1 01:30:58:14 01:31:01:26 Annenberg Media
2 01:31:01:28 01:31:57:09 §
3 01:31:57:11 01:32:01:11 *ON AN ACTIVE LAVA POOL*
LIKE THIS ONE IN HAWAII,
4 01:32:01:13 01:32:02:23 *CRUSTAL FRAGMENTS*
SEPARATE,
5 01:32:02:25 01:32:05:08 *SLIP PAST ONE ANOTHER,*
AND COLLIDE,
6 01:32:05:10 01:32:08:14 *CONTINUOUSLY REARRANGING*
AND DEFORMING THE SURFACE.
7 01:32:12:11 01:32:14:24 THE COLLISIONS
THAT WE'VE JUST SEEN
8 01:32:14:26 01:32:16:08 MAY SEEM
COMPLETELY UNRELATED
9 01:32:16:10 01:32:18:24 TO THIS SERENE
AND BEAUTIFUL LANDSCAPE,
10 01:32:18:26 01:32:21:11 BUT, IN FACT, THIS VALLEY
AND THESE MOUNTAINS
11 01:32:21:13 01:32:24:24 ARE THE DIRECT RESULT
OF VERY SIMILAR
TYPES OF INTERACTIONS
12 01:32:24:26 01:32:27:25 BETWEEN TWO OF THE EARTH'S
ADJACENT PLATES.
13 01:32:27:27 01:32:30:10 PLATES ARE
THE RIGID SLABS OF ROCK
14 01:32:30:12 01:32:32:23 THAT COMPRISE
THE OUTER SURFACE
OF THE EARTH.
15 01:32:32:25 01:32:34:08 THEY'RE TREMENDOUS
IN SIZE,
16 01:32:34:10 01:32:37:09 SOMETIMES ENCOMPASSING
ENTIRE CONTINENTS,
17 01:32:37:11 01:32:39:23 AND THEY'RE MOVING
AND INTERACTING
WITH ONE ANOTHER
18 01:32:39:25 01:32:41:13 AT THEIR BOUNDARIES.
19 01:32:41:15 01:32:43:14 BECAUSE THE PLATES
ARE RIGID,
20 01:32:43:16 01:32:46:09 THEIR INTERIORS
ARE RELATIVELY
INACTIVE TECTONICALLY.
21 01:32:46:11 01:32:48:09 THE BOUNDARY
BETWEEN PLATES, HOWEVER,
22 01:32:48:11 01:32:51:23 IS DEFINED BY A HIGH DEGREE
OF TECTONIC ACTIVITY.
23 01:32:51:25 01:32:53:09 PLATE BOUNDARIES
COINCIDE
24 01:32:53:11 01:32:56:21 WITH NARROW ZONES
OF EARTHQUAKES
AND ACTIVE VOLCANOES,
25 01:32:56:23 01:32:58:21 RAPIDLY RISING
MOUNTAIN RANGES,
26 01:32:58:23 01:33:00:20 AND DEEP-SEA TRENCHES.
27 01:33:00:22 01:33:04:06 THIS LONG, LINEAR VALLEY
IS ONE SUCH PLATE BOUNDARY.
28 01:33:04:08 01:33:07:00 THIS IS

THE SAN ANDREAS FAULT
IN CALIFORNIA.

29 01:33:07:02 01:33:09:29 ON THIS SIDE,
THE NORTH AMERICAN PLATE

30 01:33:10:01 01:33:11:15 IS GRINDING FITFULLY

31 01:33:11:17 01:33:13:22 AGAINST THE PACIFIC PLATE
OVER HERE.

32 01:33:13:24 01:33:15:21 THE RESULT
OF THIS INTERACTION

33 01:33:15:23 01:33:18:07 ARE SUDDEN AND SOMETIMES
DEVASTATING EARTHQUAKES.

34 01:33:18:09 01:33:20:23 OVER TIME,
THIS INTERACTION
HAS RESULTED

35 01:33:20:25 01:33:23:22 IN THE STEADY UPLIFT
OF THESE MOUNTAIN RANGES.

36 01:33:23:24 01:33:27:06 PLATE BOUNDARIES
ARE DIRECTLY RELATED
TO GEOLOGIC HAZARDS,

37 01:33:27:08 01:33:29:22 TO THE FORMATION
OF PETROLEUM
AND MINERAL RESOURCES,

38 01:33:29:24 01:33:31:23 AND TO THE GEOLOGIC
DEVELOPMENT

39 01:33:31:25 01:33:34:21 OF THE LANDSCAPES
ON WHICH WE LIVE.

40 01:33:34:23 01:33:36:21 SO UNDERSTANDING
HOW PLATES MOVE

41 01:33:36:23 01:33:38:22 AND INTERACT
AT THEIR BOUNDARIES

42 01:33:38:24 01:33:41:07 IS NOT ONLY ONE
OF THE MOST INTERESTING,

43 01:33:41:09 01:33:43:18 BUT ALSO ONE OF
THE MOST IMPORTANT GOALS

44 01:33:43:20 01:33:45:21 OF THE CURRENT GENERATION
OF EARTH SCIENTISTS.

45 01:33:47:01 01:33:49:07 *WRAPPING LIKE A NET*
AROUND THE GLOBE,

46 01:33:49:09 01:33:51:23 *THE BOUNDARIES*
OF THE PLATES IN MOST PLACES

47 01:33:51:25 01:33:54:21 *DO NOT CORRESPOND*
TO THE EDGES OF THE CONTINENTS

48 01:33:54:23 01:33:56:01 *AND OCEANIC BASINS.*

49 01:33:56:03 01:33:57:29 *SO, MOST PLATES CONTAIN*

50 01:33:58:01 01:34:00:20 *BOTH CONTINENTAL*
AND OCEANIC CRUST.

51 01:34:00:22 01:34:03:20 *IN ALL, ABOUT*
A DOZEN LARGE PLATES

52 01:34:03:22 01:34:05:04 *AND MANY*
SMALLER MICROPLATES

53 01:34:05:06 01:34:07:16 *HAVE BEEN IDENTIFIED*
BY EARTH SCIENTISTS.

54 01:34:09:08 01:34:11:05 *IN FEW PLACES*
CAN ONE SEE

55 01:34:11:07 01:34:13:06 *A PLATE BOUNDARY*
BETTER EXPOSED

56 01:34:13:08 01:34:16:04 *THAN IN ICELAND, ATOP*
THE MID-ATLANTIC RIDGE.
57 01:34:18:07 01:34:20:11 *IN A BROAD ZONE*
ACROSS ICELAND,
58 01:34:20:13 01:34:22:11 *GREAT TENSIONAL CRACKS*
CALLED RIFTS
59 01:34:22:13 01:34:24:21 *BREAK THE LANDSCAPE.*
60 01:34:24:23 01:34:26:06 *FREQUENT SMALL,*
SHALLOW EARTHQUAKES
61 01:34:26:08 01:34:28:12 *OCCUR BENEATH*
THIS RIFT ZONE.
62 01:34:30:06 01:34:31:25 *GEYSERS AND HOT SPRINGS*
63 01:34:31:27 01:34:34:04 *ARE EVIDENCE*
THAT THE CRUST IS HOT.
64 01:34:34:06 01:34:35:19 *FROM TIME TO TIME,*
65 01:34:35:21 01:34:38:18 *GREAT VOLUMES OF FLUID*
BASALTIC LAVA AND ASH
66 01:34:38:20 01:34:42:14 *SPEW FROM FISSURES*
AND VOLCANIC CRATERS.
67 01:34:42:16 01:34:45:21 *HERE, THE CRUST*
IS BEING PULLED APART.
68 01:34:45:23 01:34:49:04 *AS BASALTIC MAGMA FILLS*
THE FISSURES THAT OPEN,
69 01:34:49:06 01:34:50:18 *IT SOLIDIFIES,*
70 01:34:50:20 01:34:53:05 *ADDING NEW CRUST TO*
THE EDGES OF THE PLATE.
71 01:34:53:07 01:34:55:18 *AS THE OLDER ROCK*
IS PULLED AWAY,
72 01:34:55:20 01:34:58:03 *NEW MAGMA RISES*
TO COOL, HARDEN,
73 01:34:58:05 01:35:01:04 *AND FORM ADDITIONAL CRUST*
IN ITS PLACE.
74 01:35:01:06 01:35:02:19 *THIS TYPE OF BOUNDARY*
75 01:35:02:21 01:35:05:03 *IS CALLED*
A DIVERGENT BOUNDARY--
76 01:35:05:05 01:35:08:08 *FOR HERE, THE PLATES*
SEPARATE FROM ONE ANOTHER.
77 01:35:11:05 01:35:13:02 *A DRAMATIC EXAMPLE*
OF THIS
78 01:35:13:04 01:35:16:02 *CAN BE SEEN ON*
THE AFRICAN CONTINENT.
79 01:35:16:04 01:35:18:19 *IN EASTERN AFRICA,*
A DIVERGENT BOUNDARY
80 01:35:18:21 01:35:20:04 *PARTIALLY*
SPLITS THE LANDSCAPE.
81 01:35:20:06 01:35:21:19 *TO THE NORTH,*
82 01:35:21:21 01:35:24:03 *SO MUCH NEW CRUST*
HAS FORMED
83 01:35:24:05 01:35:26:03 *THAT AFRICA*
AND SAUDI ARABIA,
84 01:35:26:05 01:35:27:18 *ONCE JOINED TOGETHER,*
85 01:35:27:20 01:35:29:08 *HAVE SPLIT APART,*
86 01:35:29:10 01:35:32:19 *WITH THE RED SEA FLOODING*
THE WIDE VALLEY IN BETWEEN.
87 01:35:32:21 01:35:34:18 *RIFTING HAS*
ALSO OPENED UP

