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A TREATISE ON HOW THE PROCESS OF GRAVITATIONAL CAPTURE OF A MAJOR SATELLITE CAN ALTER THE EVOLUTIONARY HISTORY OF TWO OUTSTANDING TERRESTRIAL PLANETS

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This book is dedicated to my wife, MARY ANN, for her multidimensional support, assistance, and counsel over the years which helped to bring this project to completion. In our years together we have had many great experiences in both well-travelled and remote areas on this amazing planet.

Preface

Earth is a very unusual planet and the Moon is a very unusual satellite. Our "twin sister" planet is also a very unusual planet. If Venus had a sizeable satellite in prograde orbit as Earth does, then life would be a bit simpler for the earth and planetary science community. Furthermore, if planet Venus had a transparent moderate density atmosphere, oceans of water, and continents with linear mountain belts, we would have far fewer questions about planet Venus. And if we could spot a few pyramids, whether trigonal, tetragonal, hexagonal, or octagonal, we would be very curious about the nature and history of the civilizations on our sister planet.

The characteristics of planet Venus, however, are much different than what we normally would predict for a "sister planet". The only attributes that Earth and Venus have in common are planetary mass, planetary density, and location at a similar distance from the Sun. So the main question of this book is: What happened to planet Earth to make it the **"paradise planet"** that we live on today? Or we can turn the question around and ask: "What happened to planet Venus to make it into the **"hades planet"** that it is today?

The purpose of this book is to present a scientific story for the development of the twin sister planets, Earth and Venus, that is consistent with our present knowledge of the Solar System and that is very testable by present and future earth and planetary scientists. This book has ten chapters of varying lengths and I think that it takes ten chapters to ask the questions and to tell the story. If only Earth, Venus, the Moon, and the Sun were involved, perhaps five chapters would be sufficient. But nearly the entire Solar System is involved in this scientific story of the twin sisters. Thus the narrative gets a bit lengthy and more complex than most of us would like to believe. This book represents something like the antithesis of the basic tenants of the test of Occam's Razor. A common statement of this test is that **"the simplest explanation for some phenomenon is more likely to be accurate than more complicated explanations."** I will admit that Occam's Razor works well for many problems in the world of science. But its usefulness in the earth sciences has some limitations. As a first example let us consider the Continental Drift/Plate Tectonics model. Although the model is simple in principle, it is very complex in detail and some 40 plus years after general acceptance, and a full century after conception of the idea, concerned scientists still cannot agree on when our modern style of plate tectonics began. As a second example let us briefly consider the model of Milankovitch for explaining the ice ages on Earth. When I took a "Glacial and Pleistocene Geology" course in 1965, there were perhaps three pages on the idea in one of the best textbooks on the subject. The conclusion was that the model had failed many scientific tests and the implication was that the idea was not worthy of serious scientific consideration. Then by the middle 1970s, the Milankovitch Model emerged for serious consideration and is now a very useful paradigm in the earth sciences. Is it a simple model? NO! Is it easy to test? NO! Does this work with the Milankovitch Model support the basic tenents of the test of Occam's Razor?

How does the concept of Occam's Razor fit in with the story of the twin sister planets? I can state that the story of the twin sister planets is "simple in principle but somewhat complex in detail". In my opinion, the complexities, including the probability of a favorable outcome for certain processes, outweigh the simplicities.

A major theme of this book is that our twin sister planets had very similar physical and chemical characteristics soon after they were formed about 4.6 billion years ago. They formed in the same region of space and, according to the most recent work on planetary orbit resonances, they have been "shepherding" each other, as many twin sisters do, in a way to make their sun-centered orbits mutually stable. As a result the orbits of Venus and Earth are by far the most stable orbits in the inner part of the Solar System. Their life-long planetary partners (the planetoids that eventually become their satellites in this story) were accreted from material much closer to the Sun but also ended up in fairly stable sun-centered orbits. According to the most recent calculations their orbits were, in their first several 100 million years, the second most stable orbits in the inner Solar System. These planetoids, Luna and Adonis, eventually get perturbed out of their orbits of origin into a Venus-like orbit (for Adonis) and an Earth-like orbit (for Luna). They then get gravitationally captured by these large terrestrial planets and this is where the life histories of these planet-satellite pairs diverge. Venus captures Adonis into a **retrograde** orbit (that is, the planet is rotating in one direction and the satellite is orbiting in the opposite direction). Earth captures Luna in a **prograde** direction (that is, the planet is rotating in the same direction as the satellite is orbiting the planet). The remainder of the story is "planetary history". The end result is that the twin sisters are now "polar opposites" for habitability.

Chapter 1 is an introduction to the characteristics of the twin sister planets. Chapter 2 is a brief discourse on the early history of the Sun and how and why this early history is so important to the formation of Luna and Adonis, in particular, but really for all planets, planetoids, and asteroids out to at least the vicinity of planets Jupiter and Saturn. Chapter 3 is a brief treatment of intellectual endeavors associated with developing explanations for the origin of the Earth-Moon system. Chapter 4 is an explanation of my model of gravitational capture of planetoid Luna by planet Earth to form the Earth-Moon system. Chapter 5 consists of a series of "vignettes" (brief to the point stories) on various topics in the planetary sciences. The first three vignettes involve an analysis of the patterns of lunar maria and mascons (mass concentrations) that I think is crucial for developing a more meaningful interpretation of the features of the Moon than we have at present. Another vignette is on a process for partially recycling a primitive crust inherited from a "cool early Earth" into the Earth's mantle by way of the very high amplitude rock tides caused by the process of gravitational capture. The final vignette in the chapter is on the subject of the origin of water on the twin sister planets, a somewhat neglected subject in the earth sciences but an important issue for our planet in particular. Chapter 6 is an explanation of my model for the retrograde capture of planetoid Adonis (a planetoid that is only one-half as massive as Luna) by Venus and the subsequent evolution of the system over time. A major feature of this model is that planet Venus has the possibility of being habitable for about 3 billion years before surface conditions deteriorate. Chapter 7 is a bit different in that it is more like "make believe" or "alternate reality" in that it presents a model for a retrograde capture of a lunar-mass satellite by Earth. The final result is an earth-like planet that has many of the features of planet Venus today: i.e., a "hades-like" scene, featuring a dense, corrosive atmosphere on a planet rotating slowly in the retrograde direction and with no satellite. In Chapter 8 some new concepts are introduced. The general theme of the chapter is that Planet Orbit—Lunar Orbit Resonances may be important for explaining some critical events in Earth History such as the beginning of the modern style of plate tectonics and the transition from a bacteria-algae based biological system to one featuring metazoan-type organisms. The main characters in the Planet Orbit—Lunar Orbit Resonances are "big brother" Jupiter for one resonance episode and "twin sister" Venus for three episodes. Chapters 9 and 10 pose some questions about how all these complex episodes in the historical development of Earth and Venus, and indeed in the history of the Solar System, relate to the habitability of our planet and for the possibility of finding other candidate planets for habitability.

