2599
01:40:57,030 --> 01:40:55,520
or uh nitrogen from organics

2600
01:40:59,109 --> 01:40:57,040
if we start with the carbonaceous

2601
01:41:01,030 --> 01:40:59,119
chondrite compositions

2602
01:41:03,270 --> 01:41:01,040
we form also carbonates

2603
01:41:05,510 --> 01:41:03,280
in purple a little bit

2604
01:41:07,830 --> 01:41:05,520
as well as any of the possible dark

2605
01:41:09,830 --> 01:41:07,840
absorbers like organics magnetites

2606
01:41:11,830 --> 01:41:09,840
and sulfites

2607
01:41:13,510 --> 01:41:11,840
now what's really cool

2608
01:41:15,669 --> 01:41:13,520
is that the fluids in equilibrium with

2609
01:41:17,590 --> 01:41:15,679
these assemblages

2610
01:41:19,109 --> 01:41:17,600
also match what's being observed at the

2611
01:41:20,629 --> 01:41:19,119
bright spots

2612
01:41:23,910 --> 01:41:20,639
so you see

2613
01:41:25,189 --> 01:41:23,920

oxidized carbon the ph is about 10 to 12

2614
01:41:26,950 --> 01:41:25,199
in these fluids

2615
01:41:27,830 --> 01:41:26,960
at the mobile ph

2616
01:41:28,790 --> 01:41:27,840
and

2617
01:41:30,470 --> 01:41:28,800
so

2618
01:41:31,990 --> 01:41:30,480
we have a mixture of bicarbonate and

2619
01:41:34,229 --> 01:41:32,000
carbonate

2620
01:41:35,830 --> 01:41:34,239
sodium ions a little bit of

2621
01:41:38,070 --> 01:41:35,840
chloride ions

2622
01:41:40,709 --> 01:41:38,080
here

2623
01:41:42,470 --> 01:41:40,719
and what's not showing is this dark

2624
01:41:44,470 --> 01:41:42,480
compound here in the pie charts it

2625
01:41:46,790 --> 01:41:44,480
represents reduced carbon which is

2626
01:41:48,950 --> 01:41:46,800
mostly dissolved methane

2627
01:41:51,109 --> 01:41:48,960
and so there is no spectral evidence for

2628
01:41:52,629 --> 01:41:51,119
for methane at the surface however

2629
01:41:56,229 --> 01:41:52,639
there is some structural evidence some

2630
01:41:58,629 --> 01:41:56,239
series of methane clathrates which are

2631
01:42:00,629 --> 01:41:58,639
quite a low density and strong material

2632
01:42:02,070 --> 01:42:00,639
that would explain

2633
01:42:06,870 --> 01:42:02,080
the internal structure of series as

2634
01:42:11,270 --> 01:42:09,430
okay so i'm pretty much finished just to

2635
01:42:13,990 --> 01:42:11,280
give you a summary

2636
01:42:16,149 --> 01:42:14,000
we know from a meteorite carbonicious

2637
01:42:17,830 --> 01:42:16,159
contracts that sample some small bodies

2638
01:42:19,910 --> 01:42:17,840

beyond the snow line

2639
01:42:21,510 --> 01:42:19,920
that they contain with the serpentine so

2640
01:42:23,270 --> 01:42:21,520
they're evidence of pervasive

2641
01:42:24,390 --> 01:42:23,280
synchronization mostly

2642
01:42:27,350 --> 01:42:24,400
likely

2643
01:42:30,310 --> 01:42:27,360
early in the history of the solar system

2644
01:42:31,990 --> 01:42:30,320
um models uh predict that photorock

2645
01:42:33,270 --> 01:42:32,000
interaction took place in those small

2646
01:42:35,109 --> 01:42:33,280
bodies

2647
01:42:36,709 --> 01:42:35,119
anywhere between a few million years

2648
01:42:38,709 --> 01:42:36,719
after the formation of the solar system

2649
01:42:41,669 --> 01:42:38,719
to a few billion years and perhaps until

2650
01:42:44,390 --> 01:42:41,679
today and larger bodies

2651
01:42:47,430 --> 01:42:44,400
such as possibly ceres

2652
01:42:52,310 --> 01:42:49,510
and we know now that serious surface is

2653
01:42:54,550 --> 01:42:52,320
blanketed by spermice material

2654
01:42:56,550 --> 01:42:54,560
that the associated fluids are perhaps

2655
01:42:59,350 --> 01:42:56,560
expressed at the bright spots

2656
01:43:01,669 --> 01:42:59,360
and perhaps this is kind of tentative

2657
01:43:03,189 --> 01:43:01,679
that the alteration was called

2658
01:43:13,030 --> 01:43:03,199
and with that i'll take questions thank

2659
01:43:19,030 --> 01:43:16,790
so we have one question uh or elisa

2660
01:43:20,709 --> 01:43:19,040
castillo you were describing uh thermal

2661
01:43:22,470 --> 01:43:20,719
models

2662
01:43:23,590 --> 01:43:22,480
that are leaching materials she points

2663
01:43:25,990 --> 01:43:23,600

out that

2664
01:43:28,229 --> 01:43:26,000
displacing potassium could uh influence

2665
01:43:30,149 --> 01:43:28,239
the heating and cooling cycles i think

2666
01:43:33,990 --> 01:43:30,159
the the association there is the

2667
01:43:36,629 --> 01:43:34,000
potassium itself is radiogenic

2668
01:43:38,070 --> 01:43:36,639
yeah that's right yeah

2669
01:43:40,870 --> 01:43:38,080
i don't usually if you'll cover this in

2670
01:43:43,750 --> 01:43:40,880
your pop-up top but um

2671
01:43:45,189 --> 01:43:43,760
the idea that you would displace the

2672
01:43:47,669 --> 01:43:45,199
the heat source potassium being one of

2673
01:43:49,910 --> 01:43:47,679
the radionuclides long-lasting implants

2674
01:43:51,750 --> 01:43:49,920
from the rock which is what's commonly

2675
01:43:52,950 --> 01:43:51,760
assumed into the ocean

2676
01:43:54,310 --> 01:43:52,960
and so you might be able to generate

2677
01:43:56,229 --> 01:43:54,320
heat directly into the ocean and that

2678
01:43:57,510 --> 01:43:56,239
changes a little bit

2679
01:44:02,790 --> 01:43:57,520
how the

2680
01:44:07,030 --> 01:44:04,709
and uh thanks thanks so much for your

2681
01:44:09,189 --> 01:44:07,040
overview of chondrites at the beginning

2682
01:44:11,350 --> 01:44:09,199
uh

2683
01:44:13,669 --> 01:44:11,360
early serpentinization those carbonites

2684
01:44:18,709 --> 01:44:13,679
um

2685
01:44:20,470 --> 01:44:18,719
the so you know we we hit upon this in

2686
01:44:23,270 --> 01:44:20,480
other discussion of other talks that

2687
01:44:24,390 --> 01:44:23,280
those are the feedstock presumably of

2688
01:44:26,550 --> 01:44:24,400

all of the

2689
01:44:27,990 --> 01:44:26,560
outer solar system bodies and possibly

2690
01:44:29,270 --> 01:44:28,000
also inform

2691
01:44:31,430 --> 01:44:29,280
the composition of the terrestrial

2692
01:44:33,590 --> 01:44:31,440
planets

2693
01:44:35,270 --> 01:44:33,600
do your models predict that ceres would

2694
01:44:38,629 --> 01:44:35,280
have become anhydrous due to early

2695
01:44:42,550 --> 01:44:40,470
uh they don't they degrade that it would

2696
01:44:43,990 --> 01:44:42,560
stay once it becomes hydrated it stays

2697
01:44:45,910 --> 01:44:44,000
hydrated

2698
01:44:48,870 --> 01:44:45,920
but just to touch on the

2699
01:44:49,750 --> 01:44:48,880
on conduit as building blocks of planets

2700
01:44:51,350 --> 01:44:49,760
um

2701
01:44:52,950 --> 01:44:51,360
i think it's it's a great question

2702
01:44:55,510 --> 01:44:52,960
though we don't

2703
01:44:58,070 --> 01:44:55,520
know for sure if the building block was

2704
01:45:00,390 --> 01:44:58,080
uh the dunglass were

2705
01:45:02,870 --> 01:45:00,400
uh contradict in composition for example

2706
01:45:04,709 --> 01:45:02,880
on enceladus everything

2707
01:45:06,470 --> 01:45:04,719
looks more silica rich and

2708
01:45:09,430 --> 01:45:06,480
magnesium-rich

2709
01:45:13,750 --> 01:45:11,510
more than congoing contradicts

2710
01:45:15,109 --> 01:45:13,760
and so

2711
01:45:16,390 --> 01:45:15,119
maybe the sorry material differs a

2712
01:45:18,229 --> 01:45:16,400
little bit for series though it looks

2713
01:45:19,590 --> 01:45:18,239

like you can reproduce the current

2714
01:45:21,430 --> 01:45:19,600
composition really well with starting

2715
01:45:23,109 --> 01:45:21,440
with with contrast so

2716
01:45:25,189 --> 01:45:23,119
not a bad assumption but

2717
01:45:28,830 --> 01:45:25,199
so just a word of caution here

2718
01:45:30,790 --> 01:45:28,840
yeah so it's um it seems like

2719
01:45:33,270 --> 01:45:30,800
a we

2720
01:45:35,590 --> 01:45:33,280
that much of the material that formed

2721
01:45:38,550 --> 01:45:35,600
ceres was serpentinized prior to series

2722
01:45:42,870 --> 01:45:40,470
would be interesting how to

2723
01:45:44,790 --> 01:45:42,880
prove or disprove that

2724
01:45:46,870 --> 01:45:44,800
yeah yeah

2725
01:45:48,790 --> 01:45:46,880
again we've we've tried um different

2726
01:45:51,430 --> 01:45:48,800
starting compositions either already

2727
01:45:52,229 --> 01:45:51,440
synchronized or not yet synchronized

2728
01:45:53,910 --> 01:45:52,239
and

2729
01:45:56,470 --> 01:45:53,920
you get pretty similar results either

2730
01:45:59,030 --> 01:45:56,480
way just because the the models are

2731
01:46:00,070 --> 01:45:59,040
equilibrium models and sort of

2732
01:46:01,669 --> 01:46:00,080
you know you're just getting the

2733
01:46:03,830 --> 01:46:01,679
thermodynamic uh

2734
01:46:05,510 --> 01:46:03,840
equilibrium goes all the way

2735
01:46:07,590 --> 01:46:05,520
um

2736
01:46:09,510 --> 01:46:07,600
but maybe there were kinetic barriers to

2737
01:46:11,270 --> 01:46:09,520
certain to the reactions for the

2738
01:46:15,669 --> 01:46:11,280

direction species so

2739
01:46:15,679 --> 01:46:20,310
question are sulfates found on ceres

2740
01:46:24,070 --> 01:46:21,910
no not as

2741
01:46:26,470 --> 01:46:24,080
not as far as i know neither sulfates

2742
01:46:28,790 --> 01:46:26,480
nor sulfides actually do you have any

2743
01:46:31,189 --> 01:46:28,800
ideas about why sulfates are so

2744
01:46:34,310 --> 01:46:31,199
prevalent in cm and ci chondrites but

2745
01:46:36,070 --> 01:46:34,320
they may not be at series

2746
01:46:38,390 --> 01:46:36,080
um well julia i might want to chime in

2747
01:46:40,629 --> 01:46:38,400
on this i believe

2748
01:46:41,990 --> 01:46:40,639
that there has been a

2749
01:46:44,790 --> 01:46:42,000
heated debate

2750
01:46:46,229 --> 01:46:44,800
as to whether the sulfates are um

2751
01:46:48,149 --> 01:46:46,239
where their pre

2752
01:46:49,270 --> 01:46:48,159
impact on earth or if they're the

2753
01:46:51,750 --> 01:46:49,280
results

2754
01:46:55,430 --> 01:46:51,760
of alteration after the falls

2755
01:46:57,990 --> 01:46:55,440
um but i'm not an expert on this so

2756
01:46:59,830 --> 01:46:58,000
yeah i can call this if you want a

2757
01:47:04,390 --> 01:46:59,840
regarding the detection of cell phase

2758
01:47:06,629 --> 01:47:04,400
some serious uh there's an ongoing study

2759
01:47:08,470 --> 01:47:06,639
that is trying to put um a detection

2760
01:47:11,350 --> 01:47:08,480
limit on sulfate

2761
01:47:14,709 --> 01:47:11,360
and if they are present they are

2762
01:47:16,310 --> 01:47:14,719
an extremely small abundance

2763
01:47:18,310 --> 01:47:16,320

and as mark

2764
01:47:21,669 --> 01:47:18,320
noted i mean it's more likely that we

2765
01:47:23,750 --> 01:47:21,679
have a

2766
01:47:25,669 --> 01:47:23,760
uh in terms of the sulfates in the

2767
01:47:28,310 --> 01:47:25,679
theories uh

2768
01:47:29,430 --> 01:47:28,320
also i mean i agree with mark here the

2769
01:47:32,629 --> 01:47:29,440
debate is

2770
01:47:35,270 --> 01:47:32,639
whether the substrates were already

2771
01:47:37,270 --> 01:47:35,280
formed on the town body or on earth and

2772
01:47:39,189 --> 01:47:37,280
magdalene key

2773
01:47:41,669 --> 01:47:39,199
actually showed that even if you

2774
01:47:44,629 --> 01:47:41,679
preserve

2775
01:47:47,189 --> 01:47:44,639
either rise very well under

2776
01:47:48,870 --> 01:47:47,199
the nitrogen curve and so on even in

2777
01:47:52,310 --> 01:47:48,880
this condition

2778
01:47:54,470 --> 01:47:52,320
um a little bit of oxygen

2779
01:47:55,750 --> 01:47:54,480
makes it very easy to turn sulfide into

2780
01:47:56,709 --> 01:47:55,760
sulfate

2781
01:47:58,870 --> 01:47:56,719
in

2782
01:48:00,310 --> 01:47:58,880
meteorites

2783
01:48:01,669 --> 01:48:00,320
so it's it's most likely that you

2784
01:48:05,350 --> 01:48:01,679
calculate our

2785
01:48:08,310 --> 01:48:06,310
yeah thanks for making that

2786
01:48:10,709 --> 01:48:08,320
clarification i i cited this paper by

2787
01:48:13,109 --> 01:48:10,719
mckinnon zielinski uh

2788
01:48:15,669 --> 01:48:13,119

in my introduction uh they spent a lot

2789
01:48:18,550 --> 01:48:15,679
of that paper um

2790
01:48:20,550 --> 01:48:18,560
pointing out some of the uncertain

2791
01:48:23,350 --> 01:48:20,560
or assumptions of salinities in

2792
01:48:25,510 --> 01:48:23,360
different uh extraterrestrial oceans uh

2793
01:48:27,430 --> 01:48:25,520
and that point about uh terrestrial

2794
01:48:29,270 --> 01:48:27,440
origin of sulfates is a really critical

2795
01:48:32,550 --> 01:48:29,280
one

2796
01:48:34,149 --> 01:48:32,560
yeah and there is a paper and zolensky

2797
01:48:36,870 --> 01:48:34,159
2001

2798
01:48:39,590 --> 01:48:36,880
that looks uh at this question that's

2799
01:48:40,870 --> 01:48:39,600
already focused on uh cica meteoritism

2800
01:48:42,790 --> 01:48:40,880
and

2801
01:48:49,030 --> 01:48:42,800
i think they make a firm demonstration

2802
01:48:53,590 --> 01:48:51,189
great thanks uh well with that let's

2803
01:48:56,310 --> 01:48:53,600
let's trend let's thank mark again

2804
01:49:06,870 --> 01:48:56,320
we'll transition to our next talk uh the

2805
01:49:09,590 --> 01:49:08,229
sorry about that um it looks like your

2806
01:49:11,750 --> 01:49:09,600
webcam's uh

2807
01:49:13,750 --> 01:49:11,760
black right now if you want to uh double

2808
01:49:15,109 --> 01:49:13,760
check if the right device

2809
01:49:16,550 --> 01:49:15,119
in the upper right hand corner of the

2810
01:49:18,629 --> 01:49:16,560
video pod there's a little drop down

2811
01:49:19,750 --> 01:49:18,639
menu and there's an option to select

2812
01:49:24,229 --> 01:49:19,760
camera

2813
01:49:30,470 --> 01:49:28,390

all right trying that again now

2814
01:49:48,870 --> 01:49:30,480
okay if it doesn't fix itself quickly

2815
01:49:48,880 --> 01:49:53,189
i can certify that chris is not a robot

2816
01:49:53,199 --> 01:49:58,709
thank you steve

2817
01:50:01,109 --> 01:49:59,910
okay chris i want to take away from your

2818
01:50:03,030 --> 01:50:01,119
presentation times why don't you go

2819
01:50:03,990 --> 01:50:03,040
ahead and just uh get started we'll all

2820
01:50:07,669 --> 01:50:04,000
imagine

2821
01:50:09,750 --> 01:50:07,679
me waving my hands around

2822
01:50:11,669 --> 01:50:09,760
okay well uh thanks steve for inviting

2823
