1 01:00:04:16 01:00:07:28 Annenberg Media
2 01:00:08:00 01:01:00:10 §
3 01:01:00:12 01:01:02:23 THE MAJESTIC SIDE
OF A MOUNTAIN RANGE
4 01:01:02:25 01:01:05:08 IS AN ENDLESS SOURCE
OF WONDER AND BEAUTY.
5 01:01:05:10 01:01:06:23 TO MOST PEOPLE,
6 01:01:06:25 01:01:08:28 MOUNTAINS ARE SYNONYMOUS
WITH GREAT SIZE
7 01:01:09:00 01:01:10:04 AND PERMANENCE,
8 01:01:10:06 01:01:11:20 BUT ARE MOUNTAINS
REALLY PERMANENT?
9 01:01:11:22 01:01:13:03 RIVERS FLOW OUT OF
10 01:01:13:05 01:01:15:14 NEARLY EVERY
MOUNTAIN RANGE ON EARTH
11 01:01:15:16 01:01:16:29 CARRYING SAND AND ROCK
12 01:01:17:01 01:01:19:03 THAT ERODED FROM
THE MOUNTAINS THEMSELVES.
13 01:01:19:05 01:01:20:19 THIS PROCESS
WOULD EVENTUALLY
14 01:01:20:21 01:01:22:28 REMOVE THE MOUNTAINS
FROM THE LANDSCAPE
15 01:01:23:00 01:01:26:02 UNLESS SOMEHOW THEY WERE
BEING MAINTAINED BY UPLIFT.
16 01:01:26:04 01:01:28:09 MOUNTAINS ARE BUILT
BY TECTONIC PROCESSES
17 01:01:28:11 01:01:31:14 THAT CAUSE PORTIONS OF
THE EARTH'S CRUST TO RISE.
18 01:01:31:16 01:01:34:14 THESE PROCESSES ARE FUELED
BY THE ESCAPE OF HEAT
19 01:01:34:16 01:01:36:23 FROM THE INTERIOR
OF THE EARTH
20 01:01:36:25 01:01:39:04 CAUSING CRUSTAL UPLIFT
BY VOLCANIC ACTIVITY
21 01:01:39:06 01:01:41:24 AND BY MOVEMENT ALONG FAULTS
THAT, IN TURN,
22 01:01:41:26 01:01:44:03 IS RESPONSIBLE
FOR FORMATION OF MOUNTAINS.
23 01:01:44:05 01:01:45:24 MOUNTAIN-BUILDING
PROCESSES LIKE THESE
24 01:01:45:26 01:01:48:24 ARE CONCENTRATED
AT THE BOUNDARIES
BETWEEN TECTONIC PLATES
25 01:01:48:26 01:01:50:08 AND ARE ESPECIALLY ACTIVE
26 01:01:50:10 01:01:52:23 WHERE THE PLATES
ARE MOVING APART
27 01:01:52:25 01:01:54:08 OR CONVERGING.
28 01:01:54:10 01:01:57:02 BY STUDYING THE ORIGIN OF
INDIVIDUAL MOUNTAIN BELTS,
29 01:01:57:04 01:01:58:27 GEOLOGISTS
ARE HELPING TO UNRAVEL
30 01:01:58:29 01:02:01:21 THE TECTONIC HISTORY
OF OUR PLANET.
31 01:02:01:23 01:02:04:01 *WITH THE DEVELOPMENT*
OF THE THEORY
32 01:02:04:03 01:02:05:16 *OF PLATE TECTONICS,*

33 01:02:05:18 01:02:07:12 *GEOLOGISTS FINALLY HAD AN EXPLANATION*
34 01:02:07:14 01:02:11:06 *FOR WHAT CAUSES MOUNTAINS TO GROW.*
35 01:02:11:08 01:02:12:17 *IN ADDITION,*
36 01:02:12:19 01:02:14:17 *THE GEOGRAPHICAL DISTRIBUTION OF MOUNTAINS*
37 01:02:14:19 01:02:16:11 *ALSO BEGAN TO MAKE SENSE.*
38 01:02:17:29 01:02:20:12 *MOST OF THE WORLD'S GREAT RANGES*
39 01:02:20:14 01:02:23:07 *LIE NOT AT THE CENTER OF CONTINENTS,*
40 01:02:23:09 01:02:25:16 *BUT, INSTEAD, CLOSE TO THEIR MARGINS.*
41 01:02:25:18 01:02:27:26 *IN GENERAL, THE CENTERS OF CONTINENTS*
42 01:02:27:28 01:02:32:06 *CONSIST OF STABLE REGIONS OF VERY OLD CRUST.*
43 01:02:32:08 01:02:33:21 *THESE REGIONS,*
44 01:02:33:23 01:02:35:26 *CALLED CRATONS OR SHIELDS,*
45 01:02:35:28 01:02:38:26 *ARE DEEPLY ERODED, MOSTLY LOW LYING,*
46 01:02:38:28 01:02:40:01 *AND LEVEL.*
47 01:02:42:00 01:02:44:07 *ONE OF THE WORLD'S LARGEST CRATONS*
48 01:02:44:09 01:02:45:21 *LIES IN THE MIDDLE*
49 01:02:45:23 01:02:47:17 *OF THE NORTH AMERICAN CONTINENT,*
50 01:02:47:19 01:02:49:16 *A GREAT ROLLING FLATLAND.*
51 01:02:49:18 01:02:51:02 *TO THE NORTH,*
52 01:02:51:04 01:02:53:11 *THIS FLATLAND HAS BEEN STRIPPED BARE*
53 01:02:53:13 01:02:55:22 *OF MUCH SOIL AND SEDIMENTARY COVER*
54 01:02:55:24 01:02:57:06 *BY PAST ICE SHEETS.*
55 01:02:58:23 01:03:00:27 *THIS IS THE CANADIAN SHIELD,*
56 01:03:00:29 01:03:03:25 *AND WITHIN IT IS A VAST REGION--*
57 01:03:03:27 01:03:06:04 *THE SUPERIOR PROVINCE,*
58 01:03:06:06 01:03:09:19 *OVER 1,500 KILOMETERS ACROSS.*
59 01:03:09:21 01:03:13:05 *HERE, THE ROCK RANGES FROM 2.6 BILLION*
60 01:03:13:07 01:03:15:10 *TO 4 BILLION YEARS OLD--*
61 01:03:15:12 01:03:18:14 *THE ANCIENT HEART OF NORTH AMERICA.*
62 01:03:18:16 01:03:21:04 *CRATONS THIS ANCIENT ARE SIGNIFICANT,*
63 01:03:21:06 01:03:25:07 *FOR THEY HOLD CLUES TO THE BIRTH OF CONTINENTS.*
64 01:03:25:09 01:03:27:24 *THE TYPICAL ROCKS OF THE SUPERIOR PROVINCE*
65 01:03:27:26 01:03:29:21 *ARE GRANULITE*

AND GREENSTONE.

66 01:03:32:01 01:03:34:29 *GRANULITE IS A HIGH-GRADE METAMORPHIC ROCK*

67 01:03:35:01 01:03:38:00 *AND MAKES UP MOST OF THE LANDSCAPE.*

68 01:03:38:02 01:03:40:00 *IT IS TOO SEVERELY METAMORPHOSED*

69 01:03:40:02 01:03:42:19 *TO PROVIDE MUCH INFORMATION ABOUT THE PAST,*

70 01:03:42:21 01:03:45:17 *THOUGH ITS EXPOSURE AT THE SURFACE*

71 01:03:45:19 01:03:48:17 *INDICATES THAT THE CRUST HAS BEEN DEEPLY ERODED.*

72 01:03:48:19 01:03:50:02 *SCATTERED THROUGHOUT THE GRANULITE*

73 01:03:50:04 01:03:51:17 *ARE INTRICATE BELTS*

74 01:03:51:19 01:03:53:11 *OF VOLCANIC AND SEDIMENTARY ROCKS*

75 01:03:53:13 01:03:55:14 *CALLED GREENSTONES.*

76 01:03:55:16 01:03:58:00 *GEOLOGISTS INTERPRET THESE*

77 01:03:58:02 01:04:01:02 *AS THE REMNANTS OF NUMEROUS SMALL ISLAND ARCS*

78 01:04:01:04 01:04:04:04 *WHICH HAVE BEEN CLOSELY PACKED TOGETHER.*

79 01:04:04:06 01:04:07:01 INITIALLY, IN THE EARLY EARTH,

80 01:04:07:03 01:04:09:01 THE CRUST OF THE EARTH

81 01:04:09:03 01:04:11:16 MUST HAVE BEEN PRINCIPALLY OCEANIC CRUSTS

82 01:04:11:18 01:04:15:02 SURMOUNTED BY A THIN VENEER OF WATER

83 01:04:15:04 01:04:17:28 AND A VERY DENSE ATMOSPHERE.

