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# Lithosphere

## A Destructive Creator

Rayappa A. Kasi

An Appeal to Limit Our Consumption

Year of Priests 2009-2010

United Nations International Year
of Biodiversity 2010

# LITHOSPHERE
A DESTRUCTIVE CREATOR




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# Preface

As a kid, I always wondered at the mountains in A. Kattupadi, Vellore, India for their beauty and size: Who brought these massive stones here, not few stones, but billions of them? These heap of stones, which resemble like a giant serpentine Anaconda, we call here as *"Eastern Ghats."* We expect anything to move, but not the Earth! And we certainly do not expect mountains to throw the Earth's innards into the sky! Nothing is as frightening as to feel the Earth shake under our feet or to see flaming lava spew from unknown depths, moving mercilessly toward us. By exploring the miracle of the universe's creation*, "Lithosphere-A Destructive Creator"* leads the reader through a brief, fascinating voyage to the birth and growth of our planet with its cracked and constantly shifting crust. The origins of earthquakes and volcanoes, often called the "*crucibles of creation,"* are explained through this book with historical events and scientific findings. Homo sapiens, man the knower, wondered at the mystery of creation ever since he appeared on Earth forty thousand years ago, only fourteen hundred generations before our own. His universe was then limited to the perception of the Earth and the sky, yet the oldest myths of mankind provide strong evidence of his desire to explain this haunting mystery.

Echoing much older beliefs, the Babylonian cuneiform tablets of five thousand years ago tell us in the epic of the *"Enuma Elish"* about the fights between the young gods of order, led by Marduk (the creator of mankind, light and life), and the old gods of chaos, that resulted in the victory of the young gods and the creation of a meaningful world. Three thousand years ago the Egyptians believed that the universe was a flat disk, with the plain of the Nile at its center, supported by a circle of distant mountains, protected by a flat sky, their universe had been created out of primeval chaos by the ram god Khnum (or, perhaps, by the pure spirit Ptah or, maybe, the sun god Ra and his descendants, the air god Shu, the sky god Nut and the Earth god Geb). And only twenty-nine centuries ago the book of Genesis in the Jewish Bible described in remarkable detail how the one ineffable God created in six days the universe in all of its parts and, pleased with his creation, rested on the seventh, the Sabbath.

Modern science has allowed us to peer into the deep abyss of our planet, in particular one science known as *seismology* has come a long way. For the first time in human history the causes of the devastating physical

phenomena such as earthquakes, volcanoes, only a few centuries ago considered to be *"acts of God,"* are now understood and it is up to us to avoid their worst consequences. We are encouraged by having been able to forecast the location and magnitude of the last twelve strongest earthquakes on Earth; on the other hand, we are discouraged by our inability to have predicted the time of their occurrence with significant accuracy. At present, uncertainties in the prediction of earthquakes vary between ten and thirty years, and seismologists feel that improving the reliability of their predictions may be very difficult. But, in the meantime, earthquakes do not wait. For some years I have been thinking about how best to describe the way in which plate tectonics has changed our perception of the Earth. The world is so vast and so various that it is evidently impossible to encompass it all within one book. *Yet geology underlies everything: it founds the landscape, dictates agriculture, and determines the character of villages.* Geology acts as a kind of collective unconscious for the world, a deep control beneath the oceans and continents. For the general reader, the most compelling part of geological enlightenment is discovering what geology does, how it interacts with natural history, or the story of our own culture. Most of us engage with the landscape at this intimate level.

After the creation of man and woman, *God commanded them not to exploit the natural resources on or under the Lithosphere. "The biblical tree," featured in the creation story symbolizes the natural resources in reserve for the future generations.* The biblical story of Adam and Eve is, perhaps, the first unequivocal intimation of the fight between the will of man and the forces of nature. Tempted by the serpent, according to the psychoanalysts, their own subconscious, the first human couple had eaten the forbidden fruit of the tree of knowledge, become aware of their power to dominate the Earth, and are compelled to abandon terrestrial paradise. What do they gain by their daring? Sacrificing their innocent happiness, they have gained, through the power of knowledge, the command of their destiny and the domination of nature. After learning about the rebellion of our biblical ancestors, we had to wait over four thousand years of slow and demanding effort to gain the advantage, and learn the sorrows, and the consequences of the biblical prophecy. Two geniuses, Galileo and Newton, the first by his trial-blazing experiments, the second by his astonishing abstractions opened the door of modern science and started its accelerating race to the dominion of the Earth.

We have all grown out of the geological landscape, and perhaps unconsciously we still relate to it. Human beings seem to be programmed

to love their home territory that causes depletion of all the natural resources. Consumption has become an addiction and humanity is subjected to it. We are in grave danger of crossing a point of no return within the next ten years! By our time, we have learned to fight nature only too well and we have developed the power to destroy life on our planet. I am, now aware of the most horrifying fact in all our lives: *civilization is now capable of destroying itself.* To avoid this final catastrophe, we must learn to acquire a new sense of responsibility and temper our insatiable craving for natural resources and power. Power and natural resources are often related to each other. *Unfortunately the most powerful nations on Earth are the top exploiters of the natural resources of the Lithosphere. These powerful nations with their dominion, arrogance and exploitation, they have declared war on Lithosphere. Consequently, Lithosphere is wounded and bleeding.* Yet, so far, we have barely started to realize that our lack of humility is synonymous with collective suicide. The scientific community has deluged us with evidence of the tremendous changes we are wreaking on the Lithosphere, their version of shouting from the rooftops. Incredibly, we could be setting these changes into motion in the lifetime of our children and grandchildren. Unless we act boldly and quickly, some of the leading scientific experts are now telling us that without dramatic changes to cut the consumption that causes depletion of natural resources, we are in a grave danger of crossing a point of no return.

We see Earth as a "goldmine," as a collection of "resources" having an intrinsic value no larger than their usefulness at the moment. In our fascination with *the anthropocentric view,* we forget our connectedness with the whole. The ecological perspective begins with a view of the whole, an understanding of how the various parts of nature interact in pattern that tend toward balance and persist over time. But this perspective cannot treat the Earth as something separate from human civilization; *we are part of the whole,* and looking at it ultimately means also looking at ourselves. And if we do not see that the human part of nature, that we are, in effect, a natural force just like the winds and the tides, then we will not be able to see how dangerously we are threatening to push the Earth out of balance. Our perspective is badly foreshortened in another way as well. *Too often we are unwilling to look beyond ourselves to see the effect of our actions today on our children and grandchildren.* I am convinced that many people have lost their faith in the future, because in virtually every facet of our civilization we are beginning to act as if our future is now so much in doubt that it makes more sense to focus exclusively on our current needs and short-term problems. Our willingness to ignore the consequences of our actions has combined with our belief that we are separate from nature to produce a genuine crisis

in the way we relate to the world around us. We seem to sense something of our jeopardy; *we seem to share a restlessness of spirit that rises out of the lost connection to our world and our future.* But we feel paralyzed, too attached to old assumptions and old ways of thinking to see a resolution to our dilemma. How much is enough? When does having more cease to add appreciably to human satisfaction?

I owe thanks to many people. I am grateful to friends, colleagues, and students who shared their expertise, commented on the manuscript, and generously offered advice and encouragement. I am indebted to Fr. Raja SJ who has more confidence in me than myself; Fr. Roy Lazar, Fr. Joseph, Fr. Arasu SDB (Uganda), Fr. John Samala SDB (Ethiopia), Sr. Veda, Sr. Eluru Rakkini Mangarpu for the encouragement; and Mr. Sagayam Deva and Fatima at LTD Media Publications.

*As a Catholic priest myself, I have to proclaim hope to all. "Consume less and Conserve more," we can undo the damage we've caused to the Lithosphere.* We have encountered and accepted other great challenges in the past. We declared liberty and then won it from the British in 1947, establishing a new country. We devised a biggest democracy on Earth. We gave women the right to vote. We cured malaria and eradicated smallpox. We landed on the moon. We even solved a previous global environmental crisis, the hole in the stratospheric ozone layer, because Indians and Pakistanis; Arabs and Israelis; Americans and Russians; Africans and Australians; rich nations and poor nations; businessmen and scientists; and religious and non-religious alike came together to shape a solution. *My prayer at this point is: that we may never misuse the natural and healing gifts in our life and always find in them the source of life and salvation!*

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India

May 1st, 2010 – Worker's Day
The Feast of Joseph the Worker
Year of Priests – 2009-2010.

# Lithosphere – A Destructive Creator

*"Everything in Nature called destruction must be Creation, a change from beauty to beauty" (John Muir, 1869).*

Before you attempt to go any further, please familiarize with the following diagram of Geological Time Scale, keeping in your mind constantly that we are dealing here with not your wrist watch, but with Lithosphere and its deep time, such as eons, eras, periods, and epochs.

| EON | ERA | PERIOD |
|---|---|---|
| Phanerozoic | Cenozoic | Quaternary |
| | | Tertiary |
| | Mesozoic | Cretaceous |
| | | Jurassic |
| | | Triassic |
| | Paleozoic | Permian |
| | | Pennsylvanian |
| | | Mississippian |
| | | Devonian |
| | | Silurian |
| | | Ordovician |
| | | Cambrian |
| Proterozoic | Late Proterozoic<br>Middle Proterozoic<br>Early Proterozoic | |
| Archean | Late Archean<br>Middle Archean<br>Early Archean | |
| Pre-Archean | | |

Around 4.5 billion years ago, the sun pulled itself together out of primordial gas and dust expelled by a supernova. The infant sun was surrounded by a proto-planetary disk made of several bands of coarse particles, called planetesimals,* which accreted from grains of dust and coalesced into larger bodies. Up to 100 trillion planetesimals orbited the sun during the solar system's early stages of development. As they continued to grow, the small rocky chunks swung around the infant sun in highly elliptical orbits along the same plane. The constant collisions among planetesimals formed larger bodies, as much as 80 km or more wide. These eventually became the planets that make up our solar system. The Earth accreted into a homogenous mixture of silicates and iron nickel by numerous meteorite impacts, and the entire process of planetary formation was completed in less than half a million years. As the Earth continued to grow, its orbit began to decay due to drag forces from leftover gases in interplanetary space. The formative planet slowly spiraled closer toward the sun, sweeping up additional planetesimals along its way. Eventually, the Earth's path around the sun was swept entirely clean of planetesimals, and its orbit stabilized near where it is today.

**Planetesimals are the seeds of planets crash together in the solar nebula, gradually growing larger.*

All aspects of the Earth's history and structure, including its majestic mountains, giant rift valleys, and deep ocean basins, were fashioned by *mobile tectonic plates.* The Earth's outer shell comprises a dozen or so rigid plates composed of the upper mantle, or Lithosphere, and the overlaying crust that are always in motion. This movement accounts for all geologic activity taking place on the Earth's surface. The plated ride on the semi-molten rocks of the Earth's mantle and carry the continents along with them like ships frozen in arctic pack ice. When two plates collide, they create mountain ranges on the continents or volcanic islands on the ocean floor. *When an oceanic plate slides beneath a continental plate, it produces sinuous mountain chains, for example, such as the Eastern Ghats running through A. Kattupadi, Vellore of Tamil Nadu, India.* The breakup of a plate creates new continents and oceans. The process of rifting and patching of the continents has been ongoing for the past 2.7 billion years and possibly even longer. Along the middle of the Atlantic Ocean runs an impressive submarine mountain range called the Mid-Atlantic Ridge, which surpasses in scale the Alps and Himalayas combined. It is part of a global mid-ocean ridge system that stretches over 5000 km along the ocean floor like a giant Anaconda. A deep trough is carved down the middle of the ridge as though it were a giant crack in the Earth's crust. The rift is four times deeper than the Grand Canyon, making it the longest and deepest canyon on the planet. In this manner, plate tectonics is continuously changing and rearranging the face of the Earth. While Earth is busy doing its job, man is doing his job of exploiting the Earth. I would like to bring in some of the outrageous exploitations of natural resources to the attention of the religious institutions and its leaders (Priests, for example), hoping that they could do something with this desperate situation, while politics failed our hope to do anything in Copenhagen, Denmark, in December 2010.

**Year of Priests – An Appeal to Limit our Consumption**

*"If You Want to Cultivate Peace, Protect Creation," wrote Pope Benedict XVI.* Priests have been an instrumental part of the world to cultivate peace and protect creation. Priests are the "Living Icons of Christ" as they minister to create a kingdom of God. These icons or role models can affect people's lives very profoundly. A priest is a "mediatory agent" between God and humanity. We are celebrating the "Year of Priests" which Pope Benedict XVI inaugurated in June 2009. According to recent statistics issued by the secretary of Vatican State, there are 5000 bishops, 400,000 Catholic priests and almost 950,000 Catholic nuns all over the world. All of these members are bound by the special three vows or promises that would bind them consciously throughout their lives. *These three vows are; the vow of celibacy,*

*vow of poverty and vow of obedience. The first two vows are directly connected to the ecology and the environment.* By the vow of celibacy, a priest or a nun commit themselves to a life of consecrated celibacy and they can't marry for life. The spirit of the vow frees them to live out their vocation to love in a deeper personal union with Christ. By the vow of poverty, a priest or a nun freely renounces his/her natural right to the independent use of material goods. The spirit of poverty relieves them from personal material concerns and frees them to direct their hearts to the building up of God's kingdom. *This lifestyle should prompt one to consume few resources, on the other hand, by not having any family and children, save lots of natural resources for the future generations.* However, our life in the parishes, schools and institutions compel us to consume more and more, we are almost addicted to consumption.




New addiction has found its way in society: it is consumption. We are used to thinking of addiction in terms of drugs or alcohol. But new studies of addiction have deepened our understanding of the problem. Anyone who is unusually fearful of something such as intimacy, failure, loneliness is potentially vulnerable to addiction, because pain causes a feverish hunger for distraction. The cleavage in the modern world between mind and body, man and nature, has created a new kind of addiction: *I believe that our civilization is, in effect, addicted to the consumption of the Earth itself. Consumerism is one of the central roots of the environmental crisis, rivaled by population growth.* This addictive relationship distracts us from the pain of what we have lost. Our civilization is holding ever more tightly to its habit of consuming larger quantities every year of coal, oil, fresh air and water, trees, topsoil, and the thousand other substances *we rip from the crust of the Earth,* transforming them into not just the sustenance and shelter we need but much more that we don't need: huge quantities of pollution, products for which we spend billions on advertising to convince ourselves we want, massive surpluses of products that depress prices while the products themselves go to waste, and diversions and distractions of every kind. We seem increasingly eager to lose ourselves in the forms of culture, society, technology, the media, and the rituals of production and consumption, but the price we pay is the loss of our spiritual lives.

As a result, new form of human society is evolving: the consumer society. High rates of economic growth are regarded as signs of economic success, but over-consumption is depleting the planet's resources, creating massive waste, and often making people miserable. Consumption has become our way of life, that we convert the buying and use of goods into rituals, *that we seek our spiritual satisfaction, and our ego satisfaction.* But the consumer society's exploitation of resources threatens to exhaust, poison, or unalterably disfigure forests, soils, water, and air. The consumers of the world are responsible for a disproportionate share of all the global environmental challenges facing humanity. People living in the 2000s are on average four and a half times richer than their great-grandparents were at the turn of the century, *but they aren't four and a half times happier.* Psychological evidence shows that the relationship between consumption and personal happiness is weak. Worse, two primary sources of human fulfillment, social relations and leisure appear to have withered or stagnated in the rush to riches. Consumerist culture has been fruitlessly attempting to satisfy with material things what are essentially social, psychological, and spiritual needs. Unless we see that more is not always better, our efforts to forestall ecological decline will be overwhelmed by our appetites. We will likely fail to see the forces around us that stimulate those appetites, such as relentless advertising, proliferating shopping centers, and social pressures to keep up with consumption.

All the religions and institutions are irresistibly addicted to consumption in the name of god and community. As religions, we own land, we buy and sell. Every parish has immovable property such as land and buildings. We demolish them even though they are in good shape, because we have irresistible temptation to use project money donated by some agencies and we want our names inscribed on a granite stone. Donor agencies sometimes, block our thinking of ecological and environmental sustainability, the allure of money is so overwhelming, we make bad choices. Funding agencies provide us easy access to financial resources, compelling us to consume excessively while we abuse it without foresight. Religious institutions own sophisticated infrastructure, better buildings and facilities than the people those live around them. We destroy good buildings, beautiful cathedrals, good churches, schools, and rectories. Some of the cathedrals that I know were renovated just a decade ago with big sum of money just before they were leveled down. Most of them were in perfect condition, if not why renovate them a decade ago? Unfortunately, everyone made a bad choice in the institutions, while allowing the demolition. *Lithosphere bears deep-cut wounds and scars.* These cathedrals, some of them fifty, hundred and 150 years old, could have been a world heritage sites in the course of time for the future generations. As parish

priests, we do consume lots of natural resources for the construction of buildings, renovating and establishing. In our schools we consume huge amount of water, electricity, paper and other resources, consequently we generate waste. Every Sunday our churches use so much of electrical energy, causing so much of environmental and noise pollution. However, the basic value of a sustainable society, the ecological equivalent of the *Golden Rule,** is simple: each generation should meet its needs without jeopardizing the prospects for future generations to meet their own needs. We can curtail our use of those things that are ecologically destructive, such as fossil fuels, minerals, and paper.

Priests and the leaders of the religious institutions have a very commanding and influential role, when it comes to change. People prefer to believe them more than politicians. I believe catholic priests have huge amount of potentiality as a role models. In transforming the consumer society into a non-consuming society, or an economy of permanence, we should start by asking ourselves what we really want: for example, do we really want telephone books, newspapers, diapers, or magazines for their own sake? Or do we merely want access to the information they contain? In an economy of permanence, that information might be available to us for the same price on durable electronic readers. That would enable us to consult the same texts, but eliminate most paper manufacturing and the associated pollution. Likewise, people do not necessarily want cars as such; they buy them to gain ready access to a variety of facilities and locations. Good town planning and public transportation could provide that access equally well. *In every sector of the economy, from housing to food, there are vast opportunities to disconnect high resource consumption from a high quality of life. And we can cultivate the deeper, nonmaterial sources of fulfillment that are the main psychological determinants of happiness: family and social relationships, meaningful work, and leisure.* Virtue of sacrifice has brought peace and happiness to thousands of people. In the natural world one species is sacrificed for the well being of another. The sacrifice of our fathers, sustains our present lives. Our previous generation's sustainable lifestyle has reserved resources for our use today. Likewise, our sacrifice and sustainable use of natural resources may enable future generations live at least, with the leftovers. The virtue of sacrifice which is modeled after the lifestyle of Jesus generates a magical and spiritual transformation. Indeed, we can save future generations through our sacrifice. Or we can abrogate our responsibilities and let our life-style ruin the Earth.

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**Golden Rule is derived from the biblical statement, "do un to others as you have them to do to you*

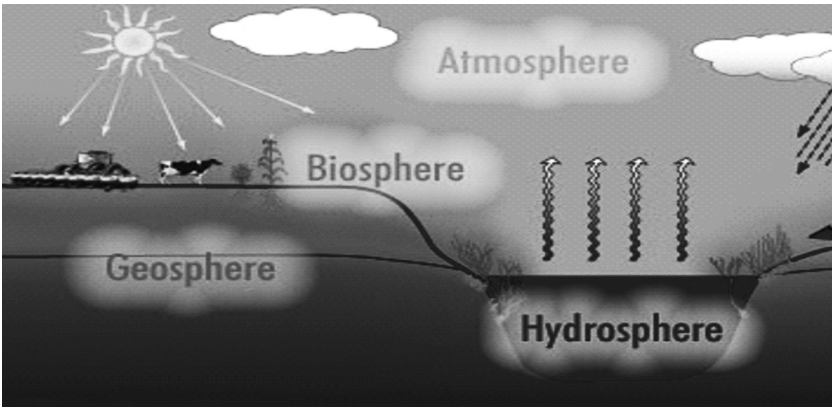
Ultimately, sustaining the environment that sustains our humanity will require that we change our values. If human desires are in fact infinitely expandable, consumption is ultimately incapable of providing fulfillment, a logical consequence ignored by economic theory. Indeed, social scientists have found striking evidence that high-consumption societies, just as high-living individuals, consume ever more without achieving satisfaction. *The allure of the consumer society is powerful, even irresistible, but it is shallow nonetheless. Consumption appears to have failed to make the consumer class any happier.* Studies on happiness indicate that the main determinants of happiness in life are not related to consumption at all; prominent among them are satisfaction with family life, especially marriage, followed by satisfaction with work, the leisure to develop talents, friendships, and relationships. The conditions of life which really make a difference to happiness are those covered by three sources: social relations, work, and leisure. And the establishment of a satisfying state of affairs in these spheres does not depend much on wealth, either absolute or relative.

Yet, while consumption fails to make us happy and even contributes to our unhappiness, many of the forces "compelling" us to consume, such as advertising, cultivate and prey on our unhappiness. Even if television commercials or magazine ads fail to sell a particular product, they sell consumerism itself by ceaselessly reiterating the idea that there is a product to solve each of life's problems, indeed that existence would be satisfying and complete if only we bought the right things. Advertisements do not simply exaggerate or distort the truth, they lie. *No one's success in business, athletics, or love ever depended on their toothpaste.* Advertisers thus cultivate needs by hitching their wares to the infinite existential yearnings of the human soul. *The desire for material things inhibits our pursuit of transcendence. Evidence of this spiritual loss abounds. Mental illness in its many forms is at epidemic levels, especially among children.* Children are addicted to consumption, especially to science and technology related electronics. Industrial civilization's great engines of distraction still seduce us with a promise of fulfillment. The false promise at the core of addiction is the possibility of experiencing the vividness and immediacy of real life without having to face the fear and pain that are also part of it. Our industrial revolution makes us a similar promise: the pursuit of happiness and comfort is paramount, and the consumption of an endless stream of shiny new products is encouraged as the best way to succeed in that pursuit. The glittering promise of easy fulfillment is so seductive that we become willing, even relieved, to forget what we really feel and abandon the search for authentic purpose and meaning in our lives. *Priesthood is a powerful tool to advocate simple lifestyle to other people around us which is*

*possible only with sacrifice by limiting our consumption.* Enough said we can together unravel the mysteries in the following pages, about planet Earth, particularly about Lithosphere that holds treasures.

**The Lithosphere or Geosphere**

The Lithosphere, also known as Geosphere is the outer solid part of the Earth, including the crust and uppermost mantle. The Lithosphere is about 100 km thick, although its thickness is age dependent, for example, older Lithosphere is thicker. The Lithosphere below the crust is brittle enough at some locations to produce earthquakes by faulting, such as within a subducted oceanic plate. The face of the Earth, crisscrossed by chains of mountains like the scars of old wounds, has changed and changed again over billions of years, and the testament of the remote past is all around us. Geology dictates the lie of the land, and climate controls how the design of the world accommodates to life. But climate itself is in thrall to geology. A landmass over the poles permits ice sheets to grow, and this mediates the sea levels of the world. There have been warm times when much of the land surface has drowned, and such times will come again. Mountain ranges modify weather systems, specify where there shall be deserts, and steal rain. Then, too, oceans are great climatic magnifiers. *Remember Isaiah 40:4, "Every valley shall be raised up, every mountain and hill made low; the rough ground shall become level, the rugged places a plain."*




The Geosphere or Lithosphere interacts with the biosphere and directly affects it by changing the environment. There have been 11 episodes of flood basalt volcanism over the past 250 million years. These large eruptions create a series of separate overlapping lava flows that give many exposures worldwide a terrace-like appearance, *called traps, the Swedish word for stairs.*

Many flood basalts are located near continental margins, where great rifts separated the present continents from Pangaea.* *Others, such as Deccan Traps of India, are related to hot-spot activity, whereby plumes of hot rocks from deep within the mantle rise to the surface.* The volcanic episodes were relatively short-lived events, with major phases lasting less than 3 million years. Furthermore, the episodes of volcanism appear to be somewhat periodic, occurring about every 32 million years. The timing of these major outbreaks correlates with the occurrence of worldwide mass extinctions of marine organisms. The largest mass extinction in the geologic record occurred at the end of the Paleozoic era 240 million years ago and was responsible for the loss of over 95 percent of all species. It also occurred at about the same time as the eruption of very large traps in Siberia.

During the eruption of a major basaltic lava flow, vigorous fit fountains inject large amounts of sulfur gases into the atmosphere. Moreover, flood basalts release 10 times more sulfur than explosive eruptions. The gases are converted into acid, which has severe climatic and biologic consequences. A major alteration in the composition of the atmosphere can also affect the climate. Volcanoes spew massive quantities of ash and aerosols into the atmosphere, which blocks out sunlight. Volcanic dust also absorbs solar radiation, which heats the atmosphere, causing thermal imbalances and unstable climatic conditions. *Heavy clouds of volcanic dust have a high albedo,** *reflecting much of the solar radiation back into space. This could shade the planet and lower global temperatures.* The reduced sunlight might also cause mass extinctions of plants and animals by lowering the rate of photosynthesis. The reduction of insulation or the amount of solar radiation reaching the surface, by 5% might result in a drop in global temperatures by as much as 5 degrees Celsius. If maintained long enough, this would allow glaciers to expand and lower the sea level, which would limit marine habitat area. The lowered temperature could also adversely affect the geographic distribution of species, confining warmth-loving organisms to the tropics.

Extensive volcanic activity 100 times more intense than it is today could produce strong acid rain showers. These in turn could cause widespread destruction of terrestrial and marine species by defoliating plants and altering the acid/alkaline balance of the ocean. Acid gases spewed into the atmosphere might also deplete the ozone layer, allowing deadly solar

**For almost one hundred million years, only one continent existed. It extended from the North Pole to the South Pole. Today, this land mass is known as Pangaea. It formed almost 250 million years ago.*

***Albedo is the fraction of solar energy (shortwave radiation) reflected from the Earth back into space. It is a measure of the reflectivity of the Earth's surface. Ice, especially with snow on top of it, has a high albedo.*

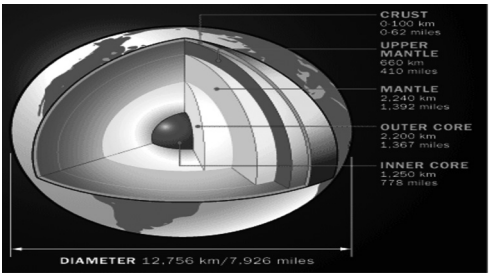
ultraviolet radiation to bathe the planet, thereby eliminating life on the surface. Massive volcanic eruptions might have had a hand in the extinction of dinosaurs. *At the end of the Cretaceous period, 65 million years ago, a giant rift opened up on the west side of India and huge volumes of molten lava poured onto the surface. Nearly 500,000 square miles of lava covering an area about the size of France erupted over a period of 500,000 years.* The eruptions consisted of about 100 lava flows, which blanketed much of west-central India known as the Deccan Traps in layers of basalt hundreds of feet thick. It was the largest volcanic catastrophe in the last 300 million years. An enormous plateau of basalts along the coasts of Greenland and Scotland might have erupted at the same time as the Deccan Traps. There is also evidence of substantial explosive volcanism in an extensive region from the South Atlantic to Antarctica. The eruptions might have dealt a major blow to the climatic and ecologic stability of the planet, forcing many species to become extinct.