01:50:13,510 --> 01:50:11,679
me and everyone for tuning in to the

2824
01:50:15,669 --> 01:50:13,520
very end some of you may be

2825
01:50:17,350 --> 01:50:15,679
spilling over into lunch right now

2826
01:50:19,750 --> 01:50:17,360
uh so i'm really pleased that we've kind

2827
01:50:22,149 --> 01:50:19,760
of marauded our way all across the solar

2828
01:50:24,149 --> 01:50:22,159
system it's been pretty impressive and

2829
01:50:26,790 --> 01:50:24,159
now for the final talk i thought we'd

2830
01:50:29,030 --> 01:50:26,800
return back to saturn where we have a

2831
01:50:31,669 --> 01:50:29,040
bunch of data that can help to inform us

2832
01:50:33,510 --> 01:50:31,679
about the geochemistry of saturn's moon

2833
01:50:35,589 --> 01:50:33,520
enceladus so that's what i'll be

2834
01:50:41,430 --> 01:50:35,599
discussing in some detail for this

2835
01:50:49,589 --> 01:50:43,109
uh

2836
01:50:54,550 --> 01:50:52,950
is the arrow at the bottom oh yeah they

2837
01:50:56,229 --> 01:50:54,560
see it

2838
01:50:57,990 --> 01:50:56,239

all right

2839
01:50:59,990 --> 01:50:58,000
right so steve started off this session

2840
01:51:02,550 --> 01:51:00,000
with europa so it's sort of fitting that

2841
01:51:04,070 --> 01:51:02,560
we first talked about europe but uh for

2842
01:51:06,390 --> 01:51:04,080
many of you you're probably aware that

2843
01:51:07,669 --> 01:51:06,400
nasa is starting this new initiative

2844
01:51:09,350 --> 01:51:07,679
of a program

2845
01:51:11,830 --> 01:51:09,360
studying ocean worlds of the solar

2846
01:51:14,149 --> 01:51:11,840
system and europa is the the most

2847
01:51:15,990 --> 01:51:14,159
obvious example that everyone has had in

2848
01:51:17,990 --> 01:51:16,000
their heads for the past

2849
01:51:20,629 --> 01:51:18,000
20 years or so since galileo found

2850
01:51:23,189 --> 01:51:20,639
evidence for a subsurface ocean

2851
01:51:25,350 --> 01:51:23,199
but now a new kid

2852
01:51:27,030 --> 01:51:25,360
has come onto the block

2853
01:51:29,270 --> 01:51:27,040
enceladus and now we're also talking

2854
01:51:30,470 --> 01:51:29,280
about ocean worlds across the solar

2855
01:51:32,950 --> 01:51:30,480
system

2856
01:51:34,390 --> 01:51:32,960
and whatever i sort of describe to my

2857
01:51:37,030 --> 01:51:34,400
friends or family

2858
01:51:39,830 --> 01:51:37,040
enceladus it's it's always kind of a

2859
01:51:41,510 --> 01:51:39,840
mystery to them what enceladus might be

2860
01:51:44,070 --> 01:51:41,520
so this is something that many of my

2861
01:51:45,750 --> 01:51:44,080
family members in san diego often think

2862
01:51:48,470 --> 01:51:45,760
about when i tell them about enceladus

2863
01:51:53,270 --> 01:51:48,480

as some kind of tasty meal which is kind

2864
01:51:56,709 --> 01:51:54,390
and so

2865
01:51:57,750 --> 01:51:56,719
kind of as you know in the 2010s as

2866
01:52:00,149 --> 01:51:57,760
we're getting close to the end of the

2867
01:52:02,390 --> 01:52:00,159
decade we basically had four

2868
01:52:03,990 --> 01:52:02,400
worlds emerge besides the earth

2869
01:52:05,189 --> 01:52:04,000
which are thought to be the key

2870
01:52:07,350 --> 01:52:05,199
candidates

2871
01:52:09,109 --> 01:52:07,360
for searching for extraterrestrial life

2872
01:52:11,430 --> 01:52:09,119
in the solar system as many of you are

2873
01:52:13,669 --> 01:52:11,440
aware there's been intense exploration

2874
01:52:15,510 --> 01:52:13,679
of the planet mars and mars is very

2875
01:52:18,310 --> 01:52:15,520
similar to the earth in terms of being a

2876
01:52:20,790 --> 01:52:18,320
terrestrial planet lots of dry land and

2877
01:52:22,470 --> 01:52:20,800
some evidence of water related features

2878
01:52:25,109 --> 01:52:22,480
and then in the outer solar system three

2879
01:52:28,229 --> 01:52:25,119
bodies have emerged as the superstars if

2880
01:52:30,310 --> 01:52:28,239
you will europa as i mentioned enceladus

2881
01:52:32,790 --> 01:52:30,320
and then kristoff in the second talk of

2882
01:52:35,430 --> 01:52:32,800
the session discuss titans so these are

2883
01:52:38,149 --> 01:52:35,440
really the key objects of focus and nasa

2884
01:52:40,790 --> 01:52:38,159
is recognizing this we have the europa

2885
01:52:43,189 --> 01:52:40,800
uh flagship mission to launch later next

2886
01:52:45,750 --> 01:52:43,199
decade and then there's calls for

2887
01:52:48,149 --> 01:52:45,760
competitions to send missions to either

2888
01:52:51,910 --> 01:52:48,159

enceladus or titan in the next decade as

2889
01:52:55,830 --> 01:52:54,070
we're just getting near the end it

2890
01:52:57,910 --> 01:52:55,840
breaks my heart to say it but we're

2891
01:52:58,950 --> 01:52:57,920
almost to the end of the cassini-huygens

2892
01:53:01,350 --> 01:52:58,960
era

2893
01:53:02,229 --> 01:53:01,360
so the image on the left shows probably

2894
01:53:15,750 --> 01:53:02,239
the

2895
01:53:17,990 --> 01:53:15,760
interesting um

2896
01:53:20,229 --> 01:53:18,000
recent geological activity might be

2897
01:53:22,390 --> 01:53:20,239
occurring and at that time recent was

2898
01:53:24,950 --> 01:53:22,400
thought to maybe be something like in

2899
01:53:26,709 --> 01:53:24,960
the past several hundred million years

2900
01:53:28,629 --> 01:53:26,719
and you can see sort of at the the

2901
01:53:31,189 --> 01:53:28,639
bottom right hand corner of that

2902
01:53:33,270 --> 01:53:31,199
left-hand image

2903
01:53:34,709 --> 01:53:33,280
there it's kind of a smooth surface it

2904
01:53:36,870 --> 01:53:34,719
looks different from

2905
01:53:39,030 --> 01:53:36,880
a lot of the moons of the solar system

2906
01:53:40,709 --> 01:53:39,040
like our moon which are very heavily

2907
01:53:46,870 --> 01:53:40,719
cratered and battered

2908
01:53:46,880 --> 01:53:52,950
whoops

2909
01:53:58,550 --> 01:53:54,790
sorry to pause for a second it looks

2910
01:54:02,390 --> 01:54:00,149
no worries chris i'm getting you back on

2911
01:54:03,669 --> 01:54:02,400
as a presenter and you should be good to

2912
01:54:05,220 --> 01:54:03,679
go

2913
01:54:11,910 --> 01:54:05,230

thanks

2914
01:54:15,589 --> 01:54:13,750
okay thank you very much and so the

2915
01:54:18,149 --> 01:54:15,599
right hand image shows now what our

2916
01:54:19,990 --> 01:54:18,159
perspective has become with the cassini

2917
01:54:21,990 --> 01:54:20,000
huygens mission the cassini spacecraft

2918
01:54:23,589 --> 01:54:22,000
has flown by enceladus many times and

2919
01:54:26,550 --> 01:54:23,599
these are some of the highest resolution

2920
01:54:28,790 --> 01:54:26,560
images of a very interesting part of

2921
01:54:31,270 --> 01:54:28,800
enceladus at the south polar region

2922
01:54:33,270 --> 01:54:31,280
which i'll show in the next slide oops i

2923
01:54:35,270 --> 01:54:33,280
mean two slides from now so this light

2924
01:54:37,910 --> 01:54:35,280
here basically just summarizes the whole

2925
01:54:40,870 --> 01:54:37,920
cassini orbital tour of the saturn

2926
01:54:44,550 --> 01:54:40,880
system so the saturn insertion was in

2927
01:54:47,510 --> 01:54:44,560
2004 the launch was in 1997 got there in

2928
01:54:50,149 --> 01:54:47,520
2004 and you can see these

2929
01:54:52,550 --> 01:54:50,159
top images of the orange ball are all

2930
01:54:54,709 --> 01:54:52,560
the flybys of titan which have been a

2931
01:54:55,589 --> 01:54:54,719
very heavily heavy point of emphasis for

2932
01:55:01,910 --> 01:54:55,599
the

2933
01:55:04,870 --> 01:55:01,920
so we've been privileged to have 23

2934
01:55:07,030 --> 01:55:04,880
relatively close flybys of enceladus

2935
01:55:09,669 --> 01:55:07,040
that range anywhere from about 50

2936
01:55:12,470 --> 01:55:09,679
kilometers at closest approach to

2937
01:55:14,310 --> 01:55:12,480
several thousand kilometers away

2938
01:55:16,550 --> 01:55:14,320

so the the earliest flybys where a lot

2939
01:55:18,390 --> 01:55:16,560
of key discoveries were made what were

2940
01:55:20,310 --> 01:55:18,400
in 2005

2941
01:55:22,470 --> 01:55:20,320
and we had we had a sort of a brief

2942
01:55:24,310 --> 01:55:22,480
hiatus then a series of intense

2943
01:55:26,709 --> 01:55:24,320
exploration sort of in the middle of the

2944
01:55:30,229 --> 01:55:26,719
tour and then our final flybys of

2945
01:55:34,229 --> 01:55:30,239
enceladus were in 2015 we had a close

2946
01:55:37,350 --> 01:55:34,239
e21 flyby in october and then the final

2947
01:55:40,470 --> 01:55:37,360
further fly by the e23 flyby was in

2948
01:55:41,270 --> 01:55:40,480
december of 2015. so that's it for our

2949
01:55:43,910 --> 01:55:41,280
um

2950
01:55:45,510 --> 01:55:43,920
cassini observations of enceladus we're

2951
01:55:47,430 --> 01:55:45,520
now gearing up for the end of the

2952
01:55:50,790 --> 01:55:47,440
cassini mission you can see these

2953
01:55:52,870 --> 01:55:50,800
for 2017 all these saturn images shown

2954
01:55:54,709 --> 01:55:52,880
on the slide which indicate that we're

2955
01:55:56,790 --> 01:55:54,719
transitioning into the proximal phase of

2956
01:55:58,709 --> 01:55:56,800
the mission where the spacecraft is

2957
01:56:01,109 --> 01:55:58,719
going to be disposed of a

2958
01:56:02,470 --> 01:56:01,119
fiery crash or burn up into saturn's

2959
01:56:06,550 --> 01:56:02,480
atmosphere so that should be kind of

2960
01:56:09,750 --> 01:56:08,310
so here's just a close-up image of

2961
01:56:12,550 --> 01:56:09,760
enceladus

2962
01:56:15,030 --> 01:56:12,560
kind of improving upon the voyager 2

2963
01:56:16,629 --> 01:56:15,040

flyby and i just want to show you so

2964
01:56:18,550 --> 01:56:16,639
there's you can see this feature i've

2965
01:56:20,790 --> 01:56:18,560
outlined here called the tiger stripes

2966
01:56:21,830 --> 01:56:20,800
that's a those are features of intense

2967
01:56:23,750 --> 01:56:21,840
interest

2968
01:56:25,189 --> 01:56:23,760
and whenever i talk to

2969
01:56:27,109 --> 01:56:25,199
friends or family or other colleagues

2970
01:56:30,070 --> 01:56:27,119
about enceladus the way i like to refer

2971
01:56:31,589 --> 01:56:30,080
to enceladus is as the harvey dent of

2972
01:56:34,790 --> 01:56:31,599
the solar system where you kind of have

2973
01:56:38,149 --> 01:56:34,800
this two-faced perspective of a very

2974
01:56:40,470 --> 01:56:38,159
heavily cratered ancient uh equatorial

2975
01:56:42,709 --> 01:56:40,480
or or mid-latitudes

2976
01:56:44,229 --> 01:56:42,719
and then you have very young terrains in

2977
01:56:46,310 --> 01:56:44,239
the south pole so this image has been

2978
01:56:48,790 --> 01:56:46,320
flipped on its side and these tiger

2979
01:56:52,149 --> 01:56:48,800
stripe features are found on the south

2980
01:56:56,870 --> 01:56:54,950
one of the early discoveries was by the

2981
01:56:59,109 --> 01:56:56,880
cassini sears instrument so this this

2982
01:57:00,229 --> 01:56:59,119
instrument measures thermal infrared

2983
01:57:02,550 --> 01:57:00,239
emission

2984
01:57:05,430 --> 01:57:02,560
and the equilibrium surface temperature

2985
01:57:07,750 --> 01:57:05,440
of bodies at saturn with cold ice

2986
01:57:08,870 --> 01:57:07,760
is around 75 kelvin

2987
01:57:10,550 --> 01:57:08,880
and so you can see some of the

2988
01:57:12,629 --> 01:57:10,560

surrounding terrains in the southport

2989
01:57:15,350 --> 01:57:12,639
region around 75 80

2990
01:57:16,790 --> 01:57:15,360
80k but then these tiger stripe features

2991
01:57:21,189 --> 01:57:16,800
which are

2992
01:57:23,030 --> 01:57:21,199
show very high excess thermal emission

2993
01:57:25,430 --> 01:57:23,040
with temperatures black body

2994
01:57:26,950 --> 01:57:25,440
temperatures of around 200 kelvin so

2995
01:57:29,830 --> 01:57:26,960
that was kind of a clue that something

2996
01:57:36,390 --> 01:57:29,840
very bizarre as far as the solar system

2997
01:57:40,550 --> 01:57:38,790
and in 2005 we indeed found what could

2998
01:57:41,750 --> 01:57:40,560
be considered the biggest discovery of

2999
01:57:44,390 --> 01:57:41,760
cassini i know there's been a lot of

3000
01:57:46,149 --> 01:57:44,400
great science at saturn and titan in

3001
01:57:47,830 --> 01:57:46,159
particular but one of the most

3002
01:57:50,390 --> 01:57:47,840
surprising findings was that there are

3003
01:57:52,790 --> 01:57:50,400
active cryovolcanic eruptions of

3004
01:57:55,589 --> 01:57:52,800
material that are happening right now at

3005
01:57:59,109 --> 01:57:55,599
enceladus and have been ongoing since

3006
01:58:00,790 --> 01:57:59,119
2005 and probably earlier

3007
01:58:02,629 --> 01:58:00,800
and so you just see this smattering of

3008
01:58:04,709 --> 01:58:02,639
images here where we called this feature

3009
01:58:07,510 --> 01:58:04,719
is called the plume and the plume is

3010
01:58:09,830 --> 01:58:07,520
actually comprised of over a hundred

3011
01:58:12,149 --> 01:58:09,840
geysering jets that are feeding material

3012
01:58:15,109 --> 01:58:12,159
from enceladus interior war material

3013
01:58:16,790 --> 01:58:15,119

that to form this plume feature and in

3014
01:58:17,669 --> 01:58:16,800
the right hand image you can see just

3015
01:58:20,149 --> 01:58:17,679
how

3016
01:58:21,830 --> 01:58:20,159
large this plume is in comparison to

3017
01:58:24,629 --> 01:58:21,840
enceladus as a whole the

3018
01:58:27,270 --> 01:58:24,639
low gravity really helps to accentuate

3019
01:58:28,950 --> 01:58:27,280
how far this material can shoot out from

3020
01:58:34,550 --> 01:58:28,960
enceladus

3021
01:58:36,470 --> 01:58:34,560
place as the smallest geologically

3022
01:58:41,189 --> 01:58:36,480
active body that we have evidence in the

3023
01:58:45,109 --> 01:58:43,350
and it really joins an exclusive club so

3024
01:58:48,709 --> 01:58:45,119
most of the bodies are kind of like our

3025
01:58:51,030 --> 01:58:48,719
moon that are sort of dead or very

3026
01:58:52,390 --> 01:58:51,040
have very feeble levels of activity but

3027
01:58:54,870 --> 01:58:52,400
enceladus joined this club where we

3028
01:58:56,709 --> 01:58:54,880
found active volcanism today so you kind

3029
01:58:58,870 --> 01:58:56,719
of have the earth we're aware of

3030
01:59:01,189 --> 01:58:58,880
silicate volcanism where silicate

