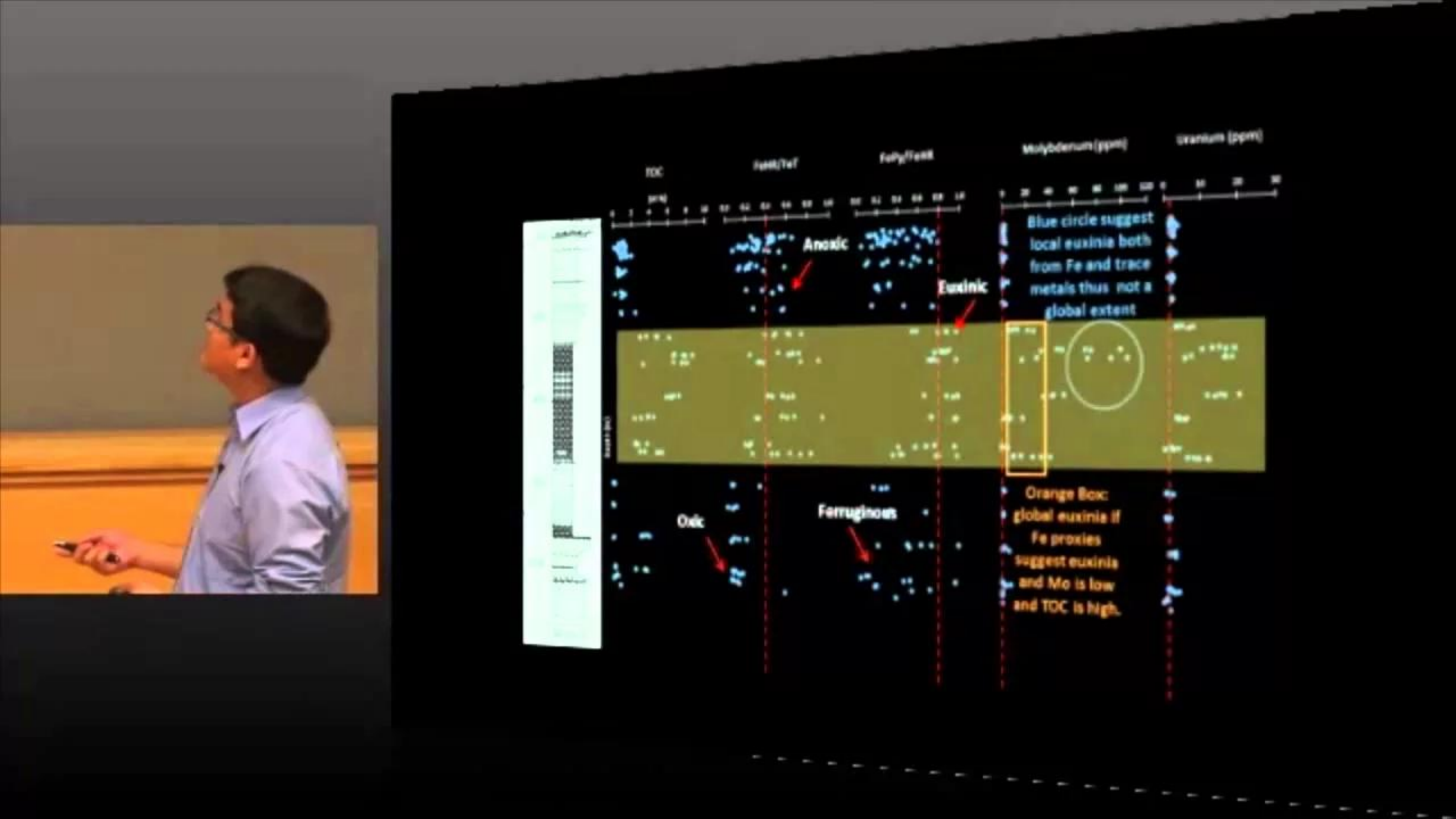
TOC
Molybdenum (ppm)
Uranium (ppm)
Anoxic
Euxinic
Blue circle suggest local euxinia both from Fe and trace metals thus not a global extent
Orange Box: global euxinia if Fe proxies suggest euxinia and Mo is low and TOC is high.
Oxic
Ferruginous

