



**330: CO-EVOLUTION OF THE GEOSPHERE &
BIOSPHERE: THE CONTEXT FOR LIFE'S
ORIGINS & EARLIEST EVOLUTION III**

1
00:00:04,309 --> 00:00:02,389
hi everyone um i'm just going to go

2
00:00:06,389 --> 00:00:04,319
ahead and say a few things as people are

3
00:00:08,390 --> 00:00:06,399
making their way to their seats we have

4
00:00:09,910 --> 00:00:08,400
short 10 minute slots so i thought i'd

5
00:00:11,110 --> 00:00:09,920
start the introduction just a little bit

6
00:00:13,669 --> 00:00:11,120
early

7
00:00:15,910 --> 00:00:13,679
so that we can give everyone their full

8
00:00:18,710 --> 00:00:15,920
10-minute slots we're trying a slightly

9
00:00:25,830 --> 00:00:18,720
new format here so everyone has uh 10

10
00:00:29,830 --> 00:00:27,189
that's my computer so i could hear

11
00:00:31,750 --> 00:00:29,840
myself talking to myself um so we have

12
00:00:33,990 --> 00:00:31,760
10 minute slots so if you want to fill

13
00:00:35,510 --> 00:00:34,000

your your whole 10 minutes um with your

14

00:00:37,350 --> 00:00:35,520

talk that's fine if you want to leave a

15

00:00:40,389 --> 00:00:37,360

little bit for questions that's fine too

16

00:00:41,990 --> 00:00:40,399

we do have one withdrawn the fourth

17

00:00:43,510 --> 00:00:42,000

talk is withdrawn so we will have a 10

18

00:00:45,190 --> 00:00:43,520

minute slot there that we can ask

19

00:00:48,470 --> 00:00:45,200

questions in

20

00:00:51,510 --> 00:00:48,480

for anyone watching online we have uh in

21

00:00:53,350 --> 00:00:51,520

the in the vimeo thing there is a

22

00:00:54,709 --> 00:00:53,360

chat box and i will be monitoring that

23

00:00:55,990 --> 00:00:54,719

so feel free

24

00:00:57,670 --> 00:00:56,000

as the speakers are talking go ahead and

25

00:00:59,349 --> 00:00:57,680

drop your questions in there and then

26
00:01:01,029 --> 00:00:59,359
when we if we have the opportunity we

27
00:01:02,549 --> 00:01:01,039
can ask them at the end

28
00:01:04,149 --> 00:01:02,559
um so

29
00:01:05,750 --> 00:01:04,159
i think those are kind of all of the the

30
00:01:07,270 --> 00:01:05,760
technical things um and with that i'd

31
00:01:09,030 --> 00:01:07,280
like to welcome you all to our session

32
00:01:11,270 --> 00:01:09,040
on the co-evolution of the geosphere and

33
00:01:13,270 --> 00:01:11,280
biosphere and we're looking at early

34
00:01:15,510 --> 00:01:13,280
earth environments and all that that

35
00:01:18,070 --> 00:01:15,520
entails from the geochemical and

36
00:01:18,870 --> 00:01:18,080
mineralogical to the organic chemistry

37
00:01:20,710 --> 00:01:18,880
and

38
00:01:22,950 --> 00:01:20,720

the biology that goes into that which i

39

00:01:26,149 --> 00:01:22,960

think is really a testament to how

40

00:01:27,910 --> 00:01:26,159

truly complex these systems are and i i

41

00:01:30,230 --> 00:01:27,920

love doing sessions like this because we

42

00:01:33,109 --> 00:01:30,240

can get this holistic uh overview of

43

00:01:34,469 --> 00:01:33,119

this so this is our last last portion of

44

00:01:36,230 --> 00:01:34,479

this session

45

00:01:38,310 --> 00:01:36,240

we had an online session yesterday that

46

00:01:40,789 --> 00:01:38,320

you can go check out and is available on

47

00:01:42,870 --> 00:01:40,799

demand online so you can all go see that

48

00:01:44,950 --> 00:01:42,880

if you'd like and without further ado

49

00:01:47,109 --> 00:01:44,960

i'd like to uh invite our first speaker

50

00:01:47,910 --> 00:01:47,119

to come up and that is nicole zellner

51

00:01:50,149 --> 00:01:47,920

and

52

00:01:52,550 --> 00:01:50,159

i thought she was great to start us off

53

00:01:55,510 --> 00:01:52,560

um because she's talking about uh

54

00:01:57,590 --> 00:01:55,520

earth's first billion years maybe not so

55

00:02:02,469 --> 00:01:57,600

hadeen after all so

56

00:02:05,429 --> 00:02:04,550

thank you shauna

57

00:02:07,109 --> 00:02:05,439

so

58

00:02:08,309 --> 00:02:07,119

we all know that lots of interesting

59

00:02:11,190 --> 00:02:08,319

things were happening in the first

60

00:02:12,949 --> 00:02:11,200

billion years and i'm going to provide

61

00:02:14,869 --> 00:02:12,959

somewhat of an overview of some

62

00:02:16,630 --> 00:02:14,879

different scientific reports from

63

00:02:18,630 --> 00:02:16,640

different scientific disciplines and i

64

00:02:20,630 --> 00:02:18,640

invite us all to have a discussion about

65

00:02:22,630 --> 00:02:20,640

how to reconcile some of these

66

00:02:24,949 --> 00:02:22,640

conflicting results that have been

67

00:02:26,630 --> 00:02:24,959

reported

68

00:02:27,990 --> 00:02:26,640

in particular because i'm coming from

69

00:02:30,630 --> 00:02:28,000

the impact

70

00:02:33,190 --> 00:02:30,640

side of these investigations i study

71

00:02:35,270 --> 00:02:33,200

lunar impact glasses to understand what

72

00:02:37,350 --> 00:02:35,280

the impact flux is like in the in our

73

00:02:39,509 --> 00:02:37,360

solar system i'm particularly interested

74

00:02:41,750 --> 00:02:39,519

in what we know about that impact impact

75

00:02:43,990 --> 00:02:41,760

flux and whether or not it really

76

00:02:47,190 --> 00:02:44,000

induced any kind of impact frustration

77

00:02:49,509 --> 00:02:47,200

or sterilization to the origin of life

78

00:02:51,750 --> 00:02:49,519

so as a reminder this is a summary that

79

00:02:54,309 --> 00:02:51,760

shows the four different scenarios that

80

00:02:57,589 --> 00:02:54,319

we have adopted over the last

81

00:02:59,509 --> 00:02:57,599

40 50 decades to try to understand what

82

00:03:01,509 --> 00:02:59,519

that impact flux looks like in the inner

83

00:03:03,589 --> 00:03:01,519

solar system whether or not it was a

84

00:03:06,630 --> 00:03:03,599

smooth decline which is what we would

85

00:03:08,470 --> 00:03:06,640

expect for planetary systems that are

86

00:03:10,630 --> 00:03:08,480

forming during final accretion and sweep

87

00:03:12,630 --> 00:03:10,640

up of planetesimals whether or not there

88

00:03:13,990 --> 00:03:12,640

was something called the cataclysm which

89

00:03:15,990 --> 00:03:14,000

is now known as the late heavy

90

00:03:18,229 --> 00:03:16,000

bombardment that may have occurred

91

00:03:20,309 --> 00:03:18,239

around 3.9 billion years ago and caused

92

00:03:21,830 --> 00:03:20,319

a bottleneck in what we think might have

93

00:03:25,030 --> 00:03:21,840

been the origin of life or if it was

94

00:03:26,949 --> 00:03:25,040

some combination of the of the the two

95

00:03:28,869 --> 00:03:26,959

and understanding what this impact flux

96

00:03:30,789 --> 00:03:28,879

is is important because of these really

97

00:03:32,390 --> 00:03:30,799

interesting biological and geological

98

00:03:33,830 --> 00:03:32,400

events that we now know were happening

99

00:03:35,830 --> 00:03:33,840

on the early earth

100

00:03:38,550 --> 00:03:35,840

including a cool early earth with land

101
00:03:40,149 --> 00:03:38,560
masses and water around 4.3 to 4.4

102
00:03:42,630 --> 00:03:40,159
billion years ago

103
00:03:45,910 --> 00:03:42,640
carbon isotopic evidence for first life

104
00:03:48,070 --> 00:03:45,920
around 3.9 or 3.85 billion years ago and

105
00:03:50,550 --> 00:03:48,080
finally uncontested evidence for fossils

106
00:03:52,070 --> 00:03:50,560
somewhere around 3.5 billion years ago

107
00:03:53,509 --> 00:03:52,080
and trying to reconcile all these

108
00:03:54,710 --> 00:03:53,519
different data sets becomes really

109
00:03:56,789 --> 00:03:54,720
important for understanding the

110
00:04:00,070 --> 00:03:56,799
conditions of what

111
00:04:01,910 --> 00:04:00,080
that were occurring on our early earth

112
00:04:04,710 --> 00:04:01,920
i'd like to remind people that we have

113
00:04:06,470 --> 00:04:04,720

lots and lots of lunar data both in the

114

00:04:08,949 --> 00:04:06,480

apollo sample collection and now the

115

00:04:10,229 --> 00:04:08,959

chinese sample collection as well as

116

00:04:11,910 --> 00:04:10,239

orbital data from the lunar

117

00:04:14,229 --> 00:04:11,920

reconnaissance orbiter and other

118

00:04:16,629 --> 00:04:14,239

spacecraft that are allowing us to have

119

00:04:18,390 --> 00:04:16,639

more refined and constrained

120

00:04:20,069 --> 00:04:18,400

measurements of the lunar surface and

121

00:04:23,909 --> 00:04:20,079

the samples that were collected from the

122

00:04:26,390 --> 00:04:23,919

surface and on the left hand side of the

123

00:04:28,469 --> 00:04:26,400

screen here you'll see the relative

124

00:04:31,270 --> 00:04:28,479

tentative ages that have been assigned

125

00:04:33,430 --> 00:04:31,280

to the largest lunar impact basins on

126

00:04:35,510 --> 00:04:33,440

the moon we use the moon as a proxy for

127

00:04:37,909 --> 00:04:35,520

understanding the impact rate in on the

128

00:04:39,670 --> 00:04:37,919

earth because the earth has an

129

00:04:41,670 --> 00:04:39,680

atmosphere plate tectonics and water and

130

00:04:42,390 --> 00:04:41,680

has erased a lot of the oldest evidence

131

00:04:44,070 --> 00:04:42,400

for

132

00:04:46,629 --> 00:04:44,080

impacts the moon on the other hand

133

00:04:48,390 --> 00:04:46,639

preserves them and so by this large

134

00:04:50,390 --> 00:04:48,400

range of ages that you can see assigned

135

00:04:53,270 --> 00:04:50,400

to these nearside impact basins you can

136

00:04:55,830 --> 00:04:53,280

see that this idea of a lunar cataclysm

137

00:04:57,430 --> 00:04:55,840

wherein all of these large impact basins

138

00:04:59,749 --> 00:04:57,440

were proposed to have been formed in a

139

00:05:02,710 --> 00:04:59,759

very narrow time period probably isn't

140

00:05:06,790 --> 00:05:04,469

we also now have evidence in the

141

00:05:10,710 --> 00:05:06,800

terrestrial record for a tailing off of

142

00:05:13,749 --> 00:05:10,720

impacts over the last uh

143

00:05:17,510 --> 00:05:13,759

3.2 to 3.4 or so billion years after the

144

00:05:19,350 --> 00:05:17,520

solar system formed these were

145

00:05:21,510 --> 00:05:19,360

impact spherule layers that are found in

146

00:05:23,590 --> 00:05:21,520

some of the oldest terrains in south

147

00:05:25,749 --> 00:05:23,600

africa and australia that provide

148

00:05:28,629 --> 00:05:25,759

evidence for a decrease in bombardment

149

00:05:30,310 --> 00:05:28,639

that was pretty long lived and not a

150

00:05:31,909 --> 00:05:30,320

sharp cut off

151
00:05:34,150 --> 00:05:31,919
as you would expect in something like a

152
00:05:37,270 --> 00:05:34,160
cataclysm

153
00:05:38,870 --> 00:05:37,280
the grail orbiting spacecraft as well

154
00:05:41,590 --> 00:05:38,880
measured

155
00:05:43,510 --> 00:05:41,600
now invisible impact basins on the moon

156
00:05:44,390 --> 00:05:43,520
basins that we cannot see with the naked

157
00:05:47,510 --> 00:05:44,400
eye

158
00:05:49,110 --> 00:05:47,520
that were formed and then eroded over

159
00:05:52,550 --> 00:05:49,120
four and a half billion years of earth

160
00:05:54,469 --> 00:05:52,560
moon system history so this spacecraft

161
00:05:57,909 --> 00:05:54,479
additionally provided evidence for many

162
00:06:00,469 --> 00:05:57,919
large degraded old basins that provide

163
00:06:03,270 --> 00:06:00,479

evidence for impacts prior to 3.9

164

00:06:05,590 --> 00:06:03,280

billion years ago so before that sharp

165

00:06:07,270 --> 00:06:05,600

spike of the proposed cataclysm would

166

00:06:09,909 --> 00:06:07,280

have happened

167

00:06:11,990 --> 00:06:09,919

so again here is uh that summary of the

168

00:06:13,670 --> 00:06:12,000

four impact scenarios that have been

169

00:06:15,590 --> 00:06:13,680

proposed and i hope i've convinced you

170

00:06:17,270 --> 00:06:15,600

that the idea for the cataclysm or

171

00:06:19,590 --> 00:06:17,280

what's known as a late heavy bombardment

172

00:06:21,830 --> 00:06:19,600

in its strictest definition

173

00:06:23,029 --> 00:06:21,840

has pretty much

174

00:06:25,110 --> 00:06:23,039

been

175

00:06:27,510 --> 00:06:25,120

replaced by

176

00:06:28,950 --> 00:06:27,520

potentially a sawtooth pattern or

177

00:06:30,629 --> 00:06:28,960

something called an early intense

178

00:06:32,629 --> 00:06:30,639

bombardment or if you average out that

179

00:06:34,870 --> 00:06:32,639

early intensive environment the smooth

180

00:06:38,309 --> 00:06:34,880

decline and the smooth decline can

181

00:06:40,710 --> 00:06:38,319

actually explain the amount of highly

182

00:06:42,629 --> 00:06:40,720

citrophile elements that we see on the

183

00:06:44,550 --> 00:06:42,639

surface of the moon we don't need to

184

00:06:47,670 --> 00:06:44,560

have it delivered all at once by

185

00:06:49,670 --> 00:06:47,680

something like a cataclysm

186

00:06:51,510 --> 00:06:49,680

we do know that organic molecules have

187

00:06:53,510 --> 00:06:51,520

been delivered in prodigious amounts

188

00:06:55,270 --> 00:06:53,520

particularly in the first billion years

189

00:06:58,550 --> 00:06:55,280

of solar system history

190

00:07:00,550 --> 00:06:58,560

uh chris chiba and and others in in over

191

00:07:02,390 --> 00:07:00,560

40 years ago proposed the delivery of

192

00:07:06,070 --> 00:07:02,400

organic molecules to be somewhere on the

193

00:07:08,309 --> 00:07:06,080

order of 10 to the 11 kilograms per year

194

00:07:10,469 --> 00:07:08,319

and investigators such as

195

00:07:12,870 --> 00:07:10,479

jennifer blank ella peterson zeta

196

00:07:14,790 --> 00:07:12,880

martins vanessa mccaffrey myself have

197

00:07:17,510 --> 00:07:14,800

shown that these organic

198

00:07:20,150 --> 00:07:17,520

molecules can actually survive impact in

199

00:07:22,710 --> 00:07:20,160

particular mccaffrey at all showed that

200

00:07:24,870 --> 00:07:22,720

the glycoaldehyde which is a very simple

201
00:07:26,550 --> 00:07:24,880
sugar can deliver can be delivered and

202
00:07:28,469 --> 00:07:26,560
survive impact

203
00:07:29,749 --> 00:07:28,479
which is an important

204
00:07:32,230 --> 00:07:29,759
factor when you think about

205
00:07:34,469 --> 00:07:32,240
glycoaldehyde being necessary for the

206
00:07:37,510 --> 00:07:34,479
foremost reaction and structure

207
00:07:39,589 --> 00:07:37,520
synthesis so organic molecules can

208
00:07:40,870 --> 00:07:39,599
actually survive these very high

209
00:07:42,870 --> 00:07:40,880
intensely

210
00:07:45,749 --> 00:07:42,880
high pressure high temperature impact

211
00:07:49,029 --> 00:07:45,759
events so let's try to reconcile some of

212
00:07:51,830 --> 00:07:49,039
this evidence then remembering that the

213
00:07:53,909 --> 00:07:51,840

moon has experienced a smooth decline in

214

00:07:55,990 --> 00:07:53,919

impacts and that organic molecules can

215

00:07:58,309 --> 00:07:56,000

actually be delivered intact

216

00:07:59,909 --> 00:07:58,319

early terrestrial evidence reported by

217

00:08:01,749 --> 00:07:59,919

john valley and others at the university

218

00:08:04,070 --> 00:08:01,759

of wisconsin and other locations have

219

00:08:06,629 --> 00:08:04,080

shown that zircons preserve evidence of

220

00:08:08,230 --> 00:08:06,639

a cool early earth in the form of land

221

00:08:10,469 --> 00:08:08,240

masses and water

222

00:08:13,430 --> 00:08:10,479

potentially suggesting a hydrosphere

223

00:08:15,510 --> 00:08:13,440

around 4.3 billion years ago

224

00:08:18,070 --> 00:08:15,520

plate tectonics probably started very

225

00:08:20,710 --> 00:08:18,080

early on there was a recent report

226

00:08:22,790 --> 00:08:20,720

by drabin at all that says these plate

227

00:08:26,070 --> 00:08:22,800

tectonics were probably a global event

228

00:08:27,990 --> 00:08:26,080

as early as 3.8 billion years ago and so

229

00:08:29,909 --> 00:08:28,000

what this means is that earth's chemical

230

00:08:32,550 --> 00:08:29,919

evolution and thermal effects not to

231

00:08:34,709 --> 00:08:32,560

mention the resupply and supply of

232

00:08:36,550 --> 00:08:34,719

organic molecules from the interior have

233

00:08:38,790 --> 00:08:36,560

been largely regulated by these plate

234

00:08:41,190 --> 00:08:38,800

tectonics throughout most of earth's

235

00:08:42,790 --> 00:08:41,200

history

236

00:08:44,630 --> 00:08:42,800

one of the biggest questions that we're

237

00:08:46,070 --> 00:08:44,640

facing in the origin of life community

238

00:08:47,990 --> 00:08:46,080

is whether or not there's a reducing

239

00:08:50,070 --> 00:08:48,000

atmosphere an environment on earth or

240

00:08:52,949 --> 00:08:50,080

whether it was oxidizing

241

00:08:54,790 --> 00:08:52,959

biology prefers a reducing atmosphere

242

00:08:57,110 --> 00:08:54,800

but the geological evidence shows our

243

00:08:59,990 --> 00:08:57,120

atmosphere was probably oxidizing as

244

00:09:02,070 --> 00:09:00,000

late as early as 3.9 billion years ago

245

00:09:05,990 --> 00:09:02,080

so somehow we have to reconcile these

246

00:09:08,389 --> 00:09:06,000

really important competing ideas

247

00:09:11,030 --> 00:09:08,399

and finally when when did biogenic

248

00:09:13,430 --> 00:09:11,040

carbon when did biology actually occur

249

00:09:16,630 --> 00:09:13,440

on earth elizabeth bell and her group at

250

00:09:18,550 --> 00:09:16,640

ucla reported

251
00:09:21,630 --> 00:09:18,560
reported evidence of the presence of

252
00:09:24,710 --> 00:09:21,640
biogenic carbon in a 4.1 year old

253
00:09:26,949 --> 00:09:24,720
4.1 billion-year-old zircon and there's

254
00:09:29,750 --> 00:09:26,959
been multiple studies about isotopic

255
00:09:31,350 --> 00:09:29,760
carbon uh related to biology being

256
00:09:33,350 --> 00:09:31,360
present in sediments in some of the

257
00:09:36,230 --> 00:09:33,360
oldest sediments around the world this

258
00:09:38,310 --> 00:09:36,240
biogenic carbon proposed biogenic carbon

259
00:09:39,990 --> 00:09:38,320
has been

260
00:09:43,670 --> 00:09:40,000
published by multiple different

261
00:09:45,350 --> 00:09:43,680
investigators in multiple different labs

262
00:09:48,949 --> 00:09:45,360
we also are starting to push back

263
00:09:51,110 --> 00:09:48,959

evidence for fossilized biology as well

264

00:09:53,430 --> 00:09:51,120

some of the earliest marine

265

00:09:55,590 --> 00:09:53,440

evidence includes these fossilized

266

00:09:58,310 --> 00:09:55,600

hematite tubes that have been found in

267

00:10:01,590 --> 00:09:58,320

canada with an age of around 3.8 billion

268

00:10:02,949 --> 00:10:01,600

years and tara jock itch and her group

269

00:10:05,430 --> 00:10:02,959

have found

270

00:10:07,750 --> 00:10:05,440

pterosites in microbial palisade fabric

271

00:10:10,949 --> 00:10:07,760

which potentially could be indicative of

272

00:10:12,310 --> 00:10:10,959

terrestrial life by 3.48 billion years

273

00:10:14,630 --> 00:10:12,320

ago

274

00:10:15,509 --> 00:10:14,640

so what i've done here now is uh showed

275

00:12:25,670 --> 00:10:15,519

a

276

00:12:28,470 --> 00:12:25,680

um but this doesn't um

277

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

sorry let me find the word um

278

00:12:33,030 --> 00:12:30,880

this doesn't mean that um

279

00:12:34,150 --> 00:12:33,040

a audience of life in the

280

00:12:40,389 --> 00:12:34,160

in the

281

00:12:42,870 --> 00:12:40,399

right so it really doesn't uh

282

00:12:44,310 --> 00:12:42,880

delete that or

283

00:12:46,949 --> 00:12:44,320

it is

284

00:12:49,030 --> 00:12:46,959

um i don't think that would

285

00:12:51,190 --> 00:12:49,040

mean that the low t

286

00:12:53,110 --> 00:12:51,200

oriented of life would be

287

00:12:55,190 --> 00:12:53,120

the most probable because you would have

288

00:12:58,550 --> 00:12:55,200

anyway this

289

00:13:01,269 --> 00:12:58,560

a deep ocean uh volcanoes where

290

00:13:03,110 --> 00:13:01,279

it could happen too sure right i mean we

291

00:13:05,110 --> 00:13:03,120

talk a lot about these um deep ocean

292

00:13:06,389 --> 00:13:05,120

hydrothermal vents um so we think about

293

00:13:07,750 --> 00:13:06,399

a high temperature

294

00:13:09,509 --> 00:13:07,760

environment where those reducing

295

00:13:10,870 --> 00:13:09,519

molecules have been erupted from the

296

00:13:12,949 --> 00:13:10,880

interior of the earth but there

297

00:13:14,710 --> 00:13:12,959

certainly is a temperature gradient

298

00:13:17,269 --> 00:13:14,720

around those hydrothermal vents where

299

00:13:19,509 --> 00:13:17,279

the temperature could get cooler or does

300

00:13:22,230 --> 00:13:19,519

get cooler and molecules could

301

00:13:23,670 --> 00:13:22,240

additionally form in um simple life

302

00:13:28,870 --> 00:13:23,680

could additionally form in those kinds

303

00:13:28,880 --> 00:13:32,949

thank you okay thank you

304

00:13:38,470 --> 00:13:35,430

thank you so much nicole that was an

305

00:13:40,069 --> 00:13:38,480

awesome talk and so next we have up uh

306

00:13:42,069 --> 00:13:40,079

monica fedori and so we're going to

307

00:13:44,150 --> 00:13:42,079

continue talking about

308

00:13:45,590 --> 00:13:44,160

impacts and i'm i'm looking forward to

309

00:13:47,269 --> 00:13:45,600

this one because i think this should be

310

00:13:49,829 --> 00:13:47,279

fun i'm looking forward to all of them

311

00:13:52,790 --> 00:13:49,839

to be clear but um

312

00:13:57,590 --> 00:13:52,800

all right it's taking a second

313

00:13:57,600 --> 00:14:03,189

okay here we go thank you monica

314

00:14:07,269 --> 00:14:04,630

it's britney

315

00:14:09,189 --> 00:14:07,279

[Music]

