

Planet Earth**Tales From Other Worlds**

- 1 04:01:47:11 MAY HAVE WIPED THEM OUT IN A SINGLE STROKE.
- 2 04:01:52:00 NOW IN ONE OF THE MOST INTRIGUING STORIES IN SCIENCE, RESEARCHERS ARE FINDING CLUES THAT LINK THE DISAPPEARANCE OF THESE BEASTS TO EVENTS IN SPACE.
- 3 04:02:03:24 THE TRAIL OF DISCOVERY BEGINS BEHIND AN ANCIENT ROMAN TOWN AND LEADS HALFWAY AROUND THE WORLD TO THE BADLANDS OF MONTANA.
- 4 04:02:18:17 ARMED WITH NEW TOOLS AND IDEAS, SCIENTISTS ARE SEEING THE UNSEEN.
- 5 04:02:24:06 ELECTRON MICROSCOPES HAVE OPENED THE DOOR TO THE INFINITE WORLD OF THE VERY SMALL.
- 6 04:02:31:17 COMPUTERS SIFT AND ORGANIZE THE FOSSIL RECORD.
- 7 04:02:36:17 GREAT TELESCOPES PROBE THE FAR REACHES OF OUR SOLAR SYSTEM AS ONE SCIENTIST SEARCHES FOR WHAT HE CALLS NEMESIS, THE DEATH STAR.
- 8 04:02:50:17 IT IS A SEARCH THAT ONE DAY MAY REVEAL THE FUTURE OF PLANET EARTH.
- 9 04:02:57:15 ON A BATTERED MOON LIES THE EVIDENCE OF A FORCE THAT SHAPED OUR PLANET.
- 10 04:03:06:25 [THUNDER] BENEATH THE HOSTILE CLOUDS OF VENUS MAY BE THE LANDSCAPE OF A PRIMITIVE EARTH.
- 11 04:03:16:01 THE RED PLANET, MARS.
- 12 04:03:18:01 UPON IT LIES THE EVIDENCE OF GIGANTIC FLOODS THAT ONCE SCOURED ITS SURFACE.
- 13 04:03:28:16 *WE A HAVLIFTOFF .*
- 14 04:03:30:16 *WE'VE CLEARED THE TOWER .*

- 15 04:03:32:16 JOIN US NOW ON A VOYAGE OF DISCOVERY TO THE EDGE OF THE SOLAR SYSTEM AND TO STRANGE, NEW WORLDS THAT HOLD THE SECRETS OF OUR OWN CREATION.
- 16 04:03:46:16 THE STORY OF PLANET EARTH BEGINS IN SPACE.
- 17 04:04:29:02 Annenberg Media
- 18 04:04:32:17 §
- 19 04:04:39:16 IBM IS PROUD TO SUPPORT THE SPIRIT OF SCIENTIFIC DISCOVERY THAT MADE THIS SERIES POSSIBLE.
- 20 04:04:52:02 THE ALLAN HILLS OF ANTARCTICA -- ONE OF THE MOST FORBIDDING PLACES ON EARTH -- AN UNLIKELY SETTING IN WHICH TO BEGIN THE EXPLORATION OF OUR SOLAR SYSTEM.
- 21 04:05:04:20 BUT IN THESE BLEAK ICE FIELDS ARE CLUES TO ITS EARLIEST HISTORY.
- 22 04:05:12:17 IN BONE-SHATTERING COLD AND WINDS THAT REACH 100 MILES PER HOUR, BANDS OF SCIENTISTS CAMP HERE EACH BRIEF ANTARCTIC SUMMER.
- 23 04:05:23:04 THEY SCOUR THE ICE FOR METEORITES, FRAGMENTS OF THE SOLAR SYSTEM THAT HAVE FALLEN TO EARTH.
- 24 04:05:31:11 METEORITES ARE TRAPPED IN ICE AND CARRIED FROM THE HEART OF THE CONTINENT TOWARD THE SEA.
- 25 04:05:40:01 AS THE ALLAN HILLS BLOCK FLOWING ICE AND ALLOW WIND TO WEAR IT AWAY, METEORITES MIGRATE TO THE SURFACE.
- 26 04:05:49:21 THESE TINY LUMPS WERE CREATED BY THE SAME TUMULTUOUS PROCESSES THAT CREATED THE SUN AND PLANETS.
- 27 04:06:02:03 THEY ARE COSMIC TIME CAPSULES.
- 28 04:06:04:18 PRESERVED IN THIS COLOSSAL FREEZER, THEY TELL A TALE AS OLD AS THE EARTH ITSELF.
- 29 04:06:14:15 BY ANALYZING THIS ANCIENT MATERIAL, SCIENTISTS

CAN RECONSTRUCT THE EVENTS THAT CREATED OUR SOLAR SYSTEM.

- 30 04:06:24:16 SOME 4 1/2 BILLION YEARS AGO, NEAR THE OUTER REACHES OF THE MILKY WAY, A HUGE CLOUD OF GAS AND DUST BEGINS TO CONDENSE.
- 31 04:06:36:02 BILLIONS OF MILES ACROSS, THE CLOUD COLLAPSES INTO A FLAT, SPINNING DISK, A SOLAR NEBULA.
- 32 04:06:43:16 WITHIN THE DISK, PARTICLES COLLIDE AND ADHERE.
- 33 04:06:47:01 THE PRIMORDIAL SUN AND PLANETS STRUGGLE TO EMERGE.
- 34 04:06:51:02 AS THE SUN IGNITES, IT BLOWS AWAY MOST OF THE GAS FROM THE INNER SOLAR SYSTEM, AND ONLY HOT, ROCKY WORLDS REMAIN.
- 35 04:07:02:03 ENORMOUS COLLISIONS SHAPED THE PLANET WE WILL ONE DAY CALL EARTH.
- 36 04:07:10:17 PERHAPS ONE LAST IMMENSE IMPACT SPINS OFF MATTER THAT WILL BECOME THE MOON.
- 37 04:07:17:01 THE EARTH BEGINS ITS SLOW TRANSFORMATION INTO THE PLANET ON WHICH WE LIVE TODAY.
- 38 04:07:28:16 4 1/2 BILLION YEARS LATER, THE EARTH IS STILL EVOLVING.
- 39 04:07:33:19 WE INHABIT A RESTLESS, SHIFTING PLANET WHOSE SURFACE CHANGES IN ENDLESS CYCLES OF CREATION AND DESTRUCTION.
- 40 04:07:42:17 MOST OF THE EARTH'S HISTORY IS PRESERVED IN ITS ROCKS, BUT VAST CHAPTERS ARE MISSING.
- 41 04:07:50:03 THE VERY EARLIEST ROCKS, FROM EARTH'S FIRST BILLION YEARS, WERE DESTROYED BY EARTH'S INCESSANT ACTIVITY HOW CAN WE KNOW WHAT HAPPENED BEFORE EARTH'S RESTLESS GEOLOGY ERASED THE RECORD?
- 42 04:08:04:18 OUR NEAREST NEIGHBOR IN SPACE WAS SHAPED BY THE SAME EVENTS THAT MADE THE INFANT EARTH.
- 43 04:08:12:16 MIGHT OUR LONG-DEAD MOON HOLD THE SECRET OF

EARTH'S MISSING HISTORY?

- 44 04:08:18:17 [PRESIDENT JOHN F. KENNEDY] IF I WERE TO SAY, THAT WE SHALL SEND TO THE MOON A GIANT ROCKET MADE OF NEW METAL ALLOYS, SOME OF WHICH HAVE NOT BEEN INVENTED, CAPABLE OF STANDING HEAT AND STRESSES SEVERAL TIMES MORE THAN HAVE EVER BEEN EXPERIENCED, FITTED TOGETHER WITH A PRECISION BETTER THAN THE FINEST WATCH, CARRYING ALL THE EQUIPMENT NEEDED FOR PROPULSION, GUIDANCE, CONTROL, COMMUNICATIONS ON AN UNTRIED MISSION TO AN UNKNOWN CELESTIAL BODY AND DO ALL THIS AND DO IT RIGHT...
- 45 04:08:59:21 JULY 20, 1969, *APOLLO 11* RELAYS LIVE PICTURES FROM THE MOON.
- 46 04:09:08:04 CRATERS GLIDE BY.
- 47 04:09:10:00 ARE THEY EXTINCT VOLCANOES OR WOUNDS LEFT BY STILL MORE VIOLENT EVENTS IN THE DISTANT PAST?
- 48 04:09:18:01 IRONICALLY, PART OF THE ANSWER LIES IN RARE, MOONLIKE REGIONS OF THE EARTH ITSELF.
- 49 04:09:24:16 IT'S NOT EASY TO SEE CRATERS ON EARTH.
- 50 04:09:28:17 MOST ARE SO ERODED, ONLY FAINT, CIRCULAR SCARS REMAIN.
- 51 04:09:33:01 HOW WERE THESE STRANGE STRUCTURES FORMED?
- 52 04:09:36:00 THE MYSTERY WAS SOLVED AT METEOR CRATER NEAR FLAGSTAFF, ARIZONA.
- 53 04:09:41:15 A MILE ACROSS AND 600 FEET DEEP, THIS ENORMOUS HOLE WAS CREATED 50,000 YEARS AGO IN AN EVENT OF UNIMAGINABLE FORCE.
- 54 04:09:55:15 MANY SCIENTISTS BELIEVE THAT METEOR CRATER WAS THE REMNANT OF AN OLD VOLCANO.
- 55 04:10:02:01 THE REAL EXPLANATION INVOLVES A MORE RADICAL IDEA -- THAT BODIES FROM SPACE HELPED SHAPE THE EARTH.

