Goddard Scientific Colloquium: The Final Day of the Cretaceous, Led by Robert DePalma

1
00:00:07,140 --> 00:00:09,442
Hello and welcome to NASA's
Goddard Space Flight Center.

2
00:00:09,676 --> 00:00:12,345
My name is Michelle Thaler,
and we have a wonderful honor

3
00:00:12,345 --> 00:00:14,447
today of presenting
a scientific colloquium

4
00:00:14,447 --> 00:00:15,982
about some amazing new results

5
00:00:15,982 --> 00:00:17,951
having to do
with the end of the dinosaurs.

6
00:00:17,951 --> 00:00:19,753
This is something
where space science

7
00:00:19,753 --> 00:00:21,321
and earth science come together

8
00:00:21,321 --> 00:00:23,857
and shows you
how very much enmeshed

9
00:00:23,857 --> 00:00:25,759
all of these different types
of study are.

10
00:00:25,759 --> 00:00:26,760
So we're honored today

11
00:00:26,760 --> 00:00:28,962
to have Robert

DePalma talking to us,

12
00:00:28,962 --> 00:00:30,497
and he'll be giving this
colloquium.

13
00:00:30,497 --> 00:00:31,364
Now, Robert,

14
00:00:31,364 --> 00:00:32,799
it turns out, is a doctoral

15
00:00:32,799 --> 00:00:34,634
candidate will be very soon
getting a doctorate,

16
00:00:34,634 --> 00:00:36,636
I hope, in there for
the University of Manchester.

17
00:00:36,636 --> 00:00:37,871
Is that is that correct, Robert?

18
00:00:37,871 --> 00:00:39,272
Yes. Michele, thank you so much.

19
00:00:39,272 --> 00:00:40,774
It's an honor to be here today.

20
00:00:40,774 --> 00:00:42,242
I will be getting a doctorate
very soon

21
00:00:42,242 --> 00:00:43,710
from University of Manchester.

22
00:00:43,710 --> 00:00:45,111
And I'm on the faculty
at University

23
00:00:45,111 --> 00:00:47,113
at Florida Atlantic University.

24
00:00:47,113 --> 00:00:48,181
And you introduce yourself

25
00:00:48,181 --> 00:00:50,950
to me
as a vertebrate paleontologist.

26
00:00:51,184 --> 00:00:51,751
And you

27
00:00:52,052 --> 00:00:54,120
and you specialize in the end
of the Cretaceous period,

28
00:00:54,120 --> 00:00:56,189
which was ended
very suddenly by an event

29
00:00:56,222 --> 00:00:58,258
we're going to talk about today.
Absolutely right.

30
00:00:58,358 --> 00:01:00,160
Okay. Well, enjoy the symposium.
We'll be back later.

31
00:01:00,160 --> 00:01:00,493
Thank you.

32
00:01:01,928 --> 00:01:02,829
Thank you very much.

33
00:01:02,829 --> 00:01:03,730
And today,

34
00:01:03,730 --> 00:01:06,599
I'll be talking about a very,
very exciting bit of research

35
00:01:06,800 --> 00:01:10,136
that deals with probably one of
the worst days of the Mesozoic.

36
00:01:10,303 --> 00:01:12,238
It's when the Cretaceous ended.

37
00:01:12,238 --> 00:01:14,240
And anything
that would have experienced

38
00:01:14,240 --> 00:01:14,908
that day would have

39
00:01:14,908 --> 00:01:18,278
had probably the worst day
that it ever, ever experienced.

40
00:01:18,745 --> 00:01:21,247
That is, of course,
the Teacher of Impact event.

41
00:01:21,714 --> 00:01:24,684
And that event is
what set in motion

42
00:01:24,884 --> 00:01:27,720
a series of events
that really changed

43
00:01:27,720 --> 00:01:30,323
the topography of life on Earth
as we know it.

44
00:01:30,757 --> 00:01:33,359

And it set the stage
for what we have today.

45
00:01:33,359 --> 00:01:34,561
The important thing to remember,
though,

46
00:01:34,561 --> 00:01:37,797
is that the teaching of events
and understanding the teaching

47
00:01:37,831 --> 00:01:42,235
of event in every detail
possible is literally our window

48
00:01:42,235 --> 00:01:43,069
into the past.

49
00:01:43,069 --> 00:01:46,773
To understand how Biota is going
to respond to impact events,

50
00:01:46,973 --> 00:01:51,010
how biota is going to respond
to global scale hazards

51
00:01:51,311 --> 00:01:54,180
, and in turn, how can we
possibly deal with that today?

52
00:01:54,180 --> 00:01:56,316
So it directly relates
to what's going on today,

53
00:01:56,583 --> 00:01:58,952
and that's where Earth and
space science really meet.

54
00:02:00,186 --> 00:02:02,288
And a little

bit about the future of impact.

55
00:02:02,288 --> 00:02:05,058
We're talking about an asteroid
that was relatively

56
00:02:05,058 --> 00:02:06,726
ten kilometers in diameter

57
00:02:06,726 --> 00:02:09,162
and that's going to come in
roughly 20 kilometers a second.

58
00:02:09,462 --> 00:02:11,831
It's going to lose enormous
amounts of energy.

59
00:02:11,998 --> 00:02:13,199
You're going to have seismicity,

60
00:02:13,199 --> 00:02:16,703
possibly magnitude
11 to a magnitude 12

61
00:02:17,237 --> 00:02:18,438
at the impact site,

62
00:02:18,438 --> 00:02:20,140
and that's greater
than you're going to see

63
00:02:20,140 --> 00:02:21,641
in the Earth normally.

64
00:02:21,641 --> 00:02:23,943
And what that did is
that set in motion

65
00:02:24,110 --> 00:02:27,046

a cascade effect
of ecological collapse.

66
00:02:27,180 --> 00:02:28,648
You're going to block out
the sun.

67
00:02:28,648 --> 00:02:29,048
You're going to have

68
00:02:29,048 --> 00:02:31,317
this injection
of a massive amount

69
00:02:31,317 --> 00:02:33,186
of contamination
into the atmosphere.

70
00:02:33,186 --> 00:02:35,421
And it's really going
to set everything off kilter.

71
00:02:35,755 --> 00:02:39,159
That is what set in motion
the massive extinction

72
00:02:39,159 --> 00:02:43,229
that basically took out
75% of species on earth.

73
00:02:44,030 --> 00:02:46,766
So all of that that we know,
we've got this tremendous

74
00:02:46,766 --> 00:02:49,169
amount of information
about the big event

75
00:02:49,169 --> 00:02:51,471
and there's still questions

that are unanswered.

76
00:02:51,471 --> 00:02:54,340
We know all sorts of things
about what happened

77
00:02:54,407 --> 00:02:57,443
on these long timescales,
talking in generalities.

78
00:02:57,710 --> 00:02:59,979
So what happened over
millions of years?

79
00:03:00,180 --> 00:03:00,680
You know,

80
00:03:00,680 --> 00:03:04,551
what's our percentage of species
that died and what happened

81
00:03:04,551 --> 00:03:05,585
on a large scale?

82
00:03:05,585 --> 00:03:08,221
But what about those finer time
scales?

83
00:03:08,354 --> 00:03:10,156
What happened in the hour today?

84
00:03:10,156 --> 00:03:11,224
Time scales.

85
00:03:11,224 --> 00:03:12,859
And the fact of the matter is,

86
00:03:12,859 --> 00:03:15,428
we just don't know the answers

to a lot of those questions,

87
00:03:15,728 --> 00:03:19,532
because the way to answer them
depends on a geologic record

88
00:03:19,632 --> 00:03:21,768
that is suited
to answering those questions.

89
00:03:21,834 --> 00:03:24,571
Most of your rock units don't
preserve that sort of data.

90
00:03:24,871 --> 00:03:26,773
And it takes a really special
sort of a

91
00:03:26,773 --> 00:03:29,475
an area special
sort of a site to preserve

92
00:03:29,676 --> 00:03:30,777
that kind of a snapshot.

93
00:03:31,744 --> 00:03:33,713
And that's
where this new site comes in.

94
00:03:33,713 --> 00:03:35,348
So there's actually a new site

95
00:03:35,348 --> 00:03:38,084
at the very end of
the Cretaceous in North America

96
00:03:38,251 --> 00:03:41,521
that preserves
a snapshot of life on Earth.

97
00:03:42,088 --> 00:03:45,892
And this site,
it gives a very, very tight

98
00:03:46,259 --> 00:03:49,596
view of what happened
in the terrestrial setting.

99
00:03:50,029 --> 00:03:52,865
It gives a view of what happened
moments after impact.

100
00:03:53,099 --> 00:03:54,434
We're able to see what happened

101
00:03:54,434 --> 00:03:56,603
with the very first stages
of ejecta accretion.

102
00:03:56,769 --> 00:04:00,340
And we're basically able to see,
well, what did happen in

103
00:04:00,340 --> 00:04:02,108
that little tiny nugget of time

104
00:04:02,108 --> 00:04:04,611
that really is sort of missing
in the geologic record now.

105
00:04:05,178 --> 00:04:06,613
How can we actually feel that

106
00:04:06,613 --> 00:04:09,048
the site actually does
that for us?

107
00:04:09,048 --> 00:04:11,517
The study region is within

the Hell Creek formation.

108
00:04:11,884 --> 00:04:12,752
So that represents

109
00:04:12,752 --> 00:04:15,455
roughly the last 1.3
million years of the Cretaceous.

110
00:04:15,788 --> 00:04:17,123
It's a terrestrial setting,

111
00:04:17,123 --> 00:04:19,292
sort of like the Gulf
Coastal Plains today.

112
00:04:19,292 --> 00:04:21,461
You had all these rivers
that would have flowed

113
00:04:21,461 --> 00:04:24,964
from the inland areas
all the way out to the Seaway

114
00:04:24,964 --> 00:04:26,799
that would have split the US
in two.

115
00:04:26,799 --> 00:04:29,369
Back then you had all these
fluvial deposits.

116
00:04:29,402 --> 00:04:30,837
You had lots of dinosaurs.

117
00:04:30,837 --> 00:04:31,804
Life was abundant.

118
00:04:31,804 --> 00:04:35,408

This was a vibrant, thriving
ecosystem in the Hell Creek,

119
00:04:35,708 --> 00:04:39,512
and it's a hotbed for Cape
Research because it just happens

120
00:04:39,679 --> 00:04:43,616
that this area is the best
terrestrial succession

121
00:04:43,816 --> 00:04:47,453
of Cretaceous
to Paleocene rocks in the world.

122
00:04:48,054 --> 00:04:51,057
And we're able to study
the impact event most places

123
00:04:51,057 --> 00:04:53,593
that is just preserved
as a single layer of fallout.

124
00:04:53,893 --> 00:04:55,061
But the new site actually

125
00:04:55,061 --> 00:04:56,429
has something
a little bit different in store.

126
00:04:57,463 --> 00:05:00,066
Normally we see the cape do
boundary, something like this.

127
00:05:00,099 --> 00:05:03,436
There I am up on the
the outcrop, studying the

128
00:05:03,970 --> 00:05:06,239
dividing line between

the Cretaceous and Paleo gene.

129
00:05:07,073 --> 00:05:07,974
There's a closer view.

130
00:05:07,974 --> 00:05:10,810
There's Professor Phil Manning
and I digging into it.

131
00:05:10,910 --> 00:05:13,346
And you can see that that layer
is very, very distinct.

132
00:05:13,346 --> 00:05:14,847
You've got your dark
gray sediments

133
00:05:14,847 --> 00:05:16,282
and this beautiful light
colored,

134
00:05:16,282 --> 00:05:18,484
this peach colored clay layer.

135
00:05:18,484 --> 00:05:22,021
And that clay layer is 100%
composed of impact

136
00:05:22,021 --> 00:05:23,056
derived materials.

137
00:05:23,056 --> 00:05:25,658
You've got shocked quartz,
you've got ejecta, spherules,

138
00:05:25,792 --> 00:05:28,227
you've got an iridium spike,
you've got all this stuff

139

00:05:28,461 --> 00:05:30,363
that was blasted into the air

140
00:05:30,363 --> 00:05:32,198
and it came down
around the entire globe

141
00:05:32,198 --> 00:05:33,633
as this little layer.

142
00:05:33,633 --> 00:05:36,269
And this is how it manifests
in the Hell Creek formation.

143
00:05:36,869 --> 00:05:39,572
We've heard about the impact
event,

144
00:05:39,572 --> 00:05:41,240
we've heard
about the future of impact,

145
00:05:41,240 --> 00:05:43,609
and we know the name
Walter Alvarez.

146
00:05:43,609 --> 00:05:44,744
It's associated with it.

147
00:05:44,744 --> 00:05:47,413
And here we are actually digging
into the layer at the site

148
00:05:47,680 --> 00:05:52,452
and working through these these
problems at this new site .

149
00:05:52,452 --> 00:05:54,754
And it's
sort of an incredible story

150
00:05:54,987 --> 00:05:57,590
as it comes together with
all the mines that are involved

151
00:05:57,890 --> 00:06:00,660
and and piecing
these little details together.

152
00:06:01,728 --> 00:06:03,863
So let's
get into the the site itself.

153
00:06:03,863 --> 00:06:05,365
The site is known as Tanis.

154
00:06:05,365 --> 00:06:08,000
And this site,
the depositional setting,

155
00:06:08,301 --> 00:06:11,471
is basically in a little river
environment

156
00:06:11,471 --> 00:06:12,772
back in the Cretaceous.

157
00:06:12,772 --> 00:06:15,508
So you have point bars
in the bends in the river.

158
00:06:15,808 --> 00:06:20,380
And essentially what occurred
is a massive surge of water left

159
00:06:20,380 --> 00:06:24,350
a layer of mud as a drape over
one of these point bars.

160

00:06:24,751 --> 00:06:28,454
And you've got maybe ten and a
half meters of elevation change.

161
00:06:28,454 --> 00:06:30,223
So it's a pretty steep
point bar.

162
00:06:30,223 --> 00:06:31,657
And you've got this
veneer of sediment

163
00:06:31,657 --> 00:06:34,160
that got deposited
really rapidly on the point bar.

164
00:06:34,460 --> 00:06:36,629
It's actually really good
for preservation.

165
00:06:36,629 --> 00:06:39,165
And you can see here, it was a
really turbulent deposit.

166
00:06:39,332 --> 00:06:41,134
You've got all these

167
00:06:41,134 --> 00:06:45,438
these chaotically deposited
laminae of silt and sand

168
00:06:45,638 --> 00:06:46,706
and mixed in with that,

169
00:06:46,706 --> 00:06:50,076
you've got this mass death
layer of mostly fish

170
00:06:50,643 --> 00:06:52,678
and you've got trees,

you've got other plants,

171
00:06:52,678 --> 00:06:54,881
you've got other organisms
all mixed in

172
00:06:54,881 --> 00:06:58,518
to this really dense
layer of dead creatures.

173
00:06:58,851 --> 00:07:01,521
And this was all pushed in at
relatively the same time.

174
00:07:01,988 --> 00:07:03,589
And you can see it, right,

175
00:07:03,589 --> 00:07:07,427
the chaotically oriented
mud class at the bottom.

176
00:07:07,427 --> 00:07:09,762
So what those are
we call a rip up class.

177
00:07:09,962 --> 00:07:12,231
And we have a really turbulent
surge of water.

178
00:07:12,331 --> 00:07:14,967
It's going to rip up
whatever sediment it encounters.

179
00:07:15,201 --> 00:07:17,336
It's going to trap basically.
Right.

180
00:07:17,336 --> 00:07:18,304
All those together,

181
00:07:18,304 --> 00:07:20,072
it's going to tumble those
and cause

182
00:07:20,072 --> 00:07:22,408
this little layer of rip up
class.

183
00:07:22,408 --> 00:07:23,543
And that's what we see there.

184
00:07:25,812 --> 00:07:26,412
We have our

185
00:07:26,412 --> 00:07:29,682
sturgeon there and that's mostly
what we see with the fish.

186
00:07:29,682 --> 00:07:31,517
We have our sturgeon
and paddlefish

187
00:07:31,517 --> 00:07:32,552
and then mixed in with those,

188
00:07:32,552 --> 00:07:34,487
we've
got other terrestrial biota.

189
00:07:34,487 --> 00:07:36,622
This is what the site looks like
today.

190
00:07:36,622 --> 00:07:37,690
It looks very, very different.

191
00:07:37,690 --> 00:07:39,592
You don't have that
subtropical area that we even

192
00:07:39,592 --> 00:07:41,160
had the Hell Creek formation.

193
00:07:41,160 --> 00:07:44,730
This is the Prairie
and the the American West.

194
00:07:45,031 --> 00:07:48,634
And you can actually kind of
get an idea of the elevation

195
00:07:48,634 --> 00:07:49,535
change there at the site.

196
00:07:49,535 --> 00:07:52,171
We're about two thirds up
that angled point bar.

197
00:07:52,472 --> 00:07:53,806
And you can see way down there

198
00:07:53,806 --> 00:07:56,142
at the vehicles is near
the base of the point bar

199
00:07:56,776 --> 00:07:58,144
and it even goes up from there .

200
00:07:58,144 --> 00:08:00,446
We've got ten and a half
meters of elevation change

201
00:08:00,780 --> 00:08:03,382
continuously unbroken
in that deposit.

202
00:08:04,283 --> 00:08:06,285
And when we start digging up

these

203
00:08:06,519 --> 00:08:08,988
these remains, you can think,
well, well, when are we?

204
00:08:08,988 --> 00:08:10,957
You know, we're basically
digging through time.

205
00:08:10,957 --> 00:08:12,124
So when are we?

206
00:08:12,124 --> 00:08:13,960
That's the big question
we always ask.

207
00:08:13,960 --> 00:08:16,362
And we have to answer
that multiple different ways,

208
00:08:16,395 --> 00:08:17,797
not just one.

209
00:08:17,964 --> 00:08:20,333
And one of those ways
is with the plants.

210
00:08:20,500 --> 00:08:22,001
So the mega floor at the site

211
00:08:22,001 --> 00:08:22,902
and this is one of the things

212
00:08:22,902 --> 00:08:25,805
that has been independently
verified by Baylor botanist

213
00:08:25,905 --> 00:08:26,506

Patrick Herren.

214
00:08:26,506 --> 00:08:30,710
DEAN And when we look
at the flora that are present

215
00:08:30,910 --> 00:08:34,881
in that that point bar deposit
and the surge deposit

216
00:08:35,081 --> 00:08:36,983
and compare
that to the underlying sediments

217
00:08:36,983 --> 00:08:38,050
that that river dug through,

218
00:08:38,050 --> 00:08:40,653
the incised sediments
which are obviously older,

219
00:08:41,053 --> 00:08:44,323
we see a distinct difference
in the flora between those

220
00:08:44,524 --> 00:08:46,592
the flora
there in the surge deposit

221
00:08:46,592 --> 00:08:48,261
and that are in the point bar

222
00:08:48,261 --> 00:08:50,730
are much younger
and they constrain to the very,

223
00:08:50,730 --> 00:08:53,533
very upper most Cretaceous,
the terminal Cretaceous

224
00:08:53,733 --> 00:08:56,135
and the uppermost
hell creek formation.

225
00:08:56,135 --> 00:08:57,737
Same with the pollen.

226
00:08:57,737 --> 00:09:01,240
And this has been independently
verified by paleontologist

227
00:09:01,407 --> 00:09:02,642
Steve Bosworth.

228
00:09:02,642 --> 00:09:05,478
And the pollen shows us the
same thing pretty much that the

229
00:09:06,045 --> 00:09:08,981
the flora show
us basically the foot,

230
00:09:09,048 --> 00:09:12,051
the pollen in the uppermost
part of the deposit

231
00:09:12,051 --> 00:09:15,521
and your point bar
and in your surge deposit match

232
00:09:15,655 --> 00:09:18,858
with the uppermost held
creek, the terminal Cretaceous

233
00:09:19,125 --> 00:09:22,061
and then the incised bedrock
is a little bit older.

234
00:09:22,094 --> 00:09:23,529

It's what you would expect.

235
00:09:23,529 --> 00:09:26,165
So we've got these
redundant ways

236
00:09:26,332 --> 00:09:29,802
of basically putting
a time stamp on our deposit.

237
00:09:31,304 --> 00:09:32,905
And the
ejected does that as well.

238
00:09:32,905 --> 00:09:34,640
And here are some examples
of the ejector here.

239
00:09:34,640 --> 00:09:38,711
We've got this, the space
component of this site, and

240
00:09:39,312 --> 00:09:42,114
this is a basic stratigraphic
column of the site.

241
00:09:42,114 --> 00:09:44,550
And you can see the
the grain size curve.

242
00:09:44,550 --> 00:09:46,085
So you go from large to small
green.

243
00:09:46,085 --> 00:09:48,020
We've got two major
pulses in the site.

244
00:09:48,020 --> 00:09:50,389
They've got one major pulse

245
00:09:50,389 --> 00:09:53,593
backflow and then another pulse
that goes all the way up.

246
00:09:53,859 --> 00:09:56,028
There's ejecta
throughout this deposit.

247
00:09:56,028 --> 00:09:58,364
You've got ejecta spherules
like you see here

248
00:09:59,098 --> 00:10:01,634
that would have come
from the impact site.

249
00:10:02,068 --> 00:10:05,004
You've got that impactor,
it hits your target rock

250
00:10:05,204 --> 00:10:07,173
and you get blobs of molten
glass

251
00:10:07,173 --> 00:10:08,841
and different material
that shoot up into the sky,

252
00:10:08,841 --> 00:10:11,143
out of the atmosphere
and they come back down again.

253
00:10:11,677 --> 00:10:15,848
And that is a diagnostic feature
of impact, as

254
00:10:15,848 --> 00:10:19,218
is your shocked quartz at right,
which we find in the capping

255
00:10:19,819 --> 00:10:22,521
jpg torn stein
which caps the site.

256
00:10:22,521 --> 00:10:25,091
So you literally have this
ejecta bearing deposit,

257
00:10:25,591 --> 00:10:28,227
which is capped by the very fine
grained debris

258
00:10:28,227 --> 00:10:29,595
from that impact event.

259
00:10:29,595 --> 00:10:31,697
So that really seals
it all together.

260
00:10:31,697 --> 00:10:33,399
You also have micro
Chris Stites.

261
00:10:33,399 --> 00:10:34,934
So these are

262
00:10:34,934 --> 00:10:38,704
formed as a condensate
from the vaporized impactor.

263
00:10:38,704 --> 00:10:41,340
So you've got that asteroid. It
vaporizes on impact.

264
00:10:41,540 --> 00:10:43,275
And as that condenses,

265
00:10:43,275 --> 00:10:44,176

you get these forming

266
00:10:44,176 --> 00:10:45,177
and you've got the

267
00:10:45,177 --> 00:10:47,213
typical enrichments
in chromium and nickel

268
00:10:47,213 --> 00:10:49,048
and iron and so forth

269
00:10:49,048 --> 00:10:52,151
that are attributed to the micro
Chris sites.

270
00:10:53,085 --> 00:10:56,022
Now getting into all the stuff
that's buried in the deposit.

271
00:10:56,022 --> 00:10:56,889
Let's get to the

272
00:10:56,889 --> 00:10:59,625
coolest thing of all time,
which is logs, right?

273
00:10:59,892 --> 00:11:02,094
Because we all think
logs are really cool, right?

274
00:11:02,261 --> 00:11:04,530
Well, these logs
actually happen to be cool

275
00:11:04,530 --> 00:11:07,900
because in this site
wrapped around the logs,

276

00:11:07,900 --> 00:11:09,535
you've got all these animals
and different things.

277
00:11:09,535 --> 00:11:10,970
But the logs themselves,

278
00:11:10,970 --> 00:11:14,340
which in some cases
can be 20 to 30 feet long,

279
00:11:14,940 --> 00:11:17,143
the longest ones we've dug up
so far,

280
00:11:17,143 --> 00:11:19,278
really well-preserved semi
three dimensional,

281
00:11:19,512 --> 00:11:21,547
but they also have
runnels of amber on them.

282
00:11:21,547 --> 00:11:23,349
So we know that resin
would go down the trees

283
00:11:23,349 --> 00:11:26,419
and we've got runnels of amber
on the exterior of the logs .

