# Planet Earth

# Gifts From The Earth

| | | |
|---|---|---|
| 1 | 05:01:20:04 | PILOT ( *over radio* ): ...approach, lead to the right and slightly, uh, straight ahead and, uh... |
| 2 | 05:01:26:26 | NARRATOR: Locked in the Earth are the riches that propel our modern world. |
| 3 | 05:01:32:05 | And woven throughout the course of human history is the saga of a perpetual search -- from the mines of King Solomon to the black gold of the 20th century. |
| 4 | 05:01:46:27 | Gathered from Earth's far frontiers, they have built the tools of war and the cities of peace. |
| 5 | 05:01:58:21 | In the rocks of planet Earth are the raw materials of our technology. |
| 6 | 05:02:03:15 | And from the Earth we have fashioned the monuments of our modern age. |
| 7 | 05:02:26:22 | A few thousand years of human civilization is linked to an ancient struggle of Titans -- as the power of the sun and the forces within the Earth wrestle over the thin crust that wraps our planet. |
| 8 | 05:02:38:12 | Over hundreds of millions of years, they have created and distributed the great treasures of this Earth. |
| 9 | 05:02:55:09 | Around the globe, scientists search to understand the creation of Earth's treasures. |
| 10 | 05:03:00:23 | At the heart of the search, two urgent questions: How long will they last? |
| 11 | 05:03:05:14 | And to find them, how far must we go? |
| 12 | 05:03:10:29 | A cedar swamp in Maine holds clues that may effect the energy resources of tomorrow. |
| 13 | 05:03:17:12 | WOMAN: We need to get farther in. |
| 14 | 05:03:20:04 | MAN: Find a good exposure. |
| 15 | 05:03:22:07 | NARRATOR: In a subterranean world, scientists unravel a |

geological mystery of incredible wealth.

16 05:03:30:12 And in the skies high above the Nevada desert, new eyes of science look down on Earth.

17 05:03:37:05 What they see could revolutionize our understanding of the planet.

18 05:03:43:04 Scientists have entered a world that until now was unexplored.

19 05:03:47:15 Our future will be determined by what they find.

20 05:04:37:00 ***WARNING FORMAT ERROR

21 05:04:40:16 *IBM is proud to support the innovative spirit of scientific inquiry that made this series possible* .

22 05:04:51:27 NARRATOR: In New York City, a world-famous auction house offers items of exquisite design and extraordinary value to a discriminating clientele.

23 05:05:02:05 AUCTIONEER: For 24... $24,000 now.

24 05:05:03:25 $25,000, $26,000 is here.

25 05:05:07:12 I have $26,000. For 26, $26,000.

26 05:05:10:24 The bid's up front and against the room now at $26,000, all gone.

27 05:05:15:18 ( *gavel bangs* ) Sold for $26,000, even, flat.

28 05:05:18:16 ( *gavel bangs* ) Sold for $110,000.

29 05:05:20:28 ( *gavel bangs* ) Sold now for $135,000.

30 05:05:23:24 All right, what should we say to start this, $500,000 start it?

31 05:05:26:15 NARRATOR: In the bidding over a flawless blue diamond, it is easily forgotten that these works of elegant beauty were transformed from stones dug from the ground.

32 05:05:37:06 AUCTIONEER: $850,000.

33 05:05:38:11 At 850, $875,000 now.

34 05:05:41:19 $900,000 in the center of the room now.

35 05:05:44:22 Down it goes then at $900,000 in the center of the room, at 900.

36 05:05:48:13 ( *gavel bangs* ): 900.

37 05:05:52:08 NARRATOR: Stones of astonishing value...

38 05:05:54:27 yet a far greater worth than the brightest diamond are mineral treasures that have played a pivotal part in human history.

39 05:06:07:07 In Pittsburgh, at the Carnegie Institute's Hillman Hall of Minerals, fantastic specimens are displayed and admired as works of art.

40 05:06:20:14 Formed by forces originating deep within the Earth, and from our distant sun, they are of a seemingly infinite variety.

41 05:06:35:00 Incredibly, they are all examples of nature's artistry, transformed by water, molten heat, sun and time.

42 05:07:09:07 Exquisitely shaped, economic and precious metals alike rival the finest creations of craftsmen.

43 05:07:16:09 In a museum gallery, they are treasures from a jewel-box Earth.

44 05:07:24:18 Although the treasures of the Earth are widespread, the places where they are concentrated and accessible are not.

45 05:07:31:10 A splendor of gold and silver light our worlds, as if glittering brightly from afar.

46 05:07:37:18 Royalty among metals, they are mined in but a few regions around the globe.

47 05:07:56:01 Shining forth are the sources of our most basic metals -- among them are lead, zinc, copper and iron.

48 05:08:04:01 Just 150 sites worldwide account for more than three-quarters of the metals and minerals essential to modern industry.

49 05:08:22:07 Fueling the fires of our age are deposits of fossil fuels.

