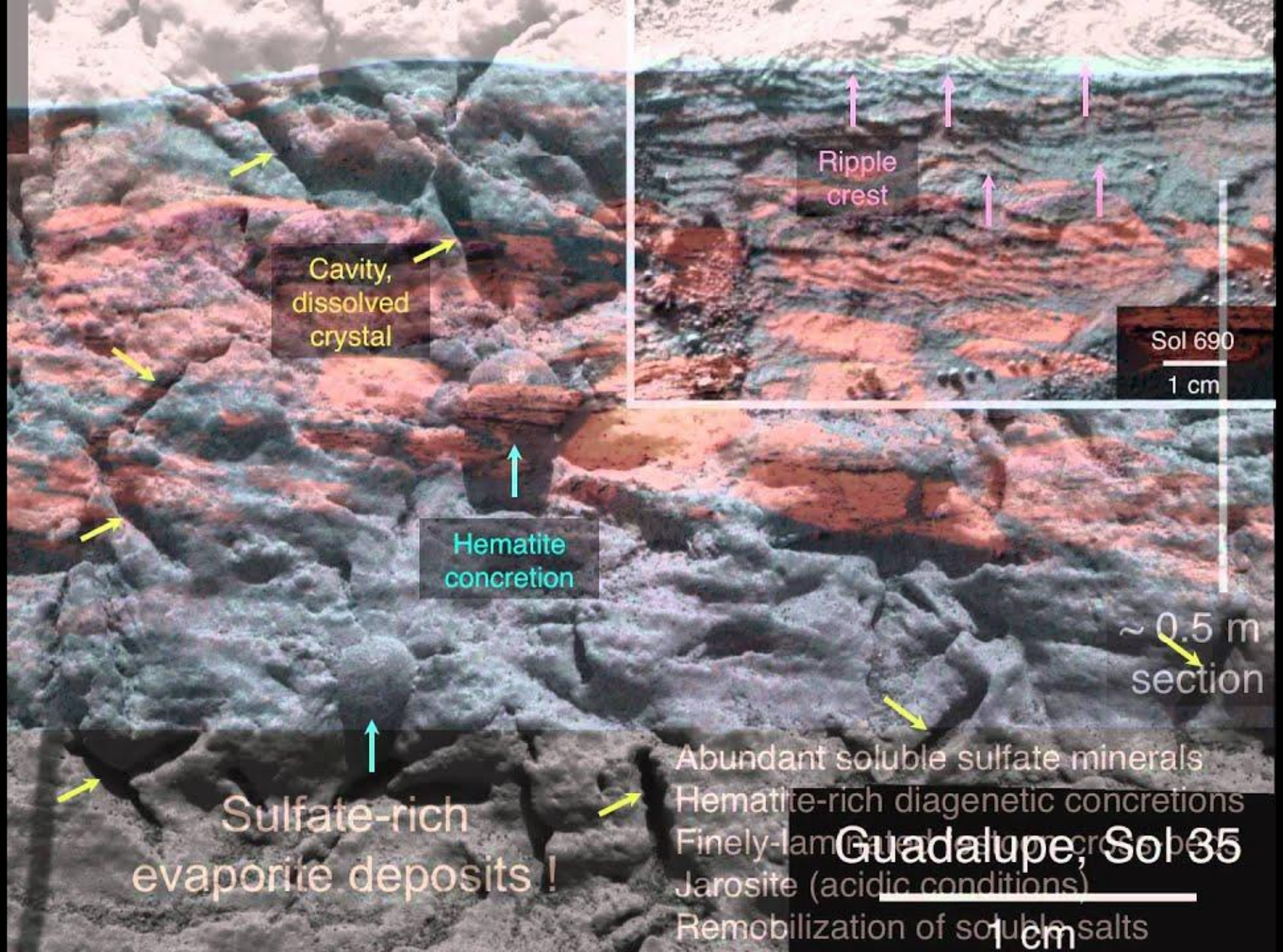
Ripple crest
Sol 690
1 cm
Cavity, dissolved crystal
Hematite concretion
~ 0.5 m section
Sulfate-rich evaporite deposits !
Abundant soluble sulfate minerals
Hematite-rich diagenetic concretions
Jarosite (acidic conditions)
Remobilization of soluble salts
Guadalupe, Sol 35
1 cm