284
00:11:26,419 --> 00:11:28,320
Okay, that's great.
We've all seen Jurassic Park.

285
00:11:28,320 --> 00:11:30,423
We know that Amber is a
great thing for paleontology.

286
00:11:30,423 --> 00:11:32,725

But in this case, Amber,

287
00:11:33,125 --> 00:11:36,128
when that resin is still
flowing, is a way to capture

288
00:11:36,128 --> 00:11:37,797
whatever is going
through the air.

289
00:11:37,797 --> 00:11:40,066
And on the day
of the chuchu of impact,

290
00:11:40,166 --> 00:11:42,702
that's the time when I really
want to see what's in the amber.

291
00:11:43,169 --> 00:11:45,471
So what are we finding here?

292
00:11:45,471 --> 00:11:46,906
Well,
we're sieving out the amber.

293
00:11:46,906 --> 00:11:47,773
We're actually going through it.

294
00:11:47,773 --> 00:11:50,409
There's Pym Cask
is another researcher

295
00:11:50,409 --> 00:11:53,112
who is doing work
out there from Vue, Amsterdam.

296
00:11:53,479 --> 00:11:55,748
And here are some of the pieces
of amber from the site.

297
00:11:55,748 --> 00:11:57,583
There's
little pieces of the wood,

298
00:11:57,583 --> 00:12:00,119
but here we've got
pieces of amber from the site.

299
00:12:00,119 --> 00:12:01,120
You can actually see

300
00:12:01,120 --> 00:12:02,588
texture
from the surface of that one

301
00:12:02,588 --> 00:12:04,757
that that matches the bark
from the tree.

302
00:12:04,790 --> 00:12:06,392
So this is really well
preserved.

303
00:12:06,392 --> 00:12:10,262
Amber And when we look inside,
we've got beautifully preserved.

304
00:12:10,429 --> 00:12:13,132
Ejecta Spherules
from the impact event.

305
00:12:13,532 --> 00:12:14,734
These haven't been exposed yet.

306
00:12:14,734 --> 00:12:16,202
They're still in the amber

307
00:12:16,202 --> 00:12:18,804
and these two spherules

have been exposed.

308
00:12:18,971 --> 00:12:19,638
And we can see that

309
00:12:19,638 --> 00:12:23,342
beautiful black
glass of of the impact spiral.

310
00:12:23,642 --> 00:12:26,712
That's not usually what you see
what the future of impact

311
00:12:26,712 --> 00:12:30,015
normally we're looking
at what you see at left

312
00:12:30,349 --> 00:12:33,185
a really awful
crumbly clay spheroidal

313
00:12:33,519 --> 00:12:36,956
because a really bad thing
happens in the geologic record.

314
00:12:37,156 --> 00:12:42,094
What happens is glass will then
alter when it takes on water

315
00:12:42,228 --> 00:12:44,930
so it hydrates and glass
will then turn to clay.

316
00:12:45,197 --> 00:12:47,066
In this case smectite clay

317
00:12:47,066 --> 00:12:49,368
and it becomes crumbly
and not too nice.

318
00:12:49,635 --> 00:12:53,439
And we look at these
as researchers of the

319
00:12:53,472 --> 00:12:55,608
of the impact event
and we think, oh, man,

320
00:12:55,641 --> 00:12:57,276
what did that look like
on the day of impact?

321
00:12:57,276 --> 00:12:58,577
What did it look like
when it was pristine?

322
00:12:58,577 --> 00:12:58,978
And we have to

323
00:12:58,978 --> 00:13:02,615
use our imaginations to think,
what did that used to look like?

324
00:13:02,948 --> 00:13:04,283
That's what
it used to look like.

325
00:13:04,283 --> 00:13:06,652
That's one of the only pristine

326
00:13:06,652 --> 00:13:09,889
pieces of impact
ejecta from the chuchu impact

327
00:13:09,889 --> 00:13:11,490
and the amber
there is full of it.

328
00:13:11,490 --> 00:13:13,626

So that's a really good hotbed
for research

329
00:13:14,093 --> 00:13:16,662
and it helps us to give
a fingerprint to the site.

330
00:13:17,129 --> 00:13:17,797
Right.

331
00:13:17,797 --> 00:13:21,333
So some of those little clay
spirals didn't completely alter.

332
00:13:21,700 --> 00:13:24,503
So this is a beautiful micro

333
00:13:24,570 --> 00:13:28,007
CD that my colleague
Lauren Gursky put together.

334
00:13:28,007 --> 00:13:30,209
And the blue portion
is the clay.

335
00:13:30,442 --> 00:13:30,810
All right.

336
00:13:30,810 --> 00:13:33,012
And the interior,
the green portion

337
00:13:33,212 --> 00:13:35,981
is the unaltered core
of that sphere.

338
00:13:36,649 --> 00:13:39,118
And looking at those
and the ones from Amber,

339
00:13:39,118 --> 00:13:41,687
we're able to establish
a geochemical fingerprint

340
00:13:41,787 --> 00:13:43,522
with the chuchu of impact

341
00:13:43,522 --> 00:13:46,659
and with glass from the tree
to the impact from elsewhere and

342
00:13:48,060 --> 00:13:50,262
geochemical
fingerprints on the crater site.

343
00:13:50,262 --> 00:13:53,365
And also that glass
has a temporal fingerprint.

344
00:13:53,632 --> 00:13:54,800
So we're able to radiometric

345
00:13:54,800 --> 00:13:56,902
date that argon argon dating

346
00:13:57,069 --> 00:13:58,270
and come up with a date

347
00:13:58,270 --> 00:14:00,272
that matches the CHUCHU
lab event.

348
00:14:00,539 --> 00:14:03,776
So able to match this
of this event with the site,

349
00:14:04,076 --> 00:14:07,780
with the biota,
with the microorganisms,

350
00:14:07,980 --> 00:14:11,717
with the geochemistry, with
the radio isotopes, everything.

351
00:14:11,951 --> 00:14:14,520
So we're able to come up
with these reinforcing ways

352
00:14:14,520 --> 00:14:16,789
of linking it with the chuchu
live event.

353
00:14:16,822 --> 00:14:17,122
So good.

354
00:14:17,122 --> 00:14:19,792
We've got something that's
linked to the day of the impact.

355
00:14:19,792 --> 00:14:20,693
That's excellent.

356
00:14:20,693 --> 00:14:22,228
So how can we get this timing

357
00:14:22,228 --> 00:14:25,030
constrained a little bit
in the ejecta sort of is our key

358
00:14:25,264 --> 00:14:28,467
because that entire
column of sediment.

359
00:14:29,435 --> 00:14:32,738
Was getting deposited
during active ejecta accretion.

360
00:14:33,272 --> 00:14:35,241

Of course grained ejecta.

361
00:14:35,241 --> 00:14:38,611
So basically
since that site is covered

362
00:14:38,611 --> 00:14:40,079
in your fine grained on stone.

363
00:14:41,247 --> 00:14:42,381
That came out later.

364
00:14:42,381 --> 00:14:45,217
And your column is filled
with your coarse grain ejecta.

365
00:14:45,317 --> 00:14:48,254
You're tied to that coarse,
grain, dejected accretion

366
00:14:48,387 --> 00:14:49,188
time window.

367
00:14:49,188 --> 00:14:51,223
And that's within roughly
the first hour,

368
00:14:51,223 --> 00:14:53,459
maybe two at most after impact.

369
00:14:53,659 --> 00:14:55,828
You want to be really, really
generous, maybe, say an hour

370
00:14:55,828 --> 00:14:57,997
and a half to 2 hours
after impact.

371
00:14:58,297 --> 00:15:01,166

And geologically speaking,
that is the blink of an eye.

372
00:15:01,367 --> 00:15:03,469
That is the sort of honey spot
that we're looking for.

373
00:15:03,702 --> 00:15:05,671
Because when you're looking
at the impact event

374
00:15:05,671 --> 00:15:07,439
in the terms
of hundreds of thousands

375
00:15:07,439 --> 00:15:08,741
to millions of years,

376
00:15:08,741 --> 00:15:10,009
and you're able to get a site

377
00:15:10,009 --> 00:15:12,177
with that
sort of temporal resolution,

378
00:15:12,177 --> 00:15:14,780
then you can answer
all sorts of questions

379
00:15:14,780 --> 00:15:16,882
if you find the right types
of material there .

380
00:15:16,882 --> 00:15:18,217
And that we know
we're in the gold now.

381
00:15:18,217 --> 00:15:20,552
Now is when we can start
answering those questions.

382
00:15:21,153 --> 00:15:23,489
Now, go back
to the temporal resolution.

383
00:15:23,489 --> 00:15:25,457
How can we possibly constrain
that a little more?

384
00:15:25,457 --> 00:15:27,092
The ejecta is our key.

385
00:15:27,092 --> 00:15:30,062
We know that whole deposit
was within the first hour

386
00:15:30,062 --> 00:15:31,330
or two after impact,

387
00:15:31,330 --> 00:15:34,533
but when we have lenses like
that throughout the deposit,

388
00:15:35,067 --> 00:15:37,970
we can work out
based on their average diameter

389
00:15:38,570 --> 00:15:40,839
when they would have arrived
at the site.

390
00:15:40,839 --> 00:15:41,540
And Walter

391
00:15:41,540 --> 00:15:44,310
actually helped by doing
a lot of those calculations.

392
00:15:44,576 --> 00:15:47,446

And what we turned up was, is

393
00:15:47,613 --> 00:15:49,281
you can get those different

394
00:15:49,281 --> 00:15:51,517
lenses throughout the thing
and those are basically

395
00:15:51,650 --> 00:15:53,585
your little time stamps
throughout the deposit.

396
00:15:53,585 --> 00:15:56,855
You could further subdivide
the chronology of this deposit

397
00:15:57,089 --> 00:15:59,959
based on the incoming
time of the ejecta spherules

398
00:16:00,326 --> 00:16:01,660
and that's
the beauty of the site.

399
00:16:01,660 --> 00:16:03,462
So you can actually get this
little

400
00:16:03,462 --> 00:16:06,598
this little tidbit of a view
every step up the column.

401
00:16:07,800 --> 00:16:08,400
But that doesn't

402
00:16:08,400 --> 00:16:11,503
actually solve the surge
where the surge come from.

403
00:16:11,737 --> 00:16:13,405
I'm not going to belabor
that too much.

404
00:16:13,405 --> 00:16:15,107
We have this big surge of water.

405
00:16:15,107 --> 00:16:17,476
It happened
at the same time of the impact.

406
00:16:17,476 --> 00:16:19,745
Where it come from?
What's the deal?

407
00:16:19,745 --> 00:16:22,948
Basically,
we know that the site was part

408
00:16:22,948 --> 00:16:25,250
of the point
guard system of a big river,

409
00:16:25,250 --> 00:16:27,720
a very large river
that cut deeply into the Hell

410
00:16:27,720 --> 00:16:28,754
Creek landscape

411
00:16:28,754 --> 00:16:31,123
and that emptied out into
the Western Interior Seaway.

412
00:16:31,523 --> 00:16:33,292
Okay. We already know that fact.

413
00:16:33,292 --> 00:16:34,360
We know there was a big surge

414
00:16:34,360 --> 00:16:36,095
that occurred
in a couple of pulses.

415
00:16:36,095 --> 00:16:36,628
We got bi

416
00:16:36,628 --> 00:16:39,965
directional flow preserved
in our sedimentary structures.

417
00:16:40,532 --> 00:16:43,068
Most of our surge was going
inland.

418
00:16:43,068 --> 00:16:45,204
Essentially,
that river was flowing backwards

419
00:16:45,204 --> 00:16:47,406
during the greatest
sedimentation

420
00:16:47,906 --> 00:16:49,341
episodes of that event.

421
00:16:49,341 --> 00:16:53,312
So we know that surge came
from the direction

422
00:16:53,312 --> 00:16:54,947
of the Western Interior Seaway.

423
00:16:54,947 --> 00:16:56,949
It was flowing westward
from an eastern direction.

424
00:16:57,649 --> 00:17:00,986

And that's kind of
like a tip off right there.

425
00:17:00,986 --> 00:17:02,855
It's a tsunami like wave.

426
00:17:02,855 --> 00:17:03,655
And it's turning out

427
00:17:03,655 --> 00:17:05,357
that the seismic waves arrived

428
00:17:05,357 --> 00:17:07,693
right around the time of
this wave

429
00:17:07,693 --> 00:17:09,495
that deposited
the Tanis sediments.

430
00:17:09,495 --> 00:17:13,232
So probably the seismic input
was what caused it,

431
00:17:13,232 --> 00:17:15,300
not a tsunami
from the impact site,

432
00:17:15,300 --> 00:17:17,136
but it's a seismic shaking.

433
00:17:17,136 --> 00:17:19,338
We're not going to get into that
too much with this one.

434
00:17:19,338 --> 00:17:20,339
But basically,

435
00:17:20,339 --> 00:17:22,141

this is what your cross-section
would look like,

436
00:17:22,141 --> 00:17:24,143
an idealized
cross-section of the site.

437
00:17:24,143 --> 00:17:27,079
Your white arrow out
is going to give your flow.

438
00:17:27,146 --> 00:17:30,482
The river easily documented
all at the site.

439
00:17:30,582 --> 00:17:32,651
Know you've got all
your typical said structures

440
00:17:32,651 --> 00:17:35,354
and then you've got
your opposite flow from

441
00:17:35,354 --> 00:17:36,822
the surge
would have been about ten

442
00:17:36,822 --> 00:17:38,891
and a half meters
and it would have filled it up

443
00:17:38,891 --> 00:17:40,559
like that, possibly more.

444
00:17:40,559 --> 00:17:42,594
But that's
what the fossil record shows us,

445
00:17:42,594 --> 00:17:45,197
and it could have been

even deeper than that.

446
00:17:45,197 --> 00:17:47,199
We've got
let's go back a little bit.

447
00:17:47,199 --> 00:17:50,903
We've got CPG boundary preserved
directly on top of the surge

448
00:17:50,903 --> 00:17:52,171
deposit here.

449
00:17:52,171 --> 00:17:54,907
We've got KPMG
boundary preserved here

450
00:17:55,074 --> 00:17:56,642
and the over bank deposit

451
00:17:56,642 --> 00:18:00,079
and then also at the edge
over at six at Brooke Butte,

452
00:18:00,079 --> 00:18:03,248
which is about one, 1.1,
1.2 kilometers to the north.

453
00:18:03,682 --> 00:18:05,584
So we've got KP boundary

454
00:18:05,584 --> 00:18:08,387
sediments
all over the place from site.

455
00:18:08,387 --> 00:18:09,354
And there it is, filling up.

456
00:18:10,322 --> 00:18:11,256

And we've

457
00:18:11,256 --> 00:18:14,293
actually got some of our Marine
fossils that show you.

458
00:18:14,293 --> 00:18:16,995
Yes, this is probably a surge
that originated from the seaway.

459
00:18:17,196 --> 00:18:19,198
We've got freshwater
organisms at. Right.

460
00:18:19,198 --> 00:18:20,265
Like the sturgeon.

461
00:18:20,265 --> 00:18:22,434
We've got this beautiful feather
which came from

462
00:18:22,434 --> 00:18:24,736
probably a bird or a man,
a raptor and dinosaur.

463
00:18:24,736 --> 00:18:27,072
We've got those mixed in
with Ammonites.

464
00:18:27,072 --> 00:18:28,574
It's a marine shelled mollusk.

465
00:18:28,574 --> 00:18:31,243
We've got sharks, mosasaurs,
different marine fish,

466
00:18:31,944 --> 00:18:35,581
marine farming, afra, and things
that just don't belong there.

467
00:18:35,581 --> 00:18:37,983
These don't exist in the Hell
Creek formation normally.

468
00:18:38,450 --> 00:18:40,719
There are two marine tongues
in the Hell Creek formation.

469
00:18:40,919 --> 00:18:42,554
But the fossils, the timing

470
00:18:42,554 --> 00:18:44,823
and the mode of preservation
don't match with the site.

471
00:18:44,823 --> 00:18:47,292
So there's no linkage there.

472
00:18:47,392 --> 00:18:49,194
So we'll talk about the animals
a little bit.

473
00:18:49,194 --> 00:18:52,798
The biota of Tanis
and the new insight into life

474
00:18:52,798 --> 00:18:54,333
at the end of the Cretaceous
based on that.

475
00:18:54,333 --> 00:18:55,601
So we've got our connection

476
00:18:55,601 --> 00:18:57,870
between the impact event
and the biota,

477
00:18:57,870 --> 00:19:00,839
and most of that biota

turns out to be fish.

478
00:19:00,839 --> 00:19:02,541
In this case, we've got a lot of

479
00:19:02,541 --> 00:19:04,576
we've got sturgeon,
we've got paddlefish,

480
00:19:04,576 --> 00:19:06,512
we've got at least three
new species of fish

481
00:19:06,512 --> 00:19:07,713
that are unnamed at this point.

482
00:19:07,713 --> 00:19:08,881
So we're already learning

483
00:19:08,881 --> 00:19:12,017
about the types of organisms
that existed back then.

484
00:19:12,985 --> 00:19:15,888
But we're going to talk about a
little more interesting things.

485
00:19:15,888 --> 00:19:17,523
They are now the pterosaurs.

486
00:19:17,523 --> 00:19:18,790
So these are winged reptiles.

487
00:19:18,790 --> 00:19:20,225
There's a flying reptiles.

488
00:19:20,225 --> 00:19:21,226
They existed back then.

489
00:19:21,226 --> 00:19:23,328
At the end of the Cretaceous,

490
00:19:23,328 --> 00:19:25,597
the Hell Creek formation
had only one type

491
00:19:25,597 --> 00:19:27,032
that we're aware of the
as dark it's

492
00:19:27,032 --> 00:19:28,433
that's the giant type

493
00:19:28,433 --> 00:19:30,302
Quetzalcoatlus
is one of the ones that's more

494
00:19:30,302 --> 00:19:32,571
well known
as the size of a small aircraft.

495
00:19:32,571 --> 00:19:35,607
So these are big pterosaurs.

496
00:19:35,607 --> 00:19:37,075
They're well known
around the world.

497
00:19:37,075 --> 00:19:39,044
This is a great example

498
00:19:39,044 --> 00:19:41,613
of the basics
of our knowledge of pterosaurs

499
00:19:41,613 --> 00:19:43,682
from their origin all the way
up to the extinction.

500
00:19:43,682 --> 00:19:45,617
We know a lot about pterosaurs.

501
00:19:45,617 --> 00:19:49,021
We've got plentiful remains
and they are sort of like,

502
00:19:49,354 --> 00:19:49,788
you know,

503
00:19:49,788 --> 00:19:51,456
one of the favorite things
to study,

504
00:19:51,456 --> 00:19:52,925
the one thing we don't know
a lot about

505
00:19:52,925 --> 00:19:54,459
is what were their eggs, babies,

506
00:19:54,459 --> 00:19:56,595
reproductive strategies
and etc..

507
00:19:56,895 --> 00:19:59,531
The embryos
are practically unknown.

508
00:20:00,265 --> 00:20:02,768
That is the temporal span
of our knowledge

509
00:20:02,768 --> 00:20:05,070
on pterosaur embryos,
not that much.

510
00:20:05,804 --> 00:20:09,007

We've got one
Terra Astro embryo.

511
00:20:09,575 --> 00:20:12,844
There are 18 embryos
for the on the occurrence.

512
00:20:13,345 --> 00:20:13,912
That's it.

513
00:20:13,912 --> 00:20:14,313
You know,

514
00:20:14,313 --> 00:20:16,114
that's
all there is in the entire world

515
00:20:16,114 --> 00:20:18,350
and none of them
from North America.

516
00:20:18,350 --> 00:20:20,686
The good part about the site
is the preservation

517
00:20:20,686 --> 00:20:22,988
potential is so good
because that rapid deposition

518
00:20:23,255 --> 00:20:25,357
that we are able to add
a data point to that

519
00:20:25,357 --> 00:20:28,293
and add the as darkens
to the end of the Cretaceous.

520
00:20:28,293 --> 00:20:32,164
So we expand this temporally
and taxonomic lee which delights

521
00:20:32,164 --> 00:20:32,898
us to no end.

522
00:20:34,066 --> 00:20:36,401
So ahead graphically,
this is where we are.

523
00:20:37,636 --> 00:20:41,039
Most of our carcass
tangle is going to be down here

524
00:20:41,273 --> 00:20:44,142
at the upper part
of the first surge pulse

525
00:20:44,276 --> 00:20:46,044
and the lower
part of the second pulse. That's

526
00:20:46,044 --> 00:20:48,113
where most of the organisms
are in this deposit.

527
00:20:48,347 --> 00:20:50,215
Although, as I mentioned,
some cross-cut

528
00:20:50,215 --> 00:20:52,985
the entire deposit
at an angle to the bedding plan.

529
00:20:52,985 --> 00:20:54,419
So there's stuff throughout

530
00:20:54,419 --> 00:20:56,822
that's
just your main concentration.

531

00:20:56,822 --> 00:20:59,758
The deposits capped by your Cape
Town dean.

532
00:20:59,758 --> 00:21:02,327
So you've got your pristine,
uninterrupted

533
00:21:02,494 --> 00:21:04,796
layer of impact debris.

534
00:21:04,796 --> 00:21:07,532
And the embryo comes
from right here within the upper

535
00:21:07,532 --> 00:21:10,802
two thirds of the deposit.

536
00:21:10,802 --> 00:21:12,004
And here it is.

537
00:21:12,004 --> 00:21:13,939
So at left, you have a view.

538
00:21:13,939 --> 00:21:15,440
It's about the size
of a hen's egg.

539
00:21:15,440 --> 00:21:17,476
This is a plain lite
view of the embryo.

540
00:21:17,476 --> 00:21:20,946
We can see the tangle of dark
brown bones there,

541
00:21:20,946 --> 00:21:22,814
which I'll show you
later, are nicely

542
00:21:22,814 --> 00:21:24,516
articulated in most cases

543
00:21:24,516 --> 00:21:27,519
a brown halo for the shell,
and it compares favorably

544
00:21:27,519 --> 00:21:29,721
with the embryos
that are found elsewhere.

545
00:21:29,755 --> 00:21:32,924
So it right is one of the more
famous embryos from Asia.

546
00:21:33,258 --> 00:21:35,761
And it's a beautiful
or if accurate embryo.

547
00:21:36,361 --> 00:21:38,130
And the mode of preservation

548
00:21:38,130 --> 00:21:41,566
and the style of folding
is very, very reminiscent of the

549
00:21:41,566 --> 00:21:42,267
Asian one.

550
00:21:42,267 --> 00:21:44,069
When we look at the Tanis one

551
00:21:44,069 --> 00:21:45,737
and here's a shot
that Dave Berman

552
00:21:45,737 --> 00:21:48,573
I got going with the laser
stimulated fluorescence,

553
00:21:48,573 --> 00:21:49,174
and you can see the

554
00:21:49,174 --> 00:21:51,243
bones come out
and you can actually see

555
00:21:51,410 --> 00:21:52,944
some of the articulation.

556
00:21:52,944 --> 00:21:53,612
So here you go.

557
00:21:53,612 --> 00:21:54,179
You've got your

558
00:21:54,179 --> 00:21:56,048
your upper arm
bone, your humerus,

559
00:21:56,048 --> 00:21:57,683
and you've
got your radius and owner

560
00:21:57,683 --> 00:22:00,719
and then the long wing elements
that are preserved there,

561
00:22:01,086 --> 00:22:02,788
they don't match anything
that should be there.

562
00:22:02,788 --> 00:22:05,190
They don't match the birds
or the dinosaurs.

563
00:22:05,390 --> 00:22:08,660
And the

the structure of the bones

564
00:22:08,894 --> 00:22:11,430
and the anatomy of this creature

565
00:22:12,064 --> 00:22:14,800
really only compares
favorably with the pterosaurs.

566
00:22:14,800 --> 00:22:16,835
So we're relatively confident

567
00:22:16,835 --> 00:22:18,603
and so is Davon,
when our coauthor,

568
00:22:18,603 --> 00:22:20,505
one of the world's
experts in pterosaurs,

569
00:22:20,505 --> 00:22:24,176
that this is a beautiful
as dark and pterosaur embryo.

