
AbSciCon
2019

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

2
00:00:12,190 --> 00:00:09,299
[Applause]

3
00:00:15,070 --> 00:00:12,200
thanks for invitin I'm somewhat an

4
00:00:17,080 --> 00:00:15,080
outsider to this field I work mostly in

5
00:00:21,189 --> 00:00:17,090
modern lake sediments but I have got

6
00:00:24,040 --> 00:00:21,199
involved into in the early Earth working

7
00:00:26,980 --> 00:00:24,050
with Sean Crowe on Lake Matano and a key

8
00:00:28,929 --> 00:00:26,990
an analog and I had an enthusiastic PhD

9
00:00:33,130 --> 00:00:28,939
student who wanted to keep modeling this

10
00:00:36,880 --> 00:00:33,140
stuff so I'll talk about how we

11
00:00:40,540 --> 00:00:36,890
interprets the sulfa set of records in

12
00:00:42,610 --> 00:00:40,550
Keene sediments and also what we mean

13
00:00:45,810 --> 00:00:42,620

maybe missin current currently from

14
00:00:47,710 --> 00:00:45,820
those models so as was just presented

15
00:00:49,770 --> 00:00:47,720
there is pretty good evidence for

16
00:00:52,150 --> 00:00:49,780
coastal oxygenation just before the

17
00:00:56,500 --> 00:00:52,160
great oxidation event before the

18
00:00:58,690 --> 00:00:56,510
atmosphere got oxygenated so we're

19
00:01:00,880 --> 00:00:58,700
interested in how this may have affected

20
00:01:03,610 --> 00:01:00,890
the sulfate concentrations possibly

21
00:01:06,039 --> 00:01:03,620
methane fluxes as well and how we can

22
00:01:08,230 --> 00:01:06,049
separate the signals that propagate from

23
00:01:10,719 --> 00:01:08,240
the atmosphere so the oceanic water

24
00:01:13,810 --> 00:01:10,729
column and get preserved in the

25
00:01:16,330 --> 00:01:13,820
sediments so when we look at this

26
00:01:18,940 --> 00:01:16,340
sulfides it obviously typical trends

27
00:01:20,710 --> 00:01:18,950
that we see or that mass independence

28
00:01:21,210 --> 00:01:20,720
also isotope fractionation disappeared

29
00:01:25,300 --> 00:01:21,220
goe

30
00:01:27,520 --> 00:01:25,310
and the predominant paradigm for some

31
00:01:32,890 --> 00:01:27,530
mass independent relation Asians is that

32
00:01:36,700 --> 00:01:32,900
ultraviolet radiation separate positive

33
00:01:41,290 --> 00:01:36,710
Delta negative Delta into the elemental

34
00:01:44,140 --> 00:01:41,300
sulfur pool and sulfate pool and these

35
00:01:48,190 --> 00:01:44,150
are incompletely mixed so the positive

36
00:01:49,690 --> 00:01:48,200
excursions get preserved the elemental

37
00:01:52,750 --> 00:01:49,700
sulfur can just proportionate also

38
00:01:55,860 --> 00:01:52,760

generate some sulfate but basically we

39
00:01:59,320 --> 00:01:55,870
are looking at the sulfides preserved as

40
00:02:01,960 --> 00:01:59,330
pyrite in marine sediments there is a

41
00:02:03,690 --> 00:02:01,970
relationship between mass independent

42
00:02:10,899 --> 00:02:03,700
fractionation Delta Center City and

43
00:02:11,800 --> 00:02:10,909
Delta 34 so for a decrease in Delta

44
00:02:15,160 --> 00:02:11,810
sata3

45
00:02:17,160 --> 00:02:15,170
that is probably a decreased role of

46
00:02:19,449 --> 00:02:17,170
elemental sulfur we also see lighter

47
00:02:24,980 --> 00:02:19,459
isotopes and sulfur which probably

48
00:02:31,100 --> 00:02:28,040
when we try to simulate preservation of

49
00:02:34,460 --> 00:02:31,110
these signals we use diagenetic models

50
00:02:36,140 --> 00:02:34,470
which importantly are analogous to the

51
00:02:39,220 --> 00:02:36,150
models that we use in modern sediments

52
00:02:41,300 --> 00:02:39,230
that is we consider these sediments as

53
00:02:43,490 --> 00:02:41,310
analogous to modern sediments with

54
00:02:46,970 --> 00:02:43,500
sulfate diffuses from the water column

55