1
00:00:05,990 --> 00:00:04,340
like to talk about exploring Mars for

2
00:00:09,020 --> 00:00:06,000
evidence of habitable environments and

3
00:00:11,540 --> 00:00:09,030
life and it really is a fascinating

4
00:00:14,720 --> 00:00:11,550
story that goes back more than a century

5
00:00:18,080 --> 00:00:14,730
of course we have basic questions about

6
00:00:19,910 --> 00:00:18,090
what Mars the planet is all about but in

7
00:00:22,220 --> 00:00:19,920
many ways the best way to address these

8
00:00:24,170 --> 00:00:22,230
questions is to address them in parallel

9
00:00:27,320 --> 00:00:24,180
with a question of searching for life

10
00:00:30,830 --> 00:00:27,330
itself and so in that vein I'd like to

11
00:00:33,080 --> 00:00:30,840
review you know Mars exploration over

12
00:00:34,970 --> 00:00:33,090
the past several decades and how we're

13
00:00:36,950 --> 00:00:34,980

getting ever better at answering this

14
00:00:40,310 --> 00:00:36,960
question of is there a second example of

15
00:00:41,900 --> 00:00:40,320
life in our solar system and you can see

16
00:00:44,959 --> 00:00:41,910
from the two graphics on this first

17
00:00:46,819 --> 00:00:44,969
slide that early Mars might have been

18
00:00:48,380 --> 00:00:46,829
quite a different place than Mars today

19
00:00:50,029 --> 00:00:48,390
and of course that adds to the

20
00:00:53,510 --> 00:00:50,039
excitement as well as the promise that

21
00:00:56,630 --> 00:00:53,520
indeed life once existed there the talk

22
00:00:58,069 --> 00:00:56,640
outline then is really just to get a

23
00:01:00,110 --> 00:00:58,079
start to compare Mars and the earth

24
00:01:03,200 --> 00:01:00,120
earth is obviously the one place where

25
00:01:05,030 --> 00:01:03,210
we know life exists today and therefore

26
00:01:06,740 --> 00:01:05,040
the characteristics of shares of Mars

27
00:01:12,039 --> 00:01:06,750
are quite relevant to the search for

28
00:01:14,960 --> 00:01:12,049
Mars life the Mars exploration Rovers

29
00:01:16,789 --> 00:01:14,970
recent exploration of Mars made several

30
00:01:17,719 --> 00:01:16,799
key discoveries that are quite important

31
00:01:19,190 --> 00:01:17,729
for the search for habitable

32
00:01:21,590 --> 00:01:19,200
environments in life and so I'd like

33
00:01:23,620 --> 00:01:21,600
briefly to review some of the key

34
00:01:27,830 --> 00:01:23,630
relevant discoveries that they've made

35
00:01:30,050 --> 00:01:27,840
this is being taped in early 2012 and at

36
00:01:32,109 --> 00:01:30,060
this point we look forward to the

37
00:01:36,020 --> 00:01:32,119
Curiosity rover which will land on

38
00:01:38,660 --> 00:01:36,030

August of 2012 and it represents really

39
00:01:42,020 --> 00:01:38,670
an extension of this long-term effort to

40
00:01:44,450 --> 00:01:42,030
explore Mars and search for life and

41
00:01:47,090 --> 00:01:44,460
this is put in sort of a lecture format

42
00:01:48,560 --> 00:01:47,100
so I've included periodically some

43
00:01:51,469 --> 00:01:48,570
questions after each of the sections

44
00:01:55,100 --> 00:01:51,479
that students might want to address and

45
00:01:57,050 --> 00:01:55,110
use it to test their comprehension the

46
00:02:00,830 --> 00:01:57,060
next slide then starts the story at

47
00:02:02,959 --> 00:02:00,840
least this lecture with the sort of

48
00:02:05,359 --> 00:02:02,969
knowledge level of Mars some hundred

49
00:02:07,819 --> 00:02:05,369
years ago a very famous astronomer

50
00:02:10,449 --> 00:02:07,829
percival lowell really was quite

51
00:02:13,610 --> 00:02:10,459
fascinated with mars and he had a

52
00:02:17,470 --> 00:02:13,620
state-of-the-art telescope at that time

53
00:02:20,180 --> 00:02:17,480
in his Arizona observatory and he

54
00:02:22,820 --> 00:02:20,190
created this map that you see here of

55
00:02:24,920 --> 00:02:22,830
Mars showing these linear features sort

56
00:02:27,680 --> 00:02:24,930
of connecting nodes these little black

57
00:02:30,050 --> 00:02:27,690
dots that you see and he became quite

58
00:02:32,780 --> 00:02:30,060
excited by you know these features that

59
00:02:34,750 --> 00:02:32,790
he perceived indicating that perhaps

60
00:02:38,229 --> 00:02:34,760
this was evidence of an advanced

61
00:02:40,970 --> 00:02:38,239
intelligent life one that was perhaps

62
00:02:42,949 --> 00:02:40,980
under stress because of the very heap

63
00:02:45,259 --> 00:02:42,959

what he would describe as a very dry

64
00:02:47,390 --> 00:02:45,269
arid environment on Mars and that these

65
00:02:49,940 --> 00:02:47,400
straight lines were perhaps canals that

66
00:02:51,800 --> 00:02:49,950
were connecting sources of water to

67
00:02:54,530 --> 00:02:51,810
agricultural fields and that perhaps

68
00:02:56,089 --> 00:02:54,540
these nodes represented cities well you

69
00:02:59,380 --> 00:02:56,099
can imagine that this created quite a

70
00:03:02,380 --> 00:02:59,390
stir in the public at that time and

71
00:03:04,789 --> 00:03:02,390
therefore heightened the interest and

72
00:03:07,309 --> 00:03:04,799
certainly contributed to the interest in

73
00:03:09,740 --> 00:03:07,319
Mars and Mars exploration in the years

74
00:03:12,589 --> 00:03:09,750
that followed but I also like to start

75
00:03:14,390 --> 00:03:12,599
here just to remind us all of just what

76
00:03:16,130 --> 00:03:14,400
our state of knowledge was just a little

77
00:03:17,539 --> 00:03:16,140
over a hundred years ago and compare

78
00:03:19,849 --> 00:03:17,549
that to what you're going to hear next

79
00:03:21,920 --> 00:03:19,859
it's a remarkable statement about the

80
00:03:27,129 --> 00:03:21,930
achievements of the 20th century and now

81
00:03:31,670 --> 00:03:27,139
moving into the 21st century based on

82
00:03:34,220 --> 00:03:31,680
lolz accounts and also the novelist's

83
00:03:36,500 --> 00:03:34,230
and others of the time there was this

84
00:03:40,190 --> 00:03:36,510
perception of these civilizations having

85
00:03:43,099 --> 00:03:40,200
these cities and these canals and you

86
00:03:44,780 --> 00:03:43,109
know hg wells you know wrote a a major

87
00:03:48,470 --> 00:03:44,790
piece about this about these

88
00:03:51,140 --> 00:03:48,480

civilizations and orson welles in 1938

89
00:03:53,659 --> 00:03:51,150
actually you know did a radio broadcast

90
00:03:55,069 --> 00:03:53,669
of Martians attacking the earth and of

91
00:03:57,229 --> 00:03:55,079
course it was meant to be entertainment

92
00:03:59,930 --> 00:03:57,239
it was meant to be a sort of science

93
00:04:02,289 --> 00:03:59,940
fiction but the public at that time took

94
00:04:06,379 --> 00:04:02,299
it quite seriously there was a lot of

95
00:04:09,619 --> 00:04:06,389
you know public angst about this and it

96
00:04:11,569 --> 00:04:09,629
just Illustrated it even in 1938 people

97
00:04:13,789 --> 00:04:11,579
were quite prepared to believe that this

98
00:04:15,890 --> 00:04:13,799
was this picture might represent Mars

99
00:04:18,949 --> 00:04:15,900
and that we were potentially under

100
00:04:20,839 --> 00:04:18,959
threat of invading forces and again this

101
00:04:22,730 --> 00:04:20,849
underscores the first of all the

102
00:04:26,930 --> 00:04:22,740
perception of what Mars environment was

103
00:04:27,270 --> 00:04:26,940
like at that time 1938 and also just our

104
00:04:29,250 --> 00:04:27,280
real

105
00:04:33,450 --> 00:04:29,260
rudimentary knowledge about that planet

106
00:04:35,879 --> 00:04:33,460
and of course as observations got better

107
00:04:38,580 --> 00:04:35,889
through the 20th century astronomical

108
00:04:40,530 --> 00:04:38,590
observations it became clear that the

109
00:04:43,140 --> 00:04:40,540
atmosphere of Mars was much thinner than

110
00:04:45,180 --> 00:04:43,150
the atmosphere of the earth perhaps only

111
00:04:47,940 --> 00:04:45,190
a few percent of Earth's atmospheric

112
00:04:51,870 --> 00:04:47,950
pressure and this led others even

113
00:04:53,640 --> 00:04:51,880

artists like Chesley bonds Dale to paint

114
00:04:56,790 --> 00:04:53,650
and he was a very famous painter of

115
00:04:58,770 --> 00:04:56,800
planetary images to paint a picture of a

116
00:05:01,920 --> 00:04:58,780
more bleak Mars one that perhaps only

117
00:05:04,050 --> 00:05:01,930
algae could survive at he still had the

118
00:05:06,570 --> 00:05:04,060
straight canals they're going as you see

119
00:05:08,909 --> 00:05:06,580
in this image but it represented a move

120
00:05:10,920 --> 00:05:08,919
towards a more perhaps that's a

121
00:05:13,409 --> 00:05:10,930
realistic view of what Mars was like

122
00:05:15,900 --> 00:05:13,419
although he still clung to the potential

123
00:05:18,090 --> 00:05:15,910
of algal life living at the surface of

124
00:05:20,370 --> 00:05:18,100
Mars and you can see in the foreground a

125
00:05:22,409 --> 00:05:20,380
snowbank and that's actually consistent

126
00:05:24,870 --> 00:05:22,419
with that astronomical observations of

127
00:05:27,390 --> 00:05:24,880
some kind of an ice cap ice caps

128
00:05:30,450 --> 00:05:27,400
actually at the poles of Mars and so in

129
00:05:32,670 --> 00:05:30,460
a way now by 1955 were giving way to a

130
00:05:35,250 --> 00:05:32,680
more realistic view of Mars but one that

131
00:05:37,650 --> 00:05:35,260
still had a ways to go to reach what we

132
00:05:40,950 --> 00:05:37,660
now understand as the surface the

133
00:05:42,870 --> 00:05:40,960
surface environment of Mars the modern

134
00:05:46,080 --> 00:05:42,880
space-age of course I think would really

135
00:05:47,880 --> 00:05:46,090
be defined for Mars as the age in which

136
00:05:50,010 --> 00:05:47,890
we were actually able to send probes

137
00:05:51,960 --> 00:05:50,020
that were close enough to Mars to

138
00:05:53,520 --> 00:05:51,970

provide observations that are superior

139
00:05:56,450 --> 00:05:53,530
to any that we could achieve using

140
00:05:59,850 --> 00:05:56,460
telescopes based on the earth and

141
00:06:03,330 --> 00:05:59,860
certainly the Mariner 4 flyby in 1965

142
00:06:05,850 --> 00:06:03,340
represents a key opening chapter of this

143
00:06:08,219 --> 00:06:05,860
phase of exploration and it was a very

144
00:06:10,290 --> 00:06:08,229
sobering observation indeed of Mars that

145
00:06:13,260 --> 00:06:10,300
only flew by Mars but what you could see

146
00:06:15,480 --> 00:06:13,270
here is a sort of a cratered surface

147
00:06:18,180 --> 00:06:15,490
that quite frankly bears strong

148
00:06:19,710 --> 00:06:18,190
resemblance to the moon and of course we

149
00:06:22,350 --> 00:06:19,720
have much better observations of the

150
00:06:23,820 --> 00:06:22,360
moon because of its proximity and even

151
00:06:25,820 --> 00:06:23,830
before we went there we were pretty sure

152
00:06:28,680 --> 00:06:25,830
this is going to be a very dry bleak and

153
00:06:32,130 --> 00:06:28,690
uninhabitable place and so by the

154
00:06:35,070 --> 00:06:32,140
observations of Mariner in 1965 and

155
00:06:36,779 --> 00:06:35,080
maybe a few years after that we really

156
00:06:38,550 --> 00:06:36,789
were sort of at the nadir of our

157
00:06:40,529 --> 00:06:38,560
perception about the habitability of

158
00:06:41,250 --> 00:06:40,539
Mars we had certainly gone full swing

159
00:06:43,500 --> 00:06:41,260
from the day

160
00:06:45,600 --> 00:06:43,510
use of Percival Lowell and even Chesley

161
00:06:47,340 --> 00:06:45,610
bond still we are now are wondering

162
00:06:49,320 --> 00:06:47,350
whether there was anything more to Mars

163
00:06:51,570 --> 00:06:49,330

than our moon as far as the prospects

164
00:06:53,340 --> 00:06:51,580
for life were concerned so this is sort

165
00:06:57,690 --> 00:06:53,350
of the low point in our perception about

166
00:06:59,420 --> 00:06:57,700
Mars as a potential habitat for life but

167
00:07:02,070 --> 00:06:59,430
as the Viking mission was launched in

168
00:07:04,740 --> 00:07:02,080
1976 and actually some of the previous

169
00:07:08,160 --> 00:07:04,750
an orbiter also was launched even before

170
00:07:10,260 --> 00:07:08,170
Viking our modern perception of Mars

171
00:07:12,420 --> 00:07:10,270
began to take a swing towards the

172
00:07:13,920 --> 00:07:12,430
positive as far as the potential for

173
00:07:16,740 --> 00:07:13,930
habitable environments were concerned

174
00:07:19,830 --> 00:07:16,750
for one thing these spacecraft of the

175
00:07:22,260 --> 00:07:19,840
70s started to make observations of the

176
00:07:25,170 --> 00:07:22,270
surface of Mars that bear resemblance to

177
00:07:26,760 --> 00:07:25,180
some features on the earth for example

178
00:07:30,330 --> 00:07:26,770
if you look to the left of this image a

179
00:07:32,700 --> 00:07:30,340
bit you'll see three features along the

180
00:07:35,790 --> 00:07:32,710
left limb here which are large volcanoes

181
00:07:38,340 --> 00:07:35,800
on Mars very reminiscent of volcanoes on

182
00:07:41,040 --> 00:07:38,350
the earth indicating that a key geologic

183
00:07:43,260 --> 00:07:41,050
process was shared by both planets also

184
00:07:46,530 --> 00:07:43,270
that large gash that you see running

185
00:07:49,440 --> 00:07:46,540
across the front of Mars which we now

186
00:07:51,600 --> 00:07:49,450
know as Valles Marineris represented

187
00:07:54,000 --> 00:07:51,610
some kind of a riff ting or breaking a

188
00:07:56,100 --> 00:07:54,010

part of the Martian crust at some time

189
00:07:58,260 --> 00:07:56,110
in the past rather reminiscent of the

190
00:08:00,810 --> 00:07:58,270
mid-ocean ridge system or other tectonic

191
00:08:02,940 --> 00:08:00,820
features on the earth again speaking to

192
00:08:05,820 --> 00:08:02,950
a similarity between Mars and the earth

193
00:08:08,790 --> 00:08:05,830
and so the closer we looked at Mars the

194
00:08:10,500 --> 00:08:08,800
more we began to see that yes it's quite

195
00:08:12,990 --> 00:08:10,510
different from the earth but perhaps

196
00:08:16,170 --> 00:08:13,000
there are some similarities as well so

197
00:08:18,150 --> 00:08:16,180
this in a way placed mars mars firmly

198
00:08:19,950 --> 00:08:18,160
between the Earth and the moon somewhere

199
00:08:22,080 --> 00:08:19,960
in the middle there between them as sort

200
00:08:24,260 --> 00:08:22,090
of an intermediate example of a planet

201
00:08:28,320 --> 00:08:24,270
and therefore a planetary environment

202
00:08:30,090 --> 00:08:28,330
this little video here shows Mars on the

203
00:08:32,430 --> 00:08:30,100
left and Earth on the right and it shows

204
00:08:34,650 --> 00:08:32,440
that they both have the same tilt the

205
00:08:36,360 --> 00:08:34,660
little highlighting that you see in this

206
00:08:38,280 --> 00:08:36,370
in the lower part of these two Globes

207
00:08:40,469 --> 00:08:38,290
indicates that we have seasons we have

208
00:08:42,450 --> 00:08:40,479
winters and summers both on the earth

209
00:08:45,060 --> 00:08:42,460
and on Mars and so that's another

210
00:08:46,770 --> 00:08:45,070
similarity also we have highlands and

211
00:08:48,600 --> 00:08:46,780
lowlands the lowlands on the earth being

212
00:08:50,310 --> 00:08:48,610
the ocean basins the loans as you can

213
00:08:53,400 --> 00:08:50,320

see on Mars being in the northern

214
00:08:55,140 --> 00:08:53,410
hemisphere and so again this speaks to

215
00:08:58,110 --> 00:08:55,150
some interesting similarities between

216
00:08:59,670 --> 00:08:58,120
Earth and Mars and so that just

217
00:09:01,740 --> 00:08:59,680
heightens our interest now and it

218
00:09:04,230 --> 00:09:01,750
exemplifies what I meant when I said

219
00:09:07,050 --> 00:09:04,240