- 56 04:10:09:29 GENE SHOEMAKER, A SCIENTIST WITH THE U.S. GEOLOGICAL SURVEY, HELPED PROVE THAT THE CRATER FORMED WHEN A NICKEL-IRON METEORITE SMASHED INTO THE EARTH.
- 57 04:10:21:22 THE EVIDENCE WAS ALL AROUND.
- 58 04:10:24:09 THE MAIN EVIDENCE FOR THE IMPACT ORIGIN OF THIS CRATER IS IN THE GEOLOGY.
- 59 04:10:31:17 THERE'S A LENS, 600 FEET DEEP, OF BROKEN ROCK THAT WAS EXPLORED BY DANIEL MOREAU BARRINGER AND HIS ASSOCIATES.
- 60 04:10:41:13 WE FIND A DEEP LENS OF BROKEN ROCK GOING TO THAT DEPTH WITH THE LOWER 50 FEET CONTAINING MELTED DROPLETS OF THE METEORITE.
- 61 04:10:53:05 ANOTHER PART OF THE EVIDENCE IS THE CRATER WALL.
- 62 04:10:56:29 THE ROCKS ARE OFFSET ALONG A LARGE FAULT.
- 63 04:11:01:01 ONE SIDE OF THE CRATER WALL'S BEEN PEELED OUT MUCH FURTHER THAN THE OTHER SIDE.
- 64 04:11:09:02 THE ROCKS THAT WERE IN THE MIDDLE WERE SPEWED OUT AND LAID OUT ON THE SURROUNDING TERRAIN AS A GIANT BLANKET OF BROKEN MATERIAL.
- 65 04:11:21:00 [BEEPING] COLLISIONS WITH EARTH ARE EXTREMELY RARE, SO TO STUDY THEIR ROLE IN THE FORMATION OF PLANETS, SCIENTISTS INVENT WAYS TO MAKE THEIR OWN.
- 66 04:11:39:13 PLANETARY GEOLOGIST PETE SCHULTZ AND HIS COLLEAGUES AT THE NASA AMES RESEARCH FACILITY NEAR SAN FRANCISCO, PERFORM UNIQUE EXPERIMENTS TO DEMONSTRATE WHAT HAPPENS WHEN A BODY FROM OUTER SPACE STRIKES THE SURFACE OF A PLANET.
- 67 04:11:57:00 WITH A VERTICAL GAS GUN, THEY RECONSTRUCT GREAT COLLISIONS.
- 68 04:12:01:14 400 FRAMES PER SECOND UP HERE, AND WE'VE GOT 8,500 FRAMES PER SECOND.

- 69 04:12:07:17 A VACUUM IS PRODUCED TO SIMULATE CONDITIONS IN SPACE.
- 70 04:12:12:01 THEN EXPLOSIONS ARE RECORDED IN EXTREME SLOW MOTION.
- 71 04:12:16:02 200 FRAMES PER SECOND WITH THE 2,000.
- 72 04:12:19:21 AT 25,000 MILES AN HOUR, THE GUN FIRES METAL PELLETS DOWN A BARREL MORE THAN THREE STORIES LONG.
- 73 04:12:31:27 LET'S SHOOT IT!
- 74 04:12:43:16 LET'S SEE WHAT WE'VE GOT.
- 75 04:12:46:05 THIS SEQUENCE SHOWS THE CRATER AS IT GROWS.
- 76 04:12:50:02 IT GROWS IN AN ORDERLY PROCESS.
- 77 04:12:53:02 UNDER A VACUUM CONDITION, THERE'S NOTHING TO INTERACT.
- 78 04:12:57:00 THE EJECTA CURTAIN MOVES OUT AS A WALL OF DEBRIS.
- 79 04:13:02:03 EJECTA MOVES UPWARD AND OUTWARD.
- 80 04:13:04:19 LATER, THAT EJECTA MOVES DOWNWARD AND OUTWARD.
- 81 04:13:08:04 THE NET EFFECT IS THIS WALL OF ADVANCING MATERIAL.
- 82 04:13:12:01 THE EJECTA CURTAIN TURNS INTO CLUMPS, AND THESE CLUMPS EVENTUALLY WILL IMPACT THE SURFACE AS IT MOVES OUTWARD IN THIS VERY ORDERLY PROCESS.
- 83 04:13:23:16 IN MINIATURE, THESE EXPERIMENTS RECREATE THE IMPACT CRATERS WE SEE ON THE MOON.
- 84 04:13:31:08 WELL, HERE'S A CRATER.
- 85 04:13:33:08 THE CRATER IS IN THE CENTER.
- 86 04:13:36:15 WE FIND A SYMMETRICAL RIM.
- 87 04:13:39:00 AS WE GO AWAY FROM THE CRATER, THE EJECTA,

- MATERIAL TOSSED OUT BY THE CRATER, THINS WITH DISTANCE.
- 88 04:13:48:15 THEN WE HAVE RAYS OF MATERIAL.
- 89 04:13:51:16 WE SAW THE EJECTA CURTAIN BREAKING INTO CLUMPS AND THEN IMPACTING THE SURFACE.
- 90 04:13:58:02 THIS IS WHAT MAKES UP THE CRATER RAYS.
- 91 04:14:02:04 THESE EXPERIMENTS REVEAL THE FORCES THAT LEFT THOUSANDS OF CRATERS AND THEIR RAYS ON THE MOON.
- 92 04:14:09:22 YET, TO READ ITS REAL HISTORY, WE HAVE TO KNOW WHEN THE BOMBARDMENTS TOOK PLACE.
- 93 04:14:17:15 THE MOON'S PLAINS AND MOUNTAINS, WHEN WERE THEY FORMED?
- 94 04:14:22:02 UNTIL MAN WALKED ON THE MOON, NO ONE KNEW.
- 95 04:14:26:03 *FANTASTIC!*
- 96 04:14:27:15 *PERFECT PRECISION.*
- 97 04:14:29:16 *ROGER. WE COPY.*
- 98 04:14:31:15 *WHAT A NEAT PLACE!*
- 99 04:14:33:12 *THE MOTOR IS RUNNING, HOUSTON.*
- 100 04:14:36:02 *DRIVE THROUGH A FEW LITTLE CRATERS.*
- 101 04:14:39:10 AS ASTRONAUTS ROAMED THE SURFACE, THEIR MOST IMPORTANT TASK IS TO GATHER SAMPLES OF ROCK.
- 102 04:14:47:16 *LOOK AT THE SIZE OF THAT ROCK!*
- 103 04:14:51:02 *THE CLOSER I GET, THE BIGGER IT IS.*
- 104 04:14:55:11 MOST SCIENTISTS BELIEVED THE MOON'S ROCKS WOULD BE ANCIENT.
- 105 04:14:59:22 DATING THE LUNAR SURFACE WOULD REVEAL THE HISTORY OF MOON AND EARTH.
- 106 04:15:05:25 THEY WERE WRONG.

- 107 04:15:07:19 MOST MOON ROCKS *WERE* BETWEEN 3 AND 4 BILLION YEARS OLD, MUCH OLDER THAN THOSE ON THE EARTH.
- 108 04:15:16:01 BUT SOME HALF A BILLION YEARS OF THE MOON'S HISTORY WAS MISSING.
- 109 04:15:22:15 THE SAMPLES GATHERED SO CAREFULLY WERE NOT PART OF THE MOON'S ORIGINAL SURFACE.
- 110 04:15:28:08 IT, TOO, HAD VANISHED LIKE THE EARTH'S IN THE PAST.
- 111 04:15:33:00 AS MORE SAMPLES WERE RETURNED, THE EARLY CHAPTERS OF THE MOON'S HISTORY BEGAN TO EMERGE.
- 112 04:15:44:16 4 1/2 BILLION YEARS AGO, THE INITIAL FORMATION OF THE MOON IS COMPLETE.
- 113 04:15:51:16 ITS SURFACE, HEATED BY REPEATED IMPACTS, COOLS.
- 114 04:15:58:15 4 BILLION YEARS AGO, A SECOND MASSIVE BOMBARDMENT MAY HAVE OCCURRED, DESTROYING MUCH OF THE ORIGINAL SURFACE ROCK.
- 115 04:16:09:01 FOR MILLIONS OF YEARS, LAVA WELLS UP THROUGH THE CRATER FLOORS, HIDING STILL MORE OF THE ORIGINAL SURFACE.
- 116 04:16:18:00 3 BILLION YEARS AGO, THE MOON'S SURFACE SOLIDIFIES.
- 117 04:16:22:01 EXCEPT FOR A SLOW RAIN OF IMPACTS FROM SPACE, IT REMAINS UNCHANGED TODAY.
- 118 04:16:28:16 OUR JOURNEY TO THE MOON PROVIDED A SURPRISE.
- 119 04:16:32:16 BOMBARDMENTS IN SPACE ARE NOT OCCASIONAL CATASTROPHES BUT THE MOST IMPORTANT FORCE IN THE FORMATION OF PLANETS.
- 120 04:16:41:01 TO GENE SHOEMAKER, METEOR CRATER REMINDS US THAT IMPACTS HELPED SHAPE EARTH.
- 121 04:16:47:13 ON THE EARTH TODAY, OTHER PROCESSES ARE MORE IMPORTANT.