88 01:35:34:20 01:35:37:04 *THE GULF OF ADEN*
TO THE EAST.
89 01:35:37:06 01:35:40:03 *IN TIME, THESE YOUNG SEAWAYS*
WILL GROW LARGER,
90 01:35:40:05 01:35:41:16 *SOMEDAY, PERHAPS,*
91 01:35:41:18 01:35:44:08 *BECOMING AS WIDE*
AS THE ATLANTIC TODAY.
92 01:35:46:08 01:35:50:03 *OCEANIC CRUST COMPRISES*
ABOUT 70% OF EARTH'S SURFACE.
93 01:35:50:05 01:35:51:20 *MOST OF THIS CRUST*
94 01:35:51:22 01:35:54:16 *ORIGINATED BY INJECTION*
AND ERUPTION OF MAGMA
95 01:35:54:18 01:35:56:02 *AT DIVERGENT BOUNDARIES,*
96 01:35:56:04 01:35:58:02 *EXPRESSED*
AS MID-OCEAN RIDGES
97 01:35:58:04 01:36:00:16 *CAPPED BY RIFT ZONES.*
98 01:36:00:18 01:36:02:16 *THIS PROCESS*
OF CRUSTAL GROWTH
99 01:36:02:18 01:36:04:16 *IS CALLED*
SEA FLOOR SPREADING.
100 01:36:04:18 01:36:07:15 *EARTH'S VOLUME HAS REMAINED*
ESSENTIALLY THE SAME
101 01:36:07:17 01:36:09:01 *FOR BILLIONS OF YEARS.*
102 01:36:09:03 01:36:10:16 *AS A RESULT,*
103 01:36:10:18 01:36:13:16 *PLATES CAN GROW LARGER*
BY SEA FLOOR SPREADING
104 01:36:13:18 01:36:17:16 *ONLY IF OTHER PLATES*
ARE GROWING SMALLER.
105 01:36:17:18 01:36:19:15 *PLATES ARE REDUCED*
IN SIZE
106 01:36:19:17 01:36:21:16 *OR DESTROYED*
WHERE THEY CONVERGE,
107 01:36:21:18 01:36:24:15 *CREATING SOME OF THE MOST*
DRAMATIC TOPOGRAPHY
108 01:36:24:17 01:36:26:01 *ANYWHERE ON EARTH.*
109 01:36:26:03 01:36:27:17 *AN IMPORTANT LAND FORM*
110 01:36:27:19 01:36:29:16 *MARKING THE COLLISION*
BETWEEN PLATES
111 01:36:29:18 01:36:32:01 *IS A DEEP MARINE TRENCH.*
112 01:36:32:03 01:36:35:00 *HERE, ONE PLATE*
SLIPS BENEATH THE OTHER
113 01:36:35:02 01:36:38:16 *IN A PROCESS*
CALLED SUBDUCTION.
114 01:36:38:18 01:36:41:17 *SOME PLATES, HOWEVER,*
ARE TOO BUOYANT TO SUBDUCT
115 01:36:41:19 01:36:43:23 *AND SIMPLY*
CRUMPLE TOGETHER.
116 01:36:46:04 01:36:50:01 THERE ARE THREE
BASIC TYPES OF CONVERGING
PLATE BOUNDARIES,
117 01:36:50:03 01:36:53:01 AND THIS IS BASED
ON THE TYPES OF CRUSTS
118 01:36:53:03 01:36:55:29 THAT ARE INVOLVED
ON BOTH SIDES OF
THE CONVERGING BOUNDARY.
119 01:36:56:01 01:36:59:15 THE FIRST TYPE WOULD

BE AN OCEAN-OCEAN
CONVERGENCE ZONE.

120 01:36:59:17 01:37:03:06 A GOOD EXAMPLE WOULD
BE THE MARIANA TRENCH
AND ISLANDS.

121 01:37:03:08 01:37:05:21 WHAT WE SEE
IN THIS AREA

122 01:37:05:23 01:37:08:14 IS THAT THERE
IS A VOLCANIC CHAIN

123 01:37:08:16 01:37:09:29 ABOVE THE
CONVERGENCE ZONE,

124 01:37:10:01 01:37:13:28 AND IN THIS CASE,
AN OCEAN-OCEAN
CONVERGENCE ZONE.

125 01:37:14:00 01:37:16:15 TYPICALLY, THE LAVAS
THAT ARE ERUPTED

126 01:37:16:17 01:37:21:17 ARE A LITTLE MORE BASALTIC
THAN WHAT YOU SEE
IN A CONTINENTAL AREA.

127 01:37:21:19 01:37:24:29 THE SECOND INSTANCE WOULD
BE WHEN AN OCEANIC PLATE

128 01:37:25:01 01:37:27:29 IS GOING DOWN UNDER
A CONTINENTAL PLATE.

129 01:37:28:01 01:37:30:14 THE TYPE EXAMPLE
OF THIS

130 01:37:30:16 01:37:33:00 WOULD BE THE ANDES
IN SOUTH AMERICA,

131 01:37:33:02 01:37:34:15 WHERE THE PACIFIC PLATE

132 01:37:34:17 01:37:37:00 IS GOING UNDERNEATH
THE SOUTH AMERICAN CONTINENT.

133 01:37:37:02 01:37:40:00 IN THIS AREA, ABOVE
THE SUBDUCTION ZONE,

134 01:37:40:02 01:37:43:10 YOU HAVE AN ANDESITIC
AND SOMETIMES
RHYOLITIC VOLCANIC CHAIN,

135 01:37:43:12 01:37:49:15 WHICH IS MUCH MORE OVERALL
GRANITIC COMPOSITION
WHICH IS ERUPTING.

136 01:37:49:17 01:37:52:15 THE THIRD EXAMPLE WOULD
BE A CONTINENT-CONTINENT
CONVERGENCE ZONE

137 01:37:52:17 01:37:54:28 OR WHAT WE CALL
A COLLISION ZONE.

138 01:37:55:00 01:37:56:13 AND IN THIS CASE,

139 01:37:56:15 01:37:58:27 WHAT HAPPENED
IS THAT THERE USED TO BE

140 01:37:58:29 01:38:01:21 AN INTERVENING
OCEAN BASIN--
AN OCEANIC PLATE--

141 01:38:01:23 01:38:04:06 BEING SUBDUCTED
OR CONVERGING

142 01:38:04:08 01:38:07:09 UNDERNEATH ONE OR BOTH
OF THE CONTINENTS.

