



1
00:00:00,790 --> 00:00:07,320

[Music]

2
00:00:11,210 --> 00:00:09,230

[Applause]

3
00:00:14,160 --> 00:00:11,220

I'm gonna be talking about

4
00:00:19,830 --> 00:00:14,170

micrometeorites as a new proxy for co2

5
00:00:21,570 --> 00:00:19,840

in the Archaean so we're all pretty

6
00:00:23,790 --> 00:00:21,580

familiar with co2 right just heard about

7
00:00:24,840 --> 00:00:23,800

it a little bit and on the modern

8
00:00:26,490 --> 00:00:24,850

Earth's right it's a it's a great

9
00:00:28,950 --> 00:00:26,500

greenhouse gas and even though it's just

10
00:00:32,070 --> 00:00:28,960

a small fraction of the total

11
00:00:34,200 --> 00:00:32,080

atmospheric ah mass it plays a very

12
00:00:35,610 --> 00:00:34,210

important role in controlling the

13
00:00:37,470 --> 00:00:35,620

surface temperature on the modern earth

14

00:00:39,299 --> 00:00:37,480

and of course this has been true and

15

00:00:41,069 --> 00:00:39,309

throughout history and we should a

16

00:00:43,500 --> 00:00:41,079

little bit about the Archaean right and

17

00:00:45,780 --> 00:00:43,510

that co2 levels were likely much higher

18

00:00:47,280 --> 00:00:45,790

than because the earth wasn't frozen at

19

00:00:50,069 --> 00:00:47,290

that time but in order for it to have

20

00:00:52,229 --> 00:00:50,079

this liquid surface but need more co2 to

21

00:00:55,200 --> 00:00:52,239

have that higher surface temperature but

22

00:00:56,819 --> 00:00:55,210

exactly how high yeah

23

00:00:59,130 --> 00:00:56,829

exactly how high the surface temperature

24

00:01:00,630 --> 00:00:59,140

was is something that's still debated

25

00:01:02,130 --> 00:01:00,640

and we have those sort of two schools of

26

00:01:05,490 --> 00:01:02,140

thought that we saw in the previous talk

27

00:01:07,499 --> 00:01:05,500

well we have this low temperature regime

28

00:01:11,010 --> 00:01:07,509

which for our purposes is under 40

29

00:01:12,899 --> 00:01:11,020

degrees C and of his Ibis isotopic

30

00:01:14,969 --> 00:01:12,909

evidence and phosphates to support this

31

00:01:17,010 --> 00:01:14,979

in addition you see evidence for

32

00:01:18,719 --> 00:01:17,020

glaciations potentially in the Archean

33

00:01:19,649 --> 00:01:18,729

which would support at least a

34

00:01:22,260 --> 00:01:19,659

transiently cool

35

00:01:23,940 --> 00:01:22,270

earth at that time on the other hand if

36

00:01:26,190 --> 00:01:23,950

you look at oxygen isotopes in the

37

00:01:29,160 --> 00:01:26,200

shirts you see a much warmer temperature

38

00:01:33,090 --> 00:01:29,170

between maybe 55 and 85 degrees C and

39

00:01:35,460 --> 00:01:33,100

you also see that thermal reconstruction

40

00:01:37,469 --> 00:01:35,470

a reconstruction of thermostable

41

00:01:40,890 --> 00:01:37,479

proteins and the RTM supports this

42

00:01:42,210 --> 00:01:40,900

high-temperature early Earth and there

43

00:01:43,980 --> 00:01:42,220

may be evidence for a low viscosity

44

00:01:46,020 --> 00:01:43,990

ocean at that time which would further

45

00:01:48,420 --> 00:01:46,030

bolster this high temperature claim and

46

00:01:51,749 --> 00:01:48,430

a big part of the uncertainty here is

47

00:01:54,020 --> 00:01:51,759

how much co2 was available at this time

48

00:01:56,219 --> 00:01:54,030

on the early Earth to one the surface

49

00:01:57,960 --> 00:01:56,229

and of course when we care about this

50

00:01:59,280 --> 00:01:57,970

because this is when the first evidence

51
00:02:00,569 --> 00:01:59,290
for life is showing up so we'd really

52
00:02:02,640 --> 00:02:00,579
like to know what these surface

53
00:02:04,170 --> 00:02:02,650
conditions were like and how much co2

54
00:02:06,569 --> 00:02:04,180
was there it can help answer that

55
00:02:09,240 --> 00:02:06,579
question of course constraints on co2

56
00:02:11,610 --> 00:02:09,250
aren't great for the RTN and if we look

57
00:02:13,590 --> 00:02:11,620
at the proxy data we see that we have on

58
00:02:16,050 --> 00:02:13,600
the low end about 10 to the minus 3 bar

59
00:02:18,569 --> 00:02:16,060
and on the upper end close to 1 bar is

60
00:02:19,620 --> 00:02:18,579