316

00:14:10,550 --> 00:14:09,199

what's up y'all i'm monica from sanford

317

00:14:12,550 --> 00:14:10,560

and i'm going to be talking about how

318

00:14:14,150 --> 00:14:12,560

impact events influence the water and

319

00:14:16,470 --> 00:14:14,160

the atmosphere in the late hadean and

320

00:14:17,990 --> 00:14:16,480

early archaean so let's get into it this

321

00:14:19,189 --> 00:14:18,000

is usually the common picture that's

322

00:14:20,629 --> 00:14:19,199

painted when people think about the

323

00:14:22,629 --> 00:14:20,639

hadian right it literally comes from the

324

00:14:24,550 --> 00:14:22,639

word hades and so everybody thinks like

325

00:14:26,470 --> 00:14:24,560

hell you know volcanoes going off the

326

00:14:28,230 --> 00:14:26,480

floor is lava all that good stuff but as

327

00:14:30,389 --> 00:14:28,240

nicole was talking about in your fantasy

328

00:14:32,389 --> 00:14:30,399

talk it likely wasn't like that

329

00:14:33,750 --> 00:14:32,399

we can look at titanium in these zircons

330

00:14:35,670 --> 00:14:33,760

these tiny little minerals that are

331

00:14:37,509 --> 00:14:35,680

about barely the width of a human hair

332

00:14:38,710 --> 00:14:37,519

and these tell us that the melting

333

00:14:40,230 --> 00:14:38,720

temperatures of the rocks during this

334

00:14:42,150 --> 00:14:40,240

time period were a lot lower than we

335

00:14:43,269 --> 00:14:42,160

think and so water was probably the big

336

00:14:44,790 --> 00:14:43,279

culprit here and i'm not just talking

337

00:14:46,230 --> 00:14:44,800

about like little puddles of water there

338

00:14:47,269 --> 00:14:46,240

probably could have been like oceans at

339

00:14:49,269 --> 00:14:47,279

this point

340

00:14:50,949 --> 00:14:49,279

so this time period probably looked a

341

00:14:53,269 --> 00:14:50,959

little bit more something like this um

342

00:14:55,189 --> 00:14:53,279

however despite this image if an alien

343

00:14:56,870 --> 00:14:55,199

observer was also looking for oxygen in

344

00:14:58,470 --> 00:14:56,880

the atmosphere they may have concluded

345

00:15:00,389 --> 00:14:58,480

that the earth was inhabitable um

346

00:15:02,069 --> 00:15:00,399

because there wasn't any oxygen but this

347

00:15:04,470 --> 00:15:02,079

wasn't really the case right life was

348

00:15:06,150 --> 00:15:04,480

already in water so

349

00:15:07,829 --> 00:15:06,160

with that let's talk about what we know

350

00:15:09,509 --> 00:15:07,839

first certain about this time period

351

00:15:11,110 --> 00:15:09,519

first share is that there were zircons

352

00:15:12,710 --> 00:15:11,120

there was already quite a bit of water

353

00:15:13,750 --> 00:15:12,720

there was negligible oxygen in the

354

00:15:15,990 --> 00:15:13,760

atmosphere

355

00:15:18,470 --> 00:15:16,000

that's about it

356

00:15:19,750 --> 00:15:18,480

and this is pretty much a big list of

357

00:15:21,829 --> 00:15:19,760

the things that we don't know this is

358

00:15:23,189 --> 00:15:21,839

not an exhaustive list but there's so so

359

00:15:25,110 --> 00:15:23,199

much we don't know about this time

360

00:15:27,189 --> 00:15:25,120

period yeah the earth has these pesky

361

00:15:29,030 --> 00:15:27,199

pesky weathering processes that uh

362

00:15:31,430 --> 00:15:29,040

pretty much all but get rid of the rock

363

00:15:32,710 --> 00:15:31,440

record during this time period but today

364

00:15:34,310 --> 00:15:32,720

um you know we want to fill in these

365

00:15:36,550 --> 00:15:34,320

missing chapters of the story right the

366

00:15:38,470 --> 00:15:36,560

story of life our story so what i'm

367

00:15:40,230 --> 00:15:38,480

going to be focusing on is the frequency

368

00:15:42,150 --> 00:15:40,240

of smaller impacts during this time

369

00:15:43,749 --> 00:15:42,160

period as well as what was in those

370

00:15:46,949 --> 00:15:43,759

impactors

371

00:15:48,949 --> 00:15:46,959

so this paper uh from martial in 2021

372

00:15:51,110 --> 00:15:48,959

says that the smaller impacts about 10

373

00:15:53,350 --> 00:15:51,120

kilometers in diameter and less were

374

00:15:54,710 --> 00:15:53,360

about 10 times more frequent than free

375

00:15:56,069 --> 00:15:54,720

previously believed in the title says

376

00:15:58,310 --> 00:15:56,079

the later km but this was proposed

377

00:16:00,150 --> 00:15:58,320

throughout the entire archean

378

00:16:01,269 --> 00:16:00,160

the reducing material from these

379

00:16:03,509 --> 00:16:01,279

impactors could have helped to keep

380

00:16:05,829 --> 00:16:03,519

oxygen low during the air key and so

381

00:16:07,509 --> 00:16:05,839

even if oxygen processes were occurring

382

00:16:09,110 --> 00:16:07,519

these impact material this impact

383

00:16:11,269 --> 00:16:09,120

material could have suppressed that

384

00:16:13,269 --> 00:16:11,279

oxygen so we want to investigate this

385

00:16:14,710 --> 00:16:13,279

further so let's look at what was in the

386

00:16:17,670 --> 00:16:14,720

impactors

387

00:16:19,350 --> 00:16:17,680

so this is our enzyme chondrite impactor

388

00:16:20,949 --> 00:16:19,360

these are inner solar system objects

389

00:16:22,470 --> 00:16:20,959

which were formed in the solar nebula

390

00:16:23,990 --> 00:16:22,480

these are high in iron so pretty

391

00:16:25,829 --> 00:16:24,000

reducing but they also brought a little

392

00:16:27,990 --> 00:16:25,839

bit of water and they are very similar

393

00:16:30,470 --> 00:16:28,000

in isotope composition to the crust and

394

00:16:32,710 --> 00:16:30,480

the mantle and so the eh just means high

395

00:16:34,150 --> 00:16:32,720

iron the el means low iron but even if

396

00:16:37,430 --> 00:16:34,160

you look at the low iron case these are

397

00:16:39,030 --> 00:16:37,440

still pretty reduced so uh the model

398

00:16:41,430 --> 00:16:39,040

that we use is called freak c it's an

399

00:16:43,269 --> 00:16:41,440

aqueous geochemistry model uh provided

400

00:16:44,870 --> 00:16:43,279

by the usgs so it is free to use if

401
00:16:46,790 --> 00:16:44,880
you're interested in um and we're going

402
00:16:49,189 --> 00:16:46,800
to use this to calculate the composition

403
00:16:51,590 --> 00:16:49,199
and the ph of the water in equilibrium

404
00:16:53,189 --> 00:16:51,600
with a post impact atmosphere

405
00:16:55,030 --> 00:16:53,199
so first we're going to give the model

406
00:16:56,949 --> 00:16:55,040
some spicy water and next we're going to

407
00:16:59,030 --> 00:16:56,959
put a post impact atmosphere that we

408
00:17:00,949 --> 00:16:59,040
took from zomliadal in 2020 we're going

409
00:17:03,350 --> 00:17:00,959
to use two bars of co2 this paper

410
00:17:04,630 --> 00:17:03,360
considers 2 and 50 bars we've also did a

411
00:17:06,309 --> 00:17:04,640
bunch of runs with other different

412
00:17:09,110 --> 00:17:06,319
levels of co2 but i'm only going to show

413
00:17:11,350 --> 00:17:09,120

you all some of the two bar stuff

414

00:17:12,630 --> 00:17:11,360

so we have three different sizes of

415

00:17:14,150 --> 00:17:12,640

impactors that we looked at and this is

416

00:17:16,630 --> 00:17:14,160

the ph of uh

417

00:17:18,789 --> 00:17:16,640

the post impact atmosphere and the spicy

418

00:17:20,949 --> 00:17:18,799

water that we used these are the masses

419

00:17:22,949 --> 00:17:20,959

of the different impactor sizes that we

420

00:17:24,549 --> 00:17:22,959

used the southpole eiken impactor is

421

00:17:26,630 --> 00:17:24,559

definitely closer in size to these

422

00:17:28,230 --> 00:17:26,640

smaller impactors that we're looking at

423

00:17:29,750 --> 00:17:28,240

for this time period but we also took a

424

00:17:31,590 --> 00:17:29,760

look at some other sizes as well to look

425

00:17:33,029 --> 00:17:31,600

at what the ph was doing and it's a

426

00:17:34,549 --> 00:17:33,039

little price it's a little surprising

427

00:17:37,190 --> 00:17:34,559

right because our water that we

428

00:17:38,630 --> 00:17:37,200

initially put in was a ph of six um

429

00:17:39,750 --> 00:17:38,640

because there's more carbon going on in

430

00:17:41,510 --> 00:17:39,760

this atmosphere so the water would have

431

00:17:43,270 --> 00:17:41,520

been a little bit more acidic but our

432

00:17:44,710 --> 00:17:43,280

results here seem pretty basic

433

00:17:46,630 --> 00:17:44,720

especially for those larger size

434

00:17:48,470 --> 00:17:46,640

impactors and at the cooler temperatures

435

00:17:49,750 --> 00:17:48,480

which is really really interesting

436

00:17:51,430 --> 00:17:49,760

something that we're also doing in

437

00:17:53,190 --> 00:17:51,440

conjunction with this again these

438

00:17:54,950 --> 00:17:53,200

results are like kind of messy at this

439

00:17:56,630 --> 00:17:54,960

point but if anyone wants to talk about

440

00:17:58,310 --> 00:17:56,640

them it's kind of just quite literally

441

00:17:59,750 --> 00:17:58,320

an excel sheet of all these rows of the

442

00:18:01,990 --> 00:17:59,760

different minerals that are

443

00:18:03,909 --> 00:18:02,000

precipitating in the water but we also

444

00:18:05,669 --> 00:18:03,919

used a mineral approximation of an

445

00:18:07,909 --> 00:18:05,679

instantite chondrite impactor in our

446

00:18:10,230 --> 00:18:07,919

freaky model my advisor was kind enough

447

00:18:11,510 --> 00:18:10,240

to share uh some of the info from her

448

00:18:13,510 --> 00:18:11,520

paper that lists out all the major

449

00:18:15,350 --> 00:18:13,520

species of these impactors and we

450

00:18:18,390 --> 00:18:15,360

equilibrated it with our post-impact

451
00:18:19,750 --> 00:18:18,400
atmosphere as well as our rain water so

452
00:18:20,710 --> 00:18:19,760
we also did that as well again i'm not

453
00:18:21,990 --> 00:18:20,720
really going to be showing you here but

454
00:18:23,430 --> 00:18:22,000
if anyone wants to discuss that i'm

455
00:18:24,789 --> 00:18:23,440
absolutely happy to

456
00:18:26,710 --> 00:18:24,799
so then we're also going to take all

457
00:18:28,390 --> 00:18:26,720
these things equilibrated over various

458
00:18:30,390 --> 00:18:28,400
volumes of water various temperatures

459
00:18:32,710 --> 00:18:30,400
various co2 concentrations all that good

460
00:18:34,549 --> 00:18:32,720
stuff and some emerging results that we

461
00:18:36,549 --> 00:18:34,559
have which are going to come very soon

462
00:18:38,549 --> 00:18:36,559
is that these highly reduced smaller

463
00:18:39,990 --> 00:18:38,559

impacts which again are maybe possibly

464

00:18:41,990 --> 00:18:40,000

you know 10 times more frequent than we

465

00:18:44,230 --> 00:18:42,000

thought could have possibly worked to

466

00:18:46,870 --> 00:18:44,240

suppress these oxidation efforts and

467

00:18:48,390 --> 00:18:46,880

subsequently oxygen as a biosignature so

468

00:18:50,630 --> 00:18:48,400

it could be that these impacts could act

469

00:18:52,310 --> 00:18:50,640

as a potential sink of oxygen during

470

00:18:55,510 --> 00:18:52,320

this time period but for now we're just

471

00:18:57,110 --> 00:18:55,520

going to look at what the water ph means

472

00:18:59,029 --> 00:18:57,120

so it results the water is not as spicy

473

00:19:01,029 --> 00:18:59,039

as we thought these larger impacts are

474

00:19:03,350 --> 00:19:01,039

probably destroying more co2 which is

475

00:19:05,029 --> 00:19:03,360

going to leave behind a higher ph um but

476

00:19:07,270 --> 00:19:05,039

why is ph really important in this case

477

00:19:08,630 --> 00:19:07,280

so a lot of weathering reactions are ph

478

00:19:10,549 --> 00:19:08,640

dependent it's these it's because of

479

00:19:12,070 --> 00:19:10,559

these weathering reactions that we don't

480

00:19:14,549 --> 00:19:12,080

have a lot of you know concrete physical

481

00:19:16,470 --> 00:19:14,559

evidence of this time period so reaction

482

00:19:18,150 --> 00:19:16,480

rates for take for example pyrite tend

483

00:19:19,990 --> 00:19:18,160

to be a little bit slower under basic

484

00:19:22,470 --> 00:19:20,000

condition and so these weathering and

485

00:19:24,390 --> 00:19:22,480

oxidation reactions might be slower

486

00:19:25,990 --> 00:19:24,400

after larger impacts so then what's that

487

00:19:28,390 --> 00:19:26,000

going to mean for oxygen growth in the

488

00:19:29,990 --> 00:19:28,400

context of more frequent smaller impacts

489

00:19:31,990 --> 00:19:30,000

but of course like i was saying there's

490

00:19:33,750 --> 00:19:32,000

more stuff to test right levels of co2

491

00:19:35,510 --> 00:19:33,760

different temperatures we are also going

492

00:19:36,789 --> 00:19:35,520

to be looking at the angle of impacts as

493

00:19:38,470 --> 00:19:36,799

well as kind of the spray from the

494

00:19:40,310 --> 00:19:38,480

ejecta that could have made it harder

495

00:19:41,430 --> 00:19:40,320

for photosynthetic organisms to you know

496

00:19:43,830 --> 00:19:41,440

do their job

497

00:19:45,830 --> 00:19:43,840

but here are my main takeaways for y'all

498

00:19:47,190 --> 00:19:45,840

the late hadean earlier kian impacts

499

00:19:48,710 --> 00:19:47,200

were tiny but mighty and they could have

500

00:19:50,470 --> 00:19:48,720

brought a lot of reducing power to the

501
00:19:52,070 --> 00:19:50,480
ancient hydrosphere and so we want to

502
00:19:54,549 --> 00:19:52,080
ask the questions are these impactors

503
00:19:56,549 --> 00:19:54,559
biosignature suppressants and then how

504
00:19:58,310 --> 00:19:56,559
do these impactors influence weathering

505
00:19:59,590 --> 00:19:58,320
reactions

506
00:20:01,270 --> 00:19:59,600
the hydrosphere is going to be the key

507
00:20:02,950 --> 00:20:01,280
to filling in these missing chapters of

508
00:20:05,270 --> 00:20:02,960
our story right we're astrobiologists we

509
00:20:06,549 --> 00:20:05,280
always follow the water and specifically

510
00:20:08,950 --> 00:20:06,559
the hydrosphere will be the key to

511
00:20:10,470 --> 00:20:08,960
thinking about how oxygen arose so later

512
00:20:12,630 --> 00:20:10,480
on in the very later key and at the

513
00:20:14,070 --> 00:20:12,640

start of the great oxidation event we

514

00:20:15,830 --> 00:20:14,080

could really benefit from a time machine

515

00:20:17,270 --> 00:20:15,840

if anyone's working on that it's really

516

00:20:18,310 --> 00:20:17,280

really hard again it's really hard to

517

00:20:19,990 --> 00:20:18,320

overstate

518

00:20:21,029 --> 00:20:20,000

how much little physical evidence we had

519

00:20:22,789 --> 00:20:21,039

but for right now we're going to work

520

00:20:24,390 --> 00:20:22,799

with that and if you're a fieldwork

521

00:20:26,470 --> 00:20:24,400

person please give me more hadees or

522

00:20:30,149 --> 00:20:26,480

cons i'd really appreciate it and with

523

00:20:33,350 --> 00:20:31,590

with that thank you all so much if i

524

00:20:34,470 --> 00:20:33,360

have time for questions i would love to

525

00:20:38,950 --> 00:20:34,480

take them and thank you all to the

526

00:20:42,230 --> 00:20:40,789

do you have time um for a question so

527

00:20:43,590 --> 00:20:42,240

please come on up to the mic if you have

528

00:20:45,350 --> 00:20:43,600

a question i would also just like to

529

00:20:48,870 --> 00:20:45,360

make a formal request that we include

530

00:20:51,190 --> 00:20:48,880

more brittany in our presentations so

531

00:20:53,270 --> 00:20:51,200

next time i have high expectations of

532

00:20:55,270 --> 00:20:53,280

everyone so yes we have a question here

533

00:20:57,430 --> 00:20:55,280

hi my name's matt i'm also from stanford

534

00:20:59,750 --> 00:20:57,440

i think you know me i think so

535

00:21:01,750 --> 00:20:59,760

uh so actually so uh you mentioned uh

536

00:21:03,350 --> 00:21:01,760

they're sort of the late sort of roughly

537

00:21:05,590 --> 00:21:03,360

around the great oxidation event i was

538

00:21:07,590 --> 00:21:05,600

wondering what the impact rates at that

539

00:21:09,990 --> 00:21:07,600

time are estimated to be and whether or

540

00:21:11,270 --> 00:21:10,000

not this could be a source of oxygen

541

00:21:13,430 --> 00:21:11,280

suppressants

542

00:21:15,430 --> 00:21:13,440

before the great oxidation event yeah

543

00:21:17,590 --> 00:21:15,440

yeah great question um so it's not

544

00:21:18,789 --> 00:21:17,600

really known what the impactor rates

545

00:21:20,950 --> 00:21:18,799

were during this time period it's

546

00:21:22,549 --> 00:21:20,960

definitely believed that as the archaean

547

00:21:24,149 --> 00:21:22,559

and specifically the archaean went on

548

00:21:25,590 --> 00:21:24,159

through time that the impact rates

549

00:21:27,510 --> 00:21:25,600

decreased and decreased we don't really

550

00:21:29,669 --> 00:21:27,520

know by like the factor or like you know

551
00:21:31,190 --> 00:21:29,679
what was happening there um but overall

552
00:21:32,789 --> 00:21:31,200
the impactors were definitely less

553
00:21:34,710 --> 00:21:32,799
frequent as you get later on into the

554
00:21:35,990 --> 00:21:34,720
archaean um but again the issue is you

555
00:21:37,510 --> 00:21:36,000
know how frequent and what were the

556
00:21:39,430 --> 00:21:37,520
sizes of these impactors you know all

557
00:21:41,510 --> 00:21:39,440
that good stuff so yeah it's still still

558
00:21:43,830 --> 00:21:41,520
not really well known

559
00:21:45,110 --> 00:21:43,840
thank you awesome thank you so much yeah

560
00:21:47,270 --> 00:21:45,120
i was wondering how do you think when

561
00:21:48,870 --> 00:21:47,280
they're so small and so you know how do

562
00:21:50,230 --> 00:21:48,880
you figure out um what was going on

563
00:21:52,630 --> 00:21:50,240

there i think that's a really tough

564

00:21:54,130 --> 00:21:52,640

problem um so let's thank uh monica

565

00:21:57,270 --> 00:21:54,140

again

566

00:21:58,950 --> 00:21:57,280

[Applause]