143 01:38:07:11 01:38:11:13 AS THE OCEANIC PLATE
DISAPPEARED BENEATH
THE CONTINENT,

144 01:38:11:15 01:38:13:28 THE TWO BUOYANT CONTINENTS
COLLIDED,
145 01:38:14:00 01:38:16:27 AND WE GET THIS ZONE
OF MOUNTAIN RANGE UPLIFTED,
146 01:38:16:29 01:38:20:10 LIKE THE HIMALAYAS
OR THE ALPS,
147 01:38:20:12 01:38:23:22 AND TYPICALLY
WHAT WILL HAPPEN
148 01:38:23:24 01:38:28:28 IS THAT CONVERGENCE
WILL STOP ALONG THAT ZONE.
149 01:38:29:00 01:38:31:27 *IN THE THREE TYPES OF PLATE*
CONVERGENCE DESCRIBED,
150 01:38:31:29 01:38:34:27 *OCEANIC ROCK ALWAYS SINKS*
BENEATH CONTINENTAL ROCK
151 01:38:34:29 01:38:36:12 *BECAUSE OCEANIC CRUST*
152 01:38:36:14 01:38:38:12 *IS TYPICALLY DENSER*
AND HEAVIER
153 01:38:38:14 01:38:40:01 *THAN CONTINENTAL CRUST.*
154 01:38:40:03 01:38:41:13 *ONCE SUBDUCTION STARTS,*
155 01:38:41:15 01:38:43:28 *IT MAY BE SUSTAINED*
IN PART
156 01:38:44:00 01:38:46:27 *AS THE WEIGHT OF*
THE DOWN-GOING SLAB
157 01:38:46:29 01:38:49:27 *DRAGS THE REST*
OF THE PLATE WITH IT.
158 01:38:49:29 01:38:51:12 *SUBDUCTION*
IS ALSO SUSTAINED
159 01:38:51:14 01:38:54:12 *BY SLOW-MOVING CURRENTS*
OF HOT MANTLE ROCK
160 01:38:54:14 01:38:57:09 *WHICH TUG AGAINST*
THE UNDERSIDE OF THE PLATE.
161 01:38:58:23 01:39:00:06 *AS THE PLATE SINKS,*
162 01:39:00:08 01:39:02:10 *EARTHQUAKES OCCUR*
WITHIN IT.
163 01:39:02:12 01:39:03:26 *THESE QUAKES RANGE*
164 01:39:03:28 01:39:06:11 *FROM SHALLOW EVENTS*
AT THE TRENCH ITSELF
165 01:39:06:13 01:39:07:25 *TO VERY DEEP CATACLYSMS*
166 01:39:07:27 01:39:10:25 *NEAR THE HEATED END*
OF THE DESCENDING SLAB,
167 01:39:10:27 01:39:14:07 *AS MUCH AS 700 KILOMETERS*
BENEATH THE SURFACE.
168 01:39:14:09 01:39:15:21 *THESE EARTHQUAKES*
ALLOW SEISMOLOGISTS
169 01:39:15:23 01:39:18:20 *TO TRACE THE DESCENT*
OF THE SUBDUCTING PLATE
170 01:39:18:22 01:39:21:06 *INTO THE MANTLE.*
171 01:39:21:08 01:39:23:06 *BY DIVING INTO THE MANTLE,*
172 01:39:23:08 01:39:26:10 *THE SUBDUCTING PLATE*
CREATES FRICTION AND HEAT,
173 01:39:26:12 01:39:28:10 *AND THE BASALTIC*
OCEANIC CRUST
174 01:39:28:12 01:39:30:28 *PARTIALLY MELTS UNDER*
THE INTENSE PRESSURE.
175 01:39:32:11 01:39:34:11 *THE MOLTEN ROCK RISES,*
176 01:39:34:13 01:39:37:02 *ULTIMATELY REACTING*

WITH OVERLYING ROCKS

177 01:39:37:04 01:39:38:26 *TO FORM ANDESITIC MAGMA,*

178 01:39:38:28 01:39:40:10 *WHICH ERUPTS IN CURVING*

179 01:39:40:12 01:39:43:25 *OR ARC-SHAPED CHAINS*
OF VOLCANOES.

180 01:39:43:27 01:39:46:22 *THE VOLCANIC CHAIN*
PARALLELS THE OCEAN TRENCH,

181 01:39:46:24 01:39:50:06 *AND AT SEA, FORMS A STRING*
OF VOLCANIC ISLANDS

182 01:39:50:08 01:39:52:25 *KNOWN AS*
AN ISLAND ARC SYSTEM.

183 01:39:55:11 01:39:58:09 *WHERE SUBDUCTION OCCURS*
ALONG CONTINENTAL MARGINS,

184 01:39:58:11 01:39:59:23 *THE ANDESITIC*
VOLCANIC CHAIN

185 01:39:59:25 01:40:01:23 *IS BUILT ATOP DRY LAND,*

186 01:40:01:25 01:40:04:23 *SOMETIMES TOWERING KILOMETERS*
ABOVE THE LANDSCAPE,

187 01:40:04:25 01:40:07:23 *RARELY VERY FAR*
FROM THE SEA.

188 01:40:07:25 01:40:10:04 *ERUPTIONS ARE*
FREQUENTLY HAZARDOUS,

189 01:40:10:06 01:40:12:23 *UNLIKE THOSE*
AT DIVERGENT BOUNDARIES,

190 01:40:12:25 01:40:14:09 *BECAUSE ANDESITIC MAGMAS*

191 01:40:14:11 01:40:18:00 *ARE MORE VISCOUS AND*
GAS-RICH THAN BASALTIC MAGMAS.

192 01:40:19:18 01:40:21:16 *EARTHQUAKES, TOO,*
ARE MORE POWERFUL

193 01:40:21:18 01:40:24:00 *AT CONVERGENT THAN AT*
DIVERGENT BOUNDARIES

194 01:40:24:02 01:40:26:26 *BECAUSE OF GREATER*
LEVELS OF STRESS

195 01:40:26:28 01:40:28:13 *RESULTING*
FROM PLATE COLLISION.

196 01:40:28:15 01:40:30:24 *IT IS THIS*
EARTHQUAKE ACTIVITY,

197 01:40:30:26 01:40:32:09 *TOGETHER WITH CRUMPLING*

198 01:40:32:11 01:40:34:09 *AND FOLDING*
OF THE CRUST,

199 01:40:34:11 01:40:37:09 *THAT CREATES THE MOUNTAIN*
RANGES LIKE THE ANDES

200 01:40:37:11 01:40:38:25 *ALONG CONTINENTAL*
MARGINS

201 01:40:38:27 01:40:41:02 *OVERLYING*
SUBDUCTION ZONES.

202 01:40:41:04 01:40:43:02 *BUT EARTH'S LARGEST*
MOUNTAIN RANGES

203 01:40:43:04 01:40:44:16 *AND PLATEAUS FORM*

204 01:40:44:18 01:40:46:02 *WHEN TWO*
CONTINENTAL MASSES

205 01:40:46:04 01:40:48:08 *ARE BROUGHT TOGETHER*
BY SUBDUCTION

206 01:40:48:10 01:40:50:16 *OF INTERVENING*
SEA FLOOR.

207 01:40:50:18 01:40:53:08 *LITTLE VOLCANIC ACTIVITY*

208 01:40:53:10 01:40:55:23 *ACCOMPANIES THIS TYPE OF MOUNTAIN-BUILDING*
209 01:40:55:25 01:40:57:09 *BECAUSE SUBDUCTION STOPS OCCURRING*
210 01:40:57:11 01:40:59:18 *ONCE THE CONTINENTS COLLIDE.*
211 01:41:01:19 01:41:03:26 *ALONG SOME PLATE BOUNDARIES,*
212 01:41:03:28 01:41:06:29 *NEITHER DIVERGENCE NOR CONVERGENCE OCCURS.*
213 01:41:07:01 01:41:09:29 *INSTEAD, TWO PLATES SLIP PAST ONE ANOTHER,*
214 01:41:10:01 01:41:13:13 *THEIR EDGES MARKED BY A SPECIAL TYPE OF RUPTURE*
215 01:41:13:15 01:41:15:24 *KNOWN AS A TRANSFORM FAULT.*
216 01:41:17:03 01:41:19:01 THERE ARE TWO MAJOR ENVIRONMENTS
217 01:41:19:03 01:41:21:15 THAT WE SEE TRANSFORM FAULTS OCCUR IN.
218 01:41:21:17 01:41:24:00 ONE IS WHOLLY OUT IN THE OCEAN BASIN,
219 01:41:24:02 01:41:25:15 AND WE CALL THOSE
220 01:41:25:17 01:41:27:15 RIDGE-RIDGE TRANSFORM FAULTS,
221 01:41:27:17 01:41:30:09 WHERE THEY OFFSET THE DIVERGING RIDGES.
222 01:41:30:11 01:41:31:23 IN A NUMBER OF INSTANCES,
223 01:41:31:25 01:41:33:24 WE FIND THAT THESE TRANSFORM FAULTS
224 01:41:33:26 01:41:35:23 WILL PROPAGATE, OR EAT THEIR WAY,
225 01:41:35:25 01:41:37:11 INTO CONTINENTAL CRUST.
226 01:41:37:13 01:41:39:25 THE TYPE EXAMPLE OF THIS
227 01:41:39:27 01:41:41:27 IS THE SAN ANDREAS FAULT,
228 01:41:41:29 01:41:44:26 WHERE THE GULF OF CALIFORNIA SPREADING SYSTEM
229 01:41:44:28 01:41:46:11 CAN BE LINKED UP
230 01:41:46:13 01:41:48:26 WITH THE JUAN DE FUCA SPREADING SYSTEM,
231 01:41:48:28 01:41:50:25 WHICH IS OFF OF NORTHERN CALIFORNIA
232 01:41:50:27 01:41:52:19 OR OFF OF CAPE MENDOCINO.
233 01:41:52:21 01:41:54:05 AND IN THIS CASE,
234 01:41:54:07 01:41:56:02 THE ZONE OF TRANSFORM FAULTING
235 01:41:56:04 01:41:58:03 IS USUALLY MUCH MORE COMPLEX
236 01:41:58:05 01:42:01:07 BECAUSE THE CONTINENTAL PLATE

