1 01:29:26:23 01:29:30:05 Annenberg Media
2 01:29:30:07 01:29:34:25 §
3 01:30:24:11 01:30:27:09 DRAMATIC LANDSCAPES
LIKE MOUNTAIN RANGES,
4 01:30:27:11 01:30:30:10 MID-OCEAN RIDGES,
AND THE GRAND CANYON
5 01:30:30:12 01:30:32:10 ARE CREATED
BY EXTRAORDINARY FORCES
6 01:30:32:12 01:30:34:14 IN THE EARTH'S CRUST.
7 01:30:34:16 01:30:36:09 THESE FORCES
GENERALLY ARISE
8 01:30:36:11 01:30:38:24 FROM THE MOVEMENT
OF TECTONIC PLATES,
9 01:30:38:26 01:30:41:09 AND THEY NOT ONLY
SHAPE THE LANDSCAPE,
10 01:30:41:11 01:30:44:24 THEY ALSO PERMANENTLY
DEFORM THE ROCKS
OF THE CRUST.
11 01:30:44:26 01:30:47:24 THE ROCKS EITHER BREAK,
OR UNDER
CERTAIN CIRCUMSTANCES,
12 01:30:47:26 01:30:50:25 ACTUALLY FLOW LIKE
A VERY THICK LIQUID.
13 01:30:50:27 01:30:53:24 WHEN ROCKS ARE DEFORMED
IN THIS WAY,
14 01:30:53:26 01:30:56:23 GEOLOGIC STRUCTURES
SUCH AS FAULTS AND FOLDS
ARE PRODUCED.
15 01:30:56:25 01:30:58:24 ROCK DEFORMATION
IS OFTEN ACCOMPANIED
16 01:30:58:26 01:31:01:09 BY VERTICAL MOTIONS
OF THE EARTH'S CRUST,
17 01:31:01:11 01:31:04:06 CAUSING IT EITHER
TO RISE OR SUBSIDE.
18 01:31:04:08 01:31:06:21 UNDERSTANDING
ROCK DEFORMATION
AND GEOLOGIC STRUCTURES
19 01:31:06:23 01:31:09:22 IS FUNDAMENTAL TO
THE SCIENCE OF GEOLOGY.
20 01:31:09:24 01:31:11:24 THESE STRUCTURES
ARE EVIDENCE
OF IMPORTANT EVENTS
21 01:31:11:26 01:31:13:09 IN EARTH HISTORY,
22 01:31:13:11 01:31:15:24 AND BECAUSE THEY ARE
OFTEN RESPONSIBLE
23 01:31:15:26 01:31:18:10 FOR CONCENTRATING
DEPOSITS
OF IMPORTANT RESOURCES,
24 01:31:18:12 01:31:21:25 INCLUDING PETROLEUM,
METALS,
AND GROUND WATER,
25 01:31:21:27 01:31:25:04 THEY CAN BE OF IMMENSE
ECONOMIC VALUE.
26 01:31:25:06 01:31:27:24 *GEOLOGIC STRUCTURES*
ARE PATTERNS
27 01:31:27:26 01:31:32:06 *IN THE ARRANGEMENT OF ROCK*

INSIDE THE EARTH.

28 01:31:32:08 01:31:35:07 *AMONG THE MOST COMMON PATTERNS IS PARALLEL LAYERING*

29 01:31:35:09 01:31:40:22 *SEEN IN SEDIMENTARY STRATA AND SOME VOLCANIC DEPOSITS.*

30 01:31:40:24 01:31:42:08 *ONE OF THE KEY INSIGHTS*

31 01:31:42:10 01:31:45:22 *LEADING TO THE BIRTH OF GEOLOGY AS A MODERN SCIENCE*

32 01:31:45:24 01:31:48:00 *CONCERNED THE NATURE OF THIS LAYERING.*

33 01:31:49:29 01:31:51:27 *IN THE EARLY 17th CENTURY,*

34 01:31:51:29 01:31:55:08 *NICOLAUS STENO, A DANISH MILITARY ENGINEER*

35 01:31:55:10 01:31:58:25 *LIVING IN ITALY, PUBLISHED AN IMPORTANT OBSERVATION.*

36 01:32:00:24 01:32:05:22 *HE NOTED THAT IN MOST PLACES AT THE BOTTOM OF WATER BODIES,*

37 01:32:05:24 01:32:08:22 *SEDIMENT SETTLES TO FORM CONTINUOUS FLAT-LYING LAYERS.*

38 01:32:08:24 01:32:12:23 *THIS EXPLAINS WHY YOUNG SEDIMENTARY STRATA*

39 01:32:12:25 01:32:14:08 *TEND TO BE HORIZONTAL*

40 01:32:14:10 01:32:16:22 *WITH THE YOUNGEST LAYER ON TOP*

41 01:32:16:24 01:32:19:07 *AND THE OLDEST AT THE BOTTOM.*

42 01:32:19:09 01:32:21:06 *STENO'S OBSERVATION BECAME KNOWN*

43 01:32:21:08 01:32:24:14 *AS THE PRINCIPLE OF ORIGINAL HORIZONTALITY.*

44 01:32:27:07 01:32:29:04 *GEOLOGISTS FIND THIS PRINCIPLE USEFUL*

45 01:32:29:06 01:32:32:05 *AS A BASIS FOR MEASURING HOW MUCH DEFORMATION*

46 01:32:32:07 01:32:34:06 *HAS OCCURRED IN ANCIENT STRATA.*

47 01:32:34:08 01:32:35:20 *IF LAYERS ARE FOLDED,*

48 01:32:35:22 01:32:37:05 *GEOLOGISTS ASSUME*

49 01:32:37:07 01:32:41:05 *THAT THE LAYERS WERE ONCE NEARLY HORIZONTAL,*

50 01:32:41:07 01:32:43:11 *AND THAT THE FOLDING CAME LATER.*

51 01:32:45:07 01:32:46:21 NICE JOINT SURFACE.

52 01:32:46:23 01:32:49:06 WE'RE ABOUT 30 FEET WEST.

53 01:32:49:08 01:32:52:02 *TO ACCURATELY MEASURE AND RECORD DEFORMATION,*

54 01:32:52:04 01:32:54:04 *GEOLOGISTS USE A SMALL INSTRUMENT*

55 01:32:54:06 01:32:57:03 *WHICH COMBINES A COMPASS WITH A HAND LEVEL.*

56 01:32:57:05 01:32:59:18 *THIS INSTRUMENT, CALLED A POCKET ALIDADE,*

57 01:32:59:20 01:33:02:05 *MEASURES TWO ASPECTS OF THE ORIENTATION*

58 01:33:02:07 01:33:04:06 *OF ANY TILTED LAYER--*

59 01:33:04:08 01:33:07:02 *THE STRIKE AND THE DIP.*

60 01:33:07:04 01:33:11:05 ONE OF THE THINGS WE ALWAYS
WANT TO DO WITH STRUCTURES

61 01:33:11:07 01:33:13:23 IS TO MEASURE THEIR ORIENTATION
IN THE FIELD.

62 01:33:13:25 01:33:17:22 THE WAY WE USUALLY DO THAT
IS TO MEASURE TWO ANGLES,

63 01:33:17:24 01:33:20:21 CALLED THE STRIKE
AND THE DIP OF A SURFACE.

64 01:33:20:23 01:33:23:21 I'LL TAKE THE UPPER BLOCK
AND REMOVE IT.

65 01:33:23:23 01:33:28:20 THEN WE CAN LOOK AT THE SURFACE
OF THE FAULT ITSELF HERE,

66 01:33:28:22 01:33:30:21 WHICH IS A PLANAR FEATURE.

67 01:33:30:23 01:33:33:01 OUR TWO ANGLES AGAIN
ARE THE STRIKE.

68 01:33:33:03 01:33:36:02 THE STRIKE IS MEASURED
FROM A HORIZONTAL LINE

69 01:33:36:04 01:33:39:04 LYING WITHIN THAT PLANE
TO TRUE NORTH,

70 01:33:39:06 01:33:42:04 SO IT'S AN ANGLE
BETWEEN THAT LINE

71 01:33:42:06 01:33:44:03 AND WHATEVER DIRECTION
NORTH IS,

72 01:33:44:05 01:33:46:17 AND IT FIXES
THE ORIENTATION OF THE PLANE

73 01:33:46:19 01:33:48:01 IN THIS DIRECTION.