When the eruptions began, India was drifting toward southern Asia. The rift separated India from the Seychelles Bank, which was left behind as the subcontinent continued on its journey northward. In the Amirante Basin on the southern edge of the Seychelles Bank about 480 km northwest of Madagascar lies a remarkably intact circular depression about 320 km wide, which appears to be a large impact structure. *A massive meteorite impact in the Amirante Basin might have triggered the great lava flows that created the Deccan Plateau and the Seychelles Islands.* Quartz grains shocked, or fragmented, by the high pressures generated by the impact were found lying just beneath the immense lava flows, suggesting that they might be linked to the impact. It is possible such large meteorite impacts create so much of disturbance in the Earth's thin outer crust that they can induce massive volcanic eruptions. Shocked quartz and iridium, an isotope of Platinum, found in the Cretaceous-Tertiary (K-T)* boundary clay throughout the world are though to be fallout from a giant meteorite impact. They might also have resulted from massive volcanic eruptions taking place over a period of hundreds of thousands of years. Explosive volcanic eruptions such as the 1980 eruption of Mount St. Helens in southwestern Washington State can produce similar shocked quartz grains. Volcanoes whose magma source lies deep within the mantle such as Kilauea on Hawaii can produce significant quantities of iridium, an isotope of platinum that is rare in the crust. *The Deccan eruptions could have emitted large amounts of iridium, which would account for the anomalously high concentrations in the K-T boundary layer.*

**The most well known extinction event is at the boundary between Cretaceous and Tertiary rocks. Cretaceous rocks are indicated K to distinguish them from Tertiary rocks, which have a T abbreviation.*

**Anatomy of the Earth**

*The Core:* Earth is divided into three major parts: *core, mantle, and crust*. How was the Earth's core discovered? Recordings of seismic waves from earthquakes gave the first clue. Seismic waves will bend and reflect at the interfaces between different materials, just like the prism below refracts and scatters light waves as its faces. *What we do know about the core is that there is a solid inner core of pure iron the size of the moon, an outer liquid core rich in iron the size of Mars,* and an irregular boundary between the liquid core and the bottom of the rocky mantle, comes mostly from studying how seismic waves travel through the Earth. Most scientists agree that Earth's magnetic field arises from convection currents in the liquid outer core, a good conductor of electricity. Convection probably starts as iron crystallizes on the surface of the inner core, about 5000 km beneath Earth's surface; lighter components like oxygen, sulfur, and silicon are excluded and rise toward the core-mantle boundary (CMB) 2000 km higher, where temperatures are a thousand degrees cooler. It has long been known that the inner core of the Earth, a sphere consisting of a solid mass with a radius of about 1200 km, is mainly made up of iron. However, seismic observations have shown that elastic waves pass more rapidly through this core in directions that are parallel to the Earth's axis of rotation than in directions parallel to the Equator a phenomenon that has not been previously explained. At the high temperatures that prevail in the core of the Earth, these waves should pass at the same speed regardless of their direction.




*The Mantle* **-** The mantle is a thick shell of red-hot rocks, separating the intensely hot metallic core from the cooler crust. *It starts at an average, depth of about 40 km below the surface and continues to a depth of about 2820 km.* The upper mantle has a layered structure composed of a rigid Lithosphere, a soft region or asthenosphere* on which the rigid Lithosphere plates ride, and a lower region that is in a plastic state and might be in convection flow. However, the continents are not buoyed up by the asthenosphere, which

**It is the uppermost mantle of a rocky planet, located below the Lithosphere. On Earth, this zone of soft, easily deformed rock lies at depths of about 100 to 250 km, it is more plastic than adjacent layers because the combination of pressure and temperature places it near the melting point.*

only offers passive resistance to sagging. The lower mantle is composed of rocks unchanged since the early history of the Earth. The mantle holds the majority of the Earth's materials, accounting for nearly half its radius, 83 percent of its volume, and 67 percent of its mass. The mantle is composed of iron-magnesium-rich silicate minerals, corresponding to the rock peridotite, whose name comes from the transparent green gemstone peridot. Starting at the surface the temperature within the Earth, increases rapidly with depth. This is mostly due to the relative abundance of radioactive elements in the Earth's crust. *At a depth of about 112 km, where the minerals that make up the major constituent of the upper mantle began to melt, the temperature is about 1200 degrees Celsius at the semimolten asthenosphere.* The temperature in the mantle increases gradually to about 2000 degrees at a depth of 480 km. It then increases more rapidly to the top of the core. Between 70 and 80 percent of the mantle's heat is generated internally by radiogenic sources that produce energy by radioactive decay. The rest comes from the core.

The increase in temperature and pressure with depth results in a change in the mineral structure of the mantle rocks, called a *phase transition.* Phase transitions in the upper mantle occur at depths of 640 km, corresponding to the boundaries of the Lithosphere, asthenosphere, and upper mantle. The phase boundaries also correspond to the depths where earthquakes wave velocities change, indicating that the upper mantle might have a layered structure. In a descending lithospheric plate, the first two phases occur at relatively shallow depths because of the plate's lower temperature. As the plate continues to descend, it changes to denser mineral forms, which help to heat the plate and speed its assimilation into the mantle. The density of the mantle increases about 60 percent from top to bottom, and its rocks are compressible. By comparison, the crust is little more than an obscure layer of thick rocks, making up only about 1 percent of the Earth's radius, and contains a thin film of ocean and atmosphere. The driving force that moves the continent around arises within the mantle, making it one powerful heat engine.

The only window scientists actually have on the mantle is through kimberlite pipes, named for the South African town of Kimberly, where they first found. Kimberlite pipes are cores of ancient, extinct volcano-like structures that extend deep into the upper mantle, as much as 240 km below the surface, and that have been exposed by erosion. *They bring diamonds to the surface from deep below by explosive eruptions. The pipes are mined extensively for these gems throughout Africa and other parts of the world.* Diamonds are produced when a pure form of carbon is subjected to

extreme temperature and pressure, conditions found only in the mantle. Most economic kimberlite pipes are cylindrical or slightly conical and range from 1000 to 5000 feet across. During the evolution of the Earth, beginning about 4.5 billion years ago, the mantle has had a profound influence on the conditions on the planet's surface. The mantle produced magma that rose to the surface and solidified. These basalt lava flows piled up layer and layer to form the early crust. *The mantle ejected water vapor and gases, which constitute the atmosphere and ocean. The mantle also expelled carbon compounds, without which there would be no life.* The surface of the Earth was shaped by the action of the mantle moving very slowly below the crust. Without this movement, erosion would wear down mountains to the level of the sea within a space of a mere 100 million years. The surface of the Earth would then be a vast, featureless plain, unbroken by mountains and valleys. There would indeed be a very uninteresting place in which to live, that is, if life could exist under these conditions.

*The Crust* **-** Not even the largest and most prominent features on the Earth's surface can be regarded as permanent and immovable. The Earth's crust comprises rigid lithospheric plates, and because they are constantly in motion, continents and oceans are continuously being reshaped and rearranged. It is becoming more apparent that plate tectonics and continental drift have played a prominent role in climate and life. Changes in continental configurations brought on by movable crustal plates have profoundly affected global temperatures, ocean currents, biologic productivity, and many other factors of fundamental importance to the living Earth. The bulk of the Earth's crust is composed of oxygen, silica, and aluminum, which form the granitic rocks that constitute the Lithosphere, which averages about 96 km thick. *The Lithosphere rides freely on the semi-molten outer layer of the mantle called the asthenosphere, which ranges in depth from about 115 to 240 km.* This gives the outer layer of the Earth a structure somewhat like a jelly sandwich, which is important for the operation of plate tectonics. Otherwise, the crust would be just jumbled up slabs of rock, and the Earth would be an alien place indeed.

The continental crust averages 40 to 48 km thick and is up to 56 km thick in the mountainous regions. The oceanic crust, however, is considerably thinner and in most places is only 5 to 8 km thick. Like an iceberg, only the tip of the crust shows, while the rest is out of sight deep below the surface. Eight major and about a half dozen minor lithospheric plates act as rafts that carry the crust around on a sea of molten rock. The plates diverge at midocean ridges and converge at subduction zones, which are expressed on the ocean floor as deep-sea trenches, where the plates are subducted

into the mantle and remelted. *The plates and oceanic crust are continuously recycled through the mantle, but the continental crust because of its greater buoyancy remains for the most part on the surface. It is due to plate tectonics that life was able to flourish on Earth. It is even possible that there would not be active plate tectonics if Earth did not possess life.* Lime-secreting organisms in the ocean remove carbon dioxide, an important greenhouse gas, from the atmosphere and store it in the bottom sediments. This keeps the Earth's temperature within the range needed for plate tectonics to operate, which in turn maintains living conditions on Earth.

**The Continental Drift**

When early cartographers drew up the first world maps, they noticed something very particular. The continents of Africa and South America seemed to fit together as though they were pieces of a giant jigsaw puzzle. Many other clues, such as matching mountain ranges and identical life forms on continents widely separated by ocean, led to speculation that at one time all the lands were united into a single large continent that subsequently broke apart. This was a preposterous notion to most scholars, who then devised all sorts of theories to explain these strange phenomena. *The Scottish geologist James Hutton, known today as the father of modern geology,* argued against neptunism* of French naturalist George de Buffon, and advanced an opposing theory called plutonism, named for Pluto, the Greek god of the underworld. His theory was based on the premise that the depths of the Earth are in constant turmoil and that molten matter rises to the surface through cracks or fissures, giving rise to an erupting volcano. However, it was not until middle 19th century when the first serious study of the Mount Vesuvius Volcano near Naples, Italy, was conducted that conclusive evidence was found supporting the theory of plutonism. But later, recognition of the slow processes by which geologic forces operate led James Hutton to propose a new theory called *"uniformitarianism"* in 1785. *Simply stated, it means that the present is the key to the past. In other words, the forces that shaped the Earth are uniform and operate in the same manner and at the same rate today as they did in the past.* Hutton envisioned the prime mover behind these slow changes to be the Earth's own internal heat. Temperatures in deep mines increased with greater depth, indicating that rocks grew progressively hotter toward the center of the Earth. *Hutton called this phenomenon the Earth's great heat engine.* He believed that the heat was left over from an earlier time when the planet was in a molten state.

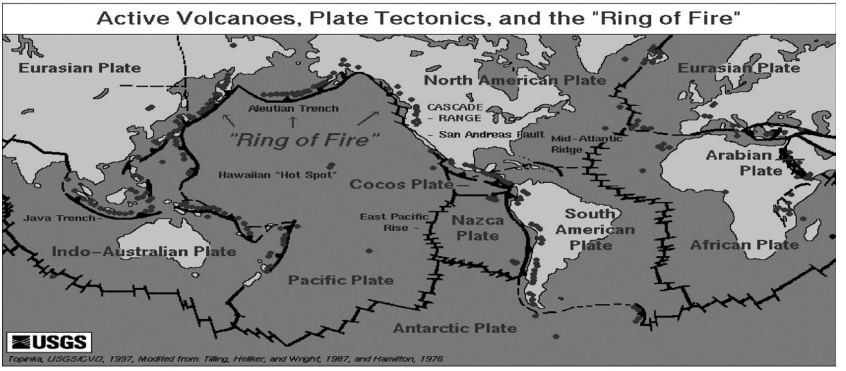
**Neptunism is a discredited and obsolete scientific theory of geology proposed in the late 18th century that rocks formed from the crystallization of minerals in the early Earth's oceans. It was named after Neptune, the ancient Roman name for the ancient Greek god of the sea, Poseidon.*

The British geologist Sir Charles Lyell, born in 1797, the same year that Hutton died, took up where Hutton left off and gained worldwide acceptance for the theory of uniformitarianism. Many geologists, however, felt that this theory was not fully adequate to explain all the geologic forces at work. There appeared to be events in the past that were not slowly evolving but occurred rather suddenly. This opposing view was called catastrophism. Its adherents pointed to gaps in the geologic record and the extinctions of large numbers of species. It was thought that the Earth underwent periods of catastrophic death of all life, after which life began anew. This also explained the abundance of fossils at certain stages in the geologic record. *In 1915, German Arctic explorer Alfred Wegener published his new theory of continental drift. He believed that 200 million years ago all the lands constituted a single large continent, which he named Pangaea, meaning "all lands."* The rest of the world was covered by an ocean he called Panthalassa, meaning "universal sea." When Pangaea broke up and the continents drifted apart, the Atlantic and Indian Oceans were formed. However, later the continental drift theory was opposed by some of the geologists. When Wegener died of a heart attack during an expedition to Greenland in 1930, the continental drift theory largely died with him for a while and again resurfaced with more scientific evidence supported by paleo-magnetism and continental movements.

**Plate Tectonics of Lithosphere**

The Earth's tectonic plates have been in motion for billions of years, and the shapes on the surface of the Earth, some 2 billion years ago, or even 50 million years ago, would not be recognizable from space, except in their color scheme: blue for the oceans, and a combination of gray and brown, with a sometime covering of white clouds. Though it is now accepted that the continents have moved dramatically since their formation, and are still moving, the concept of continental drift was completely unknown before the mid-twentieth century, and early geologists made the not unreasonable assumption that Europe had always been where it was when they were standing on it. *It is obvious to anyone looking at a map of South America and Africa that there is a remarkable similarity of the east coast of the former and the west coast of the latter, as if the two were parts of a gigantic jigsaw puzzle. Some early geologists believed that the power of the ocean had carved out a great valley between the two continents.* Despite the remarkable fit of the coastlines, however, it was not easy to see how they might have come apart. Continents are not supposed to break in half and slide over the Earth's surface like cookies on a greased tin. Weren't the continents rooted in the Earth? How could something that weighed uncountable millions of

tons slide around? As I mentioned earlier that it was Alfred Wegener who looked at the puzzle and saw the answer.




Wegener had wondered for years about the congruity of the continents. He theorized that there had been a single land mass, which he called *Pangaea,* during the Carboniferous Period, some 300 million years ago. Wegener had postulated his theory known as *"The Continental Drift."* He argued that Pangaea began to break up about 180 million years ago. He thought that the continents somehow barged around the ocean floor like ships plowing through pack ice, precipitating earthquakes before them, and leaving the sea floor behind. In 1937, Alexander du Toit, a South African geologist and a lifelong disciple of Wegener, suggested that rather than one continent, there had been two, which he named Gondwanaland and Laurasia. Before Wegener, nobody could conceive that the crust of the Earth moved in anything but a contracting manner; the cooling of the planet was thought to cause movement of the Earth's crust. Indeed, it was not until the middle of the twentieth century, when sea-floor spreading was shown to be the agent that propels the Earth's plates that most geologists finally came to accept the idea of continental drift. Continental drift was eventually employed to explain the appearance of fossils in unexpected and unexplainable places, and later the fossils would be used to verify the mechanism of continental drift, as similar species were found in places that had once been connected, such as southern America and Antarctica, or eastern North America and western Europe, but had drifted so far apart that they were separated by an entire ocean.

Only after overwhelming geologic and geographical evidence collected from the ocean floor, and supporting the theory of continental drift did geologists finally abandon the archaic thinking of the past century. By the late 1960s, most geologists agreed and convinced of the accuracy of the

continental drift model. The generally accepted model is that the present continents were sutured together into the super-continent Pangaea during the Permian and early Triassic. In the late Triassic and early Jurassic, Pangaea began to rift apart along a fracture zone now represented by the Mid-Atlantic Ridge. The breakup finally became complete sometime during the early Cretaceous, and since then all continents bordering on the Atlantic have been drifting away from each other. So convincing was the evidence that, by the late 1960s, it gave rise to an entirely new way of looking at the Earth, called the theory of plate tectonics. *Tectonics is any process by which the Earth's surface is shaped. The plate tectonic theory was first published by the British geophysicists Dan MacKenzie and Robert Parker in 1967*. The theory was also developed independently by the American geophysicist Jason Morgan at Princeton University. He regarded the Earth's outer shell as neither rigid nor fixed but made up of several movable plates about 96 km thick. Each plate was composed of the Lithosphere, the solid portion of the upper mantle, and the midocean ridges, where new oceanic crust is created as the plates are pulled apart; the transformed faults, where the plates slide past each other, often wrenching the ocean floor in the process; and the deep-sea trenches, where the plates ride on the asthenosphere, the semimolten layer of the upper mantle, and carry the continents along with them like rafts of rock riding on a sea of molten magma.

Plate tectonics has been shaping the Earth almost since its beginning. Continents were adrift practically since they were first formed some 4 billion years ago. Continuous bumps and grinds built up the crust until by the beginning of the Proterozoic Eon 2.5 billion years ago the landmass occupied up to one quarter of the Earth's surface area. It was also during this time that plate tectonics began to operate extensively, and the Earth as we know it began to take shape. The first two billion years of Earth history is known as the Archean Eon. It was a time when the Earth's interior was much hotter than it is today, probably too hot for plate tectonics to operate effectively as there was more vertical bubbling than horizontal sliding. Basalt, which is a dark, dense volcanic rock, formed most of the early crust, both on the continents and under the oceans. The crust was thin and highly unstable. *When tectonic activity melted and remelted the basaltic crust, granites were formed.* Eventually, the basaltic crust became embedded with scattered blocks of granite called rockbergs.

The formative Earth was subjected to massive volcanism and meteorite bombardment that repeatedly destroyed the crust. This is why the first 700 million years of Archean time is missing from the geologic record. Heavy turbulence in the mantle, with a heat flow three times greater than it is

today, resulted in violent agitation on the surface. This produced a sea of molten and semimolten rock broken up by giant fissures, from which fountains of lava spewed skyward. *Cratons or a piece of continental crust contain the oldest rocks found on Earth, dating back to 4 billion years. These rocks were composed of highly altered granite and metamorphosed marine sediments and lava flows.* They originated from intrusions of magma into the primitive ocean crust. This allowed the magma to slowly cool and separate into a light component, which rose toward the surface, and a heavy component, which settled to the bottom of the magma chamber. The cratons were also very mobile and moved about freely becoming independent, freewheeling mini-continents that periodically collided with and rebounded off each other. All the cratons eventually, coalesced into a single large landmass several thousands of miles wide. *The point at which the cratons collided with one another became mountain ranges,* and the sutures joining the landmasses are still visible today as cores of ancient mountains over 2 billion years old.

*The Paleozoic Tectonics* - The Paleozoic tectonic era began 570 million years ago and ended about 240 million years ago. The first half of the era was tectonically quiet, with little mountain building and volcanic activity. The land was divided into two mega-continents. The northern landmass was called Laurasia and included what are now North America, Greenland, Europe, and Asia. The southern landmass was called Gondwana and included what are now Africa, South America, Australia, Antarctica, and India. *The subcontinent of India later broke away from Gondwanaland and drifted into southern Asia. The collision uplifted the Himalaya Mountains and the broad Tibetan Plateau, most of which rises over 5 kilometers above sea level.* The two great landmasses were separated by a large body of water called the Tethys Sea,* which held thick deposits of sediments washed off the continents. The continents were lowered by erosion, and shallow seas flooded inland, covering more than half the present land area. *The weight of the sediments formed a deep depression in the ocean crust called the geosynclines. It was later uplifted into great mountain belts surrounding the Mediterranean Sea, when Africa slammed into Europe.* When Paleozoic came to a close, Gondwana and Laurasia converged into the crescent-shaped supercontinent Pangaea. The supercontinent extended practically from pole to pole. The rest of the planet was covered by a single ocean called the Panthalassa. The continental collisions crumpled the crust and pushed up huge masses of rocks into several mountain belts throughout many parts of

**In Permian times, the continents were, roughly speaking, assembled into one, enormous landmass, known as Pangaea. Tethys Sea was the body of water enclosed on four sides by Pangaea.*

the world. Volcanic eruptions were also prevalent due to frequent continental collisions. The sediments in the Tethys Sea separating Gondwana and Laurasia were squeezed and uplifted into various mountain belts, including the Ouachitas and Appalachians of North America and the ancestral Hercynian Mountains of southern Europe. As continents rose higher and the ocean basins dropped lower, the land became dryer and the climate grew colder, especially for the southernmost lands, which were covered with glacial ice.

*Mesozoic Tectonics* - At the beginning of the Mesozoic era, which spans from about 240 million to 65 million years ago, the great glaciers of the previous ice age melted and the seas began to warm. Reef building was intense in the Tethys Sea, and thick deposits of limestone and dolomite were laid down by lime-secreting organisms. *These beds were later uplifted to form the dolomite and limestone Alps. Around the close of the Triassic period, North and South America separated: India, nestled between Africa and Antarctica, began to separate from the two continents and move northward; and the great rift began to separate the North American continent with Eurasia. The rift was later breached and flooded with seawater, forming the infant North Atlantic Ocean.* During the Jurassic period which followed, South America began to separate from Africa like a zipper opening up from south and north. India was set fully adrift and headed toward southern Asia. Antarctica, still attached to Australia, swung away from Africa toward southeast, forming the proto-Indian Ocean. North America drifted westward as the North Atlantic continued to widen at the expense of the Pacific. Much of the western North America was assembled from oceanic island arcs and other crustal debris that was skimmed off the Pacific plate as the North American plate continued heading westward. South America and Africa were now separated by over 2400 km of ocean. Africa moved northward, leaving Antarctica, still joined to Australia, far behind. As the African continent approached southern Europe, it began to pinch off the Tethys Sea, which was caught in the middle. *Meanwhile, India continued to narrow the gap between it and southern Asia.*

*Cenozoic Tectonics* - The Cenozoic era, from about 65 million years to the present, is best known for its intense mountain building. Highly active tectonic forces established much of the terrain features found on Earth today. About 50 million years ago, a huge submerged plateau in the Indian Ocean separated into two platforms that now sit about 1920 km apart. The plateau rose from the ocean floor more than 90 million years ago, when a series of volcanic eruptions poured out vast amounts of molten basalt onto the Antarctic plate. During the next several million years, a long rift sliced through the plate and cut off its northern section, which latched onto the

Indian plate and started on a journey northward. Meanwhile, the southern half of the plateau currently lies off the west coast of Australia. The other half is the world's largest submerged plateau and sits north of Antarctica. The Rocky Mountains, which extend from Mexico to Canada, were pushed up during the Laramide orogeny (mountain building episode), which occurred from about 80 million to about 40 million years ago. Around 30 million years ago, the mountainous spine of the Andes in South America, running along the western edge of the continent continued to rise throughout much of the Cenozoic due to the subduction of the Nazca plate underneath the South American plate. South America was temporarily connected to Antarctica by a narrow, curved land bridge. When Antarctica and Australia broke away from South America and moved eastward, they themselves separated. Antarctica moved toward the South Pole, while Australia continued in a northeasterly direction. Between 3 and 4 million years ago, the Panama Isthmus, which separated North and South America was uplifted due to colliding oceanic plates. This halted the flow of cold water currents from the Atlantic into the Pacific, which together with the closing off of the Arctic Ocean from warm Pacific currents might have initiated the Pleistocene glacial epoch. Never before in Earth's history had there been two permanent polar ice caps, which also suggest that the planet has been steadily cooling since the Cretaceous period, when the dinosaurs held dominion over the world.

*Faults* – There are other lithospheric components which are associated to plate tectonic activity, such as faults, terranes, cratons, and rifts. Faults are breaks in the Earth's crust. Many of them are brittle fractures, which happen when rocks snap. Most rigid materials break if they are strained beyond endurance. Bones break if they are bent in the wrong direction or if they are forced to carry more than they can bear. Even steel girders will fracture given enough goading, or if some microscopic weakness lurks within them. Faults run deep. *"They say best men are molded out of faults," as Shakespeare put it in "Measure for Measure," every man his own planet, with weaknesses ingrained. The possibility of failure always lurks when pressure is exerted upon our nature, which is when we may be sure our faults will find us out. Perhaps more than any other geological process in this intimate history of the Earth it is faulting that we understand at the most visceral level, for we all know of failure, and most of us acknowledge the flaws that cut through our own thin crust.* If you had to ask the man in the street to name just one geological structure, he would probably say: *the San Andreas Fault.** Indeed, in the minds of some

**It lies in California State, near San Francesco and Los Angeles, and known for its notoriously frequent earthquakes.*

people, it is almost synonymous with geology. There are other great faults, like the Anatolian Fault that has wrought periodic havoc in Turkey, but it is the San Andreas Fault that has somehow entered common consciousness as symbol of the power of the Earth: *the great shaker.*

*Cratons and Terranes* **-** The continents are composed of cratons, the odds and ends of ancient continental crust. The cratons are patchwork mixtures, consisting of crustal pieces known as terranes, which are assembled into geologic collages. The composition of terranes generally resembles that of an oceanic island or plateau. Some, however, are composed of a consolidated conglomerate of pebbles, sand, and silt that accumulated in an ocean basin between colliding crustal fragments. The entire state of Alaska is an agglomeration of terranes. A large portion of the Alaskan Panhandle, known as the Alexander terrane was once part of eastern Australia some 500 million years ago. It broke off from Australia, traversed the Pacific Ocean, stopped briefly at the coast of Peru, sliced past California, swiping some of the Mother Lode, and bumped into North America around 100 million years ago. *Terranes come in a variety of shapes and sizes from small slivers to subcontinents such as India, which is a single great terrane.* Most terranes are elongated bodies that tend to become deformed when they collide and accrete to a continent. The assemblage of terranes in China is being stretched and displaced in an east-west direction due to the continuing squeeze India is exerting on southern Asia. The terranes range in age from less than 200 million years old to well over a billion years old.

*Rifts - The Great Rift Valley, Africa* - There are other fault lines that traverse the Earth. Cutting north-south through eastern Africa there are great valleys: a depression passes southwards from the Gulf of Aden through Ethiopia, then splits into two arms, passing either side of Lake Victoria. The eastern arm strikes southwards across Kenya, its course marked by lakes sitting in the valley base: Lake Turkana, Lake Baringo, Lake Magadi, and Lake Natron. The last named is one of the great natural sources of soda, for it is another Great Salt Lake, where evaporation has concentrated soluble salts. The lake supports a huge population of delicately pink flamingos, which use their extraordinary bills to filter out nutritious microorganisms from the warm, alkaline lake. For these birds, a soda fountain is a literal description of their source of nourishment and they derive their color from their food. The western arm is one of the most blatant lines on the face of the Earth, an almost continuous ribbon of water running southwards from Lake Albert to Lake Edward, and thence to Lake Tanganyika and Lake Nyasa (Malawi): *the Great Rift Valley. The total length of the Great Rift Valley is some 3000 kilometers. The width of the valley is about 50 kilometers along its entire length.* They are geological lines graven on the ground. Volcanoes follow the rift

line less slavishly than earthquakes, throughout Ethiopia and Kenya, and further south, there are many active or dormant volcanoes by the fault lines. The Great Rift Valley formed over the past 35 million years. This giant split in the landscape is the result of two tectonic plates separating. East Africa is the most topographically diverse region on the African continent. Topography means comparing the physical lay of the land across a region, the mountains, valleys, and other natural or human-made features.

Much of the East African landscape is defined by the Great Rift Valley, which runs Ethiopia down to Mozambique. The valley was created by the movement of two fault lines in the Earth, and it is responsible for creating mountains, valleys and lakes found throughout this area. *In fact, the highest point on the African continents is found in the Great Rift Valley, Mount Kilimanjaro in Tanzania, which reaches 19,340 feet above sea level. The Great Rift Valley is really one of the great wonders of the world.* It is impossible to describe the sensation when you first see it in Kenya, or do justice to what it feels like when you approach the Great Rift Valley, and the ground just vanishes from under you, as this great Rift opens up, cutting Kenya neatly in half, separating East from West. *The Great Rift Valley houses one of the biggest volcanic craters on the planet, known as "Ngorongoro Crater."* The Ngorongoro Crater is a natural amphitheatre created about 2 million years ago when the cone of a volcano collapsed into itself, leaving a 160 square km caldron-like cavity. This caldera, protected by a circular unbroken, 2,000-foot high rim, contains everything necessary for Africa's wildlife to exist and thrive. *Often Ngorongoro is called "Africa's Eden" and the "8th Natural Wonder of the World."* Only indigenous tribes such as the Masai* are allowed to live on this land. Lush highlands surround the crater, falling away to tawny plains and alkaline lakes of the Great Rift Valley. A descent down the rim passes rain forest and thick vegetation, and the flora and fauna open to grassy plains throughout the crater floor. The Great Rift Valley houses another natural wonder of the world: the Serengeti National Park.