3031
01:59:02,470 --> 01:59:01,199
minerals are being melted and erupting

3032
01:59:03,910 --> 01:59:02,480
onto the surface

3033
01:59:05,510 --> 01:59:03,920
and then when you move out to the outer

3034
01:59:07,589 --> 01:59:05,520
solar system mark mentioned you have the

3035
01:59:10,950 --> 01:59:07,599
snow line so that's really the domain of

3036
01:59:12,629 --> 01:59:10,960
ices that dominate as surface materials

3037
01:59:14,790 --> 01:59:12,639
on these types of bodies

3038
01:59:17,669 --> 01:59:14,800

and so we call it cryovolcanism for this

3039
01:59:20,550 --> 01:59:17,679
cold variety of extrude extrusion of

3040
01:59:23,109 --> 01:59:20,560
materials we previously had evidence at

3041
01:59:26,310 --> 01:59:23,119
neptune's moon triton for eruptions of

3042
01:59:29,270 --> 01:59:26,320
nitrogen n2 material and now enceladus

3043
01:59:33,589 --> 01:59:29,280
provides us with an example of h2o based

3044
01:59:37,589 --> 01:59:35,510
i won't go into too many details but

3045
01:59:39,990 --> 01:59:37,599
from the past 10 years or so this slide

3046
01:59:42,390 --> 01:59:40,000
basically summarizes in a cartoon form

3047
01:59:45,589 --> 01:59:42,400
what the emerging paradigm is becoming

3048
01:59:48,709 --> 01:59:45,599
for what is sourcing this pluma material

3049
01:59:50,550 --> 01:59:48,719
and what the nature of the subsurface

3050
01:59:52,390 --> 01:59:50,560
might look like on enceladus from

3051
01:59:54,550 --> 01:59:52,400
different lines of evidence involving

3052
01:59:56,629 --> 01:59:54,560
gravitational measurements like kristoff

3053
01:59:58,709 --> 01:59:56,639
mentioned compositional measurements

3054
01:59:59,589 --> 01:59:58,719
different plume modeling

3055
02:00:02,149 --> 01:59:59,599
type

3056
02:00:04,790 --> 02:00:02,159
studies so what we think we have here is

3057
02:00:06,470 --> 02:00:04,800
a rocky core of material

3058
02:00:09,350 --> 02:00:06,480
it's probably porous as christoph

3059
02:00:11,430 --> 02:00:09,360
mentioned overlaid by an ocean of liquid

3060
02:00:13,750 --> 02:00:11,440
water and then there's this still very

3061
02:00:15,270 --> 02:00:13,760
poorly understood plumbing system where

3062
02:00:17,109 --> 02:00:15,280
there are different cracks and other

3063
02:00:19,910 --> 02:00:17,119

features like that which are presumably

3064
02:00:23,270 --> 02:00:19,920
formed by tectonic stresses which are

3065
02:00:24,870 --> 02:00:23,280
serving as conduits for ocean water to

3066
02:00:27,430 --> 02:00:24,880
get close to the surface where it can

3067
02:00:29,430 --> 02:00:27,440
subsequently erupt as these geysers that

3068
02:00:31,350 --> 02:00:29,440
form the plume and then we have the

3069
02:00:33,430 --> 02:00:31,360
cassini spacecraft performing

3070
02:00:37,270 --> 02:00:33,440
fly-throughs of this plume and sampling

3071
02:00:40,950 --> 02:00:38,709
so i'd like to just discuss and

3072
02:00:43,109 --> 02:00:40,960
basically review what we think we know

3073
02:00:44,310 --> 02:00:43,119
about the composition of the ocean on

3074
02:00:46,149 --> 02:00:44,320
enceladus because there were some

3075
02:00:48,310 --> 02:00:46,159
questions earlier about what's the

3076
02:00:50,550 --> 02:00:48,320
chemistry of this stuff and we think we

3077
02:00:53,189 --> 02:00:50,560
have a pretty good idea at least a high

3078
02:00:55,669 --> 02:00:53,199
order level what the chemistry is so one

3079
02:00:59,430 --> 02:00:55,679
instrument on cassini is known as the

3080
02:01:01,830 --> 02:00:59,440
cosmic dust analyzer abbreviated as cda

3081
02:01:04,550 --> 02:01:01,840
and this is an impact ionization mass

3082
02:01:07,030 --> 02:01:04,560
spectrometer so what happens is the

3083
02:01:09,189 --> 02:01:07,040
spacecraft flies through the plume at

3084
02:01:11,669 --> 02:01:09,199
anywhere from about 8 to 20 kilometers

3085
02:01:13,030 --> 02:01:11,679
per second and the ice grains that are

3086
02:01:15,430 --> 02:01:13,040
in the plume

3087
02:01:18,149 --> 02:01:15,440
impact onto a plate and some of the

3088
02:01:19,589 --> 02:01:18,159

different molecules and ions in the um

3089
02:01:22,229 --> 02:01:19,599
flu material

3090
02:01:24,470 --> 02:01:22,239
are ionized and then detected by this

3091
02:01:26,629 --> 02:01:24,480
mass spectrometer on this instrument so

3092
02:01:28,310 --> 02:01:26,639
what this shows is this shows an example

3093
02:01:30,709 --> 02:01:28,320
of the mass spectra that are acquired

3094
02:01:32,229 --> 02:01:30,719
from that sampling process

3095
02:01:35,189 --> 02:01:32,239
and look for those of you in chemistry

3096
02:01:36,390 --> 02:01:35,199
it looks kind of similar to electrospray

3097
02:01:38,149 --> 02:01:36,400
ionization

3098
02:01:41,270 --> 02:01:38,159
where you see kind of like the dominant

3099
02:01:43,910 --> 02:01:41,280
ionic peaks of just single elements like

3100
02:01:46,790 --> 02:01:43,920
sodium plus or potassium plus as

3101
02:01:49,270 --> 02:01:46,800
prominent features and then you have a

3102
02:01:51,669 --> 02:01:49,280
bewildering array of different types of

3103
02:01:53,910 --> 02:01:51,679
combinations you can have between the

3104
02:01:59,270 --> 02:01:53,920
cations and different anions that might

3105
02:02:03,030 --> 02:02:00,629
and the second instrument we have on

3106
02:02:05,270 --> 02:02:03,040
cassini is the inn neutral mass

3107
02:02:07,510 --> 02:02:05,280
spectrometer or inms

3108
02:02:08,229 --> 02:02:07,520
and this instrument basically sniffs out

3109
02:02:12,149 --> 02:02:08,239
the

3110
02:02:14,550 --> 02:02:12,159
gas to give us an understanding of what

3111
02:02:16,870 --> 02:02:14,560
its composition might be like so

3112
02:02:19,430 --> 02:02:16,880
this spectrum shown here is just taking

3113
02:02:20,709 --> 02:02:19,440

in the plume gas in mass

3114
02:02:22,550 --> 02:02:20,719
and then

3115
02:02:24,950 --> 02:02:22,560
observing all the different mass peaks

3116
02:02:26,629 --> 02:02:24,960
that you can find and then we've been

3117
02:02:28,709 --> 02:02:26,639
able to model the spectrum so you can

3118
02:02:30,790 --> 02:02:28,719
kind of think of the model as unbaking

3119
02:02:32,310 --> 02:02:30,800
the cake where we have just everything

3120
02:02:34,470 --> 02:02:32,320
coming into the mass spectrometer at

3121
02:02:37,189 --> 02:02:34,480
once and we're trying to attribute these

3122
02:02:39,270 --> 02:02:37,199
different mass signatures to individual

3123
02:02:41,189 --> 02:02:39,280
species or the fragments of these

3124
02:02:43,830 --> 02:02:41,199
species that are produced during

3125
02:02:45,750 --> 02:02:43,840
electron impact ionization and the color

3126
02:02:47,430 --> 02:02:45,760
scheme basically shows the different

3127
02:02:49,669 --> 02:02:47,440
peaks or fragments that are attributed

3128
02:02:51,830 --> 02:02:49,679
to different molecules so you can see

3129
02:02:53,510 --> 02:02:51,840
that the dominant species is in blue so

3130
02:02:55,589 --> 02:02:53,520
that's water vapor

3131
02:02:57,510 --> 02:02:55,599
and there are other more minor species

3132
02:03:00,229 --> 02:02:57,520
like methane ammonia

3133
02:03:02,470 --> 02:03:00,239
co2 and then at higher masses we think

3134
02:03:04,790 --> 02:03:02,480
we see evidence of organic signatures

3135
02:03:06,950 --> 02:03:04,800
just simple hydrocarbons which we're

3136
02:03:09,030 --> 02:03:06,960
thinking are fragments potentially of

3137
02:03:11,990 --> 02:03:09,040
larger organic structures

3138
02:03:16,390 --> 02:03:13,990

and this slide here basically summarizes

3139
02:03:18,790 --> 02:03:16,400
at a quantitative level what we think

3140
02:03:20,870 --> 02:03:18,800
that the cda and inemis data are

3141
02:03:23,270 --> 02:03:20,880
revealing or constraining about the

3142
02:03:25,589 --> 02:03:23,280
composition of enceladus's ocean so

3143
02:03:26,790 --> 02:03:25,599
these pluton particles are not as as you

3144
02:03:29,189 --> 02:03:26,800
could see from the previous mass

3145
02:03:31,350 --> 02:03:29,199
spectrum they're not pure water ice it

3146
02:03:34,950 --> 02:03:31,360
actually looks like they represent flash

3147
02:03:37,270 --> 02:03:34,960
frozen samples of a salty liquid that's

3148
02:03:40,149 --> 02:03:37,280
dominated by sodium chloride and with a

3149
02:03:42,470 --> 02:03:40,159
little bit of potassium and carbonate

3150
02:03:43,910 --> 02:03:42,480
species

3151
02:03:45,589 --> 02:03:43,920
on the right hand side as i mentioned

3152
02:03:47,589 --> 02:03:45,599
previously it looks like mainly water

3153
02:03:48,709 --> 02:03:47,599
vapor and then you have co2 methane

3154
02:03:51,189 --> 02:03:48,719
ammonia

3155
02:03:53,270 --> 02:03:51,199
some organics and possibly

3156
02:03:55,669 --> 02:03:53,280
free molecular hydrogen which we'll talk

3157
02:03:56,870 --> 02:03:55,679
about later and at the lower left-hand

3158
02:03:58,310 --> 02:03:56,880
side of the image you can kind of see

3159
02:04:00,709 --> 02:03:58,320
for comparison what terrestrial sea

3160
02:04:03,350 --> 02:04:00,719
water looks like so it appears from the

3161
02:04:05,910 --> 02:04:03,360
cda data that enceladus ocean

3162
02:04:06,870 --> 02:04:05,920
is more dilute than sea water on the

3163
02:04:09,109 --> 02:04:06,880

earth

3164
02:04:10,470 --> 02:04:09,119
and then another marked difference is

3165
02:04:11,910 --> 02:04:10,480
sea water on the earth

3166
02:04:14,950 --> 02:04:11,920
actually has a fairly appreciable

3167
02:04:17,510 --> 02:04:14,960
concentration of sulfate and not as much

3168
02:04:20,310 --> 02:04:17,520
bicarbonate and enceladus's ocean seems

3169
02:04:22,550 --> 02:04:20,320
more like a soda ocean we have a decent

3170
02:04:24,709 --> 02:04:22,560
amount of bicarbonate and sulfate has

3171
02:04:26,550 --> 02:04:24,719
yet to be observed so these are

3172
02:04:28,709 --> 02:04:26,560
interesting similarities and differences

3173
02:04:33,270 --> 02:04:28,719
between the ocean we know and love and

3174
02:04:36,470 --> 02:04:35,109
so some of the the general science

3175
02:04:38,550 --> 02:04:36,480
themes that have been revealed by

3176
02:04:40,950 --> 02:04:38,560
cassini this is some work that i did

3177
02:04:43,270 --> 02:04:40,960
trying to constrain the the ph of this

3178
02:04:45,750 --> 02:04:43,280
ocean the ph is really a fundamental

3179
02:04:47,830 --> 02:04:45,760
geochemical parameter that quantifies

3180
02:04:50,310 --> 02:04:47,840
how acidic the water is

3181
02:04:52,790 --> 02:04:50,320
and basically i use this idea of the

3182
02:04:53,669 --> 02:04:52,800
carbonate system as a ph meter from

3183
02:04:55,910 --> 02:04:53,679
space

3184
02:04:58,629 --> 02:04:55,920
so we're not so fortunate to be able to

3185
02:05:00,709 --> 02:04:58,639
just take ph paper or ph probe like we

3186
02:05:02,470 --> 02:05:00,719
would on the earth and stick it into the

3187
02:05:04,550 --> 02:05:02,480
body of natural water enceladus so we

3188
02:05:06,790 --> 02:05:04,560

have to try to be a little clever and we

3189
02:05:08,950 --> 02:05:06,800
have to sacrifice some robustness so we

3190
02:05:10,709 --> 02:05:08,960
can try to do this using a spacecraft

3191
02:05:12,790 --> 02:05:10,719
measurement at

3192
02:05:14,069 --> 02:05:12,800
50 kilometers away from the surface

3193
02:05:15,669 --> 02:05:14,079
flying through the plume at 10

3194
02:05:17,589 --> 02:05:15,679
kilometers per second

3195
02:05:20,069 --> 02:05:17,599
but we can actually solve this carbonate

3196
02:05:22,149 --> 02:05:20,079
problem which is familiar to all of us

3197
02:05:23,990 --> 02:05:22,159
through rainwater so

3198
02:05:27,030 --> 02:05:24,000
rainwater although we've heard of acid

3199
02:05:27,990 --> 02:05:27,040
rain natural rainwater is weakly acidic

3200
02:05:30,790 --> 02:05:28,000
because

3201
02:05:33,270 --> 02:05:30,800
as shown in this left-hand uh figure you

3202
02:05:35,750 --> 02:05:33,280
have co2 dissolving in

3203
02:05:37,990 --> 02:05:35,760
rain water and then it self equilibrates

3204
02:05:39,990 --> 02:05:38,000
among different carbonate species to

3205
02:05:42,149 --> 02:05:40,000
create weak acidity

3206
02:05:43,030 --> 02:05:42,159
so at enceladus it turns out we have the

3207
02:05:45,750 --> 02:05:43,040
data

3208
02:05:47,350 --> 02:05:45,760
to use that fig right hand figure

3209
02:05:49,510 --> 02:05:47,360
showing the distribution of carbonate

3210
02:05:52,950 --> 02:05:49,520
species and we can invert that problem

3211
02:05:53,830 --> 02:05:52,960
to take observations of co2 in the plume

3212
02:05:55,910 --> 02:05:53,840
gas

3213
02:05:58,069 --> 02:05:55,920

and the carbonate salts and the plume

3214
02:06:00,470 --> 02:05:58,079
particles to try to figure out what's

3215
02:06:04,790 --> 02:06:00,480
the self-consistent ph

3216
02:06:07,910 --> 02:06:06,390
so that's what i did in this this next

3217
02:06:09,510 --> 02:06:07,920
slide here you can see on the left-hand

3218
02:06:12,069 --> 02:06:09,520
image i try to find where's the sweet

3219
02:06:14,390 --> 02:06:12,079
spot of self-consistency and when you do

3220
02:06:17,350 --> 02:06:14,400
that calculation you can see that line

3221
02:06:19,189 --> 02:06:17,360
there around 7.5 that's neutral ph

3222
02:06:21,830 --> 02:06:19,199
and that blue shaded region is that

3223
02:06:24,149 --> 02:06:21,840
self-consistent region for enceladus is

3224
02:06:25,589 --> 02:06:24,159
ocean based on the observational data so

3225
02:06:27,830 --> 02:06:25,599
it appears to be

3226
02:06:29,830 --> 02:06:27,840
elevated from neutral ph by several

3227
02:06:32,709 --> 02:06:29,840
units which indicates a fairly high

3228
02:06:34,390 --> 02:06:32,719
degree of alkalinity alkalinity or high

3229
02:06:37,109 --> 02:06:34,400
ph

3230
02:06:38,709 --> 02:06:37,119
and the interesting thing about that is

3231
02:06:40,870 --> 02:06:38,719
when you compare it to this image on the

3232
02:06:42,950 --> 02:06:40,880
right hand side here this was done by a

3233
02:06:44,629 --> 02:06:42,960
study by misha zolatov and i think

3234
02:06:47,430 --> 02:06:44,639
mark's calculations are broadly

3235
02:06:50,149 --> 02:06:47,440
