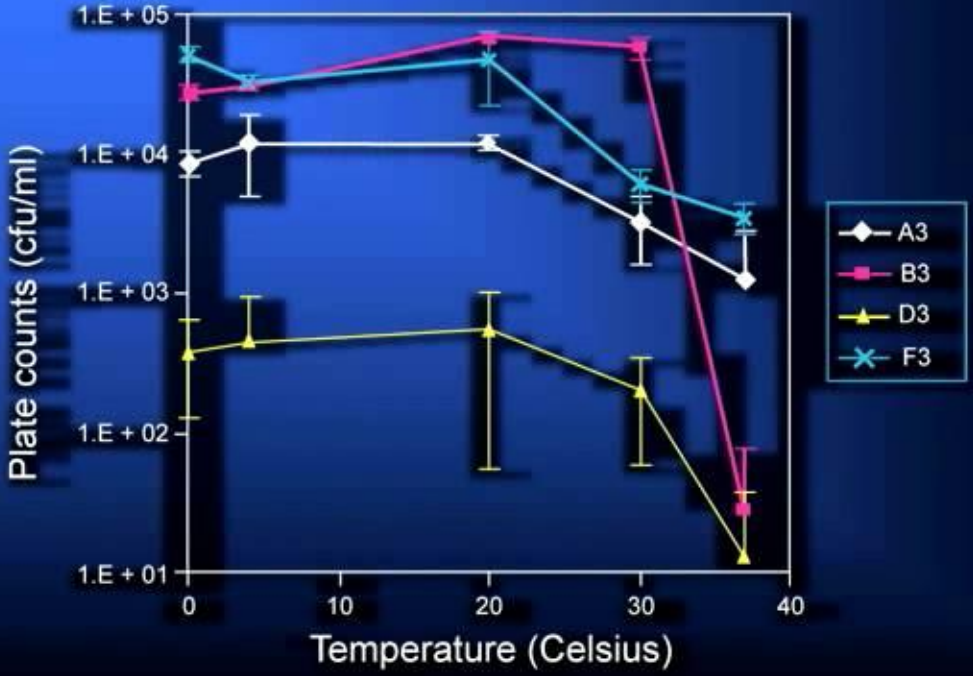
Results from Bakermans, Michigan State University
Temperature characteristics of microbial communities