50 05:08:26:10 Scattered around the globe, they are formed from prehistoric plants and microscopic animals of ancient times.

51 05:08:34:19 In North America and Asia are the major deposits of coal.

52 05:08:38:24 Oil and natural gas are spread among the continents, but a full 60% of the world's known supplies are beneath the Persian Gulf.

53 05:08:49:18 Petroleum dominates modern history, much as another resource dominated the Mediterranean world of ancient times.

54 05:09:02:16 From the froth of the sea came Aphrodite, goddess of fertility and love.

55 05:09:08:16 A Greek poet named this beach in Cyprus as her birthplace.

56 05:09:20:09 Aphrodite was born into the richest land in the classical world.

57 05:09:24:13 For in the mountains that rise from this sea lay a phenomenal treasure -- the copper mines of ancient Cyprus.

58 05:09:34:29 Copper ingots bearing the stamp of Cyprus and cast in the shape of hides were carried throughout the Mediterranean world.

59 05:09:44:25 Under the patronage of the Mycenaen god Enkomi, the island supplied much of the copper for the Bronze Age.

60 05:09:51:29 From its mines and smelters came the utensils of the hearth.

61 05:09:57:27 Other anvils forged the metal into instruments of war.

62 05:10:09:01 Cyprus, in fact, means "copper," and from 4,000 years before the birth of Christ until the decline of the Roman Empire, the mines of Cyprus were as vital to the ancient world as the oil of the Persian Gulf is to modern times.

63 05:10:27:01 Today, ruins and deserted caverns are all that remain of that great age, long ago.

64 05:10:34:12 ( *bell tolling* ) ( *dog barking* ) The mines of Cyprus lay idle for 1,600 years.

65 05:10:52:02 But in 1913, after studying the accounts written by ancient Romans, an American geologist rediscovered the mines.

66 05:11:00:08 Once more they yielded up their riches and mine tailings dotted the foothills of the Troodos Mountains.

67 05:11:11:00 By the late 1950s, Cyprus began to interest geologists for

other reasons.

68 05:11:16:29 Golgos Constantino, now head of the Cyprus Geological Survey, and Dick Hutchinson, of the Colorado School of Mines, studied the ancient sites for clues to a geological mystery.

69 05:11:31:27 Clinging to the wall of an old pit mine is a small pocket of metal ore -- a remarkable type, containing copper, gold, silver and zinc.

70 05:11:43:18 They thought that these deposits were formed when the minerals were forced into existing rock, replacing what was there before.

71 05:11:51:10 But that process would not have produced the layered bands that they found.

72 05:11:55:06 Sulfide band.

73 05:11:58:01 When I first came here to Cyprus in 1962, our understanding of the origin of these rich concentrations of metals was, at best, very poor.

74 05:12:09:16 We believed they had been formed within the rocks, long after the rocks had been laid down by a replacement process.

75 05:12:19:14 NARRATOR: But the layered bands contradicted that theory, forcing them to find a new explanation.

76 05:12:26:04 Little did they know that they were on the verge of a new scientific breakthrough.

77 05:12:34:03 Nearby was evidence that further challenged the old theories.

78 05:12:38:20 Geologists found large, swirled rock formations, referred to as pillow lavas.

79 05:12:44:19 These, they knew, could only be formed as hot lava came in sudden contact with cold seawater.

80 05:12:50:26 Could the metal deposits and the pillow lavas have formed together on the sea floor?

81 05:12:59:23 ( *crackling* ) These remarkable pictures capture a drama similar to what took place on the floor of an ancient sea.

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| 82 | 05:13:08:13 | Lava hardens into pillow shapes as its molten fire is quenched by the seawater. |
| 83 | 05:13:30:20 | The trail of the metal ore and the pillow lavas led to a whole new theory of how Cyprus formed -- part of a revolutionary view of our planet, based on the concept of plate tectonics. |
| 84 | 05:13:43:17 | The Earth's crust, far from being solid, is cracked like an egg shell. |
| 85 | 05:13:48:13 | The surface is broken into huge slabs, or plates, that slide about like a crust of lava slides over a molten lake. |
| 86 | 05:13:56:10 | Geological events on a colossal scale are the result of this dynamic, evolving Earth. |
| 87 | 05:14:04:01 | Mountain ranges rise as continents collide. |
| 88 | 05:14:09:05 | The Himalayas were thrust upward and continue to inch ever higher as the broad arc of India pushes against the belly of Asia. |
| 89 | 05:14:20:25 | Along California's San Andreas fault, earthquakes occur when the tension between plates is released in sudden spasms. |
| 90 | 05:14:29:21 | The sheering and breaking of solid rock has formed the great scar of the Carrizo Plain. |
| 91 | 05:14:39:08 | On the sea floor is the Earth's largest geological feature, an underwater mountain range that wraps the world in a jagged furrow 46,000 miles long. |
| 92 | 05:14:50:17 | At this ridge, formed as the Earth's plates pull apart, molten rock from the Earth's interior rises to become new sea floor. |
| 93 | 05:15:03:15 | In the ancient Mediterranean Sea, this same fiery genesis occurred, where the African and European plates tugged against each other. |
| 94 | 05:15:15:01 | Approximately 40 million years ago, the process reversed. |
| 95 | 05:15:18:24 | The African plate plunged beneath the European plate, and the area that became Cyprus was pushed upward. |
| 96 | 05:15:26:09 | Ancient formations from the deep sea floor became the mountains of Troodos. |

97 05:15:33:04 On its flanks rested the pillow lavas from the sea bed, and the deposits of metal ores.

