100°C water/rock experiments

80% N_2: 20% CO_2 in headspace

1
00:00:02,140 --> 00:00:06,630
[Music]

2
00:00:12,310 --> 00:00:08,629
thank you my name is hannah miller i am

3
00:00:13,350 --> 00:00:12,320
here at cu working with alexis templeton

4
00:00:14,789 --> 00:00:13,360
so we've already talked about

5
00:00:16,070 --> 00:00:14,799
serpentinization a little bit but i'm

6
00:00:18,710 --> 00:00:16,080
going to go into a little bit more

7
00:00:20,950 --> 00:00:18,720
detail to the actual

8
00:00:24,070 --> 00:00:20,960
geochemical reaction right here

9
00:00:26,710 --> 00:00:24,080
so serpentinization is a water rock

10
00:00:27,509 --> 00:00:26,720
reaction in which you get the oxidation

11
00:00:28,470 --> 00:00:27,519
of

12
00:00:30,870 --> 00:00:28,480
mantle

13
00:00:33,510 --> 00:00:30,880

rocks and minerals such as olivine which

14
00:00:35,350 --> 00:00:33,520
i show in this equation so olivine has

15
00:00:38,229 --> 00:00:35,360
this iron two in it when it reacts with

16
00:00:40,069 --> 00:00:38,239
water in an anoxic environment it

17
00:00:42,869 --> 00:00:40,079
generates magnesium bearing minerals

18
00:00:44,069 --> 00:00:42,879
such as serpentine and brucite along

19
00:00:46,950 --> 00:00:44,079
with

20
00:00:49,510 --> 00:00:46,960
oxidized minerals like magnetite here

21
00:00:51,029 --> 00:00:49,520
and hydrogen gas

22
00:00:52,549 --> 00:00:51,039
and this reaction has been very well

23
00:00:54,630 --> 00:00:52,559
studied at high temperatures that

24
00:00:56,869 --> 00:00:54,640
hydrothermal vents are spreading ocean

25
00:00:58,630 --> 00:00:56,879
or spreading ridges under the ocean but

26
00:00:59,910 --> 00:00:58,640
it hasn't been well characterized at low

27
00:01:03,910 --> 00:00:59,920
temperatures

28
00:01:05,830 --> 00:01:03,920
celsius where life can actually be

29
00:01:08,070 --> 00:01:05,840
actively harnessing that hydrogen being

30
00:01:10,230 --> 00:01:08,080
generated from these reactions

31
00:01:12,230 --> 00:01:10,240
this is an image of what a partially

32
00:01:13,910 --> 00:01:12,240
serpentized rock looks like so you can

33
00:01:16,070 --> 00:01:13,920
see why it's called serpentine because

34
00:01:19,030 --> 00:01:16,080
it generates these veins that look kind

35
00:01:23,510 --> 00:01:20,710
so what we always talk about how does

36
00:01:24,390 --> 00:01:23,520
this relate back to astrobiology

37
00:01:26,469 --> 00:01:24,400
both

38
00:01:28,469 --> 00:01:26,479

well mars we definitely know has olivine

39
00:01:30,390 --> 00:01:28,479
mineral olivine minerals on it as well

40
00:01:31,990 --> 00:01:30,400
as serpentine minerals so there's

41
00:01:33,749 --> 00:01:32,000
potential that these

42
00:01:36,149 --> 00:01:33,759
water rock reactions could be occurring

43
00:01:37,910 --> 00:01:36,159
on mars making hydrogen gas which is an

44
00:01:39,030 --> 00:01:37,920
electron donor for organisms to be

45
00:01:41,270 --> 00:01:39,040
utilizing

46
00:01:42,870 --> 00:01:41,280
additionally europa might also contain

47
00:01:46,710 --> 00:01:42,880
some of these

48
00:01:48,870 --> 00:01:46,720
rocks that could be subpoenaizing and

49
00:01:50,710 --> 00:01:48,880
also studies have been done on enceladus

50
00:01:52,469 --> 00:01:50,720
and how there might be high ph fluids

51
00:01:53,990 --> 00:01:52,479
there that indicate serpentinization is

52
00:01:55,910 --> 00:01:54,000
occurring

53
00:01:57,510 --> 00:01:55,920
so there are several metabolisms that

54
00:02:00,389 --> 00:01:57,520
could be supported by these water rock

55
00:02:03,190 --> 00:02:00,399
reactions one that is oftentimes invoked

56
00:02:05,030 --> 00:02:03,200
is methanogenesis because if you have

57
00:02:06,469 --> 00:02:05,040
all this hydrogen around if you if

58
00:02:08,869 --> 00:02:06,479
there's some carbon available you can

59
00:02:10,469 --> 00:02:08,879
