Perchlorates: Eutectic Temperatures

Sodium Perchlorate:
- Anhydrous $NaClO_4$. T_E = 180 K
- $NaClO_4 \cdot H_2O$. T_E = 230 K
- $NaClO_4 \cdot 2H_2O$. T_E = 236 K

Magnesium Perchlorate:
- $Mg(ClO_4)_2 \cdot 5H_2O$. T_E = 190 K
- $Mg(ClO_4)_2 \cdot 6H_2O$. T_E = 206 K

Calcium Perchlorate:
- Anhydrous $Ca(ClO_4)_2$. T_E = ??? K
- $Ca(ClO_4)_2 \cdot 4H_2O$. T_E = 170 K
- $Ca(ClO_4)_2 \cdot 6H_2O$. T_E = 199 K
- $Ca(ClO_4)_2 \cdot 8H_2O$. T_E = 220 K

1
00:00:10,840 --> 00:00:08,920
so this is going to be a big shift from

2
00:00:12,870 --> 00:00:10,850
the previous talks I don't have any

3
00:00:16,179 --> 00:00:12,880
pretty pictures of exoplanets or

4
00:00:19,420 --> 00:00:16,189
meteorites I have black text on a white

5
00:00:20,980 --> 00:00:19,430
background so prepare to be bored I'm

6
00:00:23,800 --> 00:00:20,990
going to talk about some of the work I'm

7
00:00:25,840 --> 00:00:23,810
doing right now and this is still

8
00:00:28,570 --> 00:00:25,850
incomplete but sort of precursor to what

9
00:00:30,730 --> 00:00:28,580
we're doing and how this plays into the

10
00:00:33,060 --> 00:00:30,740
greater astrobiology astrobiology

11
00:00:35,439 --> 00:00:33,070
community and what we're trying to do is

12
00:00:36,850 --> 00:00:35,449
build an environmental chamber that can

13
00:00:39,190 --> 00:00:36,860

simulate the temperature pressure and

14
00:00:42,280 --> 00:00:39,200
humidity of Mars and conduct laboratory

15
00:00:44,920 --> 00:00:42,290
experiments to see under what conditions

16
00:00:47,830 --> 00:00:44,930
Brian's form particularly brines with

17
00:00:49,840 --> 00:00:47,840
salts like sodium magnesium or calcium

18
00:00:53,819 --> 00:00:49,850
for Khloe so these are salts that we

19
00:00:56,709 --> 00:00:53,829
know exists from the Phoenix lander and

20
00:00:59,369 --> 00:00:56,719
salts that you know with data from MSL

21
00:01:01,060 --> 00:00:59,379
to seem to be ubiquitous on Mars so

22
00:01:03,369 --> 00:01:01,070
reinterpretation of the Viking Lander

23
00:01:04,749 --> 00:01:03,379
results also indicates that there's a

24
00:01:06,910 --> 00:01:04,759
very good chance these four claw results

25
00:01:09,790 --> 00:01:06,920
being sort of everywhere on Mars or many

26
00:01:11,199 --> 00:01:09,800
places on Mars and we want to see you

27
00:01:12,370 --> 00:01:11,209
know are these salts something that are

28
00:01:14,830 --> 00:01:12,380
able to form solutions how do those

29
00:01:16,690 --> 00:01:14,840
solutions move in the soil and you know

30
00:01:19,690 --> 00:01:16,700
if there's a chance for present-day have

31
00:01:21,820 --> 00:01:19,700
an ability or current water cycle on

32
00:01:23,469 --> 00:01:21,830
Mars what does that look like and so

33
00:01:27,370 --> 00:01:23,479
we're doing this with actual laboratory

34
00:01:28,930 --> 00:01:27,380
experiments here on earth and trying to

35
00:01:32,070 --> 00:01:28,940
extrapolate that out both you know the

36
00:01:35,620 --> 00:01:32,080
chemistry side and the astrobiology side

37
00:01:37,510 --> 00:01:35,630
so the background here is we really

38
00:01:39,999 --> 00:01:37,520

started with Phoenix lander in the 2008

39
00:01:42,309 --> 00:01:40,009
Phoenix touchdown in the area this the

40
00:01:46,150 --> 00:01:42,319
Martian polar region where it's not the

41
00:01:48,460 --> 00:01:46,160
ice caps so not quite Antarctica but you

42
00:01:50,650 --> 00:01:48,470
know more like the Alaska or northern

43
00:01:51,969 --> 00:01:50,660
Canadian tundra so this is an area where

44
00:01:54,430 --> 00:01:51,979
we know there was a lot of subsurface

45
00:01:56,800 --> 00:01:54,440
hydrogen and when it landed down we blew