74 01:33:48:03 01:33:50:18 THE OTHER ANGLE
WE NEED TO MEASURE

75 01:33:50:20 01:33:52:17 IS WHAT'S CALLED THE DIP.

76 01:33:52:19 01:33:54:19 THAT'S THE ANGLE
BETWEEN A LINE

77 01:33:54:21 01:33:56:04 PERPENDICULAR
TO THE STRIKE LINE

78 01:33:56:06 01:33:57:20 AND A HORIZONTAL PLANE.

79 01:33:57:22 01:34:00:03 IT'S AN ANGLE
FROM THE HORIZONTAL

80 01:34:00:05 01:34:01:18 DOWN TO THE PLANE,

81 01:34:01:20 01:34:04:08 AND IT FIXES
THE ORIENTATION OF THE PLANE

82 01:34:04:10 01:34:05:24 IN THIS DIRECTION. O.K.?

83 01:34:05:26 01:34:10:23 SO STRIKE FROM TRUE NORTH,
AND DIP FROM HORIZONTAL.

84 01:34:10:25 01:34:16:03 *GEOLOGIC MAPS REQUIRE MORE*
THAN STRIKE AND DIP SYMBOLS

85 01:34:16:05 01:34:18:21 *TO INDICATE DEFORMATION.*

86 01:34:18:23 01:34:21:03 *THEY ALSO INCLUDE FAULTS*
AND THE CONTACTS

87 01:34:21:05 01:34:24:06 *BETWEEN DIFFERENT LAYERS*
AND BODIES OF ROCK.

88 01:34:26:25 01:34:30:15 *WHEN COLORED IN, SUCH MAPS*
PROVIDE POWERFUL INSIGHTS

89 01:34:30:17 01:34:33:02 *INTO THE OVERALL*
GEOLOGICAL STRUCTURE

90 01:34:33:04 01:34:34:16 *OF AN AREA.*

91 01:34:37:18 01:34:41:16 TO LOCATE THE GEOLOGIC

STRUCTURES IN AN AREA LIKE THIS,
92 01:34:41:18 01:34:44:01 A GEOLOGIST FIRST LOOKS
FOR PATTERNS
93 01:34:44:03 01:34:47:02 IN THE DISTRIBUTION OF ROCKS
AT THE EARTH'S SURFACE.
94 01:34:47:04 01:34:49:17 BECAUSE SOIL AND VEGETATION
USUALLY CONCEAL ROCKS
95 01:34:49:19 01:34:51:02 WE NEED TO SEE,
96 01:34:51:04 01:34:53:16 THIS TYPE OF ANALYSIS
CAN'T BE DONE
97 01:34:53:18 01:34:56:01 FROM AN AIRPLANE
OR A SATELLITE.
98 01:34:56:03 01:34:57:15 INSTEAD, GEOLOGISTS
SPEND TIME
99 01:34:57:17 01:34:59:16 STUDYING ROCKS
ON THE GROUND.
100 01:34:59:18 01:35:01:16 INFORMATION ABOUT
INDIVIDUAL ROCK EXPOSURE
101 01:35:01:18 01:35:05:17 OR OUTCROP, IS RECORDED
THEN PLOTTED ON A BASE MAP.
102 01:35:05:19 01:35:07:17 CONSTRUCTED
OUTCROP BY OUTCROP,
103 01:35:07:19 01:35:11:03 THIS INFORMATION EVENTUALLY
BECOMES A GEOLOGIC MAP.
104 01:35:18:19 01:35:20:02 THE DIFFERENT COLORS SHOW
105 01:35:20:04 01:35:22:28 HOW ROCKS OF DIFFERENT TYPES
AND AGES ARE DISTRIBUTED
106 01:35:23:00 01:35:24:19 THROUGHOUT THE AREA.
107 01:35:24:21 01:35:29:01 THESE ROCKS ARE DESCRIBED HERE
IN THE MAP EXPLANATION.
108 01:35:29:03 01:35:31:24 FAULTS ARE SHOWN
AS DARK LINES.
109 01:35:34:21 01:35:35:29 AND SPECIAL SYMBOLS
INDICATE
110 01:35:36:01 01:35:39:08 WHERE ROCKS
ARE TILTED AND FOLDED.
111 01:35:44:02 01:35:45:29 HERE AT THE GRAND CANYON,
112 01:35:46:01 01:35:49:14 THE COLORADO RIVER HAS CUT DOWN
THROUGH THE ROCKS,
113 01:35:49:16 01:35:50:29 SHOWING US
WHAT'S UNDERGROUND,
114 01:35:51:01 01:35:52:29 BUT EXPOSURES LIKE THESE
ARE RARE.
115 01:35:53:01 01:35:55:00 IN MOST PLACES,
SURFACE INFORMATION
116 01:35:55:02 01:35:56:29 FROM THE GEOLOGIC MAP
IS USED
117 01:35:57:01 01:35:58:29 TO INFER THE UNDERGROUND
DISTRIBUTION
118 01:35:59:01 01:36:00:15 OF ROCKS AND STRUCTURES.
119 01:36:00:17 01:36:02:29 THAT'S DONE
WITH A GEOLOGIC CROSS-SECTION,
120 01:36:03:01 01:36:05:13 WHERE THE GEOLOGIST
HAS CONCEPTUALLY SLICED
121 01:36:05:15 01:36:09:14 THE EARTH OPEN TO REVEAL
THE STRUCTURE OF ITS INTERIOR.

122 01:36:09:16 01:36:12:15 *MANY DIFFERENT CROSS-SECTIONS CAN BE DRAWN*
123 01:36:12:17 01:36:15:14 *TO FIT THE SAME PATTERN OF SURFACE EXPOSURE.*
124 01:36:17:01 01:36:19:29 *BUT GEOLOGISTS RECOGNIZE THAT THE SIMPLEST ONE*
125 01:36:20:01 01:36:22:28 *USUALLY TURNS OUT TO BE THE MOST ACCURATE,*
126 01:36:23:00 01:36:25:24 *AND IN MOST CASES, EVIDENCE FROM DRILLING*
127 01:36:25:26 01:36:29:22 *OR SEISMIC SOUNDING VALIDATES THIS ASSUMPTION.*
128 01:36:32:02 01:36:35:29 *THE PROCESS OF CHOOSING THE SIMPLEST EXPLANATION*
129 01:36:36:01 01:36:37:27 *FROM A GROUP OF POSSIBILITIES*
130 01:36:37:29 01:36:40:18 *IS NOT UNIQUE TO GEOLOGY.*
131 01:36:40:20 01:36:43:18 *THIS APPROACH IS USED THROUGHOUT THE SCIENCES*
132 01:36:43:20 01:36:45:11 *FOR SOLVING DIFFERENT PROBLEMS.*
133 01:36:45:13 01:36:46:28 TWO SECONDS.
134 01:36:47:00 01:36:48:13 FAULT LOOKS GOOD.
135 01:36:48:15 01:36:50:28 *BUT DRAWING CROSS-SECTIONS INVOLVES MORE*
136 01:36:51:00 01:36:53:00 *THAN JUST APPLYING THIS TECHNIQUE.*
137 01:36:53:02 01:36:55:29 *A KNOWLEDGE OF COMMON TYPES OF GEOLOGICAL STRUCTURES*
138 01:36:56:01 01:36:58:02 *IS ALSO ESSENTIAL.*
139 01:36:59:17 01:37:02:28 *GEOLOGISTS RECOGNIZE THREE MAIN CLASSES OF STRUCTURE*
140 01:37:03:00 01:37:06:21 *CAUSED BY DEFORMATION IN EARTH'S CRUST--*
141 01:37:06:23 01:37:09:11 *UNCONFORMITIES,*
142 01:37:09:13 01:37:12:04 *FAULTS AND FRACTURES,*
143 01:37:12:06 01:37:14:04 *AND FOLDS.*
144 01:37:18:29 01:37:22:28 WE USUALLY THINK OF ROCKS AS BEING HARD AND BRITTLE.
145 01:37:23:00 01:37:26:26 THEY BREAK WHEN A FORCE SUCH AS A HAMMER BLOW
146 01:37:26:28 01:37:29:10 EXCEEDS THE STRENGTH OF THE ROCK ITSELF,
147 01:37:29:12 01:37:32:25 BUT IF ROCKS ARE HOT OR UNDER GREAT PRESSURE,
148 01:37:32:27 01:37:35:09 OR IF THEY'RE EXPOSED TO STRESS GRADUALLY
149 01:37:35:11 01:37:37:10 OVER A LONG PERIOD OF TIME,
150 01:37:37:12 01:37:39:26 A SURPRISING TYPE OF DEFORMATION TAKES PLACE.
151 01:37:39:28 01:37:42:25 THE ROCKS CAN ACTUALLY BEND OR FLOW,
152 01:37:42:27 01:37:45:12 FORMING A GEOLOGIC STRUCTURE CALLED A FOLD.
153 01:37:45:14 01:37:48:14 *FOLDED STRATA CAN ASSUME*

