



1
00:00:00,790 --> 00:00:07,320

[Music]

2
00:00:11,940 --> 00:00:09,320

[Applause]

3
00:00:14,100 --> 00:00:11,950

today I'm going to be talking about my

4
00:00:16,260 --> 00:00:14,110

PhD thesis work so we're sort of

5
00:00:19,019 --> 00:00:16,270

transitioning now from talking about

6
00:00:21,810 --> 00:00:19,029

brines and the last few talks to now

7
00:00:24,030 --> 00:00:21,820

moving on to salts and specifically

8
00:00:27,260 --> 00:00:24,040

salts and Gale Crater that have been

9
00:00:32,220 --> 00:00:27,270

measured by the MSL Curiosity rover

10
00:00:34,560 --> 00:00:32,230

um so from orbit aqueous minerals have

11
00:00:37,740 --> 00:00:34,570

been mapped extensively on Mars here I'm

12
00:00:40,710 --> 00:00:37,750

showing the distribution as of 2014

13
00:00:44,069 --> 00:00:40,720

where Philo silicates clay minerals are

14

00:00:46,229 --> 00:00:44,079

found throughout the altered noachian

15

00:00:49,410 --> 00:00:46,239

crustal materials the oldest materials

16

00:00:51,210 --> 00:00:49,420

and salts are also found but more

17

00:00:53,880 --> 00:00:51,220

scattered and distribution but they

18

00:00:56,220 --> 00:00:53,890

provide us important clues to the

19

00:00:58,560 --> 00:00:56,230

aqueous chemistry of past waters and

20

00:01:00,959 --> 00:00:58,570

they can also give us more information

21

00:01:03,600 --> 00:01:00,969

about potential transitions and

22

00:01:06,090 --> 00:01:03,610

environmental conditions such as

23

00:01:09,330 --> 00:01:06,100

potentially a global transition to more

24

00:01:11,609 --> 00:01:09,340

arid climate on Mars which can be sort

25

00:01:13,890 --> 00:01:11,619

of studied through these salts and also

26

00:01:16,890 --> 00:01:13,900

can be studied specifically at the

27

00:01:21,359 --> 00:01:16,900

landing site of MSL curiosity which is

28

00:01:24,179 --> 00:01:21,369

Gale Crater Gale Crater is a 150

29

00:01:27,060 --> 00:01:24,189

kilometer diameter crater located at the

30

00:01:29,910 --> 00:01:27,070

Crystal hemispheric dichotomy boundary

31

00:01:31,830 --> 00:01:29,920

it's a pretty deep crater this is a

32

00:01:33,600 --> 00:01:31,840

topographic map which you're looking at

33

00:01:35,130 --> 00:01:33,610

here and you can see what makes it sort

34

00:01:37,260 --> 00:01:35,140

of unique compared to the other critters

35

00:01:39,539 --> 00:01:37,270

in the surrounding area is it has this

36

00:01:42,899 --> 00:01:39,549

large mound in the center that's Mount

37

00:01:44,969 --> 00:01:42,909

sharp which is a sedimentary sequence at

38

00:01:47,789 --> 00:01:44,979

the center of the crater which has been

39

00:01:52,080 --> 00:01:47,799
mapped extensively from orbit so zooming

40

00:01:56,010 --> 00:01:52,090
into that white box there work by fram in

41

00:01:58,289 --> 00:01:56,020
at all and others has shown the from the

42

00:02:01,679 --> 00:01:58,299
base of the mound where we this is where

43

00:02:04,200 --> 00:02:01,689
we sort of started a methyls Traverse to

44

00:02:06,660 --> 00:02:04,210
the top of the mound on the bottom right

45

00:02:08,880 --> 00:02:06,670
we transition from clay mat rich

46

00:02:12,470 --> 00:02:08,890
materials to sulfate rich materials

47

00:02:16,129 --> 00:02:12,480
again potentially sort of capturing that

48

00:02:20,789 --> 00:02:16,139
transition to a more arid climate and

49

00:02:22,680 --> 00:02:20,799
this can be studied in depth and fit you

50

00:02:25,290 --> 00:02:22,690
and put together into

51
00:02:28,080 --> 00:02:25,300
Astra ticker fee so here this is frame

52
00:02:30,810 --> 00:02:28,090
and it all strat column showing a

53
