
AbSciCon
2019

1
00:00:00,790 --> 00:00:07,320
[Music]

2
00:00:12,080 --> 00:00:09,130
[Applause]

3
00:00:14,600 --> 00:00:12,090
so I'm gonna talk a bit about how we try

4
00:00:16,820 --> 00:00:14,610
to apply understanding energetics and

5
00:00:17,990 --> 00:00:16,830
biological systems on earth to these

6
00:00:19,760 --> 00:00:18,000
questions that we've been hearing about

7
00:00:21,470 --> 00:00:19,770
all week and in the plenary this morning

8
00:00:23,900 --> 00:00:21,480
about how could we tell if there might

9
00:00:25,790 --> 00:00:23,910
be life on ocean worlds and so it's

10
00:00:28,040 --> 00:00:25,800
really difficult because we don't often

11
00:00:29,870 --> 00:00:28,050
know a lot about the specific oxidants

12
00:00:32,179 --> 00:00:29,880
or reductants or gradients in these

13
00:00:33,920 --> 00:00:32,189

ocean worlds and even on earth it's

14
00:00:36,139 --> 00:00:33,930
really hard to predict what kinds of

15
00:00:37,970 --> 00:00:36,149
redox reactions even abiotic ones you

16
00:00:40,880 --> 00:00:37,980
might find in any particular environment

17
00:00:42,770 --> 00:00:40,890
so we've been working a lot with the JPL

18
00:00:45,080 --> 00:00:42,780
electric chemical technologies group who

19
00:00:46,490 --> 00:00:45,090
is a big leader in building batteries

20
00:00:48,890 --> 00:00:46,500
and fuel cells and interesting

21
00:00:50,150 --> 00:00:48,900
conditions for spaceflight and so we've

22
00:00:52,910 --> 00:00:50,160
been trying to apply some of this

23
00:00:54,950 --> 00:00:52,920
technology to give us an experimental

24
00:00:56,810 --> 00:00:54,960
methodology to try to simulate some

25
00:00:58,880 --> 00:00:56,820
electrochemical systems you might get on

26
00:01:02,420 --> 00:00:58,890
ocean worlds not just biotic ones but

27
00:01:04,160 --> 00:01:02,430
also abiotic ones and so as as you all

28
00:01:05,780 --> 00:01:04,170
know hydrothermal vents are very

29
00:01:08,749 --> 00:01:05,790
interesting for life and for life's

30
00:01:10,850 --> 00:01:08,759
origin because they provide chemical

31
00:01:13,489 --> 00:01:10,860
gradients so things like when the ocean

32
00:01:15,440 --> 00:01:13,499
has oxidants in it and in modern earth

33
00:01:18,139 --> 00:01:15,450
it's oxygen but on early Earth you could

34
00:01:19,969 --> 00:01:18,149
have had things like co2 or ferric iron

35
00:01:22,099 --> 00:01:19,979
or nitrate so there's a variety of

36
00:01:23,779 --> 00:01:22,109
possible oxidants you could have and

37
00:01:25,249 --> 00:01:23,789
this also could vary with space and also

38
00:01:27,770 --> 00:01:25,259

depending with which planet we're

39
00:01:29,300 --> 00:01:27,780
talking about and then the rock type and

40
00:01:30,679 --> 00:01:29,310
the water chemistry will provide you

41
00:01:33,830 --> 00:01:30,689
with reductants things like maybe

42
00:01:35,330 --> 00:01:33,840
hydrogen or sulfide or methane and then

43
00:01:37,370 --> 00:01:35,340
the minerals that precipitate around

44
00:01:39,199 --> 00:01:37,380
these and when these fluids mix you can

45
00:01:41,330 --> 00:01:39,209
get precipitation of catalytic minerals

46
00:01:43,489 --> 00:01:41,340
so things like iron sulphides or iron

47
00:01:46,520 --> 00:01:43,499
hydroxides or other metal sulfides and

48
00:01:47,749 --> 00:01:46,530
so it's important to understand you know

49
00:01:50,090 --> 00:01:47,759
if you're looking for life on an ocean

50
00:01:52,129 --> 00:01:50,100
world which electron donors and

51
00:01:53,660 --> 00:01:52,139
acceptors are likely but just because

52
00:01:55,399 --> 00:01:53,670
you have an electron donor or acceptor

53
00:01:57,109 --> 00:01:55,409
it doesn't mean that that metabolism

54
00:01:59,389 --> 00:01:57,119
would be dominant because it also