- 122 04:16:52:02 SO IMPACT CRATERS ARE AN INCONSPICUOUS FEATURE.
- 123 04:16:55:01 BUT ON THE MOON, MERCURY, MARS, AND SOME SATELLITES OF JUPITER AND SATURN, IMPACT CRATERS ARE THE DOMINANT FEATURE OF THE LANDSCAPE AND GEOLOGY.
- 124 04:17:07:07 TO EXPLORE THESE NEIGHBORING PLANETS, WE DEVELOPED EVEN MORE FABULOUS MACHINES.
- 125 04:17:13:01 ROBOTS, SOPHISTICATED ENOUGH TO TRAVEL MILLIONS OF MILES, WERE BUILT TO SCRUTINIZE THE WORLDS BEYOND, TO LAND UPON THEM, AND TO REPORT UPON WHAT THEY FOUND.
- 126 04:17:27:17 THE FIRST PLANET WE WOULD VISIT WAS VENUS.
- 127 04:17:31:16 FOR MILLENNIA, MAN HAS SEEN VENUS AS A BRIGHT STAR GLIMMERING ON THE HORIZON.
- 128 04:17:39:01 UNTIL RECENTLY, IT RESISTED EXPLORATION.
- 129 04:17:42:02 SCIENTISTS KNOW VENUS AS OUR SISTER PLANET -- NEARLY THE SAME SIZE AND WEIGHT AS EARTH.
- 130 04:17:50:01 STILL, IT REMAINED A PUZZLE ENSHROUDED IN A MANTLE OF CLOUDS.
- 131 04:17:55:16 OUR VOYAGES REVEALED IT TO BE A MOST UN-EARTHLIKE PLACE.
- 132 04:18:03:19 IF WE COULD DESCEND THROUGH THE DENSE ATMOSPHERE OF VENUS, WE WOULD FIND IT FILLED WITH CARBON DIOXIDE, RACKED BY STORMS AND BOLTS OF LIGHTNING.
- 133 04:18:15:16 UNLIKE THE CLOUDS OF EARTH, THOSE ON VENUS ARE THICK AND POISONOUS, FILLED WITH SULFUR AND SULFUR DROPLETS, AN ACID RAIN CAPABLE OF DISSOLVING THE HARDEST OF METALS.
- 134 04:18:30:16 WINDS UP TO 200 MILES AN HOUR WHIP THE CLOUDS AROUND THE PLANET.
- 135 04:18:36:02 AND ON THE SURFACE, THE ATMOSPHERE CREATES A PRESSURE 90 TIMES MORE CRUSHING THAN ON EARTH.

- 136 04:18:44:01 NO PLACE CAN REPLICATE THE CLIMATE OF VENUS, NO OTHER WORLD IS AS SCORCHED AND BARREN, NO OTHER LANDSCAPE SO CHARRED AND SEERED.
- 137 04:18:55:16 BUT DEATH VALLEY CAN GIVE US AN IDEA.
- 138 04:18:59:16 VENUS HAS EVOLVED DIFFERENTLY FROM EARTH.
- 139 04:19:02:18 HOW DID IT BECOME HOT AND DESOLATE?
- 140 04:19:05:25 JIM HEAD, A PLANETARY SCIENTIST AT BROWN UNIVERSITY, IS AN AUTHORITY ON VENUS.
- 141 04:19:12:12 DEATH VALLEY IS ONE OF THE HOTTEST PLACES ON THE EARTH.
- 142 04:19:18:16 IT'S NOWHERE NEAR AS HOT AS THE SURFACE OF VENUS.
- 143 04:19:23:16 EVEN THOUGH TEMPERATURES HERE CAN EXCEED 120 DEGREES FAHRENHEIT, ON VENUS, THEY GET UP TO 900 DEGREES FAHRENHEIT.
- 144 04:19:32:16 HOW DID IT GET THIS WAY?
- 145 04:19:35:16 IS IT BECAUSE VENUS IS CLOSER TO THE SUN THAN THE EARTH?
- 146 04:19:41:21 IT'S ONLY PART OF THE ANSWER.
- 147 04:19:44:21 ON EARTH, THE HEAT THAT COMES INTO THE SURFACE CAN BE RERADIATED OUT TO SPACE.
- 148 04:19:52:01 ON VENUS, THE THICK ATMOSPHERE ACTS AS A GREENHOUSE WHICH TRAPS THE HEAT UNDERNEATH THE CLOUD LAYER.
- 149 04:20:00:10 ONLY THE SOVIET UNION HAS SUCCESSFULLY LANDED PROBES ON THE SURFACE OF VENUS.
- 150 04:20:07:01 BEFORE THEY WERE DESTROYED IN THE HOSTILE ATMOSPHERE, THEY RADIOED BACK IMAGES OF A STRANGE AND HELLISH WORLD.
- 151 04:20:19:13 THE PICTURES WERE EXTRAORDINARY, BUT THEY TELL US LITTLE ABOUT THE GEOGRAPHY OF VENUS.
- 152 04:20:26:14 IN 1977, AMERICA'S PIONEER-VENUS SPACECRAFT USED RADAR TO PIERCE THE DENSE CLOUDS.

- 153 04:20:32:29 JIM HEAD AND HIS COLLEAGUES HAD A GLOBAL VIEW OF VENUS.
- 154 04:20:37:29 THE PIONEER-VENUS SPACECRAFT PROVIDED INFORMATION FROM AN ORBITER, WHICH, USING RADAR INSTRUMENTS, PROVIDED A GLOBAL TOPOGRAPHIC MAP.
- 155 04:20:47:12 WE CAN COLOR THE BLUES LOWLANDS AREAS.
- 156 04:20:50:29 WE CAN THEN COLOR INTERMEDIATE PLAINS IN GREENS AND HIGHLANDS IN YELLOWS, BROWNS, AND REDS.
- 157 04:20:58:14 WE CAN GET A BETTER IDEA OF THE THREE-DIMENSIONAL NATURE OF THE ALTITUDES.
- 158 04:21:05:16 WE CAN BEGIN TO SEE LOWLAND AREAS HERE THAT ARE LIKE OCEAN BASINS ON THE EARTH, BUT BECAUSE OF THE HEAT, DON'T HAVE ANY WATER IN THEM.
- 159 04:21:18:14 WE CAN ALSO SEE DISTINCTIVE HIGHLAND REGIONS.
- 160 04:21:22:00 ISHTAR TERRA IS ABOUT THE SIZE OF AUSTRALIA AND HAS DISTINCTIVE LINEAR MOUNTAIN RANGES.
- 161 04:21:29:01 MAXWELL MONTES RISES 30,000 FEET ABOVE THE MEAN RADIUS.
- 162 04:21:33:22 EVEN THESE PICTURES ARE INADEQUATE.
- 163 04:21:36:06 MUCH OF THE EARTH'S GEOLOGY WOULD REMAIN HIDDEN IF IT WERE DEPICTED IN THE SAME WAY.
- 164 04:21:44:01 THIS IS REALLY INTERESTING BECAUSE ALL THE FAMILIAR FEATURES REALLY LOOK DRAMATICALLY FAMILIAR.
- 165 04:21:50:16 BUT WE REALIZE THE RESOLUTION ISN'T GOOD ENOUGH TO UNDERSTAND THE NATURE OF THE GEOLOGY.
- 166 04:21:57:18 SOMETHING AS DRAMATIC AS THE GRAND CANYON ISN'T VISIBLE AT THIS RESOLUTION.
- 167 04:22:03:25 WE CAN GET A PICTURE OF VENUS' GEOGRAPHY, BUT WE HAVE NO IDEA WHAT THE GEOLOGICAL ORIGIN OF

THE SURFACE FEATURES ARE.