Acknowledgements

This project has been something like a forty-year endeavor. I thank Dick Heimlich (Kent State University) for getting me acquainted with the primitive Earth by way of the Bighorn Mountain project. Introduction to the geological literature on the primitive Earth eventually led to some very fruitful interactions with Preston Cloud (University of California, Santa Barbara). Thanks to Tom Vogel (Michigan State University) for permitting me to do a somewhat "risky" Ph. D. project on Precambrian interactions of the Earth and Moon in contrast to a more normal Precambrian Geology project. Thanks to Tom Stoeckley (Physics-Astronomy Department, Michigan State University) for the use of an n-body computer code that my Denison University colleagues and I have been using, in modified form, over the years. I also acknowledge the very positive interactions and discussions with former graduate school colleagues at MSU: Gary Byerly (University of Louisiana, Baton Rouge) and Graham Ryder (now deceased but for many years at the Lunar and Planetary Science Institute, Houston) as well as to former MSU professor Bob Ehrlich. Special thanks to Ron Winters (Denison University Physics and Astronomy Department) for sticking with the project and for the physics and computer work and dedicated time working with physics and computer science students, David Mehringer, Wentao Chen, and Albert Liau, in the late 1980's and early 1990's without whom this project would not have progressed. I give special thanks to John Valley (University of Wisconsin, Madison) for developing the "Cool Early Earth" model and for encouragement to pursue a planetoid capture model for the origin of the Earth-Moon system. I also give thanks to Fred Singer for his pioneering work on the concepts of gravitational capture.

On the local front, I am grateful to Dave Selby, Cheryl Johnson, and Leslie Smith (Denison University ITS Group) for technical support and manuscript preparation, respectively. Thanks to Denison University for office space, computer equipment, and other support over the years since retirement. I note here that most of the critical concepts that made the world safe for capture studies occurred after my retirement (e.g., stable Vulcanoid planetoid orbits, a Cool Early Earth, recycled primitive crust on Earth). Special thanks to my retired colleague, Ken Bork, for his encouragement over several decades to pursue my ideas on the origin and evolution of the Earth-Moon system. Thanks to Tom Evans for his long-term interest in this project and for sharing his knowledge of the resources in the Harold Urey Collection in the Archives at the University of California, San Diego. And finally, thanks to my active departmental colleagues and generations of geoscience students for the many questions and comments that helped in the development of my ideas on gravitational capture of satellites by planets and thanks to Ron Doering, Springer, for his guidance in manuscript preparation. And on a very personal level, I am very grateful to my wife, Mary Ann, for her perusal of several renditions of each chapter and for her special advice and constructive criticism. The manuscript is much improved because of her careful attention to detail.

Contents

Chapter 1
Introduction

"We believe that life in the form of microbes or their equivalents is very common in the universe, perhaps more common than even Drake and Sagan envisioned. However, complex life—animals and higher plants—is likely to be far more rare than is commonly assumed. We combine these two predictions of the commonness of simple life and the rarity of complex life into what we will call the Rare Earth Hypothesis." From Peter D. Ward and Donald Brownlee, 2000, Rare Earth (Why complex life is uncommon in the Universe): Copernicus (An imprint of Springer-Verlag), p. xiv.

The above statement will resonant very well with the content of this book in that I am attempting to explain some of the unusual events that have acted on our planet, EARTH, and our sister planet, VENUS, over the course of Solar System history to make them polar opposites for habitability. A currently popular explanation for the unusual nature of planets Earth and Venus is that they were affected differently by giant impacting bodies early in their respective histories. Mackenzie (2003) expounds on the virtues of the "GIANT IMPACT MODEL" for Earth and recently Davies (2008) explained how a giant impact might relate to some of the outstanding features of Venus. I do *not* agree with these *ad hoc* explanations for the contrasting differences in the conditions of these sister planets. The explanation I am developing in this book is that both Earth and Venus captured planetoids from heliocentric orbits into planet-centered orbits early in their planetary lives. Earth captured a planetoid that I am calling LUNA [a name coined by Alfven and Arrhenius (1972) for our satellite before capture] into a prograde orbit about 3.95 billion years (Ga) ago and it is still with us at the present time. In contrast, Venus captured a sibling planetoid (a sibling to Luna that I have named Adonis that was about one-half as massive as Luna) into a retrograde orbit: i.e., the satellite orbits in the opposite direction to the rotation of the planet. To make a three billion year story a bit shorter, Adonis no longer exists! This satellite coalesced with Venus after despinning the planet to essentially zero rotation rate over a period of about 3 billion years. [Note:

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The basic scenario of retrograde capture for a satellite for Venus was first proposed by Singer (1970) and I have simply added a few phases to his model.]

Let us keep in mind that a giant impact of a Mars-sized body on an Earth-like planet would be an unusual event. Likewise, capture of a moon-sized body from a heliocentric orbit is an unusual event! Indeed, gravitational capture of a one-half moon-mass planetoid from a heliocentric orbit into a venocentric orbit seems to be an additional complication, but as we will discover, this retrograde capture model for planet Venus explains many of the features of planet Venus very well.