1
00:00:06,530 --> 00:00:03,160
well good morning or good afternoon

2
00:00:09,169 --> 00:00:06,540
everyone wherever you are it's my great

3
00:00:11,440 --> 00:00:09,179
pleasure to welcome you to the first nai

4
00:00:13,459 --> 00:00:11,450
director seminar of the new year and

5
00:00:16,189 --> 00:00:13,469
this is going to be a particularly

6
00:00:18,620 --> 00:00:16,199
exciting topic because we're going to be

7
00:00:21,290 --> 00:00:18,630
hearing about a subsurface microbial

8
00:00:24,410 --> 00:00:21,300
community that lives under conditions

9
00:00:27,109 --> 00:00:24,420
that might very well obtain on other

10
00:00:28,250 --> 00:00:27,119
planets particularly Mars and we're

11
00:00:31,910 --> 00:00:28,260
going to hear a bit about that

12
00:00:33,740 --> 00:00:31,920
comparison our speakers today are two of

13
00:00:37,869 --> 00:00:33,750

our senior investigators principal

14
00:00:42,530 --> 00:00:37,879
investigator Lisa Pratt and deputy p i

15
00:00:50,090 --> 00:00:42,540
TC onstott of the Indiana of Princeton

16
00:00:52,880 --> 00:00:50,100
Tennessee team lisa is has degrees in

17
00:00:55,580 --> 00:00:52,890
both botany and geology from university

18
00:00:57,709 --> 00:00:55,590
of north carolina and princeton it turns

19
00:00:59,959 --> 00:00:57,719
out which is where her PhD is from as

20
00:01:02,990 --> 00:00:59,969
well as a master's in botany from the

21
00:01:05,479 --> 00:01:03,000
University of Illinois TC has degrees in

22
00:01:08,690 --> 00:01:05,489
geophysics and geology from Caltech and

23
00:01:11,480 --> 00:01:08,700
Princeton University the title of their

24
00:01:13,760 --> 00:01:11,490
talk today is radiolysis of water as a

25
00:01:16,490 --> 00:01:13,770
source of bioavailable energy in the

26
00:01:22,850 --> 00:01:16,500
subsurface of Earth and Mars and I turn

27
00:01:24,740 --> 00:01:22,860
it over to Lisa and TC welcome good I

28
00:01:27,170 --> 00:01:24,750
guess we'll find out now how well the

29
00:01:29,319 --> 00:01:27,180
pickup is working on this polycom is

30
00:01:34,219 --> 00:01:29,329
this loud enough for everybody to hear

31
00:01:36,560 --> 00:01:34,229
we hear you loud and clear wonderful

32
00:01:37,969 --> 00:01:36,570
well we're going to try something a

33
00:01:39,560 --> 00:01:37,979
little different today from the other

34
00:01:46,069 --> 00:01:39,570
directors seminars we're going to try

35
00:01:48,560 --> 00:01:46,079
tag team presentation so every 10 or 15

36
00:01:50,270 --> 00:01:48,570
slides will will switch speakers and

37
00:01:52,700 --> 00:01:50,280
move back and forth so you hear from

38
00:01:54,620 --> 00:01:52,710

both of us although we've we've

39
00:01:57,679 --> 00:01:54,630
interleaved everything into what is

40
00:02:00,700 --> 00:01:57,689
hopefully one coherent presentation so I

41
00:02:03,440 --> 00:02:00,710
think we can just flip by the first

42
00:02:06,499 --> 00:02:03,450
first slide which we've we've already

43
00:02:08,630 --> 00:02:06,509
had introduced and we thought we'd start

44
00:02:11,900 --> 00:02:08,640
by reminding you that this project

45
00:02:15,580 --> 00:02:11,910
actually started prior to

46
00:02:18,110 --> 00:02:15,590
our submission of a proposal to the nai

47
00:02:21,350 --> 00:02:18,120
Institute this project was actually

48
00:02:23,510 --> 00:02:21,360
initially funded by a program at NSF

49
00:02:26,840 --> 00:02:23,520
that no longer is in existence and that

50
00:02:30,290 --> 00:02:26,850
was the lexan program and and really was

51
00:02:33,410 --> 00:02:30,300
a very exciting time when tallest pulled

52
00:02:36,770 --> 00:02:33,420
together a group of collaborators from a

53
00:02:40,090 --> 00:02:36,780
number of universities and institutes

54
00:02:43,250 --> 00:02:40,100
and and convinced a group of people to

55
00:02:44,930 --> 00:02:43,260
go underground in South Africa and use

56
00:02:47,000 --> 00:02:44,940
the infrastructure of these deep and

57
00:02:48,950 --> 00:02:47,010
ultra-deep gold mines as a window into

58
00:02:51,530 --> 00:02:48,960
the deep earth taking advantage of the

59
00:02:54,620 --> 00:02:51,540
fact that under circumstances when they

60
00:02:56,870 --> 00:02:54,630
are doing exploration they have these

61
00:02:59,690 --> 00:02:56,880
water intersections some of them are

62
00:03:02,050 --> 00:02:59,700
quite high pressure the high pressure

63
00:03:04,220 --> 00:03:02,060

flushes the borehole and prevents

64
00:03:06,440 --> 00:03:04,230
contaminants in the mind from moving

65
00:03:09,110 --> 00:03:06,450
into that groundwater so if you can get

66
00:03:11,510 --> 00:03:09,120
a team of scientists on site while the

67
00:03:13,010 --> 00:03:11,520
water is still coming out under high

68
00:03:17,780 --> 00:03:13,020
pressure you have an opportunity to

69
00:03:19,820 --> 00:03:17,790
sample sequestered microbial communities

70
00:03:23,690 --> 00:03:19,830
deep below the surface of the earth and

71
00:03:25,790 --> 00:03:23,700
so that was a project that I guess had

72
00:03:28,430 --> 00:03:25,800
about a three and a half four your

73
00:03:32,390 --> 00:03:28,440
lifeline that right tell us yes right

74
00:03:33,949 --> 00:03:32,400
and it didn't just involve senior people

75
00:03:35,990 --> 00:03:33,959
I think it's important right from the

76
00:03:40,610 --> 00:03:36,000
beginning to say that that there have

77
00:03:43,070 --> 00:03:40,620
been more than more than 20 postdocs and

78
00:03:44,900 --> 00:03:43,080
PhD graduate students at institutions

79
00:03:47,540 --> 00:03:44,910
across the United States and at a number

80
00:03:51,590 --> 00:03:47,550
of schools in Canada who were the ones

81
00:03:54,020 --> 00:03:51,600
that spent many many months living at a

82
00:03:56,449 --> 00:03:54,030
house that we rented in South Africa and

83
00:03:58,490 --> 00:03:56,459
being available day and night so that if

84
00:04:01,130 --> 00:03:58,500
one of the collaborating minds phoned up

85
00:04:03,170 --> 00:04:01,140
and said there's a water intersection we

86
00:04:06,520 --> 00:04:03,180
could get a group of people on site very

87
00:04:08,930 --> 00:04:06,530
very quickly they could take samples

88
00:04:11,360 --> 00:04:08,940

bring the samples back to a laboratory

89
00:04:13,930 --> 00:04:11,370
that we had constructed in the garage of

90
00:04:18,050 --> 00:04:13,940
that house and those samples could be

91
00:04:20,340 --> 00:04:18,060
immediately put into an anaerobic glove

92
00:04:24,420 --> 00:04:20,350
bag a Koi chamber and then

93
00:04:27,230 --> 00:04:24,430
sampled for microbiology the idea behind

94
00:04:29,840 --> 00:04:27,240
that initial study was really to

95
00:04:32,790 --> 00:04:29,850
demonstrate whether or not there were

96
00:04:34,650 --> 00:04:32,800
microbial communities in these deep and

97
00:04:37,650 --> 00:04:34,660
as it turned out quite ancient ground

98
00:04:39,570 --> 00:04:37,660
waters we subsequently then proposed a

99
00:04:42,690 --> 00:04:39,580
continuation of this research moving

100
00:04:44,910 --> 00:04:42,700
into the Arctic which seemed to be a

101
00:04:47,850 --> 00:04:44,920
better analogue for life on other

102
00:04:49,980 --> 00:04:47,860
planets and icy moons and that that was

103
00:04:53,600 --> 00:04:49,990
the project that became the if thi the

104
00:04:56,190 --> 00:04:53,610
Indiana Princeton Tennessee astrobiology

105
00:04:58,260 --> 00:04:56,200
collaboration and and that the idea

106
00:05:00,060 --> 00:04:58,270
there was to again use the

107
00:05:03,320 --> 00:05:00,070
infrastructure of mines to get into the

108
00:05:06,080 --> 00:05:03,330
subsurface and to look at groundwater

109
00:05:08,160 --> 00:05:06,090
microbial ecosystems that had been

110
00:05:10,830 --> 00:05:08,170
sequestered from contact with the

111
00:05:14,040 --> 00:05:10,840
surface for thousands to millions of

112
00:05:17,190 --> 00:05:14,050
years and to take what we learned with

113
00:05:18,840 --> 00:05:17,200

those kinds of samples and use it to

114
00:05:20,910 --> 00:05:18,850
inform us about what kinds of

115
00:05:24,030 --> 00:05:20,920
instruments might be suitable for landed

116
00:05:26,370 --> 00:05:24,040
missions to Mars as a way of thinking

117
00:05:29,190 --> 00:05:26,380
about life detection within the

118
00:05:32,040 --> 00:05:29,200
permafrost and in brines below the

119
00:05:33,630 --> 00:05:32,050
permafrost so what we're going to do

120
00:05:36,240 --> 00:05:33,640
today is we're going to talk about three

121
00:05:39,780 --> 00:05:36,250
aspects of that research first the work

122
00:05:42,510 --> 00:05:39,790
that was done in the deep and ultra-deep

123
00:05:44,970 --> 00:05:42,520
South African gold mines then to talk

124
00:05:46,950 --> 00:05:44,980
about the work that has been done at

125
00:05:49,320 --> 00:05:46,960
lupin mine in the Canadian Arctic and

126
00:05:51,570 --> 00:05:49,330
finally to end with a little update on

127
00:05:53,940 --> 00:05:51,580
where we are with the scientific

128
00:05:56,850 --> 00:05:53,950
borehole at high lake in the Arctic so

129
00:05:58,890 --> 00:05:56,860
we'll we'll start with South Africa I'll

130
00:06:01,400 --> 00:05:58,900
introduce a little bit about the overall

131
00:06:04,200 --> 00:06:01,410
geology and then TC will talk about the

132
00:06:08,460 --> 00:06:04,210
microbiology of the sample so here's a

133
00:06:11,370 --> 00:06:08,470
simplified geologic map of of the of the

134
00:06:13,430 --> 00:06:11,380
South African witwatersrand Basin you

135
00:06:16,770 --> 00:06:13,440
can see it here it's a relatively

136
00:06:18,720 --> 00:06:16,780
undeformed basin for an ancient basin

137
00:06:21,090 --> 00:06:18,730
and you can see that the gold deposits

138
00:06:23,820 --> 00:06:21,100

here shown by this yellow gold fields

139
00:06:26,340 --> 00:06:23,830
color are primarily located around the

140
00:06:28,440 --> 00:06:26,350
margin of the basin at the contact

141
00:06:30,550 --> 00:06:28,450
between the central rand group and the

142
00:06:33,920 --> 00:06:30,560
west rand group

143
00:06:36,640 --> 00:06:33,930
there are a number of minds that have

144
00:06:39,499 --> 00:06:36,650
been operated for a long period of time

145
00:06:42,559 --> 00:06:39,509
decades and many of these older minds

146
00:06:44,119 --> 00:06:42,569
now extend as deep as four kilometers

147
00:06:47,210 --> 00:06:44,129
below the surface although most of the

148
00:06:50,059 --> 00:06:47,220
mining activity is between two and three

149
00:06:51,830 --> 00:06:50,069
point five kilometers so you can you can

150
00:06:54,619 --> 00:06:51,840
see from this photograph which was taken

151
00:06:58,040 --> 00:06:54,629
at the evander mind that the access to

152
00:07:00,409 --> 00:06:58,050
these underground excavations is really

153
00:07:02,149 --> 00:07:00,419
little changed from the 1800s there's a

154
00:07:03,980 --> 00:07:02,159
head frame there's a flywheel there's a

155
00:07:06,350 --> 00:07:03,990
cable there's a steel box you step into

156
00:07:09,680 --> 00:07:06,360
the steel box somebody releases the

157
00:07:14,600 --> 00:07:09,690
brake on the cable and you you you drop

158
00:07:17,689 --> 00:07:14,610
at 40 to 60 kilometers an hour into the

159
00:07:19,640 --> 00:07:17,699
subsurface interestingly enough it

160
00:07:21,379 --> 00:07:19,650
really the cage is the only part of the

161
00:07:23,719 --> 00:07:21,389
trip that's some particularly

162
00:07:26,330 --> 00:07:23,729
uncomfortable because they they jam you

163
00:07:28,159 --> 00:07:26,340

into the PAC's like sardines and the

164
00:07:30,260 --> 00:07:28,169
scientists really only have access to

165
00:07:32,659 --> 00:07:30,270
the mines as part of the cruise shift so

166
00:07:34,999 --> 00:07:32,669
we go we go in and out with the with the

167
00:07:36,649 --> 00:07:35,009
miners when you step out underground

168
00:07:39,740 --> 00:07:36,659
there's really other than the fact that

169
00:07:43,610 --> 00:07:39,750
it's a cozy and warm and humid there's

170
00:07:45,920 --> 00:07:43,620
not very dark yes melon oh smelly yeah

171
00:07:48,230 --> 00:07:45,930
there would be that but it's it's really

172
00:07:50,779 --> 00:07:48,240
not a particularly unpleasant place to

173
00:07:53,689 --> 00:07:50,789
be and you you then hike to wear these

174
00:07:56,800 --> 00:07:53,699
water intersections are and go about

175
00:08:00,409 --> 00:07:56,810
your business of collecting samples

176
00:08:03,740 --> 00:08:00,419
again the people who work there full

177
00:08:05,920 --> 00:08:03,750
time are are working in some of the

178
00:08:07,879 --> 00:08:05,930
tight spaces and the the crease

179
00:08:10,040 --> 00:08:07,889
so-called for the fact that they don't

180
00:08:11,809 --> 00:08:10,050
open it up very wide where the

181
00:08:13,550 --> 00:08:11,819
excavations are extended right up to the

182
00:08:16,279 --> 00:08:13,560
ore body and you see here a group of

183
00:08:18,140 --> 00:08:16,289
miners right at the thread at the active

184
00:08:21,830 --> 00:08:18,150
face and you'll notice that they're

185
00:08:23,659 --> 00:08:21,840
there they're seated and behind the

186
00:08:26,360 --> 00:08:23,669
shoulder of the guy on the left side you

187
00:08:27,950 --> 00:08:26,370
can see a stack of wooden logs and those

188
00:08:29,779 --> 00:08:27,960

wooden log stacks are the only thing

189
00:08:31,730 --> 00:08:29,789
that hold open the crease during mining

190
00:08:34,100 --> 00:08:31,740
activities and although some of our

191
00:08:36,139 --> 00:08:34,110
samples were up in these tight places

192
00:08:39,620 --> 00:08:36,149
for the most part the areas where we

193
00:08:41,810 --> 00:08:39,630
sampled were areas where the the tunnels

194
00:08:42,830 --> 00:08:41,820
or the drives had been opened up to a

195
00:08:44,960 --> 00:08:42,840
slightly larger

196
00:08:47,720 --> 00:08:44,970
for the most part we were we were able

197
00:08:53,270 --> 00:08:47,730
to work in a comfortable standing

198
00:08:54,710 --> 00:08:53,280
position the idea behind what we did as

199
00:08:56,960 --> 00:08:54,720
I mentioned a minute ago as we took

200
00:08:59,060 --> 00:08:56,970
advantage of water intersections during

201
00:09:01,690 --> 00:08:59,070
primarily exploration activities

202
00:09:03,950 --> 00:09:01,700
although sometimes we went to sites of

203
00:09:05,710 --> 00:09:03,960
historic water intersections where the

204
00:09:08,150 --> 00:09:05,720
mines had continued to be unable to

205
00:09:09,890 --> 00:09:08,160
control the flow of water into the mind

206
00:09:11,390 --> 00:09:09,900
so in many cases these were parts of the

207
00:09:15,770 --> 00:09:11,400
mines they were getting ready to abandon

208
00:09:17,480 --> 00:09:15,780
and and we would be allowed in you know

209
00:09:19,370 --> 00:09:17,490
often under rather unpleasant

210
00:09:21,170 --> 00:09:19,380
circumstances because hot water was

211
00:09:23,150 --> 00:09:21,180
building up on the floor of the mine

212
00:09:25,970 --> 00:09:23,160
most of these water intersections are

213
00:09:27,350 --> 00:09:25,980

quite gassy that dissolved gases are

214
00:09:30,050 --> 00:09:27,360
often ones you don't want to breathe

215
00:09:35,080 --> 00:09:30,060
like methane and carbon monoxide and

216
00:09:38,030 --> 00:09:35,090
hydrogen sulfide and hydrogen and

217
00:09:39,650 --> 00:09:38,040
ammonia you name it not not a blend that

218
00:09:43,460 --> 00:09:39,660
you really want to be inhaling with any

219
00:09:45,500 --> 00:09:43,470
regularity so the trick was to work very

220
00:09:48,260 --> 00:09:45,510
closely with the mine owners to ensure

221
00:09:51,890 --> 00:09:48,270
that they could ventilate these these

222
00:09:53,570 --> 00:09:51,900
areas where waters were coming in and

223
00:09:55,700 --> 00:09:53,580
ventilate them enough that we could

224
00:09:59,480 --> 00:09:55,710
safely breathe the air that we could

225
00:10:02,720 --> 00:09:59,490
keep the level of methane well below the

226
00:10:04,460 --> 00:10:02,730
explosive limit and where we could stay

227
00:10:07,010 --> 00:10:04,470
cool enough that we could function for

228
00:10:09,340 --> 00:10:07,020
more than four more than a few minutes

229
00:10:13,100 --> 00:10:09,350
so you're looking here at a particular

230
00:10:18,380 --> 00:10:13,110
installation of cartridges that that a

231
00:10:20,870 --> 00:10:18,390
group of us did at a site that was 3.2

232
00:10:22,760 --> 00:10:20,880
kilometers below the surface those are

233
00:10:24,590 --> 00:10:22,770
Tullus hands in the upper photograph

234
00:10:26,690 --> 00:10:24,600
loading the cartridges getting ready to

235
00:10:29,960 --> 00:10:26,700
put them into an autoclave and down at

236
00:10:32,150 --> 00:10:29,970