84 01:04:18:00 01:04:21:03 GRADUALLY, DUE TO CONVERGENT PLATE MOTION--

85 01:04:21:05 01:04:24:03 THEY WERE PROBABLY PRETTY SMALL AND THIN PLATELETS

86 01:04:24:05 01:04:26:02 BACK IN EARLY TIMES.

87 01:04:26:04 01:04:29:08 WE'RE TALKING 3, 4 BILLION YEARS AGO.

88 01:04:29:10 01:04:32:02 SMALL ISLAND ARCS BEGAN TO FORM

89 01:04:32:04 01:04:34:17 ALONG AND ABOVE CONVERGENT PLATE JUNCTIONS

90 01:04:34:19 01:04:38:03 DUE TO THE RISE OF MELT FROM THE DOWN-GOING SLAB

91 01:04:38:05 01:04:40:08 UP INTO THESE PRIMITIVE ARCS.

92 01:04:40:10 01:04:42:08 AS THOSE ISLAND ARCS FORMED,

93 01:04:42:10 01:04:43:23 THEY WERE SWEPT TOGETHER

94 01:04:43:25 01:04:47:14 BY THIS CONTINUAL SEA-FLOOR SPREADING PROCESS.

95 01:04:47:16 01:04:49:29 PROBABLY INVOLVED

A LOT OF SMALL
96 01:04:50:01 01:04:54:03 RAPIDLY-OVERTURNING
CONVECTIVE CELLS
IN THE UPPER MANTLE.
97 01:04:54:05 01:04:58:02 SO, VERY RAPID GROWTH
ACCOMPANIED EARLY--
THE EARLY EARTH
98 01:04:58:04 01:05:01:01 AND AS THESE
ACCRETED TOGETHER,
99 01:05:01:03 01:05:02:15 THEY FORMED ENLARGING,
100 01:05:02:17 01:05:05:06 EVENTUALLY
SUPERCONTINENTAL ASSEMBLIES.
101 01:05:05:08 01:05:07:26 THOSE ASSEMBLIES
WERE ANNEALED OVER TIME,
102 01:05:07:28 01:05:11:11 AND GRADUALLY THEY FORMED
RELATIVELY LARGER PLATES
103 01:05:11:13 01:05:13:19 CAPPED BY CONTINENTAL CRUST.
104 01:05:13:21 01:05:15:05 THE CONTINENTAL CRUST ITSELF
105 01:05:15:07 01:05:19:00 IS AN AMALGAM OF
THESE SMALLER ISLAND ARCS
106 01:05:19:02 01:05:20:26 WHICH HAD BEEN
ALL SWEPT TOGETHER.
107 01:05:22:02 01:05:23:15 *CONTINENTAL CRUST,*
HOWEVER,
108 01:05:23:17 01:05:25:15 *CONSISTS MOSTLY*
OF GRANITIC ROCKS
109 01:05:25:17 01:05:27:26 *AND NOT GREENSTONE LAVAS,*
110 01:05:27:28 01:05:30:05 *SO A MECHANISM*
MUST HAVE EXISTED
111 01:05:30:07 01:05:33:16 *FOR TRANSFORMING*
THE COMPOSITION
OF THE CRUST.
112 01:05:33:18 01:05:35:15 *SOME GEOLOGISTS SPECULATE*
113 01:05:35:17 01:05:38:15 *THAT THE GREENSTONE LAVAS*
WEATHERED TO FORM SEDIMENTS
114 01:05:38:17 01:05:41:18 *RICH IN POTASSIUM,*
ALUMINUM, AND SILICA.
115 01:05:43:18 01:05:46:01 *THESE SEDIMENTS COULD*
HAVE BEEN INCORPORATED
116 01:05:46:03 01:05:48:25 *BY MAGMAS*
ERUPTING AT A LATER DATE,
117 01:05:48:27 01:05:50:10 *ALTERING THE MOLTEN ROCK*
118 01:05:50:12 01:05:52:10 *TO A MORE GRANITIC*
COMPOSITION.
119 01:05:54:17 01:05:55:26 *OR PERHAPS*
120 01:05:55:28 01:05:58:00 *REPEATED PARTIAL MELTING*
OF THE LITHOSPHERE
121 01:05:58:02 01:05:59:16 *UNDERNEATH*
THE GREENSTONE ISLANDS
122 01:05:59:18 01:06:01:13 *PRODUCED*
A MORE GRANITIC CRUST.
123 01:06:03:17 01:06:05:00 *WHATEVER THE REASON,*
124 01:06:05:02 01:06:07:08 *THE WORLD OF*
GREENSTONE-BELT VOLCANISM
125 01:06:07:10 01:06:09:14 *DID NOT LAST.*
126 01:06:09:16 01:06:11:28 AT ABOUT TWO

BILLION YEARS AGO,
127 01:06:12:00 01:06:13:28 THE GENERAL
TECTONIC PATTERN
128 01:06:14:00 01:06:15:11 APPEARS TO HAVE CHANGED,
129 01:06:15:13 01:06:17:25 WHERE THERE WAS
A HIGHER ORGANIZATION
130 01:06:17:27 01:06:20:09 OF LARGER PLATES
AND CONTINENTAL MARGINS,
131 01:06:20:11 01:06:24:23 WHICH BEGAN TO MOVE INTO
MORE OF A RIGID PLATE
TECTONIC DOMAIN.
132 01:06:24:25 01:06:27:08 THAT CHANGE MAY
HAVE BEEN RELATED
133 01:06:27:10 01:06:30:09 TO THE DEVELOPMENT
OF A THICK LITHOSPHERE.
134 01:06:30:11 01:06:31:18 EARLY IN EARTH HISTORY,
135 01:06:31:20 01:06:33:28 THERE MAY
HAVE BEEN A MUCH
THINNER LITHOSPHERE
136 01:06:34:00 01:06:36:14 WHICH PROMOTED
A MUCH MORE RANDOM
137 01:06:36:16 01:06:38:29 AND FASTER,
SHORTER CYCLE PATTERN
OF CONVECTION
138 01:06:39:01 01:06:40:14 TO CREATE ANCIENT
PROTO-CONTINENTS,
139 01:06:40:16 01:06:42:28 WHICH WE CALL
THE GREENSTONE BELTS.
140 01:06:43:00 01:06:45:13 LATER ON,
AS THE EARTH COOLED
141 01:06:45:15 01:06:46:28 AND THE LITHOSPHERE
THICKENED,
142 01:06:47:00 01:06:49:28 THEN WE BEGAN TO DRIVE
AROUND THICKER PLATES.
143 01:06:50:00 01:06:52:14 THE CONTINENTS BEGAN
TO EMBED THEMSELVES
144 01:06:52:16 01:06:54:23 INTO PLATES THAT
HAD MANTLE ROOTS.
145 01:06:54:25 01:06:58:28 THEY BEGAN TO DEVELOP
THEIR OWN UNIQUE
LITHOSPHERES AS WELL.
146 01:06:59:00 01:07:02:05 *FOR ALMOST A BILLION YEARS,*
THE SUPERIOR PROVINCE
147 01:07:02:07 01:07:05:11 *WAS ALMOST ALL THAT*
EXISTED OF NORTH AMERICA,
148 01:07:05:13 01:07:07:26 *THEN OTHER REGIONS*
WERE ADDED.
149 01:07:07:28 01:07:11:16 *THE CHURCHILL/*
HUDSONIAN PROVINCE--
1.8 BILLION YEARS AGO.
150 01:07:11:18 01:07:14:16 *THE CENTRAL PROVINCE--*
1.6 BILLION YEARS AGO
151 01:07:14:18 01:07:18:22 *AND THE GRENVILLE PROVINCE--*
ABOUT ONE BILLION YEARS AGO.
152 01:07:19:28 01:07:21:11 *IN THESE REGIONS,*
153 01:07:21:13 01:07:23:26 *GEOLOGISTS FIND ROCKS*

SIMILAR TO THOSE

154 01:07:23:28 01:07:25:29 *MAKING UP MODERN*
MOUNTAIN RANGES.