55
00:02:00,949 --> 00:01:59,399
depends on how much energy there is but

56
00:02:03,199 --> 00:02:00,959
also the minerals that are present in

57
00:02:04,879 --> 00:02:03,209
these systems could affect that so for

58
00:02:07,039 --> 00:02:04,889
example if you had a mineral on the vent

59
00:02:08,690 --> 00:02:07,049
that is consuming one of your you know

60
00:02:09,949 --> 00:02:08,700
favorite electron acceptors that's not

61
00:02:12,050 --> 00:02:09,959
great because then it's not there for

62
00:02:14,330 --> 00:02:12,060
life and so we are trying to figure out

63
00:02:16,400 --> 00:02:14,340

a good experimental system to figure out

64
00:02:18,080 --> 00:02:16,410
what metabolites are actually going to

65
00:02:20,060 --> 00:02:18,090
be present and then how can this also

66
00:02:20,690 --> 00:02:20,070
interplay with a possible prebiotic

67
00:02:23,690 --> 00:02:20,700
chemist

68
00:02:25,430 --> 00:02:23,700
and so from we're looking at say Europa

69
00:02:27,350 --> 00:02:25,440
or Enceladus we don't really know much

70
00:02:29,240 --> 00:02:27,360
about exactly what the type of vents

71
00:02:30,620 --> 00:02:29,250
would be and also we have to consider

72
00:02:33,260 --> 00:02:30,630
these planets over their whole history

73
00:02:35,510 --> 00:02:33,270
so if you know maybe Enceladus is young

74
00:02:37,370 --> 00:02:35,520
maybe it's not maybe in the early

75
00:02:38,990 --> 00:02:37,380
history of Enceladus when it was still

76
00:02:40,430 --> 00:02:39,000
really actively serpentine izing you

77
00:02:41,630 --> 00:02:40,440
might have more energy or different

78
00:02:44,090 --> 00:02:41,640
types of energy than you could have

79
00:02:45,920 --> 00:02:44,100
today so in an experimental system we

80
00:02:47,720 --> 00:02:45,930
want to be able to you know have it be

81
00:02:50,150 --> 00:02:47,730
modular and very these types of things

82
00:02:52,190 --> 00:02:50,160
but also to isolate individual redox

83
00:02:54,140 --> 00:02:52,200
reactions and figure out exactly what is

84
00:02:57,680 --> 00:02:54,150
catalyzing what and which things could

85
00:02:59,390 --> 00:02:57,690
be linked together so hydrothermal vents

86
00:03:01,700 --> 00:02:59,400
are sometimes referred to as geo

87
00:03:03,710 --> 00:03:01,710
chemical fuel cells because in many ways

88
00:03:05,870 --> 00:03:03,720

they behave like a fuel cell that you

89
00:03:07,460 --> 00:03:05,880
would see in a battery context they have

90
00:03:09,590 --> 00:03:07,470
a reductant which comes up from the

91
00:03:11,300 --> 00:03:09,600
seafloor and if you have a chimney made

92
00:03:13,040 --> 00:03:11,310
of conductive material electrically

93
00:03:15,560 --> 00:03:13,050
conductive so stuff like iron minerals

94
00:03:17,390 --> 00:03:15,570
the electrons if you can oxidize that

95
00:03:19,430 --> 00:03:17,400
reductant they could flow through that

96
00:03:21,140 --> 00:03:19,440
mineral and then on the surface of the

97
00:03:23,660 --> 00:03:21,150
chimney exterior you kind of have this

98
00:03:25,190 --> 00:03:23,670
electrode situation like a geo electrode

99
00:03:27,680 --> 00:03:25,200
as we call it where you could maybe

100
00:03:28,940 --> 00:03:27,690
reduce an oxidant in the seawater so

101
00:03:31,400 --> 00:03:28,950
this has actually been observed in the

102
00:03:32,990 --> 00:03:31,410
field and it's been proposed that this

103
00:03:34,940 --> 00:03:33,000
could also be as something important for

104
00:03:37,130 --> 00:03:34,950
the origin of life for example if you

105
00:03:39,680 --> 00:03:37,140
had a co2 rich ocean if you could reduce

106
00:03:41,540 --> 00:03:39,690
co2 on these geo electrodes you can

107
00:03:42,980 --> 00:03:41,550
start making organics that way this

108
00:03:45,560 --> 00:03:42,990
