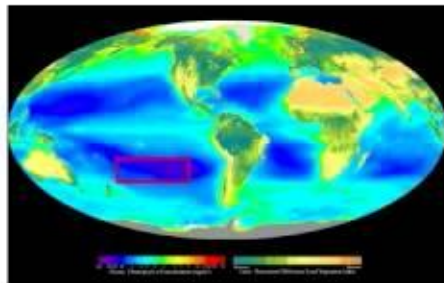
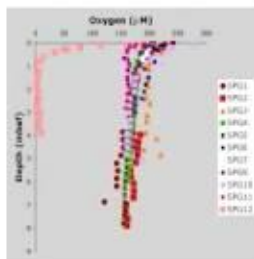




Radiolytic H₂ in gyre sediments?



1
00:00:11,540 --> 00:00:05,059
good morning or afternoon everyone this

2
00:00:14,660 --> 00:00:11,550
is carl at nai central and welcome to

3
00:00:18,680 --> 00:00:14,670
the latest in the director seminar

4
00:00:21,439 --> 00:00:18,690
series our speaker today is steve daunt

5
00:00:24,230 --> 00:00:21,449
from the university of rhode island p l

6
00:00:26,210 --> 00:00:24,240
of our alumni team and he is speaking to

7
00:00:28,970 --> 00:00:26,220
us from the Marine Biological Laboratory

8
00:00:30,710 --> 00:00:28,980
one of our current team so we have a

9
00:00:33,410 --> 00:00:30,720
little entertainment or action going on

10
00:00:37,310 --> 00:00:33,420
even real time during the seminar today

11
00:00:40,700 --> 00:00:37,320
it's a real pleasure to have Steve speak

12
00:00:42,470 --> 00:00:40,710
to us he is has been working on some

13
00:00:44,569 --> 00:00:42,480

very exciting things that we're going to

14

00:00:46,850 --> 00:00:44,579

hear about to give you a little bit of

15

00:00:49,250 --> 00:00:46,860

background on Steve he is a professor of

16

00:00:51,889 --> 00:00:49,260

Oceanography at the University of Rhode

17

00:00:54,470 --> 00:00:51,899

Island has a bachelor's in geology from

18

00:00:56,660 --> 00:00:54,480

Stanford and masters and PhD in

19

00:00:59,860 --> 00:00:56,670

geological and geophysical Sciences from

20

00:01:04,070 --> 00:00:59,870

Princeton University he has been working

21

00:01:06,200 --> 00:01:04,080

for some time on studying life in

22

00:01:10,310 --> 00:01:06,210

extreme environments particularly life

23

00:01:12,410 --> 00:01:10,320

in subsea floor sediments and biological

24

00:01:14,960 --> 00:01:12,420

controls on the chemical evolution of

25

00:01:18,770 --> 00:01:14,970

the ocean and atmosphere and he has

26

00:01:20,780 --> 00:01:18,780

written recently made a field expedition

27

00:01:23,149 --> 00:01:20,790

to the South Pacific Gyre which we're

28

00:01:25,550 --> 00:01:23,159

going to be hearing about today in a

29

00:01:28,160 --> 00:01:25,560

talk entitled microbial activities in

30

00:01:34,190 --> 00:01:28,170

deep sub seafloor sediments and Steve

31

00:01:36,620 --> 00:01:34,200

I'll turn it right over to you thank you

32

00:01:39,560 --> 00:01:36,630

very much Carl for the warm introduction

33

00:01:41,120 --> 00:01:39,570

and thank you for inviting me to have

34

00:01:45,319 --> 00:01:41,130

this opportunity to speak with all of

35

00:01:48,469 --> 00:01:45,329

our friends at nai again Carl has

36

00:01:50,630 --> 00:01:48,479

already read my title to you so i won't

37

00:01:52,370 --> 00:01:50,640

i won't repeat that the people i've

38

00:01:55,670 --> 00:01:52,380

listed as co-authors some of you will

39

00:01:58,359 --> 00:01:55,680

know as members of our team these are

40

00:02:00,289 --> 00:01:58,369

team members whose work as directly

41

00:02:02,539 --> 00:02:00,299

related to what i'm going to present

42

00:02:06,730 --> 00:02:02,549

today so this is a subset of the

43

00:02:09,760 --> 00:02:06,740

membership of our our nai alumni team

44

00:02:12,650 --> 00:02:09,770

the two images i've put up there are

45

00:02:13,790 --> 00:02:12,660

photographs of the two ships that we've

46

00:02:16,430 --> 00:02:13,800

used for most

47

00:02:19,850 --> 00:02:16,440

of our expeditions the lower photograph

48

00:02:21,790 --> 00:02:19,860

is a night photograph of the joy DS

49

00:02:27,670 --> 00:02:21,800

resolution the International drillship

50

00:02:30,680 --> 00:02:27,680

taken in San Diego harbor and the upper

51
00:02:36,260 --> 00:02:30,690
photograph is the Roger Revelle which is

52
00:02:38,900 --> 00:02:36,270
part of the University shared fleet of

53
00:02:40,340 --> 00:02:38,910
the United States there's ships in many

54
00:02:41,690 --> 00:02:40,350
different oceanographic institutions

55
00:02:45,320 --> 00:02:41,700
there's one at the University of Rhode

56
00:02:47,030 --> 00:02:45,330
Island there are a couple at Scripps

57
00:02:48,110 --> 00:02:47,040
plus some some other special things at

58
00:02:49,760 --> 00:02:48,120
Scripps and there are others scattered

59
00:02:52,250 --> 00:02:49,770
around the country this particular one

60
00:02:58,820 --> 00:02:52,260
is a script ship and we used it because

61
00:03:00,710 --> 00:02:58,830
we were working in the Pacific I'm going

62
00:03:03,230 --> 00:03:00,720
to start by drawing your attention to

63
00:03:04,910 --> 00:03:03,240

the blueness of the water there I hope

64

00:03:08,180 --> 00:03:04,920

that you all have rooms dark enough to

65

00:03:09,770 --> 00:03:08,190

see this this is a photograph of the

66

00:03:12,890 --> 00:03:09,780

surface ocean in the South Pacific Gyre

67

00:03:14,390 --> 00:03:12,900

it is the clearest water in the world

68

00:03:17,600 --> 00:03:14,400

the clearest natural water in the world

69

00:03:19,190 --> 00:03:17,610

the deep chlorophyll maximum there is a

70

00:03:22,810 --> 00:03:19,200

little over a hundred and sixty meters

71

00:03:25,880 --> 00:03:22,820

beneath the sea surface the water is a

72

00:03:28,729 --> 00:03:25,890

beautiful periwinkle blue that actually

73

00:03:29,960 --> 00:03:28,739

edges toward violet that's how clear the

74

00:03:31,160 --> 00:03:29,970

water is you're not going to see that

75

00:03:34,580 --> 00:03:31,170

color of water anywhere else in the

76

00:03:36,170 --> 00:03:34,590

world the topic I'm going to discuss

77

00:03:39,350 --> 00:03:36,180

today are listed against the backdrop of

78

00:03:41,750 --> 00:03:39,360

that water I'm going to discuss life in

79

00:03:43,880 --> 00:03:41,760

subsea floor sediments starting with a

80

00:03:48,290 --> 00:03:43,890

focus on biomass and moving on to

81

00:03:49,940 --> 00:03:48,300

activities and sort of categories of

82

00:03:52,010 --> 00:03:49,950

activities that are present then

83

00:03:55,070 --> 00:03:52,020

activity brace a little bit about

84

00:03:57,770 --> 00:03:55,080

community activity then I'll focus on

85

00:03:59,479 --> 00:03:57,780

some examples of effects on the surface

86

00:04:01,520 --> 00:03:59,489

world which some of you can think of as

87

00:04:05,810 --> 00:04:01,530

potential bio signatures on a planetary

88

00:04:07,810 --> 00:04:05,820

scale and then I will close with a

89

00:04:10,310 --> 00:04:07,820

little bit of speculation about

90

00:04:18,320 --> 00:04:10,320

potential food sources for subsea floor

91

00:04:20,599 --> 00:04:18,330

life this first image here if you go

92

00:04:24,290 --> 00:04:20,609

down right there you see a glowing green

93

00:04:26,450 --> 00:04:24,300

dot that's a microbe from a couple

94

00:04:28,969 --> 00:04:26,460

hundred meters beneath the Arctic sea

95

00:04:32,360 --> 00:04:28,979

floor this particular sample was taken

96

00:04:34,790 --> 00:04:32,370

and photographed by David Smith who who

97

00:04:39,400 --> 00:04:34,800

was a member of our team the reason that

98

00:04:41,900 --> 00:04:39,410

dot is glowing green is that it is

99

00:04:44,090 --> 00:04:41,910

stained with cyber green which

100

00:04:47,360 --> 00:04:44,100

preferentially binds to DNA and then

101
00:04:54,770 --> 00:04:47,370
causes fluorescence so that is

102
00:05:02,160 --> 00:04:58,560
these little glowing yellow orange dots

103
00:05:04,820 --> 00:05:02,170
are from another cruise of ours in this

104
00:05:09,510 --> 00:05:04,830
case 320 meters beneath the sea floor in

105
00:05:11,370 --> 00:05:09,520
the equatorial Pacific and this is a

106
00:05:14,460 --> 00:05:11,380
figure from Axl shippers who's one of

107
00:05:16,290 --> 00:05:14,470
our clothes European collaborators these

108
00:05:20,130 --> 00:05:16,300
are stained with a different stain that

109
00:05:23,940 --> 00:05:20,140
binds to RNA and this particular stain

110
00:05:26,610 --> 00:05:23,950
is specific to bacterial RNA so what

111
00:05:29,250 --> 00:05:26,620
we're seeing here is that what would

112
00:05:31,650 --> 00:05:29,260
qualify as a glowing green dot is also a

113
00:05:34,320 --> 00:05:31,660

glowing yellow dot because there's

114

00:05:36,150 --> 00:05:34,330

enough RNA in it to flash which implies

115

00:05:40,610 --> 00:05:36,160

that this organism was recently active

116

00:05:47,790 --> 00:05:42,720

that's going to have some bearing on

117

00:05:51,060 --> 00:05:47,800

what we see next the standard estimate

118

00:05:54,360 --> 00:05:51,070

of life's subsurface biomass if you look

119

00:05:56,880 --> 00:05:54,370

up here you'll see that the standard

120

00:06:00,060 --> 00:05:56,890

estimate by Whitman and colleagues pnas

121

00:06:01,950 --> 00:06:00,070

1998 infers that ninety eight percent of

122

00:06:04,980 --> 00:06:01,960

life in the oceans lies beneath the sea

123

00:06:06,960 --> 00:06:04,990

floor in the sediments you contrast that

124

00:06:09,150 --> 00:06:06,970

with the continents here where we see

125

00:06:11,430 --> 00:06:09,160

about twenty percent is inferred to be

126
00:06:14,280 --> 00:06:11,440
beneath the surface of the continent and

127
00:06:16,230 --> 00:06:14,290
then the global estimate essentially

128
00:06:18,270 --> 00:06:16,240
infers that a little over a third of

129
00:06:20,820 --> 00:06:18,280
life on earth lies beneath the sea floor

130
00:06:23,340 --> 00:06:20,830
I mean beneath the beneath the surface

131
00:06:26,909 --> 00:06:23,350
of the world most of that is beneath the

132
00:06:28,260 --> 00:06:26,919
sea floor so the standard estimate is

133
00:06:30,270 --> 00:06:28,270
essentially that a third of life on

134
00:06:33,120 --> 00:06:30,280
earth lies beneath the sea floor that

135
00:06:35,310 --> 00:06:33,130
estimate is based on the data from this

136
00:06:37,980 --> 00:06:35,320
paper which is paper by john parks and

137
00:06:40,710 --> 00:06:37,990
his collaborators in 1994 where they

138
00:06:45,570 --> 00:06:40,720

presented cell counts from five ocean

139

00:06:47,610 --> 00:06:45,580

drilling program sites and set notice

140

00:06:49,560 --> 00:06:47,620

that they to a first approximation all

141

00:06:54,180 --> 00:06:49,570

had roughly similar numbers of cells at

142

00:06:55,950 --> 00:06:54,190

every depth so there's there's basically

143

00:06:57,510 --> 00:06:55,960

two assumptions being made then in

144

00:07:00,630 --> 00:06:57,520

Whitman's estimate the first assumption

145

00:07:03,000 --> 00:07:00,640

is that the body counts correspond to

146

00:07:04,529 --> 00:07:03,010

living biomass counts in other words

147

00:07:06,980 --> 00:07:04,539

that all of the bodies counted are alive

148

00:07:10,010 --> 00:07:06,990

and the second assumption is that the

149

00:07:15,980 --> 00:07:10,020

five sites a characteristic of the world

150

00:07:18,620 --> 00:07:15,990

as a whole the ocean as a whole we saw

151

00:07:20,780 --> 00:07:18,630

some clues in 2002 that they probably

152

00:07:23,660 --> 00:07:20,790

weren't characteristic of the ocean as a

153

00:07:26,060 --> 00:07:23,670

whole that standard estimate this is

154

00:07:27,980 --> 00:07:26,070

parks at all two thousand line but it's

155

00:07:30,080 --> 00:07:27,990

not radically different than their 1994

156

00:07:33,350 --> 00:07:30,090

line the cell counts from our cruise

157

00:07:34,820 --> 00:07:33,360

these sites in 2002 you see that as we

158

00:07:37,280 --> 00:07:34,830

move offshore into the equatorial

159

00:07:40,880 --> 00:07:37,290

Pacific which is still a nutrient-rich

160

00:07:44,300 --> 00:07:40,890

up blowing zone of the ocean as we move

161

00:07:46,370 --> 00:07:44,310

offshore the counts drop off so the

162

00:07:48,530 --> 00:07:46,380

average count seem to be characteristic

163