*Hot Spots* - Hot spots are places on the Earth where columns of hot basaltic rock rise slowly from the mantle, puncturing the crust forming volcanoes and causing earthquakes. When a tectonic plate lingers over a hot spot and then moves on, a volcanic island is formed. This tectonic plate movement will eventually result in a chain of volcanic islands like those in Hawaii or a seamount, an underwater ridge that rises above the level of the surrounding seafloor. The line of volcanoes that stretches from offshore Siberia to Kilauea is proof of tectonic motion. *The Emperor Seamounts, a*

**The Masai people are a very proud and noble tribe in East Africa, known for their red-clad warriors and bead-covered women. They are very impressive people and their culture is a fascinating one.*

*chain of underwater mountains in the northern Pacific,* are ancient, extinct volcanoes that once were directly over the hot spot that is now below Hawaii. The mountains south of the Emperors are progressively younger and, in Hawaii, are active volcanoes.

*Sial-Continental Crust* - In locations where there are continents, we find a very different type of crust. The rocks found in the crust of the continents are called sial. Sial is made of silica, and aluminum, and is much lighter than the sima beneath it.

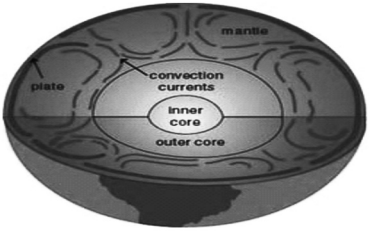
*Sima-Oceanic crust* - The ocean floor is made primarily of extremely dense rock which scientists call sima. Sima is made out of two basic substances. These substances are silica, and magnesium. Sima tends to be younger than the rocks found on continents, so that it is below them.

*Isostasy* - If you were to take a large rubber ball and place something heavy on top of it, such as a bowling ball, what do you suppose would happen to the rubber ball? The weight of the bowling ball will push the skin of the rubber ball inward, creating a dent. Scientists observe the same phenomena with the Earth's crust. When the Earth's crust is pushed down, creating a small dent, we refer to this as isostasy.

**The Convection Currents**

The collision and separation of continents appears to be controlled by convection currents in the Earth's mantle. The presence of water and carbon dioxide in the upper mantle acts like a catalyst that aids in the partial melting of rocks at lower pressures and makes the asthenosphere flow easily. Heat transferred from the mantle to the asthenosphere causes convective currents to rise and travel laterally when they reach the underside of the lithosphere. Upon giving up their heat energy the Lithosphere, the currents cool and descend back into the mantle, similar to the way air currents operate in the atmosphere. If there are any cracks or areas of weakness in the Lithosphere, the convective currents spread the fissures wider apart to form rift systems. *Here the largest proportion of the Earth's interior heat is lost to the surface, as magma flows out of the rift zones to form new oceanic crust.* Convection is the motion within a fluid medium that results from a difference in temperature from top to bottom. Fluid rocks in the mantle receive heat from the core, ascend, dissipate heat to the Lithosphere, cool, and descend to the core again to pick up more heat. The cycling of heat within the mantle is the main activities taking place on the Earth's surface. Rapid mantle convection leads to the breakup of super-continents, which compresses the ocean basins, causing a rise in sea level and a transgression of the seas onto the land. There is also an increase in volcanism, and vast amounts of lava flood onto the continental crust during the early stages of many rifts. The rise in volcanism also increases the carbon

dioxide content of the atmosphere, resulting in a strong greenhouse effect that promotes warm conditions worldwide. *The second phase of the continent cycle is a time of low mantle convection,* resulting in the assembly of continents into a super-continent. This process widens the ocean basins, causing a drop in sea level and a regression of the seas from the land. Furthermore, there is a decrease in volcanism and a reduction of atmospheric carbon dioxide, resulting in the development of an *icehouse effect* that leads to colder global temperatures.



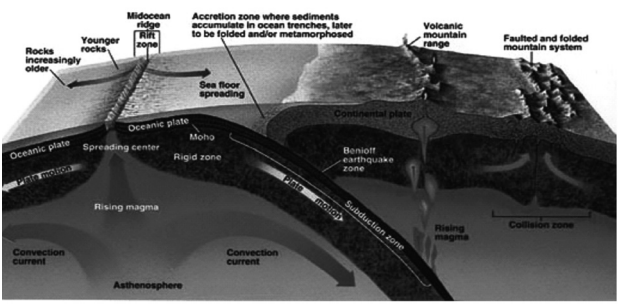

Convection currents transport heat by the motion of mantle material, which in turn drives the plates. The mantle convection currents are believed to originate over 640 km below the surface. The deepest known earthquakes are detected at this level, and since almost all large earthquakes are triggered by plate motions, the energy they release must come from the forces that drive the plates. At the plate boundaries where one plate drives under another, the sinking slab meets great resistance to its motion at a depth of about 640 km, the boundary between the upper and lower mantle. The slab should sink as far as the bottom of the lower mantle. However, it might provide the source material for hot spots. If all oceanic plates were to sink to this level, a volume of rock equal to that of the entire upper mantle would be thrust into the lower mantle every billion years. In order for the two mantle layers maintain their distinct compositions, like oil floating on water, some form of return flow back to the upper mantle would be needed, and hot spot plumes seemed to fulfill this function. The mantle rocks are churning over very slowly in large-scale convection loops. They travel only a couple of inches a year. *The convection currents might take hundreds of millions of years to complete a single loop.* Some of these loops can be extremely large in the horizontal dimension, and correspond to the dimensions of the associated plate.

The formation of molten rock and the rise of magma to the surface results from the exchange of heat within the Earth's interior. Therefore, volcanism is linked to the Earth's temperature patterns. The Earth is continuously losing heat energy from the interior through its outer shell, or Lithosphere, at a steady rate. *If the interior heat would have long since escaped into space the Earth's interior would have cooled and solidified, and the continents would have stopped dead in their tracks, with them life, too*. Most of the Earth's thermal energy is generated by radioactive isotopes, mainly uranium, thorium, and potassium. Presently, 40% of the heat flow at the surface is

generated within the crust, which accounts for its high geothermal gradients. The concentration of radioactive elements is greater in the crust than in the mantle, which suggests that they segregated early in the Earth's history. When the Earth began to melt and segregate into its various layers, over twice as much heat was generated by radioactivity than is generated today. Since the formation of the Earth, half of the radioactive isotopes have decayed into stable elements. The increased heat production was probably due to a rise in heat flow on the surface. It also implies that the original lithospheric plates were thinner, smaller, and more numerous than they are today. The asthenosphere underlying the plates was probably much more active in the past. Therefore, the plates might have moved around more vigorously, casing all sorts of calamities on the Earth's surface.

**Mountain Building – Episodes of Orogeny**

Before the continental drift theory was accepted, there was no adequate explanation for the building of mountain ranges. It was thought that mountains formed early in the Earth's history when the molten crust cooled and solidified, forcing it to contract and shrivel up. However, after further study, geologists were forced to conclude that the folding of rock layers was much too young and intense, and therefore, some other forces had to be at work in raising the world's mountains. The most impressive landforms the Earth has to offer are its mountain ranges, created by the forces of uplift and erosion. The mountains grew as ancient oceans vanished. *A mountain is defined as a topographic feature that rises abruptly above the surrounding terrain and involves the massive deformation of the rocks that form the core of the mountain.* The usual means of building mountains is for plate motions to shove crust onto another strong plate or create a deep root of light crustal rock that literally floats the mountain like an iceberg. Most mountains occur in ranges, and although a few isolated peaks do exist, they are rare. Mountains have complex internal structures formed by folding, faulting, volcanic activity, igneous intrusion, and metamorphism. Mountain building, which provides the forces necessary for folding and faulting rocks at shallow depths, also supplies the stress forces that strongly distort rocks at greater depths.

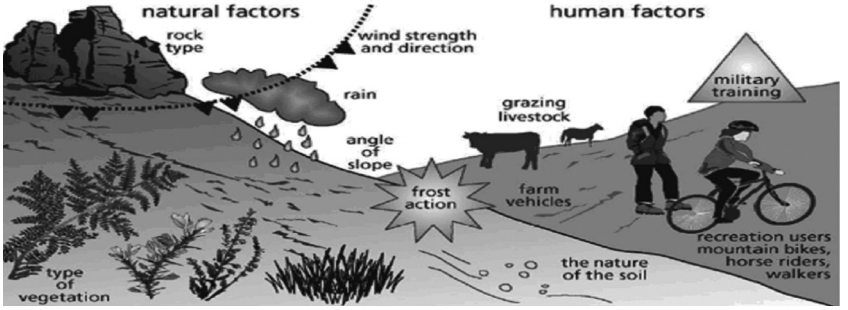


The continental collisions crumpled the crust, pushing up huge masses of rocks into several mountain chains throughout many parts of the world. *India and the rocks that now make up the Himalayas broke away from Gondwana early in the Cretaceous, sped across the ancestral Indian Ocean, and slammed into southern Asia about 40 million years ago. In the process, 9600 km of subducting plate was destroyed. As the Indian and Asian plates collided, the oceanic Lithosphere between them was thrust under Tibet. The increased buoyancy uplifted the Himalaya Mountains and the wide Tibetan Plateau.* These regions rose at an incredible rate during the past 5 to ten million years, when the entire area was uplifted more than a mile. The entire crust of Eurasian and African plates buckled upward, forming the central portions of the range. This episode of mountain building called the Alpine Orogeny, ended about 26 million years ago. It raised the Pyrenees on the border between Spain and France, the Atlas Mountains of northwest Africa, and the Carpathians in east-central Europe. The Alps of northern Italy formed in much the same manner as the Himalayas, when the Italian prong of the African plate was thrust into the European plate. But because the European plate is only half as thick as the Indian plate, the Alps are only about half as tall as the Himalayas.

**Erosion – A Grand Sculptor**

No matter how pervasive is the formation of mountain ranges by the convergence of crustal plates erosion is an equally powerful force in wearing them down. Erosion has leveled the tallest mountains, gouged deep ravines into the hardest rock, and obliterated most geologic structures on Earth, including almost all large meteorite-impact structures, which explains why few are still visible. *The rise of active mountain chains such as the Himalayas is matched by erosion so that their net growth is nearly zero.* Before the spread of vegetation on the land, soil eroded easily because there were no plant roots to hold it in place. Therefore, erosion rates were probably much higher than they are now. *It took eons of mountain building and erosion to give us our present landscape of tall mountains and deep canyons. This includes the 29,000-foot Mount Everest in the Himalayas, the world's tallest peak, and the Dead Sea in Middle East, which at 1300 feet below sea level is the lowest point on the Earth's surface.* Erosion is a geologic process that carves the landscape into jagged mountains and ragged canyons. No matter how pervasive mountain ranges formed by the forces of uplift are, they eventually lose the battle with erosion and are worn down to the level of the prevailing plain, with only their deep roots remaining to mark their existence. The cores of the world's mountain ranges contain some of the oldest rocks on Earth. What was once buried deep beneath the surface has

been thrust upward to great heights. Huge blocks of ancient granite that formed the interiors of the continents were pushed up by tectonic forces operating deep within the Earth and exposed by erosion.



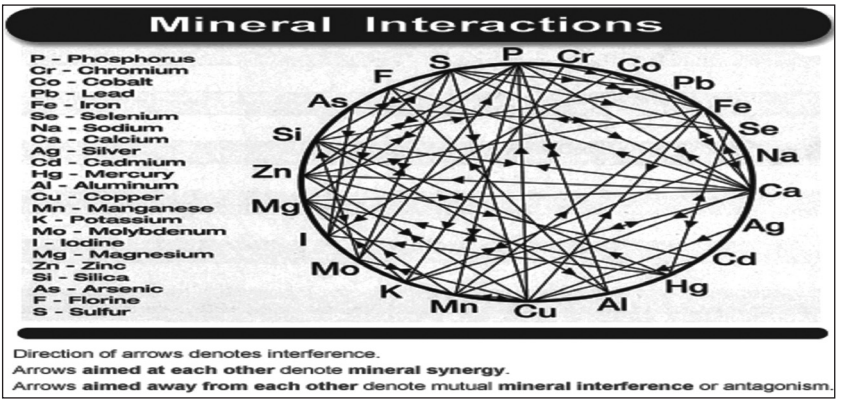

Erosion also gouges out deep ravines in the hardest rock and has obliterated most geologic structures, including ancient man-made structures. It has carved out some of the most impressive geologic features the planet has to offer, from deep canyons and broad valleys to individual monuments sculpted from stone. Massive sandstone cliffs in the western U.S have been slowly eroding for millions of years. *Perhaps nowhere else on Earth is this process better demonstrated than the Grand Canyon of northern Arizona, which was carved out by the swift-flowing Colorado River, now a mere trickle of its former self.* Erosion rates vary, depending on the amount of precipitation, the topography of the land, the type of rock and soil material, and the amount of vegetative cover. In the past, erosion rates might have been higher than they are today. Continents of the early Earth were desolated places practically devoid of soil because water washed away nearly all the loose sediments. *The greatest sources of sediments today are the towering Himalaya Mountains between India and China. Wind and water are slowly eroding the mountains into tiny grains that eventually wash into the Bay of Bengal by the Ganges and Brahmaputra rivers, which carry as much as 40 percent of the total sediment discharged by all rivers. The sediments are dumped into the adjoining basin to a depth of 19 km.*

**Homo destructus – Man of Destruction**

The most potent agent of geological erosion is, undoubtedly, ourselves. To build a dam, high rise buildings, house, roads and bridge, we blast away mountainsides to find firm footings for the foundations, and quarry deep pits for the raw materials. Mountains are pulverized, by extracting gravel for the construction of houses for the increasing population. Rivers sand is exploited

for the construction purposes, leaving the level of ground water to the great depths. As a result agriculture is affected. *From space we can see the scars on Lithosphere made by man such as, mines, bridges, pits, roads and factories.* The biggest hole in the ground made by people is Bingham Canyon copper mine in Canada reaching a depth of 774 meters over an area of 8 km, farmers, too, have a profound effect on the landscape, and have done since farming was developed in Neolithic times. Natural vegetation is removed to make room for cultivated land. Forests are cleared to make grasslands for grazing animals. If this is mismanaged, as it is in many parts of the world, the soil is destroyed. The naturally formed humus that holds the soil together deteriorates and the soil washes away as mud or blows away in sandstorms. A scheme to irrigate the desert lands of central Asia by diverting the rivers flowing into the Aral Sea backfired when the sea began to dry out and the exposed salt was blown over the new farmland where they are neither expected nor desired. *Let us hope India will not repeat the same mistake, connecting the rivers of India. If it is done, India will definitely face desertification.*

Coastal erosion is affected as well. When beach gravel is removed for building material, the pattern of coastal currents is changed and nearby villages may collapse into the sea. Breakwaters constructed to protect harbors may give rise to sandbanks where they are neither expected nor desired. *Coal mines, Gold mines, Iron Ore mines, Copper mines, and other mineral mines are all in the state of exhaustion. Fossil fuels are almost depleted. Lithosphere is wounded and bleeding. Consider Bhopal Tragedy, Chernobyl Nuclear Explosion, Love Canal, Rhine River, where one thousand tons of chemicals, including eight tons of pure mercury, were spilled, the river where St. Hildegard of Bingen and Meister Eckhart, the two greatest creation mystics of Western Europe, lived and preached their message of compassion and interconnectivity with creation*. A Swiss government official reports that "the Rhine is now dead." The whole ecosystem is destroyed due to this accident. Today one out of two fish eaten in cities around the Mediterranean Sea are imported because that sea is poisoned. It seems that every month a new ecological disaster is produced by the two-legged ones. *Nuclear bomb test by India, Pakistan, Iran, and North Korea have left deep irreparable scars on Lithosphere.* World wars punctured the Lithosphere and U.S.A continues to puncture the Earth in Iraq and Afghanistan. Mother Earth is the victim. If this continues, eventually we and our children will pay the price. If current rate of destruction persists, within the next one hundred years there will be no living species left on this planet, including humankind, since we are totally interdependent with all these other creatures. *If we persist in poisoning the Lithosphere, then we will ultimately poison ourselves. Mother Earth is in great pain, a pain inflicted by her own children as they commit matricide.*




Gold, iron ore, silver, copper, coal and oil are some of the minerals valued by humanity. The silver and the uranium were the last exhalations from the dying seas, a gift from the underworld sealed in cracks since the Carboniferous. Silver and gold are unusual in occurring in nature as the pure element. We have sulfur in the yellow-stained exhalations around the volcanoes. Copper also occurs in sheets and nuggets, often so distinctively shaped they seem to have been beaten out by an Earth sprite with an eye for abstract sculpture. *Most elements are prone to combine with one or several others to form a compound: this is a mineral.* The "noblest" metal, gold, is reluctant to become part of as mineral; it will not combine with oxygen in the atmosphere, for example, which is why it does not tarnish, and why gold hoards still glow after years in the ground. Iron, by contrast, is corrupted by water and oxygen and soon becomes crusted and fragile. Like iron, most elements cleave unto others. A mineral has a particular chemical formula, a characteristic combination of elements. An ore is just a mineral, or a set of minerals found together, that is of commercial value. Minerals carry scientific names such as: sphene, tourmaline, galena, hornblende, topaz, garnet, but majority are just "ites," such as bismutotantalite, cuproskodlowskite, fluorapophyllite, guanajuatite, monteregianite, and yofortierite. Each mineral name is a label of chemical composition first, but also has a typical crystal structure.

Diamonds, as the saying goes, are forever. Unfortunately, this is not true. Diamonds with time will disintegrate gradually and disappear. Diamonds are the same material as coal, but transformed wondrously. Under sufficient pressure, the carbon atom is forced to make a three-dimensional framework analogous to that described for silica, except that diamond is pure carbon

alone and each atom is strongly bonded to another four in a kind of unbreakable armlock. This is why diamonds are so hard. Gemstones are crystals of greater rarity, and are a more traditional barometer of wealth than mere accumulation of monetary value. *All gemstones are minerals, but not all minerals can yield gems. Grown deep in the underworld under special conditions, with the right impurity added by nature to induce color, it becomes the most regal of all jewels: ruby.* Some of the best rubies are found near the village of Mogok, in Burma. The ultimate rubies are called "pigeon's blood rubies," allegedly because their color resembles that of the blood of a freshly slaughtered dove: they are a lustrous but absolutely clear red and are most valuable of all gemstones. They are rarely found in place in their rocky source, a coarsely crystalline marble that cropped out in the wet hills of Burma. Only eight elements make up 90 percent of the Earth's crust: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium, in decreasing abundance. Their cradle is often where plates collide, or where the tectonic motor of the Earth squeezes out unusual fluxes from the stressed crust.

Throughout geologic history, in many parts of the world, a piece of crust was scraped off an oceanic plate as it plunged under the leading edge of a continent. These ophiolites, from the Greek "ophis," meaning "snake" are associated with igneous rock known as serpentinite, which has a mottled green appearance like that of a serpent. When former volcanically active regions of the ocean crust are uplifted onto the continents, they provide rich metal ore deposits that are mined throughout the world. The ore provided some of the first bronze for the earliest Greek and Indian sculptures. As the oceanic crust moves away from a spreading center, it eventually reaches the margin of the ocean basin, where it is either subducted into the mantle or collides head-on with another lithospheric plate and raises mountains. In the course of these events, fragments of oceanic crust might be uplifted and exposed on land. These fragments of ancient oceanic lithosphere have been identified in various parts of the world. The ophiolites consist of an upper layer of marine sediments, a layer of pillow lava (basalts that have erupted undersea), and a layer of dark, dense ultramafic rocks (rich in iron and magnesium and poor in silica) that are thought to be part of the upper mantle. The metal ore deposits are at the base of the sedimentary layer just above the area where it makes contact with the basalt.

Another type of metal ore deposit formed at oceanic spreading centers is called a massive sulfide. These deposits contain sulfides of iron, copper, lead, and zinc. They occur in most ophiolite complexes, such as Apennine

ophiolites, first mined by the ancient Romans. Massive sulfide deposits are mined extensively in other parts of the world for their rich ores of copper, lead, and zinc. The mineralization is similar to that found in rifts that opened more than 600 million years ago and are now mined for their copper, lead, and zinc. *Plate tectonics has also aided in the exploration for oil and gas.* The theory helps to explain why oil reserves are located where they are and might suggest new sites to explore for oil. It is commonly believed that oil and natural gas were formed from the remains of abundant plant and animal life that lived in tropical regions tens of millions to hundreds of millions of years ago. This is true for coal as well, and plant fossils are actually found between coal layers, indicating their organic origin. Deep burial and heat provided by the Earth's interior created a gigantic pressure cooker, which through geologic time has baked the organic compounds into hydrocarbons. The eventual drifting of the continents and erosion of the surface layers has brought the oil, and gas deposits within the reach of the driller's bit.

Like all mining discoveries in the old days, the initial bonanza occurred on the surface, where some sharp-eyes prospector discovered an outcrop of rock, or weathered material, showing the cherished minerals. Then the vein was chased downwards, as deep into the Earth as available technology and profit would allow. *Where humans have wormed their way into the underworld in pursuit of minerals, the heave of the violated crust often squeezed back again to obliterate their impertinence. All mines eventually become exhausted. Homo sapiens inherited a priceless fortune, the planet Earth and riches it contained. Part of that one-time bonanza is, of course, the great deposits of fossil fuels that have powered industrial civilization.* But there are other riches, less obvious, perhaps, but even more valuable. Arguably the greatest treasure consists of the millions of other kinds of organisms, plants, animals, and microbes, with which people share the planet. These other living beings have provided us with all our foods; with wood, fibers, and skins for clothing and shelter; and with medicines, oils, soaps, resins, rubber and uncountable other useful items. Many organisms, of course, we domesticated and often improved by selective breeding to make them even more useful to us. More important, that treasure of other species plays critical roles in providing us a hospitable environment. That environment includes such as essentials as a favorable climate, breathable air, and deep, fertile soils.

All these came into existence over eons, in part as outcomes of the evolution of the Earth's diversity of life forms. Similarly, the fossil fuels, coal, oil, peat, and natural gas, are the geologically processed and preserved

remains of ancient plants and microorganisms. *The human inheritance also includes inorganic treasures such as vast underground supplies of pure fresh water as well as concentrated deposits of dozens of useful metals, from copper, iron, and mercury to zinc, all of which our clever species eventually learned to exploit.* For the first several million years of their existence, human beings, like other animals, were dependent for their resources almost entirely on other living organisms, the plants and animals they ate or used for fuel or to fashion simple tools, shelter, and clothing. All these are renewable resources, naturally reproducing themselves, or in the case of water, continually being replenished by natural processes that involve, plants, animals, and microorganisms. In a real sense, early people, like the prudent elder son of our analogy, were living on the income from their inheritance. With the invention of agriculture, things began to change. *Human beings not only learned to manipulate their biological environment to enhance their food supplies, they soon discovered the value of metal, the first significant use of nonrenewable resources.* Agricultural people later overexploited some renewable resources such as soil, by depleting it of nutrients, failing to control erosion, or allowing irrigated fields to accumulate salts, and forests, by cutting them faster than they could regenerate. Consequently, Lithosphere is pillaged, stripped and destroyed.

**Tectonics and Evolution**



The motions of the continents had a major influence on the distribution, isolation, and evolution of species. The changes in continental configuration greatly affected global temperatures, ocean currents, productivity, and many other factors of fundamental importance to life. Many different environments result in a wide variety of species. Therefore, evolutionary trends varied throughout geologic time in response to major environmental changes as natural selection acted to adapt organisms to the new conditions forced on them by environmental factors that were affected by, among other things, continental drift. *When all the continents were welded into the super-continent Pangaea near the end of the Paleozoic era (250 my), there was a great diversity of plant and animal life in the ocean as well as on land.* The formation of Pangaea marked a major turning point in evolution of life, during which the reptiles emerged as the dominant

species. It is believed that most of the Pangaea climate was equable with few temperature extremes and fairly warm throughout the year. Much of the interior of Pangaea, however, was a desert, whose temperatures fluctuated wildly between seasons, with scorching summers and freezing winters. This temperature fluctuation might have contributed to the widespread extinction of land-based species during the late Paleozoic. It also explains why the reptiles, which adapted readily to hot, dry climates, replaced the amphibians as the dominant land species.

The vast majority of marine species live on continental shelves or shallow water portions of islands and subsurface rises at shallow depths generally less than 600 feet. The richest shallow-water faunas live in the tropics, which contain large numbers of highly specialized species. Progressing to higher latitudes, diversity gradually fall off, until in the polar regions there are less than one tenth as many species than in the tropics. Moreover, there is twice the species diversity in the Arctic Sea, which surrounds a continent. *Diversity is greatly affected by seasonal changes such as variations in surface and upwelling ocean currents that affect the nutrient supply.* This in turn causes large fluctuations in productivity. Therefore, the greatest diversity among species is off the shores of small islands or small continents facing large oceans, where fluctuations in the nutrient supply are least affected by seasonal effects of landmasses which often sponsor episodes of glaciation or other environmental swings. Species diversity also depends on the shapes of the continents, the width of shallow continental margins, the extent of inland seas, and the presence of coastal mountains, all of which are affected by continental motions. When the continents were assembled into Pangaea, there was a continuous shallow-water margin running around the entire perimeter of the super-continent, with no major physical barriers to the dispersal of marine life.

Furthermore, the seas were largely confined to the ocean basins, leaving the continental shelves mostly exposed. Consequently, habitat area for shallow-water marine organisms was very limited, which accounted for the low species diversity. As a result, marine biotas were more widespread but contained comparatively fewer species. Similar conditions might have occurred during the late Precambrian around 600 million years ago, when another super-continent was in existence. During the Cambrian period, it broke into perhaps four or five large continents, whose extended shoreline might have affected the explosion of new species during that time. There were twice as many phyla or organisms that share the same general body plan, during the Cambrian than before or since. *Never were there so many experimental, or unusual, organisms, none of which have any counterparts in*

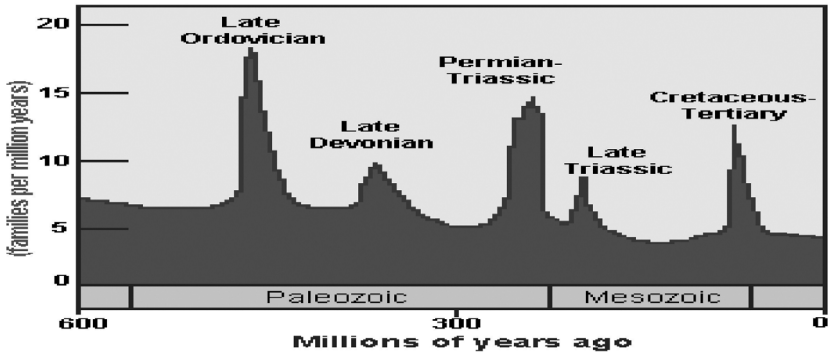
*today's living world.* When Pangaea broke up and the resulting continents migrated to their current positions, diversity again increased to unprecedented heights, providing our present-day world with a rich variety of species. The movement of continents changes the shapes of ocean basins, which affects the flow of ocean currents, the width of continental margins, and the abundance of marine habitats. When a super-continent breaks up, more continental margins are created, the land lowers, and the ocean rises, providing a larger habitat area for marine organisms. During times of highly active continental movements, volcanic activity increases. The amount of volcanism could affect the composition of the atmosphere, the rate of mountain building, and the climate, all of which invariably affects life. The drifting of the continents during the Cenozoic isolated many groups of mammals and they evolved along independent lines.