00:02:32,390 --> 00:02:30,820
transition from the lowest layers the

54
00:02:35,370 --> 00:02:32,400
memory formation these clay rich

55
00:02:37,740 --> 00:02:35,380
materials to more sulfate rich materials

56
00:02:40,590 --> 00:02:37,750
which we haven't yet reached to miss the

57
00:02:42,930 --> 00:02:40,600
rover Curiosity like I said started down

58
00:02:45,240 --> 00:02:42,940
here on the floor of Gale Crater and

59
00:02:49,590 --> 00:02:45,250
it's currently in that clay bearing unit

60
00:02:51,690 --> 00:02:49,600
which I have noted so some of

61
00:02:55,440 --> 00:02:51,700
curiosity's initial findings when it got

62
00:02:58,290 --> 00:02:55,450
to Gale is these beautiful fine-grained

63
00:03:01,200 --> 00:02:58,300

rocks and the Yellowknife Bay Area which

64

00:03:04,290 --> 00:03:01,210
record information on a long live

65

00:03:05,940 --> 00:03:04,300
ancient lake and preserve evidence for

66

00:03:08,400 --> 00:03:05,950
an environment suited to support a

67

00:03:12,060 --> 00:03:08,410
Martian biosphere founded on key Melissa

68

00:03:15,240 --> 00:03:12,070
Otto trophy another paper by a separate

69

00:03:17,730 --> 00:03:15,250
crossing or a tall paper began to study

70

00:03:19,500 --> 00:03:17,740
the Mount sharp sedimentary sequence we

71

00:03:21,780 --> 00:03:19,510
first encountered it here at the

72

00:03:25,650 --> 00:03:21,790
parentals member of the more information

73

00:03:27,890 --> 00:03:25,660
where these fine finally laminated rocks

74

00:03:32,100 --> 00:03:27,900
were observed which were consistent with

75

00:03:36,000 --> 00:03:32,110
deposition and a sub aqueous lake and so

76
00:03:38,670 --> 00:03:36,010
here the MSL team began putting together

77
00:03:40,110 --> 00:03:38,680
a strat column and so you're going to be

78
00:03:42,270 --> 00:03:40,120
seeing many strat columns in this

79
00:03:45,449 --> 00:03:42,280
presentation so to orient you with them

80
00:03:49,910 --> 00:03:45,459
this is showing elevation and showing

81
00:03:54,180 --> 00:03:49,920
all the mapped units within Mount sharp

82
00:03:58,470 --> 00:03:54,190
so this was our MSL team strat column as

83
00:04:01,560 --> 00:03:58,480
of 2015 and curiosity is now here so

84
00:04:04,140 --> 00:04:01,570
we've made it a long way and collected

85
00:04:06,900 --> 00:04:04,150
many more observations since 2015

86
00:04:08,699 --> 00:04:06,910
our stratigraphy has expanded

87
00:04:10,800 --> 00:04:08,709
dramatically as we've continued to climb

88
00:04:13,530 --> 00:04:10,810

up Mount sharp and explore more layers

89
00:04:16,460 --> 00:04:13,540
and we've gained thousands and thousands

90
00:04:19,199 --> 00:04:16,470
more observations and some of the

91
00:04:22,159 --> 00:04:19,209
information we've gained from the last

92
00:04:25,860 --> 00:04:22,169
few years is we found new evidence for

93
00:04:27,210 --> 00:04:25,870
potential oscillations in the lake level

94
00:04:29,640 --> 00:04:27,220
that are recorded in this murray

95
00:04:31,700 --> 00:04:29,650
formation so this includes some

96
00:04:34,770 --> 00:04:31,710
heterolytic sedimentary textures

97
00:04:36,119 --> 00:04:34,780
defecation cracks varying clay

98
00:04:39,869 --> 00:04:36,129
chemistry's and

99
00:04:41,909 --> 00:04:39,879
or eight salts but one of the challenges

100
00:04:44,939 --> 00:04:41,919
that we face one of the best ways to

101
00:04:48,209 --> 00:04:44,949
study paleo environment is by looking at

102
00:04:50,309 --> 00:04:48,219
the mineralogy the challenge here is you

103
00:04:52,679 --> 00:04:50,319
might observe these black dots on the

104
00:04:54,749 --> 00:04:52,689
strat column they indicate where MSL

105
