

1	00:29:45:01	00:29:48:12	Annenberg Media
2	00:29:48:14	00:30:40:12	§
3	00:30:40:14	00:30:42:02	<i>THROUGHOUT HUMAN HISTORY,</i>
4	00:30:42:04	00:30:45:00	<i>SCIENTISTS, PHILOSOPHERS,</i>
			<i>THEOLOGIANs, AND OTHERS</i>
5	00:30:45:02	00:30:48:00	<i>HAVE PONDERED THIS</i>
			<i>BEAUTIFUL GEM CALLED EARTH</i>
6	00:30:48:02	00:30:51:15	<i>FLOATING IN THE SEEMINGLY</i>
			<i>EMPTY BLACKNESS OF SPACE.</i>
7	00:30:51:17	00:30:54:16	<i>THE MOST INFLUENTIAL OF</i>
			<i>THE EARLY GREEK ASTRONOMERS</i>
8	00:30:54:18	00:30:57:15	<i>BELIEVED THAT THE EARTH</i>
			<i>WAS AT THE CENTER</i>
9	00:30:57:17	00:30:59:01	<i>OF THE UNIVERSE.</i>
10	00:30:59:03	00:31:02:00	<i>THIS VIEW PREVAILED</i>
			<i>IN THE WESTERN WORLD</i>
11	00:31:02:02	00:31:03:14	<i>UNTIL THE 16th CENTURY</i>
12	00:31:03:16	00:31:06:14	<i>WHEN COPERNICUS ADVANCED</i>
			<i>THE RADICAL NOTION</i>
13	00:31:06:16	00:31:10:04	<i>THAT THE PLANETS</i>
			<i>ORBIT THE SUN INSTEAD.</i>
14	00:31:11:06	00:31:13:20	<i>THEN, IN THE 17th CENTURY,</i>
15	00:31:13:22	00:31:16:10	<i>GALILEO POINTED</i>
			<i>A TELESCOPE SKYWARD</i>
16	00:31:16:12	00:31:18:15	<i>TO STUDY THE HEAVENS.</i>
17	00:31:18:17	00:31:21:29	<i>IN HIS OBSERVATIONS</i>
			<i>OF THE MOONS OF JUPITER,</i>
18	00:31:22:01	00:31:23:15	<i>THE PHASES OF VENUS,</i>
19	00:31:23:17	00:31:26:01	<i>AND THE CRATERS</i>
			<i>OF EARTH'S MOON,</i>
20	00:31:26:03	00:31:29:16	<i>GALILEO PROVIDED STARTLING</i>
			<i>NEW ASTRONOMICAL DATA</i>
21	00:31:29:18	00:31:32:00	<i>THAT STRONGLY SUPPORTED</i>
			<i>A HELIOCENTRIC</i>
22	00:31:32:02	00:31:34:23	<i>OR SUN-CENTERED VIEW</i>
			<i>OF THE UNIVERSE.</i>
23	00:31:38:01	00:31:40:00	<i>MEANWHILE,</i>
			<i>IN CENTRAL EUROPE,</i>
24	00:31:40:02	00:31:42:28	<i>JOHANNES KEPLER</i>
			<i>FURTHER REFINED THIS NOTION</i>
25	00:31:43:00	00:31:45:27	<i>BY DEMONSTRATING THAT</i>
			<i>EACH PLANET ORBITS THE SUN</i>
26	00:31:45:29	00:31:49:15	<i>IN A NONCIRCULAR ORBIT</i>
			<i>KNOWN AS AN ELLIPSE.</i>
27	00:31:51:01	00:31:53:28	<i>BUT NOT UNTIL THE WORK</i>
			<i>OF ISAAC NEWTON</i>
28	00:31:54:00	00:31:56:13	<i>WAS THE MYSTERY</i>
			<i>OF PLANETARY MOTION</i>
29	00:31:56:15	00:31:57:28	<i>FINALLY UNRAVELED</i>
30	00:31:58:00	00:32:00:15	<i>WITH ABSOLUTE</i>
			<i>MATHEMATICAL CERTAINTY.</i>
31	00:32:01:29	00:32:03:29	<i>IN THE YEARS SINCE THEN,</i>
32	00:32:04:01	00:32:05:14	<i>COUNTLESS SCIENTIFIC</i>
			<i>BREAKTHROUGHS</i>
33	00:32:05:16	00:32:07:14	<i>HAVE PROVIDED</i>
			<i>STILL MORE CLUES</i>

34 00:32:07:16 00:32:08:29 ABOUT WHERE  
OUR PLANET SITS

35 00:32:09:01 00:32:11:15 IN THE CELESTIAL SCHEME  
OF THINGS.

36 00:32:14:29 00:32:16:12 YET QUESTIONS LINGER

37 00:32:16:14 00:32:19:14 AS WE SEEK TO BETTER  
UNDERSTAND PLANET EARTH.

38 00:32:19:16 00:32:22:14 HOW EXACTLY DID  
THIS WORLD OF OURS FORM,

39 00:32:22:16 00:32:24:28 AND WHY IS IT  
SO DIFFERENT

40 00:32:25:00 00:32:26:28 FROM THE OTHER  
KNOWN PLANETS?

41 00:32:34:01 00:32:36:14 ONE CHARACTERISTIC  
THAT MAKES EARTH UNIQUE

42 00:32:36:16 00:32:38:14 IN OUR SOLAR SYSTEM  
IS LIFE.

43 00:32:38:16 00:32:39:28 LIVING THINGS  
CAN BE FOUND

44 00:32:40:00 00:32:41:13 VIRTUALLY EVERYWHERE  
ON EARTH--

45 00:32:41:15 00:32:44:12 HIGH ON MOUNTAIN PEAKS,  
IN DEEP OCEAN BASINS,

46 00:32:44:14 00:32:45:26 IN THE HOTTEST DESERTS,

47 00:32:45:28 00:32:47:26 AND AT THE  
ICEBOUND POLES.

48 00:32:47:28 00:32:50:25 LIFE HAS EVEN BEEN FOUND  
IN SUCH SEEMINGLY

49 00:32:50:27 00:32:52:11 INHOSPITABLE  
ENVIRONMENTS

50 00:32:52:13 00:32:53:26 AS ACTIVE  
UNDERSEA VOLCANOES,

51 00:32:53:28 00:32:56:22 AND HOT, ACIDIC  
SULFUR SPRINGS.

52 00:32:56:24 00:32:58:08 THE PRESENCE OF LIFE

53 00:32:58:10 00:32:59:22 CLEARLY  
DISTINGUISHES EARTH

54 00:32:59:24 00:33:01:09 FROM ITS  
NEIGHBORING PLANETS,

55 00:33:01:11 00:33:03:24 BUT LIFE HASN'T ALWAYS  
EXISTED HERE.

56 00:33:03:26 00:33:06:10 IN FACT, WHEN THE SOLAR  
SYSTEM CAME INTO BEING,

57 00:33:06:12 00:33:08:11 AN EVENT WE ESTIMATE  
OCCURRED

58 00:33:08:13 00:33:09:25 ABOUT 4.6 BILLION  
YEARS AGO,

59 00:33:09:27 00:33:11:25 EARTH WAS A VERY  
DIFFERENT PLANET

60 00:33:11:27 00:33:13:26 THAN THE ONE  
WE KNOW TODAY.