consistent if you just try to figure out

3236
02:06:52,870 --> 02:06:50,159
what's the equilibrium ph if you if you

3237
02:06:55,109 --> 02:06:52,880
hit calculate for equilibrium between a

3238
02:06:57,750 --> 02:06:55,119

quadratic rock composition and liquid

3239
02:07:02,149 --> 02:06:57,760
water at zero degrees c you can see that

3240
02:07:03,510 --> 02:07:02,159
that top curve goes to roughly ph 11. so

3241
02:07:05,510 --> 02:07:03,520
it seems like there's general

3242
02:07:08,149 --> 02:07:05,520
consistency between what an

3243
02:07:10,310 --> 02:07:08,159
observationally based model that

3244
02:07:12,310 --> 02:07:10,320
from the carbonate system is giving and

3245
02:07:14,629 --> 02:07:12,320
what just theoretical geochemistry would

3246
02:07:19,030 --> 02:07:14,639
predict based on an expected composition

3247
02:07:24,149 --> 02:07:21,830
and so high ph waters aren't too common

3248
02:07:26,069 --> 02:07:24,159
on the earth sea waters ph about eight

3249
02:07:28,470 --> 02:07:26,079
but if you look card like many of you

3250
02:07:32,149 --> 02:07:28,480
folks have you can find these locations

3251
02:07:33,910 --> 02:07:32,159
in limited geologic terrain so one of

3252
02:07:35,910 --> 02:07:33,920
the most famous one is the lost city

3253
02:07:38,390 --> 02:07:35,920
hydrothermal system in the mid-atlantic

3254
02:07:41,990 --> 02:07:38,400
with elevated phs from about nine to

3255
02:07:43,910 --> 02:07:42,000
eleven the ophiolite noman so i broke ph

3256
02:07:44,709 --> 02:07:43,920
of 11.5 but i think measurements have

3257
02:07:45,510 --> 02:07:44,719
been

3258
02:07:50,390 --> 02:07:45,520
found

3259
02:07:54,390 --> 02:07:50,400
and enceladus so it seems like it could

3260
02:07:55,950 --> 02:07:54,400
be in the land of 11 to 12. so it seems

3261
02:07:58,709 --> 02:07:55,960
consistent with this notion that

3262
02:08:01,189 --> 02:07:58,719
serpentinization is a key process

3263
02:08:05,589 --> 02:08:01,199

controlling the geochemistry of that

3264
02:08:09,750 --> 02:08:07,589
and then another theme that's emerged

3265
02:08:11,910 --> 02:08:09,760
from the observation observational data

3266
02:08:13,270 --> 02:08:11,920
this is very recent data from just a

3267
02:08:14,470 --> 02:08:13,280
couple years ago

3268
02:08:17,350 --> 02:08:14,480
where

3269
02:08:19,990 --> 02:08:17,360
the cosmic dust analyzer observed these

3270
02:08:22,310 --> 02:08:20,000
very small nano sized particles of

3271
02:08:24,709 --> 02:08:22,320
almost pure silica that were found

3272
02:08:26,550 --> 02:08:24,719
floating in free space around saturn and

3273
02:08:28,709 --> 02:08:26,560
when these folks did a detailed

3274
02:08:31,350 --> 02:08:28,719
investigation they were able to trace

3275
02:08:35,669 --> 02:08:31,360
the most likely point of origin of these

3276
02:08:37,510 --> 02:08:35,679
silica nanoparticles to enceladus

3277
02:08:39,350 --> 02:08:37,520
it appears that enceladus is erupting

3278
02:08:41,750 --> 02:08:39,360
ice grains that contain

3279
02:08:43,430 --> 02:08:41,760
nano nanometer size silica particles

3280
02:08:45,350 --> 02:08:43,440
embedded in them and the right hand

3281
02:08:47,109 --> 02:08:45,360
image shows an attempt to use the

3282
02:08:49,750 --> 02:08:47,119
observations combined with a model to

3283
02:08:52,950 --> 02:08:49,760
try to constrain the concentration of

3284
02:08:54,870 --> 02:08:52,960
silica in the source fluid and the

3285
02:08:59,830 --> 02:08:54,880
conclusion was that the source fluid is

3286
02:09:04,790 --> 02:09:02,390
and so in in 2015

3287
02:09:07,109 --> 02:09:04,800
a couple papers appear proposing that

3288
02:09:09,750 --> 02:09:07,119

the mechanism of producing these

3289
02:09:12,790 --> 02:09:09,760
nanometer size silica particles involved

3290
02:09:14,470 --> 02:09:12,800
hydrothermal activity at enceladus where

3291
02:09:16,390 --> 02:09:14,480
um

3292
02:09:18,629 --> 02:09:16,400
hot water could circulate through

3293
02:09:21,350 --> 02:09:18,639
silicate material in the core

3294
02:09:23,589 --> 02:09:21,360
leach out silica at high temperatures

3295
02:09:26,709 --> 02:09:23,599
and then when that water mixes with cold

3296
02:09:28,870 --> 02:09:26,719
water at the ocean floor the solubility

3297
02:09:30,629 --> 02:09:28,880
of silica would drop dramatically and

3298
02:09:33,830 --> 02:09:30,639
silica particles would crash out of

3299
02:09:35,510 --> 02:09:33,840
solution and form precipitates sort of

3300
02:09:41,030 --> 02:09:35,520
like you see at

3301
02:09:44,870 --> 02:09:43,109
and so this slide here basically shows

3302
02:09:47,270 --> 02:09:44,880
some experiments that were performed to

3303
02:09:49,270 --> 02:09:47,280
support that interpretation so these

3304
02:09:51,589 --> 02:09:49,280
investigators performed laboratory

3305
02:09:55,430 --> 02:09:51,599
studies in a gold bag where they took a

3306
02:09:58,149 --> 02:09:55,440
mixture of olivine and encite in roughly

3307
02:09:59,910 --> 02:09:58,159
ci chondritic proportions

3308
02:10:02,629 --> 02:09:59,920
heated that up with hot water and then

3309
02:10:04,790 --> 02:10:02,639
they measured silica concentrations and

3310
02:10:07,189 --> 02:10:04,800
they found these data points shown here

3311
02:10:09,350 --> 02:10:07,199
in black and it's roughly consistent

3312
02:10:12,310 --> 02:10:09,360
with the classic buffer and assemblage

3313
02:10:14,870 --> 02:10:12,320

of serpentine and talc for this kind of

3314
02:10:17,109 --> 02:10:14,880
intermediate silica activity type

3315
02:10:18,950 --> 02:10:17,119
situation

3316
02:10:21,189 --> 02:10:18,960
so that all seems to hang together

3317
02:10:22,950 --> 02:10:21,199
fairly well

3318
02:10:25,990 --> 02:10:22,960
probably a lesser known study is misha

3319
02:10:27,990 --> 02:10:26,000
zolatov the theoretical geochemist he

3320
02:10:31,109 --> 02:10:28,000
was looking at theoretical calculations

3321
02:10:33,350 --> 02:10:31,119
trying to understand if you could have a

3322
02:10:35,189 --> 02:10:33,360
quadratic or ultramafic system which may

3323
02:10:37,510 --> 02:10:35,199
not really have a lot of silica in the

3324
02:10:39,270 --> 02:10:37,520
rock and whether or not there could be

3325
02:10:41,990 --> 02:10:39,280
enough silica leeched out into a

3326
02:10:43,990 --> 02:10:42,000
hydrothermal fluid to form silica

3327
02:10:46,310 --> 02:10:44,000
precipitates by the proposed cooling

3328
02:10:47,910 --> 02:10:46,320
mechanism and he expressed a little bit

3329
02:10:48,709 --> 02:10:47,920
of hesitation

3330
02:10:51,109 --> 02:10:48,719
so

3331
02:10:53,270 --> 02:10:51,119
just to kind of give you all a total

3332
02:10:55,270 --> 02:10:53,280
story that the hydrothermal model

3333
02:10:57,109 --> 02:10:55,280
appears to be the most well developed

3334
02:10:59,270 --> 02:10:57,119
current paradigm model but there are

3335
02:11:02,069 --> 02:10:59,280
some dissenting opinions

3336
02:11:06,709 --> 02:11:02,079
to this story so let's keep that in mind

3337
02:11:09,510 --> 02:11:07,910
and because you know there's there are

3338
02:11:12,069 --> 02:11:09,520

some questions in this notion of

3339
02:11:14,629 --> 02:11:12,079
hydrothermal activity is kind of a big

3340
02:11:16,550 --> 02:11:14,639
claim so it would be important to find

3341
02:11:19,270 --> 02:11:16,560
or to at least look for as much evidence

3342
02:11:21,270 --> 02:11:19,280
as possible to test this notion of

3343
02:11:22,629 --> 02:11:21,280
hydrothermal serpentinization at

3344
02:11:24,709 --> 02:11:22,639
enceladus

3345
02:11:25,990 --> 02:11:24,719
and so one thing that our group has been

3346
02:11:28,069 --> 02:11:26,000
looking at is

3347
02:11:30,790 --> 02:11:28,079
potential analog sites

3348
02:11:33,030 --> 02:11:30,800
for enceladus on the earth and lost city

3349
02:11:35,270 --> 02:11:33,040
has emerged as a an attractive candidate

3350
02:11:37,669 --> 02:11:35,280
and when you look at lost city has these

3351
02:11:40,229 --> 02:11:37,679
warm waters that are high ph like we

3352
02:11:41,990 --> 02:11:40,239
deduce for the enceladus ocean

3353
02:11:44,470 --> 02:11:42,000
and what's also notice notable about

3354
02:11:47,109 --> 02:11:44,480
lost city is the high concentration of

3355
02:11:49,270 --> 02:11:47,119
molecular hydrogen in these hydrothermal

3356
02:11:53,830 --> 02:11:49,280
vent fluids about 10 millimolar

3357
02:11:58,229 --> 02:11:55,910
here's a theoretical perspective too

3358
02:11:59,830 --> 02:11:58,239
from just sort of like a petrological

3359
02:12:00,950 --> 02:11:59,840
modeling perspective you can look at

3360
02:12:03,430 --> 02:12:00,960
different

3361
02:12:06,390 --> 02:12:03,440
mineral combinations that could buffer

3362
02:12:07,669 --> 02:12:06,400
the hydrogen activity in hydrothermal

3363
02:12:10,229 --> 02:12:07,679

vent fluids

3364
02:12:12,790 --> 02:12:10,239
and so for a serpentinizing system you

3365
02:12:15,030 --> 02:12:12,800
might expect these top this top curve to

3366
02:12:17,669 --> 02:12:15,040
apply where you have serpentines being

3367
02:12:20,629 --> 02:12:17,679
oxidized to assemblage of say magnetite

3368
02:12:23,189 --> 02:12:20,639
and talc so at elevated temperatures

3369
02:12:30,470 --> 02:12:23,199
this type of analysis suggests higher

3370
02:12:33,669 --> 02:12:32,069
and so we've been very interested in

3371
02:12:36,069 --> 02:12:33,679
this possibility of testing for

3372
02:12:36,950 --> 02:12:36,079
hydrothermal activity at enceladus

3373
02:12:39,510 --> 02:12:36,960
and

3374
02:12:42,229 --> 02:12:39,520
we specifically designed a unique

3375
02:12:43,270 --> 02:12:42,239
operational mode for the cassini inms

3376
02:12:45,589 --> 02:12:43,280
instrument

3377
02:12:47,750 --> 02:12:45,599
with using the open source aperture of

3378
02:12:50,629 --> 02:12:47,760
the instrument which would hopefully

3379
02:12:52,470 --> 02:12:50,639
allow a more robust measure of hydrogen

3380
02:12:54,310 --> 02:12:52,480
in the plume the problem is that there's

3381
02:12:56,790 --> 02:12:54,320
also water vapor in the plume and

3382
02:13:00,229 --> 02:12:56,800
there's potential mechanisms to convert

3383
02:13:02,629 --> 02:13:00,239
water vapor to h2 in the instrument if

3384
02:13:04,950 --> 02:13:02,639
you use the normal closed source so we

3385
02:13:07,270 --> 02:13:04,960
use the open source to try to circumvent

3386
02:13:09,510 --> 02:13:07,280
that issue and we're

3387
02:13:11,270 --> 02:13:09,520
we're finishing the touches on a paper

3388
02:13:14,790 --> 02:13:11,280

and it's been submitted so stay tuned

3389
02:13:18,470 --> 02:13:16,149
i just quickly i know i'm running out of

3390
02:13:21,430 --> 02:13:18,480
time here so while we were performing

3391
02:13:23,910 --> 02:13:21,440
the data analysis of the e21 inms data i

3392
02:13:26,310 --> 02:13:23,920
was also performing a geochemical

3393
02:13:28,790 --> 02:13:26,320
analysis of all the possible sources of

3394
02:13:31,750 --> 02:13:28,800
hydrogen at enceladus because maybe it's

3395
02:13:32,950 --> 02:13:31,760
premature to say h2 equals hydrothermal

3396
02:13:35,030 --> 02:13:32,960
so we looked at all sorts of

3397
02:13:37,910 --> 02:13:35,040
possibilities like if you could have

3398
02:13:40,470 --> 02:13:37,920
primordial h2 that's somehow trapped in

3399
02:13:43,669 --> 02:13:40,480
the ison enceladus or if you could form

3400
02:13:46,229 --> 02:13:43,679
h2 by radiolysis of water either in the

3401
02:13:47,750 --> 02:13:46,239
interior or on the surface of enceladus

3402
02:13:49,830 --> 02:13:47,760
and the basic conclusion we found is

3403
02:13:52,550 --> 02:13:49,840
that these possibilities are severely

3404
02:13:54,870 --> 02:13:52,560
constrained or inconsistent with other

3405
02:13:56,950 --> 02:13:54,880
sources of observational data or

3406
02:13:59,350 --> 02:13:56,960
theoretical arguments so we think the

3407
02:14:04,390 --> 02:13:59,360
conclusion if we find h2 that could be a

3408
02:14:07,189 --> 02:14:05,510
and i'm not going to touch up on this

3409
02:14:09,510 --> 02:14:07,199
slide too much all i wanted to basically

3410
02:14:11,589 --> 02:14:09,520
point out is i think enceladus provides

3411
02:14:13,510 --> 02:14:11,599
a natural laboratory for testing a lot

3412
02:14:15,510 --> 02:14:13,520
of these notions where you can think of

3413
02:14:16,790 --> 02:14:15,520

serpentinization as the inorganic

3414
02:14:19,109 --> 02:14:16,800
foundation

3415
02:14:21,109 --> 02:14:19,119
for supporting life by making molecular

3416
02:14:23,990 --> 02:14:21,119
hydrogen that can drive all these

3417
02:14:26,310 --> 02:14:24,000
fascinating disequilibrium processes of

3418
02:14:28,790 --> 02:14:26,320
synthesizing organic molecules which can

3419
02:14:30,629 --> 02:14:28,800
then eventually support ecosystems like

3420
02:14:32,950 --> 02:14:30,639
we find on the earth so there's been a

3421
02:14:34,790 --> 02:14:32,960
lot of debate about the origin of life

3422
02:14:37,030 --> 02:14:34,800
and much of it is philosophical and i

3423
02:14:39,270 --> 02:14:37,040
think enceladus is the next logical

3424
02:14:41,270 --> 02:14:39,280
place to go to really put a lot of these

3425
02:14:45,189 --> 02:14:41,280
ideas to the test so i strongly

3426
02:14:48,470 --> 02:14:46,950
and so just for the final part of the

3427
02:14:51,830 --> 02:14:48,480
slide i thought since this last

3428
02:14:53,830 --> 02:14:51,840
presentation uh what's next it turns out

3429
02:14:56,310 --> 02:14:53,840
from cassini we've learned a lot we've

3430
02:14:59,030 --> 02:14:56,320
basically almost completely checked the

3431
02:15:00,950 --> 02:14:59,040
habitability part of searching for life

3432
02:15:03,750 --> 02:15:00,960
we think there's liquid water there's

3433
02:15:06,310 --> 02:15:03,760
evidence for organic molecules possible

3434
02:15:08,870 --> 02:15:06,320
energy sources free molecular hydrogen

3435
02:15:10,950 --> 02:15:08,880
or other sources of chemical energy that

3436
02:15:13,189 --> 02:15:10,960
could be generated by hydrothermal

3437
02:15:16,069 --> 02:15:13,199
activity so what do we do next in the

3438