the bottom is is what I would what I

237
00:10:36,920 --> 00:10:32,160
look like when I'm working in a room

238
00:10:39,440 --> 00:10:36,930

that's 120 degrees c and mohsin yeah not

239
00:10:42,170 --> 00:10:39,450
not see pardon me we did not we did not

240
00:10:44,960 --> 00:10:42,180
not break the laws of nature no this was

241
00:10:47,480 --> 00:10:44,970
that was Fahrenheit it was a very warm

242
00:10:49,640 --> 00:10:47,490
place we we found that we could be on

243
00:10:52,460 --> 00:10:49,650
site for 15 to 20 minutes before we

244
00:10:54,050 --> 00:10:52,470
started to get impossibly clumsy we'd

245
00:10:55,010 --> 00:10:54,060
hike back out to a cooler site and go

246
00:10:57,320 --> 00:10:55,020
back in but

247
00:10:59,840 --> 00:10:57,330
you can see over my shoulder one of the

248
00:11:01,100 --> 00:10:59,850
cartridges that tell us was felis was

249
00:11:02,450 --> 00:11:01,110
loading up here so there are the

250
00:11:04,370 --> 00:11:02,460
cartridges and now you can see it

251
00:11:08,330 --> 00:11:04,380
installed right here with a set of

252
00:11:10,040 --> 00:11:08,340
blowout valves and some flow meters we

253
00:11:11,330 --> 00:11:10,050
did the installation we left it for

254
00:11:13,850 --> 00:11:11,340
several days then we went back and

255
00:11:15,860 --> 00:11:13,860
harvested the filters read the flow

256
00:11:17,870 --> 00:11:15,870
meter to see how much how much water had

257
00:11:20,090 --> 00:11:17,880
moved through the filters therefore when

258
00:11:22,070 --> 00:11:20,100
we when we open these up and measure the

259
00:11:24,260 --> 00:11:22,080
amount of biomass on them we can then

260
00:11:27,770 --> 00:11:24,270
quantify the biomass per liter of

261
00:11:29,690 --> 00:11:27,780
filtered water the types of waters that

262
00:11:32,360 --> 00:11:29,700
we were filtering in these mines varied

263
00:11:35,150 --> 00:11:32,370

from from fresh to brackish and in some

264
00:11:37,640 --> 00:11:35,160
cases quite saline you can see a wide

265
00:11:39,470 --> 00:11:37,650
wide range of values here these are the

266
00:11:42,620 --> 00:11:39,480
mines where we took the majority of our

267
00:11:45,080 --> 00:11:42,630
of our samples an impending mine of

268
00:11:48,770 --> 00:11:45,090
course is the the mind where the sample

269
00:11:51,260 --> 00:11:48,780
that was recently described in the paper

270
00:11:53,570 --> 00:11:51,270
in science that's where that sample came

271
00:11:55,520 --> 00:11:53,580
from and you can see that was a quite

272
00:11:58,180 --> 00:11:55,530
brackish sample compared to the full

273
00:12:01,280 --> 00:11:58,190
range of what's available in these mines

274
00:12:06,760 --> 00:12:01,290
so I'm now going to turn it over to tell

275
00:12:11,840 --> 00:12:08,840
microbiology described in the science

276
00:12:14,180 --> 00:12:11,850
paper but to also talk about the work

277
00:12:20,630 --> 00:12:14,190
that's been done since then since then

278
00:12:23,570 --> 00:12:20,640
on these samples right so one of the

279
00:12:26,810 --> 00:12:23,580
things that we noticed when we were

280
00:12:30,650 --> 00:12:26,820
characterizing the Fulani of the

281
00:12:33,080 --> 00:12:30,660
different microbial filters from these

282
00:12:37,070 --> 00:12:33,090
different sites well is that the deeper

283
00:12:40,180 --> 00:12:37,080
we went the lower the diversity we were

284
00:12:42,080 --> 00:12:40,190
seeing archaea like methanogens and

285
00:12:44,450 --> 00:12:42,090
proteobacteria in the shallower sites

286
00:12:47,210 --> 00:12:44,460
but as we went deeper hotter more say

287
00:12:49,210 --> 00:12:47,220
line and more ancient fracture fluids

288
00:12:52,490 --> 00:12:49,220

and these are adepts greater than about

289
00:12:55,370 --> 00:12:52,500
two kilometers temperatures greater than

290
00:12:59,180 --> 00:12:55,380
about 45 degrees C we saw the diversity

291
00:13:02,650 --> 00:12:59,190
narrow to a philo a bacteria known as

292
00:13:05,199 --> 00:13:02,660
gram-positive bacteria or the firmicutes

293
00:13:09,759 --> 00:13:05,209
and in particular across the entire base

294
00:13:11,889 --> 00:13:09,769
and we started seeing one organism which

295
00:13:14,530 --> 00:13:11,899
appeared to be a sulfate-reducing type

296
00:13:17,860 --> 00:13:14,540
of organism based upon the phylogenetic

297
00:13:20,980 --> 00:13:17,870
assignment that was present and even in

298
00:13:22,360 --> 00:13:20,990
many cases predominant in the club what

299
00:13:24,400 --> 00:13:22,370
we call the clone library now we're

300
00:13:28,869 --> 00:13:24,410
characterizing the diversity of the

301
00:13:31,749 --> 00:13:28,879
bacteria in these environments now one

302
00:13:34,179 --> 00:13:31,759
of the advantages of being able to

303
00:13:36,819 --> 00:13:34,189
filter thousands of litres in some cases

304
00:13:39,759 --> 00:13:36,829
tens of thousands of liters of water is

305
00:13:42,759 --> 00:13:39,769
that you can accrue enough mass on the

306
00:13:45,040 --> 00:13:42,769
filter that you can then do a meta

307
00:13:48,490 --> 00:13:45,050
genomic analysis and in this case it was

308
00:13:51,460 --> 00:13:48,500
essential because after several years of

309
00:13:54,460 --> 00:13:51,470
attempting to enrich and isolate this

310
00:13:57,730 --> 00:13:54,470
organism we had failed basically using

311
00:14:00,550 --> 00:13:57,740
different types of media so what we

312
00:14:03,939 --> 00:14:00,560
could do under the peptide collaboration

313
00:14:07,449 --> 00:14:03,949

Isabel ourselves of the facilities that

314
00:14:10,420 --> 00:14:07,459
were present in Lawrence Berkeley

315
00:14:14,230 --> 00:14:10,430
Laboratory through the supervision of

316
00:14:17,559 --> 00:14:14,240
Terry Hazen there and Adam Arkin's group

317
00:14:19,240 --> 00:14:17,569
as well to do a meta genomic analysis

318
00:14:22,920 --> 00:14:19,250
the sequencing was performed by the

319
00:14:25,689 --> 00:14:22,930
joint genomics Institute and various

320
00:14:31,030 --> 00:14:25,699
extraction procedures were developed by

321
00:14:33,429 --> 00:14:31,040
the Pacific Northwest National Lab this

322
00:14:37,090 --> 00:14:33,439
was applied to one borehole in

323
00:14:41,679 --> 00:14:37,100
particular a timpani mine which was

324
00:14:44,230 --> 00:14:41,689
fairly hot and it was intersected at 2.8

325
00:14:46,269 --> 00:14:44,240
kilometers but in fact it was probably

326
00:14:49,329 --> 00:14:46,279
appearing from about four kilometers

327
00:14:52,689 --> 00:14:49,339
based upon the hydrogen isotope analyses

328
00:14:54,309 --> 00:14:52,699
when it's in isotopic equilibrium with

329
00:14:58,780 --> 00:14:54,319
water it provides the temperature

330
00:15:01,660 --> 00:14:58,790
estimate it's a fairly alkaline water

331
00:15:04,960 --> 00:15:01,670
about ph 9.3 which is important and that

332
00:15:07,809 --> 00:15:04,970
is again fairly typical of these deepest

333
00:15:11,769 --> 00:15:07,819
waters there's methane in this water as

334
00:15:14,519 --> 00:15:11,779
well as low carbon number hydrocarbons

335
00:15:17,639 --> 00:15:14,529
and the isotopic analyses

336
00:15:19,499 --> 00:15:17,649
Barbara Sherwood Lawler's lavin

337
00:15:21,360 --> 00:15:19,509
University anto indicates that it's a a

338
00:15:24,119 --> 00:15:21,370

biogenic methane source not amith

339
00:15:25,860 --> 00:15:24,129
antigenic methane but a biogenic Lee

340
00:15:27,809 --> 00:15:25,870
generated hydrocarbons which is

341
00:15:30,679 --> 00:15:27,819
something that we typically encountered

342
00:15:33,299 --> 00:15:30,689
at the deepest levels in South Africa

343
00:15:35,519 --> 00:15:33,309
the bulk edge of the water varied from

344
00:15:37,860 --> 00:15:35,529
15 to 25 million years depending upon

345
00:15:40,379 --> 00:15:37,870
what isotopic system you are using to

346
00:15:44,549 --> 00:15:40,389
date these waters we are looking at a

347
00:15:47,100 --> 00:15:44,559
helium to xenon radiogenic ages and this

348
00:15:50,910 --> 00:15:47,110
was performed by our colleague joanna

349
00:15:53,579 --> 00:15:50,920
Lippmann who is now at the GFC Austin

350
00:15:56,340 --> 00:15:53,589
Germany the predominant electron donor

351
00:15:58,650 --> 00:15:56,350
in the system as was many oftentimes the

352
00:16:00,900 --> 00:15:58,660
case in South Africa the deepest levels

353
00:16:03,509 --> 00:16:00,910
of hydrogen very high levels and the

354
00:16:05,759 --> 00:16:03,519
predominant electron acceptor again a

355
00:16:07,290 --> 00:16:05,769
sulphate which was quite common when we

356
00:16:10,889 --> 00:16:07,300
got to the deepest levels in South

357
00:16:12,720 --> 00:16:10,899
Africa the isotopic analyses performed

358
00:16:14,249 --> 00:16:12,730
by Lisa indicated that it was

359
00:16:16,230 --> 00:16:14,259
fractionated in a way that was

360
00:16:19,439 --> 00:16:16,240
consistent with microbial sulfate

361
00:16:22,650 --> 00:16:19,449
reduction and this is the environment

362
00:16:24,990 --> 00:16:22,660
which again was dominated by our what we

363
00:16:29,400 --> 00:16:25,000

had called the diso photo baculum like

364
00:16:33,329 --> 00:16:29,410
organism diello it dominated ninety-four

365
00:16:36,269 --> 00:16:33,339
percent of the clone library that was

366
00:16:40,829 --> 00:16:36,279
present in this particular borehole its

367
00:16:44,309 --> 00:16:40,839
closest environmental clone was actually

368
00:16:47,220 --> 00:16:44,319
discovered by James Cohen in ac4 vent so

369
00:16:48,809 --> 00:16:47,230
it bears at least phylogenetic

370
00:16:51,590 --> 00:16:48,819
relationships some similarities to what

371
00:16:55,259 --> 00:16:51,600
has been found in an old ocean floor

372
00:16:57,869 --> 00:16:55,269
rocks now with a cell density of to the

373
00:17:00,749 --> 00:16:57,879
eighth per liter and we essentially

374
00:17:03,960 --> 00:17:00,759
filtered 5,000 litres we were able to

375
00:17:07,799 --> 00:17:03,970
get up to 10 to the 12th in terms of

376
00:17:09,510 --> 00:17:07,809
some number cells we've completed the

377
00:17:13,409 --> 00:17:09,520
genomic analysis we were able to

378
00:17:17,669 --> 00:17:13,419
actually close the G the genome for this

379
00:17:19,799 --> 00:17:17,679
organism and are able to assign various

380
00:17:21,809 --> 00:17:19,809
attributes to it we've given it a

381
00:17:24,670 --> 00:17:21,819
candidate name of discipline rudis on

382
00:17:26,860 --> 00:17:24,680
tax theatre which is species name is

383
00:17:30,940 --> 00:17:26,870
upon the note that was written by Arnold

384
00:17:32,950 --> 00:17:30,950
sort Arnold sack nursin to the the party

385
00:17:35,470 --> 00:17:32,960
that descended into the crater and isand

386
00:17:38,620 --> 00:17:35,480
on the journey to the center of jules

387
00:17:40,300 --> 00:17:38,630
verne's novel the cell ruedas comes from

388
00:17:42,880 --> 00:17:40,310

latin for the rod-like morphology of

389
00:17:47,320 --> 00:17:42,890
this creature and obviously its capacity

390
00:17:49,900 --> 00:17:47,330
to reduce sulfate this is a depiction of

391
00:17:52,300 --> 00:17:49,910
the organism a cartoon-like depiction of

392
00:17:55,830 --> 00:17:52,310
all of its so potential capabilities

393
00:17:59,740 --> 00:17:55,840
based upon the genome analysis as about

394
00:18:03,270 --> 00:17:59,750
see we got here description nope okay as

395
00:18:06,870 --> 00:18:03,280
about 2.4 mega base pairs and about 2200

396
00:18:09,550 --> 00:18:06,880
protein-coding genomes present in it

397
00:18:11,230 --> 00:18:09,560
it's obviously too complicated to go

398
00:18:13,390 --> 00:18:11,240
through all of these but the bottom line

399
00:18:15,180 --> 00:18:13,400
here is that the organism is not

400
00:18:19,870 --> 00:18:15,190
streamlined in any way it actually

401
00:18:22,990 --> 00:18:19,880
carries a very metabolically plastic

402
00:18:25,650 --> 00:18:23,000
genome it's capable both the substrate

403
00:18:28,650 --> 00:18:25,660
level phosphorylation so it can it can

404
00:18:32,320 --> 00:18:28,660
live upon a substrate of sugars or

405
00:18:34,270 --> 00:18:32,330
aromatic hydrocarbons but if those are

406
00:18:37,630 --> 00:18:34,280
not present it can also utilize an

407
00:18:40,900 --> 00:18:37,640
acetyl coenzyme a system to live off of

408
00:18:45,250 --> 00:18:40,910
hydrogen and co2 or carbon monoxide and

409
00:18:49,360 --> 00:18:45,260
produce acetate as well in fact it has

410
00:18:51,430 --> 00:18:49,370
two types of acetyl coenzyme A's one of

411
00:18:55,750 --> 00:18:51,440
which appears to be a transplant from

412
00:18:57,460 --> 00:18:55,760
RKO organism that utilizes formate in

413
00:19:02,200 --> 00:18:57,470

its system which is interesting in

414
00:19:06,640 --> 00:19:02,210
itself it's capable of fixing nitrogen

415
00:19:10,420 --> 00:19:06,650
through an FB eh system or can utilize

416
00:19:12,640 --> 00:19:10,430
ammonia as well it has hydrogenases

417
00:19:14,860 --> 00:19:12,650
three different types of hydrogenases in

418
00:19:18,400 --> 00:19:14,870
fact and so that makes sense in terms of

419
00:19:20,650 --> 00:19:18,410
hydrogen electron donor and it has an

420
00:19:24,340 --> 00:19:20,660
electron transport chain which is

421
00:19:27,760 --> 00:19:24,350
strictly forced sulfate reduction it has

422
00:19:29,310 --> 00:19:27,770
the sodium sulfate transporter systems

423
00:19:33,840 --> 00:19:29,320
as well as

424
00:19:37,529 --> 00:19:33,850
a variety of sodium proton anti Porter's

425
00:19:42,690 --> 00:19:37,539
present as well as a sodium ATP a system

426
00:19:45,600 --> 00:19:42,700
and so these attributes the ATP direct

427
00:19:48,269 --> 00:19:45,610
ATP production by sulfate reduction and

428
00:19:50,940 --> 00:19:48,279
hospitalization plus any Porter's needs

429
00:19:54,720 --> 00:19:50,950
that it has the ability to work well in

430
00:19:56,970 --> 00:19:54,730
a high pH environment even without if it

431
00:19:59,759 --> 00:19:56,980
were not able to maintain a proton

432
00:20:02,060 --> 00:19:59,769
gradient the other thing that's

433
00:20:05,789 --> 00:20:02,070
interesting about it is that it has

434
00:20:09,090 --> 00:20:05,799
chemoreceptors and flagella machinery so

435
00:20:11,999 --> 00:20:09,100
it is appears to be chemotactic as to

436
00:20:15,990 --> 00:20:12,009
why it's chemotactic or what what that

437
00:20:19,230 --> 00:20:16,000
involves it with what properties that

438
00:20:22,769 --> 00:20:19,240

gives it that chemotaxis provides it is

439
00:20:24,509 --> 00:20:22,779
not entirely clear at this moment I want

440
00:20:27,600 --> 00:20:24,519
to describe a little photomicrograph oh

441
00:20:29,970 --> 00:20:27,610
yeah the right hand of the in the lower

442
00:20:33,749 --> 00:20:29,980
right hand corner is a sem image of the

443
00:20:35,730 --> 00:20:33,759
filter itself which shows the shape and

444
00:20:41,249 --> 00:20:35,740
the size of the bacterium on the on the

445
00:20:43,310 --> 00:20:41,259
filter there now from an evolutionary

446
00:20:46,740 --> 00:20:43,320
point of view it's kind of interesting

447
00:20:48,509 --> 00:20:46,750
where this organism lies as i mentioned

448
00:20:50,369 --> 00:20:48,519
earlier it's in the Firmicutes this is a

449
00:20:54,440 --> 00:20:50,379
microbial tree that was published last

450
00:20:56,430 --> 00:20:54,450
year by ciccarelli that's based upon 31

451
00:20:59,159 --> 00:20:56,440
orthologue asst genes that are

452
00:21:00,869 --> 00:20:59,169
associated with ribosomes and has been

453
00:21:03,720 --> 00:21:00,879
corrected for horizontal gene transfer

454
00:21:06,930 --> 00:21:03,730
so in this particular diagram you'll see

455
00:21:10,080 --> 00:21:06,940
the big lavender color domain there

456
00:21:12,570 --> 00:21:10,090
represents all the bacteria the pinkish

457
00:21:16,200 --> 00:21:12,580
color domain it's in the northeastern

458
00:21:18,539 --> 00:21:16,210
corner over here are the eukaryotes and

459
00:21:21,119 --> 00:21:18,549
these are the RKO over here so most of

460
00:21:23,730 --> 00:21:21,129
the genome sequences here represented in

461
00:21:25,560 --> 00:21:23,740
this diagram are for bacteria and this

462
00:21:26,730 --> 00:21:25,570
is based upon compete genomes that have

463
00:21:29,249 --> 00:21:26,740

been published at the time of this

464
00:21:30,930 --> 00:21:29,259
article now we're going to focus on the

465
00:21:32,430 --> 00:21:30,940
region where our organism lies which is

466
00:21:34,440 --> 00:21:32,440
right down here it's in the deepest

467
00:21:36,029 --> 00:21:34,450
route or the deepest branch of the

468
00:21:38,190 --> 00:21:36,039
bacterial domain

469
00:21:41,190 --> 00:21:38,200
we blow it up a little bit and you'll