that our sort of view of Mars is

220
00:09:09,210 --> 00:09:07,060
potentially habitable at some point is

221
00:09:11,550 --> 00:09:09,220
more positive than it was during those

222
00:09:15,030 --> 00:09:11,560
dark years of the 60s with our first fly

223
00:09:16,860 --> 00:09:15,040
by observations and so if we look now at

224
00:09:18,480 --> 00:09:16,870
the earth just to give it drill in a

225
00:09:21,150 --> 00:09:18,490
little bit more closely to the surface

226
00:09:22,800 --> 00:09:21,160
environment the upper panel of course

227
00:09:24,930 --> 00:09:22,810
shows the very familiar Mercator

228
00:09:27,060 --> 00:09:24,940
projection of continents and oceans on

229
00:09:29,400 --> 00:09:27,070
the earth the green highlighting the

230
00:09:32,370 --> 00:09:29,410
very productive forests and grasslands

231
00:09:34,650 --> 00:09:32,380
on the earth and really is a very

232
00:09:36,630 --> 00:09:34,660
familiar landscape to us one that's down

233
00:09:39,300 --> 00:09:36,640
below is showing you the same thing but

234
00:09:40,920 --> 00:09:39,310
with the ocean removed and showing you

235
00:09:43,200 --> 00:09:40,930
and sort of highlighted really in most

236
00:09:45,750 --> 00:09:43,210
cases there in orange this mid-ocean

237
00:09:49,350 --> 00:09:45,760
ridge rift system which is a volcanic

238
00:09:51,720 --> 00:09:49,360

feature it encircles the earth and very

239
00:09:54,090 --> 00:09:51,730
much embodies the geologic activity the

240
00:09:56,030 --> 00:09:54,100
volcanic activity of the earth and quite

241
00:09:58,200 --> 00:09:56,040
frankly that's a very important aspect

242
00:10:01,080 --> 00:09:58,210
contributing to the habitability of our

243
00:10:03,120 --> 00:10:01,090
planet so volcanism is a very important

244
00:10:05,340 --> 00:10:03,130
feature of a planet regarding the

245
00:10:08,220 --> 00:10:05,350
potential for hosting a habitable

246
00:10:09,630 --> 00:10:08,230
environment so in a way then just to

247
00:10:11,550 --> 00:10:09,640
make the transition to what I'll show

248
00:10:13,050 --> 00:10:11,560
next we can think of the continents as

249
00:10:15,990 --> 00:10:13,060
being the highlands of the earth and the

250
00:10:18,150 --> 00:10:16,000
ocean basins as you can see in the in

251
00:10:19,890 --> 00:10:18,160
blue in the upper panel or in the blue

252
00:10:22,980 --> 00:10:19,900
and orange areas in the lower panel

253
00:10:26,490 --> 00:10:22,990
these being sort of the earth lowlands a

254
00:10:29,340 --> 00:10:26,500
key aspect of Earth geography let us now

255
00:10:31,890 --> 00:10:29,350
move to the Mars image again we're

256
00:10:33,930 --> 00:10:31,900
looking at a Mercator projection and as

257
00:10:36,750 --> 00:10:33,940
you can see the blue in the upper part

258
00:10:39,150 --> 00:10:36,760
of this representation represents the

259
00:10:41,480 --> 00:10:39,160
northern lowlands of Mars and as I just

260
00:10:44,130 --> 00:10:41,490
refer back to earth it's analogous to

261
00:10:45,810 --> 00:10:44,140
the ocean basins on the earth although

262
00:10:48,840 --> 00:10:45,820
obviously there's no ocean sitting in

263
00:10:50,400 --> 00:10:48,850

that northern lowlands on Mars then we

264
00:10:52,110 --> 00:10:50,410
have the Southern Highlands which are

265
00:10:54,150 --> 00:10:52,120
shown in the warmer colors in fact if

266
00:10:56,100 --> 00:10:54,160
you look in the lower left here there's

267
00:10:58,800 --> 00:10:56,110
a little little key that indicates

268
00:11:00,540 --> 00:10:58,810
elevation and kilometers where minus

269
00:11:03,540 --> 00:11:00,550
eight is minus eight kilometers below

270
00:11:05,760 --> 00:11:03,550
the mean sort of elevation on Mars and

271
00:11:07,740 --> 00:11:05,770
as you can see Hellas Basin over here

272
00:11:08,940 --> 00:11:07,750
this large impact basin represents the

273
00:11:11,430 --> 00:11:08,950
Louis area

274
00:11:13,650 --> 00:11:11,440
on Mars and then at the top end we have

275
00:11:16,170 --> 00:11:13,660
the big volcanoes I'm these three I

276
00:11:18,840 --> 00:11:16,180
mentioned earlier which really represent

277
00:11:20,760 --> 00:11:18,850
the highs areas highest places on Mars

278
00:11:23,520 --> 00:11:20,770
and as you can see from our dual graph

279
00:11:25,140 --> 00:11:23,530
that's a plus 12 kilometers so that's

280
00:11:27,120 --> 00:11:25,150
the key thing and you can see now that

281
00:11:29,010 --> 00:11:27,130
the similarities between the Earth and

282
00:11:31,440 --> 00:11:29,020
Mars one difference here course be these

283
00:11:33,720 --> 00:11:31,450
very prominent craters every place which

284
00:11:35,960 --> 00:11:33,730
on the earth are much less obvious

285
00:11:38,040 --> 00:11:35,970
because of the constant weathering and

286
00:11:40,590 --> 00:11:38,050
resurfacing of the earth caused by our

287
00:11:43,230 --> 00:11:40,600
climate but the key point I want to make

288
00:11:45,420 --> 00:11:43,240

here with this image is that the density

289
00:11:48,180 --> 00:11:45,430
of craters that you see in the sort of

290
00:11:51,000 --> 00:11:48,190
middle and lower parts of the image here

291
00:11:53,430 --> 00:11:51,010
represent the oldest surfaces on Mars

292
00:11:54,930 --> 00:11:53,440
and to the extent that the early Mars

293
00:11:57,600 --> 00:11:54,940
environment might have been more

294
00:12:00,000 --> 00:11:57,610
interesting for life than later on these

295
00:12:03,120 --> 00:12:00,010
old surfaces represent very important

296
00:12:04,950 --> 00:12:03,130
targets of exploration as we're as you

297
00:12:08,930 --> 00:12:04,960
can see the blue to the north showing

298
00:12:11,400 --> 00:12:08,940
much fewer creators represents a younger

299
00:12:13,200 --> 00:12:11,410
resurfacing of the of that part of the

300
00:12:15,900 --> 00:12:13,210
planet and therefore maybe wouldn't be

301
00:12:17,900 --> 00:12:15,910
the best place to look for evidence of

302
00:12:21,360 --> 00:12:17,910
ancient habitable environments in life

303
00:12:23,070 --> 00:12:21,370
so the other interesting twist to this

304
00:12:24,720 --> 00:12:23,080
though is that now obviously we would

305
00:12:27,360 --> 00:12:24,730
want to explore that heavily cratered

306
00:12:29,940 --> 00:12:27,370
area in the sort of mid latitudes to

307
00:12:32,190 --> 00:12:29,950
southern hemisphere but we have to also

308
00:12:33,870 --> 00:12:32,200
land safely on Mars and to do that we

309
00:12:35,670 --> 00:12:33,880
need as much atmospheric density as

310
00:12:38,370 --> 00:12:35,680
possible as we descend to the surface

311
00:12:39,900 --> 00:12:38,380
and so that means that yeah we should

312
00:12:41,910 --> 00:12:39,910
visit the southern highlands but we

313
00:12:43,920 --> 00:12:41,920

can't visit them too high in fact any

314
00:12:46,860 --> 00:12:43,930
color that you see here that's either

315
00:12:48,690 --> 00:12:46,870
orange red or actually really yellow

316
00:12:50,970 --> 00:12:48,700
orange red or that white at the top

317
00:12:53,460 --> 00:12:50,980
those are elevations that are too high

318
00:12:57,090 --> 00:12:53,470
for us at the moment anyway to risk any

319
00:12:58,560 --> 00:12:57,100
landing mission and so we have to

320
00:13:00,960 --> 00:12:58,570
balance our desire to go to these

321
00:13:03,450 --> 00:13:00,970
ancient terrains against our desire to

322
00:13:06,000 --> 00:13:03,460
land the spacecraft safely so that's a

323
00:13:12,270 --> 00:13:06,010
key tension that we have to cope with in

324
00:13:14,280 --> 00:13:12,280
Mars exploration but as we move closer

325
00:13:16,140 --> 00:13:14,290
and look at some of the features at the

326
00:13:18,420 --> 00:13:16,150
surface of Mars we have really reason to

327
00:13:20,400 --> 00:13:18,430
be excited about that early environment

328
00:13:22,020 --> 00:13:20,410
that I mentioned and that is these large

329
00:13:22,650 --> 00:13:22,030
channels that are flowing across the

330
00:13:24,059 --> 00:13:22,660
surface

331
00:13:26,280 --> 00:13:24,069
they're now quite dry you can see a

332
00:13:28,439 --> 00:13:26,290
little scale bar here on the lower right

333
00:13:30,930 --> 00:13:28,449
corner that little tiny bar there's is

334
00:13:32,699 --> 00:13:30,940
10 kilometers and that indicates that

335
00:13:35,129 --> 00:13:32,709
these are very large channels which

336
00:13:36,420 --> 00:13:35,139
carried large amounts of water from the

337
00:13:38,730 --> 00:13:36,430
Southern Highlands which in this case

338
00:13:40,350 --> 00:13:38,740

would be to the right up down to the

339
00:13:42,540 --> 00:13:40,360
northern lowlands which in this image

340
00:13:44,309 --> 00:13:42,550
would be off to the left and you can see

341
00:13:46,350 --> 00:13:44,319
several examples of these features it's

342
00:13:47,759 --> 00:13:46,360
very prominent one at the top also

343
00:13:49,590 --> 00:13:47,769
another one that seems to erupt from

344
00:13:51,660 --> 00:13:49,600
beneath the surface and then flowing out

345
00:13:53,819 --> 00:13:51,670
towards the northern lowlands and so

346
00:13:57,499 --> 00:13:53,829
this increased our excitement and this

347
00:14:00,420 --> 00:13:57,509
was an observation that was most clearly

348
00:14:03,329 --> 00:14:00,430
documented by the Viking mission again

349
00:14:06,269 --> 00:14:03,339
in the mid 70s and so speaking again to

350
00:14:08,699 --> 00:14:06,279
a different early climate and so the

351
00:14:11,670 --> 00:14:08,709
punch line from this when just going

352
00:14:13,319 --> 00:14:11,680
over what I've summarized so far is that

353
00:14:14,670 --> 00:14:13,329
the Martian environment has really been

354
00:14:17,160 --> 00:14:14,680
more earth-like than that of any other

355
00:14:19,470 --> 00:14:17,170
planet in our solar system again you see

356
00:14:21,090 --> 00:14:19,480
earth on the left and Mars today on the

357
00:14:23,610 --> 00:14:21,100
upper right and then the lower right

358
00:14:25,590 --> 00:14:23,620
maybe an artist's representation of what

359
00:14:29,550 --> 00:14:25,600
Mars might have looked like some 4 +

360
00:14:31,980 --> 00:14:29,560
billion years ago it's clear that it has

361
00:14:34,710 --> 00:14:31,990
some very interesting features that

362
00:14:37,170 --> 00:14:34,720
merit closer inspection and for this

363
00:14:38,910 --> 00:14:37,180

reason Mars has been a major focus in

364
00:14:43,350 --> 00:14:38,920
planetary science exploration in the

365
00:14:46,860 --> 00:14:43,360
last decade or two the next slide then

366
00:14:48,389 --> 00:14:46,870
shows on the left it's shown in

367
00:14:50,340 --> 00:14:48,399
highlighting in blue here some of the

368
00:14:51,870 --> 00:14:50,350
channels and tributaries to the channels

369
00:14:54,689 --> 00:14:51,880
that were documented by the Viking

370
00:14:56,129 --> 00:14:54,699
imagery illustrating again this point

371
00:14:57,780 --> 00:14:56,139
that water used to run across the

372
00:15:00,660 --> 00:14:57,790
surface but these channels don't really

373
00:15:02,819 --> 00:15:00,670
look as robust or as dense as what we

374
00:15:04,379 --> 00:15:02,829
see on the earth and so this led to the

375
00:15:06,240 --> 00:15:04,389
idea that maybe these are just draining

376
00:15:08,730 --> 00:15:06,250
ground water that's coming up in springs

377
00:15:10,889 --> 00:15:08,740
or in any case that the water activity

378
00:15:13,259 --> 00:15:10,899
on Mars was really maybe it was there

379
00:15:15,329 --> 00:15:13,269
episodic ly but not nearly what we see

380
00:15:17,519 --> 00:15:15,339
on the earth but just to show you the

381
00:15:20,790 --> 00:15:17,529
improvement of imagery as on the right

382
00:15:23,519 --> 00:15:20,800
here this is imagery obtained from the

383
00:15:26,460 --> 00:15:23,529
Mars Global Surveyor mission which you

384
00:15:29,670 --> 00:15:26,470
know was launched you know in the past

385
00:15:30,960 --> 00:15:29,680
decade and the colors there are the same

386
00:15:34,170 --> 00:15:30,970
kinds of colors I showed you earlier

387
00:15:35,940 --> 00:15:34,180
with Mars map illustrating much better

388
00:15:37,980 --> 00:15:35,950

elevation control in our

389
00:15:39,510 --> 00:15:37,990
mapping of the surface and the little

390
00:15:41,940 --> 00:15:39,520
yellow lines that you see running all

391
00:15:43,770 --> 00:15:41,950
over here represent the channels now

392
00:15:45,840 --> 00:15:43,780
that we can document using this higher

393
00:15:47,790 --> 00:15:45,850
quality image well the interesting point

394
00:15:49,380 --> 00:15:47,800
is that the image on the right is taken

395
00:15:51,630 --> 00:15:49,390
of the same place that you're seeing on

396
00:15:54,420 --> 00:15:51,640
the left and it just shows how superior

397
00:15:57,480 --> 00:15:54,430
resolution of the imagery is making for

398
00:16:00,090 --> 00:15:57,490
a much more exciting observation about

399
00:16:01,950 --> 00:16:00,100
Mars that gee these are now channel

400
00:16:03,740 --> 00:16:01,960
densities that are approaching drainage

401
00:16:06,120 --> 00:16:03,750
channel densities on the earth and the

402
00:16:07,560 --> 00:16:06,130
argument for precipitation having

403
00:16:10,380 --> 00:16:07,570
occurred at some time in the distant

404
00:16:12,630 --> 00:16:10,390
past on Mars seems to be very compelling

405
00:16:14,850 --> 00:16:12,640
now so the key point is that our

406
00:16:16,650 --> 00:16:14,860
discoveries are very much tied to the

407
00:16:18,660 --> 00:16:16,660
quality of the observations that we can

408
00:16:20,550 --> 00:16:18,670
make and that the superior orbital

409
00:16:22,380 --> 00:16:20,560
imagery that we've been enjoying now

410
00:16:25,680 --> 00:16:22,390
since the Mars Global Surveyor mission

411
00:16:28,800 --> 00:16:25,690
of 1996 I are going to have been a clear

412
00:16:30,630 --> 00:16:28,810
driver in our exploration of Mars and in

413
00:16:32,640 --> 00:16:30,640

fact this image which again is a

414
00:16:34,530 --> 00:16:32,650
Mercator projection showing the northern

415
00:16:36,060 --> 00:16:34,540
lowlands to the high upper part of the

416
00:16:39,120 --> 00:16:36,070
image in the Southern Highlands to the

417
00:16:41,070 --> 00:16:39,130
lower part of the image highlights an

418
00:16:43,800 --> 00:16:41,080
inventory of features that are quite

419
00:16:45,600 --> 00:16:43,810
relevant to our evaluation of water if

420
00:16:48,540 --> 00:16:45,610
you look in the upper left sub panel

421
00:16:50,670 --> 00:16:48,550
here you see a nice dense drainage

422
00:16:52,500 --> 00:16:50,680
network that sort of channels watered

423
00:16:55,320 --> 00:16:52,510
down towards this lower right part of

424
00:16:57,060 --> 00:16:55,330
the image that is an example of what we

425
00:16:58,470 --> 00:16:57,070
are showing here as these little blue

426
00:17:01,590 --> 00:16:58,480
squiggles that you see all the way

427
00:17:04,650 --> 00:17:01,600
across this Mercator map up here in the

428
00:17:06,510 --> 00:17:04,660
upper right we see a a crater that has

429
00:17:08,670 --> 00:17:06,520
had a channel flowing into it and a

430
00:17:11,130 --> 00:17:08,680
channel flowing out but in any case it's

431
00:17:12,930 --> 00:17:11,140
a crater that seems to have had water in

432
00:17:15,150 --> 00:17:12,940
it at some point in the past basically a

433
00:17:16,829 --> 00:17:15,160
crater lake all these little red dots

434
00:17:19,170 --> 00:17:16,839
are that you see here with the white

435
00:17:20,490 --> 00:17:19,180
centers are examples of these types of

