

1	00:29:33:28	00:29:37:10	Annenberg Media
2	00:29:37:12	00:29:41:04	§
3	00:29:41:06	00:29:44:03	ADE POSSIBLE BY
4	00:30:25:00	00:30:27:28	SOUTHERN CALIFORNIA CONSORTIUM <i>MORE THAN 300 YEARS AGO</i>
5	00:30:28:00	00:30:30:26	<i>IN IRELAND,</i> ARCHBISHOP USSHER CALCULATED THE AGE
6	00:30:30:28	00:30:33:12	<i>OF EARTH</i> BASED ON THE BOOK
7	00:30:33:14	00:30:35:11	<i>OF GENESIS.</i> HE DETERMINED
8	00:30:35:13	00:30:36:26	<i>THAT OUR PLANET</i>
9	00:30:36:28	00:30:38:26	<i>WAS CREATED 4004 YEARS</i>
10	00:30:38:28	00:30:41:12	<i>BEFORE THE BIRTH</i>
11	00:30:41:14	00:30:43:11	<i>OF CHRIST,</i> <i>ON THE 26th OF OCTOBER,</i>
12	00:30:43:13	00:30:47:15	<i>AT 9:00 IN THE MORNING.</i> <i>WIDELY PRAISED BY SCHOLARS</i>
13	00:30:47:17	00:30:50:00	<i>AND THEOLOGAINS,</i> USSHER'S CALCULATION WAS
14	00:30:50:02	00:30:52:29	<i>NOT SERIOUSLY CHALLENGED</i> <i>IN THE WESTERN WORLD</i>
15	00:30:55:07	00:30:57:08	<i>FOR ALMOST A CENTURY.</i> TODAY,
16	00:30:57:10	00:30:59:23	<i>SCIENTIFIC EVIDENCE</i> <i>INDICATES THAT EARTH</i>
17	00:30:59:25	00:31:01:07	<i>IS MUCH OLDER</i> <i>THAN BIBLICAL TEXT</i>
18	00:31:03:09	00:31:04:22	<i>SUGGESTS.</i> <i>BY COUNTING</i>
19	00:31:04:24	00:31:06:21	<i>GROWTH RINGS,</i> <i>BOTANISTS</i>
20	00:31:06:23	00:31:09:10	<i>HAVE FOUND TREES</i> <i>AS MUCH AS</i>
21	00:31:11:28	00:31:13:12	<i>8,000 YEARS OLD.</i> <i>AND WITH THE DEVELOPMENT</i>
22	00:31:13:14	00:31:14:26	<i>OF RADIOACTIVE</i> <i>AGE DATING,</i>
23	00:31:14:28	00:31:16:11	<i>GEOLOGISTS</i> <i>HAVE CONCLUDED</i>
24	00:31:16:13	00:31:18:26	<i>THAT OUR PLANET CAME</i> <i>INTO BEING</i>
25	00:31:18:28	00:31:21:27	<i>NOT THOUSANDS, BUT</i> <i>BILLIONS OF YEARS AGO.</i>
26	00:31:36:00	00:31:38:10	HUMORIST MARK TWAIN ONCE REMARKED,
27	00:31:38:12	00:31:40:12	"NOTHING HURRIES GEOLOGY."
28	00:31:40:14	00:31:42:12	HE WAS REFERRING, OF COURSE,
29	00:31:42:14	00:31:44:27	<i>TO THE ALMOST IMPERCEPTIBLE</i> <i>GEOLOGIC CHANGE</i>
30	00:31:44:29	00:31:47:27	<i>THAT ONE SEES</i> <i>IN A HUMAN LIFETIME.</i>
31	00:31:47:29	00:31:49:27	<i>NO ASPECT OF THIS SCIENCE</i>

32 00:31:49:29 00:31:52:13 IS MORE DIFFICULT  
 33 00:31:52:15 00:31:54:13 THAN THE CONCEPT  
 34 00:31:54:15 00:31:56:13 OF GEOLOGIC TIME.  
 35 00:31:56:15 00:31:58:12 OUR LIVES  
 36 00:31:58:14 00:31:59:27 ARE GOVERNED BY EVENTS  
 37 00:31:59:29 00:32:02:27 THAT ARE MEASURED  
 38 00:32:02:29 00:32:05:12 BY CLOCKS--  
 39 00:32:05:14 00:32:07:26 IN SECONDS,  
 40 00:32:07:28 00:32:09:13 MINUTES, OR HOURS.  
 41 00:32:09:15 00:32:12:05 AT MOST, WE MAY PLAN  
 42 00:32:12:07 00:32:13:19 MONTHS OR YEARS IN ADVANCE.  
 43 00:32:13:21 00:32:16:04 BUT TO UNDERSTAND  
 44 00:32:16:06 00:32:17:19 THE NATURE OF EARTH,  
 45 00:32:17:21 00:32:20:03 WE NEED TO STRETCH  
 46 00:32:20:05 00:32:22:04 OUR CONCEPT OF TIME  
 47 00:32:22:06 00:32:23:19 BEYOND  
 48 00:32:23:21 00:32:26:05 OUR HUMAN EXPERIENCE  
 49 00:32:26:07 00:32:28:20 AND INTO A GEOLOGIC FRAME  
 50 00:32:28:22 00:32:30:18 OF REFERENCE.  
 51 00:32:30:20 00:32:33:03 EVENTS IN EARTH HISTORY  
 52 00:32:33:05 00:32:36:01 SUCH AS THE DEVELOPMENT  
 53 00:32:36:03 00:32:37:17 OF MOUNTAIN RANGES,  
 54 00:32:37:19 00:32:40:02 THE RIFTING APART  
 55 00:32:40:04 00:32:42:02 OF CONTINENTS,  
 56 00:32:42:04 00:32:44:23 AND THE CREATION  
 57 00:32:44:25 00:32:46:10 OF NEW OCEAN BASINS  
 58 00:32:46:12 00:32:47:26 HAVE BEEN REPEATED  
 59 00:32:47:28 00:32:50:10 OVER AND OVER.  
 60 00:32:50:12 00:32:52:10 EACH OF THESE  
 61 00:32:52:12 00:32:53:25 GEOLOGIC EVENTS  
 TAKES PLACE OVER  
 MANY MILLIONS OF YEARS.  
 THE ESTIMATED AGE  
 OF EARTH ITSELF  
 IS OVER  
 4.6 BILLION YEARS,  
 AN INCOMPREHENSIBLY VAST  
 PERIOD OF TIME.  
 ONE WAY TO ILLUSTRATE  
 THE IMMENSE PANORAMA  
 OF GEOLOGIC TIME  
 IS TO DRAW AN ANALOGY  
 USING A TIME PERIOD  
 THAT WE CAN  
 EASILY RELATE TO.  
 SO LET'S CONDENSE  
 THE ENTIRE AGE  
 OF THE EARTH  
 INTO ONE CALENDAR YEAR.  
 ON THIS SCALE,  
 THE EARTH AND ITS  
 NEIGHBORING PLANETS  
 WERE FORMED  
 ON JANUARY 1st.  
 BY SOMETIME

62 00:32:53:27 00:32:55:10 IN EARLY MARCH,  
 THE PLANET HAD COOLED  
 SUFFICIENTLY  
 63 00:32:55:12 00:32:57:25 TO ALLOW WATER TO STAND  
 IN POOLS  
 64 00:32:57:27 00:32:59:11 ON ITS SURFACE.  
 65 00:32:59:13 00:33:01:11 THE VERY EARLIEST FORMS  
 OF LIFE  
 66 00:33:01:13 00:33:02:26 APPEARED BY LATE MARCH,  
 67 00:33:02:28 00:33:05:10 AND OXYGEN GAS BECAME  
 AN IMPORTANT PART  
 68 00:33:05:12 00:33:06:25 OF EARTH'S ATMOSPHERE  
 69 00:33:06:27 00:33:09:01 BEGINNING SOMETIME  
 IN LATE JULY.  
 70 00:33:09:03 00:33:11:15 MULTICELLULAR ORGANISMS  
 APPEARED BY OCTOBER 25th,  
 71 00:33:11:17 00:33:14:15 BUT IT WAS NOT  
 UNTIL LATE NOVEMBER  
 72 00:33:14:17 00:33:17:15 THAT PLANTS AND ANIMALS  
 WERE ABUNDANT ON LAND.  
 73 00:33:17:17 00:33:20:14 ON ABOUT DECEMBER 15th,  
 THE DINOSAURS APPEARED,  
 74 00:33:20:16 00:33:24:03 BUT DISAPPEARED IN  
 A SUDDEN MASS EXTINCTION  
 75 00:33:24:05 00:33:26:01 ON DECEMBER 25th.  
 76 00:33:26:03 00:33:29:24 THE FIRST HUMANS APPEARED  
 AT ABOUT 11:20 P.M.  
 77 00:33:29:26 00:33:31:09 ON DECEMBER 31st,  
 78 00:33:31:11 00:33:32:24 AND THE  
 INDUSTRIAL REVOLUTION  
 79 00:33:32:26 00:33:35:24 BEGAN LESS THAN  
 A SECOND AND A HALF  
 80 00:33:35:26 00:33:36:28 BEFORE MIDNIGHT.  
 81 00:33:37:00 00:33:39:25 THE FIRST PERSON  
 TO REALIZE THE IMMENSITY  
 82 00:33:39:27 00:33:41:11 OF GEOLOGIC TIME  
 83 00:33:41:13 00:33:43:26 AND BEGIN TO INVESTIGATE IT  
 IN A SYSTEMATIC WAY  
 84 00:33:43:28 00:33:45:27 WAS AN 18th CENTURY  
 SCOTSMAN  
 85 00:33:45:29 00:33:47:12 NAMED JAMES HUTTON.  
 86 00:33:47:14 00:33:49:16 HIS OBSERVATIONS  
 AND IDEAS  
 87 00:33:49:18 00:33:51:15 ABOUT THE ORIGIN OF ROCKS  
 88 00:33:51:17 00:33:54:02 BEGAN AS A PASTIME  
 THAT HE SHARED  
 89 00:33:54:04 00:33:55:17 WITH OTHER  
 WEALTHY INTELLECTUALS  
 90 00:33:55:19 00:33:57:01 OF EDINBURGH SOCIETY.  
 91 00:33:57:03 00:33:59:01 BUT HUTTON'S  
 INTERPRETATIONS  
 AND CONCLUSIONS  
 92 00:33:59:03 00:34:02:16 IGNITED A MAJOR CONTROVERSY  
 THROUGHOUT EUROPE  
 93 00:34:02:18 00:34:05:01 AND SURVIVE TODAY  
 AS THE FOUNDATION