00:04:56,999 --> 00:04:54,759
actually drilled and so got a

106
00:04:59,100 --> 00:04:57,009
measurement of mineralogy you might

107
00:05:00,869 --> 00:04:59,110
notice that there's a big gap here and

108
00:05:04,019 --> 00:05:00,879
that was when the drill of the rover

109
00:05:06,029 --> 00:05:04,029
wasn't working but there's still lots of

110
00:05:07,379 --> 00:05:06,039
interesting change environmental changes

111
00:05:09,899 --> 00:05:07,389
potentially being recorded in these

112
00:05:13,139 --> 00:05:09,909
rocks and there's still a lot to be

113
00:05:15,749 --> 00:05:13,149

studied with this within this area so we

114

00:05:18,689 --> 00:05:15,759

need to use another tool to understand

115

00:05:21,659 --> 00:05:18,699

these transitions and the tool that I

116

00:05:23,480 --> 00:05:21,669

used for my PhD thesis is an instrument

117

00:05:26,219 --> 00:05:23,490

on board curiosity called chemcam

118

00:05:28,619 --> 00:05:26,229

chemcam is a laser-induced breakdown

119

00:05:32,369 --> 00:05:28,629

spectroscopy instrument so it performs

120

00:05:34,739 --> 00:05:32,379

lips and it's very valuable for studying

121

00:05:37,739 --> 00:05:34,749

salts because it provides a very large

122

00:05:40,790 --> 00:05:37,749

data set every day curiosity measures a

123

00:05:43,679 --> 00:05:40,800

few rocks with chemcam totaling to over

124

00:05:46,259 --> 00:05:43,689

20,000 individual locations measured on

125

00:05:49,069 --> 00:05:46,269

the surface to date it provides very

126

00:05:51,809 --> 00:05:49,079

fine scale elemental geochemistry

127

00:05:54,269 --> 00:05:51,819

measurements so each individual lives

128

00:05:57,619 --> 00:05:54,279

spots our chemistry measurement is only

129

00:05:59,879 --> 00:05:57,629

350 to 500 50 microns in diameter and

130

00:06:02,429 --> 00:05:59,889

volatile elements which allow us to

131

00:06:04,790 --> 00:06:02,439

measure and quantify salts have week but

132

00:06:07,889 --> 00:06:04,800

detectable emission lines with chemcam

133

00:06:09,989 --> 00:06:07,899

so the objective of my work has been to

134

00:06:13,609 --> 00:06:09,999

map the presence of salts and Gale

135

00:06:16,589 --> 00:06:13,619

Crater you think that chemcam instrument

136

00:06:20,429 --> 00:06:16,599

so previously assaults have been

137

00:06:23,579 --> 00:06:20,439

observed in a few different morphologies

138

00:06:26,489 --> 00:06:23,589

the first being and most common being

139

00:06:29,309 --> 00:06:26,499

these calcium sulfate filled veins or

140

00:06:30,809 --> 00:06:29,319

these fractures we also see magnesium

141

00:06:34,139 --> 00:06:30,819

sulfates enriched in some of these

142

00:06:36,059 --> 00:06:34,149

dendrites nodules and ridges of salts

143

00:06:40,079 --> 00:06:36,069

and clays and also fluorine enriched

144

00:06:43,199 --> 00:06:40,089

materials my co-author and collaborator

145

00:06:45,540 --> 00:06:43,209

William Rippon has worked extensively on

146

00:06:49,019 --> 00:06:45,550

studying salts and Gale Crater as well

147

00:06:50,010 --> 00:06:49,029

and one of his focuses has been studying

148

00:06:52,320 --> 00:06:50,020

calcium sulfate

149

00:06:54,360 --> 00:06:52,330

within the bedrock so in addition to

150

00:06:57,240 --> 00:06:54,370

those veins that I showed you on the

151

00:07:00,029 --> 00:06:57,250

last slide we've also seen bedrock

152

00:07:03,809 --> 00:07:00,039

material enriched in calcium sulfate

153

00:07:06,149 --> 00:07:03,819

likely indicating pore filling cements

154

00:07:09,210 --> 00:07:06,159

present within these bedrock so here

155

00:07:10,469 --> 00:07:09,220

