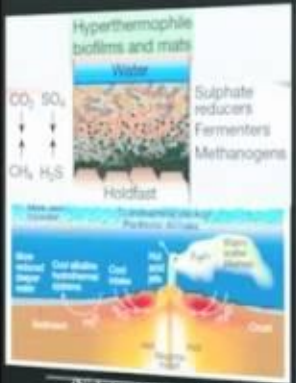
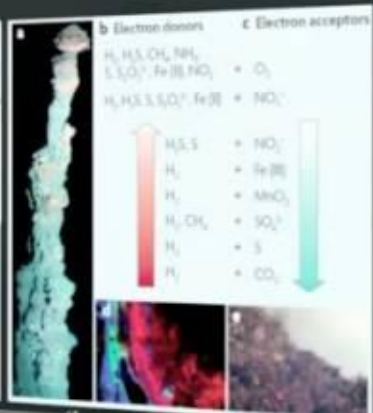
Late Archean Earth



(Nisbet and Sleep, 2001, Nature)



(Jorgensen and Boetius, 2007, Nature)

(Nisbet and Sleep, 2001, Nature)

1
00:00:15,860 --> 00:00:11,750
so today's talks are pretty much geology

2
00:00:17,179 --> 00:00:15,870
and biology chemistry esque related but

3
00:00:19,190 --> 00:00:17,189
I've been tasked with giving you a bit

4
00:00:21,740 --> 00:00:19,200
of an introduction to geology I will

5
00:00:23,660 --> 00:00:21,750
give you a disclaimer I have a degree in

6
00:00:25,700 --> 00:00:23,670
biochemistry and I've only been doing

7
00:00:30,980 --> 00:00:25,710
geology for about a year and a half I'll

8
00:00:33,080 --> 00:00:30,990
do my best but so those of you having

9
00:00:36,290 --> 00:00:33,090
met me already my name is Jess money

10
00:00:38,150 --> 00:00:36,300
organizers my talk today is geology and

11
00:00:40,250 --> 00:00:38,160
biology putting the ology and

12
00:00:43,090 --> 00:00:40,260
astrobiology so hopefully you guys watch

13
00:00:47,840 --> 00:00:43,100

my video got a bit of an intro to stuff

14
00:00:50,000 --> 00:00:47,850
so just yeah jared is really good thanks

15
00:00:51,139 --> 00:00:50,010
feel free to ask me any questions if you

16
00:00:52,610 --> 00:00:51,149
guys have any questions you don't know

17
00:00:53,479 --> 00:00:52,620
what I'm talking about throw a hand up

18
00:00:56,209 --> 00:00:53,489
this is supposed to be kind of an

19
00:00:58,400 --> 00:00:56,219
informal warm-up thing so what I'm going

20
00:01:00,740 --> 00:00:58,410
to talk about a little bit is start off

21
00:01:02,920 --> 00:01:00,750
with an intro into the geologic record a

22
00:01:05,749 --> 00:01:02,930
little bit about early Earth and Mars

23
00:01:07,850 --> 00:01:05,759
introduced the idea of life what are

24
00:01:09,230 --> 00:01:07,860
habitable paleo environments where we

25
00:01:11,960 --> 00:01:09,240
would find those in the geologic record

26
00:01:13,550 --> 00:01:11,970
on earth and mars and what evidence for

27
00:01:15,320 --> 00:01:13,560
life we see in the geologic record and

28
00:01:16,490 --> 00:01:15,330
then talk a little bit of analog so i'm

29
00:01:17,960 --> 00:01:16,500
doing i'm going to do my best to try and

30
00:01:20,359 --> 00:01:17,970
touch on what everyone today is talking

31
00:01:24,730 --> 00:01:20,369
about at least using a word or two from

32
00:01:27,260 --> 00:01:24,740
their abstract if nothing if not more so

33
00:01:30,080 --> 00:01:27,270
do you logic histories so geologic time

34
00:01:31,550 --> 00:01:30,090
for those who that aren't started you

35
00:01:33,919 --> 00:01:31,560
know 4.5 billion years ago whenever the

36
00:01:37,520 --> 00:01:33,929
Big Bang Earth and Mars started with the

37
00:01:40,070 --> 00:01:37,530
same and now here we are earth is green

38
00:01:43,609 --> 00:01:40,080

abundant life Mars is kind of a polar

39
00:01:45,830 --> 00:01:43,619
desert but why do we care about this

40
00:01:47,510 --> 00:01:45,840
well understanding geologic context is

41
00:01:49,359 --> 00:01:47,520
really interesting in the realm of

42
00:01:51,169 --> 00:01:49,369
astrobiology because it provides

43
00:01:52,639 --> 00:01:51,179
constraints for depositional

44
00:01:54,229 --> 00:01:52,649
environments if you know what the

45
00:01:55,490 --> 00:01:54,239
geologic context of in areas you can

46
00:01:58,040 --> 00:01:55,500
note that how those rocks were deposited

47
00:02:00,080 --> 00:01:58,050
there which tells you what the paleo

48
00:02:02,150 --> 00:02:00,090
environmental conditions were and this

49
00:02:03,889 --> 00:02:02,160
basically constrains habitability and

50
00:02:06,139 --> 00:02:03,899
the whether or not life could be there

51
00:02:07,760 --> 00:02:06,149
the geologic context also constrains

52
00:02:09,350 --> 00:02:07,770
whether niala bio signature is preserved

53
00:02:10,999 --> 00:02:09,360
heard about this a little bit last night

54
00:02:13,580 --> 00:02:11,009
how sediments are better than safe

55
00:02:15,260 --> 00:02:13,590
volcanics for preserving so if you

56
00:02:17,690 --> 00:02:15,270
understand that we can really kind of

57
00:02:18,650 --> 00:02:17,700
tailor our search for life in the

58
00:02:19,460 --> 00:02:18,660
universe and where we should be looking

59
00:02:22,250 --> 00:02:19,470
for evidence

60
00:02:24,530 --> 00:02:22,260
life so in the beginning we had

61
00:02:27,050 --> 00:02:24,540
planetesimals like this flying around

62
00:02:28,670 --> 00:02:27,060
hot burning balls of molten rock and

63
00:02:30,530 --> 00:02:28,680

they went through the process of

64
00:02:32,600 --> 00:02:30,540
planetary differentiation or at least

65
00:02:33,950 --> 00:02:32,610
the terrestrial planets did so this is a

66
00:02:35,750 --> 00:02:33,960
process in which denser material

67
00:02:37,910 --> 00:02:35,760
separates from the lens test materials

68
00:02:40,640 --> 00:02:37,920
so for Earth we have an iron nickel core

69
00:02:43,370 --> 00:02:40,650
all the heavy iron nickel heavy elements

70
00:02:44,990 --> 00:02:43,380
sunk to the core we have a lighter

71
00:02:47,030 --> 00:02:45,000
mantle which are iron and magnesium

72
00:02:48,290 --> 00:02:47,040
silicate minerals and then a lighter

73
00:02:51,590 --> 00:02:48,300
cross which are mostly aluminum

74
00:02:55,760 --> 00:02:51,600
potassium sodium silicate so this is

75
00:02:58,850 --> 00:02:55,770
Earth and Mars now Earth you can see

76
00:03:02,360 --> 00:02:58,860
iron nickel core you've got your liquid

77
00:03:04,640 --> 00:03:02,370
outer core mantle your crust Mars is

78
00:03:07,250 --> 00:03:04,650
also similarly differentiated you've got

79
00:03:08,810 --> 00:03:07,260
a core mantle although you can see based

80
00:03:12,140 --> 00:03:08,820
on the redness that it's not as warm on

81
00:03:13,610 --> 00:03:12,150
the inside anymore so what's going on

82
00:03:15,860 --> 00:03:13,620
when we talked about geologic processes

83
00:03:18,590 --> 00:03:15,870
well right now this is Earth and Mars

84
00:03:25,610 --> 00:03:18,600
today what are they geologically active

85
00:03:27,290 --> 00:03:25,620
or in yeah I think deep down yes but we

86
00:03:31,850 --> 00:03:27,300
don't have there's no large-scale mantle

87
00:03:36,229 --> 00:03:31,860
convection like Earth has right now yeah

88
00:03:37,400 --> 00:03:36,239

that'd be great we could get one so

89
00:03:40,490 --> 00:03:37,410
we're talking with geologic processes

90
00:03:41,660 --> 00:03:40,500
right now on impacts are the most

91
00:03:44,300 --> 00:03:41,670
ubiquitous process in the solar system

92
00:03:46,670 --> 00:03:44,310
Earth and Mars are both still subject

93
00:03:49,130 --> 00:03:46,680
impacts although on long geologic time

94
00:03:52,130 --> 00:03:49,140
scales volcanism earth definitely has

95
00:03:55,100 --> 00:03:52,140
volcanism now Mars did not so much

96
00:03:56,660 --> 00:03:55,110
anymore plate tectonics we'll hear a lot

97
00:04:01,280 --> 00:03:56,670
about this later today earth definitely

98
00:04:02,660 --> 00:04:01,290
yes Mars not really chemical weathering

99
00:04:04,729 --> 00:04:02,670
is still happening every pretty much

100
00:04:06,590 --> 00:04:04,739
everywhere you've got redox reactions to

101
00:04:10,039 --> 00:04:06,600
that happening biological weathering

102
00:04:13,130 --> 00:04:10,049
earth yes Mars not so much and wind and

103
00:04:15,110 --> 00:04:13,140
water erosion earth definitely Mars

104
00:04:16,670 --> 00:04:15,120
minimal we see evidence for water

105
00:04:18,880 --> 00:04:16,680
erosion going on now not a whole lot

106
00:04:20,960 --> 00:04:18,890
wind erosion the atmosphere is a lot

107
00:04:22,550 --> 00:04:20,970
less dense than it is here there's a

108
00:04:24,830 --> 00:04:22,560
less wind erosion going on so basically

109
00:04:26,510 --> 00:04:24,840
dearth is geologically active on billion

110
00:04:28,339 --> 00:04:26,520
year time scales Mars is kind of

111
00:04:31,400 --> 00:04:28,349
geologically dead right now if you want

112
00:04:34,090 --> 00:04:31,410
to call it that so let's talk about

113
00:04:37,040 --> 00:04:34,100

114
00:04:39,620 --> 00:04:37,050
so this is a hidden or what the Hadean

115
00:04:43,760 --> 00:04:39,630
was believed to be like in the 50s kind

116
00:04:46,010 --> 00:04:43,770
of a hellish type place but now we have

117
00:04:48,080 --> 00:04:46,020
a more I guess mellow view what the

118
00:04:50,659 --> 00:04:48,090
Hadean is like this is the more up cool

119
00:04:53,270 --> 00:04:50,669
and climate updated reconstruction so

120
00:04:54,499 --> 00:04:53,280
this is based on 4.4 old

121
00:04:57,770 --> 00:04:54,509
billion-year-old zircons that were found

122
00:04:59,089 --> 00:04:57,780
zarkon's are very very resistant

123
00:05:02,270 --> 00:04:59,099
minerals there is resistant to

124
00:05:05,360 --> 00:05:02,280
weathering and so these were data using

125
00:05:07,879 --> 00:05:05,370
a rainy uranium lead dating and they

126
00:05:09,710 --> 00:05:07,889
were found in 3.1 billion year old meta

127
00:05:11,779 --> 00:05:09,720