02:15:17,910 --> 02:15:16,079

search for life

3439
02:15:20,149 --> 02:15:17,920
this is a really nice graphic by brett

3440
02:15:22,550 --> 02:15:20,159
sherwood basically mapping out the

3441
02:15:24,310 --> 02:15:22,560
trajectory of exploration

3442
02:15:26,550 --> 02:15:24,320
along with my age just to kind of

3443
02:15:29,510 --> 02:15:26,560
emphasize that this is sort of a real

3444
02:15:31,030 --> 02:15:29,520
long range program where we're starting

3445
02:15:33,270 --> 02:15:31,040
with cassini and we basically have

3446
02:15:34,870 --> 02:15:33,280
nailed down habitability and the next

3447
02:15:37,510 --> 02:15:34,880
step you can maybe envision is to do

3448
02:15:39,350 --> 02:15:37,520
something similar to the europa multi

3449
02:15:40,950 --> 02:15:39,360
flyby mission where we do

3450
02:15:42,950 --> 02:15:40,960
in-depth

3451
02:15:45,109 --> 02:15:42,960
investigation of the plume but using

3452
02:15:46,229 --> 02:15:45,119
modern instrumentation to really start

3453
02:15:48,709 --> 02:15:46,239
to look for

3454
02:15:50,870 --> 02:15:48,719
signs of potential biomolecules in the

3455
02:15:52,709 --> 02:15:50,880
plume and eventually getting to think

3456
02:15:55,669 --> 02:15:52,719
really the really exciting possibilities

3457
02:15:58,229 --> 02:15:55,679
like returning samples from the plume or

3458
02:16:01,109 --> 02:15:58,239
possibly once i'm gone uh sending

3459
02:16:03,589 --> 02:16:01,119
submersibles into the ocean to actively

3460
02:16:05,270 --> 02:16:03,599
look at these hydrothermal systems

3461
02:16:06,790 --> 02:16:05,280
a lot of interesting possibilities for

3462
02:16:09,270 --> 02:16:06,800
the future

3463
02:16:11,669 --> 02:16:09,280

and i think i'm going to just stop there

3464
02:16:13,350 --> 02:16:11,679
i do have a movie if there's enough time

3465
02:16:15,990 --> 02:16:13,360
mike you can play the movie if not i'll

3466
02:16:18,149 --> 02:16:16,000
be happy to take questions

3467
02:16:21,189 --> 02:16:18,159
yeah chris if you play it muted and you

3468
02:16:23,589 --> 02:16:21,199
take questions while it's playing

3469
02:16:28,950 --> 02:16:26,069
yeah let's do that um okay chris we got

3470
02:16:31,830 --> 02:16:28,960
a lot of great uh questions and comments

3471
02:16:34,309 --> 02:16:31,840
online um first was from julie castillo

3472
02:16:36,070 --> 02:16:34,319
wondering um i'm curious about this too

3473
02:16:38,230 --> 02:16:36,080
do you expect the plume composition to

3474
02:16:39,270 --> 02:16:38,240
reflect the ocean composition directly

3475
02:16:42,950 --> 02:16:39,280
or could there be some kind of

3476
02:16:44,549 --> 02:16:42,960
fractionation during some formation

3477
02:16:46,790 --> 02:16:44,559
yeah that's a good question so it

3478
02:16:49,830 --> 02:16:46,800
appears that the um the ionic

3479
02:16:51,669 --> 02:16:49,840
composition of the salt particles may be

3480
02:16:53,349 --> 02:16:51,679
a pretty close match based on this

3481
02:16:56,070 --> 02:16:53,359
notion that you could have flash

3482
02:16:57,270 --> 02:16:56,080
freezing of ocean water as droplets are

3483
02:16:59,030 --> 02:16:57,280
erupting

3484
02:17:00,549 --> 02:16:59,040
into a low pressure environment making

3485
02:17:02,389 --> 02:17:00,559
their way into space

3486
02:17:05,030 --> 02:17:02,399
if you're trying to relate the gaseous

3487
02:17:07,669 --> 02:17:05,040
composition to the ocean composition you

3488
02:17:10,230 --> 02:17:07,679

actually have to start worrying about

3489
02:17:12,629 --> 02:17:10,240
condensation of material in the vents

3490
02:17:15,750 --> 02:17:12,639
and that becomes a more difficult

3491
02:17:18,150 --> 02:17:15,760
modeling exercise to try to constrain

3492
02:17:19,830 --> 02:17:18,160
what the composition of the gas how that

3493
02:17:21,589 --> 02:17:19,840
might reflect the original ocean

3494
02:17:23,030 --> 02:17:21,599
composition

3495
02:17:25,589 --> 02:17:23,040
just to give an example i think we kind

3496
02:17:27,990 --> 02:17:25,599
of got led astray when we just took a

3497
02:17:30,469 --> 02:17:28,000
direct look at the gas and said that

3498
02:17:32,389 --> 02:17:30,479
looks like the source because the plume

3499
02:17:35,110 --> 02:17:32,399
gas is actually quite enriched in

3500
02:17:36,950 --> 02:17:35,120
volatiles relative to water vapor so it

3501
02:17:39,030 --> 02:17:36,960
got many people thinking that it must

3502
02:17:41,509 --> 02:17:39,040
mean clathrates but that did not

3503
02:17:43,910 --> 02:17:41,519
consider processes that remove water

3504
02:17:45,910 --> 02:17:43,920
vapor when material is erupting through

3505
02:17:54,150 --> 02:17:45,920
the relatively cold ice

3506
02:17:59,669 --> 02:17:57,190
all right uh i i wonder even for the

3507
02:18:00,709 --> 02:17:59,679
aqueous portion if if um

3508
02:18:02,230 --> 02:18:00,719
there may be some fractional

3509
02:18:04,389 --> 02:18:02,240
crystallization you know what you

3510
02:18:06,629 --> 02:18:04,399
described sort of requires an assumption

3511
02:18:08,389 --> 02:18:06,639
that the fluids are directly in contact

3512
02:18:10,150 --> 02:18:08,399
with the source of the plumes

3513
02:18:12,070 --> 02:18:10,160

which may be the case yep

3514
02:18:14,070 --> 02:18:12,080
there could be yeah i think the next

3515
02:18:16,230 --> 02:18:14,080
step is if somebody's so inspired it'd

3516
02:18:19,509 --> 02:18:16,240
be really useful for this community to

3517
02:18:21,830 --> 02:18:19,519
perform experiments where you study

3518
02:18:24,389 --> 02:18:21,840
catastrophic and violent boiling and

3519
02:18:27,509 --> 02:18:24,399
degassing and freezing of liquid water

3520
02:18:29,509 --> 02:18:27,519
exposed to vacuum conditions and to see

3521
02:18:31,750 --> 02:18:29,519
you know what how that composition might

3522
02:18:34,709 --> 02:18:31,760
be reflected if you were to produce an

3523
02:18:36,549 --> 02:18:34,719
artificial plume in the laboratory

3524
02:18:38,549 --> 02:18:36,559
when you start with a known ocean

3525
02:18:40,549 --> 02:18:38,559
composition i think that'd be really

3526
02:18:44,469 --> 02:18:40,559
interesting and useful

3527
02:18:46,309 --> 02:18:44,479
yeah that's great uh well so

3528
02:18:48,469 --> 02:18:46,319
pop-up talks i'm gonna try to summarize

3529
02:18:51,349 --> 02:18:48,479
some of the questions that followed uh

3530
02:18:52,629 --> 02:18:51,359
so hector um pointed to some experiments

3531
02:18:54,870 --> 02:18:52,639
at virginia tech and university of

3532
02:18:56,469 --> 02:18:54,880
toronto pointed out the dependence of

3533
02:18:58,309 --> 02:18:56,479
serpentinization on the ionic

3534
02:19:00,070 --> 02:18:58,319
composition you sort of touched on that

3535
02:19:02,070 --> 02:19:00,080
in your talk uh after the question was

3536
02:19:04,150 --> 02:19:02,080
posted uh but i hope that's something we

3537
02:19:05,349 --> 02:19:04,160
can maybe consider in the chat later on

3538
02:19:08,629 --> 02:19:05,359

um

3539
02:19:10,870 --> 02:19:08,639
and general on the same lines

3540
02:19:16,469 --> 02:19:10,880
evidence uh for

3541
02:19:19,990 --> 02:19:18,309
yeah well i think that's a really good

3542
02:19:22,709 --> 02:19:20,000
question so there were some early

3543
02:19:24,870 --> 02:19:22,719
observations reported from the cassini

3544
02:19:27,349 --> 02:19:24,880
vims instrument so this looks at the

3545
02:19:31,270 --> 02:19:27,359
near ir spectra and they reported

3546
02:19:33,270 --> 02:19:31,280
signatures of co2 ice or icy complexes

3547
02:19:34,389 --> 02:19:33,280
containing co2

3548
02:19:36,549 --> 02:19:34,399
there have been

3549
02:19:38,870 --> 02:19:36,559
various reports i think in the uv saying

3550
02:19:40,790 --> 02:19:38,880
that there could be ammonia ice present

3551
02:19:43,349 --> 02:19:40,800
on the surface but that's that's not

3552
02:19:45,270 --> 02:19:43,359
really i would say that's tentative

3553
02:19:47,509 --> 02:19:45,280
evidence so far

3554
02:19:48,710 --> 02:19:47,519
uh beyond that i don't think there's

3555
02:19:50,630 --> 02:19:48,720
been any other

3556
02:19:52,870 --> 02:19:50,640
spectral evidence on the surface of

3557
02:19:54,630 --> 02:19:52,880
enceladus

3558
02:19:57,349 --> 02:19:54,640
good reason to go back

3559
02:19:59,510 --> 02:19:57,359
um absolutely

3560
02:20:02,230 --> 02:19:59,520
so julie julie hoover similarly points

3561
02:20:05,590 --> 02:20:02,240
to some uh well she points to some other

3562
02:20:09,270 --> 02:20:07,190
page is not high

3563
02:20:11,830 --> 02:20:09,280

so that link to that paper is in the

3564
02:20:14,230 --> 02:20:11,840
discussion thread um another question

3565
02:20:17,510 --> 02:20:14,240
about a working hypothesis on how to get

3566
02:20:19,670 --> 02:20:17,520
pure silicate um to precipitate from

3567
02:20:22,870 --> 02:20:19,680
silica for serpentine serpentine

3568
02:20:26,630 --> 02:20:24,870
yeah i think that's a good question too

3569
02:20:29,110 --> 02:20:26,640
so it may be the case that we talked

3570
02:20:32,469 --> 02:20:29,120
about serpentinization the classical

3571
02:20:36,230 --> 02:20:32,479
case on earth to my understanding is to

3572
02:20:39,349 --> 02:20:36,240
aqueously alter olivine to produce some

3573
02:20:41,750 --> 02:20:39,359
serpentine and brew site on for a ci

3574
02:20:44,150 --> 02:20:41,760
chondritic or solar composition rock

3575
02:20:46,070 --> 02:20:44,160
it's not quite the same as peridotite

3576
02:20:48,550 --> 02:20:46,080
the solar composition is actually a

3577
02:20:50,309 --> 02:20:48,560
little bit richer in silica and you can

3578
02:20:52,550 --> 02:20:50,319
kind of think of as of

3579
02:20:55,030 --> 02:20:52,560
ci chondrite as more being similar to a

3580
02:20:56,950 --> 02:20:55,040
peroxide on the earth

3581
02:20:58,870 --> 02:20:56,960
so it may be the case that there's a

3582
02:21:00,630 --> 02:20:58,880
little more silica there than we might

3583
02:21:02,469 --> 02:21:00,640
normally think of on the earth but it's

3584
02:21:05,110 --> 02:21:02,479
still an interesting question to see if

3585
02:21:07,670 --> 02:21:05,120
we can reconcile these observations of

3586
02:21:10,469 --> 02:21:07,680
silica particles with

3587
02:21:11,349 --> 02:21:10,479
possible models of aqueous alteration

3588
02:21:13,190 --> 02:21:11,359

of

3589
02:21:15,270 --> 02:21:13,200
rocky material

3590
02:21:17,670 --> 02:21:15,280
it could also be the case that maybe the

3591
02:21:19,429 --> 02:21:17,680
hydrothermally reacted rock

3592
02:21:21,150 --> 02:21:19,439
is not the primordial rock but there

3593
02:21:22,950 --> 02:21:21,160
could have been some kind of igneous

3594
02:21:25,270 --> 02:21:22,960
differentiation or

3595
02:21:27,190 --> 02:21:25,280
some other processes of mass transfer

3596
02:21:29,670 --> 02:21:27,200
that might have fractionated enceladus

3597
02:21:32,950 --> 02:21:29,680
core in a way that we don't presently

3598
02:21:38,830 --> 02:21:35,270
yeah so lots of lots of complexities to

3599
02:21:44,309 --> 02:21:42,389
uh supporting the idea of wondering

3600
02:21:46,950 --> 02:21:44,319
uh how directly we can interpret the

3601
02:21:51,270 --> 02:21:46,960
type of serpentinization if any uh from

3602
02:21:55,270 --> 02:21:51,280
the enceladus observations and seconding

3603
02:21:56,710 --> 02:21:55,280
other analogs we should look at

3604
02:21:59,830 --> 02:21:56,720
um yeah i

3605
02:22:00,630 --> 02:21:59,840
agree with chris german completely

3606
02:22:02,870 --> 02:22:00,640
great

3607
02:22:05,270 --> 02:22:02,880
uh also serpentinization likely

3608
02:22:06,150 --> 02:22:05,280
responsible for nitrogen fixation

3609
02:22:08,790 --> 02:22:06,160
to

3610
02:22:11,830 --> 02:22:08,800
uh ammonia uh or is there another

3611
02:22:17,190 --> 02:22:14,389
uh it's possible so if if hydrogen is

3612
02:22:18,550 --> 02:22:17,200
observed then there is a strong thermic

3613
02:22:20,309 --> 02:22:18,560

drive and there could be catalytic

3614
02:22:23,190 --> 02:22:20,319
metals that could drive the conversion

3615
02:22:25,750 --> 02:22:23,200
of n2 to ammonia

3616
02:22:28,389 --> 02:22:25,760
ammonia has been detected in the plume

3617
02:22:29,990 --> 02:22:28,399
n2 interestingly enough has not been

3618
02:22:32,870 --> 02:22:30,000
observed

3619
02:22:34,389 --> 02:22:32,880
so the question is does the ammonia

3620
02:22:36,950 --> 02:22:34,399
represent

3621
02:22:39,670 --> 02:22:36,960
a significant conversion of n2 to

3622
02:22:41,910 --> 02:22:39,680
ammonia or could the ammonia just be a

3623
02:22:43,190 --> 02:22:41,920
primordial species that has been

3624
02:22:44,070 --> 02:22:43,200
preserved

3625
02:22:46,150 --> 02:22:44,080
uh

3626
02:22:48,790 --> 02:22:46,160
until the present day i think that would

3627
02:22:51,590 --> 02:22:48,800
require a new mission to look at things

3628
02:22:54,070 --> 02:22:51,600
like the um an isotopic composition for

3629
02:22:57,830 --> 02:22:54,080
example to try to understand the source

3630
02:22:59,910 --> 02:22:57,840
of the nitrogen on enceladus

3631
02:23:01,670 --> 02:22:59,920
great

3632
02:23:04,389 --> 02:23:01,680
uh chris thanks so much for a really

3633
02:23:06,790 --> 02:23:04,399
thorough and fun talk uh we need to move

3634
02:23:09,670 --> 02:23:06,800
on to the pop-up talks now um so i'd

3635
02:23:11,990 --> 02:23:09,680
like us to bring up our next uh

3636
02:23:16,870 --> 02:23:12,000
speaker and i believe julie castillo is

3637
02:23:16,880 --> 02:23:22,230
oh

3638
02:23:28,389 --> 02:23:24,469

okay so whenever you're ready uh just

3639
02:23:31,590 --> 02:23:29,990
um and just a reminder we have about

3640
02:23:33,030 --> 02:23:31,600
five minutes for each pop-up talk now

3641
02:23:34,790 --> 02:23:33,040
and we'll do about a minute or two of

3642
02:23:41,830 --> 02:23:34,800
questions so we could try to stay on

3643
02:23:58,469 --> 02:23:44,550
adrian adrian you might be muted on your

3644
02:24:02,070 --> 02:24:00,309
this presentation is just going to be

3645
02:24:07,110 --> 02:24:02,080
short um

3646
02:24:07,120 --> 02:24:14,160
of uh

3647
02:24:14,170 --> 02:24:27,030
[Music]