00:07:51,200 --> 00:07:48,540

of margin environments like we see here

164

00:07:54,830 --> 00:07:51,210

but perhaps not characteristic of the

165

00:07:57,800 --> 00:07:54,840

sea floor as a whole so let's move a

166

00:07:59,690 --> 00:07:57,810

little bit further into this this is

167

00:08:01,190 --> 00:07:59,700

data from axle shippers paper that I

168

00:08:03,650 --> 00:08:01,200

showed you the figure from a short while

169

00:08:05,660 --> 00:08:03,660

ago what you see here basically these

170

00:08:10,250 --> 00:08:05,670

are acridine orange direct counts like

171

00:08:11,990 --> 00:08:10,260

cyber green black reading orange is

172

00:08:15,320 --> 00:08:12,000

actually a more complex stain it binds

173

00:08:18,580 --> 00:08:15,330

to both DNA and RNA but to a first

174

00:08:21,740 --> 00:08:18,590

approximation since DNA is typically

175

00:08:23,540 --> 00:08:21,750

present long after RNA we can treat this

176

00:08:27,110 --> 00:08:23,550

as a measure of the cells that contain

177

00:08:29,680 --> 00:08:27,120

DNA and then this card fish stayin here

178

00:08:33,200 --> 00:08:29,690

this is the one that binds to RNA alone

179

00:08:36,440 --> 00:08:33,210

so what you see is that roughly ten

180

00:08:40,370 --> 00:08:36,450

percent of the cells on average that are

181

00:08:43,520 --> 00:08:40,380

counted with the DNA stain have enough

182

00:08:46,250 --> 00:08:43,530

RNA to flash with the RNA steam which

183

00:08:48,920 --> 00:08:46,260

suggests that on average approximately

184

00:08:51,640 --> 00:08:48,930

ten percent of the cells may be active

185

00:08:55,300 --> 00:08:51,650

and live now there the number that's

186

00:08:57,800 --> 00:08:55,310

alive maybe even greater than this but

187

00:08:59,840 --> 00:08:57,810

it sort of depends on where you draw the

188

00:09:01,700 --> 00:08:59,850

live dead boundary they don't have

189

00:09:03,860 --> 00:09:01,710

enough RNA for for excellent as

190

00:09:05,420 --> 00:09:03,870

collaborators to see but it's

191

00:09:07,310 --> 00:09:05,430

conceivable that something could be

192

00:09:10,460 --> 00:09:07,320

alive eking out an existence at some

193

00:09:12,080 --> 00:09:10,470

level that that we can't identify so the

194

00:09:15,140 --> 00:09:12,090

easiest way to interpret this is to say

195

00:09:16,580 --> 00:09:15,150

that conservatively about ten percent of

196

00:09:19,430 --> 00:09:16,590

the counted cells that those sites are

197

00:09:20,750 --> 00:09:19,440

alive and perhaps more alive you can see

198

00:09:22,490 --> 00:09:20,760

this has big implications

199

00:09:24,920 --> 00:09:22,500

for the amount of biomass on earth

200

00:09:27,080 --> 00:09:24,930

because it can pull down by an order of

201
00:09:32,180 --> 00:09:27,090
magnitude potentially estimates of

202
00:09:33,980 --> 00:09:32,190
subsea floor biomass okay now we're

203
00:09:36,290 --> 00:09:33,990
going to go to the South Pacific Gyre I

204
00:09:38,750 --> 00:09:36,300
just got back from there in early

205
00:09:41,960 --> 00:09:38,760
februari so you're seeing shipboard data

206
00:09:43,370 --> 00:09:41,970
these are counts by a former postdoc of

207
00:09:46,360 --> 00:09:43,380
are now a faculty member at the

208
00:09:49,700 --> 00:09:46,370
University of Potsdam yawns calm i er

209
00:09:53,390 --> 00:09:49,710
this is the ODP database that define the

210
00:09:55,250 --> 00:09:53,400
line we saw before this is a log-log

211
00:09:57,920 --> 00:09:55,260
scale incidentally all of these plots or

212
00:10:01,580 --> 00:09:57,930
log log scales and this is these black

213
00:10:05,860 --> 00:10:01,590

symbols are the data from our sites in

214

00:10:09,710 --> 00:10:05,870

this red box so this site right here

215

00:10:12,880 --> 00:10:09,720

comes closest to the ODP data that's

216

00:10:15,680 --> 00:10:12,890

located here on the northern edge of the

217

00:10:17,690 --> 00:10:15,690

Antarctic convergence zone which is a

218

00:10:19,430 --> 00:10:17,700

major upwelling zone so there's more

219

00:10:22,490 --> 00:10:19,440

organic matter raining down there than

220

00:10:24,170 --> 00:10:22,500

anywhere else here now where I told you

221

00:10:27,230 --> 00:10:24,180

is the clearest water in the world is

222

00:10:30,140 --> 00:10:27,240

right here at site seven this base map

223

00:10:32,120 --> 00:10:30,150

is a site of sea service chlorophyll so

224

00:10:34,220 --> 00:10:32,130

all of these green areas are upwelling

225

00:10:35,870 --> 00:10:34,230

areas then as you move to darker and

226

00:10:38,090 --> 00:10:35,880

darker colors we're moving to lower and

227

00:10:41,020 --> 00:10:38,100

lower chlorophyll concentrations the

228

00:10:45,020 --> 00:10:41,030

concentrations actually decrease here

229

00:10:48,020 --> 00:10:45,030

this is essentially grams per square

230

00:10:52,520 --> 00:10:48,030

meter of sea surface and our range here

231

00:10:56,840 --> 00:10:52,530

is from 10 to 0 point 0 1 so they're

232

00:10:59,420 --> 00:10:56,850

ranging over four orders of magnitude

233

00:11:02,450 --> 00:10:59,430

and what we're seeing here is at the

234

00:11:04,910 --> 00:11:02,460

point zero one end what you see up here

235

00:11:06,290 --> 00:11:04,920

at that little tiny red areas at the ten

236

00:11:08,900 --> 00:11:06,300

end and what you see in these green

237

00:11:10,880 --> 00:11:08,910

areas is the one end or in the middle of

238

00:11:13,610 --> 00:11:10,890

one so what we're seeing is that

239

00:11:16,520 --> 00:11:13,620

everywhere in this red box falls over

240

00:11:20,000 --> 00:11:16,530

here with three orders of magnitude

241

00:11:23,270 --> 00:11:20,010

fewer cells than the average for all the

242

00:11:25,370 --> 00:11:23,280

previously counted sites so what's this

243

00:11:28,010 --> 00:11:25,380

telling us this is telling us that the

244

00:11:29,810 --> 00:11:28,020

standard estimate relied on sites that

245

00:11:31,820 --> 00:11:29,820

are in fact not characteristic of the

246

00:11:33,850 --> 00:11:31,830

sea floor as a whole and then for all

247

00:11:37,060 --> 00:11:33,860

practical purposes

248

00:11:40,480 --> 00:11:37,070

anywhere in the turquoise through black

249

00:11:43,030 --> 00:11:40,490

zone here has three orders of magnitude

250

00:11:46,420 --> 00:11:43,040

fewer cells than Whitman assume the sea

251
00:11:49,900 --> 00:11:46,430
floor to hold per cubic centimeter back

252
00:11:51,519 --> 00:11:49,910
up a little more when you look at the

253
00:11:54,370 --> 00:11:51,529
ocean as a whole you see that in fact

254
00:11:59,560 --> 00:11:54,380
most of the ocean is in that range of

255
00:12:02,470 --> 00:11:59,570
turquoise through dark blue so

256
00:12:06,069 --> 00:12:02,480
effectively then the vast majority of

257
00:12:08,380 --> 00:12:06,079
the sea floor has somewhere in the

258
00:12:10,630 --> 00:12:08,390
ballpark of a thousand to ten thousand

259
00:12:11,889 --> 00:12:10,640
cells per cubic centimeter I shouldn't

260
00:12:12,940 --> 00:12:11,899
say the sea the sea floor actually has

261
00:12:14,829 --> 00:12:12,950
about a million cells per cubic

262
00:12:16,810 --> 00:12:14,839
centimeter as opposed to a billion and

263
00:12:19,030 --> 00:12:16,820

then once you're down in the subsurface

264

00:12:20,380 --> 00:12:19,040

you're looking at about a thousand to

265

00:12:22,540 --> 00:12:20,390

ten thousand cells per cubic centimeter

266

00:12:26,050 --> 00:12:22,550

instead of the million or so that

267

00:12:28,120 --> 00:12:26,060

Whitman assumed so setting aside the

268

00:12:32,680 --> 00:12:28,130

issue of whether the the bodies are live

269

00:12:34,810 --> 00:12:32,690

or dead what you see is that the size of

270

00:12:37,210 --> 00:12:34,820

the subsurface biomass on earth is

271

00:12:41,680 --> 00:12:37,220

actually far lower than the standard

272

00:12:42,759 --> 00:12:41,690

estimate but don't lose heart because as

273

00:12:49,689 --> 00:12:42,769

we'll see later in this presentation

274

00:12:52,090 --> 00:12:49,699

they still get to matter so I'm going to

275

00:12:58,120 --> 00:12:52,100

speak about rates about kinds and rates

276

00:13:00,639 --> 00:12:58,130

of activities now very very briefly it's

277

00:13:03,280 --> 00:13:00,649

been a lot of work in the last few years

278

00:13:07,569 --> 00:13:03,290

looking at microbial processes in subsea

279

00:13:10,660 --> 00:13:07,579

floor sediments so we now know that a

280

00:13:13,210 --> 00:13:10,670

lot of classic microbial reactions occur

281

00:13:15,400 --> 00:13:13,220

in the subsea floor many of which were

282

00:13:18,069 --> 00:13:15,410

known to occur in shallow marine

283

00:13:20,769 --> 00:13:18,079

sediments in the past sulfate reduction

284

00:13:22,540 --> 00:13:20,779

iron manganese nitrate and oxygen

285

00:13:25,150 --> 00:13:22,550

reduction all occur in different subsea

286

00:13:27,880 --> 00:13:25,160

flower environments carbon oxidation

287

00:13:31,030 --> 00:13:27,890

occurs almost everywhere we may see an

288

00:13:33,699 --> 00:13:31,040

exception in a little bit and anywhere

289

00:13:37,060 --> 00:13:33,709

where carbon is being oxidized they're

290

00:13:38,380 --> 00:13:37,070

also intermediate products of metabolic

291

00:13:41,230 --> 00:13:38,390

pathways produced and destroyed

292

00:13:44,829 --> 00:13:41,240

including ammonia acetate lactate

293

00:13:46,120 --> 00:13:44,839

formate hydrogen methane and somewhat

294

00:13:49,120 --> 00:13:46,130

surprisingly ethane and

295

00:13:51,070 --> 00:13:49,130

propane so some of the biological

296

00:13:53,140 --> 00:13:51,080

products that are created in these

297

00:13:55,150 --> 00:13:53,150

environments are actually historically

298

00:13:58,690 --> 00:13:55,160

thought to be a biological meaning the

299

00:14:00,220 --> 00:13:58,700

ethane and propane I'm not going to get

300

00:14:01,840 --> 00:14:00,230

into evidence here for why we think

301
00:14:04,690 --> 00:14:01,850
their biological but I'd be happy to

302
00:14:06,610 --> 00:14:04,700
answer questions on it so this is sort

303
00:14:08,470 --> 00:14:06,620
of a standard model for what happens in

304
00:14:10,840 --> 00:14:08,480
anoxic sediments whether on land or in

305
00:14:14,920 --> 00:14:10,850
the sea the idea is that you start with

306
00:14:17,980 --> 00:14:14,930
organic matter it's fermented by

307
00:14:21,520 --> 00:14:17,990
fermentation the products of

308
00:14:24,970 --> 00:14:21,530
fermentation are then used as a food

309
00:14:29,560 --> 00:14:24,980
source for various reductions manganese

310
00:14:31,870 --> 00:14:29,570
iron and sulfur reduction that those

311
00:14:34,660 --> 00:14:31,880
redox activities constitute respiration

312
00:14:37,990 --> 00:14:34,670
and the products of those reactions are

313
00:14:41,310 --> 00:14:38,000

co2 which is the oxidized product of

314

00:14:43,810 --> 00:14:41,320

what started out as food and manganese

315

00:14:46,150 --> 00:14:43,820

dissolve manganese does reduce manganese

316

00:14:47,890 --> 00:14:46,160

reduced iron and hydrogen sulfide which

317

00:14:52,300 --> 00:14:47,900

are the reduced products of what started

318

00:14:54,480 --> 00:14:52,310

out as oxidants and the evidence that

319

00:14:59,430 --> 00:14:54,490

these processes occur in the sea floor

320

00:15:01,600 --> 00:14:59,440

takes the form initially at least of

321

00:15:07,690 --> 00:15:01,610

profiles of dissolved chemical

322

00:15:10,090 --> 00:15:07,700

concentrations so you see here sulfate

323

00:15:12,000 --> 00:15:10,100

is at a maximum at the top of this

324

00:15:17,640 --> 00:15:12,010

charge and at the bottom of this chart

325

00:15:20,860 --> 00:15:17,650

the top is the sea floor the bottom is

326