sediments and what what why these tell

128
00:05:13,760 --> 00:05:11,789
us that ad and earth might have been

129
00:05:16,850 --> 00:05:13,770
cooler and more Clement is that these

130
00:05:19,879 --> 00:05:16,860
zircons are similar to circles we find

131
00:05:22,460 --> 00:05:19,889
in granitic rocks modern granitic rocks

132
00:05:25,520 --> 00:05:22,470
and this tells us that we had subduction

133
00:05:27,379 --> 00:05:25,530
of Hydra hydrated basalt in subduction

134
00:05:29,210 --> 00:05:27,389
zones and this tells us there must have

135
00:05:30,890 --> 00:05:29,220
been water on the surface so there was

136
00:05:32,589 --> 00:05:30,900
some water that as well the oxygen

137
00:05:34,550 --> 00:05:32,599
isotope fractionation in these zircons

138
00:05:37,640 --> 00:05:34,560

indicates if they are formed at low

139
00:05:42,409 --> 00:05:37,650
temperatures so not necessarily a molten

140
00:05:44,960 --> 00:05:42,419
ball of rock we talked about earlier or

141
00:05:46,100 --> 00:05:44,970
the archaean from 3.8 to 2.5 billion

142
00:05:48,170 --> 00:05:46,110
years ago this is a photo you guys are

143
00:05:50,089 --> 00:05:48,180
all pretty familiar with we had a higher

144
00:05:51,620 --> 00:05:50,099
heat flow so the mantle is a lot hotter

145
00:05:53,149 --> 00:05:51,630
the plan ahead and cool as much we had

146
00:05:55,730 --> 00:05:53,159
plate tectonics although some people

147
00:05:57,230 --> 00:05:55,740
don't agree that we necessarily have

148
00:05:58,159 --> 00:05:57,240
plate tectonics in the Aegean I think

149
00:06:00,409 --> 00:05:58,169
Lina's going to touch on this a little

150
00:06:02,420 --> 00:06:00,419
bit we had abundant volcanism because we

151
00:06:04,040 --> 00:06:02,430
had a hotter mantle but we had to

152
00:06:06,680 --> 00:06:04,050
develop hydrosphere and atmosphere and

153
00:06:08,600 --> 00:06:06,690
this isn't debated anymore not like for

154
00:06:12,080 --> 00:06:08,610
instance and hid Ian but we also have

155
00:06:13,700 --> 00:06:12,090
increased weathering and tidal cycles so

156
00:06:15,589 --> 00:06:13,710
what does your keen rock record tell us

157
00:06:16,700 --> 00:06:15,599
well our key in rocks don't worry too

158
00:06:19,249 --> 00:06:16,710
much for the details of this it's a lot

159
00:06:20,990 --> 00:06:19,259
of geology dragon but basically what's

160
00:06:22,969 --> 00:06:21,000
preserved is primarily basalt so

161
00:06:24,860 --> 00:06:22,979
volcanic rock these are lava that's been

162
00:06:26,180 --> 00:06:24,870
extruded as hardened into the salt but

163
00:06:29,749 --> 00:06:26,190

we also have a special kind of volcanic

164
00:06:31,730 --> 00:06:29,759
rock called the kamati aight which wraps

165
00:06:33,290 --> 00:06:31,740
at a much higher temperature than the

166
00:06:34,459 --> 00:06:33,300
salts now so we don't see those anywhere

167
00:06:36,499 --> 00:06:34,469
in the rock record except for the

168
00:06:38,390 --> 00:06:36,509
archaean because the mantle isn't hot

169
00:06:39,649 --> 00:06:38,400
enough so they have a higher eruption

170
00:06:41,029 --> 00:06:39,659
temperature and a higher magnesium

171
00:06:42,230 --> 00:06:41,039
content and most of the rocks that we

172
00:06:44,329 --> 00:06:42,240
see preserved in the archaean are from

173
00:06:45,860 --> 00:06:44,339
regions like this so subduction zones

174
00:06:47,150 --> 00:06:45,870
where you have subduction of an oceanic

175
00:06:50,120 --> 00:06:47,160
plate

176
00:06:54,380 --> 00:06:50,130
melting lots of volcanism up a lot of

177
00:06:55,760 --> 00:06:54,390
its seafloor volcanism so what do we

178
00:06:58,540 --> 00:06:55,770
know with the atmosphere the arcane

179
00:07:01,070 --> 00:06:58,550
atmosphere well we basically have no

180
00:07:03,020 --> 00:07:01,080
direct measure of their keen atmosphere

181
00:07:05,450 --> 00:07:03,030
we don't necessarily have food and sorry

182
00:07:08,360 --> 00:07:05,460
air pockets in rocks that we can measure

183
00:07:10,160 --> 00:07:08,370
but minerals are great at recording past

184
00:07:12,590 --> 00:07:10,170
paleo environmental conditions so we

185
00:07:14,150 --> 00:07:12,600
have geochemical proxies we can use so

186
00:07:16,730 --> 00:07:14,160
redox sensor that a redox-sensitive

187
00:07:17,840 --> 00:07:16,740
elements like iron that will tell us a

188
00:07:19,550 --> 00:07:17,850

little bit about the atmospheric

189
00:07:23,750 --> 00:07:19,560
conditions so we know that it was anoxic

190
00:07:24,950 --> 00:07:23,760
high co2 lots of methane some nh3 so a

191
00:07:26,180 --> 00:07:24,960
lot of this is from there's tons of

192
00:07:28,100 --> 00:07:26,190
Vulcan isms you've got lots of volcanic

193
00:07:31,190 --> 00:07:28,110
degassing spewing this stuff into the

194
00:07:34,070 --> 00:07:31,200
atmosphere and some are around 2.5 we

195
00:07:36,080 --> 00:07:34,080
have this big bump in oxygen in the

196
00:07:39,320 --> 00:07:36,090
atmosphere so this is the goe the great

197
00:07:40,670 --> 00:07:39,330
oxidation event which is still debated

198
00:07:43,280 --> 00:07:40,680
why it happened had to do with foot

199
00:07:46,160 --> 00:07:43,290
photosynthesis maybe changes in volcanic

200
00:07:48,530 --> 00:07:46,170
outgassing and we're going to hear more

201
00:07:51,320 --> 00:07:48,540
about that today as well so what about

202
00:07:52,790 --> 00:07:51,330
our key in oceans our key notions are

203
00:07:54,860 --> 00:07:52,800
really interesting from astrobiological

204
00:07:57,590 --> 00:07:54,870
perspective we know they were a toxic

205
00:07:58,910 --> 00:07:57,600
and acidic they had high dissolved co2

206
00:08:01,610 --> 00:07:58,920
they're in equilibrium with a high co2

207
00:08:03,470 --> 00:08:01,620
atmosphere but because they're on toxic

208
00:08:04,820 --> 00:08:03,480
and acidic their enriched in reduced

209
00:08:06,890 --> 00:08:04,830
metal species so things like iron

210
00:08:09,920 --> 00:08:06,900
two-plus nickel things that would not be

211
00:08:11,360 --> 00:08:09,930
soluble in today's oceans and as the

212
00:08:13,640 --> 00:08:11,370
ocean became more oxygenated they became

213
00:08:16,100 --> 00:08:13,650

insoluble and precipitated out this is

214
00:08:17,510 --> 00:08:16,110
one of those redox proxies we can use we

215
00:08:20,350 --> 00:08:17,520
also know that it will like the ocean

216
00:08:23,090 --> 00:08:20,360
now is salty it's got sodium chlorine

217
00:08:25,460 --> 00:08:23,100
magnesium and calcium salts but abundant

218
00:08:27,500 --> 00:08:25,470
hydrothermal activity I mentioned that

219
00:08:28,820 --> 00:08:27,510
there's a lot more volcanism higher heat

220
00:08:30,409 --> 00:08:28,830
flow in the mantle so you've got more

221
00:08:32,510 --> 00:08:30,419
volcanism on the sea floor as well which

222
00:08:33,589 --> 00:08:32,520
means you have a lot hydrothermal

223
00:08:36,890 --> 00:08:33,599
activity like this going on black

224
00:08:38,900 --> 00:08:36,900
smokers and depending what sort of proxy

225
00:08:41,120 --> 00:08:38,910
used for surface temp for water

226
00:08:42,589 --> 00:08:41,130
temperature it's been estimated that the

227
00:08:44,209 --> 00:08:42,599
surface temperature the oceans were

228
00:08:46,100 --> 00:08:44,219
somewhere between 50 and 70 if you

229
00:08:48,290 --> 00:08:46,110
believe oxygen isotopes from shirts from

230
00:08:51,140 --> 00:08:48,300
that age or there's a group that day at

231
00:08:53,350 --> 00:08:51,150
work the estimated between 26 and 35

232
00:08:57,530 --> 00:08:53,360
degrees Celsius which is more closer to

233
00:08:59,240 --> 00:08:57,540
kind of tropical archaean ocean

234
00:09:00,710 --> 00:08:59,250
temperatures or sorry modern tropical

235
00:09:02,840 --> 00:09:00,720
ocean temperatures

236
00:09:04,879 --> 00:09:02,850
so what I want you to get from this is

237
00:09:07,400 --> 00:09:04,889
that minerals constrain the

238
00:09:10,610 --> 00:09:07,410

environmental conditions so if we can

239
00:09:13,249 --> 00:09:10,620
take we know the stability fields of a

240
00:09:14,720 --> 00:09:13,259
certain set of minerals and we can look

241
00:09:15,769 --> 00:09:14,730
the rock and find it if those minerals

242
00:09:17,360 --> 00:09:15,779
are there we can place them in the

243
00:09:19,699 --> 00:09:17,370
stability field and make inferences

244
00:09:22,429 --> 00:09:19,709
about what for instance the hydrogen h2

245
00:09:24,379 --> 00:09:22,439
the acidity and the co2 content of the

246
00:09:28,100 --> 00:09:24,389
atmosphere and the aquatic environment

247
00:09:29,210 --> 00:09:28,110
in that time period verb so this is what

248
00:09:30,559 --> 00:09:29,220
we know about Earth's early geologic

249
00:09:33,079 --> 00:09:30,569
history basically just a quick overview

250
00:09:34,759 --> 00:09:33,089
you've got the Hadean core formation

251
00:09:36,980 --> 00:09:34,769
differentiation this is where we see

252
00:09:39,199 --> 00:09:36,990
these early detrital zircons which tell

253
00:09:40,550 --> 00:09:39,209
us that it was not actually as hellish

254