1
00:00:10,070 --> 00:00:08,790
i want to thank you lucy and all those

2
00:00:12,310 --> 00:00:10,080
who came before me you guys did a

3
00:00:14,549 --> 00:00:12,320
wonderful job of setting up my my talk

4
00:00:17,430 --> 00:00:14,559
you saved me a bunch of time and uh that

5
00:00:21,269 --> 00:00:17,440
stress on me so this is an integrated

6
00:00:22,390 --> 00:00:21,279
study between uh inorganic and organic

7
00:00:24,630 --> 00:00:22,400
proxies

8
00:00:27,429 --> 00:00:24,640
and uh i study other tim lines and

9
00:00:28,550 --> 00:00:27,439
gordon loves so biomarkers and a lot of

10
00:00:32,069 --> 00:00:28,560
proxies is what you're going to see in

11
00:00:33,910 --> 00:00:32,079
this talk so let's get started

12
00:00:36,709 --> 00:00:33,920
you're going to see

13
00:00:39,590 --> 00:00:36,719

this huge redox timeline from about 4

14
00:00:42,790 --> 00:00:39,600
billion euro 4 billion to the present

15
00:00:44,869 --> 00:00:42,800
first off the red curve you see is the

16
00:00:47,990 --> 00:00:44,879
classic uh two-step

17
00:00:51,350 --> 00:00:48,000
oxygenation event that you know the 2.4

18
00:00:53,510 --> 00:00:51,360
and around the 0.8 or so

19
00:00:55,430 --> 00:00:53,520
the blue curve is an emerging

20
00:00:57,590 --> 00:00:55,440
model that shows that right after the

21
00:01:00,950 --> 00:00:57,600
great oxidation event occurs it dips

22
00:01:01,990 --> 00:01:00,960
down to about 10 to the -3 pal

23
00:01:05,109 --> 00:01:02,000
and

24
00:01:09,670 --> 00:01:05,119
rises again until maybe about 0.9 again

25
00:01:11,270 --> 00:01:09,680
and you can find this on lions 2014.