could also work for things like the

109
00:03:47,840 --> 00:03:45,570
nitrogen species nitrate or nitrite but

110
00:03:50,210 --> 00:03:47,850
it could also be a mechanism for

111
00:03:51,440 --> 00:03:50,220
habitability on the ocean worlds so that

112
00:03:53,240 --> 00:03:51,450
you don't just have to be living off of

113
00:03:54,980 --> 00:03:53,250

the soluble substrates that come out of

114
00:03:57,350 --> 00:03:54,990
the vent you could have life that can do

115
00:03:58,910 --> 00:03:57,360
extracellular electron transfer actually

116
00:04:00,920 --> 00:03:58,920
taking the electron directly from the

117
00:04:02,570 --> 00:04:00,930
mineral surface and so the redox

118
00:04:04,580 --> 00:04:02,580
reactions that could be physically

119
00:04:06,650 --> 00:04:04,590
linked to power an ecosystem or a

120
00:04:08,540 --> 00:04:06,660
prebiotic reaction you have to figure

121
00:04:10,250 --> 00:04:08,550
out which which you know are the two

122
00:04:13,880 --> 00:04:10,260
sides of the fuel cell and can they be

123
00:04:16,099 --> 00:04:13,890
electrically linked or not so we've been

124
00:04:18,020 --> 00:04:16,109
trying to do at JPL this is now getting

125
00:04:19,640 --> 00:04:18,030
into kind of our just ideas we have for

126
00:04:21,380 --> 00:04:19,650
the ways you could do such an experiment

127
00:04:24,320 --> 00:04:21,390
and we hope to find collaborators and

128
00:04:25,970 --> 00:04:24,330
ideas of how to refine this so if you

129
00:04:27,860 --> 00:04:25,980
actually were to build a fuel cell to

130
00:04:30,050 --> 00:04:27,870
simulate event you would want to have

131
00:04:31,760 --> 00:04:30,060
the hydrothermal fluid which is your

132
00:04:33,250 --> 00:04:31,770
fuel and you would choose a specific

133
00:04:35,590 --> 00:04:33,260
reduction to go in

134
00:04:36,910 --> 00:04:35,600
then you know on the Occident side that

135
00:04:39,190 --> 00:04:36,920
would represent your ocean and you would

136
00:04:40,540 --> 00:04:39,200
choose one oxidant to go there and then

137
00:04:42,340 --> 00:04:40,550
a fuel cell is built at these two

138
00:04:44,200 --> 00:04:42,350

reservoirs that are connected over a

139
00:04:46,840 --> 00:04:44,210
membrane and the membranes usually made

140
00:04:48,760 --> 00:04:46,850
of nafion which is a proton conductor so

141
00:04:50,470 --> 00:04:48,770
you want to have ion exchange but you

142
00:04:52,780 --> 00:04:50,480
also want to have each side of the

143
00:04:53,920 --> 00:04:52,790
membrane coated in a catalyst so in a

144
00:04:55,330 --> 00:04:53,930
real fuel cell these are things like

145
00:04:57,490 --> 00:04:55,340
platinum because you're trying to make

146
00:04:59,440 --> 00:04:57,500
the best battery but in this experiment

147
00:05:01,240 --> 00:04:59,450
we want to make the catalyst the cathode

148
00:05:02,320 --> 00:05:01,250
and the anode side represent the kind of

149
00:05:04,690 --> 00:05:02,330
minerals you would see in the

150
00:05:07,030 --> 00:05:04,700
geochemical system so basically we want

151
00:05:09,160 --> 00:05:07,040
to find ways to make geological material

152
00:05:11,260 --> 00:05:09,170
or analog planetary material into

153
00:05:13,180 --> 00:05:11,270
electrodes in a fuel cell and then pump

154
00:05:16,960 --> 00:05:13,190
relevant oxidants and reductants through

155
00:05:19,150 --> 00:05:16,970
it so in a previous paper we showed that

156
00:05:21,160 --> 00:05:19,160
this is a possibility so we took a

157
00:05:23,080 --> 00:05:21,170
sample from a black smoker vent this is

158
00:05:25,720 --> 00:05:23,090
an iron sulfide and other metal sulphide

159
00:05:27,700 --> 00:05:25,730
mix and this can be done in general with

160
00:05:29,590 --> 00:05:27,710
other minerals too so actually you know