- 168 04:22:14:11 TO STUDY THE FORCES THAT SHAPED VENUS, JIM HEAD USES A SPECIAL TOOL.
- 169 04:22:20:21 HIGH IN THE PUERTO RICAN MOUNTAINS NEAR ARECIBO RESTS THE LARGEST RADIO TELESCOPE ON EARTH.
- 170 04:22:28:21 1,000 FEET ACROSS, THIS RADAR ANTENNA BOUNCES SIGNALS OFF VENUS' SURFACE AND SCOOPS UP THE FAINT ECHOES THAT RETURN.
- 171 04:22:38:08 THE ARECIBO DATA GIVES US 50 TO 100 TIMES BETTER RESOLUTION THAN THE PIONEER-VENUS INFORMATION.
- 172 04:22:46:16 YOU CAN SEE WHAT THE EFFECT OF THIS IS BY LOOKING AT BETA REGIO USING THE HIGHER RESOLUTION ARECIBO DATA.
- 173 04:22:56:08 ACROSS 26 MILLION MILES OF SPACE, ARECIBO SENSES DETAILS DOWN TO A SINGLE KILOMETER.
- 174 04:23:03:18 AT CLOSE RANGE, VENUS IS STILL MORE ASTONISHING.
- 175 04:23:07:19 INSTEAD OF A SERIES OF VIVID COLORS, WE SEE A LOT OF DETAIL.
- 176 04:23:14:02 WE SEE IN THE MIDDLE OF THE VALLEY A SERIES OF BRIGHT LINES WHICH PROBABLY REPRESENT FAULTS.
- 177 04:23:21:21 LET'S LOOK AT THESE IN EVEN MORE DETAIL.
- 178 04:23:26:05 WE CAN SEE A LOT OF FAULTS THROUGH THE MIDDLE OF THIS EXTENSIVE TROUGH.
- 179 04:23:33:12 THIS IS LIKE THE SETTING IN THE EAST AFRICAN RIFT ON EARTH WHERE EXTENSIONAL FORCES PULL THE CRUST APART.
- 180 04:23:42:11 THE CIRCULAR FEATURE IS EVEN MORE DRAMATIC.
- 181 04:23:46:02 IT IS A VOLCANO WHICH IS BUILT UP ON TOP OF THE FAULTS, SENDING LAVA FLOWS EXTENDING AWAY FROM THE VALLEY.

- 182 04:23:56:01 WE SEE HERE EXTENSIONAL TECTONIC FORCES MUCH LIKE WE SEE ON EARTH AND VOLCANISM ASSOCIATED WITH THIS EXTENSION, MUCH LIKE MOUNT KILIMANJARO IS ASSOCIATED WITH THE EARTH'S EAST AFRICAN RIFT.
- 183 04:24:10:29 FOR BILLIONS OF YEARS, EARTH HAS BEEN CHANGING.
- 184 04:24:15:05 THE PROCESS CALLED PLATE TECTONICS IS RESTLESSLY REARRANGING ITS SURFACE, SHIFTING ITS CRUST AROUND THE PLANET.
- 185 04:24:26:15 BUT HOW DID THE PROCESS BEGIN?
- 186 04:24:29:15 CURIOUSLY, VENUS MAY HOLD THE ANSWER.
- 187 04:24:32:16 LOOKING AT VENUS MAY BE A WAY OF LOOKING AT THE EARTH BEFORE THE BEGINNING OF PLATE TECTONICS.
- 188 04:24:41:01 SAMPLES COLLECTED THERE MAY TELL US EVEN MORE.
- 189 04:24:45:00 IN A 5-BILLION-YEAR-OLD VENUS, WE MAY BE SEEING AN EARTH IN ITS YOUTH.
- 190 04:24:55:16 BEYOND VENUS LIES THE RED PLANET, MARS.
- 191 04:25:00:18 JUST 1/3 THE SIZE OF EARTH, THE ATMOSPHERE OF MARS IS SO THIN IT IS BARELY THERE AT ALL.
- 192 04:25:10:02 THE MARINER AND VIKING SPACECRAFT REVEALED A WORLD UPON WHOSE SURFACE WAS WRITTEN A VIOLENT AND RESTLESS PAST.
- 193 04:25:19:01 ACROSS THE MARTIAN EQUATOR, THEY FOUND AN ENORMOUS GASH, THE VALLES MARINERIS.
- 194 04:25:25:01 TWO MILES DEEP, IT STRETCHES THE LENGTH OF THE UNITED STATES AND COULD SWALLOW SCORES OF GRAND CANYONS.
- 195 04:25:34:16 NOTHING QUITE LIKE IT HAD BEEN SEEN ANYWHERE IN THE SOLAR SYSTEM.
- 196 04:25:42:02 ONLY IN OUR IMAGINATION CAN WE SWEEP THROUGH THESE GREAT CANYONS.

- 197 04:25:47:17 BUT FUTURE SPACECRAFT ALMOST CERTAINLY WILL.
- 198 04:25:50:15 TO THE NORTHWEST OF THE VALLES MARINERIS, *MARINER 9* PHOTOGRAPHED AN IMMENSE VOLCANO RISING THREE TIMES THE HEIGHT OF MOUNT EVEREST.
- 199 04:26:01:04 17 MILES FROM SURFACE TO SUMMIT, IT HAS A BASE AS BROAD AS THE STATE OF MONTANA, A PLACE SO MAJESTIC, IT IS NAMED MOUNT OLYMPUS.
- 200 04:26:14:01 CLEARLY, MARS IS A WORLD THAT WORKS ON A GIGANTIC SCALE.
- 201 04:26:20:17 WE EARTHLINGS HAVE ALWAYS FOUND MARS INTRIGUING EVEN BEFORE WE SENT PROBES TO INVESTIGATE.
- 202 04:26:27:16 A CENTURY AGO WE COULD ONLY VIEW IT FROM OBSERVATORIES LIKE THIS IN THE HILLS OF FLAGSTAFF, ARIZONA.
- 203 04:26:36:11 BUT WE SPECULATED IT MIGHT NOT BE A PLANET TOO DIFFERENT FROM OUR OWN.
- 204 04:26:43:00 WE NURTURED THE HOPE THAT MARS HARBORED INTELLIGENT LIFE.
- 205 04:26:47:16 TOBY OWEN IS A SCIENTIST WHO STUDIES MARS' ATMOSPHERE.
- 206 04:26:51:17 MARS IS THE MOST OFTEN IMAGINED PLANET TO BE CAPABLE OF SUPPORTING LIFE.
- 207 04:26:57:22 THESE ARE DRAWINGS OF MARS MADE BY PERCIVAL LOWELL, WHO BUILT THIS OBSERVATORY ABOUT 100 YEARS AGO SO THAT HE COULD STUDY THIS PLANET IN GREAT DETAIL.
- 208 04:27:10:15 LOWELL DESCRIBED A WORLD THAT FIRED THE PUBLIC IMAGINATION.
- 209 04:27:14:26 HE MADE AMAZING OBSERVATIONS.
- 210 04:27:17:16 EACH YEAR, HE WATCHED THE PLANET'S ICE CAPS WAX AND WANE.
- 211 04:27:23:15 DURING THE MARTIAN SUMMER, HE OBSERVED DARK

AREAS SPREAD ACROSS THE PLANET.

- 212 04:27:29:17 THESE, HE PROCLAIMED, WERE THE BLOSSOMINGS OF MARTIAN FORESTS.
- 213 04:27:34:01 CAREFULLY, HE RECORDED THESE CHANGES.
- 214 04:27:36:16 VEGETATION WAS NOT THE ONLY LIFE LOWELL SAW ON MARS.
- 215 04:27:41:16 HE BELIEVED IT WAS THE HOME OF A DYING RACE, ONE THAT HAD BUILT CANALS TO CARRY WATER FROM ITS POLAR ICE CAPS TO THE PARCHED CITIES AT ITS EQUATOR.
- 216 04:27:56:16 HE MAPPED AN INTRICATE SYSTEM OF AQUADUCTS AND PREDICTED WE WOULD FIND THE INHABITANTS OF AN ANCIENT CIVILIZATION.
- 217 04:28:05:16 THAT IS NOT HOW THINGS TURNED OUT.
- 218 04:28:09:16 THIS IS THE TELESCOPE THAT PERCEVAL LOWELL USED TO MAKE HIS OBSERVATIONS OF MARS.
- 219 04:28:16:16 LOWELL WAS TRAPPED ON THE EARTH AS ALL ASTRONOMERS WERE UNTIL WE'D LEARNED HOW TO SEND SPACECRAFT TO THE OTHER PLANETS.
- 220 04:28:27:15 WHEN WE GOT TO MARS, WE FOUND A VERY DIFFERENT PLANET -- NO EVIDENCE OF CANALS, CANAL BUILDERS, OR ANY LIFE.
- 221 04:28:37:00 TO GET A FEELING FOR WHAT MARS IS LIKE, THINK OF YOURSELF BEING THERE ON A CAMPING EXPEDITION.
- 222 04:28:45:16 YOUR JOB IS TO BOIL AN EGG.
- 223 04:28:49:00 YOU DISCOVER THERE'S NO FUEL ON MARS.
- 224 04:28:52:15 THERE'S NO ORGANIC MATERIAL.
- 225 04:28:54:16 EVEN IF THERE WERE FUEL, IT WOULDN'T BURN BECAUSE THERE'S ONLY A TINY TRACE OF OXYGEN.
- 226 04:29:02:12 THAT'S MARS AS WE FIND IT NOW -- A DRY, COLD, DESERTLIKE PLANET WITH NO POSSIBILITY FOR LIFE AS WE KNOW IT TO EXIST THERE.
- 227 04:29:15:02 FROM THE PICTURES THE VIKING LANDERS

