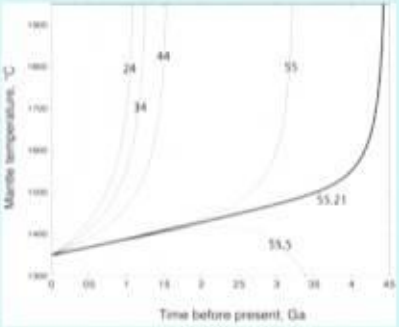
Classical parameterized convection



- Extrapolate from current state
- Need high radioactivity in mantle
- Geochemical estimate (Bulk Silicate Earth is lower)
- Require plate control rate

NASA Astrobiology Institute

Director's Seminar Series
9/29/2008 – Norm Sleep

1
00:00:05,780 --> 00:00:03,619
good morning everyone if you're in the

2
00:00:07,700 --> 00:00:05,790
name time zone and good afternoon if

3
00:00:10,430 --> 00:00:07,710
you're in a p.m. time zone welcome to

4
00:00:13,820 --> 00:00:10,440
the new season of the NAI director's

5
00:00:17,480 --> 00:00:13,830
seminar I am really really pleased that

6
00:00:20,720 --> 00:00:17,490
we can kick off the seminar series this

7
00:00:23,090 --> 00:00:20,730
year I I feel think as an academic

8
00:00:25,939 --> 00:00:23,100
obviously the year starts in September

9
00:00:27,740 --> 00:00:25,949
but then again the federal fiscal year

10
00:00:29,750 --> 00:00:27,750
starts in October so we're pretty close

11
00:00:31,460 --> 00:00:29,760
to that too so whatever new year you

12
00:00:33,560 --> 00:00:31,470
want we've got it and Rosh Hashanah the

13
00:00:35,959 --> 00:00:33,570

Jewish New Year is coming up so it's new

14
00:00:38,959 --> 00:00:35,969
year all the way around so at any rate

15
00:00:41,510 --> 00:00:38,969
it's a real pleasure to have norm sleep

16
00:00:45,619 --> 00:00:41,520
with us he's right here at nai central

17
00:00:48,380 --> 00:00:45,629
to present this morning seminar norm as

18
00:00:50,840 --> 00:00:48,390
I think most of you know is a professor

19
00:00:53,869 --> 00:00:50,850
of geophysics at Stanford University he

20
00:00:55,910 --> 00:00:53,879
is a very very distinguished member of

21
00:00:57,410 --> 00:00:55,920
the science community and the DNA I he's

22
00:01:00,349 --> 00:00:57,420
a member of the National Academy of

23
00:01:02,029 --> 00:01:00,359
Sciences he's a fellow of most of the

24
00:01:04,640 --> 00:01:02,039
professional societies that you can

25
00:01:06,080 --> 00:01:04,650
think of the triple-a s the Geological

26
00:01:08,899 --> 00:01:06,090
Society of America and the American

27
00:01:13,719 --> 00:01:08,909
Geophysical Union he's won a fistful of

28
00:01:17,690 --> 00:01:13,729
medals I won't try to list them all his

29
00:01:20,990 --> 00:01:17,700
educational background includes Michigan

30
00:01:24,560 --> 00:01:21,000
State and then masters and PhD in

31
00:01:27,050 --> 00:01:24,570
geophysics from MIT and norm is going to

32
00:01:29,420 --> 00:01:27,060
be speaking with us this morning about a

33
00:01:31,910 --> 00:01:29,430
topic that he's been working on lately

34
00:01:34,520 --> 00:01:31,920
and talked about it apps icon which is

35
00:01:36,859 --> 00:01:34,530
the habitability of super Earths many of

36
00:01:39,260 --> 00:01:36,869
which we anticipate discovering in the

37
00:01:43,840 --> 00:01:39,270
next few years in norm take it away

38
00:01:48,560 --> 00:01:43,850

ok the interest in superest comes about

39
00:01:50,749 --> 00:01:48,570
simply some sciences like the drunk

40
00:01:53,929 --> 00:01:50,759
looking for lost car keys that looks

41
00:01:56,510 --> 00:01:53,939
under the lamppost where it can see we

42
00:01:59,060 --> 00:01:56,520
obviously have a sampling bias of when

43
00:02:02,420 --> 00:01:59,070
you find silicate planets around another

44
00:02:07,690 --> 00:02:02,430
star we're going to be more to find

45
00:02:10,070 --> 00:02:07,700
large ones and small ones the tectonics

46
00:02:13,290 --> 00:02:10,080
especially if we can concentrate on what

47
00:02:15,630 --> 00:02:13,300
may be observable at a distant

48
00:02:19,200 --> 00:02:15,640
and the have ability of these objects

49
00:02:22,710 --> 00:02:19,210
are of interest we have the Earth and

50
00:02:27,420 --> 00:02:22,720
Mars a small silicate planet to provide

51
00:02:30,450 --> 00:02:27,430
at least some analogy in comparison okay

52
00:02:33,990 --> 00:02:30,460
they're basically three things you need

53
00:02:37,680 --> 00:02:34,000
in the recipe for habitability you can't

54
00:02:39,720 --> 00:02:37,690
be too hot or too cold especially if we

55
00:02:42,960 --> 00:02:39,730
consider habitability that can be

56
00:02:46,920 --> 00:02:42,970
observed at a distance we have to have

57
00:02:49,620 --> 00:02:46,930
Rock cycles that are active so we don't

58
00:02:52,050 --> 00:02:49,630
end up with Mars were essentially all

59
00:02:55,080 --> 00:02:52,060
the volatile mats are in the subsurface

60
00:02:59,340 --> 00:02:55,090
are Venus why they're all in the

61
00:03:03,150 --> 00:02:59,350
atmosphere and we need some sort of

62
00:03:15,680 --> 00:03:03,160
chemical disequilibrium so the biota can

63
00:03:19,770 --> 00:03:15,690

have lunch okay what is bad provide

64
00:03:23,580 --> 00:03:19,780
concentrating on super earth we can end

65
00:03:26,970 --> 00:03:23,590
up creating too much nother or gas this

66
00:03:29,580 --> 00:03:26,980
is detectable particularly in transit

67
00:03:33,090 --> 00:03:29,590
we have Neptune as example in our own

68
00:03:38,370 --> 00:03:33,100
solar system we can also get too close

69
00:03:42,420 --> 00:03:38,380
to the star Venus as an example we can

70
00:03:45,510 --> 00:03:42,430
get outside the habitable zone this kind

71
00:03:49,140 --> 00:03:45,520
of renders the object uninhabitable at

72
00:03:51,720 --> 00:03:49,150
the surface but probably habitable in

73
00:03:53,570 --> 00:03:51,730
the subsurface it just becomes hard to

74
00:03:57,090 --> 00:03:53,580
detect

75
00:04:08,250 --> 00:03:57,100
traditionally uninhabitable but non

76
00:04:11,699 --> 00:04:08,260
traditionally habitable what else is bad

77
00:04:13,920 --> 00:04:11,709
we need geochemical cycles as I've

78
00:04:18,320 --> 00:04:13,930
already mentioned and Garr concentrate

79
00:04:22,710 --> 00:04:18,330
us on on the talk Mars is something

80
00:04:25,050 --> 00:04:22,720
where this has happened asteroid impacts

81
00:04:26,310 --> 00:04:25,060
occur infrequently but they can spoil

82
00:04:28,560 --> 00:04:26,320
your day

83
00:04:31,290 --> 00:04:28,570
and we can end up with a planet-wide

84
00:04:33,270 --> 00:04:31,300
ocean which I'll discuss also we can end

85
00:04:36,660 --> 00:04:33,280
up with water world and I'll show this

86
00:04:39,420 --> 00:04:36,670
it's a probable fate of a super earth I

87
00:04:44,580 --> 00:04:39,430
can get different life than on the earth

88
00:04:47,280 --> 00:04:44,590

but not necessarily die up okay we've

89
00:04:51,840 --> 00:04:47,290
had a couple papers recently on plate

90
00:04:55,820 --> 00:04:51,850
tectonics and super earth balance eeeh -

91
00:05:00,140 --> 00:04:55,830
all included it was likely O'Neill

92
00:05:05,040 --> 00:05:00,150
Lonardo concluded it was highly unlikely

93
00:05:08,550 --> 00:05:05,050
I'm going to simplify the math and the

94
00:05:11,100 --> 00:05:08,560
derivations things become a nominally

95
00:05:13,770 --> 00:05:11,110
simple if you use gravity rather than

96
00:05:16,200 --> 00:05:13,780
mass as a scaling power you don't have

97
00:05:19,560 --> 00:05:16,210
to carry around mass to all kinds of

98
00:05:24,810 --> 00:05:19,570
fractional powers I'm going to derive

99
00:05:28,470 --> 00:05:24,820
both the Valencia and Lennar Dec neon

100
00:05:30,630 --> 00:05:28,480
Antarctic results some others I'm going

101
00:05:34,110 --> 00:05:30,640
to illustrate the assumptions I'm going

102
00:05:37,650 --> 00:05:34,120
to avoid tidally heated planets there

103
00:05:39,840 --> 00:05:37,660
was a paper on this at UPS icon but

104
00:05:43,820 --> 00:05:39,850
tides are going to make the fire -

105
00:05:47,010 --> 00:05:43,830
inside hotter and more vigorous probably

106
00:05:49,680 --> 00:05:47,020
possibly lead to abundant surface

107
00:05:56,010 --> 00:05:49,690
volcanism which will also give us

108
00:05:59,880 --> 00:05:56,020
geochemical cycles okay if we use

109
00:06:03,120 --> 00:05:59,890
gravity as a size parameter we use

110
00:06:06,950 --> 00:06:03,130
Gauss's law we have the other advantage

111
00:06:10,800 --> 00:06:06,960
is that gravity for large planets scales

112
00:06:15,720 --> 00:06:10,810
to the square root rather than cube root

113
00:06:17,700 --> 00:06:15,730

of mass so a ton earth-mass planet will

114
00:06:21,210 --> 00:06:17,710
have about three times the gravity of

115
00:06:23,490 --> 00:06:21,220
the earth Mars which is about 1/10

116
00:06:26,190 --> 00:06:23,500
Earth's mass planet will have about 4

117
00:06:28,320 --> 00:06:26,200
tenths so we have a parameter that for

118
00:06:32,480 --> 00:06:28,330
the range of planets that we consider

119
00:06:35,660 --> 00:06:32,490
habitable it's not going to vary a lot

120
00:06:38,719 --> 00:06:35,670
this will also lead to some

121
00:06:48,589 --> 00:06:43,519
okay we have God's us law for gravity

122
00:06:54,529 --> 00:06:48,599
the gravitational flux from an object

123
00:06:58,079 --> 00:06:54,539
getting longer or not it is it is not as

124
00:07:02,489 --> 00:06:58,089
equal to four times G times the mass of

125
00:07:06,269 --> 00:07:02,499
the planet the equilibrium Heat fall has

126
00:07:08,489 --> 00:07:06,279
the same type of formula the equilibrium

127
00:07:11,909 --> 00:07:08,499
heat flow is a minimum heat flow an

128
00:07:16,829 --> 00:07:11,919
object can have where it will cool down

129
00:07:19,980 --> 00:07:16,839
rather than heat up planet during its

130
00:07:23,909 --> 00:07:19,990
history can only cool a few hundred K

131
00:07:26,699 --> 00:07:23,919
from a dream a hot and basically Cawley

132
00:07:30,689 --> 00:07:26,709
Maldon at the surface where it's too

133
00:07:33,779 --> 00:07:30,699
cold for having any serious tectonics so

134
00:07:36,449 --> 00:07:33,789
a heat wall being crudely imbalanced

135
00:07:40,320 --> 00:07:36,459