237 01:42:01:09 01:42:03:21 OR THE
CONTINENTAL CRUST
IS MORE COMPLEX
238 01:42:03:23 01:42:05:08 THAN
THE OCEANIC CRUST.
239 01:42:05:10 01:42:06:09 IT'S THICKER,
240 01:42:06:11 01:42:08:08 IT HAS INTERNAL
STRUCTURE ALREADY
241 01:42:08:10 01:42:10:22 THAT'S EVOLVED OVER
MILLIONS OF YEARS,
242 01:42:10:24 01:42:12:07 AND IT'S AN OVERALL
243 01:42:12:09 01:42:14:06 MUCH MORE COMPLICATED
ENVIRONMENT.
244 01:42:14:08 01:42:16:21 MOST GEOLOGISTS
ARE IN GENERAL AGREEMENT
245 01:42:16:23 01:42:18:06 REGARDING PLATE TECTONIC
THEORY.
246 01:42:18:08 01:42:19:21 THERE IS
CONSIDERABLE DEBATE
247 01:42:19:23 01:42:22:07 ABOUT THE FORCES WHICH
DRIVE PLATE MOVEMENT.
248 01:42:22:09 01:42:24:21 A GREAT DEAL
OF CURRENT RESEARCH
249 01:42:24:23 01:42:26:22 FOCUSES ON FINDING
A MECHANISM.
250 01:42:26:24 01:42:29:06 THIS IS A PARTICULARLY
CHALLENGING PROBLEM
251 01:42:29:08 01:42:30:21 BECAUSE
THE MECHANISM OPERATES
252 01:42:30:23 01:42:32:06 DEEP WITHIN
THE EARTH'S INTERIOR,
253 01:42:32:08 01:42:34:21 WHICH WE CANNOT SEE
OR SAMPLE DIRECTLY.
254 01:42:34:23 01:42:36:25 THE EARTH'S CRUST
AND UPPERMOST MANTLE
255 01:42:36:27 01:42:39:01 ACT TOGETHER
AS A RIGID UNIT.
256 01:42:39:03 01:42:41:15 THIS LAYER, WHICH
COMPRISES THE PLATES,
257 01:42:41:17 01:42:43:00 IS CALLED THE LITHOSPHERE
258 01:42:43:02 01:42:45:15 AND IS ABOUT
100 KILOMETERS THICK.
259 01:42:45:17 01:42:47:14 THESE LITHOSPHERIC PLATES
FLOAT CROWDED TOGETHER
260 01:42:47:16 01:42:49:16 LIKE LILY PADS IN A POND
261 01:42:49:18 01:42:52:01 IN A DEEPER LAYER
OF THE MANTLE
262 01:42:52:03 01:42:53:16 CALLED THE ASTHENOSPHERE.
263 01:42:53:18 01:42:54:29 UNLIKE THE LITHOSPHERE,
264 01:42:55:01 01:42:57:29 THE ASTHENOSPHERE IS SOFT
AND PARTIALLY MOLTEN,
265 01:42:58:01 01:43:00:14 SO THE RELATIVELY COOL,
RIGID LITHOSPHERIC PLATES
266 01:43:00:16 01:43:02:13 CAN MOVE THROUGH
THE ASTHENOSPHERE
267 01:43:02:15 01:43:04:12 IF ENOUGH FORCE

IS APPLIED.
268 01:43:04:14 01:43:06:13 SEVERAL DIFFERENT THEORIES
HAVE BEEN ADVANCED
269 01:43:06:15 01:43:08:27 TO TRY TO EXPLAIN
THE DRIVING FORCE
270 01:43:08:29 01:43:10:14 BEHIND THIS PROCESS.
271 01:43:10:16 01:43:11:27 ALL AGREE
THAT THE MECHANISM
272 01:43:11:29 01:43:13:28 FOR PLATE MOVEMENT
IS SOMEHOW RELATED
273 01:43:14:00 01:43:15:28 TO THE UNEQUAL
DISTRIBUTION OF HEAT
274 01:43:16:00 01:43:17:17 WITHIN THE MANTLE.
275 01:43:17:19 01:43:19:01 WHEN MANTLE ROCKS
276 01:43:19:03 01:43:20:18 ARE HEATED
UNEVENLY FROM BELOW,
277 01:43:20:20 01:43:23:03 MOST GEOLOGISTS BELIEVE
THAT THEY CAN CIRCULATE
278 01:43:23:05 01:43:25:02 IN A CYCLIC FASHION
CALLED CONVECTION.
279 01:43:25:04 01:43:27:16 CURRENTLY, SOME FORM OF
CONVECTION IN THE MANTLE
280 01:43:27:18 01:43:29:17 IS THE MOST WIDELY
ACCEPTED MECHANISM
281 01:43:29:19 01:43:31:15 FOR PLATE MOVEMENT.
282 01:43:34:08 01:43:37:06 *CONVECTION OCCURS BECAUSE*
ROCK INSIDE THE EARTH
283 01:43:37:08 01:43:40:06 *FLOWS LIKE*
A GRADUALLY MOVING FLUID.
284 01:43:43:12 01:43:45:25 *JUST AS THE APPLICATION*
OF HEAT
285 01:43:45:27 01:43:47:25 *TO A POT OF WATER*
286 01:43:47:27 01:43:49:26 *CAUSES THE WARM LIQUID*
TO RISE
287 01:43:49:28 01:43:52:10 *AND THE COOLER LIQUID*
ON TOP TO DESCEND,
288 01:43:52:12 01:43:54:24 *SO, TOO, DOES HEAT*
INSIDE THE EARTH
289 01:43:54:26 01:43:57:23 *CAUSE PORTIONS*
OF THE MANTLE TO CONVECT.
290 01:44:03:04 01:44:06:01 *THE FUNDAMENTAL FORCE*
DRIVING CONVECTION,
291 01:44:06:03 01:44:09:18 *WHETHER ON THE STOVE TOP*
OR INSIDE THE EARTH,
292 01:44:09:20 01:44:10:24 *IS GRAVITY.*
293 01:44:10:26 01:44:12:17 *COOL MATTER*
IS MORE DENSE
294 01:44:12:19 01:44:15:02 *AND THEREFORE HEAVIER*
THAN WARM MATTER.
295 01:44:15:04 01:44:17:02 *UNDER GRAVITY,*
IT WILL SINK,
296 01:44:17:04 01:44:19:29 *DISPLACING THE WARMER*
MATERIAL BENEATH.
297 01:44:20:01 01:44:21:29 *IT MAY SEEM SURPRISING*
298 01:44:22:01 01:44:25:14 *THAT ROCK SHOULD ACT LIKE*
A VISCOUS LIQUID AND FLOW,

299 01:44:25:16 01:44:28:13 *EVEN ON THE MOST SLOW-MOVING TIME SCALE.*
300 01:44:28:15 01:44:31:14 *AND YET, THIS IS PRECISELY WHAT HAPPENS*
301 01:44:31:16 01:44:33:29 *IN THE EARTH'S MANTLE.*
302 01:44:34:01 01:44:36:13 OK, WE CAN USE SILLY PUTTY
303 01:44:36:15 01:44:38:13 AS AN ANALOGY FOR ROCKS,
304 01:44:38:15 01:44:40:28 PARTICULARLY IF WE'RE INTERESTED TO SEE
305 01:44:41:00 01:44:42:28 THE EFFECTS OF THE RATE
306 01:44:43:00 01:44:44:28 OF DISTORTING OR STRAINING THE ROCK.
307 01:44:45:00 01:44:46:27 I CAN GIVE YOU SEVERAL EXAMPLES.
308 01:44:46:29 01:44:49:28 I'VE GOT THREE DIFFERENT PILES HERE
309 01:44:50:00 01:44:52:19 OF THE EXACT SAME MATERIAL.
310 01:44:52:21 01:44:54:01 UM, IN ONE CASE,
311 01:44:54:03 01:44:56:18 I CAN TAKE THE SILLY PUTTY,
312 01:44:56:20 01:45:00:04 AND IF I APPLY A FAST RATE OF DEFORMATION TO IT,
313 01:45:00:06 01:45:01:20 WE CAN MAKE IT FRACTURE.
314 01:45:01:22 01:45:03:21 THIS MIGHT BE A GOOD ANALOGY
315 01:45:03:23 01:45:06:07 FOR WHAT WOULD HAPPEN NEAR THE EARTH'S SURFACE
316 01:45:06:09 01:45:07:22 WHERE OUR ROCKS ARE COLD,
317 01:45:07:24 01:45:09:21 AND IF WE DEFORM THEM QUICKLY,
318 01:45:09:23 01:45:11:21 THEY WOULD FRACTURE LIKE THAT.
319 01:45:11:23 01:45:13:21 WE COULD TAKE THE SAME MATERIAL.
320 01:45:13:23 01:45:15:20 I COULD APPLY STRESS TO IT.
321 01:45:15:22 01:45:18:07 IF I DO IT AT A SLOWER RATE--
322 01:45:18:09 01:45:20:07 I HAVE A SLOWER STRAIN RATE--
323 01:45:20:09 01:45:22:21 THEN WE SEE THAT MY MATERIAL WILL FLOW
324 01:45:22:23 01:45:24:02 INSTEAD OF FRACTURE.
325 01:45:24:04 01:45:26:03 THIS MIGHT BE A GOOD ANALOGY
326 01:45:26:05 01:45:28:02 TO WHAT WOULD HAPPEN AT DEPTH,
327 01:45:28:04 01:45:29:18 WHERE ROCKS ARE HOTTER
328 01:45:29:20 01:45:31:18 AND DEFORMING AT SLOW, LONG-TERM RATES
329 01:45:31:20 01:45:34:02 AND WE CAN GET FOLDS AND THINGS LIKE THAT.
330 01:45:34:04 01:45:37:16 WE CAN EVEN GO TO A MORE EXTREME CASE.