61 00:33:15:14 00:33:17:26 THE MOST WIDELY-HELD  
SCIENTIFIC THEORY

62 00:33:17:28 00:33:19:26 OF THE ORIGIN  
OF THE EARTH

63 00:33:19:28 00:33:22:10 AND OF THE ENTIRE

*SOLAR SYSTEM*

64 00:33:22:12 00:33:23:26 *WAS FIRST ADVANCED*  
65 00:33:23:28 00:33:26:10 *BY THE GERMAN PHILOSOPHER*  
*IMMANUEL KANT...*  
66 00:33:28:03 00:33:30:15 *AND LATER*  
*BY FRENCH MATHEMATICIAN*  
67 00:33:30:17 00:33:32:08 *PIERRE SIMON LAPLACE.*  
68 00:33:34:13 00:33:37:10 *THEY HELD THAT*  
*THE SUN AND PLANETS*  
69 00:33:37:12 00:33:38:26 *CONDENSED FROM A NEBULA.*  
70 00:33:38:28 00:33:40:14 *SUPPORT FOR THIS IDEA*  
71 00:33:40:16 00:33:42:23 *CAME WITH DEVELOPMENT OF*  
*MORE POWERFUL TELESCOPES*  
72 00:33:42:25 00:33:44:08 *AND SPECTROMETERS,*  
73 00:33:44:10 00:33:47:04 *WHICH CAN DETECT*  
*THE COMPOSITION OF MATERIAL*  
74 00:33:47:06 00:33:48:17 *DEEP IN SPACE.*  
75 00:33:53:27 00:33:56:24 *NEBULA ARE CREATED*  
*BY THE EXPLOSION OF STARS*  
76 00:33:56:26 00:33:59:17 *WHICH HAVE EXHAUSTED*  
*THEIR NUCLEAR FUEL.*  
77 00:34:01:11 00:34:03:25 *BY STUDYING THE*  
*COMPOSITIONS OF NEBULA,*  
78 00:34:03:27 00:34:05:09 *ASTRONOMERS*  
*HAVE FOUND EVIDENCE*  
79 00:34:05:11 00:34:07:10 *THAT STARS AND PLANETS*  
80 00:34:07:12 00:34:10:20 *CAN FORM FROM THESE*  
*INTERSTELLAR CLOUDS.*  
81 00:34:12:26 00:34:14:24 *99% OF NEBULAR MATERIAL*  
82 00:34:14:26 00:34:17:28 *IS COMPOSED OF HYDROGEN*  
*AND HELIUM GAS.*  
83 00:34:19:15 00:34:23:09 *BUT ABOUT 1% CONSISTS OF*  
*TINY BITS OF SOLID MATTER--*  
84 00:34:23:11 00:34:25:10 *SILICON COMPOUNDS,*  
*IRON OXIDES,*  
85 00:34:25:12 00:34:28:09 *CARBON, AND A HOST*  
*OF OTHER MATERIALS,*  
86 00:34:28:11 00:34:32:08 *ALL OF WHICH ARE FOUND*  
*IN THE SUN AND PLANETS.*  
87 00:34:34:26 00:34:36:25 *IF THE FORCE OF GRAVITY*  
88 00:34:36:27 00:34:39:10 *BETWEEN THE GAS*  
*AND BITS OF COSMIC DUST*  
89 00:34:39:12 00:34:40:24 *IS STRONG ENOUGH,*  
90 00:34:40:26 00:34:43:07 *THIS MATTER IS GRADUALLY*  
*PULLED TOGETHER.*  
91 00:34:44:19 00:34:47:14 *AS THE NEBULA CONTRACTS,*  
*IT STARTS SPINNING,*  
92 00:34:47:16 00:34:50:07 *WITH HEAT SETTING*  
*ITS PARTICLES IN MOTION.*  
93 00:34:50:09 00:34:53:28 *THE FURTHER IT CONDENSES,*  
*THE FASTER IT ROTATES.*  
94 00:34:57:10 00:34:59:08 *THE PROCESS*  
*IS SOMETHING LIKE*  
95 00:34:59:10 00:35:01:22 *WHAT HAPPENS WHEN A SKATER*  
*CONDENSES HIMSELF*  
96 00:35:01:24 00:35:03:22 *BY DRAWING IN HIS ARMS*

97 00:35:03:24 00:35:05:28 UNTIL HIS BODY  
BECOMES A BLUR.

98 00:35:11:10 00:35:13:08 GRADUALLY, THE GAS  
AND STAR DUST

99 00:35:13:10 00:35:15:08 BECOME MORE  
AND MORE CONCENTRATED

100 00:35:15:10 00:35:17:23 AT THE CENTER  
OF THE NEBULA,

101 00:35:17:25 00:35:20:07 HEATING UP  
TO FORM A STAR.

102 00:35:20:09 00:35:23:07 THE MATERIAL SPINNING  
AROUND A NEW STAR

103 00:35:23:09 00:35:24:25 FLATTENS INTO A DISK,  
104 00:35:24:27 00:35:27:21 DRAWN THERE BY GRAVITY  
FROM THE EQUATORIAL BULGE

105 00:35:27:23 00:35:29:20 CREATED BY  
THE STAR'S ROTATION.

106 00:35:31:25 00:35:34:07 OVER TENS OF MILLIONS  
OF YEARS,

107 00:35:34:09 00:35:37:07 DUST GATHERS AS CLUMPS  
IN THE HOT DISK.

108 00:35:37:09 00:35:39:07 THESE COLLIDE  
AND WELD TOGETHER

109 00:35:39:09 00:35:41:07 UNDER THE INFLUENCE  
OF GRAVITY,

110 00:35:41:09 00:35:43:20 FORMING LARGER OBJECTS  
CALLED PLANETESIMALS,

111 00:35:43:22 00:35:47:06 WHICH IN TURN COME TOGETHER  
TO FORM THE PLANETS.

112 00:35:48:25 00:35:51:21 THE PRECISE DETAILS OF  
THIS ACCRETIONARY PROCESS

113 00:35:51:23 00:35:53:06 REMAIN UNCLEAR.

114 00:35:53:08 00:35:55:05 ULTIMATELY,  
THE GASES THEMSELVES

115 00:35:55:07 00:35:57:20 PARTIALLY CRYSTALLIZE  
AND CONDENSE

116 00:35:57:22 00:36:00:20 TO FORM BALLS  
OF ICE.

117 00:36:00:22 00:36:04:06 THE CLOUD OF MATERIAL  
FROM WHICH THE PLANETS FORM

118 00:36:04:08 00:36:06:21 STARTED OUT  
AS BEING MOSTLY GAS

119 00:36:06:23 00:36:09:06 WITH A SMALL AMOUNT  
OF DUST.

120 00:36:09:08 00:36:11:21 THAT DUST  
WAS VERY FINE INDEED,

121 00:36:11:23 00:36:14:20 BUT THE PARTICLES  
COLLIDED WITH  
EACH OTHER,

122 00:36:14:22 00:36:16:20 AND DURING  
THOSE COLLISIONS,

123 00:36:16:22 00:36:19:04 THEY STUCK  
WITH EACH OTHER

124 00:36:19:06 00:36:21:19 SO THAT MATERIAL  
STARTED TO COAGULATE

125 00:36:21:21 00:36:23:06 INTO

126 00:36:23:08 STILL BIGGER BODIES,  
 00:36:27:20 SO YOU HAVE TO IMAGINE  
 THAT WE WENT FROM  
 127 00:36:27:22 DUST PARTICLES  
 00:36:31:20 ALL THE WAY UP  
 TO OBJECTS THAT WERE  
 128 00:36:31:22 KILOMETERS ACROSS.  
 00:36:34:19 THOSE OBJECTS  
 WERE COLLIDING  
 WITH EACH OTHER,  
 129 00:36:34:21 00:36:36:04 MAKING  
 STILL BIGGER BODIES,  
 130 00:36:36:06 00:36:39:05 SO THAT WE THINK  
 OF THE FORMATION  
 131 00:36:39:07 00:36:41:19 OF SOLID PLANETS  
 LIKE THE EARTH  
 132 00:36:41:21 00:36:43:19 AS BEING A HIERARCHICAL  
 PROCESS--  
 133 00:36:43:21 00:36:45:19 A PROCESS  
 THAT STARTS OFF  
 134 00:36:45:21 00:36:48:04 WITH VERY SMALL THINGS  
 VERY LARGE IN NUMBER,  
 135 00:36:48:06 00:36:51:03 TOWARDS  
 INTERMEDIATE-SIZE  
 THINGS SMALLER IN NUMBER,  
 136 00:36:51:05 00:36:52:18 AND EVENTUALLY  
 ENDING UP  
 137 00:36:52:20 00:36:55:17 WITH A VERY SMALL NUMBER  
 OF LARGE OBJECTS.  
 138 00:36:55:19 00:36:58:19 AS AN INTERMEDIATE STAGE  
 IN THIS PROCESS,  
 139 00:36:58:21 00:37:02:19 WE COULD IMAGINE  
 THAT THE REGION  
 WHERE THE EARTH FORMED  
 140 00:37:02:21 00:37:04:03 CONTAINED  
 HUNDREDS OF OBJECTS  
 141 00:37:04:05 00:37:07:18 THAT WERE ABOUT THE SIZE  
 OF THE EARTH'S MOON.  
 142 00:37:07:20 00:37:10:03 MOST OF THOSE OBJECTS  
 THEN COALESCED  
 143 00:37:10:05 00:37:13:05 TO MAKE  
 A SINGLE PLANET--  
 THE EARTH.  
 144 00:37:14:20 00:37:17:12 *THE MOST ANCIENT LANDSCAPES  
 IN OUR SOLAR SYSTEM*  
 145 00:37:17:14 00:37:19:03 *STILL BEAR THE SCARS*  
 146 00:37:19:05 00:37:21:03 *CAUSED BY*  
*THE VIOLENT IMPACT*  
 147 00:37:21:05 00:37:23:17 *OF THESE OBJECTS*  
*AS THEY WERE SWEEPED UP*  
 148 00:37:23:19 00:37:25:01 *BY THE ORBITING PLANETS.*  
 149 00:37:26:19 00:37:29:17 *INDEED, IMPACT CRATERS*  
*ARE A DOMINANT FEATURE*  
 150 00:37:29:19 00:37:32:03 *ON THE SURFACE*  
*OF MOST BODIES*  
 151 00:37:32:05 00:37:33:20 *IN THE SOLAR SYSTEM.*