- RETURNED, IT'S NOT DIFFICULT TO UNDERSTAND WHY WE FOUND NOTHING LIVING.
- 228 04:29:23:01 BUT PHOTOGRAPHS TAKEN ABOVE MARS REVEAL A DIFFERENT WORLD.
- 229 04:29:27:15 LOCKED IN THE ICE CAPS OF MARS ARE OCEANS OF WATER, AND ONCE THAT WATER FLOWED ACROSS THE MARTIAN SURFACE.
- 230 04:29:37:00 REMNANTS OF ANCIENT RIVER BEDS CLEARLY REACH OUT IN FINE, FINGERLIKE PATTERNS, AND GREAT, SCURED REGIONS THAT RESEMBLE FLOOD PLAINS SPEAK OF A TIME WHEN MARS WAS NOT ALWAYS SO DESOLATE AND COLD.
- 231 04:29:54:01 WHAT COULD HAVE CREATED THESE STRANGE FEATURES?
- 232 04:29:57:15 THE FIRST CLUE CAME FROM EARTH -- THE SCABLANDS OF CENTRAL WASHINGTON STATE.
- 233 04:30:03:21 13,000 YEARS AGO, A 3,000-SQUARE-MILE LAKE COVERED MUCH OF MONTANA UNTIL IT BURST ITS GLACIAL DAM AND ROARED ACROSS THE SCABLANDS.
- 234 04:30:16:06 A WALL OF WATER 30 STORIES HIGH EXPLODED TOWARD THE PACIFIC TO DEVASTATE EVERYTHING IN ITS PATH.
- 235 04:30:24:14 IN ITS WAKE, IT LEFT ONE OF THE STRANGEST GEOLOGICAL FORMATIONS ON EARTH.
- 236 04:30:35:28 LIKE GREAT SCARS UPON THE SKIN OF PLANET EARTH, THE SCABLANDS REMAIN, PROOF OF THE POWER UNLEASHED BY A CATASTROPHIC FLOOD.
- 237 04:30:46:27 NORMALLY, THESE CANYONS AND BUTTES WOULD TAKE MILLIONS OF YEARS TO FORM.
- 238 04:30:55:00 THE FLOOD GOUGED THEM OUT IN LESS THAN A SINGLE WEEK.
- 239 04:31:01:15 FROM HIGH ABOVE, THE SCARS LEFT BY THE GREAT FLOOD ON EARTH ARE SIMILAR TO THE TERRAIN OF MARS.

- 240 04:31:11:16 BILLIONS OF YEARS AGO, IN FLASH-FLOODS THAT DWARF THOSE ON EARTH, LIQUID WATER MUST HAVE RUSHED OVER THE SURFACE OF MARS.
- 241 04:31:23:16 PERHAPS IT WAS A PLANET MUCH LIKE EARTH.
- 242 04:31:27:16 MARS MAY HAVE HARBORED LIFE.
- 243 04:31:30:02 TOBY OWEN BELIEVES MARS HAD A WARMER CLIMATE AND HELD LIQUID WATER.
- 244 04:31:36:01 IT WOULD HAVE HAD A MUCH THICKER ATMOSPHERE, LIKE EARTH'S, A BLANKET OF GASES TO TRAP HEAT.
- 245 04:31:44:11 THAT ATMOSPHERE WOULD HAVE BEEN RICH IN CARBON DIOXIDE, WHICH IS A VERY GOOD GAS FOR HOLDING HEAT IN.
- 246 04:31:53:01 IT WOULD HAVE EXERTED ENOUGH PRESSURE, TO ALLOW LIQUID WATER TO EXIST ON THE SURFACE.
- 247 04:32:00:23 WARM TEMPERATURE, HIGH PRESSURE, LIQUID WATER, AND GASES IN THE ATMOSPHERE PROVIDE YOU WITH THE ELEMENTS YOU NEED FOR LIFE.
- 248 04:32:10:26 MARS HAS ALL THE BASIC CONDITIONS.
- 249 04:32:13:26 DID IT HAPPEN, AND WHAT DID IT PRODUCE?
- 250 04:32:17:18 IN WESTERN AUSTRALIA, THERE ARE CLUES TO WHAT LIFE ON MARS MAY HAVE BEEN LIKE.
- 251 04:32:25:01 ORGANISMS SIMILAR TO THOSE THAT FLOURISHED 3 BILLION YEARS AGO LIVE HERE.
- 252 04:32:31:13 THEY ARE STROMATOLITES, ROCKY DOMES BUILT BY MICROBIAL COMMUNITIES.
- 253 04:32:36:26 FOR OVER A BILLION YEARS, THEY WERE THE DOMINANT LIFEFORM.
- 254 04:32:41:26 IF MARTIANS EVER EXISTED, THEY VERY POSSIBLY LOOKED LIKE THIS.
- 255 04:32:48:00 BUT MARS LOST ITS ATMOSPHERE AND ITS WATER.
- 256 04:32:52:26 THE THREAD OF LIFE WOULD HAVE BEEN BROKEN.
- 257 04:32:57:16 PERCIVAL LOWELL'S RACE OF CANAL BUILDERS

- NEVER DID RULE MARS.
- 258 04:33:02:17 IF EVER THERE WAS LIFE ON THE PLANET, IT WAS NO LESS DOOMED.
- 259 04:33:10:15 MARS IS THE LAST OF THE ROCKY, EARTHLIKE PLANETS.
- 260 04:33:15:16 FAR BEYOND IT IS AN ENTIRELY DIFFERENT KIND OF SOLAR SYSTEM.
- 261 04:33:21:06 IN 1977, THE *VOYAGER* SPACECRAFT SET OUT ON A GRAND TOUR OF THESE STRANGE, FARAWAY WORLDS.
- 262 04:33:30:06 400 MILLION MILES AWAY, THE FIRST STOP IS JUPITER, THE HUGE, VAPOROUS PLANET OF GAS.
- 263 04:33:38:06 A REMARKABLE INFRARED PICTURE REVEALS JUPITER AS NEVER BEFORE.
- 264 04:33:44:00 WITH NO SOLID SURFACE, IT CONTINUALLY RADIATES HEAT FROM ITS CORE.
- 265 04:33:50:16 HAD IT BEEN SEVERAL TIMES LARGER, IT WOULD HAVE IGNITED TO BECOME A SECOND SUN.
- 266 04:33:58:02 300 TIMES MORE MASSIVE THAN THE EARTH, JUPITER SPINS ALMOST THREE TIMES AS FAST.
- 267 04:34:05:24 IMAGES RADIOED BACK BY *VOYAGER* ARE COMPUTER-ENHANCED TO REVEAL CURIOUS PATTERNS THAT COVER JUPITER'S SURFACE.
- 268 04:34:14:24 THE JOVIAN ATMOSPHERE IS FILLED WITH CLOUDS TWISTING AND TURNING IN A THOUSAND SHAPES.
- 269 04:34:21:26 HUGE ANTICYCLONES DISRUPT THE PLANET.
- 270 04:34:24:26 THE LARGEST, THE GREAT RED SPOT, IS BIGGER THAN THREE EARTHS.
- 271 04:34:30:16 SPED UP, THE TIRELESS ACTIVITY OF JUPITER'S TURBULENT ATMOSPHERE COMES TO LIFE.
- 272 04:34:38:06 STORMS ARE DRIVEN BY HEAT FROM WITHIN THE PLANET.
- 273 04:34:43:01 AROUND JUPITER ORBITS A BIZARRE SYSTEM OF

MOONS.

- 274 04:34:47:01 EACH SURPRISES THE SCIENTISTS WHO FIRST SEE THEM.
- 275 04:34:51:06 CALLISTO IS SCARRED BY GIANT IMPACTS THAT HAVE LEFT CONCENTRIC PATTERNS OF RINGS ACROSS ITS ICY SURFACE.
- 276 04:35:04:18 GANYMEDE IS THE LARGEST OF JUPITER'S MOONS.
- 277 04:35:08:04 UNLIKE OUR OWN MOON, MUCH OF IT'S MASS CONSISTS OF WATER ICE.
- 278 04:35:17:01 EUROPA IS THE BRIGHTEST OF THE MOONS.
- 279 04:35:20:15 ITS BRILLIANT, CRACKED SURFACE IS COVERED WITH A SMOOTH LAYER OF ICE.
- 280 04:35:29:02 AS *VOYAGER* PHOTOGRAPHS IO, ONE OF THE STRANGEST STORIES OF THE MISSION BEGINS TO UNFOLD.
- 281 04:35:36:29 WHAT CAUSED THE MARKINGS ON THIS ODD WORLD?
- 282 04:35:41:06 AT PASADENA'S JET PROPULSION LABORATORY, TORRENCE JOHNSON IS ONE OF *VOYAGER*'S IMAGING TEAM.
- 283 04:35:47:21 AS WE GOT CLOSER TO JUPITER, IO BEGAN TO LOOK STRANGE.
- 284 04:35:53:01 THE PICTURE YOU SEE IS MORE OR LESS TYPICAL OF WHAT WE SAW.
- 285 04:35:59:20 WE THOUGHT WE'D SEE CRATERS SUCH AS WE'VE SEEN ON THE MOON.
- 286 04:36:05:18 WE SAW STRANGE MARKINGS, BUT NO CRATERS.
- 287 04:36:09:01 WE COULDN'T FULLY INTERPRET WHAT WE WERE SEEING.
- 288 04:36:13:01 WE DID KNOW THAT WE WERE LOOKING AT A GEOLOGICALLY YOUNG SURFACE.
- 289 04:36:19:00 AND THAT THE SURFACE MUST BE RENEWING ITSELF.
- 290 04:36:24:17 THIS IMAGE, MADE FOR SPACECRAFT NAVIGATION,