1.1 The Scientific Method

The SCIENTIFIC METHOD is a procedure for testing new ideas in the natural sciences. It works for "big picture" ideas as well as for local field study problems. There are five basic steps to the process:

a. We start with a LIST OF OBSERVATIONS OF A NATURAL PHENOMENA (i.e., the facts to be explained by our hypothesis or model—a model simply being a somewhat more detailed explanation than an hypothesis)
b. We FORMULATE AN HYPOTHESIS (An hypothesis is simply an untested explanation)
c. We TEST THE HYPOTHESIS (1) by making more observations of the natural phenomena being investigated, (2) by doing relevant experiments, (3) by doing relevant calculations, and (4) by making predictions and then independently checking the predictions for accuracy.
d. The HYPOTHESIS is either VERIFIED or REJECTED based on the results of the tests. In many cases in "big picture" natural science issues, the verification or rejection can come decades after the hypothesis is proposed. And in some cases, a rejection is reversed to verification after a new test or new technology for testing the idea has been discovered or invented.
e. If VERIFIED, an HYPOTHESIS becomes a THEORY (a theory is simply a well-tested explanation)

Two recent articles on the SCIENTIFIC METHOD are Lipton (2005) and van Loon (2004). These authors emphasize the progression from speculations to hypotheses to models as well as the concept of making predictions that can be independently tested (i.e., without prejudice).

Now let us discuss some of the special characteristics of the subjects of this book: the twin sister planets, Venus and Earth. Figure 1.1 shows a planar view of the geometry of part of the Solar System and this diagram will give the reader some orientation for the discussions in this introductory chapter. Figure 1.2 shows typical images of the terrestrial planets: Earth, Venus, Mars, and Mercury. We will begin our cursory survey of Earth and Venus by listing and briefly discussing some special features of the Earth as a planet and then focus our attention on planet Venus.

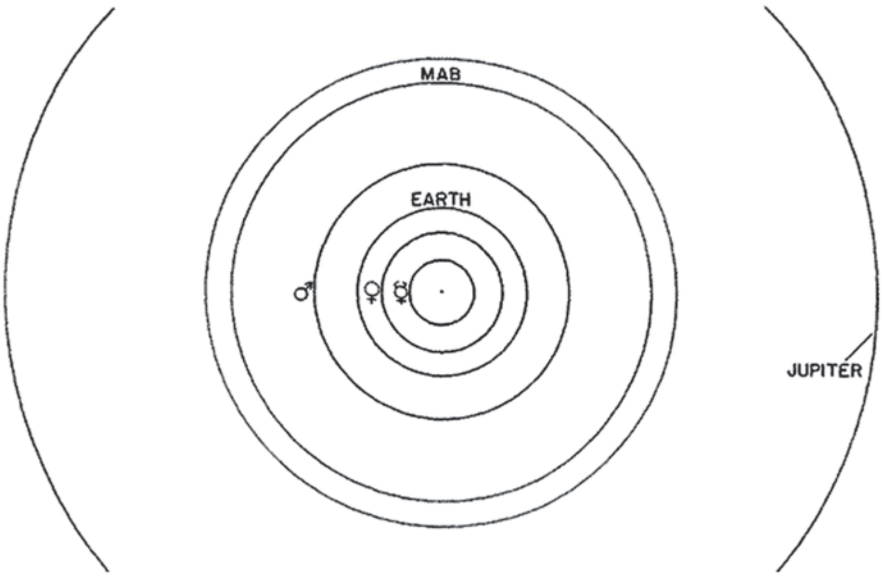

Fig. 1.1 Scale sketch of the orbits of the planets in the inner part of the Solar System. Mars is between Earth and MAB (*Main Asteroid Belt*). Venus and Mercury, respectively, are interior to Earth. For scale, Earth is located at 1 astronomical unit (*AU*)

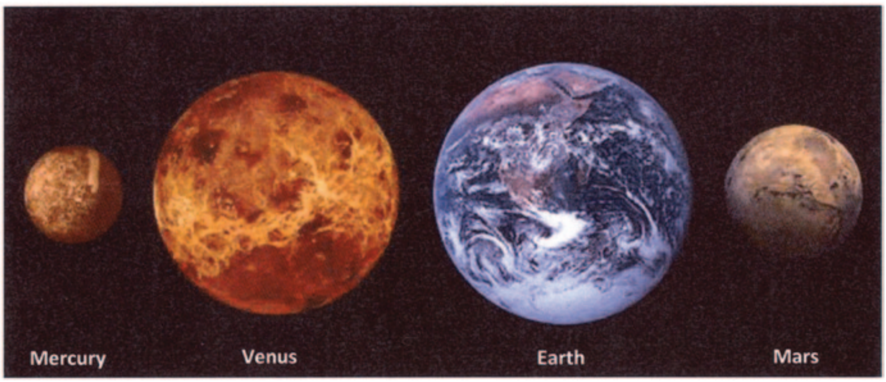

Fig. 1.2 Scale pictograms of the four terrestrial planets. Note that the twin sister planets, Venus and Earth, are very similar in diameter. (From Faure and Mensing (2007, Fig. 11.1), (NASA, LPI)

1.2 Some Special Features of Earth as a Planet

- LIQUID WATER ON THE SURFACE: At present, the Earth is the only planet with standing water on the surface and we have oceans of water as well as lakes, rivers, and streams of various shapes and sizes. By comparison our terrestrial neighbors appear not to have so much as a mud puddle at the present time. Mars does, however, have features which suggest that it did have liquid water on its surface in the past. These features are channel systems with branching tributaries which look very much like stream channels on Earth (Carr 1999). Venus apparently has even less water than Mars. The atmosphere of Venus (over 100 times denser than the Earth's) has less than 1 % water vapor (Saunders 1999). The surface rock temperature is about 600 °C, much too hot to permit liquid water on the surface. In the scientific literature there is an ongoing discussion of the "Venus Oceans Problem". The main evidence for water on Venus is the deuterium to hydrogen ratio that suggests that it may have had "oceans" of water in past eons (Young and Young 1975; Dauvillier 1976; Donahue et al. 1982; Donahue 1999).

