
NUTEERIAT:
Nut Trees,
the Expanding Earth,
Rottnest Island,
and All That ...
David Noël
Cornucopia Press
NUTEERIAT • David Noël
ISBN: 0 9593205 4 7
CARTE RÉDUITE
DES TERRES AUSTRALES
Par le Sr. Bellin Ingr. de la Marine
De la Societé Royale de Londres &c.
1753.
NOUVELLE
HOLLANDE
DU
SUD
Tropicus Capricorni
Equator
Terre d'Eendracht
ou de Concorde, en 1616.
Terre de G.F. de Wit
Découverte en 1628.
Terre de Nuits
Terre de Leeuwin
TERRE DE DIEMEN
NOUV. BRETAGNE
TERRE DU ST. ESPRIT
Découverte en 1606 par Fernand de Quir.
CÔTE qu'Abel Tasman a découverte en 1642 et qu'il a nommée NOUV. LE ZELANDE qui peut faire partie d'un grand Continent antipode de l'Europe.
KUST door Abel Tasman A. 1642 ontdekt en genaamd NIEUW ZEELAND welke een gedeelte van een groot Vast-Land, dat regt onder Europa is, kan uitmaken.

ABOUT THE COVER

The Cover is based on a map of Australia produced in 1753 by Jacques Nicolas Bellin, official hydrographer to Louis XIV of France.

Rottnest Island is shown as ‘I. des Filles’ (Island of Girls) off the lower west coast of Australia. There have been many interesting but unsubstantiated suggestions as to the reason for this name.

The map gives appropriate prominence to what are now the eastern States of Australia. The inset map of Rottnest Island is from a more modern source.

ACKNOWLEDGEMENTS

To Ros Fisher, World Freckle Record Holder, for changing the library books, and a thousand other personal services; and to Max, for fixing the stairs and the pyramids.

ABOUT THE AUTHOR

David Noël was born in 1935, on September 19, the 152nd anniversary of the ascent of the first passenger-carrying hot-air balloon, in Paris. The passengers (a sheep, a cock, and a duck) survived the eight-minute flight quite uninjured, although the cock had its right wing hurt by a kick from the sheep before the ascent commenced. Among the vast crowd of spectators was Benjamin Franklin, the printer who demonstrated the electrical nature of lightning with kite experiments; he was in Paris as the Ambassador of the United States to France.

Franklin, the Father of the U.S. Constitution, the inventor of bifocal glasses, and the man who introduced the concept of hospitals to America, was also ... ... *hold on*, who is this supposed to be about?

Oh yes, where were we? Er, um, David Noël was brought up in England, and in 1957 he gained a science degree from Cambridge University. Subsequently he obtained various minor qualifications in Russian, Geology, Librarianship, Computing, and Nursery Management.

He was a member of the Intelligence Corps in the British Army, serving in Berlin (before the Wall) and other overseas posts during National Service. He then worked in research and development in a British manufacturing company for five years, before settling in Australia in 1964.

In Australia he was a staff member of the University of Western Australia for more than 20 years, engaged in various information technology and computing activities. He is currently Director of the the Tree Crops Centre in Perth, where he is working on various projects to cover the world with nut trees. He is also currently President of the West Australian Nut & Tree Crop Association Inc.

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Printing History

The original printed edition was published in 1989. The present online edition is a corrected and reset version of the original, with substantially the same content. It was converted to PDF format in sections and placed on the Web at www.aoi.com.au/matrix/Nuteeriat.htm in 2004.

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Design, layout and typesetting, and conversion for online PDF download: David Noël

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Dedication

This book is dedicated to Samuel Warren Carey —
Emeritus Professor in Geology, the University of Tasmania
Pioneer in elucidation of the Expanding Earth
Toeless Z-Force veteran
Wise scientist and thoughtful humanitarian

FOREWORD

"The purest gems lie hidden in the bottom of the ocean or in the depths of rocks. One has to dive into the ocean or delve into the rocks to find them out. Similarly, truth lies concealed in the language, which with the passage of time has become obsolete"

— Motilal Banarsidass

It must be a rare event for material which may be of fundamental importance to geologists to have its first public airing at a conference of nutgrowers. But that was the case with the basic material presented in this book; it was the subject of a paper I gave at the 3rd Australasian Conference on Tree and Nut Crops, held in May 1986 in Auckland, New Zealand.

That paper, and this book, both contain two seemingly bizarre assertions. The first is that the Earth has, in the geological past, expanded like a blown-up balloon. It is shown that the present continents once covered the whole surface of the Earth; these have split apart under the expansion, and are now widely separated.

The second assertion is that the first assertion can be proved by a study of nut trees. Bizarre as that may seem, read on, gentle reader, and judge on the evidence presented. No doubt these two assertions are a mighty bite to take in. When I go on the third assertion, that fundamental knowledge on the origin of life, the evolution of man, and the structure and cosmology of the universe can stem from the same studies, ...!

As in most of man's intellectual advances, much of what I present here is based on the work of others, extending back into the distant past. One pivot of the present argument is based on a study of plant distributions, and that is a subject which has had many distinguished contributors active in it, going back over at least two centuries. Indeed, this study could be claimed to have its roots in comments made by the ancient Greeks, so perhaps twenty centuries is closer.

The study of the Earth is at least as ancient. However, it is true that these topics have had their most active development in the recent past. Even this active phase is not so very modern, however; we shall see that it extends back to well over a century ago. To reach high, we all must need stand upon the shoulders of giants of the past.

So, turn the page, and start the journey along a road of propositions. Go armed with a critical and perceptive view, but be ready to accept the logic of evidence and the evidence of logic. Good travelling!

— David Noël, 1989.

CHAPTER 1

SETTING THE SCENE

"The art of discovery is to see what everybody sees, and think what nobody thinks"

This book follows the conventional system of division into chapters, each dealing with one aspect of the fascinating whole to be unravelled and put back together. One novel feature is that, scattered throughout the chapters, and placed in boxes for emphasis, are a number of *Propositions.*

These Propositions are just that – propositions. They are succinct, unhedged, and uncomplicated suggestions on various aspects of the world of the present, the past, and the future. Some of them are mild and uncontroversial, virtually self-evident, others could be regarded as outrageous from the viewpoint of a conservative soul. I am not claiming that all these propositions are 'true' (for more on what 'true' means, see Chapter 17), and in fact they cannot all be true, as some of them (e.g. Propositions 12E and 12F on dinosaurs) are apparently mutually exclusive.

But I hope, at least, that they will provoke thought and perhaps some critical evaluation of their implications. Many of them have scope for setting up tests, for extrapolation, for prediction, in fact for running them through the whole gamut of objective probing which reveals the 'truth' or otherwise of any scientific theory.

Where the Evidence Comes From

A word about sources and data. This book contains almost no new data, no astounding new results of trials. Some of the conclusions reached may be quite novel. But these conclusions are based on the most prosaic data, much of it available for many years in standard sources. A lot of the hard data quoted is taken from either the current edition of the Encyclopaedia Britannica, or from the Ninth Edition of this work, published in 1875. Some comes from the Guinness Book of Records!

In fact probably half the evidence used in this book was already available a hundred years ago, and three-quarters available fifty years ago. Even the remaining 25% which has come to light more recently has been mostly in the nature of confirmatory detail, rather than some revolution in our views.

Hence the quotation at the head of this chapter. One of the side effects of this work will be to show that 'old' data can be reworked with success, like some mineral tailings, to reveal unsuspected new riches.

The Timescale of Events in this Book

It may be useful for the general reader if some background is given on the timescale of events which figure in this book.

Almost all references will be to events which occurred many millions of years (*my*) before the present. Currently, the age of our entire universe is believed to be about 15,000*my*; the

Earth itself (and its satellite, the Moon) are believed to be about 5,000*my* old.

Of course, life on Earth did not begin until a long time after the planet was formed (usually assumed to have been by condensation of gaseous material). An event occurred at around 600*my* ago which was very obvious from the record of fossils found in the rocks. Before 600*my* the rocks are almost empty of signs of life; after this time, rocks which were formed in a way suited to the preservation of fossils (say on the beds of shallow seas receiving a continuing load of sediments) may be crammed with fossils.

Fossils are often excellent indicators of the conditions which applied at the time and place where the creatures which left the fossil remains grew, and so they have been studied in great detail. Most of our knowledge of the geological past has been gained from fossils. So we have quite a good and detailed picture of events since around 600*my*, and a much poorer picture of what happened before that.

The Ages of the Rocks

Table 1 shows how geological time is divided up; the different slabs of time can be regarded as layers of rock, with the youngest at the top. The time since abundant life has existed is conventionally divided up into three large sections, called Eras. These are, in order of increasing age, the Cenozoic Era, the Mesozoic Era, and the Paleozoic Era (these terms mean, roughly, the times of Young, Middle, and Old Life).

Table 1. Time Divisions in Earth's History

	Age (my)	Period/Epoch	Era
1	3	Quaternary	**Cenozoic** (Tertiary)
2	7	Pliocene	
3	25	Miocene	
4	40	Oligocene	
5	60	Eocene	
6	70	Paleocene	
7	141	Cretaceous	**Mesozoic** (Secondary)
8	198	Jurassic	
9	230	Triassic	
10	285	Permian	**Paleozoic** (Primary)
11	350	Carboniferous	
12	400	Devonian	
13	440	Silurian	
14	510	Ordovician	
15	580	Cambrian	
16	4500		**Precambrian**

Each Era is itself divided up into smaller units called Periods or Epochs. The names of these units are shown in the table. Rock and fossil dating methods are now accurate enough so that the beginning and end of each of these Periods can be dated to the nearest *my*, in the younger rocks at least. A change from one period to the next is usually marked by a significant change in the fossil record, and in fact this change is fundamental, because it is usually the *reason* for splitting the record of the rocks up into different parts.

The oldest Period of all, that at the bottom of the Paleozoic Era, is called the Cambrian Period. It is in the oldest Cambrian rocks that the first signs of profuse, active life are found. The change is quite sudden. Something happened at the start of the Cambrian which greatly favoured the development and expansion of life on Earth.

Once it was thought that the Cambrian actually marked the first appearance of any form of life on Earth, and that the older rocks were completely devoid of fossils. More recently it has been shown that these older rocks, called Precambrian and extending back to the beginnings of the Earth itself, do in fact have some traces of life. Some of this life could be as old as 3500*my*, but the evidence is not clearcut, and argument continues on the exact nature and age of this early life.

The actual figures quoted are subject to revision and refinement, but the general picture is clear. For seven eighths of its 5,000*my* life, the Earth was almost devoid of life. About 600*my* ago, life burst forth in abundance. About 230*my* ago, a major change occurred, and about 70*my* ago, another big change. Later in this book I will suggest some of the underlying reasons for these abrupt changes.

About Rock Types

This is not the place for a detailed explanation of the different types of rock, but there is one aspect of rock types which does have considerable relevance, and that is the distinction between 'continental' and 'oceanic' rock types.

Both these rock types are 'igneous', formed by the cooling down of molten material. But the continental rocks, which form the bulk of the material of the Earth's present continents, are lighter in weight (and often in colour) than the oceanic ones and have a somewhat different chemical composition. They are also called acidic rocks, and granite is the most typical example.

Oceanic rocks, also called 'basic' rocks, are heavier in weight and usually dark in colour. Basalt is a typical example. Oceanic rocks not only form the bedrock of all the major and deeper seas and oceans, they also underlie the continental rocks of the land masses. The situation has been represented as a continuous, solidified oceanic-rock 'sea' covering the whole of the Earth, with separate 'rafts' of continental material floating on this solid 'sea'.

In agreement with this picture, the continental 'rafts', which are usually 5-40*km* thick, are said to be actually 'immersed' in the oceanic-rock sea, their bases extending below the level of rock in adjacent seabeds. And, in a classic Archimedes' Principle situation, the depth of immersion is usually greater under higher mountains such as in the Tibet region — just as if the continents were really floating.

Naming Animals and Plants

Living creatures are identified by their ‘scientific names’, which consist of two parts, a genus name and a species name. For example, the walnuts are in the genus *Juglans* (from latin, ‘Jupiter’s nut’). The common walnut is *Juglans regia* (where ‘regia’ means royal). It is normal to print these scientific names in italics or underlined, and to have a capital for the name of the genus (plural ‘genera’) and a small letter for the species (plural ‘species’).

Basically, a species represents the whole of a population which can interbreed. The genus is the next broader grouping, representing all those species which are believed to be closely related. Within a genus, interbreeding between species is sometimes possible (giving ‘hybrids’), but not assured or common. The position is explained in rather more detail in Chapter 2.

Genera are themselves grouped into the next broadest division, the family. In plants, the names of these families usually end in ‘-eae’. The walnut family, the Juglandaceae, includes not only the true walnut genus *Juglans* but also *Carya*, the genus of the pecan and hickories, and others.

We have now painted a rapid picture of the Earth, its history, and its inhabitants, using a very broad brush. To continue this saga, we start by shrinking our focus right down, to look at a very minute part — Rottnest Island.

CHAPTER 2

HOW PLANTS SPREAD AND CHANGE

“Indeed the whole of the Rottnest vegetation is so different to that on the mainland, and so much like that on the mainland 321 km north, as to warrant a surmise that the island had once formed part of the mainland in the neighbourhood of where Dongara now is, and had by some geological earth movement been shifted 321 km southward”.

— *Somerville [1976]*

Rottnest Island

Located some 19 kilometres off the coast of Western Australian, and visible from the taller buildings of its capital, Perth, lies the Island of Rottnest.

Rottnest is W.A.’s best-kept secret. A magic holiday island, with no private vehicles or private land ownership, it is a place tacitly kept for the local people; the increasing number of overseas visitors touring the rest of the State’s attractions are subtly not encouraged. Travel around the island is by bicycle, whether you are young or old. Jet-setters would be appalled at the salt-water showers.

Rottnest is an island with a history. It was probably the first landfall of Europeans in the southwest of Australia, when a Dutch party under Willem de Vlamingh landed there in 1696. Vlamingh saw the hordes of the small marsupials called quokkas on the island, and thought that they were large rats; hence the name Rottnest, meaning Rat’s Nest in his native language.

Vlamingh was enchanted with the island, too, reporting that “nature had spared nothing to render it delightful — a terrestrial paradise”. At that time, Rottnest was covered with trees, many of which, alas, were cleared away when later settlers attempted to farm the island. These trees and this island have features which, as we will see, have relevance for the ideas expressed in this book.

If there is a family of trees which is typical of Australia, it is the Eucalypts, the Australian gum trees. They exist all over the island continent. But Rottnest has no native gum trees, and moreover, it never did have [Somerville, 1976].

Its principal trees are in the genera *Melaleuca* (Tea Trees) and *Callitris* (Australian Pines). The *Melaleuca* species, *M. pubescens,* is the very distinctive Rottnest Island Tea Tree. This species is not confined to the island for which it is named, but occurs also on the mainland. But — it does not grow on the adjacent mainland around Perth, instead the closest occurrence is near Dongara, some 321 km further north!

Why does Rottnest Island have no gum trees? Why is the tea tree species so distant from its kin? These apparently trivial matters are a small part of a greater truth which we will try to uncover. For the moment we can be content with the important and perceptive observation of Somerville which is quoted at the head of this chapter.

The Spread of Plants

Plants and animals together have been of basic importance to man, extending back to the earliest times that a creature which could be called a man first existed. Together, they provided man with all of his food, most of his clothing, and much of his fuel and raw materials for artefacts and construction.

So it is natural that he has had an intense interest in these two great divisions of life, kingdoms they are justly called. Through this interest and its resulting knowledge he has been able to exploit the twin kingdoms to his own advantage, and make himself the emperor over both.

Over the years of history, one topic which received attention was the way in which plants were able to disperse themselves, to spread and propagate themselves into new areas. Some of the mechanisms used by particular plants are strange indeed, and the rich diversity and range of these mechanisms is well known. A thorough treatment of the subject appears in Ridley [1930].

Ridley's book gives many examples of long journeys made by plant seeds, found washed up on distant coasts, taken from the feet of migrating birds, carried in the fur of nomadic animals, and so on. Of course most seed dispersion mechanisms strive to separate seeds as far as possible from the parent plant, and many mechanisms clearly have the potential capability to achieve very rapid spread of the species involved. If a dandelion seed can drift 500 metres in the wind, we might expect an initial planting of dandelions to extend over a circle 10*km* wide within 10 years. Does such a spread usually occur?

In fact, the answer is usually 'No'. Actual rates of spread of plants (and of animals too) are enormously smaller than their *potential* rates as worked out from the mobility of one generation of offspring. It is clear that this must be so, otherwise the spectrum of living creatures found in one place would be more or less identical to that of somewhere else not too far away. In fact it is not terribly unusual for the species list of a given area to differ by more than half its contents from that of another area only 100*km* away, even when the areas are directly connected and superficially similar in nature.

> *Proposition 2A*
> *Actual rates of spread of plants are usually much less than the potential rates of spread implied by the dispersion mechanisms operating for an individual seed*

There are a number of reasons which can be suggested for this. There may be an obvious physical barrier to the spread, such as a stretch of water or a high mountain range. There may be a more subtle change in the environment, such as a switch to a different soil type with different nutrients or moisture retention.

But the most important reason is a factor which can be called Ecological Pressure. Different plants, and different animals too, do not use the whole spectrum of conditions in which they exist. Instead, they occupy what are called 'ecological niches'. A clear example is the epiphytic plants which grow high up on the trunks of tall trees in a tropical jungle. These plants are not parasites, they just have a strongly position-dependent ecological niche.

Other ecological niches are much more subtly defined. The 'boundaries' of the niche may be formed by such things as a change in soil texture or composition, proximity to water or

rocks, exposure to winds moving in a particular direction, dependence on the presence of particular animals or other plants, and every possible permutation of factors like this.

In order to spread, a plant or animal species would usually need to displace some other creature which is already occupying the particular ecological niche for which it has evolved. In most cases, it is unable to overcome this ecological pressure, and so it does not succeed in spreading.

> *Proposition 2B*
> *Plant and animal species do not expand their range because they are unable to overcome ecological pressure from other species already occupying their ecological niches*

There have been cases where ecological pressure is absent, and in these, rapid colonization and expansion may occur. A dramatic example occurred during the last century, when the explosion of the volcano Krakatoa removed the whole top of a small island in the sea near Java, wiping it completely clean. Within a few years, however, recolonization of the 'new' island recommenced, and now the plant cover is similar to that on adjoining islands.

That was a natural example. A more familiar example, based on the activities of man, is when areas of forest or jungle are cleared for the planting of field crops. The crops are planted, and shortly afterwards the weeds move in — the clearing provided vacant ecological niches not only for the crops, but for the weeds as well. The human activity may be quite minor, such as digging a hole to plant a tree. It has been shown that weeds will invade trial plots in some open areas in Australia only if the soil is disturbed, adjacent plots with no soil disturbance are not affected. The minor action of disturbing the soil surface is sufficient to create a vacant ecological niche for the weeds. This does raise a neglected possibility for weed control.

> *Proposition 2C*
> *Weeds may be controllable through manipulation of their microecological surroundings, rather than through direct attack by sprays or cultivation.*

Plant Mutability and the Isocons

In this book I will be referring constantly to 'Isocons'. These are like the isobars on a weather map, the 'contour lines' showing areas of equal pressure, but instead of pressure they define the boundaries of an area of equal ecological conditions.

In other words, isocons are lines drawn on a map which delineate the local boundaries of a plant's ecological niche. The area enclosed by an isocon is that which we would expect to be rapidly filled by a plant if there was no ecological pressure operating, say if disease had wiped out all its competitors for that niche.

Under settled conditions, the isocon for a given plant species is the same as its natural wild range. The point is that the plant has evolved to fit that range. We speak about 'the plant' as though it were a particular genetic identity, but in fact any plant species is a great mixture of different gene types.

The genes are continually mixing, recombining, and to some extent mutating, within a species. The boundary between one species and a closely-related one in the same family is really rather arbitrary, and taxonomists, the people whose work it is to define these boundaries, are continually arguing and moving them around to include or exclude particular plant populations.

Two related species share a high proportion of identical genes, for example it has been estimated that 98% of the genetic material of man and chimpanzee is the same. The cut-off really comes at the point where cross-compatibility is a factor.

If any individual in a given population can potentially interbreed with any other individual (of appropriate sex) in a second population, to produce fertile offspring, then those two populations are certainly in the same species. If there is no compatibility between any individuals of either population, the two populations belong to different species.

In practice these two states grade imperceptibly into one another, hence the fertile (!) ground for the taxonomists to argue on. It is not physically possible to test every individual of the two populations against each other, but what usually happens is that individuals at the ends of the ranges, those most widely separated, get more and more out of kilter.

Whatever, it is appropriate here to make the point that the ragbag of genes which we perceive to lie within the bounds of a given 'species' is in a state of continual flux, due to mixing, recombination, and mutation. A species today is different to the 'same' species a hundred, a thousand, a milllion years ago. It is as if an ant colony undertook a long migration, occupying a hundred years, across a continent. The individuals which reached the final point would all be different to those which started. And on a more basic level, the genetic constitution of the colony would have changed too, as characteristics favourable to the conditions met with were selected.

> *Proposition 2D*
> *The total genetic constitution of a species is subject to continual alteration, particularly if external conditions are changing*

Crossing the Isocons

Figure 2.1 shows the mapped distributions of some species of *Canarium* in the southeast Asian region. This is a largely tropical family of trees, which includes the Pili nut and the Java almond. It can be seen that some of the species occur over fairly wide areas, while others are small in range.

In particular, note the black dot marked '7' on the map. That dot is the total range of the species *Canarium kinabaluense,* and it coincides exactly with the site of Mount Kinabalu, the highest mountain in southeast Asia. Due to this height, the physical conditions on the mountain are naturally quite different to those below the mountain — in other words, the isocon for *C. kinabaluense* is dependent on altitude.

Another way of looking at this situation is to ask how this species got to be a separate species, how it evolved from some former common stock. The answer is that, in the past, a group of the genetic elements in the common stock which were particularly suited to the high-

altitude conditions separated off to give the new species.

Perhaps a mutation occurred in some of the *Canarium* trees which were lapping up against the potential isocon ring round the mountain. Perhaps there was slow selection of cold-tolerant genes already present. It is even possible that the change was in the reverse direction, with the mountain species being the original one, with the others adapting from it as the climate warmed up or the sea-level fell.

In any event, to cross the isocon, the species had to undergo adaption and change. These changes were great enough to reach the level where the resulting plant population has been classed as a separate species.

Fig. 2.1. Distribution of some species of Canarium [Leenhouts,1959]

This example of an isocon has a clear physical basis, it depends directly on altitude. Other isocons are more subtly based. For example, the different levels of a dense tropical jungle are worlds apart — on the upper canopy there is intense light and may be burning heat and fierce winds, accompanied by large daily temperature changes. Down below, on the forest floor, it is dim and still, with much less variation.

In one site in the Central American jungles, it has been found that of four species of bee, two are confined entirely to a lower level, and two to an upper one — there is no mixing [Perry, 1984]. Plant species may be similarly stratified, and these more subtle isocons lead to the situation where two distinct but related species evolve in what appears to be the same geographical area, because the isocon separating them is not based on location, but on some other factor.

Rates of Change in Species

Rottnest Island has one species of bird in the family *Lichenostomus,* the Singing Honeyeater, *L. virescens.* This species is the only one of the family on the island [Saunders, 1985].

The same species also occurs on the adjacent mainland, together with other species of honeyeater. What is interesting about the Rottnest population of Singing Honeyeater is the fact that it is appreciably different from the mainland population of the same species. The Rottnest birds tend to be larger, some 20% heavier, and much darker on the lower surface.

It has been suggested that these birds are evolving to fill the niches which are occupied by other honeyeater species on the mainland, because these other species are lacking on Rottnest.

They are on the way to becoming a separate species.

It has been stated that physical isolation of the two populations occurred only about 7000 years ago — 0.007*my*, a tiny amount on the scale we have been using.

Now let us look at the situation in another famous set of islands, the Galapagos islands off the coast of South America. Back in September 1835, Charles Darwin visited the Galapagos in the ship the 'Beagle', and the observations that he made there [Darwin, 1860] laid the foundations for the Theory of Evolution.

These islands are isolated some 900 km off the mainland of Ecuador, and consist of a group of about 5 larger islands and many small ones, all of recent volcanic appearance. What Darwin observed there can be summarized in terms of what are now called Darwin's Finches, a group of small birds found only on the Galapagos. He found that this group of birds, clearly related, had taken on differing characteristics from one island to another, and the differences were great enough so that the birds had to be classed under different species, and even different genera. A current classification [Grant, 1986] shows that there are now 13 species of Darwin's Finches on the Galapagos, all of which have apparently evolved from a single common stock.

It should be emphasized that most of the Galapagos islands are within sight of one another, and that these were normal birds, capable of flight. Even so, the forces which govern evolution are powerful enough so that even a relatively small separation in distance was enough to bring about genetic divergence, great enough to take the birds into different species and genera. And there was nothing special about this particular case of the finches, the same thing had happened with other animals, and with plants.

For example, Murray [1986] has shown that of the 543 native species of higher plants on the Galapagos, around 40% are endemic, that is they are species found only in that area. These endemic species must have evolved from older stocks which elsewhere have either disappeared or evolved in a different direction. Murray has calculated that 'the minimum number of immigrant progenitors needed to account for indigenous angiosperms [higher seed plants] is 306'. We will return to the point of immigration later, now only noting this as the assumed route of origin of the plant populations.

Of course when we move up to the next broader level above that of species, to the level of genus, the level of endemism is much less. The majority of the plant genera, such as *Acacia* (wattles), *Psidium* (guavas), and *Opuntia* (prickly pears) have species which are native elsewhere.

The Galapagos appear to be relatively young in geological terms, having existed in isolation for no more than 3*my* , and possibly as little as 0.5*my* [Murray, 1986; Grant, 1986]. This period has been long enough to evolve 13 species of finch from the original one. On another isolated site, the Hawaiian archipelago, Grant has shown that at least 42 species of honeycreeper finches have evolved from a single ancestor during the last 6*my*.

From these two figures we can derive a rule of thumb to estimate the rate at which species will evolve and split in the absence of ecological pressure. If we assume that a species will diverge enough to split in two every million years (doubling every *my*), it would take about 3.5*my* to produce the 13 Galapagos finches and about 5.5*my* to end up with the 42 Hawaiian finches — both close enough for a first stab.

> *Proposition 2E*
>
> *In the absence of ecological pressure, a species diverges into two species roughly every million years*

Changing Climates — March of the Isocons

So far we have only looked at the situation as of now, with today's conditions of climate and elevation in particular parts of the world. In fact, we know that both climate and sea-levels have varied dramatically in the past in most parts of the world.

We can also represent this position by saying that the isocon lines do not stay fixed with time, but move around as external conditions change. As the sea-level rises, the major sea/land isocon moves 'inland' into what was previously higher ground, as the oceans fall it moves out to sea. As the climate cools, the major frost/no-frost isocon moves towards more equatorial latitudes, and as the climate warms, so it drops back toward the poles.

In this way, every species population is subjected to a sort of ecological massage. The isocon boundary bag within which it lives is pushed back and forth, up hill and down, north and south. Every species is a nomad.

This picture leads to an important conclusion. As the isocon boundary bags are moved around over the terrain by various external changes, it is inevitable that some will cease to exist. Some will fall over a cliff into the sea (as when an island flora is inundated); others will evaporate off the tops of mountain (as when warming causes the frost line to cease to exist). When this happens, either one population of a species, or even the whole species, will also cease to exist.

> *Proposition 2F*
>
> *Species tend to die out when the ecological niches in which they exist are eliminated, and this elimination is promoted by continuing changes in external factors such as climate and sea-level*

There is also a most important counter-conclusion. When subjected to this ecological massage, when the isocon bag is nearing the edge of the cliff, some species will have the genetic resources to adapt and cross the isocons, thus becoming a new species. Natural selection is known to promote the formation of new varieties and species, so changes in natural selection pressures must speed the process of evolution up even more.

> *Proposition 2G*
>
> *Changes in external conditions increase rates of natural selection and evolution*

These two last propositions are clearly at the two ends of the tug-of-war rope. They imply that the rate of formation and extinction of species is much greater than has been assumed. During the last 2*my*, there have been five major glacial advances and five retreats (five 'ice ages'). Most isocon bags will have been shifted some hundreds of kilometres during each of these ten trips. Those situated on small islands must have had a hard time!

Conclusions on Plant Evolution and Spread

We have built up a picture of previously largely unrecognized rapid changes in the genetic bases of plant and animal species. It is clear that these species have the capacity to undergo marked changes in their total genetic bank over what are very short periods on the scale of the Earth's history.

In fact this conclusion is obvious, when we look at the rapid changes in species which have been brought about by man, purely through simple processes of selection, in periods measured in decades, not even centuries. An important point here is that most of these changes are very visible ones — bigger and brighter flowers or fruit, rapid or dwarfed growth, and so on.

Under natural selection, many of the genetic shifts which occur in species will not show up very visibly. If an isocon shift moves a plant population from a sandy soil onto a clay soil, selection of the population will occur to cope with the change in soil type and the associated nutritional factors which this implies. But there may be no visible change at all in the appearance of the plant, and even at the detailed genetic level, it could be hard to find a quantitative difference.

The ginkgo or maidenhair tree, a fascinating nut tree, has been claimed as the oldest 'living fossil'. Standing on the border between the major plant groups of gymnosperms (conifers) and angiosperms (broadleaved trees), the ginkgo was first recognized in fossil leaf impressions dating back some 200*my*, and was not originally known to Europeans as a living plant.

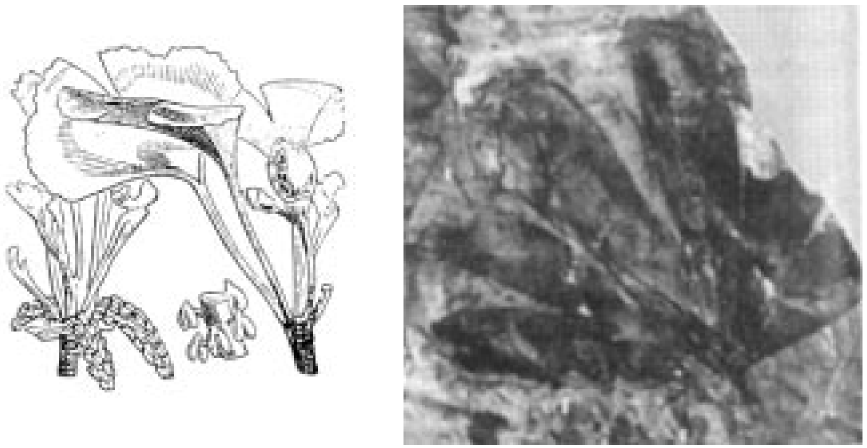

Fig. 2.2. Images of living and fossil ginkgos

However in 1712 an employee of the East India Company, Englebrecht Kaempfer, noted some cultivated ginkgos in Japan [Griffiths, 1987]. In later European travels in China, a number of living gingko trees were found, mostly planted around temples. It is still uncertain

whether there are any 'natural' or wild occurrences of ginkgos, although an area in Chekiang province in China has been suggested.

The point that is being made here is this. It has been claimed that the ginkgo has remained 'unchanged for 200 million years'. This is most unlikely. While modern ginkgos are undoubtedly related to those which produced the ancient fossil prints, they would certainly not be classed as the same species as the fossils if the latter were alive today — the underlying genetic differences must be enormous. Later on we will see why this must be so.

In fact it is likely that no species is capable of maintaining its genetic identity for any very long period, say much more than around 10*my*. Even less is it likely that this identity would be retained through a major physical turnaround like that at the end of the Mesozoic Era, some 70*my* ago. Reasons for this major upheaval will also be looked at later in this book.

> *Proposition 2H*
> *No species can maintain its genetic identity for long periods, more than around ten million years*

Are these suggestions reasonable in the light of logic and evidence? I have suggested that species are capable of splitting into two, doubling themselves, every million years (and this may turn out to be a low estimate). If there are a million different species of plant existing today (and current estimates approach this figure), then in the next 10*my* there could be ten doublings, to produce around one thousand times as many species as now.

It is believed that the 'density' of species has increased appreciably since life appeared on Earth, with less diversity in the earlier years. This is a reasonable supposition anyway, as the complexity of particular species has reached higher levels, fitting them to operate more and more efficiently in smaller and more defined ecological niches — the trend toward specialization.

Nonetheless, the actual increase in species density is far, far smaller than would be implied by general application of Proposition 2E, doubling every *my*. What is happening, of course, is that species are dying out as well as being formed, and these two processes more or less balance — the situation is not too far from a steady state as far as total number of species is concerned. Just like the atoms of a radioactive substance, we can assume that species have a half-life, the average time needed for half the total number to disappear. The actual numbers depend directly on Proposition 2E and the assumption of a long-term steady state:

> *Proposition 2I*
> *The half-life of a species is approximately one million years.*

This last proposition is actually a modification of 2H before it; the 10*my* in 2H becomes just the time at which the probability of a species surviving has become very small (around 0.1%).

CHAPTER 3

CONTINENTAL DRIFT AND EARTH EXPANSION

“Then Yima stepped forward, towards the luminous space, southwards, to meet the sun, and pressed the earth with the golden ring, and bored it with the poniard, speaking thus: ‘O Earth, kindly open asunder and stretch thyself afar, to bear flocks and herds and men’.

And Yima made the Earth grow larger by three-thirds than it was before, and there came flocks and herds and men, at his will and wish, as many as he wished.”

— Zend-Avesta, Vendidad, Fargard II, verses 18-19

Continental Drift

We turn now to quite a different part of the world, a different time, and a very different topic. The topic is what is now called Continental Drift, the place is Paris, and the time is 1858. In that year Antonio Snider, an American working in Paris, published a book.

This book [Snider, 1858] drew attention to the remarkably good match between the west coast of Africa and the east coast of South America. Snider suggested that this good match was because Africa and South America were once a single continent, which had been pulled apart in some way to form the present coasts (Fig.3.1). He gave a drawing of the combined continent, showing also Europe and North America joined, and even Australia joined to eastern Africa.

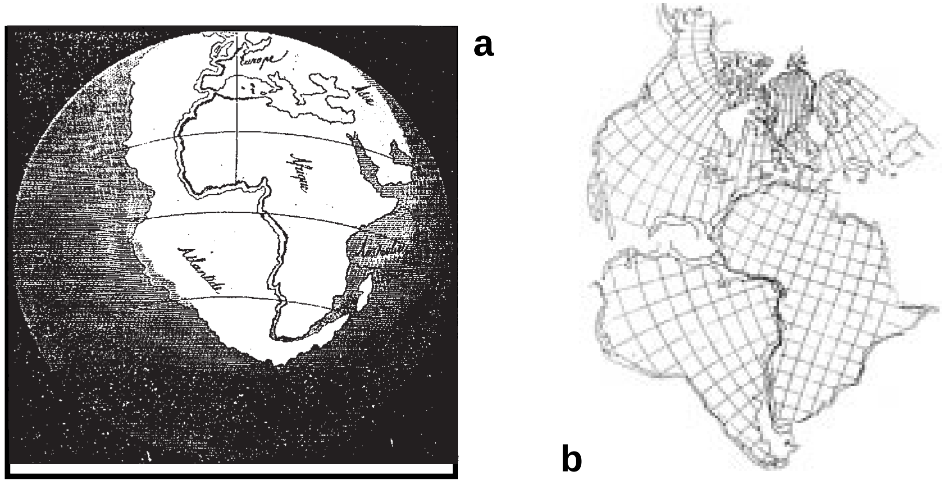

Fig. 3.1. Pre-Atlantic Ocean according to: a) Snider ; b) Bullard

This work was lost sight of in later years, but the topic was revived in 1915 when the German scientist Alfred Wegener published another book on the topic of how the continents were formed [Wegener, 1915]. Wegener’s work, unlike that of Snider, attracted considerable attention, and quite a lot of supporting comment. It really explained a lot, and if you could only

accept the possibility that the continents could actually move relative to one another, the logic of the proposal seemed clear.