470
00:21:42,779 --> 00:21:41,200
see that if we look at it in red here

471
00:21:45,359 --> 00:21:42,789
the branches that are going from the

472
00:21:47,820 --> 00:21:45,369
shortest branch in arcade domain which

473
00:21:50,450 --> 00:21:47,830
is pyrococcus abyss I which turns out is

474
00:21:53,999 --> 00:21:50,460
present in the South African subsurface

475
00:21:56,340 --> 00:21:54,009
over to where most of our firmicutes lie

476
00:21:58,469 --> 00:21:56,350
in the deepest parts of South Africa

477
00:22:02,279 --> 00:21:58,479
they lie on this short branch here very

478
00:22:05,190 --> 00:22:02,289
close to thermal lateral vector time

479
00:22:09,779 --> 00:22:05,200
Kong djinnis as well as imaging over

480
00:22:10,919 --> 00:22:09,789
here clostridium perfringens now when

481
00:22:12,719 --> 00:22:10,929
you look at the subsurface the

482
00:22:14,999 --> 00:22:12,729
continental subsurface across the planet

483
00:22:16,830 --> 00:22:15,009
we frequently encounter pretty confirmed

484
00:22:20,159 --> 00:22:16,840
kids that lie in this little cluster

485
00:22:22,879 --> 00:22:20,169
right over here and where does our

486
00:22:25,710 --> 00:22:22,889
diesel rudisill doxy be a hater occur

487
00:22:29,609 --> 00:22:25,720
this is just a when you look at the more

488
00:22:31,950 --> 00:22:29,619

recent compilation of complete sequence

489
00:22:33,539 --> 00:22:31,960
genomes and this is a protein tree here

490
00:22:35,879 --> 00:22:33,549
that's why you're showing like amino

491
00:22:38,070 --> 00:22:35,889
acid identity here here's the deepest

492
00:22:40,710 --> 00:22:38,080
rooted in the previous tree and here's

493
00:22:43,139 --> 00:22:40,720
our d sulfur Reuters on tax evader along

494
00:22:46,229 --> 00:22:43,149
with the Clostridium perfringens over

495
00:22:48,830 --> 00:22:46,239
here so it seems to indicate that the

496
00:22:51,539 --> 00:22:48,840
organism is not only a diverter

497
00:22:53,969 --> 00:22:51,549
metabolic sleep metabolic plastic it

498
00:22:56,159 --> 00:22:53,979
also is appears to be an ancient lineage

499
00:22:57,989 --> 00:22:56,169
and it could be that these deep

500
00:23:00,479 --> 00:22:57,999
subsurface environments of are in fact

501
00:23:02,669 --> 00:23:00,489
providing an environment that is

502
00:23:04,139 --> 00:23:02,679
somewhat representative of the early

503
00:23:06,269 --> 00:23:04,149
Earth perhaps preserving that

504
00:23:08,430 --> 00:23:06,279
environment therefore selectively

505
00:23:10,499 --> 00:23:08,440
preserving or enriching for these

506
00:23:11,940 --> 00:23:10,509
ancient organisms there are several

507
00:23:13,950 --> 00:23:11,950
other things present in this organism

508
00:23:16,409 --> 00:23:13,960
it's capable of sporulation germination

509
00:23:19,320 --> 00:23:16,419
and like its close relative Morello

510
00:23:21,539 --> 00:23:19,330
thermo cityca this may provide a thermal

511
00:23:23,879 --> 00:23:21,549
tolerance mechanism for it as well as

512
00:23:26,700 --> 00:23:23,889
heat shock proteins and pilots for

513
00:23:28,710 --> 00:23:26,710

machinery now it's a planktonic organism

514
00:23:30,379 --> 00:23:28,720
and what we don't know because we are

515
00:23:32,909 --> 00:23:30,389
working with filtered water samples is

516
00:23:35,519 --> 00:23:32,919
how abundant is present on the rock

517
00:23:38,339 --> 00:23:35,529
surfaces itself and the pilots forming

518
00:23:39,839 --> 00:23:38,349
machinery are important that regard the

519
00:23:42,359 --> 00:23:39,849
other interesting aspect about it is

520
00:23:45,239 --> 00:23:42,369
that it has a dearth of oxy o reductase

521
00:23:46,799 --> 00:23:45,249
genes so essentially a lot of the oxygen

522
00:23:47,840 --> 00:23:46,809
tolerance genes that are present

523
00:23:51,330 --> 00:23:47,850
other sulfate-reducing bacteria

524
00:23:53,009 --> 00:23:51,340
including morale thermostatic odors not

525
00:23:55,590 --> 00:23:53,019
a self introducing organism but it's a

526
00:23:57,210 --> 00:23:55,600
close relative are absent in de selva

527
00:24:01,019 --> 00:23:57,220
route is on dock speaker which suggests

528
00:24:05,879 --> 00:24:01,029
that has been in an obligate admirable

529
00:24:08,489 --> 00:24:05,889
environment for quite a long time most

530
00:24:10,950 --> 00:24:08,499
important question however is why

531
00:24:13,049 --> 00:24:10,960
sulfate it's in a very deep isolate

532
00:24:14,610 --> 00:24:13,059
environment it's obviously chosen

533
00:24:17,879 --> 00:24:14,620
sulfate is the principal electron

534
00:24:20,430 --> 00:24:17,889
acceptor where's the sulfate coming from

535
00:24:23,549 --> 00:24:20,440
in this environment why isn't it the

536
00:24:27,330 --> 00:24:23,559
peated now I'll turn the answer that

537
00:24:30,330 --> 00:24:27,340
question so and so here we are switching

538
00:24:33,379 --> 00:24:30,340

up again just keep you on your toes it

539
00:24:37,919 --> 00:24:33,389
really was a perplexing question because

540
00:24:39,720 --> 00:24:37,929
normally when we see sulfate brines we

541
00:24:42,090 --> 00:24:39,730
think in terms of either some sort of an

542
00:24:45,029 --> 00:24:42,100
evaporative ly concentrated marine water

543
00:24:49,080 --> 00:24:45,039
or some sort of a saline alkaline Lake

544
00:24:51,749 --> 00:24:49,090
or perhaps there are evaporites in the

545
00:24:53,700 --> 00:24:51,759
section that have been dissolved by the

546
00:24:56,879 --> 00:24:53,710
by the groundwater but in the case of

547
00:24:58,830 --> 00:24:56,889
these deep south african locations none

548
00:25:02,940 --> 00:24:58,840
of those appeared likely none of those

549
00:25:05,399 --> 00:25:02,950
options even appeared reasonable and we

550
00:25:07,710 --> 00:25:05,409
began to be quite concerned that that we

551
00:25:10,529 --> 00:25:07,720
did not have an identifiable source of

552
00:25:12,419 --> 00:25:10,539
sulfate to sustain the metabolism of

553
00:25:15,299 --> 00:25:12,429
these organisms what we did have though

554
00:25:18,359 --> 00:25:15,309
was a great deal of pyrite on in the

555
00:25:22,200 --> 00:25:18,369
section and because these are very

556
00:25:24,149 --> 00:25:22,210
ancient sand stones and conglomerates it

557
00:25:26,190 --> 00:25:24,159
also had a significant amount of to

558
00:25:28,710 --> 00:25:26,200
trial uraninite and we began to wonder

559
00:25:31,499 --> 00:25:28,720
if there was some some potential

560
00:25:33,749 --> 00:25:31,509
coupling between the radioactivity from

561
00:25:37,560 --> 00:25:33,759
the uraninite grains and the pyrite

562
00:25:40,259 --> 00:25:37,570
grains and so because we we had we had a

563
00:25:42,989 --> 00:25:40,269

lot of stable sulfur isotopic data on

564
00:25:44,820 --> 00:25:42,999
the coexisting sulphate and sulfide we

565
00:25:47,489 --> 00:25:44,830
started to also look at the isotopic

566
00:25:49,950 --> 00:25:47,499
composition of the pyrite and we began

567
00:25:52,230 --> 00:25:49,960
to do a series of sealed tube

568
00:25:55,529 --> 00:25:52,240
experiments to to look at the reaction

569
00:25:58,169 --> 00:25:55,539
or the potential reactions between the

570
00:25:59,340 --> 00:25:58,179
products that result from radiolysis of

571
00:26:02,549 --> 00:25:59,350
water meaning the

572
00:26:06,060 --> 00:26:02,559
18 of a water molecule by ionizing

573
00:26:08,610 --> 00:26:06,070
radiation from radioactive materials and

574
00:26:11,310 --> 00:26:08,620
and that also required us to educate

575
00:26:13,289 --> 00:26:11,320
ourselves about the radiolysis of water

576
00:26:15,779 --> 00:26:13,299
which is a chemistry very few of us are

577
00:26:17,610 --> 00:26:15,789
introduced to in either college or

578
00:26:20,310 --> 00:26:17,620
graduate school it just isn't something

579
00:26:22,529 --> 00:26:20,320
that we've routinely taught as part of

580
00:26:25,350 --> 00:26:22,539
the standard you know natural

581
00:26:28,230 --> 00:26:25,360
geochemistry of our planet so here are

582
00:26:29,669 --> 00:26:28,240
three quick slides that will give you

583
00:26:33,390 --> 00:26:29,679
give you a little bit of a feeling for

584
00:26:37,020 --> 00:26:33,400
how these reaction pathways work on

585
00:26:40,169 --> 00:26:37,030
there's a very very complex and rapid

586
00:26:43,289 --> 00:26:40,179
set of initial reactions after there is

587
00:26:46,169 --> 00:26:43,299
a track created by release of

588
00:26:49,500 --> 00:26:46,179

radioactive energy these initial species

589
00:26:51,480 --> 00:26:49,510
which lasts only 10 to the minus 10 to

590
00:26:53,820 --> 00:26:51,490
10 to the minus 8 second they further

591
00:26:56,159 --> 00:26:53,830
react to produce the species listed down

592
00:26:58,320 --> 00:26:56,169
below you'll notice that that very

593
00:27:00,990 --> 00:26:58,330
quickly if the water the fragments of

594
00:27:03,600 --> 00:27:01,000
the water molecule do not reckon a

595
00:27:06,930 --> 00:27:03,610
stable water molecule you very quickly

596
00:27:11,159 --> 00:27:06,940
generate molecular hydrogen and then a

597
00:27:14,070 --> 00:27:11,169
whole complex soup of reactive oxidizing

598
00:27:19,049 --> 00:27:14,080
species such as the one listed above up

599
00:27:22,409 --> 00:27:19,059
there these short-lived reactive species

600
00:27:24,690 --> 00:27:22,419
then recombine and react with one

601
00:27:27,029 --> 00:27:24,700
another to begin to develop more stable

602
00:27:29,100 --> 00:27:27,039
species and and those are in place

603
00:27:31,520 --> 00:27:29,110
within about 10 to the minus 6 to 10 to

604
00:27:35,220 --> 00:27:31,530
the minus 3rd 2nd what you end up with

605
00:27:37,850 --> 00:27:35,230
that then is stable long enough to move

606
00:27:40,710 --> 00:27:37,860
out from the site of the initial

607
00:27:43,610 --> 00:27:40,720
radiolysis our oxidants like hydrogen

608
00:27:45,810 --> 00:27:43,620
peroxide hydroxyl radicals and

609
00:27:48,360 --> 00:27:45,820
reductants like hydrogen ions and

610
00:27:50,130 --> 00:27:48,370
molecular hydrogen what people have

611
00:27:53,760 --> 00:27:50,140
found through the years in studying

612
00:27:56,700 --> 00:27:53,770
radiolysis as a process doing long-term

613
00:27:59,909 --> 00:27:56,710

damage inside nuclear reactors is that

614
00:28:01,490 --> 00:27:59,919
with continuous laboratory irradiation

615
00:28:04,789 --> 00:28:01,500
you eventually reach steady-state

616
00:28:08,159 --> 00:28:04,799
concentrations for molecular hydrogen

617
00:28:09,500 --> 00:28:08,169
hydrogen peroxide and you do under these

618
00:28:13,220 --> 00:28:09,510
laboratory conditions

619
00:28:16,280 --> 00:28:13,230
small amounts of molecular oxygen so we

620
00:28:19,220 --> 00:28:16,290
again began to think about experiments

621
00:28:22,280 --> 00:28:19,230
in which we could look at hydrogen

622
00:28:24,860 --> 00:28:22,290
peroxide both in natural systems and

623
00:28:26,750 --> 00:28:24,870
look at it in laboratory reactions under

624
00:28:29,660 --> 00:28:26,760
much more controlled conditions so we

625
00:28:31,370 --> 00:28:29,670
also started revisiting the literature

626
00:28:34,870 --> 00:28:31,380
there is actually quite a substantial

627
00:28:37,220 --> 00:28:34,880
literature from the former Soviet Union

628
00:28:39,680 --> 00:28:37,230
describing the importance of hydrogen

629
00:28:41,780 --> 00:28:39,690
peroxide in natural settings associated

630
00:28:44,800 --> 00:28:41,790
with uranium deposits very little of

631
00:28:47,360 --> 00:28:44,810
that literature was ever translated into

632
00:28:49,070 --> 00:28:47,370
into other languages with the notable

633
00:28:51,710 --> 00:28:49,080
exception of a number of pieces of

634
00:28:54,620 --> 00:28:51,720
research by vole it were translated and

635
00:28:58,910 --> 00:28:54,630
are available through the IAEA in in

636
00:29:01,640 --> 00:28:58,920
Vienna and it seems that the Russians

637
00:29:03,380 --> 00:29:01,650
were really well aware of both the

638
00:29:05,210 --> 00:29:03,390

importance of hydrogen peroxide in

639
00:29:08,210 --> 00:29:05,220
reactors as well as the importance in

640
00:29:11,060 --> 00:29:08,220
natural ground waters down down flow

641
00:29:12,680 --> 00:29:11,070
from uranium ore bodies in addition in a

642
00:29:15,650 --> 00:29:12,690
number of places people have started

643
00:29:17,420 --> 00:29:15,660
reporting the presence of peroxide

644
00:29:19,430 --> 00:29:17,430
containing minerals like the one shown

645
00:29:23,720 --> 00:29:19,440
here that was described for the first

646
00:29:26,660 --> 00:29:23,730
time in 2003 other important examples

647
00:29:28,960 --> 00:29:26,670
it's certainly been it's been described

648
00:29:31,670 --> 00:29:28,970
as an important catalytic component in

649
00:29:35,000 --> 00:29:31,680
atmospheric chemistry on earth it's it's

650
00:29:38,210 --> 00:29:35,010
also detected and and inferred in the

651
00:29:41,170 --> 00:29:38,220
Martian atmosphere and many people have

652
00:29:43,760 --> 00:29:41,180
talked about it as one of the the

653
00:29:46,850 --> 00:29:43,770
aggressive oxidizing species that might

654
00:29:50,180 --> 00:29:46,860
be sequestered on the surface of of

655
00:29:53,990 --> 00:29:50,190
minerals on in the Martian regolith so

656
00:29:55,700 --> 00:29:54,000
again once once we became aware of the

657
00:29:58,340 --> 00:29:55,710
importance the potential importance of

658
00:30:00,080 --> 00:29:58,350
these pathways turned out we certainly

659
00:30:01,550 --> 00:30:00,090
we certainly weren't discovering this

660
00:30:03,230 --> 00:30:01,560
for the first time there were many other

661
00:30:04,820 --> 00:30:03,240
people that had worked on this and

662
00:30:06,860 --> 00:30:04,830
there's really quite a quite an

663
00:30:10,250 --> 00:30:06,870

extensive literature so the kinds of

664
00:30:12,940 --> 00:30:10,260
experiments that were initiated by

665
00:30:16,190 --> 00:30:12,950
myself and Ed Ripley working with a

666
00:30:19,100 --> 00:30:16,200
wonderful postdoctoral scientist liliana

667
00:30:20,620 --> 00:30:19,110
left the car you who is just just the

668
00:30:22,740 --> 00:30:20,630
semester joined the faculty

669
00:30:25,150 --> 00:30:22,750
at Southern Illinois University are

670
00:30:29,100 --> 00:30:25,160
illustrated in this in this figure right

671
00:30:32,800 --> 00:30:29,110
here what you see are a series of sealed

672
00:30:35,230 --> 00:30:32,810
quartz glass tubes and the experiments

673
00:30:36,970 --> 00:30:35,240
that we did ran from four degrees to 150

674
00:30:40,530 --> 00:30:36,980
degrees centigrade and what we did is we

675
00:30:43,180 --> 00:30:40,540
very aggressively deoxygenated water

676
00:30:45,930 --> 00:30:43,190
aliquot it in milli molar level

677
00:30:49,300 --> 00:30:45,940
solutions of hydrogen peroxide and then

678
00:30:52,000 --> 00:30:49,310
put sealed into those tubes a small

679
00:30:54,970 --> 00:30:52,010
amount of very carefully prepared pie

680
00:30:56,440 --> 00:30:54,980
right of a uniform very fine grain size

681
00:30:58,360 --> 00:30:56,450
which you see sitting here in the bottom

682
00:31:01,810 --> 00:30:58,370
of the tube on the left and you'll

683
00:31:05,320 --> 00:31:01,820
notice that at these reactions over a

684
00:31:07,600 --> 00:31:05,330
very you know a relatively mild

685
00:31:10,390 --> 00:31:07,610
temperature range very interesting set

686
00:31:12,850 --> 00:31:10,400
of temperatures for biology we see

687
00:31:14,770 --> 00:31:12,860
market differences in the appearance of

688
00:31:16,930 --> 00:31:14,780

the tubes and and those are really the

689
00:31:21,100 --> 00:31:16,940
the products of the reaction between

690
00:31:23,950 --> 00:31:21,110
hydrogen peroxide and pyrite again in

691
00:31:27,760 --> 00:31:23,960
very pure deoxygenated water and what we

692
00:31:30,160 --> 00:31:27,770
see is around 50 degrees C we begin to

693
00:31:33,460 --> 00:31:30,170
see a visible change in the color of the

694
00:31:35,850 --> 00:31:33,470
pyrite this is also around 60 to 70

695
00:31:39,190 --> 00:31:35,860
degrees C is where hydrogen peroxide

696
00:31:41,050 --> 00:31:39,200
begins to decompose over here as we get

697
00:31:43,780 --> 00:31:41,060
around 100 degrees C we start to see

698
00:31:48,120 --> 00:31:43,790
considerable elemental sulfur we also

699
00:31:50,560 --> 00:31:48,130
see a drape of hematite and other

700
00:31:51,970 --> 00:31:50,570
oxidized iron minerals developing on the

701
00:31:54,640 --> 00:31:51,980
wall of the tube and by the time we're

702
00:31:58,350 --> 00:31:54,650
up here at 150 degrees C we see

703
00:32:01,570 --> 00:31:58,360
extensive evidence of fe three minerals

704
00:32:04,120 --> 00:32:01,580
