
AbSciCon
2019

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

2
00:00:11,419 --> 00:00:09,610
[Applause]

3
00:00:12,680 --> 00:00:11,429
thank you for the opportunity of

4
00:00:15,680 --> 00:00:12,690
speaking today and thank you all for

5
00:00:18,350 --> 00:00:15,690
being here so I'm going to go back in

6
00:00:20,359 --> 00:00:18,360
time hmm and focus this time on Mike

7
00:00:22,189 --> 00:00:20,369
microbial communities in iron rich

8
00:00:25,609 --> 00:00:22,199
oceans at the onset of the great

9
00:00:27,890 --> 00:00:25,619
oxidation event so the early Earth has

10
00:00:31,130 --> 00:00:27,900
been habitable ever since essentially

11
00:00:34,939 --> 00:00:31,140
the beginnings of its origins this is

12
00:00:38,180 --> 00:00:34,949
just a simplified diagram of some

13
00:00:40,700 --> 00:00:38,190

periods in time just to show that even

14
00:00:42,799 --> 00:00:40,710
though the earth has been inhabited ever

15
00:00:44,810 --> 00:00:42,809
since we've known of the existence of

16
00:00:46,790 --> 00:00:44,820
life four billion years ago different

17
00:00:48,860 --> 00:00:46,800
environments existed in which different

18
00:00:51,349 --> 00:00:48,870
the habitability was probably not the

19
00:00:56,209 --> 00:00:51,359
same for different species of

20
00:00:59,540 --> 00:00:56,219
microorganisms for example the origins

21
00:01:02,150 --> 00:00:59,550
of life Earth was an anoxic world with

22
00:01:03,560 --> 00:01:02,160
an anoxic atmosphere and iron rich

23
00:01:07,219 --> 00:01:03,570
oceans in which the majority of the

24
00:01:09,320 --> 00:01:07,229
metabolisms were anaerobic around the

25
00:01:12,949 --> 00:01:09,330
genomic record and fossil record tells

26
00:01:15,760 --> 00:01:12,959
us that cyanobacteria were able to begin

27
00:01:20,800 --> 00:01:15,770
to produce oxygen from water and around

28
00:01:23,089 --> 00:01:20,810
3 billion years ago if not earlier and

29
00:01:25,279 --> 00:01:23,099
even though they were able to produce

30
00:01:27,229 --> 00:01:25,289
oxygen for a long time for half a

31
00:01:28,490 --> 00:01:27,239
billion years two billion years oxygen

32
00:01:32,839 --> 00:01:28,500
was being produced but it did not

33
00:01:34,820 --> 00:01:32,849
accumulate in the atmosphere but at some

34
00:01:37,639 --> 00:01:34,830
point around 2.4 billion years ago

35
00:01:41,990 --> 00:01:37,649
oxygen production began to ramp up and

36
00:01:43,820 --> 00:01:42,000
very rapidly oxidized the globe perhaps

37
00:01:45,949 --> 00:01:43,830
not the modern countries of oxygen but

38
00:01:48,260 --> 00:01:45,959

enough to change the metabolic rules of

39
00:01:50,600 --> 00:01:48,270
the planet from an Arabic driven to a

40
00:01:54,440 --> 00:01:50,610
mostly anaerobic driven to mostly

41
00:01:57,320 --> 00:01:54,450
aerobic driven and now than in modern

42
00:02:01,850 --> 00:01:57,330
earth we met the majority of the biomass

43
00:02:04,880 --> 00:02:01,860
on earth is as an aerobic metabolism and

44
00:02:06,770 --> 00:02:04,890
at the same time well oxygen was

45
00:02:10,430 --> 00:02:06,780
produced and I'm sure you've recognized

46
00:02:12,949 --> 00:02:10,440
this not from previous talks iron

47
00:02:14,600 --> 00:02:12,959
concentrations decrease dramatically so

48
00:02:17,179 --> 00:02:14,610
what I'm interested is in understanding

49
00:02:19,520 --> 00:02:17,189
what was the microbial factors and the

50
00:02:22,240 --> 00:02:19,530
forces that shaped this period of time

51
00:02:24,640 --> 00:02:22,250
of cryptic oxygen cycling

52
00:02:28,060 --> 00:02:24,650
and what made it this ramped up the soul

53
00:02:33,670 --> 00:02:28,070