Nevertheless, over the years support again waned. It did not pick up again until 1964, when Sir Edward Bullard published a paper [Bullard, 1964] which included a computer-based fit of the coasts of South and North America against Africa and Europe (Fig. 3.1). As this work was computer-based, of course it had to be right, and from that point on the concept of Continental Drift finally began to achieve general public acceptance; it only took a little more than 100 years!

This work considered only the lands on either side of the Atlantic. Some interesting observations had been made of the occurrence of fossils of a plant genus, *Glossopteris*, in rocks in Africa, Australia, India, South America, Antarctica, and New Zealand. Of course it is only a matter of logic that plants in the same genus must have had common ancestors, and these ancestors must have existed together within a single area — otherwise they wouldn’t have been able to breed.

> *Proposition 3A*
> *Plants in the same genus must have had common ancestors, and these ancestors must have existed within a single area*

As the rocks containing the *Glossopteris* fossils are now widely separated, then using the principle of Continental Drift it was only natural to assume that these rocks were in continental masses which had drifted apart, and it was not hard to suggest how they had once fitted together (Fig. 3.2).

Further support for the idea came from a study of rocks which had been affected by an ancient glaciation, assumed to be an early south-polar icecap. Notice in Fig. 3.2 that India is part of this ancient super-continent, which has been called Gondwanaland. The drift of India northwards, and its collision with the rest of Asia, is assumed to be the cause of formation of the Himalaya Mountains.

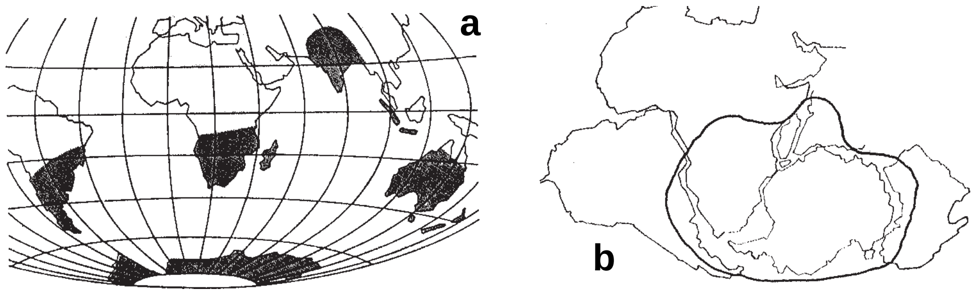

Fig. 3.2. a) Sites of Glossopteris *fossils ; b) Suggested former grouping of land around the South Pole*

Additional confirmation for the occurrence of continental drift came from studies of magnetism in rocks (paleomagnetism). Certain rocks are slightly magnetic, containing ‘magnetic domains’ which are areas of the rock magnetically aligned in a certain direction.

This magnetic direction is set by the Earth's magnetic field as the rock cools down from a hot state, and points towards the Earth's magnetic poles.

Our magnetic poles are in a different position to the geographic poles, and also vary slowly but continuously, both in position (currently the North Magnetic Pole is 11° away from the geographic pole, somewhere off northern Canada) and in strength. The polarity of the Earth's magnetism may also change, with the North and South magnetic poles interchanging in position.

By looking at the magnetic directions in old rocks of the same age, but in different continents, it becomes apparent that these continents must have shifted relative to one another — the magnetic poles they point to are not in the same place. This technique has been used to trace the apparent movement of the magnetic poles over the Earth's surface in the past.

The parts of the surface which move as one have been called 'plates', and the study of their movement 'plate tectonics'. We will see later on that the term 'plate' is not an apt one.

The currently accepted position is that the northern continents of North America, Europe, and Asia without India were once a single super-continent (called Laurasia), which, together with Gondwanaland, previously made up a single continent containing all the present land areas; this has been named Pangaea (Fig. 3.3). There is now convincing evidence that Pangaea really did exist as a single landmass about 200*my* ago, and that it has since split apart, first to form Laurasia in the north and Gondwanaland in the south, after which each of these supercontinents again split further into parts, which drifted away to form the present disposition of the continents.

Fig. 3.3. A reconstruction of Pangaea

Continental drift has 'come of age'; the fact that it occurs is no longer seriously doubted, even by more conservative scientists. It is a good example of a scientific theory, one which explains many observable features of the real world in a simple, coherent, way, and for which no alternative and more simple theory has yet been put forward.

When it comes to the *cause* of continental drift, however, the position is very different indeed.

The Convection Current Theory

In searching for a mechanism for continental drift, geophysicists came up with the idea of convection currents. The interior of the Earth is widely believed to be hot, molten in parts, and it was suggested that the molten rock moved in convection currents, like water boiling in a saucepan, and the movement of these currents forced the parts of the old supercontinents apart.

The convection-current proposition for the mechanism of continental drift has achieved an amazing acceptance, and appears in all current standard geological textbooks. The acceptance is amazing because it is a proposition wholly without any supporting evidence or plausible basis. In my view it is completely wrong.

Of course the energy required to move whole continents around is extremely large. No plausible source for this energy has ever been suggested, as far as I know. No reason for the convection currents to break up into the assumed 'convection cells' has ever come forward.

> *Proposition 3B*
>
> *The convection-current mechanism for continental drift lacks any supporting evidence or plausible basis, and is completely wrong*

We will return to this point later on, and suggest an alternative mechanism for driving continental drift which does not suffer from these drawbacks.

Sea-Floor Spreading

During the 1960's, scientists came to learn a lot more about the structure of the sea bed, and some very interesting facts came to light. Of course, by this time, accurate methods of dating the ages of rocks were well known. A series of massive structures, called 'mid-ocean ridges' (Fig. 3.4), were discovered running down the middles of the major world oceans, and these were found to be the sites of volcanic activity, producing new rock (age zero years).

As you move away from a mid-ocean ridge, you encounter progressively older rock, on either side. All the rock is of oceanic type, common to sea-beds all over the world, and quite different in nature to the rocks of the continents. The oldest oceanic rock, that most distant from a ridge, is only 200*my* old.

Because much of the newly-formed rock had magnetic content, the paleomagnetic techniques described earlier in this chapter could be used to date the rocks in great detail. On either side of the ridge, 'stripes' of rock are being formed, with the edges of the stripes representing changes in polarity or strength of the magnetic fields. The ridgepoint itself looks like a mirror, with a pattern of stripes of given age and magnetic properties reflected on either side.

The picture given was quite clear and unambiguous. At the ridges, new rock was being formed along a roughly continuous line down the ridge, and spreading off to both sides to permit even newer rock to appear. It is perhaps understandable that these ridge-lines could be interpreted as the positions where convection currents were welling up from the Earth's mantle, bringing with them molten rock to solidify and spread apart.

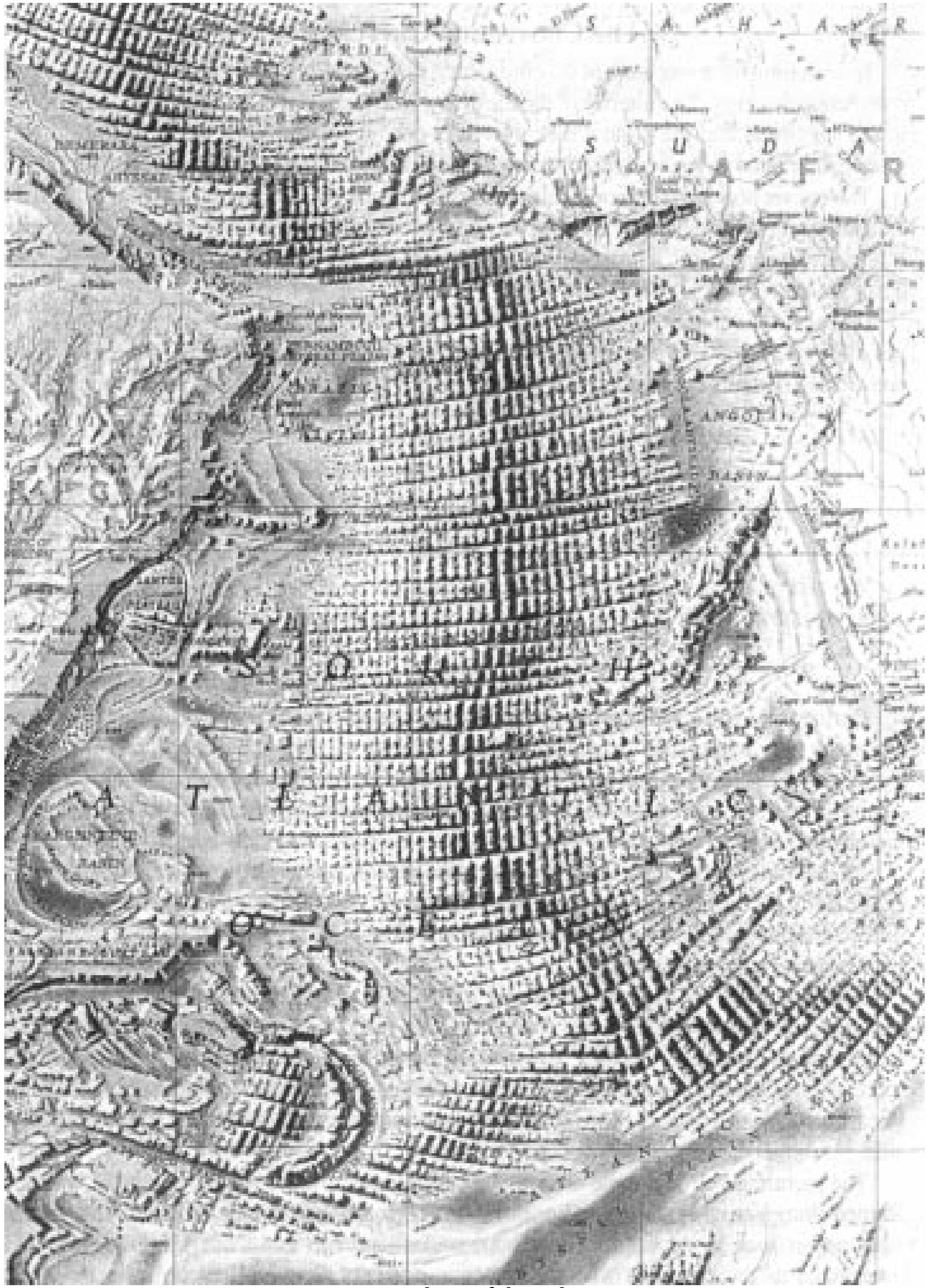

Fig. 3.4. Floor of the Atlantic Ocean

The phenomenon involved, called sea-floor spreading, appears to have created the whole of the present ocean floors during this period of 200*my*. The rate of spread varies from one ridge to another, but is something like 2-4*cm* per year — about as fast as your fingernails grow.

The fact that sea-floor spreading actually occurs is no longer in any real doubt. The driving mechanism behind it, however, is again quite a different story.

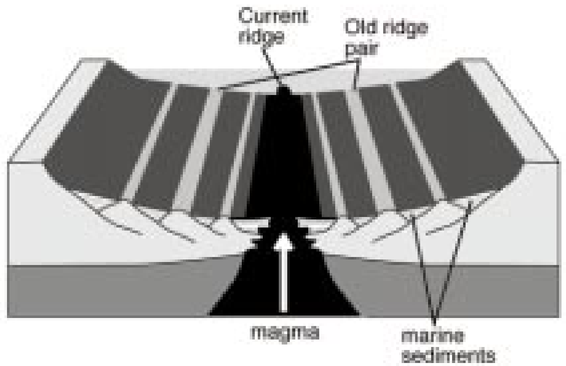

Fig.3.5. Sea-floor speading at a mid-ocean ridge

The 'Subduction Zones'

If the sea-floor was expanding at the mid-ocean ridges, where was the new surface material which was created ending up? The suggestion was made that it was disappearing down the deep ocean trenches, and either piling up under the continents, or being melted and recycled by the convection currents to appear eventually at another ocean ridge.

Although this is the currently accepted dogma, it seems to me, and others (eg [Ciric, 1981]), to be a concept which almost completely lacks any supporting evidence. It seems against logic, if one plastic plate is being pushed against and under another, for a deep trough to be formed between them. The deep ocean troughs are not continous, and do not show any of the signs of rock in motion downward, deep into the Earth. And, in the case of the mid-Atlantic ridge, there are no deep ocean troughs along the Atlantic coasts for the re-cycled rock to disappear into.

Peter James, an engineering geologist, has looked at the position from the viewpoint of the physics of materials. He concluded that 'serious difficulties exist in trying to reconcile the observed crustal features with a conventional model of mobile plate tectonics — at least on our present knowledge of material behaviour' [James, 1987].

Another problem with the subduction theory is explaining away just where the huge volumes of rock involved are ending up. The whole of the present Pacific Ocean, an area representing around one-third of the entire current surface of the Earth (more than the total land area!), has opened up during the last 200*my*. The bed of the Pacific varies in depth, but averages around 4*km* below current sealevel.

Carey [1987] has pointed out that the subduction theory just does not explain where these huge volumes of rock, more than a million cubic kilometres of material, ended up when the Pacific Ocean was created. If they were spread evenly under the present continents, these would be some 7*km* higher than they are now, just with the material from the Pacific alone (current average height of the continents is no more than 1*km* above sealevel). If the rock was really recycled in the mantle, to reappear at the mid-ocean ridges, then the Pacific would have always have had to have been its present size and depth, and not created from scratch in the last 200*my*.

The subduction theory is thus a literal attempt to sweep a problem away under the carpet — in this case, the carpet of the continents. Now is the time to drop this theory down one of the ocean trenches.

> *Proposition 3C*
> *The subduction theory lacks supporting evidence and plausibility, and is completely wrong*

Expansion of the Earth

If we return now to Bullard's fit of Africa against South America (Fig. 3.1), you will notice that as you move away from the central point of contact, the match becomes less good. In 1955, Warren Carey, Professor of Geology at the University of Tasmania, pointed out [Carey, 1955] that the match would be much better if the two continents were curved around an Earth of smaller radius. This was the beginning of the current phase of the Expanding Earth theory.

The basis of the Expanding Earth proposition is that the current continental masses were once all joined completely together, covering the whole surface of a much smaller Earth. This has since expanded internally, the current continents splitting apart and distributing themselves over the enlarged surface. In other words, the current deep-sea areas did not exist in their present conformation in earlier times, but have been formed by the expansion of the Earth's core under them.

Fig. 3.6. Unexpanded Earth views according to Barnett

At present, about 70% of the Earth's surface is covered by sea. If the present 30% surface which is land had to cover the whole of a smaller sphere, that sphere would be about 55% of the diameter of the present Earth. Instead of the current radius of about 6,400*km*, the radius would have been around 3,500*km*. The circumference of the present Earth is 40,000*km*, but an 'unexpanded' Earth, in which Pangaea covered the whole surface, would have a circumference of about 22,000*km*, that is, 18,000*km* less than now.

It is interesting to calculate how long this expansion would have taken, at the present rate observed in sea-floor spreading. Since the rate at each ridge is around 2-4*cm/yr*, and there are usually 3 ridges crossed in going right round the Earth, the total present expansion is very roughly 9*cm/yr*. Dividing this into 18,000*km* gives an expansion time of 200*my*, which agrees quite well with the time from rock age-dating.

The Expanding Earth concept is not in conflict with Continental Drift, in fact we shall see that the two are closely linked. Under an expanding Earth, the single continent Pangaea which existed around 200*my* ago would not have had exactly the conformation shown in Fig. 3.3, instead the outer edges of Pangaea would have wrapped round a much smaller Earth and be in contact, thus enveloping the whole Earth.

Further models of the pre-expanded Earth were constructed in the recent phase of interest, such as that made by Barnett [1962]. Several views of this model are shown in Fig. 3.6. Notice that Barnett's model is fairly 'loose', with many large gaps not covered by land, and that some large movements and rotations of the land masses have been suggested, such as Australia moved against North America, Greenland moved a long way over the top of Canada, and so on.

Early Work on an Expanding Earth

As with the Continental Drift theory, there were earlier workers who had suggested the possibility that the Earth was expanding. One of these was Hilgenberg [1933], who produced globes of the Earth at various stages of its expansion (Fig. 3.7).

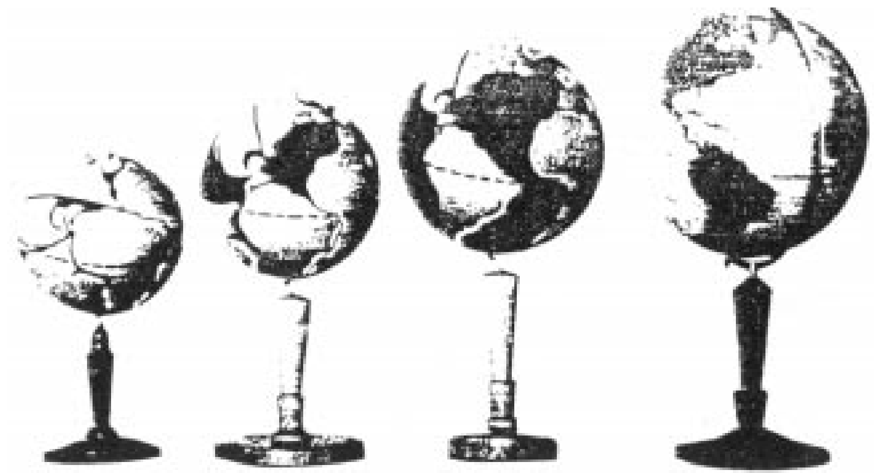

Fig. 3.7. Globes of Earth expansion according to Hilgenberg

A fascinating fact of history is that it was suggested as early as 1859 that the Earth was expanding; this was in a book by Alfred Drayson, entitled 'The Earth We Inhabit: its past, present, and probable future'. This book [Drayson, 1859] came out only one year after Snider had published his early work on Continental Drift!

Drayson is described on the title page as 'Captain Alfred W Drayson, Royal Artillery, author of "Sporting Scenes in South Africa", &c' — not the background one would expect for someone producing fundamental thoughts on the Earth's structure.

Much of Drayson's evidence for expansion does not stand up to examination in the light of modern knowledge, and he enormously overestimated the rate of expansion, at around 6000*cm/yr*, as against the current estimate, one thousandth of the size. But it must be remembered that in Drayson's time, the great age of the Earth had not yet been established — the accepted value then was perhaps 40,000*yr*, so naturally the rates for associated phenomena would be well out.

Some of Drayson's observations are still valid. He noted unexplained fractures in deep undersea cables. In his day, these cables were clad in rigid iron. If the forces rupturing an undersea cable applied along its whole length, then expansion could have been at the rate estimated by Drayson. In fact they presumably only applied at mid-ocean ridges or ‘plate boundaries’, only at the places where the fractures actually occurred.

Fig. 3.8 is a reproduction from Drayson’s book. He says “perhaps it [the Earth] was once very small, perhaps as small as fig.1., whilst the present earth is the size of the larger circle.” It is interesting that the proportions shown in Drayson’s diagram are very close to those currently assumed for an expanded and original Earth.

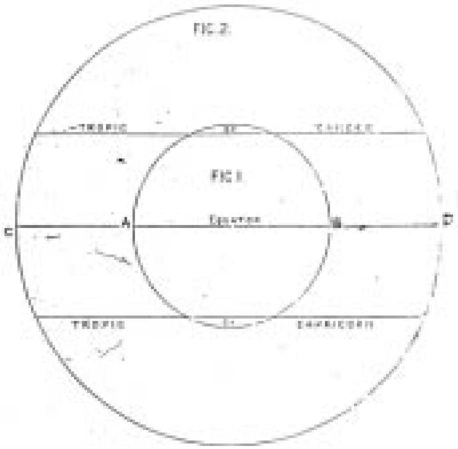

Fig. 3.8. Present and unexpanded Earth cross-sections, from Drayson [1859]

Copies of Drayson’s book are quite rare, and its existence does not seem to have been picked up by anyone else interested in the expanding Earth idea. However, if you search long enough, you can almost always find a possible earlier reference — the match across the Atlantic coasts was noted as early as 1620, by Francis Bacon! An even earlier reference to expansion of the Earth is that quoted at the head of this chapter. This is from the Zend-Avesta.

Thus Spake Zarathustra

The Zend-Avesta is the sacred book or bible of the Parsees, followers of Zoroaster. Zoroaster (another form is Zarathustra) was the founder of one of the most ancient religions still extant — he was active in the area now known as Iran, at a date not known with certainty, but believed to be around 1000 BC.

Of course the reference in the Zend-Avesta presumably has no scientific relevance, but it does justify the claim that expansion of the Earth has been a topic for some three thousand years!

ADDENDUM

Readers interested in the *geological* evidence for an expanding Earth should consult Warren Carey’s new book ‘Theories of the Earth and Universe: a History of Dogma in the Earth Sciences’ [Carey, 1988]. This gives a very thorough examination of the matter, and also brings out the knee-jerk tendency to react to revolutionary new ideas in science with ridicule, even when they are supported by the soundest evidence. If these ideas have the support of logic and evidence, then of course they do win out in the end, sometimes even bringing ridicule on those who rejected them out-of-hand when they first appeared!

CHAPTER 4

THE DISTRIBUTIONS OF NUT TREES

"I went down into the garden of nuts to see the fruits of the valley, and to see whether the vine flourished, and the pomegranates budded."

— Solomon's Song

What (or who) is a nut?

So far in this book we have looked at how plants spread and change, and at the evidence for the occurrence of Continental Drift and Earth Expansion. Now we will combine these two diverse topics, to provide a new approach to determining specific details of these movements of the Earth’s crust, using first as an example the area of nut trees.

Because the term ‘nut’ is applied to a whole range of different plant structures, occurring across almost the whole gamut of plant life, nuts are a useful starting point for this work. To the botanist, ‘nut’ has a much more specific meaning than the general understanding. What we call a nut may be a seed, a fruit, a tuber (tiger nut), a bulb (water chestnut), a pod (peanut), or any one of a range of specialized plant structures to the botanist.

Nuts not only grow on trees, they grow underground, under and on top of water, in giant gourds on 30-metre vines, in jungles, deserts, everywhere from the tropics to within the arctic circle. Examples of things called or treated as nuts occur in most of the main plant families, and appear in both the gymnosperms (conifers) and both branches of the angiosperms (broadleaved plants). Even the ginkgo, that strange fossil half-way house between them, is a nut producer.

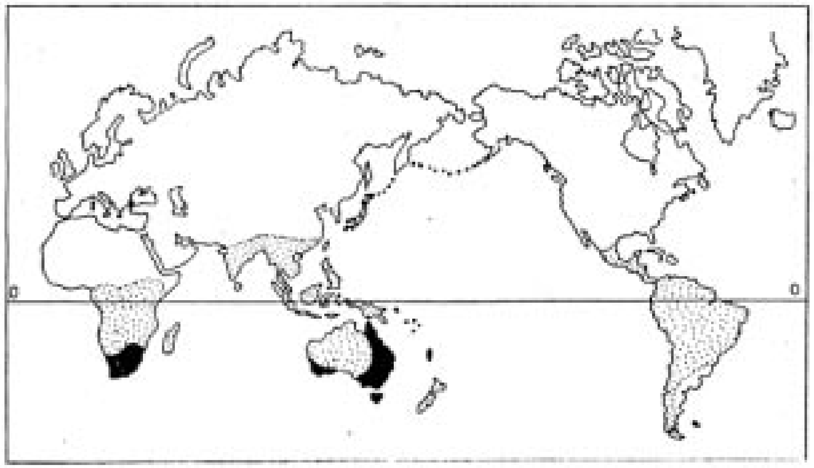

Fig. 4.1. Distribution of the Proteaceae [Rao, 1971]

In Fig. 4.1 is shown a world map giving the present distribution of the Proteaceae, the plant family containing the macadamia nut, the avellano, and some other less well-known nuts. The dark parts show heavy concentrations of species, the lighter shading the more lightly populated areas.

Now remember the principle (Proposition 3A) that species that are related must have had common ancestors existing in a single range. The only way for the current distribution of the Proteaceae to have come about, is for the species to have spread naturally by their inbuilt dispersal mechanisms (the conventional view), or for the areas of population to have been in contact with each other in the past and since moved apart through continental drift, or a combination of both.

The Continental Drift approach, which is not disputed at this time, provides a satisfactory broad-scale explanation. The continents involved are the same southern ones as those concerned with the *Glossopteris* fossils (Fig. 3.2). Notice, however, that the modern Proteaceae extend beyond the range of the Glossopteris fossils, and in particular exist all over southeast Asia and up into southern China.

Now look at Fig. 4.2, the distribution of species of true pines *(Pinus)*, containing many nut-bearing trees. Notice that this map more or less complements the first one; there are only small areas of overlap, in Central America and the Malesian area, and these are well within the range of what might be expected from natural dispersion.

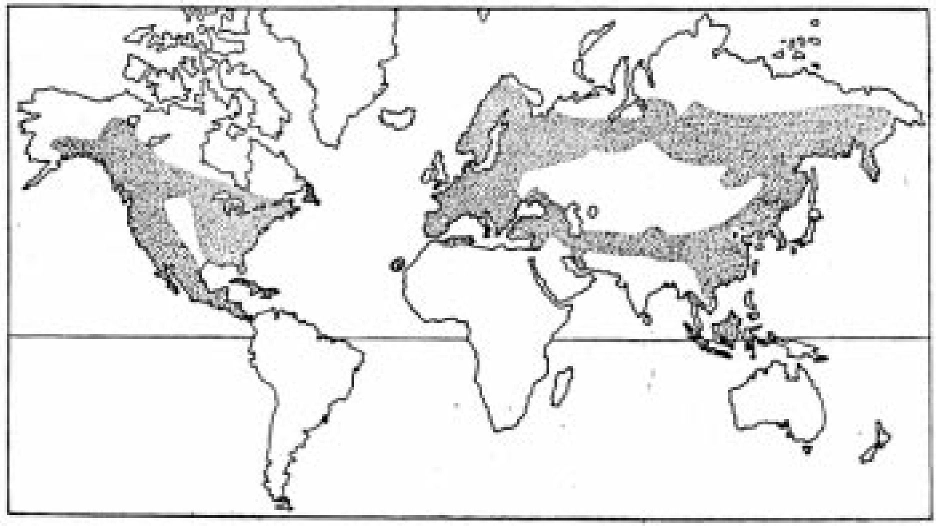

Fig. 4.2. Distribution of Pinus *[Maheshwari, 1971]*

The distribution of pines is paralleled also by that of the oaks, species of *Quercus* and some close relatives. People with European connections tend to think of oaks as a typical European tree, but in fact there are two areas with high concentrations of oak species. One is in the U.S./ Mexico region, the other is in southeast Asia. In spite of this, native oaks are completely lacking in the adjacent areas of Australia and South America, just as with the pines.

We will see later on that this situation is repeated with many other plant families. The explanation is fairly obvious at this point — the Proteaceae developed in Gondwanaland, and the pines and oaks in Laurasia. This is an unremarkable continental drift implication.

> *Proposition 4A*
> *Plant families tend to be identifiable either with Gondwanaland or with Laurasia*

Now to move on to some detailed distributions. First, in Fig. 4.3, we see the distribution of species of *Elaeis*, the oil-palm, and a major world source of oil from its kernels and fruits. In view of the accepted former juxtaposition of Africa and South America, this distribution is entirely as might be expected.

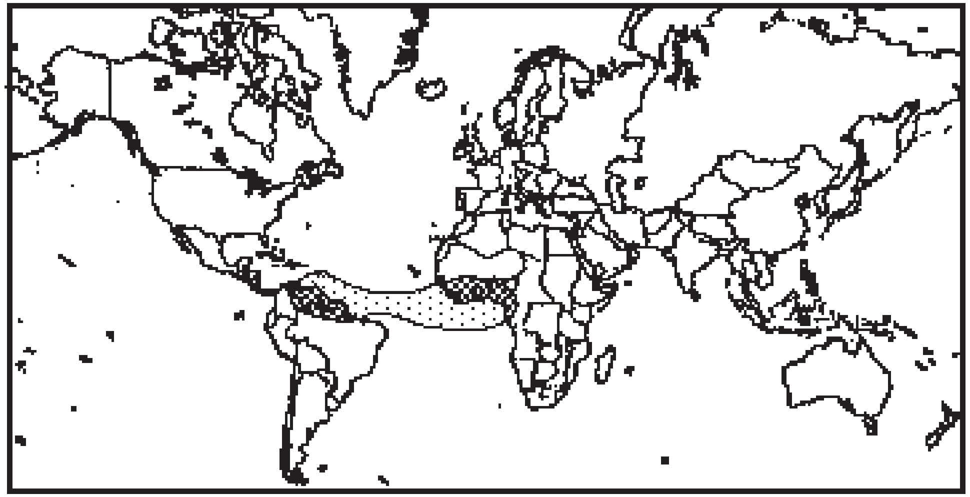

Fig. 4.3. Distribution of Elaeis

In Fig. 4.4 we have the map for the Araucarias, sources of those excellent nuts the Bunya Pine in Australia, the Monkey Puzzle in Chile, and the Paranà Pine in southern Brazil. Another species is the Norfolk Island Pine, and there are also species in New Guinea. The inference from this map is that eastern Australia once fitted against the west coast of South America, and if you try it with a model, you will find that this match is a very good one.

This distribution is our first hint that the 'basic' continental drift theory requires modification. No conventional reassembly of the Earth on a sphere of current size (eg Fig.3.3) places Australia against South America; in fact the plant distributions show that this link is both strong and relatively recent.

> *Proposition 4B*
> *Plant distributions are evidence that the Expanding Earth proposition represents the situation better than the simple Continental Drift theory*

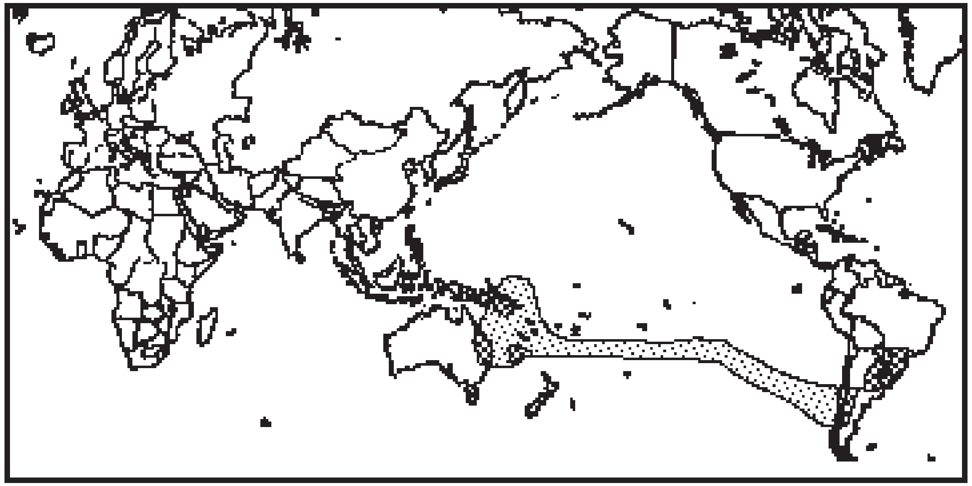

Fig. 4.4. Distribution of Araucaria

The next map (Fig. 4.5) shows where the three species of *Gevuina* exist , in Chile, eastern Australia, and New Guinea. The Chile species produces the Avellano or Chile Hazel nut, and the Queensland species also produces an edible nut [Irvine, 1980]. These two species are some 13,000 km apart, about one-third of the distance round the planet. It would be hard to explain this as chance dispersal, say by drifting on ocean currents.

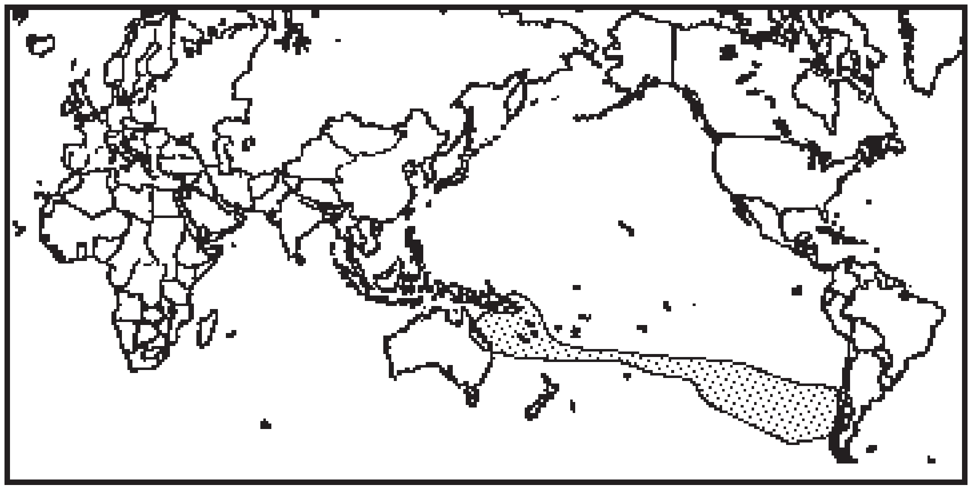

Fig. 4.5. Distribution of Gevuina

The distribution of *Adansonia*, the boab or baobab family, is shown in Fig. 4.6. There is one species in Africa, extending to India (allegedly introduced by Arab traders!), and one in northwest Australia. But the real concentration is in Madagascar, which has around 12 species. The distribution suggests that Western Australia was once in contact with the east coast of southern Africa, or possibly both were linked through Madagascar or India.

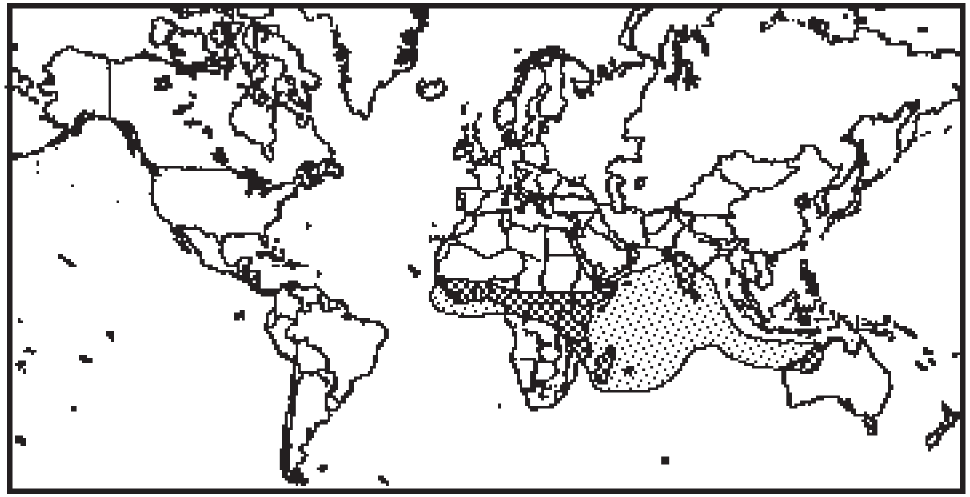

Fig. 4.6. Distribution of Adansonia

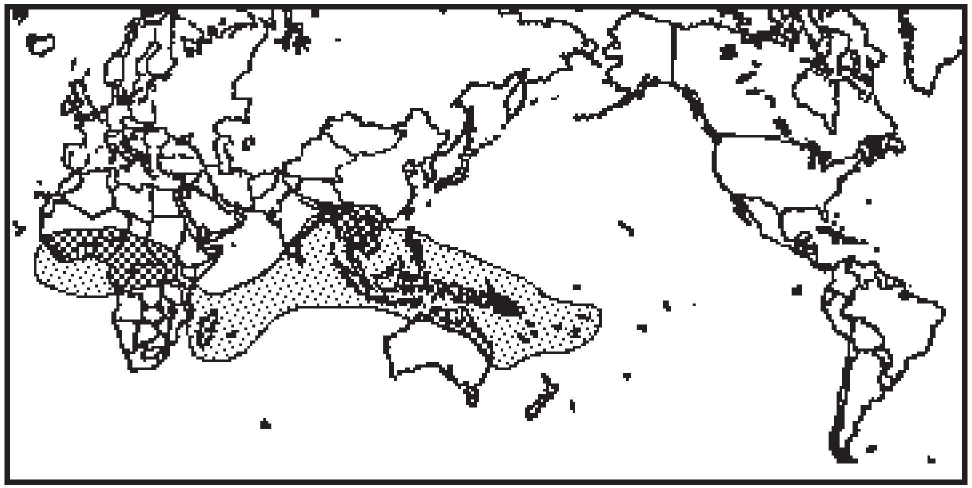

Fig. 4.7. Distribution of Canarium

The next map (Fig. 4.7), the distribution of the *Canarium* family (which contains the pili nut and the java almond), again links Madagascar with Africa (a more central spot) and with the areas of southeast Asia, the Malesian archipelago, and northern Australia. The range extends well out into the islands of the Pacific.