Around 40 million years ago, Australia drifted away from Antarctica, which acted as a bridge between it and South America and the separation isolated the continent from the rest of the world. It is now inhabited by strange egg-laying mammals called monotremes, including the spiny anteater and platypus, which should rightfully be classified as surviving mammal-like reptiles. When the platypus was first discovered, it was thought to be a missing link between mammals and their ancient ancestors. Marsupials are believed to have originated in North America around 100 million years ago. They migrated to South America, crossed over to Antarctica when the two continents were still attached to each other, and landed in Australia before it broke away from Antarctica. The Australian group consists of kangaroos, wombats, and bandicoots, while opossums and related species occupy other parts of the world. Camels originated in North America about 25 million years ago and migrated out of the continent to other parts of the world by crossing over connecting land bridges. Horses, which evolved at about the same time, took a similar route out of North America. Madagascar, which broke away from Africa about 125 million years ago, has none of the large mammals that occupy the mainland except for the hippopotamus, which somehow managed to cross over to the island after it had already drifted some distance away from the continent.

**Tectonics and Extinction**

Considering all the great upheavals in the Earth throughout geological history, it is a great wonder how life managed to survive to the present. Episodes of mass extinctions of species correlate with cycles of terrestrial phenomena. The most pervasive of these is a 300-million-year cycle of

convections currents in the Earth's mantle. Convection within the mantle is the very driving force behind plate tectonics and all geologic activity taking place on the Earth's surface. During the periods of rapid mantle convection, super-continents tend to break up. This leads to the compression of ocean basins, causing a rise in sea level and a transgression of the seas onto the land. *It also increases volcanism, which in turn increases the carbon dioxide content of the atmosphere, resulting in a strong greenhouse effect and rising global temperatures.* During times of low mantle convection, all the continents are assembled into a super-continent. This causes a widening of ocean basins with a consequent drop in global sea levels and a regression of the seas from the land. The fluctuation in sea levels is directly related to vertical tectonic movements on the continents. As the continents rise, the ocean lowers. Moreover, there is a reduction of atmospheric carbon dioxide due to low levels of volcanism, resulting in lower global temperatures. Throughout most of the Earth's history, continents and ocean basins have been continuously reshaped and rearranged by crustal plates in motion. When continents break up, they override ocean basin, which makes the seas less confined and raises global sea levels several hundred feet. Low-lying areas inland of the continents are inundated by the sea, dramatically increasing the shore-line and the shallow-water marine habitat area, which can support a larger number of species.




There is also a great deal of mountain building associated with the movement of crustal plates. This alters patterns of river drainages and climate, which in turn affects terrestrial habitats. Raising land to higher elevations, where the air is thinner and colder, allows glaciers to form, especially in the higher latitudes. *Continents scattered in all parts of the world can also interfere with ocean currents, which affect global heat distribution.* When continents are assembled into a super-continent, land no longer impeded the flow of ocean currents. They can therefore distribute heat

more evenly around the planet and maintain more uniform global temperatures. The ocean basins also widen, causing sea levels to drop. A substantial and rapid fall in sea level could directly and indirectly influence the biologic world. It would increase the seasonal extremes of temperature on the continents, thereby increasing environmental stress on terrestrial species. A drop in sea level also forces inland seas to retreat, resulting in a continuous, narrow continental margin around the super-continent. This in turn reduces the shoreline, which radically limits the habitat area. Moreover, unstable near-shore conditions result in n unreliable food supply. *Many species cannot cope with the limited living space and food supply and die out in tragically large numbers.* This occurred at the end of the Paleozoic era, when the vast majority of marine species became extinct. During the final stages of the Cretaceous period, when the seas were departing from the land and the level of the oceans began to drop, the temperatures in a broad tropical ocean belt known as the Tethys Sea began to fall. This might explain why the Tethyan species that were the most temperature sensitive suffered the heaviest extinction at the end of the period.

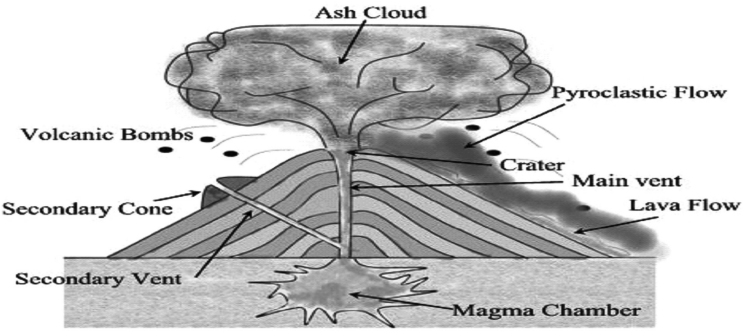
**Volcano - The Big Burp**

*"When the Lord God made the Earth and the heavens, no shrub of the field had yet appeared on the Earth and no plant of the field had yet sprung up; the Lord God had not sent man to work the ground, but streams came up from the Earth and watered the whole surface of the ground" Genesis 2:4-6.*

Early in the formation of the Earth, during a period geologists like to refer to as the "big burp," giant volcanoes belched out massive quantities of gas and stream. Volcanic eruptions provide one of the most spectacular of all natural phenomena, yet they also rank among the most dangerous of geological hazards. More than 500 million people worldwide live near active volcanoes and need to understand the risks associated with volcanic eruptions and how to respond in the event of volcanic emergencies. Eruptions may send blocks of rock, ash, and gas tens of thousands of feet into the atmosphere in beautiful eruption plumes, yet individual eruptions have also killed tens of thousands of people. The hazards associated with volcanic eruptions are not limited to the immediate threat from the flowing lava and ash, but include longer-term atmospheric and climate effects and changes to land use patterns and the livelihoods of human populations.

People have been awed by the power and fury of volcanoes for thousands of years, as evidenced by biblical passages referring to eruptions and, more recently, by the destruction of Pompeii and Herculaneum from

the eruption of Italy's Vesuvius in the year 79 AD. Sixteen thousand people died in Pompeii alone, buried by a fast-moving hot incandescent ash flow. This famous eruption buried Pompeii in thick ash that quickly solidified, which preserved the city and its inhabitants remarkably well. In the 16th century, Pompeii was rediscovered and has since been the focus of archaeological investigations. Mount Vesuvius is still active, looming over the present-day city of Naples, Italy. Most residents of Naples rarely think about the threat looming over their city. There are many apparently dormant volcanoes similar to Vesuvius around the world, and people who live near them need to understand the potential threats and hazards posed by these sleeping giants to know how to react in the event of a major eruption. At certain times in Earth's history huge amounts of volcanism have covered vast areas with lava flows, and the consequences of the release of so many volcanic gases include changes to the planetary atmosphere and the course of life on Earth. The volcanic fields from 65 million years ago are preserved as vast lava plains in western India known as the Deccan Traps and on the Seychelles and other islands in the Indian Ocean.



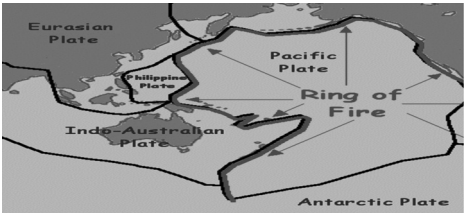

**Main Features of a Volcano**

Impacts and massive volcanism can both dramatically change the global climate on scales that far exceed the changes witnessed in the past few thousand of years. These changes have dramatic influences on evolution and extinction of species, and current ideas suggest that impacts and volcanism have been responsible for most of the great extinctions of geological time. Other rare geologic events may be less dramatic than meteorite impacts, though still beyond the scale of anything we have seen on Earth in recent times. *One example of this "extreme" geology is the formation of "kimberlite pipes," which are large volcanic pipes that come from deep in the Earth and explode their way to the surface with such force that they may blow holes through the stratosphere.* These kimberlite pipes carry

diamonds from hundreds of kilometers in the Earth and seem to form in places that were abnormally rich in fluids. The global effect of kimberlites is not known, but you certainly would not want to be in the vicinity when one punches through the crust. The local effects of these kimberlit explosions are thought to resemble the destruction wrought by nuclear blasts, with large areas of widespread devastation around the kimberlite intrusion pipes.

**The Ring of Fire – A Sorcerer's Apprentice**

*A ring of subduction zones surrounding the Pacific plate is often called the "Ring of Fire" because of frequent volcanic activity.* The subduction zones have devoured almost all the seafloor since the break up of Pangaea so that the oldest crust lies in a small patch off southeast Japan and dates about 170 million years old. In the process of subduction, the seafloor melts providing molten magma for volcanoes that fringe the deep-sea trenches. *Most of the 600 active volcanoes in the world lie in the Pacific Ocean, with nearly half residing in the western Pacific region alone.* This produces an almost continuous ring of fire along the edges of the Pacific. Starting at the western tip of the Aleutian Islands off Alaska, the ring of fire continues along the Aleutian Archipelago and includes the volcanoes of Augustine, Katmai, and Bogoslov. It turns south across the Cascade Range of British Columbia, Washington, Oregon, and northern California. The ring then runs down Baja California and southwest Mexico, where lie the volcanoes of Paricutin and El Chichon. The band of volcanoes continues down western Central America, which has numerous active cones, including the destructive Nevado del Ruiz of Columbia, which killed 25,000 people in November 1985. The ring of fire journeys along the course of the Andes Mountains on the western edge of South America. It then turns toward Antarctica and the islands of New Zealand, New Guinea, Indonesia, the Philippines, where the June 1991 eruption of Pinatubo was the most powerful eruption of the century, and Japan, finally ending on the Kamchatka Peninsula in eastern Siberia.




The ring of fire coincides with the circum-Pacific earthquake belt because the same tectonic forces that produce earthquakes are also responsible for volcanic activity. The area of greatest seismicity occurs on plate boundaries associated with deep trenches along volcanic island arcs and along the margins of continents. As the Pacific plate

inches northwestward, its leading edge dives into the mantle, forming some of the deepest trenches in the world. By studying a band of earthquakes, scientists are able to see the earliest stages in the birth of a subduction zone that will eventually form a trench to the north and west of New Guinea in the western Pacific. They discovered that gravity was lower than normal, which would be expected over a trench. Furthermore, there is a bulge in the crust to the south, indicating that the edge of a slab of crust is beginning to be thrust into the Earth. If subduction is just being initiated, it will take 5 to 10 million years before the process is fully underway. The entire western seaboard of South America is also affected by an immense subduction zone just off the coast. The lithospheric plate that the South American continent rides on is forcing the Nazca plate to buckle, causing great tensions to be built up deep within the crust. While some rocks are being forced deep down, others are buoyed up, raising the Andean Mountain chain. The resulting forces are building great stresses into the entire region. When the stresses become large enough, powerful earthquakes roll across the landscape.

Subduction zone volcanoes such as those in the western Pacific and Indonesia are among the most explosive in the world, creating new islands and destroying old ones, including the near total destruction of the Indonesian island of Krakatau in 1883. The reason for their explosive nature is that the magma contains large amounts of silica and volatiles, consisting of water and gasses derived from sediments on the ocean floor that are subducted into the mantle and melted. When the pressure is lifted as the magma reaches the surface, these volatiles are released explosively, fracturing the magma which then shoots out of the volcano like pellets from a shotgun. The Cascade Range in the western U.S is composed of a chain of volcanoes associated with a subduction zone under the North American continent, created when the North American plate overran the northern part of the now extinct Pacific rift system. As the lithosphere is being forced into the mantle, the tremendous heat melts parts of the descending plate and the adjacent lithospheric plate to form pockets of magma. The magma forces its way to the surface, resulting in explosive volcanic eruptions. The May 18, 1980, eruption of Mount St. Helens, which devastated 200 square miles of national forest is a prime example of the explosive nature of subduction zone volcanoes. As the Earth ages, the Lithosphere will continue to thicken and the asthenosphere will become more viscous, due to the cooling of the mantle after most of the radioactive heat sources have decayed into stable elements. As the plates continue to thicken and activity in the asthenosphere slows down, the movement of the plates becomes sluggish. Eventually they will come to a complete halt.

When this happens, perhaps some 2 billion years from now, volcanoes will no longer erupt, earthquakes will cease, and the Earth will become a dead planet.

**Hazards of Volcanic-Induced Earthquakes and Tsunamis**

Minor earthquakes generally accompany volcanic eruptions. The earthquakes are generated by magma forcing its way upward through cracks and fissures into the volcano from the magma chamber at depth. Gas explosions in the magma conduits under the volcano generate other earthquakes. The collapse of large blocks of rock into calderas or the shifting of mass in the volcano may also initiate earthquakes. Some of these earthquakes happen with regular frequency, or time between individual shocks, and are known as *harmonic tremors.* Harmonic tremors have been noted immediately before many volcanic eruptions. These earthquakes have therefore become one of the more reliable methods of predicting exactly when an eruption is imminent, as geologists can trace the movement of the magma by very detailed seismic monitoring. Harmonic tremor earthquakes typically form a continuous, low frequency rhythmic ground shaking that is distinct from the more isolated shocks associated with movements of faults. *If you are near a volcano and feel these harmonic tremors, it is a good warning that it is time to leave.* Some swarms of harmonic tremors precede an eruption by as little as a few hours or a day and other cases are reported where the harmonic tremors have gone on for a year before an eruption. Many volcanoes are located in tectonically active areas, and these regions also experience earthquakes that are related to plate movements instead of magma movement and impending volcanic eruptions. There is an ongoing debate in the scientific community about whether some earthquakes and plate movements have triggered magma migration and volcanic eruptions. For instance, the 1990 eruption of Mount Pinatubo in the Philippines was preceded by a large earthquake, but there is no direct evidence that the earthquake caused the eruption. It may, however, have opened cracks that allowed magma to rise to the surface, helping the eruption proceed.

Tsunamis, or giant seismic sea waves, may be generated by volcanic eruptions, particularly if the eruptions occur underwater. These giant waves may inundate coastlines with little warning and account for the greatest death toll for all volcanic hazards. For instance, in 1883 more than 36,000 people in Indonesia were killed by tsunamis, generated by the eruption of Krakatau volcano. The Indian Ocean Tsunami killed more than 300,000 people on 26th December 2004. Most volcano-induced tsunamis are

produced by the collapse of the upper part of the volcanic center into a caldera, displacing large amounts of water, which form tsunamis. Other volcanic tsunamis are induced by giant landslides, volcano-induced earthquakes, submarine explosions, and by pyroclastic material or lahars hitting sea water. Volcano-induced atmospheric shock waves may also initiate some tsunamis. The tsunamis then moves radially away from the source at speeds of about 800 km/hr. The tsunamis may have heights of a few feet at most in the open ocean and have wavelenghts of 200 or more kilometers. When the tsunamis encounters and runs up onto shorelines, the shape of the seafloor, bays, promontories, and the coastline help determine the height of the wave. Some bays that get progressively narrower tend to amplify the height of tsunamis, causing more destruction at their ends than at their mouths.

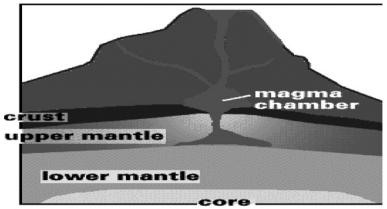
When tsunamis strike the coastal environment, the first effect is sometimes a significant retreat or drawdown of the water level; in other cases the water just starts to rise quickly. Since tsunamis have long wavelenghts, it typically takes several minutes for the water to rise to its full height. Being that there is no trough right behind the crest of the wave, on account of the very long wavelenght, the water does not recede from a considerable time after the initial crest rises on to the land. The rate of rise of the water in tsunamis depends in part on the shape of the seafloor and the coastline. If the seafloor rises slowly, the tsunamis may crest slowly, giving people time to outrun the rising water. In other cases, especially where the seafloor rises steeply, or the shape of the bay causes the wave to be amplified, the tsunami may come crashing in as huge walls of water with breaking waves that pummel the coast with a thundering roar and wreak utmost destruction because tsunamis are waves and they travel in successive crests and troughs. *Many deaths in tsunami events are related to people going to the shoreline to investigate the effects of the first wave or to rescue those injured or killed in the initial crest, only to be drowned or swept away in a succeeding crest.* Tsunamis have long wavelenghts, so there is a long lag time between individual crests. The period of a wave is the time between the passage of individual crests, and for tsunamis the period can be an hour or more. A tsunami may therefore devastate a shoreline area, retreat, and then another crest may strike an hour later, then another, and another in sequence.

Some of the largest recorded tsunamis have been generated by volcanic eruptions. The most famous volcanic eruption-induced tsunami included the series of huge waves generated by the eruption of Krakatau in 1883, which reached run-up heights of more than 200 feet and killed 36,500

people. The number of people who perished in the eruption of Santorini in 1650 BC is not known, but the toll must have been huge. The waves reached 800 feet in height on islands close to the volcanic vent of Santorini. Flood deposits have been found 300 feet above sea level in parts of the Mediterranean Sea and extend as far as 320 km southward up the Nile River. Several geologists suggest that these were formed from a tsunami generated by the eruption of Santorini. The floods from this eruption may also, according to some scientists, account for the biblical parting of the Red Sea during the exodus of the Israelites from Egypt and the destruction of the Minoan civilization on the island of Crete.

**The Origin of Magma**

There are messengers from the underworld preserved among the lavas. Eruptions are spawned from a magma chamber, a fiery stomach beneath the main volcano. As the magma builds up pressure within the chamber, the ground swells, as if the Earth were taking a deep breath, prior to strenuous activity. Magmas come from deep within the Earth, but what conditions lead to the generations of melts in the interior of the Earth? The temperature generally increases with depth in the Earth, since the surface is cool and the interior is hot. The geothermal gradient is a measure of how temperature increases with depth in the Earth, and it provides information about the depths at which melting occurs and the depths at which magma form. The differences in the composition of the oceanic and continental crusts lead to differing abilities to conduct the heat from the interior of the Earth, and thus different geothermal gradients. The geothermal gradients show that temperatures within the Earth quickly exceed 1,000 degrees Celsius with depth, so why these rocks are not molten? The answer is that pressures are very high, and pressure influences the ability of a rock to melt. As the pressure rises, the temperature at which the rock melts also rises. However, this effect of pressure on melting is modified greatly by the presence of water, because wet minerals melt lower temperatures than dry minerals. As the pressure rises, the amount of water that can be dissolved in a melt also increases. Therefore, increasing the pressure on a dry mineral and it decreases the melting temperature.




If a rock melts completely, the magma has the same composition as the rock. Rocks are made of many different minerals, all of which melt at different temperatures. Therefore, if a rock is slowly heated, the resulting

melt or magma will first have the composition of the first mineral that melts. If the rock melts further, the melt will have the composition of the first plus the second minerals that melt, and so on. If the rock continues to completely melt, the magma will eventually end up with the same composition as the starting rock, but this does not always happen. What often occurs is that the rock only partially melts, so that the minerals with low melting temperatures contribute to the magma, whereas the minerals with high melting temperatures did not melt and are left as a residue, often called as restite. In this way, the end magma can have a composition different than the rock it came from. The phrase *"magmatic differentiation by partial melting"* refers to the process of forming magmas with differing compositions through the incomplete melting of rocks. For magmas formed in this way, the composition of the magma depends on both the composition of the parent rock and the percentage of melt.

*Basaltic Magma* - Partial melting in the mantle leads to the production of basaltic magma, which forms most of the oceanic crust. By looking at the mineralogy of the oceanic crust, which is dominated by the minerals olivine, pyroxene, and feldspar, we conclude that very little water is involved in the production of the oceanic crust. These minerals are all anhydrous, that is without water in their structure. Therefore, partial melting of the upper mantle without the presence of water must lead to the formation of oceanic crust. By collecting samples of the mantle that have been erupted through volcanoes, we know that it has a composition of garnet peridotite. By taking samples of this back to the laboratory and raising the temperature and pressure so that they are equal to 100 km depth, experiments show that 10 percent to 15 percent partial melt of this garnet peridotite yields a basaltic magma. Magma that forms at 100 km depth is less dense than the surrounding solid rock, so it rises, sometimes quite rapidly. In fact, it may rise so fast that it does not cool off appreciably, erupting at the surface at more than 1,000 degrees Celsius. That is where basalt comes from.

*Granite Magma* - Granite magmas are very different from basaltic magmas. They have about 20 percent more silica, and the minerals in granite include quartz, and the complex minerals mica and amphibole, which both have a lot of water in their crystal structures. Also, granitic magmas are found almost exclusively in regions of continental crust. From these observations we infer that the source of granitic magmas is within the continental crust. Laboratory experiments suggest that when rocks with the composition of continental crust start to melt at temperature and pressure conditions found in the lower crust, where granite liquid is formed, with 30 percent partial melting. These rocks can begin to melt by either the addition of a

heat source such as basalt intruding the lower continental crust or released lowering the melting temperature by adding water from hydrous minerals buried to these depths. These granitic magmas rise slowly because of their high quartz and high viscosities until they reach the level in the crust where the temperature and pressure conditions are consistent with freezing or solidification of magma with this composition. This is about 5 to 10 km beneath the surface, which explains why large portions of the continental crust are not molten lava lakes. There are many regions with crust above large magma bodies (called batholiths) that are heated by the cooling magma. An example is Yellowstone National Park, where there are hot springs, geysers, and many features indicating that there is a large hot magma body at depth. Much of Yellowstone Park is a giant valley called a "caldera" formed when an ancient volcanic eruption emptied an older batholith of its magma and the overlying crust collapsed into the empty hole formed by the eruption.

*Andesitic Magma* - They average composition of the continental crust is andesitic, or somewhere between the composition of basalt and rhyolite. Laboratory experiments show that partial melting of wet oceanic crust yields an andesitic magma. Most andesites today are erupted along continental margin convergent boundaries where a slab of oceanic crust is subducted beneath the continent. Remember that oceanic crust is dry, but after it forms it interacts with seawater, which fills cracks to several miles depth. Also, the sediments on top of the oceanic crust are full of water, but these are for the large part non-subductable. Andesite forms above places where water is released from the subducted slabs, and it migrates up into the mantle wedge above the subducting slab, forming water-rich magmas. These magmas then intrude the continental crust above, some forming volcanic andesites, others crystallizing as plutons of diorite at depth.

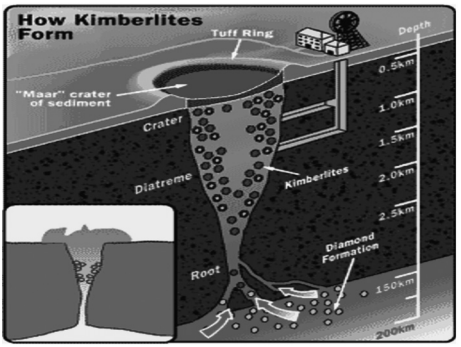
*Solidification of Magma* - Just as rocks partially melt to form different liquid compositions, magmas may solidify to different minerals at different times to form different solids. This process also results in the continuous change in the composition of the magma if one mineral is removed the resulting composition is different. The removal of crystals from the melt system can occur by several processes, including the squeezing of melt away from the crystals or by sinking of dense crystals to the bottom of a magma chamber. These processes lead to magmatic differentiation by fractional crystallization, as first described by Norman Levi Bowen. Bowen systematically documented how crystallization of the first minerals changes the composition of the magma and results in the formation of progressively more silicic rocks with decreasing temperature.

**Kimberlites and Diatremes – Home of Diamonds**

Kimberlites and diatremes represent rare types of continental volcanic rock, produced by generally explosive volcanism with an origin deep within the mantle. They form pipe-like bodies extending vertically downward and are the source of most of the world's diamonds. Kimberlites were first discovered in South Africa during diamond exploration and mining in 1869, when the source of many alluvial diamonds on the Vaal, Orange, and Riet Rivers was found to be circular mud "pans" later appreciated to be kimberlite pipes. In 1871, two very diamond-rich kimberlite pipes were discovered on the Vooruitzigt Farm, owned by Nicolas de Beer. These discoveries led to the establishment of several large mines and one of the most influential mining companies in history. Kimberlites are very complicated volcanic rocks with mixtures of material derived from the upper mantle and complex water-rich magma of several different varieties. A range of volcanic intrusive styles, including some extremely explosive events, characterizes kimberlites. True volcanic lavas are only rarely associated with kimberlites, so volcanic styles of typical volcanoes are not typical of kimberlites. Most near-surface kimberlite rocks are pyroclastic deposits formed by explosive volcanism filling vertical pipes and surrounded by rings of volcanic tuff and related features. The pipes are typically a couple hundred yards wide, with the tuff ring extending another hundred yards or so beyond the pipes. The very upper part of many kimberlite pipes includes reworked pyroclastic rocks, deposited in lakes that filled the kimberlite pipes after the explosive volcanism blasted much of the kimberlite material out of the hole. Geologic studies have suggested that they intrude the crust suddenly and behave differently from typical volcanoes.

Kimberlites intrude violently and catastrophically, with the initial formation of a pipe filled with brecciated material from the mantle, reflecting the sudden and explosive character of the eruption. As the eruption wanes, a series of tuffs fall out of the eruption column and deposit the tuff ring around the pipes. Unlike most volcanoes, kimberlite eruptions are not followed by the intrusion of magma into the pipe. The pipes simply get eroded by near-surface processes, lakes form in the pipes, and nature tries to hide the very occurrence of the explosive event. *Below these upward-expanding craters are deep vertical pipes known as diatremes that extend down into the mantle, source region of the kimberlites*. Many diatremes have features that suggest the brecciated mantle and crustal rocks were emplaced at low temperature, nonviolently, presenting a great puzzle to geologists. How can a deep source of broken mantle rocks passively move

up a vertical pipe to the surface, suddenly explode violently, and then disappear beneath a newly formed lake. Early ideas for the intrusion and surface explosion of kimberlites suggested that they rose explosively and catastrophically from their origin in the mantle.




Other diatremes may be more explosive from greater depths and may move as gas-filled bodies rising from the upper mantle. As the gases move into lower pressure areas they would expand, resulting in the kimberlite moving faster until it explodes at the surface. Still other ideas for the emplacement of kimberlites and diatremes invoke hydrovolcanism, or the interaction of the deep magma with near-surface water. Magma may rise slowly from depth until it encounters ground water in fractures or other voids then explode when the water mixes with the magma. The resulting explosion could produce the volcanic features and upward expanding pipe found in many kimberlites. It is likely that some or all of the processes discussed here play a role in the intrusion of kimberlites and diatremes, the important consequence being a sudden, explosive volcanic eruption at the surface, far from typical locations of volcanism, and the relatively rapid removal of signs of this volcanism. *The initial explosions are likely to be so explosive that they may blast material to the stratosphere, though other kimberlite eruptions may only form eruptions and ash clouds.* The hazards are thus similar to other volcanic hazards, but the location of kimberlites is more likely to be in the middle of a stable continental region. Diamonds are stable crystalline forms of pure carbon that only form at high pressures in cool locations in the Earth's mantle and thus are restricted in their origin to places in the sub-continental mantle where these conditions exist between 150 to 200 kilometers depth. *The vast majority of diamonds that make their way back to the surface are brought up from these great depths by rare explosive volcanic eruptions know as kimberlites.*

Diamonds are the hardest substance known and widely used as a gemstone. Uncut varieties may show many different crystal shapes and many show striated crystal faces. They crystallize in isometric tetrahedral forms, have concoidal fracture, have a greasy luster, and may be clear,

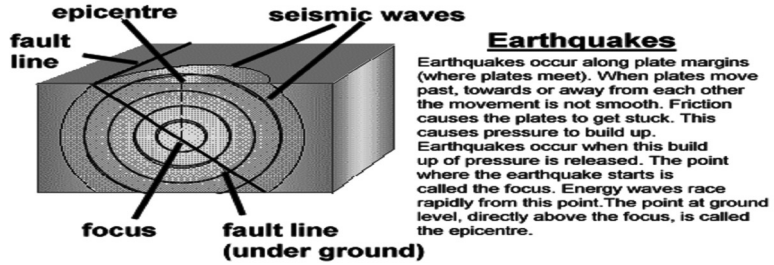
yellow, red, orange, green, blue, brown, or even black. Triangular depressions are common on some crystals, and others may form elongate or even pear-shaped forms. *Diamonds have been found in alluvial deposits such as gravel, and some mines have been located by tracing the source of the gravel back to the kimberlite pipe where the diamonds were brought to the surface.* Some diamond-mining operations such as those of the Vaal River, South Africa, proceeded for many years before it was recognized that the source was in nearby kimberlites. Dating the age of formation of small mineral inclusions in diamonds has yielded some very important results. All diamonds from the mantle appear to be Precambrian in age, with one type being up to 3.2 billion years old and another 1.0-1.6 billion years old. Since diamonds form at high pressures and low temperatures, their very existence shows that the temperature deep in the Earth beneath the continents in the Precambrian was not much hotter than it is today. The diamonds were stored deep beneath the continents for billions of years before being erupted in the kimberlite pipes.