00:02:51,220 --> 00:02:46,980
into the sediments the sulfate reduction

56
00:02:53,960 --> 00:02:51,230
happens and that's how we get our pyrite

57
00:02:55,550 --> 00:02:53,970
we also use fractionation microfracture

58
00:02:57,380 --> 00:02:55,560
nations that will learn in modern

59
00:03:00,340 --> 00:02:57,390
systems with more than microbial

60
00:03:05,990 --> 00:03:00,350
capabilities for the lack of better

61
00:03:08,900 --> 00:03:06,000
information so this this is a picture

62
00:03:10,610 --> 00:03:08,910
from Lake Madonna which has high iron

63
00:03:13,000 --> 00:03:10,620

concentrations this is in the water

64
00:03:16,540 --> 00:03:13,010
column you may as well consider

65
00:03:23,330 --> 00:03:16,550
stratified sediments sulfate diffuses in

66
00:03:24,740 --> 00:03:23,340
produces sulfide as sulfate diffuses in

67
00:03:26,720 --> 00:03:24,750
and gets reduced

68
00:03:28,880 --> 00:03:26,730
we have Rayleigh effects fractionation

69
00:03:35,390 --> 00:03:28,890
so sulfate gets isotopically havior

70
00:03:37,850 --> 00:03:35,400
sulfide while must track must be getting

71
00:03:40,880 --> 00:03:37,860
as rapidly heavy as well the reason why

72
00:03:44,780 --> 00:03:40,890
we don't get exactly zero fractionation

73
00:03:46,940 --> 00:03:44,790
is that the system is open so because

74
00:03:48,740 --> 00:03:46,950
lighter isotopes are preferentially used

75
00:03:52,750 --> 00:03:48,750
up in the sediment emergency it's deep

76
00:03:55,220 --> 00:03:52,760
water column the gradients for the

77
00:03:58,280 --> 00:03:55,230
lighter isotopes are steeper so there

78
00:04:01,240 --> 00:03:58,290
are more lighter isotopes diffusing in

79
00:04:04,430 --> 00:04:01,250
we get essentially the lighter sulphide

80
00:04:06,770 --> 00:04:04,440
if we assume that at low sulfate

81
00:04:08,979 --> 00:04:06,780
concentrations fractionation x' decrease

82
00:04:14,479 --> 00:04:08,989
because essentially all of the sulfate

83
00:04:17,990 --> 00:04:14,489
is being used up we get load isotopic

84
00:04:21,680 --> 00:04:18,000
differences Delta 34s between sulfate

85
00:04:26,060 --> 00:04:21,690
and sulfide and we could match this with

86
00:04:28,159 --> 00:04:26,070
a key and pyrite for fairly low sulfate

87
00:04:35,890 --> 00:04:28,169
very long actual sulfate can situations

88
00:04:38,500 --> 00:04:35,900

below 5 micro molar and this work we can

89
00:04:42,550 --> 00:04:38,510
develop the model further in more recent

90
00:04:46,030 --> 00:04:42,560
paper we included the oxidative cycling

91
00:04:50,590 --> 00:04:46,040
of sulfur where sulfide can get oxidized

92
00:04:52,360 --> 00:04:50,600
so in coastal environments also put in

93
00:04:54,640 --> 00:04:52,370
disproportionation of elemental sulfur

94
00:04:57,310 --> 00:04:54,650
that wasn't really considered there and

95
00:04:59,050 --> 00:04:57,320
what we found out is that oxygen well

96
00:05:00,460 --> 00:04:59,060
primarily limits sulfate reduction

97
00:05:06,040 --> 00:05:00,470
because organic matter mineralization

98
00:05:12,219 --> 00:05:06,050
happens to some degree through a orbital

99
00:05:15,150 --> 00:05:12,229
this increases Delta 34 the oxidative

100
00:05:17,530 --> 00:05:15,160
recycling but paradoxically it also

101
00:05:18,940 --> 00:05:17,540
increases preservation of mass

102
00:05:20,469 --> 00:05:18,950
independent fractionation because you

103
00:05:22,510 --> 00:05:20,479
get less sulfate reduction so more

104
00:05:27,070 --> 00:05:22,520
signal gets carried through from

105
00:05:30,010 --> 00:05:27,080
elemental sulfur if we put this in the

106
00:05:32,920 --> 00:05:30,020
context of sulfides atop records what

107
00:05:36,520 --> 00:05:32,930
this what this seems to explain is the