567

00:22:02,630 --> 00:21:58,960

and next up we're staying in the

568

00:22:05,029 --> 00:22:02,640

archaean and we have uh nathan yee uh

569

00:22:08,549 --> 00:22:05,039

from rutgers coming to talk to us

570

00:22:11,430 --> 00:22:08,559

about uh anoxic photochemical

571

00:22:14,549 --> 00:22:11,440

uh reactions and pyrite in the archaean

572

00:22:17,029 --> 00:22:14,559

thank you nathan thank you shauna

573

00:22:20,870 --> 00:22:19,029

okay so i'm going to present a paper

574

00:22:23,110 --> 00:22:20,880

entitled anoxic photochemical weathering

575

00:22:25,750 --> 00:22:23,120

of pyrite our key incontinence

576

00:22:28,149 --> 00:22:25,760

uh postdoc chihuahua and phd student

577

00:22:30,950 --> 00:22:28,159

winnie liu were co-first authors of this

578

00:22:36,630 --> 00:22:34,070

so our research is motivated by our

579

00:22:38,549 --> 00:22:36,640

interest in the biology of sulfur sulfur

580

00:22:39,669 --> 00:22:38,559

is an essential element of all living

581

00:22:42,630 --> 00:22:39,679

things

582

00:22:45,029 --> 00:22:42,640

it's found in the amino acids cysteine

583

00:22:47,510 --> 00:22:45,039

and in methionine

584

00:22:48,710 --> 00:22:47,520

and in these amino acids sulfur plays

585

00:22:51,029 --> 00:22:48,720

numerous

586

00:22:52,630 --> 00:22:51,039

critical biological functions

587

00:22:55,350 --> 00:22:52,640

including the maintenance of redox

588

00:22:57,669 --> 00:22:55,360

homeostasis the formation of disulfide

589

00:22:59,830 --> 00:22:57,679

bonds and protein structure in

590

00:23:02,149 --> 00:22:59,840

cross-linking the binding of metal

591

00:23:05,830 --> 00:23:02,159

cofactors and electron transfer

592

00:23:10,470 --> 00:23:07,750

so cysteine and methionine are

593

00:23:13,590 --> 00:23:10,480

synthesized inside the cell via a

594

00:23:16,950 --> 00:23:13,600

simulatory sulfate reduction

595

00:23:19,590 --> 00:23:16,960

so all living things have not all all

596

00:23:22,789 --> 00:23:19,600

three domains of life have evolved

597

00:23:25,430 --> 00:23:22,799

biological pathways to assimilate

598

00:23:27,990 --> 00:23:25,440

dissolves sulfate in the environment and

599

00:23:30,789 --> 00:23:28,000

incorporate it into the cell for the

600

00:23:34,310 --> 00:23:30,799

synthesis of these two amino acids

601
00:23:37,669 --> 00:23:34,320
so since sulfate is imported into the

602
00:23:40,390 --> 00:23:37,679
cell via very specific membrane bound

603
00:23:42,549 --> 00:23:40,400
transporters and is activated to

604
00:23:44,149 --> 00:23:42,559
adenosine phosphosulfate which is then

605
00:23:45,750 --> 00:23:44,159
converted to phospho-adenosine

606
00:23:48,149 --> 00:23:45,760
phosphosulfate

607
00:23:50,630 --> 00:23:48,159
then reduced via sulfite to hydrogen

608
00:23:53,350 --> 00:23:50,640
sulfide which is then incorporated into

609
00:23:57,110 --> 00:23:53,360
amino acids via the action of cysteine

610
00:24:01,029 --> 00:23:58,630
so our

611
00:24:02,830 --> 00:24:01,039
interest is understanding the sources of

612
00:24:06,789 --> 00:24:02,840
sulfate on the early

613
00:24:08,630 --> 00:24:06,799

earth so pyrite is the most abundant

614

00:24:10,390 --> 00:24:08,640

sulfide mineral in the earth's crust and

615

00:24:11,590 --> 00:24:10,400

the principle source of sulfur to the

616

00:24:14,070 --> 00:24:11,600

geosphere

617

00:24:16,950 --> 00:24:14,080

and our hypothesis is that the chemical

618

00:24:19,350 --> 00:24:16,960

breakdown of pyrite and the production

619

00:24:22,470 --> 00:24:19,360

of sulfate on the early earth was

620

00:24:24,630 --> 00:24:22,480

mediated by photochemical reactions with

621

00:24:26,390 --> 00:24:24,640

dissolved ferrous iron in ferruginous

622

00:24:28,549 --> 00:24:26,400

waters

623

00:24:30,549 --> 00:24:28,559

because the earth had an ozone-free

624

00:24:31,750 --> 00:24:30,559

stratosphere at this time ultraviolet

625

00:24:34,470 --> 00:24:31,760

light could penetrate through the

626
00:24:37,269 --> 00:24:34,480
atmosphere and interact with dissolved

627
00:24:40,470 --> 00:24:37,279
ferrous iron in surface waters

628
00:24:43,190 --> 00:24:40,480
this is a high quantum yield reaction

629
00:24:44,630 --> 00:24:43,200
where ferrous iron is photo-oxidized to

630
00:24:49,590 --> 00:24:44,640
ferric iron

631
00:24:51,269 --> 00:24:49,600
react with pyritic sulfur

632
00:24:55,190 --> 00:24:51,279
to oxidize

633
00:24:57,350 --> 00:24:55,200
sulfide minerals to form sulfate

634
00:24:59,590 --> 00:24:57,360
sulfate production river sediments could

635
00:25:02,789 --> 00:24:59,600
then be transported to the oceans where

636
00:25:04,789 --> 00:25:02,799
sulfate was assimilated by the biosphere

637
00:25:06,710 --> 00:25:04,799
this chemical reaction also produces

638
00:25:08,470 --> 00:25:06,720

lots of acid

639

00:25:10,390 --> 00:25:08,480

and releases ferrous iron from the

640

00:25:12,710 --> 00:25:10,400

pyrite structure which could then be

641

00:25:15,430 --> 00:25:12,720

re-oxidized to continuously

642

00:25:17,269 --> 00:25:15,440

continually sustain this reaction

643

00:25:18,630 --> 00:25:17,279

so to test this photochemical weathering

644

00:25:21,990 --> 00:25:18,640

hypothesis we constructed an

645

00:25:23,110 --> 00:25:22,000

experimental setup where we placed a uv

646

00:25:26,070 --> 00:25:23,120

lamp

647

00:25:29,669 --> 00:25:26,080

in the center surrounded by six uv

648

00:25:32,230 --> 00:25:29,679

transparent quartz reaction vessels

649

00:25:34,149 --> 00:25:32,240

we suspended crushed pyrite grains in

650

00:25:35,510 --> 00:25:34,159

deoxygenated solutions of ferrous

651
00:25:37,990 --> 00:25:35,520
chloride

652
00:25:39,750 --> 00:25:38,000
we capped and crimped these reaction

653
00:25:41,430 --> 00:25:39,760
vessels purged with nitrogen and

654
00:25:43,350 --> 00:25:41,440
conducted all these experiments under

655
00:25:44,870 --> 00:25:43,360
strict anoxic conditions

656
00:25:46,789 --> 00:25:44,880
we turned on the light and then we

657
00:25:49,269 --> 00:25:46,799
sampled the headspace for a change to

658
00:25:51,190 --> 00:25:49,279
observe changes in the gas phase

659
00:25:53,190 --> 00:25:51,200
sample the aqueous phase as well as the

660
00:25:55,590 --> 00:25:53,200
salts phases to track the mineral

661
00:25:57,510 --> 00:25:55,600
transformation reactions

662
00:25:59,750 --> 00:25:57,520
and this is what we observed

663
00:26:00,870 --> 00:25:59,760

in our dark control experiments we

664

00:26:03,830 --> 00:26:00,880

observed

665

00:26:07,750 --> 00:26:03,840

no change in sulfate over time

666

00:26:10,390 --> 00:26:07,760

and no change in ph over time

667

00:26:13,110 --> 00:26:10,400

but when we turned on the lamp we saw an

668

00:26:15,909 --> 00:26:13,120

enormous amount of sulfate being formed

669

00:26:18,070 --> 00:26:15,919

up to two millimolars of sulfate in

670

00:26:20,549 --> 00:26:18,080

aqueous solution after a couple weeks

671

00:26:22,789 --> 00:26:20,559

and this was concurrent to acidification

672

00:26:24,549 --> 00:26:22,799

of the waters

673

00:26:26,070 --> 00:26:24,559

to test the geological significance of

674

00:26:27,190 --> 00:26:26,080

this reaction we repeated the

675

00:26:29,390 --> 00:26:27,200

experiments

676
00:26:31,510 --> 00:26:29,400
with this archaean rock sample this is a

677
00:26:34,310 --> 00:26:31,520
2.65 year old

678
00:26:36,549 --> 00:26:34,320
pyritic shale collected from the arroyo

679
00:26:38,549 --> 00:26:36,559
formation in western australia

680
00:26:41,110 --> 00:26:38,559
we crushed the top two thirds of this

681
00:26:42,070 --> 00:26:41,120
sample which contained pyrite nodules at

682
00:26:43,990 --> 00:26:42,080
the top

683
00:26:45,430 --> 00:26:44,000
and finally disseminated

684
00:26:48,789 --> 00:26:45,440
pyrite grains

685
00:26:52,070 --> 00:26:50,549
and we observed the same thing in the

686
00:26:54,710 --> 00:26:52,080
dark controls there was no sulfate

687
00:26:56,870 --> 00:26:54,720
production no change in ph

688
00:26:58,070 --> 00:26:56,880

when we irradiated this pyrite

689

00:26:59,350 --> 00:26:58,080

suspension

690

00:27:02,390 --> 00:26:59,360

we produced

691

00:27:05,430 --> 00:27:02,400

sulfate concurrent to a decrease in

692

00:27:09,909 --> 00:27:07,909

we also tracked the mobilization and

693

00:27:11,590 --> 00:27:09,919

release of transition metals and shown

694

00:27:13,190 --> 00:27:11,600

here is the copper data

695

00:27:15,269 --> 00:27:13,200

so in the dark controls there was no

696

00:27:17,269 --> 00:27:15,279

release of copper from

697

00:27:19,350 --> 00:27:17,279

either the pyrite experiment or the

698

00:27:22,070 --> 00:27:19,360

archaeal shale experiment but in both

699

00:27:24,470 --> 00:27:22,080

these experiments when we irradiated

700

00:27:25,750 --> 00:27:24,480

the samples with ultraviolet light

701
00:27:27,430 --> 00:27:25,760
we saw

702
00:27:29,990 --> 00:27:27,440
large amounts of copper being released

703
00:27:31,590 --> 00:27:30,000
into this in the aqueous phase

704
00:27:33,350 --> 00:27:31,600
and we think this might have been an

705
00:27:34,789 --> 00:27:33,360
important reaction for

706
00:27:39,110 --> 00:27:34,799
the release of transition metals

707
00:27:42,870 --> 00:27:40,630
so uh

708
00:27:44,789 --> 00:27:42,880
my former postdoc geo ohio is now a

709
00:27:45,990 --> 00:27:44,799
faculty member

710
00:27:47,350 --> 00:27:46,000
in the university of science and

711
00:27:49,990 --> 00:27:47,360
technology

712
00:27:52,870 --> 00:27:50,000
of china constructed a photo geochemical

713
00:27:54,470 --> 00:27:52,880

model to test how much sulfate could

714

00:27:56,310 --> 00:27:54,480

have been formed

715

00:27:57,590 --> 00:27:56,320

by this photochemical weathering

716

00:27:59,430 --> 00:27:57,600

mechanism

717

00:28:02,710 --> 00:27:59,440

so what he found was that sulfate

718

00:28:05,669 --> 00:28:02,720

production increased over time

719

00:28:08,070 --> 00:28:05,679

as the continents formed throughout the

720

00:28:11,269 --> 00:28:08,080

archaeon eon

721

00:28:12,789 --> 00:28:11,279

this is the the dashboard line shows the

722

00:28:15,830 --> 00:28:12,799

estimated amount

723

00:28:16,950 --> 00:28:15,840

of sulfate production during riverine

724

00:28:19,029 --> 00:28:16,960

weathering

725

00:28:20,549 --> 00:28:19,039

this envelope represents the uncertainty

726

00:28:22,149 --> 00:28:20,559

in this calculation and there was large

727

00:28:23,590 --> 00:28:22,159

uncertainties associated with the

728

00:28:25,510 --> 00:28:23,600

physical

729

00:28:28,389 --> 00:28:25,520

crustal erosion rates and pyrite

730

00:28:30,149 --> 00:28:28,399

transport times but we think that this

731

00:28:33,590 --> 00:28:30,159

photochemical weathering mechanism could

732

00:28:36,470 --> 00:28:33,600

have produced as much uh sulfate as

733

00:28:38,630 --> 00:28:36,480

volcanic outgassing

734

00:28:39,750 --> 00:28:38,640

okay so to quickly summarize three

735

00:28:41,990 --> 00:28:39,760

things

736

00:28:44,710 --> 00:28:42,000

uh one is ultraviolet can chemically

737

00:28:47,590 --> 00:28:44,720

break down pyrite two this reaction

738

00:28:48,950 --> 00:28:47,600

doesn't require any atmospheric oxygen

739

00:28:51,909 --> 00:28:48,960

and three

740

00:28:53,430 --> 00:28:51,919

the amount of land exposed to sunlight

741

00:28:55,350 --> 00:28:53,440

could have been a major factor

742

00:28:58,549 --> 00:28:55,360

contributing the amount of sulfate

743

00:29:00,870 --> 00:28:58,559

delivered to the early oceans that i

744

00:29:03,029 --> 00:29:00,880

thank the nasa astro

745

00:29:05,350 --> 00:29:03,039

nasa astrobiology institute and the nasa

746

00:29:07,430 --> 00:29:05,360

exobiology program funding as well as

747

00:29:17,430 --> 00:29:07,440

the national science foundation thank

748

00:29:21,190 --> 00:29:18,789

uh we have some time for questions so go

749

00:29:23,430 --> 00:29:21,200

ahead sean thompson goldman nasa goddard

750

00:29:25,269 --> 00:29:23,440

space flight center um does this process

751

00:29:27,590 --> 00:29:25,279

also work regardless of the source of

752

00:29:29,830 --> 00:29:27,600

the iron oxides in other words if it was

753

00:29:32,470 --> 00:29:29,840

iron oxidizing bacteria producing them

754

00:29:34,230 --> 00:29:32,480

would this would this process still work

755

00:29:36,789 --> 00:29:34,240

more or less the same way

756

00:29:38,389 --> 00:29:36,799

right so i think your question is could

757

00:29:41,029 --> 00:29:38,399

microorganisms

758

00:29:42,789 --> 00:29:41,039

oxidize ferrous iron to ferric iron and

759

00:29:44,870 --> 00:29:42,799

with this ferric iron still chemically

760

00:29:47,430 --> 00:29:44,880

react uh with

761

00:29:48,710 --> 00:29:47,440

the pyrite and that's definitely yes

762

00:29:50,389 --> 00:29:48,720

so um

763

00:29:52,149 --> 00:29:50,399

one thing i should mention is that these

764

00:29:55,590 --> 00:29:52,159

reactions as mentioned in the earlier

765

00:30:00,310 --> 00:29:55,600

talk is strongly dependent on ph

766

00:30:02,870 --> 00:30:01,510

sulfur cycle

767

00:30:04,870 --> 00:30:02,880

that under

768

00:30:05,990 --> 00:30:04,880

acidic conditions

769

00:30:08,470 --> 00:30:06,000

there are

770

00:30:10,870 --> 00:30:08,480

iron oxidizing bacteria that oxidize

771

00:30:13,510 --> 00:30:10,880

ferrous iron to ferric iron that drive

772

00:30:16,230 --> 00:30:13,520

this chemical process but those uh

773

00:30:19,269 --> 00:30:16,240

chemolithotrophs are arrows so they

774

00:30:24,310 --> 00:30:19,279

actually need oxygen for the respiration

775

00:30:26,549 --> 00:30:24,320

to catalyze that reaction okay thank you

776

00:30:31,029 --> 00:30:26,559

awesome so you know i want to ask about

777

00:30:32,870 --> 00:30:31,039

mars of course so what do you think um

778

00:30:35,029 --> 00:30:32,880

what do you think is going on in terms

779

00:30:36,389 --> 00:30:35,039

of is this possibly how we're getting so

780

00:30:37,909 --> 00:30:36,399

much of the iron three plus on the

781

00:30:38,950 --> 00:30:37,919

surface you think this is playing a role

782

00:30:40,630 --> 00:30:38,960

there

783

00:30:42,870 --> 00:30:40,640

um and you know we're seeing a lot of

784

00:30:44,710 --> 00:30:42,880

sulfate you know what do you do you have

785

00:30:46,389 --> 00:30:44,720

anything to say about well the large

786

00:30:48,710 --> 00:30:46,399

amount of sulfate minerals on mars is

787

00:30:49,669 --> 00:30:48,720

very intriguing and i definitely think

788

00:30:51,750 --> 00:30:49,679

that

789

00:30:53,990 --> 00:30:51,760

photochemical reactions played a role in

790

00:30:56,710 --> 00:30:54,000

sulfate formation either through the

791

00:30:57,909 --> 00:30:56,720

direct action of ultraviolet light with

792

00:31:00,710 --> 00:30:57,919

volcanic

793

00:31:03,509 --> 00:31:00,720

sulfur dioxide to disproportionate that

794

00:31:05,269 --> 00:31:03,519

that sulfur dioxide to form the sulfate

795

00:31:07,909 --> 00:31:05,279

but also potentially through an indirect

796

00:31:10,230 --> 00:31:07,919

mechanism where if light

797

00:31:12,710 --> 00:31:10,240

photo oxidizes uh pharisein to ferric

798

00:31:14,710 --> 00:31:12,720

iron then that ferrakin will chemically

799

00:31:16,870 --> 00:31:14,720

react with either elemental sulfur or

800

00:31:18,710 --> 00:31:16,880

sulfide to produce

801
00:31:19,750 --> 00:31:18,720
sulfate

802
00:31:21,830 --> 00:31:19,760
thank you and i think you have another

803
00:31:23,190 --> 00:31:21,840
question bob yeah thanks nathan that's

804
00:31:25,029 --> 00:31:23,200
really interesting earlier this

805
00:31:26,310 --> 00:31:25,039
afternoon ariel and barr gave a

806
00:31:30,789 --> 00:31:26,320
beautiful talk

807
00:31:33,350 --> 00:31:30,799
on revisiting the whiff of oxygen idea

808
00:31:34,710 --> 00:31:33,360
it seems like there's a lot of evidence

809
00:31:37,990 --> 00:31:34,720
that there were

810
00:31:39,990 --> 00:31:38,000
some something analogous to oxygen um

811
00:31:42,230 --> 00:31:40,000
certainly some kind of

812
00:31:43,909 --> 00:31:42,240
electron acceptor and i wonder whether

813
00:31:45,830 --> 00:31:43,919

sulfate

814

00:31:47,990 --> 00:31:45,840

that you described might actually be

815

00:31:48,710 --> 00:31:48,000

this this whiff that they're seeing if

816

00:31:50,149 --> 00:31:48,720

it's

817

00:31:52,710 --> 00:31:50,159

um you know you're talking about

818

00:31:54,149 --> 00:31:52,720

extremely low levels of o2 there would

819

00:31:56,470 --> 00:31:54,159

have been a lot of sulfate around and

820

00:31:57,750 --> 00:31:56,480

that seems like a much more logical

821

00:32:00,950 --> 00:31:57,760

um

822

00:32:04,310 --> 00:32:00,960

electron except

823

00:32:05,430 --> 00:32:04,320

right so um this paper uh has gone

824

00:32:08,070 --> 00:32:05,440

through a peer review as science

825

00:32:09,509 --> 00:32:08,080

advances and we got similar questions

826

00:32:10,870 --> 00:32:09,519

and i'm happy to report that the

827

00:32:13,110 --> 00:32:10,880

manuscript was finally accepted for

828

00:32:14,630 --> 00:32:13,120

publication last week

829

00:32:18,470 --> 00:32:14,640

what i want to say is that this does not

830

00:32:22,870 --> 00:32:20,710

pirate weathering it's a complementary

831

00:32:24,789 --> 00:32:22,880

mechanism and i think

832

00:32:26,950 --> 00:32:24,799

both could have been at play in the late

833

00:32:29,190 --> 00:32:26,960

archean

834

00:32:30,630 --> 00:32:29,200

though i do think this reaction may have

835

00:32:33,029 --> 00:32:30,640

played a bigger role

836

00:32:34,630 --> 00:32:33,039

prior to the evolution of oxygenic

837

00:32:37,190 --> 00:32:34,640

photosynthesis

838

00:32:39,990 --> 00:32:37,200

uh what we did do with ariel ombar's

839

00:32:41,669 --> 00:32:40,000

the recent science advances paper was uh

840

00:32:43,509 --> 00:32:41,679

we took the

841

00:32:44,789 --> 00:32:43,519

estimates of this low

842

00:32:47,430 --> 00:32:44,799

o2

843

00:32:50,070 --> 00:32:47,440

constraint that they discovered

844

00:32:52,630 --> 00:32:50,080

and tried to calculate how much sulfate

845

00:32:54,230 --> 00:32:52,640

could have been produced using this low

846

00:32:56,870 --> 00:32:54,240

o2 condition

847

00:32:58,950 --> 00:32:56,880

and we think that um in order to

848

00:33:00,870 --> 00:32:58,960

reconcile with the geological evidence

849

00:33:03,509 --> 00:33:00,880

this there must have been additional

850

00:33:06,310 --> 00:33:03,519

oxidants to weather pyrite in addition

851
00:33:08,870 --> 00:33:06,320
to to oxygen at that uh during the

852
00:33:11,269 --> 00:33:08,880
bikini on and we think ferric iron

853
00:33:14,950 --> 00:33:11,279
from these photochemical sources is a

854
00:33:18,870 --> 00:33:16,789
fantastic thank you so now we're in our

855
00:33:22,149 --> 00:33:18,880
slot um that has

856
00:33:24,149 --> 00:33:22,159
uh our withdrawn talk so we have um you

857
00:33:25,269 --> 00:33:24,159
know about eight minutes to ask any

858
00:33:26,710 --> 00:33:25,279
questions you have so if you guys just

859
00:33:28,310 --> 00:33:26,720
want to line up at the microphones we

860
00:33:30,230 --> 00:33:28,320
can do that and we'll start with um i

861
00:33:31,590 --> 00:33:30,240
have a couple of questions online and

862
00:33:33,590 --> 00:33:31,600
anyone who's listening online feel free

863
00:33:35,269 --> 00:33:33,600

to keep dropping those questions in um

864

00:33:37,190 --> 00:33:35,279

so we actually have two questions for

865

00:33:38,789 --> 00:33:37,200

nicole so maybe if you just want to come

866

00:33:40,470 --> 00:33:38,799

up to the podium that then the online

867

00:33:43,269 --> 00:33:40,480

participants can hear you

868

00:33:46,389 --> 00:33:43,279

um so the first question was um from

869

00:33:47,590 --> 00:33:46,399

maggie thompson and they asked what are

870

00:33:49,110 --> 00:33:47,600

your thoughts on the ways in which we

871

00:33:51,669 --> 00:33:49,120

can try to determine if earth's early

872

00:33:53,669 --> 00:33:51,679

atmosphere was reducing or oxidizing for

873

00:33:58,070 --> 00:33:53,679

example are there particular experiments

874

00:34:03,590 --> 00:34:01,190

so i think um some of the the modeling

875

00:34:05,269 --> 00:34:03,600

that monica described i think is is a

876

00:34:07,830 --> 00:34:05,279

good way to start that we do know that

877

00:34:09,829 --> 00:34:07,840

there have been multiple impacts from

878

00:34:12,310 --> 00:34:09,839

ents to tichondrites comets other kinds

879

00:34:14,149 --> 00:34:12,320

of asteroids and really understanding

880

00:34:17,430 --> 00:34:14,159

how that

881

00:34:19,589 --> 00:34:17,440

reaction of the impact entry temperature

882

00:34:21,430 --> 00:34:19,599

velocity the breakup of the materials

883

00:34:23,990 --> 00:34:21,440

how that could affect

884

00:34:25,589 --> 00:34:24,000

any any kind of atmosphere that that

885

00:34:29,510 --> 00:34:25,599

that existed

886

00:34:32,310 --> 00:34:29,520

under various uh compositional

887

00:34:34,869 --> 00:34:32,320

uh ranges i guess uh from fully reducing

888

00:34:37,349 --> 00:34:34,879

to fully oxidizing the terrestrial

889

00:34:39,270 --> 00:34:37,359

samples zircons

890

00:34:42,230 --> 00:34:39,280

other other materials that have been

891

00:34:44,710 --> 00:34:42,240

investigated suggest that earth's mantle

892

00:34:46,710 --> 00:34:44,720

was oxidizing and and if that material

893

00:34:48,629 --> 00:34:46,720

is coming up from

894

00:34:50,470 --> 00:34:48,639

from the surface and then be being

895

00:34:52,629 --> 00:34:50,480

incorporated into our atmosphere that's

896

00:34:54,069 --> 00:34:52,639

that's one um component that that should

897

00:34:56,230 --> 00:34:54,079

be investigated a little bit more

898

00:34:57,349 --> 00:34:56,240

closely i think too

899

00:34:59,109 --> 00:34:57,359

awesome and then we have another

900

00:35:02,550 --> 00:34:59,119

question for you um and this is from

901
00:35:04,230 --> 00:35:02,560
ricardo cabrera and he asks given that

902
00:35:05,829 --> 00:35:04,240
the moon received a huge amount of

903
00:35:08,470 --> 00:35:05,839
impactors it should have been supplied

904
00:35:09,670 --> 00:35:08,480
with organics too is there any evidence

905
00:35:12,230 --> 00:35:09,680
on that

906
00:35:14,069 --> 00:35:12,240
is jamie in the room

907
00:35:15,589 --> 00:35:14,079
so that that's a really really

908
00:35:17,589 --> 00:35:15,599
interesting question and it turns out

909
00:35:19,349 --> 00:35:17,599
that the abundance of organics that have

910
00:35:22,069 --> 00:35:19,359
been investigated in the lunar soil

911
00:35:24,069 --> 00:35:22,079
samples from apollo is negligible

912
00:35:26,230 --> 00:35:24,079
and that's because the moon doesn't have

913
00:35:27,270 --> 00:35:26,240

an atmosphere to protect the surface

914

00:35:28,230 --> 00:35:27,280

from

915

00:35:31,990 --> 00:35:28,240

any

916

00:35:35,109 --> 00:35:32,000

radiation cosmic rays solar wind all of

917

00:35:37,589 --> 00:35:35,119

that so organic materials are not well

918

00:35:39,430 --> 00:35:37,599

preserved if at all in

919

00:35:41,349 --> 00:35:39,440

in the the soil in the regolith that

920

00:35:42,870 --> 00:35:41,359

we've measured so far

921

00:35:44,790 --> 00:35:42,880

awesome thank you so much and those are

922

00:35:46,470 --> 00:35:44,800

our online questions so if anyone else

923

00:35:47,910 --> 00:35:46,480

has a question that they would like to

924

00:35:49,990 --> 00:35:47,920

ask any three of our speakers or a

925

00:35:52,150 --> 00:35:50,000

preemptive question for someone coming

926

00:35:55,589 --> 00:35:52,160

up that's fine go ahead uh actually

927

00:35:57,109 --> 00:35:55,599

based on the last question um so a lot

928

00:35:58,950 --> 00:35:57,119

of worlds in the outer solar system are

929

00:36:01,670 --> 00:35:58,960

kind of reddish because of these stolens

930

00:36:03,510 --> 00:36:01,680

which are organic compounds yet

931

00:36:04,550 --> 00:36:03,520

those are often on worlds that have no

932

00:36:05,670 --> 00:36:04,560

atmosphere

933

00:36:07,750 --> 00:36:05,680

so

934

00:36:13,030 --> 00:36:07,760

how do they survive and those organics

935

00:36:16,630 --> 00:36:15,589

i don't know the answer to that question

936

00:36:20,630 --> 00:36:16,640

um

937

00:36:22,470 --> 00:36:20,640

i don't know uh

938

00:36:25,589 --> 00:36:22,480

i i don't know that anyone's looked for

939

00:36:29,109 --> 00:36:25,599

tholens in the lunar regolith um for one

940

00:36:33,910 --> 00:36:31,270

and i don't know the chemical reaction

941

00:36:35,990 --> 00:36:33,920

to create a tholen for another so i'm i

942

00:36:39,030 --> 00:36:36,000

don't have an answer to that

943

00:36:40,390 --> 00:36:39,040

so uh steely andrew steely has commented

944

00:36:43,349 --> 00:36:40,400

online and said that there is graphite

945

00:36:45,109 --> 00:36:43,359

and graphite whiskers in lunar samples

946

00:36:47,750 --> 00:36:45,119

just fyi right

947

00:36:49,589 --> 00:36:47,760

sure um and he also says these are the

948

00:36:52,710 --> 00:36:49,599

first uh discrete carbon phases

949

00:36:56,069 --> 00:36:52,720

described on the apollo samples so he

950

00:36:57,430 --> 00:36:56,079

would know yes thank you steely um

951
00:36:59,670 --> 00:36:57,440
and and then we have another question

952
00:37:00,710 --> 00:36:59,680
here yes please yeah it's one for nathan

953
00:37:02,470 --> 00:37:00,720
um

954
00:37:04,310 --> 00:37:02,480
my understanding is people who model the

955
00:37:06,630 --> 00:37:04,320
ocean think that there are vanishingly

956
00:37:07,670 --> 00:37:06,640
low amounts of sulfate in the archaean

957
00:37:10,310 --> 00:37:07,680
ocean

958
00:37:12,069 --> 00:37:10,320
how does the model of the photo are you

959
00:37:14,550 --> 00:37:12,079
getting are you getting more than those

960
00:37:20,069 --> 00:37:14,560
low estimates with the modeling or or

961
00:37:25,190 --> 00:37:23,510
look um

962
00:37:27,349 --> 00:37:25,200
so there's been estimates of how much

963
00:37:29,510 --> 00:37:27,359

sulfate were in their key notions based

964

00:37:31,270 --> 00:37:29,520

on sulfur isotope measurements right uh

965

00:37:33,190 --> 00:37:31,280

so people have tried to calibrate uh

966

00:37:35,190 --> 00:37:33,200

using the sulfuric measurements to a

967

00:37:37,589 --> 00:37:35,200

concentration scale and we think there's

968

00:37:39,510 --> 00:37:37,599

about a thousand times less sulfate in

969

00:37:41,670 --> 00:37:39,520

the archaea oceans than there are in

970

00:37:44,069 --> 00:37:41,680

today's oceans it's around 30 micro

971

00:37:47,030 --> 00:37:44,079

molar um

972

00:37:48,550 --> 00:37:47,040

so uh even with that that amount uh

973

00:37:51,109 --> 00:37:48,560

there's still some controversy about the

974

00:37:52,470 --> 00:37:51,119

sources of that sulfate uh that

975

00:37:54,550 --> 00:37:52,480

concentration of sulfate and whether or

976

00:37:56,230 --> 00:37:54,560

not volcanic outgassing could be the

977

00:37:58,630 --> 00:37:56,240

sole contributor to

978

00:38:00,550 --> 00:37:58,640

to the uh sulfate sources one

979

00:38:03,430 --> 00:38:00,560

interesting observation by aydah stuken

980

00:38:06,390 --> 00:38:03,440

is that it looks like in the neoarkins

981

00:38:08,710 --> 00:38:06,400

the last part of the archaneon there was