our estimates as we go back in time so

61
00:02:21,659 --> 00:02:19,630
we have almost three orders of magnitude

62
00:02:22,590 --> 00:02:21,669
between our upper and lower bounds on

63
00:02:25,080 --> 00:02:22,600

co2

64

00:02:27,060 --> 00:02:25,090

and models should see this nice model

65

00:02:30,120 --> 00:02:27,070

here from Chris Hansen ton has made his

66

00:02:31,710 --> 00:02:30,130

way into all the talks so far you see

67

00:02:33,480 --> 00:02:31,720

this nice model prediction for them with

68

00:02:36,150 --> 00:02:33,490

their model mean and the black curve

69

00:02:37,800 --> 00:02:36,160

here and so co2 is increasing with time

70

00:02:39,990 --> 00:02:37,810

and then the uncertainty of their model

71

00:02:42,030 --> 00:02:40,000

is shown by the gray shaded region so

72

00:02:43,110 --> 00:02:42,040

with both models and the proxy data you

73

00:02:45,960 --> 00:02:43,120

see here there's a great deal of

74

00:02:47,670 --> 00:02:45,970

uncertainty now fortunately this is

75

00:02:49,230 --> 00:02:47,680

where micrometeorites might be able to

76

00:02:50,370 --> 00:02:49,240

help us and so that's what you're

77

00:02:52,170 --> 00:02:50,380

looking at here these are for

78

00:02:54,840 --> 00:02:52,180

micrometeorites that were extracted from

79

00:02:56,820 --> 00:02:54,850

a 2.7 billion year old limestone from

80

00:02:58,770 --> 00:02:56,830

australia and if you're not familiar

81

00:03:01,950 --> 00:02:58,780

with micrometeorites they're essentially

82

00:03:03,510 --> 00:03:01,960

just sand sized space dust that falls to

83

00:03:04,650 --> 00:03:03,520

earth quite often on the modern earth

84

00:03:06,900 --> 00:03:04,660

and probably has throughout Earth's

85

00:03:09,060 --> 00:03:06,910

history and in particular when I say

86

00:03:11,040 --> 00:03:09,070

micrometeorites in this talk I mean iron

87

00:03:12,360 --> 00:03:11,050

rich micro meteorites so a special type

88

00:03:14,460 --> 00:03:12,370

and that's what you're looking at here

89

00:03:17,220 --> 00:03:14,470

and the reason we care that the

90

00:03:19,140 --> 00:03:17,230

therapies iron rich particles is if you

91

00:03:20,580 --> 00:03:19,150

take metallic iron and you put it into

92

00:03:22,920 --> 00:03:20,590

the atmosphere very rapidly it will melt

93

00:03:25,350 --> 00:03:22,930

and when you have molten iron with an

94

00:03:27,390 --> 00:03:25,360

atmosphere of like co2 rich or oxygen

95

00:03:30,150 --> 00:03:27,400

rich oxidized and that's what we're

96

00:03:31,770 --> 00:03:30,160

interested in and in addition as you can

97

00:03:34,320 --> 00:03:31,780

see from the beautiful preservation of

98

00:03:36,390 --> 00:03:34,330

all four of these there are 2.7 billion

99

00:03:39,240 --> 00:03:36,400

years old clearly these iron rich micro

100

00:03:42,150 --> 00:03:39,250

meteorites are able to stand the test of

101
00:03:45,630 --> 00:03:42,160
time and show up quite nicely even on

102
00:03:47,580 --> 00:03:45,640
the earth today so if you were to look

103
00:03:48,780 --> 00:03:47,590
at these 2.7 billion year old micro

104
00:03:50,460 --> 00:03:48,790
meteorites you would see that they were

105
00:03:52,590 --> 00:03:50,470
highly oxidized so they contain

106
00:03:53,970 --> 00:03:52,600
magnetite and moose tight and they

107
00:03:55,710 --> 00:03:53,980
actually looked remarkably similar to

108
00:03:57,810 --> 00:03:55,720
modern micro meteorites in terms of the

109
00:03:59,610 --> 00:03:57,820
amount of oxidized iron in them and so

110
00:04:02,280 --> 00:03:59,620
this has led to speculation that the

111
00:04:04,710 --> 00:04:02,290
Archaean earth had an oxygen-rich upper

112
00:04:06,450 --> 00:04:04,720
atmosphere to explain the presence of

113
00:04:10,290 --> 00:04:06,460

most it--and magnetite

114

00:04:12,570 --> 00:04:10,300

these oxidized iron species but if we

115

00:04:15,000 --> 00:04:12,580

look at oxygen through time on the earth

116

00:04:17,310 --> 00:04:15,010

as we see here at present earth and we

117

00:04:20,130 --> 00:04:17,320

go back in time these micro meteorites

118