94 00:34:05:03 00:34:07:24 FOR MODERN  
 GEOLOGIC THOUGHT.  
 95 00:34:07:26 00:34:11:05 *JAMES HUTTON WAS BORN  
 IN EDINBURGH, SCOTLAND,*  
 96 00:34:11:07 00:34:13:11 *IN 1726.*  
 97 00:34:13:13 00:34:15:26 *LIKE MOST INTELLECTUALS  
 OF HIS TIME,*  
 98 00:34:15:28 00:34:17:22 *HE EXPLORED  
 MANY DISCIPLINES--*  
 99 00:34:17:24 00:34:19:06 *FROM LAW AND MEDICINE*  
 100 00:34:19:08 00:34:20:27 *TO CHEMISTRY  
 AND AGRICULTURE.*  
 101 00:34:20:29 00:34:23:11 *AND IT WAS  
 THIS LAST PURSUIT*  
 102 00:34:23:13 00:34:27:16 *THAT WAS TO LEAD HIM  
 INTO THE FIELD OF GEOLOGY.*  
 103 00:34:27:18 00:34:30:01 HE HAD BEEN LEFT  
 A LITTLE PIECE OF LAND,  
 104 00:34:30:03 00:34:32:13 AND HE DECIDED  
 TO BECOME A FARMER.  
 105 00:34:32:15 00:34:34:13 SO HE WENT TO NORFOLK,  
 ENGLAND,  
 106 00:34:34:15 00:34:37:12 AND LIVED WITH A FARMER  
 TO LEARN HOW TO FARM,  
 107 00:34:37:14 00:34:39:13 AND FARMED FOR 15 YEARS.  
 108 00:34:39:15 00:34:40:28 BUT WHILE  
 HE WAS FARMING,  
 109 00:34:41:00 00:34:42:13 AND ALL HIS NEIGHBORS  
 BELIEVED  
 110 00:34:42:15 00:34:44:29 THAT HE WAS  
 A PERFECTLY GOOD FARMER,  
 111 00:34:45:01 00:34:48:14 HE WAS SPENDING  
 A GREAT DEAL OF HIS TIME  
 112 00:34:48:16 00:34:49:29 LOOKING  
 AND BECOMING MORE  
 113 00:34:50:01 00:34:52:13 AND MORE FASCINATED  
 WITH THE LAND--  
 114 00:34:52:15 00:34:55:29 WHAT WAS UNDER THE SOIL  
 THAT HE WAS TILLING.  
 115 00:34:56:01 00:34:58:15 *AN IMPORTANT QUESTION  
 INTRIGUED HUTTON.*  
 116 00:34:58:17 00:35:02:15 *HE SAW THAT LAND IS  
 WORN DOWN IN MANY PLACES*  
 117 00:35:02:17 00:35:04:29 *BY THE DESTRUCTIVE FORCES  
 OF EROSION.*  
 118 00:35:05:01 00:35:06:29 *HOW, THEN,  
 WAS IT POSSIBLE*  
 119 00:35:07:01 00:35:10:11 *ANY LAND WAS LEFT  
 TO SUPPORT LIFE?*  
 120 00:35:10:13 00:35:13:11 *HE BELIEVED THERE MUST  
 BE AN UNDISCOVERED FORCE*  
 121 00:35:13:13 00:35:14:26 *BUILDING UP THE LAND,*  
 122 00:35:14:28 00:35:16:10 *WHICH COUNTERACTS  
 THE PROCESSES*  
 123 00:35:16:12 00:35:17:25 *WEARING IT AWAY.*  
 124 00:35:19:09 00:35:23:05 *HE BEGAN SEARCHING FOR*

*EVIDENCE OF THIS FORCE*

125 00:35:23:07 00:35:24:20 *AND SOON FOUND IT.*

126 00:35:24:22 00:35:28:14 *HUTTON OBSERVED  
THAT STREAMS WASHED SAND*

127 00:35:28:16 00:35:30:14 *AND GRAVEL INTO THE SEA,*

128 00:35:30:16 00:35:32:00 *WHERE THIS SEDIMENT  
ACCUMULATED*

129 00:35:32:02 00:35:34:16 *IN OFFSHORE DEPOSITS.*

130 00:35:34:18 00:35:36:01 *HE FOUND  
SIMILAR MATERIAL*

131 00:35:36:03 00:35:39:02 *IN THE FORM OF ANCIENT  
SEDIMENTARY STRATA*

132 00:35:39:04 00:35:42:05 *TILTED AND RAISED  
ABOVE SEA LEVEL.*

133 00:35:42:07 00:35:43:22 *SURELY, HUTTON THOUGHT,*

134 00:35:43:24 00:35:46:20 *THESE LAYERS MUST ALSO  
HAVE FORMED UNDERWATER,*

135 00:35:46:22 00:35:49:04 *THEN RISEN TO BECOME  
NEW LAND.*

136 00:35:51:09 00:35:52:22 *HUTTON ALSO DESCRIBED*

137 00:35:52:24 00:35:54:21 *A TYPE  
OF GEOLOGIC STRUCTURE*

138 00:35:54:23 00:35:56:06 *CALLED AN UNCONFORMITY,*

139 00:35:56:08 00:35:58:20 *IN WHICH ONE GROUP  
OF LAYERS*

140 00:35:58:22 00:36:00:05 *IS TRUNCATED BY ANOTHER.*

141 00:36:01:19 00:36:03:15 *HE REASONED THAT  
UNCONFORMITIES FORM*

142 00:36:03:17 00:36:07:07 *WHEN STRATA ARE TILTED,  
UPLIFTED, AND ERODED,*

143 00:36:07:09 00:36:10:14 *THEN BURIED BY YOUNGER  
SUCCESIONS OF STRATA.*

144 00:36:12:07 00:36:13:20 *THE PRESENCE  
OF UNCONFORMITIES*

145 00:36:13:22 00:36:15:05 *IN MANY OUTCROPS*

146 00:36:15:07 00:36:17:19 *INDICATED TO HUTTON  
THAT THE LAND*

147 00:36:17:21 00:36:19:19 *WAS MOLDED  
BY REPEATED CYCLES*

148 00:36:19:21 00:36:21:04 *OF UPLIFT AND EROSION.*

149 00:36:23:01 00:36:25:14 *THIS IDEA WAS  
IN PROFOUND CONFLICT*

150 00:36:25:16 00:36:26:28 *WITH THE BIBLICAL VIEW,*

151 00:36:27:00 00:36:28:27 *WHICH HELD THAT THE LAND*

152 00:36:28:29 00:36:31:14 *HAD BEEN CREATED  
ALL AT ONCE.*

153 00:36:31:16 00:36:34:00 *OF EARTH HISTORY,  
JAMES HUTTON WROTE,*

154 00:36:34:02 00:36:37:00 *"WE FIND NO VESTIGE  
OF A BEGINNING,*

155 00:36:37:02 00:36:39:00 *NO PROSPECT OF AN END."*

156 00:36:39:02 00:36:40:29 *HUTTON WAS  
THE FIRST SCIENTIST*

157 00:36:41:01 00:36:44:14 *TO SHOW THAT THE WORLD  
MUST BE FAR OLDER*

158 00:36:44:16 00:36:46:12 *THAN MOST PEOPLE*

*BELIEVED.*

159 00:36:46:14 00:36:50:06 ONE OF THE MOST  
ASTONISHING THINGS  
TO HIM

160 00:36:50:08 00:36:53:07 AND ONE OF THE MOST  
IMPORTANT ELEMENTS

161 00:36:53:09 00:36:55:21 OF HIS, UH,  
OF HIS WORK

162 00:36:55:23 00:36:57:24 WAS TO TRY  
TO ESTABLISH

163 00:36:57:26 00:37:01:20 THAT IN FACT  
GEOLOGIC TIME, UH,

164 00:37:01:22 00:37:03:26 WAS A VERY LONG  
PERIOD

165 00:37:03:28 00:37:06:10 RATHER THAN  
THE BIBLICAL  
CREATION TIME

166 00:37:06:12 00:37:11:15 BY ARCHBISHOP USSHER  
SOMETIME LATER  
AT 4004 B.C.

