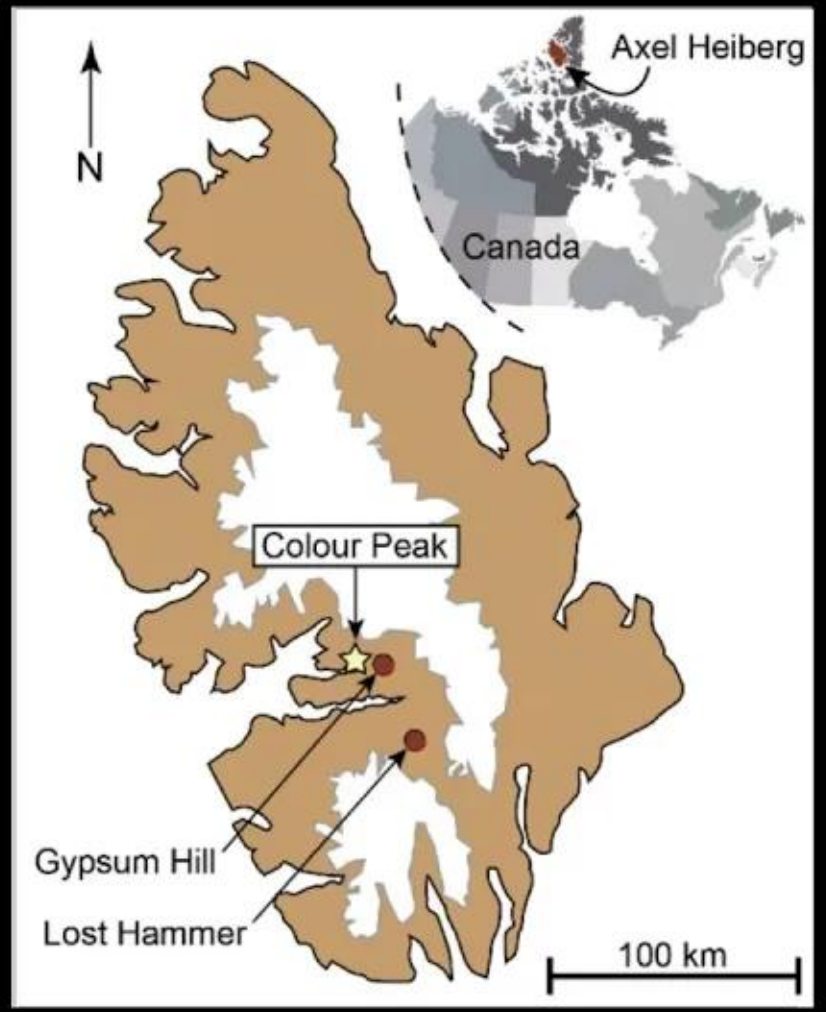
Axel Heiberg island

- Axel Heiberg island is located in the Canadian High Arctic.
- The island is characterised by polar desert conditions and lies within the region of continuous permafrost.
- The island is host to a series of sulfur rich and saline cold springs.