00:04:21,900 --> 00:04:20,140

preserved right around here where the

119

00:04:24,300 --> 00:04:21,910

total oxygen and the Earth's atmosphere

120

00:04:28,140 --> 00:04:24,310

was quite low and surface proxies

121

00:04:30,390 --> 00:04:28,150

constrain the atmospheric oxygen to

122

00:04:31,650 --> 00:04:30,400

below about one part per million so

123

00:04:33,110 --> 00:04:31,660

basically a trace gas that's

124

00:04:35,600 --> 00:04:33,120

non-existent in the atmosphere

125

00:04:39,200 --> 00:04:35,610

and even proxies for the atmosphere at

126

00:04:41,240 --> 00:04:39,210

altitude constrain it to a fairly minor

127

00:04:42,500 --> 00:04:41,250

component at best and this is an upper

128

00:04:45,379 --> 00:04:42,510

bound in the upper atmosphere of you

129

00:04:46,820 --> 00:04:45,389

know a fraction of a percent and if we

130

00:04:49,310 --> 00:04:46,830

take that with our understanding of

131

00:04:50,780 --> 00:04:49,320

atmospheric mixing it seems perhaps

132

00:04:52,490 --> 00:04:50,790

unlikely that we could have had modern

133

00:04:53,960 --> 00:04:52,500

levels of oxygen so an oxygen level up

134

00:04:56,120 --> 00:04:53,970

here and the upper atmosphere and

135

00:04:59,210 --> 00:04:56,130

nothing at the surface in the Archaean

136

00:05:00,980 --> 00:04:59,220

to oxidize these micrometeorites so

137

00:05:03,020 --> 00:05:00,990

that's sort of why we started with this

138

00:05:06,200 --> 00:05:03,030

work is if oxygen seems perhaps unlikely

139

00:05:08,000 --> 00:05:06,210

then co2 is maybe a better choice to

140

00:05:11,120 --> 00:05:08,010

oxidize these micrometeorites on the

141

00:05:13,340 --> 00:05:11,130

early Earth and so that's what we wanted

142

00:05:15,020 --> 00:05:13,350

to look at can we build a model where if

143

00:05:16,879 --> 00:05:15,030

we take a micrometer and these are

144

00:05:17,990 --> 00:05:16,889

examples of modern micro meteorites can

145

00:05:19,850 --> 00:05:18,000

we take one of these and can we measure

146

00:05:22,879 --> 00:05:19,860

the fraction of metallic iron which you

147

00:05:24,500 --> 00:05:22,889

see here in the white region and the

148

00:05:26,810 --> 00:05:24,510

oxidized region here is shown in gray

149

00:05:28,340 --> 00:05:26,820

can we measure that and then back out

150

00:05:30,230 --> 00:05:28,350

what the oxidizing power of the

151
00:05:32,150 --> 00:05:30,240
atmosphere was that these particles

152
00:05:33,529 --> 00:05:32,160
entered in I just want you to make a

153
00:05:34,820 --> 00:05:33,539
mental note of what these look like cuz

154
00:05:37,339 --> 00:05:34,830
you're gonna see a model simulation a

155
00:05:38,570 --> 00:05:37,349
moment we're gonna reproduce micro

156
00:05:39,980 --> 00:05:38,580
meteorites that look just like this in

157
00:05:41,990 --> 00:05:39,990
cross-section where you see an

158
00:05:45,110 --> 00:05:42,000
unoxidized metallic bead in the center

159
00:05:46,370 --> 00:05:45,120
and then an oxidized rim around it so of

160
00:05:49,550 --> 00:05:46,380
course we started with the modern

161
00:05:51,050 --> 00:05:49,560
atmosphere so we have no an atmospheric

162
00:05:52,580 --> 00:05:51,060
composition and we can collect modern

163
00:05:54,469 --> 00:05:52,590

micro meteorites like you just saw and

164

00:05:56,390 --> 00:05:54,479

then we can try and back out the

165

00:05:58,219 --> 00:05:56,400

atmospheric composition and so our model

166

00:06:00,080 --> 00:05:58,229

starts out with the assumption that we

167

00:06:02,600 --> 00:06:00,090

have a pure iron micro meter at the top

168

00:06:04,490 --> 00:06:02,610

of the atmosphere and then we pick

169

00:06:07,430 --> 00:06:04,500

radius for that particle we pick a

170

00:06:08,990 --> 00:06:07,440

velocity and an entry angle and then we

171

00:06:11,270 --> 00:06:09,000

drop it into the atmosphere essentially

172

00:06:13,820 --> 00:06:11,280

and see what happens and so we start

173

00:06:15,589 --> 00:06:13,830

with this very fun animation at 180

174

00:06:17,920 --> 00:06:15,599

kilometers above the Earth's surface and

175

00:06:19,790 --> 00:06:17,930