with radioactivity is something that

136
00:07:47,279 --> 00:07:40,330
will give us a scaling assumption and we

137
00:07:52,279 --> 00:07:47,289
can combine these and get the

138
00:07:55,670 --> 00:07:52,289

radioactive eath wall it's again

139
00:08:01,259 --> 00:07:55,680
depending on the mass of the planet and

140
00:08:04,469 --> 00:08:01,269
we have something that's observable for

141
00:08:07,949 --> 00:08:04,479
the earth gravity for an object if we

142
00:08:14,519 --> 00:08:07,959
can determine about the size diameter is

143
00:08:16,769 --> 00:08:14,529
observable and the balance here will

144
00:08:20,519 --> 00:08:16,779
reflect a long-lasting state of the

145
00:08:23,369 --> 00:08:20,529
planet that the planet cools extremely

146
00:08:25,649 --> 00:08:23,379
fast at during and after accretion feels

147
00:08:29,029 --> 00:08:25,659
extremely fast anytime wound farming

148
00:08:31,829 --> 00:08:29,039
impact but cool slowly at that kind of

149
00:08:35,939 --> 00:08:31,839
50 hundred pay four billion years of

150
00:08:38,120 --> 00:08:35,949
that order and has a crude balance

151
00:08:41,730 --> 00:08:38,130
between heat flow and review activity

152
00:08:44,309 --> 00:08:41,740
observe is long-lasting and if we look

153
00:08:47,250 --> 00:08:44,319
at a random planet we're going to see it

154
00:08:51,300 --> 00:08:47,260
in its long lasting state rather than

155
00:08:55,150 --> 00:08:51,310
the state that is in relatively briefly

156
00:08:58,320 --> 00:08:55,160
okay we get some simple scaling formulas

157
00:09:02,830 --> 00:08:58,330
out of this let the static pressure

158
00:09:05,110 --> 00:09:02,840
caprices a personal to gravity density

159
00:09:07,240 --> 00:09:05,120
this is the near surface density it's

160
00:09:11,050 --> 00:09:07,250
not going to very much for silicate

161
00:09:15,070 --> 00:09:11,060
planets the geothermal ative to the

162
00:09:19,320 --> 00:09:15,080
surface temperature is proportional to

163
00:09:22,120 --> 00:09:19,330

the heat wall from the planet and hence

164
00:09:25,810 --> 00:09:22,130
proportional to the deep fall from

165
00:09:28,270 --> 00:09:25,820
radioactivity again increases with depth

166
00:09:30,730 --> 00:09:28,280
and is inversely proportional

167
00:09:33,670 --> 00:09:30,740
conductivity this is a rock property

168
00:09:35,560 --> 00:09:33,680
that's not going to very much the

169
00:09:39,010 --> 00:09:35,570
surface temperature if we stick the

170
00:09:43,620 --> 00:09:39,020
palatable planets is not far from the

171
00:09:52,380 --> 00:09:43,630
freezing point of water and we can write

172
00:09:56,320 --> 00:09:52,390
the geothermal in terms of pressure and

173
00:10:00,130 --> 00:09:56,330
this means that if we plot things as a

174
00:10:01,780 --> 00:10:00,140
petrology pressure temperature gia firm

175
00:10:04,690 --> 00:10:01,790
is going to be to the first order

176
00:10:07,150 --> 00:10:04,700
invariant for planetary site if you have

177
00:10:10,000 --> 00:10:07,160
a pressure temperature geothermal earth

178
00:10:12,730 --> 00:10:10,010
it will work on Mars and we'll work on

179
00:10:14,290 --> 00:10:12,740
the super earth to the first order it

180
00:10:16,300 --> 00:10:14,300
will depend on the amount of

181
00:10:18,460 --> 00:10:16,310
radioactivity in the planet which will

182
00:10:22,390 --> 00:10:18,470
of course decrease as it's used up

183
00:10:24,700 --> 00:10:22,400
during its history but if we got a

184
00:10:27,100 --> 00:10:24,710
particular point in the evolution of a

185
00:10:31,050 --> 00:10:27,110
planet we have the same pressure

186
00:10:39,700 --> 00:10:35,500
okay we get other useful scalings from

187
00:10:44,980 --> 00:10:39,710
this the pressure at the base of all put

188
00:10:47,620 --> 00:10:44,990

the sphere early the maximum depth of

189
00:10:51,180 --> 00:10:47,630
the planet is dominated the junction is

190
00:10:57,700 --> 00:10:51,190
going to be invariant of planetary size

191
00:11:00,880 --> 00:10:57,710
we have a on the plot here we have a

192
00:11:03,170 --> 00:11:00,890
temperature pressure grid for the

193
00:11:06,290 --> 00:11:03,180
melding of basalt

194
00:11:09,440 --> 00:11:06,300
the f we have a given temperature in the

195
00:11:12,280 --> 00:11:09,450
interior the pressure we're melding

196
00:11:15,580 --> 00:11:12,290
starts is going to be invariant of

197
00:11:19,640 --> 00:11:15,590
planetary size a big super-earth may be

198
00:11:22,130 --> 00:11:19,650
hotter we put in a hotter finger and

199
00:11:24,860 --> 00:11:22,140
we'll get melting at a greater depth and

200
00:11:27,790 --> 00:11:24,870
more total melting the points B and C

201
00:11:31,100 --> 00:11:27,800
are the points where the total amount

202
00:11:34,330 --> 00:11:31,110
melt generated in a column equals the

203
00:11:37,070 --> 00:11:34,340
depth and that will be the depth of the

204
00:11:40,130 --> 00:11:37,080
top of the model of the base of the

205
00:11:43,700 --> 00:11:40,140
ocean crust if we plot anything else

206
00:11:47,960 --> 00:11:43,710
here that's pressure dependent thickness

207
00:11:52,690 --> 00:11:47,970
of oceanic crust depends on the pressure

208
00:11:58,190 --> 00:11:52,700
of where melting starts and hence will

209
00:12:00,950 --> 00:11:58,200
scale inversely with gravity thickness

210
00:12:04,070 --> 00:12:00,960
of continental crust the driving forces

211
00:12:13,360 --> 00:12:04,080
will see later to make top metal crust

212
00:12:15,770 --> 00:12:13,370
from the ridge will scale such that the

213
00:12:17,840 --> 00:12:15,780

thickness of continental crust will

214
00:12:20,480 --> 00:12:17,850
scale with the thickness of lettuce fare

215
00:12:23,630 --> 00:12:20,490
the segments of hydrothermally altered

216
00:12:29,660 --> 00:12:23,640
crusts scales with the pressure to close

217
00:12:32,270 --> 00:12:29,670
cracks and if we plot a collinear with

218
00:12:36,710 --> 00:12:32,280
the zone of hydrothermal alteration the

219
00:12:38,660 --> 00:12:36,720
salted crust the depleted mantle of

220
00:12:42,650 --> 00:12:38,670
melts heavily and the base of the

221
00:12:45,020 --> 00:12:42,660
lithosphere that diagram at a given

222
00:12:48,500 --> 00:12:45,030
interior temperature will be in varying

223
00:12:50,570 --> 00:12:48,510
the private area size though what we

224
00:12:53,690 --> 00:12:50,580
learned about the earth carries through

225
00:12:57,350 --> 00:12:53,700
one caveat is that the super earth in

226
00:12:59,780 --> 00:12:57,360
the interior may be hotter but then it

227
00:13:01,850 --> 00:12:59,790
will be like the earth early in its

228
00:13:06,290 --> 00:13:01,860
history when the interior is hotter we

229
00:13:12,170 --> 00:13:06,300
get good analogy here and we learn a lot

230
00:13:15,679 --> 00:13:12,180
fairly quick there's a socket scaling

231
00:13:17,600 --> 00:13:15,689
here that's even more universal

232
00:13:19,249 --> 00:13:17,610
the cool material you'll have to

233
00:13:22,519 --> 00:13:19,259
circulate it through the thermal

234
00:13:27,019 --> 00:13:22,529
boundary layer go let the spirit this is

235
00:13:29,419 --> 00:13:27,029
true of any large convective object the

236
00:13:32,329 --> 00:13:29,429
scaling with another proportionality

237
00:13:34,460 --> 00:13:32,339
constant would be true if we had a

238
00:13:37,460 --> 00:13:34,470

volcanic Li cold planet where the

239
00:13:41,150 --> 00:13:37,470
material erupts it has to a rough the

240
00:13:43,009 --> 00:13:41,160
cool we lose all the heat rather than

241
00:13:45,859 --> 00:13:43,019
just some in the lithosphere so there's

242
00:13:50,299 --> 00:13:45,869
a different proportionality constant so

243
00:13:53,329 --> 00:13:50,309
this time to circulate material form

244
00:13:56,030 --> 00:13:53,339
continental crust circulate material

245
00:13:58,840 --> 00:13:56,040
through the ridge axis where we know how

246
00:14:02,299 --> 00:13:58,850
material end up in the ocean crust

247
00:14:07,759 --> 00:14:02,309
produced enough volatile to recycle the

248
00:14:10,069 --> 00:14:07,769
ocean take material through the

249
00:14:13,009 --> 00:14:10,079
reservoir that forms hydrothermally

250
00:14:16,729 --> 00:14:13,019
altered crust all of this is invariant

251
00:14:19,909 --> 00:14:16,739
of planetary size and this is variance

252
00:14:23,449 --> 00:14:19,919
will depend on the cooling mechanism but

253
00:14:26,389 --> 00:14:23,459
is again there and we're dealing here

254
00:14:29,960 --> 00:14:26,399
with circulating material through the

255
00:14:32,749 --> 00:14:29,970
lithosphere the current scale time being

256
00:14:36,259 --> 00:14:32,759
couple billion years for the earth the

257
00:14:41,619 --> 00:14:36,269
scale time for anything else being the

258
00:14:49,579 --> 00:14:45,019
okay we need now to consider the

259
00:14:54,009 --> 00:14:49,589
tectonic mechanism any of our jobs it

260
00:14:57,019 --> 00:14:54,019
has to cool by conduct by convection

261
00:15:01,340 --> 00:14:57,029
conduction can dominate near the surface

262
00:15:05,359 --> 00:15:01,350
but the interior is simply too big to

263
00:15:11,650 --> 00:15:05,369

call over the regional age of the planet

264
00:15:15,799 --> 00:15:11,660
don't let CEA's group she balances

265
00:15:20,059 --> 00:15:15,809
matter wide forces it shows these are

266
00:15:22,879 --> 00:15:20,069
greater than the lithospheric forces and

267
00:15:25,129 --> 00:15:22,889
hence will have convection where it's

268
00:15:28,850 --> 00:15:25,139
controlled by the rate subscribe to

269
00:15:31,040 --> 00:15:28,860
think in the mantle O'Neill and on our

270
00:15:35,240 --> 00:15:31,050
cab models that effectively consider

271
00:15:38,620 --> 00:15:35,250
only forces in the lithosphere even

272
00:15:41,720 --> 00:15:38,630
though they're complicated and I show

273
00:15:46,760 --> 00:15:41,730