quite a diverse and complex mineralogy

705
00:32:07,660 --> 00:32:04,130
we also look at the surface of those

706
00:32:10,240 --> 00:32:07,670
samples we see that the the freshly

707
00:32:13,380 --> 00:32:10,250
prepared pyrite that's loaded into the

708
00:32:17,350 --> 00:32:13,390
tubes has a very smooth surface in

709
00:32:19,780 --> 00:32:17,360
comparison to this deeply pitted surface

710
00:32:23,140 --> 00:32:19,790
of the pyrite that results from these

711
00:32:26,020 --> 00:32:23,150
reactions with hydrogen peroxide when we

712
00:32:28,630 --> 00:32:26,030
took the residues and looked at them

713
00:32:31,830 --> 00:32:28,640

with x-ray diffraction thanks to the

714
00:32:33,810 --> 00:32:31,840
help of David fish here at Indiana we

715
00:32:36,330 --> 00:32:33,820
and again quite a complex mineralogy now

716
00:32:38,490 --> 00:32:36,340
there are three superimposed x-ray

717
00:32:41,100 --> 00:32:38,500
diffraction traces here one in black

718
00:32:44,820 --> 00:32:41,110
which is the starting pyrite one in

719
00:32:47,399 --> 00:32:44,830
green which is a reaction with 0.02

720
00:32:50,880 --> 00:32:47,409
molar solutions and then one in red

721
00:32:53,070 --> 00:32:50,890
which is a reaction with a 0.2 molar

722
00:32:55,620 --> 00:32:53,080
hydrogen peroxide solution and you can

723
00:32:57,899 --> 00:32:55,630
simply down here we haven't shown you

724
00:33:00,149 --> 00:32:57,909
the identification of every peak but

725
00:33:03,680 --> 00:33:00,159
these are the major products that result

726
00:33:06,990 --> 00:33:03,690
from that reaction a number of iron

727
00:33:08,970 --> 00:33:07,000
sulfates hydrated iron sulfates and of

728
00:33:10,940 --> 00:33:08,980
course as I mentioned before we also get

729
00:33:13,320 --> 00:33:10,950
a number of oxides and hydroxides

730
00:33:16,260 --> 00:33:13,330
perhaps most interesting for this

731
00:33:18,870 --> 00:33:16,270
audience is the fact that hydronium

732
00:33:20,549 --> 00:33:18,880
chera site was one of the common

733
00:33:23,700 --> 00:33:20,559
products that we found in these

734
00:33:27,210 --> 00:33:23,710
reactions utilizing just hydrogen

735
00:33:29,610 --> 00:33:27,220
peroxide and pyrite we also looked

736
00:33:32,220 --> 00:33:29,620
extensively at the rates of sulfate

737
00:33:34,889 --> 00:33:32,230
production in order to to try to begin

738
00:33:36,810 --> 00:33:34,899

to estimate if radiolysis was an

739
00:33:39,000 --> 00:33:36,820
important process in the witwatersrand

740
00:33:41,039 --> 00:33:39,010
basin and if hydrogen peroxide was the

741
00:33:43,460 --> 00:33:41,049
dominant stable product what kinds of

742
00:33:45,720 --> 00:33:43,470
yields could we anticipate over

743
00:33:49,380 --> 00:33:45,730
geologically interesting periods of time

744
00:33:52,560 --> 00:33:49,390
like tens of millions of years to to

745
00:33:54,149 --> 00:33:52,570
longer periods of time and again one of

746
00:33:55,710 --> 00:33:54,159
the things that we monitored in addition

747
00:33:58,110 --> 00:33:55,720
to the fate of the sulfur's we are very

748
00:34:01,680 --> 00:33:58,120
interested in the source of the oxygen

749
00:34:04,110 --> 00:34:01,690
to form these to form these sulfate ions

750
00:34:06,510 --> 00:34:04,120
and and we we have a manuscript that's

751
00:34:08,579 --> 00:34:06,520
just about to be submitted on the oxygen

752
00:34:11,849 --> 00:34:08,589
isotopic composition as well as the

753
00:34:13,680 --> 00:34:11,859
sulfur isotope composition of sulfate

754
00:34:15,780 --> 00:34:13,690
that is produced in these reactions and

755
00:34:18,889 --> 00:34:15,790
you can see here we took advantage of

756
00:34:23,040 --> 00:34:18,899
the fact that we could do a simple

757
00:34:25,050 --> 00:34:23,050
simple isotope test utilizing water with

758
00:34:27,290 --> 00:34:25,060
an isotopic starting isotopic value of

759
00:34:29,940 --> 00:34:27,300
around negative 10 and markedly

760
00:34:32,970 --> 00:34:29,950
contrasting hydrogen peroxide with an

761
00:34:35,790 --> 00:34:32,980
oxygen isotopic value of close to 50 and

762
00:34:38,339 --> 00:34:35,800
by simply having those as the only two

763
00:34:40,710 --> 00:34:38,349

sources of oxygen in the system we could

764
00:34:43,589 --> 00:34:40,720
then use the isotopic composition of the

765
00:34:45,329 --> 00:34:43,599
oxygen in the product sulfate to tell us

766
00:34:47,849 --> 00:34:45,339
rather or not and in what proportion

767
00:34:50,310 --> 00:34:47,859
oxygen was being drawn from hydrogen

768
00:34:53,220 --> 00:34:50,320
peroxide vs water what you see quite

769
00:34:55,530 --> 00:34:53,230
interestingly is this mark depression in

770
00:34:57,480 --> 00:34:55,540
the isotopic composition of product

771
00:34:59,160 --> 00:34:57,490
sulfate again right around the

772
00:35:02,609 --> 00:34:59,170
temperature when the color in those

773
00:35:05,130 --> 00:35:02,619
reaction tubes changes from from

774
00:35:09,210 --> 00:35:05,140
unpigmented to very brightly colored

775
00:35:12,990 --> 00:35:09,220
yellows oranges and reds so that's

776
00:35:15,510 --> 00:35:13,000
really where the research went driven

777
00:35:18,630 --> 00:35:15,520
driven by the samples that we had taken

778
00:35:21,630 --> 00:35:18,640
in South Africa as we moved into a

779
00:35:24,900 --> 00:35:21,640
permafrost environment we identified a

780
00:35:26,849 --> 00:35:24,910
number of mine localities both both

781
00:35:30,390 --> 00:35:26,859
mines that we're just getting started

782
00:35:32,640 --> 00:35:30,400
were largely surface active minds to

783
00:35:34,520 --> 00:35:32,650
mines like Lupin which are historical

784
00:35:37,200 --> 00:35:34,530
mines with a deep subsurface

785
00:35:39,599 --> 00:35:37,210
infrastructure you can see both loop in

786
00:35:42,020 --> 00:35:39,609
mind with the X and then high lake which

787
00:35:45,150 --> 00:35:42,030
is the location of the property where we

788
00:35:47,339 --> 00:35:45,160

where we drilled a scientific borehole

789
00:35:50,099 --> 00:35:47,349
through the permafrost last year to

790
00:35:52,589 --> 00:35:50,109
intersect sub permafrost brines we'll

791
00:35:54,690 --> 00:35:52,599
talk we'll talk first about the research

792
00:35:57,120 --> 00:35:54,700
at lupin then we'll talk about the

793
00:36:00,150 --> 00:35:57,130
drilling activities at high lake I'll

794
00:36:02,370 --> 00:36:00,160
introduce Lupin and then as we did with

795
00:36:05,310 --> 00:36:02,380
South Africa I'll turn it over to Tullus

796
00:36:07,290 --> 00:36:05,320
to talk about the the microbiology work

797
00:36:09,030 --> 00:36:07,300
that's been done this is what Lupin

798
00:36:11,820 --> 00:36:09,040
looks like as you approach from the air

799
00:36:14,070 --> 00:36:11,830
in early fall there's already a pretty

800
00:36:17,130 --> 00:36:14,080
good snow cover you can see that Lupin

801
00:36:20,220 --> 00:36:17,140
is on the margin of a of a large lake

802
00:36:21,810 --> 00:36:20,230
which here in the early fall is not not

803
00:36:24,960 --> 00:36:21,820
yet ice-covered but it will be soon

804
00:36:26,790 --> 00:36:24,970
Lupin is a very very wonderful place for

805
00:36:29,359 --> 00:36:26,800
scientists to work because it's easy to

806
00:36:32,040 --> 00:36:29,369
get in and out there's a large runway

807
00:36:34,500 --> 00:36:32,050
there's a very nice there's a very nice

808
00:36:36,900 --> 00:36:34,510
weather station and air control tower so

809
00:36:40,260 --> 00:36:36,910
even though the mine itself has been now

810
00:36:42,420 --> 00:36:40,270
shut down because of the the depth of

811
00:36:44,490 --> 00:36:42,430
their ore body and it's decreasing grade

812
00:36:47,130 --> 00:36:44,500
it this structure is going to be

813
00:36:50,260 --> 00:36:47,140

maintained for the foreseeable future as

814
00:36:53,020 --> 00:36:50,270
a as a fuel depot and

815
00:36:55,000 --> 00:36:53,030
as a as a landing strip that can you to

816
00:36:56,410 --> 00:36:55,010
be utilized by smaller minds that are

817
00:36:59,620 --> 00:36:56,420
just starting to be developed in the

818
00:37:01,870 --> 00:36:59,630
area the project that that turned out to

819
00:37:04,150 --> 00:37:01,880
provide a wonderful opportunity for us

820
00:37:06,010 --> 00:37:04,160
was a project that had been in existence

821
00:37:08,050 --> 00:37:06,020
for four or five years prior to our

822
00:37:10,540 --> 00:37:08,060
arrival at lupin that was a project

823
00:37:12,580 --> 00:37:10,550
simply called permafrost at lupin it was

824
00:37:14,470 --> 00:37:12,590
an international collaboration to look

825
00:37:17,710 --> 00:37:14,480
at the fate of ground water and model

826
00:37:19,300 --> 00:37:17,720
the fate of groundwater associated with

827
00:37:20,740 --> 00:37:19,310
permafrost localities that were

828
00:37:23,080 --> 00:37:20,750
susceptible to being covered by

829
00:37:25,800 --> 00:37:23,090
continental glaciers and it was funded

830
00:37:29,910 --> 00:37:25,810
by a collaboration of organizations in

831
00:37:31,930 --> 00:37:29,920
in high northern europe as well as

832
00:37:35,140 --> 00:37:31,940
canada and you can see the funding

833
00:37:36,700 --> 00:37:35,150
agencies there what we did is we found

834
00:37:39,220 --> 00:37:36,710
out that there was a wonderful set of

835
00:37:40,690 --> 00:37:39,230
scientific boreholes that had been

836
00:37:43,540 --> 00:37:40,700
drilled at loop in mind as a

837
00:37:45,130 --> 00:37:43,550
collaboration between investigators at

838
00:37:47,500 --> 00:37:45,140

the university of waterloo and the

839
00:37:49,660 --> 00:37:47,510
Geological Survey of Finland they had

840
00:37:52,480 --> 00:37:49,670
been looking at the inorganic chemistry

841
00:37:55,180 --> 00:37:52,490
of these this borehole array we came in

842
00:37:58,510 --> 00:37:55,190
and had the wonderful opportunity to

843
00:38:02,170 --> 00:37:58,520
hook onto those boreholes filter water

844
00:38:04,840 --> 00:38:02,180
and collect biomass the permafrost and

845
00:38:06,250 --> 00:38:04,850
Lupin is a little more than 500 meters

846
00:38:09,070 --> 00:38:06,260
in depth you can see the temperature

847
00:38:11,680 --> 00:38:09,080
profile here and tell us will touch

848
00:38:13,690 --> 00:38:11,690
again on this problem of these very cold

849
00:38:15,310 --> 00:38:13,700
temperatures near the near the top of

850
00:38:18,070 --> 00:38:15,320
the permafrost which turned out to

851
00:38:19,840 --> 00:38:18,080
plague us a little bit in in the

852
00:38:22,720 --> 00:38:19,850
borehole project we'll get back to that

853
00:38:25,690 --> 00:38:22,730
in a minute here you can see typical

854
00:38:27,820 --> 00:38:25,700
total dissolved solids for the ground

855
00:38:29,740 --> 00:38:27,830
waters at lupin not nearly as deep as

856
00:38:31,660 --> 00:38:29,750
the ground water is that we studied in

857
00:38:35,080 --> 00:38:31,670
the Wits water ran these samples are all

858
00:38:37,390 --> 00:38:35,090
taken from 1100 meters below the surface

859
00:38:42,070 --> 00:38:37,400
a little more than a kilometre up to

860
00:38:43,870 --> 00:38:42,080
about 800 meters below the surface and

861
00:38:47,530 --> 00:38:43,880
I'm going to turn it over now to tell us

862
00:38:49,690 --> 00:38:47,540
to talk about the microbiological work

863
00:38:50,920 --> 00:38:49,700

that's been done both by his graduate

864
00:38:53,180 --> 00:38:50,930
students and a number of other

865
00:38:55,819 --> 00:38:53,190
collaborators

866
00:38:58,220 --> 00:38:55,829
right so one of the questions that we

867
00:39:01,220 --> 00:38:58,230
had walking into this site which was

868
00:39:02,900 --> 00:39:01,230
quite well characterized in terms of

869
00:39:04,970 --> 00:39:02,910
understanding the origin of the water

870
00:39:06,950 --> 00:39:04,980
was whether or not we might find

871
00:39:09,440 --> 00:39:06,960
similarities between microbials

872
00:39:11,750 --> 00:39:09,450
subsurface microbial ecosystem present

873
00:39:14,660 --> 00:39:11,760
beneath the permafrost and what we had

874
00:39:17,630 --> 00:39:14,670
previously reported on in South Africa

875
00:39:19,609 --> 00:39:17,640
and we worked with green Beckerman from

876
00:39:23,059 --> 00:39:19,619
the Michigan State University group who

877
00:39:25,700 --> 00:39:23,069
were experts and culturing Sacre filling

878
00:39:27,770 --> 00:39:25,710
organisms these are results from the

879
00:39:29,839 --> 00:39:27,780
filtered water samples from ruben wine

880
00:39:31,490 --> 00:39:29,849
and what you're seeing plotted here is

881
00:39:34,460 --> 00:39:31,500
the number of plate counts this is on

882
00:39:36,589 --> 00:39:34,470
auger medium versus temperature and she

883
00:39:38,420 --> 00:39:36,599
can easily demonstrate that what we are

884
00:39:40,819 --> 00:39:38,430
seeing in the environment in terms of

885
00:39:44,089 --> 00:39:40,829
what organisms we could enrich from the

886
00:39:46,250 --> 00:39:44,099
environment are truly psycho tolerant

887
00:39:50,450 --> 00:39:46,260
organisms in other words their optimum

888
00:39:52,730 --> 00:39:50,460

growth exists at sub 25 degrees

889
00:39:55,280 --> 00:39:52,740
centigrade and then the Peter off once

890
00:39:56,569 --> 00:39:55,290
you go to higher temperatures there but

891
00:39:59,450 --> 00:39:56,579
they're still growing very very nicely

892
00:40:01,010 --> 00:39:59,460
at 0 degrees centigrade what are some of

893
00:40:03,559 --> 00:40:01,020
these organisms well the microbe error

894
00:40:05,859 --> 00:40:03,569
fill up to aerobic organisms many of

895
00:40:09,800 --> 00:40:05,869
them actually belong to pseudomonas MMR

896
00:40:11,900 --> 00:40:09,810
nitrate reducers we also did anaerobic

897
00:40:14,109 --> 00:40:11,910
enrichments and anna sulfate-reducing

898
00:40:18,319 --> 00:40:14,119
culture we were able to isolate a

899
00:40:22,339 --> 00:40:18,329
Clostridium and when you look at the

900
00:40:26,059 --> 00:40:22,349
filters and just go ahead and build

901
00:40:28,819 --> 00:40:26,069
clone libraries 16s rdna without

902
00:40:31,160 --> 00:40:28,829
culturing straight from the filters you

903
00:40:33,559 --> 00:40:31,170
find out that in fact the microbial

904
00:40:36,470 --> 00:40:33,569
ecosystem is dominated by sulfate and

905
00:40:39,260 --> 00:40:36,480
sulfur reducing bacteria and present

906
00:40:42,349 --> 00:40:39,270
also are a minor constituent of sulfide

907
00:40:44,750 --> 00:40:42,359
oxidizing bacteria that are utilizing

908
00:40:48,050 --> 00:40:44,760
nitrate reduction as the electron

909
00:40:50,960 --> 00:40:48,060
accepting process so we seem to have

910
00:40:53,870 --> 00:40:50,970
evidence here of a different type of

911
00:40:57,319 --> 00:40:53,880
subsurface cell freedom in this case

912
00:40:59,420 --> 00:40:57,329
instead of coupling it to radiolysis we

913
00:41:02,390 --> 00:40:59,430

have such

914
00:41:05,299 --> 00:41:02,400
60s evidence to suggest that it could be

915
00:41:10,339 --> 00:41:05,309
coupled through nitrate reduction and

916
00:41:13,670 --> 00:41:10,349
the reduction of ferric iron these are

917
00:41:15,349 --> 00:41:13,680
some the cells look like from Bruno self

918
00:41:18,349 --> 00:41:15,359
and tini University of Rhode Island who

919
00:41:21,109 --> 00:41:18,359
also participated in the field exercise

920
00:41:23,690 --> 00:41:21,119
when you look at the 16s close libraries

921
00:41:26,710 --> 00:41:23,700
the dominant component turns out to be a

922
00:41:29,150 --> 00:41:26,720
de celis 40 sinus this is another

923
00:41:31,520 --> 00:41:29,160
organism sulfate-reducing that belongs

924
00:41:34,579 --> 00:41:31,530
to the firmicutes and belongs to the

925
00:41:36,440 --> 00:41:34,589
same deep played that we reported about

926
00:41:40,970 --> 00:41:36,450
in South Africa here close to

927
00:41:43,760 --> 00:41:40,980
clostridium perfringens it is known to

928
00:41:47,210 --> 00:41:43,770
reduce sulfate to sulfide and can also

929
00:41:50,270 --> 00:41:47,220
grow home will receive gently just as we

930
00:41:53,210 --> 00:41:50,280
reported 4d sulfur Otis on dikes VA a

931
00:41:59,180 --> 00:41:53,220
durar and it can switch to auto trophy

932
00:42:01,579 --> 00:41:59,190
in that regard the candidate for sulfide

933
00:42:04,460 --> 00:42:01,589
oxidation is a halo file bacillus

934
00:42:06,470 --> 00:42:04,470
organism it's known to oxidize sulfide

935
00:42:09,440 --> 00:42:06,480
as well as sulfur intermediates like

936
00:42:12,490 --> 00:42:09,450
styro sulfate sulfur and tetra thigh

937
00:42:14,599 --> 00:42:12,500
innate and it belongs to the gamma

938
00:42:18,530 --> 00:42:14,609

Proteobacteria is the chemo myth ago so

939
00:42:20,750 --> 00:42:18,540
