We show that the hypothesis is consistent with both the available astronomical data regarding stellar evolution and planetary formation; as well as the evolution of the earth itself, by considerations of the available geophysical data. Where data is not available, reasonably simple experiments are suggested to demonstrate further the consistency and viability of the hypothesis.

Theories are presented to help define and explain phenomenon such as how two (or more) c-2 BHs expand and collide to form a small big bang (It is postulated that there was a small big bang to form each galaxy, similar to the big bang from a category 1 BH(s) that may have formed our universe. The Great Attractors would be massive c-2 BHs and act on galaxy clusters similar to the massive c-3 BHs at the center of Galaxies acting on stars.). This in turn afforded the material/matter to form all the galactic bodies, including the dark matter inside the galaxies that we catalogue as category-3 BH(s). We conceive that c-3 BHs form gas and dust clouds, inside galaxies, that are the incubators for new stars and planets.

The start and development of the planet earth, initially as an emergent piece from the colliding c-2 BHs, is given special attention to explain the continuing expansion/growth that takes place in all stars and planets. We present a new cross section of the earth (as a dead star). Although the dimensions of the inner core, outer core, and the mantle (inner and outer) are about the same as presently known, new insight is given to their formation, evolution and composition. We explain the formation of the land, the growing/expanding earth (proportional to the ocean bed growth), the division of the continents, and the formation of the ocean beds (possibly long before the oceans existed). Attempts will be made to explain the source of the supply of water on earth.

We explain various planetary phenomenon including: how/why the earth is growing/expanding (not based on current plate tectonic theory) causing it to retard its rotation; why the oceans are different sizes (the Pacific is about twice the Atlantic); why the masses at the poles are shifting into the Atlantic Ocean (may provide an alternative explanation for the ice ages); why various types of earthquakes occur (a new source is presented), why volcanoes occur (two types are discussed); and improved prediction methods for earthquakes and volcanic eruptions; the making/forming of the mountains from bending and compression buckling, and shear failures of the outer surfaces of the earths brittle outer skin of the 1st crust (and also from eruptions) due to reduction in curvature of the crust.

U52A-0013 1330h POSTER

Atmospheric Nitrogen Fixation by Simulated Corona Discharge in the Early Precambrian Earth

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In the early evolution of life on Earth, the production of reactive nitrogen species was a fundamental prerequisite. Reactive nitrogen could have been delivered to the early Earth by exogenous contributions or fixed by endogenous sources. Exogenous sources would have had a modest role in terms of the abiotic nitrogen fixation, while it is predicted that the endogenous sources largely supplied the primitive Earth with nitrogenated compounds. Volcanic lightning could have been the most important source of reactive nitrogen (NO and NO_2) in the terrestrial troposphere (with a production rate of $\sim 10^{12}$ - 10^{13} g NO yr^{-1}), followed closely by thunderstorm lightning ($\sim 10^{12}$ g NO yr^{-1}) and post-impact plumes ($\sim 10^{12}$ g NO yr^{-1}). While the relevance of lightning as a source of fixed nitrogen has been largely studied and confirmed, the contribution of corona discharges still remain unelucidated. Here we present the first experimental simulation of the production of nitrogen oxides by corona discharge in the primitive Earth's atmosphere during the Hadean and the Archean eras. NO was detected as the main product whereas N_2O as the secondary product. Assuming that the global coronal discharge energy available on early Earth was $\sim 5 \times 10^{17}$ J yr^{-1}, our results imply that the maximum annual production rates of NO and N_2O were of the order of 10^9 g yr^{-1} and 10^8 g yr^{-1} respectively. These rates are low and therefore corona discharges did not play a significant role in the overall pool of reactive nitrogen needed for the emergence of life.

U52A-0014 1330h POSTER

Preliminary Phase Diagram for the Richardton H-Chondrite

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The earliest history of the accreting Earth involved the removal of metallic liquids to the core and segregation of silicates into a layered Earth. One hypothesis for core formation is that descending metallic liquids equilibrated with silicate liquids in the deep mantle. Of current interest is the possibility that a primordial magma ocean may have acted as a host for both silicate and metallic liquid segregation. The silicate liquid composition may have changed by processes such as crystal settling or flotation during accretion as the planet increased in size. If these were equilibrium processes, a P-T phase diagram of representative accretion material could be used to constrain the chemical evolution of the Earth by identifying silicate minerals and liquidus phases present at elevated pressures and temperatures (Agee, 1990; Agee et al., 1995).