analytically that we can get into a

274
00:15:50,690 --> 00:15:46,770
state where plate tectonics only occurs

275
00:15:53,000 --> 00:15:50,700
in the on earth sized planets I'm going

276
00:15:54,640 --> 00:15:53,010
to again use gravity I'm going to derive

277
00:15:57,380 --> 00:15:54,650
results and going to illustrate

278
00:16:00,890 --> 00:15:57,390
assumptions and I got to come up with a

279
00:16:04,760 --> 00:16:00,900
displease result that were too ignorant

280
00:16:07,670 --> 00:16:04,770
of the earth to fully extrapolate regard

281
00:16:10,010 --> 00:16:07,680
come up with a pleasing result now if we

282
00:16:12,920 --> 00:16:10,020
don't have plate tectonics the interior

283
00:16:15,080 --> 00:16:12,930
is quite hot we'll still get lots of

284
00:16:19,090 --> 00:16:15,090
optimism will get geochemical cycles

285
00:16:22,250 --> 00:16:19,100
this will affect details but will not

286
00:16:27,530 --> 00:16:22,260
affect the fact that we have a Geo

287
00:16:30,890 --> 00:16:27,540
chemically active climate ok the heat

288
00:16:34,340 --> 00:16:30,900

flow through the lithosphere depends on

289
00:16:36,020 --> 00:16:34,350
this square root of plate by H law it

290
00:16:39,200 --> 00:16:36,030
depends on the temperature contrast

291
00:16:41,960 --> 00:16:39,210
across the lithosphere which will vary

292
00:16:44,360 --> 00:16:41,970
some but not a lot again because the

293
00:16:47,870 --> 00:16:44,370
planet is too cold we don't get sent

294
00:16:51,760 --> 00:16:47,880
Onix if the planet is too hot it cools

295
00:16:55,520 --> 00:16:51,770
extremely rapidly with a molten surface

296
00:16:57,890 --> 00:16:55,530
conductivity thermal diffusivity in the

297
00:17:01,580 --> 00:16:57,900
square root or material properties and

298
00:17:06,920 --> 00:17:01,590
we can write this dimensionally taking

299
00:17:09,020 --> 00:17:06,930
the term in the bracket to be the scale

300
00:17:11,270 --> 00:17:09,030
thickness of the lettuce fair and just

301
00:17:15,189 --> 00:17:11,280
getting the simple Fourier conduction

302
00:17:21,340 --> 00:17:19,090
okay to get subduction to go we have to

303
00:17:25,359 --> 00:17:21,350
have three things to work the slab has

304
00:17:28,059 --> 00:17:25,369
to bend with strains of order one the

305
00:17:30,460 --> 00:17:28,069
front megathrust the boundary between

306
00:17:33,789 --> 00:17:30,470
the slab and the are cast is leather

307
00:17:37,060 --> 00:17:33,799
sometimes slips and great soon tsunami

308
00:17:39,909 --> 00:17:37,070
earthquake so I can Sumatra I have slept

309
00:17:42,729 --> 00:17:39,919
one way or the other and the slab has to

310
00:17:45,879 --> 00:17:42,739
be able to kind of treat into the mouth

311
00:17:47,549 --> 00:17:45,889
and we don't really know on the earth

312
00:17:50,049 --> 00:17:47,559
which one of these is the rate-limiting

313
00:17:58,180 --> 00:17:50,059

process we know that all three have to

314
00:18:03,310 --> 00:17:58,190
occur okay to bend the slab simple way

315
00:18:05,830 --> 00:18:03,320
to model this is that we have a yield

316
00:18:07,720 --> 00:18:05,840
stress and a yield stress that acts over

317
00:18:10,299 --> 00:18:07,730
the thickness of the lithosphere and

318
00:18:12,879 --> 00:18:10,309
there has to be enough forces either

319
00:18:15,970 --> 00:18:12,889
from the buoyancy of the ridge axis or

320
00:18:23,739 --> 00:18:15,980
the negative buoyancy of the slab to

321
00:18:26,830 --> 00:18:23,749
allow this process to occur we also have

322
00:18:29,789 --> 00:18:26,840
subduction this depends on friction and

323
00:18:33,999 --> 00:18:29,799
it depends on friction thats related

324
00:18:37,779 --> 00:18:34,009
will coefficient of friction we know the

325
00:18:40,180 --> 00:18:37,789
coefficient friction of in fact rock we

326
00:18:43,899 --> 00:18:40,190
don't know the water crunch or piece of

327
00:18:47,320 --> 00:18:43,909
WF depth and I collected firms in here

328
00:18:52,060 --> 00:18:47,330
use that the pressure the lithostatic

329
00:18:55,119 --> 00:18:52,070
pressure is going to scale with depth

330
00:18:57,430 --> 00:18:55,129
and the scale thickness that this is

331
00:19:00,840 --> 00:18:57,440
going to act at is the scale thickness

332
00:19:05,499 --> 00:19:00,850
of the lithosphere and it's going to

333
00:19:07,899 --> 00:19:05,509
depend on gravity linearly the big point

334
00:19:10,889 --> 00:19:07,909
here is we don't know what the water

335
00:19:14,979 --> 00:19:10,899
pressure is so we don't know what this

336
00:19:26,440 --> 00:19:14,989
apparent coefficient of friction is new

337
00:19:34,990 --> 00:19:26,450
apparent ok we can solve

338
00:19:39,100 --> 00:19:35,000

for a driving force here the we have a

339
00:19:42,040 --> 00:19:39,110
driving force that's going to be

340
00:19:45,370 --> 00:19:42,050
proportional to the buoyancy of the slab

341
00:19:47,410 --> 00:19:45,380
a buoyancy of the ridge axis is going to

342
00:19:49,660 --> 00:19:47,420
be proportional temperature contrast

343
00:19:52,000 --> 00:19:49,670
proportional gravity proportional to

344
00:19:55,240 --> 00:19:52,010
thermal contraction coefficient I'm

345
00:19:57,400 --> 00:19:55,250
going to derive this on a later side

346
00:19:58,510 --> 00:19:57,410
that this is the classical Ridge push

347
00:20:02,050 --> 00:19:58,520
force

348
00:20:04,840 --> 00:20:02,060
buoyant material if it's not cannot

349
00:20:08,380 --> 00:20:04,850
sustain stressful but like the food I

350
00:20:11,110 --> 00:20:08,390
boil over water and we're assuming that

351
00:20:14,530 --> 00:20:11,120
this buoyancy force for the ridge is

352
00:20:17,590 --> 00:20:14,540
driving subduction if we solve this

353
00:20:21,100 --> 00:20:17,600
equation all the material parameters

354
00:20:23,050 --> 00:20:21,110
drop everything drops out except the

355
00:20:26,080 --> 00:20:23,060
temperature contrasts across the

356
00:20:28,510 --> 00:20:26,090
lithosphere the apparent coefficient of

357
00:20:30,670 --> 00:20:28,520
friction and the thermal expansion

358
00:20:33,700 --> 00:20:30,680
coefficient we're trying to get a

359
00:20:36,430 --> 00:20:33,710
numerical model this way we have to tune

360
00:20:41,230 --> 00:20:36,440
the numerical model which Armijo and an

361
00:20:43,240 --> 00:20:41,240
Arctic dead we cannot solve for the

362
00:20:46,320 --> 00:20:43,250
lettuce Pyrrhic thickness is a function

363
00:20:48,760 --> 00:20:46,330

of planetary gravity so kind of a

364
00:20:50,530 --> 00:20:48,770
partial influence here it should be

365
00:20:52,890 --> 00:20:50,540
tuned this to work on the earth that

366
00:20:57,370 --> 00:20:52,900
won't work on planets that are smaller

367
00:20:59,050 --> 00:20:57,380
or larger the other point in here is

368
00:21:01,210 --> 00:20:59,060
that we know what the thermal expansion

369
00:21:03,940 --> 00:21:01,220
coefficient is we know what the

370
00:21:06,930 --> 00:21:03,950
temperature contrast is we end up with a

371
00:21:12,430 --> 00:21:06,940
very small coefficient of friction of

372
00:21:14,650 --> 00:21:12,440
around for 100s which is too low to be

373
00:21:17,440 --> 00:21:14,660
for any reasonable material which means

374
00:21:26,560 --> 00:21:17,450
that we either need a dynamic weakening

375
00:21:28,780 --> 00:21:26,570
mechanism or we need to have a very high

376
00:21:31,660 --> 00:21:28,790
good pressure probably from subducted

377
00:21:34,090 --> 00:21:31,670
settlements so again something that we

378
00:21:35,360 --> 00:21:34,100
don't know a lot about the earth we know

379
00:21:38,330 --> 00:21:35,370
the subduction zone

380
00:21:40,610 --> 00:21:38,340
week on the earth but we don't you know

381
00:21:44,590 --> 00:21:40,620
kind of qualitatively why but certainly

382
00:21:47,390 --> 00:21:44,600
not quantitative clock ok the second out

383
00:21:54,430 --> 00:21:47,400
process I'm going to consider is the

384
00:21:57,710 --> 00:21:54,440
slab moving to viscous model if we solve

385
00:22:00,680 --> 00:21:57,720
the force balance equation between the

386
00:22:02,990 --> 00:22:00,690
slab and the resistance of the slab we

387
00:22:05,900 --> 00:22:03,000
get back the classical parametrize

388
00:22:09,050 --> 00:22:05,910

convection result the same one will

389
00:22:11,030 --> 00:22:09,060
apply to an ice of viscous fluid applies

390
00:22:14,300 --> 00:22:11,040
in this tape because the lithosphere is

391
00:22:15,590 --> 00:22:14,310
basically by assumption going on for a

392
00:22:18,350 --> 00:22:15,600
ride

393
00:22:25,190 --> 00:22:18,360
we get a very big slab it's going to be

394
00:22:26,960 --> 00:22:25,200
able possibly to overcome forces in the

395
00:22:29,540 --> 00:22:26,970
lithosphere like the friction and

396
00:22:32,720 --> 00:22:29,550
bending and all we have to consider is

397
00:22:35,410 --> 00:22:32,730
the fact that the slab can sink we see

398
00:22:39,560 --> 00:22:35,420
that we get gravity to the 1/3 power

399
00:22:44,050 --> 00:22:39,570
here we need heat flow proportional to

400
00:22:46,610 --> 00:22:44,060
gravity to balance radioactivity the

401
00:22:50,570 --> 00:22:46,620
parameters here we can change or the

402
00:22:53,420 --> 00:22:50,580
temperature contrasts at the surface and

403
00:22:55,820 --> 00:22:53,430
the viscosity we increase the

404
00:22:59,740 --> 00:22:55,830
temperature and interior it decreases

405
00:23:03,020 --> 00:22:59,750
viscosity increases this so we need

406
00:23:05,630 --> 00:23:03,030
balance radioactivity with heat form the

407
00:23:08,930 --> 00:23:05,640
silver we need to have a hotter than the

408
00:23:10,730 --> 00:23:08,940
earth on site we get relatively robust

409
00:23:14,090 --> 00:23:10,740
result this is the blunt see at all

410
00:23:18,380 --> 00:23:14,100
result you have a big slab on a small

411
00:23:21,440 --> 00:23:18,390