108
00:05:37,500 --> 00:05:36,530
increase in Delta status 3 leading up to

109
00:05:40,300 --> 00:05:37,510
the goe

110
00:05:44,140 --> 00:05:40,310
coincident with the increase in Delta 34

111
00:05:46,420 --> 00:05:44,150
and if we try to put constraints on the

112
00:05:48,850 --> 00:05:46,430
sulfate concentrations that's consistent

113
00:05:50,650 --> 00:05:48,860

with this it looks like the sulfate can

114
00:05:52,570 --> 00:05:50,660
situation increased from about 50

115
00:05:54,219 --> 00:05:52,580
micromolar we relaxed the previous

116
00:05:57,610 --> 00:05:54,229
constraints on sulphate concentration to

117
00:06:01,360 --> 00:05:57,620
about 50 micromolar up to about 200

118
00:06:06,339 --> 00:06:01,370
micro molar and oxygen concentrations

119
00:06:09,070 --> 00:06:06,349
that could reach cup well 25 so micro

120
00:06:11,170 --> 00:06:09,080
molar in the zeldo environments to

121
00:06:13,930 --> 00:06:11,180
reproduce this chance this also seems to

122
00:06:15,820 --> 00:06:13,940
suggest perhaps increase in organic

123
00:06:21,190 --> 00:06:15,830
productivity is the deposition of

124
00:06:24,700 --> 00:06:21,200
organic carbon if we carry simulations

125
00:06:27,370 --> 00:06:24,710
further in time into the Proterozoic we

126
00:06:29,710 --> 00:06:27,380
could look at the sulfur budget in the

127
00:06:32,339 --> 00:06:29,720
Proterozoic ocean so in further simple

128
00:06:36,570 --> 00:06:32,349
model that considers coastal ocean

129
00:06:41,680 --> 00:06:36,580
surface deep ocean and deep deep ocean

130
00:06:44,350 --> 00:06:41,690
for realistic fluxes input and output

131
00:06:46,540 --> 00:06:44,360
fluxes what we seem to have is that

132
00:06:49,460 --> 00:06:46,550
sulfate concentrations were in the

133
00:06:52,550 --> 00:06:49,470
hundreds of micro moles they were not

134
00:06:55,310 --> 00:06:52,560
as high as previously believed the

135
00:06:56,810 --> 00:06:55,320
important results from the sensitivity

136
00:06:59,420 --> 00:06:56,820
analysis is that the sulphate

137
00:07:00,770 --> 00:06:59,430
concentrations in the ocean seem to be

138
00:07:04,700 --> 00:07:00,780

controlled by the presence of this

139
00:07:08,870 --> 00:07:04,710
anoxic a huge anoxic compartment if you

140
00:07:11,470 --> 00:07:08,880
oxygenate the water column this D

141
00:07:13,880 --> 00:07:11,480
increases the sulphate concentrations

142
00:07:15,740 --> 00:07:13,890
tremendously by removing this deep sink

143
00:07:19,280 --> 00:07:15,750
and this is how you can get millimolar

144
00:07:21,620 --> 00:07:19,290
or higher levels of sulphate but until

145
00:07:23,870 --> 00:07:21,630
the ocean deep ocean becomes excision

146
00:07:31,430 --> 00:07:23,880
ated sulfate concentrations may have

147
00:07:33,700 --> 00:07:31,440
remained for a little low so this is

148
00:07:37,400 --> 00:07:33,710
this figure basically addresses this

149
00:07:41,870 --> 00:07:37,410
there are some exceptions to this result

150
00:07:44,930 --> 00:07:41,880
so Lagoon G seems to have high sulfate

151
00:07:47,780 --> 00:07:44,940
concentrations which may suggest that

152
00:07:49,880 --> 00:07:47,790
the water column have been oxygenated

153
00:07:54,320 --> 00:07:49,890
this have been suggested in the

154
00:07:56,750 --> 00:07:54,330
literature their genetic models show

155
00:07:58,460 --> 00:07:56,760
that basically the these sulfate

156
00:08:02,350 --> 00:07:58,470
concentrations are consistent with

157
00:08:06,680 --> 00:08:02,360
sulphur isotope records if we consider

158
00:08:10,310 --> 00:08:06,690
tens of microns Aegean in the in the

159
00:08:13,280 --> 00:08:10,320
surface ocean at these low sulfate con

160
00:08:17,600 --> 00:08:13,290