MANY DIFFERENT SHAPES,

154 01:37:48:16 01:37:52:03 *RANGING IN SIZE*
FROM A FEW CENTIMETERS

155 01:37:52:05 01:37:54:10 *TO SEVERAL KILOMETERS ACROSS.*

156 01:37:56:06 01:37:59:03 *AMONG THE MANY COMPLEX PATTERNS*
OF FOLDING, HOWEVER,

157 01:37:59:05 01:38:03:21 *GEOLOGISTS RECOGNIZE*
SEVERAL BASIC FORMS.

158 01:38:03:23 01:38:08:10 *THESE INCLUDE SYNCLINES,*
WITH DOWN-FOLDED LAYERING,

159 01:38:08:12 01:38:12:13 *AND ANTICLINES,*
HAVING UP-FOLDED LAYERING.

160 01:38:12:15 01:38:16:28 *THE LINE OF GREATEST CURVATURE*
ALONG ANY LAYER IN A FOLD

161 01:38:17:00 01:38:20:09 *IS CALLED THE FOLD HINGE.*

162 01:38:20:11 01:38:23:08 *LINKED TOGETHER,*
THE MANY DIFFERENT HINGE LINES

163 01:38:23:10 01:38:27:07 *OF A FOLD MAKE UP*
THE FOLD'S HINGE PLANE.

164 01:38:27:09 01:38:28:27 *IN AN OUTCROP,*

165 01:38:28:29 01:38:34:09 *THE POSITION OF THE HINGE PLANE*
CAN BE SEEN AT A GLANCE.

166 01:38:34:11 01:38:36:24 *THE ORIENTATION*
OF THE HINGES

167 01:38:36:26 01:38:39:08 *AND HINGE PLANE*
OF A FOLD,

168 01:38:39:10 01:38:41:08 *AND THE AMOUNT*
OF FOLDING ITSELF,

169 01:38:41:10 01:38:45:08 *SERVE AS A BASIS FOR FURTHER*
CLASSIFYING THE FOLD.

170 01:38:45:10 01:38:48:09 WE CAN CLASSIFY FOLDS
BASED ON THEIR ORIENTATIONS,

171 01:38:48:11 01:38:52:09 WHETHER CERTAIN PARTS
OF THE FOLD TEND TO BE UPRIGHT

172 01:38:52:11 01:38:56:07 OR WE COULD TURN THE FOLD
OVER, OR ON ITS SIDE.

173 01:38:56:09 01:38:59:08 THOSE WOULD ALL BE
DIFFERENT TYPES OF FOLDS

174 01:38:59:10 01:39:01:08 AND GIVE US DIFFERENT
INFORMATION.

175 01:39:01:10 01:39:05:09 WE CAN ALSO LOOK AT
THE GEOMETRIES OF THE FOLDS.

176 01:39:05:11 01:39:08:09 FOR INSTANCE, WE CAN LOOK
AT HOW TIGHT

177 01:39:08:11 01:39:09:23 THE LAYERING IS FOLDED.

178 01:39:09:25 01:39:12:23 HERE'S SOMETHING WHERE
THE LAYERING IS RATHER OPEN.

179 01:39:12:25 01:39:16:07 WE GET THESE CURVED HINGES
IN HERE

180 01:39:16:09 01:39:18:08 AND VERY PLANAR LIMBS.

181 01:39:19:28 01:39:22:26 WE COULD CONTRAST
THIS TYPE OF FOLD

182 01:39:22:28 01:39:26:08 WITH SOMETHING
THAT LOOKED LIKE THIS

183 01:39:26:10 01:39:28:08 WHERE THE FOLDS
ARE MUCH TIGHTER,

184 01:39:28:10 01:39:31:08 UH, YOU COULD
PROBABLY GUESS
185 01:39:31:10 01:39:33:18 FROM COMPARING
THESE TWO ROCKS
186 01:39:33:20 01:39:36:09 THAT THIS ONE'S
BEEN DEFORMED A LOT MORE
187 01:39:36:11 01:39:38:24 OR SHORTENED MORE
IN THIS DIRECTION
188 01:39:38:26 01:39:40:24 THAN THE OTHER FOLD
I SHOWED YOU.
189 01:39:40:26 01:39:43:23 THE SAME TECTONIC FORCES
THAT FOLD ROCKS
190 01:39:43:25 01:39:46:08 CAN ALSO CAUSE ROCKS
TO BREAK.
191 01:39:46:10 01:39:48:23 ROCKS TEND TO FRACTURE
INSTEAD OF FOLD
192 01:39:48:25 01:39:51:10 WHEN THE FORCE
IS APPLIED RAPIDLY.
193 01:39:51:12 01:39:55:10 THIS IS ESPECIALLY TRUE
IN THE SHALLOW PORTIONS
OF EARTH'S CRUST,
194 01:39:55:12 01:39:58:08 WHERE ROCKS
ARE RELATIVELY COLD
AND UNDER LOW PRESSURE.
195 01:39:58:10 01:40:00:22 WHEN TECTONIC STRESS
IS APPLIED CONSTANTLY
196 01:40:00:24 01:40:02:23 OVER A LONG PERIOD
OF TIME,
197 01:40:02:25 01:40:05:23 THE FRACTURES
ARE CONCENTRATED
ALONG A DISCREET ZONE
198 01:40:05:25 01:40:07:10 CALLED A FAULT.
199 01:40:07:12 01:40:10:10 SOME FAULTS REMAIN ACTIVE
FOR MILLIONS OF YEARS,
200 01:40:10:12 01:40:13:09 RESULTING IN HUNDREDS
OR EVEN THOUSANDS
OF KILOMETERS
201 01:40:13:11 01:40:14:10 OF DISPLACEMENT,
202 01:40:14:12 01:40:16:09 AND FAULT MOVEMENT
GENERALLY OCCURS
203 01:40:16:11 01:40:19:07 IN A SERIES
OF STEPS OR JUMPS,
204 01:40:19:09 01:40:21:15 GENERATING
A SERIES OF EARTHQUAKES.
205 01:40:21:17 01:40:24:21 *LIKE FOLDS,*
FAULTS ARE CLASSIFIED
206 01:40:24:23 01:40:27:06 *ACCORDING TO*
THEIR PHYSICAL ORIENTATION.
207 01:40:27:08 01:40:30:01 *THIS INCLUDES THE DIP*
OF THE FAULT PLANE
208 01:40:30:03 01:40:32:29 *AND THE DIRECTION OF OFFSET*
CREATED BY MOVEMENT
209 01:40:33:01 01:40:34:19 *ALONG THE FAULT.*
210 01:40:38:09 01:40:39:24 *FOR EXAMPLE,*
211 01:40:39:26 01:40:42:17 *RUPTURES ALONG WHICH*
VERTICAL MOTION HAS OCCURRED