46
00:01:59,320 --> 00:01:56,810
off these big areas here where we found

47
00:02:01,210 --> 00:01:59,330
lots and lots of ice we scoop scoop down

48
00:02:03,490 --> 00:02:01,220
into the soil we see ice there's ice

49
00:02:06,219 --> 00:02:03,500
everywhere so lots and lots of ice water

50
00:02:07,930 --> 00:02:06,229
ice very good we also have the white

51
00:02:10,320 --> 00:02:07,940
chemistry lab in Phoenix we know that

52
00:02:13,300 --> 00:02:10,330
their perchlorate salts most likely

53
00:02:14,949 --> 00:02:13,310
sodium and magnesium and also quite

54
00:02:16,600 --> 00:02:14,959
possibly calcium for Chloe based on

55
00:02:19,059 --> 00:02:16,610
reanalysis of about chemistry results

56
00:02:22,089 --> 00:02:19,069
and results we have from NFL

57
00:02:24,280 --> 00:02:22,099
and we also see the formation of some

58
00:02:26,440 --> 00:02:24,290
spheroids on one of the lander struts

59
00:02:28,539 --> 00:02:26,450
and so it was thought that maybe that

60
00:02:30,610 --> 00:02:28,549
these spheroids could be a result of

61
00:02:32,739 --> 00:02:30,620
Dell questions the absorption of

62
00:02:35,080 --> 00:02:32,749
atmospheric water vapor onto these salts

63
00:02:39,339 --> 00:02:35,090

to form the spheroid this sort of wet

64
00:02:40,599 --> 00:02:39,349
spot on the lander struck and so one of

65
00:02:44,069 --> 00:02:40,609
the things that we're doing again is

66
00:02:46,929 --> 00:02:44,079
these looking at phase diagrams as we

67
00:02:48,610 --> 00:02:46,939
sort of have a generic salt here and go

68
00:02:51,009 --> 00:02:48,620
from a hundred percent salt on the right

69
00:02:53,319 --> 00:02:51,019
to 100 cell water on the left and so

70
00:02:57,819 --> 00:02:53,329
this is a solution where you have a

71
00:02:59,800 --> 00:02:57,829
solid salt and a salt solution so sort

72
00:03:03,929 --> 00:02:59,810
of liquid plus solid salt salt has

73
00:03:06,580 --> 00:03:03,939
precipitated out on the right you have

74
00:03:08,740 --> 00:03:06,590
salt solution so it's all liquid in this

75
00:03:11,920 --> 00:03:08,750
part and then i screw sub heading out

76
00:03:14,409 --> 00:03:11,930
and so what you have is essentially many

77
00:03:17,949 --> 00:03:14,419
conditions where you'll have some amount

78
00:03:19,149 --> 00:03:17,959
of liquid solution and then up down to

79
00:03:20,920 --> 00:03:19,159
the detective temperature so you'll

80
00:03:22,629 --> 00:03:20,930
essentially have a the salt tipped it

81
00:03:25,059 --> 00:03:22,639
out if you're on the right side of this

82
00:03:26,499 --> 00:03:25,069
diagram or the ice precipitate out if

83
00:03:30,550 --> 00:03:26,509
you're on the left side and so you'll

84
00:03:33,249 --> 00:03:30,560
have some liquid solution of water and

85
00:03:35,080 --> 00:03:33,259
insult until you see Technic and then

86
00:03:38,170 --> 00:03:35,090
you just have salads all and ice as you

87
00:03:40,390 --> 00:03:38,180
reduce the temperature and so we have

88
00:03:43,960 --> 00:03:40,400

very hygroscopic salts that we found

89
00:03:45,610 --> 00:03:43,970
with Phoenix these for Floyd's and what

90
00:03:48,039 --> 00:03:45,620
we see is a huge freezing point

91
00:03:51,189 --> 00:03:48,049
depression with these salts so this is

92
00:03:55,240 --> 00:03:51,199
some work from golf and severe a few

93
00:03:56,679 --> 00:03:55,250
others fairly new work with sodium for

94
00:03:58,179 --> 00:03:56,689
quote on the left magnesium chloride on

95
00:04:01,569 --> 00:03:58,189
the right again consistent with the

96
00:04:03,429 --> 00:04:01,579
Phoenix results and we see that what

97