00:15:22,690 --> 00:15:20,870

the sediment basalt interface where the

327

00:15:24,760 --> 00:15:22,700

sediment lies on the oceanic crust below

328

00:15:27,640 --> 00:15:24,770

and sulfate is coming into the sediment

329

00:15:30,130 --> 00:15:27,650

from the crust below and from the ocean

330

00:15:31,870 --> 00:15:30,140

above in dissolve form in both cases

331

00:15:34,000 --> 00:15:31,880

seawater is the ultimate source because

332

00:15:36,010 --> 00:15:34,010

seawater flows through the basalt then

333

00:15:38,290 --> 00:15:36,020

the concentrations decreases you move

334

00:15:41,740 --> 00:15:38,300

into the sediment package meaning that

335

00:15:44,920 --> 00:15:41,750

sulfate is being reduced so the

336

00:15:48,100 --> 00:15:44,930

concentration is declining in contrast a

337

00:15:51,250 --> 00:15:48,110

standard product of respiration what we

338

00:15:54,030 --> 00:15:51,260

call dissolved inorganic carbon or total

339

00:15:56,680 --> 00:15:54,040

co₂ which is simply the sum of co₂

340

00:15:58,600 --> 00:15:56,690

carbonate and bicarbonate shows the

341

00:15:59,750 --> 00:15:58,610

opposite pattern it's at its lowest

342

00:16:02,870 --> 00:15:59,760

value at the top

343

00:16:04,280 --> 00:16:02,880

bottom where it's leaking out and its

344

00:16:07,970 --> 00:16:04,290

highest concentration in the middle

345

00:16:10,970 --> 00:16:07,980

where there is net production just is

346

00:16:12,410 --> 00:16:10,980

there's net loss of the sulfate there so

347

00:16:16,070 --> 00:16:12,420

that provides us with direct evidence

348

00:16:17,720 --> 00:16:16,080

that these processes are occurring we

349

00:16:20,300 --> 00:16:17,730

can actually use those concentration

350

00:16:25,070 --> 00:16:20,310

profiles to calculate net rates of

351

00:16:27,350 --> 00:16:25,080

activity where we use essentially the

352

00:16:32,480 --> 00:16:27,360

chemicals diffusion coefficient the

353

00:16:36,320 --> 00:16:32,490

concentration gradient depth a measure

354

00:16:39,110 --> 00:16:36,330

of porosity it cites the sediment very

355

00:16:40,940 --> 00:16:39,120

rapidly sedimentation rate and we use

356

00:16:44,720 --> 00:16:40,950

some a confirmation factor which is a

357

00:16:49,190 --> 00:16:44,730

proxy for tortuosity tortuosity is just

358

00:16:51,350 --> 00:16:49,200

the deviation from straightness if you

359

00:16:54,340 --> 00:16:51,360

will of the path that the chemical must

360

00:17:02,710 --> 00:16:54,350

follow as it moves through the sediment

361

00:17:05,000 --> 00:17:02,720

no so we've got somebody else live so

362

00:17:09,290 --> 00:17:05,010

formation factor is actually a measure

363

00:17:11,090 --> 00:17:09,300

of the problem they're having I think

364

00:17:14,449 --> 00:17:11,100

Indiana or someone is alive I'm not sure

365

00:17:18,110 --> 00:17:14,459

who I go with ham on the aim is okay

366

00:17:23,120 --> 00:17:18,120

yeah alright so formation factor is is a

367

00:17:24,800 --> 00:17:23,130

measure of the electrical path through

368

00:17:29,390 --> 00:17:24,810

the sediment following the sea water and

369

00:17:30,670 --> 00:17:29,400

the chemicals follow the same path so

370

00:17:33,140 --> 00:17:30,680

I'm not going to go over this in detail

371

00:17:35,240 --> 00:17:33,150

I'm just going to wave a sort of a

372

00:17:37,220 --> 00:17:35,250

little red wand if you will but all of

373

00:17:39,620 --> 00:17:37,230

these products of respiration peak in

374

00:17:42,640 --> 00:17:39,630

the middle of the column these anoxic

375

00:17:44,990 --> 00:17:42,650

sediments so we have methane ammonia

376

00:17:48,800 --> 00:17:45,000

dicl peaking in the middle of the column

377

00:17:51,500 --> 00:17:48,810

and then reactants like sulfate all

378

00:17:54,530 --> 00:17:51,510

decline or even disappear going into the

379

00:17:56,060 --> 00:17:54,540

column that's telling us multiple

380

00:17:58,850 --> 00:17:56,070

processes are occurring deep in the

381

00:18:01,100 --> 00:17:58,860

sediment everywhere so we take the

382

00:18:02,900 --> 00:18:01,110

results of those flux calculations we

383

00:18:04,580 --> 00:18:02,910

can calculate how much electron

384

00:18:06,890 --> 00:18:04,590

acceptance is done by these different

385

00:18:08,990 --> 00:18:06,900

processes in different regions so I'm

386

00:18:11,900 --> 00:18:09,000

just going to highlight the bold-faced

387

00:18:13,190 --> 00:18:11,910

things here the marginal sites like

388

00:18:15,440 --> 00:18:13,200

along the prune margin where

389

00:18:19,399 --> 00:18:15,450

the cell counts resemble the traditional

390

00:18:22,909 --> 00:18:19,409

ODP counts the dominant process is

391

00:18:27,769 --> 00:18:22,919

sulfate reduction then as we move into

392

00:18:29,299 --> 00:18:27,779

the progressively lower activity regions

393

00:18:30,799 --> 00:18:29,309

of the ocean move out into the epitome

394

00:18:34,039 --> 00:18:30,809

Pacific sulfate reduction still

395

00:18:35,840 --> 00:18:34,049

dominates at the most active sites but

396

00:18:38,389 --> 00:18:35,850

then metal reduction becomes

397

00:18:41,360 --> 00:18:38,399

increasingly important so at the lowest

398

00:18:43,519 --> 00:18:41,370

activity site we visited in 2002 the

399

00:18:48,220 --> 00:18:43,529

dominant process the Domino electron

400

00:18:53,930 --> 00:18:50,720

now if we go to the sites we visited in

401
00:18:56,000 --> 00:18:53,940
December and January of this winter we

402
00:18:57,710 --> 00:18:56,010
see so that the sediments in fact aren't

403
00:19:00,560 --> 00:18:57,720
anoxic they're unlike any sediments

404
00:19:03,680 --> 00:19:00,570
people have ever core deeply into and

405
00:19:05,570 --> 00:19:03,690
looked for life what we see there this

406
00:19:10,250 --> 00:19:05,580
is our little site that the Antarctic

407
00:19:11,810 --> 00:19:10,260
convergence down here their oxygen

408
00:19:13,600 --> 00:19:11,820
disappears in the first metre of the

409
00:19:15,560 --> 00:19:13,610
sediment columns that's a typical

410
00:19:18,680 --> 00:19:15,570
sediment in the sense of what people

411
00:19:20,210 --> 00:19:18,690
expect but all of the other sites the

412
00:19:23,690 --> 00:19:20,220
sites that were in that red box where

413
00:19:26,090 --> 00:19:23,700

the cell counts are so low are over here

414

00:19:28,240 --> 00:19:26,100

so there's 150 micro molar or more

415

00:19:30,350 --> 00:19:28,250

oxygen throughout the settlement column

416

00:19:32,539 --> 00:19:30,360

that's following along this arrow here

417

00:19:34,960 --> 00:19:32,549

so that's essentially again in the

418

00:19:37,820 --> 00:19:34,970

region of turquoise dark blue and black

419

00:19:41,360 --> 00:19:37,830

photos chlorophyll content in the

420

00:19:44,330 --> 00:19:41,370

overlying ocean and nitrate is always

421

00:19:47,200 --> 00:19:44,340

above or at deep water concentrations

422

00:19:50,029 --> 00:19:47,210

it's a little bit of nitrate produced by

423

00:19:51,320 --> 00:19:50,039

oxidation of organic nitrogen in the

424

00:19:53,360 --> 00:19:51,330

shallow sediments and that's what makes

425

00:19:55,009 --> 00:19:53,370

a little high and there's no nitrate

426
00:19:59,539 --> 00:19:55,019
reduction below so what we're seeing

427
00:20:11,360 --> 00:19:59,549
here and sulfate doesn't change at all

428
00:20:16,580 --> 00:20:14,049
in terms of carbon equivalents per year

429
00:20:19,580 --> 00:20:16,590
is in the range here of 10 to the minus

430
00:20:23,210 --> 00:20:19,590
16 to 10 to the minus 18 moles per cell

431
00:20:24,860 --> 00:20:23,220
per year in coastal sediments you see

432
00:20:27,650 --> 00:20:24,870
numbers more the ballpark of 10 to the

433
00:20:28,940 --> 00:20:27,660
minus 15 and in pure culture is it's

434
00:20:34,220 --> 00:20:28,950
typically in the range of ten to the

435
00:20:38,000 --> 00:20:34,230
minus 13 to 10 to the minus 11 so this

436
00:20:40,670 --> 00:20:38,010
is the sort of odd claim because

437
00:20:42,860 --> 00:20:40,680
essentially we're claiming that sub

438
00:20:45,230 --> 00:20:42,870

seafloor organisms on average are

439

00:20:46,910 --> 00:20:45,240

aspiring it much much lower rates than

440

00:20:49,640 --> 00:20:46,920

anyone's observed in the service world

441

00:20:53,410 --> 00:20:49,650

now you have a couple of possible ways

442

00:20:55,760 --> 00:20:53,420

of explaining this one the claim is true

443

00:21:00,320 --> 00:20:55,770

these things are aspiring very very

444

00:21:03,500 --> 00:21:00,330

slowly to it's conceivable that we've

445

00:21:07,430 --> 00:21:03,510

missed some huge huge source of

446

00:21:16,580 --> 00:21:07,440

respiration somehow orders of magnitude

447

00:21:18,230 --> 00:21:16,590

and three it's possible that only a

448

00:21:20,780 --> 00:21:18,240

fraction of the cells counted are

449

00:21:22,460 --> 00:21:20,790

actually alive and respiring so if we

450

00:21:24,500 --> 00:21:22,470

were to take for example the shippers

451
00:21:27,440 --> 00:21:24,510
estimate that ten percent of the cells

452
00:21:28,970 --> 00:21:27,450
are alive but perhaps no more than all

453
00:21:31,070 --> 00:21:28,980
of these could be brought down an order

454
00:21:33,290 --> 00:21:31,080
brought up in order of magnitude and

455
00:21:36,440 --> 00:21:33,300
maybe 10 to the minus 17 to 10 to the

456
00:21:45,159 --> 00:21:36,450
minus 15 the low end they'd start edging

457
00:21:49,370 --> 00:21:47,810
so what we decided to do was to see

458
00:21:52,870 --> 00:21:49,380
whether we were missing some obvious

459
00:21:56,149 --> 00:21:52,880
source of or even in obvious source of

460
00:21:57,770 --> 00:21:56,159
respiration instead of assuming as we

461
00:22:00,200 --> 00:21:57,780
did that sulfate reduction was the

462
00:22:03,380 --> 00:22:00,210
dominant process as we did in our 2002

463
00:22:05,480 --> 00:22:03,390

paper we said let's look at the amount

464

00:22:07,700 --> 00:22:05,490

of DIC produced the amount of CO₂

465

00:22:11,390 --> 00:22:07,710

produced by respiration of organic

466

00:22:13,640 --> 00:22:11,400

matter so there are two two things that

467

00:22:15,320 --> 00:22:13,650

we have to consider here the first we

468

00:22:18,279 --> 00:22:15,330

have to consider the flux of dissolved

469

00:22:21,169 --> 00:22:18,289

inorganic carbon out of the sediment

470

00:22:23,570 --> 00:22:21,179

second we have to consider the amount of

471

00:22:26,720 --> 00:22:23,580

carbon that precipitated out as a

472

00:22:29,060 --> 00:22:26,730

carbonate mineral within the sediment so

473

00:22:32,419 --> 00:22:29,070

that's enough in a sense a hit term we

474

00:22:33,649 --> 00:22:32,429

can calculate that second flux by

475

00:22:37,340 --> 00:22:33,659

looking at the calcium and magnesium

476

00:22:41,630 --> 00:22:37,350

fluxes into the sediment so it's

477

00:22:43,490 --> 00:22:41,640

quantifiable and when we do that we can

478

00:22:47,360 --> 00:22:43,500

calculate carbon oxidation rates at

479

00:22:49,520 --> 00:22:47,370

different depths take the cell counts

480

00:22:53,080 --> 00:22:49,530

and calculate the carbon oxidation rate

481

00:22:55,279 --> 00:22:53,090

per cell and you see that using this

482

00:22:58,340 --> 00:22:55,289

carbon based approach we're still

483

00:23:00,620 --> 00:22:58,350

getting average values for carbon

484

00:23:04,909 --> 00:23:00,630

oxidation of around 10 to the minus 17

485

00:23:06,529 --> 00:23:04,919

moles per cell per year so this

486

00:23:08,539 --> 00:23:06,539

essentially means that we aren't missing

487

00:23:10,549 --> 00:23:08,549

a very big source of respiration

488

00:23:12,620 --> 00:23:10,559

somewhere in the system and that either

489

00:23:14,390 --> 00:23:12,630