155 01:07:27:15 01:07:30:12 *AND IN THE VERY YOUNGEST*
PARTS OF NORTH AMERICA,

156 01:07:30:14 01:07:31:27 *MOUNTAINS*
ARE STILL GROWING.

157 01:07:33:14 01:07:35:26 *THESE OBSERVATIONS SUGGEST*
THAT MOUNTAIN BUILDING,

158 01:07:35:28 01:07:38:11 *A PROCESS GEOLOGISTS*
CALL OROGENY,

159 01:07:38:13 01:07:41:07 *IS AN ESSENTIAL PART*
OF CONTINENTAL GROWTH.

160 01:07:42:24 01:07:44:00 *GENERALLY SPEAKING,*

161 01:07:44:02 01:07:46:27 *THE FURTHER ONE TRAVELS*
FROM THE CRATON,

162 01:07:46:29 01:07:48:27 *THE YOUNGER*
A CONTINENT BECOMES,

163 01:07:48:29 01:07:51:26 *AND THE YOUNGEST, MOST*
RUGGED PARTS OF A CONTINENT,

164 01:07:51:28 01:07:54:26 *LIE AT THE EDGE*
OF THE OCEAN.

165 01:07:56:13 01:07:59:12 *IN FACT, THE ESSENTIAL KEY*
TO MOUNTAIN BUILDING

166 01:07:59:14 01:08:01:09 *LIES IN UNDERSTANDING*
THIS LINK

167 01:08:01:11 01:08:03:25 *BETWEEN OCEAN BASINS*
AND CONTINENTS.

168 01:08:06:21 01:08:08:19 *IN THE 18th CENTURY,*

169 01:08:08:21 01:08:10:10 *SCOTTISH GEOLOGIST*
JAMES HUTTON

170 01:08:10:12 01:08:12:24 *RECOGNIZED THAT MUCH*
OF THE ROCK

171 01:08:12:26 01:08:14:24 *THAT COMPOSED*
HIS NATIVE LAND

172 01:08:14:26 01:08:16:09 *ORIGINATED BENEATH THE SEA*

173 01:08:16:11 01:08:20:10 *AS SEDIMENT ACCUMULATING*
QUIETLY ON THE OCEAN FLOOR.

174 01:08:22:01 01:08:24:10 ROCKS TODAY EXPOSED
IN THE EARTH'S MOUNTAINS

175 01:08:24:12 01:08:26:20 TELL HOW THOSE MOUNTAINS
CAME TO BE.

176 01:08:26:22 01:08:27:27 JAMES HUTTON, I THINK,

177 01:08:27:29 01:08:30:24 WAS THE FIRST TO
MAKE A VERY GIANT STEP

178 01:08:30:26 01:08:34:09 WITH REGARDS TO
THE GROWTH OF MOUNTAINS.

179 01:08:34:11 01:08:36:25 HE FOUND THAT
WHEREVER HE WENT

180 01:08:36:27 01:08:38:10 INTO
THE EARTH'S MOUNTAINS,

181 01:08:38:12 01:08:39:25 HE FOUND
SEDIMENTARY ROCKS.

182 01:08:39:27 01:08:41:10 SEDIMENTARY ROCKS
THAT FORMED

183 01:08:41:12 01:08:45:09 ALWAYS FORMED

ON THE BOTTOM
OF THE OCEAN FLOOR.

184 01:08:45:11 01:08:48:09 HE REALIZED THAT THERE
HAD TO BE A CONNECTION

185 01:08:48:11 01:08:51:09 BETWEEN MARINE
DEEP-SEA SEDIMENTATION
AND MOUNTAIN BUILDING.

186 01:08:51:11 01:08:54:29 WHAT WAS ONCE
ON THE BOTTOM
OF THE OCEAN FLOOR

187 01:08:55:01 01:08:59:08 WAS LATER
DESTINED TO BECOME AT
THE TOPS OF MOUNTAINS.

188 01:09:00:10 01:09:01:23 *HUTTON HAD NO EXPLANATION*

189 01:09:01:25 01:09:04:22 *FOR HOW MARINE SEDIMENT*
COULD BE UPLIFTED

190 01:09:04:24 01:09:06:22 *AND ADDED TO DRY LAND.*

191 01:09:06:24 01:09:09:22 *HE SIMPLY OBSERVED*
THAT IT HAD OCCURRED.

192 01:09:09:24 01:09:14:23 *HE ALSO RECOGNIZED THAT*
AS THE ROCK OF MOUNTAINS
IS ERODED DOWN,

193 01:09:14:25 01:09:17:23 *IT SUPPLIES NEW SEDIMENT*
TO THE SEA FLOOR,

194 01:09:17:25 01:09:21:22 *WHICH IN TURN CAN BE*
CONVERTED TO ROCK
AND UPLIFTED,

195 01:09:21:24 01:09:23:07 *FORMING NEW MOUNTAINS.*

196 01:09:23:09 01:09:26:22 *THE FACT THAT A GREAT DEAL*
OF MATERIAL IN NATURE

197 01:09:26:24 01:09:28:23 *IS RECYCLED OVER AND OVER*

198 01:09:28:25 01:09:31:23 *WAS ONE OF HUTTON'S*
MOST BRILLIANT INSIGHTS.

199 01:09:31:25 01:09:35:07 *IT SHOWED THAT THE LAND*
GROWS FROM THE SEA.

200 01:09:36:24 01:09:38:22 *THE THEORY*
OF PLATE TECTONICS,

201 01:09:38:24 01:09:41:22 *DEVELOPED NEARLY TWO CENTURIES*
AFTER HUTTON'S TIME,

202 01:09:41:24 01:09:47:08 *EXPLAINS HOW*
THE OCEAN FLOOR RISES
TO BECOME MOUNTAINS.

203 01:09:47:10 01:09:50:08 *BECAUSE OF DIFFERENCES*
IN DENSITY AND MAKE-UP

204 01:09:50:10 01:09:52:07 *OF CONTINENTAL*
AND OCEANIC LITHOSPHERE,

205 01:09:52:09 01:09:55:22 *THE EDGE OF A CONTINENT*
IS A LIKELY PLACE

206 01:09:55:24 01:09:58:22 *FOR A CONVERGENT*
PLATE BOUNDARY TO FORM.

207 01:09:58:24 01:10:00:23 *IF ENOUGH PRESSURE*
IS APPLIED,

208 01:10:00:25 01:10:02:10 *THE LITHOSPHERE SPLITS.*

209 01:10:04:10 01:10:06:08 *HEAVIER THAN*
CONTINENTAL LITHOSPHERE,

210 01:10:06:10 01:10:09:07 *THE OCEANIC LITHOSPHERE*

BEGINS SINKING,

211 01:10:09:09 01:10:11:22 *OR SUBDUCTING, BENEATH*
THE ADJACENT CONTINENT

212 01:10:11:24 01:10:14:22 *AS THE NEW PLATES*
ARE PUSHED TOGETHER.

213 01:10:17:10 01:10:22:08 *AN OROGENY BEGINS*
AS VOLCANOES FORM
AN ISLAND ARC OR BELT

214 01:10:22:10 01:10:24:28 *ALONG*
THE CONTINENTAL MARGIN.

215 01:10:25:00 01:10:27:28 *SEA FLOOR SEDIMENT BETWEEN*
THE TRENCH AND SHORE

216 01:10:28:00 01:10:31:25 *IS CAUGHT IN THE SQUEEZE,*
CRUMPLED UP, AND UPLIFTED.

217 01:10:33:10 01:10:36:23 *ULTIMATELY SO MUCH PRESSURE*
AND HEAT MAY ACCUMULATE

218 01:10:36:25 01:10:38:08 *THAT THE SOFT SEDIMENT*

219 01:10:38:10 01:10:41:07 *RECRYSTALLIZES INTO*
DURABLE METAMORPHIC ROCK,

220 01:10:41:09 01:10:44:05 *THE VERY ROCK*
THAT MAKES UP VAST AREAS

221 01:10:44:07 01:10:45:20 *OF OLDER CONTINENTAL CRUST.*

222 01:10:47:13 01:10:48:27 *AT HIGH ENOUGH*
TEMPERATURES,

223 01:10:48:29 01:10:50:26 *THE SEDIMENT*
WILL EVEN MELT,

224 01:10:50:28 01:10:52:23 *EVENTUALLY FORMING*
IGNEOUS ROCKS,

225 01:10:52:25 01:10:54:15 *SUCH AS GRANITE.*

226 01:10:54:17 01:10:57:00 IN THE CORES
OF MOUNTAIN RANGES,

227 01:10:57:02 01:10:59:28 WE CAN SEE IN
THE METAMORPHIC ROCKS

228 01:11:00:02 01:11:02:13 THAT SEDIMENTS ARE
FOLDED AND METAMORPHOSED

229 01:11:02:15 01:11:04:13 AND ACTUALLY INVOLVED
AND MELTED

230 01:11:04:15 01:11:06:28 INTO TYPICALLY GRANITIC
TYPES OF MATERIALS.