98 05:15:39:16 Cyprus was an important clue to the mystery of how such deposits were created.

99 05:15:45:18 The next clue would come from halfway around the world: Japan...

100 05:15:52:25 land of living volcanoes, fed by immense heat and molten rock flowing from the interior of the Earth.

101 05:16:01:21 The length of Japan is laced with hot springs and mud pots, an intrinsic part of the Japanese landscape.

102 05:16:34:24 The agricultural valleys of northern Japan are famous for their rice crop, but the real wealth of the region lies beneath these rice paddies.

103 05:16:43:14 900 feet below the surface are a unique combination of metals -- compounds of copper, gold, silver, lead and zinc -- almost identical to the ore found in Cyprus.

104 05:16:56:29 In Japanese it is called *kuroko* -- black ore.

105 05:17:03:21 Japanese geologists speculated as early as the turn of the century that the deposits they were mining might have been formed by hot springs.

106 05:17:15:29 Because no papers on the subject were translated from Japanese, western geologists would not learn of these theories for another four decades.

107 05:17:28:29 ( *speaking Japanese* ) Preserved in the mines is further evidence that links the black ore to sea floor hot springs -- volcanic rocks mixed with the ore.

108 05:17:45:11 A bright red rock, thought to be left by a dying hot spring.

109 05:17:51:07 Clues frozen in stone complete a theory of how the deposits formed.

110 05:17:57:25 Drawing on their research, geologists construct a model of something no one has ever seen.

111 05:18:04:29 They theorize that millions of years ago, there was hot spring activity on the sea floor.

112 05:18:10:12 Water trickled down through fractures in the sea bed created by plate action, and then -- heated by volcanic rocks deep within the Earth -- circulated upward, carrying a variety of minerals with it.

113 05:18:24:00 When water came spewing out of the cracks on the sea floor, the minerals carpeted the bottom.

114 05:18:30:28 Jutting from the very top of this hypothetical hot spring were strange-looking chimneys of different sizes, stacks built by the minerals pouring out like black smoke.

115 05:18:46:19 The *kuroko* mines have now become a focal point for exploration geologists from around the world.

116 05:18:54:00 Steve Scott, from the University of Toronto, first came here during the 1970s.

117 05:18:59:19 Now he has returned with a group of his colleagues to share this unusual laboratory.

118 05:19:05:28 ( *indistinct voices* ) The open pit was mined for over a hundred years.

119 05:19:16:25 As they move across it, the scientists walk through what was once the interior of vents and chimneys that carried the black, metal-rich water up to the sea floor.

120 05:19:28:17 What is left behind is a rare display above ground of what they believe was a system of hot springs at the bottom of an ancient sea.

121 05:19:36:20 SCOTT: Disseminated pyrite; iron sulfite.

122 05:19:39:17 We have volcanic fragments here.

123 05:19:43:06 You can see that they are ten to 30 centimeters in diameter, and the hydrothermal fluids came up around these to feed the black smokers, which would have been about 50 meters up there.

124 05:19:56:09 In other words, we're standing 50 meters below the sea floor here.

125 05:20:03:06 NARRATOR: In 1977, on an extraordinary day for science, the evidence from Japan and Cyprus is to be confirmed.

126 05:20:11:12 Off the coast of Mexico, at a site named "21 Degrees North,"

the research submersible *Alvin* explores a dark frontier where two plates are pulling apart.

127 05:20:27:27 In a blackness never before penetrated by light, geologists witness firsthand the process that formed the deposits in Japan 13 million years ago, and in Cyprus 30 million years before that.

128 05:20:46:23 The chimneys of the hot spring are given the most obvious of names -- black smokers.

129 05:20:51:28 The metal-rich water is so hot that it melts Alvin's sensing probe.

130 05:21:17:13 The researchers return to the surface with the revolutionary news that the same process that formed the ancient deposits is occurring today.

131 05:21:28:23 Scientists can now follow the telltale clues in search of other black smoker deposits.

132 05:21:35:23 The trail leads them to the forests of northern Canada.

133 05:21:39:08 Far from any ocean are large groupings of pillow lavas.

134 05:21:43:14 Looking strangely like ancient cave drawings, they point the way.

135 05:21:52:06 Two and a half billion years ago, this was the sea floor and on it formed the richest black smoker deposit yet found, the Kid Creek Mine.