26
00:01:13,910 --> 00:01:11,280
i want to highlight that eukaryotes

27
00:01:16,710 --> 00:01:13,920
fossils were found at around 1.9 and the

28
00:01:19,350 --> 00:01:16,720
rise of animals occurred shortly at

29
00:01:21,670 --> 00:01:19,360
around 500 million years ago

30
00:01:23,910 --> 00:01:21,680
right below that is the classic redox

31
00:01:26,070 --> 00:01:23,920
structure of the ocean for the first two

32
00:01:28,789 --> 00:01:26,080
billion years you see that it's an

33
00:01:30,710 --> 00:01:28,799
anoxic or fruitiness

34
00:01:31,910 --> 00:01:30,720
water column that has free iron in the

35
00:01:34,950 --> 00:01:31,920
ocean

36
00:01:37,030 --> 00:01:34,960
and then right below that is actual data

37
00:01:39,190 --> 00:01:37,040
collected from shales and

38
00:01:41,350 --> 00:01:39,200

why is this important is because

39
00:01:42,870 --> 00:01:41,360
life as we know it started in the ocean

40
00:01:45,670 --> 00:01:42,880
and studying what the condition of the

41
00:01:47,590 --> 00:01:45,680
ocean back then was is really key to

42
00:01:51,749 --> 00:01:47,600
unraveling the mysteries of how life

43
00:01:57,749 --> 00:01:55,990
so my study take place at around 1.5

44
00:01:58,789 --> 00:01:57,759
right after eukaryotes have already

45
00:02:03,270 --> 00:01:58,799
emerged

46
00:02:08,070 --> 00:02:05,590
so the boring billion what is it it's a

47
00:02:10,550 --> 00:02:08,080
period during earth's time during the

48
00:02:11,670 --> 00:02:10,560
mid protozoax about 1.5

49
00:02:13,510 --> 00:02:11,680
and

50
00:02:16,150 --> 00:02:13,520
it got its name from

51
00:02:17,190 --> 00:02:16,160
very little variation in the delta c13

52
00:02:19,510 --> 00:02:17,200
record

53
00:02:21,030 --> 00:02:19,520
and you just see a flat line for about a

54
00:02:23,990 --> 00:02:21,040
billion years

55
00:02:25,750 --> 00:02:24,000
and we believe that this is what

56
00:02:27,350 --> 00:02:25,760
what caused the eu carryout

57
00:02:28,710 --> 00:02:27,360
diversification to

58
00:02:30,550 --> 00:02:28,720
stagnate

59
00:02:32,710 --> 00:02:30,560
and recent studies have shown that you

60
00:02:34,550 --> 00:02:32,720
know the boring billion is is a misnomer

61
00:02:36,869 --> 00:02:34,560
it's not really that boring

62
00:02:39,030 --> 00:02:36,879
because if you guys recall there's two

63
00:02:41,750 --> 00:02:39,040

oxygenation event that flanks both sides

64
00:02:44,309 --> 00:02:41,760
of the boring billion so this implies a

65
00:02:47,030 --> 00:02:44,319
very uh unique ocean chemistry it's

66
00:02:48,229 --> 00:02:47,040
neither anoxic and ferogenous like the

67
00:02:50,229 --> 00:02:48,239
archaean

68
00:02:51,910 --> 00:02:50,239
but it's not uh fully oxygen like the

69
00:02:55,110 --> 00:02:51,920
phanerozoic either so it's somewhere in

70
00:02:59,830 --> 00:02:58,070
luckily most of my data uh and uh in

71
00:03:02,149 --> 00:02:59,840
general because lucy mentioned that

72
00:03:04,869 --> 00:03:02,159
there is various uh scarcity in the rock

73
00:03:07,030 --> 00:03:04,879
record to show where these

74
00:03:09,350 --> 00:03:07,040
oceans come from

75
00:03:12,949 --> 00:03:09,360
my record my rock record comes from the

76
00:03:15,509 --> 00:03:12,959
outreach core so thank you uh

77
00:03:17,030 --> 00:03:15,519
kira for showing what you what the core

78
00:03:18,710 --> 00:03:17,040
looks like

79
00:03:20,949 --> 00:03:18,720
and

80
00:03:21,750 --> 00:03:20,959
this site in northern australia at the

81
00:03:23,110 --> 00:03:21,760
tip

82
00:03:24,710 --> 00:03:23,120
was originally

83
00:03:27,670 --> 00:03:24,720
surveyed because there were reports of

84
00:03:29,190 --> 00:03:27,680
live oil by jackson and i'm grateful for

85
00:03:31,670 --> 00:03:29,200
that because they did some

86
00:03:33,509 --> 00:03:31,680
sedimentological studies and geochemical

87
00:03:36,470 --> 00:03:33,519
studies to show that these shales were

88
00:03:38,869 --> 00:03:36,480

marine in origin and paleo geographic

89
00:03:40,550 --> 00:03:38,879
data showed that it's a lot more

90
00:03:43,589 --> 00:03:40,560
connected to the ocean than the

91
00:03:45,030 --> 00:03:43,599
previously studied barney creek where if

92
00:03:46,710 --> 00:03:45,040
you guys read any of those papers that

93
00:03:48,949 --> 00:03:46,720
they reported green and purple sulfur

94
00:03:50,949 --> 00:03:48,959
bacteria which is an indication for

95
00:03:54,070 --> 00:03:50,959
photic zone eugenia

96
00:03:58,229 --> 00:03:54,080
so eugenia is an anoxic waters with lots

97
00:04:01,910 --> 00:04:00,149