152 00:37:35:20 00:37:38:03 WHEN METEORITES  
 SLAM INTO OUR PLANET,  
 153 00:37:38:05 00:37:41:16 THEY TRAVEL AT SPEEDS  
 BETWEEN 11 AND 70 KILOMETERS  
 154 00:37:41:18 00:37:42:15 PER SECOND.  
 155 00:37:42:17 00:37:44:00 VIRTUALLY IN AN INSTANT,  
 156 00:37:44:02 00:37:46:16 THE UNDERLYING CRUST  
 CAN BE SHATTERED  
 157 00:37:46:18 00:37:49:00 TO A DEPTH  
 OF SEVERAL KILOMETERS  
 158 00:37:49:02 00:37:53:01 AND HEATED TO TEMPERATURES  
 AS HIGH AS 15,000 DEGREES.  
 159 00:37:55:18 00:37:59:16 THE RESULTING MATERIAL  
 IS A MIX OF PULVERIZED DEBRIS  
 160 00:37:59:18 00:38:02:02 AND BLACK MELTED  
 ROCK FRAGMENTS.  
 161 00:38:05:19 00:38:08:17 THIS CANADIAN CRATER  
 SEEN FROM SPACE  
 162 00:38:08:19 00:38:10:17 IS OVER  
 60 KILOMETERS ACROSS.  
 163 00:38:10:19 00:38:14:01 LAKES FILL THE TROUGHS  
 NEAR ITS RIM.  
 164 00:38:16:18 00:38:19:17 BUT UNLIKE THE REST  
 OF THE PLANETS,  
 165 00:38:19:19 00:38:21:02 EROSION AND SEDIMENTATION  
 166 00:38:21:04 00:38:24:02 HAVE REMOVED THE CRATERS  
 OF MOST IMPACT SITES  
 167 00:38:24:04 00:38:25:05 ON EARTH.  
 168 00:38:28:03 00:38:29:16 OTHER IMPORTANT  
 DIFFERENCES EXIST  
 169 00:38:29:18 00:38:32:01 BETWEEN THE PLANETS  
 AS WELL,  
 170 00:38:32:03 00:38:34:01 AND THESE ALSO  
 PROVIDE CLUES  
 171 00:38:34:03 00:38:37:00 ABOUT THE FORMATION  
 OF THE SOLAR SYSTEM.  
 172 00:38:38:19 00:38:41:16 THE NINE PLANETS  
 DIFFER GREATLY IN APPEARANCE.  
 173 00:38:43:11 00:38:46:29 FROM GAS GIANTS  
 LIKE JUPITER...  
 174 00:38:47:01 00:38:48:12 AND SATURN...  
 175 00:38:49:28 00:38:52:14 TO THE MUCH SMALLER  
 TERRESTRIAL OR ROCK PLANETS  
 176 00:38:52:16 00:38:56:00 SUCH AS VENUS AND MARS.  
 177 00:38:56:02 00:38:59:00 THE NEBULAR HYPOTHESIS  
 PROVIDES AN EXPLANATION  
 178 00:38:59:02 00:39:00:16 FOR THIS DIVERSITY.  
 179 00:39:02:17 00:39:07:09 THE PLANETS HAVE A VARIETY  
 OF COMPOSITIONS--  
 CHEMICAL MAKEUPS,  
 180 00:39:07:11 00:39:09:24 AND WE THINK  
 THAT CAME ABOUT  
 181 00:39:09:26 00:39:12:10 BECAUSE WHEN  
 THE SOLAR SYSTEM FORMED,  
 182 00:39:12:12 00:39:14:24 THERE WAS A RANGE  
 OF TEMPERATURES

183 00:39:14:26 00:39:18:09 FROM VERY  
HIGH TEMPERATURES  
CLOSE IN TO THE SUN,

184 00:39:18:11 00:39:20:29 TO MUCH  
LOWER TEMPERATURES  
FURTHER OUT.

185 00:39:21:01 00:39:23:29 THE MAIN DIFFERENCE  
IN THE SOLAR SYSTEM

186 00:39:24:01 00:39:26:29 IS BETWEEN THE PLANETS  
WHICH ARE EARTHLIKE--

187 00:39:27:01 00:39:31:00 BY WHICH WE MEAN  
MERCURY, VENUS,  
EARTH, AND MARS,

188 00:39:31:02 00:39:33:00 AND THE MORE  
DISTANT PLANETS--

189 00:39:33:02 00:39:36:20 JUPITER, SATURN, URANUS,  
NEPTUNE, AND PLUTO.

190 00:39:36:22 00:39:38:05 THESE MORE  
DISTANT PLANETS

191 00:39:38:07 00:39:40:29 ARE RICH IN ICE  
AND GAS.

192 00:39:41:01 00:39:42:14 THE ICE IN PARTICULAR

193 00:39:42:16 00:39:46:14 IS MATERIAL  
THAT WOULD NOT  
BE ABLE TO CONDENSE

194 00:39:46:16 00:39:48:15 CLOSE IN  
TO THE SUN

195 00:39:48:17 00:39:51:14 IN THE REGION  
WHERE THE EARTH FORMED,

196 00:39:51:16 00:39:52:29 SO AT FIRST APPROXIMATION,

197 00:39:53:01 00:39:55:29 THE DOMINANT DIFFERENCE  
WITHIN OUR SOLAR SYSTEM

198 00:39:56:01 00:39:58:13 LIES BETWEEN  
THE EARTHLIKE PLANETS

199 00:39:58:15 00:40:00:13 AND THE MORE DISTANT  
PLANETS,

200 00:40:00:15 00:40:02:29 AND THIS IN TURN  
IS RELATED

201 00:40:03:01 00:40:05:15 TO THE GRADUAL DECLINE  
IN TEMPERATURE

202 00:40:05:17 00:40:08:14 AS YOU GO OUTWARD  
FROM THE SUN.