161
00:05:31,420 --> 00:05:29,600
paint is made of mineral particles mixed

162
00:05:33,100 --> 00:05:31,430
with ethanol or paint thinner right and

163
00:05:35,290 --> 00:05:33,110

so you can make paint out of any rock or

164
00:05:37,510 --> 00:05:35,300
that you really want to so we have this

165
00:05:39,430 --> 00:05:37,520
rock you grind it up really small you

166
00:05:41,740 --> 00:05:39,440
get very small particles like a few

167
00:05:44,110 --> 00:05:41,750
micron in size we mix that up with a

168
00:05:45,550 --> 00:05:44,120
binder you can also add catalysts to it

169
00:05:47,620 --> 00:05:45,560
if you're not if it's not reacting well

170
00:05:50,140 --> 00:05:47,630
enough you can put some Navion in there

171
00:05:52,240 --> 00:05:50,150
so in Figure C there that's the ink that

172
00:05:53,800 --> 00:05:52,250
we made out of a rock and so that ink

173
00:05:55,900 --> 00:05:53,810
can then be spray-painted or painted

174
00:05:58,030 --> 00:05:55,910
with a brush if you like onto the two

175
00:05:59,770 --> 00:05:58,040
sides of an Avion membrane and you could

176
00:06:01,090 --> 00:05:59,780
use the same paint for both sides you

177
00:06:02,410 --> 00:06:01,100
could use two different paints if you

178
00:06:03,190 --> 00:06:02,420
think the outside and inside of the

179
00:06:05,380 --> 00:06:03,200
chimney would have different

180
00:06:07,510 --> 00:06:05,390
compositions so then we put that in the

181
00:06:09,760 --> 00:06:07,520
fuel cell and then we have two graphic

182
00:06:12,100 --> 00:06:09,770
plates and one on either side and each

183
00:06:14,140 --> 00:06:12,110
one is flowing fluid through it one has

184
00:06:16,150 --> 00:06:14,150
the vent fluid and one has the ocean and

185
00:06:18,790 --> 00:06:16,160
then we can see if this reacts the same

186
00:06:20,980 --> 00:06:18,800
way that you observe it in the field so

187
00:06:22,870 --> 00:06:20,990
for this system we were simulating a

188
00:06:24,910 --> 00:06:22,880

modern-day black smoker because that's

189
00:06:26,860 --> 00:06:24,920
whether you get a sample from and so you

190
00:06:28,480 --> 00:06:26,870
would expect oxygen as an oxidant and

191
00:06:30,880 --> 00:06:28,490
then in this case it was hydrogen

192
00:06:33,250 --> 00:06:30,890
sulfide as a reductant and so we

193
00:06:35,590 --> 00:06:33,260
observed in this hydrothermal fuel cell

194
00:06:37,660 --> 00:06:35,600
thing that we built that you we were

195
00:06:39,520 --> 00:06:37,670
actually able to see sulphide oxidation

196
00:06:41,350 --> 00:06:39,530
which is not super surprising because

197
00:06:43,720 --> 00:06:41,360
sulfide is very easy to oxidize very

198
00:06:45,940 --> 00:06:43,730
easy to oxidize but we also observed

199
00:06:46,930 --> 00:06:45,950
oxygen reduction that was coupled to the

200
00:06:48,820 --> 00:06:46,940
sulphide oxidation

201
00:06:50,560 --> 00:06:48,830
and it was driven by the presence of

202
00:06:52,450 --> 00:06:50,570
these minerals so in a control where we

203
00:06:55,360 --> 00:06:52,460
had no minerals we didn't observe this

204
00:06:57,040 --> 00:06:55,370
reaction going so this can show you this

205
00:06:58,480 --> 00:06:57,050
is a biotic but it can show you that you

206
00:07:00,220 --> 00:06:58,490
would have these things present and

207
00:07:01,630 --> 00:07:00,230
either side of the fuel cell could be a

208
00:07:05,320 --> 00:07:01,640
biotic but it could be a link to a

209
00:07:06,880 --> 00:07:05,330
biotic system and so now if we're gonna

210
00:07:08,230 --> 00:07:06,890
think about how to apply this to ocean

211
00:07:10,180 --> 00:07:08,240
world's it's you know it's always kind

212
00:07:12,640 --> 00:07:10,190
of theoretical about which exact

213
00:07:15,130 --> 00:07:12,650