167 00:37:11:17 00:37:15:09 UM, BUT HUTTON WAS  
CONVINCED THAT, UH,

168 00:37:15:11 00:37:18:25 UH, GEOLOGIC TIME  
WAS VERY EXTENSIVE.

169 00:37:18:27 00:37:22:10 *HUTTON REASONED THAT  
IF IT TAKES ABOUT A YEAR*

170 00:37:22:12 00:37:24:25 *FOR A RIVER TO DEPOSIT  
A MILLIMETER-THICK LAYER*

171 00:37:24:27 00:37:27:15 *OF SEDIMENT  
ON THE SEA FLOOR,*

172 00:37:27:17 00:37:29:25 *THAT IT MUST TAKE  
AT LEAST A MILLION YEARS*

173 00:37:29:27 00:37:32:08 *TO LAY DOWN THE 1,000-METER  
THICK SEQUENCES*

174 00:37:32:10 00:37:35:09 *OF SEDIMENTARY ROCK  
THAT HE HAD OBSERVED*

175 00:37:35:11 00:37:37:07 *IN SOME PARTS  
OF SCOTLAND.*

176 00:37:39:02 00:37:40:29 *MANY CHURCH AUTHORITIES  
WERE STUNG*

177 00:37:41:01 00:37:42:14 *BY HUTTON'S RESEARCH*

178 00:37:42:16 00:37:44:14 *AND NOT ONLY BECAUSE  
HE CLAIMED*

179 00:37:44:16 00:37:47:28 *THE WORLD IS MUCH OLDER  
THAN THE BIBLE IMPLIED.*

180 00:37:50:00 00:37:53:10 *HUTTON ALSO SHOWED  
THAT SUPERNATURAL EVENTS*

181 00:37:53:12 00:37:55:09 *LIKE THE BIBLICAL FLOOD*

182 00:37:55:11 00:37:57:01 *AREN'T NEEDED  
TO EXPLAIN*

183 00:37:57:03 00:38:00:06 *WHY THE WORLD'S SURFACE  
LOOKS THE WAY IT DOES.*

184 00:38:00:08 00:38:03:06 *ORDINARY PROCESSES,  
SEEN EVERY DAY,*

185 00:38:03:08 00:38:05:05 *COULD PRODUCE  
THE SAME LANDSCAPE,*

186 00:38:05:07 00:38:06:20 *GIVEN ENOUGH TIME.*  
 187 00:38:09:06 00:38:11:05 *HUTTON CONCLUDED*  
 188 00:38:11:07 00:38:13:19 *HAVE OPERATED*  
 189 00:38:13:21 00:38:15:04 *THROUGHOUT*  
 190 00:38:15:06 00:38:16:21 *EARTH'S HISTORY.*  
 191 00:38:16:23 00:38:18:21 *THIS IDEA BECAME KNOWN*  
 192 00:38:18:23 00:38:21:07 *AS THE THEORY*  
 193 00:38:24:27 00:38:26:10 *OF UNIFORMITY,*  
 194 00:38:26:12 00:38:28:16 *OR LATER,*  
 195 00:38:28:18 00:38:30:29 *AS UNIFORMITARIANISM.*  
 196 00:38:31:01 00:38:33:14 *THE PRINCIPLE*  
 197 00:38:33:16 00:38:35:13 *OF UNIFORMITY*  
 198 00:38:35:15 00:38:36:27 *UNDERLIES*  
 199 00:38:36:29 00:38:38:12 *MODERN GEOLOGY.*  
 200 00:38:40:08 00:38:42:06 *FOR EXAMPLE, THE PRESENCE*  
 201 00:38:42:08 00:38:43:22 *OF VAST AMOUNTS*  
 202 00:38:43:24 00:38:45:07 *OF LAYERED ROCK*  
 203 00:38:45:09 00:38:47:29 *IN THE GRAND CANYON*  
 204 00:38:48:01 00:38:49:24 *CAN BE EXPLAINED*  
 205 00:38:54:07 00:38:57:06 *AS THE RESULT*  
 206 00:38:57:08 00:38:59:06 *OF ORDINARY*  
 207 00:38:59:08 00:39:00:22 *SEDIMENTATION*  
 208 00:39:00:24 00:39:03:07 *OPERATING OVER*  
 209 00:39:03:09 00:39:05:21 *MILLIONS OF YEARS.*  
 210 00:39:05:23 00:39:08:05 *SUCH VAST SPANS*  
 211 00:39:08:07 00:39:09:21 *OF HISTORY*  
 212 00:39:09:23 00:39:11:21 *HAVE BEEN*  
 213 00:39:11:23 00:39:13:05 *DISTINGUISHED*  
 214 00:39:13:07 00:39:15:22 *FROM MORE MODEST,*  
 215 00:39:15:24 00:39:17:07 *EVERYDAY EXPERIENCE*  
*BY A SPECIAL*  
*DESIGNATION--*  
*GEOLOGIC TIME.*  
 ALTHOUGH ARGUMENTS ABOUT  
 THE AGE OF THE EARTH  
 RAGED AMONG THE  
 INTELLECTUAL COMMUNITY  
 THROUGHOUT  
 THE 19th CENTURY,  
 MOST SCIENTISTS HAD  
 ACCEPTED THE PREMISE  
 THAT THE EARTH MUST BE  
 MILLIONS OF YEARS OLD  
 INSTEAD OF JUST  
 A FEW THOUSAND.  
 ALTHOUGH THEY WERE  
 NOT ABLE  
 TO MEASURE  
 THE AGE OF ROCKS,  
 GEOLOGISTS REALIZED  
 THEY COULD DETERMINE  
 THE SEQUENCE OF EVENTS  
 IN EARTH HISTORY  
 BY COMBINING

CAREFUL OBSERVATION

216 00:39:17:09 00:39:18:24 WITH SOME SIMPLE LOGIC.  
217 00:39:18:26 00:39:20:09 THEY FIRST REASONED  
218 00:39:20:11 00:39:22:08 THAT ANY LAYERED  
SEQUENCE OF ROCKS  
219 00:39:22:10 00:39:24:09 IS FORMED WITH  
THE OLDEST LAYER  
220 00:39:24:11 00:39:25:23 AT THE BOTTOM  
221 00:39:25:25 00:39:27:25 AND SUCCESSIVELY  
YOUNGER LAYERS ON TOP.  
222 00:39:27:27 00:39:29:09 THIS PRINCIPLE,  
CALLED SUPERPOSITION,  
223 00:39:29:11 00:39:31:24 ALLOWS US TO PLACE  
ROCK UNITS  
224 00:39:31:26 00:39:33:09 IN A HISTORIC SEQUENCE  
225 00:39:33:11 00:39:35:07 ACCORDING TO THEIR  
RELATIVE AGE.  
226 00:39:35:09 00:39:37:22 THEY ALSO OBSERVED  
THAT LAYERED ROCKS  
227 00:39:37:24 00:39:40:22 SUCH AS LAVA FLOWS,  
VOLCANIC ASH LAYERS,  
228 00:39:40:24 00:39:42:22 AND SEDIMENTARY ROCKS  
ARE DEPOSITED  
229 00:39:42:24 00:39:44:21 UNDER THE INFLUENCE  
OF GRAVITY.  
230 00:39:44:23 00:39:46:08 FOR THIS REASON,  
231 00:39:46:10 00:39:47:23 THE ROCK LAYERS  
THEMSELVES  
232 00:39:47:25 00:39:48:25 ARE HORIZONTAL.  
233 00:39:48:27 00:39:50:08 ACCORDING  
TO THIS PRINCIPLE,  
234 00:39:50:10 00:39:51:22 KNOWN AS ORIGINAL  
HORIZONTALITY,  
235 00:39:51:24 00:39:54:22 ROCK LAYERS THAT ARE  
FOLDED OR TILTED  
236 00:39:54:24 00:39:56:22 MUST HAVE BEEN  
TECTONICALLY DEFORMED,  
237 00:39:56:24 00:39:58:23 AND THIS HAD  
TO HAVE HAPPENED  
238 00:39:58:25 00:40:00:14 AFTER THEY WERE  
DEPOSITED.  
239 00:40:00:16 00:40:01:29 AND FINALLY,  
ANY GEOLOGIC FEATURE  
240 00:40:02:01 00:40:03:15 THAT CUTS ACROSS  
OR TRUNCATES  
241 00:40:03:17 00:40:05:01 A GROUP OF ROCKS  
242 00:40:05:03 00:40:08:00 HAS TO BE YOUNGER THAN  
THE ROCKS THAT ARE CUT.  
243 00:40:08:02 00:40:10:00 SO FEATURES  
SUCH AS FAULTS,  
244 00:40:10:02 00:40:11:14 INTRUSIONS  
OF MOLTEN ROCK,  
245 00:40:11:16 00:40:13:00 AND EROSIONAL SURFACES  
246 00:40:13:02 00:40:15:14 CAN ALSO BE PLACED IN  
A RELATIVE AGE SEQUENCE  
247 00:40:15:16 00:40:17:01 USING THIS PRINCIPLE