3648
02:24:27,040 --> 02:24:33,510
newly toxic

3649
02:24:38,790 --> 02:24:35,270
region in western australia

3650
02:24:40,150 --> 02:24:38,800
fourth place on uh

3651
02:24:52,710 --> 02:24:40,160
analog

3652
02:24:52,720 --> 02:25:03,910
all right

3653
02:25:06,790 --> 02:25:05,110
use the arrow at the bottom of your

3654
02:25:07,990 --> 02:25:06,800
screen

3655
02:25:36,630 --> 02:25:08,000
okay got it

3656
02:25:41,429 --> 02:25:38,389
this is pretty famous this is what it

3657
02:25:44,790 --> 02:25:41,439
says it's the area where the best is the

3658
02:25:46,630 --> 02:25:44,800
oldest system in my life exists in

3659
02:25:48,950 --> 02:25:46,640
in western australia and

3660
02:25:49,910 --> 02:25:48,960
in the world i'll show you in a couple

3661
02:25:51,030 --> 02:25:49,920
of

3662
02:25:52,790 --> 02:25:51,040
moments

3663
02:25:55,830 --> 02:25:52,800

we were trying to highlight uh in this

3664
02:25:58,710 --> 02:25:55,840
paper is alteration minerals that were

3665
02:26:00,469 --> 02:25:58,720
in the norfolk zone it could be mapped

3666
02:26:03,110 --> 02:26:00,479
and uh have

3667
02:26:04,309 --> 02:26:03,120
associations with the strata that we

3668
02:26:06,550 --> 02:26:04,319
found

3669
02:26:08,070 --> 02:26:06,560
at the north pole zone and these are

3670
02:26:11,750 --> 02:26:08,080
these rocks are part of the world warner

3671
02:26:13,510 --> 02:26:11,760
group um at about 3.5 billion is old so

3672
02:26:16,309 --> 02:26:13,520
they're very similar in age to the

3673
02:26:18,469 --> 02:26:16,319
military rocks that i'll talk about

3674
02:26:21,270 --> 02:26:18,479
in a few slides time

3675
02:26:23,590 --> 02:26:21,280
now what what are what i was looking for

3676
02:26:25,670 --> 02:26:23,600
in the hyperspectrum data set were

3677
02:26:28,389 --> 02:26:25,680
alteration minerals that really stand

3678
02:26:30,550 --> 02:26:28,399
out with very strong absorption bands

3679
02:26:33,030 --> 02:26:30,560
um and my um

3680
02:26:34,950 --> 02:26:33,040
general strategy uh

3681
02:26:38,870 --> 02:26:34,960
approach when i was uh

3682
02:26:40,389 --> 02:26:38,880
trying to map these areas and uh was to

3683
02:26:42,070 --> 02:26:40,399
go back to sydney

3684
02:26:44,150 --> 02:26:42,080
uh each year and look at the remote

3685
02:26:46,230 --> 02:26:44,160
testing dataset i had and then go back

3686
02:26:48,150 --> 02:26:46,240
out in the in the winter after the

3687
02:26:50,790 --> 02:26:48,160
pilgrimage where the temperatures became

3688
02:26:52,309 --> 02:26:50,800

variable in the winter and try and

3689
02:26:54,790 --> 02:26:52,319
follow up on discoveries that i've made

3690
02:26:56,950 --> 02:26:54,800
using roommates and data set back in

3691
02:27:01,110 --> 02:26:56,960
the computer lab if you will

3692
02:27:05,750 --> 02:27:01,120
so i was very shocked to see this very

3693
02:27:09,510 --> 02:27:07,670
washed out the resulting band

3694
02:27:11,030 --> 02:27:09,520
in my second year of an office and so i

3695
02:27:13,030 --> 02:27:11,040
was pretty excited to go out there the

3696
02:27:14,830 --> 02:27:13,040
next year when i went out there this is

3697
02:27:17,190 --> 02:27:14,840
what i saw

3698
02:27:18,309 --> 02:27:17,200
um can you see my cursor on the screen

3699
02:27:20,150 --> 02:27:18,319
there

3700
02:27:21,750 --> 02:27:20,160
okay this is basically on the right hand

3701
02:27:25,270 --> 02:27:21,760
side this key

3702
02:27:29,910 --> 02:27:27,910
yeah okay all right that's it pretty

3703
02:27:32,710 --> 02:27:29,920
crappy sort of outcrop here it's covered

3704
02:27:33,510 --> 02:27:32,720
with spin effects here's my brutus scale

3705
02:27:35,270 --> 02:27:33,520
um

3706
02:27:37,990 --> 02:27:35,280
and and this stuff was what i was seeing

3707
02:27:40,389 --> 02:27:38,000
this huge absorption there and from

3708
02:27:42,790 --> 02:27:40,399
uh and it took a lot of um

3709
02:27:43,590 --> 02:27:42,800
thinking to work out what was going on

3710
02:27:47,429 --> 02:27:43,600
here

3711
02:27:50,309 --> 02:27:47,439
fact the long story short

3712
02:27:51,990 --> 02:27:50,319
it actually carbonates alteration of

3713
02:27:55,590 --> 02:27:52,000

underlying uh

3714
02:27:58,309 --> 02:27:55,600
olivine rich commoditized block uh

3715
02:28:00,230 --> 02:27:58,319
so this is around 3.5 billion years old

3716
02:28:02,389 --> 02:28:00,240
and the top really stands out in the

3717
02:28:04,550 --> 02:28:02,399
hyperspectrum there's that because

3718
02:28:06,950 --> 02:28:04,560
it's very bright and it's very friable

3719
02:28:09,510 --> 02:28:06,960
and it gets over everything and so even

3720
02:28:11,110 --> 02:28:09,520
amongst this i i know

3721
02:28:12,389 --> 02:28:11,120
the way they talked about education

3722
02:28:14,790 --> 02:28:12,399
getting in the way of

3723
02:28:16,790 --> 02:28:14,800
uh absorption bands and um signals in

3724
02:28:18,950 --> 02:28:16,800
hyper stretching data

3725
02:28:21,590 --> 02:28:18,960
this benefits just really didn't affect

3726
02:28:22,630 --> 02:28:21,600
the fact that the the health around it

3727
02:28:24,389 --> 02:28:22,640
um

3728
02:28:25,590 --> 02:28:24,399
uh really yeah

3729
02:28:26,550 --> 02:28:25,600
without

3730
02:28:29,990 --> 02:28:26,560
okay

3731
02:28:33,590 --> 02:28:31,190
this is an example of one of those

3732
02:28:35,670 --> 02:28:33,600
stromatolites that that are found in a

3733
02:28:38,710 --> 02:28:35,680
layer that's just above the ultramatic

3734
02:28:41,030 --> 02:28:38,720
laser layer that i was talking about

3735
02:28:42,950 --> 02:28:41,040
so this led to the telco date hypothesis

3736
02:28:44,870 --> 02:28:42,960
which the paper that we published in

3737
02:28:46,630 --> 02:28:44,880
2010

3738
02:28:48,550 --> 02:28:46,640

um

3739
02:28:51,110 --> 02:28:48,560
didn't get that right

3740
02:28:53,110 --> 02:28:51,120
where we actually went back to the um

3741
02:28:55,349 --> 02:28:53,120
christmas data set on mars in the nelly

3742
02:28:56,950 --> 02:28:55,359
fosse which elena also talked about and

3743
02:28:57,750 --> 02:28:56,960
we found um

3744
02:28:58,790 --> 02:28:57,760
that

3745
02:29:00,790 --> 02:28:58,800
there was

3746
02:29:03,030 --> 02:29:00,800
quite likely that

3747
02:29:05,429 --> 02:29:03,040
carbonate could explain a lot of the

3748
02:29:07,750 --> 02:29:05,439
carbonate features that we actually see

3749
02:29:09,990 --> 02:29:07,760
in milk profit

3750
02:29:11,830 --> 02:29:10,000
and so that's uh

3751
02:29:14,710 --> 02:29:11,840
the broad

3752
02:29:16,710 --> 02:29:14,720
outline of the link between the silver

3753
02:29:18,230 --> 02:29:16,720
and mars that we have

3754
02:29:20,309 --> 02:29:18,240
but um

3755
02:29:22,550 --> 02:29:20,319
but then this is me followed up by a

3756
02:29:23,429 --> 02:29:22,560
couple of papers from christina

3757
02:29:25,830 --> 02:29:23,439
who

3758
02:29:27,910 --> 02:29:25,840
elena mentioned and also um at this type

3759
02:29:30,710 --> 02:29:27,920
of white uh school

3760
02:29:37,429 --> 02:29:33,110
was making the point that it's very

3761
02:29:38,710 --> 02:29:37,439
difficult to form talc in shallow areas

3762
02:29:41,110 --> 02:29:38,720
of mars

3763
02:29:42,950 --> 02:29:41,120

um and particularly uh due to the low

3764
02:29:43,590 --> 02:29:42,960
pressure situation there

3765
02:29:45,190 --> 02:29:43,600
in

3766
02:29:48,389 --> 02:29:45,200
the martian crust

3767
02:29:51,429 --> 02:29:48,399
um and the local gradient uh that

3768
02:29:53,670 --> 02:29:51,439
we're likely that we uh see on on mars

3769
02:29:55,990 --> 02:29:53,680
well we are in the martian regular

3770
02:29:58,630 --> 02:29:56,000
that it's really difficult to perform

3771
02:30:01,030 --> 02:29:58,640
these sub-synchronization reactions he

3772
02:30:02,870 --> 02:30:01,040
uh he calculated this uh

3773
02:30:04,550 --> 02:30:02,880
map on the right of

3774
02:30:08,150 --> 02:30:04,560
our activities here's the skeleton

3775
02:30:09,990 --> 02:30:08,160
versus temperature and um formation of

3776
02:30:13,349 --> 02:30:10,000
uh towers these

3777
02:30:15,510 --> 02:30:13,359
um pc areas here

3778
02:30:18,550 --> 02:30:15,520
and up up in this gray area here is this

3779
02:30:19,990 --> 02:30:18,560
this abandonation region of um formation

3780
02:30:22,230 --> 02:30:20,000
a couple of other people have shown

3781
02:30:24,309 --> 02:30:22,240
these type of some

3782
02:30:25,670 --> 02:30:24,319
plots so i won't go into it in a lot of

3783
02:30:27,590 --> 02:30:25,680
detail

3784
02:30:29,510 --> 02:30:27,600
basically the point of our project was

3785
02:30:32,710 --> 02:30:29,520
we wanted to work out whether we could

3786
02:30:34,150 --> 02:30:32,720
get stuff forming at lower pressures um

3787
02:30:34,950 --> 02:30:34,160
i re-ran

3788
02:30:36,710 --> 02:30:34,960

um

3789
02:30:42,389 --> 02:30:36,720
uh

3790
02:30:44,469 --> 02:30:42,399
killer bar and 0.1 kilobytes

3791
02:30:45,910 --> 02:30:44,479
and again to cut along very short we

3792
02:30:48,630 --> 02:30:45,920
found that they're actually getting

3793
02:30:49,990 --> 02:30:48,640
molar temperature formation of the um

3794
02:30:52,710 --> 02:30:50,000
systemization

3795
02:30:55,110 --> 02:30:52,720
materials by etaus and so on

3796
02:30:56,870 --> 02:30:55,120
um it was moving further to the right in

3797
02:30:59,510 --> 02:30:56,880
this reaction

3798
02:31:01,910 --> 02:30:59,520
uh so that's um that's that's good

3799
02:31:03,349 --> 02:31:01,920
that's um

3800
02:31:05,110 --> 02:31:03,359
that's good as far as some computer

3801
02:31:10,469 --> 02:31:05,120
models looking to

3802
02:31:15,510 --> 02:31:13,429
but then and just to talk about the uh

3803
02:31:17,429 --> 02:31:15,520
the possible uh

3804
02:31:20,070 --> 02:31:17,439
sorry adrian we're just about to make

3805
02:31:22,389 --> 02:31:20,080
sure we can have our other speakers talk

3806
02:31:24,230 --> 02:31:22,399
yeah okay i'll just talk about the

3807
02:31:26,790 --> 02:31:24,240
the scenarios that i'm looking at now

3808
02:31:30,389 --> 02:31:26,800
for the self-carbon hypothesis

3809
02:31:31,670 --> 02:31:30,399
and potentially um this could have been

3810
02:31:33,349 --> 02:31:31,680
the carbonates that we see in early

3811
02:31:35,910 --> 02:31:33,359
phosphate could have been formed by a

3812
02:31:37,830 --> 02:31:35,920
commodiate lava flow that was buried and

3813
02:31:40,830 --> 02:31:37,840

then later exhumed

3814
02:31:42,630 --> 02:31:40,840
and we see a stratigraphy of the area

3815
02:31:47,190 --> 02:31:42,640
um

3816
02:31:48,790 --> 02:31:47,200
that our latest uh work is now

3817
02:31:50,469 --> 02:31:48,800
concentrating

3818
02:31:52,950 --> 02:31:50,479
on um

3819
02:31:54,870 --> 02:31:52,960
this will be reported at lbsd

3820
02:31:56,710 --> 02:31:54,880
on uh the jezreel crater region we'll

3821
02:31:58,950 --> 02:31:56,720
you're looking at the carbonates

3822
02:32:01,349 --> 02:31:58,960
that are forming there uh this is what

3823
02:32:03,429 --> 02:32:01,359
i'm doing with uh christina and uh two

3824
02:32:06,070 --> 02:32:03,439
garage we're actually looking at the

3825
02:32:08,710 --> 02:32:06,080
jesuit crazy delta and how we can access

3826
02:32:11,110 --> 02:32:08,720
the top carbonate bearing rocks uh that

3827
02:32:13,510 --> 02:32:11,120
might be nearby this is one of our map

3828
02:32:15,830 --> 02:32:13,520
products that we're uh working on here

3829
02:32:21,110 --> 02:32:15,840
we can see jesuit crater

3830
02:32:22,710 --> 02:32:21,120
in here and in green we see carbonate

3831
02:32:23,750 --> 02:32:22,720
harmony varying regions around the

3832
02:32:25,510 --> 02:32:23,760
crater

3833
02:32:26,550 --> 02:32:25,520
creating this this very interesting

3834
02:32:28,230 --> 02:32:26,560
layer

3835
02:32:30,469 --> 02:32:28,240
that's uh

3836
02:32:31,830 --> 02:32:30,479
near the delta but not lying on top of

3837
02:32:34,950 --> 02:32:31,840
the delta

3838
02:32:36,950 --> 02:32:34,960

and and the key point is that

3839
02:32:39,670 --> 02:32:36,960
up in the left

3840
02:32:41,990 --> 02:32:39,680
okay up on the left hand side is this

3841
02:32:44,309 --> 02:32:42,000
tower varying area up here and that's in

3842
02:32:45,590 --> 02:32:44,319
the watershed for the crater

3843
02:32:47,110 --> 02:32:45,600
we're interested in finding out what

3844
02:32:49,190 --> 02:32:47,120
lies in between

3845
02:33:04,870 --> 02:32:49,200
uh the crater and that that

3846
02:33:09,429 --> 02:33:07,110
thanks very much uh next is uh julie

3847
02:33:11,670 --> 02:33:09,439
castillo

3848
02:33:15,590 --> 02:33:11,680
hey hi

3849
02:33:21,270 --> 02:33:18,790
um as expected mark did a very i mean an

3850
02:33:23,349 --> 02:33:21,280
excellent review of the state obviously

3851
02:33:25,270 --> 02:33:23,359
in the area of

3852
02:33:27,910 --> 02:33:25,280
what we have learned from the appearance

3853
02:33:30,790 --> 02:33:27,920
and how it compared against tradition

3854
02:33:32,150 --> 02:33:30,800
so going to the second slide i'm

3855
02:33:36,710 --> 02:33:32,160
just going to

3856
02:33:42,389 --> 02:33:39,590
can you hear me okay

3857
02:33:44,950 --> 02:33:42,399
dan revealed that stereocystic surface

3858
02:33:47,030 --> 02:33:44,960
is covered by

3859
02:33:50,230 --> 02:33:47,040
hydraulic accuracy as a hydrated

3860
02:33:54,550 --> 02:33:52,550
ammonite clay serpentine and carbonate

3861
02:33:56,630 --> 02:33:54,560
and this in a crazy

3862
02:33:58,309 --> 02:33:56,640
uniform manner

3863
02:34:00,790 --> 02:33:58,319

and

3864
02:34:02,710 --> 02:34:00,800
which is very important that luckily

3865
02:34:04,469 --> 02:34:02,720
there are bright parts

3866
02:34:07,190 --> 02:34:04,479
of

3867
02:34:11,030 --> 02:34:07,200
carbonates especially sodium carbonates

3868
02:34:13,670 --> 02:34:11,040
and ammonium salts as mark said and this

3869
02:34:15,670 --> 02:34:13,680
comp you know this composition compares

3870
02:34:16,950 --> 02:34:15,680
very well with what has been found out

3871
02:34:19,670 --> 02:34:16,960
on studies

3872
02:34:21,190 --> 02:34:19,680
and also on earth we have in the uh

3873
02:34:23,030 --> 02:34:21,200
volcanic left we find similar

3874
02:34:24,309 --> 02:34:23,040
compositions like the experts in

3875
02:34:26,070 --> 02:34:24,319
california

3876
02:34:28,550 --> 02:34:26,080
another important result from the don

3877
02:34:30,950 --> 02:34:28,560
mission is a measurement of the amount

3878
02:34:34,150 --> 02:34:30,960
of iron on the surface

3879
02:34:36,550 --> 02:34:34,160
which is like this low vertex

3880
02:34:37,990 --> 02:34:36,560
usually measured on ci and cm called

3881
02:34:39,190 --> 02:34:38,000
right stands to observe that there has

3882
02:34:43,030 --> 02:34:39,200
been some

3883
02:34:47,110 --> 02:34:43,040
differentiation physical differentiation

3884
02:34:49,349 --> 02:34:47,120
of cyrus's material and so both

3885
02:34:52,710 --> 02:34:49,359
those types of observations mineralogy

3886
02:34:56,150 --> 02:34:52,720
and elemental suggest that cirrus was

3887
02:34:57,750 --> 02:34:56,160
subject to extensive global hydrothermal