570
00:22:24,843 --> 00:22:26,645
And so as scientists,

571
00:22:26,645 --> 00:22:27,546
we just have to keep picking,
picking,

572
00:22:27,546 --> 00:22:29,114
picking away at the details

573
00:22:29,114 --> 00:22:31,083
and figuring out
what we could find out.

574
00:22:31,083 --> 00:22:33,118

And with these samples

575
00:22:33,118 --> 00:22:35,053
and with the ejecta,
we ended up going

576
00:22:35,053 --> 00:22:36,955
to two of the most powerful

577
00:22:36,955 --> 00:22:39,224
synchrotron facilities
in the world.

578
00:22:39,224 --> 00:22:42,561
We went to Sorrell at Stanford
University and the Diamond

579
00:22:42,561 --> 00:22:47,332
Light Source in Oxford, UK, two
absolutely gorgeous facilities

580
00:22:47,332 --> 00:22:49,301
and I cannot say enough about

581
00:22:49,301 --> 00:22:52,304
how wonderful they were during
the analytical procedures.

582
00:22:53,004 --> 00:22:55,907
Here we are at the beamline,
scanning the specimens.

583
00:22:55,907 --> 00:22:57,576
We've got the beam pipe here

584
00:22:57,576 --> 00:22:59,845
coming out of the storage ring,
giving us our

585

00:22:59,845 --> 00:23:02,814
our lethal
synchrotron radiation.

586
00:23:02,814 --> 00:23:05,350
You don't want to be in there
when it's when it's operating.

587
00:23:05,650 --> 00:23:09,821
And we're able to find details
with these methods

588
00:23:10,555 --> 00:23:13,592
about the organisms
and their chemical makeup

589
00:23:13,759 --> 00:23:15,594
that you just
can't find otherwise.

590
00:23:15,594 --> 00:23:17,396
And this particular beamline

591
00:23:17,396 --> 00:23:19,831
enables us
to look at the chemical makeup

592
00:23:19,831 --> 00:23:22,868
and the spatial distribution
of those different chemicals

593
00:23:23,969 --> 00:23:26,104
at a molecular scale.

594
00:23:26,204 --> 00:23:28,573
And you're able to see
what does that organism made of?

595
00:23:28,974 --> 00:23:30,108
Is that material

596
00:23:30,108 --> 00:23:31,710
organically bound
or is it something

597
00:23:31,710 --> 00:23:33,812
that's an artifact
of the fossilization process?

598
00:23:34,179 --> 00:23:36,081
We're able
to take these things down

599
00:23:36,081 --> 00:23:37,249
and look at all

600
00:23:37,249 --> 00:23:39,618
these little things
that normally you can't see.

601
00:23:40,752 --> 00:23:42,521
And in this case, it's
the sulfur.

602
00:23:42,521 --> 00:23:46,425
So there's a blown up
view of the egg blue.

603
00:23:46,458 --> 00:23:49,127
You're looking at the bones
of the pterosaur.

604
00:23:49,161 --> 00:23:50,962
All of that yellow is sulfur.

605
00:23:50,962 --> 00:23:54,132
And the sulfur follows
the outline of your egg shell.

606

00:23:54,766 --> 00:23:57,402
The sulfur in this case is not
just sulfur.

607
00:23:57,402 --> 00:23:58,804
We'd be happy
if it was just sulfur.

608
00:23:58,804 --> 00:24:00,705
But in this case, it's not.

609
00:24:00,705 --> 00:24:02,808
Through the x ray absorption
spectroscopy,

610
00:24:02,808 --> 00:24:03,942
we're able to determine that

611
00:24:03,942 --> 00:24:07,345
all of the sulfur you see on the
screen was organically bound.

612
00:24:07,779 --> 00:24:09,181
That is not sulfur.

613
00:24:09,181 --> 00:24:11,917
That's a result
of the Fossilization process.

614
00:24:12,217 --> 00:24:12,984
It's not something that

615
00:24:12,984 --> 00:24:14,319
precipitated or something

616
00:24:14,319 --> 00:24:17,122
during the classification
of the outcrop.

617

00:24:17,322 --> 00:24:20,292
This is something that is tied
to the organism itself.

618
00:24:20,559 --> 00:24:22,928
Moreover, it's
probably tied to the egg shell

619
00:24:23,195 --> 00:24:25,297
because you would have had
organic sulfur

620
00:24:25,297 --> 00:24:26,898
associated
with the whole organism, but

621
00:24:26,898 --> 00:24:29,167
the egg shell would have been
a little bit more resilient.

622
00:24:29,167 --> 00:24:32,137
And we suspect that that sulfur
is probably tied

623
00:24:32,137 --> 00:24:35,740
to the cysteine
in the the eggshell proteins.

624
00:24:36,741 --> 00:24:38,743
We're going
to be looking further into that,

625
00:24:38,743 --> 00:24:39,744
going on to the shell.

626
00:24:39,744 --> 00:24:41,680
Here's some shots of the shell.

627
00:24:41,680 --> 00:24:44,115
And it turns out it's

actually a dual layered shell.

628
00:24:44,483 --> 00:24:46,151
This is a top down view.

629
00:24:46,151 --> 00:24:49,187
And here you can actually see
we're at the edge of the shell.

630
00:24:49,187 --> 00:24:51,389
There was a little bit
of a flake up that occurred.

631
00:24:51,723 --> 00:24:53,625
And you can see there's
the upper unit of the

632
00:24:53,625 --> 00:24:57,128
shell and down below is revealed
your lower unit of shell.

633
00:24:57,662 --> 00:25:00,131
And that's basically shows

634
00:25:00,131 --> 00:25:02,667
us a difference in texture,
a difference in composition.

635
00:25:03,134 --> 00:25:05,170
And you look a little bit
closer.

636
00:25:05,170 --> 00:25:06,905
You could get a closer view

637
00:25:06,905 --> 00:25:09,407
of the upper
unit of the shell top down.

638

00:25:09,941 --> 00:25:10,542
And there it is

639
00:25:10,542 --> 00:25:13,445
actually compared to a soft
shell, gecko, egg, modern day.

640
00:25:13,778 --> 00:25:15,881
And you can see them compared
side by side,

641
00:25:16,047 --> 00:25:17,916
somewhat similar to each other.

642
00:25:17,916 --> 00:25:19,050
You look at them, edge on it,

643
00:25:19,050 --> 00:25:20,352
can get a little bit of a better
view.

644
00:25:20,352 --> 00:25:22,687
This is sort of an oblique
top down view.

645
00:25:22,721 --> 00:25:24,689
You can see that
flaked edge there.

646
00:25:24,689 --> 00:25:26,625
And there's a direct
cross-section

647
00:25:26,625 --> 00:25:27,058
where you can see

648
00:25:27,058 --> 00:25:29,361
a beautiful distinction
between the upper and lower

649
00:25:29,361 --> 00:25:31,496
layers,
both in color and texture.

650
00:25:32,163 --> 00:25:34,933
And that's even more illustrated
by the ECM images,

651
00:25:34,933 --> 00:25:36,167
because you can see

652
00:25:36,167 --> 00:25:39,271
sort of this haphazard,
grainy texture of the upper unit

653
00:25:39,504 --> 00:25:40,272
and the lower unit.

654
00:25:40,272 --> 00:25:43,542
You could even see little
reminiscent structures of the

655
00:25:44,109 --> 00:25:46,077
sort of parallel bedded

656
00:25:47,479 --> 00:25:48,647
structure
that would have been there,

657
00:25:48,647 --> 00:25:50,682
sort of
like the laminated structure.

658
00:25:50,682 --> 00:25:55,287
And when you look at the seam
and the elemental difference

659
00:25:55,287 --> 00:25:57,355
between the upper and lower

layers, the textural difference,

660
00:25:57,656 --> 00:25:59,558
it actually compares
very favorably

661
00:25:59,558 --> 00:26:00,959
to the modern eggshell
there as well.

662
00:26:00,959 --> 00:26:04,095
That's a soft
shelled snake egg, modern day.

663
00:26:04,663 --> 00:26:08,667
And as we went through
this specimen, we saw more

664
00:26:08,667 --> 00:26:09,401
and more features

665
00:26:09,401 --> 00:26:10,936
that signified that

666
00:26:10,936 --> 00:26:14,005
this had a soft shelled egg
similar to the early pterosaurs.

667
00:26:14,239 --> 00:26:16,007
But now we know that
that feature existed

668
00:26:16,007 --> 00:26:19,311
into the latest Cretaceous,
which no one knew until now.

669
00:26:21,112 --> 00:26:23,014
And here we go. All right.

670

00:26:23,014 --> 00:26:24,983
This is another beautiful view
of the skeleton.

671
00:26:24,983 --> 00:26:27,018
So this is a zoomed in view.

672
00:26:27,252 --> 00:26:30,555
We can see
the shell is outlined in zinc.

673
00:26:31,289 --> 00:26:33,625
We've got strontium
outlining the bones.

674
00:26:33,959 --> 00:26:35,760
And the one thing to

675
00:26:35,760 --> 00:26:36,328
remember here

676
00:26:36,328 --> 00:26:39,931
is that the bones of
this are really well ossified.

677
00:26:40,131 --> 00:26:42,300
They're well-preserved.
Well, ossified.

678
00:26:42,634 --> 00:26:45,904
This was probably a late term
embryo based on

679
00:26:46,338 --> 00:26:47,739
how many of the bones
were ossified,

680
00:26:47,739 --> 00:26:50,075
based on the articulation,
based on the size.

681
00:26:50,075 --> 00:26:51,810
Probably was a late term embryo.

682
00:26:51,810 --> 00:26:54,012
And when you see that
much ossification occurring

683
00:26:54,012 --> 00:26:55,013
late term,

684
00:26:55,013 --> 00:26:58,383
that probably is an indication
that it would have been

685
00:26:59,551 --> 00:27:01,786
better able to fend for itself
once it hatched.

686
00:27:01,987 --> 00:27:04,556
It probably was not going to be
helpless once it hatched.

687
00:27:05,357 --> 00:27:07,959
And when looking
at some of the dimensions

688
00:27:08,059 --> 00:27:10,762
provided by other studies,
this is where ours plots in

689
00:27:11,363 --> 00:27:12,631
nature at all.

690
00:27:12,631 --> 00:27:14,532
Did a beautiful study

691
00:27:14,532 --> 00:27:16,835
on precocious reality

and pterosaurs recently

692
00:27:17,102 --> 00:27:18,803
and the tannis embryo.

693
00:27:18,803 --> 00:27:20,071
Some of the

694
00:27:20,271 --> 00:27:23,408
arm dimensions of that embryo
actually plots very close

695
00:27:23,408 --> 00:27:26,678
to the embryonic pterosaurs
or hatchling pterosaurs, rather,

696
00:27:27,045 --> 00:27:30,215
and sort of close
to the trend line

697
00:27:30,215 --> 00:27:33,251
for the non hatchling
pterosaurs as well. So.

698
00:27:33,251 --> 00:27:35,120
Long story short,

699
00:27:35,120 --> 00:27:36,254
some of the preliminary data

700
00:27:36,254 --> 00:27:39,724
about the wings shows us
that it is at least compatible

701
00:27:40,058 --> 00:27:41,860
with other pterosaur specimens

702
00:27:41,860 --> 00:27:43,628
that would have been

capable of flight.

703
00:27:43,628 --> 00:27:46,665
This probably would have been
a precocious organism,

704
00:27:47,032 --> 00:27:49,300
and that's a good advantage,

705
00:27:49,300 --> 00:27:50,769
especially if you're going to be

706
00:27:50,769 --> 00:27:52,070
in an area
where things want to eat you.

707
00:27:53,171 --> 00:27:54,372
That's how
big the thing would have been

708
00:27:54,372 --> 00:27:56,975
when it was hatched. So
this is the first reconstruction

709
00:27:57,175 --> 00:27:58,843
based on the fossil.

710
00:27:58,843 --> 00:28:02,280
And this shows the articulated,
reconstructed skeleton.

711
00:28:02,947 --> 00:28:04,816
The bones
that were not present in

712
00:28:04,816 --> 00:28:06,117
the original were reconstructed

713
00:28:06,117 --> 00:28:09,154

based on the proportions
of as dark and pterosaurs.

714
00:28:09,320 --> 00:28:11,623
But we had representatives
of a lot of these bones.

715
00:28:11,623 --> 00:28:15,827
So it is a faithful reproduction
of of how it would have looked

716
00:28:15,827 --> 00:28:18,830
if it got to hatch a little bit
skinnier than if it hatched.

717
00:28:19,664 --> 00:28:21,566
But this is how this has been

718
00:28:21,566 --> 00:28:24,235
basically
the size of a bat one hatched.

719
00:28:24,235 --> 00:28:26,404
So pterosaurs. Wonderful.

720
00:28:26,438 --> 00:28:28,673
Dinosaurs are even better.

721
00:28:28,907 --> 00:28:29,974
I think maybe.

722
00:28:29,974 --> 00:28:32,243
I think they're on par
with each other personally.

723
00:28:32,243 --> 00:28:33,311
So let's talk
about the dinosaurs.

724

00:28:33,311 --> 00:28:36,081
From the deposit
back to our trusty column.

725
00:28:36,081 --> 00:28:39,417
We already have our
our kapag boundary clay there.

726
00:28:40,051 --> 00:28:43,388
We've got our main concentration
of fossils down there.

727
00:28:43,388 --> 00:28:45,390
Where do the dinosaurs
occur in the deposit?

728
00:28:45,390 --> 00:28:47,692
That's something we really
haven't gotten into much yet.

729
00:28:47,692 --> 00:28:48,827
Two places.

730
00:28:48,827 --> 00:28:52,497
First, we've got actual
dinosaur remains in the deposit

731
00:28:52,564 --> 00:28:54,332
and the ones
we're going to talk about here

732
00:28:54,332 --> 00:28:56,901
come from right about there
in upper unit one

733
00:28:57,001 --> 00:28:59,370
at the very top
of the very first search pulse.

734
00:28:59,971 --> 00:29:02,173

And then we've got
a very cool thing that occurs.

735
00:29:02,507 --> 00:29:06,411
We've got trace fossils in the
paleo surface right under Tanis.

736
00:29:06,711 --> 00:29:08,913
So essentially
when you've got this surge

737
00:29:08,913 --> 00:29:10,815
that came in
and covered that riverbank

738
00:29:10,815 --> 00:29:12,484
and covered that point bar,

739
00:29:12,484 --> 00:29:15,386
it covered the active paleo
surface of the late Cretaceous,

740
00:29:15,553 --> 00:29:17,122
whatever it was there
got covered.

741
00:29:17,122 --> 00:29:19,157
And in this case,
we had footprints

742
00:29:19,157 --> 00:29:21,259
in that paleo surface
that got covered

743
00:29:21,259 --> 00:29:23,928
by a beautiful contiguous
layer of sediment.

744
00:29:24,129 --> 00:29:26,297
These were not older footprints

that were re-exposed.

745
00:29:26,297 --> 00:29:29,067
These are not footprints
that had formed any other way.

746
00:29:29,067 --> 00:29:31,169
This is
latest Cretaceous material.

747
00:29:32,470 --> 00:29:34,205
And here's how that shakes out.

748
00:29:34,205 --> 00:29:36,274
So at right,
you can actually see this

749
00:29:36,274 --> 00:29:37,709
beautiful angled paleo screen.

750
00:29:37,709 --> 00:29:39,811
You actually see
the angle of that point bar.

751
00:29:40,512 --> 00:29:43,047
And this is the exposed surface
because it's trampled

752
00:29:43,047 --> 00:29:44,282
all over the place. It's
not smooth.

753
00:29:44,282 --> 00:29:45,750
It's like a game trail.

754
00:29:45,750 --> 00:29:46,251
It's almost like you

755
00:29:46,251 --> 00:29:48,286

go to a cow ranch
or something today

756
00:29:48,286 --> 00:29:50,655
and then that is directly
overlain by that

757
00:29:51,322 --> 00:29:54,492
veneer of the surge deposit,
very different lithology

758
00:29:54,926 --> 00:29:58,863
and the basil sands
of that surge deposit

759
00:29:58,863 --> 00:30:02,767
fill all of those cracks
and then footprints

760
00:30:03,067 --> 00:30:05,170
and totally different
sedimentation.

761
00:30:05,170 --> 00:30:08,106
And when that dries
just a little bit in the sun,

762
00:30:08,106 --> 00:30:09,207
it just pops right off.

763
00:30:09,207 --> 00:30:11,309
And you've got all of the
beautiful tracks beneath.

764
00:30:11,943 --> 00:30:13,011
And here we've got some of them.

765
00:30:13,011 --> 00:30:17,081
There's a three toed track
from one of the dinosaurs,

766
00:30:17,415 --> 00:30:20,118
and we've got the surge deposit
resting right on top.

767
00:30:20,552 --> 00:30:23,288
And, you know,
what's the timeline of this?

768
00:30:23,288 --> 00:30:26,024
You know, what we argue is
this is probably not too long

769
00:30:26,024 --> 00:30:28,126
before impact,
not directly before impact.

770
00:30:28,126 --> 00:30:29,360
If it was the same day,

771
00:30:29,360 --> 00:30:30,895
it would have been
a muddy deposit

772
00:30:30,895 --> 00:30:32,864
and your surge
would have washed that away

773
00:30:32,864 --> 00:30:35,133
if it was too long
before the impact

774
00:30:35,266 --> 00:30:37,068
in this subtropical environment

775
00:30:37,068 --> 00:30:39,137
that would have been raining
all the time.

776

00:30:39,137 --> 00:30:41,673
Those would not have lasted
well in the record.

777
00:30:41,673 --> 00:30:45,510
So basically they would have
left these tracks in the mud.

778
00:30:45,677 --> 00:30:47,612
The mud would have dried
for long enough

779
00:30:47,612 --> 00:30:49,614
that they would not have been
washed away by the surge,

780
00:30:50,148 --> 00:30:51,249
but it wouldn't
have been too long.

781
00:30:51,249 --> 00:30:53,585
So we're talking
weeks to months, probably.

782
00:30:54,552 --> 00:30:56,754
Near some of
those beautiful tracks, theropod

783
00:30:56,754 --> 00:30:58,389
dinosaur tracks.

784
00:30:58,389 --> 00:31:00,925
These are the carnivorous
dinosaurs.

785
00:31:00,925 --> 00:31:02,427
Dave Burnham's hand for scale.

786
00:31:02,427 --> 00:31:02,660
Next,

787
00:31:02,660 --> 00:31:04,863
that beautiful trade,
tactile print there we got on

788
00:31:04,896 --> 00:31:06,631
at the moment over there.

789
00:31:06,631 --> 00:31:09,033
So we've got the meat eaters
represented.

790
00:31:09,701 --> 00:31:12,937
These are probably
from herbivorous dinosaurs,

791
00:31:12,937 --> 00:31:15,340
but they're not yet determined
which taxa they're from.

792
00:31:15,340 --> 00:31:16,241
But, you know,

793
00:31:16,241 --> 00:31:17,876
the fact of the matter is,

794
00:31:17,876 --> 00:31:19,911
we've got a diverse
assortment of dinosaurs,

795
00:31:20,111 --> 00:31:20,478
so we don't

796
00:31:20,478 --> 00:31:23,615
necessarily have to identify
the specific taxa right now.

797
00:31:23,815 --> 00:31:25,683
We've got to identify

more fat types.

798
00:31:25,683 --> 00:31:27,619
And that gives us
an idea of species richness.

799
00:31:27,619 --> 00:31:30,355
You know, how rich were
the dinosaurs right at the end?

800
00:31:30,588 --> 00:31:32,557
This gives us a very good idea.

801
00:31:32,557 --> 00:31:33,091
Not only that,

802
00:31:33,091 --> 00:31:36,728
we also have infant dinosaur
tracks, so infant hadrosaur.

803
00:31:36,928 --> 00:31:38,196
And we've got infant either

804
00:31:38,196 --> 00:31:40,865
serotypes in
or it could possibly be mammal,

805
00:31:41,566 --> 00:31:44,202
but it's probably Sarah Thompson
based on the man's prints.

806
00:31:44,569 --> 00:31:46,271
And when you look at the scale,
these things are about

807
00:31:46,271 --> 00:31:48,373
the size of a silver dollar
or a golf ball.

808

00:31:48,573 --> 00:31:49,774
Very, very small.

809
00:31:49,774 --> 00:31:52,176
That's from a baby
that would be about that big

810
00:31:52,176 --> 00:31:55,680
and that would have been from
that year's breeding season.

811
00:31:55,880 --> 00:31:56,981
So those are babies

812
00:31:56,981 --> 00:31:59,150
from the last breeding
season of the Cretaceous.

813
00:31:59,150 --> 00:32:01,219
And you know that
they were living there

814
00:32:01,452 --> 00:32:02,820
not too long before the surge.

815
00:32:04,522 --> 00:32:07,225
So about the triceratops.

816
00:32:07,225 --> 00:32:08,626
Yes, they existed in the area

817
00:32:08,626 --> 00:32:10,795
and yes,
they died in the area as well.

818
00:32:10,795 --> 00:32:13,798
So while excavating
into the surge deposit,

819

00:32:14,265 --> 00:32:17,368
we identified some soft tissue
associated with those.

820
00:32:17,635 --> 00:32:21,773
So we ordered reported a partial
hip from a set of topsy

821
00:32:21,773 --> 00:32:24,108
and in that deposit
and some soft tissue associated.

822
00:32:24,509 --> 00:32:25,510
Well we wanted to go back

823
00:32:25,510 --> 00:32:28,813
and find more if there was more
there and more there was.

824
00:32:29,547 --> 00:32:30,615
Here's Riley.

825
00:32:30,615 --> 00:32:34,953
We're one of the grad students
at FSU at initial contact

826
00:32:34,953 --> 00:32:38,856
with this beautiful, scaly
pattern, from what we now know

827
00:32:38,856 --> 00:32:40,024
is Sarah Thompson.

828
00:32:40,024 --> 00:32:42,527
At that point, we knew
it was from a large dinosaur.

829
00:32:42,527 --> 00:32:43,227
And here we have

830
00:32:43,227 --> 00:32:45,463
Lauren virtually
continuing that excavation

831
00:32:45,630 --> 00:32:47,432
and this protuberance
on the top of the very,

832
00:32:47,432 --> 00:32:48,866
very large scale

833
00:32:48,866 --> 00:32:51,536
that is very similar to what
you would see in triceratops.

834
00:32:51,769 --> 00:32:53,471
I've not seen it
in any other Sarah autopsy.

835
00:32:53,471 --> 00:32:56,341
And personally, it's almost
certainly from a triceratops.

836
00:32:56,507 --> 00:32:58,409
Like, oh, well,
how much is actually there?

837
00:32:59,377 --> 00:33:01,813
We ended up getting lots of skin
from this animal.

838
00:33:01,980 --> 00:33:04,549
We got a selection of bones,
which shows us that

839
00:33:04,549 --> 00:33:07,051
we had an associated skeleton
at one point in time.

840

00:33:07,652 --> 00:33:09,787
And that animal probably died
right there,

841
00:33:09,787 --> 00:33:12,090
probably was not transported
in like we originally thought

842
00:33:12,390 --> 00:33:14,058
with that many bones
representing

843
00:33:14,058 --> 00:33:16,728
that much of the skeleton know
probably not transported in

844
00:33:17,228 --> 00:33:18,796
but died before the impact.

845
00:33:18,796 --> 00:33:20,932
This was not something
that was part of the

846
00:33:20,932 --> 00:33:22,967
asteroid impact at the end.

847
00:33:22,967 --> 00:33:24,168
We had a lot of decay.

848
00:33:24,168 --> 00:33:25,870
The bones were disarticulated

849
00:33:25,870 --> 00:33:29,640
and this animal probably died
weeks, two months before impact.

850
00:33:29,707 --> 00:33:31,709
Again, like with the trackways,

851

00:33:31,709 --> 00:33:34,312
you're not going to have
this die years before impact

852
00:33:34,512 --> 00:33:37,115
because all that soft tissue
would have been decayed away.

853
00:33:37,448 --> 00:33:40,051
You would not have
had an opportunity to rework it.

854
00:33:40,051 --> 00:33:42,353
So it was not a fossil
at that time and reworked.

855
00:33:42,353 --> 00:33:44,856
So we're looking at probably
weeks to months before impact.