most of the cells are not active or they

490

00:23:19,730 --> 00:23:14,400

really are breathing it phenomenally

491

00:23:21,610 --> 00:23:19,740

slow rates but again if ten percent of

492

00:23:24,440 --> 00:23:21,620

the cells are active as shippers says

493

00:23:26,480 --> 00:23:24,450

then there's still less active than

494

00:23:29,590 --> 00:23:26,490

anything known in the surface world so

495

00:23:32,620 --> 00:23:29,600

just for comparison here's the total

496

00:23:35,840 --> 00:23:32,630

flux assume by looking at the oxidation

497

00:23:36,950 --> 00:23:35,850

the sort of the reduced products if you

498

00:23:39,409 --> 00:23:36,960

will which is where we've done these

499

00:23:41,390 --> 00:23:39,419

calculations in the past and this is the

500

00:23:43,460 --> 00:23:41,400

flux from the co2 mass balance which is

501
00:23:44,630 --> 00:23:43,470
Lee at the oxidized products you see

502
00:23:51,560 --> 00:23:44,640
that the two numbers are nearly

503
00:23:58,310 --> 00:23:56,540
let's go back there okay if I transfer

504
00:24:02,720 --> 00:23:58,320
this is a screen capture a few minutes

505
00:24:04,040 --> 00:24:02,730
ago and lost my fields the in here this

506
00:24:08,420 --> 00:24:04,050
is the amount of energy that price and

507
00:24:10,280 --> 00:24:08,430
sours infer is required just to keep the

508
00:24:13,840 --> 00:24:10,290
organisms ahead of rasim ization of

509
00:24:18,260 --> 00:24:17,150
isomer is reverting over time the

510
00:24:22,100 --> 00:24:18,270
traditional estimates of maintenance

511
00:24:23,540 --> 00:24:22,110
energy up around here so coastal shallow

512
00:24:26,030 --> 00:24:23,550
sediments organisms were already

513
00:24:29,750 --> 00:24:26,040

operating near the inferred maintenance

514

00:24:32,330 --> 00:24:29,760

energy necessary for life what we're

515

00:24:33,620 --> 00:24:32,340

seeing here is that these microbial

516

00:24:35,540 --> 00:24:33,630

communities are actually being

517

00:24:38,300 --> 00:24:35,550

maintained at far lower rates of

518

00:24:40,010 --> 00:24:38,310

respiration than theoretical estimates

519

00:24:44,390 --> 00:24:40,020

of maintenance energy have allowed in

520

00:24:46,430 --> 00:24:44,400

the past so if nothing else physiology

521

00:24:51,100 --> 00:24:46,440

of microbial maintenance isn't yet well

522

00:24:53,300 --> 00:24:51,110

understood I'm going to focus very

523

00:24:55,550 --> 00:24:53,310

briefly here on something that one of

524

00:24:59,240 --> 00:24:55,560

our graduate students did part of her

525

00:25:01,280 --> 00:24:59,250

thesis work on essentially there's

526
00:25:03,710 --> 00:25:01,290
thermodynamic cooperation going on in

527
00:25:05,720 --> 00:25:03,720
these systems I'm going to breeze

528
00:25:09,830 --> 00:25:05,730
through this fairly quickly but what you

529
00:25:15,410 --> 00:25:09,840
see here this table essentially

530
00:25:18,560 --> 00:25:15,420
calculates how much carbon is oxidized

531
00:25:21,580 --> 00:25:18,570
by a given process so sulfate reduction

532
00:25:25,400 --> 00:25:21,590
iron reduction manganese reduction and

533
00:25:26,900 --> 00:25:25,410
how much carbon 'it is precipitated as a

534
00:25:31,940 --> 00:25:26,910
result of the changes in the alkalinity

535
00:25:33,710 --> 00:25:31,950
due to that process and then we look at

536
00:25:36,530 --> 00:25:33,720
essentially not just then the mass

537
00:25:39,320 --> 00:25:36,540
balance of say the reductions and the

538
00:25:41,780 --> 00:25:39,330

carbon oxidation but also effectively

539

00:25:45,440 --> 00:25:41,790

the mass balance of the carbonate

540

00:25:47,930 --> 00:25:45,450

precipitation and the reductions when we

541

00:25:51,590 --> 00:25:47,940

do that we find that if you were to take

542

00:25:53,660 --> 00:25:51,600

this DIC flux and this carbon of flux

543

00:25:56,150 --> 00:25:53,670

and sum them you'd be nearly equal to

544

00:25:58,340 --> 00:25:56,160

the sulfate reduction rate so those two

545

00:26:00,080 --> 00:25:58,350

numbers are nearly balanced so from a

546

00:26:03,500 --> 00:26:00,090

DIC pulse or from a carbon production

547

00:26:05,360 --> 00:26:03,510

perspective given the uncertainties of

548

00:26:07,070 --> 00:26:05,370

our approach you don't need to

549

00:26:10,160 --> 00:26:07,080

call on anything but sulfate reduction

550

00:26:12,710 --> 00:26:10,170

for this system but it turns out when

551
00:26:14,570 --> 00:26:12,720
you reduce sulfate you actually dissolve

552
00:26:18,470 --> 00:26:14,580
a little carbon if you don't produce it

553
00:26:19,730 --> 00:26:18,480
and here it's being produced so what

554
00:26:21,380 --> 00:26:19,740
we're seeing is that the carbonate

555
00:26:24,200 --> 00:26:21,390
precipitation is too high to be

556
00:26:27,710 --> 00:26:24,210
explained by sulfate reduction so the

557
00:26:30,740 --> 00:26:27,720
simplest way to get lots of carbonate

558
00:26:32,390 --> 00:26:30,750
precipitation is to add a little iron

559
00:26:34,580 --> 00:26:32,400
reduction along with the sulfate

560
00:26:36,290 --> 00:26:34,590
reduction because it turns out the iron

561
00:26:39,020 --> 00:26:36,300
reduction you end up precipitating a lot

562
00:26:40,340 --> 00:26:39,030
of carbonate so what this is telling us

563
00:26:43,310 --> 00:26:40,350

what this balance is telling us

564

00:26:44,990 --> 00:26:43,320

effectively is that iron reduction in

565

00:26:47,510 --> 00:26:45,000

sulfate reduction of co-occurring in

566

00:26:49,640 --> 00:26:47,520

these sediments this is a little

567

00:26:58,950 --> 00:26:49,650

unexpected for some people because

568

00:27:04,680 --> 00:27:01,460

your depth what we're seeing here is

569

00:27:06,870 --> 00:27:04,690

that throughout a sediment column that

570

00:27:09,120 --> 00:27:06,880

was deposited over about 15 million

571

00:27:13,740 --> 00:27:09,130

years iron and sulfate reduction are

572

00:27:16,440 --> 00:27:13,750

occurring together so the iron hasn't

573

00:27:18,899 --> 00:27:16,450

out competed sulfate instead both of

574

00:27:25,200 --> 00:27:18,909

those two are co-occurring so take a

575

00:27:29,370 --> 00:27:25,210

closer look at that essentially what we

576

00:27:31,110 --> 00:27:29,380

believe is that is that in a sense these

577

00:27:33,720 --> 00:27:31,120

communities constitute an underground

578

00:27:36,269 --> 00:27:33,730

economy where there's an invisible hand

579

00:27:39,419 --> 00:27:36,279

of thermodynamics keeping the system in

580

00:27:42,269 --> 00:27:39,429

play you look here at these figure at

581

00:27:45,180 --> 00:27:42,279

this figure these are the Institute free

582

00:27:50,399 --> 00:27:45,190

energies of acetate oxidation using

583

00:27:51,450 --> 00:27:50,409

hematite reduction with a magenta this

584

00:27:53,970 --> 00:27:51,460

is basically just acetate

585

00:27:56,610 --> 00:27:53,980

disproportionate and sulfate reduction

586

00:27:58,490 --> 00:27:56,620

and you see that all of these free

587

00:28:02,789 --> 00:27:58,500

energies are in the range of around

588

00:28:06,899 --> 00:28:02,799

minus 52 minus 20 kilojoules per mole of

589

00:28:08,460 --> 00:28:06,909

acetate the minimum free energy of this

590

00:28:13,110 --> 00:28:08,470

reaction is typically assumed to be

591

00:28:14,970 --> 00:28:13,120

somewhere in this in this region so

592

00:28:16,680 --> 00:28:14,980

these are very low free energies needle

593

00:28:18,480 --> 00:28:16,690

you see they're also pretty constant

594

00:28:19,889 --> 00:28:18,490

throughout the sediment column the ones

595

00:28:22,200 --> 00:28:19,899

where all of the products and reactants

596

00:28:23,639 --> 00:28:22,210

are dissolved with Anna Genesis and

597

00:28:26,430 --> 00:28:23,649

sulfate reduction there they're nearly

598

00:28:29,519 --> 00:28:26,440

constant where we're inferring a mineral

599

00:28:31,080 --> 00:28:29,529

it's more variable this could mean that

600

00:28:33,180 --> 00:28:31,090

the free energy of that reaction truly

601
00:28:36,120 --> 00:28:33,190
varies from depth to depth or it could

602
00:28:37,440 --> 00:28:36,130
mean that different iron containing

603
00:28:39,000 --> 00:28:37,450
minerals are being used at different

604
00:28:42,419 --> 00:28:39,010
depths in the free energies more nearly

605
00:28:45,090 --> 00:28:42,429
constant the standard free energies of

606
00:28:46,470 --> 00:28:45,100
these reactions vary considerably the

607
00:28:48,930 --> 00:28:46,480
standard free energy of the iron

608
00:28:51,060 --> 00:28:48,940
reduction it's somewhere around minus

609
00:28:53,639 --> 00:28:51,070
fourteen hundred kilojoules per mole of

610
00:28:56,100 --> 00:28:53,649
acetate the standard free energy of the

611
00:28:58,230 --> 00:28:56,110
sulfur reduction is roughly an order of

612
00:29:00,240 --> 00:28:58,240
magnitude less than that but still well

613
00:29:02,070 --> 00:29:00,250

off the charts here so what we're seeing

614

00:29:04,230 --> 00:29:02,080

is that all of these processes are

615

00:29:06,840 --> 00:29:04,240

operating fairly close to a biological

616

00:29:10,419 --> 00:29:06,850

minimum and they're relatively constant

617

00:29:15,609 --> 00:29:12,430

so that implies that there's some sort

618

00:29:19,659 --> 00:29:15,619

of thermodynamic homeostatic you will

619

00:29:21,789 --> 00:29:19,669

with the thermodynamics sustaining this

620

00:29:24,310 --> 00:29:21,799

process I'm going to I don't have a

621

00:29:25,960 --> 00:29:24,320

slide to explain this so I'll just

622

00:29:31,330 --> 00:29:25,970

describe some examples of how this might

623

00:29:33,460 --> 00:29:31,340

work as sulfate reduction proceeds

624

00:29:35,320 --> 00:29:33,470

you're going to build up dissolved

625

00:29:40,739 --> 00:29:35,330

sulphide and you're going to build up

626

00:29:42,850 --> 00:29:40,749

dissolved CO_2 the products of

627

00:29:45,190 --> 00:29:42,860

thermodynamic reactions is you probably

628

00:29:47,169 --> 00:29:45,200

all know poison the reactions so if you

629

00:29:48,940 --> 00:29:47,179

allow product concentrations to build up

630

00:29:51,249 --> 00:29:48,950

the free energies of the reactions go

631

00:29:53,320 --> 00:29:51,259

down so if you let your dissolved iron

632

00:29:56,409 --> 00:29:53,330

concentrations go up the free energy of

633

00:29:58,600 --> 00:29:56,419

iron reduction goes down if you let your

634

00:30:01,509 --> 00:29:58,610

dissolve sulphur concentrations go up

635

00:30:04,960 --> 00:30:01,519

the free energy of sulphur reduction

636

00:30:07,840 --> 00:30:04,970

goes down very conveniently however if

637

00:30:09,450 --> 00:30:07,850

you have reduced iron and reduce sulfur

638

00:30:12,369 --> 00:30:09,460

produced in the same system that

639

00:30:16,359 --> 00:30:12,379

precipitate out together is as iron

640

00:30:19,149 --> 00:30:16,369

sulphide so the coexistence of these

641

00:30:22,720 --> 00:30:19,159

reactions allows their products to scrub

642

00:30:25,930 --> 00:30:22,730

each other out so effectively what we're

643

00:30:28,350 --> 00:30:25,940

suggesting is that in a sense these

644

00:30:30,700 --> 00:30:28,360

organisms are cleaning up the

645

00:30:33,720 --> 00:30:30,710

respiration products of each other and

646

00:30:35,950 --> 00:30:33,730

allowing the reactions to proceed

647

00:30:38,169 --> 00:30:35,960

methanogenesis similarly when methane is

648

00:30:40,090 --> 00:30:38,179

produced that methane can then be used

649

00:30:42,220 --> 00:30:40,100

as a food source by the sulfate reducers

650

00:30:44,409 --> 00:30:42,230

in the iron reduced so the implication

651

00:30:45,999 --> 00:30:44,419

is that on the timescales of millions of

652

00:30:49,060 --> 00:30:46,009

years over which ecosystems are