436
00:17:23,069 --> 00:17:20,500
crater lakes that we have been

437
00:17:24,900 --> 00:17:23,079
documenting on Mars and as you see just

438
00:17:26,550 --> 00:17:24,910

south of this what we call the dichotomy

439
00:17:28,860 --> 00:17:26,560
boundary between the northern lowlands

440
00:17:30,660 --> 00:17:28,870
and the southern highlands a very high

441
00:17:33,360 --> 00:17:30,670
density of these features both the

442
00:17:34,980 --> 00:17:33,370
channels as well as the lakes indicating

443
00:17:36,750 --> 00:17:34,990
that there was a fair amount of

444
00:17:39,000 --> 00:17:36,760
precipitation at some time in the past

445
00:17:40,770 --> 00:17:39,010
on Mars to conform these features the

446
00:17:43,050 --> 00:17:40,780
only place where they seem sparse is in

447
00:17:45,990 --> 00:17:43,060
this area here but that just happens to

448
00:17:47,670 --> 00:17:46,000
be the place where volcanism has covered

449
00:17:49,620 --> 00:17:47,680
the surface with lava flows and

450
00:17:52,050 --> 00:17:49,630
basically obscured these

451
00:17:54,510 --> 00:17:52,060
features where they happen to be too

452
00:17:57,330 --> 00:17:54,520
close to the volcanoes so it's probably

453
00:17:59,580 --> 00:17:57,340
a reasonable extrapolation to say that

454
00:18:02,070 --> 00:17:59,590
we had very dense features evidencing

455
00:18:04,440 --> 00:18:02,080
precipitation on Mars right just south

456
00:18:07,200 --> 00:18:04,450
of the dichotomy boundary and this after

457
00:18:09,000 --> 00:18:07,210
three more more billion years of Mars

458
00:18:11,250 --> 00:18:09,010
history that could have obscured a lot

459
00:18:13,560 --> 00:18:11,260
of the features that were once there so

460
00:18:16,050 --> 00:18:13,570
the argument for precipitation and water

461
00:18:18,450 --> 00:18:16,060
on Mars just from the landscape analysis

462
00:18:21,330 --> 00:18:18,460
alone has become quite more compelling

463
00:18:23,070 --> 00:18:21,340

in recent years so with this a couple of

464
00:18:25,230 --> 00:18:23,080
thought questions to test your

465
00:18:27,600 --> 00:18:25,240
comprehension one would be in what ways

466
00:18:29,220 --> 00:18:27,610
is more similar to earth and name at

467
00:18:30,900 --> 00:18:29,230
least three characteristics that you can

468
00:18:33,030 --> 00:18:30,910
think of that are similar between Mars

469
00:18:34,920 --> 00:18:33,040
and Earth so that's one question and

470
00:18:37,050 --> 00:18:34,930
another one of course could be how r

471
00:18:39,780 --> 00:18:37,060
Mars and the earth different provide at

472
00:18:42,300 --> 00:18:39,790
least three examples of that and so I

473
00:18:44,700 --> 00:18:42,310
won't provide the answers now but it is

474
00:18:47,100 --> 00:18:44,710
a bit of test of your comprehension of

475
00:18:49,080 --> 00:18:47,110
what what I've just explained okay with

476
00:18:51,450 --> 00:18:49,090
that let's move on again as it just as I

477
00:18:53,640 --> 00:18:51,460
said better resolution images from orbit

478
00:18:55,050 --> 00:18:53,650
tell us a lot more about what Mars

479
00:18:57,240 --> 00:18:55,060
environments might have been like in the

480
00:18:59,370 --> 00:18:57,250
past it's hard to argue that getting

481
00:19:01,080 --> 00:18:59,380
down on the ground and looking up close

482
00:19:04,740 --> 00:19:01,090
and personal to rocks and other features

483
00:19:07,160 --> 00:19:04,750
is you know even more compelling way to

484
00:19:09,600 --> 00:19:07,170
really understand the story about Mars

485
00:19:12,390 --> 00:19:09,610
these are some tools here that a

486
00:19:14,850 --> 00:19:12,400
geologist uses as he or she goes out

487
00:19:16,500 --> 00:19:14,860
into the field to analyze rocks and to

488
00:19:19,440 --> 00:19:16,510

try to understand the story that the

489
00:19:21,390 --> 00:19:19,450
rocks are telling him or her the boots

490
00:19:22,800 --> 00:19:21,400
represent moving around looking at

491
00:19:25,260 --> 00:19:22,810
different rocks looking at different

492
00:19:27,540 --> 00:19:25,270
outcrops and features so mobility is a

493
00:19:30,680 --> 00:19:27,550
very important character of a field

494
00:19:33,290 --> 00:19:30,690
geologist over on the Left we see

495
00:19:35,090 --> 00:19:33,300
binoculars glasses and a hand lens

496
00:19:37,500 --> 00:19:35,100
representing the importance of

497
00:19:39,720 --> 00:19:37,510
observation visual observations first

498
00:19:41,970 --> 00:19:39,730
from a distance than up close and then

499
00:19:43,440 --> 00:19:41,980
really up close with a hand lens to

500
00:19:45,810 --> 00:19:43,450
observe something like the you see you

501
00:19:48,330 --> 00:19:45,820
there the rock sort of it a little lower

502
00:19:49,920 --> 00:19:48,340
left center there the compass here

503
00:19:51,720 --> 00:19:49,930
represents the importance of the

504
00:19:54,210 --> 00:19:51,730
geologist knowing Viet where he or she

505
00:19:56,190 --> 00:19:54,220
is in the field at any one time so that

506
00:19:58,710 --> 00:19:56,200
they can record their observations to

507
00:20:00,540 --> 00:19:58,720
build a map the rock hammer represents

508
00:20:02,700 --> 00:20:00,550
the importance sometimes of breaking off

509
00:20:03,510 --> 00:20:02,710
the surface of a rock to get to a nice

510
00:20:05,610 --> 00:20:03,520
fresh and tear

511
00:20:07,410 --> 00:20:05,620
here this little rock sample to the left

512
00:20:09,000 --> 00:20:07,420
of the hammer of course is something

513
00:20:11,010 --> 00:20:09,010

that's been sawed open so that you can

514
00:20:13,860 --> 00:20:11,020
see very nicely the fabric that's inside

515
00:20:15,270 --> 00:20:13,870
so the ability to look at fresh rock

516
00:20:17,070 --> 00:20:15,280
surface and then it's a little tiny

517
00:20:19,590 --> 00:20:17,080
bottle to the left of the boot indicates

518
00:20:21,720 --> 00:20:19,600
maybe even do some rudimentary analyses

519
00:20:23,580 --> 00:20:21,730
this is just acid to see if the rock

520
00:20:25,650 --> 00:20:23,590
dissolves as a limestone would dissolve

521
00:20:27,210 --> 00:20:25,660
to get more of a sense of the

522
00:20:29,730 --> 00:20:27,220
composition of the rock in the field

523
00:20:32,490 --> 00:20:29,740
these are all very important aspects of

524
00:20:35,460 --> 00:20:32,500
field geology and one that we have tried

525
00:20:37,200 --> 00:20:35,470
to now replicate in Rovers that have

526
00:20:39,990 --> 00:20:37,210
been built to go to the surface of Mars

527
00:20:42,000 --> 00:20:40,000
in 1996 that's a little bread box size

528
00:20:45,210 --> 00:20:42,010
Sojourner represented our first attempt

529
00:20:47,750 --> 00:20:45,220
to do this and it really it made some

530
00:20:50,550 --> 00:20:47,760
interesting observations about Mars

531
00:20:52,650 --> 00:20:50,560
ellen aspects about the composition of

532
00:20:55,020 --> 00:20:52,660
the rocks indicating the how the crust

533
00:20:57,300 --> 00:20:55,030
of Mars may have evolved with volcanic

534
00:20:59,300 --> 00:20:57,310
activity in the early days Sojourner

535
00:21:01,680 --> 00:20:59,310
didn't really make a number of

536
00:21:03,450 --> 00:21:01,690
compelling observations about the story

537
00:21:05,670 --> 00:21:03,460
of water even though we landed it in one

538
00:21:08,580 --> 00:21:05,680

of those ancient large channels but it

539
00:21:09,780 --> 00:21:08,590
was really a significant mission as it

540
00:21:12,330 --> 00:21:09,790
was designed to be and that is a

541
00:21:14,580 --> 00:21:12,340
pathfinder to really do a path finding

542
00:21:16,260 --> 00:21:14,590
mission to understand how to operate a

543
00:21:18,150 --> 00:21:16,270
rover on the surface of Mars and the

544
00:21:19,560 --> 00:21:18,160
types of instruments that would be

545
00:21:21,600 --> 00:21:19,570
important to really make the key

546
00:21:23,760 --> 00:21:21,610
observations to address this question of

547
00:21:26,850 --> 00:21:23,770
just how active and for how long did

548
00:21:28,590 --> 00:21:26,860
water exist on the surface of Mars the

549
00:21:30,750 --> 00:21:28,600
the benefits of our knowledge from

550
00:21:32,940 --> 00:21:30,760
Sojourner led directly to the design

551
00:21:34,290 --> 00:21:32,950
successful design i would add of spirit

552
00:21:36,840 --> 00:21:34,300
and opportunity that were launched in

553
00:21:39,480 --> 00:21:36,850
2003 and i'd like to go over a little

554
00:21:40,800 --> 00:21:39,490
bit of summary of their findings just to

555
00:21:43,110 --> 00:21:40,810
illustrate the importance of that

556
00:21:45,000 --> 00:21:43,120
mission and how it feeds to our quest

557
00:21:47,310 --> 00:21:45,010
year to understand the potential for

558
00:21:49,530 --> 00:21:47,320
habitable environments on Mars and then

559
00:21:53,040 --> 00:21:49,540
finally the recent launch of curiosity

560
00:21:55,200 --> 00:21:53,050
and landing in August of 2012 represents

561
00:21:57,450 --> 00:21:55,210
a further extension of our capabilities

562
00:21:59,370 --> 00:21:57,460
as well as our scientific knowledge of

563
00:22:01,590 --> 00:21:59,380

Mars and certainly what will hopefully

564
00:22:04,230 --> 00:22:01,600
lead to an increased scientific

565
00:22:06,570 --> 00:22:04,240
knowledge of the surface of Mars so I'd

566
00:22:09,300 --> 00:22:06,580
like Ben just to go back to our Mars map

567
00:22:13,230 --> 00:22:09,310
and now indicate the places where nASA

568
00:22:15,630 --> 00:22:13,240
has sent some spacecraft to the surface

569
00:22:16,830 --> 00:22:15,640
of Mars and NASA landing sites as of

570
00:22:19,590 --> 00:22:16,840
2011

571
00:22:23,430 --> 00:22:19,600
and to now circle both opportunity and

572
00:22:25,049 --> 00:22:23,440
spirit here as the two landing sites

573
00:22:27,029 --> 00:22:25,059
that we pick and again as you can see

574
00:22:28,680 --> 00:22:27,039
what I said earlier we white really

575
00:22:31,320 --> 00:22:28,690
wanted to get to the north to the

576
00:22:33,570 --> 00:22:31,330
southern highlands of Mars but we also

577
00:22:35,310 --> 00:22:33,580
had to land into place safely and so we

578
00:22:37,610 --> 00:22:35,320
are in these sort of green zone here

579
00:22:42,269 --> 00:22:37,620
which represents sort of an intermediate

580
00:22:44,190 --> 00:22:42,279
elevation on Mars so first I will take

581
00:22:46,080 --> 00:22:44,200
us to the opportunity site just to get

582
00:22:48,360 --> 00:22:46,090
some of the key observations that were

583
00:22:50,610 --> 00:22:48,370
made by that and this was a place that

584
00:22:52,649 --> 00:22:50,620
we picked based on evidence of a certain

585
00:22:54,269 --> 00:22:52,659
mineral called hematite grey hematite

586
00:22:56,399 --> 00:22:54,279
which indicated that liquid water might

587
00:22:59,100 --> 00:22:56,409
have been active at the surface and when

588
00:23:01,049 --> 00:22:59,110

we landed there you're looking out from

589
00:23:02,760 --> 00:23:01,059
where we landed at an outcrop that's

590
00:23:05,039 --> 00:23:02,770
only about half a meter high here as

591
00:23:06,720 --> 00:23:05,049
shown by this bar but we've made an

592
00:23:08,760 --> 00:23:06,730
observation of a number of features that

593
00:23:11,130 --> 00:23:08,770
were consistent with water having been

594
00:23:13,680 --> 00:23:11,140
present first of all this yellowish

595
00:23:15,630 --> 00:23:13,690
color that you see here are rocks along

596
00:23:17,639 --> 00:23:15,640
the rim of the crater where we landed

597
00:23:19,950 --> 00:23:17,649
that show what we call sulfate minerals

598
00:23:22,080 --> 00:23:19,960
these are minerals that are soluble in

599
00:23:23,639 --> 00:23:22,090
water and very much different from a

600
00:23:26,370 --> 00:23:23,649
volcanic rock and they indicate that

601
00:23:28,380 --> 00:23:26,380
somehow water had to be involved in the

602
00:23:31,919 --> 00:23:28,390
in the formation of these rocks and so

603
00:23:33,860 --> 00:23:31,929
that was very exciting we found again

604
00:23:36,690 --> 00:23:33,870
these iron oxide or hematite rich

605
00:23:37,649 --> 00:23:36,700
concretions little spherical objects

606
00:23:39,510 --> 00:23:37,659
that you can see them littering the

607
00:23:42,240 --> 00:23:39,520
surface we found there in the rocks and

608
00:23:44,460 --> 00:23:42,250
these are consistent with formation in a

609
00:23:46,649 --> 00:23:44,470
saturated water environment where the

610
00:23:48,620 --> 00:23:46,659
iron oxide precipitated actually

611
00:23:51,360 --> 00:23:48,630
probably as an iron hydroxide initially

612
00:23:52,830 --> 00:23:51,370
precipitated out of a solution and

613
00:23:54,779 --> 00:23:52,840

pretty much had to be an acidic solution

614
00:23:57,840 --> 00:23:54,789
to form these little concretion these

615
00:23:59,760 --> 00:23:57,850
little sphere riyals we found another a

616
00:24:01,769 --> 00:23:59,770
bunch of other features again that were

617
00:24:03,510 --> 00:24:01,779
consistent with the presence of water

618
00:24:05,940 --> 00:24:03,520
which I can elaborate a little bit more

619
00:24:08,970 --> 00:24:05,950
on the next slide here now we're zooming

620
00:24:11,600 --> 00:24:08,980
in a close up of view of Iraq this using

621
00:24:13,919 --> 00:24:11,610
that little microscopic imager tool

622
00:24:16,019 --> 00:24:13,929
analogous to what a geologists would

623
00:24:17,880 --> 00:24:16,029
have and here you see these little

624
00:24:21,360 --> 00:24:17,890
spheria lytic hematite concretions

625
00:24:23,610 --> 00:24:21,370
embedded in the rock we see basically

626
00:24:25,409 --> 00:24:23,620
little cavities in the rock that used to

627
00:24:27,450 --> 00:24:25,419
contain some kind of a plating mineral

628
00:24:28,560 --> 00:24:27,460
but has since been dissolved away well

629
00:24:30,419 --> 00:24:28,570
the just the fact that it's been

630
00:24:34,049 --> 00:24:30,429
dissolved away means that it was water

631
00:24:36,359 --> 00:24:34,059
which means water had to be involved and

632
00:24:38,310 --> 00:24:36,369
but and of course but for us and many of

633
00:24:40,379 --> 00:24:38,320
us one of the most exciting observations

634
00:24:42,389 --> 00:24:40,389
was the observation of these ripple

635
00:24:46,379 --> 00:24:42,399
crests as you can see up here in the

636
00:24:48,060 --> 00:24:46,389
upper right and these are the same kinds

637
00:24:50,100 --> 00:24:48,070
of ripples as you would see on a beach

638
00:24:53,220 --> 00:24:50,110

or in a lake or any place where waters

639
00:24:55,440 --> 00:24:53,230
flowing across the surface so not only

640
00:24:57,659 --> 00:24:55,450
indicates that liquid water is present

641
00:25:00,060 --> 00:24:57,669
but it indicated that the liquid water

642
00:25:02,039 --> 00:25:00,070
was present at the surface and this in

643
00:25:04,379 --> 00:25:02,049
head carries a clear implication for the

644
00:25:06,570 --> 00:25:04,389
climate of Mars at that time the climate

645
00:25:08,879 --> 00:25:06,580
had to permit liquid water to be stable

646
00:25:12,450 --> 00:25:08,889
at the surface of Mars and that is not

647
00:25:14,519 --> 00:25:12,460
the case today Mars is so dry and cold

648
00:25:16,830 --> 00:25:14,529
today that liquid water is not stable

649
00:25:19,560 --> 00:25:16,840
and so this was a very important

650
00:25:21,859 --> 00:25:19,570
observation made by opportunity so as

651
00:25:24,960 --> 00:25:21,869
significant as these observations were

652
00:25:27,299 --> 00:25:24,970
just they really represent you know

653