Similar links, displaced somewhat to the south, are shown by the distribution of *Santalum*, the Sandalwood family (Fig. 4.8). The focus of the family is in Australia, and it includes the Quandong, a native West Australian nut. Important former sandalwood sources are in India, Timor, and in Hawaii; there is one species in New Zealand, and there was one on the tiny Juan Fernandez islands right across the Pacific off the coast of Chile. There is also a close relative, once classed in *Santalum* but now given its own species (*Colpoon*), in the Cape area of Africa.

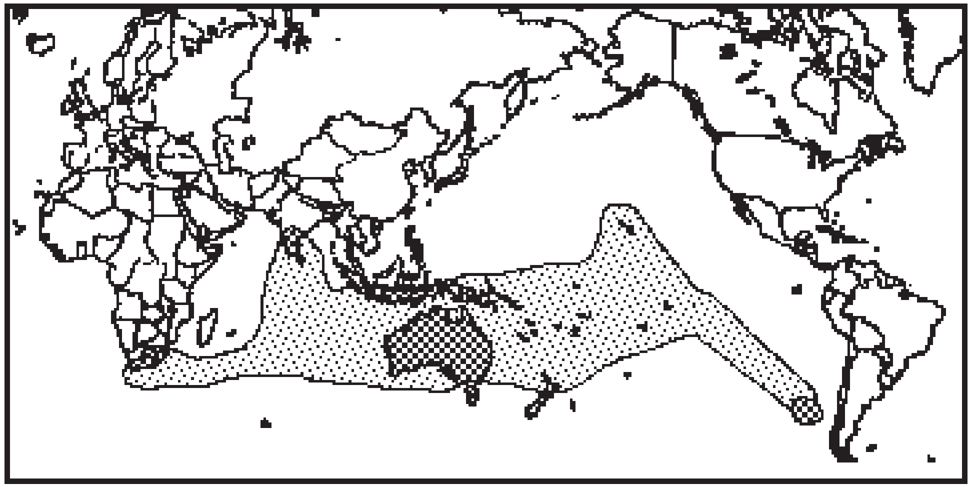

Fig. 4.8. Distribution of Santalum

Links between central Africa, Madagascar, the Malesian islands, northern Australia, and Central America are shown by the range of Omphalea (Fig. 4.9), which contains many edible nuts such as the Jamaica Cobnut, and the Candoo nut from Queensland [Irvine, 1980]. The range extends some 28,000 km. It is a relatively narrow, long strip, stretching almost three-quarters of the way around the planet—a shape virtually impossible to explain by mechanisms such as winds and ocean currents.

It is appropriate here to make another point. When you take into account the relatively fast rate at which plants evolve and genetically diverge (Propositions 2H, 2I), you have the implication that the whole of the Pacific has opened up very quickly and in relatively recent geological time. The links across the Pacific demonstrated here are, in fact, much stronger than those which exist across, say, the south Atlantic.

> *Proposition 4C*
> *The Pacific Ocean is a relatively recent formation, and was largely created after the initial formation of the Atlantic Ocean*

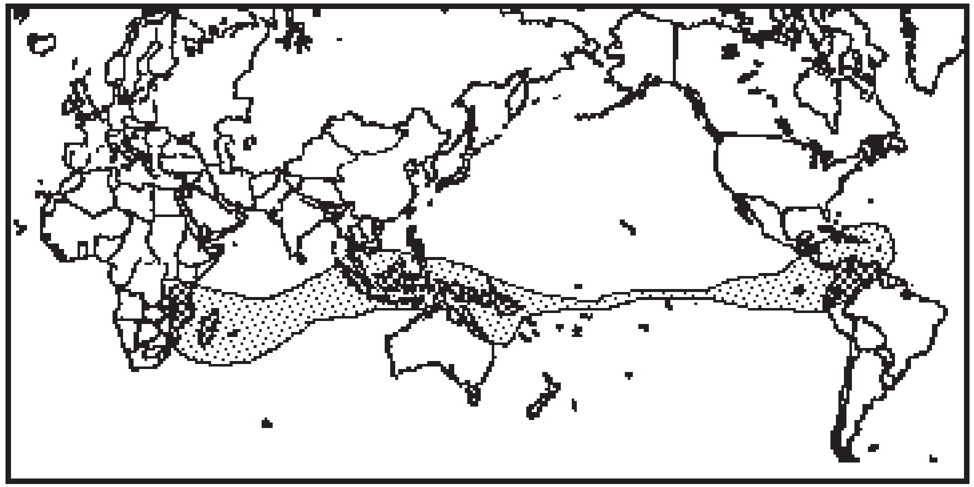

Fig. 4.9. Distribution of Omphalea

All the last seven species were ones with southern distributions. It appears that all developed in the southern ‘supercontinent’ of Gondwanaland, which included South America, Africa, Australia, India, and also Southeast Asia and Southern China. All fall within the current range of the Proteaceae (Fig. 4.1).

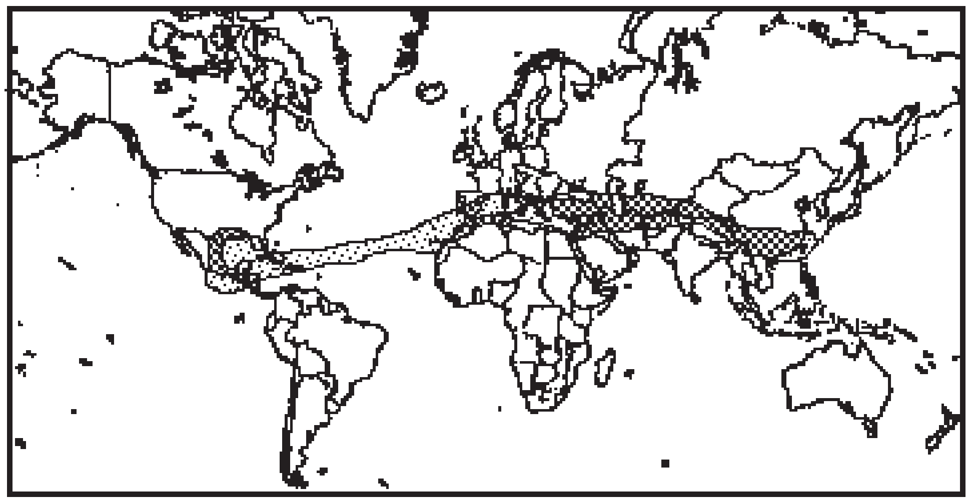

Fig. 4.10. Distribution of Pistacia

Proposition 4D
Gondwanaland included much of southeast Asia and southern China

The next map, showing the *Pistacia* family (Fig. 4.10), takes us into the northern supercontinent, Laurasia. As well as the pistachio nut and its relatives native to Central Asia,

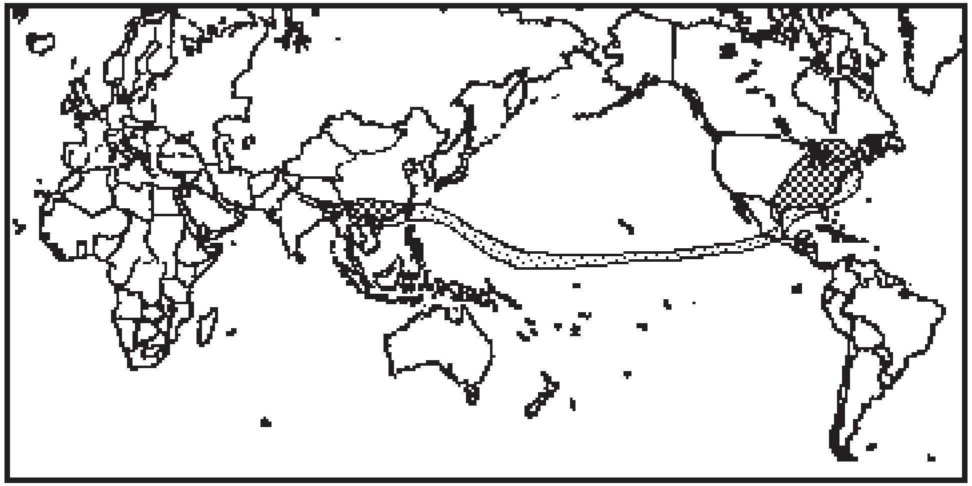

Fig. 4.11. Distribution of Carya

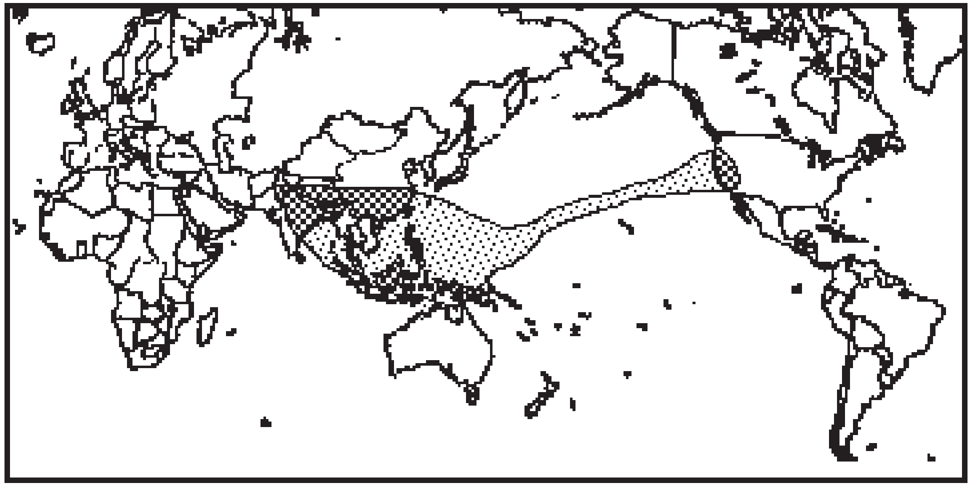

Fig. 4.12. Distribution of Castanopsis

the Mediterranean area, and the Middle East, there are other species in Burma, China, and the Atlantic islands over to Mexico, Texas, and Guatemala. The range confirms the former contact of Europe and North America, and is in no way unexpected.

Figure 4.11 illustrates the range of *Carya* species, the pecan and hickories. Almost all of these are in North America; however, a few little-known species are wild in China and the eastern Himalayas. The range confirms the former connection of North America and Asia across what is now the North Pacific.

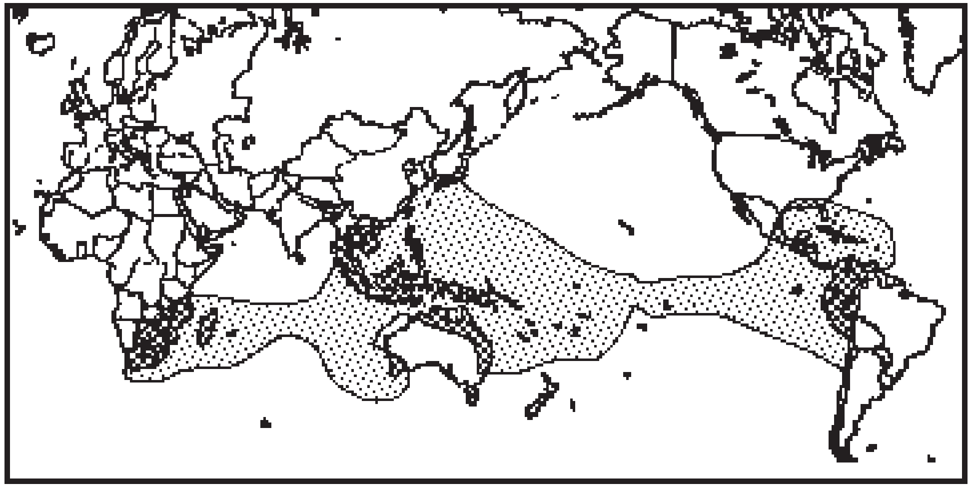

Fig. 4.13. Distribution of the Cycads

Figure 4.12 shows the range of the evergreen chestnuts, *Castanopsis*. They are almost all in Southeast Asia, around 100 species, with just two isolated species way across the Pacific on the west coast of the United States. If you think this could be due to ocean currents, consider that in both parts of the range, *Castanopsis* is a hill or mountain species which avoids seacoasts.

The maps for *Carya* and *Castanopsis* demonstrate that the links across the south Pacific are matched by ones across the north Pacific as well; Laurasia must have been wrapped round on itself too, as well as Gondwanaland.

The next map (Fig. 4.13) shows the distribution of cycads, the zamia palms common to areas which once formed part of Gondwanaland. Their nuts, after treatment to remove toxins, once formed part of the diet of the Australian aborigines. The cycads are a very ancient plant family, and their ancestors are known to be of world-wide occurrence from abundant fossil remains.

The implication of the map is that the modern species are not just those which happened to survive from a former world-wide distribution. Perhaps they are closely related, all coming from a common ancestor which achieved an evolutionary step, somewhere in Gondwanaland, which enabled it to adapt to changing conditions while its relatives became extinct. This particular distribution has a number of other implications which we will return to later.

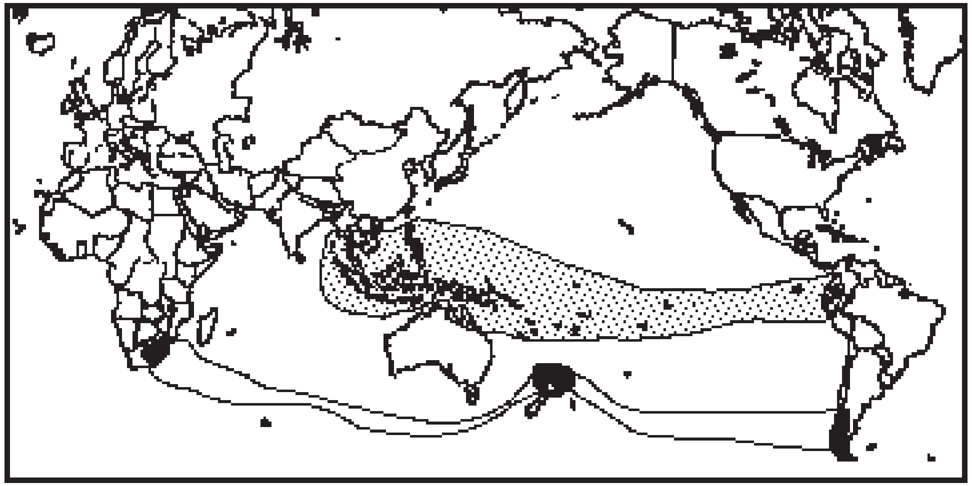

Fig. 4.14. Distribution of Cocos, Jubaea, and Jubaeopsis

Finally, the fascinating story of the coconut and its relatives. It is often possible to determine the original home of a species which has been widely dispersed from such things as the number of insects specific to it, or occurrence of close relatives. The coconut has baffled and confused researchers in the past [De Candolle, 1886; Eden, 1963] because there is strong

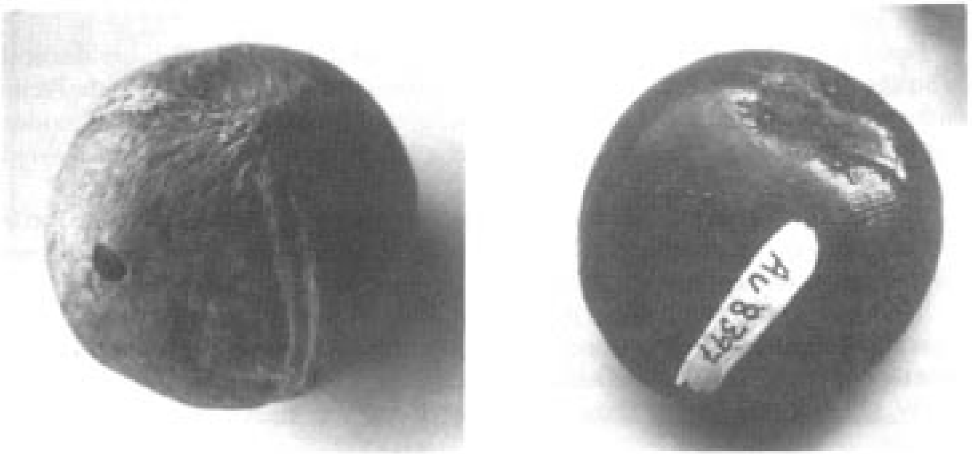

Fig. 4.15. Modern Jubaea *nut (left) and fossil 'coconut' from New Zealand*

evidence that it is a native of Southeast Asia (Fig. 4.14). There is also strong evidence that it is native tothe West Coast of northern South America. You can see now that both claims are right — its area of origin was split apart by Earth expansion.

The true coconut has some very interesting non-tropical relatives, the Pygmy Coconut from Chile (*Jubaea*), and the Pondoland Palm (*Jubaeopsis*) from Cape Province in South Africa. Their fruits are just like tiny coconuts, complete with the three eyes, and with a little 'milk' inside. They are very distinctive indeed, and although it is now extinct, what was almost certainly a close relative has been found as a fossil in North Auckland, New Zealand (Fig. 4.15). These 'fossil coconuts' are believed to be about 16-17*my* old [Grant-Mackie, 1986] — another indication that the separation of New Zealand from South America may not be so very old.

These interesting distributions are all readily explicable on the assumption that the current land areas of the Earth were once all physically linked, capping the whole surface of a much smaller sphere. The Earth has since expanded under this cap, which has split into parts which have become separated and, in some cases, moved relative to one another.

> *Proposition 4E*
> *The Earth's current continents were once all joined together to completely cover the surface of a much smaller sphere, which has since expanded*

In the next chapter we will go on to examine some of the details of this process. For the moment, we will just note that the 'unexpanded' Earth must have had less than 60% of the current radius. More detailed work suggests the figure was closer to 50%, a half-radius Earth.

If you find this Proposition hard to swallow, you should ask yourself, is there a better one? Certainly current explanations for such things as the close cross-Pacific links — usually based on hypothetical land bridges across the Bering Straits during glacial times — do not stand up to any sort of close scrutiny.

It is quite inconceivable that tropical Asian plant genera could migrate all the way north up the Bering Straits, pass over them when they were much colder and covered with more ice than now, then migrate down again to the American tropics, leaving no trace of their passage. And it is equally inconceivable that they could do this so quickly — the last glaciation ended only about 10,000 years ago, and the start of the Ice Age is not much more than a million years ago.

As Sherlock Holmes said, "when everything that is impossible has been eliminated, then what explanation remains, however improbable, must be the truth". We will go on to demonstrate that these explanations are not even improbable, but are supported by a solid weight of evidence.

CHAPTER 5

HOW THE EARTH FELL APART

"Speak to the Earth, and it shall teach thee."
— Old Testament: Job, xii, 8.

What Shall We Call the Bits?

As we develop the theme of this book further, we will be dealing with portions of the Earth's surface of every size, from small islands like Rottnest, right up through the parts and wholes of present continents and on to the complete cap of continental material which once covered the whole of the smaller Earth.

The only name commonly in use for any of these areas is the word 'plate'. We will see shortly that this is not a particularly appropriate word. If a large plate is broken into a hundred pieces, is each of these a plate?

In this book, I will will using the general word '*domain*' for areas of any size which have taken part in the Earth surface shifts described. This is on analogy with magnetic domains, the different magnetized areas of a magnetic material. These may be of any size, and if a large domain is split into a number of smaller parts, each of these is validly called a domain.

For larger domains, comparable in size to continents or the conventional tectonic plates, the form 'megadomain' will be used. However, a megadomain means something rather different to either a continent or a tectonic plate. The word 'continent' means a large, contiguous area of the Earth's surface which is above sea-level. We will see that none of the present continents is a simple megadomain, instead all are aggregations of one or more megadomains with a number of smaller parts.

In my view, so-called tectonic plates are just the areas within strings of different domain boundary segments which are currently in active movement. Different boundaries of the same domain will usually be undergoing different degrees of movement, at any one time the majority of them will be relatively stationary.

Thus a tectonic plate is not a real entity in any permanent sense. Its extent is only defined from the strings of active domain boundaries, and in reality some of these will be so inactive as to be included only to make up a complete figure. Hence the boundaries of 'plates' are only arbitrary, and their subjective nature naturally leads to arguments as to where particular plates extend to, or whether they are really several smaller plates.

> *Proposition 5A*
> *A tectonic plate is not a real entity in any permanent sense, but only the area within an arbitrary assembly of more or less active parts of domain boundaries*

Aggregates of smaller domains have been identified in various parts of the Earth, and to these the word 'terrane' has been applied. These will figure later on in the book. While I believe that 'terrane' is a valid concept and word, for consistency the term 'microdomain' will be used in this book.

For the complete cap of continental material covering the whole surface of the smaller Earth, the term 'holodomain' will be used.

The First Megadomains

We have seen from Chapter 4 that it is reasonably clear which of the major present land areas were part of the southern megadomain, Gondwanaland, and which belonged to its northern counterpart, Laurasia.

Now we can go into the nitty-gritty of how, and why, it occurred. But first we need to look at some figures on land areas, which lead to a conclusion initially surprising, but obvious in retrospect.

It is accepted that Laurasia included most of Europe, North America, and Asia, and that Gondwanaland included most of Africa, South America, Australasia, and Antarctica. The land areas of these continents (in million square kilometres) is as follows:

First Approximation:

Laurasia		**Gondwanaland**	
Europe	9.9	Africa	30.3
N. America	24.4	S. America	17.8
Asia	44.8	Australasia	8.5
TOTAL	79.1	Antarctica	14.0
		TOTAL	70.6

We can see that the two megadomains were of roughly *similar size*, even on this crude first approximation. Refining these figures one stage more, we know that there is very strong evidence that India and Southeast Asia were part of Gondwanaland rather than Laurasia. These two regions have a total area of about 7.7 m km^2. Subtracting this from Laurasia and adding it to Gondwanaland, we get:

Second Approximation:

Laurasia		**Gondwanaland**	
As above	79.1	As above	70.6
- India/SE Asia	7.7	+ India/SE Asia	7.7
TOTAL	71.4	TOTAL	78.3

On the second approximation, the two totals are a bit closer, but not satisfyingly so. Now is the time to bring in a point of detail of great importance.

Antarctica, the Fake Continent

We need to look more closely at the figure for Antarctica; it conceals a basic error which appears to have been ignored, in spite of readily available evidence. Antarctica is a fake continent. Much of its assumed land area is, in fact, sea — or rather would be if the ice was melted. The South Pole itself lies some 1000 metres below sea level.

This is not in any sense new information. It appeared, for example, in the 4th edition of the National Geographic Atlas in 1975, from which Fig. 5.1 is derived.

Figure 5.1 shows the conventional outline of Antarctica, and within it, the areas which are probably 'real' land, in the sense that they would be above sea level if the covering ice was removed and the sea allowed to flow in. In fact, only the part of Antarctica below Australia appears to contain a real landmass, the part below South America is actually only a chain of small islands. We still don't have the full picture, but as an approximation it appears that the real land area of Antarctica is only about half the 14 million square kilometres usually quoted.

> *Proposition 5B*
> *Antarctica is not a real continent, but an assembly of islands, with a land area probably totalling no more than half the 14 million square kilometres usually assumed*

This point seems to have been completely ignored in previous reconstructions of how the continents fitted together in earlier times, whether on the old continental drift basis or using the newer expanding Earth approach. Nearly all these reconstructions have a great lumpy Antarctica stuck between Africa and Australia, and of course this strongly affects the matching.

Laurasia and Gondwanaland were Equal!

When we adjust the Laurasia/Gondwanaland figures for this new smaller value for Antarctica, we get:

Third Approximation

Laurasia		**Gondwanaland**	
As above	71.4	As above	78.3
TOTAL	71.4	- Half Antarctica	7.0
		TOTAL	71.3

and this agreement is excellent. Its relevance will be becoming apparent.

Of course, it is possible to go on into a Fourth Approximation. The areas of Central America, the Caribbean, California, Florida, Spain, Arabia, Atlas Mountains, Southern China, and Japan all contain a mixture of plant elements which make their positioning in either Laurasia or Gondwanaland a little less than certain. The exact land area of Antarctica is yet to be determined. Greenland is also partly a fake, as it is hollow, and the same may apply to other Arctic islands. But the general picture is clear — Laurasia and Gondwanaland were close to having identical land areas.

> *Proposition 5C*
> *The former megadomains of Laurasia and Gondwanaland had the same surface areas*

On now to the actual course of events. Assuming that there was once a solid 'skin' of continental matter covering the whole surface of the Earth, and this Earth then expanded under the skin so it split into pieces, how might we expect this to proceed?

Formation of the Equatorial Girdle

Well, the first thing which might happen is that the skin would split in half along the equator, into two equal 'caps', leaving a depressed 'oceanic girdle' around the Earth. This would be reasonable, both from the point of view of symmetry (where else would the line of weakness be?) and from a factor relating to conservation of momentum which we will look at later. And as further supporting evidence, we have the marked equality of area of Laurasia and Gondwanaland.

> *Proposition 5D*
> *The first major event in Earth expansion was the splitting of the holodomain in half, along the Equator, to form the two megadomains of Laurasia and Gondwanaland*

There is considerable evidence for the past existence of such an 'oceanic girdle' , which has sometimes been called the Tethys or Tethyan Sea. In fact its existence has been a stumbling block to some of the earlier, pre-expansion theories of the development of the Earth. In Chapter 13 (on fossil fuels) we shall also see an important implication of this equatorial marine girdle, which will be referred to here as the Tethyan Girdle.

What Happened Before the Split?

In postulating the Equatorial Split as the first major event of Earth Expansion, it is reasonable to ask what happened before it, to make it happen when it did. Why did the Earth suddenly undergo this paroxysm of expansion?

I believe that there was no sudden event, the Equatorial Split was just a very obvious effect of processes which had been taking place for a long time previously. In this connection, we should look first at *changes in the rate* at which expansion has occurred in the past.

Carey has suggested [Carey, 1987] that the rate of Earth Expansion has been accelerating continuously during the measurable past. In earlier eras, the rate of expansion was slower, and the further you go back, the less the rate of expansion. It appears possible, in fact, that expansion has always been occurring during the Earth's physical evolution, but that the effects have only become really obvious as the rate has speeded up, especially in the last 200-400*my*.

It appears that the distinguishing feature of the Equatorial Split was that this was the first occasion during which the skin of continental material covering the Earth was stretched thin enough to split open and expose the ‘oceanic’ rock material underneath. According to this scenario, movements of the material covering the Earth’s surface had occurred previously, but these had only served to thin out the layer of lighter continental material, and not actually breach it.

Proposition 5E

The Equatorial Split which created the two megadomains of Laurasia and Gondwanaland was notable for the first surface exposure of underlying ‘oceanic’ material, as the overlying continental material was thinned out by past expansion

We will pass on now to look at what happened subsequent to formation of the Equatorial Split, when Laurasia and Gondwanaland were themselves beginning to split into smaller parts. And here we can gather further evidence through looking at what happened to domains of different sizes; their size does seem to have had an effect on their subsequent behaviour.

Flight of the Microdomains

It appears that smaller land masses have travelled further from the Equator than have larger pieces to which they were once attached. This is reasonable if the larger pieces have centres of gravity close to the equator, so that the ‘centrifugal forces’ pushing part north and part south are more evenly balanced. On the other hand, a small landmass well north of the equator has no south-moving section to push against the north-moving urge, and so may be expected to move faster and farther north.

As an example, look at Fig. 5.2, a map of areas of occurrence of fossil and modern hickories, taken from ‘Tree Ancestors’, a most interesting book by Edward Berry [1923]. This can be compared with Fig.4.11 in the previous chapter, showing the current distribution of *Carya*, the pecan and hickories.

Notice that in addition to the modern areas, fossil remains of hickories have been found in Greenland, Iceland, Alaska, and even in tiny Svalbard (Spitzbergen), only a

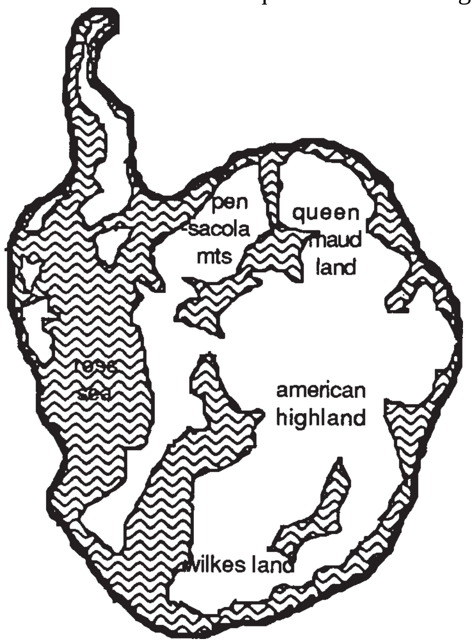

Fig 5.1. Commonly assumed and probable actual land areas in Antarctica

few degrees below the North Pole.

This leads to a most important point. The usual interpretation of Fig. 5.2 is that the climate in southern Greenland, Iceland, and the other fossil locations must once have been warm enough for hickories to grow there. While this may be true, the implied assumption that warmer climates once extended to much more northerly latitudes is not necessarily so. In reality, microdomains carrying these fossils may have individually moved north, out of warmer zones, after the fossils were deposited.

Proposition 5F

Fossils of warmer-climate plants found in areas with colder climates may have been carried there by domain movement

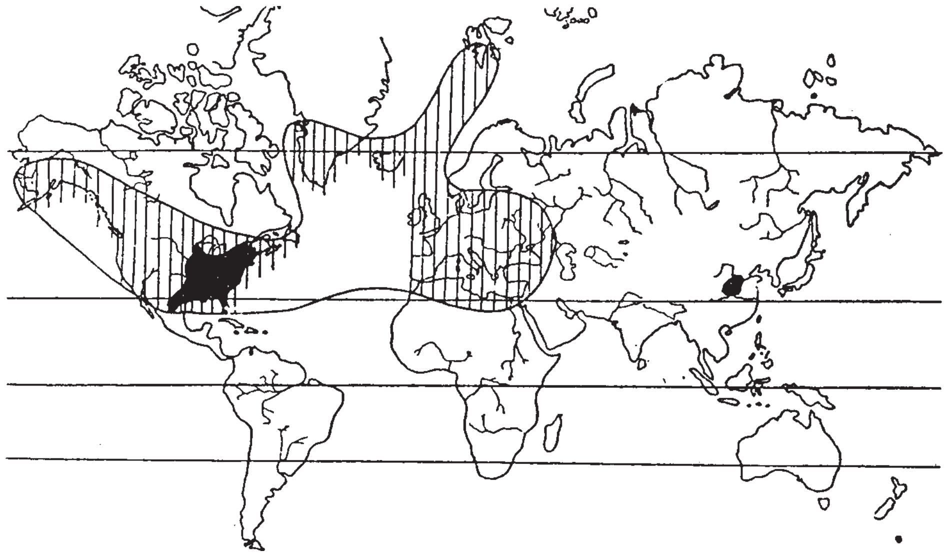

Fig. 5.2. Areas of modern occurrences of hickories (solid) and of fossil occurrences (shaded)

If this proposition is true, it does of course throw confusion and doubt into the whole area of studies of climate in past eras (paleoclimatology). The same is true of other aspects of geology and Earth sciences which assume current parts of the planet were always in the same positions as now.

Proposition 5G

All areas of the Earth sciences which implicitly assume a fixed Earth must be subject to detailed reconsideration in the light of possible domain movements

This brings us to an interesting point about the movement of microdomains and the effect of their relative sizes. The evidence from the location of plant families is that smaller domains, such as Japan, Spain, New Zealand, Ireland, Florida, and California, are now in much more temperate latitudes than the larger masses to which they once appeared to relate. We will see some more detailed evidence on this point in what follows later.

> *Proposition 5H*
> *In the movement of domains during Earth expansion and continental drift, smaller domains have moved relatively further from the Equator than larger ones*

All the movements appear to have been away from the Equator and towards the poles. There may well be a quantitative formula somewhere in this. There is a complication, in that it seems possible that the position of the Equator has varied in the past [Carey, 1987], but for the moment we will not go into this.

Islands and Peninsulas

Small islands, such as Rottnest, are the clearest form of 'free' microdomain, portions of the Earth's surface which might be expected to show the clearest effects of expansion forces. We can now see a reason for the close parallel of the Rottnest vegetation with that on the mainland some 300*km* further north, the point made at the start of Chapter 2.

Because of the way they have ventured further from the Equator than larger domains, islands often carry examples of 'tropical' life into temperate areas, examples which are not matched on adjacent larger domains. Rottnest is notable for having the most southernly examples of living corals in Western Australia.

Another example can be seen from Fig. 4.8, the distribution of the Sandalwood family — the species found on the tiny Juan Fernandez islands off Chile, and that in New Zealand, are moved well to the south, while that in Hawaii is well to the north of the main latitude of occurrence.

We can also see a reason for a most interesting point which concerns peninsulas. If you look at a world map, you can see that almost all the peninsulas in the northern hemisphere point south — Baja California, Florida, Italy, Malaya, Korea, Sakhalin are all very obvious. In the southern hemisphere, the number of peninsulas is much smaller, but those that do exist mostly point north — Cape York and Shark Bay in Australia are examples.

This pattern has a rational explanation if it is accepted that these peninsulas are merely island microdomains which have migrated away from the Equator at a faster rate than have larger domains, and have crashed into and joined up with other domains. Sometimes, as with the impact of Italy into northern Europe, the effects of the impact show up very clearly.

> *Proposition 5I*
> *Peninsulas point south in the northern hemisphere, and north in the southern hemisphere, because they were formed by island microdomains moving away from the Equator and joining with other domains*

So far we have looked at isolated islands and half-isolated peninsulas (the latter word actually means 'half-island'!) as examples of microdomains. Now we move on to another type which has only been recognized as such comparatively recently.

The Microdomain Sideshuffle

In the first half of the 1980's, geologists came to an astonishing conclusion regarding the western coast of North America. Instead of being a single geological entity, the whole area was found to be a vast patchwork or collage of different rocks. These components, which were given the name 'terranes', were very varied in age and composition, and some of them appeared to be fragments broken off from much bigger deposits which today are located many thousands of kilometres away [Howell, 1985; Gore, 1985b].