1
00:00:04,470 --> 00:00:02,629
in this talk i'm going to be covering

2
00:00:07,030 --> 00:00:04,480
some of the work we performed in

3
00:00:09,270 --> 00:00:07,040
characterizing color peak springs and

4
00:00:13,589 --> 00:00:09,280
analog environments for the waters of

5
00:00:18,950 --> 00:00:15,669
for the purpose of this talk we are

6
00:00:21,349 --> 00:00:18,960
defining an analog environment as a site

7
00:00:26,150 --> 00:00:21,359
possessing a chemistry approximating

8
00:00:30,470 --> 00:00:28,230
so in terms of an analog for the surface

9
00:00:32,470 --> 00:00:30,480
of modern day mars you would expect an

10
00:00:34,069 --> 00:00:32,480
analog environment to have one of the

11
00:00:35,670 --> 00:00:34,079
following traits

12
00:00:38,670 --> 00:00:35,680
it would be sailing

13
00:00:41,270 --> 00:00:38,680

oxidizing potentially anaerobic or

14
00:00:44,709 --> 00:00:41,280
microaerophilic and be exposed to high

15
00:00:46,630 --> 00:00:44,719
levels of ultraviolet radiation

16
00:00:49,190 --> 00:00:46,640
which of course highlights that an

17
00:00:51,189 --> 00:00:49,200
analog environment is an analog at a

18
00:00:54,150 --> 00:00:51,199
specific point in a celestial body's

19
00:00:56,069 --> 00:00:54,160
history and in a specific location the

20
00:00:57,750 --> 00:00:56,079
geology of mars is not homogeneous so

21
00:01:00,069 --> 00:00:57,760
there is variation in chemistry between

22
00:01:01,750 --> 00:01:00,079
different sites the surface of modern

23
00:01:04,070 --> 00:01:01,760
day mars is believed to be greatly

24
00:01:06,789 --> 00:01:04,080
different from the subsurface

25
00:01:09,429 --> 00:01:06,799
and mars 4 billion years ago is believed

26
00:01:11,270 --> 00:01:09,439
to be incredibly different and much more

27
00:01:14,149 --> 00:01:11,280
water-rich than its modern day

28
00:01:18,710 --> 00:01:16,230
color peak springs is located on axel

29
00:01:20,310 --> 00:01:18,720
heiberg island which is in the canadian

30
00:01:22,390 --> 00:01:20,320
high arctic

31
00:01:24,870 --> 00:01:22,400
it's characterized by polar desert

32
00:01:27,109 --> 00:01:24,880
conditions meaning it's both very cold

33
00:01:29,670 --> 00:01:27,119
and very dry and it lies within the

34
00:01:32,069 --> 00:01:29,680
region of continuous permafrost

35
00:01:34,149 --> 00:01:32,079
the island is host to a series of

36
00:01:36,390 --> 00:01:34,159
sulphur rich and saline cold springs

37
00:01:38,710 --> 00:01:36,400
with some marked on the map shown here

38
00:01:43,109 --> 00:01:38,720

with either red dots or the gold star

39
00:01:47,510 --> 00:01:45,670
color peak is incredibly sailing like

40
00:01:48,870 --> 00:01:47,520
the other springs on the island and

41
00:01:51,670 --> 00:01:48,880
sulfurous

42
00:01:54,389 --> 00:01:51,680
but one delineating trait is it is also

43
00:01:56,230 --> 00:01:54,399
incredibly sulfidic as evidenced from

44
00:01:57,990 --> 00:01:56,240
the black coloration visible in these

45
00:01:59,590 --> 00:01:58,000
sediments following from these spring

46
00:02:01,510 --> 00:01:59,600
source

47
00:02:02,630 --> 00:02:01,520
this environment was worthy of further

48
00:02:04,870 --> 00:02:02,640
characterization from the

49
00:02:07,030 --> 00:02:04,880
microbiological perspective because the

50
00:02:08,949 --> 00:02:07,040
microbes that survive and are active

51
00:02:11,270 --> 00:02:08,959
within this environment have previously

52
00:02:13,430 --> 00:02:11,280
only been partially characterized and

53
00:02:15,510 --> 00:02:13,440
from the astrobiology perspective this

54
00:02:20,229 --> 00:02:15,520
environment is argued to be an analog

55
00:02:23,990 --> 00:02:21,750
when we are considering analog

56
00:02:26,309 --> 00:02:24,000
environments we first have to ask is it

57
00:02:27,830 --> 00:02:26,319
chemically and physically relevant

58
00:02:31,030 --> 00:02:27,840
no environments on earth will be a

59
00:02:33,509 --> 00:02:31,040