environments we can simulate so now you

214
00:07:17,830 --> 00:07:15,140
know it gets a little speculative but on

215
00:07:19,420 --> 00:07:17,840
earth we know that the life life is

216
00:07:20,830 --> 00:07:19,430
found at pretty much all pressures in

217
00:07:22,720 --> 00:07:20,840
the ocean that we found there's also

218
00:07:24,670 --> 00:07:22,730
lots of subsurface life even below that

219
00:07:26,740 --> 00:07:24,680
so we haven't really found the pressure

220
00:07:28,060 --> 00:07:26,750
limit of life yet which means that if

221
00:07:30,130 --> 00:07:28,070
you're looking at a small world like

222
00:07:31,930 --> 00:07:30,140
Enceladus where the pressure at the sea

223
00:07:34,300 --> 00:07:31,940
floor is only going to be about 70 bar

224
00:07:35,860 --> 00:07:34,310
but in Stella toises deep interior it's

225
00:07:37,990 --> 00:07:35,870
kind of analogous pressure wise to

226
00:07:39,850 --> 00:07:38,000
Earth's average ocean depth and so

227
00:07:42,160 --> 00:07:39,860
because life on Earth can live in all

228
00:07:43,420 --> 00:07:42,170
these pressures if you had Enceladus or

229
00:07:45,550 --> 00:07:43,430
another planet that had a lot of

230
00:07:47,200 --> 00:07:45,560
fractures in the subsurface you might

231
00:07:49,330 --> 00:07:47,210
have life not just at vents but also

232
00:07:51,100 --> 00:07:49,340
kind of in the rocks below and who knows

233
00:07:52,900 --> 00:07:51,110
how far deep in the core if the water

234
00:07:54,940 --> 00:07:52,910
could get in there so we want to

235
00:07:56,860 --> 00:07:54,950
simulate not just the actual vent but

236
00:08:00,580 --> 00:07:56,870
the kind of the sediments around it and

237
00:08:02,020 --> 00:08:00,590
then the rocks and minerals below so

238
00:08:04,240 --> 00:08:02,030

this is you know a simulation of what

239
00:08:06,610 --> 00:08:04,250
you might see on Enceladus and possible

240
00:08:07,810 --> 00:08:06,620
metabolisms that have been proposed so

241
00:08:09,340 --> 00:08:07,820
for insulative let's say if you're

242
00:08:10,960 --> 00:08:09,350
having a serpentine izing system that

243
00:08:12,820 --> 00:08:10,970
makes hydrogen maybe methane

244
00:08:15,040 --> 00:08:12,830
you could have meth an agenda psious if

245
00:08:16,840 --> 00:08:15,050
there's co2 but you could also have

246
00:08:18,550 --> 00:08:16,850
other metabolisms that use that hydrogen

247
00:08:20,680 --> 00:08:18,560
it's not just with Anna Genesis that's

248
00:08:22,540 --> 00:08:20,690
possible you could also consume the

249
00:08:26,050 --> 00:08:22,550
methane with something like say ferric

250
00:08:27,820 --> 00:08:26,060
iron and so if you have minerals present

251
00:08:29,530 --> 00:08:27,830
as electrodes that are mixed valence and

252
00:08:31,840 --> 00:08:29,540
reactive you could actually use those as

253
00:08:34,209 --> 00:08:31,850
metabolites as well so here's an example

254
00:08:36,219 --> 00:08:34,219
of the fuel cell and one one funny thing

255
00:08:38,409 --> 00:08:36,229
that we found originally was that this

256
00:08:40,390 --> 00:08:38,419
graphite fuel cell was the surface of

257
00:08:42,670 --> 00:08:40,400
the graphite was really reactive so the

258
00:08:44,320 --> 00:08:42,680
sulfide was oxidizing but as oxidizing

259
00:08:46,360 --> 00:08:44,330
all the time and it's because you have

260
00:08:48,970 --> 00:08:46,370
to make your material choices very you

261
00:08:50,890 --> 00:08:48,980
know cleverly for this so we have a new

262
00:08:52,540 --> 00:08:50,900
fuel cell that is a custom-made version

263
00:08:54,190 --> 00:08:52,550

that's made of plastic and so it's a

264
00:08:56,560 --> 00:08:54,200
Newark electro chemically but it's also

265
00:08:59,050 --> 00:08:56,570