203 00:40:11:01 00:40:13:28 *IN ADDITION*  
*TO THE NINE FAMILIAR PLANETS,*

204 00:40:14:00 00:40:15:14 *BETWEEN MARS AND JUPITER*

205 00:40:15:16 00:40:18:13 *THERE LIES A BELT*  
*OF DRIFTING RUBBLE--*

206 00:40:18:15 00:40:19:21 *THE ASTEROIDS.*

207 00:40:22:15 00:40:24:28 *FRAGMENTS OF ROCK*  
*ARE SET FREE*

208 00:40:25:00 00:40:27:11 *BY COLLISIONS*  
*AMONG THESE ASTEROIDS.*

209 00:40:30:05 00:40:33:00 *THIS IS THE SOURCE*  
*OF MOST OF THE METEORITES*

210 00:40:33:02 00:40:35:05 *WHICH STRIKE EARTH*  
*IN PRESENT GEOLOGICAL TIME.*

211 00:40:39:02 00:40:41:12 *THESE ROCKS  
FROM THE ASTEROID BELT*  
 212 00:40:41:14 00:40:44:08 *ARE OVER 4 1/2 BILLION  
YEARS OLD.*  
 213 00:40:45:21 00:40:48:12 *THEY'RE TYPICALLY RICH  
IN SILICA, ALUMINA,  
 214 00:40:48:14 00:40:50:14 *IRON, AND NICKEL.*  
 215 00:40:51:26 00:40:55:05 *SUCH ELEMENTS ARE COMMON  
INSIDE THE EARTH.*  
 216 00:40:56:16 00:40:58:28 *THE OVERALL DENSITY  
OF THE EARTH*  
 217 00:40:59:00 00:41:01:27 *IS ALSO CLOSE  
TO THE AVERAGE DENSITY*  
 218 00:41:01:29 00:41:03:12 *OF METEORITIC MATERIAL,*  
 219 00:41:03:14 00:41:05:27 *SO IT SEEMS LIKELY  
THAT METEORITES*  
 220 00:41:05:29 00:41:08:11 *REPRESENT THE SAME TYPE  
OF RAW MATERIAL*  
 221 00:41:08:13 00:41:10:26 *WHICH ACCRETED  
TO FORM THE EARTH.*  
 222 00:41:14:00 00:41:16:12 *BUT ROCKS FORMING  
THE OUTERMOST LAYER*  
 223 00:41:16:14 00:41:17:27 *OF EARTH TODAY*  
 224 00:41:17:29 00:41:19:27 *ARE MUCH DIFFERENT  
IN COMPOSITION*  
 225 00:41:19:29 00:41:21:26 *FROM THAT  
OF MANY METEORITES.*  
 226 00:41:23:29 00:41:27:13 *FOR EXAMPLE, A COMMON  
CONTINENTAL ROCK IS GRANITE,*  
 227 00:41:27:15 00:41:30:21 *WHICH IS LIGHTER IN WEIGHT  
THAN METEORITIC MATERIAL.*  
 228 00:41:32:12 00:41:34:09 *THIS SUGGESTS  
THAT THIS PLANET*  
 229 00:41:34:11 00:41:37:10 *MUST HAVE ORIGINALLY HAD  
A VERY DIFFERENT STRUCTURE*  
 230 00:41:37:12 00:41:38:24 *THAN IT DOES TODAY.*  
 231 00:41:40:28 00:41:42:15 *SCIENTISTS BELIEVE  
THAT INITIALLY*  
 232 00:41:42:17 00:41:45:26 *IT WAS A HOMOGENEOUS BLOB  
OF SILICON COMPOUNDS,*  
 233 00:41:45:28 00:41:48:25 *IRON, MAGNESIUM OXIDES,  
AND LESSER AMOUNTS*  
 234 00:41:48:27 00:41:52:08 *OF ALL THE OTHER  
NATURAL CHEMICAL ELEMENTS.*  
 235 00:41:55:12 00:41:57:10 *UNDERSTANDING  
HOW EARTH WAS TRANSFORMED*  
 236 00:41:57:12 00:41:58:25 *FROM A HOMOGENEOUS MASS*  
 237 00:41:58:27 00:42:01:24 *TO A PLANET WITH DISTINCT  
INTERNAL LAYERS*  
 238 00:42:01:26 00:42:04:11 *IS FUNDAMENTAL  
TO UNDERSTANDING  
EARTH HISTORY.*  
 239 00:42:04:13 00:42:06:25 *THIS PROCESS,  
KNOWN AS DIFFERENTIATION,*  
 240 00:42:06:27 00:42:08:25 *IS RESPONSIBLE  
FOR DRAMATIC CHANGES**



241 00:42:08:27 00:42:10:10 IN EARTH'S PHYSICAL  
 IDENTITY  
 242 00:42:10:12 00:42:12:24 SINCE THE FORMATION  
 OF OUR PLANET  
 243 00:42:12:26 00:42:14:25 SOME 4.6 BILLION  
 YEARS AGO.  
 244 00:42:14:27 00:42:17:10 THESE CHANGES INCLUDE  
 VOLCANIC ACTIVITY,  
 245 00:42:17:12 00:42:19:05 THE FORMATION  
 OF CONTINENTS,  
 246 00:42:19:07 00:42:20:26 THE OCEAN  
 AND ATMOSPHERE,  
 247 00:42:20:28 00:42:23:27 AND EVEN INITIATION  
 OF THE EARTH'S  
 MAGNETIC FIELD.  
 248 00:42:23:29 00:42:26:26 THE EVEN WHICH TRIGGERED  
 THE DIFFERENTIATION  
 PROCESS  
 249 00:42:26:28 00:42:29:28 WAS A DRAMATIC HEATING  
 OF THE EARTH  
 250 00:42:30:00 00:42:31:13 EARLY IN ITS HISTORY.  
 251 00:42:31:15 00:42:33:26 SEVERAL FACTORS  
 MAY HAVE CONTRIBUTED  
 TO THIS HEATING.  
 252 00:42:33:28 00:42:36:26 THE MOST IMPORTANT  
 WAS THE PRESENCE  
 OF RADIOACTIVE ELEMENTS  
 253 00:42:36:28 00:42:38:10 IN THE ROCKS  
 OF PRIMITIVE EARTH.  
 254 00:42:38:12 00:42:39:26 AS THESE ELEMENTS DECAYED,  
 255 00:42:39:28 00:42:42:24 THEIR ATOMS EMITTED  
 VAST QUANTITIES  
 OF ENERGY,  
 256 00:42:42:26 00:42:45:08 WHICH WAS RAPIDLY  
 CONVERTED TO HEAT.  
 257 00:42:45:10 00:42:48:08 AS THE TEMPERATURE  
 OF THE EARTH ROSE,  
 258 00:42:48:10 00:42:51:08 THE ROCKS BEGAN TO SOFTEN  
 AND PARTIALLY MELT.  
 259 00:42:51:10 00:42:54:24 WHILE IT'S UNLIKELY  
 THAT THE EARTH  
 BECAME ENTIRELY MOLTEN,  
 260 00:42:54:26 00:42:58:09 THE HEATING AND MELTING  
 ALLOWED THE ROCKS TO FLOW  
 261 00:42:58:11 00:43:01:08 AND CHANGE POSITION  
 OR DIFFERENTIATE  
 ACCORDING TO DENSITY.  
 262 00:43:01:10 00:43:04:07 THE LIGHTEST MATERIAL  
 FLOATED TO THE SURFACE,  
 263 00:43:04:09 00:43:06:23 FORMING A SCUM  
 OR CRUST ON THE EARTH.  
 264 00:43:06:25 00:43:08:23 DENSER ROCK AND MAGMA  
 SANK,  
 265 00:43:08:25 00:43:09:27 CONCENTRATING  
 THE HEAVIEST MATERIAL  
 266 00:43:09:29 00:43:11:12 IN THE EARTH'S CORE.

267 00:43:13:26 00:43:15:09 *THE YOUNG EARTH*  
 268 00:43:15:11 00:43:18:08 *WAS AN IRREGULARLY SHAPED*  
*BALL OF ROCK*  
 269 00:43:18:10 00:43:19:28 *ADRIFT IN SPACE.*  
 270 00:43:20:00 00:43:23:07 *AS METEORITES WERE PULLED*  
*INTO THE PLANET BY GRAVITY,*  
 271 00:43:23:09 00:43:24:22 *IT GREW LARGER*  
 272 00:43:24:24 00:43:27:09 *AND GRADUALLY ACQUIRED*  
*A SPHERICAL SHAPE.*  
 273 00:43:27:11 00:43:28:24 *AT THE SAME TIME,*  
 274 00:43:28:26 00:43:31:23 *A LAYERED STRUCTURE*  
*BEGAN TO EVOLVE.*  
 275 00:43:33:10 00:43:36:08 *NO ONE KNOWS*  
*HOW LONG IT TOOK*  
 276 00:43:36:10 00:43:39:23 *FOR EARTH TO DIFFERENTIATE*  
*INTO ITS PRESENT STRUCTURE.*  
 277 00:43:39:25 00:43:42:21 *SOME OF THE OLDEST KNOWN*  
*TERRESTRIAL ROCKS*  
 278 00:43:42:23 00:43:44:21 *RESEMBLE ROCK TYPES*  
*FORMING TODAY,*  
 279 00:43:44:23 00:43:46:05 *SUGGESTING*  
*THAT EARTH'S LAYERING*  
 280 00:43:46:07 00:43:47:20 *HAD BEGUN TO DEVELOP*  
 281 00:43:47:22 00:43:50:21 *WITHIN THE FIRST*  
*HALF BILLION YEARS*  
 282 00:43:50:23 00:43:52:14 *OF THE PLANET'S HISTORY.*  
 283 00:43:54:23 00:43:58:20 *GEOPHYSICISTS HAVE DEVELOPED*  
*A REMARKABLY CLEAR PICTURE*  
 284 00:43:58:22 00:44:00:11 *OF EARTH'S INTERIOR.*  
 285 00:44:02:07 00:44:04:22 *AT THE VERY CENTER*  
*OF THE EARTH*  
 286 00:44:04:24 00:44:06:22 *WE HAVE A SOLID*  
*INNER CORE*  
 287 00:44:06:24 00:44:09:21 *WHICH IS FROZEN IRON,*  
*ABOUT THE SIZE*  
*OF THE MOON.*  
 288 00:44:09:23 00:44:12:05 *IT'S A CRYSTALLINE BALL*  
*FLOATING AT THE CENTER*  
*OF EARTH.*  
 289 00:44:12:07 00:44:15:05 *OUTSIDE OF THAT*  
*IS THE MOLTEN OUTER CORE.*  
 290 00:44:15:07 00:44:18:05 *THIS IS LIQUID IRON--*  
*VERY LOW VISCOSITY.*  
 291 00:44:18:07 00:44:20:22 *THE INNER CORE*  
*IS FLOATING INSIDE*  
 292 00:44:20:24 00:44:22:07 *THIS MOLTEN*  
*IRON BALL.*  
 293 00:44:22:09 00:44:25:21 *AS WE GET TO HALF*  
*THE RADIUS OF THE EARTH,*  
 294 00:44:25:23 00:44:27:20 *WE ENTER*  
*THE SOLID MANTLE.*  
 295 00:44:27:22 00:44:29:21 *THIS IS A SILICATE ROCK.*  
 296 00:44:29:23 00:44:33:23 *MOST OF THE EARTH--*  
*ABOUT 70% OF THE EARTH*  
*IS THE MANTLE.*  
 297 00:44:33:25 00:44:36:23 *THIS IS INACCESSIBLE*