3888
02:34:59,670 --> 02:34:57,760

circulation

3889
02:35:02,070 --> 02:34:59,680
and here is this plot again from young

3890
02:35:03,910 --> 02:35:02,080
air sergeant entry that shows up in a

3891
02:35:05,590 --> 02:35:03,920
body that is relatively large beyond a

3892
02:35:09,270 --> 02:35:05,600
few hundred kilometers

3893
02:35:12,309 --> 02:35:09,280
uh you can have multi-pass flow

3894
02:35:15,750 --> 02:35:12,319
especially if early on you had a global

3895
02:35:17,830 --> 02:35:15,760
melting event driven by addition

3896
02:35:20,870 --> 02:35:17,840
and in smaller bodies you have only a

3897
02:35:28,309 --> 02:35:20,880
single fast flow or even

3898
02:35:31,670 --> 02:35:29,429
quickly

3899
02:35:33,830 --> 02:35:31,680
just to point out that looking at just

3900
02:35:36,070 --> 02:35:33,840
at the surface mineology we can infer

3901
02:35:38,870 --> 02:35:36,080
constraints on the conditions of cirrus

3902
02:35:41,190 --> 02:35:38,880
early ocean the ammonite clays are

3903
02:35:44,070 --> 02:35:41,200
really a strong diagnostic

3904
02:35:45,670 --> 02:35:44,080
of these conditions they require some

3905
02:35:47,110 --> 02:35:45,680
relatively high partial pressure of

3906
02:35:49,110 --> 02:35:47,120
hydrogen

3907
02:35:50,710 --> 02:35:49,120
um which

3908
02:35:52,550 --> 02:35:50,720
which tells us that the material that we

3909
02:35:54,710 --> 02:35:52,560
find on stereotype surfaces form that

3910
02:35:58,309 --> 02:35:54,720
depth and were excavated by some global

3911
02:36:00,230 --> 02:35:58,319
mechanisms that we are trying to

3912
02:36:01,429 --> 02:36:00,240
identify

3913
02:36:06,389 --> 02:36:01,439

and

3914
02:36:10,070 --> 02:36:08,630
exchanges with captions

3915
02:36:11,030 --> 02:36:10,080
would stick to the production of

3916
02:36:12,870 --> 02:36:11,040
thoughts

3917
02:36:14,630 --> 02:36:12,880
and as much mercy the temperatures in

3918
02:36:17,270 --> 02:36:14,640
the early oceans were like your left to

3919
02:36:18,710 --> 02:36:17,280
be on the colder times admired by the

3920
02:36:21,670 --> 02:36:18,720
three

3921
02:36:23,270 --> 02:36:21,680
close to a ten or twenty digital system

3922
02:36:25,910 --> 02:36:23,280
and then the carbonate the fact that we

3923
02:36:29,349 --> 02:36:25,920
have two types of carbonate

3924
02:36:31,750 --> 02:36:29,359
magnesium calcium and

3925
02:36:35,830 --> 02:36:31,760
i could use with the

3926
02:36:37,910 --> 02:36:35,840
vr maybe you could help you have my

3927
02:36:42,070 --> 02:36:37,920
and dolomite on the surface

3928
02:36:44,630 --> 02:36:42,080
you have good bicarbonate in solution

3929
02:36:45,590 --> 02:36:44,640
forming the dry spot

3930
02:36:47,670 --> 02:36:45,600
sodium

3931
02:37:02,950 --> 02:36:47,680
carbonate or bicarbonate

3932
02:37:07,190 --> 02:37:04,710
there should be a lot of methane

3933
02:37:09,190 --> 02:37:07,200
solution that then form

3934
02:37:11,510 --> 02:37:09,200
uh classrooms

3935
02:37:13,830 --> 02:37:11,520
just to point out and maybe

3936
02:37:14,950 --> 02:37:13,840
there's a lot of information each of the

3937
02:37:17,590 --> 02:37:14,960
volume

3938
02:37:19,990 --> 02:37:17,600

fraction of uh

3939
02:37:21,750 --> 02:37:20,000
a consequence of accurate saturations

3940
02:37:24,550 --> 02:37:21,760
for various assumptions on the water to

3941
02:37:26,389 --> 02:37:24,560
work ratio and the the amount of certain

3942
02:37:28,950 --> 02:37:26,399
volatiles in solution

3943
02:37:30,630 --> 02:37:28,960
ammonia and co2 and what you see is that

3944
02:37:32,630 --> 02:37:30,640
for five percent of

3945
02:37:35,590 --> 02:37:32,640
weight percent of ammonia and 28 percent

3946
02:37:38,469 --> 02:37:35,600
of co2 are created early and you can

3947
02:37:42,070 --> 02:37:38,479
reproduce the compositions uh detected

3948
02:37:46,070 --> 02:37:43,830
the composition of the surface measured

3949
02:37:48,230 --> 02:37:46,080
by the donation and especially you you

3950
02:37:49,910 --> 02:37:48,240
can match your issue then of certain

3951
02:37:51,270 --> 02:37:49,920
times to plays

3952
02:37:52,630 --> 02:37:51,280
and um

3953
02:37:55,030 --> 02:37:52,640
and carbonx

3954
02:37:55,990 --> 02:37:55,040
if you do the opposite you have more you

3955
02:37:58,150 --> 02:37:56,000
form

3956
02:38:00,710 --> 02:37:58,160
you have more co2 unless ammonia you

3957
02:38:03,429 --> 02:38:00,720
find something that is very efficient

3958
02:38:05,750 --> 02:38:03,439
where you cannot form as much certain

3959
02:38:06,870 --> 02:38:05,760
time you form a lot

3960
02:38:09,349 --> 02:38:06,880
yeah i run

3961
02:38:10,070 --> 02:38:09,359
from a lot of carbonate and the iron

3962
02:38:13,110 --> 02:38:10,080
uh

3963
02:38:15,830 --> 02:38:13,120

goes presidentially with the carbonate

3964
02:38:17,990 --> 02:38:15,840
and what we find in the end is the

3965
02:38:19,750 --> 02:38:18,000
future that is very different from what

3966
02:38:21,590 --> 02:38:19,760
don observed and that is important

3967
02:38:24,230 --> 02:38:21,600
because we can i think we can put a

3968
02:38:25,590 --> 02:38:24,240
constraint on the early

3969
02:38:38,630 --> 02:38:25,600
superposition of the aggregated

3970
02:38:43,349 --> 02:38:40,870
um and that is going to be important

3971
02:38:45,270 --> 02:38:43,359
because um there is reaching of

3972
02:38:47,429 --> 02:38:45,280
potassium especially

3973
02:38:49,910 --> 02:38:47,439
from the rock we need to

3974
02:38:51,190 --> 02:38:49,920
to revisit the models of these objects

3975
02:38:53,670 --> 02:38:51,200
entirely

3976
02:38:55,910 --> 02:38:53,680
in order to

3977
02:38:57,349 --> 02:38:55,920
account for the displacement of the heat

3978
02:38:58,630 --> 02:38:57,359
store

3979
02:39:00,309 --> 02:38:58,640
the fact that there are a lot of points

3980
02:39:02,710 --> 02:39:00,319
in solution also suggest that there

3981
02:39:05,830 --> 02:39:02,720
should be a steel liquid water

3982
02:39:08,230 --> 02:39:05,840
in terraces today you'll see at ltfc and

3983
02:39:10,870 --> 02:39:08,240
upcycle that we have some

3984
02:39:12,870 --> 02:39:10,880
represents of liquid at that extensive

3985
02:39:14,550 --> 02:39:12,880
liquid at depth and that is the

3986
02:39:17,910 --> 02:39:14,560
fascinating resource

3987
02:39:19,429 --> 02:39:17,920
and we look forward to seeing that

3988
02:39:21,510 --> 02:39:19,439

yeah yeah

3989
02:39:23,510 --> 02:39:21,520
and then i just want to encourage more

3990
02:39:26,469 --> 02:39:23,520
you know interaction between the

3991
02:39:27,510 --> 02:39:26,479
icu moon community and cirrus there is a

3992
02:39:30,630 --> 02:39:27,520
lot of

3993
02:39:31,750 --> 02:39:30,640
things to learn from both communities

3994
02:39:33,030 --> 02:39:31,760
and cirrus

3995
02:39:34,710 --> 02:39:33,040
close to earth it does have the

3996
02:39:38,870 --> 02:39:34,720
playground for testing hypothesis

3997
02:39:43,429 --> 02:39:38,880
developed for ocean work thank you

3998
02:39:45,910 --> 02:39:43,439
great thanks very much um so we'll uh

3999
02:39:47,510 --> 02:39:45,920
penny morel

4000
02:39:48,870 --> 02:39:47,520
hi penny

4001
02:39:50,389 --> 02:39:48,880
hi

4002
02:39:52,389 --> 02:39:50,399
can you hear me

4003
02:39:54,550 --> 02:39:52,399
you can hear me really well yeah

4004
02:39:55,990 --> 02:39:54,560
okay perfect

4005
02:39:57,830 --> 02:39:56,000
may i start

4006
02:40:00,230 --> 02:39:57,840
please go for it

4007
02:40:02,070 --> 02:40:00,240
okay um first of all i want to say thank

4008
02:40:03,830 --> 02:40:02,080
you to jen blank who told me about this

4009
02:40:05,670 --> 02:40:03,840
workshop and who suggested highly

4010
02:40:06,469 --> 02:40:05,680
encouraged that that i give a pop-up

4011
02:40:08,550 --> 02:40:06,479
talk

4012
02:40:10,469 --> 02:40:08,560
i was inspired to give one uh based on

4013
02:40:13,510 --> 02:40:10,479

tuesday's results um where

4014
02:40:15,590 --> 02:40:13,520
microbiologists presented data both from

4015
02:40:17,750 --> 02:40:15,600
the tablelands and the cedars

4016
02:40:19,750 --> 02:40:17,760
uh and these are both ophelites in north

4017
02:40:21,990 --> 02:40:19,760
america you can see from my map and i

4018
02:40:24,870 --> 02:40:22,000
thought i would give a bio geochemist

4019
02:40:26,630 --> 02:40:24,880
perspective of these two sites

4020
02:40:28,630 --> 02:40:26,640
first of all they're both

4021
02:40:30,630 --> 02:40:28,640
ophelites they both have ultramafics

4022
02:40:33,349 --> 02:40:30,640
that are being altered by groundwater

4023
02:40:36,550 --> 02:40:33,359
they both have springs uh ultra basic

4024
02:40:40,870 --> 02:40:36,560
ultra mafic ultra basic composition so

4025
02:40:42,309 --> 02:40:40,880
high ph's uh ph 11s and 12s uh the

4026
02:40:43,830 --> 02:40:42,319
cedars let me see if i can use my

4027
02:40:45,349 --> 02:40:43,840
pointer here

4028
02:40:48,870 --> 02:40:45,359
uh did that work

4029
02:40:52,150 --> 02:40:48,880
maybe not okay the cedars has ph

4030
02:40:54,870 --> 02:40:52,160
again 11 or 12. so it has a bubbles with

4031
02:40:55,910 --> 02:40:54,880
uh hydrogen and methane while the table

4032
02:40:58,469 --> 02:40:55,920
lands we're doing with lower

4033
02:41:00,710 --> 02:40:58,479
concentration of uh dissolved

4034
02:41:02,550 --> 02:41:00,720
concentrations of methane and hydrogen

4035
02:41:04,070 --> 02:41:02,560
we heard from billy brazelton and matt

4036
02:41:06,070 --> 02:41:04,080
shrank

4037
02:41:07,110 --> 02:41:06,080
about how both these sites are similar

4038
02:41:11,429 --> 02:41:07,120

they've got

4039
02:41:15,349 --> 02:41:11,439
hydrogenophaga

4040
02:41:17,590 --> 02:41:15,359
shino suzuki published about the

4041
02:41:19,110 --> 02:41:17,600
serpentimonous at both sides

4042
02:41:20,550 --> 02:41:19,120
and so on the surface you may think

4043
02:41:23,110 --> 02:41:20,560
these sites are very similar but the

4044
02:41:24,710 --> 02:41:23,120
take-home message from my pop-up talk is

4045
02:41:26,630 --> 02:41:24,720
that they're actually quite different

4046
02:41:28,550 --> 02:41:26,640
from a bio-geochemistry perspective

4047
02:41:30,230 --> 02:41:28,560
specifically in the type of carbon that

4048
02:41:31,830 --> 02:41:30,240
the microbes can use and and the

4049
02:41:33,030 --> 02:41:31,840
products that are produced

4050
02:41:35,349 --> 02:41:33,040
so why don't we start with methane

4051
02:41:38,870 --> 02:41:35,359
because we all like to look at methane

4052
02:41:40,630 --> 02:41:38,880
how do i change the slide

4053
02:41:42,950 --> 02:41:40,640
as you just want to click the right

4054
02:41:45,830 --> 02:41:42,960
arrow icon that's in the bottom left of

4055
02:41:49,190 --> 02:41:45,840
your slides there

4056
02:41:50,630 --> 02:41:49,200
excellent so one classic way of sourcing

4057
02:41:53,190 --> 02:41:50,640
methane is to look at the carbon

4058
02:41:55,590 --> 02:41:53,200
hydrogen isotope values of those methane

4059
02:41:57,750 --> 02:41:55,600
of the methane and so i've got um

4060
02:41:59,670 --> 02:41:57,760
on the left hand plot a cd plot

4061
02:42:01,670 --> 02:41:59,680
hydrogenized methane versus carbonized

4062
02:42:03,269 --> 02:42:01,680
types of methane and on the right hand

4063
02:42:05,110 --> 02:42:03,279

side i've got a bernard plot which just

4064
02:42:08,550 --> 02:42:05,120
looks at the ratio of methane to ethane

4065
02:42:10,389 --> 02:42:08,560
propane butane divided by or plotted

4066
02:42:13,830 --> 02:42:10,399
against the carbonized total values of

4067
02:42:16,630 --> 02:42:13,840
methane the blue fuzzy areas represent

4068
02:42:19,510 --> 02:42:16,640
vaguely a field for microbial methane

4069
02:42:21,910 --> 02:42:19,520
the orange represents a vague field for

4070
02:42:23,830 --> 02:42:21,920
thermogenic and i don't have a biogenic

4071
02:42:25,910 --> 02:42:23,840
plotted on these but

4072
02:42:28,630 --> 02:42:25,920
great review by sherwood lawler by

4073
02:42:30,230 --> 02:42:28,640
etopian gerald lawler in 2013 puts the

4074
02:42:32,230 --> 02:42:30,240
methanol on the seeding plot on the

4075
02:42:34,469 --> 02:42:32,240
right hand side overlapping both the

4076
02:42:35,830 --> 02:42:34,479
thermogenic and the

4077
02:42:38,710 --> 02:42:35,840
microbial

4078
02:42:41,670 --> 02:42:38,720
let's look at the methane at these sites

4079
02:42:44,309 --> 02:42:41,680
the table lands plots in an area not

4080
02:42:45,990 --> 02:42:44,319
microbial we call it non-microbial

4081
02:42:50,710 --> 02:42:46,000
methane

4082
02:42:52,830 --> 02:42:50,720
while the table well the cedars plots in

4083
02:42:55,750 --> 02:42:52,840
some of the springs methane plot end of

4084
02:42:57,590 --> 02:42:55,760
antimicrobial area while we also have

4085
02:42:59,590 --> 02:42:57,600
other springs that suggest

4086
02:43:01,830 --> 02:42:59,600
that we have mixing between a microbial

4087
02:43:05,190 --> 02:43:01,840
and a non-microbial source

4088
02:43:06,710 --> 02:43:05,200

isotopes are just an indirect indicator

4089
02:43:08,790 --> 02:43:06,720
of the source of methane so we want to

4090
02:43:10,469 --> 02:43:08,800
look at something a little more direct

4091
02:43:12,790 --> 02:43:10,479
and so we wanted to see if we could make

4092
02:43:15,269 --> 02:43:12,800
microbial methane in the laboratory

4093
02:43:17,990 --> 02:43:15,279
using materials from both of these sites

4094
02:43:19,910 --> 02:43:18,000
and so we take water and

4095
02:43:22,150 --> 02:43:19,920
sediments from the bottom of

4096
02:43:24,870 --> 02:43:22,160
the pools where these springs come up

4097
02:43:26,469 --> 02:43:24,880
and we did experiments where we fed uh

4098
02:43:28,790 --> 02:43:26,479
different microbes but different

4099
02:43:29,990 --> 02:43:28,800
substrates like bicarbonate formate and

4100
02:43:30,790 --> 02:43:30,000
acetate

4101
02:43:33,750 --> 02:43:30,800
we

4102
02:43:35,269 --> 02:43:33,760
have um

4103
02:43:36,950 --> 02:43:35,279
and then we we look for the products

4104
02:43:38,630 --> 02:43:36,960
that are being formed and so the table

4105
02:43:40,150 --> 02:43:38,640
lands we saw no difference between our

4106
02:43:42,230 --> 02:43:40,160
live controls and our kill controls

4107
02:43:44,389 --> 02:43:42,240
which basically uh confirmed that we

4108
02:43:45,590 --> 02:43:44,399
weren't able to make microbial methane

4109
02:43:47,670 --> 02:43:45,600
in the lab

4110
02:43:50,790 --> 02:43:47,680
but the cds was a different story we

4111
02:43:53,110 --> 02:43:50,800
found elevated concentrations of

4112
02:43:55,830 --> 02:43:53,120
methane in the live versus the killed

4113
02:43:58,070 --> 02:43:55,840

controls and in the c13 labeled

4114
02:43:59,990 --> 02:43:58,080
experiments we saw methane that was

4115
02:44:02,309 --> 02:44:00,000
enriched in c13 which was an indicator

4116
02:44:05,030 --> 02:44:02,319
that we were getting microbial methane

4117
02:44:07,510 --> 02:44:05,040
from or within all the um

4118
02:44:09,190 --> 02:44:07,520
uh all the incubations that we that we

4119
02:44:11,590 --> 02:44:09,200
that we studied

4120
02:44:13,990 --> 02:44:11,600