00:25:29,669 --> 00:25:27,309
observations of just a half a meter of a

654
00:25:32,669 --> 00:25:29,679
rock layer we really would like to know

655
00:25:34,889 --> 00:25:32,679
more about what was the history of Mars

656
00:25:37,080 --> 00:25:34,899
environment at that time over here you

657
00:25:40,350 --> 00:25:37,090
see this Eagle crater this little tiny

658
00:25:42,060 --> 00:25:40,360
crater where opportunity landed and so

659
00:25:43,440 --> 00:25:42,070
we got into this mode of going to bigger

660
00:25:45,539 --> 00:25:43,450
and bigger craters here you see

661
00:25:47,700 --> 00:25:45,549
endurance crater and then this very long

662
00:25:50,639 --> 00:25:47,710
drive over here to Victoria crater and

663
00:25:52,259 --> 00:25:50,649

now we have driven off and now arrived

664
00:25:54,029 --> 00:25:52,269
at endeavour crater which is an even

665
00:25:56,310 --> 00:25:54,039
larger creator still why are we going to

666
00:25:59,279 --> 00:25:56,320
creators because craters dig down into

667
00:26:01,169 --> 00:25:59,289
the surface subsurface they expose more

668
00:26:03,119 --> 00:26:01,179
rock layers so you can think of

669
00:26:05,399 --> 00:26:03,129
successive layers of rock as being

670
00:26:07,609 --> 00:26:05,409
successive pages in this in a story book

671
00:26:10,440 --> 00:26:07,619
about the early history of Mars

672
00:26:12,180 --> 00:26:10,450
environment and so if one page is very

673
00:26:13,980 --> 00:26:12,190
interesting than the things you want to

674
00:26:15,749 --> 00:26:13,990
do with any good book or what record is

675
00:26:17,999 --> 00:26:15,759
to look at more pages to learn more

676
00:26:20,279 --> 00:26:18,009
about the progression of the story and

677
00:26:22,409 --> 00:26:20,289
so by going to endurance crater we go

678
00:26:24,480 --> 00:26:22,419
two more pages of the book and when we

679
00:26:27,029 --> 00:26:24,490
got there here's the view of the crater

680
00:26:30,029 --> 00:26:27,039
170 meters across much bigger actually

681
00:26:32,070 --> 00:26:30,039
160 meters much bigger than Eagle crater

682
00:26:34,739 --> 00:26:32,080
and much deeper and because of the depth

683
00:26:36,899 --> 00:26:34,749
we're able to access this layer of rocks

684
00:26:38,340 --> 00:26:36,909
that you see here that tell us more

685
00:26:41,029 --> 00:26:38,350
about the story of this early

686
00:26:43,529 --> 00:26:41,039
environment and to just be quite brief

687
00:26:44,250 --> 00:26:43,539
basically it's a story of Playa lakes

688
00:26:45,780 --> 00:26:44,260

mall

689
00:26:47,520 --> 00:26:45,790
ending bodies of water much like the

690
00:26:50,100 --> 00:26:47,530
ones we saw evidence for back at our

691
00:26:52,170 --> 00:26:50,110
landing site but also under lane by

692
00:26:53,880 --> 00:26:52,180
layers of what we call sand sheets which

693
00:26:56,820 --> 00:26:53,890
represent again water but not in

694
00:26:58,560 --> 00:26:56,830
standing mode just moist sand and then

695
00:27:01,230 --> 00:26:58,570
much thicker layers of what we

696
00:27:03,990 --> 00:27:01,240
characterize as sand dunes and so we

697
00:27:06,390 --> 00:27:04,000
think of a an ancient landscape of sand

698
00:27:08,670 --> 00:27:06,400
dunes wet sand sheets and playa Lakes

699
00:27:10,500 --> 00:27:08,680
much like for example what you would see

700
00:27:12,960 --> 00:27:10,510
at white sands national monument in New

701
00:27:15,810 --> 00:27:12,970
Mexico so now we get an idea about not

702
00:27:17,520 --> 00:27:15,820
only more of through time of what the

703
00:27:18,900 --> 00:27:17,530
environment was like but also more of

704
00:27:21,000 --> 00:27:18,910
what the landscape would have been like

705
00:27:23,160 --> 00:27:21,010
at that time and the important thing is

706
00:27:25,710 --> 00:27:23,170
that included standing bodies of water

707
00:27:29,220 --> 00:27:25,720
at the surface so this mission of

708
00:27:31,530 --> 00:27:29,230
opportunity really demonstrated that

709
00:27:33,360 --> 00:27:31,540
that surface environment was early

710
00:27:35,310 --> 00:27:33,370
environment was really different water

711
00:27:37,140 --> 00:27:35,320
played a more prominent role that's a

712
00:27:39,660 --> 00:27:37,150
big step towards the potential for

713
00:27:41,910 --> 00:27:39,670

habitable environments on early Mars so

714
00:27:43,740 --> 00:27:41,920
let me now expand this concept of

715
00:27:46,140 --> 00:27:43,750
habitable environments beyond just water

716
00:27:47,970 --> 00:27:46,150
this little green cube you see here

717
00:27:49,560 --> 00:27:47,980
represents what I would say the locus of

718
00:27:51,810 --> 00:27:49,570
environments within which life could

719
00:27:54,090 --> 00:27:51,820
survive and for that to be the case

720
00:27:56,490 --> 00:27:54,100
there have to be at least three basic

721
00:27:57,810 --> 00:27:56,500
features satisfied one is you have to

722
00:28:01,050 --> 00:27:57,820
have water available and that's that

723
00:28:02,430 --> 00:28:01,060
horizontal axis here if it's too if the

724
00:28:04,740 --> 00:28:02,440
things that are in the water are too

725
00:28:06,210 --> 00:28:04,750
dilute you just can't get life going but

726
00:28:07,920 --> 00:28:06,220
also if there's just not enough water

727
00:28:10,650 --> 00:28:07,930
available it to keep you chemically

728
00:28:12,810 --> 00:28:10,660
available life cannot take a foothold

729
00:28:14,370 --> 00:28:12,820
but at the same token the same

730
00:28:16,860 --> 00:28:14,380
environment has to have an available

731
00:28:19,260 --> 00:28:16,870
energy source all of us need energy to

732
00:28:21,570 --> 00:28:19,270
survive that's why we have you know our

733
00:28:24,600 --> 00:28:21,580
meals during the day that's why plants

734
00:28:26,310 --> 00:28:24,610
have to absorb the sunlight to make

735
00:28:28,200 --> 00:28:26,320
energy for themselves this is a key

736
00:28:30,750 --> 00:28:28,210
requirement for life and of course the

737
00:28:33,210 --> 00:28:30,760
third one is that we have to have the

738
00:28:35,010 --> 00:28:33,220

ingredients the carbon the sulfur the

739
00:28:38,430 --> 00:28:35,020
nitrogen and other elements available

740
00:28:39,990 --> 00:28:38,440
for life to build ourselves so all of

741
00:28:41,940 --> 00:28:40,000
these things have to be present at the

742
00:28:43,800 --> 00:28:41,950
same place at the same time can we

743
00:28:46,260 --> 00:28:43,810
demonstrate that that was ever the case

744
00:28:49,560 --> 00:28:46,270
at any place on Mars at any time in the

745
00:28:53,970 --> 00:28:49,570
past with that I'd like them to move to

746
00:28:55,530 --> 00:28:53,980
our other landing site at the Gusev

747
00:28:57,690 --> 00:28:55,540
crater which is really on the other side

748
00:28:58,140 --> 00:28:57,700
of the planet from where opportunity

749
00:29:01,800 --> 00:28:58,150
landed

750
00:29:03,540 --> 00:29:01,810
meridiani to a crater that clearly had

751
00:29:05,340 --> 00:29:03,550
water in it at some point you see here

752
00:29:06,540 --> 00:29:05,350
my team Valles flowing into the crater

753
00:29:09,510 --> 00:29:06,550
and then eventually the Creator

754
00:29:11,070 --> 00:29:09,520
overtopped and water flowed into the

755
00:29:13,290 --> 00:29:11,080
northern lowlands and for good measure

756
00:29:16,350 --> 00:29:13,300
here we even have a volcano nearby in

757
00:29:18,390 --> 00:29:16,360
the form Apollinaris Patera so just from

758
00:29:20,370 --> 00:29:18,400
the landscape of this view you can see

759
00:29:22,800 --> 00:29:20,380
that water must have been there in the

760
00:29:24,630 --> 00:29:22,810
past and so unlike the mineral that we

761
00:29:26,880 --> 00:29:24,640
found at the opportunity site at

762
00:29:29,220 --> 00:29:26,890
meridiani it was the landscape that

763
00:29:30,780 --> 00:29:29,230

compelled us to land here at Gusev

764
00:29:33,120 --> 00:29:30,790
crater which you can see is a pretty

765
00:29:35,340 --> 00:29:33,130
good-sized crater 180 meters kilometers

766
00:29:37,500 --> 00:29:35,350
across so let's go to the next slide

767
00:29:40,500 --> 00:29:37,510
however though when we landed way up

768
00:29:43,980 --> 00:29:40,510
here in the upper left corner we landed

769
00:29:46,200 --> 00:29:43,990
on a vast plains of lava rock so even

770
00:29:48,270 --> 00:29:46,210
though this huge crater had water in at

771
00:29:51,510 --> 00:29:48,280
one point guess what subsequent to that

772
00:29:53,670 --> 00:29:51,520
time lava flows had really covered much

773
00:29:55,920 --> 00:29:53,680
of this floor of this crater well this

774
00:29:57,570 --> 00:29:55,930
is a not great news for our little Rover

775
00:29:59,760 --> 00:29:57,580
because our little Rover makes a living

776
00:30:02,100 --> 00:29:59,770
actually analyzing rocks up close and

777
00:30:03,690 --> 00:30:02,110
personal for evidence of water and if we

778
00:30:05,460 --> 00:30:03,700
had a big lava flow that covered all

779
00:30:07,410 --> 00:30:05,470
that evidence then we've got a problem

780
00:30:09,600 --> 00:30:07,420
here as they would say houston we have a

781
00:30:11,700 --> 00:30:09,610
problem here well the good news is that

782
00:30:13,200 --> 00:30:11,710
as we look out from our landing site you

783
00:30:14,760 --> 00:30:13,210
can see in the upper right image here

784
00:30:17,520 --> 00:30:14,770
there were some mountains or hills off

785
00:30:19,050 --> 00:30:17,530
to the southeast which looks different

786
00:30:20,880 --> 00:30:19,060
from these lava Plains and these are

787
00:30:23,910 --> 00:30:20,890
these Columbia Hills that you see now in

788
00:30:26,340 --> 00:30:23,920

the lower big image you see also the

789
00:30:28,350 --> 00:30:26,350
orange represents our decision to drive

790
00:30:30,330 --> 00:30:28,360
over there this is our trail that we are

791
00:30:33,120 --> 00:30:30,340
path that we took and if you look very

792
00:30:35,280 --> 00:30:33,130
closely between the margin between the

793
00:30:37,020 --> 00:30:35,290
hills and the plains to the to the west

794
00:30:38,880 --> 00:30:37,030
you see what looks like almost like a

795
00:30:41,100 --> 00:30:38,890
shoreline feature and this actually is

796
00:30:43,200 --> 00:30:41,110
the edge of the lava flow indicating

797
00:30:44,310 --> 00:30:43,210
that these hills are something different

798
00:30:46,500 --> 00:30:44,320
in fact there's something of the

799
00:30:48,930 --> 00:30:46,510
underlay the lava flow and therefore

800
00:30:50,520 --> 00:30:48,940
they're probably older and so this is

801
00:30:52,530 --> 00:30:50,530
the place to go to see if we could

802
00:30:55,290 --> 00:30:52,540
finally see evidence for water having

803
00:30:58,380 --> 00:30:55,300
played a role in Gusev crater on Mars

804
00:31:00,090 --> 00:30:58,390
and of course we did drive over there as

805
00:31:03,120 --> 00:31:00,100
this map shows and we did indeed find

806
00:31:06,090 --> 00:31:03,130
some additional evidence for water and

807
00:31:09,060 --> 00:31:06,100
just to be quite quick about this of the

808
00:31:11,130 --> 00:31:09,070
indicators of liquid water could be sort

809
00:31:11,670 --> 00:31:11,140
of a raid on a scale here of very low

810
00:31:15,570 --> 00:31:11,680
water

811
00:31:17,280 --> 00:31:15,580
availability clearly at the low end if

812
00:31:19,530 --> 00:31:17,290
you're looking at fresh volcanic rocks

813
00:31:21,600 --> 00:31:19,540

that are still pretty much unaltered by

814
00:31:23,760 --> 00:31:21,610
water if you're looking at soil horizons

815
00:31:25,950 --> 00:31:23,770
we're both insoluble minerals are

816
00:31:28,020 --> 00:31:25,960
uniformly mixed with soluble salts as

817
00:31:30,300 --> 00:31:28,030
you would expect in a very dry

818
00:31:32,250 --> 00:31:30,310
environment where maybe only the wind is

819
00:31:34,320 --> 00:31:32,260
what's blowing things around then that's

820
00:31:36,710 --> 00:31:34,330
not much evidence for water but at the

821
00:31:39,000 --> 00:31:36,720
other end if you're looking at place at

822
00:31:41,760 --> 00:31:39,010
deposits where the rocks have been

823
00:31:44,850 --> 00:31:41,770
altered to clays or salts or other

824
00:31:46,950 --> 00:31:44,860
things and where they've even been

825
00:31:48,870 --> 00:31:46,960
transported around by water this

826
00:31:50,880 --> 00:31:48,880
obviously represents a very extensive

827
00:31:53,940 --> 00:31:50,890
evidence for water having been present

828
00:31:55,680 --> 00:31:53,950
and indeed as we went to the Columbia

829
00:31:57,800 --> 00:31:55,690
Hills husband Hill and some of the other

830
00:32:00,600 --> 00:31:57,810
features I'll mention we did actually

831
00:32:02,790 --> 00:32:00,610
find evidence that water had been quite

832
00:32:05,640 --> 00:32:02,800
extensively present so in that sense

833
00:32:07,530 --> 00:32:05,650
then a spirit had sort of pulled even

834
00:32:09,800 --> 00:32:07,540
with opportunity of being able to prove

835
00:32:13,320 --> 00:32:09,810
that liquid water had been present in

836
00:32:14,880 --> 00:32:13,330
air at some time in the past but it

837
00:32:17,490 --> 00:32:14,890
really got quite exciting for us we

838
00:32:19,020 --> 00:32:17,500

drove over to husband Hill we drove up

839
00:32:21,360 --> 00:32:19,030
and this is where we found that initial

840
00:32:23,130 --> 00:32:21,370
evidence for water but then we drove

841
00:32:24,900 --> 00:32:23,140
down into a place called inter-basin to

842
00:32:27,090 --> 00:32:24,910
a very fascinating feature called home

843
00:32:28,680 --> 00:32:27,100
plate and that really was the site at

844
00:32:30,780 --> 00:32:28,690
which a number of additional exciting

845
00:32:33,180 --> 00:32:30,790
observations were made relevant to this

846
00:32:35,520 --> 00:32:33,190
theme of out habitable environments we

847
00:32:38,100 --> 00:32:35,530
found at home plate that it was a

848
00:32:40,170 --> 00:32:38,110
volcanic flea created feature a violent

849
00:32:42,540 --> 00:32:40,180
volcanic eruption created the debris

850
00:32:44,490 --> 00:32:42,550
that formed this feature it's shaped

851
00:32:46,710 --> 00:32:44,500
like a pancake about 90 meters across

852
00:32:48,660 --> 00:32:46,720
and just a couple meters high here you

853
00:32:51,450 --> 00:32:48,670
can see volcanic rocks all around it

854
00:32:53,820 --> 00:32:51,460
they were probably from lava flows but

855
00:32:55,560 --> 00:32:53,830
we this this deposit home plate was

856
00:32:58,080 --> 00:32:55,570
really a product of very violent

857
00:33:00,540 --> 00:32:58,090
volcanism but for us the most exciting

858
00:33:02,910 --> 00:33:00,550
observation was the discovery of almost

859
00:33:05,070 --> 00:33:02,920
pure silica deposit purely opal and

860
00:33:07,380 --> 00:33:05,080
silica deposits around the perimeter all

861
00:33:09,450 --> 00:33:07,390
the way around this side and down on the

862
00:33:11,940 --> 00:33:09,460
far side as you look at this image we

863
00:33:13,680 --> 00:33:11,950

found the deposits that required liquid

864
00:33:17,190 --> 00:33:13,690
water for their deposition or their

865
00:33:19,260 --> 00:33:17,200
their creation which means now we have

866
00:33:21,060 --> 00:33:19,270
evidence for the volcanic activity

867
00:33:23,070 --> 00:33:21,070
occurring in concert with liquid water

868
00:33:25,650 --> 00:33:23,080
well that's exciting and why is that

869
00:33:26,850 --> 00:33:25,660
exciting because if we look at the earth

870
00:33:29,700 --> 00:33:26,860
and now we're at Yellowstone National

871