Experiments were carried out in a "Walker-type" 6-8 multi-anvil device in a 1100 ton press. Pressures from 5 to 11 GPa, at temperatures from 1050 to 2100 °C, have been investigated using an 8 mm TEL assembly with a LaCrO3 furnace and either MgO or graphite capsules. Experiment durations were from 4 to 31 minutes. We chose the Richardton H-chondrite as starting material because it is a reasonable representation of the bulk Earth. An ongoing problem with these experiments is containment of the liquids within the MgO capsules. Additionally, the MgO capsule reacts with the silicate liquids, elevating the MgO content of the silicate melt and reducing the FeO content. Experiments conducted in graphite capsules do not have a containment problem. Phases present were tentatively identified using EDS spectroscopy.

In the investigated P-T range, run products contain olivine of intermediate composition, low- and high-Ca pyroxene, and small amounts of garnet in subsolidus experiments. Runs conducted at 1700 °C contain silicate liquid, olivine, and low Ca pyroxene at 6 GPa, but silicate liquid, olivine, low and high Ca pyroxene at 9 GPa. At 1800 °C and 9 GPa runs contained silicate liquid, olivine and garnet. All runs contained metal-sulfide liquids.

Our preliminary data indicates the liquidus near 9 GPa occurs at about 1975 °C. This falls within the expected range between 1875 °C for the Allende meteorite (Agee et al., 1995), and 2100 °C for peridotite (Zhang and Herzberg, 1994). Future experiments will more fully characterize the slope of the liquidus, particularly in the pressure range of 20 to 27 GPa, the pressures most relevant to a deep magma ocean.

U52B MC: 134 Friday 1330h

Archaeological Evidence for Historic and Prehistoric Earthquakes and Volcanic Eruptions and Their Impact on Human Settlements

Presiding: **A Nur,** Stanford University**; R L Kovach,** Stanford University

U52B-01 1330h

The Collapse of Ancient Societies by Great Earthquakes

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Although earthquakes have often been associated with inexplicable past societal disasters their impact has thought to be only secondary for two reasons: Inconclusive archaeological interpretation of excavated destruction, and misconceptions about patterns of seismicity. However, new and revised archaeological evidence and a better understanding of the irregularities of the time-space patterns of large earthquakes together suggest that earthquakes (and associated tsunamis) have probably been responsible for some of the great and enigmatic catastrophes in ancient times.

The most relevant aspect of seismicity is the episodic time-space clustering of earthquakes such as during the eastern Mediterranean seismic crisis in the second half of the 4th century AD and the seismicity of the north Anatolian fault during our century. During these earthquake clusters, plate boundary rupture by a series of large earthquakes that occur over a period of only 50 to 100 years or so, followed by hundreds or even thousands of years of relative inactivity. The extent of the destruction by such rare but powerful earthquake clusters must have been far greater than similar modern events due to poorer construction and the lack of any earthquake preparedness in ancient times.

The destruction by very big earthquakes also made ancient societies so vulnerable because so much of the wealth and power was concentrated and protected by so few. Thus the breaching by an earthquake of the elites fortified cities must have often led to attacks by (1) external enemies during ongoing wars (e.g., Joshua and Jericho, Arab attack on Herods Jerusalem in 31 BCE); (2) neighbors during ongoing conflicts (e.g., Myceneas fall in @1200 BCE, Sauls battle at Michmash @1020 BCE); and (3) uprisings of poor and often enslaved indigenous populations (e.g., Sparta and the Helots @465 BCE, Hattusas @1200 BCE?, Teotihuacan @ 700 AD).

When the devastation was by a local earthquake, during a modest conflict, damage was probably limited and may have required a few tens of years to rebuild. But when severe ground shaking is widespread, and when it happened during a major military conflict the devastation may have been so great that it took hundreds of years for a society to recover- going through a dark ages period during which many of the technical skills (e.g., writing) are abandoned (e.g., the cessation of linear B), construction and repairs of monumental buildings ceased, and looting of building materials by surviving squatters was common. In contrast we can imagine the pastoral countryside, especially away from the tsunami prone coastal areas, to have been much less affected (and perhaps even flourished a little as their tax burden to the ruling elite is reduced).