00:04:05,289 --> 00:04:03,439
we're what we're doing here is

98
00:04:07,979 --> 00:04:05,299
essentially starting with assault

99
00:04:10,629 --> 00:04:07,989
exposed that the Martian atmosphere at

100
00:04:12,759 --> 00:04:10,639
similar to Mars temperatures so it goes

101
00:04:14,499 --> 00:04:12,769
down to around negative 50 see here so

102
00:04:15,520 --> 00:04:14,509
we'd like to go a lot colder and that's

103
00:04:17,699 --> 00:04:15,530
one of the things that we're trying to

104
00:04:20,349 --> 00:04:17,709
do with our experiments and we're

105
00:04:24,189 --> 00:04:20,359
ramping up the relative humidity in this

106
00:04:26,469 --> 00:04:24,199
simulated Martian air and so as we go

107
00:04:28,719 --> 00:04:26,479
from completely dry air to a completely

108
00:04:30,730 --> 00:04:28,729
wet air we're moving across in this

109
00:04:32,950 --> 00:04:30,740
phase diagram until we get a point where

110
00:04:34,930 --> 00:04:32,960
there's Dolph questions so

111
00:04:36,790 --> 00:04:34,940
the deliquescent point in this case

112
00:04:40,540 --> 00:04:36,800
depends on the hydration state of the

113
00:04:42,879 --> 00:04:40,550

initial assault and for the anhydrous

114
00:04:47,890 --> 00:04:42,889
phase you have bail questions early as

115
00:04:50,170 --> 00:04:47,900
this sort of metastable point where we

116
00:04:52,150 --> 00:04:50,180
have these yellow lines and you have

117
00:04:55,180 --> 00:04:52,160
once it's dela plus it's going to stay

118
00:05:00,150 --> 00:04:55,190
in that solution for a longer period of

119
00:05:02,909 --> 00:05:00,160
time so but yeah the I'm murdering this

120
00:05:04,960 --> 00:05:02,919
the anhydrous phase del classes early

121
00:05:07,089 --> 00:05:04,970
earlier than we would expect it just

122
00:05:11,469 --> 00:05:07,099
based on the the solution phase diagrams

123
00:05:14,080 --> 00:05:11,479
and then the monohydrate also dealt us

124
00:05:16,210 --> 00:05:14,090
it's a bit early and so this is sort of

125
00:05:18,520 --> 00:05:16,220
extending the range in which we expect

126
00:05:21,279 --> 00:05:18,530
liquid solutions to exist on Mars and so

127
00:05:22,839 --> 00:05:21,289
once you delve plus the other thing

128
00:05:25,360 --> 00:05:22,849
about these salts is you have the

129
00:05:27,820 --> 00:05:25,370
connecticut condition where once you

130
00:05:30,640 --> 00:05:27,830
delve plus it's harder for the salt to

131
00:05:32,320 --> 00:05:30,650
refreeze or to evaporate and so we don't

132
00:05:33,939 --> 00:05:32,330
actually have a fluorescence the point

133
00:05:35,680 --> 00:05:33,949
where the salt dries out until you drop

134
00:05:38,290 --> 00:05:35,690
down too much lower relative humidities

135
00:05:40,719 --> 00:05:38,300
and so what we see here is a applaud

136
00:05:43,240 --> 00:05:40,729
these red lines are some simulation of

137
00:05:44,980 --> 00:05:43,250
the Viking one lander site and you'd see

138
00:05:46,960 --> 00:05:44,990

that with these salts presence there

139
00:05:48,219 --> 00:05:46,970
there's a very good chance that during

140
00:05:51,700 --> 00:05:48,229
certain points of the day you would have

141
00:05:53,950 --> 00:05:51,710
liquid solutions form on Mars if you

142
00:05:55,570 --> 00:05:53,960
consider calcium for Cloyd as well these

143
00:06:00,120 --> 00:05:55,580
are new results not yet published in a

144
00:06:02,279 --> 00:06:00,130
paper but from knitting and golf as well

145
00:06:04,779 --> 00:06:02,289
calcium McCoy is pretty much going to be

146
00:06:07,209 --> 00:06:04,789
liquid if it's exposed to the air on

147
00:06:08,830 --> 00:06:07,219
Mars you know in many places so this is