231 01:11:07:00 01:11:10:14 WE ALSO LOOK
WITHIN THE IGNEOUS
AND METAMORPHIC CORE

232 01:11:10:16 01:11:12:14 AND SEE EVIDENCE
OF MAGMA

233 01:11:12:16 01:11:15:05 THAT MOVED DIRECTLY
OUT OF THE MANTLE

234 01:11:15:07 01:11:17:20 WHICH WILL BE MORE
BASALTIC COMPOSITION

235 01:11:17:22 01:11:19:05 AND, IN MANY INSTANCES,

236 01:11:19:07 01:11:22:05 PROMOTED THE MELTING
OF THE CRUSTAL ROCKS.

237 01:11:22:07 01:11:25:06 WE ALSO SEE EVIDENCE OF
OLDER CONTINENTAL CRUST

238 01:11:25:08 01:11:27:21 HAVING BEEN HEATED UP
AND MELTED

239 01:11:27:23 01:11:30:28 AND REJUVENATED

INTO YOUNGER
NEW CONTINENTAL CRUST.

240 01:11:31:00 01:11:34:16 *THESE HARDENED ROCK TYPES SLOWLY WEAR AWAY,*

241 01:11:34:18 01:11:37:17 *CONTRIBUTING NEW SEDIMENT TO THE SEA.*

242 01:11:37:19 01:11:40:18 *MUCH OF THE ROCK DOES NOT WEAR AWAY, HOWEVER.*

243 01:11:40:20 01:11:43:00 *INSTEAD, IT REMAINS ATTACHED,*

244 01:11:43:02 01:11:46:00 *ADDING NEW MASS TO THE CONTINENT.*

245 01:11:46:02 01:11:47:26 *NEW MATERIAL IS ALSO ADDED*

246 01:11:47:28 01:11:51:20 *AS MAGMA FROM THE UNDERLYING MANTLE AND SUBDUCTING OCEAN FLOOR*

247 01:11:51:22 01:11:54:20 *RISE UP INTO THE CRUST TO COOL AND HARDEN*

248 01:11:54:22 01:11:57:16 *OR TO ERUPT AS LAVA AND ASH.*

249 01:11:59:08 01:12:01:19 *THE CONTINUOUS TRANSFORMATION OF MATERIAL*

250 01:12:01:21 01:12:03:19 *FROM SEDIMENTARY TO METAMORPHIC*

251 01:12:03:21 01:12:05:19 *TO IGNEOUS AND BACK AGAIN*

252 01:12:05:21 01:12:08:03 *IS CALLED THE ROCK CYCLE.*

253 01:12:08:05 01:12:09:28 *THROUGHOUT A GROWING MOUNTAIN RANGE,*

254 01:12:10:00 01:12:12:18 *THE COMPLETE ROCK CYCLE MAY BE ACTIVE,*

255 01:12:12:20 01:12:14:18 *CREATING NEW CONTINENTAL CRUST.*

256 01:12:16:04 01:12:18:13 OCEANIC CRUST
REPRESENTS MATERIAL

257 01:12:18:15 01:12:22:13 WHICH HAS COME
TO THE EARTH'S SURFACE
DIRECTLY BY MAGMATISM

258 01:12:22:15 01:12:24:13 OUT OF THE EARTH'S MANTLE.

259 01:12:24:15 01:12:27:03 IT'S THE MOST
COMMON TYPE OF MAGMA

260 01:12:27:05 01:12:29:14 COMING OUT OF
THE EARTH'S MANTLE.

261 01:12:29:16 01:12:32:03 IT COMES OUT AS
A COMPOSITION OF BASALT,

262 01:12:32:05 01:12:35:06 WHICH IS A SILICA-
MAGNESIUM-RICH ROCK.

263 01:12:35:08 01:12:37:04 THE CONTINENTS
REPRESENT MATERIAL

264 01:12:37:06 01:12:40:03 THAT HAS BEEN RECYCLED
NUMEROUS TIMES

265 01:12:40:05 01:12:41:28 BY IGNEOUS ACTIVITY,
METAMORPHISM,

266 01:12:42:00 01:12:45:18 SEDIMENTATION, DEFORMATION,
MOUNTAIN BUILDING,

267 01:12:45:20 01:12:49:09 DEPOSITION INTO BASINS,
AND RECYCLED AND RECYCLED.

268 01:12:49:11 01:12:52:19 IT BASICALLY CAME FROM
PROTO-OCEANIC CRUST,
269 01:12:52:21 01:12:55:09 BUT IT HAS UNDERGONE
MANY DIFFERENT CHANGES
270 01:12:55:11 01:12:57:03 THROUGH THESE PROCESSES
THROUGH TIME
271 01:12:57:05 01:13:00:03 TO MAKE IT DISTINCT
AND COMPOSITIONALLY
MUCH LIGHTER,
272 01:13:00:05 01:13:02:26 WHICH IS A COMPOSITION
MORE SIMILAR TO GRANITE.
273 01:13:02:28 01:13:04:15 THE MOUNTAIN
BUILDING PROCESS
274 01:13:04:17 01:13:07:21 CAUSES CONTINENTS TO
INCREASE IN SIZE OVER TIME.
275 01:13:07:23 01:13:10:12 WE KNOW FROM RADIOMETRIC
DATING OF ROCKS
276 01:13:10:14 01:13:12:26 THAT THE CENTRAL PORTION
OF THE NORTH AMERICAN
CONTINENT
277 01:13:12:28 01:13:14:26 IS COMPOSED
OF VERY OLD ROCKS,
278 01:13:14:28 01:13:17:16 ALL OF WHICH FORMED
OVER A BILLION YEARS AGO.
279 01:13:17:18 01:13:19:16 THE APPALACHIAN MOUNTAINS
WERE THEN BUILT
280 01:13:19:18 01:13:21:27 ONTO THE EASTERN MARGIN
OF THE CRATON
281 01:13:21:29 01:13:23:12 IN A SERIES OF COLLISIONS
282 01:13:23:14 01:13:25:27 ENDING ABOUT
250 MILLION YEARS AGO.
283 01:13:25:29 01:13:27:26 THE SIERRA NEVADA MOUNTAINS
WERE ADDED
284 01:13:27:28 01:13:30:02 TO THE CONTINENT'S
WESTERN MARGIN
285 01:13:30:04 01:13:33:01 IN A PROCESS ENDING
ABOUT 80 MILLION YEARS AGO,
286 01:13:33:03 01:13:37:05 FOLLOWED BY FORMATION
OF THE CASCADE RANGE,
WHICH CONTINUES EVEN TODAY.
287 01:13:37:07 01:13:39:16 IN THIS WAY,
THE NORTH AMERICAN CONTINENT
288 01:13:39:18 01:13:43:02 HAS INCREMENTALLY
GROWN BY ACCRETION
IN A CONCENTRIC PATTERN
289 01:13:43:04 01:13:45:11 WITH THE OLDEST ROCKS
IN THE CENTER,
290 01:13:45:13 01:13:47:22 SURROUNDED BY YOUNGER
AND YOUNGER MOUNTAIN BELTS.
291 01:13:47:24 01:13:49:07 *SUBDUCTION OF SEA FLOOR*
292 01:13:49:09 01:13:52:07 *IS THE MOST COMMON REASON*
MOUNTAINS FORM,
293 01:13:52:09 01:13:55:06 *BUT IT IS NOT*
THE ONLY WAY.
294 01:13:55:08 01:13:57:17 *ANOTHER METHOD*
IS ACCRETION--