planet we the tactic here and just show

412
00:23:24,260 --> 00:23:21,450
it here an outline is that the slab

413
00:23:27,020 --> 00:23:24,270

sinks the drives fall and the fall of

414
00:23:29,390 --> 00:23:27,030
the lithosphere is going on for the ride

415
00:23:31,010 --> 00:23:29,400
it's all fascitis producing the only

416
00:23:34,070 --> 00:23:31,020
driving force will put the plate in

417
00:23:36,770 --> 00:23:34,080
tension we get a big enough slab it's

418
00:23:40,250 --> 00:23:36,780
going to overcome any forces in the

419
00:23:43,250 --> 00:23:40,260
lithosphere and the metal is going to be

420
00:23:46,490 --> 00:23:43,260
the dominant balance and we're back to

421
00:23:56,390 --> 00:23:46,500
the simple classical parameter ice

422
00:23:58,370 --> 00:23:56,400
so okay the again just to reiterate we

423
00:24:00,470 --> 00:23:58,380
can strive the equation either from

424
00:24:04,610 --> 00:24:00,480
force balance or work balance like

425
00:24:07,159 --> 00:24:04,620
villain see it all does the work on the

426
00:24:09,620 --> 00:24:07,169
megathrust and the bending of the slab

427
00:24:14,210 --> 00:24:09,630
becomes negligible if we have a big

428
00:24:16,399 --> 00:24:14,220
enough slab plates become likely there's

429
00:24:19,909 --> 00:24:16,409
a physical problem with this is that the

430
00:24:23,630 --> 00:24:19,919
viscosity increases without that the

431
00:24:26,690 --> 00:24:23,640
slab may do mainly work deforming the

432
00:24:30,289 --> 00:24:26,700
deep model and not have much work left

433
00:24:32,360 --> 00:24:30,299
over to be transmitted to the slab that

434
00:24:35,390 --> 00:24:32,370
the viscosity immediately under though

435
00:24:39,049 --> 00:24:35,400
if this fear may be quite well the slab

436
00:24:41,870 --> 00:24:39,059
will drive the wall but the it'll

437
00:24:44,090 --> 00:24:41,880
basically be effectively like ball

438
00:24:46,250 --> 00:24:44,100

bearings between the model and Miletus

439
00:24:47,180 --> 00:24:46,260
fare and the slab may not be able to put

440
00:24:52,460 --> 00:24:47,190
the lithosphere

441
00:24:56,680 --> 00:24:52,470
under compression a second problem here

442
00:24:58,399 --> 00:24:56,690
is if we do a parameterised convention

443
00:25:01,279 --> 00:24:58,409
calculation for the earth and

444
00:25:05,510 --> 00:25:01,289
extrapolate back in time we get into

445
00:25:11,299 --> 00:25:05,520
royal trouble the current a most

446
00:25:13,190 --> 00:25:11,309
accepted geochemical estimate for the

447
00:25:18,080 --> 00:25:13,200
radioactivity in the earth would produce

448
00:25:20,630 --> 00:25:18,090
a web land heat for a 24 noah watts per

449
00:25:23,149 --> 00:25:20,640
meter square the model on the east fall

450
00:25:25,370 --> 00:25:23,159
is seventy milliwatts per meter squared

451
00:25:30,260 --> 00:25:25,380
so if we believe this the earth is

452
00:25:34,310 --> 00:25:30,270
pulling like 180 or over a hundred

453
00:25:38,060 --> 00:25:34,320
degrees 100 K per billion years if we

454
00:25:40,669 --> 00:25:38,070
try to extrapolate back in time we

455
00:25:42,590 --> 00:25:40,679
extrapolate it back in time the metals

456
00:25:45,649 --> 00:25:42,600
hotter we have even more vigorous

457
00:25:48,260 --> 00:25:45,659
Convention and we strap away we get back

458
00:25:52,250 --> 00:25:48,270
even a billion years and we have the

459
00:25:54,529 --> 00:25:52,260
whole inside of the planet molten we

460
00:25:57,840 --> 00:25:54,539
know we have basically tectonics like

461
00:26:00,570 --> 00:25:57,850
the present at the time

462
00:26:03,750 --> 00:26:00,580
we have to crank up the heat while over

463
00:26:06,600 --> 00:26:03,760

double the box silicate earth like that

464
00:26:10,050 --> 00:26:06,610
before we get an acceptable thermal

465
00:26:12,360 --> 00:26:10,060
history or the planet starts out how to

466
00:26:15,600 --> 00:26:12,370
what we know it's H to be a really 2h

467
00:26:18,450 --> 00:26:15,610
after the month in pipe so we got two

468
00:26:21,660 --> 00:26:18,460
things here two assumptions that sound

469
00:26:24,240 --> 00:26:21,670
very good that the Madol controls the

470
00:26:28,800 --> 00:26:24,250
rate of plate tectonics and we have this

471
00:26:30,990 --> 00:26:28,810
good estimate how they constraints from

472
00:26:33,390 --> 00:26:31,000
plasma chemistry humming constraints

473
00:26:35,940 --> 00:26:33,400
from all we can sample from the interior

474
00:26:39,630 --> 00:26:35,950
of the earth Falls cannot be right at

475
00:26:43,710 --> 00:26:39,640
the time we either have to have the

476
00:26:48,900 --> 00:26:43,720
radioactivity estimate wall by over a

477
00:26:50,730 --> 00:26:48,910
factor of two will soon the neutrino

478
00:26:53,250 --> 00:26:50,740
detectors anti neutrinos from

479
00:26:55,980 --> 00:26:53,260
radioactive decay in the earth so we

480
00:26:59,100 --> 00:26:55,990
will know the absolute radioactive heat

481
00:27:01,380 --> 00:26:59,110
generation we will know the absolute

482
00:27:05,640 --> 00:27:01,390
abundance of uranium and thorium in the

483
00:27:09,180 --> 00:27:05,650
earth and we'll be able to check to see

484
00:27:11,610 --> 00:27:09,190
if what it's right

485
00:27:14,940 --> 00:27:11,620
the alternative is this elegant

486
00:27:17,520 --> 00:27:14,950
assumption that the model if big we have

487
00:27:20,100 --> 00:27:17,530
big slabs sinking into a huge metal is

488
00:27:23,550 --> 00:27:20,110

wrong and that the plates really control

489
00:27:27,000 --> 00:27:23,560
the rate on your earth if that is the

490
00:27:30,060 --> 00:27:27,010
case the the assumption that Allen

491
00:27:35,930 --> 00:27:30,070
Arctic made could possibly destructive

492
00:27:41,940 --> 00:27:35,940
original control our we have the ultra

493
00:27:45,780 --> 00:27:41,950
tip here that we have control by the

494
00:27:49,170 --> 00:27:45,790
bending and a yield stress okay

495
00:27:53,520 --> 00:27:49,180
the ridge push force its relative given

496
00:27:56,220 --> 00:27:53,530
it already relatively easy to derive we

497
00:27:59,930 --> 00:27:56,230
cannot have the vertical pressure and a

498
00:28:04,140 --> 00:27:59,940
floating object and a surrounding fluid

499
00:28:08,880 --> 00:28:04,150
equal to the horizontal stress in in

500
00:28:10,520 --> 00:28:08,890
both viewing this in terms of work if we

501
00:28:13,430 --> 00:28:10,530
have

502
00:28:15,590 --> 00:28:13,440
if we had the solid here that was

503
00:28:19,580 --> 00:28:15,600
buoyant it would spread out like oil

504
00:28:22,820 --> 00:28:19,590
over wine in the case of the earth the

505
00:28:27,800 --> 00:28:22,830
ridges weeks are have a buoyant weak

506
00:28:30,050 --> 00:28:27,810
foot and we have a strong dense

507
00:28:33,560 --> 00:28:30,060
lithosphere so the lithosphere will be

508
00:28:36,050 --> 00:28:33,570
put into compression mathematically the

509
00:28:39,290 --> 00:28:36,060
stress resolving to stress times the

510
00:28:42,110 --> 00:28:39,300
thickness of the lithosphere is equal to

511
00:28:44,060 --> 00:28:42,120
this triangle that you formed by

512
00:28:47,480 --> 00:28:44,070
clotting the vertical stress in both

513
00:28:51,200 --> 00:28:47,490

objects the vertical and here is the

514
00:28:53,210 --> 00:28:51,210
elevation of our but the plates are in

515
00:28:55,790 --> 00:28:53,220
compression on the earth we know this

516
00:28:57,980 --> 00:28:55,800
from inner plate earthquakes so we have

517
00:29:01,670 --> 00:28:57,990
the possibility that this rich forst

518
00:29:04,040 --> 00:29:01,680
forst we want to go to europa we have

519
00:29:08,690 --> 00:29:04,050
our to the situation are drawn here to

520
00:29:12,380 --> 00:29:08,700
get a simpler analogy the thinnest ice

521
00:29:17,150 --> 00:29:12,390
on Europa is the weakest so we have a

522
00:29:20,570 --> 00:29:17,160
weak fluid against a strong boy and

523
00:29:23,030 --> 00:29:20,580
solid so the thick ice the high

524
00:29:33,230 --> 00:29:23,040
elevations in Europa will be in this

525
00:29:39,310 --> 00:29:33,240
membrane attention okay we can balance a

526
00:29:44,780 --> 00:29:39,320
yield stress against this Ridge push

527
00:29:48,860 --> 00:29:44,790
stress acting through the planet and in

528
00:29:53,960 --> 00:29:48,870
that case we get the thickness of the

529
00:29:56,630 --> 00:29:53,970
lithosphere scales to 1 over gravity the

530
00:29:59,390 --> 00:29:56,640
heat flow will scale to 1 over the let

531
00:30:01,820 --> 00:29:59,400
this old lithosphere thickness so in

532
00:30:05,480 --> 00:30:01,830
that case we get heat 12 scaling to

533
00:30:09,160 --> 00:30:05,490
gravity and that we have plate tectonics

534
00:30:12,880 --> 00:30:09,170
by this mechanism on the super earth

535
00:30:15,940 --> 00:30:12,890
where we get earth-like temperatures

536
00:30:19,880 --> 00:30:15,950
throughout its history and it basically

537
00:30:22,550 --> 00:30:19,890
behaves like the earth does where it has

538
00:30:24,710 --> 00:30:22,560

a lettuce pair of thinner thickness

539
00:30:27,680 --> 00:30:24,720
but the same pressure at the base of

540
00:30:31,340 --> 00:30:27,690
express everything in terms of pressure

541
00:30:33,830 --> 00:30:31,350
things work very simply for this the

542
00:30:41,380 --> 00:30:33,840
assumption here is that depending of a

543
00:30:48,050 --> 00:30:41,390
slab rather than the slip on vection

544
00:30:50,060 --> 00:30:48,060
okay back to the friction again we get

545
00:30:52,550 --> 00:30:50,070
the result in terms of material

546
00:30:55,250 --> 00:30:52,560
properties it doesn't and you can't say

547
00:30:58,790 --> 00:30:55,260
anything from that about the

548
00:31:01,910 --> 00:30:58,800
relationship to size but it went to

549
00:31:05,120 --> 00:31:01,920
model I can on the owner anodic one will

550
00:31:08,480 --> 00:31:05,130