982

00:38:11,829 --> 00:38:08,720

more and more um

983

00:38:14,069 --> 00:38:11,839

sulfur detected in sedimentary rocks

984

00:38:15,270 --> 00:38:14,079

um so there's been a there was a rise in

985

00:38:17,030 --> 00:38:15,280

this

986

00:38:19,190 --> 00:38:17,040

sulfate inventory in the oceans at that

987

00:38:20,870 --> 00:38:19,200

time and

988

00:38:22,790 --> 00:38:20,880

various uh

989

00:38:25,589 --> 00:38:22,800

people have invoked different

990

00:38:27,349 --> 00:38:25,599

uh ideas to explain why there was this

991

00:38:29,829 --> 00:38:27,359

increase in sulfate delivery to the

992

00:38:32,390 --> 00:38:29,839

oceans at that time one was

993

00:38:35,190 --> 00:38:32,400

the rise of atmospheric oxygen and

994

00:38:38,630 --> 00:38:35,200

another is the evolution of life on land

995

00:38:40,550 --> 00:38:38,640

to promote uh weathering and

996

00:38:41,910 --> 00:38:40,560

what we think was an important factor

997

00:38:42,790 --> 00:38:41,920

was just the fact that there was more

998

00:38:45,829 --> 00:38:42,800

land

999

00:38:48,310 --> 00:38:45,839

exposed sunlight could potentially

1000

00:38:49,990 --> 00:38:48,320

explain why there was a rise in sulfate

1001
00:38:51,910 --> 00:38:50,000
concentrations in the oceans at that

1002
00:38:54,150 --> 00:38:51,920
time well i i can't remember the numbers

1003
00:38:56,630 --> 00:38:54,160
on your graph but did you did you get to

1004
00:38:59,990 --> 00:38:56,640
modern levels of sulfur in in the ocean

1005
00:39:02,710 --> 00:39:00,000
in in the modeling at 3.2 or so or we're

1006
00:39:05,349 --> 00:39:02,720
still way short right so so we think

1007
00:39:07,270 --> 00:39:05,359
there were micro molar ranges of sulfate

1008
00:39:09,109 --> 00:39:07,280
in the oceans in the archaean

1009
00:39:10,950 --> 00:39:09,119
my experiments showed that there was

1010
00:39:12,790 --> 00:39:10,960
millimolar concentrations of sulfate

1011
00:39:18,630 --> 00:39:12,800
produced by this reaction

1012
00:39:22,790 --> 00:39:20,710
um awesome do we have any other

1013
00:39:24,390 --> 00:39:22,800

questions we have um probably time for

1014

00:39:26,829 --> 00:39:24,400

one or two more we've got three minutes

1015

00:39:29,670 --> 00:39:26,839

until our next

1016

00:39:31,430 --> 00:39:29,680

speaker if not you can i'll take a break

1017

00:39:33,510 --> 00:39:31,440

and have a sip of water i think that's

1018

00:39:40,550 --> 00:39:33,520

okay

1019

00:39:40,560 --> 00:39:43,910

just

1020

00:39:43,920 --> 00:39:47,430

yeah absolutely

1021

00:39:50,950 --> 00:39:49,190

so i have a question

1022

00:39:58,550 --> 00:39:50,960

is it

1023

00:40:02,870 --> 00:40:00,550

so um the gentleman in green from

1024

00:40:07,190 --> 00:40:02,880

stanford right you had a question i

1025

00:40:11,109 --> 00:40:09,510

so one of the things that i like to do

1026

00:40:14,470 --> 00:40:11,119

is try to reconcile all these different

1027

00:40:16,390 --> 00:40:14,480

data sets and so this is a slide that

1028

00:40:17,910 --> 00:40:16,400

i've shown in various publications that

1029

00:40:19,750 --> 00:40:17,920

shows the entire four and a half billion

1030

00:40:21,430 --> 00:40:19,760

year history of the earth and the moon

1031

00:40:22,950 --> 00:40:21,440

with some exceptions

1032

00:40:25,109 --> 00:40:22,960

so the curves that you see are actually

1033

00:40:27,430 --> 00:40:25,119

the impact fluxes that we've interpreted

1034

00:40:28,790 --> 00:40:27,440

from impact glasses lunar impact brushes

1035

00:40:31,030 --> 00:40:28,800

lunar meteorites and the asteroid

1036

00:40:32,630 --> 00:40:31,040

meteorites and then superimposed on

1037

00:40:34,710 --> 00:40:32,640

there are some of these biological and

1038

00:40:36,950 --> 00:40:34,720

geological events including that great

1039

00:40:39,829 --> 00:40:36,960

oxidation event that you asked about

1040

00:40:41,829 --> 00:40:39,839

and so you can see here that impacts as

1041

00:40:42,950 --> 00:40:41,839

inferred from the lunar and asteroidal

1042

00:40:44,230 --> 00:40:42,960

meteorite

1043

00:40:49,270 --> 00:40:44,240

inventory

1044

00:40:52,870 --> 00:40:49,280

were much reduced in that 3.5 to 2.0

1045

00:40:55,270 --> 00:40:52,880

billion year range where the goe

1046

00:40:56,309 --> 00:40:55,280

appears to to happen

1047

00:40:57,589 --> 00:40:56,319

so

1048

00:41:02,470 --> 00:40:57,599

this

1049

00:41:04,710 --> 00:41:02,480

reflects what monica described

1050

00:41:07,349 --> 00:41:04,720

that if impacts are actually suppressing

1051
00:41:08,710 --> 00:41:07,359
oxy oxygenation when you don't have

1052
00:41:11,990 --> 00:41:08,720
impacts you're going to start getting

1053
00:41:12,000 --> 00:41:18,309
awesome

1054
00:41:18,319 --> 00:41:32,630
so we can talk about it later

1055
00:41:39,430 --> 00:41:34,470
okay well i just wanted to put that out

1056
00:41:39,440 --> 00:41:43,430
oh okay

1057
00:41:48,550 --> 00:41:47,270
awesome and we are right at 3 40 um so i

1058
00:41:50,309 --> 00:41:48,560
think we can go ahead and start with our

1059
00:41:52,630 --> 00:41:50,319
next speaker and that is bob hazen from

1060
00:41:54,790 --> 00:41:52,640
the carnegie institution for science and

1061
00:41:56,069 --> 00:41:54,800
he's going to be talking to us

1062
00:41:57,750 --> 00:41:56,079
sorry click the wrong button he's going

1063
00:42:00,470 --> 00:41:57,760

to be talking to us about rare elements

1064

00:42:02,870 --> 00:42:00,480

and surface sites and rock forming

1065

00:42:06,309 --> 00:42:02,880

minerals

1066

00:42:10,870 --> 00:42:08,150

and

1067

00:42:12,309 --> 00:42:10,880

here we go in the hidden so thank you

1068

00:42:13,990 --> 00:42:12,319

bob

1069

00:42:15,670 --> 00:42:14,000

thank you so much shawna and all the

1070

00:42:17,109 --> 00:42:15,680

work i'm going to be describing was done

1071

00:42:19,349 --> 00:42:17,119

in collaboration with shauna at the

1072

00:42:21,510 --> 00:42:19,359

carnegie institution

1073

00:42:25,109 --> 00:42:21,520

so i'm really excited about talking

1074

00:42:26,870 --> 00:42:25,119

about aspects of mineralogical diversity

1075

00:42:29,270 --> 00:42:26,880

in the hidden era

1076

00:42:31,510 --> 00:42:29,280

and i have three sort of major points

1077

00:42:34,790 --> 00:42:31,520

that mineral surfaces as we all know

1078

00:42:37,030 --> 00:42:34,800

interact strongly with organic molecules

1079

00:42:38,870 --> 00:42:37,040

and one solution to problem of where

1080

00:42:41,030 --> 00:42:38,880

some of these interactions occurred has

1081

00:42:43,030 --> 00:42:41,040

to do with trace and minor elements

1082

00:42:45,030 --> 00:42:43,040

in rare minerals

1083

00:42:46,550 --> 00:42:45,040

and finally that we're going to show

1084

00:42:47,990 --> 00:42:46,560

that hidden mineralogy may have been

1085

00:42:49,990 --> 00:42:48,000

much more diverse than some of the

1086

00:42:51,829 --> 00:42:50,000

previous estimates

1087

00:42:53,510 --> 00:42:51,839

so we know minerals played essential

1088

00:42:55,750 --> 00:42:53,520

roles in the origin of life they

1089

00:42:57,030 --> 00:42:55,760

catalyzed reactions they acted as

1090

00:42:59,670 --> 00:42:57,040

scaffolding

1091

00:43:01,990 --> 00:42:59,680

they selected and concentrated molecules

1092

00:43:03,829 --> 00:43:02,000

on surfaces they were reactants they

1093

00:43:05,430 --> 00:43:03,839

were containers

1094

00:43:07,829 --> 00:43:05,440

and a lot of the work that's been

1095

00:43:09,670 --> 00:43:07,839

described recently has

1096

00:43:11,190 --> 00:43:09,680

invoked minerals in various ways and

1097

00:43:13,670 --> 00:43:11,200

some of them have invoked rather rare

1098

00:43:15,510 --> 00:43:13,680

minerals particularly the work of steve

1099

00:43:17,109 --> 00:43:15,520

benner and his group fascinating work

1100

00:43:19,750 --> 00:43:17,119

that talks about borates and

1101

00:43:22,069 --> 00:43:19,760

molybdenates some phosphorus compounds

1102

00:43:23,510 --> 00:43:22,079

i'm really sorry that tom orlando wasn't

1103

00:43:24,630 --> 00:43:23,520

here to talk about that because i think

1104

00:43:26,870 --> 00:43:24,640

there would have been

1105

00:43:27,829 --> 00:43:26,880

some overlap with what we're doing

1106

00:43:28,630 --> 00:43:27,839

and

1107

00:43:30,630 --> 00:43:28,640

we

1108

00:43:32,069 --> 00:43:30,640

in the last few years have published

1109

00:43:35,190 --> 00:43:32,079

lists of what we think might have been

1110

00:43:38,150 --> 00:43:35,200

plausible hidden minerals

1111

00:43:40,069 --> 00:43:38,160

revising those lists in various ways and

1112

00:43:41,750 --> 00:43:40,079

what we see is that the commonest

1113

00:43:43,270 --> 00:43:41,760

minerals that are invoked sulfides and

1114

00:43:45,109 --> 00:43:43,280

clay minerals and carbonates are

1115

00:43:46,790 --> 00:43:45,119

certainly there but certain other

1116

00:43:49,510 --> 00:43:46,800

minerals like borates and militates

1117

00:43:51,510 --> 00:43:49,520

would have been vanishingly rare

1118

00:43:53,190 --> 00:43:51,520

and so one solution to this problem is

1119

00:43:55,829 --> 00:43:53,200

the idea of using trace and minor

1120

00:43:58,710 --> 00:43:55,839

elements basically as dopants

1121

00:44:00,710 --> 00:43:58,720

in common rock forming minerals

1122

00:44:02,790 --> 00:44:00,720

and i think that this was there are many

1123

00:44:04,309 --> 00:44:02,800

many papers that sort of explore aspects

1124

00:44:06,950 --> 00:44:04,319

of this there was a beautiful paper this

1125

00:44:09,670 --> 00:44:06,960

morning by rachel speaks who

1126
00:44:11,990 --> 00:44:09,680
showed that the small amounts of nickel

1127
00:44:14,309 --> 00:44:12,000
in pyrite can greatly enhance the

1128
00:44:17,190 --> 00:44:14,319
metabolic rates of methanogens so that

1129
00:44:19,910 --> 00:44:17,200
type of discovery i think points to the

1130
00:44:21,990 --> 00:44:19,920
role of dopants and here's our idea the

1131
00:44:24,390 --> 00:44:22,000
scores of trace and minor elements are

1132
00:44:26,950 --> 00:44:24,400
ubiquitous in the commonest rock forming

1133
00:44:29,190 --> 00:44:26,960
minerals and also talk about the mineral

1134
00:44:31,430 --> 00:44:29,200
diversity later on in this talk so here

1135
00:44:33,910 --> 00:44:31,440
is a table from a paper that's just come

1136
00:44:37,109 --> 00:44:33,920
out and i'm happy to share this with you

1137
00:44:39,510 --> 00:44:37,119
if you want what we did is we looked at

1138
00:44:42,150 --> 00:44:39,520

some of those rare elements that don't

1139

00:44:43,109 --> 00:44:42,160

form a volumetrically very many minerals

1140

00:44:44,630 --> 00:44:43,119

at all

1141

00:44:47,190 --> 00:44:44,640

yet they're present in the crust and

1142

00:44:48,710 --> 00:44:47,200

significant amounts and if you look at

1143

00:44:51,430 --> 00:44:48,720

the commonest rock foreign minerals

1144

00:44:53,829 --> 00:44:51,440

olivine pyroxene feldspar you'll see

1145

00:44:55,990 --> 00:44:53,839

orders of magnitude increase in some

1146

00:44:57,750 --> 00:44:56,000

cases in the concentration

1147

00:45:00,470 --> 00:44:57,760

in these minerals that were ubiquitous

1148

00:45:02,870 --> 00:45:00,480

for example in ocean floor basalts

1149

00:45:04,790 --> 00:45:02,880

and and so even though you may not have

1150

00:45:07,990 --> 00:45:04,800

a mineral that

1151

00:45:10,630 --> 00:45:08,000

specifically has nickel or vanadium or

1152

00:45:12,790 --> 00:45:10,640

copper as a major element

1153

00:45:15,430 --> 00:45:12,800

still these elements have been available

1154

00:45:17,670 --> 00:45:15,440

abundantly in various surfaces for kinds

1155

00:45:19,670 --> 00:45:17,680

of reactions that we see have been used

1156

00:45:21,510 --> 00:45:19,680

in prebiotic models

1157

00:45:23,109 --> 00:45:21,520

so our conclusion for the first part of

1158

00:45:24,870 --> 00:45:23,119

this talk is that these potentially

1159

00:45:27,190 --> 00:45:24,880

important minerals while they're not

1160

00:45:29,589 --> 00:45:27,200

replaced represented by common minerals

1161

00:45:31,349 --> 00:45:29,599

they are certainly widely available

1162

00:45:33,270 --> 00:45:31,359

in rock forming minerals

1163

00:45:35,990 --> 00:45:33,280

all across earth's surface

1164

00:45:38,630 --> 00:45:36,000

now you might ask i asked myself how can

1165

00:45:40,950 --> 00:45:38,640

i miss this obvious point and the answer

1166

00:45:42,870 --> 00:45:40,960

really lies in the definition of mineral

1167

00:45:44,550 --> 00:45:42,880

species so what i want to do is

1168

00:45:47,109 --> 00:45:44,560

describe a new way of thinking about

1169

00:45:49,109 --> 00:45:47,119

minerals and mineral kinds

1170

00:45:50,790 --> 00:45:49,119

the ima international mineralogical

1171

00:45:53,190 --> 00:45:50,800

association defines minerals as

1172

00:45:55,190 --> 00:45:53,200

naturally occurring crystals

1173

00:45:56,710 --> 00:45:55,200

they have an idealized n-member

1174

00:45:58,870 --> 00:45:56,720

composition they have an idealized

1175

00:46:00,710 --> 00:45:58,880

structure any combination that's unique

1176
00:46:03,349 --> 00:46:00,720
of that structure and member composition

1177
00:46:06,390 --> 00:46:03,359
is a species they're about 5700 almost

1178
00:46:08,390 --> 00:46:06,400
5800 mineral species today and what the

1179
00:46:10,309 --> 00:46:08,400
ima is doing is basically a very

1180
00:46:12,069 --> 00:46:10,319
efficient system that uses the absolute

1181
00:46:15,109 --> 00:46:12,079
minimum amount of information to

1182
00:46:17,190 --> 00:46:15,119
distinguish one mineral from another but

1183
00:46:19,190 --> 00:46:17,200
the fundamental aspect of all minerals

1184
00:46:20,630 --> 00:46:19,200
is they're incredibly information rich

1185
00:46:23,270 --> 00:46:20,640
they have trace and minor elements they

1186
00:46:24,630 --> 00:46:23,280
have isotopes defects inclusions all

1187
00:46:27,030 --> 00:46:24,640
sorts of other things that tell the

1188
00:46:29,510 --> 00:46:27,040

history of each individual sample and we

1189

00:46:32,069 --> 00:46:29,520

want to embrace that so what we do in

1190

00:46:33,030 --> 00:46:32,079

our new system of mineralogy

1191

00:46:35,510 --> 00:46:33,040

is

1192

00:46:37,910 --> 00:46:35,520

we split some ima species into several

1193

00:46:40,230 --> 00:46:37,920

natural kinds we lump other species into

1194

00:46:42,550 --> 00:46:40,240

one natural kind and we also recognize

1195

00:46:44,950 --> 00:46:42,560

amorphous materials which are not

1196

00:46:47,349 --> 00:46:44,960

treated by the ima system and what this

1197

00:46:49,670 --> 00:46:47,359

means is in some cases like pyrite there

1198

00:46:51,430 --> 00:46:49,680

can be many natural kinds more than 20

1199

00:46:52,710 --> 00:46:51,440

in the case of pyrite some are high

1200

00:46:55,349 --> 00:46:52,720

temperatures some are low temperatures

1201
00:46:57,990 --> 00:46:55,359
some are biotic some are abiotic and so

1202
00:47:00,550 --> 00:46:58,000
forth but in other cases like tourmaline

1203
00:47:02,950 --> 00:47:00,560
where ima recognizes more than 35

1204
00:47:04,710 --> 00:47:02,960
different species of tourmaline

1205
00:47:07,349 --> 00:47:04,720
in one of these crystals you can have

1206
00:47:09,589 --> 00:47:07,359
seven different ima species in a single

1207
00:47:11,190 --> 00:47:09,599
crystal because of zoning we say no

1208
00:47:13,030 --> 00:47:11,200
that's just one natural kind and there's

1209
00:47:15,109 --> 00:47:13,040
probably only two or three natural kinds

1210
00:47:17,510 --> 00:47:15,119
of tourmaline all together and we also

1211
00:47:19,589 --> 00:47:17,520
embrace as i said amorphous materials

1212
00:47:21,990 --> 00:47:19,599
volcanic glasses and other sorts of

1213
00:47:23,990 --> 00:47:22,000

amorphous materials that in some cases

1214

00:47:26,950 --> 00:47:24,000

for example the lunar

1215

00:47:29,349 --> 00:47:26,960

the martian regolith this is really

1216

00:47:31,270 --> 00:47:29,359

important 50 or more of most martian

1217

00:47:32,950 --> 00:47:31,280

soils or amorphous materials and you

1218

00:47:35,030 --> 00:47:32,960

can't really understand the evolution of

1219

00:47:37,109 --> 00:47:35,040

mars without understanding those

1220

00:47:39,190 --> 00:47:37,119

amorphous materials so we've begun an

1221

00:47:42,150 --> 00:47:39,200

evolutionary system in mineralogy we use

1222

00:47:44,069 --> 00:47:42,160

a binomial nomenclature where we have a

1223

00:47:45,829 --> 00:47:44,079

mineral like graphite linked to its

1224

00:47:49,270 --> 00:47:45,839

formational environment for example the

1225

00:47:52,309 --> 00:47:49,280

type 2 supernova here is agb moissanite

1226

00:47:54,309 --> 00:47:52,319

agb stars in which moissanite forms we

1227

00:47:56,630 --> 00:47:54,319

use network graphs helped by our

1228

00:47:58,790 --> 00:47:56,640

colleague underwood prabhu in which we

1229

00:48:01,270 --> 00:47:58,800

have two different kinds of nodes some

1230

00:48:03,510 --> 00:48:01,280

nodes represent formational environments

1231

00:48:06,630 --> 00:48:03,520

some nodes represent mineral species and

1232

00:48:08,950 --> 00:48:06,640

every link then is a binomial natural

1233

00:48:10,870 --> 00:48:08,960

kind of a mineral so here's the first

1234

00:48:13,750 --> 00:48:10,880

network we can expand that to include

1235

00:48:15,990 --> 00:48:13,760

solar condensates and cais

1236

00:48:17,589 --> 00:48:16,000

here's interstellar clouds we can expand

1237

00:48:19,910 --> 00:48:17,599

it going on these are the primary

1238

00:48:22,309 --> 00:48:19,920

chondrol minerals those igneous minerals

1239

00:48:24,630 --> 00:48:22,319

in the early solar system

1240

00:48:26,710 --> 00:48:24,640

the different alteration products impact

1241

00:48:29,349 --> 00:48:26,720

aqueous thermal alteration products we

1242

00:48:31,750 --> 00:48:29,359

see the network expanding and expanding

1243

00:48:33,990 --> 00:48:31,760

our model for earliest hidden mineralogy

1244

00:48:36,150 --> 00:48:34,000

came in part six of the evolutionary

1245

00:48:38,309 --> 00:48:36,160

system which is now in press

1246

00:48:39,990 --> 00:48:38,319

you'll notice that there is the original

1247

00:48:42,069 --> 00:48:40,000

network that i showed you of the stellar

1248

00:48:44,390 --> 00:48:42,079

minerals it's still embedded in this

1249

00:48:46,829 --> 00:48:44,400

larger expanding network

1250

00:48:49,829 --> 00:48:46,839

we also think that this network is a

1251

00:48:52,230 --> 00:48:49,839

reasonable model of martian uh yeah

1252

00:48:53,589 --> 00:48:52,240

martian mineralogy today

1253

00:48:55,510 --> 00:48:53,599

that's something that's a testable

1254

00:48:58,069 --> 00:48:55,520

hypothesis but it looks like mars got

1255

00:49:01,670 --> 00:48:58,079

about this far and fast forwarding to

1256

00:49:03,750 --> 00:49:01,680

our network of all 5700 minerals more

1257

00:49:06,630 --> 00:49:03,760

than 60 different ways of forming those

1258

00:49:08,950 --> 00:49:06,640

minerals forming a network which reveals

1259

00:49:11,109 --> 00:49:08,960

all sorts of indications about how

1260

00:49:13,829 --> 00:49:11,119

minerals diversified through time and

1261

00:49:15,190 --> 00:49:13,839

reveals that by the mid hidden certainly

1262

00:49:17,910 --> 00:49:15,200

by the end of the hadith there probably

1263

00:49:19,670 --> 00:49:17,920

were 2 000 mineral species so many many

1264

00:49:22,230 --> 00:49:19,680

more minerals to play around with in

1265

00:49:24,390 --> 00:49:22,240

your prebiotic chemistry

1266

00:49:26,549 --> 00:49:24,400

i want to make just a couple conclusions

1267

00:49:28,549 --> 00:49:26,559

one of them that was very dramatic is at

1268

00:49:30,150 --> 00:49:28,559

least 80 percent of minerals on earth

1269

00:49:32,069 --> 00:49:30,160

maybe it's as much as 90 percent

1270

00:49:34,230 --> 00:49:32,079

depending on how you count depend on

1271

00:49:36,150 --> 00:49:34,240

water they would not form without water

1272

00:49:38,390 --> 00:49:36,160

rock interactions

1273

00:49:40,309 --> 00:49:38,400

biology also is incredibly important on

1274

00:49:42,630 --> 00:49:40,319

earth for mineral diversification fully

1275

00:49:44,790 --> 00:49:42,640

half of all minerals on earth can form

1276
00:49:47,109 --> 00:49:44,800
through biological processes and a third

1277
00:49:49,510 --> 00:49:47,119
of minerals on earth form exclusively

1278
00:49:51,109 --> 00:49:49,520
through biological processes

1279
00:49:53,030 --> 00:49:51,119
so our conclusions

1280
00:49:55,349 --> 00:49:53,040
mineral molecule interactions of course

1281
00:49:57,750 --> 00:49:55,359
played key roles in life's origin and we

1282
00:50:00,390 --> 00:49:57,760
can use the trace and minor elements and

1283
00:50:02,710 --> 00:50:00,400
common rock forming minerals to help

1284
00:50:04,390 --> 00:50:02,720
catalyze some of those reactions

1285
00:50:06,870 --> 00:50:04,400
a lot of experiments need to be done to

1286
00:50:09,030 --> 00:50:06,880
test these ideas and the evolutionary

1287
00:50:11,670 --> 00:50:09,040
system in mineralogy is pointing out

1288
00:50:14,150 --> 00:50:11,680

that earth's mineralogy diversified much

1289

00:50:15,670 --> 00:50:14,160

earlier than previously suggested

1290

00:50:17,990 --> 00:50:15,680

and finally i just want to make this

1291

00:50:19,990 --> 00:50:18,000

comment about we think about is is life

1292

00:50:21,589 --> 00:50:20,000

a deterministic process well this

1293

00:50:23,430 --> 00:50:21,599

realization that these common rock

1294

00:50:25,910 --> 00:50:23,440

foreign minerals host rich diversities

1295

00:50:28,390 --> 00:50:25,920

of reactive surfaces almost any kind of

1296

00:50:30,150 --> 00:50:28,400

reactive site you might want occurs on

1297

00:50:32,710 --> 00:50:30,160

some prebiotic mineral

1298

00:50:34,390 --> 00:50:32,720

that this leads to

1299

00:50:37,430 --> 00:50:34,400

support the idea of a robust

1300

00:50:39,349 --> 00:50:37,440

deterministic prebiotic chemical mule

1301

00:50:42,069 --> 00:50:39,359

year with that i want to thank my

1302

00:50:43,510 --> 00:50:42,079

funding agencies thanks shauna again for

1303

00:50:45,910 --> 00:50:43,520

the great collaborations we've been

1304

00:50:47,270 --> 00:50:45,920

having and maybe we'll have time for a

1305

00:50:53,349 --> 00:50:47,280

question i don't know

1306

00:50:55,990 --> 00:50:54,549

yeah

1307

00:50:58,150 --> 00:50:56,000

we absolutely do have time for a

1308

00:51:00,870 --> 00:50:58,160

question so go ahead hi there bob great

1309

00:51:02,710 --> 00:51:00,880

talk thanks uh harry from cu boulder i'm

1310

00:51:04,549 --> 00:51:02,720

wondering given the absence of these

1311

00:51:06,309 --> 00:51:04,559

rare element minerals do you think the

1312

00:51:09,190 --> 00:51:06,319

other minerals would have been even more

1313

00:51:10,950 --> 00:51:09,200

enriched in these rare dopants

1314

00:51:13,430 --> 00:51:10,960

what we see in the rock-forming minerals

1315

00:51:15,589 --> 00:51:13,440

is they always have these rare elements

1316

00:51:17,750 --> 00:51:15,599

in them to some extent pyroxene always

1317

00:51:20,069 --> 00:51:17,760

concentrates the the other transition

1318

00:51:21,829 --> 00:51:20,079

elements for example and certainly if

1319

00:51:23,670 --> 00:51:21,839

they were not being swallowed up by

1320

00:51:25,430 --> 00:51:23,680

other rare minerals it might be greater

1321

00:51:27,349 --> 00:51:25,440

but i should make the point cobalt for

1322

00:51:29,430 --> 00:51:27,359

example if you take all the cobalt

1323

00:51:31,510 --> 00:51:29,440

minerals on earth and look at their

1324

00:51:34,470 --> 00:51:31,520

volume it's 1

1325

00:51:38,390 --> 00:51:34,480

50 millionth of the amount of cobalt

1326

00:51:40,150 --> 00:51:38,400

that's in basalt

1327

00:51:41,750 --> 00:51:40,160

so there's a lot of basalt and so

1328

00:51:44,390 --> 00:51:41,760

there's a lot of cobalt even though it's

1329

00:51:46,549 --> 00:51:44,400

a trace element got it thanks

1330

00:51:48,390 --> 00:51:46,559

and i think we have time for one more

1331

00:51:50,950 --> 00:51:48,400

fine i guess it's pretty quick uh matt

1332

00:51:52,470 --> 00:51:50,960

from stanford again um so question what

1333

00:51:54,950 --> 00:51:52,480

you were saying so it seemed like there

1334

00:51:57,510 --> 00:51:54,960

was fewer minerals in the distant past

1335

00:51:59,349 --> 00:51:57,520

and we've gained more over time

1336

00:52:01,109 --> 00:51:59,359

is it so in the future there should be

1337

00:52:02,870 --> 00:52:01,119

new minerals

1338

00:52:04,950 --> 00:52:02,880

that don't exist today

1339

00:52:06,230 --> 00:52:04,960

can you theoretically predict what they

1340

00:52:07,670 --> 00:52:06,240

might be

1341

00:52:09,349 --> 00:52:07,680

yes we've been doing this in a field

1342

00:52:11,109 --> 00:52:09,359

called mineral ecology which is which

1343

00:52:12,549 --> 00:52:11,119

another whole talk is a lot of fun also

1344

00:52:15,030 --> 00:52:12,559

of course there's the anthropogenic

1345

00:52:16,309 --> 00:52:15,040

signal and in terms of mineral-like

1346

00:52:18,870 --> 00:52:16,319

compounds

1347

00:52:20,390 --> 00:52:18,880

there are literally hundreds of of

1348

00:52:23,910 --> 00:52:20,400

minerals

1349

00:52:26,549 --> 00:52:23,920

that human mining human engineering

1350

00:52:28,069 --> 00:52:26,559

human waste dumps are forming and those

1351

00:52:30,390 --> 00:52:28,079

will be a permanent part of the

1352

00:52:32,630 --> 00:52:30,400

geological record for many hundreds of

1353

00:52:34,710 --> 00:52:32,640

millions of years in in cases laser

1354

00:52:37,270 --> 00:52:34,720

crystals things like that they just go

1355

00:52:40,069 --> 00:52:37,280

into waste stumps and and so indeed the

1356

00:52:42,950 --> 00:52:40,079

diversification is increasing at an ever

1357

00:52:44,470 --> 00:52:42,960

uh more rapid rate

1358

00:52:45,750 --> 00:52:44,480

and then there's one quick question

1359

00:52:47,190 --> 00:52:45,760

online that shouldn't take too long and

1360

00:52:48,790 --> 00:52:47,200

that's from jyn glass and she asks is

1361

00:52:50,309 --> 00:52:48,800

the chemical speciation of the minor

1362

00:52:52,309 --> 00:52:50,319

elements and the major rock forming

1363

00:52:54,790 --> 00:52:52,319

minerals the necessary form for

1364

00:52:57,190 --> 00:52:54,800

prebiotic chemistry eg previous theories

1365

00:52:59,589 --> 00:52:57,200

about oxidizing hi jen thanks for that

1366

00:53:01,510 --> 00:52:59,599

question and indeed

1367

00:53:04,230 --> 00:53:01,520

we think that there are many many

1368

00:53:05,990 --> 00:53:04,240

different speciations of these rare

1369

00:53:07,750 --> 00:53:06,000

elements in rock forming minerals

1370

00:53:09,270 --> 00:53:07,760

they're different kinds of surface sites

1371

00:53:10,230 --> 00:53:09,280

there's different kinds of oxidation

1372

00:53:12,790 --> 00:53:10,240

states

1373

00:53:14,230 --> 00:53:12,800

and virtually any configuration you can

1374

00:53:16,390 --> 00:53:14,240

imagine that you want any kind of

1375

00:53:18,549 --> 00:53:16,400

complexation on the surface or even

1376

00:53:20,630 --> 00:53:18,559

dissolution in forming some kind of

1377

00:53:22,390 --> 00:53:20,640

aqueous species