212 01:40:42:19 01:40:45:03 *ARE CALLED DIP-SLIP FAULTS.*
213 01:40:46:23 01:40:49:22 *RUPTURES ALONG WHICH*
HORIZONTAL MOTION HAS OCCURRED
214 01:40:49:24 01:40:52:05 *ARE CALLED*
STRIKE-SLIP FAULTS.
215 01:40:54:23 01:40:56:21 *MANY FAULTS*
SHOW SOME COMBINATION
216 01:40:56:23 01:41:00:09 *OF BOTH DIP-SLIP*
AND STRIKE-SLIP MOTION.
217 01:41:00:11 01:41:03:22 *THESE ARE CALLED*
OBLIQUE-SLIP FAULTS.
218 01:41:05:08 01:41:07:21 *GEOLOGISTS*
HAVE FOUND IT USEFUL
219 01:41:07:23 01:41:10:25 *TO SUBDIVIDE FAULT TYPES*
EVEN FURTHER.
220 01:41:12:11 01:41:14:21 *STRIKE-SLIP FAULTS,*
FOR EXAMPLE, ARE SUBDIVIDED
221 01:41:14:23 01:41:17:22 *ACCORDING TO WHETHER*
THEIR DIRECTION OF OFFSET
222 01:41:17:24 01:41:20:22 *IS TO THE LEFT*
OR THE RIGHT.
223 01:41:22:07 01:41:25:25 *IN THE CASE OF STEEPLY-INCLINED*
DIP-SLIP FAULTING,
224 01:41:25:27 01:41:28:28 *THERE ARE TWO MAIN TYPES.*
225 01:41:29:00 01:41:31:19 WE CAN HAVE WHAT WE CALL
REVERSE FAULTS,
226 01:41:31:21 01:41:34:21 WHERE THE BLOCK
ABOVE THE FAULT SURFACE
227 01:41:34:23 01:41:37:27 IS MOVING UP RELATIVE
TO THE LOWER BLOCK.
228 01:41:37:29 01:41:39:13 THE OTHER POSSIBILITY,
OBVIOUSLY,
229 01:41:39:15 01:41:41:06 IS THAT WE CAN TAKE
THIS UPPER BLOCK
230 01:41:41:08 01:41:46:03 AND MOVE IT DOWN, WHICH
WE CALL A NORMAL FAULT. O.K.?
231 01:41:46:05 01:41:49:18 WE CAN ALSO, IF WE TAKE
THAT THIRD ORIENTATION,
232 01:41:49:20 01:41:53:18 WHERE I ROTATE MY FAULT SURFACE
TO A HORIZONTAL DIRECTION,
233 01:41:53:20 01:41:55:19 OR OFTEN, THEY'RE NOT
PERFECTLY HORIZONTAL,
234 01:41:55:21 01:41:58:04 BUT THE DIP IS VERY LOW,
235 01:41:58:06 01:42:00:19 WE'LL HAVE
WHAT WE CALL THRUST FAULTS.
236 01:42:00:21 01:42:02:18 IF MY UPPER BLOCK
MOVES UP
237 01:42:02:20 01:42:05:04 WITH RESPECT
TO THE LOWER BLOCK--
238 01:42:05:06 01:42:08:04 IF WE MOVE IT
IN THE OTHER DIRECTION
239 01:42:08:06 01:42:10:28 SO THE UPPER BLOCK'S
MOVING DOWN THE DIP
240 01:42:11:00 01:42:12:20 OF MY LOW-ANGLE SURFACE,
241 01:42:12:22 01:42:15:04 WE CAN HAVE
LOW-ANGLE DETACHMENT FAULTS.

242 01:42:15:06 01:42:19:18 IN EACH CASE, WE ARE CHANGING
THE SHAPE OF THE ROCK
243 01:42:19:20 01:42:21:03 IN A DIFFERENT WAY
244 01:42:21:05 01:42:23:17 DEPENDING ON THE ORIENTATION
OF THE FAULT SURFACE
245 01:42:23:19 01:42:25:01 AND THE DIRECTION
OF DISPLACEMENT.
246 01:42:25:03 01:42:28:06 *THE MANY CATEGORIES*
OF FOLDS AND FAULTS
247 01:42:28:08 01:42:29:21 *WERE DEVELOPED*
248 01:42:29:23 01:42:33:02 *LONG BEFORE GEOLOGISTS*
HAD A CLEAR KNOWLEDGE
249 01:42:33:04 01:42:36:00 *OF HOW AND WHY*
THESE STRUCTURES FORMED.
250 01:42:36:02 01:42:38:29 *EVEN TODAY, THE ORIGIN*
OF MANY GEOLOGIC STRUCTURES
251 01:42:39:01 01:42:40:23 *IS NOT FULLY UNDERSTOOD.*
252 01:42:42:18 01:42:45:07 *BUT GEOLOGISTS DO KNOW*
THAT STRESS,
253 01:42:45:09 01:42:48:26 *WHICH IS A CONCENTRATION*
OF FORCE, PLAYS A ROLE.
254 01:42:51:04 01:42:54:16 COMPRESSIONAL
AND TENSIONAL STRESSES--
255 01:42:54:18 01:42:56:16 WE'RE REALLY TALKING
ABOUT THE STRESSES
256 01:42:56:18 01:42:58:02 AROUND A POINT
257 01:42:58:04 01:43:01:03 OR THE STRESSES OPERATING
ON A BLOCK OF ROCK.
258 01:43:01:05 01:43:04:03 I MIGHT USE MY LITTLE
FOAM MODEL HERE.
259 01:43:04:05 01:43:07:02 IN THE CASE OF
COMPRESSIONAL STRESSES,
260 01:43:07:04 01:43:09:01 THAT'S WHERE
WE HAVE STRESSES
261 01:43:09:03 01:43:12:02 DIRECTED TOWARDS
OUR LITTLE BLOCK OF ROCK
262 01:43:12:04 01:43:14:01 IN EVERY DIRECTION. O.K.?
263 01:43:14:03 01:43:19:03 SO IT'S SQUEEZING THE ROCK
IN ALL THREE DIMENSIONS.
264 01:43:19:05 01:43:21:17 TENSIONAL STRESSES
ARE THE EXACT OPPOSITE.
265 01:43:21:19 01:43:24:01 INSTEAD OF SQUEEZING
THE ROCK TOGETHER,
266 01:43:24:03 01:43:27:00 THEY'RE TRYING TO PULL
THE ROCK APART.
267 01:43:27:02 01:43:29:00 THE STRESSES
ARE DIRECTED OUTWARD,
268 01:43:29:02 01:43:30:29 AWAY FROM THE ROCK.
269 01:43:33:02 01:43:35:29 *GEOLOGIC STRUCTURES*
LIKE FOLDS AND FAULTS
270 01:43:36:01 01:43:38:01 *ARE EXAMPLES OF STRAIN--*
271 01:43:38:03 01:43:41:01 *A CHANGE IN*
THE SHAPE OF A ROCK
272 01:43:41:03 01:43:42:15 *CAUSED BY STRESS.*
273 01:43:43:24 01:43:46:21 STRESS IS THE APPLICATION
OF FORCE ON AN AREA.