**Earthquake – The Dance of Lithosphere**

Everyday parts of the surface of the Earth are rattled by Earth-quake tremors and, occasionally, some regions are shaken violently during earthquakes, resulting in widespread damage and destruction. The Earth is a dynamic planet composed of different internal layers that are in constant motion, driven by a vast heat engine deep in the planet's interior. Most destructive earthquakes are associated with motions of continents and ocean floor rocks that are part rigid tectonic plates riding on moving parts of the Earth's interior. The motions of these plates involves grinding, sticking, and sliding where the different plates are in contact and moving in different directions, causing earthquakes when sudden sliding motions occur along faults. These earthquakes release tremendous amounts of energy, raising mountains and, unfortunately, sometimes causing enormous destruction. An earthquake occurs when a sudden release of energy causes the ground to shake and vibrate, associated with passage of waves of energy released at its source. Earthquakes can be extremely devastating and costly events, sometimes killing tens or even hundreds of thousands of people and leveling entire cities in a matter of a few seconds or minutes.

Recent earthquakes have been covered in detail by the news media and the destruction and trauma of those affected is immediately apparent. A single earthquake may release the energy equivalent to hundreds of nuclear blasts, and may cost billions of dollars in damage, not to mention

the toll in human suffering. Earthquakes are also associated with secondary hazards, such as tsunamis, landslides, fire, famine, and disease that also exert their toll on humans. Most of the earthquakes in the world happen where the plates of the Earth meet and are moving past each other, such as in southern California. Recent earthquakes in Turkey, Taiwan, Sumatra, Mexico, Chile, India, China, Haiti, and Pakistan have also been located along plate boundaries. Most large earthquakes occur at boundaries where the plates are moving toward each other, or sliding past one another. Smaller earthquakes occur where the plates are moving apart, such as along mid-oceanic ridges where new magma rises and forms oceanic spreading centers.




In the U.S, the area that suffers the most earthquakes is southern California along the San Andreas Fault, where the Pacific plate is sliding north relative to the North American plate. The motion in this area is characterized as a "stick-slip" type of sliding, where the two plates stick to each other along the plate boundary as the two plates slowly move past each other, bending the rocks and causing stresses to rise over tens or hundreds of years. Eventually the stresses along the boundary rise so high that the strength of the rocks is exceeded, and the rocks suddenly break, causing the two plates to dramatically move and slip up to a few meters in a few seconds. *The sudden motion of previously stuck segments along a fault plane is an earthquake.* The severity of the earthquake is determined by how large of an area breaks in the earthquake, how far it moves, how deep within the Earth the break occurs, and the length of time that the broken or slipped area along the fault takes to move. The elastic rebound theory states that recoverable strains build up in a material until a specific level or breaking point is reached. When the breaking point or level is attained, the material suddenly breaks, releasing energy and stresses in an earthquake. In the case of earthquakes, rows of fruit trees, fences, roads, and railroad lines that became gradually bent across an active fault line as the stresses built up are noticeably offset across faults that have experienced an earthquake.

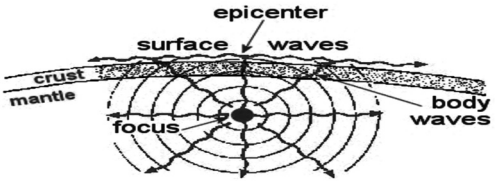
When the earthquake occurs, the rocks snap along the fault, and the bent rows of trees, fences, or roads, rail-line become straight again, but displaced across the fault.

**The Origin of Earthquakes**

Earthquakes can originate from sudden motion along a fault, or from a volcanic eruption, bomb blasts, landslides, or anything that suddenly releases energy on or in the Earth. Not every fault is associated with active earthquakes. Most faults are in fact no longer active, but were active at some time in the geologic past. Of the faults that are active, only some are characterized as being particularly prone to earthquakes. Rocks and materials exhibit brittle behavior when they respond to built up tectonic pressures by cracking, breaking or fracturing. *An earthquake originates in one place and then spreads out in all directions along the fault plane.* The focus is the point in the Earth where the earthquake energy is first released and represents the area on one side of a fault that actually moves relative to the rocks on the other side of the fault plane. After the first slip event the area surrounding the focus experiences many smaller earthquakes as the surrounding rocks also slip past each other to even out the deformation caused by the initial earthquake shock. The epicenter is the point on the Earth's surface that lies vertically above the focus. When big earthquakes occur, the surface of the earth actually forms into waves that move across the surface, just as in the ocean. These waves can be pretty spectacular and also extremely destructive. *When an earthquake strikes, these seismic waves move out in all directions, just like sound waves, or ripples that move across the water after a stone is thrown in a still pond.* After the seismic waves have passed through the ground, the ground returns to its original shape, although buildings and other human constructions are commonly destroyed. Some people who have experienced really large earthquakes have actually seen waves of rock, several feet high, moving toward them at very high speeds.

During an earthquake, several types of seismic waves can either radiate underground from the focus, called *"body waves"* or aboveground from the epicenter: *"surface waves."* The body waves travel through the whole body of the Earth and move faster than surface waves, whereas surface waves cause most of the destruction associated with earthquakes, because they briefly change the shape of the surface of the Earth when they pass. *There are two types of body waves: Primary or compressional waves (P) and "S" waves, for shear or secondary waves.* "P" waves deform material through a change in volume and density, and these can pass through solids, liquids

and gases. The kind of movement associated with passage of a "P" wave is a back and forth type of motion. "P" waves move with high velocity, about 6 km per second, and are thus the first to be recorded by seismographs. This is why they are called primary (P) waves. "P" waves cause a lot of damage because they temporarily change the area and volume of ground that humans have built things on or modified in ways that require the ground to keep its original shape, area, and volume. When the ground suddenly changes its volume by expanding and contracting, many of these constructions break. For instance, if a gas pipeline is buried in the ground, it may rupture and explode when a "P" wave passes because of its inability to change its shape along with the Earth. It is common for fires and explosions originating from broken pipeline to accompany earthquakes. History has shown that fires often do as much damage after the earthquake as the ground shaking did during the earthquake. This fact is dramatically illustrated by the 1906 earthquake in San Francisco, where much of the city burned for days after the shaking, resulting in destruction of the city.




The second kind of body waves are known as *"shear waves"* (S) or secondary waves because they change the shape of a material but not its volume. Only solids can transmit shear waves, whereas liquids can not. Shear waves move material at right angles to the direction of wave travel and thus they consist of an alternating series of sideways motion. Holding a jump rope at one end on the ground, and moving it rapidly back and forth can simulate this kind of motion. Waves form at the end being held, and move the rope sideways as they move toward the loose end of the rope. A typical shear wave velocity is 4 km per second. These kinds of waves may be responsible for knocking buildings off foundations when they pass, since their rapid sideways or back and forth motion is often not met by buildings. The effect is much like pulling a tablecloth out from under a set table, if done rapidly, the building may be left relatively intact, but detached from its foundation. Surface waves can also be extremely destructive during an earthquake. These have complicated types of twisting and circular motions, much like the circular motions exhibited by waves out past the surf zone at the beach. *Surface waves travel slower than either type of body waves, but because of their complicated types of motion they often cause the most damage*. This is a good thing to remember during an earthquake, because if the body waves have just passed a specific location, there may be a brief

period of no shaking to allow residents of the area to escape outside before the very destructive surface waves hit and cause even more destruction.

**Meteorite Impact and Crater, Coconino County, Arizona**

Throughout its long history, the Earth has been repeatedly bombarded by asteroids and comets, with a much higher incidence during the early years than recently. This is fortunate because the evolution of species would have turned out much differently if the impact rate had remained high throughout geologic history. In its early development, the Earth was possibly struck by three Mars-size bodies, one of which might have created the moon. The gigantic impacts removed the Earth's primordial atmosphere, leaving it in a vacuum like the moon is today. Sometimes asteroids the size of mountains struck the planet, inflicting a great deal of damage and causing the extinction of numerous species. Massive comet swarms, involving perhaps thousands of comets impacting all over the Earth, might also explain the disappearance of species. It is difficult searching land and sea for ancient impact craters because the Earth's highly active geology has long since erased all but their faintest signs. The Earth was probably hit by more than a dozen times as many meteorites as the moon because of the planet's larger size and greater gravitational attraction. Fortunately, several remnants of ancient craters still remain on Earth, which suggests that it was just as heavily bombarded as the rest of the solar system. If a large asteroid slammed into the planet, it would expel a huge amount of sediment and produce a deep crater. The finer material would be lofted high into the atmosphere, while the coarse debris would fall back around the perimeter of the crater, forming a high, steep-banked rim.



Not only would rocks be shattered in the vicinity of the impact, but the shock wave passing through the ground would produce shock metamorphism in the surrounding their composition and crystal structure. The most easily recognizable shock effect is the fracturing of rocks into conical and striated patterns called shatter cones. They form most readily in fine-grained rocks that have little internal structure, such as limestone and quartzite. During the height of the last ice age about 22,000 years ago, a large meteorite impacted in northern Arizona and vaporized, forming a large mushroom-

shaped cloud of debris. The meteorite ejected nearly 200 million tons of rock and excavated a crater measuring 4,000 feet across and nearly 600 feet deep. The crater rim, formed by upraised sedimentary layers, rises to 150 feet above the desert floor. Pulverized rock blanketed the area around the crater to the depth of up to 75 feet. Numerous impact structures are scattered around the world. They are large circular features created by the sudden shock of a massive meteorite landing on the surface and are about 1 to 80 km or more wide. Some impacts form distinctive craters, while others might show only subtle outlines of former craters. In this case, the only evidence of their existence might be a circular disturbed area, where the rocks were altered by shock metamorphism. Shock metamorphism requires the instantaneous application of high temperatures and pressures like those found deep in the Earth's interior.

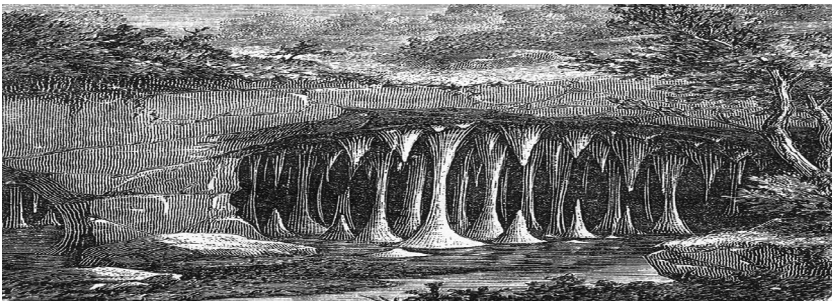
**Canyons and Valleys - Caves and Caverns**

Some of the most impressive scenery the planet has to offer is carved out of solid rock by water in motion. Erosion gouges out the deepest ravines, cuts down the tallest mountains, and obliterates most other geologic structures. Perhaps the best place to witness the power of erosion is the Grand Canyon of the Colorado River. Nowhere is the power of erosion better demonstrated than the Grand Canyon. The world's oceans rival the continents for their rugged topography, and many canyons on the seafloor can hold several Grand Canyons. The oceans are crisscrossed by vast mountain ranges and deep canyons that have no comparison on land. Several times in the Earth's history the continents have been flooded by seas, and remnants of these ancient bodies of water can still be found. The ocean bottom rivals the land for its rugged topography, and many ravines on the seafloor can hold several valleys and canyons. Some of the most monumental landforms are carved out of the Earth by massive glaciers. Rivers and streams also play a major role in sculpting the landscape, providing an abundance of unusual geologic structures.

*Possibly no other geologic structure captures the popular imagination more than caves.* They are, after all, our ancestral homes. Early geologists believed that the continents were undermined by huge subterranean caverns that collapsed and flooded the land with seawater, thereby producing the Great Flood. There is also a lot of misunderstanding about caves, and a great deal of superstition surrounds them. Some caves hold extensive mazes where one could get lost forever. Many caves are homes to countless numbers of bats, which only exacerbates the misconceptions. Many people are simply afraid of caves or become claustrophobic due to the dark, enclosed spaces.

On the other hand, spelunkers, or cavers, have an insatiable zeal for caves and are impatient to explore farther into the bowels of the Earth. The Lithosphere of the Earth has been sculpted by a number of geologic processes. Here on Earth, groundwater has produced geologic forms as impressive as impact craters. *Caves are some of the most spectacular examples of the handiwork of groundwater.* Over geologic time, water has dissolved great quantities of soluble rock, forming extensive mazes of tunnels in the Earth's crust. Running water, too, carving out solid rock, has produced some of the most magnificent scenery the planet has to offer.

**Cave Formation - Mazes of Tunnel**



Caves are the most spectacular examples of the handiwork of groundwater. The dissolving power of water is well demonstrated by the formation of caves in soluble carbonate rock such as limestone. Although limestone caves are the most common caves can also form in dolostone and gypsum. Calcite is a calcium carbonate and the most common mineral in limestone. It is soluble in water that contains dissolved carbon dioxide. Another form of calcite, called travertine, is a common mineral found in caves and hot carbonate springs. Rainwater filtering through sediment layers reacts with carbon dioxide to form a weak carbonic acid. In addition, if the overlying formation contains pyrite, the sulfur in the mineral could be oxidized by rainwater and converted into sulfuric acid. The acid is carried downward through cracks in the underlying rock layers and dissolves calcite or dolomite, the minerals that constitute limestone and dolostone. This action enlarges the fissures and eventually creates a path for more acidic water. Most of the dissolving occurs near the top of the water table, where a mixture of groundwater and water percolating from above dissolves rock more readily than either form of water by itself.

The wide variety in the shape and structure, or morphology, of cave passages is due to the chemical reactions that dissolve limestone and the

position of the base level. The base level is the level at which water flows in an area and is influenced by the elevation of a nearby stream or river. Cave passages constructed near the top of the water table are affected by changes in base level. It also plays an important role in their orientation, even in areas where the landscape is more complex. Different levels of passages in a cave develop at different times, when groundwater changes base levels. A lower level might begin to form below the water table, while an upper level forms near the top of the water table. Vertical shafts, up to several hundred feet deep, called domepits, connect the various levels. They developed relatively late in the cave-forming process, as rainwater trickles down toward the lower water table. Cave passages can be affected by different geologic conditions, such as the existence of folds and faults at different parts of the cave. The greatest variety of cave morphology occurs where rock layers are folded. In some areas, rock layers were folded and pushed downward to form synclines. Other rock layers were folded and bulged upward to form anticlines. Many caves formed on the sides of synclines and anticlines have straight, parallel passages that run along the axis of the fold in the direction of the formation strike. Most caves form on only one level, but many located near the tops of mountains have several parallel levels of passages. These passages are connected by shorter ones that run along the slopes of the folded sedimentary beds.

The stratigraphy of horizontal rock layers is another important factor to cave development. The passage orientation and morphology is largely controlled by geologic, hydrologic and structural conditions. When a cave forms near the axis of a fold, a maze of passages might develop. The axes of synclines and anticlines are usually more fractured than the sides of the folds and transmit limestone-dissolving acidic water more easily. Joints are also important to the development of cave passages in areas where rock layers are not folded or tilted. Caves also develop in the zone of seasonal water table fluctuation by the dissolution of limestone along joint planes. They form from underground channels that carry out water that seeps in from the water table. This creates an underground stream similar to how streams form on the surface by a breached water table. Caves also develop in sea cliffs by the ceaseless pounding of the surf or by groundwater flow through an undersea limestone formation that is hollowed out as the water empties into the ocean. Some caves were formed by tectonic movements of large rock masses that make up the Earth's crust. Other caves are made by weathering processes such as rock falls. Smaller caves are fashioned out of sandstone. Numerous caves are bored into the red sandstone formations around Moab, Utah. Houses built in natural and man-made caves are well insulated and maintain fairly uniform temperatures year around.

When groundwater percolates through limestone and other soluble materials, it dissolves minerals, forming cavities or caverns. When the land overlying these caverns suddenly collapses, it forms a deep sinkhole. At other times, the land surface might settle slowly and irregularly. The pits formed by dissolving soluble subterranean materials produce a pockmarked landscape called Karst terrain. The major locations for karst terrain and caverns are mainly in the southeastern and Midwestern U.S, with Alabama and Florida containing the highest percentage. Half of Alabama is covered by limestone and other soluble rocks, producing thousands of sinkholes. The karst terrain in the jungles of Mexico's Yucatan Peninsula gives birth to numerous underwater caves and sinkholes. The underlying limestone is honeycombed with huge caverns and tunnels, some several miles in length. *Just like surface caves, the Yucatan caverns contain a profusion of stalactites and stalagmites.* Creatures blinded by generations of unused eyesight live in the darkest recesses of these caves. If you want to see the caves near Vellore, you can go to *"Belum Caves" near Cuddappah* in Andhra Pradesh State.

**Desert: A Sand-dune Community**

Satellite pictures reveal that although forests, grasslands, and farms cover more than half the land surface, it is barely more than half. Over about 48 percent of the land, plants are widely scattered, with bare ground between them, and in some regions there are no plants at all. These areas are classified as dry (10%), semiarid (18%), arid (12%), or hyperarid (8%). *The arid and hyperarid areas are deserts* and the remaining areas are dry enough to resemble deserts at least some of the time. These inhospitable areas are vast and about 13 percent of all the people in the world live in them and most of them are rich. Deserts are also different one from another. Some are hot, some are cold, and some are covered with great oceans of sand that is piled into high dunes. Some are frozen and thickly covered with ice. All deserts are dry, even those buried beneath thousands of feet of ice, but this does not mean they are necessarily far from the sea. There are coastal deserts, bordered by the ocean. Other deserts lie in the heart of Asia, thousands of miles from the sea, or in the rain shadow of mountain ranges, such as the Rockies. Deserts are mainly known as a land with sand and cactus. The geography of the desert is composed of sand, rocks, mountains, and very dry plants. There are little slopes is the desert because of the sand.

The desert mostly made up of sand-dunes. People may not like the desert, because it is hot but the animals and plants that live there love the desert because it is their habitat and their biome. *There are 3 types of deserts. One type of desert is that one that is really hot. This type of desert is located at*

*near the equator at 30 degrees. Other type of desert is the polar desert. The polar desert is really cold. The last type of desert is not so cold and not so hot. This type of desert is really dry.* It doesn't get much water because they are not near the ocean they are usually in the middle, and by the time the cloud get there they already drop most of the rain. Desert geography has some mountains but most of it is flat. There are many different elevations for deserts. Such as Death Valley in U.S which is way below sea level but the Gobi Desert in China is way above sea level. The Sahara is the world's largest non-arctic desert. It covers most of Northern Africa, making it almost as large as the U.S or the continent of Europe. The desert stretches from the Red Sea, to the outskirts of Atlantic Ocean. The Sahara has an intermittent history that may go back as much as 3 million years. The Gobi desert lies southwest Mongolia and northern China. The Gobi is essentially a plateau set between higher mountains. The surface consists mostly of rolling gravel plains interspersed with low ranges and isolated hills. Most of the region has a thin growth of grass, scrub, and thorn sufficient to feed the flocks of the nomadic herders who live on the plateau.

The first Europeans to cross the Gobi were Italian Marco Polo and his father and uncle, who completed the trek about the year 1275. A well-known species of camel "the Bactrian Camel" is the permanent resident of the Gobi Desert. Atacama Desert is known for being the driest place on Earth. It runs along the Pacific Coastline of Chile and into Peru. Bordering the desert on the east is the massive Andes Mountain Chain. To the west is the Pacific Ocean. Despite this massive body of water, the only moisture that comes from the ocean is in the form of stratus clouds, which is really just a high altitude fog. This fog actually supports the only flora that grows in the desert, mostly fungus. Atacama Desert is known as the "perfect desert," which means life is absent there. The Thar Desert of Rajasthan is situated partly in India and partly in Pakistan. Also known as the "Great Indian Desert," Thar covers an area of approximately 200,000 square km. bordering the desert on four sides are, Indus plains to the west, Aravalli Range to the southeast, Rann of Kutch to the south, and Punjab plains to the north and northeast. According to geologists, it is believed to be 4000 to 10,000 years old. The desert is scattered with number of hillocks, gravel, salt marshes and some antique lakes.

Obviously we find remarkable number of plant and animal species living in desert ecosystem. Like desert animals, desert plants have adaptations for using water conservatively. The thin "spines" of some cactus plants are actually leaves shaped to reduce water loss through evaporation. The fleshy stems of cactus plants store water for use in times of need. For most of the year the branches of the night-blooming cereus cactus are drab green-

brown twigs. However, when winter rains come, small green buds appear and continue to grow through May. Then on one, and only one, night when the humidity and temperature are just right, the buds of all the cereus plants in an area burst open and reveal a beautiful, richly scented flower the size of your fist. As if by magic, sphinx moths appear, flying from one flower to another and pollinating the plants. *This is the plants' one night of glory.* Just before dawn the flowers wither, revealing a red seedpod. By sunrise the plants once again show only their drab green-brown color. When greasewood plants grow on or around a broad sand dune, they often are so evenly spaced that it seems as though they were planted that way, but they weren't. This spacing is a result of the plant's special adaptation to a climate where water is scarce. The greasewood plant puts out shallow roots that form a 25 feet wide circle around the plant. This root system gives off a harmful chemical that prevents the roots of other greasewood plants from growing too close. As a result, each plant is able to grow an extensive root system that collects the water it needs, while at the same time preventing neighboring plants from competing for water.

The saguaro cactus has a deep taproot that grows straight down, in addition to an extensive network of horizontal roots not far beneath the surface. The plant's horizontal roots, which may fan out more than 75 feet, collect summer rainwater. The water is then stored in the taproot and used during times of water shortage. The taproot also firmly anchors the plant. Some dune plants, such as the smoke bush, have tough seeds that need exactly the right amount of moisture to sprout. And sometimes, the seeds lie on the ground for years. Eventually, during a fierce storm, the rushing water of flash floods picks up the seeds and dashes them against the sand and rocks. Some become trapped in crannies in the streambed, and water soaks into the seeds through cracks created during their violent journey. Only then do the seeds germinate and new plants begin to grow. *Together, dune plants and animals form a dune community*. The creatures living in any ecosystem community depend on each other, much as the people in a city or town do. Desert plants provide seeds as food for kangaroo rats and certain other animals. The plants, in turn, depend on the animals of the community. The seeds of some dune plants cannot sprout until they are collected by a sand rat. The rats carry the seeds into their burrows and break open them. Some seed spill on the ground and life will flourish again.

# Seven Wonders of Lithosphere

**Dust – The First Wonder of Lithosphere**

Some see dust as dull stuff, useless at best, and sneeze-inducing at worst. But in the hands of God, dust becomes a dazzling, mysterious and a creative force. Dust is a messenger, and air is its medium. We are told from the Bible, that the first man Adam was made by God from dust. "The *Lord God formed man from the dust of the ground and breathed into his nostrils the breath of life, and man became a living being" (Genesis 2:7).* Humble dust, we discover, built the very planet we walk upon. It tinkers with the weather and it spices the air we breathe. Billions of tons of tiny particles rise into the air annually and eventually of course, all this dust must settle. The shower of Saharan dust nourishes Caribbean jungles. The story of restless dust begins among exploding stars, then treks through the Sahara, digs into Antarctic glaciers, and probes the dark underbelly of the living-room couch. This invisible dust isn't as harmless as it may appear. It can be a heartless little brute. It is a central suspect in the mystery of how the planet's climate is shifting. Billions of tons of it take to the sky each year, and this surely alters the behavior of the Earth's atmosphere. Between one to three billion tons of desert dust fly up into the sky annually. One billion tons would fill 14 million boxcars in a train that would wrap six times around the Earth's Equator. Some investigate its dark side: how it killed off dinosaurs and how its industrial descendents are killing us today.

Humanity's dusty history began with fire. But now nothing symbolizes our dusty effect on the world quite like a car. The most obvious kind of car dust results from burning gasoline or diesel fuel. The torching of fossil fuels is rarely a wholesome activity. They're packed with complex compounds, and they require high temperatures to burn completely. So truck and car engines shoot plenty of partially burned fuel dust out the tailpipe. All these engines also release clouds of sulfur and nitrogen gases. The fires of war, however, produce strictly human and unnatural soots. Retreating from Kuwait, Saddam Hussein's army reinvigorated the question of battle ethics when they set fire to 613 oil wells. In addition to freeing greater lakes of oil, the fires sent untold quantities of soot and other chemicals into the sky. A dark cloud, spitting black rain, spread over Kuwait, then expanded over neighboring nations. As the fires raged, the temperatures under the soot plume fell by as much as eighteen degrees. These are dramatic fires, these raging fires and vicious fires of war. But even the tame fires we set every day put dust into the

air. Every match we strike releases soot. Every hamburger we slap on the grill and every campfire we circle releases more fine black dust. *Coal is the dustiest fuel and wealthy nations burn a lot of it.* A whopping 90 percent of all the human-forged sulfur beads rise over the industrialized nations in the Northern Hemisphere. In the skies of the world these human-launched sulfur beads now outnumber the naturally made beads by two to one. And this horde has transformed acid rain from a natural necessity to a corrosive curse in many parts of the world. Particle-forming nitrogen oxide gases also escape in huge quantities from burning coal. Dust once a creative force in the hands of God becomes a destructive force in the hand of man.

Many of the dusts that roam the Earth are little bits of life, such as pollen, whose ability to travel on the wind keeps the planet healthy and green. Pollen, however, remains the golden symbol of aerobiology. Those plants that rely on insects and birds to distribute their pollen often make big spiny or pitted grains. But plants that exploit the wind make lighter, smoother grains. The stamens of a flower avail the mature pollen to the wind, and the wind whisks it away. *Even the billions of tons of lifeless rock dust that clot the air downwind of deserts are valuable to the Earth.* Certain Islands in the Caribbean would be naked, gray rock if it weren't for the dusts of deserts and volcanoes that settle heavily upon them. Instead they are humps of lush and happy vegetation. Likewise the tapestry of the Amazon rain forest is indebted to dust. In such a rainy climate, water quickly flushes nutrients out of the soil. *But each winter, when the trade winds head southwest from the Sahara, rich dust rains down on the South American forests and refreshes the soil. The dust from Thar Desert, India travels all the way to Western Ghats to nourish the vegetation in the forest.* Falling rock dust feeds tiny mouths in some of the world's most desolate places. On the Earth's glaciers, settling dust arrives like a catering service, spreading assorted dishes out for the enjoyment of some of the hardiest life forms we know of. Even inside a glacier we find that well-traveled dust can sustain a tiny web of life. Dust that falls in the ocean can also fuel a bloom of plants. These plants are microscopic phytoplankton. But despite their unobtrusive size, plankton are the bread and butter of the oceanic food chain. And in a twist on the "dust to dust" cycle, they sometimes take nutrients from falling desert dust and then send aloft a sulfur-rich dust that plays a key role in forming clouds.