just give fake tectonics on an object on

551
00:31:10,610 --> 00:31:08,490
a large object and earth size option

552
00:31:15,770 --> 00:31:10,620
cannot give plate tectonics on a big one

553
00:31:18,110 --> 00:31:15,780
or smaller and this is again the matura

554
00:31:20,690 --> 00:31:18,120
property again reminding us that we need

555
00:31:23,990 --> 00:31:20,700
a very low stress but your coefficient

556
00:31:26,720 --> 00:31:24,000
of friction we don't really understand

557
00:31:28,660 --> 00:31:26,730
why the coefficient of friction is low

558
00:31:33,070 --> 00:31:28,670
on the earth we understand qualitatively

559
00:31:37,610 --> 00:31:33,080
but certainly not quantitatively okay

560
00:31:40,750 --> 00:31:37,620
we've gone through I basically the

561
00:31:43,370 --> 00:31:40,760
Valencia doll model is matter wide

562
00:31:46,790 --> 00:31:43,380
driven flow by the effectively by the

563
00:31:49,580 --> 00:31:46,800

slab the O'Neill and Lonard ik is

564
00:31:54,650 --> 00:31:49,590
friction and balancing rich push force

565
00:31:59,540 --> 00:31:54,660
and we could see where we come from but

566
00:32:05,980 --> 00:31:59,550
we can't really extrapolate okay let's

567
00:32:09,860 --> 00:32:05,990
see about geochemical cycles we can have

568
00:32:11,990 --> 00:32:09,870
plates works nice on the earth if we're

569
00:32:15,590 --> 00:32:12,000
lucky enough to get plates things work

570
00:32:18,920 --> 00:32:15,600
fine if we have a volcanic planet we get

571
00:32:21,560 --> 00:32:18,930
very vigorous geochemical cycles we have

572
00:32:25,130 --> 00:32:21,570
very reactive material erupting to the

573
00:32:28,670 --> 00:32:25,140
surface we get Hydra straighted

574
00:32:30,650 --> 00:32:28,680
carbonated material melting at depth we

575
00:32:32,300 --> 00:32:30,660
get something that kinda looks like the

576
00:32:34,430 --> 00:32:32,310
earth and pot scientists have claimed

577
00:32:35,750 --> 00:32:34,440
the Archaean of the Earth may have

578
00:32:38,540 --> 00:32:35,760
behaved this way

579
00:32:40,490 --> 00:32:38,550
rather than strictly having plates if we

580
00:32:42,500 --> 00:32:40,500
have a stagnant lid prior that we can

581
00:32:45,650 --> 00:32:42,510
get that in two ways the thickness of

582
00:32:48,290 --> 00:32:45,660
continental crust is such that a cup

583
00:32:50,090 --> 00:32:48,300
volume of it you know big planets where

584
00:32:52,840 --> 00:32:50,100
raw material to make crust covers the

585
00:32:56,950 --> 00:32:52,850
whole planet or we can get in this

586
00:32:59,330 --> 00:32:56,960
friction dominated machine where we get

587
00:33:01,610 --> 00:32:59,340
something that may have some plate

588
00:33:04,490 --> 00:33:01,620

tectonics but it's sluggish can't

589
00:33:08,720 --> 00:33:04,500
transport the heat so we have a hot

590
00:33:11,630 --> 00:33:08,730
material the stagnant lid heat flow

591
00:33:14,210 --> 00:33:11,640
works okay because for it to get

592
00:33:18,290 --> 00:33:14,220
operated it works like the parameter ice

593
00:33:19,970 --> 00:33:18,300
convection result that I had before we

594
00:33:23,780 --> 00:33:19,980
have to have the interior of the planet

595
00:33:26,840 --> 00:33:23,790
quite hot to get the heat out of a super

596
00:33:31,010 --> 00:33:26,850
earth or even an earth-sized planet so

597
00:33:33,560 --> 00:33:31,020
we still get vulcanism we get a like ma

598
00:33:37,220 --> 00:33:33,570
maybe ma hot spot organism or I'll

599
00:33:38,840 --> 00:33:37,230
Balkan ism but we still have volcanism

600
00:33:41,840 --> 00:33:38,850
we still get a perfectly good

601
00:33:44,690 --> 00:33:41,850
geochemical cycle effect the details

602
00:33:52,670 --> 00:33:44,700
about the gift but not affect what we

603
00:33:56,030 --> 00:33:52,680
get overall okay if we use a oh it's not

604
00:33:59,570 --> 00:33:56,040
a direct analog because gravity is not

605
00:34:02,060 --> 00:33:59,580
important there and actually behavior

606
00:34:04,040 --> 00:34:02,070
closer to stagnant letters I've driven

607
00:34:07,910 --> 00:34:04,050
convection will work for our large

608
00:34:10,280 --> 00:34:07,920
planet that the inside of the planet

609
00:34:12,940 --> 00:34:10,290
must fall because the inside is not

610
00:34:15,710 --> 00:34:12,950
going to be malt on the deep inside

611
00:34:20,210 --> 00:34:15,720
planet with large gravity large pressure

612
00:34:21,830 --> 00:34:20,220
at depth and will basically get

613
00:34:25,970 --> 00:34:21,840

convection where the rate of the

614
00:34:28,369 --> 00:34:25,980
convection staying that led our front of

615
00:34:30,800 --> 00:34:28,379
our classic parameterised convection

616
00:34:33,110 --> 00:34:30,810
formula will give close to the right

617
00:34:35,899 --> 00:34:33,120
result the vulcanism gets the heat out

618
00:34:38,000 --> 00:34:35,909
the last little bit to the left is fair

619
00:34:41,690 --> 00:34:38,010
but it's not the rate limiting stuff

620
00:34:43,490 --> 00:34:41,700
like it is ideal where the gravity

621
00:34:46,909 --> 00:34:43,500
causes the pressure to just slightly

622
00:34:48,780 --> 00:34:46,919
increase with depth we could totally Mel

623
00:34:50,580 --> 00:34:48,790
the silicate planet

624
00:34:53,100 --> 00:34:50,590
they'd get material where they get

625
00:34:57,440 --> 00:34:53,110
ultramafic material like olivine will

626
00:35:00,750 --> 00:34:57,450
give them alcohol and ocean or we could

627
00:35:03,990 --> 00:35:00,760
remail tigris material and get more

628
00:35:06,720 --> 00:35:04,000
granitic Magnus we could end up with the

629
00:35:10,710 --> 00:35:06,730
crust of the planet melting at its base

630
00:35:14,370 --> 00:35:10,720
and just simply that acting is a heat

631
00:35:16,860 --> 00:35:14,380
transfer mechanism we know that this has

632
00:35:22,290 --> 00:35:16,870
not happened in the last 3.8 billion

633
00:35:24,930 --> 00:35:22,300
years probably the last 4.2 or 4.3 where

634
00:35:27,420 --> 00:35:24,940
the interior huh was hot enough that

635
00:35:30,890 --> 00:35:27,430
we've had continuous melting everywhere

636
00:35:34,650 --> 00:35:30,900
at the base of the continental crust we

637
00:35:38,070 --> 00:35:34,660
know that simply because where we start

638
00:35:40,290 --> 00:35:38,080

to see rocks of 3/8 we're not getting

639
00:35:43,230 --> 00:35:40,300
continuous volcanic scumming out of the

640
00:35:45,960 --> 00:35:43,240
interior rather receive our regular

641
00:35:48,690 --> 00:35:45,970
sedimentary rocks and there's irk on

642
00:35:51,570 --> 00:35:48,700
sweets we see peeks of activity and peak

643
00:35:53,310 --> 00:35:51,580
supply elsens in the ancient sir con

644
00:35:55,380 --> 00:35:53,320
seats just like we do now they're a

645
00:35:56,720 --> 00:35:55,390
little bit peeps are a bit closer

646
00:35:59,280 --> 00:35:56,730
together

647
00:36:01,370 --> 00:35:59,290
we couldn't observe peaks that were a

648
00:36:05,430 --> 00:36:01,380
billion years of hardware we only have

649
00:36:08,730 --> 00:36:05,440
500 million years of record but we still

650
00:36:12,210 --> 00:36:08,740
have periods of high essence and periods

651
00:36:17,670 --> 00:36:12,220
of activity rather than continuous

652
00:36:20,580 --> 00:36:17,680
melting at the base of the crust the

653
00:36:23,760 --> 00:36:20,590
statement that vulcanism again we have

654
00:36:26,040 --> 00:36:23,770
just a small layer that's not that has

655
00:36:29,130 --> 00:36:26,050
viscosity like the interior actually

656
00:36:33,870 --> 00:36:29,140
conducting leads to the interior being

657
00:36:35,970 --> 00:36:33,880
hotness of already mentioned okay we can

658
00:36:40,470 --> 00:36:35,980
compute ocean depth we make the

659
00:36:42,960 --> 00:36:40,480
assumption that most of the water in the

660
00:36:47,100 --> 00:36:42,970
planet Early's much of it ends up in the

661
00:36:52,020 --> 00:36:47,110
ocean on the earth one of the paradigms

662
00:36:55,530 --> 00:36:52,030
is that the earth model can only take so

663
00:36:57,810 --> 00:36:55,540

much water the subduction zone tries to

664
00:37:00,120 --> 00:36:57,820
spend down too much water we get melting

665
00:37:02,370 --> 00:37:00,130
at the island arc the island are

666
00:37:06,180 --> 00:37:02,380
volcanic comes up we get an eruption

667
00:37:08,850 --> 00:37:06,190
like mount st. Helen and the water is

668
00:37:10,980 --> 00:37:08,860
back at the surface this is that we have

669
00:37:13,860 --> 00:37:10,990
something like a coal trap and an old

670
00:37:16,170 --> 00:37:13,870
refrigerator this is a water trap that

671
00:37:17,280 --> 00:37:16,180
the whole model has to eventually pass

672
00:37:20,310 --> 00:37:17,290
through the regex

673
00:37:24,180 --> 00:37:20,320
subduction zone so we have a sluggish

674
00:37:27,510 --> 00:37:24,190
system but that the water gets back out

675
00:37:30,950 --> 00:37:27,520
at the subduction zone there various

676
00:37:33,450 --> 00:37:30,960
things that are basically we pipe

677
00:37:36,780 --> 00:37:33,460
reasoning that claim that you can get

678
00:37:39,780 --> 00:37:36,790
much more water in the model but this is

679
00:37:42,600 --> 00:37:39,790
basically the oniy hypothesis that

680
00:37:45,960 --> 00:37:42,610
really fully includes plate tectonics

681
00:37:48,420 --> 00:37:45,970
that may not necessarily be correct but

682
00:37:51,780 --> 00:37:48,430
it leaves there with a little bit of

683
00:37:54,680 --> 00:37:51,790
geometry the ocean depth scales with

684
00:37:57,990 --> 00:37:54,690
gravity the height of the topography

685
00:38:02,160 --> 00:37:58,000
again using the scaling relationships of

686
00:38:06,780 --> 00:38:02,170
driving force from the buoyancy of the

687
00:38:09,830 --> 00:38:06,790
ridge scales inversely with gravity and

688
00:38:14,970 --> 00:38:09,840

we have a small ocean it will protect I