295 01:13:57:19 01:14:00:25 *THE JOINING TOGETHER*
OF SEPARATE LAND MASSES.
296 01:14:02:26 01:14:05:09 *WHEN TWO MASSES*
OF CONTINENTAL LITHOSPHERE,
297 01:14:05:11 01:14:07:15 *SUCH AS INDIA AND ASIA,*
298 01:14:07:17 01:14:12:05 *ARE BROUGHT TOGETHER BY*
THE COMPLETE SUBDUCTION OF
AN INTERVENING OCEAN BASIN,
299 01:14:12:07 01:14:15:29 *THE COLLISION*
RAISES HUGE MOUNTAINS.
300 01:14:16:01 01:14:19:15 *SEA FLOOR AND*
SEDIMENTARY DEPOSITS
CAUGHT IN THE SQUEEZE
301 01:14:19:17 01:14:23:15 *ARE METAMORPHOSED*
AND CONVERTED IN PART
TO IGNEOUS ROCK.
302 01:14:23:17 01:14:28:07 *THIS PROCESS GLUES*
THE ONCE-SEPARATE
LAND MASSES TOGETHER.
303 01:14:28:09 01:14:34:00 *THE ACCRETION OF TWO SUCH*
LARGE BODIES OF LITHOSPHERE
AS INDIA AND ASIA
304 01:14:34:02 01:14:36:19 *IS NOT A COMMON*
GEOLOGICAL EVENT,
305 01:14:36:21 01:14:39:20 *BUT THERE IS EVIDENCE THAT*
MUCH SMALLER BODIES OF LAND
306 01:14:39:22 01:14:43:20 *ARE FREQUENTLY ADDED TO*
THE MARGINS OF CONTINENTS
BY SUBDUCTION.
307 01:14:45:16 01:14:52:00 *SMALL CONTINENTAL FRAGMENTS*
SUCH AS MADAGASCAR
308 01:14:52:02 01:14:53:19 *AND THE FIJI ISLANDS*
309 01:14:53:21 01:14:56:20 *ARE SCATTERED THROUGHOUT*
THE WORLD'S OCEANS.
310 01:14:59:07 01:15:00:18 *BECAUSE OF THEIR BUOYANCY,*
311 01:15:00:20 01:15:03:12 *SUCH FRAGMENTS CANNOT*
BE SUBDUCTED.
312 01:15:03:14 01:15:07:08 *THEY MERELY BECOME GLUED*
BY METAMORPHISM
AND IGNEOUS ACTIVITY
313 01:15:07:10 01:15:09:23 *TO THE CONTINENTS*
THEY COLLIDE WITH.
314 01:15:11:04 01:15:12:17 *AS THIS HAPPENS,*
315 01:15:12:19 01:15:14:13 *THE POSITION*
OF THE SUBDUCTION ZONE
316 01:15:14:15 01:15:17:27 *JUMPS TO THE SEAWARD SIDE*
OF THE ADDED LANDMASS.
317 01:15:20:05 01:15:24:08 *OCEANIC SEAMOUNTS*
AND ISLANDS ALSO
MAY NOT BE SUBDUCTED,
318 01:15:24:10 01:15:29:02 *BEING TOO THICK*
TO PASS INTO THE TRENCH
AT THE CONVERGENT BOUNDARY.
319 01:15:31:00 01:15:33:12 *MUCH OF THE LANDSCAPE*
OF WESTERN NORTH AMERICA
320 01:15:33:14 01:15:38:08 *IS MADE UP*

OF CONTINENTAL FRAGMENTS,
SEAMOUNTS, AND ISLAND ARCS.

321 01:15:38:10 01:15:41:02 *THESE LANDMASSES HAVE*
ATTACHED TO THE CONTINENT

322 01:15:41:04 01:15:44:02 *DURING THE SUBDUCTION*
OF PACIFIC OCEAN LITHOSPHERE

323 01:15:44:04 01:15:46:28 *OVER THE PAST*
150 MILLION YEARS.

324 01:15:48:20 01:15:51:27 *SUCH FRAGMENTS ARE COMMONLY*
DESCRIBED BY GEOLOGISTS

325 01:15:51:29 01:15:56:16 *AS EXOTIC, SUSPECT,*
OR ACCRETED TERRAINS.

326 01:15:58:19 01:16:01:15 *THE TERM TERRAIN*
REFERS TO AN AREA OF ROCKS

327 01:16:01:17 01:16:04:00 *HAVING CONTINUOUS STRATA,*
OR STRUCTURE,

328 01:16:04:02 01:16:06:07 *AND A DISTINCTIVE*
COMPOSITION.

329 01:16:07:20 01:16:09:25 *THE BOUNDARY BETWEEN*
AN ACCRETED TERRAIN

330 01:16:09:27 01:16:12:01 *AND THE MAIN BODY*
OF THE CONTINENT

331 01:16:12:03 01:16:14:15 *MAY BE MARKED*
BY A FAULT ZONE...

332 01:16:14:17 01:16:18:00 *OR, IN PLACES,*
BY A BELT OF OCEANIC ROCK

333 01:16:18:02 01:16:21:11 *WHICH WAS NOT SUBDUCTED*
BUT CAUGHT IN THE SQUEEZE

334 01:16:21:13 01:16:23:11 *BETWEEN THE COLLIDING*
LANDMASSES.

335 01:16:25:12 01:16:28:20 *TO DETERMINE THE ULTIMATE*
ORIGIN OF AN ACCRETED TERRAIN,

336 01:16:28:22 01:16:32:15 *GEOLOGISTS LOOK*
FOR SPECIFIC CLUES
IN THE FIELD.

337 01:16:32:17 01:16:36:26 THE KINDS OF CLUES
THAT GEOLOGISTS CAN USE
ARE FOSSILS.

338 01:16:36:28 01:16:40:11 FOSSILS IN A TERRAIN
WHICH WOULD BE
VERY DIFFERENT

339 01:16:40:13 01:16:43:02 FROM THE FOSSILS OF
A NEIGHBORING TERRAIN

340 01:16:43:04 01:16:45:06 OR THE NEIGHBORING
CONTINENT.

341 01:16:45:08 01:16:47:21 THE MAGNETISM OF ROCKS
IN A TERRAIN

342 01:16:47:23 01:16:49:02 CAN ALSO BE DISTINCTIVE.

343 01:16:49:04 01:16:51:11 GEOLOGISTS COMPARE
THE MAGNETIC DIRECTION

344 01:16:51:13 01:16:54:11 RECORDED BY ROCKS
IN AN ACCRETED TERRAIN

345 01:16:54:13 01:16:57:10 TO THE MAGNETIC
DIRECTION IN ROCKS

346 01:16:57:12 01:16:59:25 THAT FORMED ON
THE CONTINENT ITSELF.

347 01:16:59:27 01:17:02:23 IF THESE DIRECTIONS
OF MAGNETISM ARE
VERY DIFFERENT,
348 01:17:02:25 01:17:05:23 THAT'S A CLUE
THE TERRAIN
TRAVELED FAR
349 01:17:05:25 01:17:07:15 TO GET WHERE IT IS.
350 01:17:07:17 01:17:09:11 *GEOLOGISTS HAVE DISCOVERED*
351 01:17:09:13 01:17:11:11 *THAT NOT ALL*
ACCRETED TERRAINS
352 01:17:11:13 01:17:14:10 *COME FROM PLATE DRIFT*
ACROSS OCEAN BASINS.
353 01:17:16:06 01:17:19:20 *SOME TERRAINS ARE MERELY*
HUGE PIECES OF A CONTINENT
354 01:17:19:22 01:17:22:20 *WHICH ARE SLICED OFF*
AND SHIFTED GREAT DISTANCES
355 01:17:22:22 01:17:25:14 *BY MOVEMENT*
ALONG LARGE FAULTS.
356 01:17:28:01 01:17:29:19 *GEOLOGISTS*
CAN'T ALWAYS DISTINGUISH
357 01:17:29:21 01:17:31:19 *BETWEEN TERRAINS*
OF THIS ORIGIN
358 01:17:31:21 01:17:35:20 *AND THOSE WHICH TRULY COME*
FROM ACROSS AN ANCIENT SEA.
359 01:17:35:22 01:17:37:20 *IN FACT,*
MANY MOUNTAIN BELTS
360 01:17:37:22 01:17:40:20 *SEEM TO CONTAIN*
TERRAINS OF BOTH TYPES.
361 01:17:41:21 01:17:43:05 THE NOTION
THAT SOME TERRAINS
362 01:17:43:07 01:17:44:17 ARE EXOTIC OR SUSPECT
363 01:17:44:19 01:17:46:17 IS CONTROVERSIAL
BECAUSE IT'S UNCLEAR
364 01:17:46:19 01:17:50:01 AS TO HOW FAR SOME OF THESE
TERRAINS HAVE TRAVELED.
365 01:17:50:03 01:17:52:23 UH, SOME MAY BE
ONLY LOCALLY DERIVED.
366 01:17:52:25 01:17:54:08 I MEAN, LET'S SAY
367 01:17:54:10 01:17:56:23 PORTIONS OF BAJA CALIFORNIA
WERE OFFSET
368 01:17:56:25 01:17:59:24 AND THEN RAFTED
TO THE EDGE OF CALIFORNIA.
369 01:17:59:26 01:18:02:07 THAT WOULD NOT
BE VERY FAR TRAVELED.
370 01:18:02:09 01:18:03:17 BUT LET'S SAY
371 01:18:03:19 01:18:06:01 PORTIONS OF CHINA TRAVELED
ACROSS THE PACIFIC OCEAN
372 01:18:06:03 01:18:09:01 AND THEN WERE RAFTED
INTO THE SIDE OF OREGON.
373 01:18:09:03 01:18:10:16 THAT WOULD BE FAR TRAVELED.
374 01:18:10:18 01:18:14:06 IT'S CLEAR FROM,
UH, PALEOMAGNETIC EVIDENCE,
375 01:18:14:08 01:18:15:11 FOSSIL EVIDENCE,
376 01:18:15:13 01:18:16:26 THAT SOME BITS
OF MATERIAL--
377 01:18:16:28 01:18:18:11 SOME FROM THE OCEAN