During a regional seismic crisis an entire region must have been subjected to a series of devastations by earthquakes over a short period of time. The catastrophic collapse of the main eastern Mediterranean civilizations at the end of the Bronze Age may be a case in point, with the Sea People being mostly squatters and refugees.

U52B-02 1350h

Earthquake Archaeology: a logical approach?

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Ancient earthquakes can leave their mark in the mythical and literary accounts of ancient peoples, the stratigraphy of their site histories, and the structural integrity of their constructions. Within this broad cross-disciplinary tramping ground, earthquake geologists have tended to focus on those aspects of the cultural record that are most familiar to them; the physical effects of seismic deformation on ancient constructions. One of the core difficulties with this 'earthquake archaeology' approach is that recent attempts to isolate structural criteria that are diagnostic or strongly suggestive of a seismic origin are undermined by the recognition that signs of ancient seismicity are generally indistinguishable from non-seismic mechanisms (poor construction, adverse geotechnical conditions).

We illustrate the difficulties and inconsistencies in current proposed 'earthquake diagnostic' schemes by reference to two case studies of archaeoseismic damage in central Greece. The first concerns fallen columns at various Classical temple localities in mainland Greece (Nemea, Sounio, Olympia, Bassai) which, on the basis of observed structural criteria, are earthquake-induced but which are alternatively explained by archaeologists as the action of human disturbance. The second re-examines the almost type example of the Kyparissi site in the Atalanti region as a Classical stoa offset across a seismic surface fault, arguing instead for its deformation by ground instability. Finally, in highlighting the inherent ambiguity of archaeoseismic data, we consider the value of a logic-tree approach for quantifying and quantifying our uncertainities for seismic-hazard analysis.

U52B-03 1410h

Fault-Related Sanctuaries

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Beyond the study of historical surface faulting events, this work investigates the possibility, in specific cases, of identifying pre-historical events whose memory survives in myths and legends. The myths of many famous sacred places of the ancient world contain relevant telluric references: sacred earthquakes, openings

to the Underworld and/or chthonic dragons. Given the strong correspondence with local geological evidence, these myths may be considered as describing natural phenomena. It has been possible in this way to shed light on the geologic origin of famous myths (Piccardi, 1999, 2000 and 2001).

Interdisciplinary researches reveal that the origin of several ancient sanctuaries may be linked in particular to peculiar geological phenomena observed on local active faults (like ground shaking and coseismic surface ruptures, gas and flames emissions, strong underground rumours). In many of these sanctuaries the sacred area is laid directly above the active fault. In a few cases, faulting has affected also the archaeological relics, right through the main temple (e.g. Delphi, Cnidus, Hierapolis of Phrygia). As such, the arrangement of the cult site and content of relative myths suggest that specific points along the trace of active faults have been noticed in the past and worshiped as special sacred places, most likely interpreted as *Hades Doors*.

The mythological stratification of most of these sanctuaries dates back to prehistory, and points to a common derivation from the cult of the Mother Goddess (the Lady of the Doors), which was largely widespread since at least 25000 BC. The cult itself was later reconverted into various different divinities, while the sacred doors of the Great Goddess and/or the dragons (offspring of Mother Earth and generally regarded as Keepers of the Doors) persisted in more recent mythologies.

Piccardi L., 1999: The Footprints of the Archangel: Evidence of Early-Medieval Surface Faulting at Monte SantAngelo (Gargano, Italy). European Union of Geophysics Congress, Strasbourg, March 1999. Piccardi L., 2000: Active faulting at Delphi (Greece): seismotectonic remarks and a hypothesis for the geological environment of a myth. Geology, 28, 651-654. Piccardi L., 2001: Seismotectonic Origin of the Monster of Loch Ness. Earth System Processes, Joint Meeting of G.S.A. and G.S.L., Edinburgh, June 2001.