689
00:38:18,630 --> 00:38:14,980
guess a small asteroid get up a big

690
00:38:20,730 --> 00:38:18,640
enough asteroid gets to vaporize the

691
00:38:23,280 --> 00:38:20,740
ocean it takes forever for it to rain

692
00:38:25,530 --> 00:38:23,290
out at the greenhouse special and we

693
00:38:29,810 --> 00:38:25,540
sterilized any subsurface from the

694
00:38:33,120 --> 00:38:29,820
residual there's no subsurface residual

695
00:38:36,360 --> 00:38:33,130
the ocean crust is thin that the water

696
00:38:40,980 --> 00:38:36,370
is deep these kind of cancel each other

697
00:38:43,860 --> 00:38:40,990
out big asteroid impact moderately big

698
00:38:46,110 --> 00:38:43,870
when they actually assume nate'll if we

699
00:38:48,840 --> 00:38:46,120
had a dry super earth where the ocean

700
00:38:53,070 --> 00:38:48,850
crust is thin then it would be easy to

701
00:38:55,950 --> 00:38:53,080
assume that we end up with lots of

702
00:39:00,740 --> 00:38:55,960
material tricks and Carnot's this is

703
00:39:03,360 --> 00:39:00,750
just Gauss's law for water we have the

704
00:39:05,430 --> 00:39:03,370
area of the planet scared the thickness

705
00:39:07,680 --> 00:39:05,440
of the ocean the density of the water is

706
00:39:09,930 --> 00:39:07,690
equal to the concentration of water in

707
00:39:12,810 --> 00:39:09,940
the planet times the mass of the planet

708
00:39:15,530 --> 00:39:12,820
and we solve for this and we get a

709
00:39:17,690 --> 00:39:15,540
proportionality to gravity

710
00:39:20,930 --> 00:39:17,700
firstly proportional to the density of

711
00:39:22,700 --> 00:39:20,940
water which is the material property we

712
00:39:25,180 --> 00:39:22,710
don't really know what the concentration

713
00:39:27,410 --> 00:39:25,190

of the water is and super-earth if

714
00:39:29,330 --> 00:39:27,420
anything it's going to be easier to

715
00:39:32,780 --> 00:39:29,340
accrete by a pulse on a big object

716
00:39:34,460 --> 00:39:32,790
rather than small on too much volatile

717
00:39:39,770 --> 00:39:34,470
gives us nothing tunes so there's going

718
00:39:43,610 --> 00:39:39,780
to be a limit to this but if we just

719
00:39:46,310 --> 00:39:43,620
take this a first order we're likely to

720
00:39:49,460 --> 00:39:46,320
end up with Waterworld on super earth

721
00:39:51,680 --> 00:39:49,470
where I'd be we have water or a world

722
00:39:54,050 --> 00:39:51,690
Europa in our own solar system we don't

723
00:39:56,810 --> 00:39:54,060
have an earth-sized Waterworld but

724
00:39:59,150 --> 00:39:56,820
considering a water world it's worth

725
00:40:01,940 --> 00:39:59,160
doing even if we don't find a super

726
00:40:06,700 --> 00:40:01,950
earth one because we made well find an

727
00:40:09,530 --> 00:40:06,710
earth-like one elsewhere okay we have

728
00:40:12,710 --> 00:40:09,540
processes of scale to gravitational

729
00:40:15,890 --> 00:40:12,720
potential and why the processes on a

730
00:40:19,190 --> 00:40:15,900
super earth is going to be very hard for

731
00:40:22,250 --> 00:40:19,200
hydrogen to get out and we may end up

732
00:40:25,160 --> 00:40:22,260
with a hydrogen-rich atmosphere rather

733
00:40:29,420 --> 00:40:25,170
than an strongly reducing atmosphere

734
00:40:34,940 --> 00:40:29,430
where co2 is a trace constituent rather

735
00:40:37,760 --> 00:40:34,950
than a fondant one the direct effects of

736
00:40:40,850 --> 00:40:37,770
a super-earth are dead

737
00:40:44,840 --> 00:40:40,860
barring microbes are really not affected

738
00:40:46,610 --> 00:40:44,850

directly by gravity large organisms if

739
00:40:50,270 --> 00:40:46,620
you've read any science fiction book

740
00:40:52,820 --> 00:40:50,280
football to where they add water

741
00:40:55,880 --> 00:40:52,830
organisms if they're large or neutrally

742
00:40:57,650 --> 00:40:55,890
buoyant and you go get start organizing

743
00:40:59,750 --> 00:40:57,660
some land

744
00:41:03,650 --> 00:40:59,760
the interesting thing here is the

745
00:41:07,490 --> 00:41:03,660
reducing atmosphere sediments dominated

746
00:41:12,760 --> 00:41:07,500
by carbon organic carbon rather than by

747
00:41:16,990 --> 00:41:12,770
carbonates and we're also going to have

748
00:41:20,150 --> 00:41:17,000
niches we can't have both lots of hot

749
00:41:23,810 --> 00:41:20,160
hydrogen and lots of co2 together on a

750
00:41:25,220 --> 00:41:23,820
common planet while the first life forms

751
00:41:27,410 --> 00:41:25,230
to evolve on the earth

752
00:41:31,910 --> 00:41:27,420
managin so they're relatively easily

753
00:41:36,560 --> 00:41:31,920
evolved and they will react hydrogen

754
00:41:40,040 --> 00:41:36,570
with co2 if we have a reducing planet

755
00:41:44,290 --> 00:41:40,050
where hydrogen is dominant co2 will

756
00:41:47,540 --> 00:41:44,300
become the light the limiting after

757
00:41:51,140 --> 00:41:47,550
photosynthesis would help you put in Sun

758
00:41:55,220 --> 00:41:51,150
energy to help grab the co2 but you're

759
00:41:57,680 --> 00:41:55,230
still have problems there are other

760
00:42:02,300 --> 00:41:57,690
Nicias here these are highly speculative

761
00:42:07,130 --> 00:42:02,310
a shopping list various ways here to you

762
00:42:08,840 --> 00:42:07,140
methane and water as a substrate to make

763
00:42:13,359 --> 00:42:08,850

organic matter with different

764
00:42:16,310 --> 00:42:13,369
intermediate steps monoxide is a poison

765
00:42:19,849 --> 00:42:16,320
icing Li it's very good high energy

766
00:42:25,430 --> 00:42:19,859
source very good for microbes that could

767
00:42:31,730 --> 00:42:25,440
make out of that we can make hydrogen an

768
00:42:34,490 --> 00:42:31,740
organic matter we can use co2 which is

769
00:42:39,800 --> 00:42:34,500
in short supply or carbon monoxide for

770
00:42:42,440 --> 00:42:39,810
intermediate steps we don't have

771
00:42:46,790 --> 00:42:42,450
organisms that do methane photosynthesis

772
00:42:50,210 --> 00:42:46,800
at least known on the earth but so it is

773
00:42:52,550 --> 00:42:50,220
a speculation the intermediate steps

774
00:42:58,170 --> 00:42:52,560
that got that part are no longer

775
00:43:08,740 --> 00:43:01,180
what other choices we can star an

776
00:43:16,860 --> 00:43:08,750
oxidant dumb choice is o2 that oxygen

777
00:43:27,310 --> 00:43:22,480
making oxidants by gathering light we

778
00:43:30,400 --> 00:43:27,320
have organisms that do photosynthesis

779
00:43:33,730 --> 00:43:30,410
using FeO we have organisms that do

780
00:43:35,950 --> 00:43:33,740
photosynthesis doing sulfides we have

781
00:43:39,100 --> 00:43:35,960
none that I know of that directly makes

782
00:43:44,470 --> 00:43:39,110
hydrogen and store the oxygen for later

783
00:43:46,570 --> 00:43:44,480
use now we can get exotic manganese is

784
00:43:50,980 --> 00:43:46,580
hopefully involved in photosynthesis on

785
00:43:53,250 --> 00:43:50,990
the earth there's apparently no organism

786
00:43:57,790 --> 00:43:53,260
that makes a manganate or permanganate

787
00:44:01,210 --> 00:43:57,800
in photosynthesis there argan isn't that

788
00:44:05,350 --> 00:44:01,220

make nitrate from Mike right and

789
00:44:08,590 --> 00:44:05,360
photosynthesis we could make nitrates

790
00:44:10,840 --> 00:44:08,600
easy to star we could even star the

791
00:44:13,350 --> 00:44:10,850
organic matter and the nitrate together

792
00:44:17,230 --> 00:44:13,360
make something like night for cellulose

793
00:44:20,760 --> 00:44:17,240
nothing does that on the earth we can

794
00:44:25,300 --> 00:44:20,770
make calcium or manganese magnesium

795
00:44:27,880 --> 00:44:25,310
peroxide these are can be solid so to

796
00:44:32,400 --> 00:44:27,890
saturate the solution for the calcium

797
00:44:36,430 --> 00:44:32,410
one easy to star it's used on the earth

798
00:44:39,310 --> 00:44:36,440
it's not peroxides are heavily involved

799
00:44:42,070 --> 00:44:39,320
in biochemistry on the earth organisms

800
00:44:44,530 --> 00:44:42,080
can make and destroy them they don't use

801
00:44:47,320 --> 00:44:44,540
them as an energy resource as far as you

802
00:44:51,640 --> 00:44:47,330
know nothing gets its ATP as far as

803
00:44:55,120 --> 00:44:51,650
known out of oxide calcium peroxide is

804
00:44:57,700 --> 00:44:55,130
stable it has industrial uses like

805
00:45:00,700 --> 00:44:57,710
cleaning are like putting a rock on

806
00:45:02,350 --> 00:45:00,710
right seats and rice paddies so the

807
00:45:07,099 --> 00:45:02,360
environment around the right seed

808
00:45:13,679 --> 00:45:10,349
animals if we're going to get animals on

809
00:45:19,679 --> 00:45:13,689
our super earth if we like Ichi to call

810
00:45:22,769 --> 00:45:19,689
home planet did not lose lots of

811
00:45:25,679 --> 00:45:22,779
hydrogen escape when it was quite hot

812
00:45:30,839 --> 00:45:25,689
and accreting we may end up with a

813
00:45:35,459 --> 00:45:30,849

reducing metal the Earth's model is much

814
00:45:39,959 --> 00:45:35,469
more oxidized than the model Mars it

815
00:45:43,140 --> 00:45:39,969
slightly oxidized the movement which is

816
00:45:46,439 --> 00:45:43,150
reduced enough that it's close to

817
00:45:48,929 --> 00:45:46,449
equilibrium with iron nickel metal the

818
00:45:52,109 --> 00:45:48,939
model of death is also reduced so if we

819
00:45:55,049 --> 00:45:52,119
can't get hydrogen out during the

820
00:45:57,029 --> 00:45:55,059
accreting the model may stay reduced at

821
00:46:01,410 --> 00:45:57,039
high temperatures will still probably

822
00:46:04,259 --> 00:46:01,420
get slight amount co2 coming out of

823
00:46:07,679 --> 00:46:04,269
volcanoes just simply because you

824
00:46:09,829 --> 00:46:07,689
partition into all the easily produce

825
00:46:13,979 --> 00:46:09,839
species at a high enough temperature

826
00:46:18,900 --> 00:46:13,989
it's not a tempted to calculate any of