00:33:32,340 --> 00:33:29,710
Park the grand prismatic spring a very

872
00:33:34,080 --> 00:33:32,350
large spring at the in Yellowstone and

873
00:33:36,030 --> 00:33:34,090
here you can see a rather large

874
00:33:38,160 --> 00:33:36,040
boardwalk going by it and here is a 10

875
00:33:40,320 --> 00:33:38,170
metre scale here this type of an

876
00:33:44,010 --> 00:33:40,330
environment which we could well now have

877
00:33:45,810 --> 00:33:44,020
evidence for on Mars is a type example

878
00:33:48,720 --> 00:33:45,820
of a habitable environment for microbial

879
00:33:50,510 --> 00:33:48,730
life on the earth here we it's an oasis

880
00:33:53,280 --> 00:33:50,520
obviously you have near surface water

881
00:33:55,050 --> 00:33:53,290
they spring waters bring up chemicals

882
00:33:56,970 --> 00:33:55,060
that could / die provide sources of

883
00:34:00,270 --> 00:33:56,980
energy for life like the sulfur gases

884
00:34:02,010 --> 00:34:00,280
the hydrogen and some even cases that

885
00:34:04,620 --> 00:34:02,020
reduced iron that we see dissolved in

886
00:34:07,470 --> 00:34:04,630
some Springs these can be acted upon by

887
00:34:09,150 --> 00:34:07,480
microbes to obtain energy and if that's

888
00:34:11,550 --> 00:34:09,160

not good enough we have these mineral

889
00:34:14,880 --> 00:34:11,560
deposits like pure silica such as we

890
00:34:17,700 --> 00:34:14,890
have found at at this home plate feature

891
00:34:19,800 --> 00:34:17,710
on Mars that could preserve evidence of

892
00:34:21,630 --> 00:34:19,810
life and I can just call as an example

893
00:34:23,940 --> 00:34:21,640
petrified wood ather sure we're all

894
00:34:26,070 --> 00:34:23,950
familiar with that where ancient tree

895
00:34:28,290 --> 00:34:26,080
trunks have been solicit ID by silica

896
00:34:30,930 --> 00:34:28,300
and you see this beautifully faithful

897
00:34:33,270 --> 00:34:30,940
reproduction of all the woody features

898
00:34:35,370 --> 00:34:33,280
that textures of wood that were once

899
00:34:37,650 --> 00:34:35,380
present there with the tree likewise

900
00:34:39,330 --> 00:34:37,660
silicon can preserve fossils of

901
00:34:41,130 --> 00:34:39,340
microbial life as we've seen at

902
00:34:44,520 --> 00:34:41,140
Yellowstone and also in other ancient

903
00:34:46,440 --> 00:34:44,530
rocks on earth and therefore Hot Springs

904
00:34:49,080 --> 00:34:46,450
can do this for us as well and of course

905
00:34:50,690 --> 00:34:49,090
this hot to cold transitioned from the

906
00:34:52,919 --> 00:34:50,700
spring out to the stream flows

907
00:34:54,960 --> 00:34:52,929
represents a range of conditions that

908
00:34:58,320 --> 00:34:54,970
could sustain a variety of organisms and

909
00:35:00,780 --> 00:34:58,330
now we have found basically a place on

910
00:35:03,320 --> 00:35:00,790
Mars where an environment awfully

911
00:35:06,120 --> 00:35:03,330
similar to this has you know has

912
00:35:07,560 --> 00:35:06,130
potentially occurred and it could have

913
00:35:09,600 --> 00:35:07,570

been potentially habitable in the past

914
00:35:13,200 --> 00:35:09,610
so in this way we're making observations

915
00:35:14,720 --> 00:35:13,210
that advance further towards being able

916
00:35:16,920 --> 00:35:14,730
to establish that we might have had

917
00:35:19,560 --> 00:35:16,930
habitable environments for life on Mars

918
00:35:22,650 --> 00:35:19,570
maybe not life as plants and animals but

919
00:35:23,970 --> 00:35:22,660
life as microorganisms and this is an

920
00:35:25,740 --> 00:35:23,980
image that you can find in the

921
00:35:28,350 --> 00:35:25,750
Smithsonian Museum Natural History

922
00:35:30,780 --> 00:35:28,360
Museum in Washington DC beautiful mural

923
00:35:32,730 --> 00:35:30,790
trying to represent what we think the

924
00:35:34,830 --> 00:35:32,740
early Earth looked like with its

925
00:35:37,230 --> 00:35:34,840
volcanoes and it's standing water and

926
00:35:38,730 --> 00:35:37,240
it's hot springs and so forth and in

927
00:35:39,540 --> 00:35:38,740
many ways you could say that we have

928
00:35:41,550 --> 00:35:39,550
documented

929
00:35:43,890 --> 00:35:41,560
parallel features on Mars that may have

930
00:35:46,050 --> 00:35:43,900
all existed at the same time and so we

931
00:35:47,850 --> 00:35:46,060
really are making progress towards

932
00:35:49,710 --> 00:35:47,860
looking for habitable environments on

933
00:35:51,840 --> 00:35:49,720
Mars these little funny yellowish

934
00:35:54,090 --> 00:35:51,850
features that you see here are an artist

935
00:35:56,280 --> 00:35:54,100
representation of microbial colonies

936
00:35:58,350 --> 00:35:56,290
what we call stromatolites or microbial

937
00:36:00,660 --> 00:35:58,360
reef structures of course we haven't

938
00:36:02,340 --> 00:36:00,670

found those on Mars yet but net we're

939
00:36:04,200 --> 00:36:02,350
beginning to get smarter looking at the

940
00:36:06,480 --> 00:36:04,210
right for the going to the right places

941
00:36:08,910 --> 00:36:06,490
to look for these features and have a

942
00:36:10,830 --> 00:36:08,920
higher chance of finding fossil evidence

943
00:36:12,120 --> 00:36:10,840
not happened yet but we're getting

944
00:36:14,760 --> 00:36:12,130
better at looking in the right

945
00:36:16,380 --> 00:36:14,770
neighborhoods okay so let me now just

946
00:36:18,540 --> 00:36:16,390
return to this block which shows that

947
00:36:20,520 --> 00:36:18,550
you need the water the energy and the

948
00:36:23,460 --> 00:36:20,530
nutrients in order to support life and

949
00:36:24,900 --> 00:36:23,470
now to just raise the bar further okay

950
00:36:27,330 --> 00:36:24,910
me may have found some of these places

951
00:36:29,580 --> 00:36:27,340
but how long did these conditions last

952
00:36:31,530 --> 00:36:29,590
and how much time does life need in

953
00:36:33,750 --> 00:36:31,540
order to get started and to survive

954
00:36:36,540 --> 00:36:33,760
that's a really tough question we've now

955
00:36:38,220 --> 00:36:36,550
got to go to the surface of Mars to a

956
00:36:40,620 --> 00:36:38,230
place where we could be reasonably

957
00:36:42,450 --> 00:36:40,630
convinced that thing's persisted for

958
00:36:44,160 --> 00:36:42,460
let's just stick their neck out and say

959
00:36:45,750 --> 00:36:44,170
you know maybe millions of years you

960
00:36:47,490 --> 00:36:45,760
know you had in habitable conditions

961
00:36:49,620 --> 00:36:47,500
that lasted for a very long time and

962
00:36:52,440 --> 00:36:49,630
that maybe that's adequate then to

963
00:36:54,120 --> 00:36:52,450

support life and so in that regard I'll

964
00:36:56,340 --> 00:36:54,130
move on to the next talk with our

965
00:36:58,380 --> 00:36:56,350
upcoming mission but just before I do

966
00:37:00,570 --> 00:36:58,390
that here's a couple of questions from

967
00:37:02,520 --> 00:37:00,580
what we just talked about what features

968
00:37:04,170 --> 00:37:02,530
were discovered by Opportunity rover at

969
00:37:06,600 --> 00:37:04,180
meridiani planum that indicated that

970
00:37:08,040 --> 00:37:06,610
liquid water once existed there and what

971
00:37:10,380 --> 00:37:08,050
is the evidence that the water we had

972
00:37:12,210 --> 00:37:10,390
sometimes been on the surface okay so

973
00:37:14,820 --> 00:37:12,220
that's the question aimed at the

974
00:37:16,800 --> 00:37:14,830
opportunity rover for spirit what

975
00:37:18,690 --> 00:37:16,810
features did spirit rover finded Gusev

976
00:37:21,510 --> 00:37:18,700
crater that indicated that liquid water

977
00:37:23,640 --> 00:37:21,520
was present and so that's the parallel

978
00:37:25,710 --> 00:37:23,650
question for the spirit rover so that's

979
00:37:30,150 --> 00:37:25,720
for the previous section let's now move

980
00:37:35,190 --> 00:37:30,160
on we are now of course as I give this

981
00:37:37,410 --> 00:37:35,200
talk poised here for to see what the

982
00:37:40,410 --> 00:37:37,420
Mars Science Laboratory will find at the

983
00:37:42,540 --> 00:37:40,420
surface of Mars to continue this sort of

984
00:37:45,780 --> 00:37:42,550
coordinated exploration by orbiters and

985
00:37:49,080 --> 00:37:45,790
el sol by landers of the most promising

986
00:37:51,690 --> 00:37:49,090
places at the surface of Mars and so the

987
00:37:53,370 --> 00:37:51,700
Mars Science Laboratory now along those

988
00:37:55,530 --> 00:37:53,380

lines has benefited

989
00:37:58,170 --> 00:37:55,540
an even more extensive observation of

990
00:38:00,780 --> 00:37:58,180
the surface of Mars by these advanced

991
00:38:02,910 --> 00:38:00,790
orbiters and therefore we have found a

992
00:38:05,940 --> 00:38:02,920
very compelling landing site for this

993
00:38:08,070 --> 00:38:05,950
for this Rover to go to a little couple

994
00:38:10,170 --> 00:38:08,080
of comments about the capability of the

995
00:38:12,330 --> 00:38:10,180
Curiosity rover like the Mars

996
00:38:14,580 --> 00:38:12,340
exploration Rovers it has a very nice

997
00:38:17,130 --> 00:38:14,590
camera set up cameras really to make

998
00:38:18,840 --> 00:38:17,140
those field geology observations that

999
00:38:20,550 --> 00:38:18,850
any geologists would need to make in

1000
00:38:23,310 --> 00:38:20,560
order to define the best places to

1001
00:38:25,170 --> 00:38:23,320
explore it obviously has mobility with

1002
00:38:27,690 --> 00:38:25,180
its wheel system much like the Mars

1003
00:38:29,850 --> 00:38:27,700
exploration Rovers did and also like

1004
00:38:31,560 --> 00:38:29,860
them it has an arm which can look out

1005
00:38:34,110 --> 00:38:31,570
with the hand lens closely at the rocks

1006
00:38:37,320 --> 00:38:34,120
and also do some analyses of these rocks

1007
00:38:39,630 --> 00:38:37,330
for their elemental abundances it also

1008
00:38:41,850 --> 00:38:39,640
though has a very important capability

1009
00:38:43,710 --> 00:38:41,860
to bring samples back and put them

1010
00:38:45,480 --> 00:38:43,720
inside the laboratory which is why we

1011
00:38:47,640 --> 00:38:45,490
call this the Mars Science Laboratory

1012
00:38:50,520 --> 00:38:47,650
mission we have an instrument that you

1013
00:38:52,860 --> 00:38:50,530

can do x-ray analyses to terminals that

1014
00:38:54,870 --> 00:38:52,870
might be present and we also have an

1015
00:38:57,150 --> 00:38:54,880
instrument within the body of this Rover

1016
00:38:59,220 --> 00:38:57,160
that can look at organic compounds if

1017
00:39:01,050 --> 00:38:59,230
they're present or to analyze gases or

1018
00:39:03,450 --> 00:39:01,060
other volatile type species that might

1019
00:39:05,820 --> 00:39:03,460
be present in the samples and so in that

1020
00:39:07,890 --> 00:39:05,830
respect it can do a much more detailed

1021
00:39:10,200 --> 00:39:07,900
analysis of samples than what the Mars

1022
00:39:12,150 --> 00:39:10,210
exploration Rovers did so much bigger

1023
00:39:14,010 --> 00:39:12,160
over this one's about the size of a Jeep

1024
00:39:16,980 --> 00:39:14,020
whereas the others were the size of

1025
00:39:19,140 --> 00:39:16,990
riding lawnmowers looking a little more

1026
00:39:21,600 --> 00:39:19,150
closely and I'll just allude to these

1027
00:39:23,520 --> 00:39:21,610
and move on we see the remote sensing

1028
00:39:24,930 --> 00:39:23,530
instruments the cameras and and the

1029
00:39:26,580 --> 00:39:24,940
chemcam which can actually shoot a

1030
00:39:28,620 --> 00:39:26,590
little laser out and analyze the

1031
00:39:30,270 --> 00:39:28,630
elements in a rock sample that might be

1032
00:39:31,650 --> 00:39:30,280
out in front of the rover so this is

1033
00:39:33,990 --> 00:39:31,660
what we call our remote sensing

1034
00:39:35,730 --> 00:39:34,000
capability then as we get up close and

1035
00:39:37,860 --> 00:39:35,740
personal we can put at the arm out and

1036
00:39:39,720 --> 00:39:37,870
contact the rock with instruments that

1037
00:39:42,300 --> 00:39:39,730
can either look with a hand lens or

1038
00:39:43,980 --> 00:39:42,310

determine the elemental composition if

1039
00:39:46,530 --> 00:39:43,990
we take a sample and put it inside the

1040
00:39:49,200 --> 00:39:46,540
rover we can do as I said chemical and

1041
00:39:51,210 --> 00:39:49,210
isotopic measurements of organic matter

1042
00:39:52,470 --> 00:39:51,220
or gases or whatever and also with the

1043
00:39:54,570 --> 00:39:52,480
other instrument look at the minerals

1044
00:39:57,840 --> 00:39:54,580
and then of course this is also like a

1045
00:40:01,230 --> 00:39:57,850
little roving weather station it can not

1046
00:40:02,880 --> 00:40:01,240
only do meteorology of what the climate

1047
00:40:06,210 --> 00:40:02,890
is are the weather is like at the moment

1048
00:40:07,320 --> 00:40:06,220
but it actually can analyze radiation at

1049
00:40:10,290 --> 00:40:07,330
the field as well

1050
00:40:11,940 --> 00:40:10,300
subsurface availability of water of

1051
00:40:13,890 --> 00:40:11,950
hydrogen actually so a very

1052
00:40:16,440 --> 00:40:13,900
sophisticated Rover really looking

1053
00:40:19,380 --> 00:40:16,450
forward to these analyses the mission

1054
00:40:20,910 --> 00:40:19,390
overview of how it gets there of course

1055
00:40:24,000 --> 00:40:20,920
as we launch it from the earth this

1056
00:40:27,360 --> 00:40:24,010
occurred in November actually November

1057
00:40:29,070 --> 00:40:27,370
of 2011 as I give this talk we're

1058
00:40:31,710 --> 00:40:29,080
currently cruising towards Mars to

1059
00:40:33,180 --> 00:40:31,720
arrive august six east coast time then

1060
00:40:35,610 --> 00:40:33,190
we go through an entry descent and

1061
00:40:38,190 --> 00:40:35,620
landing phase and for this I'd like to

1062
00:40:41,460 --> 00:40:38,200
just show a couple of videos the first

1063
00:40:43,040 --> 00:40:41,470

video and yeah let's go through these

1064
00:40:46,800 --> 00:40:43,050
and these are available on the Mars

1065
00:40:49,650 --> 00:40:46,810
Science Laboratory website what we're

1066
00:40:52,190 --> 00:40:49,660
seeing now is the launch that occurred

1067
00:40:56,010 --> 00:40:52,200
on the saturday after thanksgiving 2011

1068
00:40:57,840 --> 00:40:56,020
this is an atlas 5 rocket the fat part

1069
00:41:01,110 --> 00:40:57,850
at the top of the rocket is the fairing

1070
00:41:03,390 --> 00:41:01,120
that include encloses the rover itself

1071
00:41:05,550 --> 00:41:03,400
stand the entry descent stuff here now

1072
00:41:07,500 --> 00:41:05,560
we see the blast-off which is a

1073
00:41:10,050 --> 00:41:07,510
combination of liquid propulsion engines

1074
00:41:11,520 --> 00:41:10,060
and solid engines that give the thrust

1075
00:41:13,650 --> 00:41:11,530
necessary to get up through the lower

1076
00:41:16,020 --> 00:41:13,660
part of the earth's atmosphere as you

1077
00:41:18,360 --> 00:41:16,030
can see it was a partly cloudy day some

1078
00:41:20,550 --> 00:41:18,370
of us said better vantage points than

1079
00:41:22,080 --> 00:41:20,560
the other but these this video that

1080
00:41:24,300 --> 00:41:22,090
you're looking really shows the best of

1081
00:41:26,190 --> 00:41:24,310
all worlds vantage points from several

1082
00:41:28,710 --> 00:41:26,200
places using telescopes to give you a

1083
00:41:32,250 --> 00:41:28,720
sense of the various stages in the

1084
00:41:34,140 --> 00:41:32,260
launch of this Atlas 5 rocket the first

1085
00:41:36,360 --> 00:41:34,150
thing that will major event that happens

1086
00:41:38,340 --> 00:41:36,370
after the ignition and the launch will

1087
00:41:40,500 --> 00:41:38,350
be the solid Rockets that you see sort