perfect fit but we want it to be as

60
00:02:35,830 --> 00:02:33,519
relevant as possible

61
00:02:38,150 --> 00:02:35,840
in terms of the temperatures experienced

62
00:02:40,710 --> 00:02:38,160
by the color peak springs these fall

63
00:02:42,710 --> 00:02:40,720

within the range of colder temperatures

64
00:02:46,150 --> 00:02:42,720
that are modeled in predictions that

65
00:02:48,710 --> 00:02:46,160
estimate a cold and wet nowakian mars as

66
00:02:50,309 --> 00:02:48,720
opposed to a warm and white snowakian

67
00:02:52,710 --> 00:02:50,319
mars

68
00:02:55,750 --> 00:02:52,720
we then analyze the chemistry of the

69
00:02:58,869 --> 00:02:55,760
color peak springs

70
00:03:00,710 --> 00:02:58,879
using icp oes

71
00:03:02,949 --> 00:03:00,720
shown on the ternary plot we have the

72
00:03:04,470 --> 00:03:02,959
three most abundant elements calcium

73
00:03:07,509 --> 00:03:04,480
sulfur and sodium

74
00:03:08,630 --> 00:03:07,519
and in the bottom right corner

75
00:03:11,030 --> 00:03:08,640
we have

76
00:03:13,430 --> 00:03:11,040
here in the red circles

77
00:03:15,509 --> 00:03:13,440
and the other circles directly on top

78
00:03:17,990 --> 00:03:15,519
the different chemistries of the color

79
00:03:20,790 --> 00:03:18,000
peak samples showing that sodium was the

80
00:03:23,830 --> 00:03:20,800
most abundant elements

81
00:03:26,070 --> 00:03:23,840
the other markings on this ternary plot

82
00:03:29,270 --> 00:03:26,080
designates other analog environments on

83
00:03:31,509 --> 00:03:29,280
earth such as the deccan traps in india

84
00:03:34,869 --> 00:03:31,519
however some also represent

85
00:03:36,550 --> 00:03:34,879
modelled martian waters

86
00:03:39,589 --> 00:03:36,560
for the purpose of this study the

87
00:03:40,789 --> 00:03:39,599
program chim-xpt was used by dr susanna

88
00:03:42,869 --> 00:03:40,799

schwentzer

89
00:03:45,270 --> 00:03:42,879
using as inputs pure water and the

90
00:03:48,470 --> 00:03:45,280
chemistry of rockness sand collected a

91
00:03:50,949 --> 00:03:48,480
gale crater by the curiosity rover chim

92
00:03:53,429 --> 00:03:50,959
xpt estimates what would the chemistry

93
00:03:56,070 --> 00:03:53,439
of the solution be like if the minerals

94
00:03:58,229 --> 00:03:56,080
were to dissolve

95
00:04:00,550 --> 00:03:58,239
and if we go back to this ternary plot

96
00:04:03,589 --> 00:04:00,560
and we look to the right of the red

97
00:04:05,990 --> 00:04:03,599
circles and to the left most side of the

98
00:04:08,710 --> 00:04:06,000
outer red circle we see two diamond

99
00:04:10,550 --> 00:04:08,720
shapes representing the thermochemically

100
00:04:12,869 --> 00:04:10,560
modelled waters based on these gale

101
00:04:14,550 --> 00:04:12,879
crater evaporates

102
00:04:16,710 --> 00:04:14,560
so at least in terms of the most

103
00:04:19,110 --> 00:04:16,720
abundant elements the chemistry of the

104
00:04:21,349 --> 00:04:19,120
waters and sediment of color peak are

105
00:04:25,590 --> 00:04:21,359
close to the modelled martian water

106
00:04:31,430 --> 00:04:28,390
the next question in our set of

107
00:04:33,430 --> 00:04:31,440
experiments was what microbes are

108
00:04:36,070 --> 00:04:33,440
present in color peak that are

109
00:04:37,270 --> 00:04:36,080
withstanding this chemical and physical

110
00:04:39,430 --> 00:04:37,280
regime

111
00:04:41,590 --> 00:04:39,440
in order to answer this we extracted the

112
00:04:42,390 --> 00:04:41,600
dna from replicate sediment samples

113
00:04:44,790 --> 00:04:42,400

using

114
00:04:46,390 --> 00:04:44,800
a specially tailored dna extraction

115
00:04:49,110 --> 00:04:46,400
technique to account for the high

116
00:04:52,790 --> 00:04:49,120
concentrations of salt within the sample

117
00:04:55,350 --> 00:04:52,800
we then sequenced the 16s rrna gene the

118
00:04:57,030 --> 00:04:55,360
universal barcode gene that's found in

119
00:05:02,150 --> 00:04:57,040
all microbes and it gave us the

120
00:05:06,870 --> 00:05:04,390