- SUPPLIES THE FIRST TANTALIZING CLUE.
- 291 04:36:30:16 WHEN IT IS ENLARGED AND ENHANCED, A FAINT SMUDGE APPEARS OVER IO'S LIMB.
- 292 04:36:37:02 *VOYAGER* HAS CAPTURED A VOLCANO IN ACTION, THE FIRST EVER SEEN OUTSIDE THE EARTH.
- 293 04:36:44:16 *VOYAGER* UNCOVERS HOW THE ERUPTIONS ARE PRODUCED.
- 294 04:36:48:16 IO'S VOLCANOES CONSIST OF HOT SULFUR COMPOUNDS THAT EXPLODE AT HUNDREDS OF MILES AN HOUR.
- 295 04:36:56:01 TOWERING PLUMES RISE 200 MILES ABOVE ITS SURFACE.
- 296 04:37:04:18 AS IT FLIES BY, *VOYAGER* CAPTURES EIGHT MORE ACTIVE VOLCANOES.
- 297 04:37:09:28 SEEN IN THESE REMARKABLE PICTURES FROM SPACE, IO IS RIDDLED WITH EVIDENCE OF MULTIPLE ERUPTIONS.
- 298 04:37:18:01 VOLCANIC CRATERS DOT ITS SURFACE.
- 299 04:37:20:18 GIANT LAKES OF MOLTEN SULFUR PRESENT A LOOK OF DECAY AND DISEASE.
- 300 04:37:27:21 IO IS A TORTURED WORLD.
- 301 04:37:30:05 CAUGHT BETWEEN GRAVITATIONAL FIELDS OF JUPITER AND EUROPA, IT IS CONSTANTLY STRETCHED AND SQUEEZED.
- 302 04:37:37:15 AS HEAT FROM INSIDE ESCAPES, THE MOON LITERALLY TURNS ITSELF INSIDE-OUT.
- 303 04:37:46:02 HALF A BILLION MILES BEYOND JUPITER, *VOYAGER* ENCOUNTERS SATURN, ANOTHER ASTONISHING WORLD.
- 304 04:37:52:06 SATURN'S GREATEST GLORY IS ITS INTRICATE SYSTEM OF RINGS.
- 305 04:37:57:12 MORE THAN 100,000 MILES WIDE, THEY MAY BE LESS THAN 100 YARDS THICK.

- 306 04:38:03:28 THE THREE MAIN RINGS SEEN FROM EARTH INCLUDE A DAZZLING ARRAY OF RINGLETS WITHIN THE RINGS.
- 307 04:38:12:01 ONE DAY THEY MAY HELP US BETTER UNDERSTAND THOSE FORCES THAT SHAPE THE DISK THAT FORMED THE SOLAR SYSTEM.
- 308 04:38:22:02 BEYOND SATURN ARE STILL OTHER WORLDS -- ICY URANUS, WITH ITS PECULIAR UPRIGHT RINGS...
- 309 04:38:32:15 AND NEPTUNE, WITH ITS MOON OF TRITON, COLDER, MORE MYSTERIOUS, AND MORE DISTANT STILL.
- 310 04:38:43:19 EVENTUALLY, *VOYAGER* LEAVES ALL THE PLANETS BEHIND.
- 311 04:38:47:01 BEYOND THE LAST OUTPOST OF OUR SOLAR SYSTEM IS THE OORT CLOUD, A SHELL OF COSMIC DEBRIS THAT REMAINED AFTER THE PLANETS WERE FORMED.
- 312 04:38:59:01 THE OORT CLOUD -- WHERE COMETS RESIDE.
- 313 04:39:04:18 UNEXPECTEDLY, THE DEBRIS FROM THIS FARAWAY PLACE MAY HAVE PROFOUND EFFECTS UPON PLANET EARTH.
- 314 04:39:14:20 FROM AFAR, EARTH SEEMS NOT SO DIFFERENT FROM THE WORLDS AROUND IT.
- 315 04:39:22:01 YET OUR JOURNEYS TO OTHER WORLDS HAVE SHOWN US THAT OF ALL THE PLANETS IN THE SOLAR SYSTEM, PLANET EARTH IS UNIQUE.
- 316 04:39:36:01 BLESSED BY ITS DISTANCE FROM THE SUN, OUR PLANET HAS BECOME A GREAT, BLUE OASIS IN THE SOLAR SYSTEM.
- 317 04:39:45:24 LIKE NO OTHER WORLD, IT IS AWASH WITH OCEANS OF LIQUID WATER.
- 318 04:39:59:05 ITS AIR IS RICH WITH OXYGEN.
- 319 04:40:02:00 AND FOR BILLIONS OF YEARS, ITS TEMPERATURES HAVE REMAINED CONSTANT.
- 320 04:40:07:01 IT'S A STAGE UPON WHICH GEOLOGY AND CHEMISTRY HAVE WORKED AMAZING MIRACLES.

- 321 04:40:13:23 3 1/2 BILLION YEARS AGO, THE EARTH PRODUCED LIFE.
- 322 04:40:17:29 FROM THE HUMBLEST BEGINNINGS, LIFE HAS GROWN, SPREAD, AND EVOLVED.
- 323 04:40:27:29 IT HAS FILLED EVERY NOOK AND CRANNY ON THE PLANET.
- 324 04:40:43:14 YET, THE BEWILDERING VARIETY OF LIFE HAS UNDERGONE IMMENSE CHANGE.
- 325 04:40:49:19 SPECIES THAT NOW ROAM THE EARTH HAVEN'T ALWAYS BEEN HERE.
- 326 04:40:54:15 EVOLUTION FAVORS THE FITTEST.
- 327 04:40:57:00 THOUSANDS AND THOUSANDS OF FAMILIES OF ANIMALS HAVE COME AND THRIVED AND THEN DISAPPEARED.
- 328 04:41:09:16 EVEN HERE, EVENTS IN SPACE MAY PLAY A PART.
- 329 04:41:15:04 THIS QUARRY IN UTAH CONTAINS AN ENTIRE HILLSIDE FILLED WITH THE REMAINS OF HUGE CREATURES THAT ONCE LIVED AND BREATHED AND NOW ARE GONE.
- 330 04:41:27:00 DINOSAURS, THE LARGEST AND MOST SPECTACULAR ANIMALS EVER, ONCE LIVED HERE.
- 331 04:41:33:22 FOR 100 MILLION YEARS, THEY DOMINATED EARTH.
- 332 04:41:37:01 THEN, 65 MILLION YEARS AGO, THE LAST DINOSAUR VANISHED.
- 333 04:41:42:11 ONLY THEIR BONES REMAIN.
- 334 04:41:45:26 THE DISAPPEARANCE OF THE DINOSAURS AND THE CREATURES THAT LIVED WITH THEM IS A GREAT MYSTERY.
- 335 04:41:53:24 A NEW THEORY LINKS THE DEATH OF THE GIANT BEASTS WITH EVENTS IN SPACE.
- 336 04:42:00:27 THE STORY BEGINS HALF A WORLD AWAY.
- 337 04:42:04:18 IN CENTRAL ITALY LIES THE LITTLE TOWN OF GUBBIO, AN UNLIKELY SETTING FOR ONE OF THE MOST

EXCITING SCIENTIFIC DETECTIVE STORIES.

- 338 04:42:19:21 GUBBIO ISN'T VERY DIFFERENT FROM OTHER TINY TOWNS.
- 339 04:42:23:17 FACES GAZING UPON ITS STREETS TODAY MIRROR THOSE OF GENERATIONS AGO.
- 340 04:42:30:06 TO ITS PEOPLE, GUBBIO IS A GOOD PLACE TO WORK AND TO PLAY.
- 341 04:42:38:16 CLUES FOUND HERE MAY LEAD TO A SCIENTIFIC BREAKTHROUGH.
- 342 04:42:43:01 CONTAINING ELEMENTS OF CHANCE AND A BRILLIANT INSIGHT, THE STORY IS STILL FIERCELY DEBATED AS SCIENTISTS WEIGH THE EVIDENCE AND TEST ALTERNATE IDEAS.
- 343 04:42:54:10 CLUES COME FROM A GORGE CONTAINING LIMESTONE LAID DOWN DURING THE CRETACEOUS ERA WHEN DINOSAURS LIVED ON EARTH.
- 344 04:43:03:17 IN 1975, WALTER ALVAREZ, A GEOLOGIST, NOTICES A LAYER OF DARK CLAY EMBEDDED IN THE ROCK JUST AT THE CRETACEOUS-TERTIARY BOUNDARY, THAT TIME WHEN DINOSAURS DISAPPEARED.
- 345 04:43:17:10 THE MYSTERY UNRAVELS WHEN WALTER SHOWS THE CLAY TO HIS FATHER, NOBEL PRIZE WINNING PHYSICIST, LUIS ALVAREZ.
- 346 04:43:27:02 THIS IS THE CLAY LAYER THAT WE FOUND.
- 347 04:43:31:01 AT FIRST GLANCE, IT LOOKS FAIRLY ORDINARY.
- 348 04:43:34:16 IT'S REMARKABLE BECAUSE IT FALLS BETWEEN THE BED OF THE CRETACEOUS, WHICH IS THE TIME DURING WHICH THE DINOSAURS WERE LIVING, AND THE TERTIARY, WHICH WAS DEPOSITED AFTER THE DINOSAURS WERE GONE.
- 349 04:43:50:26 THIS REPRESENTS A VERY SMALL PERIOD OF TIME.
- 350 04:43:55:01 WE THINK IT REPRESENTS ONLY A YEAR.
- 351 04:43:58:21 WHAT GOT THE PROJECT STARTED WAS THE QUESTION OF HOW LONG IT TOOK TO DEPOSIT THAT

CLAY LAYER.