Since that time, a similar patchwork has been found to apply to the northeast coast of the USSR [Koltypin, 1987], and, of course, this area (Fig. 5.3) is just the analogue of the northwest American coast on the other side of the Pacific.

In both these areas, the same factor was found to be operating as with the island microdomains, that is, the components were generally much further north than comparable larger deposits to which they may have once been attached. In fact, it appears no longer in dispute that both these coastal areas are continuing to move north relative to the larger continental masses to which they are attached.

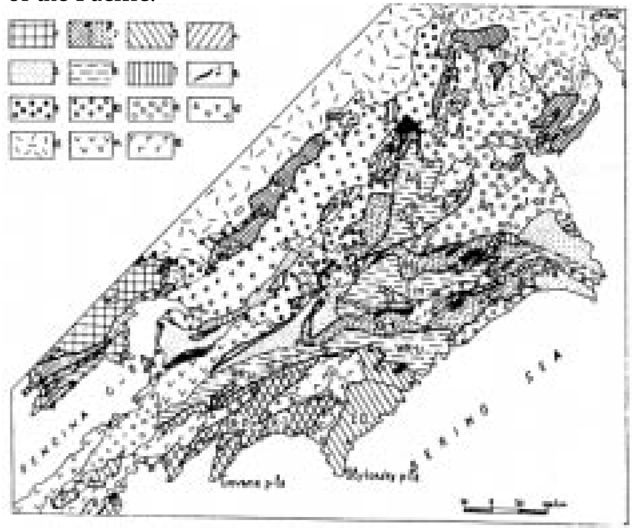

Fig. 5.3. Collage of microdomains (terranes) on northeast coast of the USSR

From what has already been shown in this book, it is obvious that this behaviour fits in very comfortably with the idea of assemblies of microdomains, together fleeing away from the Equator, and jostling and shuffling among themselves as they go.

In fact the terranes are merely random lots of island microdomains which have in some way been accreted on to the continents.

> *Proposition 5J*
> *Terranes are random lots of microdomains which have accreted to larger domains*

The conventional mechanism for this is that rock welling up at the midocean ridges is swept out and subducted under the adjacent continents, scraping off the islands as it goes, but we have seen that this mechanism cannot be accepted. And of course it would not account for the occurrence of a plant family right along chains of islands and onto a continent. This is the opposite to what would be expected if the islands were running into the continent, rather than the continent retreating and leaving islands behind it.

We have seen that the evidence from plant distributions strongly supports the idea that the Earth has expanded under the former distributions, splitting them apart, and does not require any specific 'accretion' mechanism. For example, we have seen that peninsulas would be expected to occur through the chance impact of faster-moving island microdomains with larger, slower domains. We will shortly see, however, that there may be a secondary 'accretional' factor operating.

The specific case of the U.S. west coast fits in very comfortably with the plant distributions. California has native palms, which we will see later are typical Gondwanaland plants, and the map of the distribution of *Castanopsis* (Fig. 4.12) shows how the American component has been displaced to the north.

Now we can turn this evidence on its head and make some massive predictions about geological deposits. The evidence from plant distributions is that microdomain shuffling, with aggregates of microdomains moving steadily away from the Equator, occurs down the sides of almost all continents.

This movement appears strongly along the east coasts of Africa and of Australia, and to some extent along the west coast of Australia (carrying Rottnest with it), the west coasts of North America and Europe, and the east coasts of Asia and North America. But its most massive expression is along the west coast of South America.

Here, the great range of the Andes Mountains, both very high and very long, appears to mark the boundary between the main South American megadomains and a huge army of microdomains shuffling southwards towards the pole. This huge system has been running so fast and so long that the leaders have spilled off the end of the continent at Tierra del Fuego and formed one of the few south-pointing peninsulas in the southern hemisphere.

Look again at the distribution maps (Fig. 4.1-4.14). All are consistent with the view that a previously complete distribution has been broken up and shifted, and that especially marked shifts away from the Equator have occurred with islands, peninsulas, and microdomain shuffle belts. In particular, the cycad map (Fig. 4.13) is very informative; the suggested forces provide a very satisfactory explanation for the observed distribution, extending north to Japan and Florida, south to southern Africa, Madagascar, and Chile. This distribution has been one which has puzzled researchers in the past, and as far as I am aware, no alternative explanation has ever been given for it.

> *Proposition 5K*
> *Bands of microdomains are shuffling away from the Equator along the sides of continents, particularly the west coasts of South and North America and the east coasts of Australia and Africa*

There is perhaps one subsidiary point about South America which deserves comment. This landmass has a strong bulge on the northwest. If this bulge, and the western coast to its south, is made up of microdomains, why haven't they split off into island strings as they strive to go south?

This is not a vital matter, but it does raise the possibility that gravitational attraction from an adjacent megadomain may be sufficient to make the microdomains cling to the side of the larger mass even as they shuffle on their way in a predominantly southern direction.

> *Proposition 5L*
> *Microdomain movement directly away from the Equator may be somewhat distorted by the gravitational influence of adjacent megadomains*

So far we have looked at the behaviour of the smaller domains, as islands, peninsulas, and as aggregated shuffle belts. When we move up to domains of intermediate size, we find the same sort of relocational behaviour, expressed less strongly.

The Creeping Slabs

There are a number of medium-sized bits of the holodomain which provide clear examples of intermediate-level shifts. One of these is the Iberian Peninsula — Spain and Portugal.

Figure 5.4 is a map of the Iberian Peninsula and the African coast to the south. Notice that the Iberian domain would fit almost exactly against the northwest coast of Africa. Notice also that the Pyrenees mountains look exactly as one would expect if formed by Iberia running north into what is now southwest France.

The plant evidence also supports this relocation. Spain has the only palm native to Europe, and the only yam (*Dioscorea)* found there. Both these plants are clear Gondwanan elements.

The whole of the lower east coast of the United States is now accepted as having split off from Africa in the past

Fig. 5.4. The Iberian domain and northwest Africa

and drifted north. The boundary lies along the Appalachians, and the sub-surface join position has actually been identified to within a few kilometres [Hidden, 1985]. It is not known for sure whether this area is a relatively simple slab, or is a complex microdomain belt.

Both these slabs are in a position we would expect, well north of the megadomains to which they were once attached, but not as far north as associated microdomains. Ireland, for example, was once probably attached to northern Portugal, but has now moved further on.

Perhaps the biggest of the creeping slabs is India. It is interesting that the whole of India is now well north of the Equator, although it is undoubtedly a Gondwanan domain. We will have a possible explanation for this later.

Here Come the Biggies

When we come to look at the movement of the major land masses, a similar picture is found — movement has occurred, but for the bigger domains, this has been only small. Africa, the largest of the 'original' continents left, has its centre of gravity not far from the present Equator (about 6°), while South America, a little over half Africa's size, has its centre about 14° south. Australia, much smaller than South America, has its centre of gravity about 25° south.

There is an important point here. None of the present continents are simple, unaltered megadomains, none are unchanged pieces of the original holodomain. Perhaps the three southern continents just mentioned are closest to unchanged, but even these show evidence of accretions (as in the area of Africa north of the Atlas Mountains), microdomain belt shuffling, and re-seaming.

> *Proposition 5M*
>
> *None of the present continents is a simple megadomain, all show evidence of accretion, microdomain shuffle belts, or domain re-seaming*

In the case of Australia, it is possible that, while the current eastern and western parts of the continent were always close together, the whole of the east has slipped north or south relative to the west. Similar shifts are likely for North America.

Easily the most re-seamed current continent is Asia. This is made up of a mega-collage of at least twenty major domains; every 'internal' mountain range, every long thin depression or lake (such as Baikal), represents a domain boundary which was active in the past. These points will be important when we look, in Chapter 7, at what is involved in trying to fit the holodomain back together.

Continental Shelves and Domain Edges

A point which has attracted considerable debate in the past has been that of where to mark the edges of the domain units which have figured in Continental Drift. In fitting together the domains, many workers have taken the domain edges to lie at the margins of the continental shelves.

There has been no general agreement as to the exact sea-level depth at which the shelf edges are to be drawn, but in many cases there exist abrupt changes in slope of these shelves which make their edges obvious in position. Sometimes investigators have been able to obtain better fitting of reconstructed domain assemblies using domains with associated continental shelves, than was possible using the 'naked' domains without them.

There is some conflict here with the point that it is theoretically possible to reconstruct the holodomain with a fairly high degree of accuracy. The uncertainty is no more than 100*km*, it could be as little as 10*km*, and in any case much less than the width of some continental shelves. The basis of reconstructions using the plant distribution methods I have advocated do, of course, use the naked domain boundaries. In fact I am asserting that for accurate reconstructions, domain boundaries should be taken as the present boundaries, at sea level.

> *Proposition 5N*
>
> *In making Earth-expansion reconstructions, domain boundaries should be taken as the present sea-level or abutment boundaries, ignoring continental shelves*

There is justification for this somewhat arbitrary decision. If the continuous nature of Earth Expansion suggested above is true, it simply means that continental shelves are later-event phenomena, produced after the initial continental-rock domains have split apart, through a further splitting of the 'shallow seabeds' produced during an earlier phase of expansion.

Profiles of the Ocean Floors

This view is supported by the actual conformation of the present-day seabeds. Rather than being huge sloping underwater 'valleys', these seabeds actually consist mostly of plateaus and flat plains, at varying levels below sea-level. The inference is that they were produced by Earth expansion processes in which domains of every size, both below and above sea-level, spread apart to leave essentially level or slightly inclined features, only later modified by erosional and domain interaction processes to lose some of this planarity.

Why pick sea-level as the datum point? It is accepted that sea levels have varied greatly, all over the world, during all past ages. In fact, as we shall see in Chapter 10, Earth expansion is one of the principal factors active to cause variations in sea level.

The point is, that the edges of domains produced by the splitting apart of bigger domains are not greatly altered by subsequent events, at least not on the scale on which we are working, say in distances of up to 100*km*. On this scale, the current sea-level boundaries of land domains bordering on the sea are an accurate enough indication of their edge positions in the past.

Does Erosion Make or Destroy Domains?

Obviously erosion on land will reduce the height of features and will tend to carry material out to sea, but, if there are no other factors operating, erosion is unlikely to extend or reduce a coastline by much more than about 10*km*. And, while there are admittedly huge depths of sedimentary rock built up in some deposits, these are often due to relatively localized forces, such as the infilling of river valleys or undersea outwash fans from turbidity currents acting like underwater rivers. They do not really represent actual removal or formation of even medium-sized domains. The true picture is probably that land domain boundaries are merely smoothed and blurred by erosional forces, rather than being formed by them.

Underwater, of course, erosion in the sense understood for land surfaces is almost absent. There is some scouring from the turbidity currents referred to, but most underwater forces, such as the powerful ocean currents, do not carry enough solid material to effectively erode features.

The other factor affecting domain boundaries is when they collide or slide relatively to one another. We will look at this in more detail in Chapter 9, but the fact remains that these impacts, while producing very visible features on the Earth's surface, seldom change the delineation of the domains involved by more than a few kilometres. This can be seen from a consideration of the actual rock volumes involved.

Undoubtedly one of the most major expressions of the effects of domain collisions is to be found in the Himalayas area. There the Earth's highest mountain, Everest, reaches a height of almost 9*km*. But this height is superimposed upon that of the vast plateau of Tibet, averaging around 5*km* above sea level — so the increment is only 4*km*. We can refer to an increment of this size as 'only' when it is compared to the thickness of the domains at that point, these are at least 40*km* thick, that is the thickness of the continental rock there.

So Everest, the biggest pimple on the planet, represents a variation of only about 10% in domain thickness, much less if its average rather than maximum height is considered, since most of its mass is at the base. It is clear that the material needed to make Everest could originate from only 2-3*km* of domain edge material squashed together.

> *Proposition 5O*
> *The boundaries of domains have been modified by shifts of only a few kilometres as a result of erosional and impact forces in their past.*

We have now have looked, in some detail, at how the Earth fell apart. In the next chapter we will look at some of the further evidence available to be used in the job to come, that of putting it all back together.

CHAPTER 6

MORE DISTRIBUTIONS AND EVIDENCE

"Facts are stubborn things"

— Smollett

In Chapter 4 we looked at the distributions of nut trees and how they supported the concept that the Earth has expanded. The factors operating to bring about these nut distributions will, naturally, be applicable to many other forms of life as well.

The Fruit World

Perhaps the closest grouping to nuts is that of fruits. Although most people are familiar with only ten or twenty different fruits, there are at least 10,000 different plant species which can be regarded as fruit plants. Like nuts, they extend across the whole range of plant species, and also extend over the whole planet. Some plant families include both fruits and nuts.

The fruit families give exactly the same distribution picture as the nuts. Figure 6.1 shows the distribution of the Sapotaceae, of which perhaps the best-known representative is the Sapodilla or Chico, *Manilkara zapota*. As well as producing a delicious fruit, this species is also the source of chicle, the base for chewing gum. The family produces many other fruits and plant products, including some where the masses of sweet edible flowers are the crop (*Madhuca*), and others with seeds high in edible oils (*Butyrospermum*, Shea Butter).

This distribution shows all the features which we have come to expect from an Earth-expanded family. The Sapotaceae originated in Gondwanaland, and the basis of the distribution is a band extending round the Earth through central America, central Africa,

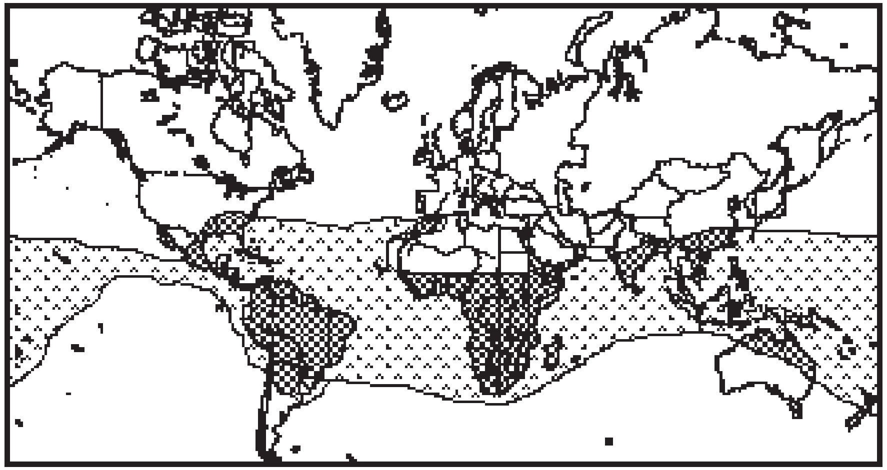

Fig. 6.1. Distribution of the Sapotaceae

across the Indian Ocean and India through the Indonesian islands and northern Australia, then back across the Pacific to America.

It seems reasonable that the distribution was once a fairly uniform band running right around the Gondwanan tropics. This uniformity has been disturbed by the 'centrifugal' movement of domains, carrying species as far north as Florida, the Bahamas, Morocco, and Taiwan, and as far south as Chile, New Zealand, and South Africa. The typical mechanisms of microdomain shuffling and flight are clearly active.

The occurrence of the same genera on either side of the Pacific (eg *Chrysophyllum*, the Star Apple genus), and even stretching right across from Central America though Asia/Australia over to southern Africa (*Manilkara* itself) show how recent and rapid the opening up of the Indian Ocean and the Pacific Ocean were.

I have already mentioned that the puzzle of the coconut (whether it originated in southeast Asia or on the northwest of South America) can be explained by assuming the original species distribution was split apart by Earth expansion. A similar case occurs with a fruit from the persimmon or ebony family, *Diospyros ebenaster*, called Zapote Prieto.

This family, the Ebenaceae, has a very similar distribution to the Sapotaceae, with a particularly strong distribution band over from Central America through Asia/Australia to central and southern Africa. The *Diospyros* genus itself (it also includes the ebonies) runs right across, and is notably strong, both in the Philippines (38 species) and in Mexico (11 species).

One species, *D. ebenaster*, occurs in both areas [Standley, 1924], and there are good separate cases for assuming that it is native in Mexico and it is native in the Philippines. The obvious conclusion is that it is native to both. Even if this particular conclusion is wrong, say because two different species of *Diospyros* happened to evolve to be almost indistinguishable in the two areas, this does not explain how the strong concentrations of *Diospyros* species came about, so far apart. Or how there is a further concentration (23 species) in southern Africa.

Since starting the work on which this book is based, I have examined the distributions of something approaching 20,000 different species of fruit plants and their relatives, keeping a particular eye out for anomalies. I have been unable to find a single example of a plant which glaringly contradicts the principles outlined.

Such mild counter-evidence as exists is usually explicable as due to either to long-distance bird migration, as with some small berry species (eg *Vaccinium*, the blueberry family), or to really ancient lineage in the case of a few genuinely world-wide families such as the Fagaceae (oaks, beeches, chestnuts) and Salicaceae (willows), which have representatives in both northern and southern temperate areas. The usual explanation of a plant with a strange distribution, that it 'was introduced by man', in fact seems to have been invoked quite unnecessarily and wrongly in many cases.

> *Proposition 6A*
> *Many cases of plants assumed to introduced to have been introduced by man, to explain their occurrence, are as readily naturally explicable through expanding-Earth principles*

The Families of Plants

When the distribution of almost any plant family is examined, a good case can usually be made for assigning it to either Laurasian or Gondwanan origin. Table 6 lists some of the world's major plant families under one of these two headings. The listed families include the majority of the Earth's tree species.

Table 6. Gondwanan and Laurasian Plant Families

Gondwana	Rubiaceae (Coffee, gardenia..)
Anacardiaceae (Mango, cashew..)	Salicaceae (Willows)
Annonaceae (Custard apples)	Sapindaceae (Lychee, rambutan..)
Araucariaceae (Araucarias)	Sapotaceae (Sapodilla, sapote..)
Cactaceae (Cacti)	Solanaceae (Potato, tomato..)
Caricaceae (Papayas)	Taxaceae (Yews, Torreyas)
Casuarinaceae (Casuarinas)	Taxodiaceae (Sequoias, cypresses..)
Combretaceae (Sea almond, myrobalans..)	
Cucurbitaceae (Melons, pumpkins..)	***Laurasia***
Cycadaceae (Cycads)	Aceraceae (Maples)
Dioscoraceae (Yams)	Betulaceae (Alders, birches)
Dipterocarpaceae (Shoreas..)	Corylaceae (Hazels)
Ebenaceae (Persimmons, ebonies)	Juglandaceae (Walnuts, hickories)
Euphorbiaceae (Rubber, tung..)	Pinaceae (Pines, firs..)
Lauraceae (Avocado, laurel..)	Pistaciaceae (Pistachios)
Leguminosaceae (Acacias, beans...)	Rosaceae (Plums, apples..)
Meliaceae (Neem, mahoganies..)	
Moraceae (Mulberries, figs..)	***?Tethyan/Cosmopolitan?***
Myrtaceae (Eucalypts, guavas..)	Fagaceae (Oaks, chestnuts, beeches)
Palmae (Palms)	Graminae (Grasses, bamboos)
Podocarpaceae (Podocarps, yellowpines)	Compositae (Daisy family)
Proteaceae (Macadamia, banksias..)	Ulmaceae (Elms)
Rhamnaceae (Jujubes..)	

Some of these families contain hundreds, or even thousands, of species. With these numbers they may be very widespread, and in a typical enumeration (such as Willis [1973]) they may be described as 'world-wide' or 'pan-tropical'.

Even so, when one of these families is examined in detail in the light of the domain movements which have been identified, it usually falls in one camp or the other. Most of the genera which look to be exceptions to the rule for their family can be explained either by these domain movements, or on the grounds that the family is an old one which was actually split apart when the Tethyan girdle was formed.

Then again, the exceptions may be purely a matter of classification. The pistachios, clearly a Laurasian genus, were usually classed in the Gondwanan mango and cashew family, the Anacardiaceae. More recently they have been separated off into their own family, the Pistaceaceae, which moves them out from being an exception. Currently the Fagaceae includes the Laurasian oaks, chestnuts, and beeches (*Fagus*), but also the Gondwanan southern beeches (*Nothofagus*) and tropical chestnuts (*Castanopsis*). Perhaps closer study will separate off these latter genera into a separate family.

We have widened the scope of our study from nuts, to all fruits, then to all plants. Now we can widen our view even more, to encompass the other great Kingdom, the animals.

Lower Animals

Some of the earliest animals which are believed to have lived partly on land, the amphibians, are assumed to have evolved from early fishes. The link between these two classes is the group of lung-fishes, fishes in which the swim-bladder has altered to perform some of the functions of an air-breathing lung.

Living lung-fishes are today found in three continents — Australia, Africa, and South America, together making up the bulk of Gondwanaland. Lungfishes live at the boundaries of land and fresh water, usually in the banks of rivers which may become seasonally dry. We will return to the matter of the land/water boundary in Chapter 10.

Further up the evolutionary scale, when we look at the crocodiles and alligators, we can see that these are exclusively Gondwanan. Africa, Australia, South America, Southeast Asia, and Florida — that is where the crocodilians are, in almost every part of the former megadomain. Even turtles, marine amphibia with the obvious opportunity to spread their range, show a similar pattern.

Marsupials

As is well known, the vast majority of marsupals living today are native to Australia. A few are found in the islands to the north, such as New Guinea. New Zealand has none.

The major exception to the Australian-only distribution is the opossoms of the Americas. There are only two American genera, one of which contains only one species — the Yapock. This sole strange aquatic and web-footed representative of the genus *Chironectes* exists from Guatemala down to southern Brazil.

Most of the species in the other genus, *Didelphys*, are also concentrated in tropical America, that is, northern South America and southern Central America. However, by the chances of European settlement, the best-known one is the Virginian Opossum, *Didelphys virginiana*. Like its Australian possum relatives, this animal has adapted well to modern civilization and can be found happily living in the roofs of houses.

Now unlike plants and lungfishes, these marsupials are clearly mobile creatures, and the fact that opossums are common over much of the United States is a reflection of that. Nevertheless, I will show that this mobility is much more limited than is generally assumed.

In the very first Proposition in this book, number 2A, I suggested that the actual rates of spread of plants are much less than their potential rates. A similar proposition can be formulated for animals too.

> *Proposition 6B*
>
> *Actual rates of spread of animals are usually much less than the potential rates of spread implied by the mobilities of individual animals*

As for the mechanism behind this, this has already been given in Proposition 2B. Like plants, animal species do not expand their range because they are unable to overcome ecological pressures.

Some of the conclusions to be drawn from the above are obvious. Marsupials exist in greatest quantities in widely-separated Australia and northern South America because these two continents were once in contact. The same is true of New Guinea and Central America — again, look how excellently New Guinea fits against the Central American coast, reproducing every in with an out, and vice versa.

The usual reason given for the virtual restriction of marsupials to Australia is that they have survived there in isolation because they lacked competion from more highly-evolved (and implicitly ‘more efficient’) creatures in the rest of the world. On examination, this view can be seen to lack credibility. The marsupials of the Americas have shown adaptability and resilience in maintaining and even extending their range in the face of ecological pressure from ‘more evolved’ creatures. The marsupials aren’t elsewhere because they never were.

> *Proposition 6C*
>
> *Marsupials evolved in the Australian and South American domains when these were in contact, and were not cut back to these areas because of competition from ‘more evolved’ creatures*

In opposition to this could be quoted the matter of fossils. Remains believed to be those of fossil marsupials have been found in England and in France. This is not a serious objection — see Proposition 5G. The areas containing these fossils in England and France are almost certainly microdomains which have been separated from their fellows on the other side of the Atlantic.

Why should marsupials be found in North America at all? The answer is to be found in those north-thrusting domain belts moving up on both sides of the North American continent, domains which were once part of Gondwanaland.

It is no coincidence that the common U.S. opossum, *Didelphys virginiana*, has Virginia in both its common and scientific names — Virginia was once part of Gondwanaland. Neither is it a concidence that the scientific name of the American Persimmon, the country’s sole representative of the Gondwanan family Ebenaceae, is *Diospyros virginiana.*

Other Mammals

When other mammals are looked at, it is a question of more of the same. Most groups of mammals can readily be classed as of either Gondwanan or Laurasian origin.

Consider bears. These are still virtually confined to Laurasian domains, the small extension down into parts of southeast Asia is a credible natural spread. The same is true of our oldest domestic pet, the dog, and its relatives the wolves.

Our other common house pet, the cat, is Gondwanan. Cats were pets in ancient Egypt, one of the closest bits of ‘Gondwanaland’ to ancient Greece. Tigers in India and Indonesia, lions there and in Africa, pumas in South America, are all relatives calling Gondwanaland home.

The north American cougar presumably rode up on the western microdomain shuffle belt.

Other Gondwanan families include the elephant — now we have a natural explanation for these animals in both Africa and southern Asia. Probably the pig, and certainly the rhinoceros (with representatives in Africa, India, and Indonesia), come in here. The positions of the deer, sheep and camel families need closer analysis to make their positions clear.

Primates

The primates are clearly of Gondwanan origin. The most primitive primates are the lemurs, lowly monkeys confined to the island of Madagascar. Their more evolved relatives extend in the familiar band up through Africa and across to India and southeast Asia.

The lower apes, such as the monkeys, exist also in the tropics of South America. They differ from the others in having prehensile tails. Although these are obviously Gondwanan, it is not clear whether they are connected with the monkeys of western Africa or with those of eastern Malesia. I would suspect the former, but the sort of detailed genetic analysis which is now becoming possible [Sibley, 1986] will probably settle the question.

The higher apes conform to the pattern, with chimpanzees and gorillas in Africa and gibbons and orang-utans in India and southeast Asia. As for the ‘naked ape’, man himself, the position is made more complex by his ability to use intelligence to overcome ecological pressure and spread very widely (or perhaps it demonstrates the rule, with no competing intelligence to stem the spread). However, man is widely assumed to have originated in Africa, which fits in. Of this, more later.

But when it comes down to the races of man, the same pattern repeats itself, now rather uncomfortably. The original inhabitants of Madagascar are known to be closely related to the Malays, even having languages in the same group. Of course, the Malays are fine seafarers, and the link can be explained through this. But what about the Negrito people of the southern Philippines, who have been said to be genetically identical to the African Pygmies?

Even I am not bold enough to make a Proposition out of this one — the times are apparently all wrong. Man himself is supposed to be no more than 1-2*my* old, with the earliest man-like apes going back no further than 5*my*, and so far no-one has suggested that the Indian Ocean opened up in as short a time as this.

The Big Birds

These give the usual pattern. The large flightless birds, the ratites, are very Gondwanan. The ostrich in Africa, the emu in Australia, and the rhea in South America are not only similar and related, but even fill similar ecological niches — they are grazing animals. In northern Australia and New Guinea the cassowary is a relative, as is the kiwi in New Zealand.

It is interesting that the ostrich once extended right across north Africa, and into Arabia, even in recent historical times — perhaps there are still a few left there. Arabia is an interesting domain to locate.

What is also interesting is that these ratites had giant relatives, now unfortunately extinct through the hands of man. The huge moa, standing 3.6*m* high, is believed to have been wiped out by the first human settlers in New Zealand, and the same fate may have overtaken the gigantic *Aepyornis* of Madagascar. At least we need not blame ourselves for the loss of probably the most massive bird of all time, the *Dromornis* of central Australia, which weighed 500*kg*; this apparently died out over 10*my* ago.

Some modern birds routinely undertake annual migrations of up to 10,000*km*, and it is perhaps understandable to assume that they must be exceptions to the restraints on spread which apply to normal creatures. Even so, the extent of this exception is not as great as it could be.

We have already seen, in Chapter 2, how the finches of the Galapagos evolved into a number of different species, even though they were normal flying birds, and were not distantly separated. A study of the basic genetic material (DNA) of birds of Australia and elsewhere [Sibley, 1986] has shown that the birds of Australia are related much more closely to each other than they are to apparently similar birds from elsewhere. This is in contrast to previous assumptions, based on similarity of form, so that the magpies of Australia are closer to Australian parrots than they are to European magpies.

Marine Life

With all the oceans of the planet linked, we might expect the easy transport afforded by floating about in ocean currents to have made ocean life fairly homogenous everywhere. Such is not the case.

One of the reasons for this is that a high proportion of marine life is restricted to shallow water, which lies mostly at the sea/land boundaries. As usual, this is because of ecological pressure — away from the seashore, in deeper water, conditions change rapidly.

This means that the boundaries within which sea plants and animals are evolving, what we have referred to as isocons, are usually quite thin strips running parallel to seashores, instead of huge ocean areas. The actual ‘surface’ areas of these isocon envelopes are often quite small in comparison to those their land analogues. And, of course, the only places where spreading can easily occur are at the two ends of the strips, rather than on all sides.

> *Proposition 6D*
> *The majority of marine creatures are ecologically restricted to shallow off-shore waters, and so inhabit long thin ecological strips of relatively small area*

Of course many marine creatures have free-floating stages, and so have the capacity to spread widely as far as their mobility is concerned. Even so, the same pattern of species is found as on land; creatures such as crabs are around almost all the world’s seashores, but the species are different in each area.

Figure 6.2 (taken from Rasmussen [1977]) shows the distribution of eelgrass, *Zostera marina*. Eelgrass is one of only 49 species of plant, collectively called seagrasses, which are true flowering plants which have adapted to live in the sea. They produce flowers and pollen and seeds, in the normal plant cycle, all entirely submerged under the water.

Most of the seagrasses are found in the southern hemisphere, particularly around Australia. Eelgrass is one of the few northern species, although it has relatives in the south, and thus has a common ancestry with them (Proposition 3A). The heavy black lines along the Atlantic parts of the distribution are where the plant was affected by a devastating disease in the 1930's.

The points to be made from this map are that eelgrass has a clear Laurasian distribution, and that even though it is a marine plant, its current distribution was presumably brought about by Earth expansion after the species had evolved and separated off from a common southern-hemisphere stock.

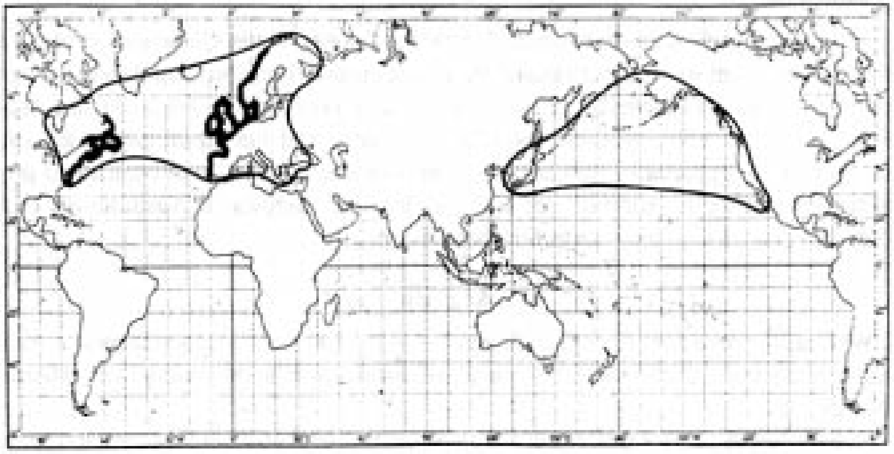

Fig. 6.2. Distribution of eelgrass, Zostera marina

Notice that the two parts of the distribution are no longer connected, although they must have been at some time in the past. Also that the vector carrying the wasting disease was able to cross the Atlantic (and hence had a different ecopressure boundary to eelgrass itself), but it did not reach into the Mediterranean (or across to the Pacific).

We have seen that the consequences of Earth expansion have been effective across the whole spectrum of animal and plant life, not only life on land, but life in the sea as well. Now we have enough evidence to go on and see how far we can reconstruct the Earth as it was in former days.

CHAPTER 7

PUTTING THE EARTH BACK TOGETHER

"We have been living in an Age of Analysis, when we have found out a great deal about many different aspects of the world in which we live. But now is the time to move into an Age of Synthesis, when we will put together all this body of knowledge"

— F.A. Sharr

We have now laid the groundwork for the task of trying to fit back together the vast spectrum of domains of every size, to reconstruct the original holodomain which once covered the whole of the Earth's surface.

It would be nice to present here the complete picture, but, alas, that is quite impossible. It will require years of painstaking work by many people, plus probably the need to go out into the field and accumulate new evidence, before all the arguments will be settled and we feel that we really have got the thing right. All we can do here is make a start on the new area of investigation called Domainography, by putting together some working rules and giving a few possible answers.

The Rules of Domainography

The first aim of the approach must be to keep it as simple as possible — we will expand on this further in Chapter 17. When the broad outlines are established, then will be the time to find the exceptions to the rules and possibly to refine or extend those rules. At the same time, we know that the general rules will be extracted from a mass of individual, detailed examples.

What general rules should we have? We can start off with the following:

RULES FOR HOLODOMAIN RECONSTRUCTION

*Rule 1. Larger landmasses are **composites** of many domains.*

*Rule 2. As domains broke up, the **relative** positions of the pieces stayed the same, while their **distances apart** increased.*

*Rule 3. There were no large **rotations** of domains.*

*Rule 4. Smaller domains have moved **further** than larger ones.*

*Rule 5. Domain splitting was according to the **normal behaviour** of materials.*

The first rule is a basic assumption. Rule 2 simply means that if Domain 26A was to the east of Domain 26B before Domain 26 split, then 26A will always be more or less to the east of 26B, even though they may end up hundreds or thousands of kilometres apart.

Rule 3 is an interesting one. At this stage it is purely a rule of thumb. There is, in fact, a physical law, called the Coriolis Force, which does cause rotation of bodies moving away from or towards the Equator (this determines the direction of rotation of cyclones and the way water swirls down the plughole). But all instances of domain rotation observed to date seem small enough to make their existence questionable.

We might expect this rule to be broken when a smaller, irregularly-shaped domain impacts against a larger one at an oblique angle. India looks as if it might have rotated a few degrees anticlockwise when it ran into Laurasia and made the Himalayas. However this apparent effect could be illusory, caused by differences in the angle of viewing a landmass at different latitudes.

Rule 4 is also an observed rule of thumb, derived from the distributions of plants and animals which we have already examined. For Rule 4 to apply, it obviously must be physically possible; there is no way a microdomain is going to force its way through a megadomain it has run into, to keep up with its fellow which was off to one side of the megadomain.

Rule 5 is an important one, with many consequences. It just says that all domains are made up of masses of rocks which have known physical properties, and the domains will obey normal physical laws of every sort. The fact that we may not have a complete picture of some of these laws does not affect the point.

We already invoked Rule 5 when it was pointed out that the deep ocean trenches could not have been formed by pushing one slab of rock against another (see Proposition 3C) — such an act could not create a gap between them. Another consequence is that the new boundary formed when a domain was torn apart could not be especially complex.

Such a new boundary might well vary from very clean and straight (such as that of the coast of Israel and Lebanon) to somewhat irregular and jagged. But normal physical forces would not permit a break to be formed in the shape of a deeply concave bay, such the Gulf of Carpentaria on Australia's north coast. This must be a composite of some sort, there must be at least two domains involved in its formation. This also applies to any other 'complex' coastline or domain boundary, complex on a scale beyond that of erosional effects. We have already seen, for example, how major peninsulas involve at least two different domains.

This is important enough to extract as a new rule:

Rule 6. Areas with ***deeply concave edges*** *or other complex shapes must have been formed from at least two different domains.*

In addition, there is one more rule which has justification to be explained later (Chapter 8):

Rule 7. All ***mountain chains****, both on land and under the sea, represent domain boundaries.*

The last item in our armoury, before we look at actual re-assembly, is a useful technique.