298 00:44:36:25 00:44:39:07 EXCEPT BY SEISMIC WAVES.  
 OCCASIONALLY, A PIECE  
 OF THE MANTLE  
 299 00:44:39:09 00:44:42:06 GETS SHOVED UP  
 ON TOP OF THE CRUST.  
 300 00:44:42:08 00:44:44:04 EVERYBODY'S FAMILIAR  
 WITH THE CRUST.  
 301 00:44:44:06 00:44:45:19 THAT'S WHAT  
 WE LIVE ON.  
 302 00:44:45:21 00:44:48:04 THAT'S WHERE WE  
 GET OUR RESOURCES,  
 303 00:44:48:06 00:44:52:15 BUT IT'S ONLY  
 A VERY THIN SCUM  
 ON TOP OF THE MANTLE.  
 304 00:44:52:17 00:44:55:09 EVEN TODAY,  
 MORE THAN 4.5 BILLION YEARS  
 305 00:44:55:11 00:44:57:20 AFTER THE FORMATION  
 OF THE EARTH,  
 306 00:44:57:22 00:45:00:13 THERE ARE TWO LAYERS  
 OF THE PLANET  
 307 00:45:00:15 00:45:02:26 THAT REMAIN MOLTEN  
 OR PARTIALLY MOLTEN.  
 308 00:45:05:06 00:45:07:15 THE UPPERMOST MANTLE  
 BENEATH THE CRUST  
 309 00:45:07:17 00:45:09:00 HAS NOW SOLIDIFIED,  
 310 00:45:09:02 00:45:11:00 BUT A ZONE BENEATH IT  
 311 00:45:11:02 00:45:12:14 SEVERAL HUNDRED  
 KILOMETERS THICK  
 312 00:45:12:16 00:45:14:23 APPROACHES  
 THE TEMPERATURE OF MELTING.  
 313 00:45:14:25 00:45:16:20 THIS IS WHERE THE LAVA  
 314 00:45:16:22 00:45:19:17 IN MOST OCEANIC VOLCANOES  
 COMES FROM.  
 315 00:45:21:06 00:45:24:00 THE OUTER PART  
 OF THE EARTH'S CORE  
 316 00:45:24:02 00:45:26:00 IS ALSO  
 STILL COMPLETELY MOLTEN,  
 317 00:45:26:02 00:45:28:23 BUT THE INNER CORE,  
 ALTHOUGH EVEN HOTTER,  
 318 00:45:28:25 00:45:30:29 REMAINS SOLID.  
 319 00:45:31:01 00:45:34:19 THIS IS DUE TO THE FACT  
 THAT WHEN ROCK MELTS,  
 320 00:45:34:21 00:45:35:29 IT EXPANDS.  
 321 00:45:36:01 00:45:38:19 BUT AT THE CENTER  
 OF THE EARTH,  
 322 00:45:38:21 00:45:40:24 THE PRESSURE  
 OF THE 5,000 KILOMETERS  
 323 00:45:40:26 00:45:43:02 OF OVERLYING ROCK  
 IS SO ENORMOUS  
 324 00:45:43:04 00:45:45:01 THAT NO EXPANSION  
 IS POSSIBLE,  
 325 00:45:45:03 00:45:46:18 AND AS A RESULT,  
 326 00:45:46:20 00:45:49:07 THE SUPERHEATED IRON  
 CANNOT TURN LIQUID.  
 327 00:45:51:19 00:45:55:02 THE GREAT AMOUNT OF HEAT  
 STILL PRESENT IN THE EARTH

328 00:45:55:04 00:45:58:15 *IS DEMONSTRATED  
BY ACTIVE VOLCANOES.*  
 329 00:45:58:17 00:46:01:14 *THE VOLCANOES OF TODAY  
ARE AN AWESOME SPECTACLE.*  
 330 00:46:03:14 00:46:05:27 *BUT MORE FEVERISH  
CONVULSIONS*  
 331 00:46:05:29 00:46:09:03 *AFFECTED THIS PLANET  
WHEN THE EARTH WAS YOUNG.*  
 332 00:46:09:05 00:46:10:20 *IN THE PRESENT EARTH,*  
 333 00:46:10:22 00:46:15:07 *THE AMOUNT OF LIQUID ROCK  
IS REALLY QUITE SMALL  
AT ANY TIME,*  
 334 00:46:15:09 00:46:17:07 *BUT IN THE EARLY EARTH,*  
 335 00:46:17:09 00:46:20:18 *A BIG FRACTION  
OF THE VOLUME  
WOULD HAVE BEEN MOLTEN,*  
 336 00:46:20:20 00:46:23:18 *SO WE IMAGINE THAT  
THE VERY EARLIEST EARTH*  
 337 00:46:23:20 00:46:26:27 *HAD AN EXTREMELY HIGH LEVEL  
OF VOLCANIC ACTIVITY.*  
 338 00:46:26:29 00:46:29:09 *WHEN THIS VOLCANIC  
ACTIVITY TAKES PLACE,*  
 339 00:46:29:11 00:46:33:02 *GASES WHICH ARE DISSOLVED  
WITHIN THE LIQUID ROCK*  
 340 00:46:33:04 00:46:35:04 *ARE EXPELLED,*  
 341 00:46:35:06 00:46:37:03 *PUT INTO  
THE EARTH'S ATMOSPHERE.*  
 342 00:46:37:05 00:46:41:01 *IN THIS WAY WE IMAGINE  
THE EARLY ATMOSPHERE  
OF THE EARTH*  
 343 00:46:41:03 00:46:43:16 *WAS BUILT UP  
BY VOLCANIC ACTIVITY.*  
 344 00:46:43:18 00:46:45:10 *OUR EARLY ATMOSPHERE  
WAS SOMETHING*  
 345 00:46:45:12 00:46:48:06 *YOU AND I WOULD NOT  
WANT TO BREATHE.*  
 346 00:46:48:08 00:46:51:00 *WE WOULDN'T, EVEN TODAY,  
WANT TO BREATHE  
THE AIR--*  
 347 00:46:51:02 00:46:52:29 *THE GASES  
COMING FROM VOLCANOES.*  
 348 00:46:53:01 00:46:55:11 *IT'S RICH IN SULFUR,  
CARBON MONOXIDE,*  
 349 00:46:55:13 00:46:56:24 *CARBON DIOXIDE.*  
 350 00:46:56:26 00:46:59:01 *THE SAME THINGS EMITTED  
FROM CARS' EXHAUST PIPES*  
 351 00:46:59:03 00:47:01:00 *ARE COMING  
OUT OF VOLCANOES.*  
 352 00:47:01:02 00:47:03:15 *THEY DID THEN.  
THEY DO TODAY.*  
 353 00:47:03:17 00:47:06:15 *IT'S A VERY ACIDIC  
AND TOXIC GAS,*  
 354 00:47:06:17 00:47:09:17 *SO OUR EARLY ATMOSPHERE  
WAS PRETTY HAZARDOUS.*  
 355 00:47:11:03 00:47:12:16 *VOLCANIC ACTIVITY  
ALSO RELEASED*