653

00:30:52,299 --> 00:30:49,070

operating these systems reach a more or

654

00:30:53,289 --> 00:30:52,309

less stable point where these processes

655

00:30:55,659 --> 00:30:53,299

that are traditionally believed to

656

00:31:00,310 --> 00:30:55,669

compete can in fact coexist because

657

00:31:03,399 --> 00:31:00,320

they're cooperating at some level so I'm

658

00:31:06,039 --> 00:31:03,409

going to briefly speak then about some

659

00:31:12,520 --> 00:31:06,049

of these processes in terms of their

660

00:31:21,150 --> 00:31:16,650

I suspect that everyone here today

661

00:31:24,820 --> 00:31:21,160

recognizes that methane is a significant

662

00:31:27,040 --> 00:31:24,830

greenhouse gas it has much lower

663

00:31:30,580 --> 00:31:27,050

concentrations than co2 which we see in

664

00:31:35,290 --> 00:31:30,590

the news a lot but its effect on global

665

00:31:38,440 --> 00:31:35,300

warming per unit of atmosphere

666

00:31:40,480 --> 00:31:38,450

constituent is much greater so one

667

00:31:42,670 --> 00:31:40,490

consequence of this subsurface world is

668

00:31:47,050 --> 00:31:42,680

that the methane produced by these

669

00:31:49,030 --> 00:31:47,060

microbes can and probably on long time

670

00:31:51,460 --> 00:31:49,040

scales does significantly affect or its

671

00:31:54,010 --> 00:31:51,470

climate for example the really big

672

00:31:56,140 --> 00:31:54,020

global warming event 255 million years

673

00:31:58,630 --> 00:31:56,150

ago is generally inferred to have been

674

00:32:00,910 --> 00:31:58,640

the result of subsea floor methane being

675

00:32:04,300 --> 00:32:00,920

discouraged that methane is principally

676
00:32:07,660 --> 00:32:04,310
created by methanogens microorganisms

677
00:32:09,370 --> 00:32:07,670
beneath the sea floor for those of you

678
00:32:12,190 --> 00:32:09,380
who are less climate focused and more

679
00:32:13,750 --> 00:32:12,200
resource focused these sub seafloor

680
00:32:15,790 --> 00:32:13,760
methane deposits are actually the

681
00:32:18,190 --> 00:32:15,800
largest untapped fossil fuel reservoir

682
00:32:21,820 --> 00:32:18,200
on earth so here's an example where

683
00:32:24,730 --> 00:32:21,830
these relatively slow activities by

684
00:32:28,150 --> 00:32:24,740
these sub seafloor microorganisms have

685
00:32:30,700 --> 00:32:28,160
global implications I'm going to point

686
00:32:34,390 --> 00:32:30,710
to another example that to the best of

687
00:32:36,400 --> 00:32:34,400
my knowledge is not publicly discussed

688
00:32:40,860 --> 00:32:36,410

except by me and hasn't actually been

689

00:32:43,990 --> 00:32:40,870

published and that is that ultimately

690

00:32:48,760 --> 00:32:44,000

subsea flower sulfate reduction affects

691

00:32:52,560 --> 00:32:48,770

atmospheric co2 or to put it a little

692

00:32:55,990 --> 00:32:52,570

differently the process of oxidation of

693

00:32:58,720 --> 00:32:56,000

sulfur reduced sulfur and reduction of

694

00:33:01,960 --> 00:32:58,730

oxidized sulfur affects atmospheric co2

695

00:33:03,700 --> 00:33:01,970

so if we increase our current

696

00:33:08,680 --> 00:33:03,710

concentration of dissolved sulfate in

697

00:33:12,130 --> 00:33:08,690

the ocean is about 28 millimolar if we

698

00:33:16,240 --> 00:33:12,140

increase the concentration by 1

699

00:33:18,610 --> 00:33:16,250

millimolar the effect on ocean

700

00:33:22,180 --> 00:33:18,620

alkalinity will drive up atmospheric co2

701
00:33:24,710 --> 00:33:22,190
by a factor of 3 so if we decrease the

702
00:33:26,960 --> 00:33:24,720
concentration by 1 millimolar

703
00:33:31,370 --> 00:33:26,970
it'll pull out mysterious co2 down to

704
00:33:33,380 --> 00:33:31,380
nearly zero this calculation is

705
00:33:35,090 --> 00:33:33,390
effectively in terms of subsea floor in

706
00:33:37,460 --> 00:33:35,100
terms of sulfate reduction this

707
00:33:39,770 --> 00:33:37,470
calculation is relative to say carbon

708
00:33:42,320 --> 00:33:39,780
oxidation by free oxygen instead of

709
00:33:49,730 --> 00:33:42,330
bisulfate effectively oxygen has no

710
00:33:52,390 --> 00:33:49,740
effect on reduction and this would be

711
00:33:54,260 --> 00:33:52,400
relative to that you get a cleaner

712
00:33:57,049 --> 00:33:54,270
relationship if you're just to look at

713
00:33:59,390 --> 00:33:57,059

pyrite oxidation if you oxidize more

714

00:34:01,100 --> 00:33:59,400

pyrite you will drive the absolute

715

00:34:03,380 --> 00:34:01,110

concentration up by this without having

716

00:34:07,010 --> 00:34:03,390

to worry about any respiration effect or

717

00:34:09,290 --> 00:34:07,020

the CO_2 so the basic point is that that

718

00:34:10,669 --> 00:34:09,300

this is a very very strong lever for

719

00:34:15,139 --> 00:34:10,679

changing the composition of the

720

00:34:19,790 --> 00:34:15,149

atmosphere and ocean put it in sort of a

721

00:34:21,770 --> 00:34:19,800

text form the removal of sulfate from

722

00:34:24,440 --> 00:34:21,780

the ocean by precipitation of iron

723

00:34:27,349 --> 00:34:24,450

sulfide is equivalent to removal of a

724

00:34:29,810 --> 00:34:27,359

strong acid similarly the addition of

725

00:34:32,450 --> 00:34:29,820

sulfate to the ocean by weathering of

726

00:34:35,450 --> 00:34:32,460

iron sulfide is equivalent to creation

727

00:34:37,550 --> 00:34:35,460

and addition of a strong acid and this

728

00:34:39,470 --> 00:34:37,560

may actually serve to modulators climate

729

00:34:42,020 --> 00:34:39,480

on long time scales you know for example

730

00:34:43,879 --> 00:34:42,030

when we have warm climates we have low

731

00:34:46,369 --> 00:34:43,889

dissolved oxygen in the ocean because

732

00:34:50,060 --> 00:34:46,379

warm water holds less gas than cold

733

00:34:51,950 --> 00:34:50,070

water consequently less organic carbon

734

00:34:54,349 --> 00:34:51,960

goes to oxygen reduction more goes to

735

00:34:56,260 --> 00:34:54,359

sulfate reduction and you can increase

736

00:34:59,030 --> 00:34:56,270

the iron sulphide burial in the deep sea

737

00:35:01,720 --> 00:34:59,040

which in turn can pull down atmospheric

738

00:35:04,220 --> 00:35:01,730

co2 and cool the atmosphere and ocean

739

00:35:06,020 --> 00:35:04,230

now this is a process that's not going

740

00:35:07,520 --> 00:35:06,030

to save us on the time scale of fossil

741

00:35:09,349 --> 00:35:07,530

fuel burning because the rates are

742

00:35:11,089 --> 00:35:09,359

relatively slow this is a sort of

743

00:35:12,560 --> 00:35:11,099

process that plays out on time scales of

744

00:35:17,720 --> 00:35:12,570

hundreds of thousands to millions of

745

00:35:19,130 --> 00:35:17,730

years now I'm going to briefly touch on

746

00:35:20,960 --> 00:35:19,140

something that's a particular interest

747

00:35:23,450 --> 00:35:20,970

to some in the NAI community

748

00:35:25,599 --> 00:35:23,460

particularly people the Indiana team who

749

00:35:29,060 --> 00:35:25,609

have done a very nice job working with

750

00:35:31,460 --> 00:35:29,070

deep gold mines we're going to look at

751

00:35:33,230 --> 00:35:31,470

something that isn't does not appear to

752

00:35:34,430 --> 00:35:33,240

be analogous but in fact maybe in some

753

00:35:36,550 --> 00:35:34,440

ways analogous to what they're looking

754

00:35:39,830 --> 00:35:36,560

at there

755

00:35:42,160 --> 00:35:39,840

the principal sources of food or

756

00:35:45,040 --> 00:35:42,170

electron donors for subsea floor life

757

00:35:48,980 --> 00:35:45,050

are the burial of photosynthesize

758

00:35:52,610 --> 00:35:48,990

organic matter the radioactive splitting

759

00:35:56,480 --> 00:35:52,620

of water potentially alteration that

760

00:36:00,400 --> 00:35:56,490

would be oxidation or reduction of

761

00:36:03,050 --> 00:36:00,410

minerals and the thermal creation of

762

00:36:05,420 --> 00:36:03,060

organic matter or other reduced

763

00:36:07,280 --> 00:36:05,430

compounds so there's sorts of sediments

764

00:36:08,960 --> 00:36:07,290

that my team principally focuses on we

765

00:36:11,030 --> 00:36:08,970

can ignore both mineral alteration and

766

00:36:13,520 --> 00:36:11,040

thermogenesis these are very cold

767

00:36:16,430 --> 00:36:13,530

sediments so thermogenesis is not an

768

00:36:17,960 --> 00:36:16,440

issue and in the lowest activity

769

00:36:19,310 --> 00:36:17,970

sediments that we look at everything is

770

00:36:22,820 --> 00:36:19,320

oxidized so there aren't any real

771

00:36:25,670 --> 00:36:22,830

minerals around to be oxidized as

772

00:36:27,710 --> 00:36:25,680

they've all been oxidized in advance so

773

00:36:30,350 --> 00:36:27,720

instead I'm going to focus on burial of

774

00:36:32,060 --> 00:36:30,360

photosynthesize organic matter here's a

775

00:36:34,930 --> 00:36:32,070

pretty picture from Steve passion

776

00:36:37,190 --> 00:36:34,940

colleagues showing microbes growing on a

777

00:36:39,620 --> 00:36:37,200

carboniferous black shale that he's

778

00:36:41,570 --> 00:36:39,630

exposed in a thin section just showing

779

00:36:42,740 --> 00:36:41,580

that if you can get organic matter to

780

00:36:45,140 --> 00:36:42,750

them they'll use it even if it's

781

00:36:46,430 --> 00:36:45,150

hundreds and millions years old this is

782

00:36:48,860 --> 00:36:46,440

a little schematic that just shows the

783

00:36:51,670 --> 00:36:48,870

process of radiolysis of water where you

784

00:36:55,790 --> 00:36:51,680

have decay of uranium thorium potassium

785

00:36:59,210 --> 00:36:55,800

creating alpha beta gamma radiation and

786

00:37:01,850 --> 00:36:59,220

that radiation some subset of it strikes

787

00:37:05,180 --> 00:37:01,860

mineral grains and essentially just goes

788

00:37:08,270 --> 00:37:05,190

into leaving fission tracks if you will

789

00:37:10,610 --> 00:37:08,280

but any of it that gets out of the

790

00:37:12,910 --> 00:37:10,620

mineral out of the rock and into the

791

00:37:15,440 --> 00:37:12,920

surrounding water will split the water

792

00:37:18,260 --> 00:37:15,450

there's about 30 of these radiolytic

793

00:37:23,390 --> 00:37:18,270

reactions but the stable products of

794

00:37:28,870 --> 00:37:23,400

them are water again hydrogen from

795

00:37:33,320 --> 00:37:31,070

when we do mass balance calculations

796

00:37:36,620 --> 00:37:33,330

based on burial rates of organic matter

797

00:37:39,380 --> 00:37:36,630

and the reduction rate such I showed you

798

00:37:42,860 --> 00:37:39,390

earlier the relatively high activity

799

00:37:44,780 --> 00:37:42,870

sites that we went to in 2002 these Peru

800

00:37:49,100 --> 00:37:44,790

margin sites and these open Pacific

801
00:37:49,799 --> 00:37:49,110
sites essentially burial of organic

802
00:37:53,249 --> 00:37:49,809
matter

803
00:37:55,620 --> 00:37:53,259
is providing enough food to sustain the

804
00:37:57,689 --> 00:37:55,630
net rates of sulfate metal and nitrate

805
00:37:59,429 --> 00:37:57,699
reduction that we see at those sites you

806
00:38:01,829 --> 00:37:59,439
see that these numbers are generally in

807
00:38:03,630 --> 00:38:01,839
the same order of magnitude or the

808
00:38:05,309 --> 00:38:03,640
second number is higher than the first

809
00:38:06,959 --> 00:38:05,319
so that's telling us there's enough

810
00:38:10,769 --> 00:38:06,969
organic matter around to sustain those

811
00:38:12,719 --> 00:38:10,779
processes so at those traditional anoxic

812
00:38:18,779 --> 00:38:12,729
settlements the principal source of food

813
00:38:20,729 --> 00:38:18,789

is basically buried organic matter so

814

00:38:22,499 --> 00:38:20,739

let's take a little closer look at how

815

00:38:25,170 --> 00:38:22,509

much energy might come from the

816

00:38:26,939 --> 00:38:25,180

alternative process the radiolysis so