331 01:45:37:18 01:45:39:17 WE'LL TAKE
THE SAME MATERIAL,
332 01:45:39:19 01:45:44:03 AND I CAN JUST PLACE IT
ON MY BLOCK RIGHT HERE.
333 01:45:44:05 01:45:45:17 WE'LL ESSENTIALLY
LET GRAVITY
334 01:45:45:19 01:45:48:02 BE THE ONLY, UH,
STRESS OPERATING
335 01:45:48:04 01:45:50:15 ON THAT, UH,
SILLY PUTTY.
336 01:45:50:17 01:45:52:00 WE'LL SEE WITH TIME
337 01:45:52:02 01:45:53:29 THAT THE ROCK
WILL STILL FLOW,
338 01:45:54:01 01:45:55:28 ALTHOUGH AT A MUCH
SLOWER RATE
339 01:45:56:00 01:45:58:18 THAN WE SAW
IN THE PREVIOUS EXAMPLE.
340 01:45:58:20 01:46:00:04 *IN THE SAME WAY,*
341 01:46:00:06 01:46:02:03 *MANTLE ROCKS CAN DEFORM*
PLASTICALLY
342 01:46:02:05 01:46:04:03 *BECAUSE OF THEIR*
HIGH TEMPERATURE
343 01:46:04:05 01:46:07:18 *WHEN STRESSED OVER*
VERY LONG TIME PERIODS.
344 01:46:10:16 01:46:13:13 *IT IS THE ABILITY*
OF ROCK TO FLOW
345 01:46:13:15 01:46:16:13 *THAT, IN PART, ALLOWS*
THE CONVECTION PROCESS
346 01:46:16:15 01:46:18:12 *TO TAKE PLACE*
INSIDE THE EARTH.
347 01:46:18:14 01:46:20:13 *THAT STILL*
DOES NOT EXPLAIN
348 01:46:20:15 01:46:23:23 *WHY CONVECTION OCCURS*
IN THE FIRST PLACE.
349 01:46:23:25 01:46:26:07 THE REASON THAT
THE EARTH'S MANTLE CONVECTS
350 01:46:26:09 01:46:28:23 IS THAT FIRST THERE IS
STILL PRIMARY HEAT
351 01:46:28:25 01:46:31:08 LEFT FROM THE FORMATION
OF THE EARTH,
352 01:46:31:10 01:46:34:07 AND THERE IS HEAT BEING
GENERATED IN THE EARTH
353 01:46:34:09 01:46:37:09 BY THE RADIOACTIVE DECAY
OF A NUMBER OF ELEMENTS,
354 01:46:37:11 01:46:39:09 PRIMARILY URANIUM,
THORIUM, AND POTASSIUM.
355 01:46:39:11 01:46:42:08 THIS HEAT WITHIN
THE INTERIOR OF THE EARTH
356 01:46:42:10 01:46:44:07 WANTS TO ESCAPE
AND FLOW OUT,
357 01:46:44:09 01:46:47:22 AND THE MOST EFFECTIVE
WAY FOR IT TO FLOW OUT
358 01:46:47:24 01:46:49:07 IS BY CONVECTING
359 01:46:49:09 01:46:53:13 JUST AS A POT OF BOILING
WATER WOULD CONVECT.
360 01:46:53:15 01:46:55:26 *THERE ARE*

A GREAT MANY QUESTIONS

361 01:46:55:28 01:46:57:10 *CONCERNING*
THE CONVECTION PROCESS.

362 01:46:57:12 01:46:59:27 *PERHAPS THE MOST*
FUNDAMENTAL OF THESE

363 01:46:59:29 01:47:02:26 *IS THE ROLE OF CONVECTION*
IN PLATE MOTION.

364 01:47:02:28 01:47:04:12 *ACCORDING TO ONE THEORY,*

365 01:47:04:14 01:47:05:26 *PLATES ARE PUSHED APART*

366 01:47:05:28 01:47:08:10 *AS THE HOT ROCK*
BENEATH THEM

367 01:47:08:12 01:47:09:25 *CONVECTS UPWARD.*

368 01:47:09:27 01:47:12:03 *ANOTHER VIEW SUGGESTS*
THAT UPWARD CONVECTION

369 01:47:12:05 01:47:14:11 *CREATES*
THE MID-OCEAN RIDGES.

370 01:47:14:13 01:47:16:27 *PLATES SLIDE AWAY*
FROM THE RIDGES

371 01:47:16:29 01:47:19:27 *BY A COMBINATION*
OF GRAVITY AND DRAG

372 01:47:19:29 01:47:22:06 *FROM THE CONVECTION*
CURRENTS THEMSELVES.

373 01:47:22:08 01:47:23:26 *BUT SOME GEOLOGISTS BELIEVE*

374 01:47:23:28 01:47:26:11 *THAT THERE IS*
A THIRD POSSIBILITY--

375 01:47:26:13 01:47:28:11 *THAT THE PLATES*
ARE LITERALLY

376 01:47:28:13 01:47:31:22 *BEING PULLED DOWN*
INTO THE EARTH.

377 01:47:31:24 01:47:33:21 THERE ARE THOSE
WHO BELIEVE

378 01:47:33:23 01:47:35:06 THAT BECAUSE
THE LITHOSPHERIC PLATES,

379 01:47:35:08 01:47:37:21 WHERE THEY DESCEND
IN THE TRENCHES,

380 01:47:37:23 01:47:39:08 ARE OF GREATER DENSITY

381 01:47:39:10 01:47:40:23 THAN THEATERIAL
THEY DISPLACE,

382 01:47:40:25 01:47:43:22 THAT, IN FACT, LIKE
THE COVERS FALLING OFF

383 01:47:43:24 01:47:45:22 THE EDGE OF THE BED,

384 01:47:45:24 01:47:47:22 THEY ARE BEING
PULLED DOWN.

385 01:47:47:24 01:47:50:07 SO, PLATE PUSH
AT THE RIDGE

386 01:47:50:09 01:47:52:07 BECAUSE OF HOT,
RISING MATERIAL

387 01:47:52:09 01:47:53:22 SLIDING OFF THE RIDGE

388 01:47:53:24 01:47:59:23 AND TRENCH PULL ARE ALL
ASPECTS OF THE PROCESS.