- 352 04:44:08:16 I HAD AN IDEA THAT WHEN METEORITES COME INTO THE ATMOSPHERE, MOST OF THEM BURN UP.
- 353 04:44:16:00 THEN THEY TURN INTO METEORIC DUST WHICH SETTLES DOWN ON THE EARTH'S SURFACE.
- 354 04:44:22:17 IT'S JUST AS THOUGH YOU SHOOK METEORIC DUST ALL OVER THE EARTH AT A CERTAIN, CONSTANT RATE.
- 355 04:44:31:01 THE BASIC IDEA WAS THAT YOU COULD TELL HOW FAST THE ROCK OR CLAY WAS LAID DOWN BY OBSERVING HOW MUCH OF THIS SPECIAL SALT WAS SPRINKLED ALL OVER THE EARTH.
- 356 04:44:46:28 MEASURING DUST IN THE CLAY WOULD REVEAL HOW LONG THE CLAY HAD FORMED.
- 357 04:44:53:16 THE CLAY AT GUBBIO IS TESTED FOR IRIDIUM, A RARE METAL FOUND IN COSMIC DUST.
- 358 04:45:01:02 IT CONTAINS FAR MORE THAN A DUSTING FROM SPACE CAN EXPLAIN.
- 359 04:45:06:18 WE CAME TO THE CONCLUSION THAT IT WAS AN IMPACT FROM AN ASTEROID OR A COMET THAT THREW UP A CLOUD OF DUST, BLACKED OUT LIGHT, MADE IT VERY COLD, PROBABLY.
- 360 04:45:22:15 MANY TERRIBLE THINGS WOULD HAPPEN IF ALL THAT DUST CAME DOWN.
- 361 04:45:27:27 IF LUIS ALVAREZ IS RIGHT, THE DINOSAURS MET THEIR END IN A COSMIC COLLISION.
- 362 04:45:38:25 DUST THROWN HIGH ABOVE THE ATMOSPHERE RAPIDLY CIRCLED THE EARTH.
- 363 04:45:43:26 SUNLIGHT WAS BLOCKED, AND DAY WAS TURNED TO PERPETUAL NIGHT.
- 364 04:45:49:01 IN THE COLD AND DARK THE DINOSAURS AND 3/4 OF ALL LIVING SPECIES BECAME EXTINCT.
- 365 04:45:56:16 AS THE DUST SLOWLY CLEARED, IT FORMED THE CLAY LAYER AND REVEALED A DEVASTATED EARTH.

- 366 04:46:04:04 IT'S AN ELEGANT IDEA, BUT IS IT TRUE?
- 367 04:46:08:02 THE CLAY LAYER HAS NOW BEEN FOUND IN DOZENS OF SITES.
- 368 04:46:13:15 MIGHT IT HAVE COME FROM VOLCANIC ACTIVITY ON EARTH?
- 369 04:46:18:00 BRUCE BOHOR, A GEOLOGIST AND AUTHORITY ON VOLCANIC CLAYS, INVESTIGATES FOR HIMSELF.
- 370 04:46:28:01 BOHOR KNOWS THESE ROCKS CONTAIN POLLEN AND SPORES FROM PLANTS THAT LIVED WITH THE DINOSAURS.
- 371 04:46:35:15 USING THEM AS A GUIDE, HE QUICKLY UNEARTHS THE CRETACEOUS-TERTIARY BOUNDARY, THE TIME WHEN THE DINOSAURS DISAPPEARED.
- 372 04:46:45:01 THE LOWEST ROCK THAT WE'VE EXPOSED HERE IS THE LAST OF THE CRETACEOUS SEDIMENTS.
- 373 04:46:52:04 WE KNOW THAT FROM THE POLLEN AND SPORES.
- 374 04:46:56:02 THIS PINK LAYER IS THE FALLOUT LAYER.
- 375 04:46:59:16 THAT IS A COAL STREAK.
- 376 04:47:02:24 WE KNOW THE PLANTS CHANGED DRASTICALLY ACROSS THIS BOUNDARY HERE MARKED BY THE CLAY.
- 377 04:47:15:17 THIS CLAY LOOKED QUITE A BIT DIFFERENT THAN THE ORDINARY VOLCANIC ASHES THAT WE'VE BEEN FINDING.
- 378 04:47:24:15 IT WAS HARDER, PINKER, FINER GRAINED.
- 379 04:47:27:27 PLUS THE LOCATION AT THE APPROXIMATE BOUNDARY LED US TO BELIEVE THAT IT WAS SPECIAL.
- 380 04:47:36:01 UNDER AN ELECTRON MICROSCOPE, BOHOR EXAMINES FRAGMENTS OF CLAY.
- 381 04:47:41:00 TREATING THEM WITH ACID, HE NOTICES QUARTZ PARTICLES.
- 382 04:47:45:04 THEY CONTAIN THE CLUE HE'S SEARCHING FOR.

- 383 04:47:48:17 THIS IS A NORMAL QUARTZ GRAIN, ONE YOU MIGHT SEE IN SEDIMENTARY, IGNEOUS, OR VOLCANIC ROCK.
- 384 04:47:56:15 IT SHOWS NO PARTICULAR FEATURES ON THE SURFACE.
- 385 04:48:00:29 IT'S FAIRLY SMOOTH.
- 386 04:48:02:17 BUT LET'S LOOK AROUND IN THE SAMPLE AND SEE WHAT ELSE WE CAN FIND.
- 387 04:48:10:01 HERE IS A QUARTZ GRAIN THAT SHOWS UNUSUAL FEATURES.
- 388 04:48:14:16 THESE GROOVES WERE APPARENTLY FORMED BY THE ACID WE USED IN ETCHING THEM.
- 389 04:48:21:15 WE HAD NEVER SEEN ANYTHING LIKE THIS THROUGH EXAMINATIONS OF THOUSANDS OF ROCKS.
- 390 04:48:28:01 WE FOUND OUT OTHER PEOPLE HAD SEEN SOMETHING LIKE THIS, BUT ONLY AT THE SITES OF KNOWN IMPACTS OF METEORITES OR THE SITES OF NUCLEAR EXPLOSIONS.
- 391 04:48:41:25 THE QUARTZ IN THE CLAY WAS FORMED BY IMPACT, TOO.
- 392 04:48:46:29 IT CONVINCES BOHOR THAT 65 MILLION YEARS AGO, AN ENORMOUS IMPACT SHOOK THE EARTH.
- 393 04:48:54:02 BUT HAVE THESE VISITORS FROM SPACE DEVASTATED THE EARTH MORE THAN ONCE?
- 394 04:49:01:08 UNIVERSITY OF CHICAGO'S JACK SEPKOSKI HAS FOUND ANOTHER TWIST TO THIS INTRIGUING TALE.
- 395 04:49:08:08 HE'S LISTING THE ANIMALS THAT BECAME EXTINCT IN THE PAST 250 MILLION YEARS.
- 396 04:49:14:28 HE NOTES WHEN EACH CREATURE LIVED AND DIED.
- 397 04:49:21:01 WITH OVER 3,500 FAMILIES ON FILE, IT'S THE MOST COMPLETE RECORD THAT EXISTS.
- 398 04:49:28:01 INTRIGUED BY THE COSMIC IMPACT IDEA, SEPKOSKI BEGINS HIS ANALYSIS.
- 399 04:49:34:17 THE RESULTS ARE UNEXPECTED.