00:09:42,619 --> 00:09:40,560
as we thought it was more cool and

255
00:09:44,150 --> 00:09:42,629
Clement with the oldest rocks here

256
00:09:46,069 --> 00:09:44,160
there's very little rock record from

257
00:09:47,269 --> 00:09:46,079
this time because our earth is so

258
00:09:49,550 --> 00:09:47,279
dynamic there's a lot of plate tectonics

259
00:09:50,749 --> 00:09:49,560
things are getting recycled but we do

260
00:09:51,889 --> 00:09:50,759
have via cast and ice which is here in

261
00:09:54,350 --> 00:09:51,899
Canada up in the Northwest Territories

262
00:09:56,869 --> 00:09:54,360
the oldest rock well this is the oldest

263
00:10:01,550 --> 00:09:56,879

mineral and then we start seeing some

264
00:10:03,679 --> 00:10:01,560
evidence of life somewhere in here so

265
00:10:06,110 --> 00:10:03,689
let's go back to Mars let's look at Mars

266
00:10:07,429 --> 00:10:06,120
his early geologic record well early in

267
00:10:09,290 --> 00:10:07,439
a wacky and Mars is very different from

268
00:10:10,879 --> 00:10:09,300
what we see Mars now it's it was

269
00:10:12,470 --> 00:10:10,889
geologically active there was tons of

270
00:10:14,569 --> 00:10:12,480
cratering is around the late heavy

271
00:10:17,809 --> 00:10:14,579
bombardment time lots of volcanism

272
00:10:19,730 --> 00:10:17,819
you've got the Tharsis volcanoes olympus

273
00:10:20,809 --> 00:10:19,740
mons starting to form erosion lots of

274
00:10:22,429 --> 00:10:20,819
valley formation but there's still

275
00:10:25,629 --> 00:10:22,439
debate over whether we had a warm and

276
00:10:27,559 --> 00:10:25,639
wet Mars or a cold with transient water

277
00:10:30,590 --> 00:10:27,569
that's still a pretty big thing in

278
00:10:33,769 --> 00:10:30,600
astrobiology so we talk about major

279
00:10:35,720 --> 00:10:33,779
geologic events we had the formation of

280
00:10:38,569 --> 00:10:35,730
the Hellas Basin happening during the

281
00:10:40,569 --> 00:10:38,579
wacky Mars good these Darcis volcanoes

282
00:10:44,090 --> 00:10:40,579
and olympus mons starting to kind of

283
00:10:45,799 --> 00:10:44,100
form interrupt and then as we we also

284
00:10:46,790 --> 00:10:45,809
see abundant evidence for water this is

285
00:10:48,799 --> 00:10:46,800
one of the more interesting things in

286
00:10:50,600 --> 00:10:48,809
astrobiology so we see several lines of

287
00:10:52,639 --> 00:10:50,610
evidence for water in a wacky Mars first

288
00:10:54,230 --> 00:10:52,649

being morphological so you've got

289
00:10:55,610 --> 00:10:54,240
evidence of stream beds like here where

290
00:11:00,490 --> 00:10:55,620
MSL just found those exciting

291
00:11:02,990 --> 00:11:00,500
conglomerates Delta's spring systems

292
00:11:04,939 --> 00:11:03,000
alluvial fans stuff like that we also

293
00:11:06,920 --> 00:11:04,949
have mineralogical evidence in no a keen

294
00:11:08,360 --> 00:11:06,930
it's primarily clays so phyllosilicate

295
00:11:11,179 --> 00:11:08,370
minerals these are kind of widespread

296
00:11:12,949 --> 00:11:11,189
throughout in Iraq and trains and these

297
00:11:16,150 --> 00:11:12,959
are formed by the interaction of water

298
00:11:25,190 --> 00:11:21,050
and what about hesperian Mars there was

299
00:11:26,329 --> 00:11:25,200
less volcanism less impacts but thirty

300
00:11:28,600 --> 00:11:26,339
percent of the surface was still

301
00:11:30,380 --> 00:11:28,610
resurfaced with fresh with salt and

302
00:11:35,240 --> 00:11:30,390
instead of having kind of this

303
00:11:37,940 --> 00:11:35,250
widespread clay alteration what you see

304
00:11:39,139 --> 00:11:37,950
is more sporadic sulfate alteration

305
00:11:43,190 --> 00:11:39,149
which also means there was water there

306
00:11:45,170 --> 00:11:43,200
but more not not as widespread but there

307
00:11:48,170 --> 00:11:45,180
was still big geologic events going this

308
00:11:49,759 --> 00:11:48,180
is Valles Marineris which I often didn't

309
00:11:51,769 --> 00:11:49,769
realize how big it actually was but when

310
00:11:53,960 --> 00:11:51,779
you place the u.s. on it it goes across

311
00:11:55,490 --> 00:11:53,970
the entire country so that's a giant

312
00:11:57,019 --> 00:11:55,500
Canyon that was formed during the

313
00:12:00,949 --> 00:11:57,029

Hesperian so there was still big things

314
00:12:02,269 --> 00:12:00,959
happening and now present Mars is cold

315
00:12:04,759 --> 00:12:02,279
and dry it's pretty much a polar desert

316
00:12:06,440 --> 00:12:04,769
it's liquid water is not stable we heard

317
00:12:07,759 --> 00:12:06,450
about this yesterday its surface

318
00:12:09,590 --> 00:12:07,769
conditions are below the triple point of

319
00:12:11,090 --> 00:12:09,600
liquid water you've got incredibly high

320
00:12:14,030 --> 00:12:11,100
UV flux because there's basically no

321
00:12:16,009 --> 00:12:14,040
atmosphere it's really oxidizing there's

322
00:12:19,970 --> 00:12:16,019
no liquid but there is maybe some ice up

323
00:12:22,100 --> 00:12:19,980
in the polls or subsurface ice so here

324
00:12:23,990 --> 00:12:22,110
we have just an overview early Nowacki

325
00:12:26,420 --> 00:12:24,000
Mars you've got clay alteration fluids

326
00:12:29,510 --> 00:12:26,430
you've got sulfate alteration in the

327
00:12:32,810 --> 00:12:29,520
kind of hysteria and then from the

328
00:12:36,860 --> 00:12:32,820
amazonian on its well pretty dull

329
00:12:38,810 --> 00:12:36,870
geologically so I'm just going to talk

330
00:12:41,060 --> 00:12:38,820
about life quickly not going to go to

331
00:12:42,949 --> 00:12:41,070
big into it there is it could talk for

332
00:12:44,150 --> 00:12:42,959
hours about the definition of life what

333
00:12:45,620 --> 00:12:44,160
life really is but for now I'm just

334
00:12:48,079 --> 00:12:45,630
going to stick with a NASA working

335
00:12:49,910 --> 00:12:48,089
definition life is a self-sustained

336
00:12:53,120 --> 00:12:49,920
chemical system capable of Darwinian

337
00:12:55,190 --> 00:12:53,130
evolution good enough for us today so

338
00:12:56,840 --> 00:12:55,200

what does life required well firstly

339
00:13:00,769 --> 00:12:56,850
life as we should say life as we know it

340
00:13:02,930 --> 00:13:00,779
so us we require liquid water the bio

341
00:13:05,810 --> 00:13:02,940
essential elements so carbon hydrogen

342
00:13:07,400 --> 00:13:05,820
oxygen nitrogen phosphorus but also a

343
00:13:09,350 --> 00:13:07,410
thermodynamic regime capable of

344
00:13:11,240 --> 00:13:09,360
supporting disequilibrium so basically

345
00:13:12,050 --> 00:13:11,250
redox if you think of life in its

346
00:13:13,819 --> 00:13:12,060
simplest form it's kind of like a

347
00:13:17,150 --> 00:13:13,829
battery you need the exchange of

348
00:13:20,030 --> 00:13:17,160
electrons and protons it's just kind of

349
00:13:22,040 --> 00:13:20,040
a simple energy exchange system so if

350
00:13:24,110 --> 00:13:22,050
you want to look at it from a almost

351
00:13:25,880 --> 00:13:24,120
like geologic mineralogical elemental

352
00:13:28,260 --> 00:13:25,890
view this is the periodic table from the

353
00:13:30,390 --> 00:13:28,270
view of a microbe or us and you saw

354
00:13:31,560 --> 00:13:30,400
of living organism as we know it so

355
00:13:33,000 --> 00:13:31,570
you've got your bio essential elements

356
00:13:35,730 --> 00:13:33,010
but you also still require some metals

357
00:13:38,070 --> 00:13:35,740
you need trace metals and salts for ion

358
00:13:40,050 --> 00:13:38,080
exchange and to act as catalysts and

359
00:13:43,200 --> 00:13:40,060
enzyme for your enzymes and things like

360
00:13:45,390 --> 00:13:43,210
that so but there's some limits so this

361
00:13:46,710 --> 00:13:45,400
is just kind of limits to life as we

362
00:13:48,840 --> 00:13:46,720
know it because we're continually

363
00:13:51,180 --> 00:13:48,850

pushing those limits like Lyle said he

364
00:13:53,700 --> 00:13:51,190
didn't think life could live below what

365
00:13:55,920 --> 00:13:53,710
five degrees now we're down to 15 sorry

366
00:13:59,010 --> 00:13:55,930
minus 15 so we have certain limitations

367
00:14:01,860 --> 00:13:59,020
to life as we know it whether they be

368
00:14:05,640 --> 00:14:01,870
temperature pH hydrostatic pressure

369
00:14:08,190 --> 00:14:05,650
water activity metal concentration so

370
00:14:09,750 --> 00:14:08,200
we're in the geologic we're in the

371
00:14:12,090 --> 00:14:09,760
geologic record will we look for life

372
00:14:13,650 --> 00:14:12,100
well we need to find habitable paleo

373
00:14:16,770 --> 00:14:13,660
environments so areas where life as we

374
00:14:18,660 --> 00:14:16,780
know it could potentially survive so

375
00:14:20,730 --> 00:14:18,670
areas that have liquid water the bio

376
00:14:23,880 --> 00:14:20,740
essential elements that we need and then

377
00:14:26,280 --> 00:14:23,890
disequilibrium so redox and pH gradients

378
00:14:28,890 --> 00:14:26,290
and realistically this is primarily in

379
00:14:30,390 --> 00:14:28,900
the sedimentary record and I should note

380
00:14:31,710 --> 00:14:30,400
I'm not going to discuss too much the

381