To some degree, scientists have learned, how an assortment of living, and dead dusts tinker with the weather. And it's now becoming clear that dust alters the world's long-term climate, too. Traditionally, climatologists have focused their fears on gases that trap heat near the Earth, but as the globe gets warmer, little airborne specks have become a very big topic. Scientists

now know that some of our dusts reflect sunlight and cool the planet. Some of the dusts that swirl around us are fearsome and invisible rogues. Leave aside for a moment poison particles launched by human activity. Plain old desert dust has a dark side of its own. Sixty-five million years ago, for instance, simple desert dust seems to have set a subtle trap for a fieldful of dinosaurs. One minute these formidable creatures were going about their domestic duties. And the next minute the dust in the surrounding sand dunes conspired to entomb them. *A world-wide cloud of dust from a giant meteorite impact darkened the sky and blotted out the sun. That dust murdered dinosaurs, birds, sea life, and small, pioneering mammal species as well*. Indoors or outdoors, dust is unavoidable. And a marvelous fraction of that dust holds the secret to our past. Some of the dust that swirls around us was knocked off distant, colliding asteroids eons ago. Some of it boiled off comets that may have passed our way a few years ago or a few centuries ago. This stuff, still holding its ancient grains of primordial stardust, settles on Earth at a rate of one magical speck per square meter per day. "Since every atom in our bodies came from inside of stars," explains astrophysicist Don Brownlee, "by studying these interstellar dust particles, we can learn about our cosmic roots."

Because these extraordinary dusts carry the secret of our cosmic past, scientists go to extreme measures to capture them. But whenever a dust scholar is able to decipher the chemical fingerprint of a grain of space dust, she comes a little bit closer to understanding the origins of our world. That is the secret of our past. A human body is mainly water and bone. Bone is mainly made up of dust particles such as calcium phosphate, plus traces of other elements, including stored pollutants like lead. The watery parts are tinged with carbon and nitrogen, iron and sulfur, chlorine and sodium, and a suite of trace elements from arsenic to zinc. *All of these elements, of course, originated in space and were bundled into the planet during the birth of the solar system*. They're yours for as long as you live. The secret of our futures, our personal, individual features is also circulating invisibly beneath our noses. *Just as the dust of dinosaurs now roams the air, so, too, will the dust of a decayed you. If your body is buried, it will eventually merge with the surrounding soil. Moisture will find a way into the casket. Little recyclers in the soil will set to work. And gradually, the elements of a body will sink into the surrounding soil, becoming part and parcel of the Earth's gritty skin.* However, in spite of the efforts of mold, maggots, erosion, and even mummy grinders, burial is still the slow route to dust. Excarnation, practiced in parts of India, Asia, and Africa, is faster. A dead body is usually positioned in a tree or at some other site dedicated to the purpose. Then animals, sometimes well accustomed to this ritual, move in to disassemble it.

In Tibet, for instance, it's still common for a dead person's family to pay a team of undertakers to carry the body of a loved one to a hill and butcher it for waiting vultures. So in a matter of forty-five minutes, the dead person's borrowed elements were incorporated into new bodies. For Tibetans who can't afford such a ceremony it is customary to leave a body in the hills for birds, dogs, bugs, and other creatures that might voluntarily perform the service. As these winged, pawed, and pincered hosts digest the body, they absorb some elements and reject others. The rejected components exit the back end of the animal in a form that quickly dries to dust. A fraction of the absorbed elements, however, might evade dustification indefinitely. *When the vulture host dies, a new circle of scavengers will take shares of its elements and carry them around for a while. And so some parts of a body will hop from vulture to dog, to fly larva before reaching dusthood,* perhaps as a mold spore, launched from the platform of a dead fly. *Finally, you will become a part of Lithosphere. Then hundreds, or even millions, of years later, erosion will open your grave and scatter you around the world.* If you are cremated and scattered, your path to dust will be much accelerated. Even the most heroic efforts that some people now undertake to evade the dust state won't forestall the inevitable. Even if a body lasts until the end of the Earth, dust is in its future. The hands-down odds are that the sun's slow demise in a few billion years will have the side effect of roasting our planet. Shortly thereafter even the sun will shudder its outer layers prettily into space, where a fraction of the glowing gases will also cool into simple dusts. The puff of smoke that was our world will blow on the solar wind, out across the dusty galaxy. Indeed, the entire solar system will be dust.

A human body that's fed to vultures continues to wander through the broad web of life, being eaten, then expelled, eaten and expelled. And the remains of our Earth will probably do likewise. *We've been granted a 10-billion-year lease on the space dust that makes up our solar system.* But even when that lease expires, the universe will still be in its tender infancy. *The dust we borrowed from it will enjoy many more incarnations.* Billions of years after our dust drifts out into the daunting distances of the galaxy, it might find itself stirred into a dark cloud that's gathering around a star seed. A smattering of our dust may find itself whirled into the new star's very core. A bit more might be rolled into a planet that circles that star. And then, if the star is a big one, it might promptly explode, spattering both old and new-made dust back into the galaxy. And so, with each generation of stars, the universe will grow dustier. As the trillions of years flow by, the night sky will darken as dust blots out more starlight. The stars themselves will burn more coolly and shine more dimly as they adapt to this dustier fuel. As the universe ages, we can foresee a generation of bizarre stars so enriched with

insulating dust that their atmospheres will swirl with ice crystals. And then, like an old newspaper in the attic, the worn-out universe will gradually disappear under the thickening dust, as the old saying goes *"You are dust and unto dust you shall return."* Without any doubt in my mind, duat could be one of the wonders of the Lithosphere.

**Uluru, Australia – The Second Wonder of Lithosphere**

Uluru, also known as Ayers Rock is one of the largest sandstone rock formation, lying in the Northern territory of Central Australia. A huge monolith 862.5 meters above the sea level, 1395 km south of Darwin and 465 km south west of Alice Springs, is rising out of the desert. No wonder the local aborigines regarded it as a sacred site. The average white Australian, clinging to the shores of this vast continent, *also regards the greatest stone on Earth, as something very special.* It is made from a single piece of sandstone, which extends 5 km beneath the desert surface. Uluru is also well known for its immense aboriginal cultural significance. Archeological evidence suggests that aboriginal people have lived in Uluru for at least 22,000 years and that both Uluru and Kata Tjuta have long been places of enormous ceremonial and cultural significance to a number of aboriginal tribes. The traditional tribe owners of Uluru are the Anangu people and they believe that ancestral spirits formed these sites during the creation period. The Anangu also believe that they are the direct descendants of these ancestral beings and, as such, responsible for the protection and management of these lands. The name Uluru means *"great pebble"* in the aboriginal language. There is some scientific disagreement about the origins of Uluru. The most widely held theory is that both Uluru and Kata Tjuta are remnants of a vast sedimentary bed which was laid down some 600 million years ago. The bed was spectacularly titled so that Uluru now protrudes at an angle of up to 85 degrees. The rock is actually grey but is covered with a distinctive red iron oxide coating.

Uluru is a completely bare rock without the least bit of vegetation, which only adds to its stark and mysterious beauty. By great contrast, however, the base of the rock is nourished by rain runoff from Uluru and is a fertile oasis of water pools, rich greenery and a variety of wildlife. It is thus an ideal ceremonial site for the aborigines, who camp in the caves and are sustained by the water and available food. Aside from its imposing size the most impressive feature of Uluru, beloved by aborigines and visitors alike, *is its beautiful range of changing colors throughout the day and year. Sunrise and sunset are particularly remarkable, with the rock glowing a deep rusty red.* The rock derives its rust color from oxidation, and the glowing effect at sunrise

and sunset is due to the arkosic sandstone of the rock, which contains reflective minerals and changes color according to the attitude of the sun. The base walk around the perimeter of Uluru is 9.4 km long. It is 1,100 feet high. The rock is arkose, a course-grained sandstone rich in feldspar at least 2.5 km thick. Uplifting and folding between 400-300 million yearsago, turned the sedimentary layers nearly 90 degrees to their present position. The surface has then been eroded. Depending on the time of day and the atmospheric conditions, the rock can dramatically change color, anything from blue to violet to glowing red. Many avid photographers set up for days and record the many changing colors of Uluru. The rock and the surrounding park were designated a World Heritage Site in 1987.

No one is sure when the first aborigines moved into the area but the best evidence suggests that it was at least 10,000 years ago. The notes on the history of Uluru National Park explain the aboriginal understanding of Uluru in the following terms: *"In the beginning the world was unformed and featureless. Ancestral beings emerged from this void and journeyed widely, creating all the living species and the characteristic features of the desert landscape you see today."* Uluru and Kata Tjuta provide physical evidence of feats performed during the creation period. Anangu are the direct descendants of these beings and are responsible for the protection and appropriate management of these ancestral lands. The knowledge necessary to fulfill these responsibilities has been passed down from generation to generation from the Tjukurpa. Located 440 km south-west of Alice Springs in the Uluru-Kata Tjuta National Park, 40 kilometers to the west of Uluru is Kata Tjuta, also known as "The Olgas." This massive pile of rock domes dates back 500 million years. Both Uluru and Kata Tjuta have great aboriginal cultural significance for the traditional landowners, who lead walking tours that inform about the local flora and fauna, bush foods and the aboriginal dreamtime stories of the area. Tjuta, meaning *"many heads"* in aboriginal language, is a collection of 36 massive rock domes located 42 km to the west of Uluru. Kata Tjuta is not one large rock but a system of gorges and valleys that allows people to walk around and soak in the quiet and spiritual environment. The tallest rock, Mount Olga, is 546 meters high, which is nearly 200 meters higher than Uluru. Indeed, Ayer's Rock of Uluru, one of the wonders of Lithosphere.

**Ellora, Kailasa Temple – The Third Wonder of the Lithosphere**

Driving in India reinforces your belief in a protective God. The dry and dusty roads of Pune bend this way and that as they climb into the foothills of the Western Ghats. As we drive northward changes in the proportions of

the landscape become obvious. For a few miles the road runs comparatively straight, then we climb for a while before another level stretch is reached. Any hills have flat tops, and in the distance more terraces rise one after the other, so that the hillsides look like a series of steps stretching away as far as the eye can see. *We are in the Deccan Traps, one of the greatest volcanic features on Earth, 1.5 million square kilometers of volcanic rock*. Each flat level was formed by the top of a single lava flow, which evidently extended for many miles. So as we climb, we ascend through flow after flow. The road climbs more steeply after the town of Aurangabad, named after the last of the Moguls, Aurangzheb (1659-1707). Looking down from the hills beyond, you can see the magnificent, but now decayed, fortress walls that had been built around the town by previous Mogul emperors for its protection. The Ellora temples and caves lie thirty kilometers on from Aurangabad. The hills in which they lie comprise another stack of horizontal lava flows. The monuments were constructed as rock temples and monasteries between the second and ninth centuries.

The Deccan Traps host the most direct link between geology and culture that we know. The work grows from the rock, which provides both inspirational and material. There are three religions celebrated at Ellora; a guidebook tells me that sixteen caves are Hindu, twelve are Buddhist, including the earliest ones, and five are dedicated to that most peaceful of all religions, the Jain faith. *Cave 16-Kailasa, Shiva's mountain abode is the one that the tourists flock to first, and you can see exactly why. It is an astonishing construction. This is the largest monolithic art in the world. It is one of the man-made wonders of the world*. I should perhaps rather call it a deconstruction, a piece of architecture in reverse. For this edifice has been fabricated by taking away rock, rather than by building up with bricks or blocks. The temple was made by removing masses of lava to leave behind monumental buildings and reliefs. Effectively a gigantic sculpture, hewn from the rock with hammer and chisel, it was made during the eight and early ninth centuries under the orders of King Krishna I. It is as if the temple lay nascent within the lava flow, until released by a century of chipping and digging by Hindu artisans. Something like 3 million cubic feet of volcanic rock had to be removed.

The Hindu, Jain and Buddhist caves at *Ellora* are among the finest in India. Unlike the caves at Ajanta, Ellora's caves were never "lost", but they were abandoned and forgotten. *The Kailasa Temple is the most magnificent of all the rock-cut structures at Ellora*. It is the only building that was begun from the top. The design and execution of the full temple plan is an extraordinary triumph of imagination and craftsmanship. Excavating three deep trenches into the rock carving started from the top of the cliff and worked down to

the base. Enormous blocks were left intact from which the porch, the free standing pillars and other shrines were subsequently carved. The main shrine was carved on what became the upper storey, as the lower floor was cut out below. It is attributed to the Rashtrakuta king Dantidurga (725-55) and must have taken years to complete. *Mount Kailasa (6,700m), the home of Siva, is a real mountain on the Tibetan Plateau beyond the Himalaya.* Its distinctive pyramidal shape, its isolation from other mountains, and the appearance to the discerning eye of a swastika etched by snow and ice on its rock face, imbued the mountain with great religious significance to Hindus and Buddhists alike. *Kailasa was seen as the center of the universe and Siva is Lord of Kailasa: Kailasanatha.* To imitate the real snow covered peaks, the sikharas here were once covered with white plaster. The temple is 50m long and 33m wide and the tower rises 29m above the level of the court. At the entrance gate the threshold between the profane and sacred worlds, the goddesses Ganga and Yamuna form the door jambs. Just inside are two seated sages: Vyasa, the legendary author of the Mahabharata, and Valmiki to whom the Ramayana has been ascribed. Ajanta and Ellora have been designated as a World Heritage Site, to be preserved as an artistic legacy that will continue to inspire and enrich the lives of generations to come.

An even grander monument lies seventy five kilometers onwards from Ellora. The Ajanta Caves are carved into a vertical scarp along a horseshoe-shaped ravine. The caves were lost for a thousand years. After Buddhism declined at the end of the seventh century, they were simply forgotten; scrub covered their entrances, and bats were left to keep their secrets. Ajanta was rediscovered in 1819 by British horseman. Ajanta, too, was rooted in the geology, and not just because the caves were hollowed out from the appropriate flow. Clay derived from weathered strata was one ingredient of the plaster used to prepare the walls for decoration, the others being cow dung and rice husks, with lime being use as the finish. The pigments were mostly of local origin, like ochre and sienna, the weathered products of iron-rich volcanic rocks. *These earthy washes provide a tone to the paintings that makes them feel as if they have grown from the rocks themselves.* It is an interesting question where the brilliant colors came from: surely the bright blue used to paint in some of the jewels must have been produced from a cobalt mineral. Other caves are full of sculpture hewn directly from the lava. Rock and man was engaging directly via the chisel. Images of three religions have appeared carved in the rocks. Neither Islam nor Christianity left its mark there, as they did elsewhere. The moguls came and went, as did the British Raj. The Deccan Traps are unique, and the richness of their human associations is without parallel. Indeed, the Kailasa Temple of Ellora and Ajanata, is one of the wonders of Lithosphere.

**Plate Tectonics – The Fourth Wonder of Lithosphere**

As the Earth, the Lithosphere cracked like an eggshell and split into seven large and twelve small floating islands with ragged edges: the tectonic plates that move continuously over the viscous mantle, rubbing or pushing against each other and even trying to mount one over the other. The majority of earthquakes originate along the plate edges, which often also define the coastlines of the continents. Geologists and seismologists have recently identified two primary bands of seismic activity: the circum-pacific belt that rings the coasts of the Pacific Ocean, and the alpide belt, along the southern boundary of the Eurasian plate, that cuts from the Atlantic Ocean across the Mediterranean into Asia. Tectonic plates, which on an average move only about 2 inches per year over the mantle, are driven by convection currents, the upward movement of heated particles rising through the mantle from the Earth's molten core. As one plate is driven against its neighbor, it will either try to slip along the boundary, slide down, or one plate will be thrust up over the other. These three actions occur at convergent or subduction boundaries, regions where volcanic eruptions and earthquakes most often occur.

At those tectonic boundaries where plates tend instead to separate, mainly along the mid-ocean rifts and ridges, red-hot magma flows up from the mantle to fill the void left by the spreading plates and cools rapidly when meeting the frigid seawater, which also causes cracking in this new crustal material of basalt. In this way, new material is constantly being added to the crust to make up for that which plunges back into the mantle and is remelted along a subduction boundary. The constant movement of the tectonic plates is resisted along their convergent boundaries by friction between their rough edges just as two bricks resist sliding when pushed one against the other. Over time this causes strain, which in turn causes stress to build up along the boundary, until a stress level is reached sufficient to overcome the plates' frictional resistance, causing a sudden slip. This is how an earthquake occurs. Since tectonic plate theory is a mere forty years old, such a clear understanding is a recent, resounding triumph of seismology of which we may be proud. Generally, major earthquakes occur along convergent boundaries on the continental coastlines, while minor earthquakes occur along mid-ocean separating boundaries. Approximately 70 percent of the continental earthquakes take place along the perimeter of the Pacific plate and 20 percent along the alpide belt, with the remaining 10 percent sprinkled around the globe. Plate tectonics has created beautiful landscapes, magnificent mountains, and mighty continents. Hence, it should be called a wonder of Lithosphere.

**Grand Canyon – The Fifth Wonder of Lithosphere**

Clearly visible from space, the Grand Canyon's magnificent breadth, depth, and length are awe inspiring. The gorge is nearly 448 km long and has been excavated by the erosive power of the Colorado River over perhaps the past 17 million years as the Colorado Plateau has lifted up. The gorge is up 6000 feet deep from rim to floor and between 0.5 and 15 km wide. More importantly to us, the Canyon reveals a section through some 1800 million years of Earth history, from the metamorphic, *late Paleoproterozoic Vishnu rocks,** up through a predominantly Paleozoic sedimentary sequence to late Cenozoic times. Like all long sequence of strata, these rocks actually record a complex history of tectonic movement, erosion, and deposition, with more gap than record. Very little of the Precambrian is preserved, there are many breaks in the Paleozoic, and all the Mesozoic and much of the Cenozoic record is missing. *But, even so, the Grand Canyon is one of Earth's most majestic geological sights.* As civil war veteran major John Wesley Powell said when he first navigated the length of the Canyon in 1869, it is like "a Book of Revelation in the rock-leaved Bible of Geology."

Some of the most magnificent examples of the power of erosion are canyons. They are generally found in arid or semiarid regions, where the effect of stream erosion is greater than that of weathering. Arizona's Grand Canyon is a great gash in the Earth's crust. It is located at the southwest end of the Colorado Plateau, a relatively mountain-free expanse that stretches from Arizona north into Utah and east into Colorado and New Mexico. Initially, the area surrounding the canyon was almost totally flat. Over the last 2 billion years, heat and pressure buckled the land into mountains that were later flattened by erosion. Again, mountains formed and were eroded and flooded by shallow seas. Afterward, the land was uplifted during a time when the Rocky Mountains were growing, between 80 and 40 million years ago. The Grand Canyon is a relatively young feature in the Earth's crust. It was formed by forces of uplift and erosion as the Colorado River sliced its way through half a billion years of accumulated sediments and Precambrian basement rock. About 10 to 20 million years ago, the Colorado River began eroding layers of sediment, and its present course is less than 6 million years old. Much of the canyon was not carved out by piecemeal erosion grain by grain but by catastrophic land-sliding that tore away entire canyon walls.

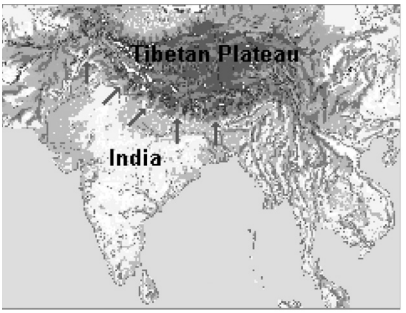
**The gigantic butte in Grand Canyon, known as the "Vishnu Rock" or "Vishnu Temple" was entirely carved by water from the Coconino sandstone. All around the temple, other smaller buttes have also been carved from the rock. Various features make it clear that these buttes were once part of the North Rim, but erosion carved away rock from all round them and left them isolated. Many of these buttes are named after ancient gods from mythology.*

The canyon provides some of the best rock exposures on the face of the Earth. It slices through rocks that are hundreds of million of years old and over 1 mile thick. Well-exposed sedimentary layers tell a nearly complete story about the geologic history of the area. On the canyon wall is a unique angular unconformity separating the upper horizontal Plateau series from the older, tilted Grand Canyon series. On the bottom of the canyon lies the ancient original basement rock, upon which sediments were slowly deposited layer by layer. *Some of the best exposures of Precambrian rocks in the world are the 1.8-billion-year-old metamorphic rocks on the bottom of the Grand Canyon.* Over a mile of sedimentary rocks overlie the bedrock of the canyon. The oldest of these rocks dates back to about 800 million years, leaving 1 billion years of history missing from the geologic record. During this time, the floor of the Grand Canyon was worn by erosion, creating a gap in time known as a hiatus. Thick deposits of marine sediments were slowly laid on the Canyon floor. The continuous buildup of sediments caused the ancient seafloor to subside due to the increased weight. In a fraction of the time it took to deposit the sediments, a gradual upheaval brought them to their present elevation, while the Colorado River gouged out layer upon layer of rock, exposing the raw Earth below. The Imperial Valley of southern California owes its rich soil to the Colorado River as it carved out the mile-deep Grand Canyon and deposited its sediments in the area to a depth of 5 km. By shaping and reshaping the land, Grand Canyon has earned the name: a wonder of Lithosphere.

**The Tibetan Plateau – The Sixth Wonder of Lithosphere**

The Tibetan plateau is the largest high area of thickened continental crust on Earth, with an average height of 16,000 feet over 1,220,000 km, bordered on the south by the Himalayan Mountains, the Kunlun Mountains in the north, the Karakorum on the west, and the Hengduan Shan on the east, Tibet is the source of many of the largest rivers in Asia. The Yangtze, Mekong, Indus, Salween, and Brahmaputra Rivers all rise in Tibet, and flow through Asia, forming the most important source of water and navigation for huge regions. Southern Tibet merges into the foothills of the northern side of the main ranges of the Himalaya, but is separated from the mountains by the deeply incised river gorges of the Indus, Sutlej, and Yarlung Zangbo (Brahmaputra) Rivers. Central and northern Tibet consists of plains and steppes that are about 3,000 feet higher in the south than the north. Eastern Tibet includes the Transverse Ranges (the Hengduan Shan) that are dissected by major faults in the river valleys of the northwest-southeast flowing Mekong, Salween, and Yangtze Rivers. Tibet has a high plateau climate, with large diurnal and monthly temperature variations. *The*

*center of the plateau has an average January temperature of 0 degrees Celsius, and an average June temperature of 17 degrees Celsius.* The southeastern part of the plateau is affected by the Bay of Bengal summer monsoons, whereas other parts of the plateau experience severe storms in fall and winter months.




Geologically, the Tibetan Plateau is divided into four terranes, including the Himalayan terrane in the south, and the Lhasa terrane, the Qiangtang terrane, and Songban-Ganzi composite terrane in the north. The Himalayan terrane contains Lower Permian Gondwanan flora, and probably represents the northern passive margin of Mesozoic India, with carbonates and clastics in the south, thickening to an all clastic continental rise sequence in the north. The Indian plate rifted from Gondwana and started its rapid northward movement about 120 million years ago. Subduction of the Indian plate beneath Eurasia until about 70 million years ago formed the Cretaceous Kangdese batholith belt, containing diorite, granodiorite, and granite. Collision of India with Eurasia at 50 to 30 million years ago formed the Lhagoi-Khangari of biotite and alkali granite, and the 20 to 10 million-year old Himalayan belt of tourmaline-muscovite granites. Tertiary faulting in Tibet is accompanied by volcanism, and the plateau is presently undergoing east-west extension with the formation of north-south graben associated with hot springs, and probably deep magnetism. Geophysical measurements have detected some regions with unusual characteristics beneath some of the graben, interpreted by some geologists as regions of melt or partially molten crust. At the top of the world, Tibetan Plateau is a wonder of lithosphere.

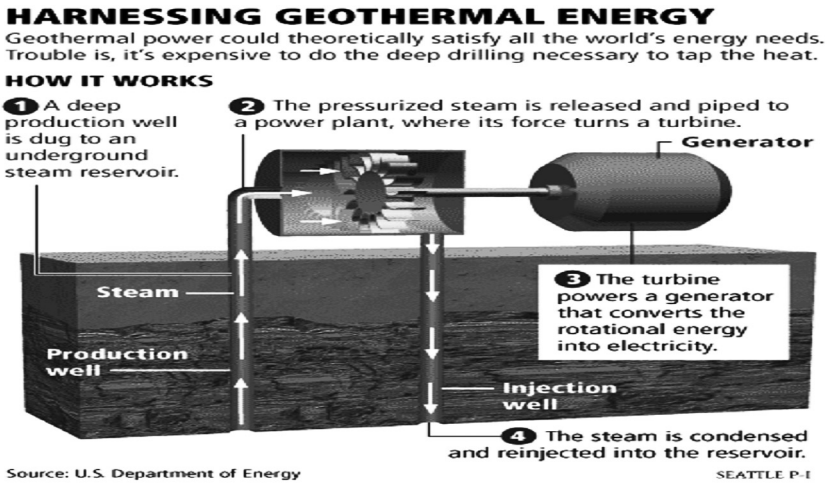
**Geothermal Energy – The Seventh Wonder of Lithosphere**

Much of the young mountain terrain in the most part of Alaska and Hawaii is of volcanic origin and forms a tempting but well-locked treasure of geothermal energy, which can provide high-pressure steam for generating electricity. The potential geothermal energy resources in the U.S alone, is estimated to equal twice the energy of the world's petroleum reserves. The dry hot rock resources are several thousand times greater. Dry hot rock lies beneath the surface in areas where the thermal gradients are

two to three times greater than normal, about 100 degrees Celsius per mile of depth. In a sense, the Earth's interior can be thought of as a natural nuclear power reactor because the heat is mainly derived by the decay of radioactive elements. Many steam and geyser areas generally associated with active volcanism located at plate margins. These are potential sites for trapping geothermal energy for steam heat and electric power generation. Iceland, Italy, Mexico, New Zealand, Soviet Union, U.S and the Scandinavian countries *utilize underground supplies of superheated steam to drive turbine generators for electric power production. Geothermal energy could prove to be far more valuable in the long run than petroleum, coal, or even nuclear energy.* Besides, it is nonpolluting. The Earth's internal heat will last for billions of years. Unlike limited resources of fossil fuels, geothermal energy has the potential of supplying our energy needs for millennia.

It may be fitting to look at a very old source of energy that is of growing importance to our future energy needs. Volcanoes and earthquakes develop tremendous amounts of energy that, if it could be marshaled, would satisfy the world's increasing energy demands. Unfortunately, earthquakes are too random in location and too unpredictable in behavior to be trapped and volcanic eruptions too violent, but there is hope *that volcanic heat may be utilized as a "geothermal energy" source.* Even our forefathers dreamed of harnessing volcanic heat, not during eruptions of course, but by capping boiling springs and fumaroles, the fuming vents often found in volcanic areas: they go deep enough into the Earth to allow the underground water to reach the rocks heated by the underlying magma and become steam. The farmers of Ischia, the "smoking" island in the Gulf of Naples, used fumaroles to warm their potatoes in winter; all over the world, natural hot-steam baths have been used since antiquity for their curative effects and on Iceland, the highly volcanic island in the North Atlantic, most of the buildings are heated by underground steam. *The enormous potential of geothermal energy has been exploited for industrial purposes only in relatively recent times.* In 1904, for the first time in the world, the fuming vents of Larderello in Tuscany began powering electric generators with the natural steam that, until then, had been only used for the extraction of boric acid. Originally, the electric energy thus obtained was sufficient to serve a limited local area, but at the present time, the Larderello and nearby Mount Amiata installations produce 1.7 percent of Italy's electric energy, replacing costly oil imports.