again I'm showing the strat column with

156

00:07:12,869 --> 00:07:10,479

all the different members of the Murray

157

00:07:16,460 --> 00:07:12,879

formation and red is where William has

158

00:07:19,790 --> 00:07:16,470

mapped calcium sulfate enriched bedrock

159

00:07:22,409 --> 00:07:19,800

such as these cue targets shown here

160

00:07:24,570 --> 00:07:22,419

Williams also been focusing on another

161

00:07:27,540 --> 00:07:24,580

type of sulfate magnesium sulfates

162

00:07:30,480 --> 00:07:27,550

within Gale Crater specifically chemcam

163

00:07:33,089 --> 00:07:30,490

was able to detect magnesium sulfates in

164

00:07:35,550 --> 00:07:33,099

the red targets shown on this slide so

165

00:07:38,999 --> 00:07:35,560

beach cliff and Norwood Cove which

166

00:07:40,589 --> 00:07:39,009

correspond more rubley Dark Materials so

167

00:07:43,230 --> 00:07:40,599

there's some thought and some evidence

168

00:07:47,129 --> 00:07:43,240

that these may be primary magnesium

169

00:07:50,760 --> 00:07:47,139

sulfate salts my focus on the other hand

170

00:07:52,770 --> 00:07:50,770

oh and then one worth light so this is a

171

00:07:54,899 --> 00:07:52,780

sort of summary of Williams work where

172

00:07:57,570 --> 00:07:54,909

we're looking at the strat column and

173

00:08:00,360 --> 00:07:57,580

then the locations of the calcium

174

00:08:03,779 --> 00:08:00,370

sulfates and the locations right here of

175

00:08:05,730 --> 00:08:03,789

the magnesium sulfate salts and you can

176

00:08:07,950 --> 00:08:05,740

see that the magnesium sulfates in

177

00:08:10,709 --> 00:08:07,960

particular are restricted and they're

178

00:08:12,959 --> 00:08:10,719

stratigraphic position so they only

179

00:08:16,409 --> 00:08:12,969

occur pretty much in the Sutton Island

180

00:08:18,689 --> 00:08:16,419

and Blunt's point members so indicating

181

00:08:24,029 --> 00:08:18,699

a brief transition to it potentially

182

00:08:25,920 --> 00:08:24,039

different more saline rich fluids so my

183

00:08:27,899 --> 00:08:25,930

focus have actually been though chloride

184

00:08:31,170 --> 00:08:27,909

salts within Gale Crater

185

00:08:32,699 --> 00:08:31,180

so we've observed a bunch of different

186

00:08:35,940 --> 00:08:32,709

morphologies within the memory formation

187

00:08:37,829 --> 00:08:35,950

three of them being bedrock this is just

188

00:08:41,010 --> 00:08:37,839

a classic Murray formation bedrock

189

00:08:43,469 --> 00:08:41,020

target these nodule rich bedrock targets

190

00:08:46,889 --> 00:08:43,479

and then also veins and we've actually

191

00:08:49,620 --> 00:08:46,899

managed to detect chlorine and isolated

192

00:08:51,810 --> 00:08:49,630

observation points of these targets so

193

00:08:54,660 --> 00:08:51,820

where you see the red circles on the

194

00:08:58,220 --> 00:08:54,670

bottom is where chlorine is detected

195

00:09:01,290 --> 00:08:58,230

within the chemcam observation just as a

196

00:09:03,540 --> 00:09:01,300

chlorine peak within our spectra and one

197

00:09:07,199 --> 00:09:03,550

individual observation point of the

198

00:09:09,690 --> 00:09:07,209

cam cam measurement so indicating that

199

00:09:12,150 --> 00:09:09,700

we're sort of observing these isolated

200

00:09:16,050 --> 00:09:12,160

sporadic enrichments potentially of

201
00:09:18,630 --> 00:09:16,060
chloride salts so here again we're

202
00:09:21,840 --> 00:09:18,640
looking at our MSL strat column along

203
00:09:25,500 --> 00:09:21,850
with in the center the apxs measurements

204
00:09:27,180 --> 00:09:25,510
of chlorine you can see apxs which is

205
00:09:29,880 --> 00:09:27,190