856
00:33:45,089 --> 00:33:46,491
So sadly,

857
00:33:46,491 --> 00:33:50,028
that was not something that died
in the impact search.

858
00:33:50,595 --> 00:33:53,731
But we did find something
that probably was.

859
00:33:54,499 --> 00:33:56,667
So here's some of the new stuff.

860
00:33:56,667 --> 00:33:58,069
We've got Dave Burnham's thumb

861
00:33:58,069 --> 00:34:01,372
for scale next to soft tissue
associated with bones

862
00:34:01,839 --> 00:34:04,909
that later turned out to be
from a dinosaur.

863
00:34:05,343 --> 00:34:07,979
And after much digging,
this is what the sediment

864
00:34:07,979 --> 00:34:09,313
looks like when you start.

865
00:34:09,313 --> 00:34:12,316
You know,
it's really this awful mess

866
00:34:12,316 --> 00:34:13,584
and you have to
make sense of this

867
00:34:13,584 --> 00:34:16,320
and you have to do a very
detailed excavation over time.

868
00:34:16,954 --> 00:34:18,022
We ended up revealing

869
00:34:19,023 --> 00:34:22,326
a herbivorous dinosaur
in that deposit, and here we are

870
00:34:22,326 --> 00:34:24,395
delineating the block
with a herbivorous dinosaur.

871
00:34:24,429 --> 00:34:26,564
There's actually a palm
frond over here,

872

00:34:26,564 --> 00:34:28,699
and we're
delineating the creature.

873
00:34:28,699 --> 00:34:30,868
This is the outline
of the rear leg.

874
00:34:30,868 --> 00:34:34,072
So we have the thigh
going to the calf.

875
00:34:34,072 --> 00:34:35,706
We've got the gastrocnemius
would have been there.

876
00:34:35,706 --> 00:34:38,943
We've got the ankle and the toes
all the way down to the claws.

877
00:34:39,510 --> 00:34:43,081
And this animal was preserved
in such a way

878
00:34:43,414 --> 00:34:44,715
that you had these

879
00:34:44,715 --> 00:34:46,851
three dimensional skin
impressions

880
00:34:46,851 --> 00:34:48,920
over the articulated skeleton,

881
00:34:48,920 --> 00:34:52,356
meaning this was not decayed
prior to impact.

882
00:34:52,356 --> 00:34:54,258
It was not decayed

prior to deposition.

883
00:34:54,258 --> 00:34:56,060
It was beautifully preserved.

884
00:34:56,060 --> 00:34:58,029
And we did not know
exactly what it was we know

885
00:34:58,029 --> 00:34:59,464
was a herbivorous dinosaur.

886
00:34:59,464 --> 00:35:00,731
We narrowed it down.

887
00:35:00,731 --> 00:35:02,934
It's probably either
from a packing surplus store

888
00:35:03,067 --> 00:35:04,802
or a vessel, a saw.

889
00:35:04,802 --> 00:35:05,336
So those are two

890
00:35:05,336 --> 00:35:08,406
herbivorous dinosaurs,
sort of like a gazelle echo more

891
00:35:08,406 --> 00:35:09,841
from the Hell Creek landscape.

892
00:35:09,841 --> 00:35:12,777
And they would have been
gorgeous little creatures,

893
00:35:12,777 --> 00:35:15,346
but we weren't quite sure
which type it was.

894
00:35:15,980 --> 00:35:17,915
So we dug deeper,

895
00:35:17,915 --> 00:35:20,751
figuratively speaking,
and did some micro CT work.

896
00:35:20,785 --> 00:35:24,288
These are micro TS,
literally a digital dissection

897
00:35:24,555 --> 00:35:26,023
of this dinosaur.

898
00:35:26,023 --> 00:35:28,259
So this is like a dinosaur CSI.

899
00:35:28,259 --> 00:35:31,295
This is the beautifully
articulated toe of that dinosaur

900
00:35:31,462 --> 00:35:34,232
inside the three dimensional
fossil skin envelope.

901
00:35:34,432 --> 00:35:36,267
So you've got
all the digits of the toe,

902
00:35:36,267 --> 00:35:39,370
you've got the claw here,
you've got the ankle at right.

903
00:35:39,370 --> 00:35:40,872
You can see the leg

904
00:35:40,872 --> 00:35:42,140
partially flexed

905
00:35:42,140 --> 00:35:44,308
and you can see some breaks
in the leg

906
00:35:44,308 --> 00:35:45,943
that are from Fossilization.

907
00:35:45,943 --> 00:35:48,112
But there are some green stick
fractures in that.

908
00:35:48,112 --> 00:35:50,781
Those green stick fractures
are from the time of death

909
00:35:50,781 --> 00:35:53,050
before Fossilization
So it actually had trauma

910
00:35:53,384 --> 00:35:55,052
before Fossilization

911
00:35:55,052 --> 00:35:56,053
And this

912
00:35:56,053 --> 00:35:58,990
turns out to be from a dinosaur
called a festival source.

913
00:35:59,157 --> 00:36:01,125
That's what this thing was from.

914
00:36:01,125 --> 00:36:04,462
And here we've got a compound
fracture of the femur

915
00:36:04,462 --> 00:36:05,930
from before death,

916
00:36:05,930 --> 00:36:08,399
and we've got all these
beautiful skin impressions

917
00:36:08,633 --> 00:36:08,799
there.

918
00:36:08,799 --> 00:36:11,102
We've got the top of the foot
with these overlapping

919
00:36:11,102 --> 00:36:13,104
screw scales
like you'd see in a chicken

920
00:36:13,337 --> 00:36:16,641
or an ostrich foot today,
just like that.

921
00:36:17,074 --> 00:36:20,111
And here we have
it, 66 million years old,

922
00:36:20,344 --> 00:36:23,948
preserved in this dinosaur
that most likely experienced

923
00:36:23,948 --> 00:36:26,083
the worst day that a dinosaur
ever could experience.

924
00:36:26,250 --> 00:36:28,052
That dinosaur probably witnessed

925
00:36:28,052 --> 00:36:30,254
the impact event in its own
special way.

926

00:36:31,189 --> 00:36:33,324
That's also teaching us
new things about this resource,

927
00:36:33,491 --> 00:36:35,526
in addition
to teaching us about the impact.

928
00:36:35,526 --> 00:36:37,361
Because the scale patterns
we're seeing on

929
00:36:37,361 --> 00:36:39,697
this leg are scale
patterns we've never seen before

930
00:36:39,864 --> 00:36:41,599
in a herbivorous dinosaur.

931
00:36:41,599 --> 00:36:44,602
So we're able
to actually reconstruct better

932
00:36:44,602 --> 00:36:48,306
than before the appearance
of the leg of a Tesla store,

933
00:36:48,639 --> 00:36:49,674
because we've got these

934
00:36:49,674 --> 00:36:51,576
very elongated,
tubercular scales,

935
00:36:51,576 --> 00:36:52,743
which probably would have

936
00:36:52,743 --> 00:36:55,880
equated to some sort
of a pattern of color

937
00:36:55,880 --> 00:36:57,582
or something like that
in the animal.

938
00:36:57,582 --> 00:36:59,116
They at least would have been
a texture pattern

939
00:36:59,116 --> 00:37:00,751
that would be visible
on the animal,

940
00:37:00,751 --> 00:37:02,420
possibly a form of camouflage.

941
00:37:02,420 --> 00:37:04,021
No one knew
they had that before.

942
00:37:04,021 --> 00:37:06,023
So because of the preservation
here,

943
00:37:06,023 --> 00:37:07,525
we're actually able to determine

944
00:37:07,525 --> 00:37:08,926
new things about this dinosaur.

945
00:37:10,061 --> 00:37:12,763
And then we have to go
through our list of our dinucci.

946
00:37:12,964 --> 00:37:14,966
What caused the death
of this thing?

947
00:37:15,833 --> 00:37:18,102

We don't want to jump
to conclusions and say, Yeah,

948
00:37:18,102 --> 00:37:20,238
yeah, this is something that was
brought down by the impact.

949
00:37:20,238 --> 00:37:20,838
We're scientists.

950
00:37:20,838 --> 00:37:22,540
We want to figure out
and weed out

951
00:37:22,540 --> 00:37:24,742
what is incompatible
with what we're looking at.

952
00:37:24,742 --> 00:37:27,812
Predation
could have been preyed upon.

953
00:37:27,812 --> 00:37:28,346
You know,

954
00:37:28,346 --> 00:37:32,250
lots of herbivores are in this
case, it's not well-supported

955
00:37:32,250 --> 00:37:33,284
by the fossil.

956
00:37:33,284 --> 00:37:34,485
We don't see tooth marks.

957
00:37:34,485 --> 00:37:36,654
We don't see anything
that indicates that it was

958

00:37:37,388 --> 00:37:39,423
either partially
or completely consumed.

959
00:37:39,423 --> 00:37:39,824
You know,

960
00:37:39,824 --> 00:37:41,292
we don't see evidence

961
00:37:41,292 --> 00:37:44,862
that a predator engaged
this animal or shed the teeth of

962
00:37:44,862 --> 00:37:46,530
the predator.
You see those sometimes two.

963
00:37:46,530 --> 00:37:48,032
We don't see that.

964
00:37:48,232 --> 00:37:49,066
How about disease?

965
00:37:49,066 --> 00:37:49,834
Was a disease

966
00:37:49,834 --> 00:37:51,335
could of died
right before impact

967
00:37:51,335 --> 00:37:53,904
maybe a day before a week
before a disease or animal?

968
00:37:54,639 --> 00:37:57,908
Well, Paul Barrett
and other people

969

00:37:57,908 --> 00:37:59,710
actually
have examined the specimen,

970
00:37:59,710 --> 00:38:03,314
and they they agree with us
that there's no obvious

971
00:38:03,314 --> 00:38:05,650
evidence of disease
associated with the leg.

972
00:38:06,384 --> 00:38:08,452
It looks like it was an animal
in good health.

973
00:38:08,452 --> 00:38:10,921
It looks like the animal
probably,

974
00:38:10,921 --> 00:38:12,990
you know,
was just a normal average

975
00:38:12,990 --> 00:38:14,592
sessile sort
just living out its life.

976
00:38:14,592 --> 00:38:16,861
We don't see any obvious
signs of a bad disease,

977
00:38:16,861 --> 00:38:17,995
so probably not disease.

978
00:38:19,930 --> 00:38:20,998
Okay, how about trauma?

979
00:38:20,998 --> 00:38:22,900
I just mentioned trauma.

We do have trauma.

980
00:38:22,900 --> 00:38:24,802
Yes, we've got green stick
fractures.

981
00:38:24,802 --> 00:38:27,071
We've got fractures
that occurred at the time

982
00:38:27,071 --> 00:38:28,272
or right around
the time of death.

983
00:38:28,272 --> 00:38:29,106
Good. Okay.

984
00:38:29,106 --> 00:38:31,542
That gives us
a little bit of evidence there.

985
00:38:31,542 --> 00:38:33,778
And could
this have been contemporaneous?

986
00:38:34,512 --> 00:38:35,546
It's compatible.

987
00:38:35,546 --> 00:38:38,482
Now, as a scientist,
I'm not going to say yes, 100%.

988
00:38:38,549 --> 00:38:41,352
We do have an animal
that died in the impact search.

989
00:38:41,652 --> 00:38:43,854
Is it compatible? Absolutely.

990

00:38:43,854 --> 00:38:45,790
Because we've already weeded out
some of the most

991
00:38:45,790 --> 00:38:48,392
obvious causes of death
and it's compatible

992
00:38:48,592 --> 00:38:51,629
that it could possibly plausibly
have been

993
00:38:52,129 --> 00:38:54,298
a victim of that impact surge.

994
00:38:54,632 --> 00:38:56,667
It did not decay before burial.

995
00:38:56,667 --> 00:38:58,903
That's that's
one good point of evidence.

996
00:38:59,837 --> 00:39:03,641
So that is really kind of an
exciting thing to think about.

997
00:39:03,641 --> 00:39:05,910
This creature could actually
have experienced that event

998
00:39:06,210 --> 00:39:09,714
this rather than thinking,
Oh yeah, the impact caused all

999
00:39:09,714 --> 00:39:10,948
this extinction.

1000
00:39:10,948 --> 00:39:13,651
You're thinking, Wow,
how did the impact affect

1001
00:39:13,651 --> 00:39:15,186
the life
of this single creature?

1002
00:39:15,186 --> 00:39:17,221
And that brings it down
to kind of like a human level.

1003
00:39:18,189 --> 00:39:19,623
Now back to the impact itself.

1004
00:39:19,623 --> 00:39:22,426
Let's talk about what the impact
tells us about the impact.

1005
00:39:23,494 --> 00:39:25,162
The ejecta spirals,
the beautiful ones

1006
00:39:25,162 --> 00:39:28,966
that are totally preserved in
glass,

1007
00:39:28,966 --> 00:39:31,602
that are not altered
at all into clay,

1008
00:39:31,602 --> 00:39:33,871
have a little bit
more to tell us.

1009
00:39:33,871 --> 00:39:34,772
They're not just pretty.

1010
00:39:34,772 --> 00:39:36,841
They actually have data
to provide.

1011

00:39:36,841 --> 00:39:38,576
This is the exterior.
We actually still have

1012
00:39:38,576 --> 00:39:40,544
some pieces of amber
adhering to those.

1013
00:39:40,544 --> 00:39:43,013
There's the interior
with some beautiful gas bubbles

1014
00:39:43,013 --> 00:39:46,484
in there like we typically will
see in the impact melt glass.

1015
00:39:46,951 --> 00:39:50,254
I'm astounded at the beauty
of the interior of this thing

1016
00:39:50,254 --> 00:39:51,889
because when you look at that
glass,

1017
00:39:51,889 --> 00:39:52,590
you can just

1018
00:39:52,590 --> 00:39:54,091
imagine the day
that it was flying

1019
00:39:54,091 --> 00:39:55,426
through the air
out of the crater,

1020
00:39:55,426 --> 00:39:57,595
out of the atmosphere
and solidifying,

1021
00:39:57,862 --> 00:39:59,797

you know,
as a little piece of glass.

1022
00:39:59,797 --> 00:40:02,666
But there's stuff in there
that is really important

1023
00:40:02,666 --> 00:40:05,870
to us as scientists,
and that's the inclusions.

1024
00:40:06,203 --> 00:40:09,840
We found bits of rocky debris
in several of these

1025
00:40:10,241 --> 00:40:11,942
that we're like, okay.

1026
00:40:11,942 --> 00:40:13,677
Just like you see an insect,
an amber.

1027
00:40:13,677 --> 00:40:16,480
Now we're seeing a piece of rock
inside the glass.

1028
00:40:16,680 --> 00:40:17,882
Perfectly preserved.

1029
00:40:17,882 --> 00:40:19,884
What's that going to tell us
about the impact?

1030
00:40:19,884 --> 00:40:20,885
There's a little nugget there.

1031
00:40:20,885 --> 00:40:23,621
There are all these
little dirty nuggets in there.

1032
00:40:23,621 --> 00:40:25,122
Every single speck

1033
00:40:25,122 --> 00:40:26,390
that takes away from this
beautiful

1034
00:40:26,390 --> 00:40:28,859
clear
glass is a piece of debris.

1035
00:40:28,859 --> 00:40:30,961
And that's essentially
the equivalent

1036
00:40:31,262 --> 00:40:32,963
of sending someone back in time

1037
00:40:32,963 --> 00:40:35,166
with a sample vial
to the point of impact,

1038
00:40:35,399 --> 00:40:37,601
collecting a sample,
bottling it up

1039
00:40:37,802 --> 00:40:40,137
and perfectly preserving it
for scientists right now.

1040
00:40:40,404 --> 00:40:42,373
And that's like research gold.

1041
00:40:42,373 --> 00:40:44,141
So what we found

1042
00:40:44,141 --> 00:40:46,644
is that almost
all of these little un melted

1043
00:40:46,644 --> 00:40:50,881
nuggets are enriched
in strontium and calcium, and

1044
00:40:50,881 --> 00:40:53,717
they are parts of the carbonate
platform of the Yucatan.

1045
00:40:53,951 --> 00:40:57,154
They're part of that limestone
platform that got hit

1046
00:40:57,955 --> 00:40:59,890
and got thrown into the air.

1047
00:40:59,890 --> 00:41:02,059
These are pieces
that didn't melt all the way.

1048
00:41:02,059 --> 00:41:03,360
We expect that.

1049
00:41:03,360 --> 00:41:05,930
It's very cool, very amazing.

1050
00:41:05,930 --> 00:41:07,798
For all intents and purposes,
those are some of the best

1051
00:41:07,798 --> 00:41:08,599
preserved pieces

1052
00:41:08,599 --> 00:41:10,134
of the Yucatan platform
that got hit

1053
00:41:10,134 --> 00:41:12,837
because they haven't been

weathered in 66 million years.

1054
00:41:13,304 --> 00:41:14,605
So you've got those little bits

1055
00:41:14,605 --> 00:41:16,407
of evidence
from the moment of impact,

1056
00:41:16,407 --> 00:41:18,742
and it brings
you kind of closer to,

1057
00:41:19,009 --> 00:41:21,145
you know, feeling like you were
actually there on that day.

1058
00:41:21,178 --> 00:41:23,013
You can picture these
being encapsulated

1059
00:41:23,013 --> 00:41:24,582
by the molten glass.

1060
00:41:24,582 --> 00:41:27,218
But when we were at Diamond
Lightsource in Oxfordshire,

1061
00:41:27,218 --> 00:41:28,486
we found a couple of

1062
00:41:28,486 --> 00:41:30,621
of these fragments
were not quite what we expected.

1063
00:41:31,255 --> 00:41:33,858
Two of the spherules
had fragments in them

1064

00:41:33,858 --> 00:41:37,194
that were wildly different
in composition than those others

1065
00:41:37,394 --> 00:41:38,929
that were not enriched
to the calcium

1066
00:41:38,929 --> 00:41:40,831
in the strontium
like we would have expected.

1067
00:41:40,831 --> 00:41:42,733
These were rich in the iron.

1068
00:41:42,733 --> 00:41:45,069
They were enriched in chromium,
the Irish nickel.

1069
00:41:45,202 --> 00:41:47,238
And a few other things I'm
not going to mention just yet,

1070
00:41:47,571 --> 00:41:51,141
but these fragments
matched what we would expect.

1071
00:41:52,009 --> 00:41:54,712
From elsewhere, not from Earth.

1072
00:41:55,212 --> 00:41:56,213
And as we go

1073
00:41:56,213 --> 00:41:59,650
through the micro analysis,
we can demonstrate that further.

1074
00:42:00,050 --> 00:42:03,587
This is an awesome
view of one of those fragments.

1075
00:42:03,821 --> 00:42:07,224
We actually have a control
or what appears to be a control

1076
00:42:07,424 --> 00:42:09,593
that is preserved within this
brush created matrix.

1077
00:42:10,060 --> 00:42:13,531
And we have the dark region
around the exterior,

1078
00:42:13,531 --> 00:42:17,401
which is likely related to the
fine grained rim of the control.

1079
00:42:18,135 --> 00:42:19,737
We've got a closer view.

1080
00:42:20,771 --> 00:42:22,072
That's a
much better view of the control.

1081
00:42:22,072 --> 00:42:22,840
Actually.

1082
00:42:22,840 --> 00:42:25,442
We've got some chromite along
the the edge there.

1083
00:42:25,543 --> 00:42:27,945
We've got beautiful
view of the brush shaded matrix,

1084
00:42:28,245 --> 00:42:34,018
really nicely formed control
and probably olivine.

1085

00:42:34,285 --> 00:42:35,219
Actually, it probably is.

1086
00:42:35,219 --> 00:42:38,889
We've got enrichments of
of manganese or magnesium there.

1087
00:42:39,957 --> 00:42:41,258
Beautiful brush headed matrix.

1088
00:42:41,258 --> 00:42:42,826
We got control. Control.

1089
00:42:42,826 --> 00:42:45,429
And this is our view
of one of those fragments.

1090
00:42:45,763 --> 00:42:47,331
So the micro structure is going

1091
00:42:47,331 --> 00:42:49,433
to tell us a lot
about where it came from.

1092
00:42:49,433 --> 00:42:49,967
And you'll be able

1093
00:42:49,967 --> 00:42:53,270
to do some of your mineralogy
with your EDC data and such.

1094
00:42:53,837 --> 00:42:57,141
And the ratios of those elements
to each other

1095
00:42:57,141 --> 00:42:59,810
tell you a lot about what
these things are made of.

1096

00:43:00,344 --> 00:43:02,880
And obviously we don't jump
to conclusions with these.

1097
00:43:02,880 --> 00:43:04,949
We let the instruments
tell us what they tell us

1098
00:43:04,949 --> 00:43:07,318
and the specimen
will tell us what it is.

1099
00:43:07,318 --> 00:43:12,389
So far, the data is showing us
that our sample falls

1100
00:43:12,389 --> 00:43:16,994
within this region, which is the
carbonaceous chondrites.

1101
00:43:17,761 --> 00:43:20,831
So most likely
this particular sample

1102
00:43:21,298 --> 00:43:23,667
is allied with the carbonaceous
chondrites.

1103
00:43:24,168 --> 00:43:25,803
And that's good to know

1104
00:43:25,803 --> 00:43:27,338
because that actually falls
in line

1105
00:43:27,338 --> 00:43:29,607
with what Frank Kight
was telling us years ago.

1106
00:43:30,341 --> 00:43:32,476

Kate,
describe this sample at right,

1107
00:43:32,476 --> 00:43:36,580
which was found in the Pacific
in a drill core 9000 kilometers

1108
00:43:36,580 --> 00:43:37,348
from the site.

1109
00:43:37,348 --> 00:43:39,717
That's like three times
farther than Tanis,

1110
00:43:39,717 --> 00:43:40,851
and it's a little larger
than mine

1111
00:43:40,851 --> 00:43:42,786
fragments, about two
and a half millimeters.

1112
00:43:42,786 --> 00:43:44,622
I don't know how two and a half
millimeter fragment

1113
00:43:44,622 --> 00:43:45,489
would have gotten that far,

1114
00:43:45,489 --> 00:43:48,225
but assuming this is actually
from the impactor,

1115
00:43:48,892 --> 00:43:50,260
there is some data
we can get from it.

1116
00:43:50,260 --> 00:43:53,430
The problem is this carbonaceous
chondrites are not resilient.

1117
00:43:53,597 --> 00:43:55,232
They're not nickel
iron meteorites.

1118
00:43:55,232 --> 00:43:57,701
They fall to hell
in the environment.

1119
00:43:57,868 --> 00:43:59,336
They hydrate, they alter.

1120
00:43:59,336 --> 00:44:02,139
And this piece is no different.

1121
00:44:02,139 --> 00:44:05,442
That particular specimen
went through 66 million years

1122
00:44:05,643 --> 00:44:07,478
of being ravaged
by the ocean waters

1123
00:44:07,478 --> 00:44:08,812
and the deep sea sediments.

1124
00:44:08,812 --> 00:44:11,582
There's no original mineralogy
that exists.

1125
00:44:11,582 --> 00:44:12,182
There is a lot of

1126
00:44:12,182 --> 00:44:14,952
chemical exchange with the
the exterior matrix,

1127
00:44:15,285 --> 00:44:19,223
and there's no way really

to tell exactly what type it is

1128
00:44:19,456 --> 00:44:21,992
except
probably carbonaceous chondrite.

1129
00:44:22,326 --> 00:44:27,765
And he proposed
it's probably either ac0 C.R.

1130
00:44:27,798 --> 00:44:30,567
or c m subtype
carbonaceous chondrite.

1131
00:44:30,567 --> 00:44:31,068
That's good.

1132
00:44:31,068 --> 00:44:32,469
That's good to narrow it down

1133
00:44:32,469 --> 00:44:35,606
a little bit further, but still,
it doesn't really give us that

1134
00:44:35,606 --> 00:44:36,640
final oomph.

1135
00:44:36,640 --> 00:44:39,043
You know, do we really know
what the asteroid was?

1136
00:44:39,576 --> 00:44:41,679
And our current specimen

1137
00:44:42,513 --> 00:44:44,815
falls
within this region of the graph.

1138
00:44:45,416 --> 00:44:47,918

And this is one of the many
different analysis.