make methane gas and methane is a

60
00:02:13,190 --> 00:02:10,479
prevalent gas to be found in these

61
00:02:15,190 --> 00:02:13,200
serpentinizing environments is source is

62
00:02:17,350 --> 00:02:15,200
oftentimes debated it may be biotic

63
00:02:19,110 --> 00:02:17,360

abiotic a mixture of the two but it's

64
00:02:21,510 --> 00:02:19,120
definitely a relevant gas along with

65
00:02:23,750 --> 00:02:21,520
hydrogen in these environments

66
00:02:25,910 --> 00:02:23,760
additionally we know we have all we have

67
00:02:27,510 --> 00:02:25,920
this electron donor hydrogen around but

68
00:02:31,110 --> 00:02:27,520
you need electron acceptors two for

69
00:02:32,630 --> 00:02:31,120
organisms oftentimes nitrate and sulfate

70
00:02:34,710 --> 00:02:32,640
are found in these environments so you

71
00:02:36,869 --> 00:02:34,720
can also have various metabolisms that

72
00:02:39,030 --> 00:02:36,879
utilize those

73
00:02:41,110 --> 00:02:39,040
one potential exciting metabolism would

74
00:02:42,949 --> 00:02:41,120
be anaerobic methane oxidation occurring

75
00:02:45,030 --> 00:02:42,959
in these environments

76
00:02:47,830 --> 00:02:45,040
so you can see that serpentinization can

77
00:02:50,070 --> 00:02:47,840
fuel a variety of life and that's kind

78
00:02:52,070 --> 00:02:50,080
of the theme of the rock powered life

79
00:02:54,470 --> 00:02:52,080
nasa astrobiology institute which alexis

80
00:02:55,910 --> 00:02:54,480
templeton heads up here at cu so we are

81
00:02:57,270 --> 00:02:55,920
really investigating this and a lot of

82
00:02:59,509 --> 00:02:57,280
different people at the conference have

83
00:03:01,830 --> 00:02:59,519
been talking about various things that

84
00:03:04,790 --> 00:03:01,840
rpl is working on

85
00:03:05,830 --> 00:03:04,800
so i'm specifically working in oman

86
00:03:08,390 --> 00:03:05,840
which is

87
00:03:10,390 --> 00:03:08,400
located right here on the eastern edge

88
00:03:11,509 --> 00:03:10,400

of the arabian peninsula

89
00:03:13,350 --> 00:03:11,519
and

90
00:03:14,630 --> 00:03:13,360
oman is a great place to study

91
00:03:16,229 --> 00:03:14,640
serpentinization because it's the

92
00:03:18,550 --> 00:03:16,239
world's largest and best exposed

93
00:03:20,710 --> 00:03:18,560
ophelite sequence and for you

94
00:03:24,149 --> 00:03:20,720
non-geologists out there an ophiolite

95
00:03:25,430 --> 00:03:24,159
sequence contains layers of upper mantle

96
00:03:26,790 --> 00:03:25,440
so if you think about the earth as an

97
00:03:28,949 --> 00:03:26,800
avocado

98
00:03:30,710 --> 00:03:28,959
you have your mantle right here so an

99
00:03:31,910 --> 00:03:30,720
ophelite would be this upper mantle

100
00:03:33,270 --> 00:03:31,920
which is the green fleshy part of the

101
00:03:34,550 --> 00:03:33,280
avocado which is actually very

102
00:03:36,070 --> 00:03:34,560
appropriate because peridotite is a

103
00:03:37,830 --> 00:03:36,080
beautiful green color because of all

104
00:03:41,030 --> 00:03:37,840
this reduced iron

105
00:03:43,110 --> 00:03:41,040
and then you have layered gabbros and

106
00:03:44,789 --> 00:03:43,120
pillar basalts on top

107
00:03:47,670 --> 00:03:44,799
but i'm really interested in this

108
00:03:50,470 --> 00:03:47,680
peridotite right here in oman and

109
00:03:52,309 --> 00:03:50,480
the opioid was originally

110
00:03:53,910 --> 00:03:52,319
at a spreading ridge on the ocean floor

111
00:03:55,509 --> 00:03:53,920
so it's already partially altered by the

112
00:03:57,350 --> 00:03:55,519
time we study it in oman it's already

113
00:03:59,830 --> 00:03:57,360

partially sepanized some of that iron

114
00:04:02,550 --> 00:03:59,840
has already been oxidized

115
00:04:04,550 --> 00:04:02,560
so i i work on water rock reactions to

116
00:04:06,630 --> 00:04:04,560
actually characterize how hydrogen is

117
00:04:08,789 --> 00:04:06,640