there's our beautiful particle and

176
00:06:20,779 --> 00:06:19,800
before I run the simulation I want to

177
00:06:22,129 --> 00:06:20,789
point out some of the parameters that

178
00:06:24,469 --> 00:06:22,139
were in a track that happens pretty fast

179
00:06:27,680 --> 00:06:24,479
so we're gonna be looking at the

180
00:06:29,029 --> 00:06:27,690
particle temperature the velocity and

181
00:06:31,400 --> 00:06:29,039
it's starting at about 12 kilometers a

182
00:06:33,560 --> 00:06:31,410
second so it's going really fast this is

183
00:06:35,689 --> 00:06:33,570
about a 50 micron and radius particle

184
00:06:37,219 --> 00:06:35,699
and its iron fraction is that a hundred

185
00:06:38,810 --> 00:06:37,229
percent by assumption right we're

186
00:06:40,640 --> 00:06:38,820
starting out with a pure iron particle

187
00:06:42,740 --> 00:06:40,650
and then we're also tracking the

188
00:06:44,240 --> 00:06:42,750

altitude and so the the kernel right

189

00:06:47,000 --> 00:06:44,250

here this is the cross-sectional area

190

00:06:49,280 --> 00:06:47,010

and so you'll notice that it's all

191

00:06:50,180 --> 00:06:49,290

dark gray which is matching the metallic

192

00:06:52,490 --> 00:06:50,190

iron so this is showing you the

193

00:06:53,720 --> 00:06:52,500

composition is currently 100% metallic

194

00:06:56,210 --> 00:06:53,730

iron and as we run this forward you're

195

00:06:58,070 --> 00:06:56,220

gonna see this shrink down to that

196

00:06:59,870 --> 00:06:58,080

central bead similar to what you saw

197

00:07:02,990 --> 00:06:59,880

for those modern micro meteorites and

198

00:07:06,650 --> 00:07:03,000

you'll see an oxidized exterior form ice

199

00:07:08,000 --> 00:07:06,660

will run it forward and so you'll watch

200

00:07:09,350 --> 00:07:08,010

that the temperature is is pretty

201
00:07:10,400 --> 00:07:09,360
minimal and it's gonna climb really fast

202
00:07:13,490 --> 00:07:10,410
and you'll see this particle get

203
00:07:15,500 --> 00:07:13,500
white-hot and melt as it exceeds 2,000

204
00:07:17,810 --> 00:07:15,510
degrees Kelvin and warms up and then if

205
00:07:20,270 --> 00:07:17,820
you watch you can see the cross-section

206
00:07:21,530 --> 00:07:20,280
shrinks and we end up at the end of our

207
00:07:22,010 --> 00:07:21,540
simulation with a particle that looks

208
00:07:23,480 --> 00:07:22,020
like this

209
00:07:25,240 --> 00:07:23,490
so you're seeing this essentially

210
00:07:27,440 --> 00:07:25,250
running in real time here where we have

211
00:07:30,350 --> 00:07:27,450
15 or so seconds from start to finish

212
00:07:32,090 --> 00:07:30,360
and the particle is only molten during

213
00:07:34,010 --> 00:07:32,100

these orange portions of the curve here

214

00:07:36,500 --> 00:07:34,020

so just a few seconds or you go from

215

00:07:38,150 --> 00:07:36,510

your iron particle and you very rapidly

216

00:07:39,530 --> 00:07:38,160

melt and you produce something that

217

00:07:42,860 --> 00:07:39,540

looks like this as you oxidize the

218

00:07:45,770 --> 00:07:42,870

exterior so we did this for the modern

219

00:07:47,990 --> 00:07:45,780

atmosphere and we essentially recorded

220

00:07:49,850 --> 00:07:48,000

this cross-section right here for each

221

00:07:53,830 --> 00:07:49,860

of our particles and then we took that

222

00:07:56,630 --> 00:07:53,840

and we bend it horizontal axis here

223

00:07:57,890 --> 00:07:56,640

based on that you know the size of that

224

00:07:58,820 --> 00:07:57,900

iron bead in the center right the

225

00:08:00,680 --> 00:07:58,830

fraction of the area of the

226

00:08:02,600 --> 00:08:00,690

cross-section particle that was this

227

00:08:03,890 --> 00:08:02,610

metallic iron and when you do that from

228

00:08:06,290 --> 00:08:03,900

the modern earth we generated a

229

00:08:08,600 --> 00:08:06,300

histogram in blue right here so 500

230

00:08:10,820 --> 00:08:08,610

randomly generated particles and we see

231

00:08:12,890 --> 00:08:10,830

that if we took the average cross

232

00:08:14,780 --> 00:08:12,900

sectional area we get around 2.3 which

233

00:08:16,760 --> 00:08:14,790