- FREE OXYGEN IN THE ATMOSPHERE: At present, the Earth is the only planet with free oxygen in the atmosphere. The present composition of the atmosphere is 78 % nitrogen (a nearly inert gas), 21 % oxygen (a very reactive gas), and 1 % inert gases such as neon, crypton, xenon, etc., and carbon dioxide). A small amount of free oxygen can be expected in a planetary atmosphere due to the photo-dissociation of water into hydrogen and oxygen and of carbon dioxide into carbon monoxide and oxygen by solar ultraviolet radiation. The amount of oxygen in the Martian atmosphere is consistent with that expected from photo-dissociation. Oxygen is a very *unlikely* gas to accumulate in a planetary atmosphere because it is very reactive and readily oxidizes the abundant metallic ions (like Fe) at a terrestrial planet surface. There is general agreement in the scientific community that if it were not for the continuous generation of free oxygen by photosynthesis, we would not have our great abundance of free oxygen (Berner et al. 2003). The oxygen content of the Earth's atmosphere has varied considerably over the past 600 million years. It has been as high as 30 % in the Carboniferous Period to as low as 12 % at the Permian-Triassic boundary (Berner 2006).
- THE ABUNDANCE AND DIVERSITY OF LIFE FORMS: The above two unique features of Earth (the presence of water on the surface and the presence of free oxygen in the atmosphere) have apparently made possible another unique feature—the presence of an abundance and significant diversity of biological forms. We do not yet know how nearly unique our biological system is in the Solar System, but we are very sure (after the data gathered by several lander and rover missions to Mars) that there are no obvious life forms on planet Mars. Nor do we expect much biological activity in the dense Venusian atmosphere. In addition, we have found no evidence for present or former life on our essentially atmosphere-free natural satellite, the Moon.
- THE PRESENCE OF A STRONG MAGNETIC FIELD RELATIVE TO THE SIZE OF THE PLANET: A fourth unusual feature of our terrestrial planet, EARTH, is the presence of an active magnetic field. There are two other bodies in the Solar System that have presently active magnetic fields—the Sun and the giant planet Jupiter. Three terrestrial bodies in the inner part of the Solar System, the Moon, planet Mercury, and planet Mars have magnetized rocks on their surfaces, but these remanent magnetic patterns appear to be the products of long-since decayed magnetic fields. (We have not yet detected strong fossil magnetic patterns or an internally generated field associated with planet Venus).

I note here that although we humans use the terrestrial magnetic field continuously for navigational purposes (as do sea turtles, birds, fish, etc.), we still do not understand the details of the mechanism of its generation. Is it due to (a) the rotation of the Earth, (b) the precession of the Earth, (c) the tidal retardation of the rotation of the mantle-crust complex relative to the inner core via lunar tidal torque, or (d) a combination of these. Concerned scientists know that the polarity of the field changes with an average period of about 1 million years but they are not sure of any definite major biological consequences of these polarity changes. However, studies of oceanic sediments suggest that extinction of some species of micro-organisms may be associated with these reversals of the magnetic field but no large animal extinctions have been associated with magnetic reversals (Strangway 1970; Glassmeier and Vogt 2010).

- THE PRESENCE OF A LARGE SATELLITE RELATIVE TO THE MASS OF THE PLANET: A fifth unique feature of the Earth as a terrestrial planet is the presence of a very large satellite, the Moon. The mass ratio of the Moon to the Earth is about 1–81: this is the highest for any satellite-planet system in the Solar System. A common ratio for satellite-planet systems is 1–5000. The only other terrestrial planet with satellites is Mars which has two very small ones. Thus, we may ask if the presence of this exceptionally large satellite, the Moon, has had anything to do with the development of the previously discussed unique features of planet Earth? My view is that the presence of the Moon in orbit about the Earth *has had a significant effect* on the pathway of evolution of our planet. In some cases the effects are "subtle" and in other cases they are "PROFOUND".

Some additional but important features of the Earth are:

- ONLY PLANET WITH "TRUE" GRANITE: The main rock type separating from the mantle of Earth is basalt. Most of this basalt is being formed at oceanic rises (i.e., ocean-floor spreading centers). In general, granitic rocks are differentiation products of basalt but it takes a good bit of processing of basalt to get much of a yield of granitic product. True GRANITE is even more difficult for nature to generate and it can be generated in significant volume in only certain geotectonic settings. The favored place is in volcanic arcs above subduction zones where basaltic ocean floor is being subducted under either continental crust or under other basaltic ocean floor. Even in this setting, a good bit of subduction must take place to get a small mass of true granite. Indeed, some very small pockets of granitic rock have been found in lunar basalts. These are called granophyres. And I would speculate that small pockets of granitic rocks will be found in the basalts of Mars and Venus also. But to find large masses of granite, like we have on Earth, we apparently need to locate some active or extinct subduction zones on our neighboring planets.
- ONLY PLANET WITH CONTINENTAL CRUST: The Earth is the only planet in the Solar System with continents and these continents are composed of granitic rocks, some of which are true granites. It is still not clear just how all of this continental crust has formed (Rudnick 1995; Polat 2012) but some parts of the continents have been on Earth for over 3 billion years. About one-third of our planet is covered by continental crust and two-thirds is covered by the basalts of