1378

00:53:23,589 --> 00:53:22,400

we think that this provides a very

1379

00:53:25,829 --> 00:53:23,599

robust

1380

00:53:27,750 --> 00:53:25,839

so so pick your favorite

1381

00:53:29,750 --> 00:53:27,760

oxidation state pick your favorite

1382

00:53:31,829 --> 00:53:29,760

configuration and you probably can have

1383

00:53:34,080 --> 00:53:31,839

it if you want it

1384

00:53:38,069 --> 00:53:34,090

thank you bob let's give bob a hand

1385

00:53:42,470 --> 00:53:40,549

and up next we have one of our two

1386

00:53:45,109 --> 00:53:42,480

invited speakers and of course that's

1387

00:53:46,790 --> 00:53:45,119

raj das gupta from rice university and

1388

00:53:49,510 --> 00:53:46,800

he's going to be talking to us about the

1389

00:53:52,150 --> 00:53:49,520

origin of life essential uh volatile

1390

00:53:54,870 --> 00:53:52,160

elements on earth thank you raj

1391

00:53:56,950 --> 00:53:54,880

thanks shauna for the invitation so here

1392

00:53:58,630 --> 00:53:56,960

i'll be talking about uh the origin of

1393

00:54:00,870 --> 00:53:58,640

life essential volatile elements on

1394

00:54:03,109 --> 00:54:00,880

earth and this is a collaborative work

1395

00:54:04,790 --> 00:54:03,119

that uh we have been doing with our

1396

00:54:07,349 --> 00:54:04,800

former student daman gravel barnard

1397

00:54:09,829 --> 00:54:07,359

marty and undergrad students taylor half

1398

00:54:12,069 --> 00:54:09,839

high school student alexander farnell

1399

00:54:13,990 --> 00:54:12,079

and this is part of the clever planets

1400

00:54:17,670 --> 00:54:14,000

initiative that was funded by nasa

1401
00:54:20,950 --> 00:54:17,680
astrology institute called can um eight

1402
00:54:23,349 --> 00:54:20,960
and we are based out of rice university

1403
00:54:26,150 --> 00:54:23,359
so um this is not a news to the audience

1404
00:54:28,710 --> 00:54:26,160
here all organisms are built from the

1405
00:54:31,030 --> 00:54:28,720
same six essential elements or elemental

1406
00:54:33,510 --> 00:54:31,040
ingredients and they are carbon hydrogen

1407
00:54:36,630 --> 00:54:33,520
nitrogen oxygen phosphorus and sulfur

1408
00:54:39,910 --> 00:54:36,640
um actually 98 percent or more than 98

1409
00:54:41,430 --> 00:54:39,920
of all organisms are built out of these

1410
00:54:43,750 --> 00:54:41,440
key elements and especially if you look

1411
00:54:46,150 --> 00:54:43,760
at carbon hydrogen and nitrogen they are

1412
00:54:48,309 --> 00:54:46,160
the true building blocks of

1413
00:54:50,150 --> 00:54:48,319

nucleotide the base and the and the

1414

00:54:52,950 --> 00:54:50,160

sugar and everything right so the

1415

00:54:54,950 --> 00:54:52,960

question is uh what supplies these key

1416

00:54:57,990 --> 00:54:54,960

life essential elements at the surface

1417

00:55:00,150 --> 00:54:58,000

environment of rocky planets

1418

00:55:01,829 --> 00:55:00,160

although these are the key elements

1419

00:55:03,670 --> 00:55:01,839

that are needed for making life at the

1420

00:55:06,150 --> 00:55:03,680

surface of rocky planets their

1421

00:55:08,230 --> 00:55:06,160

availability at the surface really

1422

00:55:11,510 --> 00:55:08,240

relies on the permission from the

1423

00:55:14,230 --> 00:55:11,520

interior of our planet these key gases

1424

00:55:16,470 --> 00:55:14,240

are the key elements available for life

1425

00:55:18,230 --> 00:55:16,480

actually are available uh by the

1426

00:55:19,990 --> 00:55:18,240

permission of the mantle because

1427

00:55:22,710 --> 00:55:20,000

volcanic degassing releases these

1428

00:55:24,630 --> 00:55:22,720

elements to the surface uh for

1429

00:55:26,230 --> 00:55:24,640

earth and as you have already heard

1430

00:55:28,710 --> 00:55:26,240

probably some sort of a plate tectonic

1431

00:55:31,670 --> 00:55:28,720

cycle started as early as 3.8 or 4

1432

00:55:33,510 --> 00:55:31,680

billion years ago so these uh cycles can

1433

00:55:36,069 --> 00:55:33,520

also sequester these elements into the

1434

00:55:38,150 --> 00:55:36,079

interior so in order to understand how

1435

00:55:40,870 --> 00:55:38,160

we have these elements at the surface we

1436

00:55:43,349 --> 00:55:40,880

truly need to be understanding how we

1437

00:55:45,990 --> 00:55:43,359

have these elements uh in the bulk

1438

00:55:47,990 --> 00:55:46,000

silicate earth of our planet meaning the

1439

00:55:49,990 --> 00:55:48,000

surface reservoirs the atmosphere as

1440

00:55:52,230 --> 00:55:50,000

well as the silicate reservoirs that are

1441

00:55:54,390 --> 00:55:52,240

in constant communication over millions

1442

00:55:56,309 --> 00:55:54,400

of years and billions of years right so

1443

00:55:58,390 --> 00:55:56,319

what we are interested in in this talk

1444

00:55:59,829 --> 00:55:58,400

is figuring out what's the origin of

1445

00:56:01,589 --> 00:55:59,839

some of these key life essential

1446

00:56:04,150 --> 00:56:01,599

volatile elements in the bulk silicate

1447

00:56:05,750 --> 00:56:04,160

earth meaning the surface inventory is

1448

00:56:07,589 --> 00:56:05,760

the atmosphere

1449

00:56:10,390 --> 00:56:07,599

and the silicate mantle meaning

1450

00:56:12,069 --> 00:56:10,400

everything in our planet minus the core

1451

00:56:14,309 --> 00:56:12,079

which is the metallic portion of our

1452

00:56:16,309 --> 00:56:14,319

planet

1453

00:56:19,270 --> 00:56:16,319

and actually uh one of the recent

1454

00:56:21,670 --> 00:56:19,280

studies uh by god guyard and others and

1455

00:56:24,150 --> 00:56:21,680

that i'm showing here argued that

1456

00:56:26,549 --> 00:56:24,160

elements such as nitrogen carbon and

1457

00:56:29,109 --> 00:56:26,559

hydrogen their surfacial abundance

1458

00:56:30,870 --> 00:56:29,119

includes including their atmospheric

1459

00:56:33,670 --> 00:56:30,880

partial pressures could have been

1460

00:56:35,510 --> 00:56:33,680

actually um established as early right

1461

00:56:37,430 --> 00:56:35,520

after the moon farming impact by magma

1462

00:56:39,589 --> 00:56:37,440

ocean degassing so meaning at that

1463

00:56:41,990 --> 00:56:39,599

period of our planet the planet was

1464

00:56:44,549 --> 00:56:42,000

mostly molten and the degassing of that

1465

00:56:46,630 --> 00:56:44,559

silicate molten silicate could supply

1466

00:56:49,190 --> 00:56:46,640

all these elements into the surface so

1467

00:56:51,430 --> 00:56:49,200

the question is um how did the magma

1468

00:56:53,270 --> 00:56:51,440

motion or that final silicate mass of

1469

00:56:55,430 --> 00:56:53,280

our planet right before the magnesium

1470

00:56:57,109 --> 00:56:55,440

crystallization acquired these key

1471

00:56:59,430 --> 00:56:57,119

elements

1472

00:57:01,750 --> 00:56:59,440

um actually interestingly all of these

1473

00:57:03,990 --> 00:57:01,760

elements are heavily depleted in our

1474

00:57:05,430 --> 00:57:04,000

planet so if you compare with the

1475

00:57:08,549 --> 00:57:05,440

nominal building blocks such as

1476

00:57:10,549 --> 00:57:08,559

chondrite you will see that um bulk

1477

00:57:12,630 --> 00:57:10,559

silicate earth is severely depleted in

1478

00:57:14,230 --> 00:57:12,640

elements such as carbon and nitrogen and

1479

00:57:15,670 --> 00:57:14,240

specifically speaking nitrogen is

1480

00:57:18,549 --> 00:57:15,680

heavily depleted

1481

00:57:21,430 --> 00:57:18,559

compared to carbon and sulfur and so on

1482

00:57:23,030 --> 00:57:21,440

so what this suggests especially the not

1483

00:57:24,630 --> 00:57:23,040

only just the absolute depletion but the

1484

00:57:26,309 --> 00:57:24,640

relative depletion with respect to

1485

00:57:27,910 --> 00:57:26,319

chondrite it suggests that post

1486

00:57:30,230 --> 00:57:27,920

differentiation meaning post code

1487

00:57:32,230 --> 00:57:30,240

formation post atmosphere formation

1488

00:57:33,910 --> 00:57:32,240

addition of quadratic meteorites cannot

1489

00:57:35,990 --> 00:57:33,920

actually explain the abundance or the

1490

00:57:37,750 --> 00:57:36,000

relative abundances of these key life

1491

00:57:39,990 --> 00:57:37,760

essential elements such as carbon and

1492

00:57:42,789 --> 00:57:40,000

nitrogen and sulfur because they are not

1493

00:57:45,109 --> 00:57:42,799

in conductive proportion

1494

00:57:47,109 --> 00:57:45,119

so what we want to do uh quickly in this

1495

00:57:48,710 --> 00:57:47,119

talk because we don't have a lot of time

1496

00:57:50,630 --> 00:57:48,720

instead of talking about all the key

1497

00:57:53,510 --> 00:57:50,640

life essential volatile elements we are

1498

00:57:55,510 --> 00:57:53,520

going to take lessons from nitrogen and

1499

00:57:57,829 --> 00:57:55,520

i am just going to quickly go through

1500

00:58:00,230 --> 00:57:57,839

snippets from two recent studies that we

1501

00:58:01,990 --> 00:58:00,240

did in our group uh one is about the

1502

00:58:03,910 --> 00:58:02,000

source of nitrogen meaning where did the

1503

00:58:05,990 --> 00:58:03,920

nitrogen from for the silicate and the

1504

00:58:07,750 --> 00:58:06,000

surficial earth potentially come from

1505

00:58:09,910 --> 00:58:07,760

and what was the processes and the

1506

00:58:11,990 --> 00:58:09,920

timing of establishing that nitrogen

1507

00:58:15,270 --> 00:58:12,000

budget for the bulk silicate earth that

1508

00:58:17,109 --> 00:58:15,280

eventually uh gave uh supply of nitrogen

1509

00:58:19,109 --> 00:58:17,119

to the surface

1510

00:58:20,789 --> 00:58:19,119

uh so as i said quadratic material

1511

00:58:22,470 --> 00:58:20,799

addition cannot really explain nitrogen

1512

00:58:23,829 --> 00:58:22,480

or carbon to nitrogen relative

1513

00:58:25,510 --> 00:58:23,839

abundances because they are not in

1514

00:58:28,150 --> 00:58:25,520

quadratic proportions but one

1515

00:58:29,270 --> 00:58:28,160

interesting thing to realize is if you

1516

00:58:31,910 --> 00:58:29,280

look at

1517

00:58:33,910 --> 00:58:31,920

the entire history right from the onset

1518

00:58:35,670 --> 00:58:33,920

of solar system formation

1519

00:58:37,589 --> 00:58:35,680

the differentiation process meaning

1520

00:58:40,069 --> 00:58:37,599

separation of metals and silicates and

1521

00:58:42,390 --> 00:58:40,079

formation of proto-atmosphere started

1522

00:58:44,069 --> 00:58:42,400

very very early not just in a large

1523

00:58:46,870 --> 00:58:44,079

planet like ours but that type of

1524

00:58:49,430 --> 00:58:46,880

process started through a

1525

00:58:51,510 --> 00:58:49,440

radioactive decay of aluminum 26

1526

00:58:53,510 --> 00:58:51,520

supplying heat so melting and

1527

00:58:56,150 --> 00:58:53,520

differentiation of protoplanetary bodies

1528

00:58:57,430 --> 00:58:56,160

started very very early within sort of

1529

00:58:59,430 --> 00:58:57,440

less than a million year of the

1530

00:59:01,270 --> 00:58:59,440

formation of the solar system so when we

1531

00:59:03,270 --> 00:59:01,280

are going to think about building blocks

1532

00:59:04,710 --> 00:59:03,280

of earth like planet we shouldn't be

1533

00:59:06,630 --> 00:59:04,720

thinking only about this

1534

00:59:08,630 --> 00:59:06,640

undifferentiated meteorite delivery but

1535

00:59:10,470 --> 00:59:08,640

delivery of all these life essential

1536

00:59:11,829 --> 00:59:10,480

elements through addition of

1537

00:59:13,750 --> 00:59:11,839

differentiated objects through

1538

00:59:15,270 --> 00:59:13,760

protoplanets through planetary embryos

1539

00:59:17,670 --> 00:59:15,280

and so on

1540

00:59:20,630 --> 00:59:17,680

so with that framework in mind what we

1541

00:59:22,549 --> 00:59:20,640

did in this study in 2021 that came out

1542

00:59:24,630 --> 00:59:22,559

and came out in nature astronomy we

1543

00:59:26,870 --> 00:59:24,640

looked at iron meteorites and the reason

1544

00:59:28,630 --> 00:59:26,880

we looked at iron meteorites are for

1545

00:59:30,789 --> 00:59:28,640

three reasons one

1546

00:59:32,789 --> 00:59:30,799

iron meteorite parent bodies are some of

1547

00:59:34,390 --> 00:59:32,799

the earliest formed protoplanets that

1548

00:59:36,069 --> 00:59:34,400

underwent differentiation

1549

00:59:38,230 --> 00:59:36,079

protoplanetary differentiation for these

1550

00:59:40,230 --> 00:59:38,240

type of bodies happened as early as 0.3

1551
00:59:41,510 --> 00:59:40,240
million year within the formation of the

1552
00:59:43,670 --> 00:59:41,520
solar system

1553
00:59:46,150 --> 00:59:43,680
nitrogen or these volatile elements are

1554
00:59:47,990 --> 00:59:46,160
well preserved in irons unlike

1555
00:59:49,829 --> 00:59:48,000
alteration induced changes that can

1556
00:59:51,589 --> 00:59:49,839
happen in silicate type of meteorites

1557
00:59:54,470 --> 00:59:51,599
irons are much more refractory in that

1558
00:59:56,390 --> 00:59:54,480
sense and not only that through

1559
00:59:57,589 --> 00:59:56,400
studies of nuclear synthetic anomalies

1560
01:00:00,390 --> 00:59:57,599
of many different elements such as

1561
01:00:01,910 --> 01:00:00,400
nickel tungsten molybdenum ruthenium we

1562
01:00:03,510 --> 01:00:01,920
know iron meteorite brain body

1563
01:00:05,430 --> 01:00:03,520

differentiation took place both in the

1564

01:00:07,589 --> 01:00:05,440

outer solar system as well as in the

1565

01:00:09,510 --> 01:00:07,599

inner solar system so perhaps

1566

01:00:12,150 --> 01:00:09,520

outside the orbit of jupiter as well as

1567

01:00:15,430 --> 01:00:12,160

inside the orbit of jupiter so what

1568

01:00:17,349 --> 01:00:15,440

daman studied showed in this 2021 study

1569

01:00:19,750 --> 01:00:17,359

is when we plot these nucleosynthetic

1570

01:00:22,710 --> 01:00:19,760

anomalies for other elements along with

1571

01:00:25,030 --> 01:00:22,720

nitrogen isotopic compositions

1572

01:00:27,589 --> 01:00:25,040

bulk silicate earth actually plots mac

1573

01:00:29,750 --> 01:00:27,599

in the middle of inner solar system

1574

01:00:31,750 --> 01:00:29,760

flavored iron meteorites and outer solar

1575

01:00:33,910 --> 01:00:31,760

system flavored iron meteorites in all

1576

01:00:36,789 --> 01:00:33,920

of these different isotopic species so

1577

01:00:38,950 --> 01:00:36,799

what this suggests that the inner solar

1578

01:00:41,910 --> 01:00:38,960

system regions where rocky planets like

1579

01:00:43,910 --> 01:00:41,920

our formed already had nitrogen and not

1580

01:00:45,990 --> 01:00:43,920

only that that nitrogen had a distinct

1581

01:00:48,150 --> 01:00:46,000

nitrogen isotropic flavor compared to

1582

01:00:50,309 --> 01:00:48,160

that of the outer solar system regions

1583

01:00:52,549 --> 01:00:50,319

so with that nitrogen isotope mass

1584

01:00:54,309 --> 01:00:52,559

balance what we could show that bulk

1585

01:00:56,710 --> 01:00:54,319

silicate earth's nitrogen isotope

1586

01:00:58,870 --> 01:00:56,720

composition actually required nitrogen

1587

01:01:00,789 --> 01:00:58,880

contribution both from the inner solar

1588

01:01:02,549 --> 01:01:00,799

system region as well as from the outer

1589

01:01:04,230 --> 01:01:02,559

solar system region so that's kind of

1590

01:01:06,069 --> 01:01:04,240

the first take home message

1591

01:01:07,589 --> 01:01:06,079

the second thing we wanted to study is

1592

01:01:09,349 --> 01:01:07,599

whether or not you can establish the

1593

01:01:10,549 --> 01:01:09,359

nitrogen budget of the bulk silicate

1594

01:01:12,870 --> 01:01:10,559

earth through some sort of

1595

01:01:14,870 --> 01:01:12,880

protoplanetary building processes so in

1596

01:01:16,950 --> 01:01:14,880

this we needed to have two kind of

1597

01:01:19,030 --> 01:01:16,960

experimental datasets that i'm not going

1598

01:01:21,030 --> 01:01:19,040

into in detail one is the solubility of

1599

01:01:23,109 --> 01:01:21,040

nitrogen when the planet was largely

1600

01:01:25,109 --> 01:01:23,119

molten meaning how much nitrogen you

1601

01:01:26,950 --> 01:01:25,119

could dissolve from an overlying

1602

01:01:29,349 --> 01:01:26,960

nitrogen bearing atmosphere into the

1603

01:01:31,589 --> 01:01:29,359

silicate magma motion and the other was

1604

01:01:32,950 --> 01:01:31,599

if coral formation was going ongoing

1605

01:01:34,710 --> 01:01:32,960

meaning silicate differentiation and

1606

01:01:36,549 --> 01:01:34,720

metal differentiation was ongoing how

1607

01:01:38,069 --> 01:01:36,559

much nitrogen actually partitioned

1608

01:01:40,069 --> 01:01:38,079

between the metallic core that

1609

01:01:42,470 --> 01:01:40,079

eventually segregated and the silicate

1610

01:01:44,710 --> 01:01:42,480

outer envelope um so the two key things

1611

01:01:46,150 --> 01:01:44,720

to remember in this context is of course

1612

01:01:48,230 --> 01:01:46,160

nitrogen is

1613

01:01:50,470 --> 01:01:48,240

highly atmophile that's why it's we call

1614

01:01:53,109 --> 01:01:50,480

it a volatile element but on top of that

1615

01:01:54,470 --> 01:01:53,119

nitrogen is also cidrophile so at high

1616

01:01:56,390 --> 01:01:54,480

pressure when you don't have a vapor

1617

01:01:57,910 --> 01:01:56,400

phase and when nitrogen is allowed to

1618

01:02:00,230 --> 01:01:57,920

only partition between the molten

1619

01:02:02,950 --> 01:02:00,240

silicate and molten metal nitrogen would

1620

01:02:04,630 --> 01:02:02,960

prefer to go to the molten metal phase

1621

01:02:06,630 --> 01:02:04,640

so with that type of dataset that we

1622

01:02:09,430 --> 01:02:06,640

generated over a range of oxygen partial

1623

01:02:11,190 --> 01:02:09,440

pressure pressure temperature

1624

01:02:12,230 --> 01:02:11,200

melt compositions and everything we

1625

01:02:15,029 --> 01:02:12,240

eventually

1626
01:02:17,029 --> 01:02:15,039
set up to set out to do a mass balance

1627
01:02:19,510 --> 01:02:17,039
calculations within three reservoir

1628
01:02:22,069 --> 01:02:19,520
meaning the proto atmosphere

1629
01:02:24,630 --> 01:02:22,079
the mag motion and the and the metallic

1630
01:02:26,710 --> 01:02:24,640
core and what um so these are the

1631
01:02:28,630 --> 01:02:26,720
equations outlining that meaning

1632
01:02:30,230 --> 01:02:28,640
nitrogen mass in the atmosphere nitrogen

1633
01:02:31,270 --> 01:02:30,240
mass in the magma motion nitrogen mass

1634
01:02:34,309 --> 01:02:31,280
in the core

1635
01:02:36,309 --> 01:02:34,319
equals to the total nitrogen um we can

1636
01:02:38,630 --> 01:02:36,319
calculate the concentration of nitrogen

1637
01:02:40,150 --> 01:02:38,640
by you know dividing the mass of

1638
01:02:41,589 --> 01:02:40,160

nitrogen divided the total mass of a

1639

01:02:43,829 --> 01:02:41,599

given reservoir and then we can

1640

01:02:46,069 --> 01:02:43,839

calculate also the silicate nitrogen

1641

01:02:47,510 --> 01:02:46,079

concentration from the solubility law

1642

01:02:49,670 --> 01:02:47,520

that varies as a function of oxygen

1643

01:02:51,510 --> 01:02:49,680

fugacity and so on so what these plots

1644

01:02:53,190 --> 01:02:51,520

are showing is what would be the

1645

01:02:55,750 --> 01:02:53,200

percentage of nitrogen in the

1646

01:02:58,789 --> 01:02:55,760

proto-atmosphere or in the mag motion or

1647

01:03:00,870 --> 01:02:58,799

in the core as a function of

1648

01:03:03,029 --> 01:03:00,880

oxygen fugacity of protoplanetary

1649

01:03:04,710 --> 01:03:03,039

differentiation for different size

1650

01:03:07,190 --> 01:03:04,720

bodies different carbs are for different

1651
01:03:09,670 --> 01:03:07,200
size bodies so the main thing you should

1652
01:03:11,670 --> 01:03:09,680
pay attention to if you look at most of

1653
01:03:13,270 --> 01:03:11,680
the solar system bodies that underwent

1654
01:03:15,270 --> 01:03:13,280
differentiation including

1655
01:03:17,349 --> 01:03:15,280
rocky planets iron meteorite parent

1656
01:03:19,109 --> 01:03:17,359
bodies urallite parent bodies and so on

1657
01:03:20,789 --> 01:03:19,119
they are thought to be occurring at

1658
01:03:22,630 --> 01:03:20,799
relatively oxidized conditions with

1659
01:03:24,470 --> 01:03:22,640
respect to this iron-ooxided buffer that

1660
01:03:25,829 --> 01:03:24,480
is sitting at zero here

1661
01:03:27,510 --> 01:03:25,839
at that type of protoplanetary

1662
01:03:29,349 --> 01:03:27,520
differentiation conditions

1663
01:03:31,029 --> 01:03:29,359

magmotion or the silicate reservoir will

1664

01:03:33,109 --> 01:03:31,039

not be able to retain almost any

1665

01:03:36,390 --> 01:03:33,119

nitrogen because nitrogen will mostly be

1666

01:03:38,069 --> 01:03:36,400

in the atmosphere however um depending

1667

01:03:39,589 --> 01:03:38,079

on the size of the body especially if

1668

01:03:41,029 --> 01:03:39,599

the size of the body that is undergoing

1669

01:03:42,630 --> 01:03:41,039

differentiation is relatively large

1670

01:03:45,349 --> 01:03:42,640

meaning like a mars

1671

01:03:47,109 --> 01:03:45,359

sized embryo type of planetary systems

1672

01:03:49,190 --> 01:03:47,119

you will be able to retain a significant

1673

01:03:51,109 --> 01:03:49,200

fraction of the initial nitrogen budget

1674

01:03:52,710 --> 01:03:51,119

into the metallic core and again this is

1675

01:03:56,390 --> 01:03:52,720

because of that pseudophile element

1676

01:04:00,549 --> 01:03:58,630

in fact this this uh figure kind of

1677

01:04:02,069 --> 01:04:00,559

builds on that so if you calculate the

1678

01:04:05,029 --> 01:04:02,079

percentage of nitrogen in the magma

1679

01:04:06,309 --> 01:04:05,039

motion again this is relatively low if

1680

01:04:07,750 --> 01:04:06,319

the body that is undergoing

1681

01:04:09,990 --> 01:04:07,760

differentiation is relatively small

1682

01:04:11,910 --> 01:04:10,000

meaning the ox nitrogen partial pressure

1683

01:04:13,990 --> 01:04:11,920

in the atmosphere is small you don't you

1684

01:04:15,430 --> 01:04:14,000

don't manage to retain that atmosphere

1685

01:04:17,829 --> 01:04:15,440

nitrogen bearing atmosphere because the

1686

01:04:20,230 --> 01:04:17,839

plant is small however if the planet is

1687

01:04:21,670 --> 01:04:20,240

big meaning if it uh grew really really

1688

01:04:23,109 --> 01:04:21,680

quickly and then underwent

1689

01:04:25,029 --> 01:04:23,119

differentiation you will be able to

1690

01:04:26,549 --> 01:04:25,039

retain some in the magma but more

1691

01:04:28,630 --> 01:04:26,559

importantly if

1692

01:04:30,789 --> 01:04:28,640

the planet underwent into instantaneous

1693

01:04:32,789 --> 01:04:30,799

very very rapid accretion then that

1694

01:04:34,230 --> 01:04:32,799

nitrogen hydrophile behavior comes in

1695

01:04:37,190 --> 01:04:34,240

and you'll be able to retain a lot of

1696

01:04:40,069 --> 01:04:37,200

nitrogen in the core of those bodies

1697

01:04:42,630 --> 01:04:40,079

and in fact if you do that way that if

1698

01:04:45,670 --> 01:04:42,640

you build planet like ours earth like

1699

01:04:47,270 --> 01:04:45,680

planet by um

1700

01:04:48,230 --> 01:04:47,280

by uh

1701
01:04:51,270 --> 01:04:48,240
building

1702
01:04:53,430 --> 01:04:51,280
earth by making amalgamating relatively

1703
01:04:55,510 --> 01:04:53,440
large site protoplanetary embryos like

1704
01:04:57,829 --> 01:04:55,520
mars size planets then you can get to

1705
01:04:59,910 --> 01:04:57,839
the present day bulk silicate earth

1706
01:05:01,829 --> 01:04:59,920
nitrogen budget by amalgamating so if

1707
01:05:03,670 --> 01:05:01,839
you are making mars to earth meaning if

1708
01:05:05,750 --> 01:05:03,680
you are accreting a bunch of mars-sized

1709
01:05:07,510 --> 01:05:05,760
planets to eventually make earth you can

1710
01:05:09,109 --> 01:05:07,520
get to the nitrogen abundance of the

1711
01:05:10,870 --> 01:05:09,119
bulk silicate earth you can do the

1712
01:05:13,029 --> 01:05:10,880
similar thing if you make go from the

1713
01:05:15,430 --> 01:05:13,039

moon to the mars and earth-sized bodies

1714

01:05:17,670 --> 01:05:15,440

but if you only make an earth-like

1715

01:05:20,309 --> 01:05:17,680

planet by amalgamating very very small

1716

01:05:22,950 --> 01:05:20,319

planetary protoplanetary

1717

01:05:24,549 --> 01:05:22,960

systems then the nitrogen budget of that

1718

01:05:26,870 --> 01:05:24,559

bulk silicate earth would have been much

1719

01:05:28,549 --> 01:05:26,880

much lower so accretion of planetary

1720

01:05:31,589 --> 01:05:28,559

embryo size bodies taking place within

1721

01:05:33,109 --> 01:05:31,599

the time scale of aluminum 26 decay that

1722

01:05:34,950 --> 01:05:33,119

gives rise to this nitrogen

1723

01:05:38,150 --> 01:05:34,960

fractionation would be able to supply

1724

01:05:39,910 --> 01:05:38,160

nitrogen budget of our earth

1725

01:05:41,990 --> 01:05:39,920

so in summary rocky planets forming

1726

01:05:43,589 --> 01:05:42,000

region of the solar system had life

1727

01:05:45,430 --> 01:05:43,599

essential volatile elements such as

1728

01:05:47,029 --> 01:05:45,440

nitrogen within one million year of the

1729

01:05:49,029 --> 01:05:47,039

solar system formation

1730

01:05:50,789 --> 01:05:49,039

um the bulk silicate earth source

1731

01:05:52,630 --> 01:05:50,799

nitrogen both from the inner and the

1732

01:05:56,150 --> 01:05:52,640

outer solar system

1733

01:05:58,630 --> 01:05:56,160

regions so not only did it rely on sort

1734

01:06:00,150 --> 01:05:58,640

of delivery of outer solar system

1735

01:06:01,990 --> 01:06:00,160

objects by planetary migrations you

1736

01:06:03,349 --> 01:06:02,000

didn't need that and rapidly grown

1737

01:06:05,990 --> 01:06:03,359

differentiated proto planets could

1738

01:06:07,510 --> 01:06:06,000

supply earth's nitrogen inventory so

1739

01:06:10,069 --> 01:06:07,520

although this session is about this

1740

01:06:12,789 --> 01:06:10,079

geosphere biosphere connection and what

1741

01:06:15,349 --> 01:06:12,799

the message from this talk is that um

1742

01:06:18,309 --> 01:06:15,359

the geosphere could supply this life

1743

01:06:21,270 --> 01:06:18,319

essential nitrogen by acquiring a

1744

01:06:23,109 --> 01:06:21,280

particular planetary building style

1745

01:06:25,430 --> 01:06:23,119

which managed to give nitrogen very very

1746

01:06:27,910 --> 01:06:25,440

early it also has implications for some

1747

01:06:30,230 --> 01:06:27,920

exoplanetary systems what that says is

1748

01:06:31,990 --> 01:06:30,240

you don't need necessarily planetary

1749

01:06:33,750 --> 01:06:32,000

dynamics bringing volatile rich

1750

01:06:35,670 --> 01:06:33,760

materials from the outer solar systems

1751

01:06:37,510 --> 01:06:35,680

of any other exoplanetary systems to

1752

01:06:39,990 --> 01:06:37,520

have life essential volatile elements as

1753

01:06:41,829 --> 01:06:40,000

such as nitrogen uh the inner regions

1754

01:06:43,190 --> 01:06:41,839

that are hot can still have volatile

1755

01:06:45,430 --> 01:06:43,200

elements because some of these volatile

1756

01:06:47,829 --> 01:06:45,440

elements are citrophile so the planets

1757

01:06:50,549 --> 01:06:47,839

as they are growing can hold on to these

1758

01:06:51,990 --> 01:06:50,559

uh life essential volatile elements even

1759

01:06:53,589 --> 01:06:52,000

though they are forming in a hotter

1760

01:06:56,069 --> 01:06:53,599

portion of the disk uh in the inner

1761

01:06:57,109 --> 01:06:56,079

regions of the planet uh close to closer

1762

01:06:59,390 --> 01:06:57,119

to the star

1763

01:07:02,150 --> 01:06:59,400

with that i'll stop thanks

1764

01:07:03,750 --> 01:07:02,160

[Applause]