356 00:47:12:18 00:47:15:17 VAST AMOUNTS  
 OF WATER VAPOR.  
 357 00:47:15:19 00:47:17:04 MANY GEOLOGISTS ARGUE  
 358 00:47:17:06 00:47:20:15 THAT THIS CONDENSED  
 TO FORM THE WORLD'S OCEANS.  
 359 00:47:20:17 00:47:22:09 RECENT WORK, HOWEVER,  
 360 00:47:22:11 00:47:24:26 SUGGESTS THAT FACTORS  
 OTHER THAN VOLCANISM  
 361 00:47:24:28 00:47:28:16 MAY ALSO HAVE  
 PLAYED A ROLE.  
 362 00:47:28:18 00:47:31:05 ANOTHER VERY INTERESTING  
 POSSIBILITY  
 363 00:47:31:07 00:47:34:13 IS THAT THE WATER  
 CAME IN COMETS,  
 364 00:47:34:15 00:47:39:13 IN BODIES THAT FORMED  
 IN THE FAR REACHES  
 OF THE SOLAR SYSTEM  
 365 00:47:39:15 00:47:42:11 AND WERE SCATTERED  
 INTO EARTH-CROSSING ORBITS.  
 366 00:47:42:13 00:47:46:12 WE NOW SEE, OF COURSE,  
 COMETS THAT CROSS  
 THE EARTH'S ORBIT,  
 367 00:47:46:14 00:47:47:27 LIKE HALLEY'S COMET,  
 368 00:47:47:29 00:47:49:11 AND VERY RARELY,  
 369 00:47:49:13 00:47:51:28 OBJECTS LIKE THIS  
 EVEN HIT THE PRESENT EARTH.  
 370 00:47:52:00 00:47:54:28 BUT IN THE EARLY HISTORY  
 OF THE SOLAR SYSTEM,  
 371 00:47:55:00 00:47:57:13 THESE COLLISIONS WOULD HAVE  
 BEEN MORE FREQUENT.  
 372 00:47:57:15 00:48:00:03 THE AMOUNT OF WATER  
 ON THE EARTH--  
 373 00:48:00:05 00:48:02:29 ALTHOUGH WE MIGHT  
 THINK OF IT AS LARGE--  
 374 00:48:03:01 00:48:04:14 IS ACTUALLY QUITE SMALL  
 375 00:48:04:16 00:48:07:03 COMPARED TO  
 THE TOTAL MASS  
 OF THE EARTH,  
 376 00:48:07:05 00:48:10:07 SO YOU DON'T NEED  
 A LARGE NUMBER OF COMETS  
 377 00:48:10:09 00:48:13:05 TO EXPLAIN ALL THE WATER  
 WE SEE IN THE OCEANS.  
 378 00:48:14:20 00:48:16:12 EARTH'S DISTANCE  
 FROM THE SUN  
 379 00:48:16:14 00:48:18:23 AND THE PRESENCE  
 OF AN ATMOSPHERE  
 380 00:48:18:25 00:48:20:23 WHICH KEPT  
 SURFACE TEMPERATURES WARM,  
 381 00:48:20:25 00:48:23:14 ALLOWED WATER TO COLLECT  
 IN A LIQUID STATE,  
 382 00:48:23:16 00:48:26:24 SUBMERGING THE YOUNG PLANET'S  
 RAW BASALTIC LOWLANDS.  
 383 00:48:30:29 00:48:33:28 NO OTHER PLANET COMBINES  
 ALL THE FACTORS REQUIRED  
 384 00:48:34:00 00:48:36:27 FOR THE EXISTENCE  
 OF A WATERY OCEAN.

385 00:48:39:00 00:48:40:27 AN OCEAN  
 MAY ALSO EXPLAIN  
 386 00:48:40:29 00:48:43:06 THE PRESENCE  
 OF LIFE ON EARTH,  
 387 00:48:43:08 00:48:46:00 FOR LIQUID WATER  
 IS AN ESSENTIAL INGREDIENT  
 388 00:48:46:02 00:48:47:19 OF BIOLOGICAL REACTIONS.  
 389 00:48:50:04 00:48:52:10 THE OCEANS  
 PLAYED A FURTHER ROLE  
 390 00:48:52:12 00:48:53:26 IN NURTURING LIFE,  
 HOWEVER,  
 391 00:48:53:28 00:48:55:12 FOR EARTH'S  
 EARLY ATMOSPHERE  
 392 00:48:55:14 00:48:58:12 WAS PROBABLY FULL  
 OF DEADLY SOLAR RADIATION.  
 393 00:48:58:14 00:49:00:27 WATER WOULD'VE SCREENED OUT  
 SUCH RADIATION,  
 394 00:49:00:29 00:49:02:26 ENABLING  
 THE FRAGILE PROCESS  
 395 00:49:02:28 00:49:05:10 OF LIFE'S ORIGIN  
 AND EARLY DEVELOPMENT  
 396 00:49:05:12 00:49:06:25 TO TAKE PLACE.  
 397 00:49:09:24 00:49:11:27 THE MOST SIGNIFICANT  
 DIFFERENCE BETWEEN EARTH  
 398 00:49:11:29 00:49:13:12 AND THE OTHER PLANETS  
 399 00:49:13:14 00:49:15:21 IS THAT  
 EARTH HAS THE CONDITIONS  
 400 00:49:15:23 00:49:18:12 TO SUPPORT LIFE  
 AS WE KNOW IT.  
 401 00:49:18:14 00:49:20:19 THE ABUNDANCE  
 OF WATER ON EARTH  
 402 00:49:20:21 00:49:22:11 WAS CRITICAL  
 TO LIFE'S ORIGIN.  
 403 00:49:22:13 00:49:23:26 WATER ALSO  
 HELPED MODERATE  
 404 00:49:23:28 00:49:26:01 THE TEMPERATURE  
 OF THE PLANET'S SURFACE  
 405 00:49:26:03 00:49:28:22 TO A RANGE WHICH  
 ENABLED LIFE TO EVOLVE.  
 406 00:49:28:24 00:49:31:12 OXYGEN GAS WASN'T PART OF  
 THIS PRIMITIVE ATMOSPHERE.  
 407 00:49:31:14 00:49:34:02 NOT UNTIL THE DEVELOPMENT  
 OF PRIMITIVE ALGAE,  
 408 00:49:34:04 00:49:35:26 ABOUT 1.8 BILLION  
 YEARS AGO,  
 409 00:49:35:28 00:49:38:10 THAT FREE OXYGEN  
 BECAME AN IMPORTANT PART  
 410 00:49:38:12 00:49:39:29 OF EARTH'S ATMOSPHERE.  
 411 00:49:40:01 00:49:43:25 THIS ALLOWED THE DEVELOPMENT  
 OF MORE COMPLEX LIFE FORMS.  
 412 00:49:43:27 00:49:46:12 PRIMITIVE  
 BLUE-GREEN ALGAE,  
 413 00:49:46:14 00:49:47:28 OR CYANOBACTERIA,  
 414 00:49:48:00 00:49:51:11 SURVIVE BY TAKING ONE  
 OF THE MOST ABUNDANT GASES  
 415 00:49:51:13 00:49:52:25 RELEASED BY VOLCANOES--

416 00:49:52:27 00:49:54:16 CARBON DIOXIDE--  
 417 00:49:54:18 00:49:56:09 AND COMBINING IT  
 WITH WATER  
 418 00:49:56:11 00:49:57:24 IN THE PRESENCE  
 OF SUNLIGHT.  
 419 00:49:57:26 00:50:00:23 THE RESULT IS CARBOHYDRATES  
 USED FOR FOOD  
 420 00:50:00:25 00:50:02:22 AND AN IMPORTANT  
 WASTE PRODUCT  
 421 00:50:02:24 00:50:04:19 CALLED OXYGEN.  
 422 00:50:07:06 00:50:08:18 SO, THROUGH TIME,  
 423 00:50:08:20 00:50:11:04 EARLY LIFE FORMS  
 HELPED TO CHANGE  
 424 00:50:11:06 00:50:13:21 THE CARBON-DIOXIDE-RICH  
 ATMOSPHERE  
 425 00:50:13:23 00:50:16:21 TO ONE RICH IN OXYGEN...  
 426 00:50:16:23 00:50:20:03 THUS PERMITTING THE EVOLUTION  
 OF MODERN LIFE.  
 427 00:50:21:29 00:50:24:11 IN ADDITION  
 TO BIOLOGICAL ACTIVITY,  
 428 00:50:24:13 00:50:26:25 ANOTHER MAJOR DIFFERENCE  
 BETWEEN OUR PLANET  
 429 00:50:26:27 00:50:28:26 AND MOST OTHER  
 TERRESTRIAL BODIES  
 430 00:50:28:28 00:50:30:11 IN THE SOLAR SYSTEM  
 431 00:50:30:13 00:50:32:27 IS THAT THE EARTH  
 STILL EXPERIENCES  
 432 00:50:32:29 00:50:36:11 A GREAT DEAL  
 OF RADIOACTIVE DECAY.  
 433 00:50:36:13 00:50:39:02 MERCURY, MARS,  
 AND THE MOON  
 434 00:50:39:04 00:50:40:25 ARE ESSENTIALLY  
 DEAD WORLDS,  
 435 00:50:40:27 00:50:43:26 TOO COLD INSIDE  
 TO CREATE NEW VOLCANOES  
 436 00:50:43:28 00:50:46:00 OR GREAT CRUSTAL MOVEMENT.  
 437 00:50:46:02 00:50:48:18 IT'S LARGELY DUE  
 TO INTERNAL RADIOACTIVITY  
 438 00:50:48:20 00:50:50:05 THAT THE EARTH  
 439 00:50:50:07 00:50:52:25 IS A GEOLOGICALLY  
 ACTIVE PLANET.  
 440 00:50:52:27 00:50:54:25 OUR EARTH IS ALIVE.  
 441 00:50:54:27 00:50:57:03 I JUST DON'T MEAN  
 BIOLOGICALLY ALIVE.  
 442 00:50:57:05 00:50:59:04 IT'S PHYSICALLY ALIVE.  
 443 00:50:59:06 00:51:01:19 IT HAS AN INTERNAL  
 HEAT ENGINE  
 444 00:51:01:21 00:51:03:15 THAT IS FUELED  
 BY RADIOACTIVITY.  
 445 00:51:03:17 00:51:06:09 WITHOUT THAT, THERE  
 WOULD BE NO VOLCANOES.  
 446 00:51:06:11 00:51:07:14 WITHOUT THAT,  
 447 00:51:07:16 00:51:09:10 THERE WOULD BE  
 NO EARTHQUAKES.  
 448 00:51:09:12 00:51:10:18 WITHOUT THAT,  
 449 00:51:10:20 00:51:13:04 THERE WOULD BE NO OCEAN,