274 01:43:46:23 01:43:49:00 IF YOU LEAN
AGAINST A WALL,
275 01:43:49:02 01:43:50:27 YOU'RE PUTTING SOME
STRESS ON IT.
276 01:43:50:29 01:43:53:12 STRAIN IS WHEN
THE WALL MOVES.
277 01:43:53:14 01:43:56:09 STRAIN IS THE CHANGE
IN SHAPE OR VOLUME.
278 01:43:56:11 01:43:59:15 PLASTIC STRAIN IS WHERE
A STRESS HAS BEEN APPLIED
279 01:43:59:17 01:44:01:14 TO AN OBJECT,
AND IT'S DEFORMED
280 01:44:01:16 01:44:03:15 AND STAYS IN
THAT SAME SHAPE.
281 01:44:03:17 01:44:05:15 IT DOESN'T RESUME
ITS ORIGINAL SHAPE.
282 01:44:05:17 01:44:09:00 ELASTIC STRAIN IS WHERE
THE OBJECT IS DEFORMED,
283 01:44:09:02 01:44:11:16 AND THEN WHEN
THE STRESS IS REMOVED,
284 01:44:11:18 01:44:13:16 IT RETURNS TO ITS
ORIGINAL SHAPE.
285 01:44:13:18 01:44:16:00 IF YOU EXCEED
ITS ELASTIC LIMIT,
286 01:44:16:02 01:44:19:00 THEN THE OBJECT
WILL BREAK AND SHATTER.
287 01:44:19:02 01:44:21:14 THUS, WHEN WE SEE
FOLDED ROCKS,
288 01:44:21:16 01:44:24:22 THEY HAVE BEEN SUBJECTED
TO A PLASTIC STRAIN.
289 01:44:24:24 01:44:27:13 FRACTURING OCCURS
WHEN THE STRAIN EXCEEDS
290 01:44:27:15 01:44:30:29 THE ELASTIC LIMITS
OF THE MATERIAL
291 01:44:31:01 01:44:33:13 AND THE ROCK BREAKS
OR FRACTURES.
292 01:44:35:15 01:44:37:13 *DIFFERENT TYPES*
OF GEOLOGIC STRUCTURES
293 01:44:37:15 01:44:39:28 *RESULT FROM DIFFERENT*
TYPES OF STRESS.
294 01:44:40:00 01:44:41:28 *FOR EXAMPLE,*
SHEAR STRESS,
295 01:44:42:00 01:44:46:29 *IN WHICH ONE MASS OF CRUST*
SLIPS LATERALLY PAST ANOTHER,
296 01:44:47:01 01:44:52:09 *CAUSES VERY LARGE*
STRIKE-SLIP FAULTS TO FORM.
297 01:44:52:11 01:44:56:28 *AND MOST FOLDS ARE FORMED*
BY COMPRESSIVE STRESS.
298 01:44:57:00 01:44:59:27 *WHERE THE STRESS OCCURS*
IS ALSO SIGNIFICANT.
299 01:45:01:14 01:45:03:14 WHEN WE TALK
ABOUT STRESSES
300 01:45:03:16 01:45:05:16 AND DIFFERENT TYPES
OF STRUCTURES,
301 01:45:05:18 01:45:07:13 WHEN WE'RE LOOKING
AT STRUCTURES

302 01:45:07:15 01:45:08:28 FORMING AT DEPTH,
303 01:45:09:00 01:45:11:13 BELOW THE SURFACE
OF THE EARTH,
304 01:45:11:15 01:45:13:27 JUST BECAUSE OF
THE OVERLYING WEIGHT
305 01:45:13:29 01:45:15:13 OF THE BODY OF ROCK,
306 01:45:15:15 01:45:17:18 WE'RE USUALLY DEALING
WITH COMPRESSIVE STRESSES.
307 01:45:17:20 01:45:20:14 THE TYPES OF STRUCTURES
WE GET THERE
308 01:45:20:16 01:45:21:29 ARE JUST A REFLECTION
309 01:45:22:01 01:45:24:11 OF THE DIFFERENT
MAGNITUDES OF STRESSES,
310 01:45:24:13 01:45:27:22 COMPRESSIVE STRESSES
IN DIFFERENT DIRECTIONS.
311 01:45:27:24 01:45:30:25 WHEN WE NEAR THE SURFACE
OF THE EARTH,
312 01:45:30:27 01:45:32:26 WE'RE DEALING WITH
A FREE SURFACE
313 01:45:32:28 01:45:35:11 WITH NO OVERLYING
WEIGHT OF ROCK.
314 01:45:35:13 01:45:38:16 WE CAN SOMETIMES GET
TENSIONAL STRESSES.
315 01:45:38:18 01:45:41:15 THESE STRESSES WILL TRY
TO PULL APART OUR ROCK
316 01:45:41:17 01:45:43:00 IN SOME DIRECTION.
317 01:45:43:02 01:45:44:26 UNDER THOSE CIRCUMSTANCES,
318 01:45:44:28 01:45:47:26 WE CAN GET THINGS
LIKE JOINTS OR FRACTURES
319 01:45:47:28 01:45:52:11 OR LITTLE VEINS OF DIFFERENT
TYPES OF MINERALS
320 01:45:52:13 01:45:54:12 THAT FLOAT INTO
THESE FRACTURES,
321 01:45:54:14 01:45:56:27 THAT DO GIVE US
SOME CLUES
322 01:45:56:29 01:45:58:26 ABOUT THE DIRECTIONS
AND MAGNITUDE
323 01:45:58:28 01:46:01:05 OF TENSIONAL STRESSES.
324 01:46:01:07 01:46:04:25 AND SO JUST BY LOOKING AT
DIFFERENT TYPES OF STRUCTURES
325 01:46:04:27 01:46:07:26 OR FOLDS OR JOINTS
OR THINGS LIKE THAT,
326 01:46:07:28 01:46:09:27 WE CAN GET SOME
CLUES ABOUT
327 01:46:09:29 01:46:11:26 WHAT THE STRESS FIELD
WAS LIKE
328 01:46:11:28 01:46:14:12 DURING THE TIME THAT
THESE STRUCTURES FORMED.
329 01:46:16:13 01:46:17:26 *UNCONFORMITIES,*
330 01:46:17:28 01:46:20:11 *THE THIRD GREAT CLASS*
OF GEOLOGIC STRUCTURE,
331 01:46:20:13 01:46:23:08 *ARE NOT AS USEFUL*
AS FOLDS AND FAULTS
332 01:46:23:10 01:46:25:08 *IN ANALYZING*
PAST CRUSTAL STRESS.
333 01:46:27:11 01:46:29:08 *NONETHELESS, THEY TOO*

HAVE PROVEN

334 01:46:29:10 01:46:32:09 *TO BE AN IMPORTANT*
KEY TO THE PAST.

335 01:46:34:03 01:46:36:09 JUST AS ASTRONOMERS
ARE PREOCCUPIED

336 01:46:36:11 01:46:38:09 WITH THE IMMENSITY
OF SPACE,

337 01:46:38:11 01:46:40:23 GEOLOGISTS ARE UNIQUELY
FASCINATED WITH TIME

338 01:46:40:25 01:46:42:09 AND EARTH HISTORY.

339 01:46:42:11 01:46:44:08 THE FIRST GEOLOGIST
TO ACTUALLY RECOGNIZE

340 01:46:44:10 01:46:46:25 THE SCALE OF GEOLOGIC TIME

341 01:46:46:27 01:46:50:02 WAS A SCOTTISH INTELLECTUAL
NAMED JAMES HUTTON.

342 01:46:50:04 01:46:51:16 OVER A CENTURY AGO,

343 01:46:51:18 01:46:54:09 HUTTON RECOGNIZED THAT
A SEQUENCE OF LAYERED ROCKS

344 01:46:54:11 01:46:57:24 IS A PHYSICAL RECORD OF
SOME PORTION OF EARTH HISTORY.

345 01:46:57:26 01:46:59:09 HE ALSO PREDICTED

346 01:46:59:11 01:47:01:25 THAT IN PLACES WHERE
MOUNTAIN-BUILDING HAS OCCURRED,

347 01:47:01:27 01:47:04:25 PART OF THAT RECORD
WOULD BE DESTROYED BY EROSION.

348 01:47:04:27 01:47:06:10 ARMED WITH THIS
HYPOTHESIS,

349 01:47:06:12 01:47:09:09 HUTTON FOUND PLACES
WHERE OLD ROCKS HAD BEEN

350 01:47:09:11 01:47:11:24 COVERED BY MUCH YOUNGER
SEDIMENTARY ROCKS.

351 01:47:11:26 01:47:14:24 THE CONTACT BETWEEN
THESE TWO ROCK FORMATIONS

352 01:47:14:26 01:47:17:08 MARKED A PERIOD
OF EARTH HISTORY

353 01:47:17:10 01:47:18:22 WITH NO ROCK RECORD.

354 01:47:18:24 01:47:21:18 THIS GEOLOGIC STRUCTURE
IS CALLED AN UNCONFORMITY.

355 01:47:21:20 01:47:23:01 UNCONFORMITIES ARE FORMED

356 01:47:23:03 01:47:25:22 WHEN ROCK IS FIRST
REMOVED BY EROSION,

357 01:47:25:24 01:47:28:22 FOLLOWED BY BURIAL
OF THE EROSION SURFACE

358 01:47:28:24 01:47:30:15 BY YOUNGER
SEDIMENTARY ROCKS.