248 00:40:17:03 00:40:18:16 CALLED CROSSCUTTING  
 RELATIONSHIPS.  
 249 00:40:18:18 00:40:20:01 ALTHOUGH THESE  
 GEOLOGIC PRINCIPLES  
 250 00:40:20:03 00:40:22:00 ARE BASED  
 ON NOTHING MORE  
 251 00:40:22:02 00:40:23:15 THAN COMMON SENSE,  
 252 00:40:23:17 00:40:25:00 THEY ARE ABSOLUTELY  
 FUNDAMENTAL  
 253 00:40:25:02 00:40:27:14 TO THE INTERPRETATION  
 OF EARTH HISTORY.  
 254 00:40:27:16 00:40:29:26 ACCORDING  
 TO THE PRINCIPLE  
 255 00:40:29:28 00:40:31:11 OF ORIGINAL  
 HORIZONTALITY,  
 256 00:40:31:13 00:40:35:13 BEDS OF SEDIMENT FORM  
 AS HORIZONTAL LAYERS  
 257 00:40:35:15 00:40:36:29 AS THE SEDIMENT SETTLES  
 258 00:40:37:01 00:40:38:27 UNDER THE FORCE  
 OF GRAVITY.  
 259 00:40:40:08 00:40:42:05 THE PRINCIPLE  
 OF SUPERPOSITION  
 260 00:40:42:07 00:40:44:05 MAINTAINS THAT  
 THE OLDEST LAYERS  
 261 00:40:44:07 00:40:46:04 OF UNDEFORMED  
 SEDIMENTARY STRATA  
 262 00:40:46:06 00:40:47:19 ARE ON THE BOTTOM  
 263 00:40:47:21 00:40:49:18 AND THE YOUNGEST ON TOP.  
 264 00:40:54:01 00:40:57:09 FINALLY, THE PRINCIPLE OF  
 CROSSCUTTING RELATIONSHIPS  
 265 00:40:57:11 00:40:59:26 STATES THAT A ROCK  
 IS YOUNGER  
 266 00:40:59:28 00:41:02:11 THAN ANY ROCKS  
 IT CUTS ACROSS,  
 267 00:41:02:13 00:41:05:25 AS IN THE CASE OF VEINS  
 OF IGNEOUS ROCK  
 268 00:41:05:27 00:41:07:23 CUTTING ACROSS STRATA  
 269 00:41:07:25 00:41:10:22 OR OF UNCONFORMITIES  
 SUCH AS HUTTON STUDIED.  
 270 00:41:10:24 00:41:13:07 THE PRINCIPLES  
 OF RELATIVE AGE DATING  
 271 00:41:13:09 00:41:15:22 ARE SIMPLE, AND YET  
 SO POWERFUL  
 272 00:41:15:24 00:41:19:04 THAT THEY WERE USED  
 BY EARLY GEOLOGISTS  
 273 00:41:19:06 00:41:21:18 IN THE 18th  
 AND 19th CENTURIES  
 274 00:41:21:20 00:41:23:18 TO CONSTRUCT A COMPLETE  
 HISTORIC SEQUENCE  
 275 00:41:23:20 00:41:25:03 OF ALL ROCKS IN EUROPE.  
 276 00:41:25:05 00:41:26:18 AND BECAUSE  
 ROCK FORMATIONS  
 277 00:41:26:20 00:41:28:17 IN A SEQUENCE LIKE THIS  
 278 00:41:28:19 00:41:30:15 OFTEN EXTEND  
 OVER A LARGE AREA,  
 279 00:41:30:17 00:41:33:01 THEY CAN BE USED

280 00:41:33:03 00:41:34:17 FROM ONE SEQUENCE  
 281 00:41:34:19 00:41:36:02 WITH HISTORICALLY  
 EQUIVALENT STRATA  
 282 00:41:36:04 00:41:37:18 IN OTHER REGIONS.  
 283 00:41:37:20 00:41:39:02 THIS IS EASY TO SEE  
 284 00:41:39:04 00:41:41:17 IN A PLACE  
 LIKE THE GRAND CANYON.  
 285 00:41:41:19 00:41:43:02 THIS FORMATION,  
 THE KAIBAB LIMESTONE,  
 286 00:41:43:04 00:41:44:17 CAN CLEARLY  
 BE RECOGNIZED  
 287 00:41:44:19 00:41:46:16 IN THE SEQUENCE  
 OF SEDIMENTARY ROCKS  
 288 00:41:46:18 00:41:49:18 ON THE OPPOSITE SIDE  
 OF THE CANYON.  
 289 00:41:49:20 00:41:51:02 BECAUSE IT'S  
 THE SAME FORMATION,  
 290 00:41:51:04 00:41:53:18 IT MARKS THE SAME PERIOD  
 OF GEOLOGIC TIME  
 291 00:41:53:20 00:41:55:02 IN BOTH PLACES.  
 292 00:41:55:04 00:41:56:17 SOME ROCK LAYERS  
 PERSIST Laterally  
 293 00:41:56:19 00:41:58:03 FOR THOUSANDS  
 OF KILOMETERS  
 294 00:41:58:05 00:42:00:18 AND CAN BE RECOGNIZED  
 IN DIFFERENT PLACES  
 295 00:42:00:20 00:42:02:19 BY THEIR THICKNESS,  
 MINERAL COMPOSITION,  
 296 00:42:02:21 00:42:04:03 AND OTHER  
 CHARACTERISTICS.  
 297 00:42:04:05 00:42:05:19 FOR EXAMPLE,  
 VOLCANIC ASH  
 298 00:42:05:21 00:42:08:03 FROM THE 1980 ERUPTION  
 OF MOUNT ST. HELENS  
 299 00:42:08:05 00:42:09:18 HAS BEEN IDENTIFIED  
 300 00:42:09:20 00:42:11:02 IN SEDIMENTARY SEQUENCES  
 301 00:42:11:04 00:42:14:02 AS FAR AWAY AS MINNESOTA  
 AND ARIZONA.  
 302 00:42:14:04 00:42:17:03 ROCK FORMATIONS CAN BE  
 VALUABLE TIME MARKERS,  
 303 00:42:17:05 00:42:18:17 BUT CORRELATION  
 IS DIFFICULT  
 304 00:42:18:19 00:42:20:21 OVER GREAT DISTANCES  
 305 00:42:20:23 00:42:22:06 BECAUSE  
 PHYSICAL CONTINUITY  
 306 00:42:22:08 00:42:26:01 AND ROCK CHARACTERISTICS  
 CAN BE AMBIGUOUS.  
 307 00:42:26:03 00:42:27:15 FOSSILS,  
 LIKE THESE SHELLS  
 308 00:42:27:17 00:42:29:00 OF MARINE ORGANISMS,  
 309 00:42:29:02 00:42:31:09 CAN BE EXTREMELY  
 VALUABLE TIME MARKERS.  
 310 00:42:31:11 00:42:34:09 EACH FOSSIL SPECIES  
 HAS ITS OWN LIFE SPAN.  
 311 00:42:34:11 00:42:36:08 AND ROCKS