it can fix carbon as well it was once

940
00:42:22,849 --> 00:42:20,760
thought to be an obligate obligate arrow

941
00:42:24,500 --> 00:42:22,859
but has been showing up more frequently

942
00:42:31,250 --> 00:42:24,510
in recent reports and anaerobic

943
00:42:34,069 --> 00:42:31,260
environments as well now the presence of

944
00:42:35,990 --> 00:42:34,079
these Proteobacteria and the firmicutes

945
00:42:38,270 --> 00:42:36,000
raised the question it could be that

946
00:42:40,640 --> 00:42:38,280
we're seeing mixing between say twenty

947
00:42:42,710 --> 00:42:40,650
five thousand year old water and that's

948
00:42:46,730 --> 00:42:42,720
why we're still seeing a community of

949
00:42:48,829 --> 00:42:46,740
nitrate and iron reducers or their

950
00:42:51,799 --> 00:42:48,839
course there was the prospect of that

951
00:42:53,599 --> 00:42:51,809
the long-term mining activities at luton

952
00:42:55,730 --> 00:42:53,609
had managed to contaminate the fractures

953
00:42:58,130 --> 00:42:55,740
so one of the motivations for moving

954
00:43:00,049 --> 00:42:58,140
north to high lake was to move to a

955
00:43:02,630 --> 00:43:00,059
region which had not seen any money

956
00:43:05,180 --> 00:43:02,640
activity at all and drilling pristine

957
00:43:07,120 --> 00:43:05,190
borehole into the sub sub permafrost

958
00:43:09,790 --> 00:43:07,130
brines there

959
00:43:11,740 --> 00:43:09,800
and the drill site selected in this case

960
00:43:14,170 --> 00:43:11,750
was highlight because it was an active

961
00:43:17,530 --> 00:43:14,180
exploration site there we had a massive

962
00:43:19,600 --> 00:43:17,540
sulfide copper zinc sulfide deposit that

963
00:43:22,030 --> 00:43:19,610

expressed itself easily from satellite

964
00:43:24,730 --> 00:43:22,040
photographs are these surficial Dawson

965
00:43:26,680 --> 00:43:24,740
deposits which are a natural form of

966
00:43:29,440 --> 00:43:26,690
acid drainage you could easily see them

967
00:43:33,460 --> 00:43:29,450
from space because of the orange

968
00:43:36,370 --> 00:43:33,470
yellowish deposits that it would occur

969
00:43:39,070 --> 00:43:36,380
on the surface there the permafrost was

970
00:43:41,500 --> 00:43:39,080
a 400 meters thick and was located

971
00:43:44,500 --> 00:43:41,510
within our key and age mafic volcanic

972
00:43:46,090 --> 00:43:44,510
belt and so many respects from a

973
00:43:48,280 --> 00:43:46,100
geological perspective it's pretty

974
00:43:52,360 --> 00:43:48,290
similar to Lupin very similar to South

975
00:43:54,430 --> 00:43:52,370
Africa this is looking from the drill

976
00:43:57,010 --> 00:43:54,440
site itself towards the southeast and

977
00:43:58,480 --> 00:43:57,020
this big orange stain that you're seeing

978
00:44:01,300 --> 00:43:58,490
here represents one of the goss and

979
00:44:03,430 --> 00:44:01,310
deposits so there's a belt of sulfides

980
00:44:05,350 --> 00:44:03,440
that runs underneath it the Gaussian

981
00:44:07,630 --> 00:44:05,360
deposits themselves to send about only a

982
00:44:09,880 --> 00:44:07,640
meter thick so they're in the active

983
00:44:11,380 --> 00:44:09,890
zone before you reach the permafrost

984
00:44:15,040 --> 00:44:11,390
once you reach the permafrost the

985
00:44:17,710 --> 00:44:15,050
Gosselin's go away this is the drill

986
00:44:20,110 --> 00:44:17,720
itself that we use exploration rig

987
00:44:21,700 --> 00:44:20,120
triple core barrel looking towards

988
00:44:23,890 --> 00:44:21,710

northeast now there's the mining camp

989
00:44:27,400 --> 00:44:23,900
there's high lake and over to the left

990
00:44:30,220 --> 00:44:27,410
hand side is the core laboratory that we

991
00:44:32,200 --> 00:44:30,230
used to process the cores and just

992
00:44:34,750 --> 00:44:32,210
stepping back a second it's an angled

993
00:44:36,310 --> 00:44:34,760
borehole from the drill site looking

994
00:44:38,170 --> 00:44:36,320
towards the southeast we're actually

995
00:44:40,390 --> 00:44:38,180
looking at the horizontal projection of

996
00:44:42,880 --> 00:44:40,400
the drilling beneath the subsurface so

997
00:44:47,890 --> 00:44:42,890
400 meters meteors beneath the gossan

998
00:44:49,420 --> 00:44:47,900
deposit is our world okay and just to

999
00:44:51,790 --> 00:44:49,430
show you the sequence of events there

1000
00:44:52,870 --> 00:44:51,800
the more hall had already been extended

1001
00:44:55,660 --> 00:44:52,880
to about the middle of the permafrost

1002
00:44:56,980 --> 00:44:55,670
own and we extended it further once we

1003
00:44:59,590 --> 00:44:56,990
reached about four hundred and eighty

1004
00:45:03,280 --> 00:44:59,600
five meters depth we pulled the drill

1005
00:45:05,680 --> 00:45:03,290
rods along with all the drill water the

1006
00:45:08,380 --> 00:45:05,690
base of the permafrost that was 400

1007
00:45:10,300 --> 00:45:08,390
meters to 430 meters depth we

1008
00:45:11,710 --> 00:45:10,310
immediately dropped casing to about two

1009
00:45:13,240 --> 00:45:11,720
hundred ninety meters and the idea there

1010
00:45:14,980 --> 00:45:13,250
was to protect the borehole from any

1011
00:45:16,750 --> 00:45:14,990
melting permafrost we didn't want the

1012
00:45:20,320 --> 00:45:16,760
borehole the seals shut with

1013
00:45:22,180 --> 00:45:20,330

that was our primary concern so by

1014
00:45:24,580 --> 00:45:22,190
casing through the active zone and well

1015
00:45:28,780 --> 00:45:24,590
into the permafrost own it prevented any

1016
00:45:31,030 --> 00:45:28,790
water from freezing in borehole removed

1017
00:45:33,190 --> 00:45:31,040
about 400 liters of water by bailing and

1018
00:45:35,110 --> 00:45:33,200
that dropped the temperature from about

1019
00:45:37,810 --> 00:45:35,120
8 degrees C at the bottom of the world

1020
00:45:39,730 --> 00:45:37,820
to 3 degrees c and the salinity increase

1021
00:45:41,890 --> 00:45:39,740
in the bottom of borehole from 30 to six

1022
00:45:45,070 --> 00:45:41,900
thousand ppm so we seem to see an influx

1023
00:45:49,060 --> 00:45:45,080
of brackish water into the bottom of

1024
00:45:51,250 --> 00:45:49,070
that borrell as we want to turn it then

1025
00:45:53,710 --> 00:45:51,260
within about 24 hours a nice plug formed

1026
00:45:55,450 --> 00:45:53,720
at 125 meters which trapped our sincere

1027
00:45:57,070 --> 00:45:55,460
is down the hole that's where the

1028
00:45:59,170 --> 00:45:57,080
borehole is about minus 6 degrees

1029
00:46:02,410 --> 00:45:59,180
centigrade and the reason why the

1030
00:46:04,300 --> 00:46:02,420
iceplug formed is because of moist air

1031
00:46:05,980 --> 00:46:04,310
during the day time was descending down

1032
00:46:08,200 --> 00:46:05,990
the hole and trapping into the bore hole

1033
00:46:10,300 --> 00:46:08,210
at the top so you should have a cold

1034
00:46:12,220 --> 00:46:10,310
trap here and unless you cap that

1035
00:46:14,590 --> 00:46:12,230
borehole and keep it capped at all times

1036
00:46:19,270 --> 00:46:14,600
to a form of ice bug very very quickly

1037
00:46:21,340 --> 00:46:19,280
in a system at the last measurement the

1038
00:46:23,440 --> 00:46:21,350

water table was up 446 and was

1039
00:46:28,170 --> 00:46:23,450
increasing at about one liter per hour

1040
00:46:30,730 --> 00:46:28,180
before the sensor was pulled and broken

1041
00:46:33,460 --> 00:46:30,740
cores were processed an anaerobic glove

1042
00:46:34,750 --> 00:46:33,470
bag on sites we collected samples for

1043
00:46:36,220 --> 00:46:34,760
tracer analysis we used a

1044
00:46:39,070 --> 00:46:36,230
perfluorocarbon tracer during the

1045
00:46:42,130 --> 00:46:39,080
drilling process we use microwaves force

1046
00:46:44,350 --> 00:46:42,140
of microspheres we also collected core

1047
00:46:47,080 --> 00:46:44,360
samples for gas analyses that we stored

1048
00:46:50,260 --> 00:46:47,090
in vacuum canisters that we evacuated on

1049
00:46:52,300 --> 00:46:50,270
site we also collected samples for

1050
00:46:55,420 --> 00:46:52,310
geophysical analysis by Steve Clifford

1051
00:46:58,270 --> 00:46:55,430
Donna LP I use part of our team refer

1052
00:47:02,110 --> 00:46:58,280
samples on site believe it or not with

1053
00:47:04,300 --> 00:47:02,120
dry ice that we flew up every time a

1054
00:47:06,940 --> 00:47:04,310
flight came up for DNA and lipid

1055
00:47:08,800 --> 00:47:06,950
analyses refrigerated samples on site

1056
00:47:11,200 --> 00:47:08,810
for electro chemical analyses radios

1057
00:47:13,960 --> 00:47:11,210
stable isotope tracer measurements i

1058
00:47:16,420 --> 00:47:13,970
might say we're quite quite famous with

1059
00:47:19,330 --> 00:47:16,430
the supply people up there for being the

1060
00:47:21,310 --> 00:47:19,340
crazy scientist that pay large sums of

1061
00:47:23,170 --> 00:47:21,320
money to fly dry ice into the Arctic

1062
00:47:25,240 --> 00:47:23,180
that's right what's gas cylinders

1063
00:47:27,970 --> 00:47:25,250

high-pressure gas cylinders went up as

1064
00:47:28,810 --> 00:47:27,980
well and this represents our first set

1065
00:47:31,600 --> 00:47:28,820
of results

1066
00:47:33,040 --> 00:47:31,610
came from a technique called phosphor

1067
00:47:36,070 --> 00:47:33,050
imaging what we were doing is we are

1068
00:47:38,440 --> 00:47:36,080
taking the cores and adding a tiny bit

1069
00:47:40,900 --> 00:47:38,450
of sulphate radioactive selfie to a

1070
00:47:42,070 --> 00:47:40,910
freshly broken fracture surface and then

1071
00:47:44,320 --> 00:47:42,080
incubating them at four degrees

1072
00:47:46,450 --> 00:47:44,330
centigrade and then you let them

1073
00:47:48,700 --> 00:47:46,460
incubate for 120 days or about three

1074
00:47:50,020 --> 00:47:48,710
months you then pull them out of the

1075
00:47:52,780 --> 00:47:50,030
refrigerator this is all done

1076
00:47:55,600 --> 00:47:52,790
anaerobically of course and you expose

1077
00:47:58,230 --> 00:47:55,610
the silver foil to a foster image screen

1078
00:48:03,190 --> 00:47:58,240
and everywhere you see a tiny black dot

1079
00:48:05,080 --> 00:48:03,200
represents radioactive 35 sulphur silver

1080
00:48:08,290 --> 00:48:05,090
sulfide that's been deposited on the

1081
00:48:11,410 --> 00:48:08,300
film presumably from localz hot spots of

1082
00:48:13,480 --> 00:48:11,420
of anaerobic sulfate reduction occurring

1083
00:48:16,690 --> 00:48:13,490
he knows that in most cases the outside

1084
00:48:19,420 --> 00:48:16,700
surfaces of the cores are clean and that

1085
00:48:23,920 --> 00:48:19,430
probably is a credit to our incredibly

1086
00:48:25,840 --> 00:48:23,930
stringent realm of drilling as well as

1087
00:48:28,090 --> 00:48:25,850
the fact that in the process of doing

1088
00:48:29,890 --> 00:48:28,100

these cores iuv irradiated the outside

1089
00:48:32,350 --> 00:48:29,900
surface before I started the experiment

1090
00:48:34,750 --> 00:48:32,360
to make sure that no contaminants would

1091
00:48:37,210 --> 00:48:34,760
bugger up the results so we didn't see

1092
00:48:40,000 --> 00:48:37,220
some signs that again a sulfate

1093
00:48:42,670 --> 00:48:40,010
reduction community could be present in

1094
00:48:44,200 --> 00:48:42,680
the system and the future analyses who

1095
00:48:46,750 --> 00:48:44,210
tell us what it's fine a lot of

1096
00:48:47,800 --> 00:48:46,760
phylogenetic origin ends as well as

1097
00:48:49,840 --> 00:48:47,810
whether or not it represents the

1098
00:48:51,850 --> 00:48:49,850
dominant constituent and then we have to

1099
00:48:55,420 --> 00:48:51,860
get back to the origin of sulfate again

1100
00:48:57,880 --> 00:48:55,430
in this system alright and that brings

1101
00:49:00,300 --> 00:48:57,890
us towards the end here I think what

1102
00:49:03,430 --> 00:49:00,310
we've been finding here is that sulfate

1103
00:49:05,110 --> 00:49:03,440
is a principal electron acceptor and

1104
00:49:07,060 --> 00:49:05,120
these deep subsurface systems which is

1105
00:49:10,330 --> 00:49:07,070
something that we didn't necessarily

1106
00:49:12,460 --> 00:49:10,340
anticipate and walking into it in the

1107
00:49:14,920 --> 00:49:12,470
case of South Africa it's clear that

1108
00:49:16,540 --> 00:49:14,930
radiolysis is the source of the sulfate

1109
00:49:19,360 --> 00:49:16,550
as well as the source of the hydrogen

1110
00:49:21,760 --> 00:49:19,370
gas we're seeing down there and could be

1111
00:49:23,470 --> 00:49:21,770
the source of several other key trace

1112
00:49:26,530 --> 00:49:23,480
nutrients in that system that are

1113
00:49:29,230 --> 00:49:26,540

sustaining these organisms over a period

1114
00:49:32,050 --> 00:49:29,240
of millions of years and you can

1115
00:49:34,540 --> 00:49:32,060
extrapolate that straight to Mars in the

1116
00:49:37,360 --> 00:49:34,550
case of Lupin radials may be playing a

1117
00:49:40,240 --> 00:49:37,370
role but we see biological evidence that

1118
00:49:40,580 --> 00:49:40,250
suggests that again a sulfur cycle is

1119
00:49:43,490 --> 00:49:40,590
prayer

1120
00:49:47,000 --> 00:49:43,500
there but perhaps in this case helpful

1121
00:49:49,490 --> 00:49:47,010
to the reduction of nitrate and ferric

1122
00:49:54,110 --> 00:49:49,500
iron not Ferris on but Farrakhan in that

1123
00:49:56,690 --> 00:49:54,120
case as well it's remains to be seen in

1124
00:49:58,340 --> 00:49:56,700
the case of these sub permafrost zones

1125
00:50:00,290 --> 00:49:58,350
whether or not we will find methanogens

1126
00:50:02,000 --> 00:50:00,300
we have not detected with antigens yet

1127
00:50:04,370 --> 00:50:02,010
in that environment although they were

1128
00:50:06,560 --> 00:50:04,380
present in South Africa and of course

1129
00:50:08,510 --> 00:50:06,570
the fantage ins is something a great

1130
00:50:11,120 --> 00:50:08,520
interest to us because of the presence

1131
00:50:15,170 --> 00:50:11,130
of methane is a trace gas the answer

1132
00:50:16,490 --> 00:50:15,180
Mars lisa is anything else no I think we

1133
00:50:19,010 --> 00:50:16,500
can stop there and open it up to

1134
00:50:22,640 --> 00:50:19,020
questions the only other thing i might

1135
00:50:24,800 --> 00:50:22,650
add in closing is that not only does

1136
00:50:28,190 --> 00:50:24,810
this have interesting consequences that

1137
00:50:32,450 --> 00:50:28,200
tell us is just mentioned for life on

1138
00:50:34,760 --> 00:50:32,460

planets where life is forced into the

1139
00:50:38,390 --> 00:50:34,770
subsurface by harsh surface conditions

1140
00:50:42,170 --> 00:50:38,400
but it might also inform us about about

1141
00:50:44,240 --> 00:50:42,180
Earth early on when the the flux from

1142
00:50:47,300 --> 00:50:44,250
radioactive decay was much higher than

1143
00:50:51,200 --> 00:50:47,310
it is in the present day and and also

1144
00:50:53,720 --> 00:50:51,210
thinking about again protecting life in

1145
00:50:55,640 --> 00:50:53,730
the subsurface during during periods of

1146
00:50:58,400 --> 00:50:55,650
particularly active bombardment we

1147
00:51:02,090 --> 00:50:58,410
really have not thought very much about

1148
00:51:05,720 --> 00:51:02,100
the subsurface environment in terms of

1149
00:51:08,090 --> 00:51:05,730
being oxidized by radiolysis and I think

1150
00:51:11,450 --> 00:51:08,100
there's going to be a very exciting time

1151
00:51:14,390 --> 00:51:11,460
ahead of us as microbiologists and Joe

1152
00:51:16,430 --> 00:51:14,400
chemist go out to look at these natural

1153
00:51:18,580 --> 00:51:16,440
waters associated with uranium ore

1154
00:51:21,410 --> 00:51:18,590
bodies and begin to rethink about

1155
00:51:23,660 --> 00:51:21,420
particularly geological features like

1156
00:51:26,450 --> 00:51:23,670
role front deposits in terms of not just

1157
00:51:29,630 --> 00:51:26,460
a biotic chemistry but potentially as

1158
00:51:37,410 --> 00:51:29,640
the as the fingerprint of complex

1159
00:51:44,050 --> 00:51:41,260
look we're not talking thank you very

1160
00:51:45,790 --> 00:51:44,060
much thank you very much Lisa in TC that

1161
00:51:48,099 --> 00:51:45,800
was great I think I'll start off with a

1162
00:51:50,970 --> 00:51:48,109
question and then we'll turn it open to

1163
00:51:53,829 --> 00:51:50,980

everyone on the net for questions is

1164
00:51:56,680 --> 00:51:53,839
there anything that you could say about

1165
00:51:59,890 --> 00:51:56,690
the source of the sulfated high lake

1166
00:52:03,520 --> 00:51:59,900
that is is it can you say anything about

1167
00:52:05,589 --> 00:52:03,530
whether it's being generated as it is in

1168
00:52:06,910 --> 00:52:05,599
South Africa perhaps by radiolysis or

1169
00:52:11,170 --> 00:52:06,920
whether you've got more of a sulfur

1170
00:52:13,540 --> 00:52:11,180
cycle at high lake and also how long has

1171
00:52:21,819 --> 00:52:13,550