so this will be the only data slide to

98
00:04:04,229 --> 00:04:01,920
see uh just stick with me and i'll guide

99
00:04:05,830 --> 00:04:04,239
you through it

100
00:04:08,789 --> 00:04:05,840
on the left is the strat column of my

101
00:04:10,149 --> 00:04:08,799
outreach core uh these are all shales so

102
00:04:11,670 --> 00:04:10,159
if you don't see them or they look like

103
00:04:13,270 --> 00:04:11,680
sandstone i apologize it's just

104
00:04:15,910 --> 00:04:13,280
compressed

105
00:04:18,870 --> 00:04:15,920
right away you notice that

106
00:04:21,509 --> 00:04:18,880
that they're aligned very nicely this is

107
00:04:24,150 --> 00:04:21,519
organic carbon by weight percent

108
00:04:25,270 --> 00:04:24,160
two iron proxies which is a ratio here

109
00:04:27,350 --> 00:04:25,280
and two

110
00:04:29,030 --> 00:04:27,360
trace metal proxies molybdenum and

111
00:04:31,670 --> 00:04:29,040
uranium

112
00:04:33,749 --> 00:04:31,680
overall they show a very unique pattern

113
00:04:36,629 --> 00:04:33,759

you can see that organic carbon tracks

114
00:04:38,310 --> 00:04:36,639
the iron and the metals very well

115
00:04:41,510 --> 00:04:38,320
and every time i meet up with my advisor

116
00:04:43,270 --> 00:04:41,520
he ends the talk with nice data

117
00:04:47,030 --> 00:04:43,280
which is something you know you want as

118
00:04:52,150 --> 00:04:49,189
so once organic carbon kicks in at

119
00:04:54,469 --> 00:04:52,160
around 700 meters you see that the iron

120
00:04:56,550 --> 00:04:54,479
also rises above this

121
00:04:58,950 --> 00:04:56,560
red dash line that i put in now this is

122
00:05:00,070 --> 00:04:58,960
the upper limit for a cutoff where

123
00:05:05,830 --> 00:05:00,080
oxygen

124
00:05:09,189 --> 00:05:08,150
on the left side of the dashed line is

125
00:05:10,870 --> 00:05:09,199
oxic

126
00:05:12,150 --> 00:05:10,880
and data points that lie on the other

127
00:05:15,430 --> 00:05:12,160
side is

128
00:05:17,749 --> 00:05:15,440
anoxic now these aren't hard cutoffs it

129
00:05:19,590 --> 00:05:17,759
depends on really a lot about your

130
00:05:22,150 --> 00:05:19,600
setting and you need to have context

131
00:05:24,550 --> 00:05:22,160
about your geologic

132
00:05:26,390 --> 00:05:24,560
rocks so that you know you can move the

133
00:05:28,790 --> 00:05:26,400
bar slightly left or right depending on

134
00:05:31,270 --> 00:05:28,800
your settings

135
00:05:33,270 --> 00:05:31,280
any rocks that are anoxic can also

136
00:05:35,510 --> 00:05:33,280
further tell you by the

137
00:05:37,670 --> 00:05:35,520
pyrite uh iron pyrite to the highly

138
00:05:39,909 --> 00:05:37,680

reactive that they're using so there was

139
00:05:42,390 --> 00:05:39,919
a lot of hydrogen sulfide that bound to

140
00:05:45,270 --> 00:05:42,400
these rocks showing that they were

141
00:05:48,629 --> 00:05:45,280
a zeozitic water column

142
00:05:51,189 --> 00:05:48,639
so these two alone tell you the local uh

143
00:05:53,590 --> 00:05:51,199
water redux right now what does the

144
00:05:56,550 --> 00:05:53,600
trace metal proxy tells you

145
00:05:58,230 --> 00:05:56,560
intrinsically they're also local so if

146
00:06:01,110 --> 00:05:58,240
you were to look at molybdenum you see

147
00:06:02,469 --> 00:06:01,120
that it's flat lining at crystal value

148
00:06:03,189 --> 00:06:02,479
until you hit

149
00:06:09,350 --> 00:06:03,199
the

150
00:06:10,790 --> 00:06:09,360
around 900 to 700 meters

151
00:06:14,469 --> 00:06:10,800
and then you see that it spikes all the

152
00:06:16,230 --> 00:06:14,479
way up to about 115 ppm now this is one

153
00:06:19,430 --> 00:06:16,240
of the highest recorded molybdenum

154
00:06:21,590 --> 00:06:19,440
concentrations in the mid protozoa

155
00:06:25,110 --> 00:06:21,600
so you know and if you were to read uh

156
00:06:27,189 --> 00:06:25,120
scott 2008 he would track the molybdenum

157
00:06:28,550 --> 00:06:27,199
all the way down to the mid protozoa and

158
00:06:30,309 --> 00:06:28,560
it's actually

159
00:06:32,309 --> 00:06:30,319
these concentrations were higher than

160
00:06:34,390 --> 00:06:32,319
his

161
00:06:37,430 --> 00:06:34,400
uranium also tells the same story it's

162
00:06:39,990 --> 00:06:37,440
independent uh berry is independently

163
00:06:42,230 --> 00:06:40,000

buried next to a molybdenum see

164
00:06:45,110 --> 00:06:42,240
molybdenum requires hydrogen sulfide to

165
00:06:47,350 --> 00:06:45,120
be buried whereas uranium only requires

166
00:06:49,830 --> 00:06:47,360
reducing conditions which is anoxic to

167