00:14:36,240 --> 00:14:31,720
origins of life we are assuming that

382
00:14:38,040 --> 00:14:36,250
life is here where would it be so when

383
00:14:39,810 --> 00:14:38,050
in the geologic where when in the

384
00:14:43,320 --> 00:14:39,820
geologic record do we start looking for

385
00:14:44,940 --> 00:14:43,330
the earliest signs of life well when we

386
00:14:49,620 --> 00:14:44,950
start seeing habitable environments so

387
00:14:53,220 --> 00:14:49,630
more cool Clement not dries where we

388
00:14:54,300 --> 00:14:53,230

have water so somewhere in here this

389
00:14:55,920 --> 00:14:54,310
area this is where it's more interesting

390
00:14:57,150 --> 00:14:55,930
because once we get beyond there there's

391
00:14:59,910 --> 00:14:57,160
no doubt we know there's life there we

392
00:15:01,920 --> 00:14:59,920
got fossils of fish and plants and all

393
00:15:03,480 --> 00:15:01,930
sorts of things so and we're not

394
00:15:05,220 --> 00:15:03,490
expecting to find those things on Mars

395
00:15:06,630 --> 00:15:05,230
in the geologic record so we're going to

396
00:15:10,530 --> 00:15:06,640
talk about this area here we've got just

397
00:15:12,300 --> 00:15:10,540
kind of microbes basically so let's talk

398
00:15:13,950 --> 00:15:12,310
about habitable paleo environments in

399
00:15:17,070 --> 00:15:13,960
Earth's geologic record so the early

400
00:15:18,330 --> 00:15:17,080
geologic record soha DNR's well like i

401
00:15:20,640 --> 00:15:18,340
mentioned earlier there's basically no

402
00:15:23,250 --> 00:15:20,650
geologic record of hiddy and earth we've

403
00:15:24,840 --> 00:15:23,260
got a couple gneisses up in Northwest

404
00:15:26,820 --> 00:15:24,850
Territories but they're not sedimentary

405
00:15:29,490 --> 00:15:26,830
they don't really have anything

406
00:15:30,900 --> 00:15:29,500
biological in them we've got some

407
00:15:35,030 --> 00:15:30,910
zircons they're not really useful either

408
00:15:37,320 --> 00:15:35,040
and this is just a view from a and

409
00:15:39,450 --> 00:15:37,330
aren't in its be 2012 is basically

410
00:15:41,070 --> 00:15:39,460
review of early earth and life this is I

411
00:15:42,030 --> 00:15:41,080
think a pretty optimistic view of how

412
00:15:43,800 --> 00:15:42,040
nice

413
00:15:45,930 --> 00:15:43,810

hey dinars might have been but I mean

414
00:15:47,069 --> 00:15:45,940
potentially we've got some some life

415
00:15:49,980 --> 00:15:47,079
going on down to the sea floor

416
00:15:51,930 --> 00:15:49,990
sympathetic Genesis but archaean earth

417
00:15:53,129 --> 00:15:51,940
and the archaean rock record is what's

418
00:15:55,139 --> 00:15:53,139
really interesting we were talking about

419
00:15:57,120 --> 00:15:55,149
early life and evidence for it but again

420
00:15:58,230 --> 00:15:57,130
like ice men sioned earlier the earth is

421
00:16:00,629 --> 00:15:58,240
really dynamic you've got plates

422
00:16:03,360 --> 00:16:00,639
abducting rocks are being melted

423
00:16:05,460 --> 00:16:03,370
destroyed or routed so even your

424
00:16:07,139 --> 00:16:05,470
archaean record is limited the archaean

425
00:16:10,079 --> 00:16:07,149
rocks only make up five percent of the

426
00:16:14,730 --> 00:16:10,089
present continental crust and most of

427
00:16:16,410 --> 00:16:14,740
them are volcanic in nature so most

428
00:16:18,090 --> 00:16:16,420
arcane rocks are preserved in what we

429
00:16:19,290 --> 00:16:18,100
call greenstone belts and this is an

430
00:16:22,069 --> 00:16:19,300
example of just kind of your typical

431
00:16:25,170 --> 00:16:22,079
greenstone belt so it's a series of

432
00:16:26,939 --> 00:16:25,180
ultramafic mafic rocks with a little bit

433
00:16:28,610 --> 00:16:26,949
of sediments on top it's called green

434
00:16:31,829 --> 00:16:28,620
stone because it's been basically

435
00:16:33,809 --> 00:16:31,839
squished and compressed and heated for 3

436
00:16:36,809 --> 00:16:33,819
billion years to what we call green

437
00:16:39,059 --> 00:16:36,819
stone facies which just means that a

438
00:16:41,910 --> 00:16:39,069

certain pressure and temperature regime

439
00:16:43,650 --> 00:16:41,920
which has formed certain metamorphic

440
00:16:48,059 --> 00:16:43,660
minerals so the minerals will get heated

441
00:16:49,590 --> 00:16:48,069
and we basically formed new minerals and

442
00:16:52,350 --> 00:16:49,600
many of which are green so things like

443
00:16:53,879 --> 00:16:52,360
epidote serpentine chlorite so that's

444
00:16:55,710 --> 00:16:53,889
why they call it green stone but what's

445
00:16:58,590 --> 00:16:55,720
important here is even though we do have

446
00:17:00,180 --> 00:16:58,600
a lot of our key and rock record not a

447
00:17:01,680 --> 00:17:00,190
whole lot of its sedimentary because

448
00:17:03,480 --> 00:17:01,690
sedimentary rocks don't stick around as

449
00:17:08,000 --> 00:17:03,490
well as may pick as Motel cannock rocks

450
00:17:12,120 --> 00:17:08,010
they tend to get eroded by glaciers they

451
00:17:15,149 --> 00:17:12,130
get yeah mostly just eroded away because

452
00:17:17,610 --> 00:17:15,159
they're not as competent so when we look

453
00:17:20,399 --> 00:17:17,620
at early Archaean earth so this is

454
00:17:21,659 --> 00:17:20,409
before we had photosynthesis we still

455
00:17:23,250 --> 00:17:21,669
definitely still have habitable

456
00:17:24,990 --> 00:17:23,260
environments so especially when you talk

457
00:17:27,319 --> 00:17:25,000
about the high degree of volcanism of

458
00:17:30,180 --> 00:17:27,329
the fact that we had water so you've got

459
00:17:34,320 --> 00:17:30,190
seafloor kind of areas so maybe some

460
00:17:36,960 --> 00:17:34,330
methanogenesis and chemo trophy going on

461
00:17:39,149 --> 00:17:36,970
here then you've got ocean vent systems

462
00:17:40,919 --> 00:17:39,159
where potentially you have life and

463
00:17:44,250 --> 00:17:40,929

maybe maybe some plankton floating

464
00:17:49,080 --> 00:17:44,260
around and then if you go to late

465
00:17:52,080 --> 00:17:49,090
archaean earth where you have a little

466
00:17:55,150 --> 00:17:52,090
more habitable let's say we have again

467
00:17:56,770 --> 00:17:55,160
potentially terrestrial or will

468
00:17:58,380 --> 00:17:56,780
terrestrial biomes that aren't

469
00:18:02,790 --> 00:17:58,390
necessarily ocean you've got swamps

470
00:18:05,560 --> 00:18:02,800
ocean continental hydrothermal systems

471
00:18:06,970 --> 00:18:05,570
maybe some shallow shelves where you

472
00:18:08,830 --> 00:18:06,980
have photosynthesis going this is when

473
00:18:10,540 --> 00:18:08,840
photosynthesis and the oxygenation of

474
00:18:13,890 --> 00:18:10,550
the atmosphere is just starting up you

475
00:18:16,300 --> 00:18:13,900
definitely have hydrothermal biomes and

476
00:18:20,830 --> 00:18:16,310
I mentioned earlier we have a co2

477
00:18:25,030 --> 00:18:20,840
methane rich atmosphere and lots of

478
00:18:27,940 --> 00:18:25,040
volcanism pushing s so2 co2 carbon gases

479
00:18:29,530 --> 00:18:27,950
into the atmosphere so what do these

480
00:18:32,220 --> 00:18:29,540
habitable environments look like so if

481
00:18:34,060 --> 00:18:32,230
you're talking about a kind of seafloor

482
00:18:36,730 --> 00:18:34,070
hydrothermal area here will you'll have

483
00:18:38,410 --> 00:18:36,740
basically the sea floor is biofilms like

484
00:18:42,970 --> 00:18:38,420
this we have hypothermia file biofilms

485
00:18:45,760 --> 00:18:42,980
and mats so these are preserved in the

486
00:18:48,900 --> 00:18:45,770
sedimentary sequence sometimes if you're

487
00:18:51,970 --> 00:18:48,910
lucky and then if you're talking about

488
00:18:54,610 --> 00:18:51,980

black smoker type areas you have a ton

489
00:18:57,130 --> 00:18:54,620
of energy there we've got lots of

490
00:18:59,500 --> 00:18:57,140
reductants locks of oxidants water heat

491
00:19:01,390 --> 00:18:59,510
everything we need for life and so it's

492
00:19:03,790 --> 00:19:01,400
actually a pretty happy place to live

493
00:19:05,680 --> 00:19:03,800
for not for us obviously but for a lot

494
00:19:11,160 --> 00:19:05,690
of microbes especially when you look

495
00:19:17,800 --> 00:19:13,930
microbes and stuff closer to Luca our

496
00:19:19,300 --> 00:19:17,810
hypothermic files so in this period this

497
00:19:21,310 --> 00:19:19,310
is definitely a very good place to be

498
00:19:22,210 --> 00:19:21,320
and then there's also i mentioned later

499
00:19:23,920 --> 00:19:22,220
in the archaean you've got more

500
00:19:26,170 --> 00:19:23,930
continental growth you've got volcanism

501
00:19:29,260 --> 00:19:26,180
of this continental volcanism and the

502
00:19:31,480 --> 00:19:29,270
potential for hydrothermal kind of

503
00:19:34,330 --> 00:19:31,490
systems like this where well they are

504
00:19:35,590 --> 00:19:34,340
pretty acidic or unhappy or for us there

505
00:19:39,490 --> 00:19:35,600
definitely are habitable so this is in

506
00:19:41,350 --> 00:19:39,500
Iceland a sulfur spring but we're in the

507
00:19:42,730 --> 00:19:41,360
rock record do we find these well like i

508
00:19:44,920 --> 00:19:42,740