312 00:42:36:10 00:42:37:25 WITH OVERLAPPING  
 LIFE SPANS  
 313 00:42:37:27 00:42:39:09 ARE ACTUAL TIME MARKERS  
 314 00:42:39:11 00:42:42:17 THAT CAN BE RECOGNIZED  
 WHEREVER THEY ARE FOUND.  
 315 00:42:42:19 00:42:44:03 THE USE OF FOSSILS  
 316 00:42:44:05 00:42:46:02 IN MAKING GEOLOGIC  
 TIME CORRELATIONS  
 317 00:42:46:04 00:42:48:17 WAS FIRST DISCOVERED  
 IN THE 15th CENTURY,  
 318 00:42:48:19 00:42:51:04 AND BY THE BEGINNING  
 OF THIS CENTURY,  
 319 00:42:51:06 00:42:52:19 GEOLOGISTS HAD USED  
 CORRELATION  
 320 00:42:52:21 00:42:54:19 TO EXTEND THE HISTORIC  
 ROCK SEQUENCE  
 321 00:42:54:21 00:42:57:16 FROM EUROPE TO EVERY  
 CONTINENT ON EARTH.  
 322 00:42:57:18 00:43:00:16 *THE WORD "FOSSIL"*  
*REFERS TO ANY EVIDENCE*  
 323 00:43:00:18 00:43:03:00 *OF A PREHISTORIC PLANT*  
*OR ANIMAL*  
 324 00:43:03:02 00:43:05:00 *THAT HAS BEEN*  
*PRESERVED IN ROCK.*  
 325 00:43:05:02 00:43:07:14 *SOMETIMES, PART*  
*OF THE ORGANISM ITSELF*  
 326 00:43:07:16 00:43:09:19 *REMAINS INTACT--*  
 327 00:43:09:21 00:43:11:04 *IN SOME INSTANCES,*  
 328 00:43:11:06 00:43:13:18 *RECRYSTALIZED*  
*OR PETRIFIED*  
 329 00:43:13:20 00:43:16:17 *LIKE THE TREES*  
*IN A PETRIFIED FOREST.*  
 330 00:43:19:23 00:43:21:12 *IN OTHER CASES,*  
 331 00:43:21:14 00:43:23:27 *THE ORGANISM MAY HAVE*  
*BEEN COMPLETELY DISSOLVED,*  
 332 00:43:23:29 00:43:25:27 *LEAVING ONLY*  
*A HOLLOW MOLD*  
 333 00:43:25:29 00:43:27:11 *OF ITS OWN IMAGE.*  
 334 00:43:30:01 00:43:31:15 *THROUGHOUT*  
*GEOLOGIC TIME,*  
 335 00:43:31:17 00:43:33:16 *FOSSIL SPECIES SUCCEED*  
*EACH OTHER*  
 336 00:43:33:18 00:43:36:21 *IN A DISTINCT,*  
*RECOGNIZABLE ORDER.*  
 337 00:43:38:08 00:43:39:13 *IN GENERAL,*  
 338 00:43:39:15 00:43:40:26 *PROGRESSIVELY*  
*OLDER FOSSILS*  
 339 00:43:40:28 00:43:42:25 *ARE INCREASINGLY*  
*DIFFERENT*  
 340 00:43:42:27 00:43:44:18 *FROM LIFE FORMS TODAY.*  
 341 00:43:47:22 00:43:49:21 *THIS OBSERVATION CAME*  
*TO BE KNOWN*  
 342 00:43:49:23 00:43:52:01 *AS THE PRINCIPLE*  
*OF FAUNAL SUCCESSION,*  
 343 00:43:52:03 00:43:55:01 *ONE OF THE STRONGEST*

344 00:43:55:03 00:43:57:18 *LINES OF EVIDENCE SUPPORTING DARWIN'S THEORY OF EVOLUTION.*  
 345 00:44:00:29 00:44:03:12 *THE 19th AND EARLY 20th CENTURIES*  
 346 00:44:03:14 00:44:06:14 *WERE THE HEYDAY OF THE AMATEUR PALEONTOLOGIST*  
 347 00:44:06:16 00:44:08:21 *OR STUDENT OF OLD LIFE.*  
 348 00:44:10:01 00:44:11:16 *THESE FOSSIL HUNTERS,*  
 349 00:44:11:18 00:44:15:02 *COMBING THE CLIFF FACES AND QUARRIES OF THE GLOBE,*  
 350 00:44:15:04 00:44:17:10 *IDENTIFIED THOUSANDS OF FOSSIL SPECIES*  
 351 00:44:17:12 00:44:18:25 *AND PAINSTAKINGLY ESTABLISHED*  
 352 00:44:18:27 00:44:20:10 *THEIR RELATIVE AGES*  
 353 00:44:20:12 00:44:23:10 *FROM THE POSITIONS OF THE ROCK LAYERS*  
 354 00:44:23:12 00:44:25:29 *IN WHICH THE FOSSILS WERE ENTOMBED.*  
 355 00:44:29:29 00:44:31:26 *REGARDLESS OF WHERE ON EARTH*  
 356 00:44:31:28 00:44:33:11 *FOSSILS ARE FOUND,*  
 357 00:44:33:13 00:44:36:10 *THEY ALWAYS OCCUR IN THE SAME SEQUENCE*  
 358 00:44:36:12 00:44:37:26 *RELATIVE TO ONE ANOTHER.*  
 359 00:44:37:28 00:44:40:12 *SOME OF THE LOWER ROCK STRATA*  
 360 00:44:40:14 00:44:41:27 *IN THE GRAND CANYON*  
 361 00:44:41:29 00:44:44:27 *CONTAIN FOSSILS OF THE SAME GENERAL GROUPINGS*  
 362 00:44:44:29 00:44:48:05 *AS THOSE IN CERTAIN VERY ANCIENT ROCK LAYERS*  
 363 00:44:48:07 00:44:49:20 *FOUND IN WALES.*  
 364 00:44:51:28 00:44:55:11 *SINCE THE ANCIENT NAME FOR WALES IS CAMBRIA,*  
 365 00:44:55:13 00:44:58:06 *THESE ROCKS WERE CALLED CAMBRIAN ROCKS,*  
 366 00:44:58:08 00:45:01:20 *AND THE GEOLOGIC PERIOD IN WHICH THEY WERE FORMED,*  
 367 00:45:01:22 00:45:03:20 *THE CAMBRIAN PERIOD.*  
 368 00:45:05:14 00:45:08:12 *19th CENTURY GEOLOGISTS USED THE NAMES OF PLACES*  
 369 00:45:08:14 00:45:10:01 *AND ANCIENT PEOPLES*  
 370 00:45:10:03 00:45:13:14 *TO LABEL OTHER TIMES IN GEOLOGIC HISTORY AS WELL.*  
 371 00:45:14:27 00:45:16:26 *FOR EXAMPLE, THE ORDOVICIAN PERIOD,*  
 372 00:45:16:28 00:45:19:24 *THE SILURIAN PERIOD,*  
 373 00:45:19:26 00:45:21:10 *AND THE DEVONIAN PERIOD,*  
 374 00:45:21:12 00:45:23:09 *AFTER DEVON IN SOUTHERN ENGLAND.*  
 375 00:45:24:17 00:45:25:23 *CHARACTERISTIC ROCKS*  
 376 00:45:25:25 00:45:27:15 *AND RELATIVE POSITIONS OF STRATA*  
 377 00:45:27:17 00:45:30:14 *WERE ALSO USED TO*

378 00:45:30:16      *DESIGNATE NEW TIME UNITS,*  
 00:45:34:01      *AND GRADUALLY,*  
 379 00:45:34:03      *THE GEOLOGIC TIME SCALE*  
 00:45:37:27      *WAS CONSTRUCTED.*  
 380 00:45:39:10      THE STANDARD GEOLOGIC  
 TIME SCALE  
 381 00:45:39:12      00:45:41:25      IS BASED, REALLY, ON THE  
 LAW OF SUPERPOSITION.  
 382 00:45:41:27      00:45:44:10      THE OLDEST ROCKS  
 ARE ON THE BOTTOM  
 383 00:45:44:12      00:45:46:24      AND THE YOUNGEST ROCKS  
 ARE ON THE TOP.  
 384 00:45:46:26      00:45:48:09      LOOKING AT ROCKS  
 385 00:45:48:11      00:45:50:11      IN VARIOUS PARTS  
 OF WESTERN EUROPE,  
 386 00:45:50:13      00:45:52:10      IT WAS RECOGNIZED  
 THAT CERTAIN FORMATIONS  
 387 00:45:52:12      00:45:54:25      COULD BE CORRELATED FROM  
 ONE REGION TO ANOTHER,  
 388 00:45:54:27      00:45:57:25      AND THE OLDER ROCKS  
 WERE VERY DISTINCTIVE  
 389 00:45:57:27      00:46:01:08      WITH A DISTINCT GROUP  
 OF FOSSILS IN THEM.  
 390 00:46:01:10      00:46:04:08      THE YOUNGER ROCKS  
 OVERLAY THE OLDER ONES.  
 391 00:46:04:10      00:46:05:23      THEY HAD  
 DIFFERENT COLORS,  
 392 00:46:05:25      00:46:06:22      DIFFERENT  
 CHARACTERISTICS,  
 393 00:46:06:24      00:46:08:03      DIFFERENT FOSSILS.  
 394 00:46:08:05      00:46:09:18      BY ARRANGING THEM  
 SEQUENTIALLY,  
 395 00:46:09:20      00:46:11:10      WHICH ONES  
 WERE THE OLDEST  
 396 00:46:11:12      00:46:13:25      AND WHICH ONES  
 WERE THE YOUNGEST,  
 397 00:46:13:27      00:46:15:26      THEY WERE ABLE  
 TO ESTABLISH  
 398 00:46:15:28      00:46:18:27      A CHRONOLOGY JUST ON THE  
 BASIS OF SUPERPOSITION.  
 399 00:46:18:29      00:46:22:12      EACH OF THE ROCK UNITS  
 TOOK A NAME  
 400 00:46:22:14      00:46:25:11      FROM THE ORGANISMS  
 THAT WERE IN IT  
 401 00:46:25:13      00:46:28:10      OR THE REGION WHERE  
 IT WAS FIRST STUDIED,  
 402 00:46:28:12      00:46:31:09      GIVING US THE MODERN  
 GEOLOGIC TIME SCALE.  
 403 00:46:31:11      00:46:34:24      THE RELATIVE  
 AGE RELATIONSHIPS  
 THAT WE SEE IN ROCKS  
 404 00:46:34:26      00:46:36:25      ALLOW US  
 TO RECOGNIZE  
 GEOLOGIC EVENTS  
 405 00:46:36:27      00:46:38:25      IN A HISTORIC  
 SEQUENCE