1088
00:41:42,540 --> 00:41:40,510

of around the back of the rocket being

1089
00:41:44,550 --> 00:41:42,550
ejected once they've done their work

1090
00:41:46,980 --> 00:41:44,560
here we're still looking at the main

1091
00:41:49,140 --> 00:41:46,990
engines thrust and of course very

1092
00:41:53,850 --> 00:41:49,150
quickly getting the rock up to high

1093
00:41:55,860 --> 00:41:53,860
altitudes this image probably taken by

1094
00:41:58,440 --> 00:41:55,870
it from a telescope it's down range from

1095
00:41:59,880 --> 00:41:58,450
the launching pad those of us who

1096
00:42:02,340 --> 00:41:59,890
witnessed the launch we're just amazed

1097
00:42:05,850 --> 00:42:02,350
to see these later it's a beautiful set

1098
00:42:07,350 --> 00:42:05,860
of images and I think now as and also as

1099
00:42:08,730 --> 00:42:07,360
this gets higher and higher in the

1100
00:42:11,010 --> 00:42:08,740
atmosphere you'll notice that the tail

1101
00:42:13,520 --> 00:42:11,020
the exhaust is spreading out as the

1102
00:42:16,800 --> 00:42:13,530
atmospheric pressure decreases that

1103
00:42:19,320 --> 00:42:16,810
exhaust tail gets wider and wider now

1104
00:42:21,120 --> 00:42:19,330
and see a beautiful close-up of you can

1105
00:42:22,789 --> 00:42:21,130
see the solid Rockets are still firing

1106
00:42:26,160 --> 00:42:22,799
around the perimeter of the main rocket

1107
00:42:30,509 --> 00:42:26,170
and the tale begins to widen as the

1108
00:42:32,549 --> 00:42:30,519
atmospheric pressure decreases so now is

1109
00:42:35,579 --> 00:42:32,559
you can almost begin to definitely see

1110
00:42:37,650 --> 00:42:35,589
the flaring now and you still see the

1111
00:42:39,480 --> 00:42:37,660
glow of the solid Rockets but now

1112
00:42:41,609 --> 00:42:39,490
they're beginning to lose steam as they

1113
00:42:43,980 --> 00:42:41,619

use up their propellant and you can

1114
00:42:45,900 --> 00:42:43,990
still see the liquid Rockets firing away

1115
00:42:48,120 --> 00:42:45,910
there we're now to the point where we

1116
00:42:50,370 --> 00:42:48,130
really need to get rid of the weight of

1117
00:42:52,559 --> 00:42:50,380
those solid rockets which you'll see

1118
00:42:57,329 --> 00:42:52,569
them peeling off shortly here as they

1119
00:42:58,920 --> 00:42:57,339
there's goes there they go okay and of

1120
00:43:01,650 --> 00:42:58,930
course we do this to make this a much

1121
00:43:03,930 --> 00:43:01,660
more weight efficient spacecraft and the

1122
00:43:06,539 --> 00:43:03,940
liquid Rockets continue to burn this

1123
00:43:08,789 --> 00:43:06,549
will this you'll continue to see the

1124
00:43:11,339 --> 00:43:08,799
tail flare out and the rocket gets

1125
00:43:13,799 --> 00:43:11,349
smaller and harder to see and I think

1126
00:43:16,859 --> 00:43:13,809
perhaps at this point we could just

1127
00:43:19,920 --> 00:43:16,869
transition from this to the next video

1128
00:43:22,259 --> 00:43:19,930
which is now that that has gotten into

1129
00:43:25,319 --> 00:43:22,269
an orbit it actually never orbits the

1130
00:43:28,499 --> 00:43:25,329
earth completely we get up into an

1131
00:43:31,079 --> 00:43:28,509
orbital altitude but then we cruise out

1132
00:43:33,359 --> 00:43:31,089
over across Africa into the Indian Ocean

1133
00:43:35,490 --> 00:43:33,369
and this is sort of where we are now

1134
00:43:37,410 --> 00:43:35,500
we're now over the Indian Ocean you can

1135
00:43:38,490 --> 00:43:37,420
see now the upper stage is just fired to

1136
00:43:41,579 --> 00:43:38,500
make sure we're in the right trajectory

1137
00:43:43,559 --> 00:43:41,589
it is now positioning the spacecraft in

1138
00:43:46,109 --> 00:43:43,569

order to be inserted out of Earth orbit

1139
00:43:48,210 --> 00:43:46,119
and towards Mars and so you can see now

1140
00:43:49,890 --> 00:43:48,220
it's taken on this angle you can see the

1141
00:43:51,630 --> 00:43:49,900
little rockets firing to make sure and

1142
00:43:54,390 --> 00:43:51,640
also you can see we're giving a nice

1143
00:43:55,890 --> 00:43:54,400
slow spin this is spin stabilization

1144
00:43:58,440 --> 00:43:55,900
once that's done we get rid of that

1145
00:44:00,480 --> 00:43:58,450
boost that upper stage rocket and now

1146
00:44:03,120 --> 00:44:00,490
you're looking at the actual spacecraft

1147
00:44:05,309 --> 00:44:03,130
that is heading off to Mars consists of

1148
00:44:07,079 --> 00:44:05,319
two things it consists of what's called

1149
00:44:08,700 --> 00:44:07,089
the cruise stage that what you're seeing

1150
00:44:11,309 --> 00:44:08,710
now which are the solar panels that

1151
00:44:14,130 --> 00:44:11,319
provide power to the spacecraft is its

1152
00:44:16,470 --> 00:44:14,140
cruising to Mars and in the front as

1153
00:44:18,480 --> 00:44:16,480
sort of clamshells safe shaped enclosure

1154
00:44:20,730 --> 00:44:18,490
than it actually contains the rover and

1155
00:44:22,970 --> 00:44:20,740
the entry descent landing hardware and

1156
00:44:26,400 --> 00:44:22,980
so eight and a half months later and

1157
00:44:28,620 --> 00:44:26,410
that would be now as in August of 2012

1158
00:44:30,210 --> 00:44:28,630
we dumped the cruise stage and pay

1159
00:44:32,099 --> 00:44:30,220
tribute to all the engineers who

1160
00:44:34,860 --> 00:44:32,109
designed that it's always a very solemn

1161
00:44:36,750 --> 00:44:34,870
moment and now the

1162
00:44:39,450 --> 00:44:36,760
entry vehicle is going in and of course

1163
00:44:42,000 --> 00:44:39,460

we have to now d accelerate from 13,000

1164
00:44:44,400 --> 00:44:42,010
miles an hour down to a much lower speed

1165
00:44:46,440 --> 00:44:44,410
where we can deploy a parachute so this

1166
00:44:48,300 --> 00:44:46,450
now is it accelerates towards Mars it

1167
00:44:50,640 --> 00:44:48,310
actually reaches that Peaks velocity of

1168
00:44:52,410 --> 00:44:50,650
13,000 miles an hour you can see how

1169
00:44:54,390 --> 00:44:52,420
it's maintaining attitude control with

1170
00:44:56,370 --> 00:44:54,400
those little firing to the Jets this

1171
00:44:57,870 --> 00:44:56,380
tremendous heat that occurs is the

1172
00:44:59,940 --> 00:44:57,880
friction of the atmosphere interacts

1173
00:45:01,740 --> 00:44:59,950
with that each yield and it's a great

1174
00:45:03,930 --> 00:45:01,750
way to slow it down we're just D

1175
00:45:05,430 --> 00:45:03,940
accelerating right now but in a way that

1176
00:45:07,710 --> 00:45:05,440
doesn't burn up the spacecraft we

1177
00:45:09,510 --> 00:45:07,720
learned early on how to design these

1178
00:45:11,580 --> 00:45:09,520
entry vehicles so that you can actually

1179
00:45:14,040 --> 00:45:11,590
survive this coming in through the

1180
00:45:15,510 --> 00:45:14,050
atmosphere some point then we've gotten

1181
00:45:18,000 --> 00:45:15,520
down to a speed that's slow enough to

1182
00:45:20,280 --> 00:45:18,010
deploy deploy the parachute and we don't

1183
00:45:23,160 --> 00:45:20,290
need that heat shield anymore it's done

1184
00:45:25,650 --> 00:45:23,170
its job and once we get that parachute

1185
00:45:27,840 --> 00:45:25,660
out and it's deploying it I've almost

1186
00:45:30,510 --> 00:45:27,850
Mach 2 it's still over a thousand miles

1187
00:45:32,640 --> 00:45:30,520
an hour we can dump the heat shield and

1188
00:45:35,340 --> 00:45:32,650

now there's a radar on the spacecraft

1189
00:45:36,960 --> 00:45:35,350
can determine the location of the ground

1190
00:45:38,340 --> 00:45:36,970
and this determines the timing of

1191
00:45:40,530 --> 00:45:38,350
everything of that you're going to see

1192
00:45:43,110 --> 00:45:40,540
from here to the surface for example

1193
00:45:44,790 --> 00:45:43,120
dropping of what we call the sky crane

1194
00:45:47,730 --> 00:45:44,800
this is actually a descent rocket

1195
00:45:50,450 --> 00:45:47,740
assembly that takes us down and slows us

1196
00:45:53,640 --> 00:45:50,460
down as we go to the surface do a very

1197
00:45:56,310 --> 00:45:53,650
modest speed to where within a few

1198
00:46:00,090 --> 00:45:56,320
hundred meters of the surface we can now

1199
00:46:02,430 --> 00:46:00,100
lower the rover down from the descent

1200
00:46:04,620 --> 00:46:02,440
rocket the sky crane and that's hence

1201
00:46:07,190 --> 00:46:04,630
the name crane it's basically got a

1202
00:46:09,750 --> 00:46:07,200
tether that it can use to lower the

1203
00:46:11,520 --> 00:46:09,760
rover down and here you see a little

1204
00:46:13,290 --> 00:46:11,530
close-up of the camera as it's looking

1205
00:46:15,600 --> 00:46:13,300
at the surface the cameras mounted on

1206
00:46:17,400 --> 00:46:15,610
the rover it's telling us now with the

1207
00:46:19,020 --> 00:46:17,410
surface around the landing site looks

1208
00:46:20,640 --> 00:46:19,030
like this will be quite useful once we

1209
00:46:23,070 --> 00:46:20,650
get down and start driving around here

1210
00:46:26,550 --> 00:46:23,080
you see now the sky crane lowering on a

1211
00:46:28,350 --> 00:46:26,560
tether the rover it now has sensors

1212
00:46:30,720 --> 00:46:28,360
which will tell it when that thing then

1213
00:46:31,890 --> 00:46:30,730

that Rover touches the ground and when

1214
00:46:33,810 --> 00:46:31,900
that touches the ground that will

1215
00:46:37,020 --> 00:46:33,820
trigger what you see happening next year

1216
00:46:38,940 --> 00:46:37,030
the sky crane now slowly lowering the

1217
00:46:40,470 --> 00:46:38,950
rover to the surface we actually put six

1218
00:46:42,570 --> 00:46:40,480
wheels on the ground as part of the

1219
00:46:45,000 --> 00:46:42,580
landing sequence when it senses that

1220
00:46:47,330 --> 00:46:45,010
it's landed it cuts the cables and flies

1221
00:46:48,900 --> 00:46:47,340
off in its program to fly far away and

1222
00:46:50,970 --> 00:46:48,910
frankly crash

1223
00:46:53,160 --> 00:46:50,980
so that it doesn't interfere with the

1224
00:46:55,740 --> 00:46:53,170
mission here we now have the rover on

1225
00:46:57,450 --> 00:46:55,750
the ground and unlike with the Mars

1226
00:47:00,060 --> 00:46:57,460
rovers that had to drive off a platform

1227
00:47:02,520 --> 00:47:00,070
we are on the ground and ready to go

1228
00:47:03,870 --> 00:47:02,530
however for the first several weeks we

1229
00:47:05,850 --> 00:47:03,880
will be checking out all the very

1230
00:47:07,590 --> 00:47:05,860
complicated systems on this Rover and

1231
00:47:09,630 --> 00:47:07,600
it'll take us a while before we can

1232
00:47:11,160 --> 00:47:09,640
actually strike out and explore the

1233
00:47:14,460 --> 00:47:11,170
countryside but this shows it in the

1234
00:47:16,800 --> 00:47:14,470
video pretty much a sequence that you

1235
00:47:19,410 --> 00:47:16,810
could expect us to do once we get moving

1236
00:47:22,890 --> 00:47:19,420
on Mars looking around figuring out the

1237
00:47:24,540 --> 00:47:22,900
best places to go and then driving as

1238
00:47:26,130 --> 00:47:24,550

you can see from the tracks here up to

1239
00:47:28,500 --> 00:47:26,140
something that looks quite promising a

1240
00:47:30,150 --> 00:47:28,510
layer of rocks here we have our little

1241
00:47:32,700 --> 00:47:30,160
laser on board you'll see the little

1242
00:47:34,200 --> 00:47:32,710
light there is it fires out and hits the

1243
00:47:36,240 --> 00:47:34,210
rock first of all we're looking at it

1244
00:47:38,520 --> 00:47:36,250
with our camera okay that's a good place

1245
00:47:40,410 --> 00:47:38,530
to shoot our laser there you can see it

1246
00:47:42,990 --> 00:47:40,420
a little flickering light that is

1247
00:47:45,270 --> 00:47:43,000
actually analyzing the rock there it

1248
00:47:46,800 --> 00:47:45,280
looks promising and it's so promising

1249
00:47:48,810 --> 00:47:46,810
that we're now going to drive up and put

1250
00:47:51,090 --> 00:47:48,820
our arm out you can see now the arm of

1251
00:47:52,920 --> 00:47:51,100
the rover being put out first to do a

1252
00:47:55,320 --> 00:47:52,930
close-up observation of the rock with

1253
00:47:57,600 --> 00:47:55,330
our microscopic imager but then to drill

1254
00:47:59,160 --> 00:47:57,610
into the rock and take a sample to bring

1255
00:48:01,560 --> 00:47:59,170
back to our laboratory and I think this

1256
00:48:03,930 --> 00:48:01,570
is just jumping to the drill where we

1257
00:48:05,870 --> 00:48:03,940
now have a percussion drill that can set

1258
00:48:10,140 --> 00:48:05,880
of rotates and drills into the rock and

1259
00:48:11,670 --> 00:48:10,150
obtains a sample for the you know for

1260
00:48:13,890 --> 00:48:11,680
the laboratory and now we have put this

1261
00:48:15,570 --> 00:48:13,900
powder that's come from the drill into

1262
00:48:18,480 --> 00:48:15,580
our x-ray diffraction instrument called

1263
00:48:20,850 --> 00:48:18,490

chemin and the little depiction here you

1264
00:48:22,260 --> 00:48:20,860
see is of x rays hitting the sample you

1265
00:48:24,090 --> 00:48:22,270
wouldn't actually be able to see this

1266
00:48:25,950 --> 00:48:24,100
but the light showing it here just

1267
00:48:28,130 --> 00:48:25,960
illustrates it and as it hits the

1268
00:48:31,440 --> 00:48:28,140
various layers of atoms in the mineral

1269
00:48:33,450 --> 00:48:31,450
these x-rays are bounced off at various

1270
00:48:36,270 --> 00:48:33,460
characteristic angles to form these ring

1271
00:48:37,830 --> 00:48:36,280
patterns that you see and the spacing of

1272
00:48:40,470 --> 00:48:37,840
those ring patterns and their relative

1273
00:48:42,270 --> 00:48:40,480
intensities are a fingerprint for the

1274
00:48:45,240 --> 00:48:42,280
actual mineral that's present and it's a

1275
00:48:46,920 --> 00:48:45,250
very very diagnostic way of determining

1276
00:48:48,540 --> 00:48:46,930
the minerals that are present even if we

1277
00:48:50,790 --> 00:48:48,550
have never discovered a mineral before

1278
00:48:53,750 --> 00:48:50,800
we can figure out what it is by this

1279
00:48:56,520 --> 00:48:53,760
analysis and so that's a little bit of a

1280
00:48:58,950 --> 00:48:56,530
overview of the capabilities that this

1281
00:49:01,740 --> 00:48:58,960
Rover can do the question then is where

1282
00:49:02,880 --> 00:49:01,750
are we going with that and that is to

1283
00:49:06,120 --> 00:49:02,890
Gale Crater and you can

1284
00:49:09,059 --> 00:49:06,130
here over on the right side of the of

1285
00:49:11,279 --> 00:49:09,069
the Mercator map that I have shown

1286
00:49:13,250 --> 00:49:11,289
several times a crater that's located

1287
00:49:15,960 --> 00:49:13,260
right at the dichotomy boundary between

1288
00:49:19,890 --> 00:49:15,970

the southern highlands in the northern

1289
00:49:21,329 --> 00:49:19,900
lowlands Gale Crater as with Gusev

1290
00:49:23,849 --> 00:49:21,339
crater showed evidence that liquid water

1291
00:49:26,460 --> 00:49:23,859
might have been there in the past here

1292
00:49:28,589 --> 00:49:26,470
is a close-up of that crater showing

1293
00:49:31,710 --> 00:49:28,599
that it's it's pretty good size it's 150

1294
00:49:34,200 --> 00:49:31,720
5 kilometers in diameter but it has

1295
00:49:35,609 --> 00:49:34,210
quite a quite a relief inside of it if

1296
00:49:37,019 --> 00:49:35,619
you look at the little scale bar over

1297
00:49:40,740 --> 00:49:37,029
here you can see that it's several

1298
00:49:43,289 --> 00:49:40,750
kilometers in depth and unlike Gusev

1299
00:49:46,170 --> 00:49:43,299
crater we can look at this with our more

1300
00:49:48,599 --> 00:49:46,180
advanced orbiters and say that the

1301
00:49:50,880 --> 00:49:48,609