389 01:47:59:25 01:48:01:24 WHAT WE KNOW FOR CERTAIN

390 01:48:01:26 01:48:03:23 IS THAT
THE LITHOSPHERIC MOTIONS

391 01:48:03:25 01:48:06:25 ARE AS DESCRIBED
IN ALL THOSE MODELS,

392 01:48:06:27 01:48:11:14 BUT NONE OF THEM

IS A PARAMOUNT ARGUMENT
393 01:48:11:16 01:48:15:02 OR MODEL FOR EXPLAINING
THE PROCESS
394 01:48:15:04 01:48:19:03 OF ACTUAL, UH,
PLATE MOTIVATION--
395 01:48:19:05 01:48:20:19 WHY PLATES MOVE.
396 01:48:20:21 01:48:22:05 I PERSONALLY BELIEVE
397 01:48:22:07 01:48:25:04 THAT BECAUSE THE PLATES
THAT HAVE TRENCHES,
398 01:48:25:06 01:48:27:04 THAT ARE MOVING
DOWN TRENCHES,
399 01:48:27:06 01:48:28:18 ARE GOING FAIRLY FAST--
400 01:48:28:20 01:48:30:19 10, 12 CENTIMETERS
A YEAR--
401 01:48:30:21 01:48:33:18 WHEREAS THOSE THAT ARE
SIMPLY MOVING AWAY
FROM RIDGES
402 01:48:33:20 01:48:35:20 THAT ARE NOT
TIED OR HOOKED
403 01:48:35:22 01:48:37:05 TO DESCENDING LIMBS
404 01:48:37:07 01:48:40:05 ARE ONLY GOING A FEW
CENTIMETERS A YEAR,
405 01:48:40:07 01:48:42:19 THAT THERE IS
AN IMPORTANT TRENCH PULL.
406 01:48:42:21 01:48:44:19 I BELIEVE
IT'S ALSO POSSIBLE
407 01:48:44:21 01:48:47:19 THERE IS A SMALL,
AT LEAST, PLUME DRIVE
408 01:48:47:21 01:48:50:09 OR RISING
ASTHENOSPHERE COLUMN
409 01:48:50:11 01:48:53:09 WHICH CAUSES A--
THE PLATES TO MOVE AWAY
410 01:48:53:11 01:48:55:28 FROM THE RIDGE CRESTS
AS WELL.
411 01:48:56:00 01:48:58:29 *THE DEPTH AT WHICH*
MANTLE CONVECTION OCCURS
412 01:48:59:01 01:49:00:28 *IS ANOTHER*
CONTROVERSIAL ISSUE
413 01:49:01:00 01:49:02:24 *WITHIN THE GEOLOGIC*
COMMUNITY.
414 01:49:02:26 01:49:04:23 *A SINGLE CONVECTION CELL*
415 01:49:04:25 01:49:08:06 *EXTENDING THROUGHOUT PART*
OR ALL OF THE MANTLE
416 01:49:08:08 01:49:09:22 *WAS FIRST PROPOSED*
417 01:49:09:24 01:49:12:21 *AS PART OF THE SEA FLOOR*
SPREADING HYPOTHESIS.
418 01:49:14:23 01:49:16:08 *MOST CURRENT MODELS,*
HOWEVER,
419 01:49:16:10 01:49:18:08 *USE A TWO-TIERED APPROACH*
420 01:49:18:10 01:49:21:08 *KNOWN AS THE BOUNDARY LAYER*
THEORY OF CONVECTION.
421 01:49:21:10 01:49:22:22 *ACCORDING TO THIS THEORY,*
422 01:49:22:24 01:49:25:21 *ONE SET OF CELLS*
IN THE UPPER MANTLE
423 01:49:25:23 01:49:29:07 *IS DRIVEN BY ANOTHER SET*
IN THE LOWER MANTLE.

424 01:49:29:09 01:49:31:28 *ALTHOUGH THE ISSUE OF MANTLE CONVECTION*
425 01:49:32:00 01:49:33:20 *IS STILL UNRESOLVED,*
426 01:49:33:22 01:49:36:21 *EVIDENCE FROM SEISMIC STUDIES OF THE EARTH'S INTERIOR*
427 01:49:36:23 01:49:39:22 *POINTS TOWARD A TWO-TIERED PROCESS.*
428 01:49:39:24 01:49:43:05 I THINK THE MANTLE IS SPLIT INTO TWO LAYERS
429 01:49:43:07 01:49:45:05 THAT WE CALL THE UPPER MANTLE
430 01:49:45:07 01:49:46:19 AND THE LOWER MANTLE.
431 01:49:46:21 01:49:48:10 THE EVIDENCE FOR THIS
432 01:49:48:12 01:49:50:17 IS THE PLATES THAT SUBDUCT
433 01:49:50:19 01:49:52:01 AROUND THE RING OF FIRE
434 01:49:52:03 01:49:53:16 AROUND THE PACIFIC OCEAN
435 01:49:53:18 01:49:54:29 AND GENERATE MOST EARTHQUAKES.
436 01:49:55:01 01:49:56:29 WE CAN TRACE THESE EARTHQUAKES
437 01:49:57:01 01:49:59:14 DOWN TO ABOUT 700 KILOMETERS DEPTH,
438 01:49:59:16 01:50:00:29 THEN THE EARTHQUAKES STOP.
439 01:50:01:01 01:50:03:14 WE CAN ALSO USE SEISMIC IMAGES
440 01:50:03:16 01:50:06:00 TO FIND OUT WHERE THESE SLABS ARE,
441 01:50:06:02 01:50:08:14 AND THE SLABS THEMSELVES APPEAR TO STOP
442 01:50:08:16 01:50:10:00 AT 700 KILOMETERS.
443 01:50:10:02 01:50:12:14 BELOW THAT, WE HAVE THE LOWER MANTLE,
444 01:50:12:16 01:50:13:29 WHICH IS ALSO CONVECTING,
445 01:50:14:01 01:50:15:29 AND TO SOME EXTENT INFLUENCING CONVECTION
446 01:50:16:01 01:50:17:14 IN THE SHALLOW MANTLE,
447 01:50:17:16 01:50:20:13 BUT IT PROBABLY HAS A HIGHER VISCOSITY
448 01:50:20:15 01:50:22:00 AND A HIGHER DENSITY.
449 01:50:22:02 01:50:23:14 IT'S LIKELY THAT THE SLABS
450 01:50:23:16 01:50:25:15 CANNOT SINK INTO THE LOWER MANTLE
451 01:50:25:17 01:50:28:14 BUT HAVE TO STOP

AT THE 700 KILOMETER
BOUNDARY,

452 01:50:28:16 01:50:30:29 WHICH IS
A SHARP SEISMIC
DISCONTINUITY.

453 01:50:31:01 01:50:33:13 SO IN MY VIEW,
WE HAVE TWO LAYERS.

454 01:50:33:15 01:50:36:15 THE UPPER MANTLE
PROVIDES MID-OCEAN
RIDGE BASALTS.

455 01:50:36:17 01:50:39:14 THEN AS THE
LITHOSPHERE COOLS,

456 01:50:39:16 01:50:41:00 IT SINKS BACK DOWN

457 01:50:41:02 01:50:43:14 TO THE BOTTOM
OF THE LOWER MANTLE,

458 01:50:43:16 01:50:45:14 THEN EVENTUALLY
HEATS UP AGAIN

459 01:50:45:16 01:50:47:14 AND COMES UP
TO THE SURFACE.

460 01:50:47:16 01:50:49:28 THE LOWER MANTLE
IS CONVECTING
VERY SLOWLY,

461 01:50:50:00 01:50:51:14 BUT BECAUSE IT'S
CONVECTING SLOWLY,

462 01:50:51:16 01:50:53:13 THE PARTS
OF THE LOWER MANTLE

463 01:50:53:15 01:50:55:00 THAT ARE
PARTICULARLY HOT

464 01:50:55:02 01:50:56:15 STAY HOT
A LONG TIME

465 01:50:56:17 01:50:58:27 AND HEAT UP
THE UPPER MANTLE.

466 01:50:58:29 01:51:00:12 I THINK
THE LOWER MANTLE

467 01:51:00:14 01:51:01:27 IS DEFINITELY
INFLUENCING
CONVECTION

468 01:51:01:29 01:51:03:12 IN THE UPPER MANTLE

469 01:51:03:14 01:51:05:12 WHERE THERE'S HOT,
UPWELLING MATERIAL,

470 01:51:05:14 01:51:08:11 BUT I DON'T THINK
MATERIAL IS COMING

471 01:51:08:13 01:51:09:26 DIRECTLY FROM
THE LOWER MANTLE

472 01:51:09:28 01:51:11:11 INTO THE
UPPER MANTLE,

473 01:51:11:13 01:51:13:11 NOR IS UPPER
MANTLE MATERIAL

474 01:51:13:13 01:51:15:12 SINKING INTO
THE LOWER MANTLE.

475 01:51:15:14 01:51:17:28 *WHETHER THERE IS*
BOUNDARY LAYER CONVECTION

476 01:51:18:00 01:51:19:12 *IN THE MANTLE OR NOT,*

477 01:51:19:14 01:51:21:12 *THERE'S ANOTHER KIND*
OF CONVECTION

478 01:51:21:14 01:51:23:26 *THAT OCCURS*

IN THE OUTER PORTION

479 01:51:23:28 01:51:25:11 *OF THE EARTH'S CORE.*

480 01:51:25:13 01:51:27:28 AS WE CROSS THE CORE
MANTLE BOUNDARY,

481 01:51:28:00 01:51:29:28 THERE'S A VERY
LOW-VISCOSITY FLUID

482 01:51:30:00 01:51:31:13 MOLTEN IRON CORE.

483 01:51:31:15 01:51:32:28 THIS IS CONVECTING
VERY RAPIDLY,

484 01:51:33:00 01:51:34:28 FORMING THE EARTH'S
MAGNETIC FIELD.

485 01:51:35:00 01:51:37:12 BASICALLY, TWO
PARTS OF THE EARTH
ARE CONVECTING.

486 01:51:37:14 01:51:38:26 THE MANTLE HAS
A SLUGGISH,

487 01:51:38:28 01:51:40:12 HIGH-VISCOSITY
FLUID,

488 01:51:40:14 01:51:42:12 LIKE TAR THAT'S
TRYING TO CONVECT

489 01:51:42:14 01:51:43:28 ON A HOT DAY,

490 01:51:44:00 01:51:45:13 WHEREAS
THE CORE ITSELF

491 01:51:45:15 01:51:48:04 HAS MORE THE
VISCOSITY OF WATER.