827
00:46:23,009 --> 00:46:18,910
these okay we have a question from Penn

828
00:46:28,019 --> 00:46:23,019
State I know I'm the chimp casting can

829
00:46:30,029 --> 00:46:28,029
you hear me out and Claire yeah so

830
00:46:31,979 --> 00:46:30,039
you're you conclude that these super

831
00:46:35,160 --> 00:46:31,989
Earths will have reduced atmospheres

832
00:46:37,079 --> 00:46:35,170
with lots of methane you know that's

833
00:46:38,910 --> 00:46:37,089
true on giant planets but those

834
00:46:41,759 --> 00:46:38,920
atmospheres are infinitely deep

835
00:46:44,609 --> 00:46:41,769
essentially so that methane is reformed

836
00:46:46,380 --> 00:46:44,619
at depth these atmospheres of theory if

837
00:46:48,299 --> 00:46:46,390
the planets are habitable are not that

838
00:46:50,999 --> 00:46:48,309

deep it's not that easy to make methane

839
00:46:53,279 --> 00:46:51,009
in the atmosphere but it is easy to

840
00:47:04,349 --> 00:46:53,289
destroy it photochemically I mean what's

841
00:47:08,579 --> 00:47:04,359
the source for the methane a biotic Lea

842
00:47:10,949 --> 00:47:08,589
their other source the methane would be

843
00:47:14,069 --> 00:47:10,959
that we have very vigorous tectonics of

844
00:47:17,910 --> 00:47:14,079
any of the methane haze Falls to the

845
00:47:19,020 --> 00:47:17,920
surface the materials very soon if it's

846
00:47:23,790 --> 00:47:19,030
not Eden is going

847
00:47:28,290 --> 00:47:23,800
gets abducted worse abducting material

848
00:47:30,680 --> 00:47:28,300
into a presumably hydrous model so we

849
00:47:36,710 --> 00:47:30,690
should get some methane back at the heat

850
00:47:41,790 --> 00:47:39,270
approximation look at it kinetically

851
00:47:44,940 --> 00:47:41,800
because you know if you've got hydrogen

852
00:47:47,240 --> 00:47:44,950
escaping to space probably coming from

853
00:47:50,370 --> 00:47:47,250
water that gives you a source of oxygen

854
00:47:53,220 --> 00:47:50,380
not pre oxygen but enough oxygen to

855
00:47:54,960 --> 00:47:53,230
oxidize some of that methane to co2 so

856
00:47:57,270 --> 00:47:54,970
I'm not that convinced it would be that

857
00:47:59,940 --> 00:47:57,280
different from the early Earth the a

858
00:48:03,780 --> 00:47:59,950
body I agree with your scenario

859
00:48:07,290 --> 00:48:03,790
completely for the earth there's going

860
00:48:10,080 --> 00:48:07,300
to be a significantly high gravitational

861
00:48:12,420 --> 00:48:10,090
potential where it becomes difficult for

862
00:48:15,870 --> 00:48:12,430
hydrogen to get out I there's

863
00:48:19,640 --> 00:48:15,880

disagreement like with the between Dave

864
00:48:23,310 --> 00:48:19,650
cowling that and with the TMO all paper

865
00:48:26,910 --> 00:48:23,320
on whether the efficacy of hydrogen

866
00:48:30,390 --> 00:48:26,920
escape even from the earth

867
00:48:34,140 --> 00:48:30,400
so I basically taken an agnostic

868
00:48:38,760 --> 00:48:34,150
position there but recognized that we

869
00:48:41,270 --> 00:48:38,770
may get a reducing planet so we need to

870
00:48:43,650 --> 00:48:41,280
think about it and I agree kinetics

871
00:48:47,520 --> 00:48:43,660
considering what really happens in the

872
00:48:49,770 --> 00:48:47,530
atmosphere and then throwing relatively

873
00:48:52,830 --> 00:48:49,780
simple life forms into it it's the right

874
00:48:55,680 --> 00:48:52,840
wait involved I just did the simplest

875
00:48:58,650 --> 00:48:55,690
gases I could think of that would farm

876
00:49:01,320 --> 00:48:58,660
if we had a reducing atmosphere okay I

877
00:49:03,180 --> 00:49:01,330
agree I've got fun Ken visiting this

878
00:49:10,250 --> 00:49:03,190
week so fun we need to do that

879
00:49:16,980 --> 00:49:12,870
okay do we have any questions here in

880
00:49:23,650 --> 00:49:16,990
nai central we have a room fo Kevin's on

881
00:49:25,720 --> 00:49:23,660
Lake the largest planet

882
00:49:27,670 --> 00:49:25,730
have more and I imagine that every

883
00:49:34,109 --> 00:49:27,680
parcel I bring to the surface from the

884
00:49:40,200 --> 00:49:37,870
was in my model right and so I have the

885
00:49:52,569 --> 00:49:40,210
surface to volume ratio would give me a

886
00:50:10,589 --> 00:49:52,579
larger amount of he'll spread out and

887
00:50:15,400 --> 00:50:13,420
couple things here the we don't know the

888
00:50:19,450 --> 00:50:15,410

efficacy which the continent will get

889
00:50:22,270 --> 00:50:19,460
lease abductive we have more material to

890
00:50:26,520 --> 00:50:22,280
make it if we end up in that case we'll

891
00:50:30,579 --> 00:50:26,530
end up with probably a continental

892
00:50:32,559 --> 00:50:30,589
vulcanism dominated planet with some

893
00:50:39,329 --> 00:50:32,569
basaltic volcanism that makes it up

894
00:50:41,500 --> 00:50:39,339
through we have-we eppley the planets

895
00:50:47,980 --> 00:50:41,510
well have the planet covered with

896
00:50:50,440 --> 00:50:47,990
volcanoes yes yes we will not get shale

897
00:50:52,870 --> 00:50:50,450
will not get Paul mountains if you want

898
00:50:56,230 --> 00:50:52,880
something like the Appalachians the

899
00:50:58,180 --> 00:50:56,240
aliens there will have to put out their

900
00:51:01,569 --> 00:50:58,190
low gravity suit and travel to the earth

901
00:51:06,700 --> 00:51:01,579
you will not have this you will not get

902
00:51:11,440 --> 00:51:06,710
the basic classes of sedimentary rocks

903
00:51:14,980 --> 00:51:11,450
we will not get organisms that evolved

904
00:51:18,760 --> 00:51:14,990
to do soil weathering will have some

905
00:51:20,950 --> 00:51:18,770
organisms that evolved to whether the

906
00:51:23,890 --> 00:51:20,960
whatever rock they find on the base of

907
00:51:28,299 --> 00:51:23,900
the ocean but will still have things

908
00:51:30,549 --> 00:51:28,309
recycle but we will get a little

909
00:51:33,430 --> 00:51:30,559
offending land we may end up with the

910
00:51:35,280 --> 00:51:33,440
continental crust getting from a DAT

911
00:51:38,310 --> 00:51:35,290
culkin ism can get through

912
00:51:41,490 --> 00:51:38,320
Bahria that may get swamped and gets

913
00:51:44,640 --> 00:51:41,500

abducted so they're both enemies for

914
00:51:50,490 --> 00:51:44,650
here but this line of continental crust

915
00:51:52,410 --> 00:51:50,500
and ocean as definitely a possibility a

916
00:51:57,390 --> 00:51:52,420
possibility that we'll have geochemical

917
00:52:00,090 --> 00:51:57,400
cycles but not plates we have a question

918
00:52:02,550 --> 00:52:00,100
from Jack Lutz our you made a

919
00:52:05,280 --> 00:52:02,560
super-earth from generally more

920
00:52:11,430 --> 00:52:05,290
refractory material so you have a

921
00:52:14,850 --> 00:52:11,440
reasonable amount of water what would be

922
00:52:16,710 --> 00:52:14,860
what would be like most of the current

923
00:52:20,370 --> 00:52:16,720
hiepro comes from the uranium and

924
00:52:23,460 --> 00:52:20,380
thorium so if you if you make it more

925
00:52:25,470 --> 00:52:23,470
refractory you'll get more of that you

926
00:52:28,550 --> 00:52:25,480
lose a little bit of potassium so the

927
00:52:32,130 --> 00:52:28,560
radioactivity will be just a bit hotter

928
00:52:35,850 --> 00:52:32,140
the radioactivity declines by a factor

929
00:52:38,910 --> 00:52:35,860
of a few over the Prentice age so I

930
00:52:47,760 --> 00:52:38,920
think I'll have a modest effect if we

931
00:52:50,970 --> 00:52:47,770
end up getting we very little material

932
00:52:54,180 --> 00:52:50,980
to make crust the part of the crust is

933
00:52:56,330 --> 00:52:54,190
aluminium and calcium which is silica

934
00:52:58,890 --> 00:52:56,340
which we have officer I have plenty up

935
00:53:00,960 --> 00:52:58,900
we'd end up with something that's more

936
00:53:02,990 --> 00:53:00,970
like a plaid your granite the granite

937
00:53:07,940 --> 00:53:03,000
formed at the mid-ocean ridge axis

938
00:53:14,880 --> 00:53:07,950

sodium granite than a classic granite

939
00:53:17,730 --> 00:53:14,890
again going to affect details the long

940
00:53:19,130 --> 00:53:17,740
as we have some trace potassium that

941
00:53:22,950 --> 00:53:19,140
will be available as a biological

942
00:53:25,380 --> 00:53:22,960
element that almost all the potassium of

943
00:53:28,370 --> 00:53:25,390
the earth even near the surface is not

944
00:53:35,340 --> 00:53:32,490
yeah the Amazon Arnulfo region with a

945
00:53:37,800 --> 00:53:35,350
soils are almost quantitatively depleted

946
00:53:43,160 --> 00:53:37,810
of pass him yep

947
00:53:50,130 --> 00:53:47,670
we have another question in art I know

948
00:53:52,560 --> 00:53:50,140
him this is Dave again I had a question

949
00:53:54,240 --> 00:53:52,570
it's so the idea is that maybe the super

950
00:53:56,190 --> 00:53:54,250
earth would be rather like the ad on

951
00:53:58,230 --> 00:53:56,200
earth that but maybe persisting for a

952
00:53:59,730 --> 00:53:58,240
longer period of time in that state but

953
00:54:01,950 --> 00:53:59,740
then the flip side of that is that the

954
00:54:04,140 --> 00:54:01,960
ad and earth might be rather like the

955
00:54:06,030 --> 00:54:04,150
super planet in the sense that you'd

956
00:54:07,740 --> 00:54:06,040
have this pervasive ocean so do you

957
00:54:09,690 --> 00:54:07,750
think that actually is some insight for

958
00:54:12,870 --> 00:54:09,700
the nature of the Haidee and earth in

959
00:54:17,790 --> 00:54:12,880
this I think so that it

960
00:54:20,310 --> 00:54:17,800
we might not has been probably not as

961
00:54:23,960 --> 00:54:20,320
reducing on the hit a and earth we

962
00:54:26,280 --> 00:54:23,970
probably did not get a Percival wide

963
00:54:30,240 --> 00:54:26,290

continent even though people of argue

964
00:54:39,270 --> 00:54:30,250
that we did that's just mass balance

965
00:54:43,110 --> 00:54:39,280