1139
00:44:47,918 --> 00:44:49,386
I'm not going to bore you
with all of them,

1140
00:44:49,386 --> 00:44:51,889
but ours falls
within that region,

1141
00:44:51,889 --> 00:44:55,492
which identifies it as most
probably a CM

1142
00:44:55,826 --> 00:44:58,729
type carbonaceous chondrite,
which is excellent

1143
00:44:58,729 --> 00:45:01,999
because that actually falls
right within Frank Kite's range.

1144
00:45:02,332 --> 00:45:07,304
There's Frank Kite's proposed
region and we go right here.

1145
00:45:07,471 --> 00:45:10,441
So we probably do have a CM
carbonaceous chondrite.

1146
00:45:10,841 --> 00:45:15,112
And in addition to that,
just being a phenomenally cool

1147
00:45:15,112 --> 00:45:17,014
aspect of the impact story,
you're able

1148
00:45:17,014 --> 00:45:19,750

to look at a fragment,
even if you haven't identified

1149
00:45:19,750 --> 00:45:23,320
that fragment and say
this is a of of cosmic origin.

1150
00:45:23,754 --> 00:45:27,024
And almost certainly
this is related to the bolide

1151
00:45:27,024 --> 00:45:28,492
that hit
at the end of the Cretaceous.

1152
00:45:28,492 --> 00:45:30,227
That's amazing. It's phenomenal.

1153
00:45:30,227 --> 00:45:31,762
Then if you're able

1154
00:45:31,762 --> 00:45:32,830
to actually identify it

1155
00:45:32,830 --> 00:45:34,898
and we're on the road
to doing that,

1156
00:45:34,898 --> 00:45:38,001
then you can actually say,
Amazing, we know what it was.

1157
00:45:38,202 --> 00:45:41,672
But it's not just cool that
actually has some significance

1158
00:45:42,005 --> 00:45:44,708
because when that asteroid came
in, you're looking

1159
00:45:44,708 --> 00:45:47,544
at a ten kilometer diameter
piece of rock.

1160
00:45:47,811 --> 00:45:50,481
The composition of that rock
is not trivial.

1161
00:45:50,781 --> 00:45:52,149
The composition of that rock,

1162
00:45:52,149 --> 00:45:54,218
when it was vaporized
and went into the atmosphere,

1163
00:45:54,351 --> 00:45:57,387
contributed
that atmospheric perturbation

1164
00:45:57,387 --> 00:46:01,391
that contributed to whatever
happened to Earth's biota .

1165
00:46:01,391 --> 00:46:04,027
So knowing what that composition
was, was it high in sulfur?

1166
00:46:04,027 --> 00:46:06,263
Was it high in something else?
What actually went up?

1167
00:46:06,530 --> 00:46:07,865
You can combine that
with what you know

1168
00:46:07,865 --> 00:46:10,200
about the Target Rock
and have a better idea

1169

00:46:10,400 --> 00:46:13,771
about the dynamics of what
occurred on the day of impact

1170
00:46:13,771 --> 00:46:16,473
and why the things happened
the way they did.

1171
00:46:16,874 --> 00:46:18,308
So this is an important step

1172
00:46:18,308 --> 00:46:20,310
forward
in our story of understanding

1173
00:46:20,310 --> 00:46:22,379
about the entire impact event.

1174
00:46:22,746 --> 00:46:24,815
And one thing that we do know
is the impact

1175
00:46:24,815 --> 00:46:27,384
did not have a very
good effect on Earth's biota.

1176
00:46:28,852 --> 00:46:30,120
It was not compatible with life.

1177
00:46:30,120 --> 00:46:32,422
It led to the
massive extinction.

1178
00:46:32,422 --> 00:46:34,558
I'm going to go through these
very rapidly,

1179
00:46:34,558 --> 00:46:36,693
a couple of high points
about this pterosaur.

1180
00:46:37,261 --> 00:46:39,062
Again,
this is the first pterosaur

1181
00:46:39,062 --> 00:46:40,531
embryo from North America,

1182
00:46:40,531 --> 00:46:42,533
the first one from the late
Cretaceous Worldwide,

1183
00:46:42,533 --> 00:46:44,468
the first one from Nasdaq,
a pterosaur.

1184
00:46:44,468 --> 00:46:46,436
There's a lot to learn
from this.

1185
00:46:46,436 --> 00:46:49,473
And also we're talking about
when did the impact hit?

1186
00:46:49,473 --> 00:46:51,008
You know, the impact occurred

1187
00:46:51,008 --> 00:46:52,910
sometime in the spring,
the summer months.

1188
00:46:52,910 --> 00:46:56,346
You know, we
we actually just performed

1189
00:46:56,346 --> 00:46:58,949
a study that determined
that's the most likely range.

1190

00:46:59,483 --> 00:47:02,152
And there are a whole bunch
of vulnerabilities

1191
00:47:02,152 --> 00:47:05,889
that are inherent to that time
span that are going to occur.

1192
00:47:05,923 --> 00:47:08,025
These things are over obvious.

1193
00:47:08,025 --> 00:47:09,960
They do have precocious, young,
probably.

1194
00:47:09,960 --> 00:47:12,663
How does that affect now?
We can actually postulate?

1195
00:47:12,663 --> 00:47:14,832
Well, you know,
we can figure out

1196
00:47:15,532 --> 00:47:18,235
different ways that could have
been affected by the impact.

1197
00:47:18,602 --> 00:47:21,171
We look at the vessel saw,
basically

1198
00:47:21,338 --> 00:47:24,208
we've got a dinosaur
at the KPC boundary.

1199
00:47:24,208 --> 00:47:25,809
It closes the gap
and usually you don't

1200
00:47:25,809 --> 00:47:28,145

find dinosaurs
right at the big boundary.

1201
00:47:28,278 --> 00:47:29,913
You've got a significant gap.

1202
00:47:29,913 --> 00:47:31,715
This closes that gap completely.

1203
00:47:31,715 --> 00:47:32,182
In addition,

1204
00:47:32,182 --> 00:47:32,716
we've got

1205
00:47:32,716 --> 00:47:34,184
details about that particular

1206
00:47:34,184 --> 00:47:36,987
type of dinosaur
that weren't available before

1207
00:47:37,588 --> 00:47:39,389
and this could have been killed.

1208
00:47:39,389 --> 00:47:40,123
By the impact.

1209
00:47:40,123 --> 00:47:41,925
That's some significance right
there.

1210
00:47:41,925 --> 00:47:43,393
Very, very interesting.

1211
00:47:43,393 --> 00:47:46,964
And also, if we do histological
studies on the bones,

1212
00:47:47,130 --> 00:47:48,665
we can work backwards

1213
00:47:48,665 --> 00:47:50,734
and find out what things
were like

1214
00:47:50,734 --> 00:47:52,803
leading up to the impact
in the environment,

1215
00:47:52,803 --> 00:47:54,538
because the growth lines

1216
00:47:54,538 --> 00:47:57,341
in those bones
give us a record of that animal.

1217
00:47:57,341 --> 00:47:59,576
Then, of course,
the fragment is a beautiful map

1218
00:47:59,810 --> 00:48:02,179
of one of the fragments
inside the sphere.

1219
00:48:02,179 --> 00:48:03,981
And, of course, that fragment
is going to tell us

1220
00:48:03,981 --> 00:48:06,049
more about the dynamics
of the impact event.

1221
00:48:06,049 --> 00:48:09,419
What the asteroid was made of
and possibly how it could have

1222
00:48:09,620 --> 00:48:10,854

affected life on earth.

1223
00:48:10,854 --> 00:48:13,891
And this gets us so excited

1224
00:48:14,224 --> 00:48:18,495
because we know the asteroid
caused the extinction

1225
00:48:18,495 --> 00:48:19,663
at the end of the Cretaceous.

1226
00:48:19,663 --> 00:48:22,633
To see a piece of

1227
00:48:22,633 --> 00:48:25,669
the culprit is just a
goosebump, bumpy experience.

1228
00:48:26,970 --> 00:48:29,006
And lastly,

1229
00:48:29,006 --> 00:48:29,907
the story that's

1230
00:48:29,907 --> 00:48:30,674
kind of brought forward

1231
00:48:30,674 --> 00:48:32,943
about this whole event
in the Cretaceous

1232
00:48:33,810 --> 00:48:34,778
kind of comes full circle.

1233
00:48:34,778 --> 00:48:37,481
It's not just about the late
Cretaceous.

1234
00:48:37,481 --> 00:48:39,383
It's not just about
what happened back then.

1235
00:48:39,383 --> 00:48:41,952
It relates to today as well,

1236
00:48:42,185 --> 00:48:45,455
the mode and tempo
of the extinction event.

1237
00:48:45,889 --> 00:48:48,992
It is very, very similar
to what we see today. The.

1238
00:48:50,060 --> 00:48:51,428
Rapid.

1239
00:48:52,496 --> 00:48:55,299
Damaging effects to the ecology
today mirror

1240
00:48:55,599 --> 00:48:59,102
to a startling extent
what we see in the fossil record

1241
00:48:59,269 --> 00:49:00,437
for how fast

1242
00:49:00,437 --> 00:49:03,206
the extinction event occurred
in the Cretaceous, much more

1243
00:49:03,206 --> 00:49:05,876
so than the other mass
extinctions in Earth's history.

1244
00:49:06,243 --> 00:49:11,315
So that is a startling thing,

and obviously it's up to us.

1245
00:49:11,415 --> 00:49:13,517
We have the capability
of doing something

1246
00:49:13,517 --> 00:49:15,619
about that and learning
from the fossil record.

1247
00:49:15,719 --> 00:49:17,754
And it is indeed
the fossil record

1248
00:49:17,754 --> 00:49:21,491
that is our way to learn
how to do something about it.

1249
00:49:21,525 --> 00:49:23,527
We are the only species on earth

1250
00:49:23,527 --> 00:49:25,696
that's ever
been able to learn from this.

1251
00:49:25,696 --> 00:49:27,531
It's up to us to do it.

1252
00:49:27,531 --> 00:49:30,634
And the fossil record is our way
of looking back

1253
00:49:30,634 --> 00:49:32,269
into that window of time

1254
00:49:32,269 --> 00:49:34,938
and actually
seeing how to Earth's biota.

1255

00:49:34,972 --> 00:49:37,507
How do these animals and plants,

1256
00:49:37,507 --> 00:49:39,676
how do they react
to a global scale hazard?

1257
00:49:40,010 --> 00:49:41,178
It's not a simulation.

1258
00:49:41,178 --> 00:49:43,146
It's not a question
mark. It's not a hypothesis.

1259
00:49:43,146 --> 00:49:44,281
You're actually looking

1260
00:49:44,281 --> 00:49:47,150
through time at the fossil
record to see what happens.

1261
00:49:47,317 --> 00:49:49,553
That's our best way
of understanding

1262
00:49:49,886 --> 00:49:52,022
what's happening today,
what could happen today,

1263
00:49:52,255 --> 00:49:54,091
and how could we have
an effect on that.

1264
00:49:54,091 --> 00:49:55,926
So that's our obligation.

1265
00:49:55,926 --> 00:49:57,627
And with that, I will thank

1266

00:49:57,627 --> 00:49:59,863
the following individuals
and all of you as well.

1267
00:50:07,304 --> 00:50:08,271
Thank you so much.

1268
00:50:08,271 --> 00:50:09,740
Thank you
so much for your presentation.

1269
00:50:09,740 --> 00:50:10,140
Thank you.

1270
00:50:10,140 --> 00:50:11,708
I think a lot of you understand

1271
00:50:11,708 --> 00:50:14,678
now that a number of us
had trouble sleeping last night.

1272
00:50:15,579 --> 00:50:17,147
These results are so exciting.

1273
00:50:17,147 --> 00:50:18,215
I think you can say that

1274
00:50:18,215 --> 00:50:20,050
these are some of
the most significant results

1275
00:50:20,050 --> 00:50:21,151
in our century

1276
00:50:21,151 --> 00:50:23,754
and to to really nail down
what happened on that day

1277
00:50:24,021 --> 00:50:24,788

when we were struck

1278
00:50:24,788 --> 00:50:28,458
by this tremendous
now better identified asteroid.

1279
00:50:29,259 --> 00:50:30,727
So that was incredibly exciting.

1280
00:50:30,727 --> 00:50:32,095
Thank you so much
for your presentation.

1281
00:50:32,095 --> 00:50:34,331
We will have questions,
questions and answers later.

1282
00:50:34,331 --> 00:50:35,465
So we'll take a break now.

1283
00:50:35,465 --> 00:50:36,233
Thank you.

1284
00:50:42,039 --> 00:50:44,207
Hello and welcome to NASA's
Goddard Space Flight Center.

1285
00:50:44,274 --> 00:50:45,375
My name is Michelle Thaler,

1286
00:50:45,375 --> 00:50:47,310
and I'm here to host
the question and answer period

1287
00:50:47,310 --> 00:50:49,112
about some extraordinary
findings

1288
00:50:49,112 --> 00:50:51,415

about the date
that the asteroid hit

1289
00:50:51,415 --> 00:50:53,050
that made the dinosaurs
go extinct.

1290
00:50:53,050 --> 00:50:55,085
And we have Robert DePalma here

1291
00:50:55,085 --> 00:50:58,522
in his team, have just had some
incredible discoveries.

1292
00:50:58,622 --> 00:51:00,390
I'm still speechless,
I have to say.

1293
00:51:00,390 --> 00:51:02,392
There were so many things
that when you were talking,

1294
00:51:02,392 --> 00:51:04,828
we were just emotionally
reacting to people.

1295
00:51:04,995 --> 00:51:06,463
I saw I saw Christa was

1296
00:51:06,463 --> 00:51:08,732
she was nodding
and she was going, oh, my God.

1297
00:51:08,732 --> 00:51:11,234
There was just amazing evidence
today presented

1298
00:51:11,435 --> 00:51:14,771
that you have captured
the moment that asteroid hit.

1299
00:51:14,771 --> 00:51:17,941
The ejecta came, seismic waves
ripped through the planet

1300
00:51:18,241 --> 00:51:20,677
and some of these organisms
were swept together and died.

1301
00:51:20,710 --> 00:51:21,411
I mean, it's amazing to be

1302
00:51:21,411 --> 00:51:23,380
standing in front of that
right here.

1303
00:51:23,380 --> 00:51:24,481
So this question,

1304
00:51:24,481 --> 00:51:26,716
the question answer period
can start many different ways.

1305
00:51:26,716 --> 00:51:28,885
But one of the things
that I wanted to begin with

1306
00:51:28,885 --> 00:51:31,955
is that just putting the science
aside for a second.

1307
00:51:32,222 --> 00:51:32,589
There's

1308
00:51:32,589 --> 00:51:34,291
this quite interesting
personal story

1309
00:51:34,291 --> 00:51:35,492

here for you, too,

1310
00:51:35,492 --> 00:51:38,161
because as you began
to look into this deposit.

1311
00:51:38,462 --> 00:51:39,463
Well, for one thing,
I understand

1312
00:51:39,463 --> 00:51:41,331
this deposit was thought
it was kind of confusing.

1313
00:51:41,331 --> 00:51:42,766
People didn't know
what to do with it.

1314
00:51:42,766 --> 00:51:44,167
And so a lot of scientists
kind of

1315
00:51:44,167 --> 00:51:46,303
didn't want to work with it,
didn't seem very clear.

1316
00:51:46,670 --> 00:51:47,804
You stuck with it,

1317
00:51:47,804 --> 00:51:50,006
but your findings
were controversial

1318
00:51:50,006 --> 00:51:52,109
and you got some
some pushback about.

1319
00:51:52,142 --> 00:51:54,144
Can you tell us a bit
about that, that journey,

1320
00:51:54,144 --> 00:51:56,546
about people being skeptical
and now people being

1321
00:51:56,713 --> 00:51:58,348
very excited about these?

1322
00:51:58,348 --> 00:52:00,050
Science
is about being skeptical.

1323
00:52:00,050 --> 00:52:02,052
You really have to ask questions

1324
00:52:02,052 --> 00:52:04,254
and don't take anything on face
value.

1325
00:52:04,254 --> 00:52:06,756
That's what happened
with Alvarez and everybody else

1326
00:52:06,756 --> 00:52:09,726
when they first proposed
that an impact occurred.

1327
00:52:09,993 --> 00:52:11,661
Nobody agreed with it.

1328
00:52:11,661 --> 00:52:13,697
And if everybody agreed with
something,

1329
00:52:13,697 --> 00:52:14,998
I'd be kind of worried.

1330
00:52:14,998 --> 00:52:16,032
That's that's

when people weren't

1331
00:52:16,032 --> 00:52:17,467
really thinking
critically about it.

1332
00:52:17,467 --> 00:52:20,770
In this case, what you do
and what you do

1333
00:52:20,770 --> 00:52:24,174
as a scientist is
you find what evidence lines up.

1334
00:52:24,508 --> 00:52:26,843
What does it mean
and what does it tell you?

1335
00:52:26,877 --> 00:52:28,111
You don't tell the story,

1336
00:52:28,111 --> 00:52:31,748
the evidence, the fossils,
the data that tells the story.

1337
00:52:32,048 --> 00:52:34,818
And the longer you work on it
and the more of all of

1338
00:52:34,818 --> 00:52:37,487
those items you collect
and you are able to interpret,

1339
00:52:37,888 --> 00:52:40,790
they are actually forwarding
that information forward.

1340
00:52:41,124 --> 00:52:43,960
And in this case,
all of the data,

1341
00:52:44,194 --> 00:52:45,662
the information
that different teams

1342
00:52:45,662 --> 00:52:47,731
are putting together,
our team is interpreting

1343
00:52:47,731 --> 00:52:50,233
based on these specimens,
all it's coming together

1344
00:52:50,467 --> 00:52:52,903
to sort of support
this rich story

1345
00:52:53,170 --> 00:52:55,672
that is linked
with the end of the Cretaceous,

1346
00:52:55,672 --> 00:52:57,674
the end
of that time of dinosaurs.

1347
00:52:58,742 --> 00:52:59,643
It's a very

1348
00:52:59,643 --> 00:53:00,577
calm and very

1349
00:53:00,577 --> 00:53:03,246
measured scientific response,
I have to say.

1350
00:53:03,246 --> 00:53:06,249
To me,
it doesn't match the excitement

1351

00:53:06,249 --> 00:53:07,150
I feel about this.

1352
00:53:07,150 --> 00:53:09,553
The joy, I have to say,

1353
00:53:09,553 --> 00:53:11,021
a bunch of us
were just jumping up and down

1354
00:53:11,021 --> 00:53:13,223
when we heard about this and
what was going to be presented.

1355
00:53:13,223 --> 00:53:15,492
So there's also
an emotional story about,

1356
00:53:15,692 --> 00:53:18,061
you know, as you began
to piece these things together,

1357
00:53:18,595 --> 00:53:20,697
realizing what you had found.

1358
00:53:20,697 --> 00:53:23,667
Can you take us a little bit
on that as well?

1359
00:53:24,834 --> 00:53:27,537
When looking at the fossil
record, usually you're looking

1360
00:53:27,537 --> 00:53:31,374
at really long timescales,
millions of years, tens

1361
00:53:31,374 --> 00:53:32,809
of thousands of years.

1362
00:53:32,809 --> 00:53:36,446
And really, as paleontologists,
we are passionate

1363
00:53:36,446 --> 00:53:37,414
about the animals.

1364
00:53:37,414 --> 00:53:39,349
I am passionate
about the animals

1365
00:53:39,349 --> 00:53:41,618
and whatever
was existing at that time.

1366
00:53:41,618 --> 00:53:44,254
So whenever I'm able
to look at something

1367
00:53:44,254 --> 00:53:47,057
and kind of have a fossil
in front of me

1368
00:53:47,357 --> 00:53:49,392
and be able to tell what
that animal experience,

1369
00:53:49,426 --> 00:53:50,827
what was its life like?

1370
00:53:50,827 --> 00:53:53,263
What did what happened
during its life?

1371
00:53:53,263 --> 00:53:54,097
How did it die?

1372
00:53:55,065 --> 00:53:57,367
That's a special thing

because it gives you a window

1373
00:53:57,367 --> 00:53:59,869
into that animal's life.
There's one creature

1374
00:53:59,936 --> 00:54:01,738
experiencing
what another creature did.

1375
00:54:01,738 --> 00:54:03,173
And in this case,

1376
00:54:03,173 --> 00:54:04,341
all of these animals

1377
00:54:04,341 --> 00:54:06,676
that are just tumbled together
in this deposit

1378
00:54:07,244 --> 00:54:09,980
sort of had what I like
to refer to as a front row seat

1379
00:54:09,980 --> 00:54:13,250
to one of the most magnificent
events of the late Cretaceous,

1380
00:54:13,250 --> 00:54:15,652
the impact event
and its aftermath.

1381
00:54:16,086 --> 00:54:19,623
And how did it affect them
on an individual level?

1382
00:54:20,090 --> 00:54:21,725
And that's
just such a personal story.

1383
00:54:21,725 --> 00:54:22,993
Each one of them

1384
00:54:22,993 --> 00:54:25,061
would have experienced it
a little bit differently.

1385
00:54:25,295 --> 00:54:29,366
And to see that kind of develop
in front of your face,

1386
00:54:29,366 --> 00:54:33,637
in the outcropping in the lab
is a really personal experience.

1387
00:54:33,803 --> 00:54:37,140
You're there and you're
listening to that animal story.

1388
00:54:37,974 --> 00:54:39,442
There's something
really immediate about this.

1389
00:54:39,442 --> 00:54:41,978
Again, I'm looking down
on a specimen of a fish,

1390
00:54:42,345 --> 00:54:44,281
and you pointed out to me
that there are tiny

1391
00:54:44,281 --> 00:54:46,850
little spheres of glass
stuck in its gills.

1392
00:54:47,183 --> 00:54:49,286
You know, that this creature
died, it suffocated

1393

00:54:49,486 --> 00:54:51,254
because its gills were clogged

1394
00:54:51,254 --> 00:54:53,223
with ejecta
that had to do with this

1395
00:54:53,223 --> 00:54:55,659
huge impact,
this asteroid hitting the earth.

1396
00:54:55,859 --> 00:54:57,727
And there it is right there.

1397
00:54:57,727 --> 00:54:59,963
You know, these things had this

1398
00:55:00,563 --> 00:55:02,932
you know, they died, we think,
because of this happening

1399
00:55:03,400 --> 00:55:04,401
like we were talking about
today.

1400
00:55:04,401 --> 00:55:06,169
You're looking at this moment

1401
00:55:06,169 --> 00:55:08,438
and we were all just
mentioning this even

1402
00:55:08,571 --> 00:55:10,240
while we were having lunch
together today.

1403
00:55:10,240 --> 00:55:13,777
This was a moment
our ancestors also experienced.

1404
00:55:14,044 --> 00:55:16,479
We we are related to things
that lived through that day.

1405
00:55:16,913 --> 00:55:20,483
And, of course, things changed
incredibly, this incredible

1406
00:55:20,483 --> 00:55:24,788
rich ecosystem dominated
by the dinosaurs that went away

1407
00:55:24,788 --> 00:55:28,725
and this mammalian ecosystem
begins to become more dominant.

1408
00:55:28,725 --> 00:55:30,694
So we're
looking at an amazing change.

1409
00:55:30,694 --> 00:55:32,762
Maybe we wouldn't
even be here talking about this

1410
00:55:32,996 --> 00:55:34,864
if that event hadn't happened.

1411
00:55:34,864 --> 00:55:36,966
If you put your finger

1412
00:55:37,634 --> 00:55:39,903
on a single point
in time in the rock record

1413
00:55:40,136 --> 00:55:44,040
and say that point was
absolutely pivotal to the world,

1414
00:55:44,541 --> 00:55:47,944

this was one of those points
because you can literally

1415
00:55:47,944 --> 00:55:50,847
get your finger and put it
on the Cape boundary grade,

1416
00:55:51,147 --> 00:55:54,417
the impact fallout and say,
that's your dividing line,

1417
00:55:54,451 --> 00:55:57,087
that's your pivotal moment,
because you're absolutely right,

1418
00:55:58,521 --> 00:56:02,459
the mammals rising up
and being able to diversify that

1419
00:56:02,459 --> 00:56:06,363
massive shift in ecologies
and ecosystems across the globe,

1420
00:56:07,030 --> 00:56:10,467
they're tied to that moment,
to that impact, and

1421
00:56:11,301 --> 00:56:12,202
to see these animals

1422
00:56:12,202 --> 00:56:13,770
that would have experienced
that event

1423
00:56:13,770 --> 00:56:15,739
and then to look closer,
like you say,

1424
00:56:15,739 --> 00:56:16,072
and you can

1425
00:56:16,072 --> 00:56:19,976
see some of the impact debris
packed in the gills of the fish

1426
00:56:19,976 --> 00:56:22,312
so that fish interacted
with the impact debris.