The Rubber Band Technique

There is a convenient visual approach we can use in this. Look again at some of the plant distribution maps given in Chapter 4. Assume all the land areas have been divided up into domains.

Now regard the distribution boundary as a rubber band, and shrink this band down. It will tighten, and pull together all the domains which were once connected by the early distribution

range of the plant genus or species. This will give a preliminary picture of how the domains involved once fitted together on the pre-expanded Earth.

This technique can be used not once for each domain, but hundreds of times — once for each plant species, genus, or family represented on it. It can even be used for 'races' within a species, and if the genetic patterns of individuals are available, say through the isozyme analysis method, it can be used with them too.

Of course this technique will also drag in a ring of domains which do not form part of the original distribution, but instead are just current neighbours of original domains, neighbours onto which the plants have spread through natural dispersion processes. These neighbour domains need to be discarded.

The width of the neighbour ring to be discarded depends on how specific the level of plant description is, and what the likely rate of natural spread is judged at. To deal with the last part first, we will set up the last of our rules, which is an attempt to put numbers to Proposition 2A:

Rule 8. Natural ***rates of spread*** *of a plant species average no more than 1 metre per year.*

At first sight, this estimate seems incredibly low. One metre per year is only 1*km* in a thousand years, which seems very little, however it is also 1000*km* in a million years, and that is quite a lot. Many plant species lie entirely within a range which is less than 1000*km* across. We have already suggested (Proposition 2I) that the half-life of a species is around one million years, so, in fact, this figure does seem to be of at least the right order of magnitude.

On the matter of plant description specificity, the broadest grouping, that of plant family, is too broad to be of much help here. Most modern plant families, such as the Fagaceae (which includes the oaks, chestnuts, and the northern and southern beeches) date back to the early part of the Cenozoic Era, 50-70*my* ago. This would give them the opportunity to spread 50-70,000*km*, much more than the distance right round the Earth (40,000*km*). However, again it does seem of the right order of magnitude, if anything favouring a *lower* figure than that in Rule 8.

We have never put a figure to the half-life of a plant genus, such as *Araucaria*, but it would be somewhere between the species half-life and the known age of the family it is part of. Suppose we put a value of 10*my* to this half-life. Then the average distance we would expect a genus to spread naturally would be 10,000*km*, and the most a species would extend would be 1,000*km*.

Although the Rubber Band technique presented above was a simple visual technique, it could in fact be developed into a computer approach, in which the width of the discardable neighbour rings could be easily varied to see the effect on the final re-assembly. I suspect that in many cases the width of these rings could be cut down to less than the distances implied by the above estimates without affecting the validity of the technique.

For example, look again at Figure 2.1, which shows the distributions of seven different *Canarium* species (the map for the whole genus is Fig. 4.7). It would be my contention that all the areas within the range of the most widely-spread species, number 1, *C. littorale*, were once joined and the species has ended up in the different major islands and peninsulas principally through Earth expansion. This is even though the name of the species means it is a sea-shore plant, and the seeds are designed to float and could well cross from island to island, making this is a worst-case example.

The current range of the species is about 2000*km* across. If the islands were all pushed together by tightening the rubber band, it would drop down to a width of around 1000*km* — which is equivalent to an overland spread from a single centre of only 500*km*.

Now we can look at different areas of the current world, suggesting how they may have been related in past times before the Earth expanded, and applying all the above rules. As usual, the main evidence comes from the distribution of plant species, genera, and families.

Australia

Australia appears to contain at least two megadomains, probably with a common boundary running roughly north-south through Lake Eyre and down to Spencer Gulf. In addition, it has either a long thin wedge or a microdomain shuffle belt running down the east coast, to the east of the Great Dividing Range.

The east coast geology looks more like a shuffle belt. Certainly there is a marked movement of species down the east side of Australia. Typical 'tropical' genera which extend as far south as northern New South Wales include *Canarium* (Fig. 4.7) and *Carissa*. The Bunya Pine (*Araucaria*, Fig. 4.4) of southern Queensland (but with an outlier in North Queensland, and most of the family in New Guinea) has also presumably been carried down on this belt.

The whole of the northeast coast of Queensland has a complex rain-forest flora with strong links with the northwest coast of South America. Virtually every major family present in that area of South America has close relatives in northeast Queensland, often in the same genus (*Pouteria, Syzygium, Endiandra, Litsea, Cryptocarya)*. The excellent fit of eastern Australia against western South America has already been remarked upon, the evidence is overwhelming that these two areas were once in contact.

In fact the evidence for this contact is much stronger than that for the Africa-South America contact which has been taken for granted since the earliest days of the Continental Drift idea, with its origins with Francis Bacon, right back when the Spanish and Portuguese explorers first mapped the southern Atlantic coasts.

This contact is a major distinction between the Continental Drift approach and its later Expanding Earth derivative. In the former, Australia is invariably placed at the opposite end of Gondwanaland to South America, and usually has adjacent New Guinea poking out into an unmapped sea. In the latter, Australia and New Guinea nestle snugly against South America and Central America, and the strong family links are easily explained.

Although the Myrtaceae family which contains the Eucalypts is well represented in South America (*Eugenia* has representatives in both domains), the typically Australian *Eucalyptus* is not. In fact the eucalypts are not especially common in the northeast Queensland rainforest, and this domain may have been separate from the rest of Australia at one time. Certainly the eucalypts appear to have evolved after the two megadomains separated. This separation presumably took place before the migration of monkeys from west Africa into northern South America.

The whole of the northern coast of Australia shows strong floristic links with adjoining areas of Asia. Nut-bearing genera such as *Canarium* and *Terminalia* are typical examples, although these extend well beyond the immediate area. One interesting genus is *Horsfieldia*, a relative of the nutmeg. This has around 80 species scattered through southeast Asia, including Indonesia and southern China, and one species, *H. australasica*, found only in the Northern Territory and the Gulf of Carpentaria. It has been recommended for development as a commercial nut species [Hearne, 1976].

Australia also has species of *Myristica* (nutmeg) and *Zizyphus* (jujube or chinese date) matching those found in southern Asia as far north as the Himalayas. The jujubes are notable for the fact that they thrive in arid inland areas and could not be expected to cross sea barriers.

The west coast of Australia shows typical features of microdomain flight, as we have seen with Rottnest Island and various peninsula formations. As far as more distant links are concerned, a major feature is the strong connection between southwest Australia and South Africa, as shown especially through the Proteaceae family. These, typified by the beautiful Proteas of South Africa and the Banksias of southern Australia, provide probably the strongest southern link between the two continents; there are hundreds of species in each. On the nut side, the Van Riebeck almond, *Brabejum stellatifolium*, of South Africa, is closely related to the woody pears (*Xylomelum)* of Western Australia.

There are plenty of links between northwest Australia and eastern Africa, as for example *Canarium* (Fig. 4.7). Recently a new species of blind hunting spider was discovered in the Cape Range peninsula of the west coast [Harris, 1988], and its nearest relative was noted as originating in southern Africa.

On balance, it seems likely that southwest Australia was once in actual contact with what is now southeast Africa. The fit is quite good. It is possible that Madagascar intervened, but this has probably come down from further north — see later. The separation of Australia and Africa must have been of middle age — not ancient, but before the evolution of the eucalypts.

It should be pointed out here that if Australia was in contact with Africa and South America on the west and east, and these two other continents were themselves in contact along their Atlantic coasts, this means a very tight fit of these three continents around the South Pole must have occurred, if their shapes were the same as now. This would have left very little room for Antarctica, even the small one which we have seen is actually there (Proposition 5B). All this is evidence both of re-seaming and domain shifting in the megadomains. It also implies a pre-expanded Earth somewhat smaller than that usually assumed, closer to 50% of the present diameter instead of the 55-60% sometimes assumed.

Direct evidence of modern plant links between Australia and Antarctica is virtually lacking, because Antarctica proper supports no higher plants, and there are no major islands between Australia and Antarctica. As for the island State of Tasmania, this is a typical island microdomain, with a flora easily represented as having evolved from a much earlier 'tropical' assembly, carried well to the south. It has *Nothofagus*, the Southern Beech, which it shares with the New Guinea highlands and with New Zealand and southern Chile. It has one representative of an ancient conifer genus, *Dacrydium*, most species of which are found in Malaya and Indonesia (Malesia), but which has representatives in New Zealand, New Caledonia, Fiji, and Chile.

More Propositions

The distribution of *Dacrydium* is a good starting point to generalize some inferences into formal propositions. No conifer is noted for its ability to spread by sea, and it appears impossible to explain this distribution rationally except by assuming that all the above areas, now tens of thousands of kilometres distant, were once linked. The distributions, and the current characteristics of the species involved, follow naturally from the following Propositions:

> *Proposition 7A*
> *In the early part of the current (Cenozoic) era, 50-70my ago, the immediate ancestors of most of our current plant genera were evolving out*

> *Proposition 7B*
> *This evolution took place in one or more 'equatorial bands' of physically interlinked domains extending right round the Earth, with easy spread of species along the bands*

> *Proposition 7C*
> *The climatic conditions in these equatorial bands were closer to those of currently temperate areas than to modern tropical ones*

One note to this last Proposition — it is based on the twin observations that there are a few families with representatives of the same (or closely-allied) genera in both southern-hemisphere and northern-hemisphere temperate areas, and that when representatives of these genera still exist in equatorial areas, they appear to have mostly retreated to the cooler upland areas.

Examples include the Beeches, represented in the north by *Fagus* and in the south by *Nothofagus*, with the latter having species in the uplands tropics, the willows (*Salix*), and the Junipers (*Juniperus*). Most instances of these dual-temperate genera fall easily into this pattern. The inference is that the families involved are the more ancient ones, and the corollary is that typical 'tropical' families are of more recent origin.

> *Proposition 7D*
> *Typical 'tropical' plant families are of relatively recent origin, less than about 50my old*

New Zealand and the Pacific Islands

In spite of its clearly temperate location, New Zealand is noted for the 'tropical' appearance of its plants. We have seen that it has one of the most southern representatives of the Sapotaceae, it also has representatives of *Eugenia, Aleurites*, *Freycinetia*, and a palm, *Rhopalostylis*, as well as a host of other 'tropical' genera. However, it has no native eucalypts or wattles, and evidently was not attached to Australia in recent times. It has very few deciduous trees, another indication of non-temperate origin.

In fact, in spite of the modern separations, New Zealand has links perhaps closer to Chile than to Australia, particularly in the South Island — it is quite possible that the two major islands were not so closely linked in the past. It seems likely that both islands have moved south relative to larger landmasses, possibly to different extents.

The islands of the Pacific show all the features of equatorial-band development and domain flight which we have come to expect. These islands are not tricky to reassemble into their pre-expansion conformations with a high degree of precision, purely by repeated rubber-banding of all their native species. The general picture is unmistakenly one of a tropical development band stretching from Indonesia across to Central America, split into thousands of smaller parts, with a few islands on the northern and southern limits of the band showing equatorial flight into more temperate areas.

In the rubber-banding, it is important to question (Proposition 6A) the usual assumption that many species have been introduced. The Hawaian group, in particular, has many species assumed to have been introduced, but which fit excellently into the expansion pattern. An example is the legume *Leucaena*, with 50 species in tropical America and two others stretching across through Hawaii to Polynesia. In fact is is probably more sensible to reverse the procedure, and determine whether or not a species has been introduced by seeing whether or not it 'rubber-bands' in a normal way. This test is quite independent of any historical evidence, such as the assumed spread of the coconut across the Pacific through the canoes of the islanders.

> *Proposition 7E*
> *The match of a plant's current distribution pattern with other local isocons gives evidence of whether or not the plant was introduced by man*

South and Central America

South America appears to contain two large domains, the bigger mostly made up of Brazil south of the Amazon, and the smaller the Guiana Highlands area to its north. It also has the most prominent domain shuffle belt in the world running down its west coast. There is an area of accreted islands or re-seamed domains east of Panama and extending over much of Columbia and Venezuela.

We have already seen how the western shuffle belt has acted as a raft to carry species southwards. A good example is the Pygmy Coconut, *Jubaea spectabilis*, which is confined to an area of central Chile (Fig. 4.14). Of course palms are typically tropical, but this one is the most southern and cold-resistant palm of all, able to withstand snow.

Like all palms, *Jubaea* is of Gondwanan origin. There are, however, a number of species of Laurasian origin which have managed to jump onto the shuffle belt. Figure 7.1 shows the distribution of modern and fossil occurrences of the walnuts, *Juglans*. It is taken from Berry's classic book [1923].

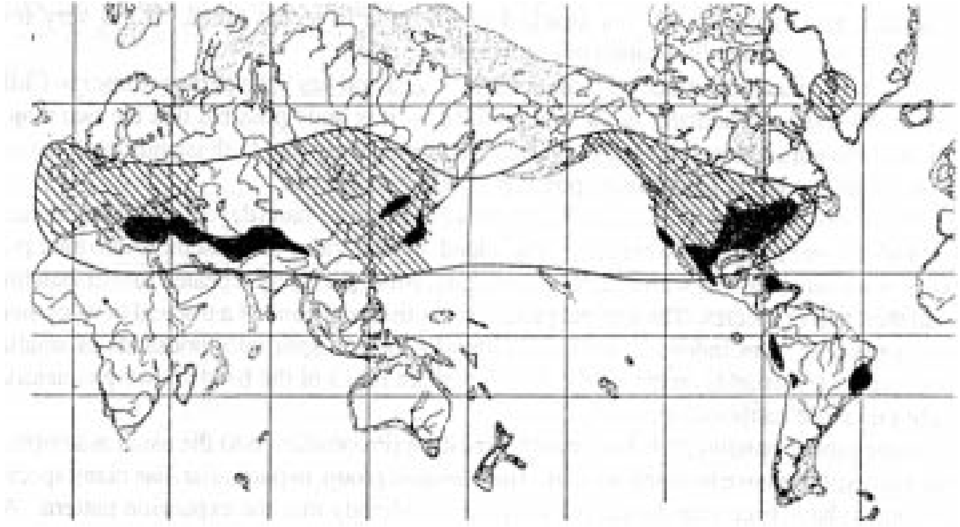

Fig. 7.1. Distribution of walnuts: modern (black areas) and fossil (shaded)

Notice that the modern walnuts occur right across what we can regard as the South Laurasian Equatorial Band — they are obviously Laurasian — and that the fossil occurrences (clearly somewhat sweepingly brushed in) extend up to Greenland. We know now why this is so. Notice also that occurrences of modern walnuts are shown in the Caribbean and extending down the Andes as far as Ecuador and Peru. These are also readily understandable, typical microdomain band shuffling.

But look again, and notice a large area shown for walnut in *eastern* Brazil, on the coast. This does not fit our pattern at all. I believe that it is an error.

Everyone can make mistakes — there may well be some in the maps I have put together myself — but the important point here is that we can use the reasoning developed so far to *predict* that this walnut placing is an error, and that prediction can be checked. Ability to produce predictions, and their verification, is one of the most important facets of any scientific theory.

Another interesting point which emerges, if you look at the various plant species of northern South America, is that species and genera on the Amazon Basin side are often quite different to those on the western coast. As an example, look at Figure 7.2, taken from Mitchell [1987], which shows the distribution of species of *Anacardium*, the cashew genus.

The Anacardiaceae family which includes the cashews has representatives across the tropics, including the Australian cashew, which however is no longer placed in the genus *Anacardium*, but in *Semecarpus*. The former is now restricted to 10 species, the nine shown in Fig. 7.2, and the cashew nut itself (*A. occidentale*), which occurs in the same area as the rest. However, the closest relatives to A*nacardium* are not species of *Semecarpus*, but the three species of *Fegimanra* which grow in tropical West Africa — again fitting the pattern precisely.

The point being made here is that neither the cashew genus itself, nor its close relatives, occur on the Andes coast of South America except in the extreme north, so it is presumably a fairly recent passenger on the shuffle belt. The genus does extend much further southwards on the east of the Andes, right down to northern Uruguay.

The walnut and cashew maps also help to define the status of the Caribbean islands and 'mainland' Central America. The walnut does not occur on the mainland, only on the islands. The converse is true for the cashew. Clearly there has been mixing of Laurasian and Gondwanan species in this zone, but the general position is consistent with the assumption that both parts are made up of a collage of microdomains which formerly lay right across the boundary of the two megadomains — part of what we have called the Tethyan Girdle. Detailed reconstruction involves only repeated application of the rubber-banding technique.

Fig. 7.2. Distributions of some species of Anacardium

It also seems that the present land bridge between North and South America is not particularly old, and previous land connections may have been further east. Mainland Central America is a clear aggregation of different domains, showing very obvious peninsulas and large lakes formed through the chance conjunction of different island outlines. The Galapagos islands off the coast of Ecuador have cacti (*Opuntia*) closely related to those of Mexico, and have been shifted southwards.

The relation of South America to Australia has already been discussed. The link between South America and Africa is obvious and inarguable. But even here, we can perhaps add a little, on relative ages.

The Brazil-West African connection is strong. We have seen it with the oil palm (Fig. 4.3) and with the cashew (Fig. 7.2). The connection can be shown again and again, through different plant families; a further good example is the custard apple genus, *Annona*. This is most widely represented in northern South America, although there are a few species right across tropical Africa and down the east coast. There is also a close relative, Asimina, which extends from Florida up the east coast of North America — of this more later.

But when you look further south, for connections between Argentina, Uruguay, and southern Africa, the links are quite weak. This can be seen from the Proteaceae map, Fig. 4.1, which has a notable blank area in southeast South America. The inference is that the southern gulf between Africa **and South America opened up** well before the northern separation.

Africa and the Indian Ocean

Africa appears to be a relatively simple construction. It contains a number of large domains — these could be represented as Nubia, Congo, Kalahari, Somali, and North and South Sahara. Most of these appear to have undergone some shifting and re-seaming, giving rise to features such as the Adamawa Highlands between Nigeria and Cameroon.

The most obvious domainographic feature of Africa is the east coast. This is another shuffle belt, not as dramatic as that of South America, but considerably more complex in the sizes and nature of the domains involved. These have all moved southwards, leading to such typical features as the many long, thin lakes. The Ethiopian Highlands and those surrounding Lake Victoria could probably be accorded the status of separate domains.

The plant distribution pattern is fairly plain — most families have bands of genera and species extending along the tropical lines of latitude, with extensions southwards along the east coast. The coffee genus, *Coffea*, is a typical example, as are the African examples of *Annona*.

In the north and east we run into the Tethyan Girdle, in this case including Spain, Italy, Greece, Turkey, and the Mediterranean islands, all mixtures of Laurasian and Gondwanan elements, with the former predominating. From the plant distributions, the Canary Islands are clearly Gondwanan and the Azores Laurasian. The Atlas mountains in northwest Africa are made up of several aggregated microdomains.

On the northeast, the major Arabian domain has separated off in the past and come back into contact, ending up with the triangular Sinai microdomain jammed in the gap. Arabia, which impacted with Laurasia to form the Zagros mountains, is shown by the plant distributions to be a Gondwanan domain. But it probably separated off relatively early, as it *has its own gener*a within the common families, such as the carob, Ceratonia siliqua, within the *legumes.* It even has its own families, such as the pomegranate, Punicaceae, with only one genus and two species, one of which is confined to the tiny island of Socotra in the Gulf of Aden.

India was indisputably part of Gondwanaland, and positioned against the east African domains, but finding its exact former position is complicated by the fact that these domains have been shifted south, possibly to differing extents.

Madagascar was probably positioned against where Mozambique is now, but again with the complication that the northeast half of Mozambique may have been shifted south relative to the southwest half. Madagascar has coffee species, which fi*ts in wel*l with the pattern. Another excellent 'tie-in' genus is Adansonia, the boab or baobab family. This has one species growing right across north-tropical Africa and down the east coast, extending also to India

(supposedly 'introduced by Arab traders'!), and a second species native to the Kimberly area of northwest Australia. But the big concentration, some 8-10 species, is in Madagascar.

Application of rubber-banding to Madagascan species will reveal its former connections, and because the island has many unique species related distantly or closely to those elsewhere, it should also be possible to work out when the different splits occurred, whether anciently or more recently. Of course the various edges of this domain were probably formed at different times.

The major link across from east Africa and the Mascarenes through India, southeast Asia, Indonesia and across the Pacific to Central America has already been shown. An excellent subject for rubber-banding is provided by the Seychelles islands north of Madagscar. These tiny, scattered islands include some with towering granite cliffs, virtually unique for isolated oceanic islands, and clear evidence of their 'continental' origin.

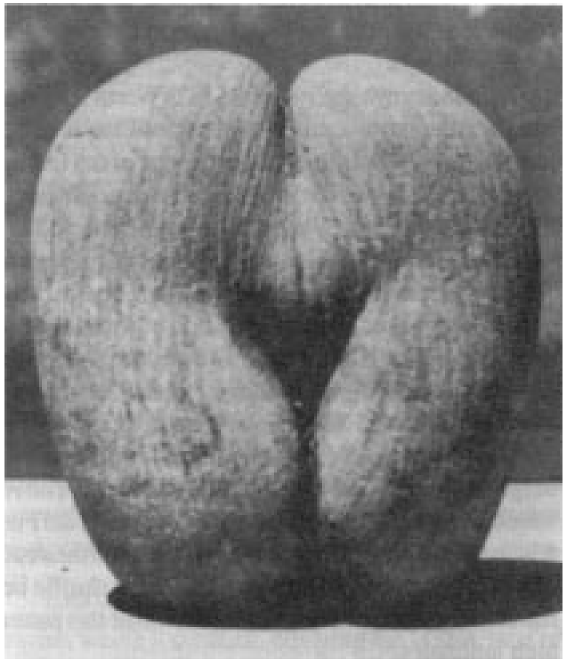

Fig. 7.3. A Coco-de-Mer nut

The Seychelles has a number of endemic species (confined to that area), in the genera *Acalypha*, *Begonia*, *Carissa*, *Dillenia* (elephant apple), *Diospyros* (persimmon), *Eugenia*, *Ficus* (fig), *Grewia*, *Pandanus* (screwpine), and *Pittosporum*, all of which are typical of the major link. It also has the unique Double Coconut palm or Coco-de-Mer, *Lodoicea*, which has the largest seed in the world, weighing up to 20kg. It takes seven years for the fruit to mature, three years to germinate [Lionnet,1976]. The nut bears an astounding resemblance to portions of the human female anatomy (Fig. 7.3), so much so that observers could quite understandably assume that some cosmic prankster has been at work!

North America

We have already identified some of the domains which make up the present North American continent, which is of medium complexity. The major domainographic features are the marked movements of shuffle belts or other domain aggregates north, on both sides of the continent.

These shifts have carried palms up into California and Florida, and representatives of the Sapotaceae up into Florida (Fig. 6.1). Florida also has representatives of the Gondwanan custard-apple family, the Annonaceae. These include both Annona itself (the genus of the soursop, cherimoya, sugar apple, sweetsop, and most other custard apples) and also a genus restricted to North America, *Asimina*.

This contains several species, but the only one well known, even in North America, is the American Banana or Pawpaw (this is quite unrelated to the papaya, *Carica papaya*, which is also called a pawpaw in some parts of the world). The Asimina is said to be the larges*t* native fruit in North America, good specimens weighing up to 500g. This again is a reflection of its origin, the larger fruits all originated in Gondwanaland — we will go into the reason for this later.

Asiminas grow over wide areas of North America, principally on the Mississippi domain and the Atlantic domain (the coast from Florida to New York). Their distribution is evidence that the genus was split off from the rest of the family some time ago. The boundary between *Asimina* and *Annona* is reasonably distinct, running across northern Florida, and indicates that Florida itself is a fairly recently accreted island domain.

Other domains which could be distinguished in North America include the Rockies, western Mexico, Laurentia and three or four other large areas in continental Canada. Presence of the Great Lakes shows interaction of a mess of microdomains, but the most complex area of all is the west coast, which will take much study to sort out in detail.

Alaska is a complex of microdomains, as are the islands of northern Canada and, beyond them, Greenland. The Aleutian islands, stretching from Alaska right across the North Pacific to Asia, provide a very graphic illustration of fragments falling from the movement of the huge hinge formed as the North Pacific opened up. The Aleutians, and the Alaska Peninsula with which they terminate, appear to parallel Tierra del Fuego and the islands and submarine ridges which sweep down from South America to Antarctica, in that they represent the oldest ends of a microdomain shuffle belt. Both these shuffle belt ends show divergence from the usual equatorial-flight patterns, and indicate that this pattern of behaviour may not always apply in high latititudes.

> *Proposition 7F*
>
> *Propositions relating to* equatorial flight of domains may lose validity at high latitudes

North America also shows a similar pattern to South America, in that plants native to the west coastal strip appear to ‘intervene’ between those east of the Rockies and the relatives of the latter across the Pacific. There is a strong link between the Texas-southern Mississippi flora and those of eastern Asia which appears to ‘jump’ over the west coast flora. This can be seen in the distribution maps of *Pistacia* (Fig. 4.10) and *Carya* (Fig. 4.11). The ‘jump’ is very obvious in Figure 7.4, from Berry [1923], showing the distribution of the magnolia family.

Try explaining the distributions in Figure 7.4 on the basis of migration across Bering Strait land bridges! There are also many other examples in Berry [1923], often with distribution maps, showing the same pattern with such diverse genera as Tulip tree (*Tupilifera*), Sweetgum (*Liquidambar*), Tupelo (*Nyssa*), and Sassafras.

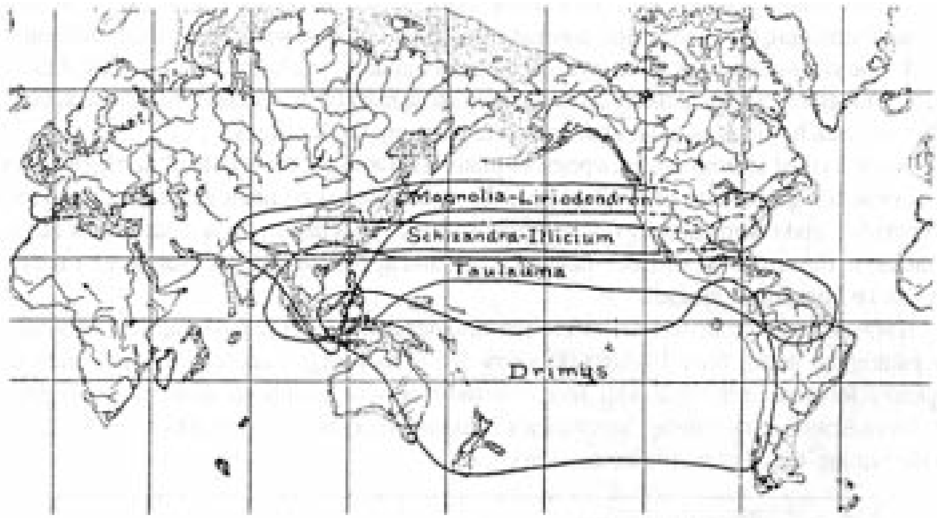

Fig. 7.4 Distributions of genera of the Magnolia family

This pattern is not confined to plants. The existence of relational links between the fossil dinosaurs of China and western North America is well known and is the subject of current study [Holley, 1987]. What is interesting is that the American dinosaur occurrences are mostly east of the Rockies, especially in the Canadian province of Alberta. Of course all these points confirm that the western shuffle belt has moved north along the coast, driving a wedge between the main North American flora and their counterparts at the same latitudes on the Asian coast.

Europe

Europe is a mess. The only major domain which it contains, covering the USSR west of the Urals and the North European Plain over as far as Germany, is structurally part of Asia (although it has undergone some re-seaming, along the Central Russian Uplands and the Volga Heights). Everything else is accreted and distorted domains and microdomains.

Running all along its south it has the scattered parts of the Tethyan Girdle — the band of island domains left from the original split of the holodomain into Gondwanaland and Laurasia. European domains in this band include Spain, Italy, Greece, the Mediterranean islands, and on to Turkey and the Central Asian republics of the USSR south of the Caucasus. All these domains have predominantly Laurasian rather than Gondwanan flora, and so should probably be classed with Laurasia. Also probably included with them is Ireland.

Ireland has, in its south-west corner, native occurrences of the Strawberry-Tree, *Arbutus unedo*. This also occurs right across the Mediterranean, and other species in the genus extend the range eastwards into the USSR (along the Tethyan Girdle) and, in the usual pattern, across the Atlantic (including the Azores) into Mexico and southwest U.S.A. (there is a concentration of seven species in Mexico).

The inference is that Ireland once lay in this band, and in fact, Ireland does fit quite snugly against northwest Portugal. Britain is a most complex mishmash of microdomaFrance,

France, Germany, central Europe and the Balkans are also much re-worked, the most prominent feature being the Alps, formed when Italy collided with the northern domains.

To the north, Denmark, Norway, Sweden and Finland clearly consist of several domains pushed together. The Scandinavian mountains show marked dissection through the action of glaciers, which brings us to an observation concerning the Ice Ages.

When looked at from the viewpoint of plant distributions, the whole of northern Europe is notable for the poverty of its plant species. It has almost no plant genera confined to its boundaries, and comparatively few endemic species. This makes the application of rubber-banding to the area more difficult than for most, and also raises the question of why the area should be botanically sparse.

It appears that the answer to the last question lies in the Ice Ages. These were very recent in geological terms, only 10-110,000 years ago (.01-.11my). There seems no doubt that glaciers formerly extended well south of their present European distribution, reaching southern Britain, for example. Inevitably, a consequence of being overrun by massive glaciers is the wiping-out of plant life in the area overrun.

> *Proposition 7G*
> *Northern Europe has a relatively low level of plant diversity because much* of it was cleared of living plants through the action of glaciers

Of course, when the glaciers retreated, vast areas of blank ecological niches were exposed, and plants came in to colonise these niches reasonably quickly. But because the ice ages were not so very long ago — not only within the era of the species of man, but butting right up against the development of civilization — there has just been insufficient time to develop the diversity of species and families which exist elsewhere.

It might be asked why the same situation does not exist across the whole of the temperate parts of the Northern Hemisphere. To some extent it does, in that colder areas are relatively poorer in plant diversity, but there is also another possibility. That is, that the recent ice-age glaciers were not centered on the North Pole (as is usually implicitly assumed), but were displaced more onto the European side for some reason.

> *Proposition 7H*
> *Ice-age glaciers were not centered on the North Pole, but had an area of influence displaced over into northern Europe*

Asia

We have already seen that all the domains along the southern boundary of present-day Asia — including Arabia, India, Indochina, and southern China — are Gondwanan 'borrowings' since accreted to Laurasia. The Iran-Afghanistan domain is probably also one of these borrowings. The Tethyan Girdle which shows up in the Americas and Europe apparently either was never formed or was absorbed. There is a parallel formation, which includes the island domains and peninsulas of Indonesia, Malaya, and the Philippines, but in this the

Gondwanan influence is predominant.

In the main mass of Asia, north of the Gondwanan components, extensive re-seaming and shifting of domains has taken place, especially in south and west Siberia and in China. These actions have given rise to the many mountain ranges and to the strings of long lakes — such as Baikal and Balkhash — and to the Turfan Depression in northwest China.

The Siberian area is notable for having the largest isocon envelopes currently existing on our planet. Stretching across the vast plains are huge areas in which the ecological conditions are relatively uniform, and so a particular plant species may come to have a very wide extent. One of the most prominent plants in this respect is, of course, a nut tree, the Siberian Stone Pine (*Pinus sibirica*).

Fig. 7.5. Needles, cones and nuts of the Siberian Stone Pine

This plant extends densely over more than 50 million hectares [Savel'ev, 1980]. The potential for producing nuts is huge, as a large tree may produce 1500 cones each year. The average biological harvest of nuts from each hectare reaches 800kg, so the potential annual yield of nuts is 40 million tonnes. This is many times the total weight of all nuts which figure in world trade.

From the domainographic viewpoint, the most interesting area in Asia is the Pacific Coast. This shows extensive evidence of domain flight. Japan and Korea, though rich in Laurasian flora such as oaks (*Quercus*), also have Gondwanan components such as yams (*Dioscorea*) and cycads which have clearly come up from much further south. Both show the typical north-south oriented island or peninsula form, as do Sakhalin and Kamchatka to their north.

Southern China is one of the most floristically diverse regions of the world, with dense intermixtures of Laurasian and Gondwanan components. Any proposed boundary line would be open to argument, but it could lie somewhere along the line of the Nan Shan range.

As elsewhere, extensive equatorial flight has taken place along this coast. The whole of Manchuria and southeast USSR has apparently shifted north. The position is made more complex by the fact that domains of every size have been involved; we already saw in Chapter 5 (Fig. 5.3) how the northeast USSR coast was a mass of microdomains. Instead of a straightforward shuffle belt like that of South America, we have a great mingling and jostling of large and small domains.

Plant distributions reflect the northward movement. A good example is the genus *Actinidia*, which contains the kiwifruit, A*ctinidia deliciosa*. The kiwifruit, once called the chinese gooseberry, is one of 40 species in the genus, which is distributed not only in China (and across to Burma) but also north, right up into Siberia, where there are some very cold-hardy species. As well as Actinidia, the Actinidaceae family contains the genus *Clematocle-*

thra, with 10 species confined to China, and the big genus *Saurauia*.

In Asia *Sauraia* overlaps the southern range of *Actinidia*, extending through Burma (six species) as far east as Nepal. But *Sauraia* is also well represented in America, with species running from southern Mexico through Central America and right down the west coast as far as Chile. The genus is absent from the Caribbean and almost absent from the Guianas and Brazil. Again this is an absolutely typical pattern, the family showing strong links across the north equatorial Pacific, and strong equatorial flight, northwards in Asia and southwards in America.

The Polar Regions

Because of the paucity of living plants in the polar regions, it is hard to apply standard rubber-banding techniques to these areas. However, some information can be got from studies of fossil plants and of animal distributions. Although difficult to apply, studies of marine flora and fauna may also be productive.

Having looked at where domain movements have taken place around the planet, we are now in a position to move on to the effects of these movements on the local landscapes — how they got their ups and downs.

CHAPTER 8

MAKING MOUNTAINS OUT OF MOVEMENTS

"Rocks rich in gems, and mountains big with mines,
that on the high equator ridgy rise"
— James Thomson, 'The Seasons'

How Mountains are Made

Mountain building (or, in the jargon, orogeny) is a topic which has been been one of the basics of geology. Details of the manner and conditions under which most of the Earth's present mountain chains were formed, and the times at which they arose, have reached a settled state.

However the basic mechanisms by which mountains have been formed are not so settled, there has been no completely satisfying explanation for why mountains have been formed where they were. If you look at the mountains on Earth, they mostly fall into one of two classes, which we can call 'long' and 'fat'.

The 'long' mountains are those which form extensive chains. A prime example is the Andes Mountains in South America, stretching right down the west coast of the continent. Often they are regarded as an extension of the Rocky Mountains of North America, connected to these by the mountain chain running right through Central America. Other mountain chains have been identified which are partly submerged, like the Aleutian Island chain in the north Pacific, or even wholly submerged like the mid-Atlantic ridges.