another chemistry instrument aboard

206
00:09:33,540 --> 00:09:29,890
Curiosity observes pretty much constant

207
00:09:35,910 --> 00:09:33,550
chlorine throughout the stratigraphy not

208
00:09:38,759 --> 00:09:35,920
much variation on the other hand chemcam

209
00:09:41,100 --> 00:09:38,769
shown on the right plot here which is my

210
00:09:43,650 --> 00:09:41,110
work you can see there's a lot of

211
00:09:45,480 --> 00:09:43,660
variation in chlorine and specifically a

212
00:09:47,460 --> 00:09:45,490
lot of enrichments up here in these

213
00:09:50,490 --> 00:09:47,470

Sutton Island and blunts point members

214

00:09:52,199 --> 00:09:50,500

of the Murray formation this is likely

215

00:09:54,780 --> 00:09:52,209

due to the very difference in

216

00:09:56,910 --> 00:09:54,790

observation scale of the two instruments

217

00:09:59,100 --> 00:09:56,920

where chemcam like I said is observing

218

00:10:01,380 --> 00:09:59,110

these really fine points so we're likely

219

00:10:05,550 --> 00:10:01,390

targeting individual chlorine rich

220

00:10:07,440 --> 00:10:05,560

grains or porcelain cements apxs is

221

00:10:10,079 --> 00:10:07,450

averaging chemistry over a much larger

222

00:10:13,590 --> 00:10:10,089

area it might not be sensitive to these

223

00:10:15,690 --> 00:10:13,600

small scale enrichments another

224

00:10:18,720 --> 00:10:15,700

interesting observation about these

225

00:10:21,540 --> 00:10:18,730

targets that are chlorine rich are that

226

00:10:22,860 --> 00:10:21,550

they're also sodium rich so you can see

227

00:10:25,650 --> 00:10:22,870

that there's a pretty clear correlation

228

00:10:27,990 --> 00:10:25,660

between sodium and chlorine which

229

00:10:33,269 --> 00:10:28,000

indicates to us that this is likely a

230

00:10:35,639 --> 00:10:33,279

sodium chloride salt thank you so we

231

00:10:37,910 --> 00:10:35,649

also have some supporting evidence that

232

00:10:40,350 --> 00:10:37,920

the phase were observing is halite

233

00:10:42,000 --> 00:10:40,360

specifically the chemin instrument that

234

00:10:44,610 --> 00:10:42,010

mineralogy instrument I mentioned to you

235

00:10:46,560 --> 00:10:44,620

earlier has measured halite within the

236

00:10:48,780 --> 00:10:46,570

Kaela drill site which is indicated by

237

00:10:51,990 --> 00:10:48,790

the orange star and the Sam instrument

238

00:10:55,110 --> 00:10:52,000

also from Archer at all work showed that

239

00:10:57,360 --> 00:10:55,120

there was a transition from perchlorate

240

00:11:00,240 --> 00:10:57,370

rich materials to chloride rich

241

00:11:02,670 --> 00:11:00,250

materials as we transitioned up to where

242

00:11:06,180 --> 00:11:02,680

the orange dots are within the Murray

243

00:11:08,930 --> 00:11:06,190

formation so to wrap this all together

244

00:11:11,460 --> 00:11:08,940

into a potential and placement scenario

245

00:11:13,769 --> 00:11:11,470

but we think the sort of combined

246

00:11:17,130 --> 00:11:13,779

evidence of the sulfate salts and the

247

00:11:21,060 --> 00:11:17,140

chloride salts that these were first

248

00:11:24,090 --> 00:11:21,070

deposited potentially via evaporation of

249

00:11:28,320 --> 00:11:24,100

lake waters as summary formation was

250

00:11:31,980 --> 00:11:28,330

deposited but later on sulfate rich

251
00:11:32,940 --> 00:11:31,990
ground waters were prevalent and we

252
00:11:35,490 --> 00:11:32,950
think there may have been multiple

253
00:11:38,940 --> 00:11:35,500
sulfate rich groundwater events which

254
00:11:42,480 --> 00:11:38,950
mostly - completely dissolved the halite

255
00:11:45,810 --> 00:11:42,490
which is a very mobile phase and