406 00:46:38:27 00:46:41:10 BUT KNOWING ONLY  
 THE ORDER OF EVENTS  
 407 00:46:41:12 00:46:42:25 IS A BIT  
 UNSATISFYING.  
 408 00:46:42:27 00:46:44:09 WITHOUT THE ABILITY  
 TO MEASURE  
 409 00:46:44:11 00:46:46:09 THE ABSOLUTE AGE  
 OF THESE ROCKS,  
 410 00:46:46:11 00:46:49:10 IT'S IMPOSSIBLE  
 TO FULLY UNDERSTAND  
 EARTH HISTORY.  
 411 00:46:49:12 00:46:51:24 AND WITHOUT  
 A CALIBRATION  
 OF GEOLOGIC TIME,  
 412 00:46:51:26 00:46:54:10 WE CAN'T STUDY  
 THE RATES  
 OF GEOLOGIC CHANGE  
 413 00:46:54:12 00:46:56:09 THAT ARE USED  
 TO MAKE FORECASTS  
 414 00:46:56:11 00:46:57:27 ABOUT FUTURE EVENTS.  
 415 00:46:57:29 00:46:59:27 SCIENTIFIC DISCOVERY  
 IS OFTEN BORN  
 416 00:46:59:29 00:47:02:28 OF CHANCE EVENTS  
 COUPLED WITH KEEN  
 PERCEPTION.  
 417 00:47:03:00 00:47:04:27 IN THE LATE  
 19th CENTURY,  
 418 00:47:04:29 00:47:06:13 MADAME MARIE CURIE  
 DISCOVERED  
 419 00:47:06:15 00:47:08:27 THAT WHEN CERTAIN  
 TYPES OF ROCKS  
 420 00:47:08:29 00:47:11:11 WERE STORED  
 IN THE SAME DRAWER  
 OVERNIGHT  
 421 00:47:11:13 00:47:12:26 WITH UNDEVELOPED  
 PHOTOGRAPHIC FILM,  
 422 00:47:12:28 00:47:15:00 THE FILM  
 WAS EXPOSED.  
 423 00:47:15:02 00:47:16:15 THIS CHANCE EVENT  
 424 00:47:16:17 00:47:19:00 LED TO  
 THE DISCOVERY  
 OF RADIOACTIVITY.  
 425 00:47:19:02 00:47:21:29 IN THIS PROCESS,  
 CERTAIN TYPES  
 OF ATOMS  
 426 00:47:22:01 00:47:24:23 SPONTANEOUSLY  
 DISINTEGRATE  
 OR DECAY.  
 427 00:47:24:25 00:47:26:10 THE DECAY IS RANDOM,  
 428 00:47:26:12 00:47:29:10 BUT IT PROCEEDS  
 AT A CONSTANT RATE  
 THROUGH TIME  
 429 00:47:29:12 00:47:32:19 FOR EACH PARTICULAR  
 TYPE OF ATOM  
 OR ISOTOPE.

430 00:47:32:21 00:47:34:19 BECAUSE MANY  
DIFFERENT TYPES  
OF ROCKS

431 00:47:34:21 00:47:36:05 CONTAIN RADIOACTIVE  
ISOTOPES,

432 00:47:36:07 00:47:38:20 ERNEST RUTHERFORD  
REASONED IN 1905

433 00:47:38:22 00:47:41:20 THAT THE  
UNIFORM RATE  
OF RADIOACTIVE DECAY

434 00:47:41:22 00:47:44:19 COULD BE USED  
TO MEASURE  
GEOLOGIC TIME.

435 00:47:44:21 00:47:46:06 FROM  
THIS REALIZATION

436 00:47:46:08 00:47:48:20 CAME THE EVENTUAL  
DEVELOPMENT  
OF TECHNIQUES

437 00:47:48:22 00:47:51:06 TO MEASURE  
THE ABSOLUTE AGE OF  
GEOLOGIC MATERIALS.

438 00:47:51:08 00:47:53:21 NOW, FOR EXAMPLE,  
  
NOT ONLY DO WE KNOW

439 00:47:53:23 00:47:55:06 THAT THE DINOSAURS  
DISAPPEARED

440 00:47:55:08 00:47:57:05 IN A GLOBAL  
MASS EXTINCTION,

441 00:47:57:07 00:48:00:04 WE KNOW IT HAPPENED  
64 MILLION  
YEARS AGO.

442 00:48:02:22 00:48:05:23 *EACH ELEMENT CAN BE  
SEPARATED INTO ISOTOPES,*

443 00:48:05:25 00:48:08:22 *GROUPS OF ATOMS WITH  
SIMILAR ATOMIC STRUCTURE,*

444 00:48:08:24 00:48:11:06 *THOUGH SLIGHTLY  
DIFFERENT MASS.*

445 00:48:12:20 00:48:14:02 *SOME ISOTOPES  
ARE RADIOACTIVE,*

446 00:48:14:04 00:48:16:14 *AND THEREFORE, UNSTABLE.*

447 00:48:18:07 00:48:20:04 *THIS INSTABILITY CAUSES  
THE ATOMS*

448 00:48:20:06 00:48:21:19 *TO RADIATE ENERGY,*

449 00:48:21:21 00:48:24:06 *MUCH OF IT IN THE FORM*

450 00:48:24:08 00:48:25:21 *ICALLY-CHARGED*

451 00:48:24:08 00:48:25:21 *PARTICLES.*

452 00:48:25:23 00:48:28:20 *THE RADIATION GRADUALLY  
CAUSES THE ELEMENT*

453 00:48:28:22 00:48:30:21 *TO DISINTEGRATE  
OR DECAY,*

454 00:48:30:23 00:48:33:02 *TRANSFORMING THE ORIGINAL  
RADIOACTIVE ISOTOPE*

455 00:48:33:04 00:48:36:04 *OR PARENT INTO  
A STABLE ISOTOPE*

456 00:48:36:06 00:48:38:06 *KNOWN AS  
A DAUGHTER PRODUCT.*

457 00:48:40:28 00:48:43:12 *IT IS THIS PROCESS  
OF DECAY*  
 458 00:48:43:14 00:48:44:27 *THAT WE CALL  
RADIOACTIVITY.*  
 459 00:48:51:12 00:48:54:11 *GRAINS OF SAND TRICKLING  
THROUGH THE NARROW OPENING*  
 460 00:48:54:13 00:48:55:25 *OF AN HOURGLASS*  
 461 00:48:55:27 00:48:58:10 *ARE SOMEWHAT ANALOGOUS  
TO ISOTOPES DECAYING*  
 462 00:48:58:12 00:49:00:07 *IN A RADIOACTIVE  
ELEMENT.*  
 463 00:49:01:20 00:49:05:01 *THE SAND IN THE UPPER HALF  
OF THE HOURGLASS*  
 464 00:49:05:03 00:49:07:16 *REPRESENTS A SUPPLY  
OF PARENT ISOTOPE.*  
 465 00:49:07:18 00:49:10:00 *THE SAND  
IN THE LOWER HALF*  
 466 00:49:10:02 00:49:11:15 *IS ITS DAUGHTER PRODUCT.*  
 467 00:49:11:17 00:49:13:29 *THE PROPORTION OF PARENT  
TO DAUGHTER*  
 468 00:49:14:01 00:49:17:08 *DEPENDS UPON  
HOW MUCH TIME HAS ELAPSED.*  
 469 00:49:18:28 00:49:21:25 *THIS CAN BE DETERMINED  
SIMPLY BY MEASURING*  
 470 00:49:21:27 00:49:24:24 *THE RATIO OF PARENT  
TO DAUGHTER SAND.*  
 471 00:49:26:23 00:49:29:10 *THIS IS HOW RADIOACTIVE  
DATING WORKS.*  
 472 00:49:29:12 00:49:31:02 *THE MOST  
FAMILIAR EXAMPLE*  
 473 00:49:31:04 00:49:32:27 *IS RADIOCARBON DATING.*  
 474 00:49:34:21 00:49:37:03 *THE CARBON IN AIR  
AND WATER*  
 475 00:49:37:05 00:49:40:03 *IS MADE UP OF THREE  
DIFFERENT ISOTOPES.*  
 476 00:49:40:05 00:49:43:13 *ONE OF THESE, CARBON 14,  
IS RADIOACTIVE.*  
 477 00:49:45:17 00:49:47:14 *AS PART  
OF THE ATMOSPHERE,*  
 478 00:49:47:16 00:49:51:28 *CARBON 14 IS ABSORBED BY  
LIVING PLANTS AND ANIMALS.*  
 479 00:49:52:00 00:49:55:13 *IN THIS WAY, THE CARBON  
IN ALL LIVING ORGANISMS*  
 480 00:49:55:15 00:49:56:29 *CONTAINS  
THE SAME PROPORTION*  
 481 00:49:57:01 00:50:00:05 *OF CARBON 14 TO  
NONRADIOACTIVE CARBON.*  
 482 00:50:02:16 00:50:03:29 *WHEN THE ORGANISM DIES,*  
 483 00:50:04:01 00:50:06:28 *IT STOPS TAKING IN  
ANY NEW CARBON,*  
 484 00:50:07:00 00:50:09:29 *AND THE AMOUNT  
OF CARBON 14 INSIDE IT*  
 485 00:50:10:01 00:50:12:00 *GRADUALLY DECREASES  
AS IT DECAYS.*  
 486 00:50:12:02 00:50:15:23 *IT IS THIS SHRINKING  
PROPORTION OF CARBON 14*