'Long' mountains are almost always associated with volcanic activity, either now or in the past. As a result, they are usually assumed to have been formed by volcanic activity. If the mountain chain is part of a continent, the rocks which make it up are usually high in silica, of a class called 'acidic' or continental. In contrast, mountain chains formed in the sea have rocks which, like the sea-bed around them, are lower in silica and are called 'basic' or oceanic. Both types of rock are classed as 'igneous' (derived from fire), that is, they are assumed to have been

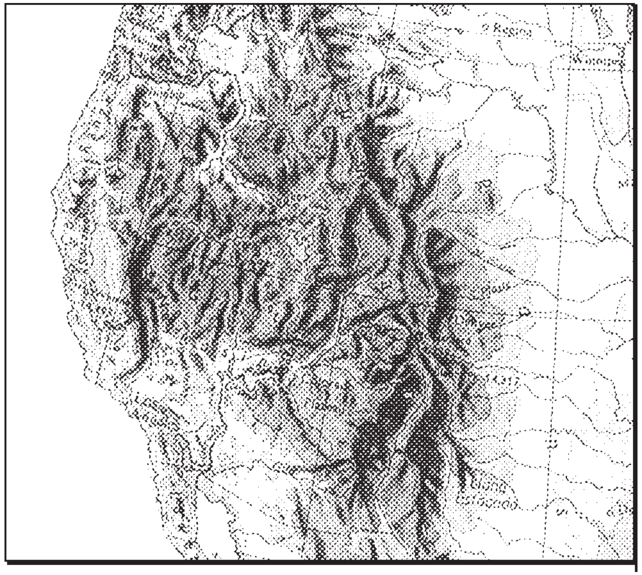

Fig. 8.1. Mountains of the western U.S.A.

formed from the cooling down of molten rock.

'Fat' mountains, in the sense used here, tend to be oval in outline rather than linear, and often contain plateaus and wide basins. The rocks they contain are often of sedimentary origin rather than of igneous (volcanic) origin, and sometimes they contain elaborate folded structures, in which beds of sedimentary rock have clearly been crumpled up and pushed against each other, sometimes right over each other. They usually don't contain volcanos. And they are not found submerged, as 'undersea massifs', on the deeper ocean beds.

A clear example of 'fat' mountains is the Himalayas. Fat mountains are assumed to result from various forces of compression occurring in the Earth's crust. The origin of these forces is often glossed over, but is sometimes purely a matter of impact. The Himalayas are now generally accepted as resulting from an impact between India (drifting north after breaking off from Gondwanaland) and that part of Laurasia which is now occupied by western China and the south-eastern section of the USSR.

Other mountains appear more mixed in origin. However, in these, it is usually possible to say that *both* the 'long' mechanism and the 'fat' mechanism have operated, rather than a single 'intermediate' mechanism. Thus the mountains of the western United States (Fig. 8.1) appear to consist of a 'long' component, running along parallel to the coast, backed by a 'fat' component (the 'Rockies' proper) further inland.

In Chapter 7 we had evidence that most of the present land surface is a patchwork of 'domains' of very varying sizes, pushed together or pulled apart by forces associated with Earth expansion. This leads very naturally to the suggestion that *all* mountain-building is a result of forces due to Earth expansion, expressed through the interaction of Earth domains.

> *Proposition 8A*
> *All mountains have been created through the interaction of domains*

Taking the 'fat' mechanism first, the suggestion is that all 'fat' mountains have been formed by impacts between Earth domains. As the domains are very varied in size, composition, and origin, the resulting landforms are themselves very varied. Some areas may have been worked over more than once, having been impacted from more than one side. As already noted, such a mechanism has already been accepted for the origin of the Himalayas. Other fairly clear 'fat' areas are the Swiss-Austrian Alps, formed by the impact of Italy against what is now central Europe, and the Pyrenees, formed by Spain hitting against France.

> *Proposition 8B*
> *'Fat' mountains have been created by domain impacts*

The suggested origin of 'long' mountains is more controversial. As these mountains are almost invariably associated with volcanos, to date it has been implicitly assumed that the volcanism caused the mountains. From the evidence already given in this book, it appears that a simpler and more reasonable explanation is that 'long' mountains are formed by the frictional

action of domains sliding one against the other. As before, the domains are in motion because of Earth expansion.

> *Proposition 8C*
> *'Long' mountains have been created by domain rubbing*

It is reasonable that any two domains in sliding contact will have somewhat rough edges, which do not match each other. If they move relative to one another, the 'burrs' along the edges will naturally pile up to create local high spots. If they continue to slide and rub, or if there is a chain of them active in a shuffle belt, eventually a whole mountain chain will be built up along the junction.

This gives a simple explanation for an observed phenomenon. It also leads to a most important conclusion relating to volcanos and other geothermic phenomena such as hot springs.

The Origin of Volcanos

Volcanos are hot — hot enough to contain molten rock. It has been more or less taken for granted in the past that this hot rock has welled up from the molten core of the Earth, which has pushed up through 'lines of weakness' in the crust.

In the next chapter, we will see that the concept that the heat of volcanos comes from the Earth's molten core has little evidence to support it. Leaving the evidence of this point aside for the moment, we can see that it has a vital implication for the origin of volcanos. If their heat does not come from the molten core of the Earth, where does it come from?

It appears likely to me that the heat in volcanos is generated by frictional heating of the edge rocks of two domains sliding one against the other. The intense heat generated through friction is well known — a classic example is making fire by rubbing two sticks together.

The heat generated through friction is usually dependent on the coefficient of friction ('roughness') and the masses and relative speed of the objects rubbing together. When we are talking about about Earth domains, these masses are enormously large compared to the everyday objects we see involved in friction, and their capacity to generate heat is equally enormous. It is certainly easily great enough to melt rocks.

> *Proposition 8D*
> *Volcanos are created by the friction between rubbing domains*

This proposition accords well with the fact that the molten rocks coming out of volcanos are generally of similar overall chemical composition to the surrounding country. If they were really formed by molten core rock, pushing up through 'weak places' in the Earth's crust, they might all be expected to be of 'basic' composition like the rock assumed to underlie the 'acidic' continental material. In practice, only volcanos sitting on oceanic-rock sea beds produce basic-rock flows, those which are sited on typical continental rocks produce acidic-rock flows.

The proposition also fits in with the known physical properties of rocks, especially their thermal properties. Rocks conduct heat quite poorly and also hold a lot of heat well. This is just the sort of situation where, if a massive amount of heat is injected through friction, a section of rock will melt and possibly become 'superheated' enough for the heat to spread slowly into adjacent rocks.

If the heat input is great enough, or is created close enough to the surface, it may spread enough to melt its way through to the surface and create a volcano — essentially an artesian molten-rock flow or rock 'gusher'. If there is not enough heat for this, the molten rock will slowly cool, insulated by the surrounding rock, and allow crystallization to occur — visible crystals are specially characteristic of acidic rocks such as granite.

Igneous Rocks

An important corollary of Proposition 8D relates to the rock the volcanos produce, and also to other igneous rocks. That is, that igneous rocks are produced by domain friction, and are not 'primeval' products left over from the Earth's assumed molten beginnings.

> *Proposition 8E*
> *Igneous rocks are produced locally, through domain rubbing, and not from a 'primeval' Earth source*

The existence under the surface of vaguely spherical bodies of igneous rocks is well known; smaller ones are represented as 'magma chambers' (magma is molten rock), and larger, solidified ones as 'batholiths'. An interesting point is that batholiths are normally *elongated* along the line of a mountain chain.

Figure 8.2 is a conventional representation of the rise of hot molten rock from the Earth's largely unknown inner reaches, and its further ascent to form a volcano. Shown is a large batholith, at the base of a thick layer of crustal rocks, itself connected to a magma chamber which has intruded into the layers of sedimentary rock beneath the land surface. This again is connected through a magma pipe with the cone and mouth of a volcano formed by the rock which solidified after flowing out from it.

Why should the magma come up from below and force its way through at this particular point? This is assumed to be due to 'weaknesses' in the Earth's crust at those points.

Now Figure 8.2 is obviously very diagrammatic and not to scale, but the situation it illustrates is, in my view, nonsense. No credible mechanisms have ever been suggested for why immense batholiths should happen to form at particular places, no reason for magma to be intruded and melt out 'chambers' at odd points within the sedimentary layers. In fact such behaviour is quite contrary to what we know about the flow of heat through materials such as rocks.

Worst of all, as we shall see in the next chapter, there is no evidence that the inner reaches of the Earth are made up of molten rock in the ordinary sense. This takes away the whole basis for the supposed pushing out of molten rock from volcanos through pressure from reserves within the Earth.

The concept of igneous rocks being formed locally, through the heat of friction caused by

domain-edge rubbing, provides a far more satisfactory explanation for the observed facts. It explains why bodies of molten rock can be formed at quite different depths (friction having been more active there, due to waviness of the domain-edge surfaces). It removes the need to explain how molten rock manages to intrude into particular spots of the crust and melt out chambers. And it explains why batholiths are elongated, they are elongated along the rubbing domain edges.

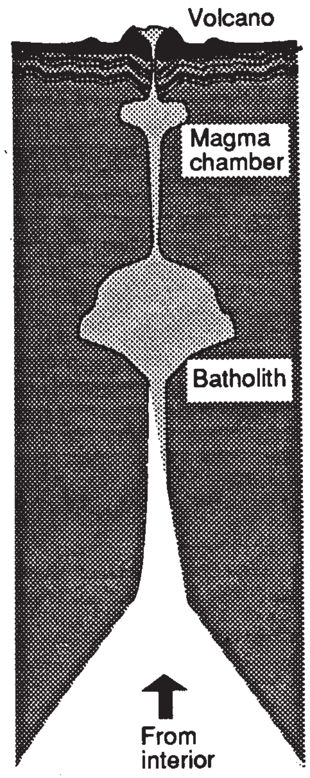

Fig. 8.2. Conventional representation of volcanos and batholiths

Geysers and Hot Springs

As well as volcanos, there are a number of other 'geothermal' phenomena which are not so dramatic in nature, such as geysers and hot springs.

With geysers, visible jets of hot water and steam are emitted periodically from holes in the earth, and some well-known ones have remarkably regular intervals between eruptions. Geysers and hot springs are very often associated with volcanic regions, but they need not be. Along the Perth coastal sandplain, just inland from Rottnest and close to the low granite hills of the Darling Range, some hot springs and hot artesian bores are known. There is no sign of volcanic activity in the area.

From the domainographic viewpoint, these more minor geothermal phenomena are just a natural consequence of less dramatic domain movements. In the Perth case, the sandplain area is a slowly-moving microdomain shuffle belt, wending its way south with just enough frictional movement to produce the odd hot spring.

> *Proposition 8F*
> *All geothermal phenomena obtain their heat components from domain rubbing*

Metamorphic Rocks

Intermediate between the igneous rocks, cooled down from the molten state, and the sedimentary rocks made from aggregates of erosion particles there lie the metamorphic rocks.

Metamorphic rocks are ones which have been changed or 'metamorphosed' from their original condition. Mostly they were once sedimentary rocks, such as limestone, which can be metamorphosed into marble, although igneous rocks can be metamorphosed too. Often they show marked layering; this can be a relic of the original sedimentary layering, but is sometimes clearly a result of the metamorphic process. The sheets of the transparent mineral known as mica are an example.

It is hard to explain some of the features of metamorphic rocks on the conventional concept of minor heat flows from a hot inner core. How could such minor heat flows lead to the perfectly level layered features found in metamorphic rocks, tens or hundreds of kilometres above the presumed heat source?

A natural explanation is found in the domainographic approach, which can supply the required localized sources of heat and pressure from the grinding together of moving domain edges.

> *Proposition 8G*
> *Metamorphic rocks are formed by the heat and pressure produced by rubbing domain edges*

Earthquakes

What causes earthquakes? Even though earthquakes have been an object of terror since the earliest days of man, and have been studied in detail for several centuries, no satisfactory answer to this question has ever been given.

Of course, when Continental Drift was discovered, impacts between drifting 'plates' were suggested. Unfortunately for this idea, the 'fat' mountains formed by impact are not the usual places where earthquakes appear. Earthquakes are almost invariably associated with 'long' mountains.

Then, when the idea of hot-rock 'convection cells' was put forward, the movements associated with these were a candidate. This was closer, in that earthquakes *are* associated with active mid-ocean ridges, supposed sites of upwelling hot rock. But they are not associated with the deep ocean trenches, into which subducted material was supposed to be disappearing. And the convection cells had no immediate connection with the established mountain chains which are the real places where earthquakes are most active.

We can see now that earthquakes are a natural consequence of domain movement, in fact, they *are* domain movements. When one Earth domain moves relative to another adjacent one, it is performing an earth movement, which is another name for an earthquake. The stating of this proposition is therefore almost a logical redundancy:

> *Proposition 8H*
> *Earthquakes are the relative movements of adjacent domains*

A few points which clearly support this proposition. First, it is common in earthquakes for surface displacements to occur, to create 'steps' in railways or roads of a metre or more. This would be expected if one domain was moving relative to another. Moreover, the displacements give the direction of relative domain movements. For example, on the California coast, which is accepted as moving north compared to the adjacent main mass of North America, displacement should normally reflect this relative movement.

Then there is the matter of the depth of earthquakes. The focus of an earthquake, the point

where it is most active (the assumed actual shearing zone), is not usually on the surface of the Earth, but deeper down. In a particular broad area, the earthquake foci are not at identical depth, but they do tend to cluster at somewhat similar depths. The focus can lie anywhere from a few kilometres down to as much as 700*km* below the surface. The cause of these last 'deep' earthquakes is completely unknown.

If the inner Earth is expanding, and this may be in a very regular way, then adjustments to the surface can be expected to extend quite deeply down. And, more important, a rational reason can be given for the fact that earthquake foci occur at different depths. The differences are due to differences in the size, shape, and physical compositions of the different domains.

So far, we have mostly looked at domains as two-dimensional objects, flat areas on the surface of the Earth. To get a more exact idea of what is happening with earthquakes, it is necessary to consider domains as three-dimensional objects, with not only width and breadth, but also height.

We had the first intimation of this concept with Proposition 5E, where it was suggested that the split of the original holodomain of continental material into Laurasia and Gondwanaland was not an isolated event, but was just the time when continuing expansion had reached the point of exposing underlying oceanic rock for the first time. Now we need to look at the outer layer of the Earth as being made up of layers of domains of varying thicknesses and sizes.

> *Proposition 8I*
> *Domains are three-dimensional objects of varying thicknesses, and the surface domains which are directly observable may be underlain by other domain-type structures*

An incidental consequence of this Proposition is that there will be considerable heat generated by friction between surface domain bottoms and sub-domain tops. A more important consequence is that multi-level domain concepts can be developed in a quantitative way which, for the first time, gives a real possibility of being able to *predict* earthquakes. This would be a very useful thing to be able to do.

Earthquakes happen when shearing occurs between the sides of two adjacent domains. Before the actual earthquake, huge tensions build up as the rock faces are compressed or stretched; it is sometimes possible to detect these forces with strain gauges. Although very rigid, different rocks have known physical properties, and the tearing, stretching or compression they will undergo under given conditions can be calculated quite precisely.

I can see no reason why it would not be possible to calculate where and when earthquakes will occur, once a better knowledge of the physical dimensions of domains and of the physical properies of their component materials is obtained, and a value for the rate of Earth expansion assumed. Such calculations may be complex and tedious, but there is nothing basically new about them.

> *Proposition 8J*
> *It should be possible to calculate where and when earthquakes will occur, once fuller data on the domains involved is known*

Hot Spots

Another mountain-building phenomenon which has been suggested in recent years is known as 'hot spots'. According to this theory, within the Earth there are a number of localized sources of heat, of unknown origin. As the 'tectonic plates' pass over these hot spots, each in a string of volcanic mountains is formed over the hot spot. From the ages of the various members of a volcanic-mountain string, the direction and speed of the associated plate movement can be calculated.

The hot-spot theory does not fit in at all with the concepts I have proposed. It is undeniable that strings of volcanic mountains exist, and it is perfectly feasible to join up the isolated points and conclude they represent the path of a tectonic plate over a hot spot. I believe this conclusion is wrong.

I suspect that the apparent 'hot spots' are what is called an 'artifact'. They can be seen, but paradoxically, they are not real. Like a moving dislocation vacancy in a crystal structure, or the passage of an electron 'hole' in a semiconductor, the movement is only apparent, not real. The situation is comparable to when the head of an organization resigns and is replaced by his deputy, who is replaced by his deputy, and so on down the tree until eventually a new recruit is taken in at the bottom.

In this situation, the job 'vacancy' starts at the top, and appears to move downwards through the organizational tree until it is filled by the new recruit sucked in at the bottom. In the same way, I suspect that the apparent 'hot spots' are only artifacts, created perhaps by opposing chance protrusions in adjacent domain boundaries happening to come together as the domains move.

> *Proposition 8K*
> *'Hot Spots' in the Earth are artefacts created by domain edge movements, and not real phenomena*

Of course the acceptance of this Proposition removes the nagging need to explain the *source* of the energy needed to drive the hot spots. These sources would have to be pretty special, if they were able to raise mountain after mountain, maintaining their power for many millions of years unchanged.

We have now spent some time looking at the surface of the Earth and its uppermost layers. We are ready now to plunge down, deep into the core of the planet.

CHAPTER 9

INSIDE THE EARTH

"The goal of scientific endeavour is to learn the truth of nature, and not to win debates"

Man lives, together with the complex assembly of plant and animal life which make up the biosphere, on the surface of the Earth. So it is natural that we know most about the surface, which is a surprisingly thin piece of real estate. When we go beneath the surface, down into the depths of the Earth, we can make direct observations for only about one-fifth of one percent of the way down. Everything we know about the other 99.8% has had to be deduced from indirect evidence and assumption and calculation — so it is again natural that the picture we have may be inaccurate.

In fact almost everything we have worked out about the insides of the Earth comes from a study of one thing — earthquake waves. When an earthquake occurs, it produces shock waves which run through and around the Earth.

These waves do not just radiate out and dissipate, they actually bounce off various levels within the Earth, called discontinuities, where the physical properties of the rocks change. Observations of the waves reveal just where under the surface the discontinuities are located, and give an indication of the properties of the rocks on either side.

Figure 9.1 shows a conventional summary of what has been deduced about the properties of the Earth, from its surface to its centre (about 6370*km* down). A fuller explanation can be found in any modern text (e.g. [Physical, 1977]), but the main features are these:

• **Feature A** • Four discontinuities, at depths of around 20, 200, 2900, and 5150*km*, where there are abrupt changes in density;

• **Feature B** • Density increasing from about 2.7 (*g/cc*) at the surface to about 13.6 at the centre;

• **Feature C** • Assumed chemical composition changing from oxides high in silicon and aluminium (Sial) or high in silicon, magnesium, iron and calcium (Sima) at the surface, down through layers with increasingly less silicon and more iron, until a core region is reached containing mostly iron oxides;

• **Feature D** • Temperature increasing from around 20 (°C) at the surface to 3000 at the centre.

The Lithosphere

Virtually everything in the area of domainography which has been mentioned so far concerns the region called the lithosphere, which lies beween the uppermost solid surface and a depth of around 60-100*km*.

This region is made up of the Crust and the uppermost division of the Mantle. The boundary between these two is the first discontinuity, called the Moho (after Mohorovicic, who discovered it). There the density changes abruptly, from 2.9 to 3.3.

The Moho varies in position from about 10 to 35*km* below sealevel. Under the seabeds, where the oceanic basic rock or Sima is exposed, it is at its shallowest, while it is furthest down under the continents, which consist mostly of continental acidic rocks, or Sial. Where Sial exists, in the continental areas, it is nevertheless believed to have Sima underneath it, so the Sima extends over the whole of the Earth. The Moho also extends over the whole Earth, apparently almost entirely within the Sima.

There is no doubt that the Moho, and the other three discontinuities mentioned in Feature A, all exist. What is not certain is what their nature is. They have been associated with changes in chemical composition to some extent, but this is purely speculative. Even the Moho is only just within the range of feasibilility for reaching by modern drilling techniques (the current record depth is around 11*km*), but to date no drill core recovered has provided hard evidence that rock below the Moho is of different composition to that above.

From all the evidence produced to date, it is clear that extensive domain movements have occurred in the past, and it seems that the influence of these movements has extended at the very least to the base of the lithosphere, up to 100*km* down. On the old plate tectonic theory, the ‘plates’ were supposed to be drifting on the mushy rock layer, the asthenosphere, immediately below the lithosphere.

It is interesting that as long ago as 1782, Benjamin Franklin speculated that “the surface of the globe might be a shell, capable of swimming on an internal fluid”. We will see later that this attractive idea, which has now actually reached general acceptance, is false.

It seems logical that if such ‘floating’ movements occurred, they could not leave intact a boundary based on differences in chemical composition. Even on Continental Drift principles, we have taken it for granted that one such ‘chemical boundary’, that between the Sial and the Sima, has already been broken up by domain movements.

It therefore seems likely that the Moho is a physical boundary. Its most probable nature is that of a *phase change*, brought about by increasing pressure. A given mineral or compound can exist in different states or ‘phases’, caused by the application of external pressures — an example is diamond and graphite, both of which are phases of carbon. Diamonds can be made from graphite by application of very high pressures — amusingly enough, they have actually been made from peanuts, after extracting the carbon from these.

> *Proposition 9A*
> *The Moho discontinuity represents a phase change boundary where the rocks are changing their phase in response to increasing pressure*

From this Proposition it follows directly that if the Moho is dependent on pressure, it will alter its position as the pressures change, as will happen when domains move and break up.

> *Proposition 9B*
> *The position of the Moho will change as the pressure of overlying rock changes in consequence of domain movement*

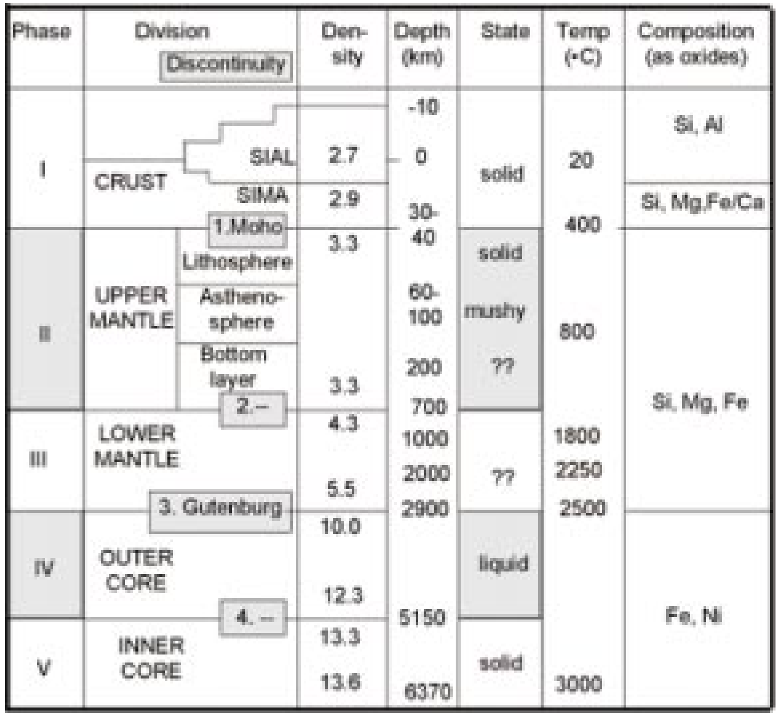

Fig. 9.1. Structure of the Earth, from surface to centre

These propositions are in accord with Features A and B above, but Feature C looks a bit more shaky. Let us now look further at the matter of chemical compositions.

Internal Chemistry of the Earth

Once we descend below the 10*km* or so of the Crust which can be analysed directly, our knowledge of the Earth’s chemistry is purely speculative. So we are quite within our rights to question some of the assumptions made, assumptions often repeated as fact, from textbook to textbook through the decades, without any real evidence.

One of these ‘facts’ is that the core of the Earth is very rich in iron and poor in silicon. According to the text used to construct Fig. 9.1 [Physical, 1977], some 90% of the core consists of iron oxides, and another 8% of nickel oxide, leaving 2% unspecified. Where did this idea come from?

Well, firstly there is the fact that the core material is very dense, and both iron and its oxides are also dense, though not as dense as the core material. So this does not get us far. Perhaps the strongest argument comes from material assumed to be derived from outside the Earth, from meteorites.

Meteorites are solid objects falling to the Earth from space, of a size great enough to survive vaporization through the friction of falling through the atmosphere (another instance of the great heat available from friction). They are of two types, either stony, made of rocks similar to those found on Earth, or of iron (with some nickel).

It has been suggested that meteorites are the remains of a planet similar to Earth which broke up at some time in the past. The proportion of stony to iron meteorites falling on Earth is similar to the proportion of iron to stone within the Earth if its core was made of iron. And this appears to be the main argument for an iron core.

This connection is not only tenuous, it is also flawed. The iron in meteorites is native metal, while the iron assumed to be in the core is represented as iron oxides. No mechanism has ever been suggested whereby, if a planet broke up, the bits of iron oxide from its core could all be converted to iron metal.

There is one further possible link, with magnetism. The Earth has an appreciable magnetic field, and iron and its compounds are normally linked with magnetism. However, any possible connection with the core is ruled out by the fact that magnetic materials lose their magnetism when heated up — this is the basis of the technique of paleomagnetism, mentioned in Chapter 3, whereby newly-created rock from volcanos took on the direction of the local magnetic field as it cooled down.

So it appears that the idea that the Earth has an iron-rich core is without basis.

Proposition 9C
The Earth does not have an iron-rich core

What then is the basis for the density discontinuities in the Earth's inner structure? I think it is reasonable to assume that all four of the known discontinuities mentioned in Feature A are, like the Moho, the result of pressure-induced phase changes.

Proposition 9D
The four discontinuities marking the boundaries between the Earth's Crust, Upper Mantle, Lower Mantle, Outer Core, and Inner Core are all due to pressure-induced phase changes

This Proposition is at least as reasonable as any other. It is supported by the manner in which masses of molten rock material segregate. Some segregation might be expected, perhaps with lighter components rising closer to the surface (as with the Sial and Sima), but not a sharp division based on chemical composition.

A corollary of Proposition 9D is that all pressure-dependent discontinuities may be expected to alter their position as the Earth expands, as suggested for the Moho.

Proposition 9E
All the density discontinuities within the Earth may be expected to change position as internal pressures change with Earth expansion

Heat of the Earth

Of the four Features listed above, the one most open to attack is the one which assumes that the Earth's temperature increases continuously towards its centre. After all, why should it?

When confronted with this question, probably the responses of most geophysicists would fall into two areas. One is to say, whatever the reason for the phenomenon, it describes known behaviour — it does get hotter as you go downward in the Earth. The other response might be to say that pressures are very great within the Earth (this is undisputed), and high pressures and high temperatures are usually associated.

Neither of these responses hold water. The most obvious manifestation of heat from within the Earth is through geothermal phenomena such as volcanos. We have already seen that these essential *local* phenomena are, in fact, an expected outcome of domain rubbing (Proposition 8D).

Well then, what about the observed fact that temperatures increase as you go downwards in mines? This is perhaps the strongest argument which can be produced, and we need to look at it more closely.

Temperatures down mines

As you go progressively deeper in the Earth, temperature variations due to seasonal and climatic effects smooth out, and in an undisturbed site the temperature is virtually constant when a depth of 20-30*m* is reached. Of course this constant temperature is different for different sites and depths.

As you go deeper still, the temperature invariably rises regularly. The rate of rise, at least for the more shallow mines, is around 1°C for each 40*m* of descent (equivalent to 25°C/*km*), but it does vary by a factor of two, and even varies at different depths in the same mine. This effect has been known since mines were first dug.

More recently, information has been gained from deep oil wells, showing a similar picture [Bergman, 1989]. Producing oil wells have been drilled, in different parts of the world, down to depths of around 8*km*. The temperature of the oil produced varies according to the area of production and the geology of the host rocks, but invariably increases with the depth of origin. Oil from a depth of 1*km* might be at a temperature of 55°C, that from the deepest wells could reach 240°C. Again these figures represent rises of around 25°C/*km*.

The pertinent question now is whether these rises increase regularly as you go even deeper, and if so, what the source of the deep heat is. For the first part, a regular rise of the type found in the accessible top 10*km* implies a temperature at the Earth's core of over 150,000°C. This is the sort of temperature believed to exist only in the interiors of very hot stars, and no one has ever suggested it as a real possibility for the Earth — 3000°C is a conventional figure.

This last figure represents an average rise of less than half a degree per kilometre, so even on the conventional view it is accepted that any rate of rise must fall off as you go deeper.

For the second part, the accepted origin of the heat rising from the Earth's interior is that it comes from the molten core, presumed to be left over from when the planet was first formed in a molten state. We now look at the flow of this heat.

Heat Flow in the Earth

The matter of the flow of heat through the body of thy Earth has received considerable attention in the past. Rocks are poor conductors of heat, and so if the centre of the Earth was once very hot, it can be expected that it would take some time for the inner heat to escape. But just how long?

Towards the end of the last century, the famous physicist Lord Kelvin (William Thomson) looked at this problem in an attempt to work out the age of the Earth. Kelvin was an expert in matters relating to heat flow, in fact the absolute scale of temperature, that starting from absolute zero (around -273°C), is measured in degrees K (K for Kelvin).

Kelvin concluded that if the Earth started off very hot, it could not take more than 400*my* for it to cool down to its present temperature, and it could be as little as 20*my*. His study was one of the earlier scientific attempts to work out the age of the Earth, and his result of 20-400*my* was accepted as valid. It had already been realised that previously assumed values, of a few thousands of years only, were far too low, but the full extent of the Earth's age had not yet been guessed at.

After the discovery of radioactivity, it was realized that the radioactive decay of elements in rocks provided a way of working out their age. Many elements have forms, called radioactive isotopes, which are unstable, that is they break down to form other elements and give out radioactivity. For example, a uranium isotope may change slowly into lead.

Each radioactive isotope decays at a fixed rate, called its half-life (the time taken for half of all the original isotope atoms to change). This half-life may vary, for different isotopes, from many thousands of years down to a fraction of a second. Isotopes with long half-lives can be used to work out ages of rocks. This is done by analyzing the amount of a particular radioisotope in a mineral and the amount of the element it is changing into — the ratio and the half-life give the time since the original mineral was formed.

What this method showed, when applied to rocks, was that most of them were very much older than Kelvin's result suggested. Confirmation of this great age came from other results also, so the Earth was clearly too old for its internal heat to be 'left over' from when it was first formed.

The next suggestion for the origin of this heat again was connected to radioactivity. When radioisotopes decay, they give off heat — it is this heat which is used in nuclear power stations. All rocks contain a larger or smaller amount of radioactive material, and a currently suggested cause for the Earth's heat is that it stems from the decay of radioactive material within the crust, perhaps at depth.

There are problems with this theory. The main one is that the rocks which are richer in radioactive material are known to be concentrated in continental-type rocks, rather than oceanic ones. Upward heat flow does vary in different parts of the Earth, but not in a manner which has any relationship with content of radioactive materials. Another problem is that the content of radioactive material in the rocks is quite insufficient to produce the amount of heat actually recorded, especially since the evidence is that concentrations of radioactives, always relatively uncommon, are mostly confined to the topmost continental Sial layer of the Earth.

The Encyclopaedia Britannica article on the Earth's heat concludes that 'no satisfactory theory ... yet formulated explains the Earth's thermal constitution' [Britannica/ 6:26]. In summary, it appears that there is no convincing evidence that the core of the Earth is very hot.

> *Proposition 9F*
> *The core of the Earth is not especially hot*

Where then does the observable heat flow originate? We already have an answer — from domain movements. In this case, however, we probably need to include the deeper domains, down to a depth of around 100*km*. We will see later, in Chapter 16, that there are other possible contributions to this heat, but this is suggested as the main source.

> *Proposition 9G*
> *The principal source of the heat observed to flow from the depths of the Earth is friction from movement of domains, including deeper domains*

Is the Earth Made of Brown Sugar?

The Earth is not made of any sort of sugar. But in some respects we get a better intuitive picture of what is happening with the Earth if we regard it as made of a substance similar to sugar crystals, rather than of a baked-clay material as implied by the term 'plate'.

The hardness and physical strength of various rock materials are readily observed and measured, and so people have an intuitive feel for how a boulder or pebble will behave. There is a difficulty when this feeling is extended to something on quite a different scale, such as a mountain range. The behaviour of a microdomain is not the same as that of a boulder of the same material, scaled up in proportion.

An instance of this has already been looked at, in Rule 3 of Chapter 7, where it was noted that rotation of domains was not normally observed, say when one collided obliquely with another. What actually happens in such an impact is that the material at the point of impact just crumples up, like a mass of sugar crystals, rather than a whole 'plate' swinging about the point of first contact.

The sugar picture also gives a better feel for what happens with deeper domains and under-domains. If a surface domain is split apart by Earth expansion, its edges will be 'soft and crumbly' on the larger scale, and if sub-surface domains split, like sugar cubes embedded in a mass of crystals, the higher material will tumble down into the gaps.

Figure 9.2 is a representation of how surface and subsurface domains might be represented in a cross-section of the top 100*km* of the Earth's surface. If they are looked at as lumps and cubes of sugar in a sugar crystal matrix, this may give a better feel for the situation than one showing them as single rigid flat plates floating on a molten surface (the conventional picture). Another image might be that of a dry-stone wall, pieces of rock fitted together with only smaller rock fragments and no mortar in the gaps.

Another advantage of these pictures is that they make it easier to visualize the independent movement of domains and sub-domains at different levels. The old tectonic plate image only considers movement of one-layer massive plates of more or less uniform thickness, around 100*km*.

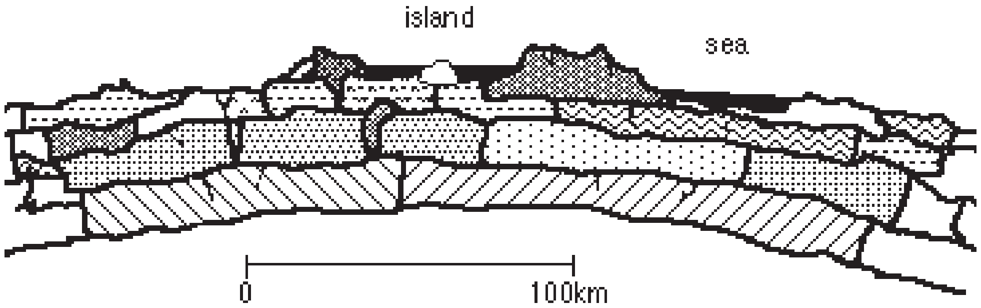

Fig. 9.2. A domainographic representation of the Earth's upper layers

Having looked inside the Earth, we now return to its surface, but this time we look not at the solid land, but at its rolling oceans.

CHAPTER 10

THE ROLLING OCEANS

"Earth, Ocean, Air — beloved brotherhood"
— Shelley: Alastor 1:1

The vast majestic oceans which cover so much of the Earth are intricately interlocked with the history of our planet. Accepted as the medium in which life itself began and evolved, and covering some 70% of the surface of the Earth, their 'unfathomable deeps' might seem as ponderous and unchanging as the most stable object in nature.

In fact the oceans have been subjected to the same sort of massive upheavals and tortured history as we have seen overtook the lands. In some ways the changes have been greater, as they have altered the very nature and composition of the seas.

The Extent of the Oceans

Only around 30% of the Earth's surface is land, and of this land probably a good deal less than 30% does not show clear signs of marine inundation of some sort in the past. So no more than 10%, and possibly very much less, of the current land surface has escaped a period under the waves.

The average depth of the oceans [Guinness, 1983] is around 3.5*km*, and the average height of the land above sealevel is only about 750*m*. The deepest spot in the oceans is believed to be the Marianas Trench, off the Philippines, with a depth of 11*km* (more than the highest mountain, at 9*km*).

How does this situation fit in with the aspect of Expanding-Earth domains, and in particular, what is known or believed in regard to changes in sealevel? This turns out to be a complex question, with a number of forces active, some in opposition and some together.