359 01:47:30:17 01:47:32:00 THE HORIZONTAL CONTACT

360 01:47:32:02 01:47:34:01 SEPARATING THE LOWER
DARK ROCKS

361 01:47:34:03 01:47:36:15 FROM THE OVERLYING
CHOCOLATE-BROWN ROCKS

362 01:47:36:17 01:47:39:22 IS THE GREAT UNCONFORMITY
OF THE GRAND CANYON.

363 01:47:39:24 01:47:43:08 THE LOWER ROCKS ARE OVER
1.5 BILLION YEARS OLD.

364 01:47:43:10 01:47:45:22 AFTER THEY WERE DEPOSITED
AS SEDIMENTS,

365 01:47:45:24 01:47:48:06 THEY WERE DEFORMED
AND TECTONICALLY UPLIFTED
366 01:47:48:08 01:47:50:12 DURING A MOUNTAIN-BUILDING
EPISODE.
367 01:47:50:14 01:47:53:11 EROSION THEN CARVED AWAY
AT THESE ROCKS,
368 01:47:53:13 01:47:55:06 UNTIL SEA LEVEL
FINALLY ROSE
369 01:47:55:08 01:47:58:08 AND FLOODED THE AREA
ABOUT 500 MILLION YEARS AGO.
370 01:47:58:10 01:47:59:22 THE YOUNGER ROCK LAYERS
371 01:47:59:24 01:48:01:07 COVERING THE
UNCONFORMITY SURFACE
372 01:48:01:09 01:48:03:07 ARE SANDSTONES
THAT WERE DEPOSITED
373 01:48:03:09 01:48:05:06 AT THE BOTTOM
OF THAT SEA.
374 01:48:05:08 01:48:06:21 THE GREAT UNCONFORMITY
375 01:48:06:23 01:48:09:22 REPRESENTS ABOUT A BILLION
YEARS OF GEOLOGIC TIME
376 01:48:09:24 01:48:11:23 AND REVEALS
AN IMPORTANT CHAPTER
377 01:48:11:25 01:48:14:22 IN THE GEOLOGIC HISTORY
OF THE GRAND CANYON.
378 01:48:17:09 01:48:18:23 *THE CLASSIFICATION*
OF UNCONFORMITIES
379 01:48:18:25 01:48:22:20 *IS LESS COMPLEX THAN*
THAT OF FOLDS AND FAULTS.
380 01:48:22:22 01:48:26:04 *EROSION, RATHER THAN STRESS,*
CAUSES THEM TO FORM.
381 01:48:28:07 01:48:30:21 THERE'S THREE KINDS
OF UNCONFORMITIES,
382 01:48:30:23 01:48:33:05 THREE MAJOR KINDS
OF UNCONFORMITIES.
383 01:48:33:07 01:48:34:21 THE MOST READILY
RECOGNIZED
384 01:48:34:23 01:48:36:20 IS CALLED
AN ANGULAR UNCONFORMITY,
385 01:48:36:22 01:48:38:20 WHERE YOU HAVE
SEDIMENTARY ROCKS.
386 01:48:38:22 01:48:40:04 THOSE BENEATH
THE UNCONFORMITY
387 01:48:40:06 01:48:42:20 HAVE BEEN TILTED
AT AN ANGLE,
388 01:48:42:22 01:48:44:05 THEY HAVE BEEN ERODED
389 01:48:44:07 01:48:46:08 THEN OVERLAIN
BY HORIZONTAL ROCKS.
390 01:48:46:10 01:48:49:06 THE IMPLICATION IS THEN
THAT THE SEDIMENTARY ROCKS,
391 01:48:49:08 01:48:52:20 WHICH WERE ORIGINALLY
DEPOSITED HORIZONTALLY--
392 01:48:52:22 01:48:55:05 IN ACCORDANCE WITH THE LAW
OF ORIGINAL HORIZONTALITY--
393 01:48:55:07 01:48:57:04 HAVE BEEN DEFORMED
BY STRUCTURAL FORCES,
394 01:48:57:06 01:48:58:10 TECTONICS, UPLIFT,

395 01:48:58:12 01:49:00:20 AND THEN EROSION
HAS TAKEN OVER,
396 01:49:00:22 01:49:02:21 TRUNCATED AND CUT OFF
THE EDGES.
397 01:49:02:23 01:49:04:06 LATER THE SEAS RETURNED
398 01:49:04:08 01:49:07:06 AND NEW LAYERS WERE
DEPOSITED ON TOP OF THEM.
399 01:49:07:08 01:49:09:05 THE IMPLICATIONS OF
AN ANGULAR UNCONFORMITY
400 01:49:09:07 01:49:11:19 IS THAT THERE WAS
A GREAT TIME LAPSE
401 01:49:11:21 01:49:13:01 BETWEEN THE ORIGINAL
DEPOSITION
402 01:49:13:03 01:49:14:16 AND THE SUBSEQUENT
DEPOSITION.
403 01:49:14:18 01:49:17:15 IT TELL US A LOT
OF HISTORY HAS TAKEN PLACE,
404 01:49:17:17 01:49:20:00 AND MUCH OF IT'S MISSING,
BECAUSE OF EROSION.
405 01:49:20:02 01:49:21:14 ANOTHER KIND
OF UNCONFORMITY
406 01:49:21:16 01:49:22:29 IS THE NONCONFORMITY.
407 01:49:23:01 01:49:25:26 THIS ONE REPRESENTS
THE GREATEST LAPSE OF TIME
408 01:49:25:28 01:49:28:10 BETWEEN THE FORMATION
OF THE UNDERLYING ROCKS
409 01:49:28:12 01:49:29:25 AND THE OVERLYING ROCKS.
410 01:49:29:27 01:49:32:20 NONCONFORMITIES ARE THOSE
IN WHICH CRYSTALLINE ROCKS--
411 01:49:32:22 01:49:35:04 EITHER METAMORPHIC
OR IGNEOUS ROCKS,
412 01:49:35:06 01:49:37:06 PRIMARILY PLUTONIC ROCKS--
413 01:49:37:08 01:49:39:21 ARE OVERLAIN BY
SEDIMENTARY ROCKS.
414 01:49:39:23 01:49:41:29 PLUTONIC ROCKS
AND METAMORPHIC ROCKS
415 01:49:42:01 01:49:43:25 FORM DEEP IN THE EARTH--
416 01:49:43:27 01:49:45:20 10, 15 KILOMETERS DEEP--
417 01:49:45:22 01:49:49:05 AND IN ORDER FOR THEM
TO BE AT THE SURFACE,
418 01:49:49:07 01:49:51:21 THERE HAS TO HAVE BEEN
THE REMOVAL
419 01:49:51:23 01:49:53:06 OF ALL THE OVERLYING ROCKS.
420 01:49:53:08 01:49:55:06 THIS TAKES MANY
MILLIONS OF YEARS,
421 01:49:55:08 01:49:57:05 MAYBE TENS OF MILLIONS
OF YEARS,
422 01:49:57:07 01:49:59:20 AND EVENTUALLY THOSE ROCKS
REACH THE SURFACE,
423 01:49:59:22 01:50:01:04 WHERE THEY'RE EXPOSED
TO EROSION.
424 01:50:01:06 01:50:03:05 A RETURN OF THE OCEANS
425 01:50:03:07 01:50:05:05 WILL RESULT IN
SEDIMENTARY ROCKS
426 01:50:05:07 01:50:07:06 BEING DEPOSITED
ON TOP OF THEM,