1427
00:56:22,812 --> 00:56:24,247
The whole story is there.

1428
00:56:24,247 --> 00:56:27,584
You've got the impact that
caused that tremendous shift.

1429
00:56:27,784 --> 00:56:30,053
You've got the animal
that experienced it

1430
00:56:30,053 --> 00:56:32,989
and then you've got all of this
in one layer

1431
00:56:33,289 --> 00:56:35,992
that gives you a moment by
moment record of the aftermath.

1432
00:56:36,359 --> 00:56:39,062
You've got this layer
cake of an incredible story.

1433
00:56:39,963 --> 00:56:41,164
So just kind of give people
a chance

1434
00:56:41,164 --> 00:56:43,066
to start asking questions.

1435

00:56:43,066 --> 00:56:44,267
We have we got Dr.

1436
00:56:44,267 --> 00:56:47,303
Jim Garvin, who is the chief
scientist here at NASA Goddard.

1437
00:56:47,771 --> 00:56:49,439
I was sitting next to you
during the presentation.

1438
00:56:49,439 --> 00:56:50,673
You were reacting.

1439
00:56:50,673 --> 00:56:52,208
You were really excited.
At one point.

1440
00:56:52,208 --> 00:56:54,377
You actually were almost like
at the point of tears.

1441
00:56:54,377 --> 00:56:55,211
What are some of the moments

1442
00:56:55,211 --> 00:56:57,180
you remember that
that you were looking at

1443
00:56:57,180 --> 00:56:59,182
the evidence thinking, wow,
look what they have?

1444
00:56:59,349 --> 00:57:03,353
Well, I think what Robert's done
with his team here is connect.

1445
00:57:03,353 --> 00:57:04,053
The way we looked

1446
00:57:04,053 --> 00:57:05,822
at the history
of the rock record on Earth

1447
00:57:05,822 --> 00:57:08,525
as defined by life
in these names of errors

1448
00:57:08,525 --> 00:57:09,526
we all grew up with

1449
00:57:09,526 --> 00:57:12,262
that became
known as Cretaceous and Triassic

1450
00:57:12,295 --> 00:57:13,029
and all that

1451
00:57:13,029 --> 00:57:14,464
to the record of Impact

1452
00:57:14,464 --> 00:57:17,000
This Life on the Rocks
cosmic collision story

1453
00:57:17,200 --> 00:57:19,302
that we've
already used on other worlds.

1454
00:57:19,502 --> 00:57:21,004
How do we define
the errors on the moon?

1455
00:57:21,004 --> 00:57:23,039
We named them
for the errors of impacts

1456
00:57:23,206 --> 00:57:25,241
that defined different time

horizons.

1457
00:57:25,241 --> 00:57:27,477
We've made a link
now beyond our planet

1458
00:57:27,811 --> 00:57:29,813
through the lens of the bigger
universe.

1459
00:57:30,146 --> 00:57:33,016
Roberts Stuff
now starts to give us data

1460
00:57:33,116 --> 00:57:36,186
I see for that connection
being expanded.

1461
00:57:36,319 --> 00:57:38,855
So, you know, maybe CBGBs,
the wrong name, maybe

1462
00:57:38,855 --> 00:57:43,593
should be the big C for Jigsaw
because it defined a change.

1463
00:57:43,993 --> 00:57:46,830
And those connections aren't
only at the big animal scale

1464
00:57:46,830 --> 00:57:47,797
in some of your findings,

1465
00:57:47,797 --> 00:57:51,901
but also the microbial scale
and how we read those records.

1466
00:57:51,935 --> 00:57:55,071
I can't wait to see what you
learn, because my question is,

1467
00:57:55,305 --> 00:57:58,608
you found preserved elements
of this micro comminuted

1468
00:57:59,309 --> 00:58:02,645
impactor that made this event
that changed the course

1469
00:58:02,645 --> 00:58:03,847
of the history of life.

1470
00:58:03,847 --> 00:58:05,014
You played the tape backwards.

1471
00:58:05,014 --> 00:58:08,151
We wouldn't be here
to quote a certain Yankee fan.

1472
00:58:08,384 --> 00:58:10,520
So what do you think
about those?

1473
00:58:10,553 --> 00:58:13,890
I mean, that's a finding
of cosmic significance.

1474
00:58:13,890 --> 00:58:14,691
It's Mother Nature's

1475
00:58:14,691 --> 00:58:16,726
best sample
return to give us a little piece

1476
00:58:16,726 --> 00:58:18,795
of what she did
to change the course of life.

1477
00:58:18,795 --> 00:58:21,164

I mean, why don't you tell us
about that, Robert?

1478
00:58:21,164 --> 00:58:21,731
Well,

1479
00:58:21,731 --> 00:58:23,433
to find any sort of material

1480
00:58:23,433 --> 00:58:26,503
that's associated
with the impact event and really

1481
00:58:26,503 --> 00:58:28,037
well preserved fragments like

1482
00:58:28,037 --> 00:58:32,041
the cosmic material we've got,
it is like going back in time.

1483
00:58:33,209 --> 00:58:35,078
Getting a
sample vial and getting material

1484
00:58:35,078 --> 00:58:37,280
from the site of impact
and being able to study it

1485
00:58:37,814 --> 00:58:40,316
and working out
the dynamics of the impact

1486
00:58:40,316 --> 00:58:43,253
event itself is incredibly,
incredibly important.

1487
00:58:43,419 --> 00:58:46,022
That is paramount
to understanding

1488
00:58:46,222 --> 00:58:47,590
how that impact affected

1489
00:58:47,590 --> 00:58:49,859
life on Earth
and how natural hazards

1490
00:58:49,859 --> 00:58:52,529
are going
to affect global ecosystems.

1491
00:58:53,196 --> 00:58:57,100
But it is a tremendously moving
kind of a feeling

1492
00:58:57,100 --> 00:59:00,870
because you are literally
connected to these moments

1493
00:59:00,870 --> 00:59:04,741
in time
that are better understood now,

1494
00:59:04,741 --> 00:59:07,043
but still poorly understood
in many different ways.

1495
00:59:07,377 --> 00:59:08,478
And they interfere

1496
00:59:08,478 --> 00:59:10,914
with so many different
aspects of science and life.

1497
00:59:11,581 --> 00:59:14,984
So these questions are
incredibly important to answer.

1498
00:59:15,285 --> 00:59:19,122

And as the answers are kind of
flowing out, each one

1499
00:59:19,122 --> 00:59:22,025
kind of builds the excitement an

1500
00:59:23,026 --> 00:59:24,627
Well speaking,
leading to more questions.

1501
00:59:24,627 --> 00:59:26,429
So there were people here
that were paleontologist

1502
00:59:26,429 --> 00:59:28,298
Jim that were asking you
about meteorites.

1503
00:59:28,298 --> 00:59:30,800
So so where where would this
meteorite have come from?

1504
00:59:30,800 --> 00:59:31,834
Does anything about the

1505
00:59:31,834 --> 00:59:32,402
the structure,

1506
00:59:32,402 --> 00:59:33,202
the analysis they've done,

1507
00:59:33,202 --> 00:59:35,305
does that give you any clue
about the history,

1508
00:59:35,305 --> 00:59:37,440
the structure of the meteorite,
this kind of meteorite?

1509

00:59:37,440 --> 00:59:38,541
Well, Robert

1510
00:59:38,541 --> 00:59:41,578
Roberts and his team showed us
that this is a carbonaceous.

1511
00:59:41,811 --> 00:59:43,613
We think from the preserved
evidence

1512
00:59:43,613 --> 00:59:47,183
in those time capsules of amber
within a sphere rule

1513
00:59:47,417 --> 00:59:49,819
that was made by the
by the impact ejecta.

1514
00:59:49,852 --> 00:59:51,921
I love the impact ejecta
personally. It's very moving.

1515
00:59:52,622 --> 00:59:53,990
Didn't want to experience
anything

1516
00:59:53,990 --> 00:59:56,059
like the gills on the fish,
but not monster.

1517
00:59:56,359 --> 00:59:59,696
So there is a little piece
of those things

1518
00:59:59,696 --> 01:00:02,865
that we're now going to
to sample what they tell us.

1519
01:00:03,032 --> 01:00:06,035

We just completed
sampling the asteroid bennu.

1520
01:00:06,202 --> 01:00:06,869
Not as big

1521
01:00:06,869 --> 01:00:09,372
as the one that hit the earth
and takes a little granted,

1522
01:00:09,405 --> 01:00:11,007
you know,
less than a kilometer across.

1523
01:00:11,007 --> 01:00:12,508
And we're going to bring back
those materials

1524
01:00:12,508 --> 01:00:14,510
to study in the way
Robert is studying

1525
01:00:14,510 --> 01:00:17,647
the impactor
that made this cosmic event.

1526
01:00:17,914 --> 01:00:19,515
So those connections

1527
01:00:19,515 --> 01:00:21,117
to that part of the inner
solar system

1528
01:00:21,117 --> 01:00:22,552
that records that stuff,

1529
01:00:22,552 --> 01:00:24,954
those artifacts of the
collisional history of Earth.

1530
01:00:25,355 --> 01:00:27,256
You know, he's got it.

1531
01:00:27,256 --> 01:00:28,591
So we're bringing it back.

1532
01:00:28,591 --> 01:00:30,393
Thanks to robotic spaceflight.

1533
01:00:30,393 --> 01:00:32,528
Wonderful job by osiris-rex.

1534
01:00:32,528 --> 01:00:35,565
And just a little deposit,
a little sample of our own

1535
01:00:35,632 --> 01:00:38,001
for us to study
and maybe other impacts.

1536
01:00:38,301 --> 01:00:41,371
Other ones not as consequential,
but equally interesting.

1537
01:00:41,638 --> 01:00:44,240
Just in the last 40 years,
understanding the role of impact

1538
01:00:44,540 --> 01:00:46,542
in the history of life, climate

1539
01:00:46,542 --> 01:00:49,278
and all
that is a profoundly new change

1540
01:00:49,479 --> 01:00:51,481
that was heretical,
as you said, Robert.

1541
01:00:51,481 --> 01:00:53,716
It was you know,
you got to be skeptical

1542
01:00:53,716 --> 01:00:55,785
because everyone was telling you
that's not the way it was.

1543
01:00:55,952 --> 01:00:57,520
And so I think I don't know.

1544
01:00:57,520 --> 01:01:01,290
Your work is showing us what
could could really have been.

1545
01:01:01,357 --> 01:01:04,227
And that's the way science
works, changing paradigms.

1546
01:01:05,561 --> 01:01:06,629
Also with us, we have Dr.

1547
01:01:06,629 --> 01:01:07,163
Krista Peters

1548
01:01:07,163 --> 01:01:09,198
Ledgard,
who is our deputy director

1549
01:01:09,198 --> 01:01:11,501
of science at our science
exploration director here.

1550
01:01:11,801 --> 01:01:14,103
And you're a hydrologist
by training as well.

1551
01:01:14,137 --> 01:01:16,172
So so what what are some of the

things that jumped out to you?

1552
01:01:16,172 --> 01:01:16,606
Oh, yeah.

1553
01:01:16,606 --> 01:01:19,575
Well, I mean,
thinking about the storm surge.

1554
01:01:19,575 --> 01:01:22,145
Right. You know,
and the power of water. Right.

1555
01:01:22,211 --> 01:01:24,747
Ten meter high deposit.

1556
01:01:25,548 --> 01:01:28,117
And just thinking about how,

1557
01:01:28,584 --> 01:01:30,253
you know,
what the bed load was like.

1558
01:01:30,253 --> 01:01:33,122
I mean, there was there
were logs recovered at the site.

1559
01:01:33,122 --> 01:01:37,960
I mean, just the power of the
of the water in this event,

1560
01:01:38,494 --> 01:01:42,231
magnitude 11 or 12 earthquakes.

1561
01:01:42,231 --> 01:01:44,934
I mean, it just it's
just blowing my mind.

1562
01:01:44,967 --> 01:01:47,770

So, you know, one of the things
that occurred to me is,

1563
01:01:48,104 --> 01:01:51,641
you know, you have these two
deposition episodes, right? So,

1564
01:01:52,909 --> 01:01:56,479
you know, how how did the

1565
01:01:56,479 --> 01:01:59,482
composition change, you know,
from those two episodes?

1566
01:01:59,482 --> 01:02:02,785
And what what does that say
about, you know,

1567
01:02:02,785 --> 01:02:05,555
the physics of the surge
in those two episodes?

1568
01:02:05,955 --> 01:02:07,390
That's a phenomenal question.

1569
01:02:07,390 --> 01:02:08,024
And that's one thing

1570
01:02:08,024 --> 01:02:09,959
that we've been thinking
about quite a bit.

1571
01:02:09,959 --> 01:02:13,296
The sedimentary record
is going to give you

1572
01:02:13,329 --> 01:02:15,298
the details about that story

1573

01:02:15,298 --> 01:02:17,700
and the grain size
and the bed forms

1574
01:02:17,700 --> 01:02:18,835
and everything else
you get there.

1575
01:02:18,835 --> 01:02:20,770
They're going to tell you
what it was like

1576
01:02:20,770 --> 01:02:21,804
if you know how to read it.

1577
01:02:21,804 --> 01:02:24,707
And in this case,
we had two pulses to that surge.

1578
01:02:24,707 --> 01:02:27,376
There was one initial pulse,
it back flowed

1579
01:02:27,577 --> 01:02:29,612
and then there was a second
long pulse.

1580
01:02:29,612 --> 01:02:32,048
And we know that they occurred
right after each other

1581
01:02:32,515 --> 01:02:34,450
because you have animals
and plants

1582
01:02:34,450 --> 01:02:35,852
that would have been
very delicate

1583
01:02:35,852 --> 01:02:37,987

that cross-cut all the deposit.

1584
01:02:37,987 --> 01:02:39,756
So you're not going to have

1585
01:02:39,756 --> 01:02:41,791
a long hiatus
between those two pulses.

1586
01:02:42,625 --> 01:02:43,893
And then when you look
at the pulses,

1587
01:02:43,893 --> 01:02:45,628
there's a little bit
of a difference in composition.

1588
01:02:45,628 --> 01:02:47,663
So the first one
was much more turbulent.

1589
01:02:47,663 --> 01:02:48,865
That first pulse

1590
01:02:48,865 --> 01:02:51,634
had a lot of rip up class,
had a lot of sand content.

1591
01:02:51,868 --> 01:02:54,137
The grain size was a lot,
a lot bigger.

1592
01:02:54,504 --> 01:02:56,873
So you had a much more turbulent
surge,

1593
01:02:57,306 --> 01:03:00,810
the second surge, more mud,
more clay size particles.

1594
01:03:01,010 --> 01:03:03,112
And it appeared
to be a longer surge.

1595
01:03:03,112 --> 01:03:06,849
So this massive, really bad
turbulent surge backflow

1596
01:03:07,083 --> 01:03:09,452
and then a longer,
more protracted

1597
01:03:09,952 --> 01:03:12,355
final surge
before it slowed down

1598
01:03:12,355 --> 01:03:15,191
and all the water's receded,
leaving this veneer

1599
01:03:15,391 --> 01:03:18,528
of mud and animals and logs
and everything on the landscape.

1600
01:03:19,495 --> 01:03:21,531
Really cool.

1601
01:03:21,531 --> 01:03:23,232
Long live the lodge. Yes.

1602
01:03:24,567 --> 01:03:25,301
We also have Dr.

1603
01:03:25,301 --> 01:03:26,969
John Mather, the other senior
project

1604
01:03:26,969 --> 01:03:29,071
scientist for the James

1605
01:03:29,372 --> 01:03:30,540
and and a physicist.

1606
01:03:30,540 --> 01:03:32,809
So, John, what's your take,
bringing the physics into this?

1607
01:03:32,909 --> 01:03:33,810
Oh, my goodness.

1608
01:03:33,810 --> 01:03:37,213
I'm excited, extremely excited
to see the evidence that we've

1609
01:03:37,213 --> 01:03:40,183
now got for the details
of what happened on that day.

1610
01:03:40,650 --> 01:03:43,019
Because this is the first chance
we really have to check

1611
01:03:43,319 --> 01:03:45,755
all the incredible calculations
that people can do

1612
01:03:45,755 --> 01:03:47,590
with hydrodynamics
and simulations

1613
01:03:47,590 --> 01:03:50,560
of computer versions of rock
hitting the earth.

1614
01:03:51,661 --> 01:03:55,131
But I'm also led to think about
implications for our search

1615
01:03:55,131 --> 01:03:56,599
for life
elsewhere in the universe,

1616
01:03:56,599 --> 01:03:59,035
because, well,
it was pretty tricky here.

1617
01:03:59,402 --> 01:04:01,771
How much could we forecast?
How could we predict?

1618
01:04:02,004 --> 01:04:04,140
So if we're going to look
for life on other planets,

1619
01:04:04,574 --> 01:04:06,609
are we going to imagine
that they're just sort of

1620
01:04:06,609 --> 01:04:08,311
sitting there
passively producing life?

1621
01:04:08,311 --> 01:04:11,581
Or do we imagine that
they also have a chaotic history

1622
01:04:11,581 --> 01:04:16,452
with crashes and evolution
and extinctions and disasters,

1623
01:04:17,019 --> 01:04:20,056
one after another of the same
sort that we've had here.

1624
01:04:20,056 --> 01:04:22,758
We've had Snowball Earth,
where Earth was frozen solid.

1625
01:04:22,758 --> 01:04:24,393
Apparently, we warmed up.

1626
01:04:24,393 --> 01:04:26,462
We've had huge changes,

1627
01:04:26,829 --> 01:04:29,232
catastrophic to everything
that lived there at the time.

1628
01:04:29,632 --> 01:04:31,300
And here is one catastrophe

1629
01:04:31,300 --> 01:04:33,936
we can examine in detail
because it happened so quickly.

1630
01:04:34,804 --> 01:04:36,205
But we should

1631
01:04:36,205 --> 01:04:36,739
we should be

1632
01:04:36,739 --> 01:04:38,875
picturing
catastrophes everywhere

1633
01:04:38,875 --> 01:04:41,310
that we're looking for
living things, not just here.

1634
01:04:41,510 --> 01:04:45,848
So look on Mars, look on on
Europa, look on Titan.

1635
01:04:45,848 --> 01:04:46,983
And look at the other places

1636

01:04:46,983 --> 01:04:49,619
that are interesting
as sources of life,

1637
01:04:49,619 --> 01:04:51,187
catastrophe everywhere.

1638
01:04:51,187 --> 01:04:55,057
So and you're thinking also,
what does it feel like to be

1639
01:04:55,057 --> 01:04:58,728
there as a living, sentient
creature experiencing that day,

1640
01:04:58,928 --> 01:05:00,029
which is something people

1641
01:05:00,029 --> 01:05:01,864
I don't think
can fully appreciate it

1642
01:05:01,864 --> 01:05:03,966
because you feel it
and you see it.

1643
01:05:03,966 --> 01:05:05,468
You think, I'm
like an animal there.

1644
01:05:05,468 --> 01:05:08,037
I'm feeling the heat, I'm
feeling the water.

1645
01:05:08,337 --> 01:05:10,940
And I don't think
we've really been able to

1646
01:05:11,440 --> 01:05:12,909
picture that part in the past.

1647
01:05:12,909 --> 01:05:15,645
So thank you for making
that so possible for us.

1648
01:05:17,647 --> 01:05:19,348
It's an
absolutely fascinating thing.

1649
01:05:19,348 --> 01:05:21,751
And you mentioned life
on other planets

1650
01:05:21,751 --> 01:05:25,054
and how a catastrophe
might play a role

1651
01:05:25,054 --> 01:05:27,657
that could also go the other way
in that

1652
01:05:27,957 --> 01:05:31,861
the frequency
of certain levels of catastrophe

1653
01:05:32,161 --> 01:05:34,630
could have a positive effect
in some ways,

1654
01:05:34,630 --> 01:05:37,099
because those could actually
spark different changes

1655
01:05:37,233 --> 01:05:38,868
in the evolution of life
on those planets.

1656
01:05:38,868 --> 01:05:41,938
So in the short term,
meaning in the,

1657
01:05:41,938 --> 01:05:44,774
you know, million
to 10 million years scale,

1658
01:05:44,941 --> 01:05:47,243
it might not be so good for
those that are experiencing it.

1659
01:05:47,410 --> 01:05:48,544
But in the grand scheme,

1660
01:05:48,544 --> 01:05:50,713
that actually could bring
about different changes

1661
01:05:50,713 --> 01:05:53,182
in the trajectory
of those evolutionary schemes

1662
01:05:53,282 --> 01:05:54,784
and bring about
different innovations.

1663
01:05:54,784 --> 01:05:58,487
So it's really fascinating to
think how that interplay occurs.

1664
01:06:00,423 --> 01:06:01,924
And also just
finding the evidence for it.

1665
01:06:01,924 --> 01:06:03,292
I mean, one of the things
that really

1666
01:06:03,292 --> 01:06:05,494
you know, I worked on the
the Spitzer Space Telescope,

1667
01:06:05,494 --> 01:06:08,097
which is an infrared telescope,
and we would see events

1668
01:06:08,431 --> 01:06:09,699
where there would be this huge

1669
01:06:09,699 --> 01:06:12,335
blast of heat
from a young planetary system .

1670
01:06:12,335 --> 01:06:12,735
And really,

1671
01:06:12,735 --> 01:06:15,171
the only explanation was
that two planets had collided,

1672
01:06:15,404 --> 01:06:17,206
and that was something
that seemed impossible.

1673
01:06:17,206 --> 01:06:19,976
But then when the lunar samples
were brought back from Apollo,

1674
01:06:19,976 --> 01:06:21,177
there were possible
clues of that.

1675
01:06:21,177 --> 01:06:22,912
Having been
the origin of the moon,

1676
01:06:22,912 --> 01:06:24,780
we wouldn't have even known
what could have happened

1677
01:06:24,780 --> 01:06:26,082

in an exoplanet system.

1678
01:06:26,082 --> 01:06:28,217
Have we not been to the moon
to get that sample?

1679
01:06:28,517 --> 01:06:31,654
So, I mean, the tremendous
cataclysms that drive

1680
01:06:31,821 --> 01:06:34,256
the formation of planets,
the evolution of life.

1681
01:06:34,857 --> 01:06:38,027
Well, and Goddard thought
that the small craters on

1682
01:06:38,027 --> 01:06:39,562
the moon were volcanoes

1683
01:06:39,562 --> 01:06:42,932
and described them in his
is motivating some of his work,

1684
01:06:43,132 --> 01:06:44,300
leading to the rockets,

1685
01:06:44,300 --> 01:06:47,203
the early fuel rockets
that led to what we have today.

1686
01:06:47,570 --> 01:06:48,471
Didn't realize

1687
01:06:48,471 --> 01:06:52,408
that the mirror were impact
basins that we speak with Robert

1688

01:06:52,808 --> 01:06:56,178
has shown us here on earth
can do to a life bearing system.

1689
01:06:56,212 --> 01:06:58,314
So I think that's stunning.

1690
01:06:58,881 --> 01:07:00,750
We're becoming aware. Yeah.

1691
01:07:00,750 --> 01:07:02,885
And then finally,
we also have Dr. Gavin Schmidt.

1692
01:07:02,885 --> 01:07:06,622
He works for the Institute
of Space Studies up in New York.

1693
01:07:06,956 --> 01:07:09,392
And the director, I should say,
that is works there.

1694
01:07:09,658 --> 01:07:10,493
But we were

1695
01:07:10,493 --> 01:07:11,427
we were talking a bit

1696
01:07:11,427 --> 01:07:12,495
earlier in the day,

1697
01:07:12,495 --> 01:07:13,596
and you had all kinds of

1698
01:07:13,596 --> 01:07:15,297
questions
that were coming into your head

1699
01:07:15,297 --> 01:07:16,966

about what would
the atmosphere have been like,

1700
01:07:16,966 --> 01:07:18,434
how would the chemistry
have changed,

1701
01:07:18,434 --> 01:07:20,669
and what are some of the things
that stood out to you here?