being produced in these low temperature

118
00:04:10,710 --> 00:04:08,799
reactions so first of all we take some

119
00:04:12,550 --> 00:04:10,720
rock from oman you can see it has a

120
00:04:14,470 --> 00:04:12,560
beautiful oxidized weathering rind on

121
00:04:17,110 --> 00:04:14,480
the outside we cut that off because

122
00:04:20,069 --> 00:04:17,120
we're just interested in looking at this

123
00:04:22,069 --> 00:04:20,079
relatively unoxidized iron and then we

124
00:04:23,990 --> 00:04:22,079
go through this arduous process of

125
00:04:25,749 --> 00:04:24,000
grinding it up into really small pieces

126
00:04:27,510 --> 00:04:25,759
so there's higher surface area and these

127
00:04:29,670 --> 00:04:27,520
reactions actually proceed on the level

128
00:04:31,270 --> 00:04:29,680
of a phd time scale

129
00:04:36,390 --> 00:04:31,280
and

130
00:04:38,390 --> 00:04:36,400
into these anaerobic vials we add some

131
00:04:39,990 --> 00:04:38,400
water of various compositions some that

132
00:04:42,790 --> 00:04:40,000
simulate seawater or simulate the

133
00:04:45,350 --> 00:04:42,800
groundwater in the area and then we

134
00:04:48,629 --> 00:04:45,360
purge the headspace with a nitrogen and

135
00:04:50,710 --> 00:04:48,639
co2 gas mixture so that there's no

136
00:04:51,909 --> 00:04:50,720
oxygen in there and these the iron can

137
00:04:53,749 --> 00:04:51,919
oxidize

138
00:04:55,909 --> 00:04:53,759

without oxygen around

139
00:04:57,110 --> 00:04:55,919
and the results we see so i did these

140
00:04:58,870 --> 00:04:57,120
reactions with this partially

141
00:05:00,230 --> 00:04:58,880
subpoenaized rock from oman at 100

142
00:05:02,230 --> 00:05:00,240
degrees celsius

143
00:05:03,990 --> 00:05:02,240
and this is showing hydrogen production

144
00:05:05,270 --> 00:05:04,000
right here the two different colors

145
00:05:07,830 --> 00:05:05,280
indicate

146
00:05:09,430 --> 00:05:07,840
the rock was reacting with two different

147
00:05:11,270 --> 00:05:09,440
see what with two different water

148
00:05:13,110 --> 00:05:11,280
compositions i'm not really going to go

149
00:05:15,590 --> 00:05:13,120
into that but you get different hydrogen

150
00:05:16,950 --> 00:05:15,600
production based off of the media

151
00:05:19,110 --> 00:05:16,960
composition you're reacting the rock

152
00:05:21,510 --> 00:05:19,120
with but you can see that we generate

153
00:05:23,510 --> 00:05:21,520
hydrogen up to about 500 animals per

154
00:05:25,110 --> 00:05:23,520
gram of mineral reactant which is

155
00:05:26,950 --> 00:05:25,120
actually quite significant for a

156
00:05:29,029 --> 00:05:26,960
temperature of 100 degrees celsius it's

157
00:05:30,390 --> 00:05:29,039
one of the highest rate highest

158
00:05:31,590 --> 00:05:30,400
concentrations reported in the

159
00:05:33,110 --> 00:05:31,600
literature

160
00:05:34,950 --> 00:05:33,120
and it's also important to note that

161
00:05:37,029 --> 00:05:34,960
it's sustained hydrogen production it

162
00:05:39,270 --> 00:05:37,039
doesn't make hydrogen for one day and

163
00:05:41,189 --> 00:05:39,280

then just stop it's actually sustained

164
00:05:43,670 --> 00:05:41,199
so there's a chance a microbe could

165
00:05:44,950 --> 00:05:43,680
actually be using that hydrogen over

166
00:05:46,550 --> 00:05:44,960
time

167
00:05:48,550 --> 00:05:46,560
additionally we look at the aqueous

168
00:05:50,550 --> 00:05:48,560
chemistry during these reactions and we

169
00:05:53,270 --> 00:05:50,560
can see that there's an increase in ph

170
00:05:54,469 --> 00:05:53,280
to about ph 9 after just 24 hours of

171
00:05:56,870 --> 00:05:54,479
reaction

172
00:05:58,469 --> 00:05:56,880
and that aligns with what you see in

173
00:06:02,150 --> 00:05:58,479
serpentinizing environments they have

174
00:06:04,070 --> 00:06:02,160
high ph's usually they go up to ph 11.