situations methane fluxes are sufficient

161
00:08:20,030 --> 00:08:17,610
to maintain concentrations above 25 ppm

162
00:08:22,159 --> 00:08:20,040
v which have been suggested as

163
00:08:30,830 --> 00:08:22,169

sufficient to maintain the Earth's

164
00:08:32,630 --> 00:08:30,840
glaciation free so I have in the

165
00:08:34,909 --> 00:08:32,640
Romanian a few minutes I'd like to talk

166
00:08:37,400 --> 00:08:34,919
about the factors that we may not have

167
00:08:39,560 --> 00:08:37,410
put into this model like I said

168
00:08:41,600 --> 00:08:39,570
previously we can say that sulfate

169
00:08:43,760 --> 00:08:41,610
diffusion in from the water column that

170
00:08:46,400 --> 00:08:43,770
was the primary source of sulfur to the

171
00:08:49,630 --> 00:08:46,410
sediments well if we look into the

172
00:08:53,240 --> 00:08:49,640
modern lake sediments low sulfate lakes

173
00:08:54,829 --> 00:08:53,250
sulfate or salt and sulfide seem to be

174
00:08:58,340 --> 00:08:54,839
generated within the sediment from

175
00:09:00,950 --> 00:08:58,350
organic matter well these are the plots

176
00:09:02,720 --> 00:09:00,960
from Lake Superior which is oxygen like

177
00:09:04,660 --> 00:09:02,730
Malawi which is borderline ferruginous

178
00:09:07,100 --> 00:09:04,670
of

179
00:09:09,200 --> 00:09:07,110
sulphate concentrations in the top

180
00:09:12,980 --> 00:09:09,210
layers of sediment are actually above

181
00:09:14,600 --> 00:09:12,990
the layers the levels of sulphate in the

182
00:09:19,730 --> 00:09:14,610
overlying water so sulphate actually

183
00:09:22,100 --> 00:09:19,740
fluxes out of the sediment well in lake

184
00:09:24,140 --> 00:09:22,110
montana serious fraction which is

185
00:09:27,370 --> 00:09:24,150
basically pyrite plus elemental sulfur

186
00:09:29,840 --> 00:09:27,380
increases but the total amount of sulfur

187
00:09:33,110 --> 00:09:29,850
actually decreases so we have a

188
00:09:35,780 --> 00:09:33,120

conversion from non serious fraction to

189
00:09:38,780 --> 00:09:35,790
share a fraction and this decrease is

190
00:09:41,480 --> 00:09:38,790
consistent with the organic sulfur being

191
00:09:43,760 --> 00:09:41,490
mineralized and so the ratio of sulfate

192
00:09:45,890 --> 00:09:43,770
sulfur total sulfur to total organic

193
00:09:48,230 --> 00:09:45,900
carbon remains remarkably constant

194
00:09:51,170 --> 00:09:48,240
within the sediment which can suggest

195
00:09:53,900 --> 00:09:51,180
the role for organic sulfur now this has

196
00:09:55,760 --> 00:09:53,910
a profound effect instead of considering

197
00:09:59,840 --> 00:09:55,770
rayleigh distillation in the sediment

198
00:10:03,200 --> 00:09:59,850
column of water column we have sulfate

199
00:10:04,670 --> 00:10:03,210
and sulfide being generated within the

200
00:10:07,730 --> 00:10:04,680
sediment possibly with the isotopic

201
00:10:09,770 --> 00:10:07,740
effect of afghan excel for hydrolysis

202
00:10:13,670 --> 00:10:09,780
and so this changes the paradigm of how

203
00:10:18,920 --> 00:10:13,680
we generate the isotopic signatures and

204
00:10:21,080 --> 00:10:18,930
sediments if we put if we construct a

205
00:10:22,820 --> 00:10:21,090
model that simulates how much pyrite it

206
00:10:24,650 --> 00:10:22,830
you can generate turns out you can

207
00:10:27,410 --> 00:10:24,660
generate at low sulphate concentrations

208
00:10:33,470 --> 00:10:27,420
you can generate all pyrite in the

209
00:10:37,550 --> 00:10:33,480
sediment from organic sulfur and so if

210
00:10:41,780 --> 00:10:37,560
you consider organic sulfur in organic

211
00:10:45,020 --> 00:10:41,790
debris prokaryotic cells actually leg

212
00:10:46,850 --> 00:10:45,030
Lac plus six like sulfates but they do