1702
01:07:20,669 --> 01:07:24,306
So I'm very interested
in the climatic impacts of this.

1703
01:07:24,306 --> 01:07:27,843
So so I mean, we've talked about
the the instantaneous impacts,

1704
01:07:27,843 --> 01:07:31,180
you know, the fire from the sky,
the impact, the the

1705
01:07:31,213 --> 01:07:34,350
the earthquakes,
the sizes in there in the water.

1706
01:07:34,683 --> 01:07:35,751
But, you know,

1707
01:07:35,751 --> 01:07:37,053
some things
will have survived that,

1708
01:07:37,053 --> 01:07:38,521
but they might not have survived
all the

1709
01:07:38,521 --> 01:07:39,755
things that came afterwards.

1710
01:07:39,755 --> 01:07:41,891
So what happened to the carbon
cycle?

1711
01:07:41,891 --> 01:07:43,225
What happened to

1712
01:07:44,193 --> 01:07:45,361
things in the stratosphere?

1713
01:07:45,361 --> 01:07:48,597
How long and how deep was there
an impact?

1714
01:07:48,764 --> 01:07:50,900
Winter?
Was it warm? Then it got cold.

1715
01:07:50,900 --> 01:07:51,801
Then it got warm again.

1716
01:07:51,801 --> 01:07:53,569
What happened to the carbon
dioxide

1717
01:07:53,569 --> 01:07:55,337
that was released
from all the fires?

1718
01:07:55,337 --> 01:07:58,007
Was that the cause
of the acidification events?

1719
01:07:58,474 --> 01:08:01,610
And I think we haven't
really been able

1720
01:08:02,011 --> 01:08:05,281

to kind of piece together
that history

1721
01:08:05,414 --> 01:08:08,184
in very much detail so far,
because we haven't had,

1722
01:08:08,484 --> 01:08:09,218
you know,

1723
01:08:09,518 --> 01:08:12,521
specific information
from the time event itself,

1724
01:08:12,521 --> 01:08:14,156
which I think this is going
to help with a lot.

1725
01:08:14,156 --> 01:08:17,893
But we also haven't had
the models or the understanding

1726
01:08:17,893 --> 01:08:19,428
of how all those things
fit together,

1727
01:08:19,428 --> 01:08:21,797
particularly
in a Cretaceous context,

1728
01:08:22,298 --> 01:08:23,599
for us to be able to do that.

1729
01:08:23,599 --> 01:08:26,535
So really, it's only
in the last five or ten years

1730
01:08:27,136 --> 01:08:29,839
that all kind of global scale
models

1731
01:08:30,106 --> 01:08:33,776
have enough physics to be able
to answer these questions.

1732
01:08:34,210 --> 01:08:34,577
And that

1733
01:08:34,577 --> 01:08:37,680
and then this information
coming in kind of really primes

1734
01:08:37,880 --> 01:08:41,851
the pump for, I think,
future explorations of that

1735
01:08:42,985 --> 01:08:45,888
of that
whole series of cataclysms,

1736
01:08:46,021 --> 01:08:47,089
because you've got the impacts,

1737
01:08:47,089 --> 01:08:48,891
but then you've got the winter,
then you've got the starvation,

1738
01:08:48,891 --> 01:08:51,427
then you've got the fires
and whatever order, you know.

1739
01:08:51,427 --> 01:08:52,595
And maybe, you know,

1740
01:08:52,595 --> 01:08:54,497
there are some places
that were refugia,

1741
01:08:54,497 --> 01:08:55,664

maybe there were some places

1742
01:08:55,664 --> 01:08:57,933
that were not affected
by some of these things.

1743
01:08:57,933 --> 01:09:00,803
And maybe we can learn
a little bit more about,

1744
01:09:01,070 --> 01:09:05,474
you know, just even the short
term changes that that occurred.

1745
01:09:06,408 --> 01:09:10,312
And like climatically,
it's the same processes

1746
01:09:10,446 --> 01:09:13,849
that, as you say,
that we're changing now

1747
01:09:14,150 --> 01:09:17,052
through a different mechanism,
you know, changes in carbon

1748
01:09:17,052 --> 01:09:19,855
dioxide, changes in ocean
acidification, changes

1749
01:09:20,222 --> 01:09:23,159
potentially in stratospheric
input if we ever decide

1750
01:09:23,159 --> 01:09:25,394
to to geoengineering
our way out of this,

1751
01:09:26,195 --> 01:09:28,430
all of these things,

the extinction events,

1752
01:09:28,531 --> 01:09:32,301
all of these things have
parallels to the impact event,

1753
01:09:32,368 --> 01:09:33,769
but also to some of the other

1754
01:09:33,769 --> 01:09:34,803
kind of interesting events

1755
01:09:34,803 --> 01:09:37,306
that happened in the Cretaceous
or or in the years.

1756
01:09:37,473 --> 01:09:40,176
But that, you know, it's
a fascinating tableau

1757
01:09:40,276 --> 01:09:43,045
for us to be able
to build credibility

1758
01:09:43,245 --> 01:09:46,649
in our understanding
of what's happening now

1759
01:09:47,183 --> 01:09:49,318
by by explaining
what happened then.

1760
01:09:51,220 --> 01:09:52,721
I couldn't
agree more, and I couldn't

1761
01:09:52,721 --> 01:09:54,523
say it better than you just did.

1762

01:09:54,523 --> 01:09:56,292
I absolutely agree.

1763
01:09:56,292 --> 01:09:58,961
And and adding to that,

1764
01:10:00,329 --> 01:10:01,197
you know, you're talking

1765
01:10:01,197 --> 01:10:01,630
about all these

1766
01:10:01,630 --> 01:10:03,666
different processes
that occurred afterward

1767
01:10:03,666 --> 01:10:05,467
and you're
talking about injection of

1768
01:10:05,467 --> 01:10:08,237
of different debris
into the atmosphere.

1769
01:10:08,237 --> 01:10:10,973
Every little tiny step forward,
we're going to add more data

1770
01:10:10,973 --> 01:10:11,407
to that.

1771
01:10:11,407 --> 01:10:14,777
And by we, I mean
the whole scientific community.

1772
01:10:15,277 --> 01:10:18,747
And that makes that
a more complete picture.

1773

01:10:19,081 --> 01:10:20,683
And part of that is

1774
01:10:20,683 --> 01:10:23,052
if we do have
these pieces of cosmic material

1775
01:10:24,553 --> 01:10:26,789
by ascertaining
what they're made of,

1776
01:10:26,789 --> 01:10:28,090
what's the makeup,

1777
01:10:28,090 --> 01:10:28,891
that's what's being

1778
01:10:28,891 --> 01:10:31,660
injected into the atmosphere
along with the target rock.

1779
01:10:31,994 --> 01:10:32,394
So that's

1780
01:10:32,394 --> 01:10:35,564
helping us to better constrain
what was being put up there.

1781
01:10:36,265 --> 01:10:39,068
And by studying other things
at the site, including the PGE

1782
01:10:39,101 --> 01:10:41,537
boundary, that's that's capping
the deposit.

1783
01:10:42,137 --> 01:10:45,241
We're working on
kind of constraining

1784
01:10:45,841 --> 01:10:48,510
how long that impact winter
would have been,

1785
01:10:48,677 --> 01:10:50,746
how long would the blockage
of sunlight occurred.

1786
01:10:50,746 --> 01:10:55,584
And we're actually kind of fine
tuning the previous data

1787
01:10:55,584 --> 01:10:56,652
that's been collected on that.

1788
01:10:56,652 --> 01:10:59,989
So hopefully that gives us
some really interesting numbers.

1789
01:11:00,322 --> 01:11:01,657
But obviously

1790
01:11:01,657 --> 01:11:04,927
all these factors come into play
of how these poor things

1791
01:11:05,427 --> 01:11:08,931
had to weather those first
years, ten years, you know,

1792
01:11:08,964 --> 01:11:11,166
100,000 years, whatever it was.

1793
01:11:11,166 --> 01:11:13,636
And that applies exactly
like you said to today.

1794
01:11:13,969 --> 01:11:14,770
Yeah. Yeah.

1795
01:11:14,770 --> 01:11:16,705
I mean, you mentioned earlier

1796
01:11:16,705 --> 01:11:18,474
that there's some evidence
that this happened

1797
01:11:18,474 --> 01:11:20,976
in the Northern Hemisphere
spring. Right.

1798
01:11:21,110 --> 01:11:22,811
That's that's
kind of interesting, right.

1799
01:11:22,811 --> 01:11:25,381
Because the impact itself
is quite close to the equator,

1800
01:11:25,514 --> 01:11:26,982
but in the northern hemisphere.

1801
01:11:26,982 --> 01:11:27,983
And so what does that mean

1802
01:11:27,983 --> 01:11:31,553
for how much this debris
spread across the hemispheres?

1803
01:11:31,553 --> 01:11:31,754
You know,

1804
01:11:31,754 --> 01:11:33,789
maybe
in the southern hemisphere,

1805
01:11:33,789 --> 01:11:34,757
you know,

things were a little bit

1806
01:11:34,757 --> 01:11:36,225
different
and maybe not so dramatic.

1807
01:11:36,225 --> 01:11:36,692
I mean, there's a

1808
01:11:36,692 --> 01:11:40,296
there's a lot of things
to explore by looking at

1809
01:11:40,429 --> 01:11:43,866
the details of what's
coming out of these new studies.

1810
01:11:44,333 --> 01:11:44,833
Think as well

1811
01:11:44,833 --> 01:11:45,934
about the trajectory

1812
01:11:45,934 --> 01:11:49,605
of the impact and the angle
of impact of this bolide.

1813
01:11:49,938 --> 01:11:53,108
There are some impact
angles that are incompatible

1814
01:11:53,108 --> 01:11:55,377
with any fragment
surviving the impact event,

1815
01:11:55,644 --> 01:11:57,613
and there are some
that are somewhat compatible

1816

01:11:57,613 --> 01:11:58,714
and there are some impact

1817
01:11:58,714 --> 01:12:01,150
angles that would lead
to a much better,

1818
01:12:02,017 --> 01:12:04,286
you know, likelihood
that you would find a fragment.

1819
01:12:04,286 --> 01:12:06,422
So the fact that we do have
a couple of fragments

1820
01:12:06,722 --> 01:12:08,791
kind of helps us to constrain
that a little bit better.

1821
01:12:08,791 --> 01:12:09,825
I know there have been a bunch

1822
01:12:09,825 --> 01:12:11,760
of different ideas
put forward in the past.

1823
01:12:11,760 --> 01:12:13,562
This might help us
to kind of weed through those

1824
01:12:13,562 --> 01:12:15,764
a little bit better
and have an idea of what

1825
01:12:15,764 --> 01:12:17,866
that impact angle
would have been.

1826
01:12:17,866 --> 01:12:21,370
And of course, in turn,

the angle of impact has its own

1827
01:12:21,370 --> 01:12:24,039
set of implications in itself.

1828
01:12:24,740 --> 01:12:27,810
I think one of the sidebars of
what Gavin and he was saying is

1829
01:12:28,210 --> 01:12:30,913
so we think
by theoretical physics

1830
01:12:31,313 --> 01:12:34,917
that this scale of impact
10 to 20 million megatons

1831
01:12:34,917 --> 01:12:36,151
of TNT equivalent

1832
01:12:36,151 --> 01:12:38,287
would have mostly blown
off the Earth's atmosphere

1833
01:12:38,554 --> 01:12:40,322
as it existed at the time.

1834
01:12:40,322 --> 01:12:41,623
It's all gone.

1835
01:12:41,657 --> 01:12:42,524
What happened?

1836
01:12:42,524 --> 01:12:43,759
It obviously didn't do that

1837
01:12:43,759 --> 01:12:45,661
completely
because life persisted.

1838
01:12:45,661 --> 01:12:47,663
You have
the most record in your stuff.

1839
01:12:47,663 --> 01:12:49,898
So what was the early time like?

1840
01:12:50,232 --> 01:12:54,203
Because, you know, we're
also dumping gigatons of stuff

1841
01:12:54,203 --> 01:12:57,306
into the stratosphere,
mostly from the target,

1842
01:12:57,306 --> 01:13:01,043
which was the carbonate bank
with ocean waters and all that.

1843
01:13:01,043 --> 01:13:03,178
So that's the primary load,
not the impact.

1844
01:13:03,178 --> 01:13:04,380
That's a little thing.

1845
01:13:04,380 --> 01:13:09,051
It's excavating to 30 kilometers
in the quasi oceanic crust,

1846
01:13:09,318 --> 01:13:11,320
only grabbing at 30 kilometers
down,

1847
01:13:11,387 --> 01:13:13,088
probably the transient greater.

1848
01:13:13,088 --> 01:13:14,823

Absolutely.

1849
01:13:14,890 --> 01:13:16,692
So on. My God.

1850
01:13:16,692 --> 01:13:17,159
I mean, now

1851
01:13:17,159 --> 01:13:19,128
we're through the skin of
I mean,

1852
01:13:19,128 --> 01:13:21,096
like the continental crust
by the oceanic crust.

1853
01:13:21,096 --> 01:13:22,231
Be right through it.

1854
01:13:22,231 --> 01:13:25,200
So, you know, God forbid,
what does that all mean?

1855
01:13:25,501 --> 01:13:25,768
You know,

1856
01:13:25,768 --> 01:13:28,370
and these are the implications
of that early time life record

1857
01:13:28,570 --> 01:13:30,506
and the chemical record
you were getting to.

1858
01:13:30,506 --> 01:13:31,840
Any of that's preserved,

1859
01:13:31,840 --> 01:13:32,574
those are going to be

1860
01:13:32,574 --> 01:13:36,612
those model constraints
that we can use for models that,

1861
01:13:36,645 --> 01:13:39,448
you know, that can produce
where everything's going.

1862
01:13:39,648 --> 01:13:41,517
But what else is going on?

1863
01:13:41,517 --> 01:13:43,018
You know,
they got down that deep.

1864
01:13:43,018 --> 01:13:44,453
I mean, did it actually like

1865
01:13:44,453 --> 01:13:46,622
was that like a volcano
that hit magma or something?

1866
01:13:46,722 --> 01:13:49,825
Well, it would have hit
whatever's at the 30 kilometer

1867
01:13:49,825 --> 01:13:52,394
depth in the transient cavity
propagation, like Robert said.

1868
01:13:52,394 --> 01:13:56,698
But then the excavation stage
moved this massive stuff out

1869
01:13:56,698 --> 01:13:59,334
and rippled it through over
a period of a few hours.

1870

01:13:59,635 --> 01:14:01,036
And the resonant thermal pulse

1871
01:14:01,036 --> 01:14:01,770
was probably,

1872
01:14:01,770 --> 01:14:04,873
you know, thousands of years
in that region, in that area.

1873
01:14:04,873 --> 01:14:07,543
So that Relic's scar
is going to be part

1874
01:14:07,543 --> 01:14:09,311
of the Earth's history
in that region.

1875
01:14:09,311 --> 01:14:10,612
You're 3000 kilometers away.

1876
01:14:10,612 --> 01:14:12,714
So that's a great place
to look at the consequences

1877
01:14:12,714 --> 01:14:13,582
without having been,

1878
01:14:13,582 --> 01:14:17,085
you know, eradicated quickly
or more quickly than you'd like.

1879
01:14:17,386 --> 01:14:18,554
Probably didn't feel a thing.

1880
01:14:18,554 --> 01:14:20,923
Well, I don't know if anybody
likes to be eradicated, right?

1881

01:14:20,923 --> 01:14:21,857
No, no. Eradication

1882
01:14:23,792 --> 01:14:24,927
eradication is not.

1883
01:14:24,927 --> 01:14:26,562
Yeah, there's
no that's not a good thing.

1884
01:14:26,562 --> 01:14:27,729
Well, actually and Christo,

1885
01:14:27,729 --> 01:14:29,598
as the hydrologist,
we were talking about how

1886
01:14:29,598 --> 01:14:31,900
they were fresh water
animals and saltwater animals

1887
01:14:32,134 --> 01:14:33,335
all mixed together. Yeah.

1888
01:14:33,335 --> 01:14:35,604
So so this really was
a catastrophic flow

1889
01:14:35,737 --> 01:14:38,006
of a saltwater body
into a river system.

1890
01:14:38,006 --> 01:14:39,041
Yes, exactly.

1891
01:14:39,041 --> 01:14:40,642
So, I mean, that that's

1892
01:14:40,642 --> 01:14:43,278

that was such a compelling piece
of evidence here.

1893
01:14:43,278 --> 01:14:44,480
Right, that,

1894
01:14:44,480 --> 01:14:44,980
you know, that

1895
01:14:44,980 --> 01:14:48,083
you see these species together
that shouldn't be together.

1896
01:14:48,750 --> 01:14:50,686
And, you know, again.

1897
01:14:50,686 --> 01:14:52,855
I like it. It made me.

1898
01:14:53,755 --> 01:14:57,192
You know, curious
about how I mean, it is

1899
01:14:57,292 --> 01:15:01,930
it was sort of a jumble of
of lots of things together. So.

1900
01:15:02,197 --> 01:15:06,101
I mean, as you approach this
jumble and you started to say,

1901
01:15:06,101 --> 01:15:07,769
wait a minute,
that shouldn't be here.

1902
01:15:07,769 --> 01:15:09,404
Like, how did you approach?

1903
01:15:10,506 --> 01:15:11,507

You know,

1904
01:15:11,507 --> 01:15:14,843
going forward, once you started
to realize like, wait a minute,

1905
01:15:14,843 --> 01:15:17,412
this is different,
this should not be here.

1906
01:15:17,412 --> 01:15:20,382
Well, before there was anything
involving the impact,

1907
01:15:20,382 --> 01:15:24,520
even in our brains,
the two real red flags are okay.

1908
01:15:24,520 --> 01:15:27,289
You've got a river
that would normally run somewhat

1909
01:15:27,289 --> 01:15:30,259
east and it's running
westward now

1910
01:15:30,759 --> 01:15:33,061
based on the flow direction that
that doesn't make any sense.

1911
01:15:33,629 --> 01:15:35,364
And you couple that
with the fact

1912
01:15:35,364 --> 01:15:38,200
that you've got Marine fossils
there, microfossils, you've got

1913
01:15:38,767 --> 01:15:41,370
dinoflagellates,

you've got form and infra,

1914
01:15:41,603 --> 01:15:43,539
and then you've got Ammonites
and other things,

1915
01:15:43,539 --> 01:15:47,776
mosasaur pieces and and marine
fish and sharks teeth.

1916
01:15:48,210 --> 01:15:51,947
You've got all those marine
fossils mixed in this deposit

1917
01:15:52,281 --> 01:15:56,184
that was created by a westward
flowing surge.

1918
01:15:56,184 --> 01:15:59,421
And obviously, it's not supposed
to be that way, right?

1919
01:15:59,454 --> 01:16:01,356
That's not the way rivers
usually behave.

1920
01:16:01,356 --> 01:16:03,592
So it's an exceptional event
that got us thinking,

1921
01:16:03,625 --> 01:16:05,160
what the heck went on over here?

1922
01:16:05,160 --> 01:16:07,462
Why did the surge occur?

1923
01:16:07,462 --> 01:16:09,498
And then we were finding ejecta

1924

01:16:09,498 --> 01:16:11,767
and different things
that connected it to the impact.

1925
01:16:11,767 --> 01:16:14,803
And then there was the cap
of the big clay, like, oh.

1926
01:16:15,170 --> 01:16:17,239
Oh, what's that? Yeah. Yeah.

1927
01:16:18,140 --> 01:16:20,309
I bet you reacted
more dramatically than that.

1928
01:16:20,342 --> 01:16:21,710
I mean, you're talking about

1929
01:16:21,710 --> 01:16:23,211
wanting to be
in the minds of these creatures.

1930
01:16:23,211 --> 01:16:25,213
I want to be in your mind
as you started

1931
01:16:25,213 --> 01:16:28,684
piecing this together
and like, oh, my gosh, that's

1932
01:16:29,251 --> 01:16:30,252
that was a wild place.

1933
01:16:31,887 --> 01:16:34,189
Yeah, I can see the part.

1934
01:16:34,189 --> 01:16:38,427
So did you find this site or was
that was it found in Matt?

1935
01:16:39,127 --> 01:16:40,729
But people
didn't really know what it was.

1936
01:16:40,729 --> 01:16:41,697
The site is actually

1937
01:16:41,697 --> 01:16:44,866
a really incredible story
and it's actually

1938
01:16:45,067 --> 01:16:48,170
a beautiful situation
of how things really should work

1939
01:16:49,171 --> 01:16:51,073
of people working together.

1940
01:16:51,073 --> 01:16:54,076
I worked on a site
for my master's

1941
01:16:54,309 --> 01:16:56,545
thesis
that dealt with really fine time

1942
01:16:56,545 --> 01:16:57,679
scales in the fossil record,

1943
01:16:57,679 --> 01:17:00,248
and we wanted to find one
closer to the boundary.

1944
01:17:00,682 --> 01:17:04,353
And there was a group of
of avocation

1945
01:17:04,453 --> 01:17:07,222
or fossil hunters

who have a company that

1946
01:17:07,756 --> 01:17:10,258
digs up and sells
fossils of paleo prospectors

1947
01:17:10,459 --> 01:17:12,094
Steve Nicholas and Rob Silva.

1948
01:17:12,094 --> 01:17:14,429
They originally set
foot on the site

1949
01:17:14,663 --> 01:17:16,765
and they saw all these fish
poking out of the site,

1950
01:17:16,765 --> 01:17:19,034
which was a big red flag
for them.

1951
01:17:19,067 --> 01:17:20,402
You don't see fish

1952
01:17:20,402 --> 01:17:22,638
in the Hell Creek formation
before that site.

1953
01:17:22,871 --> 01:17:25,040
There were, I think, three
or four articulated fish.

1954
01:17:25,040 --> 01:17:26,642
It doesn't happen.

1955
01:17:26,675 --> 01:17:29,544
The preservation bias is against

1956
01:17:29,578 --> 01:17:31,013

the preservation of fish
like that.

1957
01:17:31,013 --> 01:17:31,980
So that was exceptional.

1958
01:17:31,980 --> 01:17:34,049
Oh, my God, we've got fish
at the site.

1959
01:17:34,049 --> 01:17:35,984
And little
did we know that we'd be,

1960
01:17:35,984 --> 01:17:37,519
you know, wowing over
everything else later.

1961
01:17:37,519 --> 01:17:40,889
But that point, it was the fish
and they thought it was a lake

1962
01:17:40,889 --> 01:17:42,924
at first
because of the striations.

1963
01:17:43,325 --> 01:17:45,494
And that was interesting to me.

1964
01:17:45,961 --> 01:17:50,365
And they facilitated the work
to move forward to

1965
01:17:50,365 --> 01:17:51,299
my research group.

1966
01:17:51,299 --> 01:17:53,201
And that's the best thing
that could ever have happened

1967
01:17:53,201 --> 01:17:55,103
because we were able to piece
together

1968
01:17:55,103 --> 01:17:58,740
everything that occurred
thus far in our research

1969
01:17:59,074 --> 01:18:03,278
and we were able to get all of
these specimens, preserve them,

1970
01:18:03,612 --> 01:18:06,281
because the environment out

1971
01:18:06,281 --> 01:18:09,217
there is not conducive
to the preservation of fossils.

1972
01:18:09,518 --> 01:18:11,987
They're imperiled every moment
they're in the outcrop,

1973
01:18:12,020 --> 01:18:14,756
they will get washed away.
The winter is bad on them.

1974
01:18:14,956 --> 01:18:17,793
So that whole situation ended up

1975
01:18:18,026 --> 01:18:20,762
culminating
in a tremendous research project

1976
01:18:21,363 --> 01:18:25,701
and an amazing interpretation
of the site and data

1977
01:18:25,701 --> 01:18:28,970

that is now able to be used
by God knows how many people

1978
01:18:29,237 --> 01:18:30,839
to try
to put the story together.