492 01:51:48:06 01:51:49:17 IT'S CONVECTING
VERY RAPIDLY.

493 01:51:49:19 01:51:52:05 SO THERE'S TWO
SCALES OF CONVECTION

494 01:51:52:07 01:51:53:18 AND TWO KINDS OF
CONVECTION.

495 01:51:55:13 01:51:58:10 *CURRENT MEASUREMENTS*
OF EARTH'S SURFACE FROM SPACE

496 01:51:58:12 01:51:59:25 *HAVE PROVIDED*
ADDITIONAL EVIDENCE

497 01:51:59:27 01:52:02:28 *THAT CONVECTION IS OCCURRING*
WITHIN THE PLANET.

498 01:52:04:07 01:52:05:20 INTERESTINGLY
ENOUGH,

499 01:52:05:22 01:52:09:13 CONVECTION
CHANGES THE SHAPE
OF THE EARTH.

500 01:52:09:15 01:52:12:25 IF WE LOOK
AT THE EARTH
FROM A SATELLITE

501 01:52:12:27 01:52:14:11 AND LOOK AT IT

502 01:52:14:13 01:52:16:11 WITH VERY DETAILED
RADAR TECHNIQUES,

503 01:52:16:13 01:52:17:28 WE FIND OUT

504 01:52:18:00 01:52:20:26 THE EARTH ISN'T
A SMOOTH SPHERE
AT ALL.

505 01:52:20:28 01:52:23:12 EVEN IF WE GET RID
OF THE MOUNTAINS

506 01:52:23:14 01:52:24:14 AND THE CONTINENTS,

507 01:52:24:16 01:52:26:11 WE FIND THAT

WHAT'S LEFT OVER

508 01:52:26:13 01:52:27:26 IS A VERY BUMPY
OBJECT.

509 01:52:27:28 01:52:29:10 THE UPWELLING
CONVECTION CURRENTS

510 01:52:29:12 01:52:31:10 TEND TO MAKE BUMPS
AND SWELLS

511 01:52:31:12 01:52:32:26 IN THE EARTH'S
SURFACE,

512 01:52:32:28 01:52:34:12 AND DOWNWELLING
COLD CURRENTS

513 01:52:34:14 01:52:35:27 TEND TO MAKE
DEPRESSIONS

514 01:52:35:29 01:52:37:11 IN THE SEA FLOOR.

515 01:52:37:13 01:52:39:27 SO BY LOOKING AT
THE EARTH'S SHAPE,

516 01:52:39:29 01:52:43:06 WE'RE ABLE TO MAP
THE CONVECTION
PATTERNS.

517 01:52:45:03 01:52:46:24 *IN THE LATE 1960s,*

518 01:52:46:26 01:52:49:09 *IT WAS SUGGESTED*
THAT THERE ARE PLACES

519 01:52:49:11 01:52:51:08 *BENEATH THE MIDDLE*
OF THE PLATES

520 01:52:51:10 01:52:54:06 *WHERE A SPECIAL KIND*
OF CONVECTION TAKES PLACE.

521 01:52:55:20 01:52:59:02 *COMPARATIVELY NARROW COLUMNS*
OF HOT MANTLE ROCK

522 01:52:59:04 01:53:00:16 *RISE FROM BELOW*

523 01:53:00:18 01:53:02:02 *AND SPREAD*
RADIALLY OUTWARD

524 01:53:02:04 01:53:05:00 *AS THEY REACH*
THE LITHOSPHERE.

525 01:53:05:02 01:53:07:22 *THESE ARE KNOWN*
AS MANTLE PLUMES.

526 01:53:07:24 01:53:10:07 *THIS KIND OF CIRCULATION*
CAN BE SEEN

527 01:53:10:09 01:53:12:06 *IN OTHER,*
MORE FAMILIAR PHENOMENA

528 01:53:12:08 01:53:14:07 *THAT OCCUR*
IN OUR ATMOSPHERE.

529 01:53:14:09 01:53:16:23 *WHEN THUNDERHEAD CLOUDS*
FORM, FOR EXAMPLE,

530 01:53:16:25 01:53:18:22 *A SIMILAR TYPE*
OF PLUME CONVECTION

531 01:53:18:24 01:53:20:08 *IS TAKING PLACE,*

532 01:53:20:10 01:53:22:21 *BUT IN AN ACCELERATED*
MANNER.

533 01:53:22:23 01:53:26:00 *EVIDENCE OF MANTLE PLUMES*
HAS BEEN FOUND

534 01:53:26:02 01:53:28:05 *IN THE FORM OF HOT SPOTS--*

535 01:53:28:07 01:53:30:05 *REGIONS OF CONCENTRATED*
VOLCANIC ACTIVITY

536 01:53:30:07 01:53:32:19 *WHICH ARE ROUGHLY*
CIRCULAR IN SHAPE.

537 01:53:36:18 01:53:39:01 WHEN YOU LOOK

AT THE TOPOGRAPHY

538 01:53:39:03 01:53:40:16 OF THE GENERAL SEA FLOOR,

539 01:53:40:18 01:53:42:01 OCCASIONALLY,
YOU FIND A SEAMOUNT.

540 01:53:42:03 01:53:43:16 THEY'LL BE LITTLE
ROUND CONES.

541 01:53:43:18 01:53:45:15 THEY RANGE
FROM SMALL TO HUGE.

542 01:53:45:17 01:53:47:02 HAWAII IS ONE.

543 01:53:47:04 01:53:49:16 WE DON'T KNOW
ABOUT ALL OF THEM,

544 01:53:49:18 01:53:52:01 BUT MANY OF THEM
SEEM TO BE RELATED

545 01:53:52:03 01:53:53:21 TO HOT SPOTS.

546 01:53:53:23 01:53:55:20 A HOT SPOT VOLCANISM
HAPPENS

547 01:53:55:22 01:53:58:05 WHEN THERE'S A PLACE
DOWN IN THE MANTLE

548 01:53:58:07 01:54:00:20 THAT FOR SOME REASON
PRODUCES EXTRA LAVA,

549 01:54:00:22 01:54:03:20 SO MUCH EXTRA
THAT IT BUBBLES UP

550 01:54:03:22 01:54:05:04 THROUGH THE PLATE

551 01:54:05:06 01:54:07:21 AND BUILDS
A SEAMOUNT ON TOP.

552 01:54:07:23 01:54:10:06 OFTEN IT BUILDS
AN ISLAND LIKE HAWAII

553 01:54:10:08 01:54:12:19 AND THE CHAIN OF ISLANDS
STRUNG BEHIND HAWAII.

554 01:54:12:21 01:54:14:04 THE REASON
THEY'RE INTERESTING

555 01:54:14:06 01:54:17:04 IS THAT THE HOT SPOTS
SEEM TO BE STILL,

556 01:54:17:06 01:54:19:18 OR NEARLY STILL,
DOWN IN THE MANTLE,

557 01:54:19:20 01:54:22:03 SO WHEN THE PLATE
MOVES OVER IT,

558 01:54:22:05 01:54:24:19 IT KEEPS MAKING
NEW VOLCANOES IN A LINE.

559 01:54:24:21 01:54:28:14 SO RIGHT NOW,
THE BIG ISLAND OF
HAWAII IS BEING BUILT--

560 01:54:28:16 01:54:31:19 THE ISLANDS UP
THE CHAIN GET OLDER.

561 01:54:31:21 01:54:33:03 IN FACT,
THERE'S A CHAIN

562 01:54:33:05 01:54:35:03 THAT STRETCHES
ACROSS THE SEA FLOOR

563 01:54:35:05 01:54:37:18 UP TO THE ALEUTIANS,
WHICH ARE OLDER,

564 01:54:37:20 01:54:40:19 SHOWING US THE MOTION
OF THE PACIFIC PLATE

565 01:54:40:21 01:54:43:09 OVER THAT HAWAIIAN
HOT SPOT.