so rapidly so in order to dig a little

54
00:02:35,860 --> 00:02:33,680
bit deeper into these one of the focuses

55
00:02:40,000 --> 00:02:35,870
that one of the mythologies that I'm

56
00:02:42,400 --> 00:02:40,010
interested is the the reactivity of

57
00:02:43,870 --> 00:02:42,410
oxygen in a four genus ocean so to come

58
00:02:45,490 --> 00:02:43,880
up with optogenetic photosynthesis or to

59
00:02:48,160 --> 00:02:45,500
produce oxygen in a virginal environment

60
00:02:53,050 --> 00:02:48,170
is not really a good idea because oxygen

61
00:02:56,320 --> 00:02:53,060
not only will react with cellular

62
00:02:58,660 --> 00:02:56,330
components DNA proteins and lipids and

63
00:03:00,750 --> 00:02:58,670

as being especially detrimental in an

64
00:03:03,250 --> 00:03:00,760
anaerobic world where metabolisms are

65
00:03:05,380 --> 00:03:03,260
have enzymes that our oxygen sensitive

66
00:03:07,180 --> 00:03:05,390
but under high iron conditions you have

67
00:03:10,590 --> 00:03:07,190
that Fenton type of chemistry which

68
00:03:14,770 --> 00:03:10,600
accelerates iron toxicity on top of that

69
00:03:18,160 --> 00:03:14,780
iron gets oxidized by oxygen producing

70
00:03:20,550 --> 00:03:18,170
solid iron 3 which can also in

71
00:03:24,220 --> 00:03:20,560
crustacean and and be another reason for

72
00:03:27,310 --> 00:03:24,230
toxicity but there's a problem with this

73
00:03:28,720 --> 00:03:27,320
scenario so in this scenario it is

74
00:03:30,640 --> 00:03:28,730
proposed that cyanobacteria would have

75
00:03:32,979 --> 00:03:30,650
had a hard time to overcome iron

76
00:03:36,940 --> 00:03:32,989
toxicity and this could have delayed the

77
00:03:39,190 --> 00:03:36,950
oxygenation of earth and there's a very

78
00:03:41,080 --> 00:03:39,200
important piece missing though and which

79
00:03:43,540 --> 00:03:41,090
is what I want to focus on which is

80
00:03:46,330 --> 00:03:43,550
other other species other microbes so

81
00:03:48,190 --> 00:03:46,340
around 2.4 billion years ago which I am

82
00:03:49,930 --> 00:03:48,200
circled here in yellow there were

83
00:03:51,190 --> 00:03:49,940
already many ancestral lineage is

84
00:03:53,590 --> 00:03:51,200
present and diverged

85
00:03:55,539 --> 00:03:53,600
for example the ancestors of Delta

86
00:03:58,420 --> 00:03:55,549
fertile bacteria the under gammas and

87
00:04:01,690 --> 00:03:58,430
betas and Terra bacterial ancestors were

88
00:04:05,229 --> 00:04:01,700

already likely coexisting at that time

89
00:04:08,550 --> 00:04:05,239
and that means increased number of genes

90
00:04:10,920 --> 00:04:08,560
and functionalities and potentially

91
00:04:13,500 --> 00:04:10,930
mechanisms to cooperate together

92
00:04:15,070 --> 00:04:13,510
particularly important could have been

93
00:04:16,599 --> 00:04:15,080
proteobacteria many of the

94
00:04:18,699 --> 00:04:16,609
Proteobacteria that we know today are

95
00:04:20,710 --> 00:04:18,709
experts in cycling metals both iron

96
00:04:24,180 --> 00:04:20,720
oxidation and iron reduction so if you

97
00:04:27,250 --> 00:04:24,190
include a metal reducer in this scenario

98
00:04:29,560 --> 00:04:27,260
you can have many protective effects by

99
00:04:33,250 --> 00:04:29,570
the reduction of oxygen or the reduction

100
00:04:35,350 --> 00:04:33,260
of iron 3 preventing incrustation so in

101
00:04:38,159 --> 00:04:35,360
order to understand this

102
00:04:41,770 --> 00:04:38,169
potential scenario a little bit better

103
00:04:44,589 --> 00:04:41,780
one can study potential early earth

104
00:04:47,740 --> 00:04:44,599
analogs on earth the problem with that

105
00:04:49,420 --> 00:04:47,750
is that they could be very complex you