mentioned mostly are key and rock record

509
00:19:47,050 --> 00:19:44,930
is volcanic so these are a couple

510
00:19:48,820 --> 00:19:47,060
pictures from the abitibi greenstone

511
00:19:51,460 --> 00:19:48,830
belt these are what we call pillow vault

512
00:19:53,350 --> 00:19:51,470
sorry pillow lavas so you can see they

513
00:19:55,600 --> 00:19:53,360

got these weird little pillow shape and

514
00:19:58,450 --> 00:19:55,610
this is formed when you have lava

515
00:20:00,550 --> 00:19:58,460
extruding on the seafloor as it comes

516
00:20:03,100 --> 00:20:00,560
out it's it's almost like when you have

517
00:20:04,450 --> 00:20:03,110
a candle melting and you've got bits

518
00:20:05,680 --> 00:20:04,460
melting and it's kind of the outsides

519
00:20:08,080 --> 00:20:05,690
hardening a little bit and you get these

520
00:20:09,039 --> 00:20:08,090
weird little shapes so basically as the

521
00:20:11,499 --> 00:20:09,049
lava hits

522
00:20:13,690 --> 00:20:11,509
the cold ocean water it's you're getting

523
00:20:15,190 --> 00:20:13,700
kind of a quick glassy crystallization

524
00:20:17,200 --> 00:20:15,200
on the outside it's forming these weird

525
00:20:18,460 --> 00:20:17,210
pillow formations and these are actually

526
00:20:20,830 --> 00:20:18,470
preserved pretty well in a lot of our

527
00:20:22,720 --> 00:20:20,840
key greenstone belts the problem is

528
00:20:24,129 --> 00:20:22,730
there's not a whole lot of evidence for

529
00:20:27,190 --> 00:20:24,139
life in these because I mentioned

530
00:20:29,320 --> 00:20:27,200
earlier they are volcanic rocks we also

531
00:20:33,159 --> 00:20:29,330
have seafloor hydrothermal systems that

532
00:20:36,369 --> 00:20:33,169
are preserved so this is a VMs deposit

533
00:20:37,629 --> 00:20:36,379
in Brazil this would have been formed

534
00:20:41,220 --> 00:20:37,639
from a black smoker system where you've

535
00:20:43,119 --> 00:20:41,230
got a whole sedimentary pile of sulfides

536
00:20:45,039 --> 00:20:43,129
primarily these are preserved in mines

537
00:20:47,440 --> 00:20:45,049
or you see them better in mines because

538
00:20:49,450 --> 00:20:47,450

a lot of archaean hydrothermal systems

539
00:20:51,340 --> 00:20:49,460
are really really well mineralized which

540
00:20:53,200 --> 00:20:51,350
is good from the perspective that you've

541
00:20:56,379 --> 00:20:53,210
got the rocks or exposed and there's a

542
00:20:57,519 --> 00:20:56,389
lot known about them so this is a sea

543
00:20:59,560 --> 00:20:57,529
floor hydrothermal system here and this

544
00:21:01,659 --> 00:20:59,570
is kind of a sub seafloor hydrothermal

545
00:21:03,489 --> 00:21:01,669
system you can see here this black stuff

546
00:21:04,899 --> 00:21:03,499
up here these are sediments this is a

547
00:21:06,940 --> 00:21:04,909
graphic argillite that's a sea floor

548
00:21:09,369 --> 00:21:06,950
sediment and you've got volcanics and

549
00:21:10,570 --> 00:21:09,379
right in here you've got some carbonate

550
00:21:13,720 --> 00:21:10,580
veins these are a sub seafloor

551
00:21:15,700 --> 00:21:13,730
hydrothermal vein so these are preserved

552
00:21:17,169 --> 00:21:15,710
in the rock record and then also more

553
00:21:19,450 --> 00:21:17,179
sedimentary environments oh these are

554
00:21:21,940 --> 00:21:19,460
banded iron formations again seafloor

555
00:21:25,539 --> 00:21:21,950
formations where you've got the kind of

556
00:21:29,529 --> 00:21:25,549
record the transition from an oxidizing

557
00:21:32,099 --> 00:21:29,539
to reducing or sorry a from the oh too

558
00:21:34,899 --> 00:21:32,109
rich or too poor to rich atmosphere and

559
00:21:36,700 --> 00:21:34,909
oceans where you've got in our key and

560
00:21:39,279 --> 00:21:36,710
Fe 2 plus is soluble in the ocean

561
00:21:41,349 --> 00:21:39,289
whereas it's not now because the ocean

562
00:21:42,940 --> 00:21:41,359
has too much oxygen in it so it

563
00:21:45,430 --> 00:21:42,950

basically when the oxygen levels went up

564
00:21:47,799 --> 00:21:45,440
on earth the fe 2 plus precipitated out

565
00:21:50,289 --> 00:21:47,809
and you end up with these banded iron

566
00:21:52,119 --> 00:21:50,299
formations but again these are 2.5

567
00:21:53,619 --> 00:21:52,129
billion years old so they've been cooked

568
00:21:56,619 --> 00:21:53,629
squished here you can see a nice little

569
00:21:57,759 --> 00:21:56,629
fold bent and now instead of being on

570
00:22:01,479 --> 00:21:57,769
the subsea floor there in the middle of

571
00:22:04,299 --> 00:22:01,489
canada so what about habitable paleo

572
00:22:08,019 --> 00:22:04,309
environments in the Martian geologic

573
00:22:09,879 --> 00:22:08,029
record well I would argue the best place

574
00:22:11,799 --> 00:22:09,889
to look is no a keen and early history

575
00:22:13,330 --> 00:22:11,809
in sedimentary environments because we

576
00:22:14,680 --> 00:22:13,340
know that the Amazonian doesn't have a

577
00:22:16,720 --> 00:22:14,690
whole lot of water or anything we

578
00:22:18,700 --> 00:22:16,730
consider necessary for life as we know

579
00:22:20,590 --> 00:22:18,710
it so we do have a pretty good handle on

580
00:22:22,930 --> 00:22:20,600
some of these environments they have

581
00:22:24,370 --> 00:22:22,940
been studied pretty extensively using

582
00:22:26,230 --> 00:22:24,380
overall data which granted is not the

583
00:22:27,430 --> 00:22:26,240
highest resolution but we can still

584
00:22:30,490 --> 00:22:27,440
distinguish some things we know we've

585
00:22:32,590 --> 00:22:30,500
got layered sulfates carbonates the salt

586
00:22:34,030 --> 00:22:32,600
so we can put certain things in geologic

587
00:22:37,150 --> 00:22:34,040
context to try and make inferences about

588
00:22:38,470 --> 00:22:37,160

was happening there so examples of

589
00:22:40,360 --> 00:22:38,480
Martian paleo environments that might

590
00:22:41,980 --> 00:22:40,370
have been habitable our areas like here

591
00:22:43,390 --> 00:22:41,990
in Arabia Terra where it's been proposed

592
00:22:45,100 --> 00:22:43,400
these are actually remnant spring

593
00:22:46,690 --> 00:22:45,110
systems where you've got kind of

594
00:22:50,440 --> 00:22:46,700
terraces that are formed that have been

595
00:22:53,320 --> 00:22:50,450
preserved so these have evaporated

596
00:22:55,150 --> 00:22:53,330
minerals like sulfates and carbonates

597
00:22:57,300 --> 00:22:55,160
which have been shown on earth to

598
00:22:59,650 --> 00:22:57,310
actually preserve certain bio signatures

599
00:23:01,960 --> 00:22:59,660
also I would argue that impact

600
00:23:03,310 --> 00:23:01,970
environments are really important when

601
00:23:05,800 --> 00:23:03,320
you're thinking about possibilities for

602
00:23:08,500 --> 00:23:05,810
life because they're ubiquitous they're

603
00:23:09,850 --> 00:23:08,510
everywhere but a lot of impacts they

604
00:23:11,590 --> 00:23:09,860
generate a lot of heat a lot of energy

605
00:23:13,360 --> 00:23:11,600
they meld different minerals they

606
00:23:15,820 --> 00:23:13,370
release certain elements but they also a

607
00:23:19,420 --> 00:23:15,830
lot of times forum post impact

608
00:23:22,180 --> 00:23:19,430
hydrothermal systems so you have a kind

609
00:23:24,340 --> 00:23:22,190
of a transient energy and water rich

610
00:23:29,230 --> 00:23:24,350
environment in which life could have

611
00:23:31,390 --> 00:23:29,240
lived then you've got fluvial deposits

612
00:23:34,140 --> 00:23:31,400
so areas like it was evers while they

613
00:23:37,930 --> 00:23:34,150

created we've got large fluvial fans

614
00:23:39,220 --> 00:23:37,940
they'll take deltas and basins these are

615
00:23:41,320 --> 00:23:39,230
definitely areas where there might have

616
00:23:43,720 --> 00:23:41,330
been life during the Amazonian hesperian

617
00:23:46,120 --> 00:23:43,730
or even more terrestrial volcanic

618
00:23:47,830 --> 00:23:46,130
environments when you've got somewhere

619
00:23:51,100 --> 00:23:47,840
like maybe Tharsis if you've got any

620
00:23:52,690 --> 00:23:51,110
sort of sedimentary kind of hydrothermal

621
00:23:53,860 --> 00:23:52,700
fumaroles you don't need a ton of water

622
00:23:59,770 --> 00:23:53,870
to have a few merle going you're going

623
00:24:02,500 --> 00:23:59,780
to have water in the in the mantle lava

624
00:24:03,700 --> 00:24:02,510
anyways right so you might have areas

625
00:24:06,280 --> 00:24:03,710
like this fumaroles and hot springs in

626
00:24:11,440 --> 00:24:06,290
volcanic environments and then you also

627
00:24:14,200 --> 00:24:11,450
have more hydrothermal environments so

628
00:24:16,060 --> 00:24:14,210
for instance here this is opportunity I

629
00:24:18,670 --> 00:24:16,070
think found this gypsum vein which is

630
00:24:21,280 --> 00:24:18,680
formed by hydrothermal alteration gypsum

631
00:24:25,110 --> 00:24:21,290
zuv sulfate so definitely that could be

632
00:24:27,550 --> 00:24:25,120
or I think this is yeah this is still

633
00:24:30,160 --> 00:24:27,560
the conglomerate that we were discussing

634
00:24:31,420 --> 00:24:30,170
last night that msl found those who