the water you're sampling at high Lake

1172
00:52:24,880 --> 00:52:21,829
likely been isolated from the surface I

1173
00:52:27,069 --> 00:52:24,890
guess based upon our experience our one

1174
00:52:29,980 --> 00:52:27,079
experience that we encountered at lupin

1175
00:52:33,400 --> 00:52:29,990
the formation of the permafrost may have

1176
00:52:35,530 --> 00:52:33,410
occurred relatively recently recently IE

1177
00:52:37,540 --> 00:52:35,540
being in the period of the last twenty

1178
00:52:40,170 --> 00:52:37,550
five thousand years so there may have

1179
00:52:42,640 --> 00:52:40,180
been a time prior to that or

1180
00:52:44,970 --> 00:52:42,650
intermittently between glaciations when

1181
00:52:48,579 --> 00:52:44,980
freshwater could have mixed with these

1182
00:52:50,380 --> 00:52:48,589
deep Canadian Grimes and may have

1183
00:52:54,760 --> 00:52:50,390
colonized the environment over that

1184
00:52:56,920 --> 00:52:54,770
period of time as for the origin of the

1185
00:52:58,630 --> 00:52:56,930
sulfate this is a separate question I

1186
00:53:00,760 --> 00:52:58,640
don't think we have any strong

1187
00:53:04,150 --> 00:53:00,770
constraints yet although actually Lisa

1188
00:53:05,589 --> 00:53:04,160

may have some evidence that's starting

1189
00:53:07,750 --> 00:53:05,599
to play some constraints on the origin

1190
00:53:09,490 --> 00:53:07,760
of sulfate in the in the system we're

1191
00:53:11,980 --> 00:53:09,500
just completing a study in which we're

1192
00:53:14,349 --> 00:53:11,990
comparing the isotopic composition of

1193
00:53:17,050 --> 00:53:14,359
coexisting sulfate and sulfide in the

1194
00:53:20,620 --> 00:53:17,060
water with coexisting sulfate and

1195
00:53:23,859 --> 00:53:20,630
sulfide in quartz and calcite veins that

1196
00:53:27,790 --> 00:53:23,869
cut across these these are key and meta

1197
00:53:31,750 --> 00:53:27,800
sediments and so we what we what we know

1198
00:53:33,880 --> 00:53:31,760
so far is that big Delta the isotopic

1199
00:53:36,300 --> 00:53:33,890
difference between sulfate and sulfide

1200
00:53:40,120 --> 00:53:36,310
is very similar in the present day water

1201
00:53:42,940 --> 00:53:40,130
and these and these much older fractures

1202
00:53:44,800 --> 00:53:42,950
again we don't have a handle on the ages

1203
00:53:45,940 --> 00:53:44,810
of these waters but we are collaborating

1204
00:53:47,790 --> 00:53:45,950
with

1205
00:53:50,370 --> 00:53:47,800
Canadian researchers who are again

1206
00:53:53,829 --> 00:53:50,380
attempting a variety of techniques

1207
00:53:57,040 --> 00:53:53,839
primarily noble gases to see if if they

1208
00:53:58,450 --> 00:53:57,050
can get some reliable some reliable ages

1209
00:54:00,940 --> 00:53:58,460
at least for the most concentrated

1210
00:54:04,270 --> 00:54:00,950
brines and then develop some mixing

1211
00:54:07,270 --> 00:54:04,280
models of of flushing of these brines

1212
00:54:10,120 --> 00:54:07,280
with waters from the surface right now

1213
00:54:11,349 --> 00:54:10,130

we just don't know we do know that from

1214
00:54:13,630 --> 00:54:11,359
the chemistry of the water is that these

1215
00:54:16,390 --> 00:54:13,640
are these say line components of water

1216
00:54:18,730 --> 00:54:16,400
are not formed by by enrichment by

1217
00:54:21,150 --> 00:54:18,740
freezing recently we they are definitely

1218
00:54:24,280 --> 00:54:21,160
old brines they were formed as

1219
00:54:26,530 --> 00:54:24,290
hydrothermally or as very very ancient

1220
00:54:34,920 --> 00:54:26,540
evaporative deposits but there were not

1221
00:54:41,890 --> 00:54:37,270
okay we have a question from Ames

1222
00:54:45,940 --> 00:54:41,900
Research Center yeah hi this is Dave

1223
00:54:47,530 --> 00:54:45,950
Desmarais I got extensions to Mars and

1224
00:54:50,109 --> 00:54:47,540
the interesting question about

1225
00:54:52,990 --> 00:54:50,119
methanogens versus the sulfur cyclers

1226
00:54:55,059 --> 00:54:53,000
and so forth it correct me if I'm wrong

1227
00:54:56,800 --> 00:54:55,069
but I think most of your sites are in

1228
00:54:59,260 --> 00:54:56,810
sort of continental terrains that are

1229
00:55:01,630 --> 00:54:59,270
sort of more felsic you know granitic

1230
00:55:04,450 --> 00:55:01,640
silica rich and of course the uranium

1231
00:55:06,430 --> 00:55:04,460
concentration maybe also related to that

1232
00:55:08,349 --> 00:55:06,440
because as you know those those types of

1233
00:55:10,059 --> 00:55:08,359
crusts tend to be richer in uranium as

1234
00:55:12,339 --> 00:55:10,069
you move towards Mars though you're

1235
00:55:14,050 --> 00:55:12,349
moving more towards a basaltic matric

1236
00:55:16,329 --> 00:55:14,060
type composition now the good news is

1237
00:55:18,370 --> 00:55:16,339
that the ferrous iron would give you

1238
00:55:20,200 --> 00:55:18,380

more reducing potential within the rock

1239
00:55:22,900 --> 00:55:20,210
on the other hand you know the uranium

1240
00:55:25,000 --> 00:55:22,910
stories is TBD have you thought at all

1241
00:55:27,130 --> 00:55:25,010
about just how the bulk rock composition

1242
00:55:28,720 --> 00:55:27,140
might be affecting your consideration of

1243
00:55:33,579 --> 00:55:28,730
methanogens versus other groups of

1244
00:55:36,190 --> 00:55:33,589
organisms well we thought quite a bit

1245
00:55:38,800 --> 00:55:36,200
about this problem of how much radiation

1246
00:55:41,170 --> 00:55:38,810
is potentially on Mars given the

1247
00:55:43,630 --> 00:55:41,180
difference both in its bulk rock type

1248
00:55:45,849 --> 00:55:43,640
and in the apparent overall

1249
00:55:49,089 --> 00:55:45,859
concentration of radioactive materials

1250
00:55:51,190 --> 00:55:49,099
and the interesting thing is on Mars the

1251
00:55:53,079 --> 00:55:51,200
way in which the groundwater is forming

1252
00:55:54,730 --> 00:55:53,089
and the very ancient age of the

1253
00:55:56,770 --> 00:55:54,740
groundwater kind of works to our

1254
00:55:57,680 --> 00:55:56,780
advantage even though there's there's

1255
00:56:03,590 --> 00:55:57,690
less

1256
00:56:06,080 --> 00:56:03,600
radioactive material these these brines

1257
00:56:07,370 --> 00:56:06,090
are aging for long periods of time so

1258
00:56:10,340 --> 00:56:07,380
that you you actually have the

1259
00:56:13,010 --> 00:56:10,350
possibility to to build up over billions

1260
00:56:15,200 --> 00:56:13,020
of years fairly significant oxidizing

1261
00:56:17,360 --> 00:56:15,210
potential in those brians if you can

1262
00:56:20,540 --> 00:56:17,370
move away and not back react the

1263
00:56:22,400 --> 00:56:20,550

hydrogen so that's that's our one

1264
00:56:24,110 --> 00:56:22,410
thought at the moment I don't I again I

1265
00:56:27,830 --> 00:56:24,120
don't think it shuts this out as a

1266
00:56:30,050 --> 00:56:27,840
process but obviously it's not it's not

1267
00:56:32,840 --> 00:56:30,060
going to operate at this with the same

1268
00:56:35,810 --> 00:56:32,850
kind of fluxes that you have in a you

1269
00:56:37,490 --> 00:56:35,820
know a year a nanite bearing or body but

1270
00:56:39,020 --> 00:56:37,500
I still I still think it's something we

1271
00:56:42,460 --> 00:56:39,030
have to look at in our preliminary

1272
00:56:46,250 --> 00:56:42,470
modeling it's quite a substantial source

1273
00:56:48,560 --> 00:56:46,260
of sulfate in the subsurface did you

1274
00:56:50,720 --> 00:56:48,570
want to comment on the methanogens TC

1275
00:56:52,610 --> 00:56:50,730
yeah yeah so the you know the

1276
00:56:54,740 --> 00:56:52,620
ventersdorp lava is in South Africa are

1277
00:56:56,060 --> 00:56:54,750
actually may pick the salts to start

1278
00:56:57,590 --> 00:56:56,070
with and one of the reasons why we moved

1279
00:57:01,070 --> 00:56:57,600
to high lake was to get back into a

1280
00:57:02,810 --> 00:57:01,080
thick volcanic terrain and as Lisa Lisa

1281
00:57:05,840 --> 00:57:02,820
alluded to when you do the calculations

1282
00:57:07,760 --> 00:57:05,850
for radiolysis to Mars not drop it by an

1283
00:57:10,790 --> 00:57:07,770
order of magnitude or tours of magnitude

1284
00:57:14,480 --> 00:57:10,800
the rates distraught by that factor

1285
00:57:17,120 --> 00:57:14,490
essentially but when you include or

1286
00:57:21,620 --> 00:57:17,130
calculate how much would be required to

1287
00:57:24,020 --> 00:57:21,630
sustain microbial ecosystem there's

1288
00:57:27,230 --> 00:57:24,030

still plenty of energy there to do

1289
00:57:29,330 --> 00:57:27,240
exactly that particularly if you believe

1290
00:57:33,530 --> 00:57:29,340
that this you know this issue the

1291
00:57:35,090 --> 00:57:33,540
maintenance energy rate is more on Mars

1292
00:57:37,640 --> 00:57:35,100
because the temperatures are lower on

1293
00:57:40,580 --> 00:57:37,650
Mars now with respect to the methanogens

1294
00:57:43,370 --> 00:57:40,590
at least in South Africa what appears to

1295
00:57:46,820 --> 00:57:43,380
be going on there is that as you go

1296
00:57:49,400 --> 00:57:46,830
deeper into the crust the calcium

1297
00:57:50,780 --> 00:57:49,410
carbonate levels begin to our she say

1298
00:57:52,370 --> 00:57:50,790
the carbonate what was begin to diminish

1299
00:57:54,740 --> 00:57:52,380
and that's because the calcium

1300
00:57:57,230 --> 00:57:54,750
concentrations brians have increased pH

1301
00:58:00,470 --> 00:57:57,240
stays very very elevated so the DIC

1302
00:58:02,960 --> 00:58:00,480
sinks like a stack of logs and that

1303
00:58:04,340 --> 00:58:02,970
removes co2 as the principal electron

1304
00:58:05,540 --> 00:58:04,350
acceptor from the system even though

1305
00:58:06,350 --> 00:58:05,550
there's copious amounts of hydrogen

1306
00:58:09,800 --> 00:58:06,360
available

1307
00:58:11,930 --> 00:58:09,810
that seems to be what is controlling the

1308
00:58:14,750 --> 00:58:11,940
diminution of methanogens as you go

1309
00:58:16,730 --> 00:58:14,760
deeper into the subsurface we haven't

1310
00:58:18,440 --> 00:58:16,740
done a similar type of analyses however

1311
00:58:21,080 --> 00:58:18,450
for Lupin mines and I'm frankly a little

1312
00:58:24,140 --> 00:58:21,090
bit puzzled still as why we are seeing

1313
00:58:28,190 --> 00:58:24,150

any archaia at lupin as yet although you

1314
00:58:35,630 --> 00:58:28,200
find our KO present in ice deposits so

1315
00:58:42,200 --> 00:58:35,640
I'm battle by that okay we have a

1316
00:58:45,950 --> 00:58:42,210
question from Penn State Yoshio moto

1317
00:58:49,390 --> 00:58:45,960
Lisa and TC enjoyed your presentation

1318
00:58:54,890 --> 00:58:49,400
very much my question concerns the

1319
00:59:00,080 --> 00:58:54,900
origin and age of the sulphate area in

1320
00:59:04,190 --> 00:59:00,090
deep mines in South Africa I am except

1321
00:59:07,640 --> 00:59:04,200
those the water itself is very old 15 to

1322
00:59:11,270 --> 00:59:07,650
25 million years but I'm not quite sure

1323
00:59:14,210 --> 00:59:11,280
how you can date those microbes

1324
00:59:16,400 --> 00:59:14,220
themselves whether they were

1325
00:59:19,340 --> 00:59:16,410
contaminated from the surface quite

1326
00:59:23,180 --> 00:59:19,350
recently or they are transported from

1327
00:59:26,750 --> 00:59:23,190
the surface water body 15 25 million

1328
00:59:30,610 --> 00:59:26,760
years ago brought back and down by a

1329
00:59:33,860 --> 00:59:30,620
circulating meteoric water deep down and

1330
00:59:37,090 --> 00:59:33,870
they survived all the 15 25 million

1331
00:59:41,330 --> 00:59:37,100
years period and they have any

1332
00:59:44,630 --> 00:59:41,340
constraints of age or microbes do they

1333
00:59:49,580 --> 00:59:44,640
have a different DNA sequence compared

1334
00:59:53,750 --> 00:59:49,590
to the modern one in those area just

1335
00:59:56,300 --> 00:59:53,760
answer the question Hiroshi they do you

1336
00:59:59,420 --> 00:59:56,310
do yeah they're good oh yeah I mean we

1337
01:00:01,870 --> 00:59:59,430
characterize the water that's used in

1338
01:00:04,690 --> 01:00:01,880

the mining process in terms of the

1339
01:00:07,280 --> 01:00:04,700
diversity of organisms present there

1340
01:00:09,560 --> 01:00:07,290
they they leave a very clear fingerprint

1341
01:00:13,340 --> 01:00:09,570
you see a distinctive set of iron

1342
01:00:15,260 --> 01:00:13,350
oxidizing proteobacteria as well as some

1343
01:00:16,770 --> 01:00:15,270
of the other usual culprits that show up

1344
01:00:20,820 --> 01:00:16,780
in drilling wheels

1345
01:00:23,010 --> 01:00:20,830
a couple lovers you don't find our

1346
01:00:26,520 --> 01:00:23,020
organism presence with your self a root

1347
01:00:29,040 --> 01:00:26,530
asst in any mining water whatsoever also

1348
01:00:30,750 --> 01:00:29,050
it's absent from any water that is

1349
01:00:34,050 --> 01:00:30,760
shallower than one and a half kilometers

1350
01:00:35,640 --> 01:00:34,060
as well it's just as showing up doesn't

1351
01:00:38,220 --> 01:00:35,650
necessarily mean it isn't there for

1352
01:00:40,260 --> 01:00:38,230
instance if we had used the technique

1353
01:00:43,050 --> 01:00:40,270
that that Mitch Sullivan has been

1354
01:00:45,660 --> 01:00:43,060
recently publishing is the base of is

1355
01:00:47,490 --> 01:00:45,670
river biosphere it could be that

1356
01:00:49,890 --> 01:00:47,500
disulfiram ight be up there in the

1357
01:00:52,620 --> 01:00:49,900
shallow or aquifers but as a very very

1358
01:00:55,380 --> 01:00:52,630
very tiny undetectable constituent that

1359
01:00:58,230 --> 01:00:55,390
we haven't seen yet we can't preclude

1360
01:00:59,910 --> 01:00:58,240
that while we knew do know is that it

1361
01:01:03,240 --> 01:00:59,920
dominates the environment once you're

1362
01:01:08,940 --> 01:01:03,250
below 15 kilometers and the ages of the

1363
01:01:13,110 --> 01:01:08,950

water are over three million years does

1364
01:01:16,020 --> 01:01:13,120
that answer your other life lessons do

1365
01:01:18,360 --> 01:01:16,030
you look at the drill water itself the

1366
01:01:20,910 --> 01:01:18,370
helium gas ratios are quite radiogenic

1367
01:01:23,340 --> 01:01:20,920
be rich and they don't show an isotopic

1368
01:01:26,190 --> 01:01:23,350
in fact they're depleted in isotopic

1369
01:01:30,690 --> 01:01:26,200
noble gases it's kind of hard to imagine

1370
01:01:33,180 --> 01:01:30,700
how a fracture zone is exposed to mine

1371
01:01:35,970 --> 01:01:33,190
error or mine microbes without

1372
01:01:38,130 --> 01:01:35,980
essentially depleting its noble gases

1373
01:01:41,070 --> 01:01:38,140
and replacing it with an atmospheric

1374
01:01:42,690 --> 01:01:41,080
noble gas composition that's really our

1375
01:01:46,260 --> 01:01:42,700
strongest line of evidence to suggest

1376
01:01:48,720 --> 01:01:46,270
that the fracture zone waters have not

1377
01:01:51,080 --> 01:01:48,730
been exposed to mining water that's not

1378
01:01:53,190 --> 01:01:51,090
to say that the waters don't have some

1379
01:01:54,660 --> 01:01:53,200
constituents which might be contaminants

1380
01:01:58,410 --> 01:01:54,670
that it picks up on the way out of the

1381
01:02:00,260 --> 01:01:58,420
borehole but the dominant organisms seem

1382
01:02:03,570 --> 01:02:00,270
to be entrapped literally entombed

1383
01:02:06,260 --> 01:02:03,580
within these fracture waters now could

1384
01:02:08,850 --> 01:02:06,270
it be older than 25 to 30 million years

1385
01:02:13,080 --> 01:02:08,860
that we had no constraint that we cannot

1386
01:02:15,120 --> 01:02:13,090
say I think also as we mentioned as we

1387
01:02:17,490 --> 01:02:15,130
mentioned earlier it there's also this

1388
01:02:19,740 --> 01:02:17,500

intriguing absence of the 02 tolerance

1389
01:02:24,390 --> 01:02:19,750
genes I mean this organism appears to

1390
01:02:28,710 --> 01:02:24,400
have been removed from regular contact

1391
01:02:29,770 --> 01:02:28,720
with at least 02 for an extended period

1392
01:02:32,920 --> 01:02:29,780
of time

1393
01:02:37,390 --> 01:02:32,930
that it it has completely lost those

1394
01:02:39,340 --> 01:02:37,400
pathways but they must have originated

1395
01:02:42,790 --> 01:02:39,350
from the surface right and then

1396
01:02:45,220 --> 01:02:42,800
transported down by the water a sulfate

1397
01:02:49,230 --> 01:02:45,230
reducing bacteria rather than and then

1398
01:02:51,580 --> 01:02:49,240
evolved this time in deep subsurface

1399
01:02:54,880 --> 01:02:51,590
environmental happy we're gonna say that

1400
01:02:56,410 --> 01:02:54,890
that we don't know of the win you know

1401
01:03:01,030 --> 01:02:56,420
they could be moving up and down in the

1402
01:03:08,290 --> 01:03:01,040
crust for quite a long time but we have

1403
01:03:10,450 --> 01:03:08,300