- 400 04:49:36:16 THE PEAKS ON THE GRAPH REVEAL A WHOLE SERIES OF MASS EXTINCTIONS -- SOME LARGE, SOME SMALL.
- 401 04:49:44:16 REMARKABLY, THEY ARE NOT RANDOM EXTINCTIONS.
- 402 04:49:47:17 THEY SEEM TO OCCUR IN REGULAR CYCLES EVERY 26 MILLION YEARS.
- 403 04:49:53:01 THE PATTERN OF EXTINCTIONS IS A SURPRISE TO SEPKOSKI AND TO HIS COLLEAGUE, DAVID RAUP.
- 404 04:50:00:13 WHAT WE SAW WAS THAT THESE DIDN'T APPEAR TO BE RANDOMLY ARRAYED IN TIME...
- 405 04:50:11:15 BUT RATHER HAPPENING RATHER REGULARLY.
- 406 04:50:15:13 THIS MUST BE A STATISTICAL FLUKE.
- 407 04:50:18:04 HOW DO WE TEST THAT?
- 408 04:50:20:24 EACH OF THESE EVENTS ISN'T AN ENTITY UNTO ITSELF, BUT PART OF A REGULAR PATTERN.
- 409 04:50:28:16 IF WE'RE GOING TO UNDERSTAND EXTINCTION, WE'VE GOT TO UNDERSTAND EACH AND EVERY ONE.
- 410 04:50:35:13 THE SECOND IMPLICATION IS THAT WE CAN'T CONSIDER THE BIOSPHERE AS A CLOSED SYSTEM THAT HAS A HISTORY INDEPENDENT OF NOT JUST THE EARTH, BUT THE EARTH'S EXTRAPLANETARY ENVIRONMENT.
- 411 04:50:50:14 TO UNDERSTAND LIFE'S HISTORY, WE HAVE TO UNDERSTAND THE SOLAR SYSTEM'S HISTORY, AS WELL.
- 412 04:50:58:03 IS THE PLANET WE LIVE ON DEVASTATED EVERY 26 MILLION YEARS?
- 413 04:51:03:26 MANY SCIENTISTS DOUBT THAT SUCH CYCLIC EXTINCTIONS REALLY OCCUR.
- 414 04:51:10:26 LUIS ALVAREZ, LIKE MANY SCIENTISTS, IS SKEPTICAL ABOUT THESE RESULTS UNTIL HE MENTIONS THEM TO RICH MULLER, A YOUNG COLLEAGUE.
- 415 04:51:21:00 MULLER THINKS. HOW TO EXPLAIN THE REGULARITY?
- 416 04:51:24:15 IF THE SUN HAD A COMPANION STAR IN A STABLE

- ORBIT, FAR ENOUGH AND FAT ENOUGH, IT WOULD STILL AFFECT COMETS.
- 417 04:51:37:01 EACH TIME MULLER SUGGESTS A SOLUTION, LUIS ALVAREZ PROMPTLY KNOCKS IT DOWN.
- 418 04:51:43:02 FINALLY, AN INGENIOUS THEORY EMERGES, ONE THAT ALVAREZ AGREES IS WORTH TESTING.
- 419 04:51:50:01 MULLER PROPOSES THAT THE SUN HAS A DARK COMPANION STAR WHICH HE NAMES NEMESIS.
- 420 04:51:57:01 EVERY 26 MILLION YEARS, NEMESIS COMES CLOSE ENOUGH TO DISRUPT THE OORT CLOUD, THAT DISTANT SHELL OF COMETS.
- 421 04:52:06:18 ON THE SCREEN, I HAVE A SIMULATION OF THE SOLAR SYSTEM.
- 422 04:52:12:01 THE DARK CIRCLE WITH THE BRIGHT CENTER REPRESENTS THE SUN.
- 423 04:52:17:05 THOSE SMALL BLACK DOTS ORBITING AROUND IT REPRESENT JUST A FEW OF THE MANY COMETS THAT ARE ORBITING THE SUN.
- 424 04:52:27:16 THAT LARGE DOT REPRESENTS NEMESIS.
- 425 04:52:30:05 IT TRAVELS SLOWLY WHEN IT'S FAR FROM THE SUN.
- 426 04:52:34:20 IT HAS VERY LITTLE EFFECT ON THE COMETS THEN.
- 427 04:52:39:11 EVERY 26 MILLION YEARS, IT SWEEPS CLOSE TO THE SUN, COMING CLOSE TO THE COMETS.
- 428 04:52:47:01 IT DISTURBS THEIR ORBITS, SENDING MANY OF THEM SHOWERING TOWARD THE EARTH AND THE SUN.
- 429 04:52:56:16 RICH MULLER'S IDEAS ARE NOT THAT BIZARRE.
- 430 04:53:00:03 THE SUN MIGHT HAVE A COMPANION SINCE MOST STARS WE CAN SEE ARE PART OF MULTIPLE-STAR SYSTEMS.
- 431 04:53:09:01 IF NEMESIS EXISTS, WE HAVE LITTLE TO FEAR.
- 432 04:53:13:00 IT WON'T BE BACK FOR 15 MILLION YEARS.
- 433 04:53:19:16 THE SEARCH FOR NEMESIS IS UNDERWAY AT THE

LEUCHNER OBSERVATORY NEAR BERKELEY.

- 434 04:53:25:16 WHILE MOST SCIENTISTS REMAIN SKEPTICAL ABOUT THE EXISTENCE OF THE SUN'S COMPANION, MULLER AND HIS COLLEAGUES SURVEY THE SKIES.
- 435 04:53:37:15 WE'RE USING THIS TELESCOPE IN OUR SEARCH FOR NEMESIS.
- 436 04:53:42:01 THE IDEA IS TO PHOTOGRAPH A STAR AND LOOK AT IT AGAIN SIX MONTHS LATER.
- 437 04:53:50:01 A NEARBY STAR WILL LOOK LIKE IT'S AT A SLIGHTLY DIFFERENT ANGLE THAN IT HAD BEEN.
- 438 04:53:57:27 WE HAVE 5,000 CANDIDATE STARS THAT HAVE BEEN CATALOGUED AND PHOTOGRAPHED.
- 439 04:54:03:28 ANY ONE COULD BE NEMESIS.
- 440 04:54:07:03 MULLER'S QUEST PROVIDES NOT ONLY A LINK BETWEEN THE DEATH OF THE DINOSAURS AND A DARK STAR, IT MAY ILLUMINATE OUR OWN HUMAN ORIGINS, TOO.
- 441 04:54:19:01 MAMMALS WERE NEVER ABLE TO TAKE THE EARTH FROM THE DINOSAURS UNTIL THEIR EXTINCTION.
- 442 04:54:26:07 THE PICTURE OF WHERE WE CAME FROM AND WHERE WE'RE GOING IS AFFECTED BY THIS.
- 443 04:54:33:01 IT'S NOT JUST PHYSICS OR ASTROPHYSICS.
- 444 04:54:36:17 IT'S BIOLOGY. IT'S EVOLUTION.
- 445 04:54:38:16 IT'S PALEONTOLOGY.
- 446 04:54:40:02 IT'S A QUESTION OF WHY WE'RE HERE.
- 447 04:54:43:24 THE SEARCH FOR NEMESIS MAY BE IN VAIN.
- 448 04:54:47:15 ATTEMPTS TO UNDERSTAND THE WORLD AROUND US OFTEN ARE.
- 449 04:54:51:26 AS OTHER RESEARCHERS DEVELOP COMPETING IDEAS, SCIENCE MOVES ON.
- 450 04:54:56:26 THE MEANING OF THE CLAY LAYER, THE REGULARITY OF EXTINCTIONS, THE EXISTENCE OF NEMESIS ARE

HOTLY DEBATED.

- 451 04:55:05:22 FROM JUST SUCH CONFLICTS, NEW TRUTHS WILL EMERGE.
- 452 04:55:12:07 THE CONNECTION BETWEEN COMETS AND OUR OWN EXISTENCE MAY BE GREATER THAN WE THOUGHT.
- 453 04:55:19:01 THESE MESSENGERS OF DESTRUCTION MAY HAVE BEEN THE HARBINGERS OF LIFE.
- 454 04:55:24:15 IN THE BIRTH OF OUR SOLAR SYSTEM, COUNTLESS COMETS FELL TO EARTH, BRINGING AIR, WATER, AND THE CHEMICALS FROM WHICH LIFE EVOLVED.
- 455 04:55:39:01 OUR WORLD IS MADE FROM STARDUST, AND SO IS THE GREAT ARRAY OF LIFE UPON IT.
- 456 04:55:47:04 EVOLVED FROM THE RAW MATERIAL ONCE BORNE FROM SPACE, WE NOW RETURN TO VISIT.
- 457 04:55:54:10 IN FARAWAY AND FROZEN PLACES ON EARTH WE'RE FINDING THE EVIDENCE OF OUR CONNECTION TO THE COSMOS.
- 458 04:56:04:18 THE REMNANTS OF MIGHTY COLLISIONS TELL US THAT FORCES FAR FROM HOME ONCE SHAPED OUR PLANET.
- 459 04:56:12:16 AND THEY INDEED HAVE ALTERED THE COURSE OF EVOLUTION.
- 460 04:56:21:06 WE HAVE VISITED OTHER WORLDS AND DISCOVERED NEW WONDERS ABOUT OUR OWN.
- 461 04:56:27:05 OUR JOURNEYS HAVE BROUGHT US FULL CIRCLE.
- 462 04:56:35:01 WE HAVE COME HOME FROM OUR JOURNEYS WITH A SENSE OF WONDER FOR A PLACE CALLED PLANET EARTH.
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- 465 04:58:14:12 FOR INFORMATION CONCERNING THE *PLANET EARTH*

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