unlikely and we may have well had they

966
00:54:47,540 --> 00:54:43,120
at least appeared in our kyun something

967
00:54:51,030 --> 00:54:47,550
were exterminated by volcanic s-- rather

968
00:54:53,270 --> 00:54:51,040
than by plates but in the D in

969
00:54:58,610 --> 00:54:53,280
particular people have even argued that

970
00:55:02,480 --> 00:54:58,620
for the okiya we get surface weathering

971
00:55:05,490 --> 00:55:02,490
probably by 3/8 sensors well-preserved

972
00:55:08,460 --> 00:55:05,500
shales with sedimentary structures by

973
00:55:11,820 --> 00:55:08,470
them and arguments from the Zutons that

974
00:55:15,960 --> 00:55:11,830
we have some surficial weathering a33 of

975
00:55:18,870 --> 00:55:15,970
4-3 or so so not a complete a toward the

976
00:55:23,160 --> 00:55:18,880
tectonically somewhat of a like the

977
00:55:27,750 --> 00:55:23,170
earth gets hot not hot enough inside and

978
00:55:30,060 --> 00:55:27,760
enough heat loss radioactivity plate

979
00:55:44,830 --> 00:55:30,070
tectonics or the simple form is no

980
00:55:51,710 --> 00:55:49,130
about that if you're in the limit of

981
00:55:58,270 --> 00:55:51,720
diffusion limited hydrogen escape which

982
00:56:11,030 --> 00:56:01,400
that's governed by buoyancy so the

983
00:56:24,650 --> 00:56:11,040
bigger the gravity of separating

984
00:56:26,630 --> 00:56:24,660
hydrogen okay okay baby rock I get

985
00:56:42,650 --> 00:56:26,640
Jeffers how about a stroke needs to do

986
00:56:44,810 --> 00:56:42,660
this worse even if it's not the soup

987
00:56:47,050 --> 00:56:44,820
earth were considering what a very

988
00:56:50,540 --> 00:56:47,060

reduced end of a planet would be we have

989
00:56:54,500 --> 00:56:50,550
we have Titan on our own solar system

990
00:56:59,090 --> 00:56:54,510
that does not have a silicate surface

991
00:57:02,600 --> 00:56:59,100
but may well have a water ocean so if we

992
00:57:04,610 --> 00:57:02,610
go deep enough into Titan we start to

993
00:57:06,500 --> 00:57:04,620
approach these conditions even on the

994
00:57:11,960 --> 00:57:06,510
inside is probably not extremely

995
00:57:11,970 --> 00:57:16,849
okay Jim you have your assignment Oh

996
00:57:26,010 --> 00:57:20,099
long do you want to say anything about

997
00:57:37,230 --> 00:57:26,020
that well I'd love to do that some kind

998
00:57:41,640 --> 00:57:37,240
of hard to do okay do we have any other

999
00:57:43,530 --> 00:57:41,650
hands raised Marco and WebEx okay if

1000
00:57:45,480 --> 00:57:43,540
anybody would like to just jump in with

1001
00:57:49,920 --> 00:57:45,490
the question just open your mic and go

1002
00:57:51,540 --> 00:57:49,930
ahead Noren to say again add the

1003
00:57:53,400 --> 00:57:51,550
question about the Hadean on the earth

1004
00:57:56,700 --> 00:57:53,410
do you think the more globally pervasive

1005
00:58:02,370 --> 00:57:56,710
ocean is an interesting concept that has

1006
00:58:05,760 --> 00:58:02,380
some merit to it enough we call Galileo

1007
00:58:10,710 --> 00:58:05,770
this kind of a subtle effect here that

1008
00:58:13,579 --> 00:58:10,720
the Obito of the ocean is lower than the

1009
00:58:15,839 --> 00:58:13,589
albedo of the terrestrial deserts

1010
00:58:23,210 --> 00:58:15,849
apparently this is visible with the

1011
00:58:27,660 --> 00:58:23,220
naked eye when the crescent moon is over

1012
00:58:29,460 --> 00:58:27,670
the terrestrial deserts the earth shine

1013
00:58:31,559 --> 00:58:29,470

is brighter than when it's over the

1014
00:58:35,599 --> 00:58:31,569
ocean this is in Galileo and the

1015
00:58:40,079 --> 00:58:35,609
dialogues so this is at least a partial

1016
00:58:45,329 --> 00:58:40,089
way around their weak young Sun paradox

1017
00:58:47,490 --> 00:58:45,339
is that a mostly ocean covered planet

1018
00:58:51,720 --> 00:58:47,500
would have sard morrow of a sunlight

1019
00:58:54,390 --> 00:58:51,730
rather than reflective and there's also

1020
00:58:58,800 --> 00:58:54,400
a daisyworld thing here for the earth if

1021
00:59:01,620 --> 00:58:58,810
we have a anoxygenic or the iron based

1022
00:59:06,000 --> 00:59:01,630
photosynthetic microbial mat covering

1023
00:59:10,440 --> 00:59:06,010
the planets desert front as a law albedo

1024
00:59:13,380 --> 00:59:10,450
compared to reflective still desert the

1025
00:59:15,680 --> 00:59:13,390
Egyptians raised goats they've been able

1026
00:59:19,230 --> 00:59:15,690
to get rid of the desert crust in the

1027
00:59:24,030 --> 00:59:19,240
Sinai and it's 2 degrees centigrade or

1028
00:59:27,840 --> 00:59:24,040
than the Israeli Sinai where they

1029
00:59:31,770 --> 00:59:27,850
now over grazing braig um so you can end

1030
00:59:34,800 --> 00:59:31,780
up with this daisyworld situation where

1031
00:59:37,110 --> 00:59:34,810
the microbial mats will spread warming

1032
00:59:39,030 --> 00:59:37,120
the temperature of the planet and do

1033
00:59:41,010 --> 00:59:39,040
they cover enough of the planet that

1034
00:59:43,880 --> 00:59:41,020
they get warm enough that they're

1035
00:59:47,760 --> 00:59:43,890
limited by desiccation and then this

1036
00:59:50,160 --> 00:59:47,770
stable buffer of temperature will occur

1037
00:59:51,540 --> 00:59:50,170
at the point of desiccation at the warm

1038
00:59:54,330 --> 00:59:51,550

end of the daisyworld

1039
00:59:58,800 --> 00:59:54,340
rather than the cold freezing it so

1040
01:00:04,320 --> 00:59:58,810
there is a potential Gihon like

1041
01:00:07,590 --> 01:00:04,330
mechanism here I think there's a work of

1042
01:00:12,780 --> 01:00:07,600
Blair hedges on the family tree alight

1043
01:00:15,720 --> 01:00:12,790
some evidence of cyanobacteria evolved

1044
01:00:18,540 --> 01:00:15,730
on land from soil bacteria and fire and

1045
01:00:22,280 --> 01:00:18,550
evolved from an ecosystem that

1046
01:00:24,720 --> 01:00:22,290
originally and it was doing an toxigenic

1047
01:00:29,040 --> 01:00:24,730
photosynthesis so probably thoroughly

1048
01:00:31,770 --> 01:00:29,050
early on before 3/8 we had the

1049
01:00:37,250 --> 01:00:31,780
continents covered by these micro

1050
01:00:40,440 --> 01:00:37,260
pervasive microbial mats anoxygenic

1051
01:00:43,620 --> 01:00:40,450
photosynthesis getting the iron out is a

1052
01:00:49,290 --> 01:00:43,630
big prize you need four irons to make

1053
01:00:51,630 --> 01:00:49,300
one organic carbon so we may have had an

1054
01:00:54,480 --> 01:00:51,640
ethical system that would have evolved

1055
01:00:59,190 --> 01:00:54,490
and eventually ended up with the soil

1056
01:01:03,090 --> 01:00:59,200
bacteria cyanobacteria would evolve to

1057
01:01:05,550 --> 01:01:03,100
be able to inhabit low ion Regents that

1058
01:01:07,440 --> 01:01:05,560
were the AFOL to the eventual weathering

1059
01:01:10,560 --> 01:01:07,450
melting and tectonics whole iron

1060
01:01:13,710 --> 01:01:10,570
Granite's low iron shales borne court

1061
01:01:16,290 --> 01:01:13,720
sites where there would be a strong

1062
01:01:22,380 --> 01:01:16,300
selective pressure for an organism with

1063
01:01:25,950 --> 01:01:22,390

that ability and the evidence for this

1064
01:01:29,910 --> 01:01:25,960
is that the cyanobacteria seem to be

1065
01:01:32,210 --> 01:01:29,920
related to bacteria that are originally

1066
01:01:35,819 --> 01:01:32,220
and still primarily have a

1067
01:01:38,700 --> 01:01:35,829
all probably combining through organisms

1068
01:01:41,279 --> 01:01:38,710
that have the ability inadvertently to

1069
01:01:45,809 --> 01:01:41,289
make a little bit of oxygen and when it

1070
01:01:49,380 --> 01:01:45,819
gets the ability to make a lot of any

1071
01:01:52,890 --> 01:01:49,390
bit more becomes valuable each oxygen

1072
01:01:55,380 --> 01:01:52,900
you make that means you don't even need

1073
01:01:57,870 --> 01:01:55,390
for ions which is a big deal when you in

1074
01:02:02,160 --> 01:01:57,880
your iron limited in the ocean there be

1075
01:02:04,140 --> 01:02:02,170
iron and sulfide around so the it

1076
01:02:08,370 --> 01:02:04,150
becomes less advantageous to do an

1077
01:02:10,980 --> 01:02:08,380
oxygen photosynthesis you the producing

1078
01:02:14,430 --> 01:02:10,990
an oxidant that you don't immediately

1079
01:02:16,620 --> 01:02:14,440
get back yourself it's not it does not

1080
01:02:23,430 --> 01:02:16,630
become a storehouse of energy so it

1081
01:02:26,609 --> 01:02:23,440
becomes beyond my new quantity in the

1082
01:02:30,960 --> 01:02:26,619
air if you forgive ferric iron and it

1083
01:02:33,809 --> 01:02:30,970
stays around microbial mat you get

1084
01:02:36,359 --> 01:02:33,819
benefit from that your close call no

1085
01:02:37,740 --> 01:02:36,369
relatives benefit from that oxidant that

1086
01:02:42,840 --> 01:02:37,750
you've just made if you can do the

1087
01:02:42,850 --> 01:02:48,810
any more questions

1088
01:02:56,970 --> 01:02:53,450

okay then let me remind you that the

1089
01:02:59,400 --> 01:02:56,980
this seminar will be archived it'll be

1090
01:03:01,680 --> 01:02:59,410
available and up on the NA our website

1091
01:03:04,830 --> 01:03:01,690
probably in about 3-4 days certainly by

1092
01:03:07,020 --> 01:03:04,840
next week and anybody who missed it this

1093
01:03:10,100 --> 01:03:07,030
time or who wants to hear it again will

1094
01:03:13,860 --> 01:03:10,110
have the opportunity to in perpetuity

1095
01:03:15,960 --> 01:03:13,870
and once again the next nai director

1096
01:03:17,460 --> 01:03:15,970
seminar will be given by Jack szostak of

1097
01:03:20,730 --> 01:03:17,470
Hubbard University in Massachusetts

1098
01:03:23,190 --> 01:03:20,740
General Hospital and that will be on

1099
01:03:27,480 --> 01:03:23,200
Monday November 3rd same time same

1100
01:03:33,360 --> 01:03:27,490
channel and one last opportunity for

1101
01:03:40,470 --> 01:03:33,370
questions to norm going once going twice