the key takeaway from this bar graph is

121
00:05:07,830 --> 00:05:06,880
the dominance of purple and shades

122
00:05:09,830 --> 00:05:07,840
thereof

123
00:05:12,070 --> 00:05:09,840
across these three different bars from

124
00:05:14,070 --> 00:05:12,080
the replicate sediment samples

125
00:05:16,310 --> 00:05:14,080
these represent sulfur oxidizing

126
00:05:18,469 --> 00:05:16,320
bacteria and as is clear from these

127
00:05:21,270 --> 00:05:18,479
graphs

128
00:05:23,029 --> 00:05:21,280
sulfur oxidizing bacteria dominates the

129
00:05:25,749 --> 00:05:23,039
color peak sediment

130
00:05:28,070 --> 00:05:25,759
so who are the sulfur oxidizers

131
00:05:29,749 --> 00:05:28,080
sulfur oxidizing microbes are those that

132
00:05:31,909 --> 00:05:29,759
yield energy through the oxidation of

133
00:05:34,469 --> 00:05:31,919
reduced sulfur compounds which we know

134
00:05:36,469 --> 00:05:34,479
to be abundant within the color peak and

135
00:05:39,510 --> 00:05:36,479
present on the surface of mars and

136
00:05:42,390 --> 00:05:39,520
within martian meteoritic materials

137
00:05:46,070 --> 00:05:42,400
sulfide oxidation can occur using oxygen

138
00:05:47,990 --> 00:05:46,080

as a terminal electron acceptor

139
00:05:51,350 --> 00:05:48,000
it can also occur in the absence of

140
00:05:54,469 --> 00:05:51,360
oxygen using nitrate as an alternate

141
00:05:56,390 --> 00:05:54,479
terminal electron acceptor which is also

142
00:05:58,710 --> 00:05:56,400
relevant in terms of mars given the

143
00:06:00,870 --> 00:05:58,720
detection of nitrates within martian

144
00:06:04,629 --> 00:06:00,880
mudstone samples as reported in the

145
00:06:06,390 --> 00:06:04,639
sternatile 2015 paper

146
00:06:07,830 --> 00:06:06,400
many of the sulfur oxidizing bacteria

147
00:06:10,870 --> 00:06:07,840
that we detected within the color peak

148
00:06:12,790 --> 00:06:10,880
sediment are also autotrophic organisms

149
00:06:15,270 --> 00:06:12,800
that convert inorganic carbon in this

150
00:06:16,469 --> 00:06:15,280
case carbon dioxide to produce organic

151
00:06:19,830 --> 00:06:16,479
carbon

152
00:06:23,270 --> 00:06:19,840
in the same way that plants

153
00:06:25,990 --> 00:06:23,280
they do not need nor can they utilize an

154
00:06:31,510 --> 00:06:26,000
external source of organic carbon as we

155
00:06:35,990 --> 00:06:34,150
there is however a slight issue with

156
00:06:39,430 --> 00:06:36,000
identifying what microbes are present in

157
00:06:41,990 --> 00:06:39,440
color peak only by looking at dna

158
00:06:43,189 --> 00:06:42,000
and that is in a cold and saline

159
00:06:44,950 --> 00:06:43,199
environment

160
00:06:48,469 --> 00:06:44,960
dna from long dead cells could

161
00:06:50,790 --> 00:06:48,479
hypothetically persist for millennia

162
00:06:53,430 --> 00:06:50,800
in order to try and move past this issue

163
00:06:55,430 --> 00:06:53,440

we also extracted rna from the color

164
00:06:57,589 --> 00:06:55,440
peak sediment in order to try and look

165
00:07:01,270 --> 00:06:57,599
at what microbes were more genuinely

166
00:07:04,150 --> 00:07:01,280
present within this specific environment

167
00:07:07,029 --> 00:07:04,160
as rna has a much shorter half-life even

168
00:07:09,749 --> 00:07:07,039
under optimal conditions

169
00:07:12,469 --> 00:07:09,759
comparing a collapsed dna profile

170
00:07:13,990 --> 00:07:12,479
to the rna profile

171
00:07:16,390 --> 00:07:14,000
we see that there is a significant

172
00:07:18,150 --> 00:07:16,400
reduction in the diversity present

173
00:07:19,909 --> 00:07:18,160
within the environment

174
00:07:21,189 --> 00:07:19,919
and we see that there is this continued

175
00:07:23,350 --> 00:07:21,199
persistence

176
00:07:25,510 --> 00:07:23,360
both of these sulfur oxidizing bacteria

177
00:07:28,070 --> 00:07:25,520
represented again in purple

178
00:07:30,870 --> 00:07:28,080
and of some of the additional diversity

179
00:07:32,710 --> 00:07:30,880