was that iron bead in terms of area and

234

00:08:18,200 --> 00:08:16,770

then we can compare that to modern

235

00:08:19,790 --> 00:08:18,210

micrometeorite data which was shown in

236

00:08:20,930 --> 00:08:19,800

orange collected from Antarctica and

237

00:08:23,060 --> 00:08:20,940

you'll see that we do a pretty good job

238

00:08:25,730 --> 00:08:23,070

of reproducing the distribution and the

239

00:08:28,100 --> 00:08:25,740

mean of our model and the data mean vary

240

00:08:29,660 --> 00:08:28,110

quite nicely so the next step in was

241

00:08:31,460 --> 00:08:29,670

right to apply this to the Archean and

242

00:08:33,350 --> 00:08:31,470

so that's what you see here and this is

243

00:08:35,240 --> 00:08:33,360

the main result from our model or once

244

00:08:37,190 --> 00:08:35,250

again you're looking at that fractional

245

00:08:39,200 --> 00:08:37,200

area of the micrometeorite and this

246

00:08:42,800 --> 00:08:39,210

black curve here is showing you right

247

00:08:45,080 --> 00:08:42,810

that fe fractional area means so you

248

00:08:46,940 --> 00:08:45,090

know up here low co2 which is the

249

00:08:49,520 --> 00:08:46,950

increasing on the horizontal axis so as

250

00:08:52,010 --> 00:08:49,530

you increase co2 concentrations you see

251

00:08:53,420 --> 00:08:52,020

this monotonic decrease in that fe

252

00:08:55,640 --> 00:08:53,430

fractional area that you would expect to

253

00:08:56,720 --> 00:08:55,650

find and collected micrometeorites and

254

00:08:58,250 --> 00:08:56,730

this is pretty exciting right because

255

00:08:59,660 --> 00:08:58,260

you could go out and find a couple of

256

00:09:00,950 --> 00:08:59,670

micro meteorites you section them and

257

00:09:03,440 --> 00:09:00,960

you measure that Fe

258

00:09:04,490 --> 00:09:03,450

area in your section micrometeorites you

259

00:09:05,930 --> 00:09:04,500

find the mean and then you basically

260

00:09:07,910 --> 00:09:05,940

just come over to the line you can drop

261

00:09:09,920 --> 00:09:07,920

down and back out the co2 concentration

262

00:09:12,889 --> 00:09:09,930

of the atmosphere at that time and

263

00:09:14,329 --> 00:09:12,899

that's exactly what we did with the 2.7

264

00:09:16,610 --> 00:09:14,339

billion year old micrometeorites which

265

00:09:18,079 --> 00:09:16,620

is shown by this orange dot here you

266

00:09:21,889 --> 00:09:18,089

come down right we just went over and so

267

00:09:22,970 --> 00:09:21,899

you find you know it's about 64% co2 the

268

00:09:24,139 --> 00:09:22,980

arrow bars are quite bad on this

269

00:09:24,560 --> 00:09:24,149

measurement and I'll get to that in a

270

00:09:25,970 --> 00:09:24,570

moment

271

00:09:28,250 --> 00:09:25,980

but there's one of the things that I

272

00:09:30,230 --> 00:09:28,260

want to point out here which is this -

273

00:09:32,900 --> 00:09:30,240

blue curve along the bottom here that

274

00:09:35,480 --> 00:09:32,910

starts to come off zero at around 70%

275

00:09:36,680 --> 00:09:35,490

and that line is showing you the

276

00:09:38,210 --> 00:09:36,690

fraction of my communities that were

277

00:09:40,100 --> 00:09:38,220

fully oxidized so if you think back to

278

00:09:42,110 --> 00:09:40,110

the simulation where we had that iron

279

00:09:44,510 --> 00:09:42,120

bead in the centre shrinking well if you

280

00:09:45,740 --> 00:09:44,520

encounter enough oxidant then you can

281

00:09:47,389 --> 00:09:45,750

actually oxidize the micrometer right

282

00:09:49,340 --> 00:09:47,399

all the way through and in our model

283

00:09:51,410 --> 00:09:49,350

that happens the red around 70 percent

284

00:09:55,160 --> 00:09:51,420

higher in terms of co2 you start seeing

285

00:09:56,840 --> 00:09:55,170

these fully oxidized particles so what

286

00:10:00,110 --> 00:09:56,850

does that tell us about co2 in the

287

00:10:01,850 --> 00:10:00,120

Archaean well the reason that the error

288

00:10:04,010 --> 00:10:01,860

bars are so bad on that that orange dot

289

00:10:06,380 --> 00:10:04,020

that you see here is that we only have

290

00:10:08,120 --> 00:10:06,390