not giving us you know fake organic

266
00:09:00,970 --> 00:08:59,060
signatures so choosing materials here is

267
00:09:02,740 --> 00:09:00,980
important because the things that you

268
00:09:04,240 --> 00:09:02,750
would normally pick to make a good fuel

269
00:09:07,150 --> 00:09:04,250
cell are not what you want for this type

270
00:09:09,340 --> 00:09:07,160
of experiment so if we have a cathode on

271
00:09:11,290 --> 00:09:09,350
an O in this case the anode is going to

272
00:09:13,210 --> 00:09:11,300
be the interior and the cat'll be the

273
00:09:15,190 --> 00:09:13,220
exterior you could have a chimney

274
00:09:16,660 --> 00:09:15,200
environment and so life can live in

275
00:09:18,730 --> 00:09:16,670
chimneys this is great it can kind of

276
00:09:20,410 --> 00:09:18,740
interface directly with the ocean and so

277
00:09:21,970 --> 00:09:20,420
we could make simulated chimneys in lab

278
00:09:24,010 --> 00:09:21,980
you could get samples from things that

279
00:09:25,780 --> 00:09:24,020
are analogous on earth so that's one

280
00:09:28,150 --> 00:09:25,790
possibility that we could simulate here

281
00:09:29,950 --> 00:09:28,160
another possibility is if you have

282
00:09:31,720 --> 00:09:29,960
plumes and sediments forming in your

283
00:09:33,550 --> 00:09:31,730
event those sediments can be very

284
00:09:36,310 --> 00:09:33,560
reactive too so you can get things like

285
00:09:38,140 --> 00:09:36,320
sulfides hydroxides metal oxides and

286
00:09:39,970 --> 00:09:38,150
those are great as well for electro

287
00:09:42,190 --> 00:09:39,980
catalysts so we can either make

288
00:09:43,780 --> 00:09:42,200

simulated sediments and then make paint

289
00:09:46,420 --> 00:09:43,790
from that or we can get different types

290
00:09:48,280 --> 00:09:46,430
of sediments from the field or you can

291
00:09:50,260 --> 00:09:48,290
go deeper and consider things like say

292
00:09:52,510 --> 00:09:50,270
chondrite rich rocky core because

293
00:09:54,640 --> 00:09:52,520
chondrites will have bits of metallic

294
00:09:56,050 --> 00:09:54,650
iron nickel and meteorite material is

295
00:09:57,610 --> 00:09:56,060
definitely very electro chemically

296
00:10:00,579 --> 00:09:57,620
reactive this has been shown in several

297
00:10:02,170 --> 00:10:00,589
studies so if you imagine the Enceladus

298
00:10:04,120 --> 00:10:02,180
not quite yet serpentine eyes but also

299
00:10:05,800 --> 00:10:04,130
pretty chondritic with you know iron

300
00:10:07,720 --> 00:10:05,810
nickel chondrite stuff in there you

301
00:10:09,670 --> 00:10:07,730
could get some reactions going on there

302
00:10:12,130 --> 00:10:09,680
as well and all of this links to make a

303
00:10:14,500 --> 00:10:12,140
fairly complex abiotic / biotic

304
00:10:16,210 --> 00:10:14,510
electrochemical system so any of these

305
00:10:19,540 --> 00:10:16,220
or all of these could be your geo

306
00:10:21,820 --> 00:10:19,550
catalysts and so the thing to consider

307
00:10:24,100 --> 00:10:21,830
is that on earth we see a lot of

308
00:10:26,199 --> 00:10:24,110
examples where biological systems are

309
00:10:28,030 --> 00:10:26,209
linked physically to something farther

310
00:10:29,650 --> 00:10:28,040
away so you have a lot of synergy going

311
00:10:31,600 --> 00:10:29,660
on with different microbial communities

312
00:10:33,550 --> 00:10:31,610
you can have one say doing redox at like

313
00:10:35,230 --> 00:10:33,560

the bottom of a sediment column but then

314
00:10:36,790 --> 00:10:35,240
you have conductive sediment material

315
00:10:39,730 --> 00:10:36,800
that then connects that physically to

316
00:10:41,079 --> 00:10:39,740
another colony at the top and so what if

317
00:10:43,510 --> 00:10:41,089
you had something like this on an ocean

318