U52B-04 1430h

Impacts of Large Historical Earthquakes on Ancient Cities in the Buyuk Menderes and Gediz Grabens, Western Turkey

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Western Turkey is currently experiencing roughly NNE-SSW stretching and this stretching has give rise to a distributed horst and graben topography that characterises most of western Turkey. The Buyuk Menderes and Gediz grabens, which are the most tectonically active structures of western Turkey, were important routeways for peoples and armies travelling either from west or east between the coastal cities and Anatolia. Thus, important ancient cities were established both on the coast and along the grabens. The Menderes graben (ancient Maeander Valley) provided the easiest pathway from the Aegean coast via Miletus, Priene, Magnesia, Tralles and Nysa but the Gediz Graben was also a vital route from the coast via Sardis and Philadelphia to the interior cities such as Laodicea, Hierapolis and Aphrodisias.

The Buyuk Menderes and Gediz grabens contain active normal fault geometric segments that have ruptured during major events in the historical period. Field survey in the major ancient cities along the grabens showed that they contain an abundance of ground shaking damage and faulted archaeological relics related to damaging earthquakes. Analysis of field evidence indicates that large historical earthquakes played important role in the history of ancient cities located along the Buyuk Menderes and Gediz grabens. On the basis of field observations, it is concluded that: (1) the ancient cities were damaged by earthquakes several times and they were reconstructed; (2) the present locations of Priene and Hierapolis are not the original sites where they were first founded. The original sites of Priene and Hierapolis were destroyed by destructive earthquakes in 350 B.C. and 60 A.D., respectively, and the cities were shifted to their present locations; (3) the ancient cities of Laodicea and Hierapolis were abandoned after a destructive earthquakes in 1354 A.D.; and (4) Miletus (modern Balat) was ruined during the 16 July 1955 earthquake (M=6.8) and the modern town of Balat was shifted about 5 km southward.

U52B-05 1510h

A Case Study in Archaeoseismology: the Collapses of the Temples at Selinunte (South-Western Sicily)

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This work presents the results of a research that was carried out to further our knowledge of the active faults in south-western Sicily. The only seismic event of particular significance that is known to have occurred is that of 15 January 1968 (Io= XMCS, Me 6.5) in the Belice valley. The archaeological park of Selinunte, the largest in the Mediterranean area, with its great temples and evidence of spectacular collapses, has been taken as a source of information capable of analysis by means of the methodological approach of archaeoseismology. The identification of the seismic indicators at Selinunte necessitated a detailed analysis of both old and new archaeological evidence, together with a critical re-examination of all the archaeological literature and existing documents dating from to the eighteenth century, together with travelers accounts of that time. The history of the archaeological deposits, spoliation, and excavations has been reconstructed. These data are reinterpreted in the light of both the new discoveries of the most recent research, and of a number of methodological criteria already used in previous works on archaeoseismology. This long and complex analysis was carried out in 1998-99 with Anna Muggia, Clemente Marconi and Enzo Boschi in the research programme of the Istituto Nazionale di Geofisica e Vulcanologia. It resulted in the identification of two seismic events that struck Selinunte and led to the collapse of the temples. The chronology of the earthquakes can be dated, for the first, to a period between the fourth and third century BC; for the second, to a period between the sixth and the thirteen century AD. Although the time span proposed, particularly for the second earthquake, is very broad, it does not mean that this earthquake is in anyway hypothetical from a geophysical point of view. Its traces are clear, but the long periods when the site was abandoned mitigate against the fixing of a precise date for the event. In order to reach the conclusions it was necessary in addition to analyze and visualize in a systematic way the direction of collapse of the temples. This work provided new information for an archaeological identification of the two seismic events, as well as making an important contribution from the seismic point of view, namely data on the direction of collapse and the general relationship of these data to the whole Selinunte site. These results now make it possible to engage on new paleoseismic research into the location of the faults involved, and engineering research to construct a model of the response of the temples to a seismic event, and calculate an possible acceleration value.

U52B-06 1530h

The Earliest Hominid Migration out of Africa and Near East Colonization

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It is generally accepted that Central East Africa was the springboard for hominid evolution in the latest Miocene or Early Pliocene. However the timing and pathways of migrations from Africa to Eurasia are still debatable. The only certain land bridge and main route between Africa and Eurasia since the Late Pliocene-Early Pleistocene is the Levantine Corridor. This is evident in some of the most ancient remains of early hominids and tools outside Africa in the Middle East.

The study of Lower Paleolithic sites in this region and in the neighboring area sheds some light on several potential migration and colonization events. The determination of ages of the prehistoric sites is crucial for any study of early human migration events, but it is also the most difficult data to recover. The typo-technological studies yield only relative age, and so do sequences of raised Pleistocene beaches, marine deposits, river terraces and paleo-lake formations. The scarcity of volcanic ash deposits excludes radiometric dating.