The second largest fields of geothermal energy in the world are now being exploited at Ohaaki and Waikirei, New Zealand, where two additional fields will soon join them. The Ohaaki installation is distinguished by its




development of modern technology "in harmony with tribal values" of the native Maori. Water is piped through the underground steam, causing the water to boil into the steam used to run the turbines; as the steam gives up its heat to the turbines, it is converted back into water, starting the cycle over again. The largest fields of geothermal energy in the U.S started operating in 1960 in the area of "the geysers" at Sonoma, California, potentially the largest source of geothermal energy discovered so far in the world. In view of the predicted early exhaustion of our oil reserves, it is getting serious consideration by all nations where it might be available. In 1970 the U.S enacted the Geothermal Steam Act, which recognizes the development of geothermal energy "as a national goal." Italian governmental agencies have explored the entire area of central Italy west of the Apennine Mountains with wells as deep as 10,000 feet, and discovered that the entire area is a promising source of the new energy.

Direct use of geothermal heat for heating homes and hot water has been developed in Japan, the territories of the former USSR, Bulgaria and Hungary. Geothermal energy already supplies 25 percent of the electricity in New Zealand, 27 percent in Kenya. Untapped resources are known to be available in Bolivia, Costa Rica, Ethiopia, India and Thailand, and may be available in two dozen other countries, including Brazil and Pakistan. Making use of the world's superficially available geothermal energy to meet our need for electricity would certainly give us time to develop nuclear fusion energy from hydrogen. *Development of this unlimited form of energy is being carried out in many scientifically advanced countries of the world and is expected to become available within the next decades of this century.* But the

supply of superficially available heat energy is limited and hence exhaustible. Although drilling deeper into the magma would certainly give us an inexhaustible supply of heat energy, magma's high temperature 2,800 degrees Celsius would melt the drills needed to reach it even if they were made of tungsten steel, the most temperature-resistant metal available today. Yet our rapidly advancing materials technologies suggest to the optimists that we should not give up this wonderful dream of tapping the unbounded energy of the deep magma. "Hope is the last goddess to die," said the Romans and, we add the best road to success. Future looks bright with Geo-thermal energy and we can call it a wonder of Lithosphere.

# Seven Mega-Disasters of Lithosphere

**Mysterious Disappearance of Dinosaurs – Disaster Number One**

Around 65 million years ago, a giant asteroid is thought to have struck the Earth, creating an explosion thousands of times stronger than all the nuclear weapons in the world and tearing a hole in the crust at least 160 km wide. An incredible amount of debris was lofted high into the atmosphere, shutting out the sun and placing the Earth in a deep freeze. The dinosaurs probably could not have tolerated these sudden frigid conditions. Instead a single large impact, a swarm of meteorites or comets might have peppered the Earth. Five craters have thus far been identified that date to the end of the dinosaur era. If the asteroid had landed in the sea, it is conceivable that it disappeared along with the oceanic crust upon which it impacted due to the plate tectonics. Since the end of the Cretaceous, roughly half of the oceanic crust has been recycled into the mantle. Nevertheless, what appears to be an impact site that is mostly intact is located 480 km northwest of Madagascar off the coast of Africa.

The impact site also has the correct age, around 65 million years old, to make it a prime candidate for the dinosaur killer. An asteroid 16 km or more wide would be required to have gouged out the 320 km wide circular depression. The impact might have also triggered the Deccan Traps volcanism in India, which was in the vicinity at the time and heading for Asia. The Deccan Traps are the greatest outpouring of basalt on land over the last 250 million years. The massive eruptions that created them might have had a hand in the demise of the dinosaurs by drastically changing the environment. A crater, now worn down and partly under ocean, was found along the Mexican Yucatan Peninsula and its creation coincides nicely with the K-T boundary. NASA scientists estimate that the asteroid that made Chicxulub Crater,* as it is now known, would have been about 6 to 12 miles in diameter. The crater is about 130 miles across. Whatever it may be, the disappearance of the dinosaurs is one of the mega disasters of the Lithosphere.

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**The Chicxulub Crater is an ancient impact crater buried underneath the Yucatan Peninsula in Mexico. Its center is located near the town of Chicxulub, after which the crater is named. The crater is more than 180 km in diameter, making the feature one of the largest confirmed impact structures in the world.*

**The Disappearance of Minoan Civilization - Disaster Number Two**

One of the greatest volcanic eruptions in the history of the human race happened approximately 3,650 years ago in the eastern Mediterranean region, then the cradle of civilization. Santorini is a small, elliptically shaped archipelago approximately 16 km across, located about 110 km north of the island of Crete. These islands are dark and ominous in stark contrast to Greece's other white limestone islands and they form ragged, 1,300-foot peaks that seem to point up toward something that should be in the center of the ring-shaped archipelago, but is no longer there. The peaks are pointing in toward the center of a giant caldera complex that erupted in the late Bronze Age, approximately 3,650 years ago, devastating much of the eastern Mediterranean. The largest island on the rim of the caldera is Thera and across two circular 900-foot deep calderas rests the opposing island of Therasia, once part of the same volcano. In the center of the composite caldera complex are several smaller islands known as the Kameni Islands, which represent newer volcanic cones growing out of the old caldera.

Santorini and Thera are part of the Cyclades Islands that form part of the Hellenic volcanic arc that stretches from western Turkey through Greece, lying above a subduction zone in the Mediterranean along which part of the African plate is being pushed beneath Europe and Asia. Volcanoes in the Hellenic arc are widely spaced, and numerous earthquakes also characterize the region. The area was apparently densely populated, as remnants of Bronze Age and earlier Neolithic settlements and villages along the coastal Aegean are buried in ash from Thera. Settlers who arrived about 6,000 to 7,000 years ago and traded with Crete and Greece populated the island of Thera. In 1967, archaeologists discovered a Bronze Age city buried by ash from the eruption and uncovered numerous paved streets and frescoes, estimating that the city was at least the size of Pompeii when it was buried by the eruption of Vesuvius more than 1,700 years later. *At the time of the eruption in Thera, the region was dominated by the Minoan culture, derived from Crete.* The eruption occurred while a primitive form of writing was used by the Minoans, which has not been deciphered, and the Greek language had not yet been codified in writing. Thus, no local recorded texts record the eruption, although Hebrew text was in use in nearby Egypt and Israel. *Some scholars have tried to link the eruption of Thera with biblical events such as the plagues, days of darkness, and parting of the Red Sea during the Exodus of the Israelites from Egypt, although the timing of the eruption seems to be off by a couple of centuries for such a correlation to be made.* The best current estimates for the age of the eruption are between 1690-1620 BC.

Before the cataclysmic eruption, the Santorini Islands were one giant volcano known to the Greeks as Stronghyle, or the round one, and now referred to as Thera. We have no written firsthand accounts of the eruption of Thera, so the history has been established by geological mapping and examination of historical and archaeological records of devastation across the Mediterranean region. The inside of Thera's caldera is marked by striking layers of black lava alternating with red and white ash layers, capped by a 200-foot-thick layer of pink to white ash pumice that represents the deposits from the cataclysmic Bronze Age eruption. Ash from the eruption spread over the entire eastern Mediterranean and also on North Africa and across much of the Middle East. The most violent eruptions are thought to have occurred when the calderas collapsed and seawater rushed into the crater, forming a tremendous steam eruption and tsunami. The tsunamis moved quickly across the Mediterranean, devastating coastal communities in Crete, Greece, Turkey, North Africa, and Israel. The tsunami was so powerful that it caused the Nile to run backward for hundreds of miles.

*The legend of Atlantis, a mythical island kingdom described by the Greek philosopher Plato as a "utopia," has long been suspected of having been based on the history of the island of Santorini (for Thera), the Minoan settlement in the Aegean Sea.* The Minoan peoples had inhabited Crete since the third millennium BC, erecting there the great palaces of Knossos and Phaistos and developing linear writing from early hieroglyphic writing. Yet for unknown reasons, the Minoan civilization rapidly faded into poverty and obscurity after about 1500 BC. *Plato provided a clue to this mystery when he wrote: "there occurred (in Atlantis) violent earthquakes and floods; and in a single day and night of misfortune … the island … disappeared in the depths of the sea."* Today's visitor to the peaceful island of Thera finds another clue to the mystery of Atlantis's disappearance when noticing the conical hill rising from the moon-shaped harbor, a clear indication of a caldera from an ancient volcano. Such a large cone must have been the site of a catastrophic eruption spewing massive amounts of ash into the atmosphere.

Moreover, reported Plato, following the "earthquake" the sea around Atlantis *"became an impassable barrier of mud to voyagers sailing from hence to any part of the ocean."* Such a mud barrier could have been the consequence of a heavy fall of ash mixed with water and proof of the correctness of this assumption was uncovered late in the nineteenth century when volcanic ash, a key ingredient in the manufacture of the waterproof cement needed for the construction of the Suez Canal was discovered in the sediment of the eastern Mediterranean, in Egypt's Nile delta, in parts of the Black Sea and on Thera. Excavations of Thera's ash

deposits, which were as deep as 900 feet, led to the discovery of the buried city of Akrotiri and to the well-preserved wall paintings documenting in vivid detail the Minoan way of life. There remained little doubt then that a destructive explosion had, some time in the past, destroyed Thera, but precise dating of the event remained elusive until 1994 when, deep in central Greenland, scientists drilled and recovered ice cores that are providing clues to historic events. Such cores, drilled as deep as 9,000 feet, are silent witnesses to natural events that occurred in the Northern Hemisphere during the last nine thousand years, starting at a time when the great ice sheets were melting.

The eruption of Thera seems to coincide with the fall of the Minoan civilization, certainly in the Santorini archipelago, but also on Crete and throughout the eastern Mediterranean. The cause of the collapse of the Minoan society was probably multifold, including earthquakes that preceded the eruption, ashfalls, and the 30-foot tsunamis waves that swept the eastern Mediterranean from the eruption. Since the Minoans were sea merchants, the tsunamis would have devastated their fleet, harbor facilities, and coastal towns causing such widespread destruction that the entire structure of their society fell apart. Vessels at sea would have been battered by the atmospheric pressure waves, covered in ash and pumice, and stranded in floating pumice far from ports. Crops were covered with ash, and palaces and homes were destroyed by earthquakes. The ash was acidic, so crops would have been ruined for years, leading to widespread famine and disease. People sought relief by leaving Crete, the homeland of the Minoan culture. Many of the survivors are thought to have migrated to Greece and North Africa, including the Nile Delta region, Tunisia, and the Levant, where the *fleeing Minoans became known as the Philistines.*

The age of the ash layers found in the ice cores have been identified by their sulfur content and over 80 percent have been matched with known volcanic eruptions of the last two thousand years (such as that in 79 AD at Vesuvius). By using the known eruptions to establish a time scale*, the destruction of Thera has been definitely dated at 1623 BC, a solid link to the legend of Atlantis.* Modern science and technology have thus provided a solution to the mystery of Atlantis and verified the "hard to believe," statements of Plato. But what happened to Minoans? No one can state their destiny with certainty, but it is reasonable to assume that, following the destruction of Thera, because of changes in weather, in the composition of the soil and in the riches of the sea, crop failures and a reduction of fish may have caused the beginning of a slow decline of the golden Minoan civilization and we could call this event, a mega disaster of the Lithosphere.

**Earthquake – Shaanxi, China - Disaster Number Three**

The 1556 Shaanxi earthquake or Jiajing earthquake is the deadliest in history of the world, killing 830,000 people. It occurred on the morning of 23 January 1556 in Shaanxi, China. More than 97 counties in the provinces were affected. Area of 840-kilometers wide was destroyed and in some counties, 60 percent of the populations were killed. Most of the population in the area at the time lived in Yaodongs, artificial caves in Loess cliffs, many of which collapsed during the catastrophic occurrence causing a huge number of deaths. The Shaanxi earthquake epicenter was in the Wei River Valley in the Shaanxi Province, near the cities of Huaxian, Weinan and Huayin. In Huaxian, no building remained standing and more than half the residents of the city died. Sixty six feet deep crevices opened in the Earth, landslides caused also many deaths and the earthquake affected area located as far as 500 km away from the epicenter.

The earthquake's magnitude had been of approximately 9 on the moment magnitude scale and the intensity XI on the Mercalli scale. While it was the most deadly earthquake and the third deadliest natural disaster in history, there have been earthquakes with considerably higher magnitudes. Nowadays the cost of material loses caused by Shaanxi earthquake is almost impossible to estimate. The earthquake with the highest magnitude ever recorded was the 1960 Valdivia earthquake or Great Chilean Earthquake of 22 May 1960 with 9.5 degrees on the moment magnitude scale. It occurred in the afternoon and produced tsunamis affecting southern Chile, Hawaii, Japan, the Philippines, eastern New Zealand, south east Australia and the Aleutian Islands in Alaska. Estimations of the total number of fatalities from the earthquake and tsunamis have been published and the number of death was believed to be around 5700. Indeed, Shaanxi earthquake is the mega disaster of the Lithosphere.

**Krakatau, Indonesia – Disaster Number Four**

Indonesia has seen catastrophic volcanic eruptions other than Tambora. Indonesia has more volcanoes than any other country in the world, with more than 130 known active volcanoes. One of the most spectacular and devastating eruptions of all time was that of Krakatau, an uninhabited island in the Sunda Strait off the coast of the islands of Java and Sumatra, in 1883. This eruption generated a sonic blast that was heard thousands of miles away, spewed enormous quantities of ash into the atmosphere, and initiated huge tsunamis that killed roughly 40,000 people and wiped out more than 160 towns. The main eruption lasted for three days and the huge

amounts of ash ejected into the atmosphere circled the globe and remained in the atmosphere for more than three years, forming spectacular sunsets and affecting global climate. Locally, the ash covered nearby islands killing crops, natural jungle vegetation, and wildlife. Prior to the 1883 eruption, the Sunda Strait was densely populated with many small villages built from bamboo and palm-thatched roofs. Krakatau is located in the middle of the strait, with the many starfish-shaped arms of the strait extending toward the islands of Sumatra and Java. On May 20, 1883, Krakatau entered a violent eruption phase, witnessed by ships sailing through the Sunda Strait. The initial eruptions heard 160 km away in Jakarta. As the eruption expanded, ash covered villages in a 60 km radius. For several months, the volcano continued to erupt sporadically, covering the straits and surrounding villages with ash and pumice, while the earthquakes continued.

On August 26, the style of the eruptions took a severe turn for the worse. A series of extremely explosive eruptions sent an ash column 25 km into the atmosphere, sending many pyroclastic flows spilling down the island's slopes and into the sea. A tsunami associated with the flows and earthquakes sent waves into the coastal areas surrounding the Sunda Strait, destroying or damaging many villages on Sumatra and Java. Ships passing through the straits were covered with ash, while others were washed ashore and shipwrecked by the many and increasingly large waves of the tsunami. *On August 27, Krakatau put on its final show, exploding with a massive eruption that pulverized the island and sent an eruption column 40 km into the atmosphere. The blasts from the eruption were heard as far away as Australia, the Philippines, India, and Sri Lanka.* Atmospheric pressure waves broke windows on surrounding islands and traveled around the world as many as seven times, reaching the antipode, the area on the exact opposite side of the Earth from the eruption, at Bogota, Columbia, 19 hours after the eruption. The amount of lava and debris erupted at 75-80 cubic km, making this one of the largest eruptions known in the past several centuries. Many sections of the volcano collapsed into the sea, forming steep-walled escarpments cutting through the volcanic core, some of which are preserved to this day. These massive landslides were related to the collapse of the caldera beneath Krakatau and contributed to the huge tsunamis that ravaged the shores of the Sunda Strait, with waves of average heights of 50 feet, some reached up to 140 where the V-shaped bays amplified wave height. Many of the small villages were swept away with no trace, boats were swept away with no trace, and thousands of residents in isolated villages in the Sunda Strait perished.

The tsunami was so powerful that many trees were ripped from the soil leaving only shattered stumps remaining as vestiges of the previous forest. In some places the forest was uprooted to elevations of 130 feet above the sea level. Bodies were strewn around the shores of the Sunda Strait and formed horrible scenes of death and destruction that survivors were not equipped to clean up. The population was decimated, food supplies and farmland were destroyed, and entire villages and roads were wiped off the islands or buried in deep layers of mud. Survivors were in a state of shock and despair after the disaster and soon had to deal with additional loss when disease and famine took over their lives. A state of anarchy ensued as rural people and farmers from the mountains descended to the coastal region and engaged in gang-like tribal looting and robbery, creating a state of chaos. Weeks after the eruption huge floating piles of debris and bodies were still found in the Sunda Strait, Java Strait, and Indian Ocean, providing grim reminders of the disaster to sailors in the area. Some areas were so densely packed with debris that sailors reported some regions appeared to look like solid-ground, and people were able to walk across the surface. Fields of pumice from Krakatau reportedly washed up on the shores of Africa a year after the eruption, some even mixed with human skeletal remains. Other pumice rafts carried live plant seeds and species to distant shores, introducing exotic species across oceans that normally acted as barriers to plant migration. Ash from the eruption fell for more than 2,500 km from the eruption for days after, and many fine particles remained in the atmosphere for years, spreading across the globe on atmospheric currents. The ash and sulfur dioxide from the eruption caused a lowering of global temperatures by several degrees and created many spectacular sunsets and atmospheric light phenomenon by reflected and refracted sunlight through the particles and gas emitted into the atmosphere. Indeed Krakatau is called a mega disaster of the Lithosphere.

**Hiroshima, Nagasaki, Japan - Disaster Number Five**

August 6$^{th}$ 1945, was just a regular normal day. Little did the citizens of Hiroshima know, but for thousands of them, life was about to come to an end. Hiroshima had been selected by the U.S as the very first atomic bomb target. Nobody knew for certain what the effect would be. An uranium bomb 3-235, weighed 4 tons, which is 3,600 kilograms, was exploded 1850 feet in the air above Hiroshima, for maximum explosive effect. The person who dropped the bomb was Major Tom Ferebee from the aircraft, the "Enola Gay." The pilot who was flying the "Enola Gay" at the time was Colonel Paul Tibbets. The plane stopped in Calcutta, India for refueling before proceeding to Hiroshima. The dropping happened just after 8.00 am. Less

than a minute after the dropping, the atomic bomb exploded. The explosion produced a temperature of 5,400 Fahrenheit, which is twice as high as the melting point of iron. Victim's skin began to peel off their faces, hands, and arms. It has been estimated that people living within 1 km of the bomb site burned to death. It devastated six square kilometers, and killed 140,000 of the 255,000 inhabitants. Thousands of bodies were evaporated. Survivors were in a state of shock. Dead and dying people lay all around Hiroshima. Other survivors, after 50 years, are still suffering from the radioactive effects.

After the bombing, Japan rejected the United States' ultimatum to surrender unconditionally, so America dropped a second bomb on Nagasaki. When the U.S Air Force dropped the second atomic bomb on Nagasaki, on August 9, 1945, the principal target was a Catholic Church. The roof and masonry of the Catholic cathedral fell on the kneeling worshippers. All of them died. Nicknamed "the Fat Man," the bomb devastated Nagasaki and demonstrated that the attack on Hiroshima three days earlier was repeatable. It is estimated that the bomb killed another 80,000 people in Nagasaki. Japan surrendered to the United States on August 14, 1945, eight days following the first bombing. Back in the U.S the news of the bombing of Hiroshima was greeted with a mixture of relief, pride, joy, shock and sadness. Amid the astonishing devastation wrought by the two atomic bombs that ended World War II, it quickly became clear that the twin graveyards of Hiroshima and Nagasaki, where the bombs killed at least 225,000 people, could say a lot about the long-term health effects of ionizing radiation. When the Atomic Bomb Casualty Commission started studying Hiroshima and Nagasaki, it focused on searching for genetic abnormalities caused by radiation. Radiation is causing a lifelong increase in cancer risk, for people who were exposed. For example, between 1950 and 2000, among 48,000 bomb survivors with elevated radiation exposures, there were about 5,900 solid cancer deaths, of which only 480 cases could be blamed on radiation exposure. But the permanent scar left on Lithosphere is a constant reminder of the destructive nature of humanity and it is a mega disaster of the Lithosphere.

**Indian Ocean Tsunami, 2004 – Disaster Number Six**

One of the worst natural disasters of the 21st century unfolded on December 26, 2004, following a magnitude 9.3 earthquake off the coast of northern Sumatra in the Indian Ocean. The earthquake was a largest since the 1964 magnitude 9.2, event in southern Alaska, and released more energy than all the earthquakes on the planet in the last 25 to 30 years

combined. During this catastrophic earthquake a segment of the seafloor the size of Tamil Nadu State, India, lying above the Sumatra subduction zone trench, suddenly moved upward and seaward by several tens of feet (30 feet). The slip event continued for nearly 10 minutes as the central section of the faulted area moved 65 feet and the rupture propagated laterally more than 1,000 kilometers, the sudden displacement of this volume of under seafloor displaced a huge amount of water and generated the most destructive tsunami known in recorded history.

Within minutes of the initial earthquake a mountain of water more than 30 feet high was ravaging northern Sumatra, sweeping into coastal villages and resort communities with a fury that crushed all in its path, removing buildings, vegetation, and in many cases eroding shoreline areas down to bedrock leaving no traces of the previous inhabitants or structures. Similar scenes of destruction and devastation rapidly moved up the coast of nearby Indonesia, where residents and tourists were enjoying a holyday weekend. Tsunami waves moved up to 20 km inland in northern Sumatra and Indonesia. Firsthand accounts and numerous videos made of the catastrophe reveal similar scenes of horror, where unsuspecting tourists and residents are enjoying beachfront playgrounds, resorts, and villages, and watch as large breaking waves appear off the coast. Many moved toward the shore to watch with interest the high surf, then ran in panic as the sea rapidly rose beyond expectations, and walls of water engulfed entire beachfronts, rising tens of feet (30 feet) above hotel lobbies, and washing through towns with the force of Niagara Falls. In some cases, the sea retreated to unprecedented low levels before the waves struck, inducting many people to move to the shore to investigate the phenomena; in other cases, the sea waves simply came crashing inland without warning. Buildings, vehicles, trees, boats, and other debris was washed along with the ocean waters, forming projectiles that smashed at speeds of up to 50 km/hr, into other structures, leveling all in its path, and killing more than 300,000 people.



The displaced water formed a deepwater tsunami that moved at speeds of 800 km/hr across the Indian Ocean smashing within an hour into Sri Lanka and southern India, wiping away entire fishing communities and causing additional widespread destruction of the shore environment. Ancient Indian legends speak of villages that have disappeared into the sea (Mahabalipuram and Dwaraka),* that many locals now understand as relating of previous tsunamis, long since forgotten by modern residents. South of India are many lands including the Maldives, Chagos, and Seychelles, many of which have maximum elevations of only a few to a few tens of feet (12 feet) above normal sea level. As the tsunami approached these islands, many wildlife species and primitive tribal residents fled to the deep forest, perhaps sensing the danger as the sea retreated and the ground trembled with the approaching wall of water. Several hours later, the tsunami reached the shores of Africa and Madagascar, and though its height was diminished to less than 8 feet at this distance from the source, several hundred people were killed in these regions by the waves and high water. Kenya and Somalia were hit relatively severely, with harbors experiencing rapid and unpredictable rises and falls in sea level, and many boats and people washed to sea. The tsunami traveled around the world, being measured as minor changes in sea level more than 24 hours later in the north Atlantic and Pacific. Indian Ocean communities have now set up a tsunami warning system as a response to the 2004 tsunami. Tsunami warning system is designed to alert people the dangers of incoming tsunamis. Without any doubt, this event is a mega disaster of the Lithosphere.

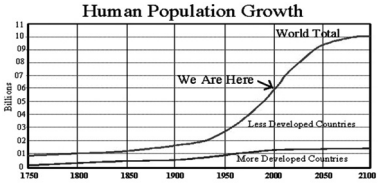
**Human Population – Disaster Number Seven**

We continue to add ninety million people to the world mostly by India and China, each year without eventually destroying the natural systems and resources on which eventually we depend for sustenance. With almost 7 billion people on this fragile planet, humanity is undoubtedly facing a biggest disaster of all time. Lithosphere is scarred, destroyed, pillaged, stripped, squandered and exploited by humanity. Humans are experiencing a population explosion that cannot be sustained by the planet's limited resources. Very soon, freshwater and food sources will not be able to sustain the global population, and hunger, famine, disease, and war will follow. Can this fate be controlled? People are migrating in huge numbers to hazard-prone areas including coastlines, river flood plains, and the flanks of active

**Both of these coastal cities from India, and they are believed to be submerged under the ocean after being hit by tsunamis.*

volcanoes. Natural geologic hazards in these areas will cause disasters, and thousands of people will die. Perhaps greater understanding of natural geologic hazards will cause people to move to safer areas or to be better prepared for the hazards in the areas in which they live. Why has the population of the human race exploded so dramatically? About 1 million years ago, there are estimated to have been a few thousand migratory humans on the Earth and by about 10,000 years ago this number had increased to only 5-10 million. It was not until about 8,000 years ago when humans began stable agricultural practices and domesticated some species of animals that the population rate started to increase substantially. The increased standards of living and nutrition caused the population growth to soar to about 200 million by 2,000 years ago and 100 million by 1,000 years ago.

By the 18th century, humans began manipulating their environments more, began public health services, and began to recognize and seek treatments for diseases that were previously taking many lives. The average life span began to soar, and world population surpassed 1 billion in the year 1810. A mere 100 years later, world population doubled again to 2 billion and had reached 4 billion by 1974. World population is now close to 7 billion and climbing more rapidly than at any time in history, doubling every 50 years. This rate of growth is not sustainable. At this rate, in about 800 years, there will be one human for every three square feet on Earth! What will humans do when the population exceeds the ability of the Earth to support them? Perhaps there will be fighting and wars as with past isolated societies that reached their capacity to be supported by the land's natural resources. Alternatively, maybe humans will succumb to disease and famine, perhaps induced by drought. It is possible that a huge natural disaster such as an impact from outer space may send the human race back to a small fraction of the current population. Alternatively, the population rate could decrease in response to cultural changes. *Some evidence suggests that the population growth rate is decreasing in developed countries and continues to rise in undeveloped and third-world countries*. This could be in response to increased medical care reducing the need to have many children to ensure that some survive to adulthood or it could be a reflection of increased opportunities for women in developed societies.




Humans are causing mass extinction on a global scale that rivals the mass extinctions caused by massive flood basalt volcanism and meteorite impacts. Thousands of species are vanishing every year. There is the rapid

global decline in amphibians, particularly frogs, in the past 15 years. *Frogs could represent the proverbial canary in the coal mine, warning that changes in the environment are exceeding the limits to sustain certain kinds of life on the planet*. If frogs are in trouble, it is needless to say that we are also in trouble. Humans are destroying environments through uncontrolled population growth competing for limited resources, perhaps contributing to rapid decrease in global diversity. People are destroying many of the organisms that may be crucial to survival of the race, perhaps without even knowing it. Interrelationships between different organisms are complex. Humans may find themselves at the point of some day realizing that the simple bacteria that went extinct or the fungi that disappeared a few years back were essential for some process needed to survive, such as removing some greenhouse gas from the atmosphere. Rarely does one change in the environment go without consequence. Death of one species may allow another to expand, and this new species may be a predator to a third or carry parasites that can wipe out large segments of the population. Exponential population growth is hazardous and could be the ultimate demise of the human race and the excessive human population is a mega disaster of Lithosphere.

# Ten Heroes of Lithosphere

### Mountain – Hero Number One of Lithosphere

Mountains create clouds, control temperature and dispense minerals for vegetation. The important role that mountains and mountain forests play in the Global Fresh Water Cycle is not generally known about. Fresh water always starts its journey high on the mountain. Considering how important fresh water is, it is surprising how little the general public knows about things such as: how it is formed? What factors it is dependent upon and how to preserve it? The result of mountain ecosystem degradation through clear-cut and unsustainable forestry and agricultural practices are tremendous and costly to downstream water users. They include drier aquifers and wells, siltation of hydropower and irrigation reservoirs through hillside erosion, and less water in the dry season. *The mountains around Vellore, India are clear-cuts and hence, no trees to hold water, thereby Vellore District is speeding up its desertification.* Research has shown that the environment of the Tibetan Plateau, at an average altitude of 12,000 feet above the sea level, which is the highest plateau on Earth, affects the global jet-streams. These in turn affect Pacific typhoons, the El Nino (warm ocean current) phenomenon and monsoon patterns. These patterns affect all of Earth's weather systems and climates. As mountain forests disappear, less rain falls, less snow is made, land drains more quickly, and soil temperatures rise. The stability of Earth's fresh water system depends upon maintaining the integrity of watersheds. These, in turn depend upon the health of the high altitude indigenous mountain and its forests. Indeed, every mountain is a hero.