175
00:06:05,670 --> 00:06:04,080
so we don't see that in the time scales

176
00:06:06,710 --> 00:06:05,680
of our reactions but it's probably just

177
00:06:08,469 --> 00:06:06,720
because

178
00:06:10,710 --> 00:06:08,479
this low temperature reaction isn't

179
00:06:12,150 --> 00:06:10,720
actually in equilibrium right now

180
00:06:15,029 --> 00:06:12,160
additionally we see the loss of

181
00:06:17,270 --> 00:06:15,039
magnesium iron and manganese ions

182
00:06:19,350 --> 00:06:17,280
initially during the reaction

183
00:06:21,430 --> 00:06:19,360
so there must be some mineral phase

184
00:06:24,150 --> 00:06:21,440
that's dissolving

185
00:06:26,150 --> 00:06:24,160
and we add co2 to the head space as i

186
00:06:27,350 --> 00:06:26,160
noted that also gets drawn down pretty

187
00:06:30,230 --> 00:06:27,360
immediately

188
00:06:32,070 --> 00:06:30,240

and when we see that co2 get drawn down

189
00:06:33,430 --> 00:06:32,080
we also see a formation of formate and

190
00:06:34,469 --> 00:06:33,440
acetate

191
00:06:38,309 --> 00:06:34,479
these

192
00:06:40,550 --> 00:06:38,319
see just what their formulas are right

193
00:06:42,070 --> 00:06:40,560
here but this likely forms through this

194
00:06:43,830 --> 00:06:42,080
reaction right here you have hydrogen

195
00:06:46,390 --> 00:06:43,840
combining with some of that co2 that's

196
00:06:47,670 --> 00:06:46,400
dissolved in the fluid to make formate

197
00:06:48,629 --> 00:06:47,680
the fact that we have acetate is a

198
00:06:50,309 --> 00:06:48,639
little bit

199
00:06:51,990 --> 00:06:50,319
interesting and enigmatic because it's a

200
00:06:53,189 --> 00:06:52,000
lot more complicated to form acetate

201
00:06:55,510 --> 00:06:53,199
than formate

202
00:06:56,950 --> 00:06:55,520
but this is still an interesting result

203
00:06:58,469 --> 00:06:56,960
that we found through these water rock

204
00:06:59,909 --> 00:06:58,479
reactions

205
00:07:01,589 --> 00:06:59,919
additionally we also really want to

206
00:07:03,990 --> 00:07:01,599
characterize the mineralogy during these

207
00:07:05,749 --> 00:07:04,000
water rock reactions to see how the iron

208
00:07:07,270 --> 00:07:05,759
is actually oxidizing and what are the

209
00:07:09,110 --> 00:07:07,280
different reservoirs

210
00:07:11,510 --> 00:07:09,120
of iron in the system

211
00:07:13,029 --> 00:07:11,520
so first this is a

212
00:07:15,110 --> 00:07:13,039
picture of a thin section from ramen

213
00:07:18,469 --> 00:07:15,120

micro microscopy

214
00:07:20,309 --> 00:07:18,479
and these yellow blobs here olivine and

215
00:07:22,150 --> 00:07:20,319
then the light blue in the background is

216
00:07:24,710 --> 00:07:22,160
all serpentine and this is just a big

217
00:07:25,670 --> 00:07:24,720
like chromite diopside thing

218
00:07:28,150 --> 00:07:25,680
but

219
00:07:30,469 --> 00:07:28,160
we can see that before this rock reacts

220
00:07:31,830 --> 00:07:30,479
we have serpentine so this rock is

221
00:07:34,070 --> 00:07:31,840
already reacted we can see it's a

222
00:07:35,670 --> 00:07:34,080
partially subpoenaized rock but when we

223
00:07:37,430 --> 00:07:35,680
look at the serpentine right here this

224
00:07:38,950 --> 00:07:37,440
is the fingerprint region in raman so

225
00:07:41,749 --> 00:07:38,960
these are the characteristic serpentine

226
00:07:44,150 --> 00:07:41,759
peaks but when we look at the oh the od

227
00:07:45,990 --> 00:07:44,160
the oh stretch of the serpentine we see

228
00:07:48,309 --> 00:07:46,000
this bump right here that corresponds to

229
00:07:49,670 --> 00:07:48,319