566 01:54:43:11 01:54:46:23 *AS THE ISLANDS OF HAWAII*
AGE AND WEATHER AWAY,

567 01:54:46:25 01:54:48:10 *THEY ULTIMATELY BECOME*
568 01:54:48:12 01:54:51:14 *FLAT-TOPPED SUBMERGED*
SEAMOUNTS OR GUYOTS.
569 01:54:51:16 01:54:54:17 *THOUSANDS OF SUCH SEAMOUNTS*
DOT THE OCEAN FLOOR.
570 01:54:56:03 01:54:57:29 SOMETHING INTERESTING
ABOUT OCEANIC ISLANDS
571 01:54:58:01 01:55:00:05 IS THAT THEY
DON'T LAST LONG.
572 01:55:00:07 01:55:02:06 THE EROSIVE POWER
OF THE WAVES
573 01:55:02:08 01:55:03:20 IS SO STRONG
574 01:55:03:22 01:55:06:19 THAT ANY ISLAND
THAT ISN'T BEING
CONTINUALLY BUILT
575 01:55:06:21 01:55:09:19 WILL BE ERODED AWAY
IN A FEW MILLION YEARS,
576 01:55:09:21 01:55:11:18 PLANED RIGHT DOWN
TO WAVE FACE.
577 01:55:14:08 01:55:16:21 *AS PLATE MOVEMENT*
CARRIES THE ISLANDS
578 01:55:16:23 01:55:19:20 *AWAY FROM HOT SPOTS*
AND MID-OCEAN RIDGES,
579 01:55:19:22 01:55:23:04 *THE UNDERLYING SEA FLOOR*
COOLS AND SUBSIDES.
580 01:55:24:29 01:55:27:26 *IN LOWER LATITUDES,*
CORAL REEFS BUILD UP,
581 01:55:27:28 01:55:29:13 *COMPLETELY CAPPING*
THE REMNANTS
582 01:55:29:15 01:55:31:07 *OF THE SINKING ISLANDS.*
583 01:55:31:09 01:55:34:06 *SUCH CAPS ARE CALLED*
CORAL ATOLLS.
584 01:55:35:15 01:55:36:25 *ULTIMATELY,*
THE ATOLLS THEMSELVES
585 01:55:36:27 01:55:38:26 *MAY SINK FROM VIEW.*
586 01:55:39:29 01:55:41:11 THE BIG ISLAND
OF HAWAII
587 01:55:41:13 01:55:43:12 IS BEING BUILT
RIGHT NOW.
588 01:55:43:14 01:55:44:28 THERE'S NEW LAND
BEING ADDED
589 01:55:45:00 01:55:46:13 OUT TO THE OCEAN.
590 01:55:46:15 01:55:47:28 EVEN THE OTHER
HAWAIIAN ISLANDS,
591 01:55:48:00 01:55:50:01 EVEN THOUGH THEY'RE
STILL ISLANDS,
592 01:55:50:03 01:55:51:18 ARE PLANED AWAY.
593 01:55:51:20 01:55:55:01 WHEN YOU DRIVE UP
ON A SHIP WITH A SONAR,
594 01:55:55:03 01:55:56:16 YOU COME UP THE SIDE,
595 01:55:56:18 01:55:58:16 AND THERE'S
A BIG FLAT SURFACE
596 01:55:58:18 01:56:01:01 AND THEN THE ISLAND'S
THE LAST EROSIONAL REMNANT
597 01:56:01:03 01:56:03:10 THAT HASN'T BEEN CHEWED
BY THE WAVES YET.

598 01:56:03:12 01:56:05:28 *IF THE THEORY OF HAWAII'S FORMATION IS CORRECT,*
599 01:56:06:00 01:56:09:04 *HAWAII WILL DRIFT OFF THE HOT SPOT*
600 01:56:09:06 01:56:10:19 *IN A FEW MILLION YEARS*
601 01:56:10:21 01:56:13:18 *AS THE PACIFIC PLATE CARRIES IT AWAY*
602 01:56:13:20 01:56:15:01 *IN A NORTHWESTERLY DIRECTION.*
603 01:56:15:03 01:56:17:08 *THE MANTLE PLUME WILL STAY WHERE IT IS*
604 01:56:17:10 01:56:20:08 *AND EVENTUALLY CREATE A NEW ISLAND OVER ITSELF.*
605 01:56:20:10 01:56:23:08 *INDEED, A YOUNG SUBMARINE VOLCANO DUBBED LOIHI*
606 01:56:23:10 01:56:26:28 *HAS BEEN DISCOVERED FORMING SOUTHWEST OF HAWAII.*
607 01:56:27:00 01:56:30:14 *IT RISES SOME 8,000 FEET FROM THE SEA FLOOR,*
608 01:56:30:16 01:56:33:14 *BUT HAS ANOTHER 3,000 FEET TO GO*
609 01:56:33:16 01:56:35:13 *BEFORE IT BREAKS THE SURFACE*
610 01:56:35:15 01:56:36:29 *AND BECOMES A REAL ISLAND.*
611 01:56:37:01 01:56:39:14 *LOIHI SHOULD BUILD UP TO THE SURFACE*
612 01:56:39:16 01:56:42:07 *SOMETIME BETWEEN 19,000*
613 01:56:42:09 01:56:44:28 *AND 100,000 YEARS FROM NOW.*
614 01:56:45:00 01:56:48:00 *THE ENDURING MYSTERY IS WHY A MANTLE PLUME,*
615 01:56:48:02 01:56:50:15 *SUCH AS THE ONE UNDERLYING HAWAII,*
616 01:56:50:17 01:56:52:29 *SHOULD REMAIN IN THE SAME PLACE*
617 01:56:53:01 01:56:56:00 *FOR OVER 75 MILLION YEARS.*
618 01:56:56:02 01:56:58:29 *NOT ALL HOT SPOTS OCCUR UNDER THE SEA FLOOR.*
619 01:56:59:01 01:57:00:16 *THERE IS GOOD EVIDENCE*
620 01:57:00:18 01:57:02:16 *THAT THE AREA UNDERNEATH YELLOWSTONE,*
621 01:57:02:18 01:57:04:00 *WHICH HAS LONG BEEN FAMOUS*
622 01:57:04:02 01:57:06:15 *FOR ITS GEOTHERMAL HOT SPRINGS AND GEYSERS,*
623 01:57:06:17 01:57:08:19 *IS OCCUPIED BY A HOT SPOT.*
624 01:57:08:21 01:57:11:05 *THIS HOT SPOT LIES BENEATH THE INTERIOR*
625 01:57:11:07 01:57:12:21 *OF A CONTINENT,*
626 01:57:12:23 01:57:15:25 *AND WHILE IT ISN'T RESPONSIBLE FOR ISLAND FORMATION,*
627 01:57:15:27 01:57:17:10 *IT CERTAINLY CONTRIBUTES*
628 01:57:17:12 01:57:19:16 *TO THE GEOTHERMAL ACTIVITY THERE.*
629 01:57:22:24 01:57:24:07 PLATE TECTONICS IS A MODEL

630 01:57:24:09 01:57:26:21 OF THE WAY
THE EARTH WORKS.
631 01:57:26:23 01:57:28:06 THE SIGNIFICANCE
OF THIS THEORY
632 01:57:28:08 01:57:30:22 LIES IN THE FACT
THAT IT CONNECTS
633 01:57:30:24 01:57:33:22 MANY SEEMINGLY UNRELATED
GEOLOGIC PHENOMENA,
634 01:57:33:24 01:57:35:22 SUCH AS EARTHQUAKES,
VOLCANIC ACTIVITY,
635 01:57:35:24 01:57:37:23 MOUNTAIN BUILDING,
SEA FLOOR SPREADING.
636 01:57:37:25 01:57:40:14 YET, CERTAIN
QUESTIONS REMAIN.
637 01:57:40:16 01:57:41:29 FOR ONE THING,
638 01:57:42:01 01:57:44:13 WE DON'T FULLY UNDERSTAND
THE MECHANISMS
639 01:57:44:15 01:57:45:29 THAT DRIVE PLATE MOVEMENT.
640 01:57:46:01 01:57:47:29 ALSO, IT'S UNDENIABLE
THAT THERE ARE PLACES
641 01:57:48:01 01:57:49:15 WHERE THE GEOLOGIC
RELATIONSHIPS
642 01:57:49:17 01:57:51:29 DON'T FIT EASILY INTO
THE PLATE TECTONIC MODEL.
643 01:57:52:01 01:57:53:28 THE WESTERN MARGIN
OF NORTH AMERICA
644 01:57:54:00 01:57:56:12 BETWEEN THE PACIFIC
AND THE ROCKIES
645 01:57:56:14 01:57:57:17 IS ONE SUCH EXAMPLE.
646 01:57:57:19 01:57:59:18 HOWEVER, UNANSWERED
QUESTIONS LIKE THESE
647 01:57:59:20 01:58:01:02 DON'T MEAN FAILURE.
648 01:58:01:04 01:58:03:02 INSTEAD, THEY PROPEL
SCIENCE FORWARD,
649 01:58:03:04 01:58:05:17 FORCING SCIENTISTS
TO RE-EVALUATE
650 01:58:05:19 01:58:07:17 THE ASSUMPTIONS
OF EXISTING THEORIES.
651 01:58:07:19 01:58:09:02 NEARLY 100 YEARS AGO,
652 01:58:09:04 01:58:13:02 ALFRED WEGENER CHALLENGED
THE SCIENTIFIC ORTHODOXY
653 01:58:13:04 01:58:15:19 WITH HIS THEORY
OF CONTINENTAL DRIFT.
654 01:58:15:21 01:58:18:04 THAT CHALLENGE RESULTED
IN NOTHING LESS
655 01:58:18:06 01:58:21:03 THAN A REVOLUTION
IN THE EARTH SCIENCES.
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