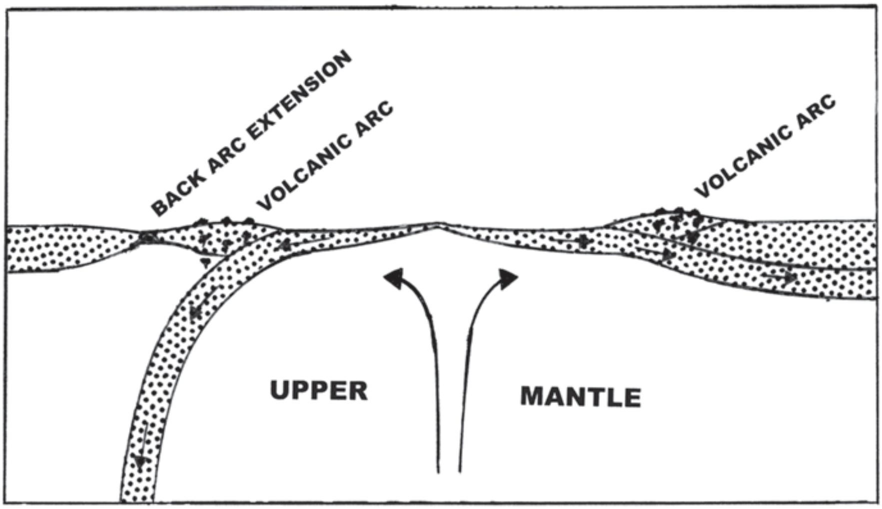

Fig. 1.3 Diagrammatic cross-section of two subduction zones showing different angles of subduction. The main point is that the down-going plate will sink by gravity if the slab is higher density than the surrounding mantle. If the density of the slab is equal to or less than the surrounding mantle, the slab must be forced into the mantle or forced under another surface plate. High angles of subduction are commonly associated with westward dipping subduction zones as well as back arc spreading centers (example: the Japanese arc-trench complex); low angles of subduction are commonly associated with eastward dipping subduction zones (example: the Andes arc-trench complex)

the ocean floors. Although most of the biological system of Earth originated in the shallow waters of the continental shelf areas, it is the continental platforms (i.e., above sea level) that are very important for human civilization. Thus, we not only have oceans of water and a thriving biological system but we also have continental crust above sea level on which to to build our structures.

- ONLY PLANET WITH OPERATIONAL PLATE TECTONICS: We could have granite and granitic rocks and continental crust even without plate tectonics. The granitic rocks and continental crust could have been formed by other processes at an earlier era in Earth history. The surprising thing is that the mechanism that we geologists think generated much of the granite, granitic rocks, and eventual additions to these large masses of continental crust is still operating today. One would think that a warmer Earth would lead to more vigorous plate movements and as the Earth cools, the motion would slow down or cease. But the plate movements are more vigorous today than perhaps 1.5 billion years ago. This is one of the major paradoxes of the plate tectonics paradigm—one would think that plate motion would be slower on a cooler Earth. The explanation probably lies in the mechanism of subduction. There are two major mechanisms for subduction: one is *slab-push* and the other is *slab-pull* (Fig. 1.3). Both of these mechanisms are operated by gravity but the main difference for their operation is the temperature of the associated mantle. For *slab-push* the pressure for subduction is caused by the elevation of an oceanic ridge. The higher the ridge elevation the more effective is this mechanism and the cooler slab is FORCED down the subduction zone; i.e., it does not sink on its own and the slab melts as it is being forced into the mantle. On the other hand, *slab-pull* can only work when the slab can maintain its coolness relative to the hotter mantle. The cooler slab then "sinks" into the warm mantle. If the mantle is too warm, then the sinking slab will melt before it sinks very far. For effective slab-pull the sinking slab should maintain its identity, and excess density, for about 600 km. Since the Earth's mantle is cooler than it was 1 billion years ago, this gravity sinking operation is more effective as geologic time moves forward. Some investigators think that this slab-pull mechanism could only operate during the last 1 billion years of earth history (e. g., Davies 1992; Stern 2005) and any plate tectonics before that time would be dominated by the slab-push mechanism.

1.3 Some Special Features of Venus as a Planet

- *NO* LIQUID WATER ON THE SURFACE: The surface is simply too hot and any water would be in the form of water vapor in the atmosphere.
- *NO* FREE OXYGEN IN THE ATMOSPHERE: The gases of the atmosphere are all reduced gases and any free oxygen formed by photo-dissociation of water and/or carbon dioxide in the top layers of the atmosphere would be consumed quickly by these reduced gases.
- *NO* LIFE DETECTED: The surface of Venus appears to be very hostile for life as we understand it on Earth. There is a possibility that some form of life could live in the outer (cooler) layers of the atmosphere.
- *NO* MEASURABLE MAGNETIC FIELD: There is no measurable internally generated magnetic field associated with planet Venus. If rotation rate is an important factor in generating a planetary magnetic field, the very slow retrograde rotation rate of Venus could be the reason for the lack of a planetary magnetic field.
- *NO* SATELLITE (NOW): If a large satellite is important for the development of habitable condition on planet Earth, perhaps the absence of a large satellite can help explain the lack of habitable conditions for Venus. This simple explanation may not be very effective. Maybe we should consider the possibility that Venus *had* a sizable satellite in the past but that satellite no longer exists. WOULD THAT MINOR SPECULATION MAKE A DIFFERENCE TO THE HISTORY OF OUR SISTER PLANET, VENUS?

Some additional but important features of planet Venus are:

- A TEMPERATURE OF 450 °C AT THE SURFACE: This temperature is hot enough to melt lead (as in angler's gear). And the atmosphere has a significant content of hydrogen sulfide. This hydrogen sulfide along with some water molecules in the atmosphere yields a sulfuric acid mist.
- ESSENTIALLY NO ROTATION RATE: The rotation rate is really very slow in the *retrograde* direction—one day on Venus (one sidereal rotation of the planet

takes 243 earth days of time). Has it always been that way? Probably not in that the primordial rotation rate according to the empirical plot of MacDonald (1963) should be about 13.5 h/day in the *prograde* direction (Fig. 1.4). Perhaps an explanation of how Venus lost its prograde rotation may help to explain the adverse condition of our sister planet.