brucite so we can see that bruceite is

230
00:07:52,070 --> 00:07:49,680
intimately intermixed with this

231
00:07:53,350 --> 00:07:52,080
serpentine and based off of the peak of

232
00:07:55,110 --> 00:07:53,360
this bruce site

233
00:07:57,110 --> 00:07:55,120
we've calibrated how much iron is

234
00:07:59,670 --> 00:07:57,120
present in the brew site so we can see

235
00:08:01,189 --> 00:07:59,680
there's 15 weight percent iron present

236
00:08:02,710 --> 00:08:01,199
and that's important because this could

237
00:08:04,070 --> 00:08:02,720
be an important source of iron that

238
00:08:06,550 --> 00:08:04,080

could be oxidizing and leading to

239
00:08:09,029 --> 00:08:06,560
hydrogen generation

240
00:08:10,950 --> 00:08:09,039
so when we look at the

241
00:08:13,510 --> 00:08:10,960
the grains that have reacted and formed

242
00:08:16,790 --> 00:08:13,520
hydrogen these are some powder xod

243
00:08:19,189 --> 00:08:16,800
spectrum spectra and you can see

244
00:08:21,189 --> 00:08:19,199
that right here red

245
00:08:22,950 --> 00:08:21,199
is the unreacted rock and there's a

246
00:08:24,790 --> 00:08:22,960
bunch of olivine and serpentine peaks

247
00:08:26,790 --> 00:08:24,800
but the peak i'm going to focus on this

248
00:08:28,869 --> 00:08:26,800
one right here this black bump right

249
00:08:30,710 --> 00:08:28,879
here is bruceite so you can see in the

250
00:08:32,790 --> 00:08:30,720
unreacted rock there's a fair amount of

251
00:08:35,589 --> 00:08:32,800
bruceite but then when we act when we

252
00:08:36,949 --> 00:08:35,599
react the rock with various medias we

253
00:08:39,350 --> 00:08:36,959
can see that that brewsight peak

254
00:08:41,350 --> 00:08:39,360
disappears so bruceite is being consumed

255
00:08:42,790 --> 00:08:41,360
during these water rock reactions

256
00:08:45,350 --> 00:08:42,800
and that's likely why we saw that

257
00:08:47,509 --> 00:08:45,360
release of magnesium manganese and iron

258
00:08:48,949 --> 00:08:47,519
in the aqueous chemistry

259
00:08:50,790 --> 00:08:48,959
and we also know that brucite contains

260
00:08:52,310 --> 00:08:50,800
iron so that's a very likely source of

261
00:08:55,430 --> 00:08:52,320
the iron ii that's been leading to

262
00:08:57,269 --> 00:08:55,440
hydrogen generation as it gets oxidized

263
00:08:59,269 --> 00:08:57,279

additionally we've seen

264
00:09:01,110 --> 00:08:59,279
these are some images of just the thin

265
00:09:03,269 --> 00:09:01,120
sections of the rock before and after

266
00:09:05,670 --> 00:09:03,279
reaction so you can see all these little

267
00:09:07,430 --> 00:09:05,680
splotches of mineral that are forming

268
00:09:09,030 --> 00:09:07,440
there's definitely serpentine formation

269
00:09:10,790 --> 00:09:09,040
during these reactions it's very

270
00:09:11,910 --> 00:09:10,800
amorphous and white and there's not that

271
00:09:13,590 --> 00:09:11,920
much of it

272
00:09:15,350 --> 00:09:13,600
but that is important because we know

273
00:09:17,190 --> 00:09:15,360
from that initial reaction i showed you

274
00:09:18,630 --> 00:09:17,200
serpentine should be forming

275
00:09:20,470 --> 00:09:18,640
at these high temperatures we know it

276
00:09:21,750 --> 00:09:20,480
definitely does but it also does at low

277
00:09:23,590 --> 00:09:21,760
temperatures

278
00:09:25,829 --> 00:09:23,600
additionally we use magnetic

279
00:09:27,990 --> 00:09:25,839
susceptibility methods to show that

280
00:09:30,070 --> 00:09:28,000
magnetite forms and that's also

281
00:09:31,990 --> 00:09:30,080
important to note because at these high