148
00:06:11,709 --> 00:06:08,840
going to be it's extremely hygroscopic

149
00:06:16,060 --> 00:06:11,719
salt and it's going to want form a

150
00:06:19,839 --> 00:06:16,070
liquid solution so again these need to

151
00:06:21,790 --> 00:06:19,849
be probed more carefully you see again

152
00:06:23,740 --> 00:06:21,800
we're stuck about negative 50 here and

153
00:06:25,990 --> 00:06:23,750
if we're talking about eutectic

154
00:06:29,020 --> 00:06:26,000
temperature is on the order of 200 or

155
00:06:30,279 --> 00:06:29,030
maybe 170 Kelvin we really need to take

156
00:06:31,930 --> 00:06:30,289
these experiments further and that's

157
00:06:34,930 --> 00:06:31,940
what we're trying to do with our chamber

158
00:06:36,550 --> 00:06:34,940
so again we don't quite know these based

159
00:06:39,969 --> 00:06:36,560
on the models alone especially models

160
00:06:42,939 --> 00:06:39,979
with aqua solutions and so we're trying

161
00:06:45,219 --> 00:06:42,949
to oh sorry one more we're trying to do

162
00:06:46,719 --> 00:06:45,229
that experimentally this is an example

163
00:06:49,269 --> 00:06:46,729

of why you would care about

164
00:06:51,369 --> 00:06:49,279
natural biology community obviously we

165
00:06:55,290 --> 00:06:51,379
need liquid water for life and this is

166
00:06:59,559 --> 00:06:55,300
from Jones and lien waiver and Clark and

167
00:07:01,860 --> 00:06:59,569
we have plotted here the pressure on the

168
00:07:05,589 --> 00:07:01,870
left hand side and temperature on the

169
00:07:08,320 --> 00:07:05,599
horizontal axis and this is essentially

170
00:07:10,959 --> 00:07:08,330
the phase space of Mars and then on on

171
00:07:13,239 --> 00:07:10,969
top of that the Samaras being the brown

172
00:07:17,589 --> 00:07:13,249
area we have the phase space of liquid

173
00:07:18,999 --> 00:07:17,599
water and the phase space of life as we

174
00:07:21,489 --> 00:07:19,009
know it on earth and sort of extrapolate

175
00:07:23,889 --> 00:07:21,499
it out and so this is trying to help us

176
00:07:25,450 --> 00:07:23,899
identify regions on Mars where you can

177
00:07:26,980 --> 00:07:25,460
start to discuss present-day

178
00:07:29,260 --> 00:07:26,990
habitability or where life might still

179
00:07:31,149 --> 00:07:29,270
exist so we're life did exist and so

180
00:07:34,689 --> 00:07:31,159
that's what we're trying to do and the

181
00:07:36,459 --> 00:07:34,699
grand scheme of things so this is what

182
00:07:39,760 --> 00:07:36,469
our chamber looks like now sort of the

183
00:07:41,230 --> 00:07:39,770
cartoon version vacuum chamber with a

184
00:07:44,019 --> 00:07:41,240
thermal plate single thermal plate

185
00:07:47,499 --> 00:07:44,029
inside a sample holder the thermal play

186
00:07:50,350 --> 00:07:47,509
is 24 inches by 24 inches so we can have

187
00:07:51,730 --> 00:07:50,360
quite large samples it's a very large

188
00:07:54,969 --> 00:07:51,740

vacuum chamber which you know

189
00:07:56,949 --> 00:07:54,979
essentially I can fit in it we go to

190
00:07:59,559 --> 00:07:56,959
Martian pressures we have a simulated

191
00:08:01,469 --> 00:07:59,569
Martian atmosphere temperatures we can

192
00:08:03,550 --> 00:08:01,479
go down to negative 196 Celsius

193
00:08:04,629 --> 00:08:03,560
essentially the the boiling point of

194
00:08:08,320 --> 00:08:04,639
liquid nitrogen that's our primary

195
00:08:11,290 --> 00:08:08,330
coolant and then we add water vapor into

196
00:08:13,570 --> 00:08:11,300
the system using a bubbler condenser

197
00:08:16,089 --> 00:08:13,580
system and we're trying to sort of fine

198
00:08:17,379 --> 00:08:16,099