635
00:24:32,920 --> 00:24:31,430
definitely could have been potentially

636
00:24:35,140 --> 00:24:32,930
habitable and their sedimentary

637
00:24:36,730 --> 00:24:35,150
environments where the sedimentary

638
00:24:38,290 --> 00:24:36,740

environment on Mars is preserved

639
00:24:39,580 --> 00:24:38,300
cuz you're not having plates abducting

640
00:24:41,890 --> 00:24:39,590
or not it's not being eroded off by

641
00:24:44,049 --> 00:24:41,900
glaciers so these are definitely

642
00:24:45,370 --> 00:24:44,059
potential places to look and then of

643
00:24:46,780 --> 00:24:45,380
course Gale Crater I did haven't

644
00:24:49,030 --> 00:24:46,790
mentioned phyllosilicates too much yet

645
00:24:51,190 --> 00:24:49,040
but they're all over vacuum ours and

646
00:24:53,440 --> 00:24:51,200
gale crater where MSL right now is right

647
00:24:55,900 --> 00:24:53,450
now has a really really well exposed

648
00:24:58,360 --> 00:24:55,910
sedimentary record you can see several

649
00:25:00,220 --> 00:24:58,370
layers of phyllo silicates and sulfates

650
00:25:02,350 --> 00:25:00,230
and why we're so interested in fellow

651
00:25:03,640 --> 00:25:02,360
silicates is other than the fact that

652
00:25:05,710 --> 00:25:03,650
they're formed by water there's also

653
00:25:09,640 --> 00:25:05,720
some implications for preservation of

654
00:25:11,530 --> 00:25:09,650
life as well as potential for the

655
00:25:13,150 --> 00:25:11,540
origins of life because phyllosilicates

656
00:25:16,240 --> 00:25:13,160
like was mentioned yesterday almost like

657
00:25:18,460 --> 00:25:16,250
phyllo pastry there are layers of silica

658
00:25:21,100 --> 00:25:18,470
tetrahedra which could almost act as a

659
00:25:23,710 --> 00:25:21,110
scaffold and they also taken all sorts

660
00:25:25,930 --> 00:25:23,720
of important cations iron magnesium

661
00:25:26,860 --> 00:25:25,940
things that are required for life so

662
00:25:28,419 --> 00:25:26,870
they're really interesting from the

663
00:25:30,100 --> 00:25:28,429

perspective of preservation of life and

664
00:25:31,570 --> 00:25:30,110
also origins of life and we have a

665
00:25:36,000 --> 00:25:31,580
perfect opportunity to look at the

666
00:25:39,549 --> 00:25:36,010
Miguel crater so what about present Mars

667
00:25:41,380 --> 00:25:39,559
well let's be honest right now present

668
00:25:42,880 --> 00:25:41,390
surface conditions are not so habitable

669
00:25:45,480 --> 00:25:42,890
we're not likely to find anything there

670
00:25:48,070 --> 00:25:45,490
that we consider life as we know it

671
00:25:50,410 --> 00:25:48,080
because there's hot UV flux water is

672
00:25:53,140 --> 00:25:50,420
unstable it's really oxidizing but there

673
00:25:56,020 --> 00:25:53,150
are still potential habitable

674
00:25:57,220 --> 00:25:56,030
environments on present Mars so it's

675
00:26:00,130 --> 00:25:57,230
been put forward that there might

676
00:26:02,620 --> 00:26:00,140
actually still be some sub surface water

677
00:26:04,419 --> 00:26:02,630
and ice on Mars so that's definitely

678
00:26:06,910 --> 00:26:04,429
subsurface the trick is to get down

679
00:26:08,980 --> 00:26:06,920
there need a big drill we're not going

680
00:26:11,350 --> 00:26:08,990
to get one of Mars anytime soon but I

681
00:26:12,790 --> 00:26:11,360
mean it's possible and then also looking

682
00:26:14,530 --> 00:26:12,800
at the polls but you've got ice we know

683
00:26:16,000 --> 00:26:14,540
that there's water ice up there you can

684
00:26:19,150 --> 00:26:16,010
see some evidence weren't these

685
00:26:22,410 --> 00:26:19,160
polygonal trains are formed in the polls

686
00:26:24,940 --> 00:26:22,420
you see them on earth as well so maybe

687
00:26:28,510 --> 00:26:24,950
there's some habitable environments on

688
00:26:31,390 --> 00:26:28,520

really present Mars and then just to not

689
00:26:32,860 --> 00:26:31,400
leave anybody out I'm not really talking

690
00:26:34,120 --> 00:26:32,870
about moons because we don't know a lot

691
00:26:35,830 --> 00:26:34,130
about the geologic record and we don't

692
00:26:38,860 --> 00:26:35,840
have access to the geologic record and

693
00:26:40,330 --> 00:26:38,870
no one today is talking about moons so

694
00:26:43,419 --> 00:26:40,340
but I just do this in there there are

695
00:26:46,210 --> 00:26:43,429
habitable potentially habitable moons

696
00:26:48,940 --> 00:26:46,220
icy moons like Enceladus Europa even

697
00:26:50,560 --> 00:26:48,950
Titan with its hydrocarbon Lakes these

698
00:26:55,419 --> 00:26:50,570
are all potentially interesting ass

699
00:26:57,279 --> 00:26:55,429
biological targets but so what kind of

700
00:26:59,950 --> 00:26:57,289
evidence do we see for life in the

701
00:27:04,620 --> 00:26:59,960
geologic geologic record and what sort

702
00:27:13,389 --> 00:27:09,310
well first one of many lines of evidence

703
00:27:15,159 --> 00:27:13,399
is biomarkers so chemical fossils these

704
00:27:17,289 --> 00:27:15,169
are molecules associated with

705
00:27:21,149 --> 00:27:17,299
biochemical processes so some things

706
00:27:23,590 --> 00:27:21,159
like complex hydrocarbons hoping strains

707
00:27:25,269 --> 00:27:23,600
but it has to be something where we have

708
00:27:27,279 --> 00:27:25,279
constrained its synthesis we know how it

709
00:27:30,039 --> 00:27:27,289
synthesized and we know its abundance

710
00:27:31,899 --> 00:27:30,049
and distribution in nature so we have to

711
00:27:33,879 --> 00:27:31,909
be able to say definitively that this

712
00:27:36,340 --> 00:27:33,889
came from life and we know how it went

713
00:27:39,940 --> 00:27:36,350

from this really complex biomolecule was

714
00:27:42,070 --> 00:27:39,950
buried heated squished lost some of its

715
00:27:43,149 --> 00:27:42,080
volatiles and now it's turned into this

716
00:27:47,740 --> 00:27:43,159
we need to build constraint as

717
00:27:51,490 --> 00:27:47,750
diagenetic record and we also another

718
00:27:54,519 --> 00:27:51,500
biomarker is isotopic fractionation so

719
00:27:59,379 --> 00:27:54,529
first with organic biomarkers these are

720
00:28:02,049 --> 00:27:59,389
great but even if you find them and you

721
00:28:03,490 --> 00:28:02,059
think you know that they're actually the

722
00:28:06,249 --> 00:28:03,500
same age as of roxie found them and it's

723
00:28:08,680 --> 00:28:06,259
incredibly hard to prove because these

724
00:28:09,879 --> 00:28:08,690
are 2.5 billion or rocks 2.7 billion

725
00:28:12,519 --> 00:28:09,889
years old there's been lots of

726
00:28:14,110 --> 00:28:12,529
contamination sampling there's been

727
00:28:16,810 --> 00:28:14,120
later fluids coming through they've been

728
00:28:18,460 --> 00:28:16,820
squished heated so I don't know if any

729
00:28:19,899 --> 00:28:18,470
of you follow this but a couple years

730
00:28:22,629 --> 00:28:19,909
ago jochen Brock's put out several

731
00:28:25,360 --> 00:28:22,639
papers saying look I found evidence for

732
00:28:26,499 --> 00:28:25,370
early life in Australia and then a

733
00:28:29,259 --> 00:28:26,509
couple years later put another paper

734
00:28:33,759 --> 00:28:29,269
saying sorry guys I was wrong I think

735
00:28:35,320 --> 00:28:33,769
it's all contamination or not real so

736
00:28:37,090 --> 00:28:35,330
that's that's the part it's hard to

737
00:28:38,619 --> 00:28:37,100
prove that the organics are actually the

738
00:28:41,350 --> 00:28:38,629

same age as the rocket coming taking

739
00:28:43,119 --> 00:28:41,360
from which is tricky because if we can

740
00:28:45,730 --> 00:28:43,129
barely prove that we have life fun early

741
00:28:47,470 --> 00:28:45,740
Earth definitively think about how hard

742
00:28:49,060 --> 00:28:47,480
it's going to be to prove that we these

743
00:28:51,330 --> 00:28:49,070
organics if we find on Mars are actually

744
00:28:54,090 --> 00:28:51,340
from Mars and actually from those rocks

745
00:28:56,980 --> 00:28:54,100
but there are still some cases where

746
00:28:59,049 --> 00:28:56,990
organic biomarkers have been less

747
00:29:01,269 --> 00:28:59,059
disputed so this is for instance the

748
00:29:04,300 --> 00:29:01,279
area i'm working in in Timmins these are

749
00:29:05,680 --> 00:29:04,310
2.7 billion year old volcanics

750
00:29:07,030 --> 00:29:05,690
and in the meta sediments here these are

751
00:29:09,370 --> 00:29:07,040
sea floor meta sediments they have found

752
00:29:11,440 --> 00:29:09,380
evidence for early life so an early

753
00:29:13,270 --> 00:29:11,450
seafloor biosphere using organic

754
00:29:16,290 --> 00:29:13,280
molecules Soho pains alkanes and by

755
00:29:19,060 --> 00:29:16,300
patents so on the isotopic fractionation

756
00:29:24,730 --> 00:29:19,070
so we mentioned yesterday that the idea

757
00:29:26,710 --> 00:29:24,740
of isotopes so an element that has two

758
00:29:28,150 --> 00:29:26,720
different weights so like carbon-12 and

759
00:29:29,950 --> 00:29:28,160
carbon-14 same elements but just a

760
00:29:32,860 --> 00:29:29,960
different weight and the fact that life

761
00:29:34,300 --> 00:29:32,870