within the sediment

180
00:07:35,270 --> 00:07:32,720
but the active microbes

181
00:07:38,469 --> 00:07:35,280
are still mostly sulfur oxidizing

182
00:07:41,990 --> 00:07:40,070
the question is then

183
00:07:44,469 --> 00:07:42,000
independent of the microbiology point of

184
00:07:46,469 --> 00:07:44,479
view why is this an interesting result

185
00:07:49,189 --> 00:07:46,479
why is it interesting that microbes with

186
00:07:51,029 --> 00:07:49,199
this specific metabolism are living and

187
00:07:53,110 --> 00:07:51,039
thriving in this

188
00:07:55,350 --> 00:07:53,120

cold pool in the arctic

189
00:07:56,710 --> 00:07:55,360
and moreover why do we perform any kind

190
00:07:58,230 --> 00:07:56,720
of characterization of analog

191
00:08:00,230 --> 00:07:58,240
environments

192
00:08:03,029 --> 00:08:00,240
and the answer is it enables us to

193
00:08:04,950 --> 00:08:03,039
generate hypotheses

194
00:08:06,869 --> 00:08:04,960
we know that a lot of the diversity

195
00:08:08,869 --> 00:08:06,879
detected within this sediment of this

196
00:08:11,350 --> 00:08:08,879
self-oxidizing bacteria

197
00:08:13,270 --> 00:08:11,360
are capable of autotrophy meaning that

198
00:08:14,790 --> 00:08:13,280
they can fix carbon dioxide as their

199
00:08:16,309 --> 00:08:14,800
sole carbon source

200
00:08:18,070 --> 00:08:16,319
combined with how carbon poor the

201
00:08:19,749 --> 00:08:18,080
sediment is they're most likely

202
00:08:23,270 --> 00:08:19,759
surviving within this environment

203
00:08:25,350 --> 00:08:23,280
through the fixation of carbon dioxide

204
00:08:27,189 --> 00:08:25,360
however as these cells are growing some

205
00:08:29,990 --> 00:08:27,199
will be leaking either intentionally or

206
00:08:32,550 --> 00:08:30,000
unintentionally and as some are growing

207
00:08:34,149 --> 00:08:32,560
they will be dying releasing a pool of

208
00:08:36,389 --> 00:08:34,159
organic carbon that they themselves

209
00:08:37,750 --> 00:08:36,399
cannot utilize and we know that there is

210
00:08:39,430 --> 00:08:37,760
this additional

211
00:08:41,670 --> 00:08:39,440
package of diversity within the color

212
00:08:43,190 --> 00:08:41,680
peak sediment

213
00:08:45,590 --> 00:08:43,200

it is therefore possible that the other

214
00:08:47,350 --> 00:08:45,600
bacteria within the color peak sediments

215
00:08:49,509 --> 00:08:47,360
are surviving by growing on the carbon

216
00:08:51,350 --> 00:08:49,519
produced by the autotrophic sulfur

217
00:08:53,190 --> 00:08:51,360
oxidizers and this is something shown to

218
00:08:54,949 --> 00:08:53,200
occur in other environments such as

219
00:08:58,870 --> 00:08:54,959
hydrothermal vents

220
00:09:01,350 --> 00:08:58,880
and also in cultivation-based studies

221
00:09:02,870 --> 00:09:01,360
now in terms of this metabolic process

222
00:09:05,269 --> 00:09:02,880
we know the concentrations of the

223
00:09:07,670 --> 00:09:05,279
individual elements that are key for

224
00:09:10,150 --> 00:09:07,680
sulfur oxidation

225
00:09:12,389 --> 00:09:10,160
the same is also true

226
00:09:14,230 --> 00:09:12,399
for martian conditions we know the

227
00:09:16,310 --> 00:09:14,240
concentrations of nitrates detected

228
00:09:19,030 --> 00:09:16,320
within the mudstone samples and we know

229
00:09:20,870 --> 00:09:19,040
the thermochemical composition of the

230
00:09:23,829 --> 00:09:20,880
waters that were derived from the

231
00:09:26,150 --> 00:09:23,839
chemistry of the gal crater evaporates

232
00:09:28,710 --> 00:09:26,160
using gibbs energy equations it's

233
00:09:30,150 --> 00:09:28,720
possible to deduce whether based on the

234
00:09:31,829 --> 00:09:30,160
abundance of the elements that are

235
00:09:33,670 --> 00:09:31,839
required for specific metabolic

236
00:09:36,030 --> 00:09:33,680
processes whether there would be

237
00:09:39,110 --> 00:09:36,040
sufficient energy yielded to make this a

238
00:09:40,310 --> 00:09:39,120