CROSSING,
378 01:18:18:13 01:18:20:22 SOME FROM OTHER PARTS
OF CONTINENTS--
379 01:18:20:24 01:18:22:07 HAVE BEEN BROUGHT
GREAT DISTANCE--
380 01:18:22:09 01:18:23:16 SOME THOUSANDS
OF KILOMETERS--
381 01:18:23:18 01:18:25:27 AND ACCRETED TO THE EDGE
OF CONTINENTS.
382 01:18:25:29 01:18:28:06 WHEN WE LOOK AT MODERN-DAY
MOUNTAIN BELTS,
383 01:18:28:08 01:18:31:02 WE RECOGNIZE THERE ARE
REALLY TWO PORTIONS--
384 01:18:31:04 01:18:32:17 AN INTERIOR PORTION
385 01:18:32:19 01:18:34:17 OF METAMORPHIC ROCKS
AND IGNEOUS ROCKS
386 01:18:34:19 01:18:37:02 THAT ARE INTRINSIC
TO THAT CONTINENT,
387 01:18:37:04 01:18:39:02 AND THEN AN OUTBOARD
PORTION,
388 01:18:39:04 01:18:42:18 AN AMALGAMATION OF EXOTIC
OR SUSPECT TERRAINS
389 01:18:42:20 01:18:44:18 THAT HAVE COME
FROM VARIOUS DISTANCES
390 01:18:44:20 01:18:48:03 AND REPRESENTING VARIOUS
AGES OF ANCIENT ROCK.
391 01:18:49:07 01:18:51:03 *REGARDLESS*
OF HOW THEY FORM,
392 01:18:51:05 01:18:53:03 *MOUNTAIN BELTS*
ALONG CONVERGENT BOUNDARIES
393 01:18:53:05 01:18:56:03 *STOP GROWING*
WHEN SUBDUCTION ENDS.
394 01:18:56:05 01:18:57:19 *THEY GRADUALLY DETERIORATE*
395 01:18:57:21 01:19:01:22 *TO BECOME PART OF THE*
LOW-LYING CRATON ITSELF.
396 01:19:01:24 01:19:03:22 ULTIMATELY, OF COURSE,
397 01:19:03:24 01:19:07:02 MOUNTAIN BUILDING ENDS,
398 01:19:07:04 01:19:12:02 AND THAT SIGNALS THE END
OF CONVERGENT PLATE MOTION.
399 01:19:12:04 01:19:13:17 A SETTLING BACK
400 01:19:13:19 01:19:18:18 OR PERHAPS LOW-ANGLE
DISTRIBUTIVE FAULTING OCCURS
401 01:19:18:20 01:19:20:18 WHICH EXTEND
THE MOUNTAIN BELT
402 01:19:20:20 01:19:22:12 RATHER THAN COMPRESS IT,
403 01:19:22:14 01:19:25:02 AND THE FORCES
OF EROSION,
404 01:19:25:04 01:19:28:13 ONCE THIS CONSTRUCTIONAL
STAGE IS OVER,
405 01:19:28:15 01:19:29:17 TAKE OVER.
406 01:19:29:19 01:19:32:03 GONE, TOO, ALSO,
IS THE VOLCANISM
407 01:19:32:05 01:19:34:03 THAT CHARACTERIZES
EARLY AND MIDDLE STAGES
408 01:19:34:05 01:19:35:22 OF MANY MOUNTAIN BELTS.
409 01:19:35:24 01:19:39:27 BUT THE ACTUAL

GEOLOGIC MOUNTAINS
410 01:19:39:29 01:19:42:28 ARE THEN, UM...
411 01:19:43:00 01:19:45:13 TERMINATED
BY EROSIVE PROCESSES.
412 01:19:45:15 01:19:47:13 THERE MAY BE
LATER UPLIFT,
413 01:19:47:15 01:19:49:03 WHICH PROVIDES
STRONG RELIEF
414 01:19:49:05 01:19:51:03 AND GIVES YOU
TOPOGRAPHIC MOUNTAINS,
415 01:19:51:05 01:19:54:12 BUT THIS LAYER PROCESS
IS NOT, STRICTLY SPEAKING,
416 01:19:54:14 01:19:56:02 THE MOUNTAIN BUILDING
PROCESS.
417 01:19:56:04 01:19:59:05 IT IS SIMPLY AN UPLIFT
IN EROSIONAL PROCESS.
418 01:19:59:07 01:20:01:05 *IN EASTERN NORTH AMERICA,*
419 01:20:01:07 01:20:03:20 *THE APPALACHIAN MOUNTAINS*
CONTINUE TO EXIST
420 01:20:03:22 01:20:05:19 *MORE THAN 200 MILLION YEARS*
421 01:20:05:21 01:20:08:19 *AFTER THE PLATE COLLISIONS*
THAT FORMED THEM.
422 01:20:08:21 01:20:10:04 *GIVEN RATES OF EROSION,*
423 01:20:10:06 01:20:12:19 *THESE MOUNTAINS*
SHOULD HAVE WORN FLAT
424 01:20:12:21 01:20:15:05 *TENS OF MILLIONS*
OF YEARS AGO,
425 01:20:15:07 01:20:16:20 *YET THEY STILL STAND,*
426 01:20:16:22 01:20:20:14 *INDICATING THAT SOME UPLIFT*
MUST BE CONTINUING.
427 01:20:21:28 01:20:24:25 *THE CAUSE OF THIS PUZZLING*
LATE STAGE UPLIFT
428 01:20:24:27 01:20:26:10 *WAS DISCOVERED IN 1859*
429 01:20:26:12 01:20:29:10 *BY BRITISH SURVEYOR*
G.B. AIRY.
430 01:20:29:12 01:20:31:00 *WHILE WORKING IN INDIA,*
431 01:20:31:02 01:20:33:20 *AIRY DISCOVERED*
THAT PLUMB-BOBS--
432 01:20:33:22 01:20:36:21 *IRON WEIGHTS USED TO LEVEL*
SIGHTING INSTRUMENTS--
433 01:20:36:23 01:20:38:21 *WERE LESS ATTRACTED*
BY THE GRAVITY
434 01:20:38:23 01:20:40:06 *FROM THE NEARBY*
HIMALAYAN MOUNTAINS
435 01:20:40:08 01:20:41:21 *THAN THEY SHOULD BE,*
436 01:20:41:23 01:20:43:22 *IF THE HIMALAYA*
WERE DIRECTLY UNDERLAIN
437 01:20:43:24 01:20:45:07 *BY THE SAME DENSE ROCK*
438 01:20:45:09 01:20:47:27 *PRESUMED TO FORM MOST*
OF THE EARTH'S INTERIOR.
439 01:20:50:23 01:20:52:05 *THIS SUGGESTED*
440 01:20:52:07 01:20:55:02 *THERE WAS LESS MASS PRESENT*
BENEATH THE HIMALAYA
441 01:20:55:04 01:20:56:20 *THAN PREVIOUSLY THOUGHT.*
442 01:20:56:22 01:20:58:16 *TO EXPLAIN*
THIS DISCREPANCY,