817

00:38:29,789 --> 00:38:26,949

these are the same sites ordered from

818

00:38:32,479 --> 00:38:29,799

high to low energy what we've done here

819

00:38:35,269 --> 00:38:32,489

is we've calculated how much radioactive

820

00:38:37,829 --> 00:38:35,279

radiologic hydrogen would be created

821

00:38:39,630 --> 00:38:37,839

given the uranium thorium of potassium

822

00:38:42,120 --> 00:38:39,640

content of the sediment in its porosity

823

00:38:43,679 --> 00:38:42,130

we compare that to the carbon fueled

824

00:38:47,219 --> 00:38:43,689

respiration that you saw in the previous

825

00:38:49,769 --> 00:38:47,229

slide and get a ratio of the two what

826

00:38:53,640 --> 00:38:49,779

you find is that at the ocean margin

827

00:38:55,559 --> 00:38:53,650

sites like 1230 less than 1 percent of

828

00:38:58,829 --> 00:38:55,569

the energy or the food that fuels that

829

00:39:02,160 --> 00:38:58,839

system comes from radioactive splitting

830

00:39:05,039 --> 00:39:02,170

of water as we move offshore into lower

831

00:39:07,079 --> 00:39:05,049

and lower activity sediments to get to

832

00:39:11,219 --> 00:39:07,089

the pru basin where manganese reduction

833

00:39:15,599 --> 00:39:11,229

is the dominant process radioactive

834

00:39:17,699 --> 00:39:15,609

splitting of water at least based on our

835

00:39:19,410 --> 00:39:17,709

calculations appears to provide a little

836

00:39:21,029 --> 00:39:19,420

over ten percent of the amount of energy

837

00:39:24,959 --> 00:39:21,039

that the Buried organic matter is

838

00:39:27,299 --> 00:39:24,969

providing to the system so what is

839

00:39:29,279 --> 00:39:27,309

another way of looking at this that's a

840

00:39:31,529 --> 00:39:29,289

site where we had around a hundred

841

00:39:34,559 --> 00:39:31,539

thousand cells per cubic centimeter of

842

00:39:37,109 --> 00:39:34,569

sediment so if we were to go to a site

843

00:39:38,669 --> 00:39:37,119

where we simply had radioactive

844

00:39:39,900 --> 00:39:38,679

splitting of water as our only source of

845

00:39:42,259 --> 00:39:39,910

energy and we had the same amount of

846

00:39:45,449 --> 00:39:42,269

radiolysis we'd be able to support

847

00:39:50,480 --> 00:39:45,459

around ten thousand cells per cubic

848

00:40:02,420 --> 00:39:56,240

and when we go to the gyre this is this

849

00:40:06,980 --> 00:40:02,430

is sort of right here you see that

850

00:40:09,530 --> 00:40:06,990

oxygen didn't disappear our estimates of

851

00:40:11,120 --> 00:40:09,540

total act of net activity are three

852

00:40:14,900 --> 00:40:11,130

orders of magnitude less than in any

853

00:40:17,600 --> 00:40:14,910

sites where people have looked before so

854

00:40:19,400 --> 00:40:17,610

it looks like this is a region where if

855

00:40:21,010 --> 00:40:19,410

the sediments are as radioactive is

856

00:40:23,300 --> 00:40:21,020

those we've seen at the other sites

857

00:40:24,890 --> 00:40:23,310

radiolysis may in fact be the principal

858

00:40:27,500 --> 00:40:24,900

source of food for the subsurface

859

00:40:32,950 --> 00:40:27,510

ecosystem now it's important to bear in

860

00:40:37,430 --> 00:40:32,960

mind that radioactive splitting of water

861

00:40:40,790 --> 00:40:37,440

does not add to the net processes that

862

00:40:43,070 --> 00:40:40,800

we see in these profiles because oxygens

863

00:40:45,109 --> 00:40:43,080

created at the same time as hydrogen so

864

00:40:46,910 --> 00:40:45,119

you're creating oxidant the same time

865

00:40:50,960 --> 00:40:46,920

you're creating reductant when you have

866

00:40:52,820 --> 00:40:50,970

radiolysis of water so in a sense we can

867

00:40:55,340 --> 00:40:52,830

use these profiles simply as a measure

868

00:40:56,900 --> 00:40:55,350

of the organic fueled respiration what

869

00:40:59,840 --> 00:40:56,910

you're seeing is that organic fueled

870

00:41:01,849 --> 00:40:59,850

respiration nearly stops within the

871

00:41:05,780 --> 00:41:01,859

first meter of the sediment then goes to

872

00:41:11,420 --> 00:41:05,790

essentially zero or very close to zero

873

00:41:12,940 --> 00:41:11,430

in the heart of the gyre and if you

874

00:41:15,440 --> 00:41:12,950

think back to what I showed you before

875

00:41:17,840 --> 00:41:15,450

you'll remember that concentrations

876

00:41:19,370 --> 00:41:17,850

sorry I'm jumping ahead to see if I had

877

00:41:21,320 --> 00:41:19,380

another slide you remember that

878

00:41:23,900 --> 00:41:21,330

concentrations of cells in this region

879

00:41:25,130 --> 00:41:23,910

were three orders of magnitude less than

880

00:41:27,109 --> 00:41:25,140

the average so we're seeing about a

881

00:41:29,000 --> 00:41:27,119

thousand cells per cubic centimeter in

882

00:41:31,550 --> 00:41:29,010

most of these sediments the range of

883

00:41:33,349 --> 00:41:31,560

10,000 to a thousand and so one of the

884

00:41:35,780 --> 00:41:33,359

things we'll be pursuing over the next

885

00:41:37,700 --> 00:41:35,790

year it's testing whether or not those

886

00:41:40,550 --> 00:41:37,710

1000 to 10,000 cells per cubic

887

00:41:42,980 --> 00:41:40,560

centimeter are likely to be supported

888

00:41:46,130 --> 00:41:42,990

principally by the radioactive splitting

889

00:41:51,770 --> 00:41:46,140

of the pore water here instead of by the

890

00:41:53,330 --> 00:41:51,780

Buried organic matter and with that I'll

891

00:41:58,640 --> 00:41:53,340

bring this to a close and answer

892

00:42:01,849 --> 00:41:58,650

questions Steve thank you very much that

893

00:42:03,740 --> 00:42:01,859

was quite fascinating I think I'll ask

894

00:42:06,110 --> 00:42:03,750

the first question and

895

00:42:09,560 --> 00:42:06,120

if others would raise their hands in the

896

00:42:13,280 --> 00:42:09,570

meanwhile on the the chat side of WebEx

897

00:42:16,580 --> 00:42:13,290

will then go around the loop this this

898

00:42:20,270 --> 00:42:16,590

whole idea of thermodynamic cooperation

899

00:42:22,730 --> 00:42:20,280

between different groups of organisms so

900

00:42:24,850 --> 00:42:22,740

that you have metabolisms coexisting

901
00:42:27,290 --> 00:42:24,860
that you wouldn't have normally thought

902
00:42:28,610 --> 00:42:27,300
coexist is sort of fascinating it

903
00:42:30,830 --> 00:42:28,620
reminds me a bit of the anaerobic

904
00:42:34,040 --> 00:42:30,840
oxidation of methane where perhaps

905
00:42:35,750 --> 00:42:34,050
that's also going on as well so given

906
00:42:37,940 --> 00:42:35,760
that you have another very prominent

907
00:42:41,000 --> 00:42:37,950
example that may actually apply to a

908
00:42:45,200 --> 00:42:41,010
very large segment of the sea floor

909
00:42:47,510 --> 00:42:45,210
surface I'm wondering how much do you

910
00:42:50,690 --> 00:42:47,520
think might you speculate remains to be

911
00:42:53,290 --> 00:42:50,700
discovered are we going to discover a

912
00:42:57,140 --> 00:42:53,300
lot more of these thermodynamic

913
00:42:59,420 --> 00:42:57,150

cooperations that yield metabolisms or

914

00:43:01,750 --> 00:42:59,430

coexistence of metabolisms that we

915

00:43:04,490 --> 00:43:01,760

wouldn't otherwise have expected and

916

00:43:08,000 --> 00:43:04,500

should this kind of thermodynamic

917

00:43:10,040 --> 00:43:08,010

cooperation open up our ideas about what

918

00:43:15,200 --> 00:43:10,050

might be possible on another planet

919

00:43:17,180 --> 00:43:15,210

let's say Mars that's a good series of

920

00:43:19,220 --> 00:43:17,190

questions and I'm going to start by

921

00:43:21,140 --> 00:43:19,230

saying you're you're right this many

922

00:43:23,540 --> 00:43:21,150

respects resembles the situation with an

923

00:43:25,490 --> 00:43:23,550

aerobic oxidation of methane in fact

924

00:43:29,690 --> 00:43:25,500

work that Torvalds did particularly in

925

00:43:31,610 --> 00:43:29,700

his thesis provides a sort of guide if

926

00:43:34,250 --> 00:43:31,620

you will to this sort of behavior where

927

00:43:36,470 --> 00:43:34,260

he first estimated free energy yields in

928

00:43:38,690 --> 00:43:36,480

relatively shallow sediments for that

929

00:43:41,300 --> 00:43:38,700

process so you can think of this in a

930

00:43:44,390 --> 00:43:41,310

way as an extension of that of that idea

931

00:43:45,860 --> 00:43:44,400

into other processes and into deeper

932

00:43:53,540 --> 00:43:45,870

sediments and much longer periods of

933

00:43:56,770 --> 00:43:53,550

time in a way the aom example and the

934

00:44:00,910 --> 00:43:56,780

example I gave are both extensions of an

935

00:44:05,030 --> 00:44:00,920

older recognition which is that

936

00:44:10,280 --> 00:44:05,040

organisms feed each other you know for

937

00:44:13,010 --> 00:44:10,290

example it's it's well known that the

938

00:44:15,260 --> 00:44:13,020

sorts of organisms that undertake redox

939

00:44:16,520 --> 00:44:15,270

activities like sulfate reduction and

940

00:44:20,230 --> 00:44:16,530

iron reduction

941

00:44:23,630 --> 00:44:20,240

in anoxic sediments rely ultimately on

942

00:44:25,850 --> 00:44:23,640

fermentation of organic matter for their

943

00:44:28,310 --> 00:44:25,860

food in sort of typical swamp sediments

944

00:44:30,860 --> 00:44:28,320

so it is so you can think of this as a

945

00:44:32,870 --> 00:44:30,870

way of formalizing that that older

946

00:44:38,930 --> 00:44:32,880

microbiological recognition and putting

947

00:44:41,390 --> 00:44:38,940

it in sort of a thermodynamic basis and

948

00:44:42,710 --> 00:44:41,400

I think we will see a lot more of it as

949

00:44:45,440 --> 00:44:42,720

people begin to think in that more

950

00:44:47,000 --> 00:44:45,450

explicitly thermodynamic way one of the

951
00:44:49,430 --> 00:44:47,010
things that I'm not going to get into

952
00:44:51,770 --> 00:44:49,440
too much detail here but what we've seen

953
00:44:53,990 --> 00:44:51,780
in in our more recent calculations are

954
00:44:56,360 --> 00:44:54,000
that processes that don't even occur in

955
00:44:58,400 --> 00:44:56,370
the surface world because the free

956
00:45:00,770 --> 00:44:58,410
energies don't allow it actually occur

957
00:45:02,330 --> 00:45:00,780
in the in the subsurface world because

958
00:45:04,430 --> 00:45:02,340
in situ free energies are very different

959
00:45:08,840 --> 00:45:04,440
in the subsurface than they are in the

960
00:45:10,580 --> 00:45:08,850
surface and so there are interactions in

961
00:45:12,050 --> 00:45:10,590
the nitrogen cycle for example that you

962
00:45:14,960 --> 00:45:12,060
won't see in the service world then here

963
00:45:16,850 --> 00:45:14,970

to occur in the subsurface and I suspect

964

00:45:18,400 --> 00:45:16,860

that if people were to move back out of

965

00:45:21,110 --> 00:45:18,410

the subsurface into the water column

966

00:45:23,150 --> 00:45:21,120

particularly in anoxic sediments we

967

00:45:27,860 --> 00:45:23,160

would see these rules apply there as

968

00:45:30,290 --> 00:45:27,870

well and by extension if we were to

969

00:45:34,130 --> 00:45:30,300

search for these processes on other

970

00:45:36,320 --> 00:45:34,140

planets I suspect or other bodies if

971

00:45:37,820 --> 00:45:36,330

there's life there we would find that

972

00:45:39,080 --> 00:45:37,830

they would follow similar rules if the

973

00:45:43,240 --> 00:45:39,090

environments are stable enough for

974

00:45:46,610 --> 00:45:43,250

example if there is an anoxic community

975

00:45:49,460 --> 00:45:46,620

beneath the ice of Europa or beneath the

976
00:45:52,310 --> 00:45:49,470
surface of Mars one would expect that

977
00:45:54,770 --> 00:45:52,320
over relatively geologically short

978
00:45:59,810 --> 00:45:54,780
periods of time you'd reach these sorts

979