427 01:50:07:08 01:50:10:05 SO THE TIME LAPSE THERE IS IMMENSE,
428 01:50:10:07 01:50:13:05 AND THE NUMBER OF EVENTS THAT HAVE OCCURRED
429 01:50:13:07 01:50:15:05 ARE REALLY PHENOMENAL.
430 01:50:15:07 01:50:18:04 WHOLE MOUNTAIN RANGES ARE BUILT AND THEN WORN AWAY
431 01:50:18:06 01:50:19:19 AND THEN COVERED OVER.
432 01:50:20:26 01:50:22:18 ANOTHER KIND OF UNCONFORMITY
433 01:50:22:20 01:50:24:03 IS THE DISCONFORMITY,
434 01:50:24:05 01:50:26:17 WHERE THE LAPSE BETWEEN THE DEPOSITION
435 01:50:26:19 01:50:29:18 OF THE UNDERLYING LAYERS AND THE OVERLYING LAYERS
436 01:50:29:20 01:50:31:04 HAS BEEN VERY SHORT,
437 01:50:31:06 01:50:33:18 SO THAT THE LAYERS ABOVE AND BELOW
438 01:50:33:20 01:50:35:17 ARE PRETTY CLOSE TO PARALLEL,
439 01:50:35:19 01:50:38:03 AND THERE'S JUST A SLIGHT DISCORDANCE
440 01:50:38:05 01:50:39:19 BETWEEN THE TWO--
441 01:50:39:21 01:50:43:17 PERHAPS A SOIL PROFILE OR A LITTLE BROKEN-UP MATERIAL.
442 01:50:43:19 01:50:46:18 THEY'RE A LITTLE BIT MORE DIFFICULT TO RECOGNIZE.
443 01:50:46:20 01:50:50:03 A SHORTER TIME LAPSE HAS BEEN LOST IN THE RECORD,
444 01:50:50:05 01:50:53:04 SO THEY ARE NOT AS EASILY SEEN.
445 01:50:54:20 01:50:56:03 *BY IDENTIFYING FOSSILS,*
446 01:50:56:05 01:50:58:19 *OR THROUGH RADIOMETRIC AGE-DATING,*
447 01:50:58:21 01:51:00:06 *GEOLOGISTS CAN FIND OUT*
448 01:51:00:08 01:51:04:04 *APPROXIMATELY WHEN AN EXPOSED UNCONFORMITY DEVELOPED.*
449 01:51:04:06 01:51:06:03 *BECAUSE UNCONFORMITIES ARE CREATED*
450 01:51:06:05 01:51:09:02 *BY IMPORTANT CHANGES IN THE GEOLOGIC ENVIRONMENT,*
451 01:51:09:04 01:51:10:17 *KNOWING WHEN THEY FORMED*
452 01:51:10:19 01:51:13:03 *HELPS GEOLOGISTS CONSTRUCT A CHRONOLOGY*
453 01:51:13:05 01:51:16:02 *OF PAST EVENTS IN EARTH'S HISTORY.*
454 01:51:18:06 01:51:20:03 *GEOLOGIC STRUCTURES ARE ALSO USEFUL*
455 01:51:20:05 01:51:23:16 *NOT ONLY FOR WHAT THEY REVEAL ABOUT EARTH'S PAST,*
456 01:51:23:18 01:51:26:16 *BUT BECAUSE OF THEIR ECONOMIC ROLE AS WELL.*
457 01:51:29:03 01:51:32:15 *IN THIS REGARD, FOLDS ARE ESPECIALLY IMPORTANT.*
458 01:51:35:14 01:51:38:17 UNDERSTANDING FOLDS AND THE WAY THEY FORM

459 01:51:38:19 01:51:42:01 IS NOT ONLY INTRIGUING FROM
A SCIENTIFIC POINT OF VIEW,
460 01:51:42:03 01:51:45:00 IT CAN ALSO HAVE ENORMOUS
ECONOMIC BENEFITS AS WELL.
461 01:51:45:02 01:51:47:15 THE COMPRESSIVE STRESS
THAT FOLDS ROCKS
462 01:51:47:17 01:51:50:16 CAN ALSO CONTRIBUTE TO
THE FORMATION OF PETROLEUM
463 01:51:50:18 01:51:52:17 AND THE STRUCTURES
THAT TRAP IT.
464 01:51:52:19 01:51:54:16 FOR EXAMPLE,
MANY FOLDED REGIONS
465 01:51:54:18 01:51:56:02 ARE COMPOSED
OF ALTERNATING
466 01:51:56:04 01:51:58:16 PERMEABLE AND IMPERMEABLE
ROCK LAYERS.
467 01:51:58:18 01:52:00:15 SOME OF
THE PERMEABLE STRATA
468 01:52:00:17 01:52:02:01 CONTAIN WATER AND OIL,
469 01:52:02:03 01:52:05:01 WHICH ACTUALLY FLOW
THROUGH THE ROCKS THEMSELVES.
470 01:52:05:03 01:52:07:17 IN FACT, THIS FLOW
IS SOMETIMES DRIVEN
471 01:52:07:19 01:52:09:02 BY THE SAME
COMPRESSIVE STRESS
472 01:52:09:04 01:52:10:17 THAT FOLDS THE ROCK LAYERS.
473 01:52:10:19 01:52:12:17 BECAUSE PETROLEUM
IS LIGHTER THAN WATER,
474 01:52:12:19 01:52:15:15 IT FLOATS TO THE HIGHEST
POINT IN THE FOLD
475 01:52:15:17 01:52:17:01 AND IS TRAPPED THERE
476 01:52:17:03 01:52:19:17 IF THE OVERLYING LAYER
IS IMPERMEABLE.
477 01:52:19:19 01:52:21:01 THE INTENSELY FOLDED ROCKS
478 01:52:21:03 01:52:23:14 OF THE WESTERN
APPALACHIAN MOUNTAINS
479 01:52:23:16 01:52:25:28 PRODUCED THE FIRST
COMMERCIAL OIL WELL
480 01:52:26:00 01:52:28:15 IN THE UNITED STATES
IN 1859.
481 01:52:28:17 01:52:31:15 SINCE THEN, FOLDED STRATA
HAVE BEEN RECOGNIZED
482 01:52:31:17 01:52:34:14 AS SUPERB PETROLEUM STRUCTURES
ALL OVER THE WORLD,
483 01:52:34:16 01:52:38:01 AND HAVE YIELDED TREMENDOUS
QUANTITIES OF OIL AND GAS.
484 01:52:40:15 01:52:41:29 *TYPICALLY,*
PETROLEUM IS FOUND
485 01:52:42:01 01:52:44:00 *IN CERTAIN*
SEDIMENTARY ROCKS
486 01:52:44:02 01:52:45:24 *FORMING FROM*
THE DECOMPOSITION
487 01:52:45:26 01:52:47:24 *OF ORGANIC MATTER.*
488 01:52:49:07 01:52:51:04 PETROLEUM, OF COURSE,
IS GENERATED
489 01:52:51:06 01:52:55:00 FROM THE DEAD OR DECAYED

REMAINS OF LIVING ORGANISMS.
490 01:52:55:02 01:52:57:29 MOST OF THAT COMES
FROM MICRO-ORGANISMS.
491 01:52:58:01 01:53:00:15 AS THESE ORGANISMS DIE
492 01:53:00:17 01:53:03:00 AND THEY'RE BURIED
WITH SEDIMENTS,
493 01:53:03:02 01:53:05:29 THEY BECOME PART OF
THE SEDIMENTARY SECTION.
494 01:53:06:01 01:53:09:14 THOSE ORGANISMS MAY--
THE ORGANIC MATTER MAY ALSO BE
495 01:53:09:16 01:53:12:29 FROM LEAFY MATERIALS,
WOOD MATERIALS,
496 01:53:13:01 01:53:15:00 THAT SORT OF THING.
497 01:53:15:02 01:53:17:15 ANYTHING THAT HAS
CARBON IN IT,
498 01:53:17:17 01:53:18:29 CARBON-BASED MATERIALS.
499 01:53:19:01 01:53:20:14 HENCE THE NAME
HYDROCARBON,
500 01:53:20:16 01:53:21:24 LIQUID CARBON.
501 01:53:23:15 01:53:25:27 *LIGHTER THAN BOTH*
ROCK AND WATER,
502 01:53:25:29 01:53:28:27 *PETROLEUM DRIFTS UPWARDS*
THROUGH THE POROUS SPACES
503 01:53:28:29 01:53:30:11 *AND FRACTURES IN ROCKS.*
504 01:53:31:29 01:53:33:11 *SOME FINDS IT WAY*
505 01:53:33:13 01:53:35:28 *ALL THE WAY TO*
THE EARTH'S SURFACE,
506 01:53:36:00 01:53:37:28 *WHERE IT DISSIPATES*
INTO THE OCEANS
507 01:53:38:00 01:53:39:27 *OR COLLECTS IN POOLS.*
508 01:53:41:29 01:53:43:27 *THE REMAINDER, HOWEVER,*
BECOMES TRAPPED
509 01:53:43:29 01:53:46:11 *BY GEOLOGIC STRUCTURES*
WITHIN THE EARTH.
510 01:53:47:29 01:53:50:12 *ONE OF THE MOST*
EFFECTIVE STRUCTURES
511 01:53:50:14 01:53:52:13 *FOR CREATING*
A PETROLEUM RESERVOIR
512 01:53:52:15 01:53:55:13 *IS KNOWN AS*
AN ANTICLINAL TRAP.
513 01:53:55:15 01:53:58:12 *HERE AN IMPERMEABLE*
LAYER OF ROCK
514 01:53:58:14 01:54:00:27 *FORMS A CAP OVER A LAYER*
515 01:54:00:29 01:54:03:26 *OF POROUS, PERMEABLE*
SEDIMENTARY ROCK.
516 01:54:03:28 01:54:05:26 *IF PETROLEUM IS PRESENT,*
517 01:54:05:28 01:54:07:11 *IT DRIFTS UPWARD*
518 01:54:07:13 01:54:10:28 *AND IS CAUGHT WITHIN*
THE FOLD OF THE ANTICLINE.
519 01:54:11:00 01:54:14:12 *NATURAL GAS, WHICH IS THE*
LIGHTEST FORM OF PETROLEUM,
520 01:54:14:14 01:54:15:27 *COLLECTS AT THE TOP.*
521 01:54:15:29 01:54:17:26 *NEXT COMES OIL.*
522 01:54:20:14 01:54:22:25 *WATER, WHICH IS HEAVIER*
THAN PETROLEUM,
523 01:54:22:27 01:54:24:09 *FORMS A LAYER UNDERNEATH.*