no constraint on that good good question

1404
01:03:12,790 --> 01:03:10,460
sir oh sure I would I wish we did know

1405
01:03:15,400 --> 01:03:12,800
the answer I wish there was a way of

1406
01:03:17,290 --> 01:03:15,410
hearing a lot dating a bacterium that

1407
01:03:21,610 --> 01:03:17,300
would be great but we don't have that

1408
01:03:25,150 --> 01:03:21,620
much okay thank you okay we have a

1409
01:03:26,830 --> 01:03:25,160
question for a limited edition from it

1410
01:03:32,530 --> 01:03:26,840
university of arizona we have a question

1411
01:03:35,140 --> 01:03:32,540
and then we'll go back presumably you

1412
01:03:39,840 --> 01:03:35,150
can ask you question huh okay my

1413
01:03:44,460 --> 01:03:39,850

question is that Mulally waters on Mars

1414
01:03:49,790 --> 01:03:44,470
are likely highly enriched in co2

1415
01:03:53,540 --> 01:03:49,800
that evidence in part by a lot explosive

1416
01:03:57,240 --> 01:03:53,550
closer flooding that you've seen and by

1417
01:04:01,859 --> 01:03:57,250
volcanism societal catharsis fault and

1418
01:04:03,839 --> 01:04:01,869
so the water chemistry is likely to be a

1419
01:04:07,800 --> 01:04:03,849
lot different because it's just like

1420
01:04:10,680 --> 01:04:07,810
ready to expose here to get suckled of

1421
01:04:16,650 --> 01:04:10,690
the static sometimes you can possibly

1422
01:04:23,670 --> 01:04:16,660
even the present day that was the

1423
01:04:27,480 --> 01:04:23,680
question okay so the question is are you

1424
01:04:29,700 --> 01:04:27,490
questions asking us to say whether we

1425
01:04:33,810 --> 01:04:29,710
think that the water is high in co2

1426
01:04:38,460 --> 01:04:33,820
omar's or not no I'm saying where you

1427
01:04:41,070 --> 01:04:38,470
told me that it is I think giving them

1428
01:04:43,470 --> 01:04:41,080
likelihood that it is per certain

1429
01:04:48,020 --> 01:04:43,480
theories how would that high of

1430
01:04:56,370 --> 01:04:48,030
concentration of co2 affect your

1431
01:04:58,109 --> 01:04:56,380
policies I'm really sorry I'm afraid I'm

1432
01:05:00,270 --> 01:04:58,119
afraid we're not understanding exactly

1433
01:05:04,790 --> 01:05:00,280
what you're asking if you know if you're

1434
01:05:07,920 --> 01:05:04,800
asking would co2 out-compete sulfate um

1435
01:05:10,560 --> 01:05:07,930
yeah energetically it would be quite

1436
01:05:13,320 --> 01:05:10,570
favorable and I'm sure if there are

1437
01:05:15,990 --> 01:05:13,330
organisms there they would take they

1438
01:05:19,980 --> 01:05:16,000

would take advantage of co2 as an

1439
01:05:24,839 --> 01:05:19,990
electron acceptor it would be it'd be a

1440
01:05:27,180 --> 01:05:24,849
free lunch yeah so it's a different

1441
01:05:31,689 --> 01:05:27,190
chemistry than your comparison that was

1442
01:05:40,449 --> 01:05:34,579
okay yes that means that you know that

1443
01:05:45,259 --> 01:05:42,619
depends who you talk to about a lot

1444
01:05:48,739 --> 01:05:45,269
theories say yes if you have a lot of

1445
01:05:51,439 --> 01:05:48,749
co2 in the subsurface especially given

1446
01:05:54,289 --> 01:05:51,449
the back I think we'd also have to

1447
01:05:56,269 --> 01:05:54,299
assume though that these these ancient

1448
01:05:57,829 --> 01:05:56,279
very slowly circulating ground waters

1449
01:05:59,539 --> 01:05:57,839
are likely to be quite stratified

1450
01:06:02,809 --> 01:05:59,549
vertically in terms of their chemistry

1451
01:06:05,989 --> 01:06:02,819
and if most of the co2 is is in the

1452
01:06:07,879 --> 01:06:05,999
atmosphere then is it and yet we see all

1453
01:06:09,589 --> 01:06:07,889
this evidence of sulfate then perhaps as

1454
01:06:11,389 --> 01:06:09,599
you go down it would become a sulfate

1455
01:06:14,929 --> 01:06:11,399
dominated system i don't know but that's

1456
01:06:16,819 --> 01:06:14,939
just kind of a kind of a guess well the

1457
01:06:20,269 --> 01:06:16,829
only input to groundwater that you have

1458
01:06:25,219 --> 01:06:20,279
is water being forced down underneath

1459
01:06:31,129 --> 01:06:25,229
the north polar cap so which in any case

1460
01:06:36,289 --> 01:06:31,139
I'm satisfied thank you we had a

1461
01:06:39,429 --> 01:06:36,299
question from Goddard oh yeah it's mike

1462
01:06:42,819 --> 01:06:39,439
Mumma here I'm actually interested to

1463
01:06:47,599 --> 01:06:42,829

ask for your opinion on the maximum

1464
01:06:49,339 --> 01:06:47,609
viable time span is the maximum times

1465
01:06:52,669 --> 01:06:49,349
member which to our organism might

1466
01:06:55,429 --> 01:06:52,679
remain viable in a truly closed

1467
01:06:59,239 --> 01:06:55,439
environment below the permafrost layer

1468
01:07:01,579 --> 01:06:59,249
and the driver here is we think the

1469
01:07:03,559 --> 01:07:01,589
promo cross on Mars they might be

1470
01:07:05,869 --> 01:07:03,569
inactive for a billion years or more

1471
01:07:09,229 --> 01:07:05,879
this is little evidence of tectonic

1472
01:07:11,029 --> 01:07:09,239
activity in recent times and I wonder if

1473
01:07:14,509 --> 01:07:11,039
you thought much about how to

1474
01:07:17,119 --> 01:07:14,519
extrapolate twenty five thousand year

1475
01:07:22,749 --> 01:07:17,129
old communities in the Arctic to maybe

1476
01:07:27,439 --> 01:07:25,309
right well I think that's essentially

1477
01:07:29,269 --> 01:07:27,449
what we're doing if you characterize the

1478
01:07:30,889 --> 01:07:29,279
environment well enough and you

1479
01:07:35,059 --> 01:07:30,899
understand the major players and the

1480
01:07:36,289 --> 01:07:35,069
processes makes the extrapolation you

1481
01:07:38,389 --> 01:07:36,299
can make that extrapolation with a

1482
01:07:40,730 --> 01:07:38,399
little bit greater confidence from zero

1483
01:07:42,680 --> 01:07:40,740
knowledge at all

1484
01:07:44,510 --> 01:07:42,690
all we can say right now at this stage

1485
01:07:48,710 --> 01:07:44,520
of the game is that there's there's

1486
01:07:52,130 --> 01:07:48,720
nothing that suggests to us that there's

1487
01:07:55,040 --> 01:07:52,140
any showstopper there's nothing that

1488
01:07:57,620 --> 01:07:55,050

would prevent a subsurface microbial

1489
01:08:00,859 --> 01:07:57,630
ecosystem that's separated from the

1490
01:08:03,170 --> 01:08:00,869
surface by permafrost from surviving for

1491
01:08:06,290 --> 01:08:03,180
billions of years because it will always

1492
01:08:08,510 --> 01:08:06,300
have a source of energy from radiolysis

1493
01:08:11,600 --> 01:08:08,520
as long as there's a water present in

1494
01:08:14,270 --> 01:08:11,610
the system yogita krimmer problem it's

1495
01:08:18,740 --> 01:08:14,280
the only answer that we can get at the

1496
01:08:21,499 --> 01:08:18,750
stage welcome only they're not totally

1497
01:08:24,019 --> 01:08:21,509
closed because the if they are losing

1498
01:08:26,690 --> 01:08:24,029
the thing to the atmosphere there's some

1499
01:08:29,599 --> 01:08:26,700
clear exchange where there must be some

1500
01:08:33,320 --> 01:08:29,609
kind of permeability to pores and crater

1501
01:08:35,900 --> 01:08:33,330
walls or scarps sailor may well be some

1502
01:08:38,990 --> 01:08:35,910
back diffusion possible at other times

1503
01:08:41,450 --> 01:08:39,000
co2 confusing in words for example and

1504
01:08:43,940 --> 01:08:41,460
so forth so I don't know if you've

1505
01:08:45,620 --> 01:08:43,950
thought about a kind of a breathing

1506
01:08:49,010 --> 01:08:45,630
event if you like where there's gas

1507
01:08:50,900 --> 01:08:49,020
exchange between this subsurface

1508
01:08:53,900 --> 01:08:50,910
communities across community on the

1509
01:08:57,980 --> 01:08:53,910
atmosphere itself or not would that

1510
01:08:59,840 --> 01:08:57,990
change your we certainly have thought

1511
01:09:02,300 --> 01:08:59,850
about that and I know you know a number

1512
01:09:06,019 --> 01:09:02,310
of us at the workshop last week talked

1513
01:09:07,610 --> 01:09:06,029

about needing to do some some active

1514
01:09:10,010 --> 01:09:07,620
measurements and needing to look more

1515
01:09:13,760 --> 01:09:10,020
carefully at how things like methane and

1516
01:09:17,210 --> 01:09:13,770
hydrogen move in and out of these these

1517
01:09:19,730 --> 01:09:17,220
Isis in permafrost both the the pure

1518
01:09:21,920 --> 01:09:19,740
water ices and the various clathrates

1519
01:09:24,530 --> 01:09:21,930
it's a big unknown and I think you're

1520
01:09:27,980 --> 01:09:24,540
absolutely right we we need to know if

1521
01:09:31,700 --> 01:09:27,990
this is a nearly impermeable barrier or

1522
01:09:34,430 --> 01:09:31,710
if if if it's quite quite permeable

1523
01:09:38,450 --> 01:09:34,440
selectively to various gases moving back

1524
01:09:40,670 --> 01:09:38,460
and forth certainly and you know Maya

1525
01:09:44,240 --> 01:09:40,680
through this already your hydrogen will

1526
01:09:46,070 --> 01:09:44,250
diffuse through ice no problem at all so

1527
01:09:48,140 --> 01:09:46,080
if we see any signs of hydrogen coming

1528
01:09:50,459 --> 01:09:48,150
out of the system hydrogen's being

1529
01:09:52,779 --> 01:09:50,469
neighbor I radiolysis that's a given

1530
01:09:54,160 --> 01:09:52,789
if it's if there's no hydrogen coming

1531
01:09:56,589 --> 01:09:54,170
out at all that's actually a good sign

1532
01:10:00,160 --> 01:09:56,599
for us means that it's being consumed

1533
01:10:02,500 --> 01:10:00,170
down there probably McNally you you

1534
01:10:06,160 --> 01:10:02,510
mentioned that you do collect the

1535
01:10:09,549 --> 01:10:06,170
effluent gases from your column the core

1536
01:10:13,020 --> 01:10:09,559
and do you then do mass spec analysis on

1537
01:10:19,750 --> 01:10:13,030
those or any other kind of that's right

1538
01:10:23,169 --> 01:10:19,760

you did and you see hydrogen yes what

1539
01:10:25,989 --> 01:10:23,179
does the heat retention election you

1540
01:10:29,649 --> 01:10:25,999
mean i didn't know i don't think i have

1541
01:10:30,939 --> 01:10:29,659
to leave that for Barbara it'll be a

1542
01:10:33,189 --> 01:10:30,949
question as whether there's enough

1543
01:10:35,680 --> 01:10:33,199
hydrogen and those rock cores to give us

1544
01:10:37,390 --> 01:10:35,690
an answer yeah well sorry certainly

1545
01:10:40,449 --> 01:10:37,400
there were very high concentrations of

1546
01:10:42,699 --> 01:10:40,459
hydrogen in the ground waters in South

1547
01:10:46,479 --> 01:10:42,709
Africa right and there's less hydrogen

1548
01:10:48,219 --> 01:10:46,489
in the loop and lions right but your

1549
01:10:54,160 --> 01:10:48,229
pressures they're still fairly high

1550
01:10:56,319 --> 01:10:54,170
under the loop in mind for example last

1551
01:10:58,479 --> 01:10:56,329
because right the pressures actually set

1552
01:10:59,859 --> 01:10:58,489
at the base of the permafrost and so

1553
01:11:02,799 --> 01:10:59,869
we're only a few hundred meters below

1554
01:11:04,839 --> 01:11:02,809
the banks of the permafrost yeah because

1555
01:11:07,149 --> 01:11:04,849
it's in equilibrium I just hydrostatic

1556
01:11:11,529 --> 01:11:07,159
equilibrium there that's exactly right

1557
01:11:15,310 --> 01:11:11,539
yeah okay around your number of five

1558
01:11:17,890 --> 01:11:15,320
bars driving pressure in the deep mines

1559
01:11:20,620 --> 01:11:17,900
in South Africa they don't murmuring

1560
01:11:24,540 --> 01:11:20,630
incorrectly is that right you can't

1561
01:11:31,550 --> 01:11:24,550
possibly be right mr. know well now

1562
01:11:31,560 --> 01:11:38,920
yeah you don't want getting fun of that

1563
01:11:45,740 --> 01:11:41,660

gently hit man for him you get your

1564
01:11:50,080 --> 01:11:45,750
imagination in there yeah yes they were

1565
01:11:54,890 --> 01:11:50,090
about what eight megapascals dink I

1566
01:12:02,600 --> 01:11:54,900
would have to go look it up now can we

1567
01:12:04,700 --> 01:12:02,610
have another question from Penn State hi

1568
01:12:07,280 --> 01:12:04,710
and there was a wonderful talk this is

1569
01:12:08,840 --> 01:12:07,290
irene schneider I had some brief

1570
01:12:11,810 --> 01:12:08,850
communication over the email with you

1571
01:12:13,910 --> 01:12:11,820
two is about we're interested in your

1572
01:12:16,730 --> 01:12:13,920
results because it directly relates to

1573
01:12:18,590 --> 01:12:16,740
my thesis I'm doing radiation

1574
01:12:21,920 --> 01:12:18,600
environments on Mars surface and

1575
01:12:23,780 --> 01:12:21,930
subsurface so I I wanted to know i'm not

1576
01:12:25,610 --> 01:12:23,790
sure if I heard you well before but I

1577
01:12:30,140 --> 01:12:25,620
think you you mentioned something like

1578
01:12:33,890 --> 01:12:30,150
an order of magnitude less on Mars in

1579
01:12:35,560 --> 01:12:33,900
regards with your radiogenic output in

1580
01:12:39,080 --> 01:12:35,570
the subsurface and I wanted to know

1581
01:12:40,820 --> 01:12:39,090
exactly if that's what you said or if so

1582
01:12:47,180 --> 01:12:40,830
why why do you have an order of

1583
01:12:52,040 --> 01:12:47,190
magnitude less for or Mars I was just

1584
01:12:53,810 --> 01:12:52,050
using the uranium thorium concentrations

1585
01:12:56,720 --> 01:12:53,820
that have been reported for snick

1586
01:12:58,970 --> 01:12:56,730
meteorites and the potassium

1587
01:13:02,210 --> 01:12:58,980
concentration that has been reported by

1588
01:13:04,520 --> 01:13:02,220

Rovers but that's relative to these

1589
01:13:08,780 --> 01:13:04,530
uranium mines right which are not

1590
01:13:12,920 --> 01:13:08,790
representative of average earth isn't or

1591
01:13:14,900 --> 01:13:12,930
is no re thanks no no no those are

1592
01:13:18,390 --> 01:13:14,910
orders itself

1593
01:13:20,970 --> 01:13:18,400
no no I'm saying Mars itself is depleted

1594
01:13:23,790 --> 01:13:20,980
with respect to bulk continental crust

1595
01:13:25,560 --> 01:13:23,800
yeah okay so in other words the

1596
01:13:28,440 --> 01:13:25,570
concentrations the concentrations that

1597
01:13:30,780 --> 01:13:28,450
we see in South Africa of hydrogen is

1598
01:13:34,620 --> 01:13:30,790
actually consistent with the bulk value

1599
01:13:37,920 --> 01:13:34,630
and in fact you look at the details of

1600
01:13:40,920 --> 01:13:37,930
uranium chemistry uranium is high only a

1601
01:13:42,540 --> 01:13:40,930
very very thin layers and that Robert

1602
01:13:48,030 --> 01:13:42,550
Ren says well overall it's actually

1603
01:13:50,040 --> 01:13:48,040
depleted okay so okay so that's

1604
01:13:52,020 --> 01:13:50,050
basically a safe estimate right for Mars

1605
01:13:55,590 --> 01:13:52,030
you just go and order magnitude lesson

1606
01:13:57,150 --> 01:13:55,600
in that kind of vow that assessment cuz

1607
01:13:58,830 --> 01:13:57,160
I was taking basically the equivalent to

1608
01:14:00,480 --> 01:13:58,840
Earth's but I wasn't sure if there was a

1609
01:14:02,610 --> 01:14:00,490
safe estimate for Mars so that's why I'm

1610
01:14:04,710 --> 01:14:02,620
asking you right I think I published

1611
01:14:06,210 --> 01:14:04,720
something in the astrobiology journal

1612
01:14:10,050 --> 01:14:06,220
last year that sort of gives you the

1613
01:14:12,780 --> 01:14:10,060

numbers that i'm talking about it thanks

1614
01:14:15,030 --> 01:14:12,790
and i think you'd find that the people

1615
01:14:18,510 --> 01:14:15,040
looking at the differences in the

1616
01:14:21,990 --> 01:14:18,520
tectonic styles for the two planets like

1617
01:14:28,380 --> 01:14:22,000
like numbers in that range order of

1618
01:14:37,390 --> 01:14:31,390
okay we're back here at nai central is

1619
01:14:40,960 --> 01:14:37,400
everyone still there Lisa and TC we're

1620
01:14:42,190 --> 01:14:40,970
here and we can hear you okay okay we

1621
01:14:44,800 --> 01:14:42,200
got dropped for a couple of minutes

1622
01:14:53,500 --> 01:14:44,810
there but it carry on if the questions

1623
01:14:56,950 --> 01:14:53,510
were still going we are hearing funny

1624
01:14:59,170 --> 01:14:56,960
echoes though so we may have hit a point

1625
01:15:01,390 --> 01:14:59,180
of diminishing returns kind of you know

1626
01:15:06,390 --> 01:15:01,400
space time cause all the roofers are

1627
01:15:08,590 --> 01:15:06,400
here ok I think James had one question

1628
01:15:12,700 --> 01:15:08,600
if they don't that was the last

1629
01:15:15,550 --> 01:15:12,710
questions I believe ok if that's it then

1630
01:15:18,820 --> 01:15:15,560
I think we should once again thank Lisa

1631
01:15:20,680 --> 01:15:18,830
and TC for a great talk and thanks for

1632
01:15:22,270 --> 01:15:20,690
summarizing all of your work in this

1633
01:15:24,310 --> 01:15:22,280
area it's really fascinating we look

1634
01:15:26,710 --> 01:15:24,320
forward to hearing the next installments