exploits kinetics life is lazy basically

762
00:29:37,210 --> 00:29:34,310
wants to do the most thermodynamically

763
00:29:39,490 --> 00:29:37,220

favorable thing so biochemical processes

764
00:29:41,410 --> 00:29:39,500
will cause fluctuations in the amount of

765
00:29:43,840 --> 00:29:41,420
different isotopes of things like carbon

766
00:29:45,100 --> 00:29:43,850
sulfur oxygen and nitrogen that are

767
00:29:48,940 --> 00:29:45,110
being taken up into the being and

768
00:29:50,350 --> 00:29:48,950
affecting the ratio of isotopes in their

769
00:29:52,320 --> 00:29:50,360
environment because they're taking up

770
00:29:55,240 --> 00:29:52,330
preferentially one more than the other

771
00:29:59,350 --> 00:29:55,250
so you measure this as a delta value so

772
00:30:02,680 --> 00:29:59,360
this is basically just a comparison if

773
00:30:04,870 --> 00:30:02,690
your say for instance Delta sorry c-13

774
00:30:07,720 --> 00:30:04,880
versus c12 compared to some arbitrary

775
00:30:11,050 --> 00:30:07,730
standard so for instance for sulfur

776
00:30:13,390 --> 00:30:11,060
isotope fractionation here is bacterial

777
00:30:15,940 --> 00:30:13,400
sulfate reduction will fraction 8 your

778
00:30:17,970 --> 00:30:15,950
Delta s 34 will go this way whereas just

779
00:30:20,200 --> 00:30:17,980
a plain mineral process with no

780
00:30:22,080 --> 00:30:20,210
biological input will fraction it like

781
00:30:25,980 --> 00:30:22,090
this so you can differentiate between

782
00:30:30,040 --> 00:30:25,990
minerals that have had biological input

783
00:30:31,810 --> 00:30:30,050
into their formation and so an example

784
00:30:33,910 --> 00:30:31,820
of a nice topic signature one that's

785
00:30:36,430 --> 00:30:33,920
still pretty controversial this is

786
00:30:37,600 --> 00:30:36,440
arguably the oldest isotopic bio

787
00:30:40,630 --> 00:30:37,610
signature we have these are in the issue

788
00:30:44,710 --> 00:30:40,640

alerts so cherts are sedimentary rock

789
00:30:47,170 --> 00:30:44,720
and basically they have argued that they

790
00:30:49,600 --> 00:30:47,180
find a carbon isotopic fractionation

791
00:30:53,740 --> 00:30:49,610
that indicates that there was life there

792
00:30:55,540 --> 00:30:53,750
that was affecting this well they found

793
00:30:58,060 --> 00:30:55,550
carbonaceous material and inclusions in

794
00:31:00,220 --> 00:30:58,070
the church and argument is actually

795
00:31:04,630 --> 00:31:00,230
biogenic based on the carbon ox carbon

796
00:31:07,900 --> 00:31:04,640
isotope signature another very early

797
00:31:09,670 --> 00:31:07,910
earth bio signature is sulfur isotopes

798
00:31:12,220 --> 00:31:09,680
in three point four or five billion year

799
00:31:15,900 --> 00:31:12,230
old stromatolites so here they looked at

800
00:31:17,950 --> 00:31:15,910
pyrite and sulfur in the care in the

801
00:31:20,049 --> 00:31:17,960
organics that they found in eastern

802
00:31:23,919 --> 00:31:20,059
highlights and it found evidence that it

803
00:31:25,750 --> 00:31:23,929
was microbial mediated and so another

804
00:31:27,250 --> 00:31:25,760
type of bio signature will look at which

805
00:31:30,010 --> 00:31:27,260
are a little bit less definitive of life

806
00:31:31,389 --> 00:31:30,020
things like complex organic molecules so

807
00:31:33,070 --> 00:31:31,399
PAH is these are really interesting

808
00:31:34,389 --> 00:31:33,080
their complex they look very convincing

809
00:31:36,669 --> 00:31:34,399
but we find them in the internal

810
00:31:37,720 --> 00:31:36,679
interstellar medium they're pretty much

811
00:31:39,159 --> 00:31:37,730
everywhere so you can't really argue

812
00:31:41,110 --> 00:31:39,169
because they're there there was life

813
00:31:42,549 --> 00:31:41,120

there I mean it means there is potential

814
00:31:43,990 --> 00:31:42,559
for life because you have complex

815
00:31:47,320 --> 00:31:44,000
organic molecules which are required for

816
00:31:49,990 --> 00:31:47,330
life but we can't say definitively they

817
00:31:52,210 --> 00:31:50,000
were formed by life as well as

818
00:31:53,350 --> 00:31:52,220
atmospheric gases it's great if we find

819
00:31:55,990 --> 00:31:53,360
another planet that has a really

820
00:31:57,190 --> 00:31:56,000
oxygen-rich atmosphere but we can't

821
00:31:58,919 --> 00:31:57,200
necessarily say that means there's

822
00:32:02,950 --> 00:31:58,929
forests growing all over it right and

823
00:32:04,930 --> 00:32:02,960
things like microfossils so an example

824
00:32:10,320 --> 00:32:04,940
of microfossils which are still pretty

825
00:32:18,880 --> 00:32:10,330
contested is these are from the

826
00:32:22,659 --> 00:32:18,890
barberton greenstone belt yep that's a

827
00:32:25,570 --> 00:32:22,669
good question maybe some weird

828
00:33:02,219 --> 00:32:25,580
weathering processes if you're having

829
00:33:08,830 --> 00:33:06,759
exactly thanks Mike so here are some

830
00:33:10,930 --> 00:33:08,840
examples of microfossils so these are

831
00:33:12,789 --> 00:33:10,940
actually one of the few signs for early

832
00:33:15,279 --> 00:33:12,799
life there or not in this sedimentary

833
00:33:17,259 --> 00:33:15,289
record these are in basalts so these are

834
00:33:18,219 --> 00:33:17,269
volcanic rocks so these are pillow

835
00:33:20,109 --> 00:33:18,229
basalts what I mentioned earlier

836
00:33:22,239 --> 00:33:20,119
volcanics being extruded on the seafloor

837
00:33:23,739 --> 00:33:22,249
they hit the cold sea water and you

838
00:33:25,029 --> 00:33:23,749

basically get this kind of glassy rind

839
00:33:26,919 --> 00:33:25,039
on the outside and what they found is

840
00:33:28,539 --> 00:33:26,929
these weird structures they look pretty

841
00:33:30,369 --> 00:33:28,549
convincing like maybe there is a microbe

842
00:33:32,619 --> 00:33:30,379
living there burrowing and eating the

843
00:33:34,029 --> 00:33:32,629
glass but most people don't agree on

844
00:33:35,320 --> 00:33:34,039
anything to do with you so these are

845
00:33:38,649 --> 00:33:35,330
these are the barberton greenstone belt

846
00:33:41,919 --> 00:33:38,659
sure about 3.4 billion years old this is

847
00:33:44,109 --> 00:33:41,929
in the abitibi greenstone belt about 2.8

848
00:33:47,080 --> 00:33:44,119
to 2.5 billion years old and these are

849
00:33:49,089 --> 00:33:47,090
from modern ontong java plateau like sea

850
00:33:50,649 --> 00:33:49,099
floor glasses so these are something

851
00:33:53,919 --> 00:33:50,659
that we see kind of throughout the

852
00:33:56,080 --> 00:33:53,929
geologic record but not everyone is

853
00:34:02,099 --> 00:33:56,090
convinced that there actually happened

854
00:34:03,820 --> 00:34:02,109
through biology and stromatolites so

855
00:34:04,930 --> 00:34:03,830
we're gonna have to talk about traumatic

856
00:34:06,639 --> 00:34:04,940
lights later today but these are

857
00:34:09,240 --> 00:34:06,649
basically finally laminated sedimentary

858
00:34:11,619 --> 00:34:09,250
structures so you get them kind of in

859
00:34:14,139 --> 00:34:11,629
shallow coastal environments we see them

860
00:34:15,639 --> 00:34:14,149
in today's geologic record as well but

861
00:34:17,349 --> 00:34:15,649
these are basically the earliest

862
00:34:19,809 --> 00:34:17,359
accepted evidence of life most people

863
00:34:21,399 --> 00:34:19,819

believe that stromatolites were formed

864
00:34:23,799 --> 00:34:21,409
with some sort of biogenic input and

865
00:34:28,659 --> 00:34:23,809
these are from the 3.4 billion year old

866
00:34:30,250 --> 00:34:28,669
straley shirt and then the last thing is

867
00:34:32,109 --> 00:34:30,260
bio minerals so these are minerals

868
00:34:34,029 --> 00:34:32,119
produced directly by the activities of

869
00:34:35,349 --> 00:34:34,039
living organisms so our teeth for

870
00:34:38,440 --> 00:34:35,359
instance or a bio mineral there are

871
00:34:40,569 --> 00:34:38,450
hydroxyapatite calcite shelves something

872
00:34:41,889 --> 00:34:40,579
like that or interact precipitation of

873
00:34:45,789 --> 00:34:41,899
carbonates and sulfates and things like

874
00:34:47,369 --> 00:34:45,799
that so on Mars what are we looking for

875
00:34:50,529 --> 00:34:47,379
in terms of these types of biosignatures

876
00:34:54,549 --> 00:34:50,539
well we've got MSL it's drilling it's

877
00:34:56,680 --> 00:34:54,559
taking cool photos of itself and this is

878
00:34:58,180 --> 00:34:56,690
from summons 2011 at all 2011 they

879
00:34:59,470 --> 00:34:58,190
basically outlined the main bio

880
00:35:00,339 --> 00:34:59,480
signatures that they think msl can

881
00:35:03,249 --> 00:35:00,349
detect in which

882
00:35:04,960 --> 00:35:03,259
to be most definitive so the most highly

883
00:35:06,729 --> 00:35:04,970
definitive they think would be finding

884
00:35:08,170 --> 00:35:06,739
biogenic organic molecules so those are

885
00:35:10,390 --> 00:35:08,180
those organic biomarkers I was

886
00:35:13,329 --> 00:35:10,400
mentioning earlier and then biogenic

887
00:35:16,630 --> 00:35:13,339
gases bio fabrics isotope compositions

888
00:35:18,579 --> 00:35:16,640