487 00:50:15:25 00:50:18:07 THAT TELLS US  
 HOW LONG AGO  
 488 00:50:18:09 00:50:19:22 THE ORGANISM DIED.  
 489 00:50:25:06 00:50:28:03 THE RATE OF DECAY  
 OF ANY RADIOISOTOPE  
 490 00:50:28:05 00:50:31:01 IS MEASURED IN TERMS  
 OF ITS HALF-LIFE--  
 491 00:50:31:03 00:50:35:17 HOW LONG IT TAKES FOR HALF  
 OF ITS ATOMS TO DECAY.  
 492 00:50:35:19 00:50:38:03 THE HALF-LIFE  
 OF CARBON 14  
 493 00:50:38:05 00:50:41:11 IS 5,730 YEARS.  
 494 00:50:41:13 00:50:44:16 CARBON 14 IS  
 MOST COMMONLY PRESERVED  
 495 00:50:44:18 00:50:47:00 IN THE FORM  
 OF CHARRED WOOD  
 496 00:50:47:02 00:50:49:06 THAT IS BURIED  
 BY SEDIMENT,  
 497 00:50:49:08 00:50:50:25 LAVA, OR VOLCANIC ASH.  
 498 00:50:53:03 00:50:56:00 IF A SAMPLE CONTAINS  
 ONLY HALF THE LEVEL  
 499 00:50:56:02 00:50:59:05 OF CARBON 14 FOUND  
 IN LIVING ORGANISMS,  
 500 00:50:59:07 00:51:02:04 GEOLOGISTS CONCLUDE  
 THAT IT MUST BE  
 501 00:51:02:06 00:51:04:14 5,730 YEARS OLD.  
 502 00:51:04:16 00:51:06:29 IF THE RATIO  
 OF CARBON 14  
 503 00:51:07:01 00:51:10:14 IS ONLY A QUARTER THAT  
 OF A LIVING ORGANISM,  
 504 00:51:10:16 00:51:12:14 ANOTHER HALF-LIFE  
 HAS ELAPSED,  
 505 00:51:12:16 00:51:16:22 AND IT MUST BE 11,460  
 YEARS OLD, AND SO ON.  
 506 00:51:18:18 00:51:20:16 THIS METHOD  
 IS ONLY RELIABLE  
 507 00:51:20:18 00:51:23:28 FOR DATING THINGS BACK  
 ABOUT 50,000 YEARS.  
 508 00:51:26:07 00:51:29:05 BEYOND THAT, THE AMOUNT  
 OF RADIOCARBON REMAINING  
 509 00:51:29:07 00:51:32:02 IS TOO SMALL TO PERMIT  
 ACCURATE MEASUREMENT.  
 510 00:51:36:20 00:51:39:04 TO DATE ROCKS  
 THAT ARE MILLIONS  
 511 00:51:39:06 00:51:41:19 OR EVEN BILLIONS  
 OF YEARS OLD,  
 512 00:51:41:21 00:51:43:26 GEOLOGISTS WORK  
 WITH RADIOISOTOPES  
 513 00:51:43:28 00:51:46:10 THAT TAKE MUCH LONGER  
 TO DECAY--  
 514 00:51:46:12 00:51:48:28 SUCH AS URANIUM-235.  
 515 00:51:50:26 00:51:53:24 THIS ELEMENT MAKES AN  
 EXCELLENT GEOLOGIC CLOCK  
 516 00:51:53:26 00:51:56:09 BECAUSE IT TAKES  
 713 MILLION YEARS  
 517 00:51:56:11 00:52:00:14 FOR HALF OF IT TO DECAY

INTO LEAD-207.

518 00:52:02:19 00:52:04:17 BY MEASURING  
THE RELATIVE AMOUNTS

519 00:52:04:19 00:52:07:17 OF THESE TWO ISOTOPES  
IN A ROCK,

520 00:52:07:19 00:52:09:17 IT'S POSSIBLE  
TO FIGURE OUT

521 00:52:09:19 00:52:11:02 THE ROCK'S AGE,  
522 00:52:11:04 00:52:14:02 EVEN IF IT IS SEVERAL  
BILLION YEARS OLD.

523 00:52:15:16 00:52:18:15 THE FIRST STEP  
IN DETERMINING  
THE AGE OF THE ROCK

524 00:52:18:17 00:52:21:00 IS FINDING  
THE PROPER ROCK  
IN THE FIELD

525 00:52:21:02 00:52:23:00 AND DETERMINING  
ITS MINERALOGY.

526 00:52:23:02 00:52:25:29 ONCE WE'VE  
DETERMINED WHAT IT  
IS WE WANT TO DATE,

527 00:52:26:01 00:52:28:27 THEN WE SAMPLE IT  
IN THE FIELD,

528 00:52:28:29 00:52:31:11 BRING IT BACK  
INTO THE LABORATORY,

529 00:52:31:13 00:52:34:10 SEPARATE OUT  
THE MINERALS THAT  
WE WANT TO DATE

530 00:52:34:12 00:52:37:10 THAT TELL US THE AGE  
OF THE ROCK.

531 00:52:37:12 00:52:41:01 ONCE WE HAVE A CLEAN  
MINERAL SEPARATE,

532 00:52:41:03 00:52:43:11 WE TAKE IT  
INTO THE LABORATORY

533 00:52:43:13 00:52:45:27 AND WE SEPARATE OUT  
CHEMICALLY

534 00:52:45:29 00:52:48:12 THE ELEMENTS THAT  
ARE WITHIN THE ROCK

535 00:52:48:14 00:52:50:11 THAT HAVE  
THE ISOTOPIC SYSTEM

536 00:52:50:13 00:52:52:08 THAT WE'RE  
INTERESTED IN.

537 00:52:55:16 00:52:58:14 AND THEN, ONCE WE HAVE  
THE ELEMENTS SEPARATED,

538 00:52:58:16 00:52:59:28 WE BRING THE ELEMENTS  
539 00:53:00:00 00:53:01:20 INTO THE MASS  
SPECTROMETER,

540 00:53:01:22 00:53:03:21 AND WITH THE  
MASS SPECTROMETER,

541 00:53:03:23 00:53:06:20 WE ANALYZE THE ISOTOPES  
OF THE ELEMENTS

542 00:53:06:22 00:53:08:07 THAT WE'RE  
INTERESTED IN.