136 05:22:04:03 Two shafts have been dug to 3,000 feet, and the ore continues still deeper.

137 05:22:10:20 The value of the deposit is estimated at $30 billion.

138 05:22:18:14 The trail that began in Cyprus and led to Japan does not end here.

139 05:22:24:00 Since the discovery at 21 Degrees North, scientists have found 17 black smoker sites on the ocean bottom.

140 05:22:36:27 Along the 46,000 miles of spreading centers that circle the globe, there are undoubtedly others.

141 05:22:44:15 Perhaps one has begun to form another Kid Creek.

142 05:23:01:13 Around the globe are a handful of ancient stable areas,

some nearly as old as the Earth itself.

143 05:23:08:28 The most remarkable of these is in southern Africa, in a region known as the Bushveld Complex.

144 05:23:18:16 When molten magma cooled here, it trapped within it one of the richest concentrations of metals known to man.

145 05:23:25:12 In an area the size of Delaware are chromium, titanium, vanadium and, most importantly, platinum.

146 05:23:35:15 Some two billion years ago, molten rock from deep within the Earth welled upward through weak points in the Earth's crust and cooled beneath the surface.

147 05:23:47:05 Over the next half-million years, the magma slowly cooled and the rich deposits of the Bushveld settled into a layer cake more than eight kilometers thick.

148 05:24:04:24 The Bushveld's most extraordinary feature is its platinum.

149 05:24:08:27 In a continuous band not more than a foot thick, but extending for miles, is over three-quarters of the world's known reserve of platinum.

150 05:24:18:15 Though not as well known as other precious metals, the soft luster of platinum commands a price second only to gold.

151 05:24:42:24 Hard, durable, with a high melting point, platinum will not rust or corrode.

152 05:24:48:03 It is used to make lasers and coat razor blades.

153 05:24:51:27 A metal as indispensable to the jeweled masterpieces of Cartier as it is to the workings of a rocket engine.

154 05:25:04:03 Buried together with the platinum is the mystery of how it formed.

155 05:25:07:15 Why is this precious metal isolated in a single thin layer, the platinum at the top of the layer cake and the other metals at the bottom?

156 05:25:18:24 The search for an answer is going on in Canada at the University of Toronto by geologist Tony Naldrett.

157 05:25:27:19 NALDRETT: This is a sample of the Merensky Reef, which is one of the largest ore deposits of platinum in the world.

158 05:25:35:13 In fact, it counts for three-quarters of the platinum that we know about.

159 05:25:39:02 And as you can see, it's a layered rock, with this light-colored layer overlain by this much darker-colored layer.

160 05:25:47:06 The platinum is contained as small specks of sulfide in this upper, darker-colored part, and recent research on the Bushveld Complex has shown that the Complex is the result of successive introductions of new magma, and it's when this new magma came into the chamber and mixed with the old magma that it caused the ore deposits of chromium and platinum to settle and form the layers which we now mine today.

161 05:26:19:04 The process that we're talking about is very much like that which goes on in a smelter, and really, the Bushveld Complex has acted as nature's version of a smelter.

162 05:26:33:03 NARRATOR: By reading the record left in the rocks, science can reconstruct events of an ancient past.

163 05:26:39:08 Yet even with new understanding of how the metals of the Bushveld formed, there remains another mystery.

164 05:26:46:23 Why is so much of the world's platinum concentrated here, and almost nowhere else on Earth?

165 05:26:56:14 The magma of the Bushveld and the hydrothermal vents of the black smokers are dramatic evidence of the immense energy in the interior of the Earth, energy that drives the planet's engine of creation.

166 05:27:24:10 But the force that builds mountains and creates volcanoes is forever pitted against another, even more immense power, the sun.

167 05:27:34:06 The fraction of the sun's energy that strikes the Earth makes wind blow and rivers flow.

168 05:27:39:14 It is the sun that orchestrates the weather of the entire planet.

169 05:27:44:09 ( *wind whooshing* ) Powered by the sun, the elements work to refashion the face of planet Earth.

170 05:27:58:01 But even in the destruction they cause, a cycle of creation is set in motion.

171 05:28:02:25 The beginnings of one of the most precious gifts of all -- soil.

172 05:28:25:14 The backs of mountains are broken into rocks and sand and clay.

173 05:28:29:28 Living creatures and organic matter transform the dirt into soil -- living soil.

174 05:28:35:27 Almost half of each handful is bugs, bacteria, and microorganisms in their habitat of Earth.

175 05:28:43:14 In life and in death, creatures in it and on it fertilize the soil.

176 05:29:35:14 Most soil evolves from the weathering of bedrock.

177 05:29:38:29 But here in the young volcanic earth of the Hawaiian Islands is a most unusual story.

178 05:29:51:29 Weathering and erosion, the continual shuffling and moving and redistributing of the Earth's surface, is the focus of soil scientists.

179 05:30:01:24 Goro Uehara, of the University of Hawaii, has found evidence of just how mobile the surface of the Earth can be.