- YOUNG SURFACE ROCKS: It certainly was a surprise for the Magellan mission investigators to discover that nearly the entire surface of Venus was covered by basaltic volcanic rocks—mainly sequences of massive lava flows on the surface. It was an even greater surprise to find that the impact craters on the surface were all about the same age: i.e., the crater density patterns over the entire surface of the planet were about the same. This led investigators to propose the concept of a "global resurfacing event". Based on crater-count studies on other planets and satellites, the educated guess for the timing of this "global resurfacing event" was that it happened over a short period of time somewhere between 1000 million years ago and 500 million years ago (Herrick 1994). At present there are three models for this condition on Venus. (1) Perhaps Venus undergoes alternating eras of heating up and cooling down and the last heating up period resulted in the global resurfacing we see now (Herrick and Parmentier 1994). (2) Perhaps a "giant-impact" of some sort caused the resurfacing event (Davies 2008). (3) Perhaps the capture of a satellite in a retrograde orbit could cause the damage to the surface of Venus. This retrograde capture scenario was first proposed by Singer (1970) and further work was done by Malcuit and Winters (1995) to demonstrate that retrograde capture was physically possible, and Malcuit (2009) to show that the time scale for post-capture orbit evolution could be up to 3 billion years.
- VERY DENSE CARBON DIOXIDE-RICH ATMOSPHERE: The atmosphere of Venus is about 100 Earth atmospheres of pressure and it is mainly carbon dioxide (Grinspoon 1997). An outstanding question is: WHERE DID ALL THIS CARBON DIOXIDE COME FROM? Well, the main gas coming from the Earth's interior via volcanic eruptions is carbon dioxide. But the Earth's atmosphere at present contains only about 0.6 % carbon dioxide by volume. We know that the volcanic carbon dioxide gets fixed as carbonate rock via a combination of organic and inorganic processes and then gets recycled via the plate tectonic process in which ocean floor gets subducted beneath volcanic arcs. But Venus does not have either ocean water or subduction zones at present, so the carbon dioxide accumulates in the atmosphere. But the question is: WHY IS THERE SO MUCH CARBON DIOXIDE IN THE ATMOSPHERE OF VENUS? Cloud (1972, 1974) concluded that the carbon dioxide content of the atmosphere of Venus contains about 1.6 times the combined carbon dioxide of the carbonate rocks and sediments of Earth as well as that in the atmosphere and in solution in ocean water. His conclusion was that the mantle of Venus is more completely depleted (degassed) than the mantle of Earth. So there is very little doubt as to where this carbon dioxide came from. It came from the mantle of the planet by way of the extreme volcanism that is associated with the mysterious GLOBAL RESURFACING EVENT.

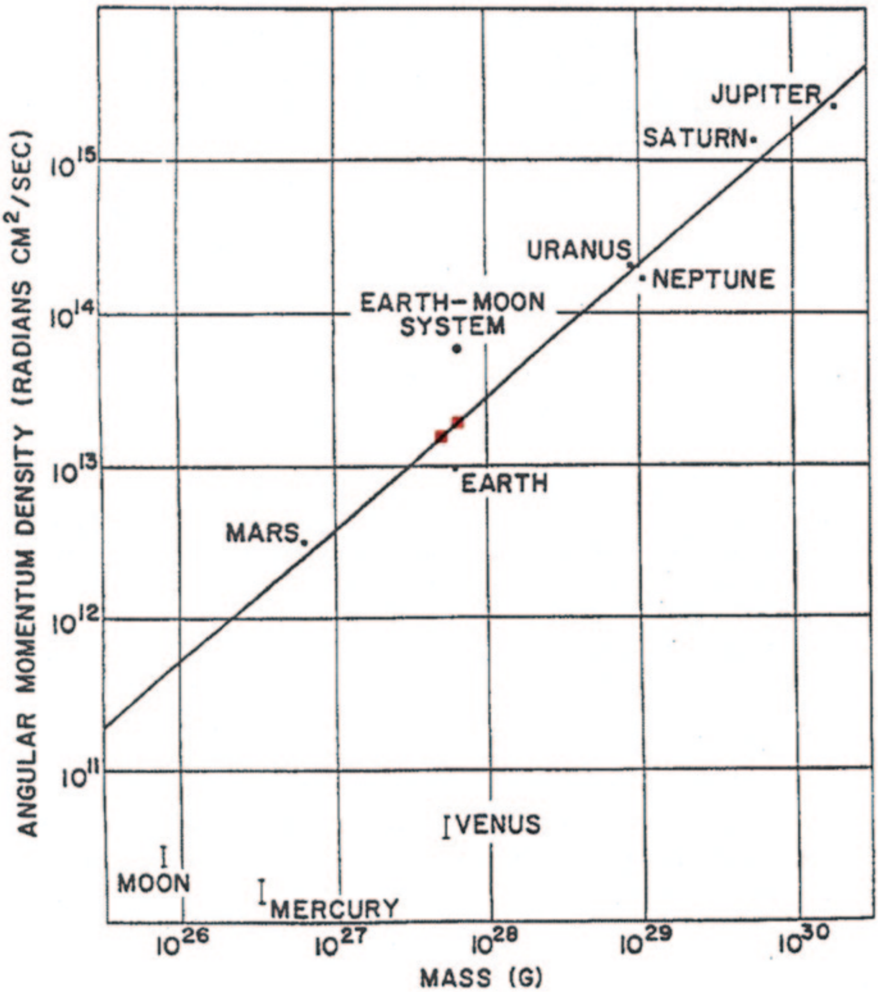

Fig. 1.4 Plot of Angular Momentum Density vs. Mass for the planets of the Solar System as well as for the Earth's Moon and the Earth-Moon system. (Diagram adapted from MacDonald (1963, Fig. 38), with permission from Springer.). The line was placed for the best fit of the information for the rotation rates for the outer planets and Mars. The assumption, which is suggested by the plot, is that Mars has a rotation rate very close to its primordial rotation rate (~25 h/day). If all the angular momentum of the Earth-Moon system is placed in the Earth, the rotation rate would be ~4.5 h/day. If the Earth is rotating ~10 h/day, the Earth would plot on the line between the position of the Earth-Moon System and the Earth (the *red square* symbol on the *right*). This information suggests that the original rotation rate for Earth was ~10 h/day. If the angular momentum of a lunar-mass body in a 30 earth radii circular orbit in the prograde direction is added to the prograde angular momentum of an Earth rotating at 10 h/day, then that combination plots in the position of the Earth-Moon system on the plot. Likewise, if Venus is elevated to the line vertically above its position on the graph (the *red square* symbol on the *left*), then the original rotation rate would be ~13.5 h/day prograde. The primordial rotation rates of the Moon and Mercury can be estimated using the same procedure

The "big question" of this project is "WHY ARE THESE SISTER PLANETS SO DIFFERENT?" What happened to planet Earth to develop it into a "paradise" for bacteria and algae and later for abundant plant and animal life. And what happened to planet Venus to develop it into a "hellish" environment that still persists today?