1765

01:07:05,910 --> 01:07:03,760

thank you so much raj that was an

1766

01:07:09,029 --> 01:07:05,920

awesome talk um so we have a question

1767

01:07:10,390 --> 01:07:09,039

online uh that i will ask um so ben

1768

01:07:11,750 --> 01:07:10,400

johnson says that in a couple of the

1769

01:07:14,390 --> 01:07:11,760

plots showing nitrogen and metal

1770

01:07:16,150 --> 01:07:14,400

isotopes a couple of them had earth

1771

01:07:17,990 --> 01:07:16,160

not right in between the inner and outer

1772

01:07:19,109 --> 01:07:18,000

solar system field could you elaborate

1773

01:07:21,589 --> 01:07:19,119

on that

1774

01:07:23,910 --> 01:07:21,599

um yes so i think the question is about

1775

01:07:25,349 --> 01:07:23,920

these two plots actually they do appear

1776

01:07:28,309 --> 01:07:25,359

right in the middle when you are looking

1777

01:07:30,630 --> 01:07:28,319

at y-axis meaning nitrogen isotope wise

1778

01:07:33,109 --> 01:07:30,640

they are still intermediate what you are

1779

01:07:35,270 --> 01:07:33,119

seeing is on x-axis they are not and

1780

01:07:37,829 --> 01:07:35,280

just because some of these elements like

1781

01:07:39,990 --> 01:07:37,839

molybdenum and ruthenium uh they are

1782

01:07:42,549 --> 01:07:40,000

calcophile and siderophiles so they got

1783

01:07:45,029 --> 01:07:42,559

added or they fractionated

1784

01:07:47,750 --> 01:07:45,039

at different stages of planet formation

1785

01:07:49,910 --> 01:07:47,760

so if these elements are delivered early

1786

01:07:52,789 --> 01:07:49,920

they will go all the all the way to the

1787

01:07:55,430 --> 01:07:52,799

core on the other hand things like um

1788

01:07:57,349 --> 01:07:55,440

tungsten calcium and other synthetic

1789

01:07:59,750 --> 01:07:57,359

anomalies they are not cedrophile

1790

01:08:02,630 --> 01:07:59,760

enemies so for some of these systems

1791

01:08:04,950 --> 01:08:02,640

on on the x-axis

1792

01:08:06,390 --> 01:08:04,960

bse may not plot exactly in the middle

1793

01:08:08,230 --> 01:08:06,400

but that's not really the point here

1794

01:08:10,230 --> 01:08:08,240

it's really the y-axis spread where the

1795

01:08:11,270 --> 01:08:10,240

nitrogen isotope bc is always smack in

1796

01:08:13,510 --> 01:08:11,280

the middle

1797

01:08:17,349 --> 01:08:13,520

awesome thank you so much for ash and

1798

01:08:21,829 --> 01:08:19,189

and next we have

1799

01:08:24,630 --> 01:08:21,839

uh secret ranjon who is

1800

01:08:26,149 --> 01:08:24,640

currently hailing from

1801

01:08:28,470 --> 01:08:26,159

northwestern although i think we may

1802

01:08:30,789 --> 01:08:28,480

have some congratulations in in the next

1803

01:08:32,950 --> 01:08:30,799

step coming up soon and today he is

1804

01:08:35,990 --> 01:08:32,960

going to uh talk to us about sulfite

1805

01:08:39,510 --> 01:08:36,000

concentrations in in early waters on

1806

01:08:40,709 --> 01:08:39,520

earth so take it away

1807

01:08:42,390 --> 01:08:40,719

thanks very much thanks to the

1808

01:08:44,309 --> 01:08:42,400

organizers for the opportunity to be

1809

01:08:46,470 --> 01:08:44,319

here my name is secret i'm currently a

1810

01:08:48,070 --> 01:08:46,480

post-doctoral fellow at northwestern and

1811

01:08:49,669 --> 01:08:48,080

today i'm excited to tell you about some

1812

01:08:51,590 --> 01:08:49,679

of our work trying to understand the

1813

01:08:52,390 --> 01:08:51,600

nature and speciation of sulfur on early

1814

01:08:53,910 --> 01:08:52,400

earth

1815

01:08:55,990 --> 01:08:53,920

and what that might mean for origins of

1816

01:08:57,590 --> 01:08:56,000

life chemistry

1817

01:08:59,829 --> 01:08:57,600

just to take a step back and kind of

1818

01:09:01,110 --> 01:08:59,839

establish the motivation what i what

1819

01:09:03,910 --> 01:09:01,120

we're really interested in helping

1820

01:09:07,030 --> 01:09:03,920

understand is how a dead planet gave

1821

01:09:08,309 --> 01:09:07,040

rise to a living one specifically we're

1822

01:09:10,470 --> 01:09:08,319

really interested in understanding

1823

01:09:12,070 --> 01:09:10,480

sulfur on on early earth prior to the

1824

01:09:14,070 --> 01:09:12,080

origin of life

1825

01:09:15,829 --> 01:09:14,080

what kinds of sulfur what species of

1826

01:09:17,910 --> 01:09:15,839

sulfur were available

1827

01:09:19,749 --> 01:09:17,920

what environments were they available in

1828

01:09:21,990 --> 01:09:19,759

and what concentrations approximately

1829

01:09:23,430 --> 01:09:22,000

were available

1830

01:09:25,910 --> 01:09:23,440

oh this has an earlier version of my

1831

01:09:28,070 --> 01:09:25,920

talk such as life anyhow for this

1832

01:09:30,070 --> 01:09:28,080

version of my talk i'll say uh

1833

01:09:32,309 --> 01:09:30,080

the key takeaway messages from my talk

1834

01:09:33,829 --> 01:09:32,319

is that sulfite was a prebiotic reagent

1835

01:09:35,910 --> 01:09:33,839

specifically in shallow terrestrial

1836

01:09:37,910 --> 01:09:35,920

waters in early earth and this is

1837

01:09:39,829 --> 01:09:37,920

matters because including sulfide and

1838

01:09:42,149 --> 01:09:39,839

models of prebiotic chemistry enables

1839

01:09:43,990 --> 01:09:42,159

dramatic advances

1840

01:09:46,149 --> 01:09:44,000

the specific idea that we kind of set

1841

01:09:47,990 --> 01:09:46,159

out to explore is the atmosphere as a

1842

01:09:50,070 --> 01:09:48,000

source of sulfur for origins of life

1843

01:09:52,390 --> 01:09:50,080

chemistry specifically to terrestrial

1844

01:09:55,189 --> 01:09:52,400

waters systems like shallow ponds

1845

01:09:56,709 --> 01:09:55,199

the idea is that on early earth as today

1846

01:09:58,070 --> 01:09:56,719

volcanoes would have been the main

1847

01:09:59,750 --> 01:09:58,080

sources of sulfur to the ocean

1848

01:10:01,510 --> 01:09:59,760

atmosphere system

1849

01:10:02,550 --> 01:10:01,520

that's assert to the surface atmosphere

1850

01:10:04,310 --> 01:10:02,560

system

1851

01:10:05,990 --> 01:10:04,320

unlike modern earth there was very

1852

01:10:07,350 --> 01:10:06,000

little oxygen so the lifetime of that

1853

01:10:09,350 --> 01:10:07,360

sulfur should have been significantly

1854

01:10:11,270 --> 01:10:09,360

higher particularly in aqueous solution

1855

01:10:12,790 --> 01:10:11,280

and so we explored the idea that you

1856

01:10:14,390 --> 01:10:12,800

might have been able to establish henry

1857

01:10:16,070 --> 01:10:14,400

equilibrium with the atmosphere

1858

01:10:17,990 --> 01:10:16,080

consequently you dissolve that sulfur it

1859

01:10:20,390 --> 01:10:18,000

speciates and then it gives rise to

1860

01:10:21,669 --> 01:10:20,400

these so-called self-bearing anions and

1861

01:10:23,189 --> 01:10:21,679

the kind of point that we tried to make

1862

01:10:24,709 --> 01:10:23,199

is that if you model if you kind of do

1863

01:10:26,630 --> 01:10:24,719

the simplistic model if you assume the

1864

01:10:28,790 --> 01:10:26,640

atmosphere sets what's going on in

1865

01:10:30,310 --> 01:10:28,800

terrestrial waters you overall find that

1866

01:10:31,910 --> 01:10:30,320

this mechanism can't give you very much

1867

01:10:34,390 --> 01:10:31,920

reduced sulfur species it can't give you

1868

01:10:36,149 --> 01:10:34,400

much very much sulfide but it can give

1869

01:10:38,790 --> 01:10:36,159

you a great deal of sulfite sulfur in

1870

01:10:41,590 --> 01:10:38,800

the plus four oxidation state HSO_3^- minus

1871

01:10:42,709 --> 01:10:41,600

SO_3^{2-} two minus uh specifically we argue

1872

01:10:44,070 --> 01:10:42,719

that you could have had more than

1873

01:10:46,229 --> 01:10:44,080

micromolar concentrations of this

1874

01:10:48,070 --> 01:10:46,239

compound and in the largest

1875

01:10:49,430 --> 01:10:48,080

explosions of volcanic explosions you

1876

01:10:51,189 --> 01:10:49,440

could have approached near millimolar

1877

01:10:53,110 --> 01:10:51,199

concentrations

1878

01:10:54,390 --> 01:10:53,120

why do you care about this we care about

1879

01:10:56,229 --> 01:10:54,400

this because if you try to fold that

1880

01:10:58,149 --> 01:10:56,239

sulfite into experimental studies of

1881

01:10:59,990 --> 01:10:58,159

origins of life chemistry particularly

1882

01:11:01,430 --> 01:11:00,000

towards the rna world it produces

1883

01:11:03,830 --> 01:11:01,440

dramatic advances

1884

01:11:06,229 --> 01:11:03,840

specifically it turns out that sulfite

1885

01:11:08,229 --> 01:11:06,239

enables hcn homologation chemistry that

1886

01:11:09,590 --> 01:11:08,239

has been invoked for uh in a systems

1887

01:11:11,510 --> 01:11:09,600

chemistry approach to synthesis of

1888

01:11:13,510 --> 01:11:11,520

various ribonucleotides

1889

01:11:16,390 --> 01:11:13,520

lipid precursors amino acids and so

1890

01:11:17,270 --> 01:11:16,400

forth sulfite also underlies the only

1891

01:11:18,790 --> 01:11:17,280

known

1892

01:11:21,270 --> 01:11:18,800

pathway for the potentially probiotic

1893

01:11:22,790 --> 01:11:21,280

synthesis of all four ribonucleotides

1894

01:11:25,430 --> 01:11:22,800

and it's also been proposed as a

1895

01:11:26,790 --> 01:11:25,440

solution to a problem that nicole

1896

01:11:29,030 --> 01:11:26,800

identified first the beginning of the

1897

01:11:31,430 --> 01:11:29,040

session how do you access reducing power

1898

01:11:32,950 --> 01:11:31,440

on an on a mostly oxidizing early earth

1899

01:11:34,550 --> 01:11:32,960

maybe you can get that by photolyzing

1900

01:11:36,229 --> 01:11:34,560

that sulfide and giving off a solid

1901

01:11:38,070 --> 01:11:36,239

electron

1902

01:11:39,270 --> 01:11:38,080

so because it seems like sulfite might

1903

01:11:40,709 --> 01:11:39,280

be really productive for prebiotic

1904

01:11:43,270 --> 01:11:40,719

chemistry we really wanted to go back to

1905

01:11:44,630 --> 01:11:43,280

our calculation do it more carefully and

1906

01:11:46,070 --> 01:11:44,640

really ask how much of it could have

1907

01:11:47,990 --> 01:11:46,080

been there and was it where was it

1908

01:11:49,830 --> 01:11:48,000

really available to do this we built a

1909

01:11:52,390 --> 01:11:49,840

kinetic model balancing the sources of

1910

01:11:54,630 --> 01:11:52,400

sulfur in the ultimately from volcanism

1911

01:11:56,709 --> 01:11:54,640

mediated by the atmosphere and the sinks

1912

01:11:58,310 --> 01:11:56,719

of sulfur the things that destroy it we

1913

01:11:59,910 --> 01:11:58,320

particularly focused on this process

1914

01:12:01,830 --> 01:11:59,920

over here disproportionation where

1915

01:12:03,590 --> 01:12:01,840

sulfite molecules get together and

1916

01:12:05,430 --> 01:12:03,600

exchange electrons ultimately making

1917

01:12:07,590 --> 01:12:05,440

more reduced and more oxidized forms of

1918

01:12:10,310 --> 01:12:07,600

sulfur this has been previously proposed

1919

01:12:11,990 --> 01:12:10,320

as the main sink mechanism for uh sulfur

1920

01:12:13,510 --> 01:12:12,000

on anoxic earth

1921

01:12:14,790 --> 01:12:13,520

there's a little problem with modeling

1922

01:12:17,030 --> 01:12:14,800

this unfortunately which is that the

1923

01:12:18,310 --> 01:12:17,040

rate constants for the uh estimates for

1924

01:12:20,950 --> 01:12:18,320

how fast this reaction goes in the

1925

01:12:22,870 --> 01:12:20,960

literature vary by more than a hundred a

1926

01:12:24,709 --> 01:12:22,880

factor of a hundred the literature

1927

01:12:26,149 --> 01:12:24,719

estimate spanned two weeks to greater

1928

01:12:27,669 --> 01:12:26,159

than five years

1929

01:12:29,030 --> 01:12:27,679

and in fact if you check the liter the

1930

01:12:30,630 --> 01:12:29,040

deep literature you find that

1931

01:12:32,630 --> 01:12:30,640

disagreements about this go back uh

1932

01:12:35,270 --> 01:12:32,640

slightly over two centuries

1933

01:12:36,790 --> 01:12:35,280

uh and so we set out to try to do our

1934

01:12:38,709 --> 01:12:36,800

part in trying to resolve this debate to

1935

01:12:40,390 --> 01:12:38,719

some degree and by re i really need to

1936

01:12:42,390 --> 01:12:40,400

give extensive credit to my experimental

1937

01:12:44,550 --> 01:12:42,400

collaborators who are colette abdulazim

1938

01:12:45,830 --> 01:12:44,560

karina kufner and gabriela lozano who

1939

01:12:47,430 --> 01:12:45,840

did most of the actual measurements i'll

1940

01:12:49,030 --> 01:12:47,440

be sharing next

1941

01:12:50,950 --> 01:12:49,040

these are preliminary results so please

1942

01:12:52,310 --> 01:12:50,960

take them with a big grain of salt we're

1943

01:12:54,229 --> 01:12:52,320

we are still doing ex follow-up

1944

01:12:56,790 --> 01:12:54,239

experiments to make sure they're right

1945

01:12:58,070 --> 01:12:56,800

anyhow so what did we do uh our

1946

01:12:59,750 --> 01:12:58,080

experimental objective was to

1947

01:13:01,430 --> 01:12:59,760

differentiate between an anoxic room

1948

01:13:03,510 --> 01:13:01,440

temperature sulfite lifetime of greater

1949

01:13:06,470 --> 01:13:03,520

than a year versus a couple of weeks

1950

01:13:08,470 --> 01:13:06,480

to do this we took solutions of sulfite

1951

01:13:10,709 --> 01:13:08,480

we put them in airtight cuvettes we

1952

01:13:12,550 --> 01:13:10,719

monitored them non-destructively with uv

1953

01:13:14,390 --> 01:13:12,560

spectroscopy and at the end of our

1954

01:13:15,669 --> 01:13:14,400

nine-month experiments we did solution

1955

01:13:17,910 --> 01:13:15,679

analytics to see what had happened to

1956

01:13:19,830 --> 01:13:17,920

that sulfite key experimental constraint

1957

01:13:22,310 --> 01:13:19,840

concerns included o₂ exclusion if you

1958

01:13:24,390 --> 01:13:22,320

have o₂ it'll kill this it'll really

1959

01:13:26,390 --> 01:13:24,400

robustly oxidize that sulfide very very

1960

01:13:28,229 --> 01:13:26,400

quickly and the long experimental time

1961

01:13:30,470 --> 01:13:28,239

scales

1962

01:13:32,229 --> 01:13:30,480

this summarizes the uv vis monitoring

1963

01:13:34,390 --> 01:13:32,239

results of an initial nine-month pilot

1964

01:13:35,990 --> 01:13:34,400

study we did this is a busy set of plots

1965

01:13:38,630 --> 01:13:36,000

to let me walk you through it

1966

01:13:40,870 --> 01:13:38,640

the top row all represents raw

1967

01:13:42,070 --> 01:13:40,880

raw extinction measured from our uv

1968

01:13:44,070 --> 01:13:42,080

spectrometer

1969

01:13:46,790 --> 01:13:44,080

the bottom row represents the fractional

1970

01:13:48,630 --> 01:13:46,800

change relative to day zero more purple

1971

01:13:50,950 --> 01:13:48,640

cars colors correspond to earlier in the

1972

01:13:52,470 --> 01:13:50,960

experiment more red colors correspond to

1973

01:13:55,030 --> 01:13:52,480

later in the experiment

1974

01:13:57,030 --> 01:13:55,040

the leftmost column gives you the entire

1975

01:13:58,310 --> 01:13:57,040

spectrum that was measured but the short

1976

01:13:59,590 --> 01:13:58,320

wavelengths are useless because they're

1977

01:14:01,270 --> 01:13:59,600

saturated the long wavelengths are

1978

01:14:02,870 --> 01:14:01,280

useless because you have no signal what

1979

01:14:04,630 --> 01:14:02,880

matters is the middle wavelengths which

1980

01:14:05,990 --> 01:14:04,640

are zoomed into the middle column this

1981

01:14:07,990 --> 01:14:06,000

is the linear regime where you have some

1982

01:14:10,149 --> 01:14:08,000

useful information and then the

1983

01:14:11,750 --> 01:14:10,159

rightmost column zooms in specifically

1984

01:14:13,910 --> 01:14:11,760

at 216 nanometers and looks at the

1985

01:14:15,430 --> 01:14:13,920

evolution of that extinction and we see

1986

01:14:17,590 --> 01:14:15,440

that over a time scale of about eight

1987

01:14:19,270 --> 01:14:17,600

and a half months the uh total

1988

01:14:21,669 --> 01:14:19,280

absorption only changed by about 40

1989

01:14:23,430 --> 01:14:21,679

percent indicating a lifetime naively

1990

01:14:24,550 --> 01:14:23,440

indicating a lifetime of sulfite of

1991

01:14:26,070 --> 01:14:24,560

years

1992

01:14:28,310 --> 01:14:26,080

to check this we then did solution

1993

01:14:30,470 --> 01:14:28,320

analytics we found that indeed after

1994

01:14:31,990 --> 01:14:30,480

about nine months only about half of the

1995

01:14:33,350 --> 01:14:32,000

sulphide had been lost

1996

01:14:34,950 --> 01:14:33,360

interestingly it had been converted

1997

01:14:36,470 --> 01:14:34,960

almost entirely into sulfate into

1998

01:14:38,790 --> 01:14:36,480

oxidized sulfur

1999

01:14:41,110 --> 01:14:38,800

uh this is a little bit unexpected

2000

01:14:42,950 --> 01:14:41,120

because and if disproportionation is

2001

01:14:45,110 --> 01:14:42,960

happening we would have expected to find

2002

01:14:47,430 --> 01:14:45,120

reduced forms of sulfur as well such as

2003

01:14:49,590 --> 01:14:47,440

this thiosulfate sulfide elemental

2004

01:14:51,590 --> 01:14:49,600

sulfur but we didn't find any of those

2005

01:14:53,350 --> 01:14:51,600

what we interpret in this tumbin is that

2006

01:14:54,950 --> 01:14:53,360

sulfide disproportionation is even

2007

01:14:57,270 --> 01:14:54,960

slower than implied here what we're

2008

01:14:59,430 --> 01:14:57,280

seeing here is actually direct oxidation

2009

01:15:01,430 --> 01:14:59,440

of the sulfur by o₂ leaking in through

2010

01:15:02,870 --> 01:15:01,440

our normally airtight cuvettes and we

2011

01:15:04,630 --> 01:15:02,880

did another couple of quick experiments

2012

01:15:06,310 --> 01:15:04,640

that seemed to confirm this

2013

01:15:08,149 --> 01:15:06,320

since then we've launched a longer term

2014

01:15:10,550 --> 01:15:08,159

series of experiments ultimately started

2015

01:15:13,110 --> 01:15:10,560

last year exploring a range of initial

2016

01:15:15,350 --> 01:15:13,120

sulfide concentrations initial ph and

2017

01:15:17,430 --> 01:15:15,360

background compositions and the results

2018

01:15:18,790 --> 01:15:17,440

of all of them are roughly the same

2019

01:15:19,910 --> 01:15:18,800

this is the same type of plot i showed

2020

01:15:22,390 --> 01:15:19,920

you earlier just for one of our

2021

01:15:23,750 --> 01:15:22,400

experimental runs

2022

01:15:25,350 --> 01:15:23,760

here the

2023

01:15:27,189 --> 01:15:25,360

after about seven and a half months the

2024

01:15:28,950 --> 01:15:27,199

degree of sulfite loss is even less only

2025

01:15:30,149 --> 01:15:28,960

about 10 percent and we think that's

2026

01:15:32,149 --> 01:15:30,159

because we did a much better job

2027

01:15:33,669 --> 01:15:32,159

excluding o2 this time

2028

01:15:35,669 --> 01:15:33,679

so this is consistent with a very long

2029

01:15:37,669 --> 01:15:35,679

sulfite lifetime does this mean that

2030

01:15:39,910 --> 01:15:37,679

sulphite lifetime is going to really

2031

01:15:41,270 --> 01:15:39,920

accumulate to higher high concentrations

2032

01:15:42,709 --> 01:15:41,280

we don't think so because of another

2033

01:15:44,870 --> 01:15:42,719

process that we think is relevant which

2034

01:15:46,630 --> 01:15:44,880

is uv photolysis we know that there was

2035

01:15:48,390 --> 01:15:46,640

a lot of uv on early earth as we've

2036

01:15:50,229 --> 01:15:48,400

heard earlier in this session it turns

2037

01:15:52,070 --> 01:15:50,239

out sulfite really efficiently absorbs

2038

01:15:54,149 --> 01:15:52,080

that uv and it's photolyzed by it

2039

01:15:55,510 --> 01:15:54,159

ultimately going to sulfate and so that

2040

01:15:57,270 --> 01:15:55,520

will provide an upper limit on the

2041

01:16:00,310 --> 01:15:57,280

sulfide concentrations

2042

01:16:01,830 --> 01:16:00,320

uh the preliminary results of our like

2043

01:16:03,189 --> 01:16:01,840

very very preliminary results we haven't

2044

01:16:05,430 --> 01:16:03,199

done anywhere near the sophistication we

2045

01:16:07,510 --> 01:16:05,440

want yet indicates that sulfite remains

2046

01:16:08,550 --> 01:16:07,520

high in some shallow ponds but again

2047

01:16:10,229 --> 01:16:08,560

it's not able to reach high

2048

01:16:12,310 --> 01:16:10,239

concentrations in others specifically in

2049

01:16:14,870 --> 01:16:12,320

ponds with high rates of seepage or in

2050

01:16:16,950 --> 01:16:14,880

deep waters like marine waters

2051
01:16:18,630 --> 01:16:16,960
to summarize the key takeaways i we

2052
01:16:21,590 --> 01:16:18,640
argue that sulfite was a prebiotic

2053
01:16:23,590 --> 01:16:21,600
reagent but in some shallow terrestrial

2054
01:16:25,430 --> 01:16:23,600
waters on early earth with ultimately

2055
01:16:26,870 --> 01:16:25,440
derived from dissolution of volcanogenic

2056
01:16:28,870 --> 01:16:26,880
so₂

2057
01:16:30,229 --> 01:16:28,880
and this is based ultimately on

2058
01:16:31,590 --> 01:16:30,239
experiments we've been doing which seem

2059
01:16:34,550 --> 01:16:31,600
to show that room temperature sulfide

2060
01:16:36,470 --> 01:16:34,560
disproportionation is slow

2061
01:16:37,750 --> 01:16:36,480
over overall the sulfide is really

2062
01:16:39,350 --> 01:16:37,760
interesting because it turns out it

2063
01:16:40,630 --> 01:16:39,360

enables really diverse prebiotic

2064

01:16:42,229 --> 01:16:40,640

chemistries particularly towards the

2065

01:16:43,990 --> 01:16:42,239

origin of rna

2066

01:16:46,550 --> 01:16:44,000

and we want to do further laboratory

2067

01:16:48,470 --> 01:16:46,560

measurements to advance both to refine

2068

01:16:50,630 --> 01:16:48,480

kind of the kinetics of this process and

2069

01:16:52,149 --> 01:16:50,640

ideally to look for s4 proxies on the

2070

01:16:54,310 --> 01:16:52,159

rock record i don't know how to do the

2071

01:16:56,470 --> 01:16:54,320

last bit so if any of you do please get

2072

01:16:58,390 --> 01:16:56,480

in touch i'd like to thank my colleagues

2073

01:16:59,830 --> 01:16:58,400

and collaborators and

2074

01:17:01,510 --> 01:16:59,840

funding sources and i'd love to take

2075

01:17:06,470 --> 01:17:01,520

questions thank you

2076

01:17:10,470 --> 01:17:08,229

fantastic thank you for that awesome

2077

01:17:11,350 --> 01:17:10,480

talk do we have a question

2078

01:17:13,590 --> 01:17:11,360

someone

2079

01:17:15,270 --> 01:17:13,600

nope

2080

01:17:17,669 --> 01:17:15,280

all right does anyone have a question if

2081

01:17:19,590 --> 01:17:17,679

not we are a little bit behind so we

2082

01:17:21,110 --> 01:17:19,600

could move on to our next speaker and if

2083

01:17:23,590 --> 01:17:21,120

you have questions for super please find

2084

01:17:30,470 --> 01:17:23,600

them after or or email so thank you so

2085

01:17:36,070 --> 01:17:33,430

up next we have everett shock from asu

2086

01:17:37,990 --> 01:17:36,080

and he is going

2087

01:17:39,189 --> 01:17:38,000

to be let's see if it will come up for

2088

01:17:40,709 --> 01:17:39,199

us

2089

01:17:42,470 --> 01:17:40,719

hi he's going to be talking about um the

2090

01:17:46,470 --> 01:17:42,480

release of energy through organic

2091

01:17:49,350 --> 01:17:48,310

good afternoon it's really a pleasure to

2092

01:17:51,430 --> 01:17:49,360

be here

2093

01:17:53,430 --> 01:17:51,440

first time i've been to a meeting in 27

2094

01:17:54,149 --> 01:17:53,440

months probably like many of the rest of

2095

01:17:56,229 --> 01:17:54,159

you

2096

01:17:58,470 --> 01:17:56,239

it's very exciting times i have an

2097

01:18:00,950 --> 01:17:58,480

optimistic message today

2098

01:18:04,550 --> 01:18:00,960

to go along with that enthusiasm i have

2099

01:18:05,990 --> 01:18:04,560

for being back at a meeting

2100

01:18:08,630 --> 01:18:06,000

this

2101
01:18:10,229 --> 01:18:08,640
work is part of the exploring ocean

2102
01:18:12,790 --> 01:18:10,239
worlds program

2103
01:18:14,390 --> 01:18:12,800
you can also as i will explain later you

2104
01:18:18,070 --> 01:18:14,400
too can do all of these sorts of

2105
01:18:19,350 --> 01:18:18,080
calculations by visiting the worm portal

2106
01:18:22,310 --> 01:18:19,360
so the transform a lot of the

2107
01:18:24,470 --> 01:18:22,320
transformations we're interested in uh

2108
01:18:26,790 --> 01:18:24,480
throughout perhaps many people in this

2109
01:18:29,270 --> 01:18:26,800
audience are various transformations

2110
01:18:32,310 --> 01:18:29,280
from like inorganic to organic simple to

2111
01:18:34,630 --> 01:18:32,320
complex abiotic to biotic transitions

2112
01:18:36,630 --> 01:18:34,640
geochemistry to biochemistry

2113
01:18:38,310 --> 01:18:36,640

the theme of this sort of session and

2114

01:18:41,350 --> 01:18:38,320

what i'm going to try to show you is

2115

01:18:44,950 --> 01:18:41,360

that all of these transitions can be

2116

01:18:47,990 --> 01:18:44,960

accompanied by the release of energy now

2117

01:18:50,950 --> 01:18:48,000

it's not true that i tore this out of

2118

01:18:53,110 --> 01:18:50,960

bob hazen's freshman chemistry notebook

2119

01:18:55,590 --> 01:18:53,120

but this is an idea that's well

2120

01:18:57,750 --> 01:18:55,600

established that if you go from

2121

01:19:00,310 --> 01:18:57,760

reactants to products there's an

2122

01:19:02,790 --> 01:19:00,320

associated energy change if that is a

2123

01:19:05,270 --> 01:19:02,800

spontaneous reaction we talk about the

2124

01:19:07,510 --> 01:19:05,280

gibbs energy change of that reaction the

2125

01:19:10,070 --> 01:19:07,520

higher energy state to lower energy

2126

01:19:12,229 --> 01:19:10,080

state in between we have all the kinetic

2127

01:19:14,310 --> 01:19:12,239

difficulties of how to get from one

2128

01:19:17,430 --> 01:19:14,320

state to the other but the point of this

2129

01:19:19,510 --> 01:19:17,440

is any sort of spontaneous process

2130

01:19:21,350 --> 01:19:19,520

associated with this lowering of the

2131

01:19:23,270 --> 01:19:21,360

gibbs energy and that's what i'm talking

2132

01:19:25,350 --> 01:19:23,280

about today an initial set of

2133

01:19:28,550 --> 01:19:25,360

circumstances or compositions over there

2134

01:19:31,430 --> 01:19:28,560

where it says substrate and then the

2135

01:19:32,870 --> 01:19:31,440

products at a lower energy state and so

2136

01:19:35,750 --> 01:19:32,880