282
00:09:34,630 --> 00:09:32,000
temperatures magnetite is

283
00:09:35,990 --> 00:09:34,640
thermodynamically expected to form but

284
00:09:38,070 --> 00:09:36,000
at lower temperatures it hasn't been

285
00:09:40,230 --> 00:09:38,080
observed as much but we definitely see

286
00:09:42,150 --> 00:09:40,240
that magnetite is forming and likely

287
00:09:45,030 --> 00:09:42,160
that's what's accommodating this iron

288
00:09:48,630 --> 00:09:46,070

okay

289
00:09:50,790 --> 00:09:48,640
so overall why we think we want to

290
00:09:53,030 --> 00:09:50,800
propose some sort of reaction for this

291
00:09:54,870 --> 00:09:53,040
low temperature serpentinization and we

292
00:09:56,310 --> 00:09:54,880
believe that the dissolution of iron ii

293
00:09:57,910 --> 00:09:56,320
bearing bruce site is leading to

294
00:10:00,230 --> 00:09:57,920
hydrogen generation at these low

295
00:10:02,550 --> 00:10:00,240
temperatures so because this rock was

296
00:10:03,990 --> 00:10:02,560
already partially sepantonized

297
00:10:06,150 --> 00:10:04,000
there are some thoughts well is it even

298
00:10:08,710 --> 00:10:06,160
still reacted is it reactive is there

299
00:10:10,550 --> 00:10:08,720
still iron two available for oxidation

300
00:10:14,230 --> 00:10:10,560
and yes there is and we think a lot of

301
00:10:16,069 --> 00:10:14,240
that iron too is coming out of brucite

302
00:10:19,670 --> 00:10:16,079
additionally these reactions can make up

303
00:10:21,030 --> 00:10:19,680
to 37 nanomoles of hydrogen so this is

304
00:10:22,230 --> 00:10:21,040
the hydrogen that's dissolved in the

305
00:10:24,069 --> 00:10:22,240
fluid the hydrogen that's more

306
00:10:26,870 --> 00:10:24,079
biologically available

307
00:10:28,630 --> 00:10:26,880
and that's more than enough to support

308
00:10:31,430 --> 00:10:28,640
some sort of microorganism because

309
00:10:32,550 --> 00:10:31,440
methanogens require much lower levels

310
00:10:34,069 --> 00:10:32,560
than that

311
00:10:36,310 --> 00:10:34,079
additionally these reactions make

312
00:10:38,389 --> 00:10:36,320
reduced energy sources such as formating

313
00:10:40,790 --> 00:10:38,399

acetate which can support support

314
00:10:44,150 --> 00:10:40,800
fermenters living in the

315
00:10:49,030 --> 00:10:47,110
so overall that's how we think that low

316
00:10:50,790 --> 00:10:49,040
temperature hydrogen generation is

317
00:10:53,829 --> 00:10:50,800
happening in oman of course it's very

318
00:10:55,910 --> 00:10:53,839
site-specific because these minerals had

319
00:10:57,430 --> 00:10:55,920
a lot of brewside in them

320
00:10:59,190 --> 00:10:57,440
i would like to thank everyone in my lab

321
00:11:00,770 --> 00:10:59,200
and our collaborators and i would like

322
00:11:06,389 --> 00:11:00,780
to take any questions

323
00:11:22,630 --> 00:11:06,399
[Applause]

324
00:11:26,710 --> 00:11:24,230
i was just curious what the average

325
00:11:28,790 --> 00:11:26,720
ratio of supreme tonight to prototype

326
00:11:31,190 --> 00:11:28,800
that you had for your samples

327
00:11:34,470 --> 00:11:31,200
it started off as about 50 serpentine

328
00:11:35,750 --> 00:11:34,480
and 50 um olivine

329
00:11:37,910 --> 00:11:35,760
was that your question like the mineral

330
00:11:41,030 --> 00:11:37,920
proportions and

331
00:11:42,630 --> 00:11:41,040
during the reaction it barely changes

332
00:11:44,470 --> 00:11:42,640
so just a little bit of blue site we

333
00:11:46,470 --> 00:11:44,480
think it's about five percent by mass

334
00:11:50,470 --> 00:11:46,480
brucite reacted to generate the hydrogen