biomineralization things like that so

889
00:35:20,109 --> 00:35:18,589
things we find in early earth are

890
00:35:23,259 --> 00:35:20,119
informing us on what we can look for on

891
00:35:28,029 --> 00:35:23,269
early Mars so what about this idea of

892
00:35:30,430 --> 00:35:28,039
analogs we're gonna have some people

893
00:35:31,509 --> 00:35:30,440
talking about analogs later today we've

894
00:35:34,660 --> 00:35:31,519
already heard a little bit yesterday

895
00:35:36,160 --> 00:35:34,670
about it so analogs are basically

896
00:35:37,989 --> 00:35:36,170
environmental conditions found on earth

897
00:35:39,339 --> 00:35:37,999
that possess physical or chemical

898
00:35:41,469 --> 00:35:39,349
features similar to those on other

899
00:35:43,359 --> 00:35:41,479
planetary bodies we don't have access to

900
00:35:45,579 --> 00:35:43,369
every planet about every planetary body

901
00:35:47,079 --> 00:35:45,589
or environment we want to look at so we

902
00:35:50,319 --> 00:35:47,089
do what we can and try and find it on

903
00:35:54,729 --> 00:35:50,329
earth and as scientists we like to go

904
00:35:57,729 --> 00:35:54,739
for fact not fiction so we have certain

905
00:35:59,979 --> 00:35:57,739
parameters by which we judge what would

906
00:36:03,400 --> 00:35:59,989
be a suitable analogue so things like

907
00:36:05,650 --> 00:36:03,410
temperature salinity pH pressure UV

908
00:36:08,170 --> 00:36:05,660
conditions oxidation state water

909
00:36:10,150 --> 00:36:08,180
activity and geologic antiquity so we

910
00:36:12,729 --> 00:36:10,160
need to be pretty rigorous in what we

911
00:36:15,219 --> 00:36:12,739
consider an analog and most analogs will

912
00:36:17,019 --> 00:36:15,229
not have all these conditions we can't

913
00:36:19,660 --> 00:36:17,029

recreate everything but we could we do

914
00:36:21,640 --> 00:36:19,670
the best we can and these are necessary

915
00:36:23,079 --> 00:36:21,650
things you be places we can also create

916
00:36:24,339 --> 00:36:23,089
analogue environments in a lab for

917
00:36:26,259 --> 00:36:24,349
instance we heard about environment

918
00:36:27,489 --> 00:36:26,269
chambers yesterday things like that and

919
00:36:29,950 --> 00:36:27,499
they don't need to be for other planets

920
00:36:31,450 --> 00:36:29,960
they can be for past paleo environments

921
00:36:35,950 --> 00:36:31,460
so we have analogs of early Archaean

922
00:36:37,719 --> 00:36:35,960
earth so what are some Mars analogs well

923
00:36:39,370 --> 00:36:37,729
we have analogs on earth for basically

924
00:36:41,079 --> 00:36:39,380
every period in Mars's geologic history

925
00:36:43,509 --> 00:36:41,089
so this is a paper by Ferran and all

926
00:36:46,930 --> 00:36:43,519
2011 2010 where they basically outlined

927
00:36:50,200 --> 00:36:46,940
an analog for every part of history so

928
00:36:52,539 --> 00:36:50,210
for the early noachian and whereas a

929
00:36:55,809 --> 00:36:52,549
colder and wetter mars areas like Rio

930
00:36:58,539 --> 00:36:55,819
Tinto in Spain which are these acidic

931
00:37:01,209 --> 00:36:58,549
kind of rivers that wrote are red and

932
00:37:03,370 --> 00:37:01,219
have lots of iron in them hesperian

933
00:37:05,950 --> 00:37:03,380
which is snowball Mars a little bit

934
00:37:07,239 --> 00:37:05,960
colder you've got this is axel Heiberg

935
00:37:10,120 --> 00:37:07,249
which is in the High Arctic this is

936
00:37:11,709 --> 00:37:10,130
where Lyle does a lot of work and then

937
00:37:13,420 --> 00:37:11,719
for present-day Mars just pretty much a

938
00:37:14,289 --> 00:37:13,430

polar desert you've got the Antarctic

939
00:37:15,459 --> 00:37:14,299
Dry Valleys

940
00:37:20,229 --> 00:37:15,469
and things like the Attic Amma desert

941
00:37:21,699 --> 00:37:20,239
Mojave so here's a couple analogues that

942
00:37:24,729 --> 00:37:21,709
old types of analogs that will be

943
00:37:26,319 --> 00:37:24,739
discussed today for early Mars so spring

944
00:37:28,509 --> 00:37:26,329
systems spring system so this is a

945
00:37:31,380 --> 00:37:28,519
hypersaline spring system in Manitoba

946
00:37:34,269 --> 00:37:31,390
where I did some work in undergrad it's

947
00:37:36,939 --> 00:37:34,279
basically you've got these silica

948
00:37:39,900 --> 00:37:36,949
centers with hypersaline fluids running

949
00:37:42,189 --> 00:37:39,910
out all year even when it's minus 35 in

950
00:37:44,339 --> 00:37:42,199
northern Manitoba which it gets to

951
00:37:47,620 --> 00:37:44,349
pretty much every day in the winter and

952
00:37:51,669 --> 00:37:47,630
you've got iron and sulfate and sorry

953
00:37:54,339 --> 00:37:51,679
gypsum calcite all sorts of evaporating

954
00:37:55,419 --> 00:37:54,349
minerals so this has been proposed in a

955
00:37:57,400 --> 00:37:55,429
paper we put out last year as a

956
00:38:00,160 --> 00:37:57,410
potential analog for Arabia Terra those

957
00:38:01,900 --> 00:38:00,170
terrorists spring systems areas like

958
00:38:04,870 --> 00:38:01,910
this is a golden deposit this is a

959
00:38:07,449 --> 00:38:04,880
Jairus site deposit in I think it's bc

960
00:38:11,259 --> 00:38:07,459
or northwest territories but basically

961
00:38:13,319 --> 00:38:11,269
acidic iron sulfate so Jerry site has

962
00:38:18,969 --> 00:38:13,329
been proposed to be found on Mars or

963
00:38:21,699 --> 00:38:18,979

cold cold kind of Arctic spring system

964
00:38:25,229 --> 00:38:21,709
so this is color peak i believe which is

965
00:38:28,269 --> 00:38:25,239
also in the Canadian High Arctic so

966
00:38:30,459 --> 00:38:28,279
about analogs for a present dryer Mars

967
00:38:31,809 --> 00:38:30,469
so this is the Mojave Desert where a

968
00:38:33,819 --> 00:38:31,819
bishop at I'll put out of paper

969
00:38:36,160 --> 00:38:33,829
proposing these carbonates as a

970
00:38:38,289 --> 00:38:36,170
potential analog for Martian carbonates

971
00:38:40,209 --> 00:38:38,299
or we've got the Canadian High Arctic

972
00:38:41,919 --> 00:38:40,219
where you see these kind of polygonum I

973
00:38:45,459 --> 00:38:41,929
strains which we also see in the poles

974
00:38:47,829 --> 00:38:45,469
of Mars and then I mentioned earlier we

975
00:38:49,749 --> 00:38:47,839
can have early earth analogs so my

976
00:38:51,969 --> 00:38:49,759
personal favorite is seafloor

977
00:38:53,650 --> 00:38:51,979
hydrothermal systems and we see that on

978
00:38:55,839 --> 00:38:53,660
present earth we find them pretty much

979
00:38:57,939 --> 00:38:55,849
everywhere where you have some sort of

980
00:38:59,669 --> 00:38:57,949
volcanism of the seafloor this is just a

981
00:39:01,299 --> 00:38:59,679
map showing all the different

982
00:39:04,059 --> 00:39:01,309
hydrothermal systems that have been

983
00:39:06,669 --> 00:39:04,069
identified on early Earth I mean on

984
00:39:08,079 --> 00:39:06,679
present earth so these are basically

985
00:39:09,400 --> 00:39:08,089
black smokers which are these high

986
00:39:12,009 --> 00:39:09,410
temperature hydrothermal vents and

987
00:39:13,630 --> 00:39:12,019
they're cooler or warmer sorry cooler

988
00:39:16,059 --> 00:39:13,640

temperature counterparts white smokers

989
00:39:18,400 --> 00:39:16,069
and then also I mentioned we have

990
00:39:20,739 --> 00:39:18,410
stromatolites going back and geologic

991
00:39:22,390 --> 00:39:20,749
time back to 3.4 billion years we also

992
00:39:24,910 --> 00:39:22,400
find modern-day stromatolites these are

993
00:39:28,100 --> 00:39:24,920
in pavillion lake in bc or microbial

994
00:39:30,530 --> 00:39:28,110
lights if you want to go so we have both

995
00:39:31,970 --> 00:39:30,540
use it we can look at to try and

996
00:39:35,480 --> 00:39:31,980
understand what environments were like

997
00:39:37,610 --> 00:39:35,490
on earlimart earlier sorry and then of

998
00:39:39,710 --> 00:39:37,620
course we also these analogs also can be

999
00:39:41,900 --> 00:39:39,720
used for other planets so for instance

1000
00:39:43,880 --> 00:39:41,910
Europa black smoker systems we heard

1001
00:39:46,160 --> 00:39:43,890
about this yesterday you've got an

1002
00:39:47,960 --> 00:39:46,170
interface between a rocky mantle and

1003
00:39:51,470 --> 00:39:47,970
potential and an ocean and then you've

1004
00:39:52,940 --> 00:39:51,480
got an icy crust so you might have water

1005
00:39:54,560 --> 00:39:52,950
rock interactions and hydrothermal

1006
00:39:57,650 --> 00:39:54,570
systems on the bottom and you also have

1007
00:40:00,580 --> 00:39:57,660
sea ice and glaciers which brittney

1008
00:40:05,090 --> 00:40:00,590
mentioned she uses as analogs for Europa

1009
00:40:06,800 --> 00:40:05,100
so just in conclusion basically the

1010
00:40:08,090 --> 00:40:06,810
sediments the evidence the present that

1011
00:40:12,080 --> 00:40:08,100
tells us the past I don't know if you

1012
00:40:14,390 --> 00:40:12,090
guys watch my video but the sedimentary

1013
00:40:16,940 --> 00:40:14,400

record tells us everything we need to

1014
00:40:19,340 --> 00:40:16,950
know about the environments on early

1015
00:40:22,670 --> 00:40:19,350
Earth and the history of life so it's