Israel located at the Levantine Corridor yields a wealth of prehistoric findings and sites. We combine paleomagnetic and thermoluminescence measurements as dating tools. This new combination yields high quality, surprising results. Several preliminary paleomagnetic studies of lake deposits, cave deposits and soil sequences in well known sites in Israel such as the Erk-El Ahmar formation, and the Lower Paleolithic Tabun Cave in Mount Carmel, the Evron Quarry in northern Israel, and Rochama site in southern Israel.

We conclude that the part of Erk-El-Ahmar Formation, which bears core-choppers and flakes, identified as typical Oldowan tools were deposited about 1.7-2.0 Ma. We found that the Rochama and Evron sites are located in soil sequences, several meters below the 0.78 Ma Brunhes-Matuyama boundary. Based on continuous soil accumulation rates and pedogenesis processes the age of these sites is about 1 Ma. This new data provides the first constraint for the 1 Ma and older hominid colonization along the Levantine Corridor, offering a glimpse at the first journey out of Africa.

U52B-07 1550h

Tectonic Activity during the Harappan Civilization

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The Harappan civilization in South Asia existed between 3,300 and 1,900 BC. Extensive remnants from this era are found in Pakistan and northwestern India. The region is far from plate boundaries and, until recently, has been considered tectonically inactive. A combination of data from current and historic seismicity, marine seismic surveys, and prevalent geologic and tectonic features with archeological findings, historical and scriptural records, and GIS mapping of large scale areas shows:

1. Occurrence of earthquakes starting from the 26th January, 2001 event to as far back as 2500 BC
2. Existence of an ancient river, Saraswati corroborated with historical records, GIS mapping, marine seismic surveys
3. Sea level changes from archeological excavations of variations in fauna.

We show how a cross-disciplinary study can provide ways of filling information gaps and providing new insights. A comparison between isoseismal lines from the Magnitude 8 event of 26^{th} January, 2001 with location of Harappan cities shows that most cities would have been obliterated by such an event.

URL: http://pangea.stanford.edu/∼manika/harappa.html

U52B-08 1605h

Evidence for Ancient Mesoamerican Earthquakes

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Evidence for past earthquake damage at Mesoamerican ruins is often overlooked because of the invasive effects of tropical vegetation and is usually not considered as a casual factor when restoration and reconstruction of many archaeological sites are undertaken. Yet the proximity of many ruins to zones of seismic activity would argue otherwise. Clues as to the types of damage which should be soughtwere offered in September 1999 when the M = 7.5 Oaxaca earthquake struck the ruins of Monte Alban, Mexico, where archaeological renovations were underway. More than 20 structures were damaged, 5 of them seriously. Damage features noted were walls out of plumb, fractures in walls, floors, basal platforms and tableros, toppling of columns, and deformation, settling and tumbling of walls. A Modified Mercalli Intensity of VII (ground accelerations 18-34 %b) occurred at the site.

Within the diffuse landward extension of the Caribbean plate boundary zone M = 7+ earthquakes occur with repeat times of hundreds of years arguing that many Maya sites were subjected to earthquakes. Damage to re-erected and reinforced stelae, walls, and buildings were witnessed at Quirigua, Guatemala, during an expedition underway when then 1976 M = 7.5 Guatemala earthquake on the Motagua fault struck. Excavations also revealed evidence *(domestic pttery vessels and skeleton of a child crushed under fallen walls)* of an ancient earthquake occurring about the teim of the demise and abandonment of Quirigua in the late 9^{th} century. Striking evidence for sudden earthquake building collapse at the end of the Mayan Classic Period ∼A.D. 889 was found at Benque Viejo (Xunantunich), Belize, located 210 north of Quirigua. It is argued that a M = 7.5 to 7.9 earthquake at the end of the Maya Classic period centered in the vicinity of the Chixoy-Polochic and Motagua fault zones cound have produced the contemporaneous earthquake damage to the above sites. As a consequences this earthquake may have accelerated the collapse of the hiearchical authority at these locations and may have contributed to the end of the Classic culture at other nearby sites in proximity to the Caribbean plate boundary zone.