References

Alfven H, Arrhenius G (1972) Origin and evolution of the Earth-Moon system. The Moon 5:210–230

Berner RA (2003) Phanerozoic atmospheric oxygen. Annu Rev Earth Planet Sci 31:105–134

Berner R A (2006) GEOCARBSULF: a combined model for phanerozoic atmospheric O_2 and CO_2. Geochim Cosmochim Acta 70:5653–5664

Carr MH (1999) Mars. In: Beatty JK, Petersen CC, Chaikin A (eds) The new solar system. Cambridge University Press, Cambridge, pp 141–156

Cloud PE Jr (1972) A working model of the primitive earth. Am J Sci 272:537–548

Cloud PE Jr (1974) Rubey conference on crustal evolution (meeting report). Science 183:878–881

Dauvallier A (1976) The venus oceans problem. J Br Astron Assoc 86:147–148

Davies G F (1992) On the emergence of plate tectonics. Geology 20:963–966

Davies J H (2008) Did a mega-collision dry Venus' interior? Earth Planet Sci Lett 268:376–383

Donahue T M (1999) New analysis of hydrogen and deuterium escape from Venus. Icarus 141:226–235

Donahue TM, Hoffman JH, Hodges RR Jr, Watson AJ (1982) Venus was wet: a measurement of the ratio of deuterium to hydrogen. Science 216:630–633

Faure G, Mensing TM (2007) Introduction to planetary science. The geological perspective. Springer, Berlin, p 526

Glassmeier K-H, Vogt J (2010) Magnetic polarity and biospheric effects. Sp Sci Rev 155:387–410

Grinspoon DH (1997) Venus revealed. Helix Books, Addison-Wesley, Reading (MA) p 355

Herrick RR (1994) Resurfacing history of Venus. Geology 22:703–706

Herrick DL, Parmentier EM (1994) Episodic large-scale overturn of two-layer mantles in terrestrial planets. J Geophys Res 99:148–227. doi 1029/93JE03080.

Lipton P (2005) Testing hypotheses: prediction and prejudice. Science 307:219–221

MacDonald JGF (1963) The internal constitutions of the inner planets and the Moon. Sp Sci Rev 2:473–557

Mackenzie D (2003) The big splat (or how our Moon came to be). Wiley, New York, p 232

Malcuit RJ (2009) A retrograde planetoid capture model for planet Venus: implications for the Venus oceans problem, an era of habitability for Venus, and a global resurfacing event about 1.0–0.5 Ga ago. Geol Soc Am Abstr Progr 41(7):266

Malcuit RJ, Winters RR (1995) Planetoid capture models: implications for the great contrast in planetological features of planets Venus and Earth. Geol Soc Am Abstr Progr 27(6):A–208

Polat A (2012) Growth of Archean continental crust in oceanic island arcs. Geology 40:383–384

Rudnick RL (1995) Making continental crust. Nature 378:571–578

Saunders RS (1999) Venus. In: Beatty JK, Petersen CC, Chaikin A (eds) The new solar system. Cambridge University Press, Cambridge, pp 97–110

Singer SF (1970) How did Venus lose its angular momentum? Science 170:1196–1198

Stern RJ (2005) Evidence from ophiolites, blueschists, and ultrahigh-pressure metamorphic terranes that the modern episode of subduction tectonics began in Neoproterozoic time. Geology 33:556–560

Strangway DW (1970) History of the Earth's magnetic field. McGraw-Hill, New York, p 168

van Loon AJ (2004) From speculation to model: the challenge of launching new ideas in the earth sciences. Earth Sci Rev 65:305–313

Ward PD, Brownlee D (2000) Rare earth (why complex life is uncommon in the Universe). Copernicus (An imprint of Springer), New York, p 333

Young A, Young L (1975) Venus. Sci Am 233(3):70–81

Chapter 2
The Origin of the Sun and the Early Evolution of the Solar System

The direct investigation of such inner regions around protostars and young stars will also provide us with knowledge about the physics and evolution of circumstellar disks. It is within such disks that planetary systems are believed to be formed. We now have reason to believe that, as we progress toward a greater understanding of star formation, we will also begin to unlock the secrets of the origin of planetary bodies.
From Lada and Shu (1990, p. 572).

The origin of the Solar System has intrigued scientists for centuries. As recently as five decades ago the models were still very general (e. g., Cameron 1962) and were concerned mainly with the collapse of a cloud of stellar dust and gas of roughly solar composition and the transformation of that cloud into a rapidly rotating disk-shaped mass around a proto-sun. The next few decades were dominated by calculations of equilibrium chemical condensation models from a cooling nebula of solar composition (e. g., Lewis 1972, 1974; Grossman 1972) based mainly on the temperature and pressure conditions for the solar nebula from Cameron and Pine (1973). Identification of high-temperature condensates [calcium-aluminum inclusions (CAIs)] in the Allende meteorite was a critical event in the development of more sophisticated models for the evolution of the Solar System. After the discovery of CAIs it was important to develop models to explain (a) the origin of chondrules (the main constituent of chondritic meteorites), (b) the origin of CAIs, as well as (c) the origin of the very fine-grained matrix of the chondritic meteorites.

In the decades of the 1980s and 1990s, groups of astrophysicists presented the results of simulations of the dynamics of the early history of the Sun in an attempt to relate the rapidly rotating disk stage of Solar System evolution to observations of T-Tauri stars of roughly solar mass. For example, Lada and Shu (1990) and Shu et al. (1994) published the results of simulations of the dynamic interaction between the material infalling along the nebular midplane and the strong magnetic fields associated with a very hot, rapidly rotating nascent Sun. Major features of the magnetic field action were the formation, breaking, and reconnection of the magnetic flux lines. The breaking (snapping) and reconnection of the flux lines is associated with very high temperature pulses that may relate to the thermally generated features recorded in the various types of CAIs (summaries of the types of CAIs are in Taylor 2001). Shu et al. (1997) attempted to explain the origin of both CAIs and chondrules

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via the X-Wind model (the name of the model refers to the 2-D cross-sectional geometry of the intersection of magnetic flux lines and the midplane disk). After critical consideration of the merits of the X-Wind model, Taylor (2001) and Wood (2004) proposed that something like the X-Wind model can be used to explain many of the features of CAIs but that the X-Wind model does *not* relate to the environmental conditions for chondrule formation. Although the X-Wind model has its critics (e. g., Desch et al. 2010), it is generally accepted as a reasonable explanation for the origin of CAIs.