213
00:10:49,850 --> 00:10:46,860

have sulfonates which is plus four and

214
00:10:51,740 --> 00:10:49,860
of course they have plus minus two

215
00:10:55,550 --> 00:10:51,750
oxidation state so you generate both

216
00:10:58,310 --> 00:10:55,560
sulfide and sulfite from mineralization

217
00:10:59,570 --> 00:10:58,320
and sulfite reduction is actually

218
00:11:05,150 --> 00:10:59,580
energetically more favorable than

219
00:11:07,070 --> 00:11:05,160
sulfate reduction so if you form pyrite

220
00:11:08,600 --> 00:11:07,080
out of this source the resultant

221
00:11:10,910 --> 00:11:08,610
signatures are also consistent with the

222
00:11:13,850 --> 00:11:10,920
ork record it's also consistent with

223
00:11:16,519 --> 00:11:13,860
some other lines of evidence that show

224
00:11:19,220 --> 00:11:16,529
while sulfate reduction has a

225
00:11:23,679 --> 00:11:19,230
volved laters and sulfate reduction in

226
00:11:27,530 --> 00:11:23,689
fact as late as 2.7 billion years ago

227
00:11:29,540 --> 00:11:27,540
and this also seems to suggest that you

228
00:11:34,519 --> 00:11:29,550
don't need as much sulfate in the water

229
00:11:37,549 --> 00:11:34,529
column so if you look at the sulfur to

230
00:11:39,980 --> 00:11:37,559
carbon ratio in living cells it's pretty

231
00:11:43,879 --> 00:11:39,990
similar to phosphorous to carbon ratio

232
00:11:46,869 --> 00:11:43,889
about 1% so these levels sulfate could

233
00:11:49,939 --> 00:11:46,879
have been a limiting nutrient for life

234
00:11:52,689 --> 00:11:49,949
the well depending on what you believe

235
00:11:55,220 --> 00:11:52,699
about a key in productivity

236
00:11:58,720 --> 00:11:55,230
mineralization of organic sulfur could

237
00:12:03,739 --> 00:11:58,730
generate enough sulfur to account for

238
00:12:05,660 --> 00:12:03,749

global pyrite fluxes and it's comparable

239
00:12:07,429 --> 00:12:05,670
to the flux of sulfur in from the

240
00:12:11,929 --> 00:12:07,439
hydrothermal system or actually exceeds

241
00:12:17,840 --> 00:12:11,939
that works so organic sulfur probably

242
00:12:22,670 --> 00:12:17,850
needs to be considered if you try to

243
00:12:24,319 --> 00:12:22,680
forecast the effects on the isotopic

244
00:12:27,319 --> 00:12:24,329
signatures this is Delta set of 3

245
00:12:29,030 --> 00:12:27,329
Delta's 34 depending on what you believe

246
00:12:31,429 --> 00:12:29,040
about the simulation of organic sulfur

247
00:12:33,889 --> 00:12:31,439
into the organisms it's probably false

248
00:12:39,860 --> 00:12:33,899
on the continuum between elemental

249
00:12:42,379 --> 00:12:39,870
sulfur and sulfate sulfide the microbial

250
00:12:46,429 --> 00:12:42,389
reactions would make would shift the

251
00:12:50,710 --> 00:12:46,439
result and solve pyrite to the left here

252
00:12:54,049 --> 00:12:50,720
interestingly around this area we find

253
00:12:57,670 --> 00:12:54,059
sulfides in microbial mats which again

254
00:13:05,749 --> 00:12:57,680
organic reach system with abundant

255
00:13:08,650 --> 00:13:05,759
organic sulfur I have just a few more

256
00:13:12,650 --> 00:13:08,660
minutes I want to briefly comment on

257
00:13:15,980 --> 00:13:12,660
other factors that other uncertainties

258
00:13:19,160 --> 00:13:15,990
in our interpretations we don't really

259
00:13:21,290 --> 00:13:19,170
know what happens at low concentrations

260
00:13:24,350 --> 00:13:21,300
and low concentrations and low rates are

261
00:13:27,499 --> 00:13:24,360
not the same this is a figure from a

262
00:13:29,870 --> 00:13:27,509
recent review that showed that these are

263
00:13:33,620 --> 00:13:29,880

the bars

264
00:13:35,210 --> 00:13:33,630
are the specific cell specific sulfate

265