### Volcano – Hero Number Two of Lithosphere

Researchers have discovered the pivotal role that volcanoes played in a deadly ice age 450 million years ago. Volcanoes came to rescue. Perhaps ironically, these volcanoes first caused global warming by releasing massive amounts of carbon dioxide into the atmosphere. When they stopped erupting, Earth's climate was thrown off balance, and the ice age began. The aerosols emitted by strong volcanic eruptions tend to persist in the atmosphere for years, changing Earth's radiation budget for that period. Unlike human produced aerosols, or other natural aerosols that settle out of the atmosphere in a matter of days, volcanic eruptions can spew aerosols high into the stratosphere, where the winds can spread their effects worldwide. The stable air in the stratosphere that lacks strong vertical

motions help prevent some types of these aerosols from settling quickly. Some examples of volcanic eruptions that have apparently had an effect on Earth's radiation budget include Tambora, Krakatau, and most recently Pinatubo. After Tambora erupted in 1815, much of the world experienced the *"year without a summer."* In 1816, crops failed throughout the world. Snowfalls were reported in Europe in the middle of summer. The cold was attributed to the effects of Tambora. *More recently, Mount Pinatubo, in the Philippines erupted in 1991. The following years saw a 1 degree Celsius drop in average temperatures worldwide.* Although volcanoes emit a lot of solid particulate aerosols into the atmosphere, these tend to settle out in a relatively short period of time. Major cooling is thought to be largely due to large amounts of a liquid aerosol, *sulfuric acid (H2SO4) that reflects incoming solar radiation back to space.* Some volcanoes emit great amounts of sulfuric acid. This way Volcanoes keep the planet warm with CO2 when it is too cold and keep the planet cool with aerosols when it is too hot, make volcano a hero of Lithosphere.

**Humus – Hero Number Three of Lithosphere**

Whenever a plant, or other organic matter, completely decomposes, it becomes humus. Humus attracts positively charged nutrient in the soil like calcium, potassium, magnesium, and sodium. This is what your plants will thrive off of! Humus soil is soil with quite a bit of completely decomposed organic matter in it. Humus, the end product of the composting process when organic matter has fully broken down, can be summed up as *the "life-force of the soil."* Yet it is difficult to define humus in precise terms; it is a highly complex substance, the full nature of which is still not fully understood. Physically humus can be differentiated from organic matter in that the latter is rough looking material, with coarse plant remains still visible, whilst once fully humified it become more uniform in appearance and amorphous in structure. That is, it has no determinate shape, structure or character. Plant remains contain organic compounds: sugars, starches, proteins, carbohydrates, lignins, waxes, resins and organic acids. This process of organic matter decay in the soil begins with the decomposition of sugars and starches from carbohydrates which break down easily as saprophytes initially invade the dead plant, whilst the remaining cellulose breaks down more slowly. Proteins decompose into amino acids at a rate depending on sugars. Organic acids break down rapidly, whilst fats, waxes, resins and lignins remain relatively unchanged for longer periods of time.

The humus that is the end product of this process is thus a mixture of compounds and complex life chemicals of plant, animals or microbial origin

which has many functions and benefits in the soil. *Humus should not be thought of as "dead," rather it is the "raw material" of life, the transition stage between one life form and another.* It is a part of a constant process of change and organic cycling. Humus which is readily capable of further decomposition is referred to *as effective or active humus.* It is principally derived from sugars, starches and proteins and consists of simple organic acids. It is an excellent source of plant nutrients. *Stable (passive) humus* consisting of humic acids, or humins, on the other hand, are so highly insoluble that they are greatly resistant to further decomposition. Thus they add few readily available nutrients to the soil, but play an essential part in providing its physical structure. Some very stable humus complexes have survived for thousands of years. This why we need to substitute compost and other sources of organic matter to maintain the fertility of our productive land. It is excellent for growing plants. When making compost pile, you can encourage the production of humus through fermentation. In fact, you can produce quite a bit of humus. You can produce enough humus that it attracts enough surrounding nutrients to become a colloid. Then you have colloidal humus compost and it is awesome for your garden.

**Clay – Hero Number Four of Lithosphere**

You probably have memories of playing with clay as a child. Clay is ubiquitous. If you gathered it all up and spread it evenly over the surface of the Earth like butter, you would create a mud layer a mile in thickness. Certainly, there are places in the world where there is no clay, deserts, some mountain ranges, but in most areas of the world, it is readily available, often plentiful. In addition to its abundance, two additional qualities have made clay instrumental to many key human endeavors: *its plasticity and its durability after being treated with heat*. The word clay comes from the German word *"kleben," which means "to stick to."* Wet clay is plastic in nature. If you squeeze it, it responds to the pressure and retains the shape you squeezed it into. Even more remarkable, once clay is fired or baked in a kiln, it becomes rocklike. If you drop it, it will shatter, but the pieces will last forever. *It is these three qualities of clay, its abundance, its plasticity, and its durability that has made it so valuable to the progression of culture and the rise of civilization.* Writing began on clay tablets; clay ovens and pots enabled the development of cookery; fired and unfired bricks made the building of houses and whole cities possible; and clay figures have had a vital role in religious practices.

Today, clay is crucial to the computer and space industries, to biotechnology, to the publishing industry, for water clarification, and for a

wide range of manufacturing processes. It is part of your everyday life. Your toilet is clay. Your coffee mug is, too. The coating on your favorite magazine's glossy paper is clay. Some scientists believe that clay played a crucial role in the origins of life itself. They hypothesize that montmorillonite, a particularly fine-particled kind of clay, is the key to the transition between the nonliving and the living *that perhaps life began in a sort of muddy soup of clay and water, "energized" by a bolt of lightning. Indeed, the idea that the first humans were made of clay predates scientific thought. Adam is Hebrew for red Earth or clay.* Clay is alumina, silica, and chemically bonded water. The clay particles are flat, two-dimensional, and electrically charged, and they touch on only two sides. When flooded with water a strong attraction is created between the particles, yet the water also acts as a lubricant, allowing the particles to slide. This is what gives clay its plasticity. Clay was once stone. Billions of years ago, as the molten magma of the Earth slowly cooled it crystallized into a hard crust, mostly granite. In time the granite was exposed to rain, ice, snow, wind, and glaciers. It expanded during the hot summers and contracted in the frigid winters. It was pummeled by sleet and hail. Floodwaters washed over it. The granite weathered and began to break apart. In some places it was exposed to organic acids from decaying vegetation and underwent chemical changes.

After millions of years, both weathering and chemical action caused the granite to decompose, first into feldspathic minerals which, over time, released some of their minerals such as silica, calcia, potash, and soda, and then, as water molecules replaced the released minerals, *the granite became clay. Some clay remained in place where the original rock lay. This is called residual clay, and it tends to be "short" or less plastic. Other clay was carried away by wind and volcanic ash, by rains, rivers, and streams, and, in time, deposited great distances from the original bedrock. This is called sedimentary clay, and it is very plastic.* The great adobe houses of the American Southwest, the walled cities of ancient, Indian and Mesopotamian cultures, the cob houses of England are all built of this kind of "raw" clay, also called "unfired." Unfired clay is used to line ponds, to clean up toxic waste, as an ingredient in some cosmetics: spas even pamper their clients with mud facials. Much can be done with this unfired clay. Clay has played a crucial role in the development of the culinary arts, the rise of international trade. *Ancient broken clay pots keep records of the Earth's magnetic field, help geologists to understand the matrix of magnetism.* Stoneware clays, porcelain, ball clay, shale, earthenware, sedimentary, and residual, no matter what type, to most of us it is mud. It is a slippery mud along a riverbank, and the heavy mud in our garden. It is the goo of our childhoods, and the mess our boots leave on the floor. The most exciting thing with clay,

this most humble and common of Earth materials, was the crucial component in many of the most important events of human progress. *This substance is not just the clay, but clay with potential.* This humble substance indeed, should be exalted to the status of hero.

**Extremophile – Hero Number Five of Lithosphere**

Life is tougher than we think. An extremophile is an organism that thrives under "extreme" conditions. No matter how though environmental conditions can be, life always finds a way on this planet. The existence of extremophiles, organisms which prosper in inconceivable ecological niches such as hot pools, toxic dumps and Polar Regions, opens up the possibility of life even in the cold, dry climate of Mars or beyond our solar system. Perhaps the most unexpected aspect of these extremophiles was that many of the bacteria in these regions not only support, but also demand and thrive on, temperatures above 80 degrees Celsius. One species discovered in the deep-sea hydrothermal vents reproduces best in water at temperatures above 105 degrees Celsius and remains able to reproduce in water as hot as 112 degrees Celsius. The deep-sea vents are characterized by three conditions previously considered deleterious to life: *high pressure, high heat, and lack of light.* Because of the great pressures encountered deep in the sea, water can be heated well past its boiling point at Earth's surface. The majority of research on extremophiles has centered on two types of habitats: *the undersea hydrothermal vents: geysers and hot pools on land.* Volcanic processes create both of these habitats, and accordingly, they provide windows into the deep Earth. Of bacteria-like organisms can inhabit high-temperature geysers they can live deep in Earth's crust in the subterranean blackness and heat of the underworld.

The term extremophile is relatively anthropocentric. We judge habitats based on what would be considered "extreme" for human existence. Many organisms, for example, consider oxygen to be poisonous. While oxygen is a necessity for life as we know it, some organisms flourish in anoxic environments. There are number of terms used to describe extremophiles; they are generally straightforward. For example, "acidophiles" are organisms that love acid. The others are: alkaliphile, halophile, piezophile, psychrophile, thermophile, and xerophile. The discovery that life is abundant and diverse in extreme environments is one of the most important of the astrobiological revolution. It gives us hope that microbial life may be present and even common elsewhere in the universe. Besides, extremophiles are providing resources to pharmaceuticals and new array of medicines are discovered. These invisible brothers and sisters of our planet are serving us in many ways and each extremophile is truly a hero.

**Fossil – Hero Number Six of Lithosphere**

Fossils are the remains of plants and animals that have been preserved in sedimentary rocks. Fossils are generally rare. For every animal that dies, its chances of becoming fossilized are estimated to be less than one in a million. But at the Cradle of Humankind in Africa, the chances are greater because the area has the right mix of conditions that promote fossilization. For a fossil to be successfully formed and found a number of steps have to take place in succession. One missed step, and the ancient remains of an animal or plant will either not be preserved, or not be discovered. Fossils are formed when minerals such as calcium carbonate envelope or replace bones and other organic matter, hardening or casting them within a rock matrix such as breccia that remains unchanged for millions of years. If the sediment is composed of the right minerals, it can suffuse through the bones and organic material, making them as hard as rock in a process called "mineralization." Over millions of years, these fossils are covered by layers of new rock and sediments. Finally, either through natural occurrences such as, erosion, earthquakes or human activity, such as limestone mining, the fossils can become exposed again, giving scientists a window to our past.

Paleontologists examine the age, characteristics and surrounding environment of a fossilized animal to understand its place on the evolutionary timeline. The age of fossils can be determined using radio-isotope dating on rocks close to them. Some chemical elements occur in slightly different forms called isotopes, and some of these isotopes found in rocks are unstable and decay over millions of years at a set rate. By checking the amount of decay of an isotope, scientists can work backwards and determine how old a rock is and from that estimate the age of a fossil. Once a few species have been classified, experts can start to examine trends in the evolution of animals. For instance, with fossilized remains of *Autralopithecus africanus* and *Homo ergaster** in the Sterkfontein deposits in South Africa, we can see the trend towards a bigger brain as hominids evolved. The Cradle of Humankind gives us some of the richest evidence of our earliest direct ancestors: Australopithecus africanus and Homo ergaster hominids, and our "distant cousins," *Paranthropus robustus.*** Fossils from some of the earliest organisms ever discovered have been found in South Africa and date to about 3.5 billion years ago. Paleontologists have also found remains of our distant mammalian ancestors that lived more than 200 million years ago and fossils of some of the earliest known dinosaurs

**These are the early specimens of humanity in Africa somewhere between 1 to 4 million years ago.*
***Another specimen around 1 to 2 million years ago with powerful jaws, capable of eating tough* vegetation.

from about the same period, in the Karoo. We can tell the history from the fossil remains that they have left behind them in the rocks. Fossil is a history book of Lithosphere and indeed a hero.

**Mineral – Hero Number Seven of Lithosphere**

Did you know we use minerals every day? Without them there would be no cars, trains, or planes. You wouldn't be able to clean your teeth or wash your clothes. Clocks, watches, and jewelry, tin cans and aluminum foil, are all minerals. Minerals are among the most beautiful objects in nature, and they are used to make objects you use every day of your life, including the computer you are looking at right now! Minerals are natural compounds formed through geological processes. *Our bodies, plants and animals are made up of minerals. Most of the medicines we use are taken from minerals. Lithosphere is one big pharmaceutical.* A mineral is a naturally occurring, inorganic solid with a definite chemical composition and a crystalline structure. A crystal structure is the orderly geometric spatial arrangement of atoms in the internal structure of the minerals. A rock is an aggregate of one or more minerals. There are currently just over 4,000 known minerals. If you take rock, any rock, and look at it through a hand lens or a microscope you will see that it is made up of a mosaic of interlocking particles. Sometimes, in rocks such as granite, these are so big that you can see them with the naked eye. These particles are the minerals, naturally occurring homogenous solids which have been inorganically formed. They have definite chemical compositions and definite atomic structures.

When a rock forms, the chemicals organize themselves into a number of different types, each with its own particular chemical composition, but some are more common than others. Every rock is made up of a mixture of different minerals, but usually no more than half a dozen or so. *For convenience we can divide the minerals into two broad classifications: the rock-forming minerals and the ore minerals.* The latter are those that usually come to mind when the word mineral is mentioned, those that can be mined and processed for a product, but they are a very minor constituent of the Earth's crust. Some of the well-known minerals are: amphibole, calcite, apatite, dolomite, feldspar, fluorite, garnet, gypsum, hematite, mica, olivine, quartz, and halite. We can't live without minerals and we call it a hero.

**Energy – Hero Number Eight of Lithosphere**

Energy is an important component of Lithosphere. Internal heat helps build and redeploy great sections of the Earth's crust. External energy from the sun and moon keeps sea and air in motion, and sculpts the crustal

surface. The immense amount of heat trapped below the Earth's crust has several origins, most dating from the Earth's formation. Thus there is impact energy from colliding planetesimals, energy released by core formation, heat produced by outer layers pressing on the core, and radioactive energy from isotopes incorporated in the early Earth. From the Earth's core, convection currents convey heat through mantle to the crust. More is added on the way by radioactive decay of crust and mantle minerals. Here, some heat escapes in violent volcanic eruptions, hot springs, and earthquakes. But most simply leaks out quietly through continents and ocean floors, especially from the thin crust below some oceans. The surface of the Earth's crust receives far more energy from above than below. Sunshine warms the atmosphere and crust. But sunshine warms tropics than Polar Regions. This uneven heating creates belts of differing atmospheric pressure. Winds blow from high to low pressure areas. In turn, winds drive ocean waves and surface currents. Between them, winds and currents help to spread heat more evenly around the world. Besides gaining heat from above and below, the surface of the Earth's crust loses heat by radiation into space. Loss roughly matches gain, so surface temperature has long remained about the same. Lastly, the gravitational energy provided by the moon and sun produces our ocean tides, and tidal energy inside the Earth itself.

For centuries no one knew just why a magnetic compass worked. By 1600 AD, experiments suggested that the Earth itself exerted a magnetic force on compass needles. Observations proved that the Earth indeed has a magnetic field whose force aligns compass needles with north and south magnetic poles fairly near the geographic poles. Just why the Earth should be magnetic became clear only in the middle 1900s. Scientists now realize that the Earth is less a huge bar magnet than a self-existing dynamo. Inside the Earth radioactive heat keeps streams of molten metal flowing through the outer core. *This process generates electric currents that produce magnetic fields, much as an electric current flowing through a coil of copper wire creates a magnetic field around the wire. Earth's spin around its axis helps steer currents and create magnetic poles.* Mighty eddies in the currents probably explain why magnetic poles slightly shift position from year to year. More puzzling are the hundreds of reversals of polarity occurring through Earth's history. Some rocks retain a record of the Earth's polarity at the time those rocks were formed. Paleomagnetism, the study of the Earth's magnetic field in prehistoric times, helps geologists to date certain rocks. It also helps them understand past and present movements of vast slabs of crust. There are other forces such as, gravity, strong and weak nuclear forces. All these supply energy to the planet so energy is the hero of Lithosphere.

**Matter – Hero Number Nine of Lithosphere**

Matter is divided into four essential parts: *solids, liquids, gas and plasma.* All matter is made from atoms with the configuration of the atom, the number of protons, neutrons, and electrons, determining the kind of matter present. Every substance has a unique number of protons, neutrons, and electrons. Oxygen, for example, has 8 protons, 8 neutrons, and 8 electrons. Individual atoms can combine with other atoms to form molecules. Water molecules contain two atoms of hydrogen (H2), and one atom of oxygen (O) and is chemically called H2O. Oxygen and nitrogen, which are the major components of air, occur in nature as diatomic (two atoms) molecules. Regardless of the type of molecules, matter normally exists as either: solid, liquid, gas, or plasma. We call this property of matter *"the state of the matter."* The four normal states of matter have unique characteristics which are listed as follows. In a solid the molecules are closely bound to one another by molecular forces. A solid holds its shape and the volume of a solid is fixed by the shape of the solid. In a liquid the molecular forces are weaker than in a solid. A liquid will take the shape of its container with a free surface in a gravitational field. In microgravity, a liquid forms a ball inside a free surface. Regardless of gravity, a liquid has a fixed volume. In a gas the molecular forces are very weak. A gas fills its container, taking both the shape and the volume of the container.

Liquids and gases are called fluids because they can be made to flow, or move. In any fluid, the molecules themselves are in constant, random motion, colliding with each other and with the walls of any container. When studying gases, we can investigate the motions and interactions of individual molecules, or we can investigate the large scale action of the gas as a whole. *Scientists refer to the large scale motion of the gas as the macro scale and the individual molecular motions as the micro scale.* The fourth state of the matter is found at the high temperatures and pressures which typically occur on the sun or during re-entry from space. Under these conditions, the atoms themselves begin to break down electrons are stripped from their orbit around the nucleus leaving a positively charged ion behind. The resulting mixture of neutral atoms, free electrons, and charged ions is called plasma. Plasma has some unique qualities that scientists label it a *"fourth state" of matter.* Matter surrounds us all, we are never alone. We call matter a hero.

**Carbon – Hero Number Ten of Lithosphere**

Carbon is the foundational element of all organic substances on Earth, from fossil fuels to family pets. Carbon moves through the Earth's systems in several different ways. In geologic time, weathering and erosion wash carbon-containing compounds into the ocean. Eventually they settle to the

bottom where they are eventually drawn into the Earth's mantle through a process called subduction. That carbon is eventually reintroduced into the atmosphere as carbon dioxide during volcanic eruptions. On a shorter time scale, plants use solar energy and the process of photosynthesis to remove carbon dioxide from the air and produce carbohydrates. Plants and animals return that CO2 to the atmosphere through respiration and also through decomposition. In the ocean, carbon dioxide processed by phytoplankton gets processed into calcium carbonate shells by some organisms. Those shells settle to the bottom of the ocean and form sediment. Carbon dioxide also enters sea water through simple diffusion at the surface, and some of that gets mixed into the deep ocean. Fire consumes biomass material and releases carbon dioxide to the atmosphere. Carbon dioxide in the atmosphere has diminished over several billion years of geologic history. Some of that carbon dioxide was locked into fossil fuels and sedimentary rock. All of these things happen without human intervention. So how are we impacting the carbon cycle? When we burn fossil fuels, we're releasing carbon into the atmosphere at a rate of 5.5-6 gigatons of carbon per year (giga=1 billion). In addition, land use changes such as deforestation add about 1.6 GtC per year to the atmosphere. Some of that human-produced carbon is captured by the oceans and other carbon sinks, but the net result is an addition of 3-4 GtC per year added to the atmosphere, which is why a graph of carbon dioxide is increasing steadily.

Using energy from the sun, nature's carbon cycle goes around, from the atmosphere to the forest and back. When firewood is used as an energy source, part of the natural carbon cycle is brought into our homes to heat them. A fire on the hearth releases the solar energy stored by the tree as it grew. Since all living things contain the element carbon, it is one of the most abundant elements of Earth. The total amount of carbon on Earth, whether we are able to measure it accurately or not, always remains the same, although the carbon regularly changes its form. *A particular carbon atom located in someone's eyelash may have at one time been part of some now-extinct species, like a dinosaur. Since the dinosaur died and decomposed millions of years ago, its carbon atoms have seen many forms before ending up as part of a human being.* Carbon occurs both as an element and in combined forms. As an element, it exists in at least three different allotropic forms. Allotrops are forms of an element that differ from each other in physical and, sometimes, chemical properties. *The two best known allotropes of carbon are graphite and diamond.* Graphite is a soft, shiny, dark gray or black, greasy-feeling minerals used to make the "lead" in lead pencils. Graphite is soft enough to be scratched with a fingernail. The second common allotrope of carbon is diamond. In striking contrast with graphite,

diamond is the world's hardest natural mineral. Its ability to bend and spread light produces the spectacular rainbow "fire" that is often associated with diamond jewelry. Skillful gem cutters are able to cut and polish diamonds in a way that maximizes the effect of this natural property.

**The Ten Commandments of Lithosphere**

1. Thou shall not put pressure on Lithosphere with greed: remember you have only one Lithosphere and you have very limited natural resources: Limit your consumptions.
2. Thou shall not exploit Lithosphere for its minerals, fossil fuels, water, and other non-renewable materials.
3. Thou shall not dump hazardous and toxic wastes on Lithosphere, do not litter and dispose waste in proper way.
4. Thou shall keep Lithosphere holy and friendly: respect the land, value the mountains and valleys: be inspired by natural forces.
5. Thou shall honor Lithosphere by honoring Earth and its systems such as Hydrosphere, Atmosphere and Biosphere.
6. Thou shall not damage any part of Lithosphere such as mining, dumping, drilling and blasting. Remember you are the steward.
7. Thou shall not commit abuse on Lithosphere, extracting radio-active substances and poisoning the land by fertilizers, pesticides and other chemicals.
8. Thou shall not steal gold, diamonds, coal, oil and other mineral deposits from Lithosphere: remember they are not yours: keep in your mind the generations yet to come.
9. Thou shall not harm your neighbors on the Lithosphere by your over-consumption and wasting the valuable resources like water and oil.
10. Thou shall not covet: Lithosphere has enough for all your need, but not for all your greed.

**Finally …**

Change the plates, and you will rearrange everything else. Mankind is no more than a parasitic tick gorging himself on temporary plenty while the seas are low and the climate comparatively clement. But the present arrangement of land and sea will change, and with it our brief supremacy. Meanwhile, spirituality with ethical lifestyles could sustain humanity and nature for a long time. I have therefore come to believe that the world's ecological equilibrium depends on more than just our ability to restore a

balance between civilization's ravenous appetite for natural resources and the fragile equilibrium of the Earth's environment; it depends on more, even, than our ability to restore a equilibrium between ourselves as individuals and the civilization we aspire to create and sustain. In the end, we must restore equilibrium within ourselves between who we are and what we are doing. Each of us must take a greater personal responsibility for this deteriorating condition on Lithosphere; each of us must take a hard look at the habits of mind and action that reflect, and have led to this grave crisis. *Humanity's addiction to unbridled consumerism only promises to get worse.* At the same time consumer practices serve to temporarily alleviate the anguish of an empty life.

Members of the consumer class enjoy a degree of personal independence, unprecedented in human history, yet hand in hand comes a decline in our attachments to each other. Informal visits between neighbors and friends, family conversation, and time spent at family meals have all diminished in the consumerist society. Consequently, the whole creation and human relationships are out of balance. Again I repeat, *"If You Want to Cultivate Peace, Protect Creation," wrote Pope Benedict XVI.* As priests and leaders of religious institutions, we can help protect creation by replacing, never-satisfying-consumerism with the advantages of life of sacrifice. *Sacrifice is the key to sustainable development.* Lowering consumption need not deprive people of goods and services that really matter. To the contrary, life's most meaningful and pleasant activities are often paragons of environmental virtue. The preponderance of things that people name as their most rewarding pastimes, are infinitely sustainable. Religious practice, conversation, sports, poetry, artistic and creative pursuits, education, and appreciation of nature all fit readily into a culture of permanence, a way of life that can endure through countless generations. The greatest gift we can give to our descendents is nothing but the gift of sacrifice.

Lithosphere and its forces create lots of bad and ugly stuff such as volcanoes, earthquakes and tsunamis. But it doesn't stop there. On the other hand, there's a significant amount of good, too. New islands are born, new crust is added to planet's surface, and there is change from beauty to beauty. You could argue that, without disasters, the Earth wouldn't "work right." It's like passion and death, but immediately followed by resurrection. When you are appointed in a parish or institution, even you don't like, just grin and bear it. Take advantage of every opportunity you get, because you have nothing to loose. Sometimes our parishes resemble like wilderness. Remember Israel after Egypt! The wilderness was the place where Israel was tested in its faithfulness to Yahweh and where it repeatedly failed. The

wilderness is a place of extremes, and choices are more clear-cut. Food and water are essential for physical survival. Security from external threat and internal stability are essential for social survival. These are legitimate needs, but in the wilderness, they become temptations for Israel's faith: Will they maintain their faith in the God who brought them safely from Egypt and who guides them in the wilderness? They often failed. They could not unlearn so quickly and easily all the old values of their previous way of life.

In our priestly life we find twofold problem. Some priests are oppressed because others are oppressors. History eloquently attests that most often, when a people are freed from oppression, they quickly become the oppressors tomorrow. The problem is that both share a common set of values; they agree on the basic issues, but disagree on the present arrangement of things. The chain of oppression goes on. If the Israelites, newly freed from oppression in Egypt, were to go directly into Canaan and assume power there, why would they be any different? Instead of Canaan, they come to Sinai for an extended period of *"attitude adjustment."* Jesus was also in the wilderness, was also tempted about food: unlike Israel, he kept his faith in God. What of us? As strongly as we may say that we want—and really intend—to follow God, many forces remain, within and without, to pull us away and push us toward idols. It is always the most legitimate needs (e.g., food, water, defense, internal order) which can become the most seductive idols.

Is our service of God the true foundation of our life? Our hierarchy and parish people can make our parish life as desert experience as Israelites were threatened by enemies from Egyptians first, then the Amalekites (Ex 17:8-15); later they will face others (Nm 21:1-3). Do not allow anybody or anything to sit on you and depress you. This is my motto: *"Life is never more fun than when you're the underdog competing against the giants."* I have been all my life in the boondocks, very remote parishes, making me to think that I was being harassed and abused by my superiors. I thought small parish was a burden, a disaster! However, I was able to enjoy so much of freedom and free time that gave me a new start: writing books. Therefore, I found it was no more a burden, but a blessing! I call my desert experience as a Destructive Creator. *"Everything in Nature called destruction must be Creation, a change from beauty to beauty."* We are not alone; "God is with us!" The words addressed first to Israel speak to us as well: "Do not be afraid, for I am with you (Ex 3:12). Whatever future brings, we will make it together; we will preserve even through death itself!

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