tune this and calibrate it now but the

199
00:08:19,149 --> 00:08:17,389
temperature and pressure are very good

200
00:08:20,499 --> 00:08:19,159
still a little more work to do with the

201
00:08:21,909 --> 00:08:20,509
humidity but we're getting to the point

202
00:08:25,719 --> 00:08:21,919
where we can start you do to do

203
00:08:27,730 --> 00:08:25,729
experiments with this and so a picture

204
00:08:29,170 --> 00:08:27,740
of it actually in the lab again pretty

205
00:08:34,719 --> 00:08:29,180
big you know you could crawl inside has

206
00:08:36,730 --> 00:08:34,729
a space feet if you want the the range

207
00:08:38,819 --> 00:08:36,740
we've designed this specifically for

208
00:08:42,519 --> 00:08:38,829
Mars but you can also extrapolate to

209
00:08:44,370 --> 00:08:42,529
tighten and if you wanted to do studies

210
00:08:49,090 --> 00:08:44,380
of the moons of Saturn or Jupiter

211
00:08:50,350 --> 00:08:49,100
something like that and we have Raman

212
00:08:52,000 --> 00:08:50,360
spectrometer inside to measure

213
00:08:53,710 --> 00:08:52,010

deliquescent but we have a number of

214
00:08:56,860 --> 00:08:53,720
view ports available to also look at

215
00:09:00,190 --> 00:08:56,870
other to enable other instruments as

216
00:09:03,040 --> 00:09:00,200
well so and then just

217
00:09:05,680 --> 00:09:03,050
some nice shiny pictures so the cooling

218
00:09:07,870 --> 00:09:05,690
system all PID controlled we're running

219
00:09:10,780 --> 00:09:07,880
a negative 150 Celsius at this point the

220
00:09:12,190 --> 00:09:10,790
thermal play inside and then just

221
00:09:17,310 --> 00:09:12,200
looking down from above at a very small

222
00:09:19,390 --> 00:09:17,320
sample holder you know about that big so

223
00:09:21,280 --> 00:09:19,400
what we're planning to do is again these

224
00:09:24,970 --> 00:09:21,290
improve these phase diagrams

225
00:09:26,500 --> 00:09:24,980
experimentally determine I not only if

226
00:09:28,090 --> 00:09:26,510
the assault will deliquesce on Mars I

227
00:09:30,790 --> 00:09:28,100
think that's been answered that these

228
00:09:32,800 --> 00:09:30,800
salts will deliquesce but how much time

229
00:09:35,220 --> 00:09:32,810
are they going to form you know for how

230
00:09:37,870 --> 00:09:35,230
long will they form liquid solutions and

231
00:09:40,900 --> 00:09:37,880
how much times they need and how much

232
00:09:43,540 --> 00:09:40,910
time does you know your extreme a file

233
00:09:48,240 --> 00:09:43,550
or any Martian life that may exist need

234
00:10:05,230 --> 00:09:48,250
to survive in this environment and so

235
00:10:07,120 --> 00:10:05,240
with that thank in open up questions I'm

236
00:10:09,160 --> 00:10:07,130
pretty curious with those perchlorates

237
00:10:10,660 --> 00:10:09,170
has anybody done kind of like the

238
00:10:12,190 --> 00:10:10,670

half-life of the reactivity of

239
00:10:13,750 --> 00:10:12,200
perchlorate versus how long you can

240
00:10:15,190 --> 00:10:13,760
actually keep that liquid solution I

241
00:10:16,960 --> 00:10:15,200
mean perchlorates pretty wrecked of

242
00:10:18,970 --> 00:10:16,970
stuff and if you have even basalts or

243
00:10:22,120 --> 00:10:18,980
anything like that I would assume it's

244
00:10:25,960 --> 00:10:22,130
going to react pretty quickly in terms

245
00:10:27,820 --> 00:10:25,970
of I don't know that much with the

246
00:10:30,700 --> 00:10:27,830
reaction rates but I think that it's

247
00:10:32,890 --> 00:10:30,710
actually quite stable so in the in a

248
00:10:34,240 --> 00:10:32,900
salt form especially so once you have

249
00:10:36,580 --> 00:10:34,250