443 01:20:58:18 01:20:59:29 *AIRY CONCLUDED*
444 01:21:00:03 01:21:04:23 *THAT A LOW-DENSITY ROOT MUST LIE BENEATH THE RANGE.*
445 01:21:04:25 01:21:06:28 *GEOPHYSICAL STUDIES HAVE SINCE CONFIRMED*
446 01:21:07:00 01:21:09:13 *THAT THE CRUST BENEATH THE HIMALAYA*
447 01:21:09:15 01:21:12:03 *EXTENDS TO A DEPTH OF 75 KILOMETERS,*
448 01:21:12:05 01:21:15:13 *TWICE AS THICK AS ORDINARY CONTINENTAL CRUST.*
449 01:21:17:05 01:21:18:14 *IT'S NOW KNOWN*
450 01:21:18:16 01:21:20:18 *THAT MOST MOUNTAIN RANGES ARE UNDERLAIN*
451 01:21:20:20 01:21:22:04 *BY CRUSTAL ROOTS*
452 01:21:22:06 01:21:25:13 *FLOATING ATOP THE HOT, PLASTICALLY-DEFORMING MANTLE.*
453 01:21:25:15 01:21:26:28 *THE ROOTS GROW*
454 01:21:27:00 01:21:29:28 *AS A RESULT OF COMPRESSION DURING PLATE CONVERGENCE.*
455 01:21:31:16 01:21:33:29 *AS MOUNTAIN RANGES ARE WORN DOWN,*
456 01:21:34:01 01:21:36:29 *THEIR ROOTS ARE BUOYED UPWARD BY THE MANTLE.*
457 01:21:38:06 01:21:40:04 *BECAUSE THE MANTLE IS FAR STIFFER*
458 01:21:40:06 01:21:41:23 *THAN THE MOST FLUID LAVA,*
459 01:21:41:25 01:21:44:09 *THE CRUST FLOATS UPWARD QUITE SLOWLY,*
460 01:21:44:11 01:21:47:09 *SUSTAINING A HILLY TOPOGRAPHY IN THE LANDSCAPE*
461 01:21:47:11 01:21:49:18 *FOR HUNDREDS OF MILLIONS OF YEARS.*
462 01:21:51:05 01:21:52:29 *AS THE CRUST RISES,*
463 01:21:53:01 01:21:55:28 *ROCKS FROM EVER-DEEPER LEVELS INSIDE THE EARTH*
464 01:21:56:00 01:21:59:28 *ARE BROUGHT TO THE SURFACE AND WORN AWAY.*
465 01:22:00:00 01:22:02:21 *THE FLOATING OF EARTH'S CRUST ATOP THE MANTLE*
466 01:22:02:23 01:22:05:01 *IS TERMED ISOSTASY.*
467 01:22:08:18 01:22:11:06 *THIS IS SIMILAR TO WHAT HAPPENS AT SEA,*
468 01:22:11:08 01:22:12:21 *WHERE LARGE ICEBERGS FLOAT*
469 01:22:12:23 01:22:15:02 *WITH MORE ICE EXTENDING BENEATH THE SURFACE*
470 01:22:15:04 01:22:16:17 *THAN SMALL ONES DO.*
471 01:22:18:19 01:22:20:01 *IN THE SAME WAY,*
472 01:22:20:03 01:22:22:01 *TALL MOUNTAINS USUALLY HAVE ROOTS*
473 01:22:22:03 01:22:23:16 *EXTENDING DEEPER INTO THE EARTH*
474 01:22:23:18 01:22:27:01 *THAN LOW MOUNTAINS MADE UP OF THE SAME ROCK TYPE.*
475 01:22:28:18 01:22:30:02 *IN BOTH CASES,*
476 01:22:30:04 01:22:32:17 *FAR MORE MASS*

LIES HIDDEN FROM VIEW

477 01:22:32:19 01:22:35:08 *THAN CAN BE SEEN*
AT THE SURFACE.

478 01:22:35:10 01:22:37:16 ISOSTASY IS THE PROCESS
BY WHICH

479 01:22:37:18 01:22:40:15 DIFFERENT THICKNESS
AND DIFFERENT DENSITY
IRREGULARITIES

480 01:22:40:17 01:22:42:00 IN THE OUTER EARTH

481 01:22:42:02 01:22:44:15 FLOAT IN GRAVITATIONAL
EQUILIBRIUM WITH ONE ANOTHER.

482 01:22:44:17 01:22:47:01 WHEN YOU BUILD UP
A LARGE MOUNTAIN RANGE,

483 01:22:47:03 01:22:49:16 YOU'RE LIABLE TO HAVE
A ROOT UNDERNEATH

484 01:22:49:18 01:22:54:00 AND A LOT OF MATERIAL
PILED UP HIGH
ON THE EARTH'S SURFACE.

485 01:22:54:02 01:22:58:00 ULTIMATELY, IF
YOU DON'T HAVE FORCES
TO KEEP IT PILED UP,

486 01:22:58:02 01:23:00:13 THAT IS GOING TO TEND
TO WANT TO EQUILIBRATE

487 01:23:00:15 01:23:02:13 AND FLOAT IN
GRAVITATIONAL EQUILIBRIUM

488 01:23:02:15 01:23:04:26 WITH THE OTHER AREAS
AROUND IT.

489 01:23:04:28 01:23:08:29 AS MOUNTAIN BELTS
UPLIFT LATE
IN THEIR STAGES,

490 01:23:09:01 01:23:11:29 THEY MAY BEGIN TO ACTUALLY
UNDERGO EXTENSIONAL COLLAPSE,

491 01:23:12:01 01:23:13:14 OR BREAKING APART,

492 01:23:13:16 01:23:16:28 AT THE HIGH LEVELS DUE
TO THE FORCE OF GRAVITY.

493 01:23:17:00 01:23:18:13 AT THEIR DEEPER LEVELS,

494 01:23:18:15 01:23:20:13 THERE MAY BE PLASTIC FLOW
UNDERNEATH THEM

495 01:23:20:15 01:23:22:28 OR COMPENSATION BY FLOW
IN THE MANTLE

496 01:23:23:00 01:23:27:06 IN ORDER TO LET WHATEVER
ROOT THAT EXISTS
TO EQUILIBRATE

497 01:23:27:08 01:23:29:21 AND TO COME TO
GRAVITATIONAL EQUILIBRIUM

498 01:23:29:23 01:23:33:28 WITH THE MANTLE AND
THE LOWER CRUST AROUND IT.