180 05:30:12:26 In parts of Hawaii, the soil is enriched by a gray clay, found to be a hundred million years old.

181 05:30:20:26 But there is a curious paradox.

182 05:30:24:02 The volcanic islands themselves are only two million years old.

183 05:30:33:09 We suspect that this gray layer is the material that is blown in from the Asian continent and is scrubbed out of our atmosphere by heavy rainfalls.

184 05:30:43:11 The significance of this material is that it is very rich in potassium, and is the means *by which much of this vegetation in this area received the potassium for its nutrition* .

185 05:30:55:14 NARRATOR: And so these young tropical islands, in part, owe their fertile soil to the dust from an ancient desert in China, far across the sea.

186 05:31:09:03 At the end of the Ice Age, the soil in western Tennessee was formed from material deposited by colossal dust storms.

187 05:31:16:21 The finely-ground debris from the wake of glaciers, it is called loess.

188 05:31:23:02 When early settlers came to this land at the bend of the river, it was covered in thick hardwood forest.

189 05:31:30:08 They cleared the trees and plowed fields to make the breadbasket of the South.

190 05:31:38:17 Today the land is still rich and productive, but it is also victim to severe soil erosion.

191 05:31:45:29 Each year over ten tons of precious topsoil is washed or blown away from each acre of cropland.

192 05:31:52:18 At that rate, Tennessee loses one inch of soil every 25 years.

193 05:31:59:17 In order to conserve this rich but fragile resource, a new breed of scientists now studies the formation and structure of different types of soil.

194 05:32:09:12 John Jenkins of the Soil Conservation Service analyzes the overall health of this field by marking off sections, or strata, called horizons.

195 05:32:18:25 JENKINS: ...and we have a good subsoil that runs down...

196 05:32:21:24 NARRATOR: Drawing his knife from the rich topsoil to the less productive subsoil, to the dense clay below that stops any root or water, he can tell just how productive this soil is.

197 05:32:36:07 The deeper he goes, the less valuable the land.

198 05:32:41:04 JENKINS: We're going to point out the rooting activity zone here.

199 05:32:43:27 This is your surface layer right here.

200 05:32:45:20 And if you look, you can see these little roots are pretty predominant and there's a bigger root down in there.

201 05:32:51:18 This zone right here is extremely silty and it's laid down in what we call windblown silt or loess, and this area right in here tends to erode very easily.

202 05:33:02:06 NARRATOR: The Soil Conservation Service is monitoring the erosion problem.

203 05:33:07:29 Photographing it from the air is the work of Jim Billue.

204 05:33:11:16 BILLUE: *Soil erosion is not new* .

205 05:33:13:23 *Geological erosion is well known* .

206 05:33:15:29 *What happens when man comes along and disturbs the soil material and plants a crop in it, he accelerates the erosion processes* .

207 05:33:24:18 *And most of the cropland soils in Tennessee that we deal with, we say that it will have a soil-loss tolerance of five tons per acre per year* .

208 05:33:34:20 *Now, that what that simply means is, as long as we're not losing more than five tons per acre per year, then we're going to be able to maintain production well into the future* .

209 05:33:46:15 NARRATOR: In the natural order of things, the land will yield to wind and water.

210 05:33:51:16 But science can help us to use the soil wisely, and to slow down the inevitable.

211 05:33:58:02 BILLUE: *I myself would say that soil is more valuable than oil or gold* .

212 05:34:02:04 *You can't eat gold and you can't drink oil and survive, but you can grow food in good soil* .

213 05:34:08:29 *So if it comes down to a matter of survival -- are we going to have enough to eat or are we going to have all the oil we want -- I'll take the best land every time* .

214 05:34:24:29 NARRATOR: In the mountains of India begins a drama of sun and water.

215 05:34:33:26 The sun, ultimate arbiter of nature.

216 05:34:37:28 Not all the erosion caused by its power is for ill.

217 05:34:41:17 High in the Himalayas in snow and ice, the River Ganges begins its journey.

218 05:34:51:05 Water, that liquid essential to life, is sacred in this river.

219 05:34:56:03 Its holy beginnings are told in a Hindu verse -- "A torrent of water fell on the head of Shiva the Destroyer.

220 05:35:05:10 "Running down a lock of his hair, "it became the River Ganges, flowing from the top of the world to the sea." The sacred waters of the Ganges tumble down from the mountains to begin their long descent.

221 05:35:18:28 To Indians, it is the river of life, and the entire drama of this world is played along its course.

222 05:35:36:20 At Benares, the holiest city on its banks, the river is a temple of worship.

223 05:35:42:17 ( *person chanting* ) As they carve their way through valley and plain, the sacred waters carry organic flotsam, silt and sand.

224 05:36:01:11 Where the river meets the sea, much of this matter is trapped together in the huge fantail of the Ganges delta.

225 05:36:12:04 Seen from space, the tangled pattern of the delta takes on a new dimension.