piccata saves around for a long time

250
00:10:38,500 --> 00:10:36,590
actually on earth a lot of the it's

251
00:10:41,920 --> 00:10:38,510
mostly microbial breakdown that destroys

252
00:10:44,740 --> 00:10:41,930
Purefoy so the reason you see it build

253
00:10:46,360 --> 00:10:44,750
up on Mars is because you have you might

254
00:10:48,250 --> 00:10:46,370
have some source process and there's not

255
00:10:49,600 --> 00:10:48,260
really anything to theirs it's so dry

256
00:10:51,160 --> 00:10:49,610
that the water is not washing it away

257
00:10:52,570 --> 00:10:51,170
which is what would happen in the

258
00:10:54,250 --> 00:10:52,580
Earth's system you know you only find

259
00:10:56,260 --> 00:10:54,260
perchlorates in very dry areas like

260
00:11:05,940 --> 00:10:56,270
southwestern united states that it kind

261
00:11:09,580 --> 00:11:08,260
what effect do you think depth has on

262
00:11:11,650 --> 00:11:09,590
this or are they going to just

263
00:11:13,360 --> 00:11:11,660

deliquesce at the surface so you said

264
00:11:15,130 --> 00:11:13,370
like if you have perchlorate on the

265
00:11:17,290 --> 00:11:15,140
surface you're going to make a liquid

266
00:11:18,610 --> 00:11:17,300
solution but presumably for habitability

267
00:11:20,650 --> 00:11:18,620
purposes you would want it to be a

268
00:11:22,390 --> 00:11:20,660
little bit deeper down into soil where

269
00:11:24,310 --> 00:11:22,400
it's a nice little habitat so with a

270
00:11:25,870 --> 00:11:24,320
deliquesce if they're frozen up in a

271
00:11:27,790 --> 00:11:25,880
permafrost or something like that yeah

272
00:11:29,170 --> 00:11:27,800
so the reason why the chamber is so big

273
00:11:32,650 --> 00:11:29,180
is because we want to look at you know

274
00:11:33,880 --> 00:11:32,660
essentially the soil soil depths and we

275
00:11:35,290 --> 00:11:33,890
want to see how perchlorate would move

276
00:11:37,330 --> 00:11:35,300
around in the soil we don't see poor koi

277
00:11:38,530 --> 00:11:37,340
immediately on the surface especially at

278
00:11:40,420 --> 00:11:38,540
the phoenix landing site you have to dig

279
00:11:42,070 --> 00:11:40,430
a little bit once you dig you find lots

280
00:11:43,330 --> 00:11:42,080
of pockets of it so that's one of the

281
00:11:44,950 --> 00:11:43,340
things that we really want to understand

282
00:11:47,350 --> 00:11:44,960
is how is / clarity being transported

283
00:11:49,330 --> 00:11:47,360
through the surface from the surface to

284
00:11:53,740 --> 00:11:49,340
these pockets and pore spaces in the

285
00:11:56,380 --> 00:11:53,750
soil but from what I've seen I think it

286
00:11:58,750 --> 00:11:56,390
will actually you know that's the thing

287
00:12:00,400 --> 00:11:58,760
like if you have calcium for Chloe open

288
00:12:01,570 --> 00:12:00,410

to the air it's going to della place on

289
00:12:02,680 --> 00:12:01,580
Mars and it's going to form a liquid and

290
00:12:04,450 --> 00:12:02,690
it's going to sink down into the soil

291
00:12:06,460 --> 00:12:04,460
and then it's going to be maybe less

292
00:12:08,680 --> 00:12:06,470
likely to form a liquid it's going to be

293
00:12:10,180 --> 00:12:08,690
it'll maybe stay liquid longer because

294
00:12:12,880 --> 00:12:10,190
the soil will help hold on the moisture

295
00:12:14,980 --> 00:12:12,890
so that's what we want to know is how

296
00:12:16,720 --> 00:12:14,990
you know not just how these salts you

297
00:12:18,370 --> 00:12:16,730
know the first stage is the salt in the

298
00:12:19,870 --> 00:12:18,380
atmosphere but the second stage is

299
00:12:21,460 --> 00:12:19,880
really how does the soil interact with