i'm wondering what happens if i do this

4121
02:44:15,910 --> 02:44:14,000
oh oh there we go okay um so this just

4122
02:44:18,630 --> 02:44:15,920
shows in our kill controls uh the

4123
02:44:20,950 --> 02:44:18,640
methane has the exact same isotope value

4124
02:44:22,389 --> 02:44:20,960
um and in our

4125
02:44:24,469 --> 02:44:22,399
our isotope control so this is

4126
02:44:28,070 --> 02:44:24,479
non-isotopically labeled experiments we

4127
02:44:29,429 --> 02:44:28,080
had depleted uh c13 values

4128
02:44:32,469 --> 02:44:29,439
and then

4129
02:44:34,790 --> 02:44:32,479
there we go that listener

4130
02:44:37,110 --> 02:44:34,800
okay perfect so we're seeing enriched

4131
02:44:38,469 --> 02:44:37,120
methane great at the cedars but not the

4132
02:44:40,630 --> 02:44:38,479
tablelands

4133
02:44:42,550 --> 02:44:40,640
um on tuesday we were also talking about

4134
02:44:45,670 --> 02:44:42,560
acetogenesis so i wanted to show you

4135
02:44:48,150 --> 02:44:45,680
that we did find microbial voa

4136
02:44:51,349 --> 02:44:48,160
volatile organic acid production in the

4137
02:44:54,790 --> 02:44:51,359
live versus the the killed and then as i

4138
02:44:56,790 --> 02:44:54,800

zoom through this speedy talk

4139
02:44:58,950 --> 02:44:56,800
everett shock also talked about the

4140
02:45:01,590 --> 02:44:58,960
possibility of microbialization of

4141
02:45:02,870 --> 02:45:01,600
carbon monoxide and so we did those

4142
02:45:04,550 --> 02:45:02,880
experiments as well both of the

4143
02:45:06,150 --> 02:45:04,560
tablelands and the cedars and the data

4144
02:45:08,230 --> 02:45:06,160
here shown from the table lands where we

4145
02:45:11,110 --> 02:45:08,240
did get carbon monoxide utilization but

4146
02:45:12,389 --> 02:45:11,120
we did not get it at the cedars so the

4147
02:45:13,590 --> 02:45:12,399
take home

4148
02:45:15,510 --> 02:45:13,600
point from my talk is just that these

4149
02:45:17,190 --> 02:45:15,520
sites are extremely um different

4150
02:45:19,830 --> 02:45:17,200
biogeochemically and these are just

4151
02:45:21,670 --> 02:45:19,840
looking at ophelites um uh

4152
02:45:23,590 --> 02:45:21,680
we have we're not even talking about the

4153
02:45:25,910 --> 02:45:23,600
dispensation in the ocean or

4154
02:45:29,510 --> 02:45:25,920
spentanization happening in ultramasic

4155
02:45:31,670 --> 02:45:29,520
in say like procambium rocks um so

4156
02:45:33,750 --> 02:45:31,680
and all of these sites have potential to

4157
02:45:35,510 --> 02:45:33,760
have biogenic signatures abiogenic

4158
02:45:37,670 --> 02:45:35,520
signatures and we should be using these

4159
02:45:39,030 --> 02:45:37,680
sites to look for the preservation of

4160
02:45:40,309 --> 02:45:39,040
those signatures

4161
02:45:43,670 --> 02:45:40,319
that's it

4162
02:45:46,550 --> 02:45:45,670
all right well thanks so much um i'm

4163
02:45:48,309 --> 02:45:46,560

gonna

4164
02:45:52,070 --> 02:45:48,319
take the last minute to send it back to

4165
02:45:56,070 --> 02:45:53,830
great uh thank you steve thanks to all

4166
02:45:57,429 --> 02:45:56,080
of our speakers for the day

4167
02:45:59,830 --> 02:45:57,439
i thought that we should wrap up the

4168
02:46:01,670 --> 02:45:59,840
workshop just by revisiting uh the

4169
02:46:03,590 --> 02:46:01,680
perspective that alexis supplied at the

4170
02:46:05,830 --> 02:46:03,600
very beginning which is uh why did we do

4171
02:46:09,110 --> 02:46:05,840
this in the first place and really

4172
02:46:10,790 --> 02:46:09,120
this workshop comes about as a result of

4173
02:46:13,110 --> 02:46:10,800
recognizing that we've had something

4174
02:46:15,110 --> 02:46:13,120
like a decade now or so worth of of

4175
02:46:17,030 --> 02:46:15,120
interest and work done in an

4176
02:46:19,269 --> 02:46:17,040
astrobiological context on

4177
02:46:21,349 --> 02:46:19,279
serpentinizing systems and so

4178
02:46:23,269 --> 02:46:21,359
um as we step back and take a look at

4179
02:46:26,230 --> 02:46:23,279
that work and in particular a lot of the

4180
02:46:27,590 --> 02:46:26,240
exciting new results um you know that

4181
02:46:30,469 --> 02:46:27,600
have we changed our perspective on

4182
02:46:32,070 --> 02:46:30,479
serpentinizing systems as as a target of

4183
02:46:33,750 --> 02:46:32,080
astrobiology in particular are there

4184
02:46:35,990 --> 02:46:33,760
things that we've learned

4185
02:46:38,070 --> 02:46:36,000
that help inform us better

4186
02:46:41,030 --> 02:46:38,080
about the habitability of these systems

4187
02:46:43,349 --> 02:46:41,040
and for me one uh exciting aspect of

4188
02:46:45,590 --> 02:46:43,359

this is a lot of what we heard here

4189
02:46:47,429 --> 02:46:45,600
considers serpentinization

4190
02:46:49,830 --> 02:46:47,439
as a process and i think that's really

4191
02:46:51,910 --> 02:46:49,840
important as we

4192
02:46:53,990 --> 02:46:51,920
evolve our perspective of habitability

4193
02:46:56,710 --> 02:46:54,000
not as a not as a snapshot of current

4194
02:46:59,110 --> 02:46:56,720
conditions but as a as an evolution of

4195
02:47:01,030 --> 02:46:59,120
conditions uh through time and so i

4196
02:47:02,870 --> 02:47:01,040
think it's really valuable to

4197
02:47:05,030 --> 02:47:02,880
uh consider how to consider

4198
02:47:07,110 --> 02:47:05,040
serpentinization as a process

4199
02:47:08,710 --> 02:47:07,120
applied to habitability and the other

4200
02:47:10,469 --> 02:47:08,720
thing is we wanted to to integrate

4201
02:47:12,150 --> 02:47:10,479
perspective so we purposely constructed

4202
02:47:13,190 --> 02:47:12,160
this workshop in a way that that

4203
02:47:15,670 --> 02:47:13,200
included

4204
02:47:17,750 --> 02:47:15,680
uh or hopefully spanned from biological

4205
02:47:19,750 --> 02:47:17,760
to planetary perspectives and one thing

4206
02:47:21,670 --> 02:47:19,760
i at least was very struck by in the

4207
02:47:24,630 --> 02:47:21,680
talks today

4208
02:47:26,630 --> 02:47:24,640
is in part uh how

4209
02:47:28,790 --> 02:47:26,640
how much the planetary sciences folks

4210
02:47:31,269 --> 02:47:28,800
are obligated to do with relatively

4211
02:47:33,030 --> 02:47:31,279
limited data but also how much they're

4212
02:47:34,630 --> 02:47:33,040
able to do with that limited data so i

4213
02:47:36,150 --> 02:47:34,640

think there's a remarkable level of

4214
02:47:39,110 --> 02:47:36,160
inference and constraint that can be

4215
02:47:41,910 --> 02:47:39,120
drawn from from what are often sort of

4216
02:47:44,309 --> 02:47:41,920
uh you know distant uh data sets of

4217
02:47:46,790 --> 02:47:44,319
imagery or spectroscopy

4218
02:47:48,950 --> 02:47:46,800
can we extend that inference all the way

4219
02:47:51,110 --> 02:47:48,960
down into the biological so can we take

4220
02:47:53,269 --> 02:47:51,120
the sorts of data that we're seeing from

4221
02:47:54,550 --> 02:47:53,279
from spacecraft as we explore the solar

4222
02:47:56,550 --> 02:47:54,560
system

4223
02:47:58,309 --> 02:47:56,560
and begin to integrate biological and

4224
02:48:00,950 --> 02:47:58,319
geochemical perspectives as well to come

4225
02:48:03,429 --> 02:48:00,960
up with a sort of holistic picture so

4226
02:48:05,030 --> 02:48:03,439
um these are things that that we hope to

4227
02:48:07,349 --> 02:48:05,040
sort of capture i think these are things

4228
02:48:09,750 --> 02:48:07,359
that the nasa astrobiology institute is

4229
02:48:12,790 --> 02:48:09,760
is interested in understanding as a as a

4230
02:48:14,630 --> 02:48:12,800
statement of community uh perception um

4231
02:48:16,950 --> 02:48:14,640
at this point in time and so we

4232
02:48:19,110 --> 02:48:16,960
encourage you to if if you have any

4233
02:48:21,910 --> 02:48:19,120
insights that have resulted from the

4234
02:48:23,750 --> 02:48:21,920
last couple of days of workshop um

4235
02:48:25,590 --> 02:48:23,760
please help supply them and and in the

4236
02:48:27,190 --> 02:48:25,600
beginning we suggested that any such

4237
02:48:29,910 --> 02:48:27,200
insights could be emailed to chen maybe

4238
02:48:32,469 --> 02:48:29,920

jen will supply her uh her email address

4239
02:48:35,030 --> 02:48:32,479
again so that um this can be an ongoing

4240
02:48:36,550 --> 02:48:35,040
process in which we consider continue to

4241
02:48:39,590 --> 02:48:36,560
sort of uh

4242
02:48:41,190 --> 02:48:39,600
pull in your perspectives um so and and

4243
02:48:43,190 --> 02:48:41,200
also just in bringing this to a close

4244
02:48:45,349 --> 02:48:43,200
there are a number of people to thank in

4245
02:48:47,990 --> 02:48:45,359
all of this first i really would like to

4246
02:48:50,230 --> 02:48:48,000
thank all of you for participating so i

4247
02:48:52,070 --> 02:48:50,240
know we had people tuned in from around

4248
02:48:54,870 --> 02:48:52,080
the world um

4249
02:48:57,830 --> 02:48:54,880
we bounced i think between sort of 50 60

4250
02:48:59,429 --> 02:48:57,840
to sometimes as many as 100 participants

4251
02:49:00,950 --> 02:48:59,439
i think that was awesome and what i

4252
02:49:03,110 --> 02:49:00,960
really was

4253
02:49:04,950 --> 02:49:03,120
gratified by is the the level of

4254
02:49:06,630 --> 02:49:04,960
interaction amongst people i i thought

4255
02:49:07,830 --> 02:49:06,640
it was just really fantastic the extent

4256
02:49:10,630 --> 02:49:07,840
to which people chimed in and

4257
02:49:13,349 --> 02:49:10,640
participated uh in this process and made

4258
02:49:15,030 --> 02:49:13,359
it a dialogue not just a monologue so um

4259
02:49:16,710 --> 02:49:15,040
thank you all very much for that

4260
02:49:20,230 --> 02:49:16,720
participation

4261
02:49:23,830 --> 02:49:20,240
um thanks very much to nai uh to estelle

4262
02:49:25,990 --> 02:49:23,840
and to mike and to uh to sam

4263
02:49:27,910 --> 02:49:26,000

from my perspective this really felt

4264
02:49:30,630 --> 02:49:27,920
seamless and i think it's remarkable

4265
02:49:32,630 --> 02:49:30,640
that we had 100 people distributed at

4266
02:49:34,870 --> 02:49:32,640
their own individual computers around

4267
02:49:36,870 --> 02:49:34,880
the world and yet it felt like many of

4268
02:49:39,030 --> 02:49:36,880
you were here in the room and

4269
02:49:42,790 --> 02:49:39,040
um you know that didn't just happen

4270
02:49:44,630 --> 02:49:42,800
that's a result of of the

4271
02:49:46,870 --> 02:49:44,640
the really excellent management of this

4272
02:49:48,309 --> 02:49:46,880
event by the nai folks so thanks to all

4273
02:49:51,750 --> 02:49:48,319
of you thank you i feel like it was a

4274
02:49:53,349 --> 02:49:51,760
really really well done thing um

4275
02:49:55,590 --> 02:49:53,359
thank you very much to all of our

4276
02:49:57,429 --> 02:49:55,600
speakers to both our invited speakers

4277
02:49:59,990 --> 02:49:57,439
and to our pop-up speakers so to the

4278
02:50:01,990 --> 02:50:00,000
invited speakers um you all were chosen

4279
02:50:03,990 --> 02:50:02,000
because you represented the set of

4280
02:50:06,469 --> 02:50:04,000
perspectives that we hope to capture in

4281
02:50:08,230 --> 02:50:06,479
order to give a well-rounded perspective

4282
02:50:10,710 --> 02:50:08,240
and i don't think that this would have

4283
02:50:12,950 --> 02:50:10,720
come off as well uh had you not been

4284
02:50:15,510 --> 02:50:12,960
willing to do that and really thank you

4285
02:50:17,429 --> 02:50:15,520
also to the pop-up speakers um you know

4286
02:50:18,950 --> 02:50:17,439
we we sort of uh

4287
02:50:20,389 --> 02:50:18,960
put that out there in the hopes that

4288
02:50:22,389 --> 02:50:20,399

people would contribute and i was so

4289
02:50:23,990 --> 02:50:22,399
glad that that we got such a high level

4290
02:50:25,030 --> 02:50:24,000
of of interest and participation in

4291
02:50:27,750 --> 02:50:25,040
people willing to contribute

4292
02:50:29,030 --> 02:50:27,760
perspectives in what was a very

4293
02:50:30,550 --> 02:50:29,040
um

4294
02:50:34,790 --> 02:50:30,560
uh

4295
02:50:36,389 --> 02:50:34,800
talk i mean to give you five minutes and

4296
02:50:38,150 --> 02:50:36,399
ask you to say something comprehensible

4297
02:50:40,389 --> 02:50:38,160
is kind of a big challenge but i think

4298
02:50:41,990 --> 02:50:40,399
you all delivered so so thank you very

4299
02:50:43,990 --> 02:50:42,000
much um

4300
02:50:46,230 --> 02:50:44,000
thank you to billy and to tom and to

4301
02:50:48,630 --> 02:50:46,240
steve um each of you guys did a

4302
02:50:50,710 --> 02:50:48,640
fantastic job not only in organizing

4303
02:50:53,110 --> 02:50:50,720
your days but also in in managing them

4304
02:50:55,269 --> 02:50:53,120
very well so effectively we asked each

4305
02:50:56,230 --> 02:50:55,279
of those three people to to

4306
02:50:58,790 --> 02:50:56,240
um

4307
02:51:01,110 --> 02:50:58,800
to organize and run a one-day workshop

4308
02:51:02,230 --> 02:51:01,120
uh and i think that was very well done

4309
02:51:07,429 --> 02:51:02,240
um

4310
02:51:09,110 --> 02:51:07,439
collaborative endeavor in organizing

4311
02:51:11,910 --> 02:51:09,120
this workshop um

4312
02:51:13,750 --> 02:51:11,920
many many times where uh where two heads

4313
02:51:15,269 --> 02:51:13,760

were better than one in in addressing

4314
02:51:17,429 --> 02:51:15,279
some of the things that we came up with

4315
02:51:18,630 --> 02:51:17,439
and so i really appreciate that and

4316
02:51:20,309 --> 02:51:18,640
finally

4317
02:51:23,110 --> 02:51:20,319
thank you to alexis

4318
02:51:25,510 --> 02:51:23,120
this this really was uh alexis's

4319
02:51:29,190 --> 02:51:25,520
brainchild i think to to see the need

4320
02:51:31,990 --> 02:51:29,200
for this workshop um and to also uh sort

4321
02:51:33,830 --> 02:51:32,000
of consistently apply uh motivation and

4322
02:51:36,710 --> 02:51:33,840
enthusiasm in seeing this come to

4323
02:51:38,710 --> 02:51:36,720
fruition so as she mentioned um this

4324
02:51:40,230 --> 02:51:38,720
really came about sort of as a result of

4325
02:51:41,990 --> 02:51:40,240
something that happened at the last abs

4326
02:51:44,309 --> 02:51:42,000
icon and and we're about a year and a

4327
02:51:46,550 --> 02:51:44,319
half away from that so it's been a while

4328
02:51:48,309 --> 02:51:46,560
for this to come together but i i'm glad

4329
02:51:49,750 --> 02:51:48,319
that it finally has and i think that it

4330
02:51:52,230 --> 02:51:49,760
really came together in a way that we

4331
02:51:53,510 --> 02:51:52,240
all appreciate so um so thanks alexis

4332
02:51:54,469 --> 02:51:53,520
for that

4333
02:51:56,150 --> 02:51:54,479
um

4334
02:51:57,830 --> 02:51:56,160
and i think that's it thanks everyone

4335
02:51:58,830 --> 02:51:57,840
for coming

4336
02:52:01,190 --> 02:51:58,840
thank

4337
02:52:03,190 --> 02:52:01,200
you oh that's right

4338
02:52:05,110 --> 02:52:03,200

jen reminds me to just mention that uh

4339
02:52:06,870 --> 02:52:05,120
all of this has been captured so the the

4340
02:52:08,710 --> 02:52:06,880
talks and the commentary and everything

4341
02:52:10,630 --> 02:52:08,720
will all be online and you can find that

4342
02:52:12,150 --> 02:52:10,640
through the ni website so anything that