To clear the field a bit, it must first be reiterated that all measurements and deductions of where the sea reached on different pieces of terrain in the past, and former comparative sealevels in different parts of the world, are close to worthless. In the image of jostling, moving, and rising and falling domains and microdomains which we have arrived at (Fig. 9.2), the unqualified comparison of the present heights above sealevel of two distant points on the Earth is meaningless.

So also is a deduction that the sea has risen or fallen generally, working from the present position of a point in relation to local sealevel. As an example, a recent drilling programme for a gas production platform off the Northwest Shelf of Western Australia showed that seabed strata 125*m* below the seabottom (itself over 100*m* down) had been dry land in geologically recent times, and yet were sandwiched between strata believed deposited in water deeper than 100*m*.

The normal inference from this information would be that the sea had retreated at least 225*m* in the past at the time the dry-land formation was created. While this is quite possible, it is equally possible that that portion of the seabed was on a domain which had risen and fallen by this distance relative to a sea of unchanged level.

> *Proposition 10A*
> *Most observations and deductions on the position of sealevel relative to particular points on land today are meaningless when applied to general sealevels in the past*

This Proposition (or at least the reasoning behind it) is already accepted in detail, if not in large. Measurements and calculations are often produced and accepted which claim that Continent A is rising relative to Continent B by several millimetres each year, and so on. One millimetre per year is one metre in a thousand years, or 1*km/my*, so that a tiny change of this sort continued on for what is a short time by the standards we have been using — less than the existence of the human race — would be ample to sink all current landmasses beneath the sea and raise new ones.

And yet, maps are still being drawn for geological textbooks, showing the position of the sea in Carboniferous times, 300 million years ago!

Volume of the Sea and Earth Expansion

Whether on the conventional view or using the outlook explained in this book, it does, in reality, appear that land areas in the past were by and large the same bits of real estate as the land areas now. The domains involved may have sunk or risen relative to the local sealevels, or vice versa, but virtually all the deep ocean beds are less than 200*my* old. We have seen the reason for this — these seabed areas did not exist in any form on the pre-expanded Earth — but this still leaves us with a problem. Why wasn't the entire globe underwater in earlier times?

Assume that, at the beginning of Devonian times, 400*my* ago, the Earth had half its present radius. Its surface area would be a quarter of that now. If the water in the present oceans was spread uniformly over the present Earth, it would form a layer about 2.5*km* thick. On the Devonian Earth, the same water would be 10*km* thick. If the Earth had the similar landforms to now, except that all the present land areas were pushed together to cover a half-radius Earth, not even the tallest mountain would be above the surface.

The first life on land, both plant and animal, appears to have emerged around the Devonian, so real land areas clearly existed then. What is the explanation of this paradox?

The simple answer is that there was much less seawater on the Earth in Devonian times. This leaves with another problem, explaining where the 'new' water has come from, but that is another issue. For the moment we should accept this explanation.

> *Proposition 10B*
> *In earlier ages the Earth had a smaller total volume of water on its surface*

This is not to say that the total *land* area was any greater in those days, in fact the converse is probably true. Although life appeared in profusion some 600*my* ago, its earliest records date back 3500*my* — microbial lifeforms found in the rocks of northern Western Australia. Of course all these early forms of life were water-living creatures; it is only when we reach the comparatively short time of 400*my* ago that the first land creatures appear.

Why did it take so long? We have seen that lifeforms evolve really quite rapidly, with major changes occurring during a few million years. The vast majority of extant lifeforms, and their immediate and more distant ancestors, have all evolved during the Tertiary Era, the last 70*my*. Why was there no life on land till the Devonian, while 200*my* of intense evolution had just taken place in the sea?

The answer to this, I believe, is that land itself only appeared around the Devonian. Before this, the Earth had not expanded enough to expose more than perhaps a few peaks through the surface of whatever seas existed at that time.

> *Proposition 10C*
> *The first substantial land appeared above the sea around 400 million years ago*

The scenario is thus of an expanding but much smaller Earth, with less water distributed over its surface, but sufficient to cover irregularities in the surface almost completely until the highest of these were exposed in the Devonian — the Earth having already reached more than 90% of its present age.

This scenario is consistent with the fact that marine sedimentary rocks exist over so much of the present land.

Where Has the Water Come From?

To return to the matter of where so much of the present ocean water has come from, and to highlight a related point. Way back in Chapter 5, the suggestion was made (Proposition 5M) that in making pre-expanded Earth constructions, domain boundaries should be taken as the present sea-level boundaries, ignoring continental shelves.

This proposition still holds, and will be further supported by more evidence later, but it will now be clear that this proposition does *not* imply that domains with current sea-level boundaries had sea-level boundaries in those older periods. Nevertheless, there has been a very approximate preservation of land areas since the Devonian, implying some continuing source of new water since then to at least partly keeps the oceans 'topped up' as their basins expanded away under them.

The problem of explaining where the present ocean water came from is heightened by the fact that, as we shall see in the next chapter, the Earth has lost very considerable amounts of water into space.

The only credible source for this water would be one which tended to keep pace with the expansion process. I believe that this source derives from the expansion process itself.

The point is that Earth expansion continually exposes new rock to the surface, or at least takes it into the lithosphere where domain churning lets it be worked on. Although not obvious, it seems quite probable that this rock contained some water. The fact that volcanos give out steam, as well as other gases, is well known. In analysis of rocks, any water present is usually assumed to have come from groundwater, or from the sea in the case of seabed cores, and the water is often not taken into account as a rock component.

> *Proposition 10D*
> *Water is being added to the Earth's hydosphere from internal materials brought into the active domain zone by Earth expansion*

This proposition is a reasonable explanation of the position, since the volume of rock brought into play will be proportional to the new surface area created by expansion, thus releasing enough 'new' water to keep pace, partly at least, with the new ocean volume. Any other explanation unconnected with expansion — such as the Earth gathering hydrogen from interplanetary space during its passage, which is still a distinct possibility — would not have this important proportional feature.

Also, from the cosmological viewpont, hydrogen is the most common element in the universe, and oxygen is the most common element on Earth. Water is a compound of these two elements, and however the Earth was formed, it seems reasonable that a significant proportion of these two elements should exist right throughout the Earth's substance.

Is the amount of 'new' water generated enough to keep the oceans fully topped up? I suggest that it is not, and this causes a continuing small fall in average sealevels, with the result that the total land area of the Earth is increasing. Let us try and put some figures to this.

The Level of the Seas

For the moment we will only be concerned with long-term change in sealevel which stem from Earth expansion, and will not think about short-term or local effects due to ice ages, Greenhouse effects, or domain jostling.

According to the latest figures [Carey, 1988], the current rate of increase of the Earth's radius is around 3*cm/yr*. If there was no 'new' water coming in from below, we would expect the average sealevel to be dropping because of this each year.

The actual amount is quite hard to calculate (it needs to make assumptions on the average rate of slope of the solid surface over all the Earth's seashores and seabeds, and the places where the actual expansion shows up), but it looks to work out at only around one-thousandth of a centimetre per year (I am open to correction on this). This is equivalent to a drop of 1 metre in 100,000 years, or 10*m/my*, and clearly can have no short-term effect.

Even so, on the longer term this figure looks to be of the right order. The drop in sealevel since the Devonian, 400*my* ago, would be 4000*m* or 4*km* — about half the 7.5*km* difference between the current 2.5*km* thick layer and the 10*km* layer which would have existed if the same water had been present on a half-radius Earth.

> *Proposition 10E*
> *The average annual fall in mean world sealevel as a result of Earth expansion is of the order of one hudredth of a millimetre per year*

In the next chapter, evidence will be brought forward supporting the suggestion that Earth has also lost a huge amount of water into space. As a very approximate first stab, let us assume that the other half of the 7.5*km* drop in sealevel is due to this mechanism, which thus produces a similar rate of fall.

> *Proposition 10F*
> *The average annual fall in mean world sealevel as a result of loss of water to space is also of the order of a hundredth of a millimetre per year*

Both these figures are admittedly open to considerable adjustment and correction from a more detailed approach to the calculations involved — since all the mechanisms involved have only now been put forward in a broad context, with even the existence of such figures perhaps suggested for the first time, it is a bit rash to put numbers to them. Where angels fear to tread ....?

Early Man and Shorter-term Sealevel Changes

It is currently believed that the earliest creatures which might be regarded as the direct ancestors of modern man existed some five million years ago. These were not men in the modern sense, but were a distinct branch of the higher primates — about as different from the other apes as chimpanzees are from gorillas.

True men have probably existed for much less than a million years, with the beginnings of civilization no more than 20,000 years in the past. Our knowledge of the evolution of man is sparse — only relatively isolated remains have been found, really quite a small number of 'missing links' between the apes and man.

Against this 5*my* background, perhaps the most important physical events have been the Ice Ages. These were times when the polar icecaps apparently covered much larger areas than now (however, see proposition 7H), and there were a number of cycles of advancement and retreat. The oldest was around 110,000 years ago. The most recent was only about 10,000 years ago (we may be in the middle of a cycle now), so the Times of Ice were well known to man, perhaps even civilized man.

These Ice Ages are claimed to have had huge effects on sealevels, at times amounting to hundreds of metres, through the locking-up of water in the great icecaps. As an example, evidence has been put forward for the existence of a huge freshwater lake, dubbed Lake Carpentaria, in what is now the Gulf of Carpentaria [Fig. 10.1]. The lake existed between 26,000 and 10,000 years ago, caused by a drop in sealevel due to polar ice accumulation of 150*m* [Ford, 1985].

One item of supporting evidence is that the same species of freshwater frogs and turtles exist both in the Arnhem Land area of the Northern Territory and in Papua New Guinea and West Irian to the north. These are presumed to have dispersed through the lake.

The Aquatic Ape and the Missing Link

Marked falls in sealevel in the period of man's evolution have an interesting implication.

In 1982 Elaine Morgan published a book, ‘The Aquatic Ape’, containing a great deal of persuasive evidence suggesting that man had been through a partly aquatic phase in his evolution. This book was based on a proposition put forward by the British marine biologist, Sir Alister Hardy, in 1962. It is not possible to summarize a whole book in a couple of paragraphs here, but the evidence seems undeniable that man differs fundamentally from the other higher primates in ways which suggest a much higher degree of linkage to a water-dependent existence.

Physically, humans are notable for such things as hairlessness, deposits of fat under the skin, prominent mammaries in the female, ‘flow lines’ in remaining hair deposits, and tendency to webbing between the toes (up to 7% of the population). All these are features which are common to aquatic mammals but are completely lacking in the other land apes.

Psychologically, the love of mankind for water (swimming, sailing, and surfing are regarded as very pleasurable by many) and the tendency for towns and cities to be built on the edge of water are well known, again in contrast to the other apes, which generally have a strong dislike of water.

Fig. 10.1. Former ‘Lake Carpentaria’ between Australia and New Guinea

On the other hand, some non-primate mammals such as elephants and pigs possess many of these ‘aquatic’ features and are also believed to have had an aquatic phase in their evolution. Both are strong swimmers, elephants having been known to swim distances as far as 500*km* in the sea, of their own volition. It is not suggested that man was ever a completely water-adapted mammal, like the whale, only that during his evolution at least part of the race became adapted to very regular use of water and so brought in these ‘aquatic’ genes.

Here then is a possible explanation for the comparative dearth of hard fossil evidence of man’s evolution. If much of this evolution took place in the shallow waters, or at least on the sea’s edge, and water levels have since risen generally, they would conceal much of this fossil evidence.

> *Proposition 10G*
> *Most of man’s evolution took place in a semi-aquatic environment, and rising sealevels have concealed most of the fossil evidence for this evolution*

Of course it is possible to try and verify this proposition. It seems highly likely that human evolution was especially active around the African and Asian shores of the Indian Ocean. It should be possible to select likely sites for underwater archaeology — the Red Sea and areas near river mouths in East Africa are possibilities — to try and recover such remains.

There is a further implication. Back in Chapter 6, I noted the apparent close genetic links beween the Pygmies of Africa and the Negrito people of the Philippines, and pointed out that the elapsed time was insufficient for these two groups to have evolved together and been later separated by Earth expansion. In Proposition 6D of the same chapter I suggested that the isocons for marine seashore creatures were thin and long — creatures could spread rapidly along the shores, but not over them into the land or the sea depths.

Putting these two together we have the possibility that early man lived mostly in the long, thin shallow-marine isocons and not in the squarer land isocons of most land animals. This does provide some sort of explanation for the Pygmy-Negrito puzzle.

The ‘Land Bridges’ of the Past

The short-term tying-up of large amounts of water in polar ice caps must inevitably lead to falls in average sealevels. But we know that this is not the only mechanism affecting sealevels, nor will sealevel changes necessarily be uniform over the whole globe.

There has been a tendency to find evidence that two areas of land now separated by sea were once linked, and assume that this was through a ‘land bridge’ between them. This then leads to the assumption that the sea had retreated generally, enough to expose the seabed to at least the depth needed to form a continuous land link, and the depths needed have sometimes been very large. Even between Rottnest and the mainland, this reasoning has been used to suggest that the sea must have receded the 24*m* needed to expose a land bridge between these points in the comparatively recent past.

We can see now that this reasoning may be defective in two ways. Firstly, two currently separated domains may have been moved apart by normal domain movement, so that there was never an actual ‘land bridge’ between them which has since been inundated. Secondly, specific relative movements of sealevel may have been purely local phenomena due to domain shuffling, rather than general movements of sealevel.

> *Proposition 10H*
> *Geological and biological evidence explained in the past by hypothesized land bridges may be more readily explicable through domain movements*

Again this is a proposition where the implications are already accepted in detail, if not in large. Relative rises and falls of two continents of the order of 1*cm/yr* have been calculated and accepted generally in the past. This is equivalent to a change of 1 metre in 100 years or 1*km* in 100,000 years, the period of active modern human evolution. Changes of this order through domain movements can clearly explain many observed variations in apparent sealevel.

The Salty Sea

Of the more than 200 islands larger than 10*ha* which lie off the coast of Western Australia, Rottnest is unique in possessing a salt-lake complex [Saunders, 1985]. In fact the salt-lake system dominates the eastern half of the island, and in total occupies 229*ha*, more than 10%

of Rottnest's 1900*ha*.

Most of these lakes are exceedingly salty, up to seven times as salty as seawater in the dry season, and in one area a 2*ha* saltpan dries out each year leaving thick deposits of salt. Collecting salt from the Rottnest saltpan was one of Western Australia's earliest industries, and very large quantities were taken out in the past, as much as 1016 tonnes in a single year [Somerville, 1976].

One of the mysteries of Rottnest is where all this salt comes from. It has been suggested that it is washed out of the atmosphere — surprisingly large amounts of salt are contained in rain, even that falling well inland (1000*mm* of rain deposits about 500*Kg/ha* of salt on the West Australian coastal town of Geraldton, and over 170*Kg/ha* on Coolgardie, more than 500*km* inland). Another possibility is that seawater percolates through the porous Rottnest limestone into the lakes (which are below sealevel) and there evaporates.

There is a lot of salt in seawater — on average about 3.5% is dissolved solids, of which the majority (85%) is common salt, sodium chloride. In the open seas, the proportion varies both with latitude and proximity to land and river mouths, and with depth. Where does this salt come from and was there always so much of it?

The Ancient Seas

It seems a reasonable assumption that the source of the salt is the Earth's rocks — clearly most of the solid matter on Earth originates there, and even, as we have seen, at least some of the water. This salt circulates throughout the biosphere, coming from the sea onto the lands with wind and rain and returning through the rivers and underground aquifers.

As well as this rapid turnover, there is a much longer-term cycle in which salt is deposited in beds from continuing evaporation of water, and eventually converted into rock salt. Some rock salt beds are of great thickness, up to 400*m*. Salt deposits are in the process of formation today, and have been formed in rocks of varying ages stretching back at least as far as the Permian, some 300*my* ago. Before this they are not known with certainty.

There are grounds for believing that the salinity of the ancient seas was much less than that of today. The evidence is indirect, but reasonable. One interesting item concerns the composition of blood.

When creatures evolve to suit a change in their ecological conditions, when they cross the isocons, some of their characteristics are altered to suit the new conditions. But other of their characteristics are ecologically neutral, they have neither positive nor negative influence on the creatures' prospects of survival. With no forces pushing for a change, these neutral characteristics tend to remain unaltered.

We know that life on land evolved around 400*my* ago, in the Devonian, and it is believed that it evolved from fish through amphibians and on to reptiles. The blood of higher land creatures contains an appreciable amount of salt, but much less than that in seawater, around 1% as opposed to 3.5%. On the other hand, modern marine fishes have a blood salt level similar to that of seawater.

The inference is that the salt level of the ancient seas was much less than that of today.

To put a figure on this increase, if the change was regular from 1% to 3.5% in 400*my*, this is a rate of increase of 0.006%/*my*.

> *Proposition 10I*
> *The average salinity of seawater has increased continuously for at least the last 400my*

There is other evidence for this proposition. The most ancient groups of higher land plants with living descendants are the ferns and the cycads. Both these groups avoid saline water, being almost never found as seashore plants. The same is true of lower land plants, such as the mosses. This feature is understandable if, when these plants evolved (presumably from water plants), the seas were much less saline so that there was no incentive for these plants to develop the ability to live with salt.

On the other hand, plants which are at home in saline conditions are usually specialized members of younger, modern genera, such as the pistachio nut and the date palm. Some species of the recently evolved grasses, for example *Distichlis* (Australian beach grass), will grow when irrigated with seawater, and a tomato species native to the Galapagos Islands will actually grow in the sea. The ultimate is the group of seagrasses referred to in Chapter 6, true flowering plants whose ancestors undoubtedly evolved on land before re-adapting to live entirely under the sea.

Similarly, specific adaptions to cope with a salty environment are found in sea-going representatives of what we would regard as land animals. These adaptions give the ability to excrete excess salt in some way, usually with a mechanism related to tears [Morgan, 1982]. Seabirds secrete drops of an almost pure salt solution from nasal glands, shaking the drops off to eliminate salt. Normal land lizards do not produce tears, but the marine iguana of the Galapagos, the only sea-going lizard, does. Salt-water crocodiles 'cry', freshwater ones do not. And the only two land mammals with the ability to produce tears are man — and the elephant.

The inference is that when life on land first developed, the seas contained water which was much fresher than that of the modern oceans. We can restate Proposition 10I from the viewpoint of the evolution of life:

> *Proposition 10J*
> *Land creatures first evolved, around 400my ago, from sea creatures adapted to seawater much fresher than that of today*

This proposition also fits in well with the other Earth-expansion evidence we have had in this book. As with the Earth's water (Proposition 10D), the salt available at the surface would increase as the Earth expanded and more rock was taken into the active-domain zone. But, in contrast to this water, the salt would not be partly lost into space, and so its concentration relative to the water would increase.

The fact that the oldest rock salt deposits are around 300*my* old, while the first land probably appeared around 400*my* ago (Proposition 10C), also fits. Rock salt deposits could not form until there was enough land to enclose seas or lakes, and conditions arose suitable to achieve virtually complete evaporation of these waters, such as uplifted low domains not circled by mountains (which would give rise to freshwater inflow from rains).

An interesting feature of salt deposits are that they are often associated with deposits of petroleum, mineral oils. We will return to this point, and its significance, in Chapter 13.

Another interesting question is whether the *chemical composition* of the salts dissolved in seawater was different in former ages. We will look at evidence on this point in the next chapter, which deals with the Earth's atmosphere.

CHAPTER 11

THE EARTH'S ATMOSPHERE

"There is nothing particularly scientific about excessive caution. Science thrives on daring generalizations"

— Lancelot Hogben, 1938

We have seen that both the surface of the Earth, its interior, and the oceans which cover so much of its surface have apparently been subject to dramatic changes during our long geological history. Core, lithosphere, surface, and hydrosphere have all altered out of recognition. And now we will look at evidence of even more dramatic changes in the other component of the biosphere, the Earth's atmosphere.

Composition of the Atmosphere

The present atmosphere of the Earth consists mainly of about 78% nitrogen and 21% oxygen. The biggest minor component is the inert gas argon, making up 0.93%. Components at trace level include carbon dioxide (0.035%) and the inert gases neon, helium, krypton, and xenon (all well under 0.002%).

In addition, natural air always contains a certain amount of water vapour. This is often not emphasized (or even mentioned) in giving the composition of air, because it varies strongly with the air temperature, pressure, and humidity, but it is very important.

Saturated air (100% humidity) contains about 0.4% water vapour at freezing point (0°C), more than ten times the level of carbon dioxide. At 20°C, saturated air contains about 1.7% water vapour, and at 40°C, more than 4%.

In Western Australia, air humidity will nearly always reach 100% (making dew form) if the temperature falls to freezing, but will become much lower as the thermometer rises to 40°. Even so, the amount of water vapour in our air will nearly always be over 1%, so that water is the third largest component of our air.

Considerable attention has been paid recently to the level of the fifth largest component, carbon dioxide. This is because of its importance in the 'Greenhouse Effect', which we will look at later. For the moment, we need only note that, at about one-third of one percent, it is really a minor constituent of the atmosphere.

The evidence we shall look at now indicates that this was not always the case. In the past, carbon dioxide was once a major component of the atmosphere. And in the more distant past, it did not figure at all; the Earth's atmosphere has had several complete re-workings in its history, and its present composition bears no resemblance at all to that of the primitive Earth.

> *Proposition 11A*
> *The composition of the Earth's atmosphere has changed very markedly at different times in the past, and present and early compositions are completely different.*

Composition of the Early Atmosphere

If the composition of the young Earth's atmosphere was very different, what did it consist of? It is believed that the major components were hydrogen, methane, and ammonia.

There are a number of reasons for this belief. It accords well with what is known of the atmospheres of the other planets in our solar system (we will look at this more in Chapter 15). And it does fit in also with the types of sedimentary rocks known to have been formed in the past. For example, the great iron ore deposits of the world are in ancient Pre-Cambrian rocks, and are thought to have been laid down at a time when the Earth had a reducing atmosphere — an atmosphere with very little oxygen, such that iron would not rust in it like it does in our current oxidising atmosphere.

Later we will look also at biological evidence. But first we need to look at some of the physical properties of the gases which have been present in the Earth's atmosphere at different times (Table 11).

Table 11. Gases of the Atmosphere

Gas	Formula	Molecular Weight
Hydrogen	H_2	2
Methane	CH_4	16
Ammonia	NH_3	17
Water Vapour	H_2O	18
Nitrogen	N_2	28
Oxygen	O_2	32
Argon	A	40
Carbon Dioxide	CO_2	44

The molecular weight is very important because it has a vital effect on the escape velocity of the gas.

How Gases Work

The physical properties of gases have been studied for some centuries, and are now well-known and easy to understand. Many of these properties, such as change with different temperatures and pressures, depend only on the number of gas molecules present, and not on the type of molecules or mixture of these.

Other properties depend directly on the molecular weights of the molecules. These weights are just the sums of the weights of the atoms involved, with the weight of a hydrogen atom, the lightest element, taken as 1. A hydrogen molecule contains two atoms, so its molecular weight is equal to 2.

In a gas, all the molecules are in a state of continuous movement, flying back and forth in every direction. Some are travelling fast, others more slowly — there is a continuous distribution of speeds, from very fast to stationary. If these molecules are in a closed balloon, they continually beat against the sides of the balloon, exerting a pressure which keeps the balloon extended.

If a gas is heated up, on average its molecules move faster (molecular movement is the same thing as heat, in a gas) and so exert more pressure on the sides. Similarly, if the air in a balloon is squeezed down by outside pressure, there are more gas molecules hitting against a given area of the side, and so the internal pressure rises to match the outside one.

The interesting thing is that a particular volume containing a given number of molecules of a light gas shows exactly the same internal pressure as the same volume with the same number of molecules of a heavier gas. But the *weight* of the gas depends directly on the molecular weights of the molecules involved. This is why a balloon filled with hydrogen will float; the gas in the balloon is less dense, because it contains the same number of lighter molecules. But to maintain the same internal pressure, the light molecules have to move faster, on average, than the heavy ones.

Flight into Space

The gas molecules making up the Earth's atmosphere are not in an enclosed space, but can mix freely. They beat against the Earth's surface, exerting what is called atmospheric pressure. What about straight up? Why don't they all fly straight off into space?

To be able to escape from the planet, gas molecules have to be able to climb out of the Earth's 'gravity well'. Figure 11.1 is a diagrammatic representation of this 'well' — not a real thing, just a mind model, a means of giving a graphic image of some physical laws.

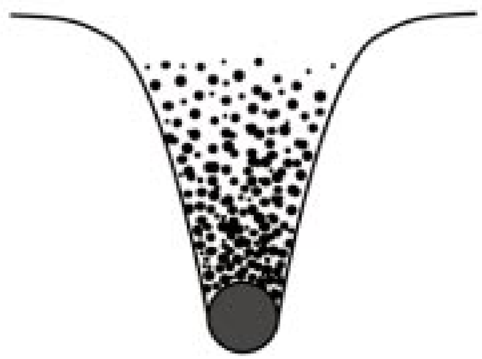

Fig. 11.1. Gas molecules in the Earth's gravity well

At the bottom of the well, on the Earth's surface, the gas molecules are thickly clustered and the air is dense. A gas molecule near the bottom which happened to be in flight straight up would most likely collide with another molecule on the way up, but the likelihood of such a collision would be less higher up where the air is thinner and there are fewer molecules around. A rising molecule which did not collide with another would gradually lose speed, as gravity pulled on it, and eventually would stop and fall back to the denser layers.

However, this mind model is called a well because it has a rim. At the rim of the well, the gravity of the Earth is exactly equal to the gravitational forces of the rest of the Universe — that is what the rim means in this image. If a gas molecule — or any other object, such as a spacecraft — is travelling upwards fast enough to be able to reach the rim before gravity saps off all its speed, it can pass the rim and go off into outer space.

Finally we come to the relevance of all this. Molecules of a lighter gas, which on average are travelling faster than those of a heavier gas, are more likely to attain this 'escape velocity' and leave the Earth forever.

Proposition 11B

Light atmospheric gases are much more likely to be lost from Earth into space than heavy gases

This is not a new Proposition, and not one disputed in any way today, but it is worth making a special point of it now, because of all its implications.

The Snow-Capped Mountains

We need to look now briefly at how air temperature and pressure alter as you go higher. Virtually all the phenomena we experience in the atmosphere, such as winds, clouds and rainfall, and pressure-related weather patterns, exist in the lower layer of the atmosphere, which is called the Troposphere. The troposphere is about 10*km* thick (more at the Equator, less at the poles), so even our highest mountains lie within it.

Within the troposphere, air temperatures fall as you go higher. There are many somewhat peculiar explanations for this to be found in textbooks, but it is really just a matter of the physics of gases — the thinner atmosphere higher up needs to be cooler to remain in equilibrium with the denser (and so warmer) layers below. If the effects of all local factors (latitude, season, special topography and so on) are taken out, the rate of fall of temperature with height works out at about 6°C/*km*. This fall is enough to allow snow to remain on the tops of high mountains in the summer, even in tropical areas.

Incidentally, this feature provides another virtually unrecognized reason for temperatures to increase as you go down mines. We looked at this in Chapter 9, where it was suggested that the observed rate of increase in the top 10*km* was around 25°C/*km*. We can see now that part of this increase, perhaps around a quarter of it, may be due purely to consequences of the physics of atmospheric gases.

> *Proposition 11C*
>
> *Part of the temperature increase observed in going down mines stems from the same basis of atmosphere gas physics as that causing a fall in temperature with increasing altitude*

Air pressure also decreases as you go higher, a direct consequence of climbing up the gravity well. As well as the more obvious results, a more subtle one comes from the fact that thinner air can 'hold' less water vapour. So there is a double reason for rain or snow to fall on mountains, because the temperatures are lower, and the pressures less.

Another apparently trivial consequence comes from the fact that water boils at a lower temperature under reduced temperatures. Because of this, it is not possible to hard-boil an egg in an open saucepan on the top of Mount Everest — the water boils below the temperature needed for the biochemical and physical processes involved in hardening the egg. We will return to this trivial point when we consider the fate of the dinosaurs, in Chapter 12.

The Great Reworkings

Apart from the fact that the early Earth's atmosphere probably contained little or no oxygen, but probably held a lot of methane and ammonia, very little is generally agreed concerning the history of our atmosphere. In what follows I will suggest a series of events which lend a much higher degree of detail to what happened.

The boundaries between the great geological eras, Pre-Cambrian, Paleozoic, Mesozoic, and Cenozoic, may have been assigned intuitively. But it seems that these boundaries have a physical basis too; they appear to be times of marked change in the atmosphere. In these changes, the role of carbon and its compounds appears to have been a crucial one.

This is not just a physical role. Carbon compounds are the basis of all life on Earth. While physical factors did have an influence, it appears that living organisms were the principal agents in achieving the Great Reworkings of our atmosphere.

The Role of Carbon

The great coal deposits of this planet were laid down in the Carboniferous and Permian periods which ended the Paleozoic. Coal is, of course, mostly carbon, and gave its name to the Carboniferous. Where did the carbon come from? The only credible major source is the atmosphere, presumably by conversion from gaseous hydrocarbons (compounds of carbon and hydrogen, especially methane) or possibly from free carbon dioxide.

The massive deposits of high-carbon rocks laid down at the end of the Paleozoic therefore imply a major change in the atmosphere at that time.

The period ending the Mesozoic era, the Cretaceous, was also apparently a time of major atmospheric change. Cretaceous means 'chalky', and chalk and limestone are forms of calcium carbonate, a compound of carbon, oxygen, and calcium. Again, the only credible ultimate source of the carbon is the atmosphere, in this case almost certainly from conversion of carbon dioxide.

The massive deposits of carbonate rock laid down at the end of the Mesozoic era imply a second major change in the atmosphere, involving a massive withdrawal of carbon dioxide from the atmosphere.

The size of the changes involved make them ones of kind, rather than degree. At the present day, estimates are that the ratio of carbon in rock deposits to that in the atmosphere is more than 90,000 to 1 [Beckmann, 1988], so the amount of carbon left in the atmosphere is very small, only one-hundredth of one percent of the whole. Almost everything that once was in the atmosphere has since been incorporated in the rocks.

Of course, both the coal deposits laid down in the Paleozoic and much of the carbonate deposits of the Mesozoic were formed through the action of living things. Most of the coal came from the giant plants of the Carboniferous swamps, and much of the carbonates from the shells of sea creatures, especially corals and molluscs.

The Primeval Earth's Atmosphere

It has been widely assumed that as part of its formation processes, the Earth inherited a primeval atmosphere consisting mostly of hydrogen, hydrocarbons such as methane, and ammonia. This is reasonable enough.

Hydrogen is the most common element in the Universe, and the hydrocarbons are a credible source for the carbon which exists in the biosphere. The ammonia would be the source of the nitrogen in our air. Both carbon and nitrogen are normal products from the nuclear conversion processes which go in stars, and we would expect them to combine with the abundant hydrogen. We will have further evidence in support of this when we look at the atmospheres of other planets, in Chapter 15.

Another common stellar conversion product is oxygen, the most abundant element on Earth. There would also be quite a lot of this, but it would combine immediately with hydrogen to form water. Whether this water would be liquid or vapour would depend on the conditions of heat and pressure on the early Earth.

It is assumed almost as being self-evident that the Earth was originally completely molten. There is, however, little real evidence for this assumption, and it may be that the primeval Earth was never in a particularly hot condition.

> *Proposition 11D*
> *The primeval Earth was never molten or at a particularly high temperature*

This Proposition appears never to have been examined in any detail, and whether it is true or not, we do not currently have enough evidence to say whether the Earth's initial water was liquid or gaseous. But it must have become liquid fairly early on, because water-deposited sedimentary rocks exist far back into the Precambrian.

We have also seen (Chapter 1) that abundant life on Earth did not appear until the start of the Cambrian, about 600*my* ago. However, primitive life existed considerably earlier, as far back as 3500*my* ago, through the vast reaches of the Precambrian. What was the nature of this primitive life, and how did it differ from that of today?

Again this is a question on which we have very little evidence, but there is one point of importance. It seems likely that these primitive life-forms lived without free oxygen, and were the forerunners of creatures such as the anaerobic bacteria of today, active in relatively minor oxygen-free environments such as the bottoms of swamps.

How the Precambrian Ended

We also have very little knowledge of the biochemical processes of these primitive organisms, but it seems possible that they were the motors which drove the conversion of the primitive atmosphere. All the higher forms of life which first appeared in the Cambrian were oxygen-breathers. Those which preceded them were probably not, instead they were lifeforms for which oxygen was a waste product. And in producing this waste product over a period of not thousands or millions of years, but extending to perhaps three billion years, two-thirds of the age of the Earth, they made the oxygen we breathe now.

At first all the oxygen they made would be chemically reacted with free hydrogen or the hydrocarbons, but eventually they would have used all this up. And this is the crucial point, the sharp division which marks the boundary between the Precambrian and the Cambrian is probably the time when free oxygen first became common in the Earth's atmosphere. It was this development which permitted the evolution of the oxygen-breathing life which predominates on the Earth today, it was the passing of this threshold which led to the surge in evolution at the start of the Paleozoic.

> *Proposition 11E*
> *The Precambrian-Cambrian boundary marks the time when free oxygen first became common in the atmosphere and permitted the development of oxygen-breathing life*

This was a massive change in the basic nature of the atmosphere. There may also have been changes in the seas as a reaction to this. In particular, the substances dissolved in seawater may have somewhat different.

There are some biochemical differences in lower forms of life which could be traced back to this time, such as the notable percentage of copper in the blood of cuttlefishes, a very ancient line of sea creatures. In more modern creatures this metal is usually replaced by iron. But the most notable change was the one in the shells of shellfish.

The sea creatures of the early Cambrian which possessed shells, skeletons, or other stiffening apparently mostly made this stiffening either out of silica or or calcium phosphate. More modern sea creatures normally use calcium carbonate. In one group of shellfish, the mollusc-like brachiopods, once very common but now rare, a change-over can be traced within the group. Brachiopods which developed at the start of the Cambrian have calcium phosphate shells, but those which had evolved by the end of it have calcium carbonate ones [Rhodes, 1960].

Perhaps not too much should be made of these differences. However, the seas and the substances dissolved within them have to exist in equilibrium with the atmosphere above, and if this changes in composition, we may expect the seas to be affected also.

> *Proposition 11F*
> *With the development of free oxygen in the air above the seas, changes occurred in the composition of substances dissolved in them*

The Paleozoic-Mesozoic Boundary

We have had evidence that the beginning of the Paleozoic was marked by the first significant amount of free oxygen in the Earth's atmosphere and by the appearance of oxygen-breathing life. Now we can look at what happened during the rest of the Paleozoic.

Of the 'primeval' atmospheric gases — hydrogen, methane, and ammonia — the first would have disappeared completely by the start of the Paleozoic, either completed reacted with the newly formed oxygen to give water, or evaporated off into space. It is likely that the last two would also have undergone transformation during the Paleozoic, the ammonia to form nitrogen and water, and the methane to give carbon dioxide and water. The chemical reactions involved can be easily worked out from Table 11, by adding oxygen to the original gases.

> *Proposition 11G*
> *Atmospheric ammonia was converted to nitrogen, and methane to carbon dioxide, during the course of the Paleozoic*

There are a few riders to add to this simple statement. The process suggested was unlikely to be sudden, and need not have been complete. There could still have been significant amounts of ammonia and methane left in the atmosphere at the end of the Paleozoic, but the proposal is that they were no longer major components.

In addition, as already noted, significant amounts of carbon had been taken out of the atmosphere by the end of the Paleozoic to form deposits of coal (and some oil). The only obvious source of this carbon was that in the atmosphere. Whether this carbon was in the form of the original methane or its conversion product, carbon dioxide, is not certain, but it is likely to have been the latter.