what i'm going to show you is how that's

2137

01:19:38,310 --> 01:19:35,760

possible for that organic synthesis

2138

01:19:39,110 --> 01:19:38,320

happens can happen this way and that

2139

01:19:41,830 --> 01:19:39,120

even

2140

01:19:43,830 --> 01:19:41,840

biological processes can operate in this

2141

01:19:45,990 --> 01:19:43,840

same way

2142

01:19:48,550 --> 01:19:46,000

the point here is that we have many

2143

01:19:50,630 --> 01:19:48,560

cases where the products are more stable

2144

01:19:52,310 --> 01:19:50,640

in a thermodynamic sense than the

2145

01:19:55,110 --> 01:19:52,320

reactants

2146

01:19:57,750 --> 01:19:55,120

so the initial challenge faced by

2147

01:19:59,030 --> 01:19:57,760

practically everything we do is reducing

2148

01:20:00,870 --> 01:19:59,040

co₂

2149

01:20:02,709 --> 01:20:00,880

and of course life does this really well

2150

01:20:06,709 --> 01:20:02,719

life continues to do this on a planetary

2151

01:20:07,430 --> 01:20:06,719

scale on earth that's like life's job

2152

01:20:09,510 --> 01:20:07,440

so

2153

01:20:11,990 --> 01:20:09,520

right now of course we are surrounded by

2154

01:20:14,310 --> 01:20:12,000

plenty of photosynthesis where that

2155

01:20:16,629 --> 01:20:14,320

process driven by light involves CO_2 and

2156

01:20:20,149 --> 01:20:16,639

water to produce organic compounds and

2157

01:20:22,229 --> 01:20:20,159

oxygen but continuously and

2158

01:20:24,709 --> 01:20:22,239

preceding photosynthesis are the

2159

01:20:27,590 --> 01:20:24,719

chemosynthetic reactions where you have

2160

01:20:30,790 --> 01:20:27,600

CO_2 being reduced to organic compounds

2161

01:20:33,510 --> 01:20:30,800

i'm using hydrogen here to keep track of

2162

01:20:36,310 --> 01:20:33,520

the reductant in reductance involved to

2163

01:20:38,070 --> 01:20:36,320

make organic compounds from CO_2 and the

2164

01:20:40,470 --> 01:20:38,080

reductants are in the rocks and so this

2165

01:20:43,430 --> 01:20:40,480

is how we're connecting the geosphere to

2166

01:20:48,629 --> 01:20:44,870

what's involved of course is the

2167

01:20:50,390 --> 01:20:48,639

transfer of electrons on the left is a

2168

01:20:52,709 --> 01:20:50,400

plot

2169

01:20:55,669 --> 01:20:52,719

of hydrogen production during late

2170

01:20:58,149 --> 01:20:55,679

stages of serpentinization at

2171

01:21:00,870 --> 01:20:58,159

essentially ambient conditions and it

2172

01:21:02,550 --> 01:21:00,880

depends on what exactly are the minerals

2173

01:21:04,790 --> 01:21:02,560

that are being produced in terms of the

2174

01:21:07,110 --> 01:21:04,800

amount of hydrogen that is produced but

2175

01:21:09,030 --> 01:21:07,120

serpentinization as widely discussed at

2176

01:21:11,830 --> 01:21:09,040

this meeting and elsewhere is a great

2177

01:21:13,510 --> 01:21:11,840

way to liberate hydrogen or

2178

01:21:15,830 --> 01:21:13,520

electrons so of course the electrons

2179

01:21:18,229 --> 01:21:15,840

have the ha that has to be accompanied

2180

01:21:19,990 --> 01:21:18,239

by the ability of the ferrous iron to

2181

01:21:23,590 --> 01:21:20,000

actually in the rocks to actually get

2182

01:21:25,910 --> 01:21:23,600

oxidized to ferric iron um and so these

2183

01:21:28,390 --> 01:21:25,920

processes have to be coupled which all

2184

01:21:30,790 --> 01:21:28,400

comes down to the mineralogy that can

2185

01:21:34,149 --> 01:21:30,800

form during the alteration and this has

2186

01:21:36,310 --> 01:21:34,159

gone into in great detail in the figure

2187

01:21:38,310 --> 01:21:36,320

from the paper on the right showing the

2188

01:21:40,709 --> 01:21:38,320

in different units hydro hydrogen

2189

01:21:42,629 --> 01:21:40,719

productivity uh related to different

2190

01:21:45,750 --> 01:21:42,639

rock types

2191

01:21:48,070 --> 01:21:45,760

and on the right side of the the upper

2192

01:21:49,990 --> 01:21:48,080

left the middle plot there you would

2193

01:21:53,669 --> 01:21:50,000

have ultramafic rocks peridotites and

2194

01:21:56,310 --> 01:21:53,679

going from right to left peridotites uh

2195

01:21:58,149 --> 01:21:56,320

comadites picrites and basalts in terms

2196

01:22:00,310 --> 01:21:58,159

of magnesium number and so you can see

2197

01:22:02,470 --> 01:22:00,320

that the real big hydrogen

2198

01:22:05,350 --> 01:22:02,480

production capability is in the

2199

01:22:07,350 --> 01:22:05,360

ultramafic rocks and what's involved is

2200

01:22:09,590 --> 01:22:07,360

the where the iron ends up which

2201

01:22:11,750 --> 01:22:09,600

minerals are stable and that's in how

2202

01:22:14,310 --> 01:22:11,760

the hydrogen is liberated and this is

2203

01:22:17,669 --> 01:22:14,320

the the release of electrons that are

2204

01:22:19,510 --> 01:22:17,679

essential to the reduction of co₂

2205

01:22:21,510 --> 01:22:19,520

there we go we're inventorying that

2206

01:22:23,830 --> 01:22:21,520

again as hydrogen

2207

01:22:26,310 --> 01:22:23,840

so here's a process that biology does

2208

01:22:28,390 --> 01:22:26,320

methanogenesis again there's our

2209

01:22:30,550 --> 01:22:28,400

hydrogen think of that hydrogen as being

2210

01:22:32,390 --> 01:22:30,560

connected to the reactions happening in

2211

01:22:34,470 --> 01:22:32,400

the rock there's the necessity of

2212

01:22:37,110 --> 01:22:34,480

disequilibrium if you're going to make a

2213

01:22:38,870 --> 01:22:37,120

living by being a methanogen you have to

2214

01:22:41,270 --> 01:22:38,880

live in environment where you have CO_2

2215

01:22:43,510 --> 01:22:41,280

and hydrogen in greater abundance than

2216

01:22:45,110 --> 01:22:43,520

methane so that if you make methane you

2217

01:22:46,470 --> 01:22:45,120

get paid to do it

2218

01:22:48,070 --> 01:22:46,480

we keep track of that with this

2219

01:22:51,030 --> 01:22:48,080

thermodynamic property called the

2220

01:22:53,350 --> 01:22:51,040

affinity there that's at a sub r

2221

01:22:55,590 --> 01:22:53,360

and what it is all it comes down to is a

2222

01:22:57,830 --> 01:22:55,600

comparison of what the equilibrium state

2223

01:22:59,990 --> 01:22:57,840

is versus what are the conditions in a

2224

01:23:01,669 --> 01:23:00,000

natural environment so the equilibrium

2225

01:23:04,709 --> 01:23:01,679

state is involved in that equilibrium

2226

01:23:07,110 --> 01:23:04,719

constant k and the q term is where we

2227

01:23:09,510 --> 01:23:07,120

tie into the natural environment so

2228

01:23:12,390 --> 01:23:09,520

affini when affinities are positive that

2229

01:23:14,709 --> 01:23:12,400

means that energy can be released if the

2230

01:23:16,790 --> 01:23:14,719

reaction is to proceed from left to

2231

01:23:19,110 --> 01:23:16,800

right as written and on the right are a

2232

01:23:23,430 --> 01:23:19,120

couple of examples from a recent paper

2233

01:23:26,149 --> 01:23:23,440

where we show the energy supply for this

2234

01:23:29,510 --> 01:23:26,159

process from mixing of hydrothermal

2235

01:23:31,510 --> 01:23:29,520

fluids released in submarine systems at

2236

01:23:34,070 --> 01:23:31,520

present so based on

2237

01:23:36,390 --> 01:23:34,080

measured data from a basalt hosted

2238

01:23:38,790 --> 01:23:36,400

system there endeavor and an ultramafic

2239

01:23:40,950 --> 01:23:38,800

hosted system rainbow and as those

2240

01:23:43,750 --> 01:23:40,960

fluids mix there's there's greater and

2241

01:23:46,229 --> 01:23:43,760

greater potential for energy to release

2242

01:23:48,470 --> 01:23:46,239

to be released through methanogenesis

2243

01:23:50,470 --> 01:23:48,480

which helps explain why methanogens

2244

01:23:52,870 --> 01:23:50,480

thrive in the vicinity of submarine

2245

01:23:53,910 --> 01:23:52,880

hydrothermal systems

2246

01:23:55,750 --> 01:23:53,920

okay

2247

01:23:57,910 --> 01:23:55,760

let's make this a little bit more

2248

01:24:00,390 --> 01:23:57,920

complex i was saying we can we can go

2249

01:24:03,030 --> 01:24:00,400

from inorganic to organic and from

2250

01:24:05,430 --> 01:24:03,040

simple to complex so let's consider

2251

01:24:07,430 --> 01:24:05,440

something like an amino acid

2252

01:24:09,430 --> 01:24:07,440

synthesis here we're going from co2 to

2253

01:24:11,510 --> 01:24:09,440

ammonia and once again our friend

2254

01:24:12,950 --> 01:24:11,520

hydrogen think again think of that as

2255

01:24:15,350 --> 01:24:12,960

the connection to the reactions

2256

01:24:18,070 --> 01:24:15,360

happening in the rocks producing alanine

2257

01:24:21,189 --> 01:24:18,080

and a whole bunch of water

2258

01:24:24,229 --> 01:24:21,199

again this kind of process involves

2259

01:24:27,030 --> 01:24:24,239

a link to those electrons released by a

2260

01:24:28,149 --> 01:24:27,040

water rock alteration and the question

2261

01:24:30,790 --> 01:24:28,159

is can

2262

01:24:33,030 --> 01:24:30,800

can there be positive affinities

2263

01:24:34,470 --> 01:24:33,040

associated with these kinds of reactions

2264

01:24:36,550 --> 01:24:34,480

now we want to compare a whole bunch of

2265

01:24:38,709 --> 01:24:36,560

these because there's a bunch of amino

2266

01:24:41,189 --> 01:24:38,719

acids we might be interested in one way

2267

01:24:43,350 --> 01:24:41,199

of keeping track of this is to

2268

01:24:45,990 --> 01:24:43,360

account for the average oxidation state

2269

01:24:47,750 --> 01:24:46,000

of carbon in these compounds it's just a

2270

01:24:50,470 --> 01:24:47,760

charge balance thing it's just

2271

01:24:53,189 --> 01:24:50,480

arithmetic to work this out

2272

01:24:56,149 --> 01:24:53,199

but here's how amino acids plot in terms

2273

01:24:58,550 --> 01:24:56,159

of the average oxidation state of carbon

2274

01:25:01,110 --> 01:24:58,560

in amino acids um

2275

01:25:03,590 --> 01:25:01,120

they all of the protein forming amino

2276

01:25:06,310 --> 01:25:03,600

acids span the range of plus one to

2277

01:25:07,830 --> 01:25:06,320

minus one in average oxidation state

2278

01:25:10,310 --> 01:25:07,840

you'll see several that are fairly

2279

01:25:12,470 --> 01:25:10,320

oxidized they're indicated with blue in

2280

01:25:15,110 --> 01:25:12,480

this and the following figures some that

2281

01:25:17,270 --> 01:25:15,120

are right around zero um indicated by

2282

01:25:19,669 --> 01:25:17,280

black in the

2283

01:25:22,070 --> 01:25:19,679

upcoming figures and then the ones where

2284

01:25:27,350 --> 01:25:22,080

the carbon is more reduced

2285

01:25:31,510 --> 01:25:29,510

so here is a plot again for that same

2286

01:25:34,709 --> 01:25:31,520

sort of mixing between a submarine

2287

01:25:37,350 --> 01:25:34,719

hydrothermal fluid and seawater as those

2288

01:25:39,990 --> 01:25:37,360

two fluids mix there is increasing below

2289

01:25:42,950 --> 01:25:40,000

about 200 degrees there is increasingly

2290

01:25:46,390 --> 01:25:42,960

positive affinity for many of the amino

2291

01:25:47,750 --> 01:25:46,400

acid synthesis reactions those overall

2292

01:25:50,550 --> 01:25:47,760

reactions so

2293

01:25:53,110 --> 01:25:50,560

the this is a kind of situation then

2294

01:25:54,629 --> 01:25:53,120

where the organic synthesis you might be

2295

01:25:58,629 --> 01:25:54,639

interested in

2296

01:26:01,110 --> 01:25:58,639

there is energy release associated

2297

01:26:03,430 --> 01:26:01,120

with that organic synthesis process that

2298

01:26:06,070 --> 01:26:03,440

means the organic compounds are more

2299

01:26:08,709 --> 01:26:06,080

stable than the inorganic mixture of

2300

01:26:11,990 --> 01:26:08,719

stuff that happens spontaneously as hot

2301
01:26:14,470 --> 01:26:12,000
water pours into cold seawater now there

2302
01:26:16,470 --> 01:26:14,480
are many other kinds of processes on the

2303
01:26:18,629 --> 01:26:16,480
earth where various

2304
01:26:21,830 --> 01:26:18,639
disequilibrium can be generated i'm

2305
01:26:23,750 --> 01:26:21,840
using this hydrothermal mixing example

2306
01:26:25,910 --> 01:26:23,760
today because it's one i'm particularly

2307
01:26:29,189 --> 01:26:25,920
familiar with

2308
01:26:30,310 --> 01:26:29,199
but i want to make this point that even

2309
01:26:32,790 --> 01:26:30,320
on our

2310
01:26:35,110 --> 01:26:32,800
heavily oxidant polluted world because

2311
01:26:38,149 --> 01:26:35,120
of all that photosynthesis going on out

2312
01:26:40,310 --> 01:26:38,159
there this process remains in these

2313
01:26:43,030 --> 01:26:40,320

kinds of environments at the bottom of

2314

01:26:45,669 --> 01:26:43,040

our ocean right now an energy releasing

2315

01:26:48,550 --> 01:26:45,679

process let's ask a methanogen here's

2316

01:26:50,950 --> 01:26:48,560

some baby pictures of mathana kaldakakis

2317

01:26:53,430 --> 01:26:50,960

yanashii one of the

2318

01:26:55,110 --> 01:26:53,440

types of methanogens living around

2319

01:26:57,350 --> 01:26:55,120

submarine hydrothermal systems it's an

2320

01:27:00,070 --> 01:26:57,360

autotrophic methanogen it uses co2 and

2321

01:27:02,470 --> 01:27:00,080

hydrogen to make methane it also uses

2322

01:27:04,070 --> 01:27:02,480

co2 and hydrogen to make all of its

2323

01:27:05,669 --> 01:27:04,080

organic compounds all of its

2324

01:27:08,229 --> 01:27:05,679

biomolecules

2325

01:27:11,590 --> 01:27:08,239

so we take the genome

2326

01:27:13,990 --> 01:27:11,600

of methane haldococcus enagi convert it

2327

01:27:17,189 --> 01:27:14,000

over into all the protein sequences and

2328

01:27:18,550 --> 01:27:17,199

when we do so we get 1787

2329

01:27:20,629 --> 01:27:18,560

proteins

2330

01:27:23,430 --> 01:27:20,639

and here's just one example

2331

01:27:26,629 --> 01:27:23,440

of an overall reaction to produce this

2332

01:27:28,709 --> 01:27:26,639

protein this is what this organism does

2333

01:27:32,390 --> 01:27:28,719

it takes in co2

2334

01:27:35,590 --> 01:27:32,400

ammonia sulfur and a whole boatload of

2335

01:27:37,590 --> 01:27:35,600

hydrogen again remember that hydrogen is

2336

01:27:40,470 --> 01:27:37,600

our link to the rocks it's the water

2337

01:27:42,550 --> 01:27:40,480

rock reaction that is really that's

2338

01:27:44,390 --> 01:27:42,560

written where the iron is being oxidized

2339

01:27:46,149 --> 01:27:44,400

the water is being reduced to hydrogen

2340

01:27:48,149 --> 01:27:46,159

and you get a rather astonishing

2341

01:27:49,590 --> 01:27:48,159

stoichiometric reaction coefficient on

2342

01:27:51,430 --> 01:27:49,600

that hydrogen and there's the

2343

01:27:53,350 --> 01:27:51,440

composition of the protein we don't

2344

01:27:56,629 --> 01:27:53,360

usually think of protein synthesis this

2345

01:27:58,790 --> 01:27:56,639

way but if we were to ask our buddy mj

2346

01:28:00,709 --> 01:27:58,800

about it

2347

01:28:01,430 --> 01:28:00,719

mj would say yeah that's what i have to

2348

01:28:03,590 --> 01:28:01,440

do

2349

01:28:04,790 --> 01:28:03,600

i start with co₂ i've got to make this

2350

01:28:06,709 --> 01:28:04,800

protein

2351

01:28:09,350 --> 01:28:06,719

well let's consider the affinities of

2352

01:28:10,310 --> 01:28:09,360

these reactions to make these proteins

2353

01:28:15,669 --> 01:28:10,320

um

2354

01:28:18,070 --> 01:28:15,679

states with the conditions that are

2355

01:28:21,189 --> 01:28:18,080

available in the environment

2356

01:28:24,390 --> 01:28:21,199

these are the resulting affinities for

2357

01:28:26,870 --> 01:28:24,400

producing all 1787

2358

01:28:28,950 --> 01:28:26,880

of those proteins in that same mixing

2359

01:28:30,550 --> 01:28:28,960

environment where the hydrothermal

2360

01:28:33,030 --> 01:28:30,560

fluids from the rainbow of enfield on

2361

01:28:36,629 --> 01:28:33,040

the mid-atlantic ridge mix with seawater

2362

01:28:37,910 --> 01:28:36,639

on the left the data are presented in uh

2363

01:28:40,709 --> 01:28:37,920

affinities

2364

01:28:43,350 --> 01:28:40,719

per mole of protein notice that the unit

2365

01:28:45,189 --> 01:28:43,360

the units here are mega joules so that's

2366

01:28:47,189 --> 01:28:45,199

some serious energy

2367

01:28:48,229 --> 01:28:47,199

they're presented in the on the right

2368

01:28:49,669 --> 01:28:48,239

side

2369

01:28:52,790 --> 01:28:49,679

in terms of

2370

01:28:54,870 --> 01:28:52,800

affinities per mole of amino acid in the

2371

01:28:58,470 --> 01:28:54,880

proteins and you'll notice this familiar

2372

01:29:00,709 --> 01:28:58,480

now structure of the blue black and red

2373

01:29:04,070 --> 01:29:00,719

colors where the more reduced the

2374

01:29:06,149 --> 01:29:04,080

protein is the more energy is released

2375

01:29:08,470 --> 01:29:06,159

by its synthesis but the point i want to

2376

01:29:10,950 --> 01:29:08,480

make hopefully is not

2377

01:29:14,149 --> 01:29:10,960

escaping here is that

2378

01:29:15,990 --> 01:29:14,159

all the proteins in this methanogen are

2379

01:29:19,189 --> 01:29:16,000

more stable

2380

01:29:21,270 --> 01:29:19,199

than the inorganic starting material

2381

01:29:23,750 --> 01:29:21,280

that in the surrounding environment

2382

01:29:24,550 --> 01:29:23,760

where it lives

2383

01:29:26,470 --> 01:29:24,560

so

2384

01:29:27,590 --> 01:29:26,480

if you're thinking about

2385

01:29:29,750 --> 01:29:27,600

ways to

2386

01:29:32,470 --> 01:29:29,760

to do organic synthesis you're thinking

2387

01:29:34,709 --> 01:29:32,480

about ways to build complexity to go

2388

01:29:36,870 --> 01:29:34,719

from inorganic to organic to go from

2389

01:29:40,310 --> 01:29:36,880

abiotic to biotic and geochemistry to

2390

01:29:43,750 --> 01:29:40,320

biochemistry don't fight thermodynamics

2391

01:29:46,070 --> 01:29:43,760

you can find lots of ways in which you

2392

01:29:48,629 --> 01:29:46,080

can get thermodynamics on your side you

2393

01:29:51,750 --> 01:29:48,639

can have energy release

2394

01:29:54,070 --> 01:29:51,760

associated with all of those processes

2395

01:29:57,189 --> 01:29:54,080

you can then reduce your problem to

2396

01:29:59,030 --> 01:29:57,199

mechanisms and kinetics only he says ha

2397

01:30:00,950 --> 01:29:59,040

but anyway the point is get

2398

01:30:03,110 --> 01:30:00,960

thermodynamics on your side if you want

2399

01:30:06,310 --> 01:30:03,120

to know learn how to do all of these

2400

01:30:08,629 --> 01:30:06,320

calculations visit the worm portal

2401

01:30:10,950 --> 01:30:08,639

there's the link to it where all of

2402

01:30:13,590 --> 01:30:10,960

these calculations are made available to

2403

01:30:15,669 --> 01:30:13,600

you it's free it's all in jupiter

2404

01:30:17,450 --> 01:30:15,679

notebooks let's go

2405

01:30:22,310 --> 01:30:17,460

all right thank you

2406

01:30:25,510 --> 01:30:24,229

thank you so much everyone um i think

2407

01:30:27,350 --> 01:30:25,520

all right well nathan has a question

2408

01:30:29,510 --> 01:30:27,360

right here

2409

01:30:31,189 --> 01:30:29,520

all right that's a fascinating talk

2410

01:30:34,629 --> 01:30:31,199

so my question to you is do you think

2411

01:30:36,070 --> 01:30:34,639

there are abiotic amino acids being

2412

01:30:37,990 --> 01:30:36,080

formed today

2413

01:30:40,070 --> 01:30:38,000

in hydrothermal vents and the sites that

2414

01:30:41,669 --> 01:30:40,080

you are describing and

2415

01:30:43,510 --> 01:30:41,679

the extension to that question is do you

2416

01:30:47,030 --> 01:30:43,520

think there are abiotic

2417

01:30:49,430 --> 01:30:47,040

proteins that are being formed in these

2418

01:30:53,430 --> 01:30:49,440

locations today

2419

01:30:54,709 --> 01:30:53,440

i have no idea i know that there are

2420

01:30:57,189 --> 01:30:54,719

abiotic

2421

01:30:58,149 --> 01:30:57,199

amino acids that have formed

2422

01:31:01,030 --> 01:30:58,159

on

2423

01:31:04,390 --> 01:31:01,040

meteor in the meteorite record a lot of

2424

01:31:06,310 --> 01:31:04,400

that makes a considerable sense

2425

01:31:08,229 --> 01:31:06,320

when you link it to the aqueous

2426

01:31:10,950 --> 01:31:08,239

alteration events that occurred on

2427

01:31:13,590 --> 01:31:10,960

meteorite parent bodies it's also an

2428

01:31:16,070 --> 01:31:13,600

energy releasing process in the similar

2429

01:31:17,990 --> 01:31:16,080

way i have a feeling that if there were

2430

01:31:21,110 --> 01:31:18,000

a bio that

2431

01:31:23,990 --> 01:31:21,120

i i kind of doubt that there's that it

2432

01:31:26,390 --> 01:31:24,000

would be easy to um measure

2433

01:31:27,430 --> 01:31:26,400

abiotic amino acids

2434

01:31:29,189 --> 01:31:27,440

in a

2435

01:31:33,750 --> 01:31:29,199

setting on the earth

2436

01:31:34,709 --> 01:31:33,760

because life operates faster than

2437

01:31:41,510 --> 01:31:34,719

the

2438

01:31:42,629 --> 01:31:41,520

that burst into flame are not good to

2439

01:31:43,910 --> 01:31:42,639

eat

2440

01:31:46,229 --> 01:31:43,920

and so you

2441

01:31:49,189 --> 01:31:46,239

biology has to beat the abiotic

2442

01:31:51,510 --> 01:31:49,199

reactions um and and that's usually what

2443

01:31:53,510 --> 01:31:51,520

it does so i suspect that it would be

2444

01:31:55,510 --> 01:31:53,520

hard to find because biology would be

2445

01:31:59,110 --> 01:31:55,520

there uh pounding on it and in terms of

2446

01:32:01,750 --> 01:31:59,120

proteins i i don't imagine that there

2447

01:32:03,830 --> 01:32:01,760

would be an a full abiotic synthesis of

2448

01:32:05,910 --> 01:32:03,840

a protein but there is a thermodynamic

2449

01:32:08,470 --> 01:32:05,920

drive to for energy to be released if

2450

01:32:10,310 --> 01:32:08,480

that were to occur

2451
01:32:11,750 --> 01:32:10,320
thank you and i think we can do one more

2452
01:32:13,510 --> 01:32:11,760
question and then we'll move on to the

2453
01:32:16,149 --> 01:32:13,520
next speaker

2454
01:32:17,430 --> 01:32:16,159
well okay let me say also we um i want

2455
01:32:18,629 --> 01:32:17,440
to move on to the next speaker just

2456
01:32:20,070 --> 01:32:18,639
because i think we'll probably get cut

2457
01:32:22,149 --> 01:32:20,080
off online but we are not going to be

2458
01:32:23,669 --> 01:32:22,159
kicked out of this room so um everett if

2459
01:32:25,030 --> 01:32:23,679
you don't mind sticking around and

2460
01:32:26,310 --> 01:32:25,040
anyone else who is a speaker and if you

2461
01:32:28,149 --> 01:32:26,320
have questions for any of our speakers

2462
01:32:30,470 --> 01:32:28,159
oh you can we can still do one more but

2463
01:32:31,750 --> 01:32:30,480

um but after that you know that we can

2464

01:32:33,510 --> 01:32:31,760

all stick around and keep asking

2465

01:32:35,669 --> 01:32:33,520

questions within the room i just don't

2466

01:32:37,030 --> 01:32:35,679

want the us to get cut off online so go

2467

01:32:38,950 --> 01:32:37,040

ahead with your questions i'll start by

2468

01:32:40,790 --> 01:32:38,960

saying i enjoyed your talk and i suspect

2469

01:32:42,950 --> 01:32:40,800

that this might be better hashtag over

2470

01:32:44,709 --> 01:32:42,960

drinks but i'll say for this room that

2471

01:32:46,470 --> 01:32:44,719

the ribosome will disagree with you

2472

01:32:50,390 --> 01:32:46,480

because it takes three equivalents of

2473

01:32:52,390 --> 01:32:50,400

ntp to put an amino acid into a protein

2474

01:32:54,149 --> 01:32:52,400

that's a kinetic problem no it's not a

2475

01:32:56,149 --> 01:32:54,159

kinetic problem it has to do with the

2476

01:32:57,990 --> 01:32:56,159

fact that it takes energy to be accurate

2477

01:33:00,149 --> 01:32:58,000

it takes energy to do kinetic proof

2478

01:33:03,270 --> 01:33:00,159

reading and takes energy to activate a

2479

01:33:05,110 --> 01:33:03,280

carboxylic acid into a phospholipid form

2480

01:33:07,270 --> 01:33:05,120

to get into the amine

2481

01:33:09,910 --> 01:33:07,280

well those all sounded like kinetic

2482

01:33:12,629 --> 01:33:09,920

problems to me and mechanistic problems

2483

01:33:15,270 --> 01:33:12,639

and not thermodynamic problems

2484

01:33:16,709 --> 01:33:15,280

this does sound like a beer conversation

2485

01:33:18,310 --> 01:33:16,719

all right so up next we're going to

2486

01:33:20,870 --> 01:33:18,320

learn about uh formation rates of

2487

01:33:22,950 --> 01:33:20,880

ferrocyanide in the early earth and that

2488

01:33:24,390 --> 01:33:22,960

is going to be with zoe todd who's

2489

01:33:27,590 --> 01:33:24,400

joining us from

2490

01:33:29,430 --> 01:33:27,600

the university of washington

2491

01:33:36,070 --> 01:33:29,440

and

2492

01:33:39,110 --> 01:33:37,750

all right hi everyone thanks for

2493

01:33:41,189 --> 01:33:39,120

sticking around we'll try not to take

2494

01:33:42,070 --> 01:33:41,199

too much of the poster time uh so today

2495

01:33:43,830 --> 01:33:42,080

i'm going to be telling you about

2496

01:33:45,590 --> 01:33:43,840

formation rates of ferrocyanide on the

2497

01:33:47,189 --> 01:33:45,600

early earth and implications for

2498

01:33:48,870 --> 01:33:47,199

prebiotic chemistry

2499

01:33:51,110 --> 01:33:48,880

so in case you haven't heard it at this

2500

01:33:52,709 --> 01:33:51,120

conference so far hydrogen cyanide is

2501

01:33:54,470 --> 01:33:52,719

commonly implicated in prebiotic

2502

01:33:56,310 --> 01:33:54,480

chemistry it's gotten lots of shout outs

2503

01:33:57,910 --> 01:33:56,320

in various sessions so i'm either going

2504

01:33:59,669 --> 01:33:57,920

to reiterate that or if you haven't

2505

01:34:03,270 --> 01:33:59,679

heard it before state it for the first

2506

01:34:06,070 --> 01:34:03,280

time so this historically dates back to

2507

01:34:08,070 --> 01:34:06,080

oro synthesis back in the 1960s where he

2508

01:34:11,270 --> 01:34:08,080

first determined that you can synthesize

2509

01:34:13,030 --> 01:34:11,280

adenine so the letter a in dna and rna

2510

01:34:16,229 --> 01:34:13,040

the a and atp it's all throughout

2511

01:34:18,310 --> 01:34:16,239

biology from pantomimerizing hcn so take

2512

01:34:19,510 --> 01:34:18,320

five hcns put them together you get

2513

01:34:21,510 --> 01:34:19,520

adeny

2514

01:34:23,430 --> 01:34:21,520

so that's back in history cyanide is