543 00:53:08:09 00:53:10:07 AND IT'S  
THE ISOTOPIC RATIOS

544 00:53:10:09 00:53:13:29 BETWEEN THE PARENT AND

545 00:53:14:01 THE DAUGHTER ISOTOPES  
00:53:16:13 AND BETWEEN THE VARIOUS  
546 00:53:16:15 DAUGHTER ISOTOPES  
00:53:19:04 THAT GIVE US THE AGE  
OF THE ROCK.  
547 00:53:20:16 00:53:22:27 THE MASS SPECTROMETER  
ACCELERATES THE IONS  
548 00:53:22:29 00:53:25:12 OR CHARGED ATOMS  
OF AN ELEMENT  
549 00:53:25:14 00:53:27:11 SO THAT THEY FORM  
A BEAM,  
550 00:53:27:13 00:53:28:28 WHICH IS THEN SPREAD OUT  
551 00:53:29:00 00:53:30:24 INTO A SUCCESSION  
OF POINTS--  
552 00:53:30:26 00:53:32:09 A MASS SPECTRUM.  
553 00:53:34:17 00:53:37:16 FROM THE POSITION  
AND INTENSITY OF THE POINTS,  
554 00:53:37:18 00:53:39:15 THE MASS AND RELATIVE  
ABUNDANCE  
555 00:53:39:17 00:53:42:00 OF INDIVIDUAL ISOTOPES  
CAN BE DETERMINED.  
556 00:53:45:09 00:53:48:06 ONCE THE ELEMENT  
THAT WE'RE GOING  
TO MEASURE  
557 00:53:48:08 00:53:50:13 IS LOADED INTO  
THE MASS SPECTROMETER,  
558 00:53:50:15 00:53:53:14 IT'S IONIZED  
AT A TEMPERATURE  
559 00:53:53:16 00:53:56:15 OF BETWEEN 1,000  
AND 2,000 DEGREES  
CENTIGRADE,  
560 00:53:56:17 00:53:59:00 DEPENDING ON WHAT  
ELEMENT IT IS.  
561 00:53:59:02 00:54:00:29 THE IONS ARE THEN  
ACCELERATED  
562 00:54:01:01 00:54:06:01 BY 8,000-10,000-VOLT  
DROP DOWN THE TUBE,  
563 00:54:06:03 00:54:08:15 WHICH IS  
A HIGH-VACUUM TUBE,  
564 00:54:08:17 00:54:10:17 AND AS THEY'RE  
BEING ACCELERATED,  
565 00:54:10:19 00:54:13:16 THEY'RE FOCUSED INTO  
A VERY FINE BEAM.  
566 00:54:13:18 00:54:17:01 ONCE THEY ENTER  
THE TUBE  
AS A FINE BEAM,  
567 00:54:17:03 00:54:19:16 THEY MOVE THROUGH  
A MAGNETIC FIELD.  
568 00:54:19:18 00:54:23:15 THE MAGNETIC FIELD  
PUTS A DRAG  
ON THE ION BEAM,  
569 00:54:23:17 00:54:25:17 WHICH CAUSES  
THE HEAVY ISOTOPES  
570 00:54:25:19 00:54:28:29 TO BEND ALONG  
THE OUTER PART  
OF THE TUBE

571 00:54:29:01 00:54:30:15 AND THE LIGHTER ONES  
572 00:54:30:17 00:54:32:29 INTO THE INNER PART  
OF THE TUBE.  
573 00:54:33:01 00:54:34:14 BY THE TIME  
THE BEAM  
574 00:54:34:16 00:54:37:20 COMES OUT OF  
THE MAGNETIC PART  
OF THE TUBE,  
575 00:54:37:22 00:54:40:05 IT'S BROKEN INTO  
ITS VARIOUS ISOTOPES,  
576 00:54:40:07 00:54:43:05 AND AT THE FAR END  
OF THE TUBE  
577 00:54:43:07 00:54:46:06 WE COUNT THE IONS  
OF EACH ISOTOPE,  
578 00:54:46:08 00:54:48:23 WHICH ULTIMATELY  
GIVES US  
OUR ISOTOPIIC RATIO.  
579 00:54:48:25 00:54:51:23 *THE COMPLETE PROCESS*  
*OF COLLECTING ROCK SAMPLES,*  
580 00:54:51:25 00:54:53:23 *PREPARING THEM*  
*FOR ANALYSIS,*  
581 00:54:53:25 00:54:55:24 *AND DOING*  
*THE MASS SPECTROMETRY*  
582 00:54:55:26 00:54:59:16 *REQUIRES A GREAT DEAL*  
*OF TIME AND SKILL.*  
583 00:55:02:18 00:55:05:16 [JASON SALEEBY]  
THEN YOU FINALLY  
PUT THE FINAL DATA  
584 00:55:05:18 00:55:08:16 INTO YOUR COMPUTER  
AND CALCULATE YOUR AGE,  
585 00:55:08:18 00:55:11:17 AND IT ALL COMES  
TO SOMEWHAT  
OF A CRESCENDO  
586 00:55:11:19 00:55:13:17 AND YOU GET  
VERY EXCITED--  
587 00:55:13:19 00:55:15:05 FINALLY, YOU HAVE  
YOUR RESULTS.  
588 00:55:15:07 00:55:16:22 SOMETIMES YOU'RE  
TOTALLY SURPRISED,  
589 00:55:16:24 00:55:18:08 SOMETIMES  
YOU'RE DISAPPOINTED,  
590 00:55:18:10 00:55:21:00 AND SOMETIMES  
YOU'RE ELATED  
WITH YOUR RESULTS.  
591 00:55:21:02 00:55:24:00 AND THEN THE FINAL  
ASPECT OF IT  
592 00:55:24:02 00:55:26:17 IS REALLY APPLYING  
THE AGE DATA  
593 00:55:26:19 00:55:28:13 TO YOUR ACTUAL  
GEOLOGICAL RELATIONS.  
594 00:55:31:04 00:55:34:02 MINERALS WHICH CONTAIN  
RADIOACTIVE ISOTOPES  
595 00:55:34:04 00:55:37:02 ACT LIKE TINY CLOCKS  
INSIDE OF ROCKS,  
596 00:55:37:04 00:55:38:19 CLOCKS WHICH ARE RESET  
597 00:55:38:21 00:55:41:19 WHEN A ROCK IS FORMED

598 00:55:41:21 OR METAMORPHOSED.  
 00:55:43:19 BEFORE GEOLOGISTS LEARNED  
 TO MEASURE  
 599 00:55:43:21 00:55:46:18 THE ABSOLUTE AGES OF ROCKS  
 USING RADIOACTIVE ISOTOPES,  
 600 00:55:46:20 00:55:49:03 THEY COULD ONLY ESTABLISH  
 RELATIVE AGES  
 601 00:55:49:05 00:55:52:03 USING THE COMMON SENSE  
 LOGIC OF SUPERPOSITION,  
 602 00:55:52:05 00:55:53:21 ORIGINAL HORIZONTALITY,  
 603 00:55:53:23 00:55:55:06 AND CROSSCUTTING  
 RELATIONSHIPS.  
 604 00:55:55:08 00:55:58:06 THEY KNEW THAT ONE ROCK  
 FORMED BEFORE ANOTHER,  
 605 00:55:58:08 00:56:01:06 BUT NEVER HOW OLD THE ROCKS  
 ACTUALLY WERE.  
 606 00:56:01:08 00:56:04:05 THE RELIABILITY AND ACCURACY  
 OF RADIOMETRIC AGE DATING  
 607 00:56:04:07 00:56:05:22 IS TRULY IMPRESSIVE.  
 608 00:56:05:24 00:56:08:21 THE RESULTS OF OVER  
 HALF A CENTURY  
 609 00:56:08:23 00:56:10:21 OF RADIOMETRIC  
 AGE DATING STUDIES  
 610 00:56:10:23 00:56:12:06 ARE ENTIRELY CONSISTENT  
 611 00:56:12:08 00:56:14:06 WITH THE RELATIVE  
 AGE RELATIONSHIPS  
 612 00:56:14:08 00:56:15:28 DEVELOPED BY  
 EARLY GEOLOGISTS.  
 613 00:56:16:00 00:56:17:28 SO THE SCIENCE OF GEOLOGY  
 614 00:56:18:00 00:56:21:14 HAS GIVEN US TWO WAYS  
 TO UNDERSTAND EARTH HISTORY.  
 615 00:56:21:16 00:56:23:29 FIRST, WE DETERMINE  
 THE RELATIVE AGE  
 616 00:56:24:01 00:56:26:14 OF ROCK FORMATIONS  
 AND GEOLOGIC STRUCTURES  
 617 00:56:26:16 00:56:28:13 AND THEN USE THESE AGES  
 618 00:56:28:15 00:56:31:26 TO CONSTRUCT A HISTORIC  
 SEQUENCE OF EVENTS  
 THROUGH TIME.  
 619 00:56:31:28 00:56:34:26 THEN, BY APPLYING RADIOMETRIC  
 AGE DATING TECHNIQUES,  
 620 00:56:34:28 00:56:37:26 WE DETERMINE  
 THE ABSOLUTE TIMING  
 OF THESE EVENTS  
 621 00:56:37:28 00:56:40:26 AND MEASURE THE RATES  
 OF GEOLOGIC CHANGE AS WELL.  
 622 00:56:40:28 00:56:43:27 SO NOT ONLY  
 DOES OUR STUDY  
 OF GEOLOGIC TIME  
 623 00:56:43:29 00:56:46:12 ALLOW US TO UNDERSTAND  
 EARTH'S PAST,  
 624 00:56:46:14 00:56:48:11 IT GIVES US  
 A HISTORIC FRAMEWORK  
 625 00:56:48:13 00:56:51:10 AND THE TOOLS  
 FOR PREDICTING  
 THE PLANET'S FUTURE.

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