00:06:52,870 --> 00:06:49,840
be buried so you know that these signals

168
00:06:56,870 --> 00:06:52,880
are genuine and they're not a

169
00:06:59,029 --> 00:06:56,880
false positive by maybe they try to flux

170
00:07:01,350 --> 00:06:59,039
when you combine these trace elements

171
00:07:03,270 --> 00:07:01,360
with the iron proxy

172
00:07:04,870 --> 00:07:03,280
you can get a lot of data and even infer

173
00:07:06,550 --> 00:07:04,880
global reservoirs

174
00:07:08,950 --> 00:07:06,560
so in the orange box when you have

175
00:07:10,629 --> 00:07:08,960
molybdenum data that is very low in the

176
00:07:13,029 --> 00:07:10,639
20s to 40s

177
00:07:14,469 --> 00:07:13,039
global usania is only possible if you

178
00:07:15,670 --> 00:07:14,479
have

179
00:07:17,830 --> 00:07:15,680
iron proxies that suggest that

180
00:07:21,670 --> 00:07:17,840
molybdenum is low which is here

181
00:07:24,150 --> 00:07:21,680
and the toc is high which you see right

182
00:07:25,830 --> 00:07:24,160
and also when the iron proxies show that

183
00:07:27,830 --> 00:07:25,840
it's eugenic

184
00:07:30,070 --> 00:07:27,840
however that's not the case and we know

185
00:07:31,830 --> 00:07:30,080
that it's not globally eugenic a

186
00:07:34,230 --> 00:07:31,840
canfield ocean if you will

187
00:07:36,710 --> 00:07:34,240
because there were a lot of molybdenum

188
00:07:39,350 --> 00:07:36,720

being enriched during this time

189
00:07:41,749 --> 00:07:39,360
and it's using a cure so therefore it's

190
00:07:43,350 --> 00:07:41,759
not a global extent

191
00:07:47,110 --> 00:07:43,360
uranium on the other hand just tells you

192
00:07:50,550 --> 00:07:47,120
that yes this was both also anoxic

193
00:07:52,230 --> 00:07:50,560
so when you when you when you develop a

194
00:07:54,390 --> 00:07:52,240
paleo organic

195
00:07:55,830 --> 00:07:54,400
proxies like this you build a backdrop

196
00:07:57,830 --> 00:07:55,840
so that you can look for biomarkers a

197
00:07:59,510 --> 00:07:57,840
lot easier and this is one of the first

198
00:08:01,909 --> 00:07:59,520
integrated search

199
00:08:04,150 --> 00:08:01,919
where i combine inorganic proxies so

200
00:08:06,070 --> 00:08:04,160
that i can look for molecular biomarkers

201
00:08:07,749 --> 00:08:06,080
a lot easier

202
00:08:09,350 --> 00:08:07,759
i didn't want to bore you guys with you

203
00:08:11,510 --> 00:08:09,360
know boring chromatograms but i'll tell

204
00:08:12,390 --> 00:08:11,520
you that i targeted areas that have high

205
00:08:14,070 --> 00:08:12,400
molybdenum

206
00:08:16,469 --> 00:08:14,080
because it's an essential

207
00:08:19,029 --> 00:08:16,479
nutrient for nitrogen fixation

208
00:08:21,909 --> 00:08:19,039
and areas of high organic carbon

209
00:08:23,749 --> 00:08:21,919
just so that you know animals or fecal

210
00:08:26,469 --> 00:08:23,759
pellets were buried there or just whole

211
00:08:29,029 --> 00:08:26,479
pains

212
00:08:29,990 --> 00:08:29,039
you also want areas that are above and

213
00:08:32,230 --> 00:08:30,000

below

214
00:08:34,870 --> 00:08:32,240
the eugenic transition so that you can

215
00:08:36,389 --> 00:08:34,880
have a comparison

216
00:08:37,990 --> 00:08:36,399
this is one of the very few studies

217
00:08:39,829 --> 00:08:38,000
where if you find something it's

218
00:08:41,670 --> 00:08:39,839
fantastic news but if you don't find

219
00:08:44,230 --> 00:08:41,680
anything that's also good news too

220
00:08:45,269 --> 00:08:44,240
because it's what you predict so in this

221
00:08:48,550 --> 00:08:45,279
case

222
00:08:50,470 --> 00:08:48,560
i wasn't in a losing situation at all

223
00:08:54,389 --> 00:08:50,480
uh the bottom line was that when i went

224
00:08:56,389 --> 00:08:54,399
through all these samples about 120 i

225
00:08:59,670 --> 00:08:56,399
don't really see any detectable steering

226
00:09:00,550 --> 00:08:59,680
so steering is a cholesterol that is for

227
00:09:06,150 --> 00:09:00,560
a

228
00:09:09,509 --> 00:09:06,160
in these

229
00:09:13,910 --> 00:09:12,070
so to sum it up the evolution of the

230
00:09:15,670 --> 00:09:13,920
atmosphere in the ocean is a lot more

231
00:09:17,030 --> 00:09:15,680
complicated than originally theorized

232
00:09:18,949 --> 00:09:17,040
and that makes sense

233
00:09:21,590 --> 00:09:18,959
uh long-lived geochemical stability of

234
00:09:23,110 --> 00:09:21,600
the boring billion the flat line delta

235
00:09:25,110 --> 00:09:23,120
c13

236
00:09:26,230 --> 00:09:25,120
australia has some of the best data in

237
00:09:27,590 --> 00:09:26,240
the world