00:46:01,730 --> 00:45:59,820
of community equilibria if you will and

980
00:46:04,700 --> 00:46:01,740
one of the things that they're there are

981
00:46:08,030 --> 00:46:04,710
complications in this that that

982
00:46:10,640 --> 00:46:08,040
potentially make it even deeper interest

983
00:46:14,120 --> 00:46:10,650
for example you can imagine a system

984
00:46:16,100 --> 00:46:14,130
where iron reducers oxidized sulfur and

985
00:46:18,140 --> 00:46:16,110
then sulfur reducers oxidize an organic

986
00:46:20,060 --> 00:46:18,150
matter and the iron reducers don't do

987
00:46:22,460 --> 00:46:20,070
the organic matter directly well in that

988
00:46:25,400 --> 00:46:22,470

case you create an electron shuttle if

989

00:46:27,530 --> 00:46:25,410

you will where you can actually sustain

990

00:46:29,620 --> 00:46:27,540

more organisms than with the same amount

991

00:46:31,269 --> 00:46:29,630

of energy but the iron reducer

992

00:46:34,480 --> 00:46:31,279

the sulfur reducers both going for the

993

00:46:35,769 --> 00:46:34,490

organic matter we've not observed that

994

00:46:37,930 --> 00:46:35,779

in any of these systems we haven't

995

00:46:39,789 --> 00:46:37,940

looked for it either so it's possible to

996

00:46:43,480 --> 00:46:39,799

imagine ways of not only sustaining a

997

00:46:45,009 --> 00:46:43,490

more richer community metabolically but

998

00:46:46,480 --> 00:46:45,019

sustaining a community that uses its

999

00:46:49,749 --> 00:46:46,490

resources much more efficiently and

1000

00:46:53,470 --> 00:46:49,759

sustains a larger biomass I'll stop

1001
00:46:59,499 --> 00:46:53,480
there okay we have a question from Penn

1002
00:47:01,569 --> 00:46:59,509
State hi Steve Jim casting I thought the

1003
00:47:04,299 --> 00:47:01,579
most provocative thing you said was it's

1004
00:47:08,049 --> 00:47:04,309
oceanic sulfate controlled atmospheric

1005
00:47:11,380 --> 00:47:08,059
co2 and climate and uh when I give my

1006
00:47:14,259 --> 00:47:11,390
talk on climate I usually emphasize that

1007
00:47:17,109 --> 00:47:14,269
co2 is more controlled by the inorganic

1008
00:47:19,630 --> 00:47:17,119
carbon cycle the carbonate silicates

1009
00:47:21,579 --> 00:47:19,640
cycle and that the organic carbon cycle

1010
00:47:25,799 --> 00:47:21,589
can't really do it because it buffers

1011
00:47:29,440 --> 00:47:25,809
oxygen what are your thoughts on that

1012
00:47:31,120 --> 00:47:29,450
and that's that's the that's usual

1013
00:47:33,400 --> 00:47:31,130

perspective and it's a it's a very good

1014

00:47:37,569 --> 00:47:33,410

one the the easiest way to put the

1015

00:47:40,720 --> 00:47:37,579

control here is that to step aside from

1016

00:47:42,789 --> 00:47:40,730

the one problem with the salt with

1017

00:47:44,470 --> 00:47:42,799

sulfate reduction as a control is you

1018

00:47:47,049 --> 00:47:44,480

know you're creating DIC at the same

1019

00:47:49,089 --> 00:47:47,059

time that you're removing sulfate so in

1020

00:47:53,980 --> 00:47:49,099

a sense you're replacing an anion with

1021

00:47:57,549 --> 00:47:53,990

another anion and so the effect on it's

1022

00:47:59,650 --> 00:47:57,559

more nearly a zero-sum game there then I

1023

00:48:01,420 --> 00:47:59,660

presented it at colloquially but it's

1024

00:48:03,880 --> 00:48:01,430

it's a more pure case where you look at

1025

00:48:07,599 --> 00:48:03,890

safe pyrite oxidation where you start

1026

00:48:09,249 --> 00:48:07,609

with iron sulfide if you oxidize that

1027

00:48:12,190 --> 00:48:09,259

and you get it you get an oxidized iron

1028

00:48:13,690 --> 00:48:12,200

that doesn't go anywhere and you get an

1029

00:48:16,329 --> 00:48:13,700

oxidized sulfur that goes into the

1030

00:48:21,099 --> 00:48:16,339

aqueous system that's a strong acid and

1031

00:48:23,559 --> 00:48:21,109

it's going to drive off CO_2 so so the

1032

00:48:27,819 --> 00:48:23,569

cleanest way of imagining of imagining

1033

00:48:31,329 --> 00:48:27,829

this operating would be to essentially

1034

00:48:35,190 --> 00:48:31,339

just change your rates of precipitation

1035

00:48:37,240 --> 00:48:35,200

and oxidation of metal sulfides and

1036

00:48:40,960 --> 00:48:37,250

through the alkalinity system it will

1037

00:48:47,569 --> 00:48:44,210

Lee Kump is here Lee do you want to have

1038

00:48:49,370 --> 00:48:47,579

anything hey how you doing well I mean I

1039

00:48:50,720 --> 00:48:49,380

guess part it on the weathering side it

1040

00:48:53,299 --> 00:48:50,730

depends what happens to the protons

1041

00:48:54,859 --> 00:48:53,309

right and so there's a big a lot of

1042

00:48:57,170 --> 00:48:54,869

interest I've been seeing these days and

1043

00:48:59,509 --> 00:48:57,180

looking at pyrite induced weathering of

1044

00:49:03,650 --> 00:48:59,519

silicates for example and so if those

1045

00:49:04,910 --> 00:49:03,660

protons are are taken up during silicate

1046

00:49:06,529 --> 00:49:04,920

weathering before they ever made to the

1047

00:49:09,769 --> 00:49:06,539

ocean then you get sulfate going in for

1048

00:49:11,480 --> 00:49:09,779

sure but the but the but the protons are

1049

00:49:13,730 --> 00:49:11,490

actually being neutralized on land and

1050

00:49:15,589 --> 00:49:13,740

so then it goes back into Jim's camp so

1051

00:49:17,180 --> 00:49:15,599

I think part of it on the pirate

1052

00:49:19,730 --> 00:49:17,190

oxidation side depends on the fate of

1053

00:49:22,160 --> 00:49:19,740

those protons now on the on the flip

1054

00:49:25,160 --> 00:49:22,170

side the net sulfate reduction and

1055

00:49:27,200 --> 00:49:25,170

barrel of barrel of pyrite there you

1056

00:49:28,730 --> 00:49:27,210

know that's a sort of like a proxy for

1057

00:49:31,460 --> 00:49:28,740

organic carbon burial so there I think

1058

00:49:34,009 --> 00:49:31,470

you have a co2 driver associated with

1059

00:49:35,539 --> 00:49:34,019

that with that very loop i right but it

1060

00:49:37,670 --> 00:49:35,549

does have implications for oxygen as

1061

00:49:41,480 --> 00:49:37,680

well and so all you need to think about

1062

00:49:43,640 --> 00:49:41,490

that yes usually co2 driven thing that

1063

00:49:45,380 --> 00:49:43,650

that is based on organic carbon burial

1064

00:49:47,150 --> 00:49:45,390

you have to worry about what what what's

1065

00:49:51,109 --> 00:49:47,160

the fate of that oxygen did you drive up

1066

00:49:53,359 --> 00:49:51,119

an O2 pulse with the CO2 draw down yeah

1067

00:49:56,269 --> 00:49:53,369

it is you're well aware it's both of you

1068

00:50:00,349 --> 00:49:56,279

are well aware people have often looked

1069

00:50:02,319 --> 00:50:00,359

at sulfur in terms of oxygen sinks it's

1070

00:50:05,930 --> 00:50:02,329

sort of an extension of a the classic

1071

00:50:07,370 --> 00:50:05,940

burner type approach I find it

1072

00:50:12,499 --> 00:50:07,380

interesting that people rarely look at

1073

00:50:18,779 --> 00:50:12,509

the alkalinity side of it okay we have a

1074

00:50:26,679 --> 00:50:24,459

Carnegie are you there yeah hi for

1075

00:50:28,839 --> 00:50:26,689

sukkos from Carnegie have a question

1076

00:50:35,769 --> 00:50:28,849

regarding do see have you measured you

1077

00:50:38,529 --> 00:50:35,779

seeing these segments we do measure do

1078

00:50:40,390 --> 00:50:38,539

see I can't right offhand remember any

1079

00:50:41,969 --> 00:50:40,400

numbers for you when we measure do see

1080

00:50:43,859 --> 00:50:41,979

and sometimes we also actually measure

1081

00:50:47,199 --> 00:50:43,869

classes of do see for example

1082

00:50:50,529 --> 00:50:47,209

carbohydrates amino acids etc does in

1083

00:50:52,209 --> 00:50:50,539

dissolve form the DLC of course is

1084

00:50:53,499 --> 00:50:52,219

always dissolved but I'm Clark trying to

1085

00:50:54,819 --> 00:50:53,509

clarify the carbohydrates and amino

1086

00:50:58,269 --> 00:50:54,829

acids we look at those in dissolved form

1087

00:51:02,919 --> 00:50:58,279

also do you have a question specifically

1088

00:51:05,919 --> 00:51:02,929

about the DLC so I'm having issues with

1089

00:51:06,819 --> 00:51:05,929

my sound so it's okay it's okay I don't

1090

00:51:11,919 --> 00:51:06,829

kind of don't know what we're talking

1091

00:51:17,439 --> 00:51:11,929

about okay we have a question from

1092

00:51:19,359 --> 00:51:17,449

Indiana to the morning handsome 15 if

1093

00:51:21,640 --> 00:51:19,369

you want to find out what is the

1094

00:51:24,939 --> 00:51:21,650

contribution of radiologically provide

1095

00:51:27,120 --> 00:51:24,949

energy in contrast to organic matter in

1096

00:51:29,589 --> 00:51:27,130

deep-sea sediments have you looked at

1097

00:51:32,919 --> 00:51:29,599

horizons where you have a dilution of

1098

00:51:35,349 --> 00:51:32,929

settlement by tephra in those intervals

1099

00:51:39,909 --> 00:51:35,359

you might expect less organic material

1100

00:51:43,239 --> 00:51:39,919

but more realistic energy and do you

1101

00:51:45,519 --> 00:51:43,249

have maybe a blip in bacterial

1102

00:51:52,749 --> 00:51:45,529

abundances at the margins of his temper

1103

00:51:56,409 --> 00:51:52,759

layers or in this association we haven't

1104

00:52:00,489 --> 00:51:56,419

specifically looked at this question of

1105

00:52:02,919 --> 00:52:00,499

tephra vs normal sediments in the main

1106

00:52:04,989 --> 00:52:02,929

reason for that is that the

1107

00:52:06,819 --> 00:52:04,999

concentration of organic matter is you

1108

00:52:10,779 --> 00:52:06,829

go from the continental margins to the

1109

00:52:12,699 --> 00:52:10,789

middle of the gyre varies by an

1110

00:52:15,779 --> 00:52:12,709

extraordinary amount you know we're

1111

00:52:18,189 --> 00:52:15,789

talking orders of magnitude and so

1112

00:52:20,109 --> 00:52:18,199

essentially you can take a grab sample

1113

00:52:24,669 --> 00:52:20,119

of sediment from the middle of the gyre

1114

00:52:30,069 --> 00:52:24,679

and have an essentially organic free

1115

00:52:31,180 --> 00:52:30,079

sample for comparison and this allows us

1116

00:52:33,819 --> 00:52:31,190

to use thou

1117

00:52:35,170 --> 00:52:33,829

of kilometers distance for controlling

1118

00:52:38,800 --> 00:52:35,180

our system instead of worrying about

1119

00:52:40,599 --> 00:52:38,810

centimeters I don't know if that answers

1120

00:52:41,800 --> 00:52:40,609

you yeah I'm answering your question by

1121

00:52:43,510 --> 00:52:41,810

saying no we haven't looked at the

1122

00:52:47,140 --> 00:52:43,520

temper case but that's because we have a

1123

00:52:54,760 --> 00:52:47,150

very big Geographic case that that we're

1124

00:52:59,290 --> 00:52:54,770

looking at thanks a lot you know okay we

1125

00:53:02,470 --> 00:52:59,300

have a question from Goddard hi Steve

1126

00:53:05,380 --> 00:53:02,480

it's mike boomer here I like I was a

1127

00:53:07,960 --> 00:53:05,390

nice talk I enjoyed that one has to be a

1128

00:53:09,730 --> 00:53:07,970

quick question about the balance of

1129

00:53:12,450 --> 00:53:09,740

reductants to oxidants in the

1130

00:53:15,309 --> 00:53:12,460

radiologist radiolysis dominated regime

1131

00:53:18,460 --> 00:53:15,319

and that depends strongly on the

1132

00:53:21,250 --> 00:53:18,470

tortuosity of the medium since molecular

1133

00:53:23,500 --> 00:53:21,260

hydrogen is much more mobile than like

1134

00:53:26,950 --> 00:53:23,510

their oxygen squeeze through tighter

1135

00:53:29,140 --> 00:53:26,960

spaces if you like I think that it would

1136

00:53:33,510 --> 00:53:29,150

escape more readily and leaving the

1137

00:53:36,880 --> 00:53:33,520

medium relatively Oxford which oxidizes

1138

00:53:38,680 --> 00:53:36,890

yeah it depends on you're absolutely

1139