450 00:51:13:06 NO ATMOSPHERE,  
 00:51:15:22 NO RUNNING WATER,  
 NO BIOLOGIC LIFE.  
 451 00:51:15:24 00:51:18:07 THE EARTH  
 IS VERY HOT INSIDE  
 452 00:51:18:09 00:51:20:04 AND COOL  
 ON THE OUTSIDE.  
 453 00:51:20:06 00:51:22:29 THIS MEANS THERE IS A LARGE  
 TEMPERATURE DIFFERENCE.  
 454 00:51:23:01 00:51:25:29 WHEN YOU HAVE A TEMPERATURE  
 DIFFERENCE LIKE THIS,  
 455 00:51:26:01 00:51:28:09 YOU CAN DRIVE  
 A HEAT ENGINE.  
 456 00:51:28:11 00:51:31:24 THIS ENGINE IS NOT  
 TOO MUCH DIFFERENT  
 CONCEPTUALLY  
 457 00:51:31:26 00:51:33:24 FROM AN INTERNAL  
 COMBUSTION ENGINE  
 458 00:51:33:26 00:51:35:09 OR ANY OTHER ENGINE  
 459 00:51:35:11 00:51:38:24 THAT OPERATES  
 WITH TWO DIFFERENT  
 TEMPERATURE RESERVOIRS.  
 460 00:51:38:26 00:51:41:07 IN THE CASE  
 OF THE EARTH,  
 461 00:51:41:09 00:51:43:27 WHAT HAPPENS IS THAT  
 THAT TEMPERATURE DIFFERENCE  
 462 00:51:43:29 00:51:46:22 IS SUFFICIENTLY LARGE  
 TO DRIVE CONVECTION--  
 463 00:51:46:24 00:51:49:27 AN OVERTURNING  
 OF THE FLUID  
 WITHIN THE EARTH  
 464 00:51:49:29 00:51:51:28 RATHER SIMILAR  
 TO WHAT HAPPENS  
 465 00:51:52:00 00:51:55:13 WHEN YOU HEAT A BOWL--  
 A POT OF SOUP--  
 466 00:51:55:15 00:51:57:12 HEAT IT FROM THE BOTTOM  
 467 00:51:57:14 00:52:00:27 AND PRODUCE  
 CONVECTION CURRENTS  
 WITHIN THAT FLUID.  
 468 00:52:00:29 00:52:02:12 A SIMILAR  
 CYCLING MOTION  
 469 00:52:02:14 00:52:04:27 SEEMS TO OCCUR  
 WITHIN THE EARTH,  
 470 00:52:04:29 00:52:07:13 BUT AT  
 A FAR SLOWER PACE--  
 471 00:52:07:15 00:52:12:03 OVER TENS OR EVEN HUNDREDS  
 OF MILLIONS OF YEARS.  
 472 00:52:12:05 00:52:14:12 LOCAL CONCENTRATIONS  
 OF THE EARTH'S HEAT  
 473 00:52:14:14 00:52:17:06 CAUSE SOME PARTS  
 OF THE MANTLE TO EXPAND,  
 474 00:52:17:08 00:52:18:23 BECOME LESS DENSE,  
 475 00:52:18:25 00:52:20:08 AND FLOAT UPWARDS  
 476 00:52:20:10 00:52:23:22 AS FAR AS THE EARTH'S  
 OUTER SKIN WILL ALLOW.  
 477 00:52:24:29 00:52:27:07 THE WARMER ROCK



478 00:52:27:09 00:52:29:07 *THEN SPREADS OUT AND GRADUALLY  
RADIATES ITS HEAT*  
 479 00:52:29:09 00:52:30:21 *THROUGH  
THE OVERLYING BLANKET*  
 480 00:52:30:23 00:52:32:11 *OF MORE BRITTLE CRUST.*  
 481 00:52:34:08 00:52:35:23 *AS IT COOLS,*  
 482 00:52:35:25 00:52:37:08 *THE ROCK CONTRACTS,*  
 483 00:52:37:10 00:52:39:07 *ONCE AGAIN  
BECOMING DENSE ENOUGH*  
 484 00:52:39:09 00:52:43:05 *FOR GRAVITY TO PULL IT  
BACK DOWN INTO THE MANTLE.*  
 485 00:52:45:16 00:52:47:00 *THIS CONSTANT CHURNING*  
 486 00:52:47:02 00:52:48:26 *OF MATERIAL  
WITHIN THE EARTH*  
 487 00:52:48:28 00:52:51:09 *EVENTUALLY BUCKLES  
AND BREAKS THE CRUST,*  
 488 00:52:51:11 00:52:53:01 *PRODUCING EARTHQUAKES...*  
 489 00:52:55:03 00:52:58:05 *VOLCANIC ACTIVITY...*  
 490 00:52:58:07 00:53:00:27 *AND MAJESTIC  
MOUNTAIN RANGES.*  
 491 00:53:03:06 00:53:04:20 *IN ANCIENT GREECE,*  
 492 00:53:04:22 00:53:07:05 *A BUILDER  
WAS CALLED A TEKTON.*  
 493 00:53:07:07 00:53:10:06 *SCIENCE HAS COINED THE TERM  
"TECTONIC FORCES"*  
 494 00:53:10:08 00:53:12:06 *TO DESCRIBE  
THE INTERNAL PROCESSES*  
 495 00:53:12:08 00:53:13:21 *THAT MOVE MOUNTAINS*  
 496 00:53:13:23 00:53:17:02 *AND UNLEASH EARTHQUAKES  
AND VOLCANISM.*  
 497 00:53:17:04 00:53:19:16 *OUR GRADUAL UNDERSTANDING  
OF THESE PROCESSES*  
 498 00:53:19:18 00:53:23:02 *HAS LED TO THE FORMULATION  
OF WHAT IS PERHAPS*  
 499 00:53:23:04 00:53:26:00 *THE MOST PROFOUND CONCEPT  
IN GEOLOGY.*  
 500 00:53:28:07 00:53:29:21 *FROM TIME TO TIME,*  
 501 00:53:29:23 00:53:31:20 *THEORIES RESULT  
FROM SCIENTIFIC INQUIRY*  
 502 00:53:31:22 00:53:34:20 *THAT FUNDAMENTALLY ALTER  
OUR VIEW OF THE WORLD.*  
 503 00:53:34:22 00:53:36:11 *THESE SCIENTIFIC  
REVOLUTIONS*  
 504 00:53:36:13 00:53:38:16 *ARE ELEGANT  
IN THEIR SIMPLICITY*  
 505 00:53:38:18 00:53:40:04 *AND DEMONSTRATE  
NEW CONNECTIONS*  
 506 00:53:40:06 00:53:43:14 *BETWEEN PHENOMENA THAT HAD  
ONCE APPEARED UNRELATED.*  
 507 00:53:43:16 00:53:45:28 *SOME OF  
THE BETTER-KNOWN EXAMPLES*  
 508 00:53:46:00 00:53:47:13 *INCLUDE THE THEORY*  
 509 00:53:47:15 00:53:50:12 *DESCRIBING THE STRUCTURE  
OF THE ATOM IN CHEMISTRY,*  
 510 00:53:50:14 00:53:52:13 *THE THEORIES*