226 05:36:17:21 It is a natural bowl being filled with mud and organic matter, carried by the river.

227 05:36:24:28 The deltas of rivers around the world are places of natural alchemy.

228 05:36:29:25 In these environments are created coal, oil and natural gas.

229 05:36:38:15 The Mississippi River, liquid highway and watershed for the heart of North America.

230 05:36:45:05 In its delta is deposited the outwash of a continent.

231 05:36:49:22 Over millions of years, sediments have piled up ten miles thick, beneath the muddy waters.

232 05:36:55:26 Here, in a natural chemical factory, they are transformed.

233 05:37:02:08 In the geological magic of a sedimentary basin, organic matter is trapped and accumulates before it has a chance to decay.

234 05:37:11:03 As the amount of sediment grows, its increasing weight actually presses down on the floor of the basin.

235 05:37:17:29 And over time the organic matter is transformed in a natural pressure cooker.

236 05:37:24:11 Now there must be a layer of impermeable rock laid over the deposit.

237 05:37:29:10 Without such a cap, the riches of a potential field will simply drift away.

238 05:37:38:22 As the mighty river flows, a cycle continues -- the fossil fuels of the future being formed even as we mine the living matter of the past.

239 05:37:56:06 Vast deposits of fossil fuels can have modest beginnings.

240 05:38:01:13 This cedar swamp in Maine may one day be a coal field.

241 05:38:06:09 Even now it has begun its transformation.

242 05:38:10:02 As moss and other aquatic plants begin to take over the swamp, organic matter accumulates in the low-oxygen environment of the bog.

243 05:38:22:08 Gradually, peat begins to form -- the first step in the creation of coal.

244 05:38:29:05 In the search for clean-burning coal, scientists are studying the formation of peat bogs like these, that have low sulfur content.

245 05:38:38:21 Understanding the conditions under which they form will increase the chances of finding clean-burning coal in the future.

246 05:38:49:02 WOMAN: Station 4,000.

247 05:38:51:18 NARRATOR: Past her 70th birthday, Cornelia Cameron has mapped peat bogs for the U.S. Geological Survey for the past 30 years.

248 05:39:03:10 Because the summer months mean slogging hip-deep through the mire, her work in Maine begins early in the spring, while the surface is still frozen.

249 05:39:13:01 It is much easier for traveling.

250 05:39:14:27 NARRATOR: Once through the ice, she uses a coring tool of her own design to sample the thickness of the peat.

251 05:39:25:18 Sample after sample, she can read the history of the bog, a history that, when analyzed in the lab, may reveal clues

about the bog's future.

252 05:39:43:13 Look at the grass for the marsh.

253 05:39:46:26 This is sphagnum peat and moss.

254 05:39:53:19 This deposit of peat is made by the building up...

255 05:40:01:02 plants on plants, of the type of plants that you see right here, the shrubs.

256 05:40:07:08 NARRATOR: 20 feet of core reveals 12,000 years of history.

257 05:40:13:29 Beneath the 15 feet of peat are the remains of a forest.

258 05:40:18:16 Below that, a fresh-water pond.

259 05:40:21:00 And at the very bottom...

260 05:40:22:22 Oh, we're in the clay.

261 05:40:29:18 NARRATOR: The sticky clay was laid down at the end of the last Ice Age.

262 05:40:33:28 The sea followed the retreating glacier, flooding this part of New England.

263 05:40:39:29 This part up here is in the fresh water pond.

264 05:40:44:17 The peat deposit that you see all through here was laid down on the marine clay.

265 05:40:51:05 Many coal beds are laid on marine clay.

266 05:40:55:14 And then they're covered up.

267 05:40:59:05 If this deposit was covered up by another invasion of the sea, maybe in a few millennia you'd find coal here.

268 05:41:10:12 But maybe.

269 05:41:20:01 NARRATOR: It was King Coal throughout the 19th century -- the raw material that powered steel mills, factories and railroads.

270 05:41:29:11 Today, despite environmental problems, coal still plays a major industrial role around the world.

271 05:41:43:09 By far the most abundant of any energy source, the

challenge is to find coal that can burn hot and clean.

272 05:41:55:04 In the search for oil, approximately three million wells have been drilled in the United States.

273 05:42:01:13 Several hundred thousand more have been drilled in the rest of the world.

274 05:42:05:09 The days of wildcatting and gushers are probably over.

275 05:42:08:29 Today, the search demands a highly-coordinated effort of men and machines.

276 05:42:28:26 Beyond the edge of a continent is a search for oil.

277 05:42:33:15 200 miles off the coast of Newfoundland, it was not far from here that the *Titanic,* the ship that couldn't be sunk, collided with an iceberg and went down on her maiden voyage.

278 05:42:45:19 These semi-submersible rigs are floating outposts, staffed with crews of over a hundred people.

279 05:42:54:13 Their immense legs contain drinking water, a power generator, a sewage treatment plant, even a small gymnasium.