00:10:45,820 --> 00:10:43,520
world where there's one bacteria archaea

319
00:10:47,290 --> 00:10:45,830
doing something you know at one location

320
00:10:49,180 --> 00:10:47,300
and then it's connected with minerals

321
00:10:51,430 --> 00:10:49,190
that are conductive like a wire to some

322
00:10:53,920 --> 00:10:51,440
abiotic reaction or a prebiotic reaction

323
00:10:55,420 --> 00:10:53,930
so in that sense maybe the the origin of

324
00:10:56,980 --> 00:10:55,430
life or the prebiotic stuff that's

325
00:10:58,930 --> 00:10:56,990
happening is also kind of linked to the

326
00:11:03,190 --> 00:10:58,940
emerging metabolism it's not all one

327
00:11:04,900 --> 00:11:03,200
event so an example of a abiotic yet

328
00:11:05,949 --> 00:11:04,910
pretty organic looking reaction that

329
00:11:07,720 --> 00:11:05,959
might end up being linked here I

330
00:11:09,730 --> 00:11:07,730
presented a more detailed version of

331
00:11:11,750 --> 00:11:09,740
this on Wednesday but you can have for

332
00:11:13,880 --> 00:11:11,760
example iron hydroxide minerals that

333
00:11:15,950 --> 00:11:13,890
very catalytic and if you have simple

334
00:11:17,870 --> 00:11:15,960
organic molecules produced in vents or

335
00:11:19,520 --> 00:11:17,880
delivered from meteorites those can

336
00:11:22,130 --> 00:11:19,530
react to give you other stuff like amino

337
00:11:24,050 --> 00:11:22,140
acids or alpha hydroxy acids and so this

338
00:11:26,060 --> 00:11:24,060

is a redox reaction driven by a mineral

339
00:11:27,530 --> 00:11:26,070
that's not biological but would be a

340
00:11:30,070 --> 00:11:27,540
pretty confusing thing to see if you're

341
00:11:32,810 --> 00:11:30,080
trying to determine a bio signature and

342
00:11:35,510 --> 00:11:32,820
so if this could be linked to something

343
00:11:37,850 --> 00:11:35,520
more biological for example a sulfide

344
00:11:39,560 --> 00:11:37,860
oxidation by a microbe on let's say a

345
00:11:41,480 --> 00:11:39,570
metal sulphide or a chondritic type

346
00:11:43,280 --> 00:11:41,490
surface and that could be electrically

347
00:11:45,560 --> 00:11:43,290
linked in the fuel cell to something

348
00:11:47,120 --> 00:11:45,570
that's a biotic or prebiotic so one of

349
00:11:48,560 --> 00:11:47,130
the one of the technical challenges we

350
00:11:50,180 --> 00:11:48,570
faced is that you have to be able to

351
00:11:52,160 --> 00:11:50,190
actually conduct those electrons from

352
00:11:53,360 --> 00:11:52,170
one side to the other and it's hard when

353
00:11:55,820 --> 00:11:53,370
the minerals aren't actually touching

354
00:11:57,440 --> 00:11:55,830
the electrode surface so we've been

355
00:11:59,420 --> 00:11:57,450
developing different ways to do that and

356
00:12:01,940 --> 00:11:59,430
one of those is to have this mesh of a

357
00:12:03,440 --> 00:12:01,950
bimetallic mesh that connects to the

358
00:12:05,390 --> 00:12:03,450
mineral and then that conducts the

359
00:12:07,250 --> 00:12:05,400
electrons to the other side and the

360
00:12:09,080 --> 00:12:07,260
important thing is that when you do this

361
00:12:11,240 --> 00:12:09,090
in an actual fuel cell you separate the

362
00:12:13,250 --> 00:12:11,250
two sides of the redox reaction and that

363
00:12:15,230 --> 00:12:13,260

way you can you can tell exactly which

364
00:12:17,390 --> 00:12:15,240
half reaction is causing which product

365
00:12:18,650 --> 00:12:17,400
it as opposed to say a full bottle or

366
00:12:20,060 --> 00:12:18,660
closed system where you just get

367
00:12:22,820 --> 00:12:20,070
products out but you might not know what

368
00:12:25,060 --> 00:12:22,830
exactly is catalyzing what so fuel cells

369
00:12:27,500 --> 00:12:25,070
can be fairly useful in this regard

370
00:12:29,090 --> 00:12:27,510