two measurements from the Archaean data

291

00:10:09,470 --> 00:10:08,130

to constrain that point so we have

292

00:10:10,760 --> 00:10:09,480

really big uncertainties on that but

293

00:10:12,040 --> 00:10:10,770

this is something that could be easily

294

00:10:15,079 --> 00:10:12,050

addressed by collecting additional

295

00:10:17,329 --> 00:10:15,089

micrometeorites unfortunately there were

296

00:10:20,600 --> 00:10:17,339

fully oxidized micrometeorites in the

297

00:10:22,460 --> 00:10:20,610

2.7 billion year old samples and so we

298

00:10:24,440 --> 00:10:22,470

can get a tentative lower bound on co₂

299

00:10:27,560 --> 00:10:24,450

in the Archaean of about 70 percent of

300

00:10:28,940 --> 00:10:27,570

the atmosphere by volume based on the

301
00:10:35,600 --> 00:10:28,950
presence of those fully oxidized

302
00:10:36,890 --> 00:10:35,610
micrometeorites and I put some some nice

303
00:10:38,840 --> 00:10:36,900
and OGIS here to say that one is not

304
00:10:43,070 --> 00:10:38,850
great I'm gonna get the green smiley

305
00:10:45,440 --> 00:10:43,080
that one is pretty cool right so these

306
00:10:47,090 --> 00:10:45,450
improved co2 constraints are really

307
00:10:48,740 --> 00:10:47,100
important for the Archaean earth we can

308
00:10:51,110 --> 00:10:48,750
not only potentially address the

309
00:10:53,690 --> 00:10:51,120
temperature question for the Archaean so

310
00:10:56,810 --> 00:10:53,700
if we took our sort of 70% atmospheric

311
00:10:58,819 --> 00:10:56,820
co2 estimate and if we assume a paleo

312
00:11:00,980 --> 00:10:58,829
pressure of about 0.5 bar and the

313
00:11:02,840 --> 00:11:00,990

Archaean then with a very simple climate

314

00:11:05,000 --> 00:11:02,850

model we can estimate about 30 degrees

315

00:11:08,360 --> 00:11:05,010

Celsius for the surface temperature as a

316

00:11:09,740 --> 00:11:08,370

potential upper limit there but these

317

00:11:11,949 --> 00:11:09,750

improved constraints can also help

318

00:11:14,240 --> 00:11:11,959

inform our understanding of exoplanets

319

00:11:16,940 --> 00:11:14,250

if you think of the earth as an analogue

320

00:11:18,830 --> 00:11:16,950

sort of a different habitable world and

321

00:11:20,750 --> 00:11:18,840

in addition I think this is when life

322

00:11:23,000 --> 00:11:20,760

the evidence for life first appears on

323

00:11:24,470 --> 00:11:23,010

earth is during this time and the co2

324

00:11:25,790 --> 00:11:24,480

concentration of the atmosphere plays a

325

00:11:28,070 --> 00:11:25,800

really important role in controlling

326

00:11:30,740 --> 00:11:28,080

surface temperature and the pH of the

327

00:11:32,950 --> 00:11:30,750

ocean which we really like to know for

328

00:11:36,620 --> 00:11:32,960

its period of Earth's history

329

00:11:37,820 --> 00:11:36,630

so from this model right we see that we

330

00:11:40,040 --> 00:11:37,830

could potentially get much better

331

00:11:41,990 --> 00:11:40,050

constraints on our k_i and co_2 if we go

332

00:11:43,880 --> 00:11:42,000

and collect more micrometeorites and in

333

00:11:45,860 --> 00:11:43,890

addition this same technique could

334

00:11:48,200 --> 00:11:45,870

actually be applied potentially for the

335

00:11:50,270 --> 00:11:48,210

Proterozoic where co_2 may remain the

336

00:11:51,980 --> 00:11:50,280

main oxidant at altitude and so these

337

00:11:54,050 --> 00:11:51,990

micrometeorite oxidations could still be

338

00:11:55,820 --> 00:11:54,060

sensitive to total co2 concentration in

339

00:11:58,370 --> 00:11:55,830

the atmosphere and be able to provide

340

00:12:00,290 --> 00:11:58,380

insight there but for all this work we

341

00:12:01,940 --> 00:12:00,300

need more micrometeorites so we need

342

00:12:08,710 --> 00:12:01,950

people to go collect them and measure

343

00:12:15,920 --> 00:12:13,730

Thank You Owen we'll take questions yeah

344

00:12:18,290 --> 00:12:15,930

I think this is the currying at about

345

00:12:21,050 --> 00:12:18,300

100 kilometers yes so these are melting

346

00:12:22,250 --> 00:12:21,060

between about 70 and 90 in the modern

347