1979
01:18:30,839 --> 01:18:34,409
So yeah, that one group actually
first set foot on the site,

1980
01:18:34,743 --> 01:18:36,878
and if they hadn't done that,

1981
01:18:36,878 --> 01:18:38,513
who knows if it ever
would have been found?

1982
01:18:38,513 --> 01:18:40,882
Because there were other people,
researchers

1983
01:18:40,882 --> 01:18:43,985
working in that area for decades
and they never saw the site.

1984
01:18:44,219 --> 01:18:45,687
They never even found it.

1985
01:18:45,687 --> 01:18:47,856
No, they knew you like fish.

1986
01:18:47,856 --> 01:18:49,658
And so they were like,
Hey, there's something cool.

1987
01:18:49,658 --> 01:18:53,862
Just look at this fish and and
look what history made for us.

1988
01:18:53,862 --> 01:18:57,199
You know, it goes from fish
to putting together little, tiny

1989
01:18:57,199 --> 01:19:00,769
details of this massive story
of the end of the Cretaceous.

1990
01:19:01,336 --> 01:19:03,371
Who would guess you're talking
about the data and all that?

1991
01:19:03,371 --> 01:19:05,073
I mean I mean,
you guys are all here also.

1992
01:19:05,073 --> 01:19:05,974
I mean, collaborate.

1993
01:19:05,974 --> 01:19:06,141
I mean,

1994
01:19:06,141 --> 01:19:07,909
what would you like
to get from this group

1995
01:19:07,909 --> 01:19:09,478
and what would you like
to get from NASA

1996
01:19:09,478 --> 01:19:11,480
that will make, you know, things
even better?

1997
01:19:11,480 --> 01:19:12,681
The story even more interesting,

1998
01:19:12,681 --> 01:19:14,750
making

you guys think here at NASA,

1999
01:19:14,750 --> 01:19:16,284
the stuff you really like
to get a hold of the years.

2000
01:19:18,754 --> 01:19:20,956
I mean, not, not physically,
but I mean, we, we just.

2001
01:19:20,956 --> 01:19:24,626
We discussed, um, just earlier,
you know,

2002
01:19:24,760 --> 01:19:26,995
what else is in those? Right.

2003
01:19:27,195 --> 01:19:29,931
I mean,
if there are air inclusions

2004
01:19:30,232 --> 01:19:33,635
that can give us hints
of what that paleo atmosphere

2005
01:19:33,802 --> 01:19:38,106
was like in terms of carbon
dioxide levels, methane levels.

2006
01:19:38,340 --> 01:19:41,343
I, you know, it it's
I mean, like, just like in

2007
01:19:41,376 --> 01:19:43,979
an ice core, you know,
we preserve these bubbles,

2008
01:19:44,946 --> 01:19:46,581
you know, that
go back a million years.

2009
01:19:46,581 --> 01:19:46,748
Okay.

2010
01:19:46,748 --> 01:19:49,351
This is this is another this is
another level, of course.

2011
01:19:49,351 --> 01:19:52,821
But but if if there if there is
air that can be analyzed,

2012
01:19:53,388 --> 01:19:57,526
that's that would be
that would be a huge a huge

2013
01:19:58,693 --> 01:20:00,595
input into what we're doing,

2014
01:20:00,595 --> 01:20:03,031
because we know that,
you know, at that period.

2015
01:20:03,231 --> 01:20:03,732
Right.

2016
01:20:04,032 --> 01:20:05,934
You know,
the kind of end Cretaceous time

2017
01:20:05,934 --> 01:20:09,805
climate was changing
even before the impact happened,

2018
01:20:10,038 --> 01:20:12,440
that there were
there were climate changes. And

2019
01:20:13,542 --> 01:20:14,976

and, you
know, this is a long period.

2020
01:20:14,976 --> 01:20:17,712
There's lots of other things
that happened in the Cretaceous,

2021
01:20:18,280 --> 01:20:20,148
the ocean, anoxic events and,

2022
01:20:20,148 --> 01:20:21,616
you know,
the peak Cretaceous times.

2023
01:20:21,616 --> 01:20:23,051
But there were things happening

2024
01:20:23,051 --> 01:20:25,954
right then that
that we don't really understand.

2025
01:20:25,954 --> 01:20:28,323
You know, it was it was it
related to tectonic changes,

2026
01:20:28,356 --> 01:20:33,128
you know, closures of various
seaways, the sea in Europe?

2027
01:20:33,862 --> 01:20:36,031
You know, it's
very it's unclear.

2028
01:20:36,498 --> 01:20:38,200
And so there's a lot of focus on

2029
01:20:38,200 --> 01:20:40,368
what was happening immediately
before the impact.

2030
01:20:40,535 --> 01:20:43,138
But then to have,
you know, like examples

2031
01:20:43,972 --> 01:20:44,940
that could really kind of ground

2032
01:20:44,940 --> 01:20:47,275
truth,
some of those speculations

2033
01:20:47,275 --> 01:20:49,311
would be of enormous interest.

2034
01:20:49,311 --> 01:20:53,782
And then you have the
the things that could evaluate

2035
01:20:54,115 --> 01:20:57,452
how well our simulations
are working, right?

2036
01:20:57,452 --> 01:20:59,721
So, you know,
so we put in these assumptions,

2037
01:20:59,721 --> 01:21:00,055
we run

2038
01:21:00,055 --> 01:21:03,291
these models of various kinds,
and you'd have to string them

2039
01:21:03,291 --> 01:21:05,760
all together, you know,
kind of one after the other.

2040
01:21:05,760 --> 01:21:07,796
And then, you know, okay, well,

we predict

2041
01:21:07,796 --> 01:21:08,797
this may have happened

2042
01:21:08,797 --> 01:21:11,466
all this tell us from the data
which one it was.

2043
01:21:11,700 --> 01:21:13,768
Right. And then we can kind of
constrain things coming back.

2044
01:21:14,269 --> 01:21:16,404
And so so
those kinds of things like,

2045
01:21:16,404 --> 01:21:18,773
you know, things
like temperature is things like

2046
01:21:18,773 --> 01:21:21,810
know water isotopes
or you know, all sorts of,

2047
01:21:22,344 --> 01:21:23,378
you know, the,

2048
01:21:23,378 --> 01:21:25,146
you know, how much burning there
was, how much

2049
01:21:25,146 --> 01:21:26,948
how much charcoal you find.

2050
01:21:26,948 --> 01:21:28,917
Those are
the kinds of things that are

2051

01:21:28,917 --> 01:21:31,319
that are really key
for evaluating

2052
01:21:31,853 --> 01:21:35,023
our kind of suppositions
of more than that.

2053
01:21:35,023 --> 01:21:35,190
Right?

2054
01:21:35,190 --> 01:21:37,425
I mean, you don't have
all of the little bits of amber

2055
01:21:37,425 --> 01:21:39,794
that you're going to find
these things that that site has.

2056
01:21:40,195 --> 01:21:42,297
We've only seen
the tip of the iceberg,

2057
01:21:42,731 --> 01:21:45,033
only the tip of the iceberg
every single season

2058
01:21:45,500 --> 01:21:47,469
that we go out there
and that the other research

2059
01:21:47,469 --> 01:21:49,638
groups from other universities
join us out there.

2060
01:21:50,071 --> 01:21:52,707
Something is found
that we've never seen before

2061
01:21:52,707 --> 01:21:54,809

and it carries
the research forward.

2062
01:21:54,809 --> 01:21:56,244
And we were just having
a conversation

2063
01:21:56,244 --> 01:21:58,179
before
about nondestructive analysis.

2064
01:21:58,179 --> 01:22:02,017
I can think of a whole host
of things that would be amazing

2065
01:22:02,017 --> 01:22:04,286
for collaborative work,
on the nondestructive analysis,

2066
01:22:04,286 --> 01:22:06,554
on the ejecta
and the other items here.

2067
01:22:06,788 --> 01:22:09,858
That would be they would offer
volumes of data.

2068
01:22:10,125 --> 01:22:13,995
And with the hydro
modeling in terms of of better

2069
01:22:13,995 --> 01:22:17,032
modeling of the of the dynamics
of the surge wave,

2070
01:22:17,799 --> 01:22:20,835
that's something
that is an amazing project

2071
01:22:21,069 --> 01:22:23,138

that could probably lead
to multiple papers,

2072
01:22:23,138 --> 01:22:24,005
you know, down the road.

2073
01:22:25,073 --> 01:22:26,374
And I
think there's another aspect,

2074
01:22:26,374 --> 01:22:28,476
which is Roberts
already talked about it,

2075
01:22:28,476 --> 01:22:29,244
which is,

2076
01:22:29,244 --> 01:22:32,514
you know, this is one cosmic
event recorded in Earth history

2077
01:22:32,514 --> 01:22:34,616
with all the climate
and other implications.

2078
01:22:34,616 --> 01:22:36,051
But there's others.

2079
01:22:36,051 --> 01:22:38,920
I mean, recently the Hiawatha
structure in Greenland was

2080
01:22:39,621 --> 01:22:41,723
identified as being relevant
to this

2081
01:22:42,090 --> 01:22:43,625
transitional period of time,

2082

01:22:43,625 --> 01:22:45,927
you know, into the PG,
the paleo gene.

2083
01:22:46,695 --> 01:22:48,330
We have others
where there were mass

2084
01:22:48,330 --> 01:22:50,332
extinctions
observed of different magnitude.

2085
01:22:50,565 --> 01:22:53,835
The Oligocene that puppy guy the
promote Triassic further back.

2086
01:22:54,102 --> 01:22:56,404
These are the Earth record
as the chronology

2087
01:22:56,705 --> 01:22:59,541
of the solar system
that we use relative to the moon

2088
01:22:59,541 --> 01:23:00,976
and other chronometers.

2089
01:23:00,976 --> 01:23:03,111
This is critical
for planetary sciences.

2090
01:23:03,111 --> 01:23:04,579
So I think Robert's

2091
01:23:04,579 --> 01:23:06,247
data and materials

2092
01:23:06,247 --> 01:23:08,350
can be analyzed
through some of those techniques

2093
01:23:08,350 --> 01:23:08,817
he mentioned,

2094
01:23:08,817 --> 01:23:10,585
which we're
now using on lunar rocks,

2095
01:23:10,585 --> 01:23:13,288
some of which have been, you
know, stored away for 50 years.

2096
01:23:13,521 --> 01:23:16,891
So we have the
better tools so that cross,

2097
01:23:18,560 --> 01:23:20,628
you know, cross-disciplinary

2098
01:23:20,628 --> 01:23:22,464
collaboration,
I think would be very fertile.

2099
01:23:22,464 --> 01:23:24,466
And I have a question for you
which relates to that,

2100
01:23:24,466 --> 01:23:26,601
which is so
what about the pollen?

2101
01:23:26,601 --> 01:23:29,304
You've now got Amber,
you've got zeros,

2102
01:23:29,337 --> 01:23:31,873
you've got pieces
of the impacting object.

2103

01:23:32,674 --> 01:23:33,575
Then there's pollen,

2104
01:23:33,575 --> 01:23:36,711
which is a very good indicator
of many aspects of environment

2105
01:23:36,978 --> 01:23:39,547
and really robust
one in the earth history

2106
01:23:40,048 --> 01:23:41,349
you've
talked about a little bit,

2107
01:23:41,349 --> 01:23:44,152
but maybe that's an area
of very exciting

2108
01:23:44,753 --> 01:23:47,022
sample analysis
and it's underexplored right now

2109
01:23:47,022 --> 01:23:48,990
too, because the pollen so far,

2110
01:23:48,990 --> 01:23:51,359
yes, it exists at the site,
beautifully preserved.

2111
01:23:51,659 --> 01:23:54,362
And thus far
it has been explored

2112
01:23:54,362 --> 01:23:56,464
mainly
as a bio stratigraphic marker.

2113
01:23:56,464 --> 01:23:59,067
So we're establishing

where we are in time.

2114
01:23:59,467 --> 01:24:03,304
But in terms of
working out the biota back then

2115
01:24:03,304 --> 01:24:06,975
and the the turnover
of the ecological turnover

2116
01:24:06,975 --> 01:24:08,276
and what happened

2117
01:24:08,276 --> 01:24:10,678
right at that moment
and then up into the lower

2118
01:24:10,678 --> 01:24:12,213
paleo gene
that has been done over

2119
01:24:12,213 --> 01:24:14,816
there yet
and it is ripe for the study.

2120
01:24:14,816 --> 01:24:16,251
So I was going to ask
before, when

2121
01:24:16,251 --> 01:24:18,319
do you want to get started? But.

2122
01:24:18,319 --> 01:24:20,321
You know,
with the pollen, too, I think

2123
01:24:21,823 --> 01:24:24,192
we're already in the danger.

2124

01:24:24,325 --> 01:24:26,795
So I'm ruminating on

2125
01:24:26,795 --> 01:24:29,330
this is like the archetype
of hands on research.

2126
01:24:29,631 --> 01:24:30,131
Quack, quack, quack

2127
01:24:30,432 --> 01:24:31,599
with your tools and dig

2128
01:24:31,599 --> 01:24:33,802
in a little bit into the rock
and see what you find.

2129
01:24:34,235 --> 01:24:34,569
And then

2130
01:24:34,569 --> 01:24:35,103
if you're lucky,

2131
01:24:35,103 --> 01:24:35,904
you notice that there's

2132
01:24:35,904 --> 01:24:37,572
this little brown layer
and you realize it's

2133
01:24:37,572 --> 01:24:39,941
a dinosaur skin
and you're really super careful.

2134
01:24:40,408 --> 01:24:41,876
But I keep thinking,

2135
01:24:41,876 --> 01:24:44,212
isn't there something high tech

engineering could give you?

2136
01:24:44,546 --> 01:24:46,881
And I don't know what you need,
but I sure think

2137
01:24:47,482 --> 01:24:49,617
it's worth finding it,
whatever it is,

2138
01:24:49,617 --> 01:24:52,087
because this is so important
and it's so precious

2139
01:24:52,353 --> 01:24:53,688
and there's no other site
like this

2140
01:24:53,688 --> 01:24:55,690
in the entire planet
that we know of.

2141
01:24:55,690 --> 01:24:57,358
So we need to get everything
we can.

2142
01:24:57,358 --> 01:25:00,161
And so
before it all washes away,

2143
01:25:01,696 --> 01:25:02,630
let's find it and

2144
01:25:02,630 --> 01:25:04,966
let's give you all the help
we can possibly imagine.

2145
01:25:05,700 --> 01:25:08,136
I'll never try to turn away any

2146
01:25:08,136 --> 01:25:11,272
really, really, really good
recommendations on that end.

2147
01:25:11,272 --> 01:25:12,040
And putting

2148
01:25:12,040 --> 01:25:15,310
on the thinking caps,
because you're absolutely right,

2149
01:25:15,810 --> 01:25:19,013
with the fossils and their mode
of preservation, they're there.

2150
01:25:19,013 --> 01:25:20,248
They're very fragile.

2151
01:25:20,248 --> 01:25:22,650
They're they're
almost impossible to prepare

2152
01:25:22,917 --> 01:25:24,319
and to stabilize.

2153
01:25:24,319 --> 01:25:25,720
We have had to develop

2154
01:25:25,720 --> 01:25:29,357
new techniques and excavation
and stabilization for these

2155
01:25:29,591 --> 01:25:31,059
that are different
than what you normally use.

2156
01:25:31,059 --> 01:25:32,494
And they'll creek formation.

2157
01:25:32,494 --> 01:25:35,396
They dictate that
we have to do that.

2158
01:25:35,830 --> 01:25:38,600
And basically
through that process

2159
01:25:38,600 --> 01:25:41,302
we have developed incredibly,

2160
01:25:41,302 --> 01:25:44,506
painfully detailed excavation
practices

2161
01:25:44,739 --> 01:25:48,476
going centimeter by centimeter
and then stabilizing as we go

2162
01:25:49,744 --> 01:25:51,613
to accomplish this.

2163
01:25:51,613 --> 01:25:52,313
But we're

2164
01:25:52,313 --> 01:25:54,282
always trying to up our game

2165
01:25:54,282 --> 01:25:55,383
and we are always trying

2166
01:25:55,383 --> 01:25:57,652
to refine these methods
and find better methods

2167
01:25:57,785 --> 01:25:59,954
and really think
outside the box.

2168
01:25:59,954 --> 01:26:01,489
We recently

2169
01:26:01,489 --> 01:26:05,126
got some of the specimens that
were almost impossible to move

2170
01:26:05,393 --> 01:26:08,763
because you put plaster
jackets on the matrix.

2171
01:26:08,930 --> 01:26:12,867
But if that is saturated with
moisture, you can't move it.

2172
01:26:12,867 --> 01:26:15,370
It's going to be basically the
consistency of peanut butter.

2173
01:26:15,370 --> 01:26:17,805
It'll it'll get destroyed.
So what do we do?

2174
01:26:17,906 --> 01:26:20,175
You can't put glue on that
because the glue is not going

2175
01:26:20,175 --> 01:26:22,277
to go. It's already
saturated with something else.

2176
01:26:22,277 --> 01:26:25,713
So we decided, okay, we'll use
whatever it's saturated in,

2177
01:26:25,713 --> 01:26:27,782
which is water to
then stabilize it.

2178

01:26:27,782 --> 01:26:30,618
So we flash froze
this block with liquid nitrogen,

2179
01:26:31,286 --> 01:26:33,054
turned it into a solid block,

2180
01:26:33,054 --> 01:26:35,323
stabilized it
that way, moved it out.

2181
01:26:35,323 --> 01:26:38,226
And then we thought it
in a controlled environment

2182
01:26:38,326 --> 01:26:39,494
before research

2183
01:26:39,494 --> 01:26:42,797
and we determined
via SDM analysis and the

2184
01:26:43,031 --> 01:26:46,267
thin sections that that was
not harmful to the fossil.

2185
01:26:46,601 --> 01:26:48,703
So we need a lot more,

2186
01:26:48,736 --> 01:26:51,039
a lot more thinking
outside the box like that

2187
01:26:51,039 --> 01:26:53,208
and it's not just
going to come from us.

2188
01:26:53,575 --> 01:26:55,944
So you are liquid
nitrogen factory on site.

2189
01:26:56,811 --> 01:26:59,581
I was thinking about
you and I get liquid nitrogen.

2190
01:26:59,581 --> 01:27:00,481
We got liquid nitrogen.

2191
01:27:00,481 --> 01:27:02,083
We know how to do that.

2192
01:27:02,083 --> 01:27:03,051
I was actually thinking about

2193
01:27:03,051 --> 01:27:05,453
I can work on stabilizing
organic compounds,

2194
01:27:05,453 --> 01:27:08,022
which is useful in the Mars
analysis.

2195
01:27:08,289 --> 01:27:09,557
I mean, in that case,
you're basically going

2196
01:27:09,557 --> 01:27:12,160
molecule by molecule
to stabilize the sample.

2197
01:27:12,260 --> 01:27:13,661
That's something people do here

2198
01:27:13,661 --> 01:27:15,063
that would be absolutely useful.

2199
01:27:15,063 --> 01:27:15,763
Absolutely.

2200
01:27:15,763 --> 01:27:17,665
Also,
the new classes of topographic

2201
01:27:17,665 --> 01:27:21,402
imaging at outcrop scale
that are now being used

2202
01:27:21,402 --> 01:27:22,570
in certain sectors,

2203
01:27:22,570 --> 01:27:24,672
including in geophysical
exploration,

2204
01:27:24,973 --> 01:27:28,009
could image at centimeter scale
in a three dimensional volume

2205
01:27:28,376 --> 01:27:30,311
into a target
depending on wavelength.

2206
01:27:30,311 --> 01:27:32,080
So that could characterize

2207
01:27:32,080 --> 01:27:34,048
your site before
you've actually dug into it.

2208
01:27:34,048 --> 01:27:36,451
The biology group, I
think, needs to be very helpful.

2209
01:27:37,151 --> 01:27:38,620
Yeah, absolutely.

2210
01:27:38,620 --> 01:27:40,321
It was speaking of astrobiology

and stuff

2211
01:27:40,321 --> 01:27:41,656
in the search for life outside.

2212
01:27:41,656 --> 01:27:42,390
So I mean,

2213
01:27:42,523 --> 01:27:44,325
understanding
impacts like this here,

2214
01:27:44,325 --> 01:27:46,060
how does that help us understand
other planets better?

2215
01:27:46,060 --> 01:27:47,996
I know that's something
you think a lot about.

2216
01:27:47,996 --> 01:27:51,899
Well, I'm just struck because on
Mars and Venus, we have two

2217
01:27:51,933 --> 01:27:54,702
excellent class impacts
in the more and more recent

2218
01:27:55,169 --> 01:27:56,938
eras of their record.

2219
01:27:56,938 --> 01:27:59,440
And we use those on the moon
to characterize all time blocks.

2220
01:27:59,707 --> 01:28:00,742
We see them on Mars.

2221
01:28:00,742 --> 01:28:04,212

We wonder about them in this,
you know, more recent history,

2222
01:28:04,412 --> 01:28:06,314
historical period of Mars

2223
01:28:06,314 --> 01:28:07,715
as not something from Gale

2224
01:28:07,715 --> 01:28:09,284
Crater three
and a half billion years ago,

2225
01:28:09,284 --> 01:28:10,718
but something
from the last billion.

2226
01:28:10,718 --> 01:28:13,755
And then there's Venus, where
there's only one in this size

2227
01:28:13,755 --> 01:28:16,557
class, maybe two
if you get sketchy.

2228
01:28:16,858 --> 01:28:20,628
So, wow, what did Venus did,
as some climate models suggest

2229
01:28:20,628 --> 01:28:25,133
done, in fact, at Gavin's group
have persistent surface

2230
01:28:25,133 --> 01:28:26,901
waters for billions of years

2231
01:28:26,901 --> 01:28:29,370
and that suppressed
the record of impact.

2232
01:28:29,370 --> 01:28:30,571
And the only ones we see

2233
01:28:30,571 --> 01:28:32,740
are those that happened later
that are more recent,

2234
01:28:32,740 --> 01:28:35,677
that are the sixth lives
of Venus or other worlds.

2235
01:28:35,677 --> 01:28:37,578
And I just thinking of Mars
and Venus

2236
01:28:37,578 --> 01:28:41,949
because they're climate relevant
objects nearby and exoplanets

2237
01:28:41,949 --> 01:28:44,719
where John's telescope
and others will be able to start

2238
01:28:44,719 --> 01:28:47,055
ferreting out
those classes of objects.

2239
01:28:47,455 --> 01:28:49,691
You know,
they might have reflected

2240
01:28:49,691 --> 01:28:52,593
an impact preserved
aspect of atmospheric change.

2241
01:28:52,894 --> 01:28:54,862
Unbelievable the connections.

2242
01:28:54,862 --> 01:28:56,564

And so we need Earth
Ground Truth

2243
01:28:56,564 --> 01:28:58,199
to apply that message forward.

2244
01:28:58,199 --> 01:28:59,300
And you've done that.

2245
01:28:59,300 --> 01:29:01,536
And I think
we can learn from you

2246
01:29:01,536 --> 01:29:03,538
and we can continue doing it
forward. Right?

2247
01:29:03,538 --> 01:29:04,305
Right, right.

2248
01:29:04,305 --> 01:29:04,939
Yeah. Not just me.

2249
01:29:04,939 --> 01:29:06,708
It's a massive,
massive collaboration.

2250
01:29:06,708 --> 01:29:09,077
Lots of women, men working on
this is all good.

2251
01:29:09,677 --> 01:29:12,180
I think we've got a plan
going forward and I guess emails

2252
01:29:12,280 --> 01:29:13,815
want to say thing before
we wrap up our discussion.

2253

01:29:15,850 --> 01:29:17,085
When can we visit?

2254
01:29:17,085 --> 01:29:18,453
One incredible day.
That's right.

2255
01:29:18,453 --> 01:29:19,554
Well, we'll start making plans.

2256
01:29:19,554 --> 01:29:21,889
It's mushy right now.

2257
01:29:22,090 --> 01:29:23,524
And that's the technical
term. Right.

2258
01:29:23,524 --> 01:29:24,592
But. But.

2259
01:29:25,693 --> 01:29:26,728
The sky's the limit.

2260
01:29:26,728 --> 01:29:29,330
Let me know
when that will wrap it up.

2261
01:29:29,364 --> 01:29:30,331
Thank you so much for joining