106
00:04:53,260 --> 00:04:49,430
even though they're more realistic and

107
00:04:56,439 --> 00:04:53,270
also what I wanted to do is come up with

108
00:04:58,510 --> 00:04:56,449
an experimental setting to simplify the

109
00:05:00,969 --> 00:04:58,520
conditions and also simplify the number

110
00:05:02,559 --> 00:05:00,979
of individuals to control the parameters

111
00:05:03,640 --> 00:05:02,569
better and understand the mechanisms

112
00:05:07,330 --> 00:05:03,650
that could have been involved in these

113
00:05:09,129 --> 00:05:07,340

interactions another problem with this

114
00:05:10,600 --> 00:05:09,139
setting the previous scenarios that

115
00:05:13,089 --> 00:05:10,610
there are no modern analogs it's really

116
00:05:15,399 --> 00:05:13,099
hard to find a serve an illuminated

117
00:05:21,969 --> 00:05:15,409
surface in on earth that has an anoxic

118
00:05:24,040 --> 00:05:21,979
atmosphere so what I did is I built a

119
00:05:28,119 --> 00:05:24,050
semi high throughput pre goe consortium

120
00:05:30,640 --> 00:05:28,129
to explore cooperation on earth by in an

121
00:05:33,399 --> 00:05:30,650
anaerobic chamber so I used to model

122
00:05:39,159 --> 00:05:33,409
organisms cyanobacteria see no Coco's

123
00:05:41,430 --> 00:05:39,169
BCC 7002 and strains of Salmonella the

124
00:05:46,779 --> 00:05:41,440
Shannara genus which are metal producers

125
00:05:49,930 --> 00:05:46,789
used use them either alone or together

126
00:05:51,550 --> 00:05:49,940
in pairs in an anoxic atmosphere and

127
00:05:53,409 --> 00:05:51,560
oxygen was allowed to be produced from

128
00:05:55,390 --> 00:05:53,419
photosynthesis but it was allowed to

129
00:05:57,610 --> 00:05:55,400
diffuse into the anaerobic chamber so

130
00:06:02,110 --> 00:05:57,620
this is conducted these experiments into

131
00:06:05,260 --> 00:06:02,120
in in 10 milliliter volumes inside 20

132
00:06:07,480 --> 00:06:05,270
milliliter wells culture plates so

133
00:06:10,119 --> 00:06:07,490
oxygen would diffuse into a 300 liter

134
00:06:12,279 --> 00:06:10,129
chamber mimicking the anoxic

135
00:06:15,999 --> 00:06:12,289
environments and the treatments were

136
00:06:18,430 --> 00:06:16,009
different concentrations of iron - so as

137
00:06:22,300 --> 00:06:18,440
expected like previous work had shown

138
00:06:24,089 --> 00:06:22,310

cyanobacteria as iron concentration

139
00:06:27,820 --> 00:06:24,099
increased to 1 millimolar

140
00:06:29,769 --> 00:06:27,830
lost their ability to grow and it has

141
00:06:32,649 --> 00:06:29,779
previously been shown that it's due to

142
00:06:36,939 --> 00:06:32,659
iron toxicity already at 500 a they were

143
00:06:39,010 --> 00:06:36,949
showing a lag in their growth and here

144
00:06:40,269 --> 00:06:39,020
I'm showing growth of cyanobacteria in

145
00:06:43,029 --> 00:06:40,279
the presence of different strains of

146
00:06:45,519 --> 00:06:43,039
Salmonella species and as you can see

147
00:06:46,959 --> 00:06:45,529
the reverse happens as iron increases in

148
00:06:48,490 --> 00:06:46,969
the presence of Salmonella most

149
00:06:50,860 --> 00:06:48,500
cyanobacteria

150
00:06:52,180 --> 00:06:50,870
speech I mean this one species but in

151
00:06:55,990 --> 00:06:52,190
all these different experiments I know

152
00:06:59,620 --> 00:06:56,000
Vettori is able to grow and the growth

153
00:07:02,320 --> 00:06:59,630
is restored annoying Salmonella and in

154
00:07:05,470 --> 00:07:02,330
the same culture under higher iron

155
00:07:07,000 --> 00:07:05,480
concentrations the growth is favored too

156
00:07:09,460 --> 00:07:07,010
so there's a relationship between the

157