280 05:43:02:21 The platform floats in a frigid sea, its ballast constantly monitored and adjusted by computers.

281 05:43:15:00 This rig cost nearly $100 million to build.

282 05:43:19:01 It costs a quarter of a million dollars a day to operate it.

283 05:43:22:07 But high cost is not the only risk in this hostile environment.

284 05:43:30:14 Floating mountains of ice the size of city blocks move down from the Sea of Labrador into the North Atlantic.

285 05:43:42:10 For the past 54 days, this rig has not been able to drill, because of sea ice and the menacing presence of icebergs.

286 05:43:52:04 If an iceberg should collide with a drill rig, it would be certain disaster.

287 05:44:02:15 With 150 feet of it above water, and 300 feet below, a mountain of ice weighing 6.1 million tons drifts across the sea toward a flagship of technology.

288 05:44:19:22 Only the constant vigil of men and machines makes such

exploration possible.

289 05:44:25:24 Only modern civilization's great dependence on oil makes it necessary.

290 05:44:35:02 The long search for oil begins in offices and research laboratories, where science plays a crucial role.

291 05:44:44:08 Core samples from around the world reveal the histories of ancient environments.

292 05:44:50:08 They are layers of time etched in stone.

293 05:44:57:25 A plug from a core sample is ground to microscopic thinness, and colored with special dyes.

294 05:45:04:12 It can lead geologists to the unique kind of rock that will hold oil.

295 05:45:09:06 Between the particles of stone, minute droplets of oil and water are held, much like a sponge holds liquid.

296 05:45:20:00 Processing data from a satellite, the computer outlines hidden contours and streambeds that may reveal clues to the geology beneath the surface.

297 05:45:30:04 ( *computer beeping* ) But the most critical decisions are not made by machines.

298 05:45:43:12 Guided by a map of the sedimentary basins around the globe, and drawing on their knowledge of plate tectonics, petroleum geologists like Don Ziegler and Cary Mrozowski lead the search.

299 05:45:57:21 Of the some 600 known sedimentary basins around the world, only about 125 have produced oil or gas.

300 05:46:06:20 The educated guesses of these men carry high stakes.

301 05:46:10:05 In the plate tectonics scheme, the breaking up of the continents, one of the key ingredients is a...

302 05:46:19:06 that when the continents split apart, they break on about a 120-degree angle and one of the breakages will take over, and the other breakage that is left behind is called a failed arm.

303 05:46:32:13 And because it was a rifting area and subsiding area, it

captures a lot of sediments and it becomes a site that is...

304 05:46:40:15 can be very favorable for oil accumulation.

305 05:46:43:13 NARRATOR: Plate tectonics is the catalyst in a bold plan to explore for oil where no one had ever looked before.

306 05:46:55:04 The Sudan in Africa.

307 05:46:57:28 There are no clues on the surface that beneath the scrubbed forests and arid landscapes, there might be the structures that trap oil.

308 05:47:10:25 Seismic studies play the crucial role in deciding whether or not to drill a well.

309 05:47:22:20 Like sonar, seismic devices probe the Earth with sound.

310 05:47:26:25 A cross-section portrait of the Earth is gathered from the reflected waves of an explosive charge.

311 05:47:39:00 ( *deep rumbling* ) Geologists interpret and mark the resulting maps to reconstruct the various levels of the basin as sediments were forming.

312 05:47:55:27 In the research laboratory, wall map and pins are aided by the very latest technology.

313 05:48:04:11 ( *computer blips* ) The computer slices through a three-dimensional chunk of the Sudan like slicing through a loaf of bread.

314 05:48:12:12 Each red line, or picking, isolates information that is used to construct a three-dimensional picture of the subterranean world.

315 05:48:24:19 Like geological time travel, the computer peels back the skin of Earth to reveal part of an ancient freshwater lake.

316 05:48:32:26 Once flat, it has since been tilted.

317 05:48:36:08 The slope is color coded by the computer -- from red at the higher end, to blue at the lower.

318 05:48:42:07 It is an environment that could have trapped oil.

319 05:48:50:03 The tools of science have revealed what human eyes could never see.

320 05:48:54:13 An important decision is made.

321 05:48:58:00 ( *machinery rumbling* ) The first well was dry.

322 05:49:19:17 But one year and several wells later, commercial amounts of crude began to flow.

323 05:49:30:13 The exploration in the Sudan is a success.

324 05:49:34:02 But it is also a preview of the future...

325 05:49:36:21 a future that will require all the knowledge and tools of science.

326 05:49:50:17 At the NASA Ames Research Center near San Francisco, a specially-equipped aircraft prepares for takeoff.

327 05:50:06:25 The converted C-130 is equipped as a flying laboratory to test and develop a new generation of exotic instruments.

328 05:50:17:03 ( *garbled radio transmission* ) Scientists know these machines by the general label "remote sensing," instruments that see beyond the range of human vision.