00:12:24,800 --> 00:12:22,260

Earth's atmosphere now I've been told

348

00:12:26,270 --> 00:12:24,810

that under the troposphere you have

349

00:12:28,160 --> 00:12:26,280

mixing of the gases but as you get

350

00:12:30,800 --> 00:12:28,170

further up if you get some segregation

351

00:12:31,820 --> 00:12:30,810

density and co2 is rather heavy so I

352

00:12:33,320 --> 00:12:31,830

would have thought that there was some

353

00:12:34,970 --> 00:12:33,330

type of gradient in the co2

354

00:12:37,910 --> 00:12:34,980

concentrations as a function of height

355

00:12:40,940 --> 00:12:37,920

when you get to those altitudes the

356

00:12:43,460 --> 00:12:40,950

other problem I have is you said half a

357

00:12:45,290 --> 00:12:43,470

bar presumably there that's quite a

358

00:12:47,210 --> 00:12:45,300

there's an uncertainty on that it could

359

00:12:48,650 --> 00:12:47,220

be I don't know two bar of ten bar I'm

360

00:12:50,450 --> 00:12:48,660

not sure how large it is I'll have to

361

00:12:53,270 --> 00:12:50,460

ask somebody else but that also

362

00:12:55,700 --> 00:12:53,280

increases the air bars I suppose on your

363

00:12:57,620 --> 00:12:55,710

death yes so both those great points so

364

00:12:59,329 --> 00:12:57,630

to address the question of mixing first

365

00:13:01,010 --> 00:12:59,339

and so on the modern earth right even

366

00:13:02,900 --> 00:13:01,020

though the purpose was the troposphere

367

00:13:05,180 --> 00:13:02,910

is where you have turbulent mixing oh

368

00:13:07,130 --> 00:13:05,190

sorry you have connected mixing so it's

369

00:13:08,690 --> 00:13:07,140

very rapidly mixed you still have mixing

370

00:13:09,920 --> 00:13:08,700

up to about a hundred kilometers which

371

00:13:11,600 --> 00:13:09,930

is the homo Paz region and the

372

00:13:13,340 --> 00:13:11,610

atmosphere remains well mixed below that

373

00:13:15,440 --> 00:13:13,350

due to turbulent mixing of breaking

374

00:13:17,510 --> 00:13:15,450

gravity waves so you get that from

375

00:13:19,190 --> 00:13:17,520

airflow versus a topography or from jets

376

00:13:21,290 --> 00:13:19,200

in the atmosphere and that would occur

377

00:13:22,430 --> 00:13:21,300

throughout Earth's history so even in

378

00:13:24,199 --> 00:13:22,440

the our team we would expect the same

379

00:13:27,400 --> 00:13:24,209

thing so these are melting at a pressure

380

00:13:28,749 --> 00:13:27,410

below that well mixed height so it

381

00:13:30,100 --> 00:13:28,759

the atmosphere should be well mixed up

382

00:13:31,990 --> 00:13:30,110

to the altitude where these are melting

383

00:13:34,720 --> 00:13:32,000

regardless of how much co2 is in the

384

00:13:36,790 --> 00:13:34,730

atmosphere and then to address the

385

00:13:38,379 --> 00:13:36,800

second point of the total pressure of

386

00:13:40,360 --> 00:13:38,389

the atmosphere that is a great point to

387

00:13:41,980 --> 00:13:40,370

bring up and so this technique is not

388

00:13:43,150 --> 00:13:41,990

sensitive to the total pressure of the

389

00:13:44,679 --> 00:13:43,160

atmosphere because it's it's only

390

00:13:47,499 --> 00:13:44,689

sampling the upper atmosphere

391

00:13:50,079 --> 00:13:47,509

essentially and so if you had you know

392

00:13:51,490 --> 00:13:50,089

1/2 bar atmosphere then the altitude the

393

00:13:53,699 --> 00:13:51,500

altitude at which the micrometeoroids

394

00:13:56,319 --> 00:13:53,709

melt would shift closer to the surface

395

00:13:57,850 --> 00:13:56,329

but the overall reaction that's

396

00:13:59,019 --> 00:13:57,860

occurring would be identical and the

397

00:14:00,369 --> 00:13:59,029

same is true if you're putting on a 10

398

00:14:01,900 --> 00:14:00,379

bar atmosphere then they would be

399

00:14:04,509 --> 00:14:01,910

melting at a higher altitude with the

400

00:14:06,100 --> 00:14:04,519

same pressures and so you know we can't

401
00:14:07,449 --> 00:14:06,110
constrain the total surface pressure so

402
00:14:09,249 --> 00:14:07,459
you need an alternative method to

403
00:14:10,869 --> 00:14:09,259
constrain total pressure and then this

404