2515

01:34:25,910 --> 01:34:23,440

important what about more recent

2516

01:34:27,750 --> 01:34:25,920

prebiotic chemistry well cyanide is

2517

01:34:31,350 --> 01:34:27,760

still very important

2518

01:34:33,270 --> 01:34:31,360

so i'm going to show a variety of very

2519

01:34:35,350 --> 01:34:33,280

detailed chemical schemes here you're

2520

01:34:36,790 --> 01:34:35,360

not supposed to understand every detail

2521

01:34:38,629 --> 01:34:36,800

of all of them that's not the purpose

2522

01:34:41,350 --> 01:34:38,639

for having them here mainly i just want

2523

01:34:43,830 --> 01:34:41,360

to point out that hey in steve benner's

2524

01:34:45,590 --> 01:34:43,840

2020 paper describing one version of

2525

01:34:47,830 --> 01:34:45,600

prebiotic chemistry

2526

01:34:49,750 --> 01:34:47,840

hcn is used as a feedstock molecule and

2527

01:34:52,390 --> 01:34:49,760

has a source of synthesis to make

2528

01:34:53,910 --> 01:34:52,400

biomolecules and precursors of life

2529

01:34:55,510 --> 01:34:53,920

hcn is not specific just to this

2530

01:34:57,189 --> 01:34:55,520

chemistry you can also look at the

2531

01:34:59,590 --> 01:34:57,199

cyanosulfidic chemistry coming out of

2532

01:35:01,430 --> 01:34:59,600

john sutherland's lab and again hydrogen

2533

01:35:03,990 --> 01:35:01,440

cyanide is the basis for this network

2534

01:35:06,229 --> 01:35:04,000

that can make amino acids lipids sugars

2535

01:35:07,750 --> 01:35:06,239

and ribonucleotides finally i'll just

2536

01:35:10,470 --> 01:35:07,760

throw up one more and again this is

2537

01:35:12,790 --> 01:35:10,480

becker at all 2016. hydrogen cyanide is

2538

01:35:14,390 --> 01:35:12,800

a source molecule different type of

2539

01:35:16,629 --> 01:35:14,400

synthesis to get to the same

2540

01:35:19,030 --> 01:35:16,639

biomolecules and precursors of life

2541

01:35:21,189 --> 01:35:19,040

so by now hopefully i have reiterated or

2542

01:35:22,629 --> 01:35:21,199

reinstated the fact that hcn is commonly

2543

01:35:24,629 --> 01:35:22,639

implicated in various probiotic

2544

01:35:26,629 --> 01:35:24,639

chemistry and hcn makes the building

2545

01:35:29,270 --> 01:35:26,639

blocks of life

2546

01:35:31,189 --> 01:35:29,280

so that's awesome but does hcn actually

2547

01:35:33,189 --> 01:35:31,199

exist on the early earth and we can ask

2548

01:35:35,910 --> 01:35:33,199

that question and fortunately the answer

2549

01:35:37,990 --> 01:35:35,920

is probably there are sources of hcn on

2550

01:35:39,750 --> 01:35:38,000

the early earth so these range from

2551

01:35:41,590 --> 01:35:39,760

things like lightning generation in the

2552

01:35:43,830 --> 01:35:41,600

atmosphere so you can think the

2553

01:35:45,990 --> 01:35:43,840

classical miller uri spark discharge

2554

01:35:47,750 --> 01:35:46,000

experiment this done in a fairly

2555

01:35:50,070 --> 01:35:47,760

reducing atmosphere can give you quite

2556

01:35:52,229 --> 01:35:50,080

efficient amounts of hydrogen cyanide

2557

01:35:54,229 --> 01:35:52,239

similarly uv photochemistry interacting

2558

01:35:56,149 --> 01:35:54,239

in the atmosphere can also synthesize

2559

01:35:58,149 --> 01:35:56,159

hydrogen cyanide and both of those two

2560

01:36:00,149 --> 01:35:58,159

processes are much more efficient in

2561

01:36:01,669 --> 01:36:00,159

more reducing atmospheres drop-off

2562

01:36:03,510 --> 01:36:01,679

inefficiency when you go to a more

2563

01:36:05,430 --> 01:36:03,520

oxidizing atmosphere if you want an

2564

01:36:06,870 --> 01:36:05,440

atmosphere composition independent

2565

01:36:09,270 --> 01:36:06,880

source of hydrogen cyanide you could

2566

01:36:12,229 --> 01:36:09,280

look to impact delivery or perhaps also

2567

01:36:14,470 --> 01:36:12,239

impact synthesis of hydrogen cyanide so

2568

01:36:16,950 --> 01:36:14,480

hcn is important and hcn could have been

2569

01:36:19,510 --> 01:36:16,960

there through a variety of means

2570

01:36:21,109 --> 01:36:19,520

but there's one catch you knew it was

2571

01:36:23,270 --> 01:36:21,119

coming right it sounded too good to be

2572

01:36:25,270 --> 01:36:23,280

true and that is that hydrogen cyanide

2573

01:36:27,510 --> 01:36:25,280

can degrade over time so you can begin

2574

01:36:29,430 --> 01:36:27,520

to see a premise of a potential issue

2575

01:36:31,830 --> 01:36:29,440

for prebiotic chemistry either you have

2576

01:36:33,830 --> 01:36:31,840

to be continuously synthesizing hcn it

2577

01:36:35,350 --> 01:36:33,840

has to be continuously available or the

2578

01:36:38,790 --> 01:36:35,360

prebiotic chemistry that makes use of

2579

01:36:40,709 --> 01:36:38,800

hcn has to happen on such a faster scale

2580

01:36:43,030 --> 01:36:40,719

than the degradation occurs

2581

01:36:45,270 --> 01:36:43,040

or you need some other geochemical

2582

01:36:47,109 --> 01:36:45,280

source to kind of save you from this

2583

01:36:49,350 --> 01:36:47,119

potential issue

2584

01:36:50,870 --> 01:36:49,360

so one potential suggestion here and i

2585

01:36:52,709 --> 01:36:50,880

should state we do not know at this

2586

01:36:54,310 --> 01:36:52,719

point how fast necessarily that

2587

01:36:56,229 --> 01:36:54,320

chemistry works under a planetary

2588

01:36:57,750 --> 01:36:56,239

environment so these are open questions

2589

01:36:58,870 --> 01:36:57,760

that we're not entirely sure about at

2590

01:37:00,550 --> 01:36:58,880

this time

2591

01:37:02,629 --> 01:37:00,560

so one potential solution is that you

2592

01:37:04,790 --> 01:37:02,639

could store hydrogen cyanide in the form

2593

01:37:07,189 --> 01:37:04,800

of ferrocyanide so if you have a ferrous

2594

01:37:09,270 --> 01:37:07,199

iron center Fe^{2+} plus you have six

2595

01:37:12,550 --> 01:37:09,280

cyanide ligands bound to it this becomes

2596

01:37:14,070 --> 01:37:12,560

a much more stable form of cyanide you

2597

01:37:16,070 --> 01:37:14,080

can potentially store this in stock

2598

01:37:17,430 --> 01:37:16,080

plotted for later use so this is

2599

01:37:19,590 --> 01:37:17,440

demonstrated in this really nice figure

2600

01:37:21,510 --> 01:37:19,600

from Sasilov at all 2020 where if you

2601
01:37:23,350 --> 01:37:21,520
have h standing the atmosphere you can

2602
01:37:26,310 --> 01:37:23,360
potentially concentrate that in surface

2603
01:37:27,910 --> 01:37:26,320
waters with things like Fe^{2+} plus and we

2604
01:37:29,990 --> 01:37:27,920
heard a lot about sulfur and you can see

2605
01:37:31,910 --> 01:37:30,000
sulfide appears in these lakes as well

2606
01:37:33,830 --> 01:37:31,920
then if you evaporate and ultimately

2607
01:37:35,590 --> 01:37:33,840
precipitate out some of these salts this

2608
01:37:37,990 --> 01:37:35,600
is a good way to potentially accumulate

2609
01:37:41,270 --> 01:37:38,000
decent amounts of ferrocyanide and be

2610
01:37:44,470 --> 01:37:41,280
able to use cyanide later on

2611
01:37:46,790 --> 01:37:44,480
and this again goes back to 1995 Keith

2612
01:37:48,870 --> 01:37:46,800
and Miller with a paper titled was

2613
01:37:50,390 --> 01:37:48,880

ferrocyanide a prebiotic reagent but

2614

01:37:52,390 --> 01:37:50,400

they investigate this primarily from a

2615

01:37:54,390 --> 01:37:52,400

thermodynamic perspective and also with

2616

01:37:56,629 --> 01:37:54,400

a focus on the oceans

2617

01:37:58,550 --> 01:37:56,639

so what i wanted to know was how fast

2618

01:38:00,470 --> 01:37:58,560

does this chemistry work you know if

2619

01:38:02,310 --> 01:38:00,480

we're thinking about kinetics is this an

2620

01:38:03,750 --> 01:38:02,320

issue or is this not an issue at all or

2621

01:38:06,070 --> 01:38:03,760

what can the environment constrain about

2622

01:38:07,910 --> 01:38:06,080

the chemistry so we ask the question how

2623

01:38:09,910 --> 01:38:07,920

fast and efficiently does ferrocyanide

2624

01:38:11,910 --> 01:38:09,920

form under a range of plausible

2625

01:38:13,669 --> 01:38:11,920

planetary conditions so we tested the

2626

01:38:15,669 --> 01:38:13,679

rate of formation and the yield as a

2627

01:38:17,270 --> 01:38:15,679

function of concentration of reactants

2628

01:38:19,669 --> 01:38:17,280

and ph

2629

01:38:22,390 --> 01:38:19,679

so to show you some sets of experimental

2630

01:38:24,709 --> 01:38:22,400

data this is showing 0.1 millimolar of

2631

01:38:27,669 --> 01:38:24,719

fe² plus and varying concentrations of

2632

01:38:29,830 --> 01:38:27,679

cyanide at a ph of 9. so what you can

2633

01:38:33,270 --> 01:38:29,840

see is that this reaction occurs quite

2634

01:38:36,070 --> 01:38:33,280

fast so if you you see a very steep

2635

01:38:37,669 --> 01:38:36,080

increase initially in your concentration

2636

01:38:39,590 --> 01:38:37,679

of ferrocyanide which is determined

2637

01:38:41,189 --> 01:38:39,600

through uv vis absorption measurements

2638

01:38:43,030 --> 01:38:41,199

you can see we only have to monitor this

2639

01:38:44,950 --> 01:38:43,040

reaction for about four minutes for it

2640

01:38:46,470 --> 01:38:44,960

to be pretty much done

2641

01:38:48,470 --> 01:38:46,480

so we can determine the rate constant

2642

01:38:50,790 --> 01:38:48,480

from that first 10 seconds and the final

2643

01:38:52,229 --> 01:38:50,800

concentration of ferrocyanide under a

2644

01:38:53,990 --> 01:38:52,239

range of conditions

2645

01:38:55,990 --> 01:38:54,000

so here the left-hand panel is showing

2646

01:38:57,510 --> 01:38:56,000

you k that rate constant of initial

2647

01:38:59,510 --> 01:38:57,520

formation and the right-hand panel is

2648

01:39:01,350 --> 01:38:59,520

showing you the final concentration as a

2649

01:39:03,270 --> 01:39:01,360

function of concentration of cyanide and

2650

01:39:04,950 --> 01:39:03,280

across a range of pHS

2651

01:39:07,590 --> 01:39:04,960

so a couple things stick out here and

2652

01:39:09,350 --> 01:39:07,600

this is primarily in the ph dependence

2653

01:39:11,830 --> 01:39:09,360

so this reaction is fastest and most

2654

01:39:13,910 --> 01:39:11,840

efficient at ph 8 to 9 and it's

2655

01:39:16,310 --> 01:39:13,920

interesting that it drops off at

2656

01:39:18,310 --> 01:39:16,320

more acidic phs but also what really

2657

01:39:20,470 --> 01:39:18,320

caught my eye is that ph 10 is not

2658

01:39:23,750 --> 01:39:20,480

better than ph 9 you do not see this

2659

01:39:25,830 --> 01:39:23,760

linear increase when you change the ph

2660

01:39:27,910 --> 01:39:25,840

so this is with varying cyanide

2661

01:39:29,910 --> 01:39:27,920

concentrations we can do the same set of

2662

01:39:32,229 --> 01:39:29,920

experiments holding cyanide constant and

2663

01:39:35,669 --> 01:39:32,239

then varying the concentration of Fe^{2+}

2664

01:39:37,270 --> 01:39:35,679

plus again investigate the same pH range

2665

01:39:39,430 --> 01:39:37,280

make similar plots and again we find

2666

01:39:41,270 --> 01:39:39,440

that pH 8.9 are going to generally be the

2667

01:39:43,350 --> 01:39:41,280

fastest and the most efficient and we

2668

01:39:45,109 --> 01:39:43,360

observe the similar behavior

2669

01:39:46,950 --> 01:39:45,119

so what does this mean for ferrocyanide

2670

01:39:49,910 --> 01:39:46,960

in the planetary context

2671

01:39:51,590 --> 01:39:49,920

so on a planet you can have pretty much

2672

01:39:54,149 --> 01:39:51,600

you know free choice or constrain

2673

01:39:55,189 --> 01:39:54,159

choices of concentrations pH and

2674

01:39:57,189 --> 01:39:55,199

temperature depending on what

2675

01:39:59,030 --> 01:39:57,199

environment you're considering and just

2676
01:40:00,390 --> 01:39:59,040
as a reminder hydrogen cyanide we like

2677
01:40:02,790 --> 01:40:00,400
it because it can synthesize

2678
01:40:04,709 --> 01:40:02,800
biomolecules so we can start to imagine

2679
01:40:06,310 --> 01:40:04,719
a little model of a lake on the surface

2680
01:40:07,669 --> 01:40:06,320
of early earth we have some partial

2681
01:40:09,910 --> 01:40:07,679
pressure hydrogen cyanide in the

2682
01:40:11,990 --> 01:40:09,920
atmosphere can equilibrate with surface

2683
01:40:13,910 --> 01:40:12,000
waters through henry log equilibrium

2684
01:40:15,510 --> 01:40:13,920
that we heard about earlier

2685
01:40:17,750 --> 01:40:15,520
and then if you have a stream coming in

2686
01:40:19,510 --> 01:40:17,760
that contains some amount of Fe^{2+} plus

2687
01:40:22,149 --> 01:40:19,520
which you would likely have on the early

2688
01:40:24,550 --> 01:40:22,159

earth before the oxygenation event then

2689

01:40:25,910 --> 01:40:24,560

you can form ferrocyanide and we can ask

2690

01:40:27,270 --> 01:40:25,920

the question all right given our

2691

01:40:29,270 --> 01:40:27,280

experimentally determined rates and

2692

01:40:30,950 --> 01:40:29,280

yields how much ferrocyanide can you

2693

01:40:33,430 --> 01:40:30,960

possibly accumulate

2694

01:40:35,350 --> 01:40:33,440

so this is a preliminary calculation and

2695

01:40:37,109 --> 01:40:35,360

i would caution you that the numbers are

2696

01:40:38,950 --> 01:40:37,119

very dependent on what assumptions you

2697

01:40:41,189 --> 01:40:38,960

make so what is the flow rate into the

2698

01:40:43,030 --> 01:40:41,199

lake what is the volume of the lake what

2699

01:40:45,270 --> 01:40:43,040

is the concentration of free ferrous

2700

01:40:46,950 --> 01:40:45,280

iron that you're assuming but what i do

2701

01:40:49,030 --> 01:40:46,960

have a lot more confidence in is the

2702

01:40:51,750 --> 01:40:49,040

change between different phs and the

2703

01:40:53,990 --> 01:40:51,760

trends with ph and concentration of

2704

01:40:56,070 --> 01:40:54,000

ferrous iron so what i'll draw your

2705

01:40:57,669 --> 01:40:56,080

attention to here is that you really do

2706

01:40:59,350 --> 01:40:57,679

not get a lot of ferrocyanide

2707

01:41:01,109 --> 01:40:59,360

accumulation i'm showing you the amount

2708

01:41:03,189 --> 01:41:01,119

of time here to reach one millimolar of

2709

01:41:04,790 --> 01:41:03,199

ferrocyanide which is kind of like a

2710

01:41:06,229 --> 01:41:04,800

thumbs up concentration for getting

2711

01:41:07,430 --> 01:41:06,239

prebiotic chemistry to work in the

2712

01:41:09,830 --> 01:41:07,440

laboratory

2713

01:41:11,669 --> 01:41:09,840

so at ph 6 and low fe2 plus

2714

01:41:14,070 --> 01:41:11,679

concentrations this can take a really

2715

01:41:16,390 --> 01:41:14,080

long time talking millions of years

2716

01:41:18,629 --> 01:41:16,400

but if you go to more basic phs and bump

2717

01:41:20,470 --> 01:41:18,639

up the ferrous iron concentration you

2718

01:41:22,310 --> 01:41:20,480

can have this occurring plausibly than

2719

01:41:23,430 --> 01:41:22,320

tens of thousands of years or a thousand

2720

01:41:26,870 --> 01:41:23,440

years or even if you're really

2721

01:41:29,030 --> 01:41:26,880

optimistic 100 years 10 years

2722

01:41:30,390 --> 01:41:29,040

so overall conclusions we measured these

2723

01:41:32,470 --> 01:41:30,400

rates of formation and yields of

2724

01:41:34,149 --> 01:41:32,480

ferrocyanide over a range of planetarily

2725

01:41:35,910 --> 01:41:34,159

relevant parameters including

2726

01:41:37,830 --> 01:41:35,920

concentration of ph temperature

2727

01:41:39,510 --> 01:41:37,840

experiments are in progress so we will

2728

01:41:40,390 --> 01:41:39,520

be able to add that parameter in here as

2729

01:41:42,070 --> 01:41:40,400

well

2730

01:41:43,750 --> 01:41:42,080

and we find that the accumulation of

2731

01:41:46,229 --> 01:41:43,760

ferrocyanide is favored at slightly

2732

01:41:49,109 --> 01:41:46,239

alkaline phs and under these favorable

2733

01:41:51,109 --> 01:41:49,119

conditions and with assumptions that are

2734

01:41:53,270 --> 01:41:51,119

hopefully reasonable but again subject

2735

01:41:55,990 --> 01:41:53,280

to your range of constraints for the

2736

01:41:57,750 --> 01:41:56,000

early earth ferrocyanide stock piling to

2737

01:41:59,669 --> 01:41:57,760

significant concentrations may be able

2738

01:42:02,149 --> 01:41:59,679

to occur on reasonable time scales for

2739

01:42:04,229 --> 01:42:02,159

probiotic chemistry and with that i will

2740

01:42:05,430 --> 01:42:04,239

thank david catling and nick woken for

2741

01:42:07,910 --> 01:42:05,440

helping collaborations on this

2742

01:42:10,229 --> 01:42:07,920

experiment this project funding sources

2743

01:42:16,790 --> 01:42:10,239

and of course peter my pony he says

2744

01:42:21,350 --> 01:42:18,629

we'll have to bring peter with you next

2745

01:42:23,990 --> 01:42:21,360

time um all right do we have a question

2746

01:42:25,669 --> 01:42:24,000

for zoe

2747

01:42:27,350 --> 01:42:25,679

yeah it looks like we have a couple and

2748

01:42:28,629 --> 01:42:27,360

and we can ask as many and if you have

2749

01:42:29,910 --> 01:42:28,639

questions for other people feel free to

2750

01:42:32,470 --> 01:42:29,920

go ahead and start lining up i know we

2751
01:42:34,950 --> 01:42:32,480
had one for everett and so yeah go ahead

2752
01:42:39,430 --> 01:42:34,960
um how he seems to get out the hype

2753
01:42:41,350 --> 01:42:39,440
today how do you cyanide from the paris

2754
01:42:45,189 --> 01:42:41,360
sorry say that again yes

2755
01:42:47,030 --> 01:42:45,199
who is to recover the hcn from

2756
01:42:48,629 --> 01:42:47,040
yeah that's a great question so it has

2757
01:42:49,910 --> 01:42:48,639
been suggested that you can do thermal

2758
01:42:51,750 --> 01:42:49,920
processing

2759
01:42:53,510 --> 01:42:51,760
so you might need somewhat high

2760
01:42:54,629 --> 01:42:53,520
temperatures to this there are various

2761
01:42:55,750 --> 01:42:54,639
references that have been said in

2762
01:42:58,310 --> 01:42:55,760
literature but i would love to see

2763
01:43:00,870 --> 01:42:58,320

someone do that study um much more

2764

01:43:02,550 --> 01:43:00,880

thoroughly and revisit that question

2765

01:43:04,390 --> 01:43:02,560

there's another possibility is that uv

2766

01:43:06,709 --> 01:43:04,400

irradiation of ferrocyanide can do a

2767

01:43:08,709 --> 01:43:06,719

reaction called photoequation where you

2768

01:43:10,950 --> 01:43:08,719

can kick off one cyanide and put a water

2769

01:43:12,870 --> 01:43:10,960

molecule on and then it might rapidly

2770

01:43:14,470 --> 01:43:12,880

lose more cyanide so it might be

2771

01:43:16,310 --> 01:43:14,480

possible to get some amount of cyanide

2772

01:43:18,149 --> 01:43:16,320

from that mechanism as well

2773

01:43:20,470 --> 01:43:18,159

thanks for the question

2774

01:43:23,990 --> 01:43:20,480

awesome and we can come right over here

2775

01:43:25,669 --> 01:43:24,000

uh paul remember university of cambridge

2776

01:43:27,189 --> 01:43:25,679

really nice talk um

2777

01:43:29,750 --> 01:43:27,199

it looked to me from your plot although

2778

01:43:31,430 --> 01:43:29,760

is it difficult to tell from um from the

2779

01:43:33,270 --> 01:43:31,440

way that the gradients are shown that it

2780

01:43:34,870 --> 01:43:33,280

seems that the concentration of iron

2781

01:43:36,550 --> 01:43:34,880

matters a lot more

2782

01:43:38,390 --> 01:43:36,560

than the ph it looks like if you just

2783

01:43:40,950 --> 01:43:38,400

have a lot of iron it works pretty

2784

01:43:43,030 --> 01:43:40,960

quickly regardless of the ph would that

2785

01:43:45,270 --> 01:43:43,040

be an accurate interpretation or does ph

2786

01:43:47,270 --> 01:43:45,280

matter more than the way that i'm kind

2787

01:43:48,870 --> 01:43:47,280

of looking at them no i agree with you

2788

01:43:50,629 --> 01:43:48,880

there and i think the other thing too is

2789

01:43:52,470 --> 01:43:50,639

i'm showing you six orders of magnitude

2790

01:43:54,629 --> 01:43:52,480

of ferrocyanide or ferrous iron

2791

01:43:57,350 --> 01:43:54,639

concentration so that's really a wide

2792

01:43:59,189 --> 01:43:57,360

range of parameter space there and your

2793

01:44:00,629 --> 01:43:59,199

ferrous iron concentration is somewhat

2794

01:44:02,629 --> 01:44:00,639

degenerate with the volume of the lake

2795

01:44:04,709 --> 01:44:02,639

you're assuming in your flow rate in my

2796

01:44:06,629 --> 01:44:04,719

proline preliminary model here so

2797

01:44:08,390 --> 01:44:06,639

depending on those assumptions

2798

01:44:10,550 --> 01:44:08,400

i think the role of ph should not be

2799

01:44:13,270 --> 01:44:10,560

understated but again the dominating

2800

01:44:14,629 --> 01:44:13,280

factor is going to be those assumptions

2801

01:44:16,149 --> 01:44:14,639

thanks paul

2802

01:44:17,350 --> 01:44:16,159

awesome thank you and then i think we

2803

01:44:20,149 --> 01:44:17,360

have a question right here i think

2804

01:44:21,990 --> 01:44:20,159

everett this might have been for you go

2805

01:44:24,390 --> 01:44:22,000

ahead and you can ask a question

2806

01:44:25,750 --> 01:44:24,400

hi jessica bowman from georgia tech um

2807

01:44:27,270 --> 01:44:25,760

maybe i missed it in the beginning but i

2808

01:44:28,950 --> 01:44:27,280

was wondering if you could comment on

2809

01:44:31,669 --> 01:44:28,960

your assumptions about presence of

2810

01:44:37,109 --> 01:44:31,679

oxygen in these uh reactions and also on

2811

01:44:41,109 --> 01:44:39,189

yes this is for me not everett is that

2812

01:44:43,189 --> 01:44:41,119

true okay yes yes so we did these all

2813

01:44:45,830 --> 01:44:43,199

exclusively in an anaerobic environment

2814

01:44:49,590 --> 01:44:45,840

so in a glove box oxygen free oxygen

2815

01:44:51,750 --> 01:44:49,600

reduced degas water zero ppm oxygen

2816

01:44:52,550 --> 01:44:51,760

inside the glove box if you don't do

2817

01:44:53,990 --> 01:44:52,560

that

2818

01:44:55,669 --> 01:44:54,000

this reaction is

2819

01:44:57,669 --> 01:44:55,679

you know you can't study it properly

2820

01:44:59,430 --> 01:44:57,679

because the ferrous iron oxidizes very

2821

01:45:01,030 --> 01:44:59,440

quickly in an oxygen environment so

2822

01:45:02,310 --> 01:45:01,040

you've got to be careful about that and

2823

01:45:04,629 --> 01:45:02,320

you know the early earth we're assuming

2824

01:45:06,550 --> 01:45:04,639

it's pretty anoxic free so yeah

2825

01:45:09,480 --> 01:45:06,560

thank you for the question awesome and

2826

01:45:12,790 --> 01:45:09,490

let's let's thank zoe thank you so much

2827

01:45:15,910 --> 01:45:14,470

thank you and i think that we had some

2828

01:45:17,430 --> 01:45:15,920

questions online and if there was anyone

2829

01:45:18,870 --> 01:45:17,440

else in the room you guys can feel free

2830

01:45:20,310 --> 01:45:18,880

to stand up and i'm just going to ask

2831

01:45:22,709 --> 01:45:20,320

the questions and if the speakers are

2832

01:45:24,149 --> 01:45:22,719

still here great if not um raj are you

2833

01:45:27,270 --> 01:45:24,159

still here i think this one is for you

2834

01:45:29,669 --> 01:45:27,280

so um and in i'm not exactly sure who

2835

01:45:31,830 --> 01:45:29,679

that is but someone in in uh says can

2836

01:45:34,070 --> 01:45:31,840

you comment on the observed difference

2837

01:45:36,470 --> 01:45:34,080

of uh nitrogen between the inner and

2838

01:45:39,270 --> 01:45:36,480

outer solar system materials and what's

2839

01:45:41,990 --> 01:45:39,280

the main loss mechanism for n from a

2840

01:45:45,270 --> 01:45:42,000

rocky protoplanet

2841

01:45:52,709 --> 01:45:45,280

nitrogen yeah yeah yeah i can give you

2842

01:45:58,709 --> 01:45:55,990

um yeah so isotopically i guess

2843

01:46:00,870 --> 01:45:58,719

the outer solar system materials are

2844

01:46:03,910 --> 01:46:00,880

heavier in delta 15

2845

01:46:06,550 --> 01:46:03,920

higher values uh inner solar system uh

2846

01:46:08,790 --> 01:46:06,560

lower delta 59 values

2847

01:46:10,709 --> 01:46:08,800

uh so we do need certain amount of outer

2848

01:46:12,470 --> 01:46:10,719

solar system or cc type of material as

2849

01:46:14,950 --> 01:46:12,480

far as nitrogen isotopic compositions

2850

01:46:17,590 --> 01:46:14,960

will as far as the loss mechanism the

2851
01:46:19,669 --> 01:46:17,600
majority of the loss from quantitative

2852
01:46:22,390 --> 01:46:19,679
building blocks as they are forming

2853
01:46:25,030 --> 01:46:22,400
protoplanets would be through formation

2854
01:46:26,870 --> 01:46:25,040
of atmosphere that eventually gets lost

2855
01:46:29,030 --> 01:46:26,880
because these protoplanets are

2856
01:46:30,950 --> 01:46:29,040
so small they cannot hold on to their

2857
01:46:32,950 --> 01:46:30,960
onto their atmosphere because

2858
01:46:35,109 --> 01:46:32,960
there is not enough gravitational pull

2859
01:46:37,030 --> 01:46:35,119
so that's so that differentiation and

2860
01:46:39,430 --> 01:46:37,040
atmosphere formation and atmospheric

2861
01:46:41,109 --> 01:46:39,440
glow out would be the dominant mechanism

2862
01:46:43,189 --> 01:46:41,119
of losing nitrogen

2863
01:46:45,510 --> 01:46:43,199

uh at the same time you do need to

2864

01:46:46,629 --> 01:46:45,520

retain certain amount to make nitrogen

2865

01:46:48,550 --> 01:46:46,639

budget

2866

01:46:49,350 --> 01:46:48,560

explained in our planet and that's why

2867

01:46:51,830 --> 01:46:49,360

we

2868

01:46:52,550 --> 01:46:51,840

explain like relatively faster growth of

2869

01:46:54,550 --> 01:46:52,560

some

2870

01:46:56,229 --> 01:46:54,560

protoplanets so that nitrogen can be

2871

01:46:58,070 --> 01:46:56,239

filled onto the body

2872

01:47:00,310 --> 01:46:58,080

and partitioned into the pore and

2873

01:47:02,229 --> 01:47:00,320

retained in the atmosphere but the major

2874

01:47:04,870 --> 01:47:02,239

loss mechanism is through protoplanetary

2875

01:47:06,709 --> 01:47:04,880

atmospheric blowout

2876

01:47:08,149 --> 01:47:06,719

awesome thank you

2877

01:47:09,750 --> 01:47:08,159

and i think we hit all the questions

2878

01:47:11,270 --> 01:47:09,760

online so thank you everyone who stuck

2879

01:47:12,870 --> 01:47:11,280

through to the end and thank you again

2880

01:47:15,270 --> 01:47:12,880

to all of our speakers this was an

2881

01:47:16,950 --> 01:47:15,280

awesome very dynamic session so thank