499 01:23:34:00 01:23:36:28 DURING THIS STAGE
OF ULTIMATE ISOSTATIC
EQUILIBRATION,

500 01:23:37:00 01:23:42:29 IF THERE ARE NO LONGER
MAJOR FORCES UPLIFTING
THE MOUNTAIN RANGE,

501 01:23:43:01 01:23:47:13 THEN EROSION WILL
ULTIMATELY WIN OUT
OVER THE UPLIFT PROCESS

502 01:23:47:15 01:23:50:13 AND THE MOUNTAIN BELT
WILL BE BEVELED
503 01:23:50:15 01:23:53:13 TO A MUCH FLATTER,
LOWER RELIEF SURFACE.
504 01:23:53:15 01:23:54:28 AT THIS STAGE,
505 01:23:55:00 01:23:57:29 THE MOUNTAIN BELT
IS WELL ON ITS WAY
506 01:23:58:01 01:24:00:07 TO BECOMING
PART OF THE CRATON.
507 01:24:01:14 01:24:02:27 *THROUGH GEOLOGIC TIME,*
508 01:24:02:29 01:24:05:12 *THE AMOUNT OF CONTINENTAL*
MATERIAL ON EARTH
509 01:24:05:14 01:24:07:11 *HAS SLOWLY*
GROWN IN SIZE
510 01:24:07:13 01:24:10:17 *AT THE EXPENSE*
OF THE OCEAN BASINS.
511 01:24:12:01 01:24:14:26 *BUT TRACING THE GROWTH*
ON INDIVIDUAL CONTINENTS
512 01:24:14:28 01:24:16:12 *IS A GREAT CHALLENGE,*
513 01:24:16:14 01:24:17:27 *FOR EACH*
CONTINENT TODAY
514 01:24:17:29 01:24:21:12 *HAS BEEN JOINED TO OTHER*
CONTINENTS IN THE PAST.
515 01:24:22:23 01:24:25:11 THE GENERAL PATTERN
IN CONTINENTS
516 01:24:25:13 01:24:29:26 IS TO FIND THE OLDEST
MATERIAL IN THE INTERIORS
OF THE CRATONS.
517 01:24:29:28 01:24:33:12 THIS IS BECAUSE THE CORES
OF THE CONTINENTS FORMED
518 01:24:33:14 01:24:35:27 AND THEN THE SUCCESSIVE
MOUNTAIN BELTS
519 01:24:35:29 01:24:39:11 AND CONTINENT EDGE
ACCRETIONS OCCURRED
AROUND THEIR MARGINS.
520 01:24:40:28 01:24:44:11 *BUT GEOLOGISTS FIND THAT*
PATTERN TO BE IMPERFECT,
521 01:24:44:13 01:24:48:27 *BECAUSE CONTINENTAL MASSES TEND*
TO BREAK AND RIFT APART
522 01:24:48:29 01:24:50:12 *DURING THEIR GROWTH.*
523 01:24:51:29 01:24:53:27 AND SO
AS THEY BREAK APART,
524 01:24:53:29 01:24:56:26 THEY MAY BREAK APART
ACROSS OLDER INTERIORS
OF CONTINENTS,
525 01:24:56:28 01:24:58:25 ACROSS YOUNGER
MOUNTAIN BELTS,
526 01:24:58:27 01:25:00:10 AND THEN SUBSEQUENTLY,
527 01:25:00:12 01:25:03:09 THEY MAY FORM
A NEW MOUNTAIN BELT
ACROSS A BROKEN EDGE.
528 01:25:03:11 01:25:05:24 THAT LEADS US WITH
A COMPETING SERIES
OF PROCESSES
529 01:25:05:26 01:25:07:09 OF MARGINAL GROWTH
AND BREAKING APART

530 01:25:07:11 01:25:09:25 AND DRIFTING AND THEN
COLLIDING BACK TOGETHER
531 01:25:09:27 01:25:11:14 AND GROWING AGAIN.
532 01:25:14:12 01:25:16:24 *MOUNTAIN RANGES,*
NEWLY FORMING AND ANCIENT,
533 01:25:16:26 01:25:18:24 *MARK THE GROWTH*
OF CONTINENTS
534 01:25:18:26 01:25:20:09 *IN RESPONSE*
TO PLATE MOVEMENTS.
535 01:25:22:10 01:25:24:08 *FLOATING ON EARTH'S*
PLASTIC MANTLE,
536 01:25:24:10 01:25:27:10 *THESE GIGANTIC TOPOGRAPHIC*
FEATURES DISAPPEAR SLOWLY,
537 01:25:27:12 01:25:31:09 *AS THEIR LOW-DENSITY*
ROOTS ARE BUOYED UP.
538 01:25:31:11 01:25:35:02 *SO MOUNTAINS OWE THEIR*
EXISTENCE TO TWO FACTORS--
539 01:25:35:04 01:25:37:24 *THE HEAT THAT DRIVES*
PLATE TECTONICS,
540 01:25:37:26 01:25:40:25 *AND THE EFFECTS*
OF GRAVITY.
541 01:25:40:27 01:25:43:25 *IN TIME,*
MOUNTAINS WEAR FLAT,
542 01:25:43:27 01:25:46:03 *ADDING NEW CRUST*
TO THE CRATONS--
543 01:25:46:05 01:25:49:24 *THE OLDEST, MOST STABLE*
LANDS ON PLANET EARTH.
544 01:25:52:03 01:25:54:09 ONE OF THE BENCHMARK
DISCOVERIES IN GEOLOGY
545 01:25:54:11 01:25:56:10 OVER THE LAST
HALF CENTURY
546 01:25:56:12 01:25:58:05 IS THE ORIGIN
OF MOUNTAIN RANGES.
547 01:25:58:07 01:26:00:18 CONTINENTS
AND OCEAN CRUST
HAVE COLLIDED
548 01:26:00:20 01:26:03:03 OR SUBDUCTED
AT TECTONIC
PLATE MARGINS,
549 01:26:03:05 01:26:05:03 MOUNTAIN RANGES
HAVE BEEN FORMED,
550 01:26:05:05 01:26:08:02 AND PROCESSES OF EROSION
HAVE TORN THEM DOWN.
551 01:26:08:04 01:26:10:17 EVENTUALLY,
THE CONTINENTS
ARE SPLIT APART
552 01:26:10:19 01:26:12:03 BY RENEWED
PLATE DIVERGENCE
553 01:26:12:05 01:26:13:26 AND ARE ON THEIR WAY
TO NEW COLLISIONS,
554 01:26:13:28 01:26:15:11 OFTEN FORMING
A SUPERCONTINENT.
555 01:26:15:13 01:26:17:08 THIS TECTONIC CYCLE,
556 01:26:17:10 01:26:20:08 SOMETIMES REFERRED
TO AS THE DANCE
OF THE CONTINENTS,

557 01:26:20:10 01:26:23:08 HAS BEEN REPEATED
MANY TIMES IN
THE GEOLOGIC PAST,
558 01:26:23:10 01:26:24:22 WITH EACH
COMPLETE CYCLE
559 01:26:24:24 01:26:26:20 LASTING
SEVERAL HUNDRED
MILLION YEARS.
560 01:26:26:22 01:26:29:05 SOME ASPECTS OF
THIS TECTONIC DANCE
561 01:26:29:07 01:26:31:07 HAVE SURPRISINGLY
COMPLICATED STEPS.
562 01:26:31:09 01:26:32:23 ALASKA, FOR EXAMPLE,
563 01:26:32:25 01:26:34:23 IS LARGELY COMPOSED
OF PLATE FRAGMENTS
564 01:26:34:25 01:26:37:23 THAT HAVE BEEN
PACKED TOGETHER BY
SUCCESSIVE COLLISIONS.
565 01:26:37:25 01:26:39:08 SOME OF THESE
TERRAINS
566 01:26:39:10 01:26:41:22 HAVE BEEN TECTONICALLY
TRANSPORTED THOUSANDS
OF KILOMETERS
567 01:26:41:24 01:26:44:22 BY SEA FLOOR SPREADING
AND STRIKE-SLIP FAULTING
568 01:26:44:24 01:26:47:19 BEFORE COLLIDING
WITH NORTH AMERICA
TO FORM ALASKA.
569 01:26:47:21 01:26:50:18 THE MEDITERRANEAN
SEA IS A SHRINKING
OCEAN BASIN
570 01:26:50:20 01:26:53:18 CAUGHT IN A COLLISION
BETWEEN THE COLLIDING
CONTINENTS
571 01:26:53:20 01:26:55:03 OF AFRICA AND EUROPE.
572 01:26:55:05 01:26:57:03 THE FAMOUS VOLCANOES
AND EARTHQUAKES
573 01:26:57:05 01:26:59:19 AND INTENSELY DEFORMED
MOUNTAINS OF THIS REGION
574 01:26:59:21 01:27:02:05 ARE EVIDENCE
OF THE PROFOUND
MOUNTAIN BUILDING
575 01:27:02:07 01:27:04:20 THAT ACCOMPANIES
THE DEATH OF AN OCEAN.
576 01:27:04:22 01:27:06:05 TECTONIC CYCLES
AND MOUNTAIN BUILDING
577 01:27:06:07 01:27:09:05 ARE NEARLY AS OLD
AS THE EARTH ITSELF.
578 01:27:09:07 01:27:13:00 AND THE FORECAST FOR
THE GEOLOGIC FUTURE
IS CONTINUED CHANGE--
579 01:27:13:02 01:27:16:27 CHANGE IN THE OCEAN
BASINS AND CONTINENTS
AND MOUNTAIN RANGES
580 01:27:16:29 01:27:19:05 THAT TOGETHER ARE
THE FACE OF THE EARTH.

581 01:27:19:07 01:27:21:20 A MAP OF THE WORLD
A BILLION YEARS FROM NOW
582 01:27:21:22 01:27:23:05 WILL BEAR
SCANT RESEMBLANCE
583 01:27:23:07 01:27:25:16 TO THE WORLD
WE KNOW TODAY.
584 01:28:17:21 01:28:20:19 CAPTIONING PERFORMED BY
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