329 05:50:27:20 Developed as sensing devices to radio back information from other planets, these machines provide valuable new insights about the surface of Earth.

330 05:50:38:00 One of the newest of these instruments is the airborne imaging spectrometer, known by its initials, AIS.

331 05:50:45:18 It is being tested in skies over Cuprite, a remote mining district in the Nevada desert.

332 05:50:52:10 WOMAN ( *over radio* ): Line start, 17, 53, 51.

333 05:50:58:19 MAN ( *over radio* ): Camera started at 245.

334 05:51:03:16 ( *over radio* ): I think that's it right there.

335 05:51:05:14 ( *over radio* ): Okay, well, it looks like the gravel pit's dead center on our TV screen here.

336 05:51:14:09 NARRATOR: The Jet Propulsion Laboratory in Pasadena, California, where AIS is being developed under the guidance of Alexander Goetz.

337 05:51:24:26 The AIS is the first step in a new generation of machines that will eventually allow us to prospect from space.

338 05:51:33:05 Now these machines are different from earlier satellite instruments, in that they allow us to identify specific minerals which are indicators for deposits buried below.

339 05:51:43:29 This is done by taking pictures in many different wavelengths in the infrared, beyond the range of human vision.

340 05:51:52:21 NARRATOR: The reflected light of each wavelength is combined to form a graph, the unique curve that identifies each mineral.

341 05:52:00:07 A computer is loaded with the graphs of over 200 known minerals.

342 05:52:04:15 It scans an AIS picture of the ground in a swath a thousand feet wide and three miles long.

343 05:52:11:13 The computer is able to compare each of the known minerals with the data recorded in the air, and actually identifies the different minerals on the surface below.

344 05:52:21:08 ( *computer blipping* ) On the narrow map, the computer then colors all the locations of each mineral.

345 05:52:28:06 ( *computer blipping* ) The blue, yellow and red colors seen from the air all relate to minerals found together with gold.

346 05:52:40:01 In a puzzling development, it also marks the location of a mineral that the computer cannot identify.

347 05:52:54:22 Guided by the computer-drawn map, Goetz and his assistant, Greg Vane, make the long, dusty trip to Cuprite to look for a sample of the mystery mineral.

348 05:53:07:12 Goetz and Vane make use of a new kind of tool in their search.

349 05:53:11:26 A smaller version of the spectrometer, flown in the aircraft, acts as a homing device to lead them to the area marked by the computer.

350 05:53:21:28 Yeah, the ratios look good.

351 05:53:23:18 I think we're right on the money.

352 05:53:25:02 Okay.

353 05:53:27:20 Looks pretty good.

354 05:53:30:21 NARRATOR: It looks no different from dozens of other rocks lying about.

355 05:53:35:07 But the spectrometer indicates this rock contains the mineral they are searching for.

356 05:53:41:27 Uh-huh.

357 05:53:44:01 That's probably a sample we ought to take.

358 05:53:45:24 NARRATOR: When analyzed by the U.S. Geological Survey, it will prove to be a rare discovery of an obscure mineral called buddingtonite -- a possible pathfinder for locating deposits of gold.

359 05:54:01:18 GOETZ: Remote sensing measurements will never replace the geologist in the field, but with the new instruments that we have now, the new kinds of measurements like imaging spectrometers -- in particular the airborne imaging spectrometer -- we can make measurements that allow us to see things that can't be seen by the eye, or can't be seen by a geologist.

360 05:54:19:01 NARRATOR: This kind of remote sensing will speed up mapping of minerals on the surface by orders of magnitude.

361 05:54:26:28 What once took years by conventional methods can now be done in an afternoon, and with far greater detail than ever before.

362 05:54:36:07 Flown on the space shuttle, and on a space station, AIS has the potential to map for the first time the surface minerals of the entire United States, and perhaps the world.

363 05:54:50:19 As we begin to acquire a global perspective of the Earth's great gifts, this new technology allows us to see our world in a completely new way.

364 05:55:05:00 Probing with electronic eyes, satellites reveal the face of an Earth at once familiar and unexplored.

365 05:55:11:26 We know little of what lies beneath these rugged landscapes and icy terrain.

366 05:55:33:05 We have learned more about our planet in the past 30 years than in the previous 300.

367 05:55:38:28 And yet much of the interior of the Earth remains a mystery.

368 05:55:43:25 Understanding the forces that fashion our world is becoming increasingly important.

369 05:55:50:18 It is clear that the metals and minerals of this restless Earth are being used more quickly than they are being created.

370 05:56:03:18 If civilization is to continue in its present form, the search for new discoveries will go on, possibly even beyond our own planet.

371 05:56:14:00 In that search, there will be yet newfound knowledge about the wondrous ways the Earth is shaped and formed.

372 05:56:20:16 And perhaps the most precious discovery of all will be a new understanding of Planet Earth.

373 05:58:19:18 *For information about this and other Annenberg Media programs, call 1-800-LEARNER, and visit us at www.learner.org*