00:53:41,950 --> 00:53:38,690

right the hydrogen should escape more

1140

00:53:43,270 --> 00:53:41,960

easily in this circumstances we're

1141

00:53:47,620 --> 00:53:43,280

looking at here we're essentially

1142

00:53:49,089 --> 00:53:47,630

looking at sediment thicknesses on this

1143

00:53:50,800 --> 00:53:49,099

recent cruise the deepest sediment

1144

00:53:54,130 --> 00:53:50,810

record was about eight meters and the

1145

00:53:58,420 --> 00:53:54,140

deepest sediment piles that we cord into

1146

00:54:01,720 --> 00:53:58,430

or around 130 meters okay so we're

1147

00:54:06,490 --> 00:54:01,730

essentially looking for diffusive

1148

00:54:10,030 --> 00:54:06,500

distances that are in the shortest

1149

00:54:12,099 --> 00:54:10,040

systems sure in the shortest distance

1150

00:54:13,780 --> 00:54:12,109

going to say halfway through the

1151

00:54:15,970 --> 00:54:13,790

sediment column to the surface or to the

1152

00:54:18,069 --> 00:54:15,980

basement below it could be as little as

1153

00:54:20,500 --> 00:54:18,079

two and a half meters where this

1154

00:54:24,569 --> 00:54:20,510

sediments really thin or in another

1155

00:54:28,660 --> 00:54:24,579

system it could be as much as 70 meters

1156

00:54:30,400 --> 00:54:28,670

so if you've got a dead system where the

1157

00:54:34,480 --> 00:54:30,410

hydrogen or the oxygen aren't being

1158

00:54:36,250 --> 00:54:34,490

utilized you would expect your steady

1159

00:54:39,190 --> 00:54:36,260

state concentrations of those two

1160

00:54:41,290 --> 00:54:39,200

products to be different because the

1161

00:54:45,090 --> 00:54:41,300

hydrogen's escaping more readily you'd

1162

00:54:50,560 --> 00:54:47,560

but in a system where you've got

1163

00:54:53,170 --> 00:54:50,570

organisms cropping it typically they

1164

00:54:56,830 --> 00:54:53,180

crop the hydrogen you know in time

1165

00:54:58,990 --> 00:54:56,840

scales of minutes or less and the the

1166

00:55:00,820 --> 00:54:59,000

distances over which the hydrogen must

1167

00:55:04,680 --> 00:55:00,830

diffuse is again meters to tens of

1168

00:55:08,440 --> 00:55:04,690

meters so that will take many years to

1169

00:55:12,730 --> 00:55:08,450

to thousands of years has anyone

1170

00:55:15,640 --> 00:55:12,740

actually done any kind of measurements

1171

00:55:18,400 --> 00:55:15,650

of net gas escaped from these media to

1172

00:55:20,620 --> 00:55:18,410

identify use that as a marker for the

1173

00:55:23,050 --> 00:55:20,630

kinds of biology that's going on whether

1174

00:55:27,310 --> 00:55:23,060

it's driven radial radiologically as

1175

00:55:29,740 --> 00:55:27,320

opposed to what are the mechanisms well

1176

00:55:32,950 --> 00:55:29,750

we took samples on our recent cruise we

1177

00:55:36,130 --> 00:55:32,960

measure hydrogen routinely and what we

1178

00:55:38,560 --> 00:55:36,140

found was that hydrogen is always below

1179

00:55:43,480 --> 00:55:38,570

our detection limit in our detection

1180

00:55:44,980 --> 00:55:43,490

limit is a typically two or three orders

1181

00:55:47,860 --> 00:55:44,990

of magnitude lower than the

1182

00:55:49,360 --> 00:55:47,870

concentration you'd expect if the

1183

00:55:50,800 --> 00:55:49,370

sediment is as radioactive as the

1184

00:55:56,530 --> 00:55:50,810

sediment we've looked at in the past and

1185

00:55:59,470 --> 00:55:56,540

the system is dead okay we also took

1186

00:56:02,200 --> 00:55:59,480

samples for measuring helium

1187

00:56:03,880 --> 00:56:02,210

concentrations to get a measure of the

1188

00:56:07,210 --> 00:56:03,890

Alpha flux out of the sediment if you

1189

00:56:10,330 --> 00:56:07,220

will and it's steady state those helium

1190

00:56:12,850 --> 00:56:10,340

concentrations the helium flux should be

1191

00:56:14,920 --> 00:56:12,860

equal to the helium bombardment of water

1192

00:56:16,120 --> 00:56:14,930

because obviously any alpha radiation

1193

00:56:18,730 --> 00:56:16,130

that didn't get out of the mineral

1194

00:56:21,280 --> 00:56:18,740

grains won't be in the water to diffuse

1195

00:56:22,840 --> 00:56:21,290

out so we're hoping to use that as a

1196

00:56:24,970 --> 00:56:22,850

check if you will both of those are

1197

00:56:26,380 --> 00:56:24,980

variations on things that the indiana

1198

00:56:29,440 --> 00:56:26,390

princeton team has done in there deep

1199

00:56:30,670 --> 00:56:29,450

mines one difference being that

1200

00:56:35,680 --> 00:56:30,680

effectively they're measuring

1201
00:56:37,870 --> 00:56:35,690
concentrations there and they don't have

1202
00:56:39,010 --> 00:56:37,880
the advantage of depth that we that we

1203
00:56:42,190 --> 00:56:39,020
have where we can actually calculate

1204
00:56:44,650 --> 00:56:42,200
fluxing directly using transport models

1205
00:56:48,360 --> 00:56:44,660
but but we're measuring the same

1206
00:56:48,370 --> 00:56:55,380
okay

1207
00:57:02,250 --> 00:56:59,579
well thank you Mike it looks like that's

1208
00:57:05,789 --> 00:57:02,260
all that's all the questions I just

1209
00:57:07,920 --> 00:57:05,799
wanted to make one other comment and if

1210
00:57:09,390 --> 00:57:07,930
anybody has a last-minute question

1211
00:57:11,609 --> 00:57:09,400
please raise your hand while I'm doing

1212
00:57:13,349 --> 00:57:11,619
so otherwise we'll sign off and that is

1213
00:57:16,289 --> 00:57:13,359

that one of the things that we have been

1214

00:57:19,440 --> 00:57:16,299

doing is working to improve the quality

1215

00:57:21,720 --> 00:57:19,450

of our archives of these seminars and

1216

00:57:24,630 --> 00:57:21,730

others and so I just want to remind you

1217

00:57:26,940 --> 00:57:24,640

that all the director seminars are

1218

00:57:29,220 --> 00:57:26,950

archived the archives are available on

1219

00:57:31,950 --> 00:57:29,230

our website one of the things we have

1220

00:57:34,799 --> 00:57:31,960

not had archived is the video feed what

1221

00:57:37,289 --> 00:57:34,809

we've had is the audio feed and the

1222

00:57:40,650 --> 00:57:37,299

WebEx or at least the slides I should

1223

00:57:43,079 --> 00:57:40,660

say and we now have an archive that

1224

00:57:46,620 --> 00:57:43,089

includes the video feed so you can see

1225

00:57:49,410 --> 00:57:46,630

Steve's handsome face hopefully when we

1226

00:57:51,990 --> 00:57:49,420

archive this we will maintain both

1227

00:57:54,509 --> 00:57:52,000

options however because the archived

1228

00:57:56,759 --> 00:57:54,519

version that has the video feed is a

1229

00:57:58,920 --> 00:57:56,769

much larger file size and it's going to

1230

00:58:01,710 --> 00:57:58,930

be inconvenient for anybody who doesn't

1231

00:58:03,960 --> 00:58:01,720

have ready access to a fairly broadband

1232

00:58:06,809 --> 00:58:03,970

link so we will have both options

1233

00:58:09,120 --> 00:58:06,819

available but I just wanted to let you

1234

00:58:11,160 --> 00:58:09,130

all know that and let me just ask if

1235

00:58:13,319 --> 00:58:11,170

there are any last questions from anyone

1236

00:58:19,680 --> 00:58:13,329

around the net like Arizona has a

1237

00:58:22,670 --> 00:58:19,690

question Arizona go ahead please hi dr.

1238

00:58:26,009 --> 00:58:22,680

danse Joe Russell hi Joe how are you

1239

00:58:28,609 --> 00:58:26,019

good I was just wondering it's sort of a

1240

00:58:30,749 --> 00:58:28,619

method question really is uh how do you

1241

00:58:32,880 --> 00:58:30,759

since you're taking these core samples

1242

00:58:34,440 --> 00:58:32,890

from the ocean how do you make sure that

1243

00:58:35,880 --> 00:58:34,450

like it's not contaminated by ocean

1244

00:58:38,640 --> 00:58:35,890

water and obviously there's you know a

1245

00:58:40,829 --> 00:58:38,650

lot of microorganisms in ocean water so

1246

00:58:42,120 --> 00:58:40,839

exactly how do you you know did you

1247

00:58:44,579 --> 00:58:42,130

account for that you have to account for

1248

00:58:48,059 --> 00:58:44,589

that at all yeah that's a very good

1249

00:58:50,190 --> 00:58:48,069

question when we're drilling it's easier

1250

00:58:51,390 --> 00:58:50,200

to do than when we're simply piston

1251
00:58:55,499 --> 00:58:51,400
coring is we were on the most recent

1252
00:58:57,960 --> 00:58:55,509
cruise what we do when we're drilling is

1253
00:59:01,079 --> 00:58:57,970
we we do two things when we put a little

1254
00:59:04,799 --> 00:59:01,089
bag Roy pack bag with fluorescent

1255
00:59:07,640 --> 00:59:04,809
cereals into the cutting shoe so when

1256
00:59:11,870 --> 00:59:07,650
the piston drives the

1257
00:59:14,300 --> 00:59:11,880
the horror forward it ruptures the bag

1258
00:59:17,440 --> 00:59:14,310
and those those microspheres all just

1259
00:59:19,820 --> 00:59:17,450
stream up the sides and into the core

1260
00:59:22,220 --> 00:59:19,830
I'm not real fond of that technique

1261
00:59:23,720 --> 00:59:22,230
because it tends to disturb the core but

1262
00:59:24,890 --> 00:59:23,730
microbiologists like it because they can

1263
00:59:28,340 --> 00:59:24,900

see little glowing beads and their

1264

00:59:30,470 --> 00:59:28,350

microscope slides the technique that we

1265

00:59:33,590 --> 00:59:30,480

use its quantifiable and more precise

1266

00:59:39,040 --> 00:59:33,600

and more accurate in a sense except as a

1267

00:59:44,570 --> 00:59:42,800

very easily measured chemical into the

1268

00:59:47,030 --> 00:59:44,580

drilling fluid and circulate it through

1269

00:59:49,570 --> 00:59:47,040

the system it's a perfluorocarbon tracer

1270

00:59:51,590 --> 00:59:49,580

that we can measure at the ppt level and

1271

00:59:54,050 --> 00:59:51,600

because we know the rate at which we're

1272

00:59:56,030 --> 00:59:54,060

metering it into the drilling fluid when

1273

00:59:57,410 --> 00:59:56,040

we find it in in the core we know

1274

00:59:59,990 --> 00:59:57,420

exactly how much contamination has

1275

01:00:02,450 --> 01:00:00,000

occurred and incidentally the drilling

1276

01:00:04,790 --> 01:00:02,460

fluid is surface seawater so that's how

1277

01:00:07,040 --> 01:00:04,800

we do it when we're drilling there are

1278

01:00:11,540 --> 01:00:07,050

much less subtle approaches at you that

1279

01:00:13,490 --> 01:00:11,550

people have used for example you can use

1280

01:00:15,980 --> 01:00:13,500

the difference in chemistry between the

1281

01:00:18,200 --> 01:00:15,990

surface water and the pore water as a

1282

01:00:19,540 --> 01:00:18,210

proxy for contamination that's usually

1283

01:00:22,670 --> 01:00:19,550

only picking out really gross

1284

01:00:24,710 --> 01:00:22,680

contamination so for example you could

1285

01:00:27,530 --> 01:00:24,720

use the occurrence of oxygen and anoxic

1286

01:00:29,480 --> 01:00:27,540

sediments as a measure or the occurrence

1287

01:00:31,340 --> 01:00:29,490

of sulfate and sulfate free sediment as

1288

01:00:34,610 --> 01:00:31,350

a measure but the perfluorocarbon tracer

1289

01:00:36,260 --> 01:00:34,620

is much much more sensitive so

1290

01:00:38,900 --> 01:00:36,270

essentially our detection limit for the

1291

01:00:44,990 --> 01:00:38,910

pft is equal to somewhere between 1 and

1292

01:00:46,550 --> 01:00:45,000

10 cells of contaminating microbe which

1293

01:00:48,680 --> 01:00:46,560

is about as low as anyone's gotten it

1294

01:00:56,260 --> 01:00:48,690

although there are hypothetically ways

1295

01:01:03,740 --> 01:00:59,810

thank you thank you you're welcome

1296

01:01:06,080 --> 01:01:03,750

thanks for your question okay Steve I

1297

01:01:09,260 --> 01:01:06,090

think that's the end of the question so

1298

01:01:11,930 --> 01:01:09,270

let us all thank you again for really

1299

01:01:13,880 --> 01:01:11,940

fascinating and stimulating provocative