00:07:10,660 --> 00:07:09,470
high amount of iron and the yields and

158
00:07:11,980 --> 00:07:10,670
growth rates of Shanina and

159
00:07:14,410 --> 00:07:11,990
cyanobacteria when they're growing

160
00:07:15,940 --> 00:07:14,420
together so when I went and measured

161
00:07:18,430 --> 00:07:15,950
iron concentrations iron ii

162
00:07:22,930 --> 00:07:18,440
concentrations with the cyanobacteria

163
00:07:26,530 --> 00:07:22,940

alone in both higher and 501 millimolar

164
00:07:28,660 --> 00:07:26,540
iron ii concentrations in the iron

165
00:07:30,670 --> 00:07:28,670
levels immediately decreased in the

166
00:07:33,400 --> 00:07:30,680
first few days but which human ella the

167
00:07:36,310 --> 00:07:33,410
iron levels remained essentially stable

168
00:07:39,940 --> 00:07:36,320
which means that there was not enough

169
00:07:40,600 --> 00:07:39,950
oxygen to oxidize iron probably consumed

170
00:07:42,700 --> 00:07:40,610
by shewanella

171
00:07:45,090 --> 00:07:42,710
or iron could have been reduced but in

172
00:07:47,950 --> 00:07:45,100
any case the mechanisms of protection

173
00:07:50,290 --> 00:07:47,960
were related to the availability of

174
00:07:52,510 --> 00:07:50,300
oxygen and iron so among all the

175
00:07:55,270 --> 00:07:52,520
different strains tested shewanella

176
00:07:58,990 --> 00:07:55,280
baltica and shewanella alga were the two

177
00:08:02,620 --> 00:07:59,000
that yielded the yield similar under

178
00:08:06,810 --> 00:08:02,630
high iron or low iron conditions so to

179
00:08:09,909 --> 00:08:06,820
understand potential reason for this I

180
00:08:12,610 --> 00:08:09,919
incubated each shinola independently on

181
00:08:14,140 --> 00:08:12,620
its own under different concentrations

182
00:08:15,880 --> 00:08:14,150
of hydrogen peroxide meaning different

183
00:08:19,060 --> 00:08:15,890
concentrations of hydro peroxide stress

184
00:08:22,770 --> 00:08:19,070
and so the better helpers the ones that

185
00:08:26,080 --> 00:08:22,780
were able to get cynical Coco's to grow

186
00:08:28,150 --> 00:08:26,090
almost like no iron in Noren conditions

187
00:08:32,350 --> 00:08:28,160
they were able to resist hydrogen

188
00:08:37,180 --> 00:08:32,360

peroxide better so ro s stress better

189
00:08:39,279 --> 00:08:37,190
than the poor poorer helper so bringing

190
00:08:41,770 --> 00:08:39,289
everything all these different lines of

191
00:08:43,810 --> 00:08:41,780
evidence together you can I conclude

192
00:08:45,520 --> 00:08:43,820
that iron concentration will impact the

193
00:08:48,790 --> 00:08:45,530
interactions between the Proteobacteria

194
00:08:50,110 --> 00:08:48,800
and cyanobacteria and this could have

195
00:08:51,960 --> 00:08:50,120
driven the community structure in

196
00:08:54,220 --> 00:08:51,970
ferruginous and early oceans

197
00:08:56,079 --> 00:08:54,230
cyanobacteria Fitness also increased

198
00:08:57,640 --> 00:08:56,089
when there was a metal reducing partner

199
00:09:00,809 --> 00:08:57,650
so it suggests that the habit of

200
00:09:01,769 --> 00:09:00,819
habitability arranged in a community

201
00:09:03,989 --> 00:09:01,779
change depending on the community

202
00:09:06,029 --> 00:09:03,999
composition in a given environment so

203
00:09:08,819 --> 00:09:06,039
this would be important too for future

204
00:09:12,090 --> 00:09:08,829
habitability tests whether there's one

205
00:09:14,429 --> 00:09:12,100
species or more will likely change the

206
00:09:16,859 --> 00:09:14,439
the results also cyanobacteria

207
00:09:18,449 --> 00:09:16,869
benefitted by coin inhabiting with

208
00:09:22,229 --> 00:09:18,459
shewanella only at higher iron

209