256
00:11:49,470 --> 00:11:45,820
redeposit the halite as individual

257
00:11:50,970 --> 00:11:49,480
grains and potentially cements within

258
00:11:53,310 --> 00:11:50,980
the bedrock explaining sort of it's

259
00:11:55,860 --> 00:11:53,320
sporadic occurrence throughout the

260
00:12:02,600 --> 00:11:55,870
murray formation for more information on

261
00:12:08,180 --> 00:12:06,780
so just to wrap this talk up and give

262
00:12:11,940 --> 00:12:08,190
you some conclusions

263
00:12:14,100 --> 00:12:11,950

MSL has identified a variety of salts

264

00:12:16,500 --> 00:12:14,110

within Gale Crater including calcium

265

00:12:19,140 --> 00:12:16,510

sulfates and a medium sulfates borates

266

00:12:21,420 --> 00:12:19,150

and chlorides these salts can help us

267

00:12:22,800 --> 00:12:21,430

get a better understanding of the

268

00:12:24,990 --> 00:12:22,810

ancient lake and groundwater

269

00:12:28,440 --> 00:12:25,000

environments present at Gale and they

270

00:12:31,250 --> 00:12:28,450

also record fluctuating water levels of

271

00:12:33,540 --> 00:12:31,260

the lake and also potentially increased

272

00:12:35,940 --> 00:12:33,550

salinity and certain periods

273

00:12:37,710 --> 00:12:35,950

specifically where we saw those Sutton

274

00:12:39,210 --> 00:12:37,720

Island and blunz point members of the

275

00:12:41,610 --> 00:12:39,220

Murray formation where there was an

276

00:12:45,030 --> 00:12:41,620

enrichment and more magnesium sulfates

277

00:12:47,190 --> 00:12:45,040

and chlorides present more studies

278

00:12:50,280 --> 00:12:47,200

though are needed to understand how this

279

00:12:53,880 --> 00:12:50,290

might impact our understanding of gales

280

00:12:55,950 --> 00:12:53,890

habitability so how does varying or

281

00:12:58,560 --> 00:12:55,960

alternating saline and fresh waters

282

00:13:01,890 --> 00:12:58,570

affect microbial communities and also

283

00:13:03,840 --> 00:13:01,900

how viable are these for our search for

284

00:13:06,990 --> 00:13:03,850

life since they've been so impacted by

285

00:13:08,900 --> 00:13:07,000

later groundwater at diagenesis that's

286

00:13:13,769 --> 00:13:08,910

about all I have thank you

287

00:13:15,780 --> 00:13:13,779

[Applause]

288

00:13:20,049 --> 00:13:15,790

jen has a question

289

00:13:21,639 --> 00:13:20,059

take chairs prerogative how do you know

290

00:13:24,059 --> 00:13:21,649

that the chlorine you're seeing from

291

00:13:27,040 --> 00:13:24,069

libs is chloride and not perchlorate

292

00:13:28,929 --> 00:13:27,050

that's a great question so that's where

293

00:13:31,509 --> 00:13:28,939

we're relying on evidence from other

294

00:13:32,769 --> 00:13:31,519

instruments as well so the Sam

295

00:13:34,809 --> 00:13:32,779

instrument and some recent work by

296

00:13:36,850 --> 00:13:34,819

Archer at all has given us more

297

00:13:39,280 --> 00:13:36,860

confidence that this is likely chloride

298

00:13:41,739 --> 00:13:39,290

we also have some evidence from chemcam

299

00:13:43,509 --> 00:13:41,749

which points to the fact that this is of

300

00:13:45,610 --> 00:13:43,519

chloride rather than thirty law right

301

00:13:46,360 --> 00:13:45,620

which is the fact that we do measure

302

00:13:51,129 --> 00:13:46,370

oxygen

303

00:13:54,819 --> 00:13:51,139

variety of phases within the rock and

304

00:13:57,699 --> 00:13:54,829

also due to atmospheric breakdown so but

305

00:13:59,530 --> 00:13:57,709

there's no clear correlation with oxygen

306

00:14:02,259 --> 00:13:59,540

for these targets so we have some

307

00:14:04,640 --> 00:14:02,269

evidence there they as well thanks to