00:13:38,240 --> 00:13:35,220
reduction rates in more than marine

266
00:13:42,140 --> 00:13:38,250
sediments these are the data points

267
00:13:46,870 --> 00:13:42,150
found in more than experiments we will

268
00:13:53,080 --> 00:13:46,880
lack data on low sulfate reduction rate

269
00:13:56,240 --> 00:13:53,090
specifics sulfate reduction rate low

270
00:13:58,460 --> 00:13:56,250
reduction rates however cell specific

271
00:14:01,340 --> 00:13:58,470
production rates are not necessarily

272
00:14:04,850 --> 00:14:01,350
associated with low concentrations below

273
00:14:06,770 --> 00:14:04,860
about 500 micro molar of sulfate sulfate

274
00:14:08,390 --> 00:14:06,780
reduction rate starts being limited by

275
00:14:10,460 --> 00:14:08,400
sulfate but organic matter is still

276
00:14:13,160 --> 00:14:10,470
important so when you look at the

277
00:14:15,380 --> 00:14:13,170
software production rates in lakes where

278
00:14:17,150 --> 00:14:15,390
concentrations of sulfate adjust tens of

279
00:14:18,620 --> 00:14:17,160
micrometer they're not that different

280
00:14:20,600 --> 00:14:18,630
from marine sediments were

281
00:14:22,370 --> 00:14:20,610
considerations of sulfate are a thousand

282
00:14:26,710 --> 00:14:22,380
times greater because they are

283
00:14:29,660 --> 00:14:26,720
controlled mostly by organic matter so

284
00:14:32,210 --> 00:14:29,670
we probably don't need to look that deep

285
00:14:37,400 --> 00:14:32,220
into marine sediments to those low cell

286
00:14:39,790 --> 00:14:37,410
specific rate and finally we have to be

287
00:14:41,960 --> 00:14:39,800
conscious of the sampling bias the

288
00:14:43,430 --> 00:14:41,970

sulfate reduction modern sediments

289
00:14:45,590 --> 00:14:43,440
happens predominantly in coastal

290
00:14:48,530 --> 00:14:45,600
sediments and coastal sediment extremely

291
00:14:50,030 --> 00:14:48,540
heterogeneous environments if we we try

292
00:14:52,130 --> 00:14:50,040
to say something about modern

293
00:14:54,050 --> 00:14:52,140
environments by looking at the more than

294
00:14:56,000 --> 00:14:54,060
Ocean at just a few locations that try

295
00:14:57,860 --> 00:14:56,010
to extrapolate to the entire planet we

296
00:14:59,720 --> 00:14:57,870
probably would have been laughed at but

297
00:15:01,340 --> 00:14:59,730
that's Excel essentially what we do for

298
00:15:03,170 --> 00:15:01,350
the early Earth for the lack of better

299
00:15:06,360 --> 00:15:03,180
alternative I think we have to be

300
00:15:09,920 --> 00:15:06,370
conscious of that I'll end here

301
00:15:28,500 --> 00:15:09,930
[Applause]

302
00:15:33,020 --> 00:15:30,600
going from you know the sulfate

303
00:15:35,820 --> 00:15:33,030
reduction pathway or disproportionation

304
00:15:38,190 --> 00:15:35,830
how is the sulfur complex to organic

305
00:15:39,480 --> 00:15:38,200
matter once it gets out of the cell but

306
00:15:41,430 --> 00:15:39,490
does that matter in terms of the

307
00:15:42,960 --> 00:15:41,440
isotopic signature fractionation or the

308
00:15:44,730 --> 00:15:42,970
way it's process in other words it can

309
00:15:47,280 --> 00:15:44,740
be bound to different types of organic

310
00:15:49,740 --> 00:15:47,290
functional groups right I think it's

311
00:15:51,780 --> 00:15:49,750
very important especially which step

312
00:15:54,330 --> 00:15:51,790
during our mineralization is a rate

313
00:15:56,280 --> 00:15:54,340

limiting we don't have that much

314
00:15:58,230 --> 00:15:56,290
information on how sulfur gets

315
00:15:59,940 --> 00:15:58,240
fractionated there are there is some

316
00:16:01,500 --> 00:15:59,950
information primarily from lab studies

317
00:16:04,980 --> 00:16:01,510
but I think that's what we need to