511 00:53:52:15 OF QUANTUM MECHANICS  
 00:53:53:28 AND RELATIVITY  
 IN PHYSICS,  
 512 00:53:54:00 00:53:57:14 AND THE DISCOVERY OF GENES  
 AND DNA IN BIOLOGY.  
 513 00:53:57:16 00:53:59:08 WITHIN  
 THE LAST FEW DECADES,  
 514 00:53:59:10 00:54:01:08 THE THEORY  
 OF PLATE TECTONICS  
 515 00:54:01:10 00:54:03:22 HAS REVOLUTIONIZED OUR  
 UNDERSTANDING OF THE EARTH.  
 516 00:54:03:24 00:54:05:08 THE THEORY TIES TOGETHER  
 517 00:54:05:10 00:54:07:18 A WIDE RANGE  
 OF GEOLOGIC PHENOMENA  
 518 00:54:07:20 00:54:09:18 AND MAKES IT  
 ABUNDANTLY CLEAR  
 519 00:54:09:20 00:54:13:02 THAT THE EARTH IS INDEED  
 A VITALLY ACTIVE PLANET.  
 520 00:54:15:04 00:54:17:17 *THE CENTRAL IDEA*  
*OF PLATE TECTONICS*  
 521 00:54:17:19 00:54:18:28 *IS SIMPLE.*  
 522 00:54:19:00 00:54:21:04 *THE EARTH'S CRUST*  
*AND UPPER MANTLE*  
 523 00:54:21:06 00:54:24:03 *ARE BROKEN INTO ABOUT*  
*A DOZEN LARGE RIGID PLATES,*  
 524 00:54:24:05 00:54:26:13 *SOMEWHAT LIKE*  
*SEGMENTS OF CRACKED SHELL*  
 525 00:54:26:15 00:54:28:12 *ON A HARD-BOILED EGG.*  
 526 00:54:31:11 00:54:33:02 *THESE GIGANTIC*  
*SLABS OF ROCK*  
 527 00:54:33:04 00:54:34:21 *SLIP AND SLIDE*  
 528 00:54:34:23 00:54:37:18 *AS THEY ARE CARRIED ABOUT*  
*BY THE CONVECTION CURRENTS*  
 529 00:54:37:20 00:54:39:18 *IN THE PARTIALLY*  
*MOLTEN LAYER*  
 530 00:54:39:20 00:54:41:01 *OF THE UPPER MANTLE.*  
 531 00:54:44:09 00:54:47:08 *A SIMILAR PATTERN*  
*OF CRUSTAL PLATE MOTION*  
 532 00:54:47:10 00:54:48:22 *IS SOMETIMES OBSERVED*  
 533 00:54:48:24 00:54:52:06 *ON THE SURFACE*  
*OF MOLTEN LAVA LAKES.*  
 534 00:54:52:08 00:54:55:06 *THE COOLED SKIN OF LAVA*  
*ACROSS THE LAKE*  
 535 00:54:55:08 00:54:57:03 *IS BROKEN INTO PLATES*  
 536 00:54:57:05 00:54:59:01 *BY THE TURBULENT LIQUID*  
*BENEATH.*  
 537 00:55:00:12 00:55:02:26 THE EARLIEST EARTH  
 WAS VIGOROUSLY CONVECTED  
 538 00:55:02:28 00:55:05:26 AS IT TRIED  
 TO GET RID OF HEAT.  
 539 00:55:05:28 00:55:08:26 THE SURFACE OF THE EARTH  
 AT THAT TIME  
 540 00:55:08:28 00:55:11:26 WOULD HAVE HAD  
 SOME STIFFNESS TO IT  
 541 00:55:11:28 00:55:13:17 BECAUSE IT WAS COLDER,  
 542 00:55:13:19 00:55:15:17 BUT AS TIME WENT ON,

543 00:55:15:19 00:55:19:15 THAT SURFACE LAYER  
BECAME THICKER  
AND STILL MORE STIFF.

544 00:55:19:17 00:55:22:14 WE SEE THIS PROCESS  
EVEN TAKING PLACE TODAY

545 00:55:22:16 00:55:24:20 IN LAVA LAKES,  
FOR EXAMPLE,

546 00:55:24:22 00:55:28:11 ON THE BIG ISLAND  
OF HAWAII.

547 00:55:28:13 00:55:31:10 THE STIFF SURFACE LAYER  
OF THE EARTH

548 00:55:31:12 00:55:32:26 BECOMES SO STIFF

549 00:55:32:28 00:55:36:01 THAT IT BREAKS UP  
INTO PLATES.

550 00:55:36:03 00:55:38:12 AND SO

551 00:55:38:14 00:55:41:13 WE EXPECT AS PART  
OF THE CONVECTION PROCESS  
OF THE EARTH,

552 00:55:41:15 00:55:46:15 THAT THE SURFACE BECOMES  
A SET OF MOBILE PLATES

553 00:55:46:17 00:55:50:00 WHICH ARE ABLE TO BE  
CONTINUALLY CREATED

554 00:55:50:02 00:55:52:15 AND RECYCLED  
WITHIN THE EARTH,

555 00:55:52:17 00:55:56:19 AND THIS PROCESS  
IS NOW KNOWN  
AS PLATE TECTONICS.

556 00:55:56:21 00:55:58:04 IN THE EARLIEST EARTH,

557 00:55:58:06 00:56:01:15 IT MUST HAVE HAD  
SOME SIMILAR BEHAVIOR--

558 00:56:01:17 00:56:03:04 PERHAPS MORE COMPLICATED,

559 00:56:03:06 00:56:05:09 PERHAPS MORE DYNAMIC,

560 00:56:05:11 00:56:07:06 PERHAPS MORE PLATES--

561 00:56:07:08 00:56:08:29 BUT THE PLATE  
TECTONIC PROCESS

562 00:56:09:01 00:56:11:19 THAT WE NOW SEE  
AS THE GUIDING PRINCIPLE

563 00:56:11:21 00:56:13:29 OF SO MUCH  
OF GEOLOGIC EVOLUTION,

564 00:56:14:01 00:56:15:14 HAD ITS BEGINNING

565 00:56:15:16 00:56:18:13 RIGHT IN THE EARLY  
HISTORY OF EARTH.

566 00:56:20:02 00:56:22:00 ALTHOUGH SCIENTISTS  
SOMETIMES DISAGREE

567 00:56:22:02 00:56:24:14 ABOUT THE DETAILS  
OF OUR PLANET'S ORIGINS,

568 00:56:24:16 00:56:26:04 THERE IS LITTLE ARGUMENT

569 00:56:26:06 00:56:28:25 THAT EARTH IS UNIQUE  
IN OUR SOLAR SYSTEM.

570 00:56:28:27 00:56:30:19 THE FANTASTIC  
DIVERSITY OF LIFE,

571 00:56:30:21 00:56:32:04 THE ABUNDANCE OF WATER,

572 00:56:32:06 00:56:34:15 AND OUR  
OXYGEN-RICH ATMOSPHERE

573 00:56:34:17 00:56:36:15 ARE ALL  
THE DIRECT RESULT

574 00:56:36:17 00:56:38:09 OF THIS PLANET'S  
 UNUSUAL HISTORY--  
 575 00:56:38:11 00:56:40:07 A HISTORY OF PHYSICAL,  
 CHEMICAL,  
 576 00:56:40:09 00:56:41:21 AND GEOLOGICAL  
 EVOLUTION,  
 577 00:56:41:23 00:56:44:18 AS WELL AS  
 THE EVOLUTION OF LIFE.  
 578 00:56:44:20 00:56:46:03 WHAT'S ESPECIALLY  
 COMPELLING  
 579 00:56:46:05 00:56:48:12 IS THAT  
 THIS PROCESS OF CHANGE  
 580 00:56:48:14 00:56:51:08 IS NOT JUST  
 PART OF EARTH'S PAST.  
 581 00:56:51:10 00:56:52:23 IT CONTINUES  
 WITHOUT INTERRUPTION.  
 582 00:56:52:25 00:56:54:08 THIS RESTLESS PLANET,  
 583 00:56:54:10 00:56:56:22 WITH ITS INTERPLAY  
 OF TECTONIC FORCES,  
 584 00:56:56:24 00:56:59:23 IS AS TURBULENT  
 AND DYNAMIC AS EVER.  
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