thermodynamically favorable metabolism

239
00:09:41,590 --> 00:09:40,320
and doing these gibbs energy

240
00:09:46,710 --> 00:09:41,600
calculations

241
00:09:49,509 --> 00:09:46,720
only was aerobic and anaerobic sulfur

242
00:09:51,430 --> 00:09:49,519
oxidation feasible under these proposed

243
00:09:53,430 --> 00:09:51,440
martian conditions

244
00:09:56,550 --> 00:09:53,440
they were two of some of the few

245
00:10:00,630 --> 00:09:56,560
metabolisms that were indeed capable in

246
00:10:02,949 --> 00:10:00,640
this specific chemical environment

247
00:10:05,509 --> 00:10:02,959
so how can we take this one step further

248
00:10:08,550 --> 00:10:05,519
how can we test if the analog community

249
00:10:10,069 --> 00:10:08,560
is viable in genuine martian chemistries

250
00:10:11,509 --> 00:10:10,079
moving one step beyond the

251
00:10:13,670 --> 00:10:11,519
characterization of the proxy

252
00:10:14,870 --> 00:10:13,680
environments and the modeling of martian

253
00:10:16,550 --> 00:10:14,880
chemistries

254
00:10:18,630 --> 00:10:16,560
and we can do this through performing

255
00:10:20,949 --> 00:10:18,640
simulation experiments

256
00:10:23,590 --> 00:10:20,959
if we take one step back to the chim

257
00:10:25,190 --> 00:10:23,600
modeling of the rockness sand chemistry

258
00:10:27,269 --> 00:10:25,200
and the pure water

259
00:10:29,350 --> 00:10:27,279
we can use this output to produce a

260
00:10:31,110 --> 00:10:29,360
liquid medium in which to challenge

261
00:10:33,670 --> 00:10:31,120
cells

262
00:10:36,230 --> 00:10:33,680
we can then combine this with two

263
00:10:37,750 --> 00:10:36,240

different chemically accurate martian

264
00:10:40,069 --> 00:10:37,760
regolith simulants one based on the

265
00:10:42,790 --> 00:10:40,079
chemistry of rock nest and one based on

266
00:10:45,030 --> 00:10:42,800
the more iron iii enriched chemistry of

267
00:10:47,509 --> 00:10:45,040
hematite slope

268
00:10:49,670 --> 00:10:47,519
establishing two distinct simulated

269
00:10:51,190 --> 00:10:49,680
martian chemistries performing this

270
00:10:53,269 --> 00:10:51,200
under anaerobic conditions in

271
00:10:55,350 --> 00:10:53,279
combination with the color peak sediment

272
00:10:57,750 --> 00:10:55,360
to more accurately simulate martian

273
00:11:00,550 --> 00:10:57,760
conditions

274
00:11:03,030 --> 00:11:00,560
the question is then is the analog

275
00:11:05,990 --> 00:11:03,040
community that we're arguing is viable

276
00:11:08,710 --> 00:11:06,000
under a proxy martian condition

277
00:11:10,550 --> 00:11:08,720
viable under simulated conditions

278
00:11:12,829 --> 00:11:10,560
and do we see the persistence of these

279
00:11:14,790 --> 00:11:12,839
sulfur oxidizing

280
00:11:16,630 --> 00:11:14,800
bacteria we look at the general

281
00:11:18,310 --> 00:11:16,640
microbial community again

282
00:11:19,829 --> 00:11:18,320
and compare this to under rock nest

283
00:11:22,310 --> 00:11:19,839
conditions we see that the answer is

284
00:11:24,230 --> 00:11:22,320
indeed yes the purple persists

285
00:11:27,190 --> 00:11:24,240
indicating that sulfur oxidizers can

286
00:11:29,670 --> 00:11:27,200
grow under these chemical conditions

287
00:11:31,670 --> 00:11:29,680
however we do not observe this under the

288
00:11:33,990 --> 00:11:31,680

iron iii in rich conditions of hematite

289
00:11:36,630 --> 00:11:34,000
slope where the sulfur oxidizers are in

290
00:11:38,630 --> 00:11:36,640
fact eliminated and substituted by these

291
00:11:40,630 --> 00:11:38,640
sulfate-reducing bacteria with the

292
00:11:43,750 --> 00:11:40,640
reasons why requiring further

293
00:11:47,509 --> 00:11:46,069
in conclusion color peak is an

294
00:11:50,069 --> 00:11:47,519
appropriate analogue for mars in the

295
00:11:52,230 --> 00:11:50,079
late nowakian and it's dominated by

296
00:11:54,550 --> 00:11:52,240
sulfur oxidizing bacteria a metabolic

297
00:11:57,110 --> 00:11:54,560
process that is feasible and proposed