again inert plastic is important because

371
00:12:32,660 --> 00:12:29,100
when the fuel cell is reactive

372
00:12:33,860 --> 00:12:32,670
experiments don't make any sense so in

373
00:12:35,900 --> 00:12:33,870
conclusion you know if we're gonna

374
00:12:37,430 --> 00:12:35,910
consider hydrothermal redox chemistry on

375
00:12:39,950 --> 00:12:37,440
other worlds both for the origin of life

376
00:12:42,350 --> 00:12:39,960
or for life to survive it's not just

377
00:12:44,510 --> 00:12:42,360
what energy is present it's also how are

378
00:12:46,070 --> 00:12:44,520
the minerals reacting with those suppose

379
00:12:47,630 --> 00:12:46,080
that electron donors or acceptors and

380
00:12:49,520 --> 00:12:47,640
how does it affect their availability

381
00:12:52,310 --> 00:12:49,530
for life and so this would probably

382
00:12:54,140 --> 00:12:52,320
requires some modeling as well and an

383
00:12:56,450 --> 00:12:54,150
understanding you know which prebiotic

384
00:12:58,220 --> 00:12:56,460
reactions are most favored and could you

385
00:13:00,740 --> 00:12:58,230
link those together electrochemically

386
00:13:02,840 --> 00:13:00,750
over what kinds of distances even so for

387
00:13:04,640 --> 00:13:02,850
in celle tiss-you no possible oxidants

388
00:13:06,740 --> 00:13:04,650

include lots of interesting things like

389
00:13:08,810 --> 00:13:06,750
what about sulfate or I don't know

390
00:13:10,130 --> 00:13:08,820
nitrous oxide and then possible

391
00:13:12,470 --> 00:13:10,140
reductants could include things like

392
00:13:14,630 --> 00:13:12,480
ferrous iron or hydrogen or methane and

393
00:13:16,460 --> 00:13:14,640
we could do tests in this fuel cell to

394
00:13:18,500 --> 00:13:16,470
determine you know to differentiate

395
00:13:20,360 --> 00:13:18,510
between hypotheses of say biogenic

396
00:13:22,490 --> 00:13:20,370
versions of any of these things that you

397
00:13:23,990 --> 00:13:22,500
might eventually see in a plume and by

398
00:13:25,220 --> 00:13:24,000
the way it is thought that the plume

399
00:13:26,600 --> 00:13:25,230
material is

400
00:13:28,550 --> 00:13:26,610
coming from deeper below just the

401
00:13:30,170 --> 00:13:28,560
seafloor and so if that's the case then

402
00:13:32,090 --> 00:13:30,180
if you have redox stuff going on below

403
00:13:33,500 --> 00:13:32,100
the sea floor and we could simulate that

404
00:13:35,360 --> 00:13:33,510
here we might be able to predict what

405
00:13:37,910 --> 00:13:35,370
how to interpret something from a plume

406
00:13:39,680 --> 00:13:37,920
that's a potential bio signature and the

407
00:13:40,910 --> 00:13:39,690
mineral catalyst that might be important

408
00:13:43,130 --> 00:13:40,920
that we're working on right now for

409
00:13:45,200 --> 00:13:43,140
making electrodes include olivine the

410
00:13:48,140 --> 00:13:45,210
iron hydroxides the phyllosilicates the

411
00:13:50,300 --> 00:13:48,150
chondrites and so on so stay tuned and

412
00:13:52,970 --> 00:13:50,310
hopefully an in celle de steel cell will

413
00:13:54,860 --> 00:13:52,980

yield some interesting results and so I

414
00:13:56,960 --> 00:13:54,870
just want to thank our lab group the JPL

415
00:13:58,760 --> 00:13:56,970
origins in habitability lab and in

416
00:14:00,920 --> 00:13:58,770
particular our collaborators John Paul

417
00:14:02,660 --> 00:14:00,930
Jones and Keith chin so they're the

418
00:14:04,130 --> 00:14:02,670
electrochemical technologies group who

419
00:14:06,800 --> 00:14:04,140
are using their battery expertise to

420
00:14:08,510 --> 00:14:06,810
apply it to astrobiology and also Nino's

421
00:14:09,560 --> 00:14:08,520
hermus and Erika Flores who the grad

422
00:14:11,890 --> 00:14:09,570
students who have helped with these