The origin of chondrules (the main features of chondritic meteorites and spherical particles that are much simpler in composition and structure than CAIs) is another story with a long history dating back to Henry Sorby and the petrographic microscope about 1870 (McSween 1999). Although chondrules appear to have less complex features, their origin appears to be more difficult to explain. Most investigators agree that a "flash-melting" process as well as rapid cooling are involved. The rapid heating melts whatever clumps of dust that are in the environment at that time and the resulting features are glass beads (some with crystallites and crystals of identifiable minerals). These chondrules, plus or minus a few CAIs, are the main megascopic components of chrondritic meteorites. These components of chondritic meteorites are bound together by a matrix material. Most investigators agree that the fine-grained material of the matrix is composed of a combination of fine-grained silicate-rich material which contains various quantities of chondrule fragments, CAI fragments, and very fine-grained nebular dust as well as some material that was infalling along the midplane from the molecular cloud (Rubin 2010, 2013). It is interesting to note that the matrix of some enstatite chondrites has a significant quantity of flakes or chips of iron-nickel metal and sulfide minerals embedded in a mainly silicate matrix (Rubin 2010). The chemistry of chondrules varies considerably but there is a trend related to distance from the proto-Sun and the volatile content of the chondrules increases with heliocentric distance. Many investigators think that the Disk-Wind model of Bans and Konigl (2012) and Salmeron and Ireland (2012) looks promising as an explanation for the origin of chondrules. In general, chondrules are a few million years younger than CAIs and were formed by significantly different thermal processes. There is, however, evidence that there may be some overlap in time of formation (Brearley and Jones 1998).

As chondritic meteorites and associated CAI particles are formed, an accretion process begins. There are probably several embryonic planetary nucleation sites early in the accretion process, but in the later stages only a few would remain in the accretion torus (an accretion torus is a heliocentric doughnut-shaped geometric form from which smaller bodies are gravitationally attracted to participate in the planet-building process). The accretion torus, then, constitutes the "feeding" zone for the planet accretion process.

The chemical composition of the resulting planet or planetoid is determined by the composition of the particles in the accretion torus. For example, if the material in the accretion torus is mainly CAI material, then the planet or planetoid will be composed of CAI chemistry. If the accretion torus has particles and agglomerates of particles that are rich in iron, then the resulting planet or planetoid will be rich in iron and have a high specific gravity relative to a body composed mainly of silicates. Thus, the composition and density of an accreted body probably reflects the composition of the particles that were in the accretion torus.

In general, I think that nearly all (and possibly all) features of a Solar System origin model, from the origin of CAIs, chondrules, and the matrix of chondritic meteorites, and their derivative bodies, are involved in the processes that led to the formation of the terrestrial planets (e. g., the twin sister planets, Venus and Earth) and associated Vulcanoid planetoids and Asteroids, as well as the outer (gaseous) planets.

Figure 2.1 is composed of two simplified scale diagrams of the orbits of the planets of the Solar System. Figure 2.1a shows the orbits of the outer (gaseous) planets relative to the orbit of Mars. Figure 2.1b shows the orbits of the inner (terrestrial) planets relative to the orbit of Jupiter. The reader may ponder the following question: Why involve a large slice of the Solar System when discussing the condition of planets Venus and Earth? A reasonable answer is that when dealing with a capture origin for the Moon as well as a capture origin for a satellite for Venus, it is necessary to have a place of origin for the Moon and related planetoids. The best fit, both chemically and physically, seems to be a Vulcanoid Zone (Wiedenschilling 1978; Leake et al. 1987; Evans and Tabachnik 1999, 2002) between the orbit of Mercury and the Sun. Thus it appears necessary to involve at least the zone inside the orbit of Mercury and out to the vicinity of Earth's orbit.

Then we have the problem of a large volume of ocean water on Earth as well as the possibility of water on Venus in an earlier era [i. e., the "Venus Oceans problem" (Donahue 1982, 1999)]. I think that the model of Albarede (2009) explains the origin of ocean water problem fairly well. His suggested source is water-bearing asteroids from the middle to outer Asteroid Zone. Thus, our sphere of influence needs to be extended to include the entire Asteroid Zone.

Then we need a delivery system for the Aquarioid Asteroids (my name for the water-bearing asteroids). The most reasonable delivery mechanism for getting the Aquarioids from the Asteroid Zone to near Earth orbit is a process of gravitational perturbations by a combination of Jupiter and Saturn, a process that has been studied by celestial mechanicians for many decades.

Since there is also an interest in explaining the source of water for planet Mars, we must explain the deuterium to hydrogen (D/H) ratio of the water associated with that planet. [For readers who are not familiar with the importance of the deuterium/hydrogen ratio, some definitions and an explanation are in order. The hydrogen atom (H) (also called protium) has only one proton in the nucleus. Deuterium (D) has both a proton and a neutron in the nucleus and has twice the atomic weight as hydrogen. In many cases thermal processes will cause molecules with the lighter hydrogen to be separated from those with heavier hydrogen. As a result many substances can be characterized by their D/H ratio.] Since the D/H ratio of martian water is much different from that of Earth we must search for a source of martian water. Well, the D/H ratio of martian water is similar to that of comets (Robert 2001). Most investigators think that the effective source of these comets is the Asteroid Zone and that these comets are Jupiter-captured bodies: i. e., captured into heliocentric asteroid-like orbits after a close encounter with Jupiter. The apparent ultimate source of all comets, however, is the Oort Cloud/Kuiper Belt which is