00:09:23,849 --> 00:09:22,239
concentration so and again suggesting

210
00:09:25,710 --> 00:09:23,859
that partnerships that may have been

211
00:09:27,809 --> 00:09:25,720
important during the Proterozoic or late

212
00:09:29,669 --> 00:09:27,819
Archaean may be very different than

213
00:09:32,519 --> 00:09:29,679

those found in modern environments so

214
00:09:36,319 --> 00:09:32,529
again analog choice versus experimental

215
00:09:39,629 --> 00:09:36,329
setup can yield different results and

216
00:09:41,400 --> 00:09:39,639
important to consider and also a cryptic

217
00:09:43,529 --> 00:09:41,410
oxygen cycle would have been sustained

218
00:09:45,479 --> 00:09:43,539
under high iron oceans by cyanobacteria

219
00:09:47,549 --> 00:09:45,489
and protocol partners which would

220
00:09:49,979 --> 00:09:47,559
explain why this would be another

221
00:09:53,189 --> 00:09:49,989
biological factor instead of abiotic

222
00:09:56,309 --> 00:09:53,199
reasons why oxygen would have persisted

223
00:09:59,929 --> 00:09:56,319
at low concentrations red cryptic levels

224
00:10:04,469 --> 00:09:59,939
without accumulating at the atmosphere

225
00:10:06,509 --> 00:10:04,479
so the end of the results and I would

226
00:10:10,009 --> 00:10:06,519
like to thank Jen lassen Chris Reinhard

227
00:10:12,829 --> 00:10:10,019
for their support during these MPP

228
00:10:14,669 --> 00:10:12,839
postdoc experience things to NASA for

229
00:10:17,129 --> 00:10:14,679
allowing me to carry out this research

230
00:10:19,109 --> 00:10:17,139
on the amazing people at the glass lab

231
00:10:37,199 --> 00:10:19,119
on the astrobiology community at Georgia

232
00:10:39,809 --> 00:10:37,209
Tech have you looked at the formation of

233
00:10:42,809 --> 00:10:39,819
colloids for example maybe iron 3 could

234
00:10:44,969 --> 00:10:42,819
form a chloride and maybe other elements

235
00:10:46,590 --> 00:10:44,979
a nitrogen cycle cycling you know

236
00:10:49,289 --> 00:10:46,600
different oxidation states of another

237
00:10:57,749 --> 00:10:49,299
element that might go through iron to

238
00:10:59,989 --> 00:10:57,759

iron 3 so I I put ammonium as a nitrogen

239
00:11:04,319 --> 00:10:59,999
source of nitrate which is a typical

240
00:11:05,549 --> 00:11:04,329
component of cyanobacteria media but I

241
00:11:07,769 --> 00:11:05,559
didn't look at that but that may be

242
00:11:10,109 --> 00:11:07,779
interesting to see whether reactive

243
00:11:13,700 --> 00:11:10,119
species could also be produced by that

244
00:11:29,520 --> 00:11:24,510
please come to my i dial psycho so I did

245
00:11:31,500 --> 00:11:29,530
not take points that would be I was

246
00:11:34,050 --> 00:11:31,510
thinking about doing that on a future

247
00:11:36,900 --> 00:11:34,060
experiment I was I'm going to select one

248
00:11:40,200 --> 00:11:36,910
of these shewanella species and then get

249
00:11:41,400 --> 00:11:40,210
more resolution and more resolved type

250
00:11:43,470 --> 00:11:41,410
of growth curve to see if there are

251
00:11:48,150 --> 00:11:43,480
changes between the iron and the oxygen

252
00:11:49,980 --> 00:11:48,160
levels over day and night cycles this

253
00:11:51,810 --> 00:11:49,990
was more like a high-throughput to see

254
00:11:54,060 --> 00:11:51,820
the range because even though they're

255
00:11:58,590 --> 00:11:54,070
also on another all metal reducers they

256
00:12:00,480 --> 00:11:58,600
do not have the same effect on the sign

257
00:12:02,010 --> 00:12:00,490
of a true growth which is also means

258
00:12:04,890 --> 00:12:02,020
that there's it's not a biomass issue

259
00:12:14,040 --> 00:12:04,900
there's other biological components in