00:14:12,490 --> 00:14:10,879
can give you the fraction of the

405
00:14:15,579 --> 00:14:12,500
atmosphere that's co2 I would have

406
00:14:19,480 --> 00:14:15,589
thought that when you change the ball

407
00:14:23,889 --> 00:14:19,490
pressure you it's true that you have you

408
00:14:25,990 --> 00:14:23,899
guess oxidized you could oxidize a

409
00:14:27,160 --> 00:14:26,000
larger when you're higher it could be a

410
00:14:28,240 --> 00:14:27,170
longer time for example you should have

411
00:14:30,220 --> 00:14:28,250
certain periods that it's only molten

412
00:14:32,650 --> 00:14:30,230
for about 2 or 3 seconds doesn't that

413
00:14:34,240 --> 00:14:32,660

number depend on how high you are which

414

00:14:36,040 --> 00:14:34,250

would then depend on the pressure and so

415

00:14:37,329 --> 00:14:36,050

just described yes so we actually we did

416

00:14:38,860 --> 00:14:37,339

test in the mall and it's a very minor

417

00:14:41,170 --> 00:14:38,870

effect really the only difference is for

418

00:14:42,309 --> 00:14:41,180

the gravity term with scaling so you

419

00:14:44,139 --> 00:14:42,319

know off the top of my head I don't know

420

00:14:46,030 --> 00:14:44,149

it's actually where the corresponding

421

00:14:47,800 --> 00:14:46,040

level 10 bar atmosphere would be but

422

00:14:50,319 --> 00:14:47,810

presumably it's not a huge difference in

423

00:14:51,639 --> 00:14:50,329

total altitude and so we didn't look at

424

00:14:53,710 --> 00:14:51,649

a 10 bar we looked at actually just

425

00:14:54,670 --> 00:14:53,720

decreasing pressure on that effect but

426

00:15:01,929 --> 00:14:54,680

it's definitely something that could be

427

00:15:03,879 --> 00:15:01,939

considered so rather naive question in

428

00:15:06,160 --> 00:15:03,889

your physical samples the iron core

429

00:15:08,379 --> 00:15:06,170

that's left over seems to be shifted in

430

00:15:09,879 --> 00:15:08,389

one direction do you think that there's

431

00:15:13,329 --> 00:15:09,889

a possibility that some of these could

432

00:15:15,129 --> 00:15:13,339

just fully segregate the remaining solid

433

00:15:16,629 --> 00:15:15,139

core from the molten portion and that's

434

00:15:19,210 --> 00:15:16,639

actually what you're seeing in some of

435

00:15:20,740 --> 00:15:19,220

these fully oxidized samples yes so that

436

00:15:22,329 --> 00:15:20,750

is definitely a possibility that the

437

00:15:24,939 --> 00:15:22,339

sort of more dense iron bead could

438

00:15:27,579 --> 00:15:24,949

separate from the mic from meteorite and

439

00:15:29,199 --> 00:15:27,589

so again Jackie has a number of papers

440

00:15:31,150 --> 00:15:29,209

on that where he speculates that that

441

00:15:32,769 --> 00:15:31,160

isn't likely so they don't think that

442

00:15:33,970 --> 00:15:32,779

that's occurred because you don't see

443

00:15:35,049 --> 00:15:33,980

that often when you're looking at Mike

444

00:15:37,150 --> 00:15:35,059

from meteorite so you don't see ones

445

00:15:38,199 --> 00:15:37,160

that are sort of partially separated and

446

00:15:40,090 --> 00:15:38,209

you would expect me when it separates

447

00:15:40,840 --> 00:15:40,100

that the central bead would maybe split

448

00:15:43,809 --> 00:15:40,850

and so you don't know

449

00:15:45,129 --> 00:15:43,819

with other other features I'm not super

450

00:15:47,439 --> 00:15:45,139

confident on that but I do believe that

451
00:15:49,449 --> 00:15:47,449
that has been somewhat addressed but it

452
00:15:51,189 --> 00:15:49,459
is definitely a concern that you could

453
00:15:53,019 --> 00:15:51,199
have you out of the beat separate so

454
00:15:54,280 --> 00:15:53,029
actually that's why in our model we

455
00:15:55,689 --> 00:15:54,290
don't consider fully oxidized

456
00:15:57,519 --> 00:15:55,699
micrometers we're only looking at ones

457
00:15:58,480 --> 00:15:57,529
that still have the metallic bead so

458
00:16:00,340 --> 00:15:58,490
that way we can be certain that we're

459
00:16:02,170 --> 00:16:00,350
looking at well as certain as we can be

460
00:16:03,879 --> 00:16:02,180
right that we're looking at partially