524 01:54:26:27 01:54:28:11 *OTHER GEOLOGIC STRUCTURES*
525 01:54:28:13 01:54:30:11 *CAN ALSO CREATE*
OIL TRAPS.
526 01:54:30:13 01:54:33:11 *A FAULT, FOR EXAMPLE,*
527 01:54:33:13 01:54:35:10 *OR AN UNCONFORMITY.*
528 01:54:37:12 01:54:39:10 *LOCATING*
GEOLOGIC STRUCTURES
529 01:54:39:12 01:54:42:02 *WHICH CAN TRAP*
MIGRATING PETROLEUM
530 01:54:42:04 01:54:44:04 *IS JUST ONE OF*
THE CONSIDERATIONS
531 01:54:44:06 01:54:46:29 *TAKEN INTO ACCOUNT BY*
GEOLOGISTS LOOKING FOR OIL.
532 01:54:48:05 01:54:49:27 WE HAVE TO ASSESS
THE BASIN
533 01:54:49:29 01:54:51:11 FOR ITS SOURCE-ROCK
POTENTIAL.
534 01:54:51:13 01:54:54:10 ONCE WE ASSESS THAT THERE ARE
SOURCE ROCKS
535 01:54:54:12 01:54:55:25 APPROPRIATE FOR THAT,
536 01:54:55:27 01:54:58:29 WE HAVE TO SAY, HAS THE TIMING
BEEN APPROPRIATE?
537 01:54:59:01 01:55:02:00 HAS THAT SOURCE ROCK
SET DOWN THERE LONG ENOUGH
538 01:55:02:02 01:55:03:14 AND BECOME BURIED
DEEP ENOUGH
539 01:55:03:16 01:55:05:19 THAT THE TEMPERATURE
HAS ALLOWED HYDROCARBONS
540 01:55:05:21 01:55:06:27 TO GENERATE?
541 01:55:06:29 01:55:09:25 WE HAVE TO LOOK
AT SOURCE, MIGRATION,
542 01:55:09:27 01:55:12:09 AND THE MIGRATION
HAS TO BE TIMELY.
543 01:55:12:11 01:55:14:25 WE HAVE TO LOOK AT
AN APPROPRIATE TRAP,
544 01:55:14:27 01:55:17:20 AND WE HAVE TO LOOK
FOR RESERVOIR QUALITY.
545 01:55:21:24 01:55:23:08 AUTHOR JOHN McPHEE
546 01:55:23:10 01:55:25:24 ONCE TRIED TO REDUCE
THE STUDY OF GEOLOGY
547 01:55:25:26 01:55:27:08 TO A SINGLE SENTENCE.
548 01:55:27:10 01:55:28:22 HE WROTE,
549 01:55:28:24 01:55:31:23 "THE SUMMIT OF MT. EVEREST
IS MARINE LIMESTONE."
550 01:55:31:25 01:55:33:07 THIS STATEMENT SUMMARIZES
551 01:55:33:09 01:55:36:22 CENTURIES OF HUMAN FASCINATION
ABOUT GEOLOGIC STRUCTURES,
552 01:55:36:24 01:55:38:09 INCLUDING MOUNTAIN RANGES,
553 01:55:38:11 01:55:41:24 FOLDED AND CONTORTED ROCKS,
AND GREAT FAULTS.
554 01:55:41:26 01:55:44:07 THESE STRUCTURES ARE BOTH
THE PRODUCT
555 01:55:44:09 01:55:45:23 OF TECTONIC PLATE MOVEMENT
556 01:55:45:25 01:55:48:24 AND A RECORD OF EARTH'S
DYNAMIC HISTORY.
557 01:55:48:26 01:55:50:26 AN UNDERSTANDING

OF GEOLOGIC STRUCTURES

558 01:55:50:28 01:55:53:25 IS NOT ONLY ESSENTIAL
TO INTERPRETING EARTH'S PAST,

559 01:55:53:27 01:55:57:08 IT'S OFTEN THE SOLUTION
TO PRACTICAL PROBLEMS AS WELL.

560 01:55:57:10 01:55:58:19 FOR EXAMPLE,

561 01:55:58:21 01:56:01:14 FAULTS ARE THE RECORD
OF ANCIENT EARTHQUAKES,

562 01:56:01:16 01:56:03:13 AND THE STUDY
OF THESE STRUCTURES

563 01:56:03:15 01:56:05:23 IS FUNDAMENTAL TO EARTHQUAKE
HAZARD ANALYSIS

564 01:56:05:25 01:56:07:08 AND QUAKE PREDICTION.

565 01:56:07:10 01:56:10:09 THE TECTONIC ACTIVITY
THAT CREATES MOUNTAIN RANGES

566 01:56:10:11 01:56:13:09 IS ALSO RESPONSIBLE
FOR OIL AND GAS FIELDS,

567 01:56:13:11 01:56:15:23 SO AN UNDERSTANDING
OF GEOLOGIC STRUCTURES

568 01:56:15:25 01:56:18:23 IS ESSENTIAL TO THE SEARCH
FOR THESE FUELS.

569 01:56:18:25 01:56:21:07 IN ADDITION,
STRUCTURAL GEOLOGY IS VITAL

570 01:56:21:09 01:56:22:21 TO LANDSLIDE ANALYSIS,

571 01:56:22:23 01:56:24:20 AND IN PLANNING
DISPOSAL SITES

572 01:56:24:22 01:56:27:11 FOR THE WASTE PRODUCTS
OF HUMAN CIVILIZATION,

573 01:56:27:13 01:56:30:06 FROM SPENT NUCLEAR FUEL
TO HOUSEHOLD GARBAGE.

574 01:56:30:08 01:56:32:06 THE STUDY
OF GEOLOGIC STRUCTURES

575 01:56:32:08 01:56:35:05 IS ONE IMPORTANT WAY
THAT THE SCIENCE OF GEOLOGY

576 01:56:35:07 01:56:36:21 LINKS ACADEMIC KNOWLEDGE

577 01:56:36:23 01:56:39:21 TO THE PRACTICAL CONCERNS
OF PEOPLE AND CIVILIZATIONS.

578 01:56:39:23 01:56:43:05 THE STRUCTURE OF THE EARTH
BENEATH OUR FEET IS VITAL--

579 01:56:43:07 01:56:45:07 BOTH TO INTERPRETING
EARTH'S PAST

580 01:56:45:09 01:56:47:28 AND TO PLANNING
OUR OWN FUTURE.

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