surface is not covered with lava flows

1302
00:49:52,500 --> 00:49:50,890
it's actually covered with deposits that

1303
00:49:54,299 --> 00:49:52,510
may well have borne the evidence of

1304
00:49:56,930 --> 00:49:54,309
liquid water so right there we have an

1305
00:49:59,099 --> 00:49:56,940
advantage over Gusev crater here at Gale

1306
00:50:02,339 --> 00:49:59,109
and the other interesting thing about

1307
00:50:04,529 --> 00:50:02,349
Gale again it's about 155 kilometers

1308
00:50:06,930 --> 00:50:04,539
across it has the central mound in the

1309
00:50:09,180 --> 00:50:06,940
middle and it has layers in this in the

1310
00:50:11,249 --> 00:50:09,190
mound and it indicates indicated that

1311
00:50:13,920 --> 00:50:11,259
these layers formed perhaps over a very

1312
00:50:15,420 --> 00:50:13,930
extended period of time and so the

1313
00:50:17,640 --> 00:50:15,430

question then is how much as water

1314
00:50:21,210 --> 00:50:17,650
influenced these layers and what kind of

1315
00:50:22,980 --> 00:50:21,220
story could we reconstruct about the

1316
00:50:25,079 --> 00:50:22,990
history of the the deposition of these

1317
00:50:30,089 --> 00:50:25,089
layers where I'm showing the arrow now

1318
00:50:31,829 --> 00:50:30,099
is our landing site at Gale where it's

1319
00:50:33,990 --> 00:50:31,839
safe to land you can see it's relatively

1320
00:50:35,999 --> 00:50:34,000
flat and then so we land where it's safe

1321
00:50:37,890 --> 00:50:36,009
and then we drive over to where it's

1322
00:50:40,620 --> 00:50:37,900
it's scientifically interesting namely

1323
00:50:43,339 --> 00:50:40,630
to begin to analyze the lower layers of

1324
00:50:45,960 --> 00:50:43,349
this mound in the center of Gale Crater

1325
00:50:48,779 --> 00:50:45,970
what's exciting about it is illustrated

1326
00:50:50,460 --> 00:50:48,789
in this diagram you're looking at the

1327
00:50:52,499 --> 00:50:50,470
lower part of the mound here where that

1328
00:50:53,999 --> 00:50:52,509
safe areas to the upper left and the

1329
00:50:56,099 --> 00:50:54,009
upper part of the mound is to the lower

1330
00:50:58,200 --> 00:50:56,109
right so you're looking at a slope sort

1331
00:51:00,809 --> 00:50:58,210
of going from the lower right down to

1332
00:51:02,640 --> 00:51:00,819
the upper left these colors are meant to

1333
00:51:04,980 --> 00:51:02,650
represent different minerals and there's

1334
00:51:07,230 --> 00:51:04,990
listed here on the left side all of

1335
00:51:09,630 --> 00:51:07,240
these minerals are formed by some kind

1336
00:51:12,480 --> 00:51:09,640
of interaction with water the most easy

1337
00:51:15,509 --> 00:51:12,490
ones to see about that are the clay

1338
00:51:16,560 --> 00:51:15,519

minerals which are shown here in sort of

1339
00:51:18,420 --> 00:51:16,570
the light blue

1340
00:51:20,400 --> 00:51:18,430
color in their scale so you can see that

1341
00:51:22,110 --> 00:51:20,410
there are clay minerals here but also

1342
00:51:23,940 --> 00:51:22,120
there's other minerals like sulfates

1343
00:51:26,760 --> 00:51:23,950
just like the ones that opportunity

1344
00:51:28,860 --> 00:51:26,770
found at meridiani indicating also water

1345
00:51:31,640 --> 00:51:28,870
interactions keys right as a sulfate

1346
00:51:34,710 --> 00:51:31,650
mineral as are these darker blue

1347
00:51:36,810 --> 00:51:34,720
indicated minerals here and so and then

1348
00:51:39,060 --> 00:51:36,820
we have plays in the form of nitrogen

1349
00:51:42,330 --> 00:51:39,070
what we call smectite plays shown here

1350
00:51:43,980 --> 00:51:42,340
in yellow so we have layers that are

1351
00:51:46,350 --> 00:51:43,990
very rich in minerals that right at the

1352
00:51:48,690 --> 00:51:46,360
get-go we can tell you involve liquid

1353
00:51:50,760 --> 00:51:48,700
water and so this is very exciting for

1354
00:51:52,980 --> 00:51:50,770
us as a target to go and actually

1355
00:51:55,200 --> 00:51:52,990
explore so this will be the first time

1356
00:51:57,240 --> 00:51:55,210
now where we have a rover that can go to

1357
00:51:59,130 --> 00:51:57,250
a place and see clay minerals that were

1358
00:52:00,780 --> 00:51:59,140
identified from the orbit and that's

1359
00:52:03,570 --> 00:52:00,790
because the clay minerals were found

1360
00:52:06,180 --> 00:52:03,580
long after the mars to Mars rovers were

1361
00:52:08,240 --> 00:52:06,190
launched and landed and so now we have

1362
00:52:10,620 --> 00:52:08,250
this unique opportunity really to pair a

1363
00:52:13,950 --> 00:52:10,630

compelling orbital observation with the

1364
00:52:16,080 --> 00:52:13,960
landed exploration and so we have this

1365
00:52:18,090 --> 00:52:16,090
mound showing very interesting minerals

1366
00:52:20,430 --> 00:52:18,100
and as if that's not enough these blue

1367
00:52:22,290 --> 00:52:20,440
features that you see here represent

1368
00:52:24,300 --> 00:52:22,300
evidences of standing water that

1369
00:52:26,670 --> 00:52:24,310
occurred even after this mound was

1370
00:52:28,200 --> 00:52:26,680
formed so the mound tell us that tells

1371
00:52:30,300 --> 00:52:28,210
us that at one point this crater was

1372
00:52:32,400 --> 00:52:30,310
completely filled with sediments then

1373
00:52:34,320 --> 00:52:32,410
the sub most some of the sediments were

1374
00:52:35,880 --> 00:52:34,330
taken away by some process and we were

1375
00:52:38,600 --> 00:52:35,890
compelled to think that it actually may

1376
00:52:40,590 --> 00:52:38,610
have been wind that did this and so a

1377
00:52:42,090 --> 00:52:40,600
considerable period of time must have

1378
00:52:44,580 --> 00:52:42,100
passed while all this was happening and

1379
00:52:46,380 --> 00:52:44,590
then after that we have evidence that

1380
00:52:49,110 --> 00:52:46,390
water was standing in this sort of moat

1381
00:52:51,180 --> 00:52:49,120
like area around the perimeter of the of

1382
00:52:52,740 --> 00:52:51,190
the central mound and so we have

1383
00:52:54,810 --> 00:52:52,750
evidence that water was involved in the

1384
00:52:56,580 --> 00:52:54,820
formation of the mound the time pass for

1385
00:52:58,770 --> 00:52:56,590
that mound to be eroded down or for the

1386
00:53:00,990 --> 00:52:58,780
sediments to be removed to reveal the

1387
00:53:02,430 --> 00:53:01,000
mound and then water that formed in the

1388
00:53:05,700 --> 00:53:02,440

moat surrounding the mound so this

1389
00:53:07,170 --> 00:53:05,710
perhaps is our most compelling site for

1390
00:53:08,760 --> 00:53:07,180
the argument that liquid water much a

1391
00:53:11,190 --> 00:53:08,770
person must have persisted over an

1392
00:53:13,380 --> 00:53:11,200
extended period of time so maybe this is

1393
00:53:15,210 --> 00:53:13,390
really one of the best places to go to

1394
00:53:17,490 --> 00:53:15,220
really address the question about a

1395
00:53:19,200 --> 00:53:17,500
habitable environment occurring on early

1396
00:53:21,480 --> 00:53:19,210
Mars and so we're very excited about

1397
00:53:23,070 --> 00:53:21,490
that here's another view that's similar

1398
00:53:25,680 --> 00:53:23,080
to the one I showed earlier the landing

1399
00:53:29,460 --> 00:53:25,690
site the little green squeal here

1400
00:53:30,420 --> 00:53:29,470
showing the Traverse that we would take

1401
00:53:32,480 --> 00:53:30,430
up through the lower man

1402
00:53:35,099 --> 00:53:32,490
to explore some of those very

1403
00:53:37,200 --> 00:53:35,109
interesting clay layers and sulfate

1404
00:53:38,700 --> 00:53:37,210
layers to really see what kind of story

1405
00:53:40,500 --> 00:53:38,710
they can tell us about this early

1406
00:53:42,599 --> 00:53:40,510
environment an environment that may have

1407
00:53:46,349 --> 00:53:42,609
persisted for millions of years as best

1408
00:53:47,790 --> 00:53:46,359
as we can tell and this just shows sort

1409
00:53:49,740 --> 00:53:47,800
of the distance that we have to drive

1410
00:53:51,960 --> 00:53:49,750
from where we land assuming that we land

1411
00:53:54,030 --> 00:53:51,970
in the middle of the safe area and the

1412
00:53:56,579 --> 00:53:54,040
elevation in kilometers that we don't

1413
00:53:58,170 --> 00:53:56,589

really have to climb very much compared

1414
00:54:00,120 --> 00:53:58,180
to the distance we're driving to get to

1415
00:54:01,770 --> 00:54:00,130
some of these very interesting deposits

1416
00:54:04,290 --> 00:54:01,780
so even though the mound looks

1417
00:54:06,240 --> 00:54:04,300
intimidating at first our analyses from

1418
00:54:09,359 --> 00:54:06,250
orbit indicate that we should be able to

1419
00:54:10,740 --> 00:54:09,369
achieve these several of these very

1420
00:54:13,200 --> 00:54:10,750
interesting sites within a reasonable

1421
00:54:15,270 --> 00:54:13,210
life time period of time in the mission

1422
00:54:18,089 --> 00:54:15,280
and at elevations that are not that

1423
00:54:19,829 --> 00:54:18,099
challenging to attain this is an

1424
00:54:21,359 --> 00:54:19,839
interesting view showing some of the

1425
00:54:22,950 --> 00:54:21,369
deposits that were formed perhaps

1426
00:54:26,130 --> 00:54:22,960
associated with those lakes that were in

1427
00:54:27,630 --> 00:54:26,140
the moats this area around the base of

1428
00:54:29,910 --> 00:54:27,640
the mound and then going up into the

1429
00:54:32,220 --> 00:54:29,920
mound itself very interesting terrain

1430
00:54:35,130 --> 00:54:32,230
that the rover would traverse sort of as

1431
00:54:37,109 --> 00:54:35,140
my arrow indicates here to interrogate

1432
00:54:38,430 --> 00:54:37,119
these different layers to see what story

1433
00:54:40,650 --> 00:54:38,440
they can tell about that early

1434
00:54:42,990 --> 00:54:40,660
environment and so it's very it should

1435
00:54:45,390 --> 00:54:43,000
be a very visually compelling mission

1436
00:54:47,339 --> 00:54:45,400
this is created from orbital images that

1437
00:54:49,200 --> 00:54:47,349
allow us to do a stereo reconstruction

1438
00:54:50,490 --> 00:54:49,210

of what the surface looks like but of

1439
00:54:52,109 --> 00:54:50,500
course we'll get much more compelling

1440
00:54:55,410 --> 00:54:52,119
images once we're on the ground with our

1441
00:54:57,630 --> 00:54:55,420
Rover again just to recapitulate the

1442
00:55:00,120 --> 00:54:57,640
kind of Traverse that we might take as

1443
00:55:02,130 --> 00:55:00,130
we drive along driving up into the mound

1444
00:55:03,839 --> 00:55:02,140
and encountering as these colors

1445
00:55:05,520 --> 00:55:03,849
indicate some of these very interesting

1446
00:55:07,740 --> 00:55:05,530
minerals that could tell us the story

1447
00:55:10,650 --> 00:55:07,750
about the early environment in Gale

1448
00:55:11,940 --> 00:55:10,660
Crater going up even further you can

1449
00:55:13,349 --> 00:55:11,950
imagine what the scenery is going to

1450
00:55:15,839 --> 00:55:13,359
look like as we drive up into this

1451
00:55:17,400 --> 00:55:15,849
Canyon and we begin to encounter stream

1452
00:55:19,680 --> 00:55:17,410
type deposits that are bringing

1453
00:55:21,329 --> 00:55:19,690
materials down from an upper part of the

1454
00:55:24,059 --> 00:55:21,339
mound that we may never be able to visit

1455
00:55:25,349 --> 00:55:24,069
directly but we can analyze based on the

1456
00:55:28,079 --> 00:55:25,359
material that has been brought down by

1457
00:55:29,789 --> 00:55:28,089
this stream channel so i mean we could

1458
00:55:32,250 --> 00:55:29,799
be reading millions and millions of

1459
00:55:35,700 --> 00:55:32,260
years of history by traversing in a very

1460
00:55:37,589 --> 00:55:35,710
sort of guided way up the side of the

1461
00:55:40,650 --> 00:55:37,599
flanks of this mound so we're very

1462
00:55:42,480 --> 00:55:40,660
excited about this site and and the

1463
00:55:44,069 --> 00:55:42,490

capabilities at the rover brings to it

1464
00:55:46,349 --> 00:55:44,079
and

1465
00:55:49,079 --> 00:55:46,359
just to sort of finish this off we can

1466
00:55:51,259 --> 00:55:49,089
compel compare the gale mound here sort

1467
00:55:53,519 --> 00:55:51,269
of illustrated on the right with the

1468
00:55:56,099 --> 00:55:53,529
sequence of rocks that you could see at

1469
00:55:58,469 --> 00:55:56,109
the Grand Canyon in Arizona and it's a

1470
00:56:00,390 --> 00:55:58,479
visually compelling set of rocks to look

1471
00:56:03,359 --> 00:56:00,400
at as anybody who's gone to that park

1472
00:56:06,299 --> 00:56:03,369
and a test but it also contains an

1473
00:56:08,190 --> 00:56:06,309
amazing record of Earth history that

1474
00:56:10,499 --> 00:56:08,200
spans hundreds of millions of years and

1475
00:56:13,170 --> 00:56:10,509
that's the point perhaps Gale also

1476
00:56:14,279 --> 00:56:13,180
contains a remarkably informative record

1477
00:56:17,400 --> 00:56:14,289
and as you can see here it actually

1478
00:56:20,039 --> 00:56:17,410
continues up even higher a parallel

1479
00:56:21,599 --> 00:56:20,049
record of a period of Mars history that

1480
00:56:23,309 --> 00:56:21,609
is very relevant to our search for

1481
00:56:25,349 --> 00:56:23,319
habitable environments in life on Mars

1482
00:56:27,479 --> 00:56:25,359
and so I think this comparison with

1483
00:56:29,459 --> 00:56:27,489
Grand Canyon illustrates our level of

1484
00:56:32,039 --> 00:56:29,469
excitement and anticipation of the per

1485
00:56:34,650 --> 00:56:32,049
this mission and again the point to be

1486
00:56:37,079 --> 00:56:34,660
being to try to reconstruct what an

1487
00:56:38,969 --> 00:56:37,089
early environment in Mars might be might

1488
00:56:41,069 --> 00:56:38,979

have been like analogous to our efforts

1489
00:56:43,109 --> 00:56:41,079
in the past to reconstruct early Earth

1490
00:56:44,759 --> 00:56:43,119
environments with implications for

1491
00:56:46,739 --> 00:56:44,769
understanding better the early history

1492
00:56:49,259 --> 00:56:46,749
of our biosphere and of course

1493
00:56:51,209 --> 00:56:49,269
ultimately by finding the right time of

1494
00:56:53,729 --> 00:56:51,219
sight and making the kind of compelling

1495
00:56:56,219 --> 00:56:53,739
observations that we feel the upper that

1496
00:56:58,259 --> 00:56:56,229
the Curiosity rover can do we'd be in a

1497
00:57:01,459 --> 00:56:58,269
position to select samples to bring back

1498
00:57:03,930 --> 00:57:01,469
to earth so now we have this wonderful

1499
00:57:05,939 --> 00:57:03,940
juxtaposition of going to one of the

1500
00:57:08,160 --> 00:57:05,949
most compelling sites on Mars for the

1501
00:57:10,109 --> 00:57:08,170
potential for life and bringing samples

1502
00:57:11,640 --> 00:57:10,119
back to the most capable

1503
00:57:12,930 --> 00:57:11,650
state-of-the-art instruments in

1504
00:57:14,160 --> 00:57:12,940
existence which of course are the

1505
00:57:16,229 --> 00:57:14,170
instruments that we have on the earth

1506
00:57:17,729 --> 00:57:16,239
and this is the great promise that we

1507
00:57:20,130 --> 00:57:17,739
look forward to with the Mars sample

1508
00:57:21,930 --> 00:57:20,140
return mission and we look forward to

1509
00:57:24,410 --> 00:57:21,940
the Mars Science Laboratory mission to

1510
00:57:28,170 --> 00:57:24,420
make additional compelling arguments

1511
00:57:30,089 --> 00:57:28,180
observations to bring closer to the in

1512
00:57:32,099 --> 00:57:30,099
the future the the day we can do the

1513
00:57:34,650 --> 00:57:32,109

sample return mission and with that

1514
00:57:36,959 --> 00:57:34,660
that's our summary of Mars exploration

1515
00:57:38,789 --> 00:57:36,969
and the discoveries we've made and the