Although the question has probably never been examined in detail, it seems reasonable to assume that the plants which developed on land during the Devonian, Carboniferous, and Permian were at least similar enough to modern ones to be chlorophyll-based. This implies that they gained their energy and substance by photosynthesizing carbohydrates from carbon dioxide, water, and sunlight.

At the same time as the methane was being converted to carbon dioxide, it seems likely that the ammonia was being converted to nitrogen. Apart from the direct changes, there may have been an important indirect effect. Ammonia is alkaline, it dissolves easily in water to form a weak base. Carbon dioxide dissolves in water to form a weak acid, carbonic acid. The implication is that during the course of the atmospheric conversion, the seas changed their state from being weakly alkaline to weakly acid.

Proposition 11H

The Paleozoic-Mesozoic boundary was marked by the disappearance of methane and ammonia as major atmospheric components, and the appearance of carbon dioxide and nitrogen in their place

Proposition 11I

Atmospheric changes at the Paleozoic-Mesozoic boundary caused a switch in the state of the seas from being weakly alkaline to weakly acidic

These propositions are supported by observations from the plant world. The lower plants, such as the mosses, often prefer alkaline conditions, and for example can be seen growing on old lime mortar. Moulds grow on shower walls because of the alkaline conditions set up by the regular use of soap. However, higher plants have adapted, and can tolerate a wide range of acid, alkaline, and neutral conditions.

Modern Times: The Mesozoic-Cenozoic Boundary

The Mesozoic was the time of strongest development of life on land. It ended with the death of the dinosaurs and other marked changes in land life. Only with the onset of the Cenozoic do we begin to recognize all the plants and animals as relatives of those we know today.

It appears that the atmosphere of the Mesozoic was similar to that of today, with one notable exception. As well as the major components of nitrogen and oxygen, it had a third major component, carbon dioxide.

According to Chambers Encyclopaedia [Carbon, 1970], the relative amounts of carbon in different forms on the Earth are as follows (measured in million million tonnes):

Limestone etc. rocks	23,100
Dissolved in sea	22
As coal, oil etc	6.6
In atmosphere	0.68
In living plants, timber etc.	0.009

These figures are somewhat different from those in Beckmann [1988], who shows rather higher figures for almost all areas except the atmosphere itself (0.58 in 1860, 0.75 now), but the point is very obvious. Hardly any of the Earth's carbon is still left in the atmosphere, it has almost all been withdrawn and deposited in the rocks.

Since we know that a massive part of this withdrawal took place in the Mesozoic, especially in the Cretaceous (the Time of Chalk — calcium carbonate), it seems almost obvious that the boundary between the Mesozoic and the Cenozoic is the time by which carbon dioxide had ceased to form a significant part of the atmosphere.

Proposition 11J

The Mezozoic-Cenozoic boundary marks the time at which carbon dioxide levels in the atmosphere had fallen to trace levels

We will return to this point, also, when we consider the Greenhouse Effect in Chapter 17. For the moment we will just comment that this proposition is supported by the fact that modern plants have evolved to be carbon-dioxide hungry; they have produced mechanisms to chase after really quite tiny amounts in the air.

Many commercially-grown vegetables greatly improve their growth in a carbon-dioxide enriched atmosphere, up to five times the normal level (0.15% instead of 0.03%). But at even higher levels, around 0.5%, the carbon dioxide actually seems to become toxic [Beckmann, 1988]. It would be an interesting exercise, and a test of Proposition 11J, to see if the more ancient plant groups (such as the cycads and ferns) could tolerate a much higher carbon dioxide level.

The Pressure of Earth's Atmosphere

We have seen that there may have been some fundamental upheavals in the composition of the Earth's atmosphere in the past. Now we look at another aspect of the atmosphere: its pressure.

The pressure of the air on the Earth's surface is principally governed by two things — the mass of the atmosphere (how much there is of it) and the forces due to gravity. Once more we will find that the conditions of today are very different to what they may have been in the past.

One of the main factors here is, once more, the carbon dioxide. Working from Beckmann's figures, if all the carbon which he estimates is present in the rocks were in the atmosphere as carbon dioxide instead, this carbon dioxide would weigh some 35 times as much as the whole of the present atmosphere. In other words, if everything else was the same except this carbon was in the air instead of the rocks, we would be living under a pressure of 36 atmospheres.

This might seem incredible, but surprisingly enough, it fits in very well. In Chapter 15 we will see that on Venus, where the atmosphere is mostly carbon dioxide, its pressure at the surface is around 100 atmospheres. And there are several plausible reasons to account for the difference which does exist — we will look at these, too, later.

The conclusion seems inevitable that atmospheric pressures were very much higher in the Earth's past than they are now.

> *Proposition 11K*
> *Atmospheric pressures were very much higher on Earth in the past, because carbon now present in the rocks was formerly present in the air as atmospheric gases*

When we come to consider the effects of Earth expansion, we find that this jump is further compounded. A half-radius Earth would have a quarter of the surface area for the same amount of gas to press on, and so under otherwise equal conditions would have four times the atmospheric pressure, around 144 atmospheres.

> *Proposition 11L*
> *Atmospheric pressures were also higher in the past because the same amount of atmosphere was present on a much smaller Earth*

This calculation is obviously only a very first stab at giving a figure to the pressure. If we want to try and put a little more detail into the resulting figures, we need to take into account the period in the past when the carbon was taken out of the air, and its form in that air.

I have already suggested that at the beginning of the Paleozoic, some 600*my* ago, the carbon was in the form of methane. Methane has a molecular weight of 16 (Table 11), while carbon dioxide is the heaviest of the gases listed, with a molecular weight of 44. The ratio of weights is 2.75, and since the mass of the atmosphere and hence its pressure on the surface is directly dependent on the weights of its molecules, we would need to divide the above figure of 144 by this ratio. The result, for a methane atmosphere, is around 52 atmospheres.

More Cooking the Books

There are a number of other factors to take into account to try and derive more accurate figures. This is all new ground to break, and here I will just list some of these factors.

1. Figures for the amount of carbon in the Earth's crust are only estimates, and could be well out. For example, the figures in Beckmann [1988] are around twice those in Carbon

[1970].

2. Almost all the carbon in rocks has been deposited since the start of the Paleozoic.

3. If methane was being converted to carbon dioxide during the Paleozoic, this would increase the atmospheric mass and pressure.

4. Decrease in pressure due to Earth expansion and hence greater surface area would depend on the actual expansion experienced. For example, an Earth of half the present radius may not have been achieved till around 400my ago, while carbon deposition may have started 600my ago.

5. Substances later converted into atmospheric gases are likely to have been released from the Earth's interior as more surface was exposed, as with the Earth's water (Proposition 10D). These could include carbon dioxide.

6. A considerable amount of atmosphere is almost certain to have been lost into space in the past.

Factor 6 is a most important one, which we will look at again in Chapter 15.

The Pea-Soup Scenario

We have now arrived at a set of scenarios for the Earth's earlier atmospheres which differ fundamentally from any proposed elsewhere which I have been able to find. The conventional view is that while the primeval atmosphere contained carbon dioxide and ammonia, these were converted to give an air composition close to that of the present Earth within a few million years after life evolved [Cramer, 1988].

The scenarios I have presented depict atmospheres of very different composition, in particular of ones containing huge amounts of carbon dioxide compared to today. They are atmospheres of much higher pressures. And they may be ones of very different temperatures.

The higher pressures and temperatures lead to an important consequence which could make the scenarios even more extreme. Air at higher temperatures can hold a lot more water. For example, we have already seen that the amount of water the air can hold increases by a factor of 10 on going from 0°C to 40°. At a higher extreme, on reaching 100°C , water evaporates completely under normal pressure, and in theory at least the atmosphere could consist mostly of water vapour at this point.

Similarly, the temperature at which water condenses from steam (same as boiling point) increases markedly with higher pressures. At two atmospheres, it is up to 121°C, and at 12*atm* it has reached 190°. When the pressure of the air is reduced, as when it rises up to the clouds, it can hold less water and this condenses out as clouds or rain.

At this stage it is very hard to put even tentative figures to the water-vapour content of the Earth's earlier atmospheres, because so much is unknown. But it does seem quite likely that the air contained a great deal more water than it does now.

> *Proposition 11M*
> *The amount of water vapour held in the Earth's atmosphere during Paleozoic and Mesozoic times was much greater than now.*

As it would be present in gaseous form, this water would itself increase the atmospheric pressure. Water vapour is one of the lighter atmospheric gases (molecular weight 18), but if even 1% of the Earth's present water was moved into the atmosphere, it would more than triple the atmospheric pressure. Whether such movements in the past have significantly affected sealevels is too hard to work out at the moment, but it is a possibility worth raising.

We end up with scenarios in which the atmosphere is close to pea soup — very thick, very moist, very rich in 'Greenhouse Effect' gases. There is another consequence. It may have been perpetually cloudy. The creatures of the Cenozoic, those we start to regard as 'modern', may have been the first on Earth to see the stars.

> *Proposition 11N*
> *The Earth was completely shrouded in clouds at all times during the Paleozoic and the Mesozoic*

This Proposition is supported by evidence from Venus — a planet with a high-pressure, carbon-dioxide rich atmosphere, and one perpetually shrouded in clouds. There is also a further implication, relating to nitrogen fixation by thunderstorms.

Thunderbolts of Life

One of the beneficial effects of thunderstorms which is often overlooked is that they fix atmospheric nitrogen into a form which can be used directly by plants. Passage of high-energy thunderbolts through the mixture of nitrogen and oxygen in the air converts some of this to nitrogen oxides, which easily dissolve in water and react to give nitrates, directly usable by plants for food (so-called 'nitrogen-fixing' plants are actually symbiotic associates with micro-organisms which do the actual fixing).

Nitrates are a relatively scarce resource for wild plants, and thunderstorms provide quite a significant amount of their needs. In fact they must provide almost all that is not recycled from decaying organisms, either in the same spot or brought in as atmospheric nitrogen gases or dissolved in water. Since it is possible to grow a dense forest containing a lot of nitrogen fixed in its substance from an open field with very little, the nitrogen-transfer activities discussed must be quite significant.

Nitrate fixation through thunderbolts requires a nitrogen-oxygen atmosphere and clouds separated from the planet's surface by a layer of low-conductance air (to allow the build up of an electric-charge potential difference). One or both of these conditions may have been lacking in past eras, so the modern thunderbolt nitrogen-fixing mechanism may have been inoperative.

> *Proposition 11O*
> *Conditions necessary for atmospheric nitrogen fixing by thunderbolts were not always present in past eras*

Naturally such a situation would have its effects on plant life. In earlier times, there may have been other nitrogen sources — we have seen that free ammonia may have been much more plentiful in the past. Modern plants are notably 'nitrogen-hungry', especially in our most highly-evolved areas, the tropical rainforests. That is why some of these plants, in the intensely competitive environment, have developed carnivorous habits — animals are a rich and mobile source of nitrogen.

Flying Creatures of the Past

There is further indirect evidence of a formerly much denser atmosphere, from the Earth's flying creatures. The maximum wingspan of the largest modern flying creature, the albatross, is about 3.5 metres. Creatures tend to evolve to the limits of what is physically possible, and it is unlikely that any modern bird with a wingspan much above 4 metres could survive.

However, fossil examples of flying creatures from the Cretaceous, such as the giant pterosaur *Quetzlcoatalus alcotaius*, are known with wingspans of over 12*m* [Cramer, 1988], three times this 'theoretical limit'! Similarly, fossil dragonflies have been found with much bigger wingspans than any modern flying insect. Obviously, as the atmosphere thickens, 'flying' moves towards 'swimming', and much bigger wingspans will be feasible at higher atmospheric pressures.

The giant extinct dinosaurs, such as Brontosaurus, were much bigger than any modern land creature, in fact probably bigger than any modern land creature could be (and still move). It has been suggested that creatures like Brontosaurus lived mostly in the water. Could it be that they actually lived on land, but in a much denser and more buoyant atmosphere?

Plants in a Denser Atmosphere

The physical structures of the ancient plants also suggest that they lived in atmospheres much denser than those applying today. The huge trees of Coal Measure times were apparently buoyed up by the dense air, since their cells were large water-filled sacs with comparatively thin walls [Rhodes, 1960], lacking the strength to stand up under today's conditions.

The modern survivors of the most ancient plants, such as the mosses, the ferns, and the cycads, are noted for their affinity for very moist conditions. One of the more primitive of the modern cycads, a *Zamia* species from the West Indies, actually has sperm which swim in water instead of the immobile pollen of modern plants. The high atmospheric density suggested also fits in well with the mild climatic conditions deduced for earlier times, with no strong winds.

It has often been remarked that the occurrence of the same fossils world-wide in rocks of the Paleozoic and Mesozoic means that conditions must have been much more uniform over the whole world then than they are now. This is true even if it is supposed that, say, fossils now found in the Arctic might have been moved up from warmer areas of origin by domain shifts, because there is no evidence of differing 'cold-weather' and 'warm-weather' fossils for those times, in contrast to modern flora and fauna.

Much more uniform conditions are what would be expected from much denser, moister atmospheres, with higher heat capacities. Temperatures at seaports are much less extreme than those in inland cities, because of the moderating influence of the sea, which is due to its high heat capacity. It would be useful to test whether ancient plants such as the cycads would fare better in much denser atmospheres than modern plants.

All this is positive, but indirect evidence. Wouldn't it be nice if there were direct evidence? And there is.

Truth Frozen in Amber

In an article entitled 'Dinosaur Breath', John Cramer [1988] reported on work done by Richard Kerr on the analysis of tiny air bubbles trapped in amber, and the suggested implications of this work. The amber, fossilized resin from extinct species of *Pinus*, those ancient nut trees, contains tiny air inclusions which Kerr analysed with a mass spectrometer, an instrument which accurately counts the proportion of different atoms in even very tiny samples.

Kerr found that the proportion of oxygen atoms in Cretaceous-amber bubbles 80*my* old was much higher than that in modern air, averaging around 30%. On the other hand, the amount of oxygen in bubbles from 40*my*-old Cenozoic samples was similar to that in modern air (about 21%).

The conclusion drawn from this was that the Cretaceous air was much richer in oxygen than that of today. Cramer also raises the question of how such large creatures were able to fly during the Cretaceous, and the suggestion given is that the dinosaurs' metabolisms were 'supercharged' by all the extra oxygen, enabling them to overcome the theoretical barriers to flight.

This may be an interesting example of drawing a wrong conclusion from correct data. The point is, that Kerr's technique only counts the number of oxygen atoms, not their chemical state. This excess oxygen could just as well be present as carbon dioxide, which would support the Propositions I have given above. This matter can be tested directly, by re-running analyses to see if carbon from carbon dioxide is present as well.

An even more telling point is mentioned in passing by Cramer. In many cases, the pressure inside the bubbles trapped in the amber was as high as 10 atmospheres. This was attributed to 'the geological forces that converted the pitch to amber'. Is it not more likely that the air trapped in the bubbles was already at a higher pressure? William of Occam would say yes!

CHAPTER 12

DEATH OF THE DINOSAURS

"Dinosaurs: the remains point to an organism resembling in some respects that of birds, in others that of mammals"
— Oxford English Dictionary

Everybody else seems to have had a stab at suggesting why the dinosaurs died out, so I don't mean to be left out. In fact, I will make not one suggestion, but three.

Suggestions already made cover a huge range, from simplistic to erudite, from common-sense to comedy. The dinosaurs died out because the Earth got too hot, or too cold, or too much radiation (frizzling them up) or too little (not enough mutations occurring to let them adapt). The climate became too wet, or too dry. Their food was eaten by the newly-evolved caterpillars of butterflies and moths, or their eggs were eaten by the cunning small mammals. The Earth was bombarded by meteorites or passed through the tail of a comet, with many dire effects. The list goes on and on — parasites, diseases, slipped discs, shrinking brains, over-specialization, racial old age, sunspots — even boredom!

One of the more recent theories is based on the discovery that a fine layer of material rich in the rare metal iridium is found close to the Cretaceous-Paleocene boundary in many locations scattered about the world. A layer of finely-divided carbon is also found at the same boundary. It is accepted that the creatures referred to as dinosaurs also disappeared at this time, which marks the change from the second (Mesozoic) to the third and current (Cenozoic) great period of life, some 70*my* ago.

The suggestion is that a huge chondritic meteor collided with the Earth at this time, that this meteor was rich in iridium which was scattered throughout the atmosphere in a very dense dust-storm, bringing on a sort of 'nuclear winter' which was connected with the extinction of the dinosaurs [Cramer, 1988]. Cramer also adds the suggestion that the carbon layer is soot from an immense world-wide fire which was promoted by the high oxygen levels he hypothesizes to exist in the Cretaceous.

No theory put forward to date has received anything approaching general acceptance. I will put forward three more. The first one is really only an extension of an existing theory, while the second and third may be new.

The No-Disappearance Theory

The first theory is that the dinosaurs didn't die out. This is not a novel suggestion, but is one which has gained increasing support in recent years. The old idea of dinosaurs as just big lizards, typical reptiles, is falling into disrepute in the light of new discoveries and research.

The first nail in the coffin of the older theories was when it was realised that many of the dinosaurs were 'warm-blooded' (that is, maintained a relatively constant body temperature), like modern mammals [Ostrom, 1978]. They had to be warm-blooded to maintain levels of activity which were clearly much above those thermodynamically possible for a 'coldblooded' reptile. A clear example is of the flying dinosaurs, such as the pterodactyls. No modern reptile can fly, presumably because this mode of travel is not possible with sluggish reptile metabolism — but see the comment which appears towards the end of the last chapter.

In addition, it is believed that at least some of the pterodactyls were covered in fur, again a feature not found in any known modern reptile. The icthyosaurs, huge marine dinosaurs, apparently bore live young— they were not egg-layers [Stanley, 1987]. In fact, on close examination it gets harder and harder to find features which clearly distinguish the dinosaurs, or at least some of the later ones, from modern warm-blooded animals — birds and mammals.

One suggestion, in fact, has been that modern birds are the current dinosaurs, so that dinosaurs are not extinct at all, only their older forms are gone. The situation gets even more interesting when one looks at the most primitive mammals, the monotremes of Australia. There are only two animals in this ancient group, the Echidnas and the Duckbilled Platypus.

This platypus has a combination of features so bizarre as to make it understandable that the first specimens brought to Europe were widely assumed to be hoaxes, stitched together from different animals. The duck bill and webbed feet, coupled with fur, were very striking at the first encounter. Then it was found that the platypus lays eggs, and has a single passage for both excretion and copulation, just like birds. And, although a mammal, it does not have teats for the milk, this just oozes out through a network of pores.

Later came the discovery that males have poison glands, unlike all other mammals and birds. Recently it has been demonstrated that the platypus has an electrical detection system, like that of some fishes. But a more subtle and very recent discovery concerns body temperatures of the platypus and the other primitive monotreme, the echidna. These creatures do not maintain typical mammalian constancy of body temperature, instead they vary dramatically by some 10°C. A variation of this size could be enough to kill one of the higher mammals.

What it comes down to, is that there are no obvious fundamental differences between some dinosaurs, some ancient mammals like the platypus, and some modern birds like penguins. The inference is that there is no difference; the dinosaurs were just early forms of modern mammals and birds. The only point that remains, and is undisputed, is that all the big ones disappeared towards the end of the Mesozoic.

> *Proposition 12A*
>
> *Dinosaurs as a class are not extinct, they were only early forms of modern birds and mammals. Mass extinction was limited to larger forms of these classes*

The Great Extinction — Which One?

If Proposition 12A is true, this still leaves the matter of explaining why all the bigger animals became extinct towards the end of the Mesozoic. It appears that all animals with a mass of over around 40*kg* were affected. Plants were not involved in any mass changes, although of course they continued to evolve. The large marine animals, such as the ichthyosaurs, did disappear — modern marine giants like the whales are believed to have developed from land-based ancestors during the Cenozoic.

To put some background in place for another proposition, we should look at another great extinction, one which is taking place today. This is one directly due to the activities of man.

Dramatic extinctions of species by man, such as that of the dodo, the large flightless bird of Mauritius, are a well-known cause of public concern. But behind these dramatic cases stands a huge, all-pervading influence on all species of life on Earth which stretches back well beyond modern man, well beyond civilization, to the beginnings of man.

This realization is comparatively recent, but evidence and suggestions supporting this trend are coming in thick and fast. Huge changes wrought directly and indirectly by man have affected this planet to an extent far exceeding those due to effects such as major climate shifts. In fact it appears that the influence of man on the isocons, those envelopes which define ecological niches, is now greater than that of any 'natural' factors.

Historical changes such as the conversion of the middle eastern 'Fertile Crescent' of the Bible into desert, and the degradation of the great grain fields of Carthage into useless arid lands in North Africa are well documented. But there is far more.

Figure 12.1 (taken from [Axelrod, 1967]) shows recorded evidence of the past distribution of the elephant in North Africa. Clearly the elephant was once native over the whole of this huge area, right up to the shores of the Mediterranean. There is no way that the elephant could survive in large numbers under present Saharan conditions, and the inescapable conclusion is that these conditions have changes dramatically since the time when the elephant ranged freely over this huge area.

Was it way back in the distant past when these conditions were found? No, it was only yesterday, in the scale we are used to. Almost all the elephant records referred to are less than 10,000 years old, and some are as young as 4000 years, within the time of known civilizations and cities.

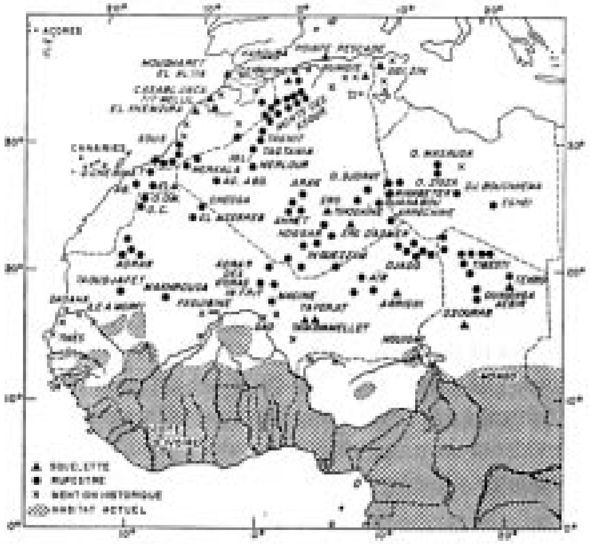

Fig. 12.1. Records of past distribution of the Elephant in North Africa

Around the Earth, extinctions of large animals of every sort have taken place under circumstances which show an increasing correlation with the development of mankind. We can reckon that man, as an evolved and intelligent thinker, has been active on Earth for around 100,000 years, with the emergence of what we can regard as the beginnings of civilizations going back more than 12,000 years. It is within these spans that the use of fire has been harnessed, and far-reaching changes have overtaken the Earth.

In North America, this period has seen the disappearance of a host of large animals. These included mastodons (types of mammoth), giant ground sloths, camels, giant armadillos, sabretooths, llamas, and glyptodons, all of genera now extinct [Axelrod, 1967]. Some genera became extinct in North America but survived elsewhere, such as the horse and the yak (still found in Asia) and the capybara and speckled bear (still alive in South America).

Europe saw the disappearance of the mammoth and the elephant, the hippopotamus, the rhinoceros, and many large species of horse, bear, ox, and deer. South America lost many large animals, including the giant ground sloth, which stood up to 6*m* tall. Africa apparently suffered least from these extinctions, and so has the most survivors — including the gorilla and the chimpanzee.

Australia was perhaps the heaviest sufferer of all [Stuart, 1986]. It once had several species of giant kangaroos, a wombat relative as big as a rhinoceros, and a massive creature, the procoptodon, which stood up to 2.6*m* tall. It has been estimated that within the last 100,000 years, Africa lost 5% of its large mammals, Europe 30%, North America 73%, South America 80%, and Australia 94%. The classification of 'large' means creatures weighing over about 40*kg*.

Not all these extinctions took place at the same time. However, in North and South America, many were quite tightly clustered around 11,000 years ago. In Europe, the time was the same, but the extinctions were more spread out. And in Australia, the main peak was much earlier, around 30,000 years ago [Stanley, 1987]. In all these cases, man is becoming more and more implicated in the extinctions.

> *Proposition 12B*
> *Extinctions of creatures weighing over about 40kg in the last 100,000 years were mostly due to the activities of man*

The earlier age of the Australian extinctions has caused some concerns in tying in with the accepted time of settlement of the country by aboriginals. Until recently, the oldest human relics known, dated to about 40,000 years ago, were a set of 900 stone artefacts found on the banks of the Upper Swan near Perth. However, much earlier remains have now been found near Lake Eyre [Maslen, 1989] which push this date back to as much as 80,000 years ago. Australia has never been subjected to intense archeological scrutiny, and there may be ample evidence awaiting discovery which would indicate a much more active role for man in the country's history than has previously been supposed.

The Relentless Invasion

No doubt many of the extinctions were directly caused by man, as a result of hunting. This is particularly true for larger animals, which are attractive objects for hunters in that a big haul is obtained from a single kill. Twentieth-century man is not usually regarded as a hunter any more, but he still is. In the last few hundred years alone, advances in technology have let him invade a whole new realm, and bring many species of whale to the verge of extinction.

The direct actions of hunting large animals have produced major changes. But many much more significant effects have occurred through indirect actions.

The clearing of forested land for agriculture is an activity for which public acceptance has completely somersaulted, and this in as short a period as the last three decades. It is now accepted more and more widely that the loss of tree cover to create cropping and grazing lands is the root cause of a range of social and economic ills, directly including soil erosion by water and wind, salt build-up, and declining soil fertility. These problems lead indirectly to phenomena such as floods and famines which, while they can be combatted with modern science, are so much more expensive than the natural ecosystems which have been replaced as to be economically unthinkable in less developed economies.

The question of man's responsibility for the environment is regarded, quite justly, as one of the leading philosophical and ethical issues of the day. But, as I have suggested earlier [Noël, 1985b], it is much more than that, it is an economic topic too.

The ratio of food-raising efficiencies between a well-integrated tree-crop based ecology and one based on extended cattle ranging is astounding; the former is some ten thousand times more efficient. That is why countries with extensive tree-based industries, such as the Philippines and Indonesia, are virtually proof against famines, while in places such as Ethiopia, with the tree cover reduced from the original 80% down to less than 10%, there is a constant danger of this scourge.

> *Proposition 12C*
> *Countries with economies having extensive integrated tree-based industries enjoy much more stable economic and environmental conditions than those without*

Involuntarily through the use of fire, and purposely for use in agriculture and to extract natural products, man has been clearing the forests and scrub throughout his history. This, more than anything else, has been responsible for vast changes in the environment, for immense changes to the isocons. These changes extend wherever man has laid his hand. The vast central plains of North America which are the habitat of bison may have been promoted, at least in part, by the activities of the early American Indians.

In Australia it has been suggested that the whole nature of the landscape has changed since the arrival of the Aboriginals. It may be that our sweeping plains and arid deserts were actually created by the actions of the aboriginals from scrub and forest, largely through the use of fire. Many studies show that regular burning-off changes the whole ecology of forested sites, tending to move them over to grasslands.

Naturally enough, these man-made alterations in the isocons have caused great changes to all life-forms. We tend to think of the rest of nature as relatively static, until we are confronted with evidence such as that of the great extinctions. There is only one species of gorilla today, with three sub-species. How many were there a million years ago, when man was in early evolution? We assume the same, but there may have been twenty species then — such is the rate of change.

We know that there have been major and involuntary changes in man himself, over periods of only a few hundred years — few modern Europeans are small enough to fit into an average medieval suit of armour. When the changes are intended, as with breeding races of dogs or wheat, the pace is even more rapid. And when the environment is drastically altered, whether by act of man or by some 'natural' cause, it is inevitable that animal and plant species in that environment will also alter drastically, or else die out. All those plant species marvellously adapted to the deserts may only be as old as man's influence in creating those deserts.

> *Proposition 12D*
> *Man's actions over the last 100,000 years have caused major changes in the composition of animal and plant species*

The Civilized Dinosaurs

Back now to the dinosaurs, and the relevance of what has just been put forward to this. We are accustomed to regard the dinosaurs as generally being large and stupid, or at least as having brains very small in relation to their size. In many cases this generalization may hold. We are interested here in the exceptions (Fig. 12.2).

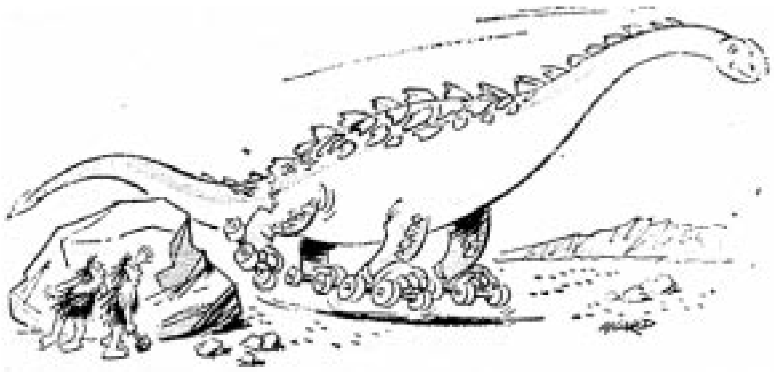

Fig. 12.2. "Are you sure their brains are only the size of peas?"
[Charig, 1979]

Sometime towards the end of the Cretaceous a new family of dinosaurs developed. These are commonly called the Ostrich Dinosaurs or Ornithomimids, and they are represented by eight known species of *Ornithomimus*. This is roughly the same as the current number of anthropoid apes — man, gorilla, chimpanzee, orangutan, and four or five species of gibbon.

The Ornithomimids were very definitely exceptions to the general stupid-dinosaur rule, just as the anthropoid apes can be regarded as exceptions to a rule of general stupidity in mammals, based on observations of species of rats and rabbits. They were also exceptional in their physical form; they were bipeds, with large brains, large eyes, and long, strong fingers.

The suggestion is irresistible that one of these species of *Ornithomimus* made the not very great leap into an intelligence level sufficient to support civilization. The time available was quite sufficient for this — recent evidence based on DNA analyses, for example, suggests that of all the anthropoid apes, man is closest to the chimpanzee, and the two species evolved from a common ancestor over just 5*my* [Phillips, 1989]. The Ornithomimids were around a good deal longer than this.

We have seen all the evidence that 'civilization' has led to the extinction of larger animals, over about 40*kg*, in the case of man. What more natural than that the same extinction, of animals over about 40*kg*, should occur in the case of civilized Ornithomimids? And since our own civilization has teetered on the brink of world mutually-assured destruction through the agency of nuclear bombs, could there be a more dire warning than in the Ostrich Dinosaurs' development and use of the Iridium Bomb to wipe themselves out after they had finished off the others?

> *Proposition 12E*
> *At the end of the Cretaceous, a species of Ornithomimid developed intelligence and civilization, caused the mass extinction of large animals associated with this, then wiped itself out in a nuclear war*

Death by Thermodynamics

As with any dinosaur theory, objections can be raised to the Iridium Bomb suggestion just made. Some can be countered quite easily, for example, if a previous civilization existed, where are its remains? We need only point to the very scanty evidence of our own evolution in the last million years to excuse the lack of Ornithomimid relics from 70*my* ago. As for their buildings, remember the fine layer of sooty carbon left behind with the iridium?

There are, however, some more subtle objections which turn out to be more serious. It is true that the dinosaurs, as commonly defined, did not survive a reasonably sharp boundary in the fossil record. But they did not all go out overnight. According to Stanley [1987], there was a progressive decline of dinosaur species during the final 10*my* of Cretaceous time.

This is a short time geologically, but a long time anthropologically — man has made his extinctions in less than 1% of this. Is there a more slow-acting mechanism which can better account for the dinosaur extinctions?

I believe that there is. It is a subtle matter, and I cannot identify its exact nature, but I suggest that it is a question of the thermodynamics of some biophysical or biochemical process which is related to body size. There is ample evidence of external conditions altering sufficiently to cause some such thermodynamic threshold to be reached — changes in carbon-dioxide levels (Proposition 11J), changes in pressure (11K, 11L), and changes in water-vapour content (11M).

It could be argued that these are only changes in degree, and not in kind. But remember the hard-boiled egg on Mount Everest? At some particular altitude, the chemical action needed to allow the egg to set is no longer possible, the thermodynamic threshold for the reaction can no longer be reached.

The important factor may have been the clearing of cloud cover suggested in Proposition 11N. Such a change would have immense repercussions on such things as winds, humidity, input of radiation from space, and bodily insulation. One of these may have primed the thermodynamic time fuze which gradually and inexorably brought the dinosaurs down. Not with a bang, but a whimper.

> *Proposition 12F*
> *Changes in external conditions close to the Mesozoic-Cenozoic boundary adversely affected the thermodynamics of biochemical / biophysical processes dependent on body size and caused the extinction of creatures heavier than about 40kg*

CHAPTER 13

THE ORIGINS OF FOSSIL FUELS

"Science when well digested is nothing but good sense and reason"
— Stanislaus, King of Poland: Maxims, No.43.

By now we have set the scene for a more detailed look at the origin of fossil fuels. Of course, the main fossil fuels are coal, mineral oil, and natural gas, with a few less important sources such as lignite, bitumen, and tar sands.

The outstanding feature of all fossil fuels is that they contain a lot of carbon. Coal is especially rich, with up to 95%. The others are mainly hydrocarbons, compounds of carbon with hydrogen, sometimes with other elements present, but even in these the proportion of carbon is high, around 82-87% by weight.

About Coal

Coal was one of the earliest minerals to be be developed in today's technological society, in fact it was one of the main props for the Industrial Revolution, which started in Britain. Britain has considerable coal deposits and a long history of geological discovery, so the nature of coal deposits in that country have become known in great detail.

Figure 13.1 (taken from the 1875 Encyclopaedia Britannica) shows the various geological strata found in conjunction with the Coal Measures of different parts of Britain. The actual coal seams vary in thickness from a mere film to as much as 15 metres. In other parts of the world even thicker seams have been found, as in the south of France and in India, up to 60*m* thick or more.

Of course even the rich coal deposits form only a small fraction of the total rock strata, which in the Carboniferous of Britain can be more than 4*km* thick. The majority of the rock is made up of typical sedimentary strata, in particular sandstones, limestones, and shales.

Although the majority of important coal deposits of the world are of Carboniferous age, some are found in the Permian period which follows, and also in the younger rocks of the Mesozoic and Cenozoic. The younger deposits are usually much less compacted ('brown coal'), have more moisture, and have clearly undergone less conversion from the original plant remains.

Older, more compact coals have little moisture and are richest in carbon, having as much as 95%, the rest being hydrogen, water, and ash. In good coals of any age the ash content is quite low, below 2%. This is similar to the ash content of the above-ground portions of modern plants.

How did coal originate? The answer to this is to be found in any geology textbook, which describes the vast swamps of the Carboniferous Period, with their giant primitive trees and strange animals. That some such plant provenances existed is undoubted — there are too many well-preserved fossil plants involved in the Coal Measure deposits of the Earth to be able to reject the notion. But the standard swamp picture has a number of serious deficiencies.

Puzzles of Coal Formation

All the sedimentary strata enclosing coal are typical of offshore deposits, deposits laid down in the seas. Limestones are almost invariably of marine origin, sandstones are normally produced on the sea floor from particles washed in by rivers or off the coasts. Shales may be formed from the mud of lakes, but are more typical of offshore seabed areas, beyond the point where the coarser sand particles have already settled.

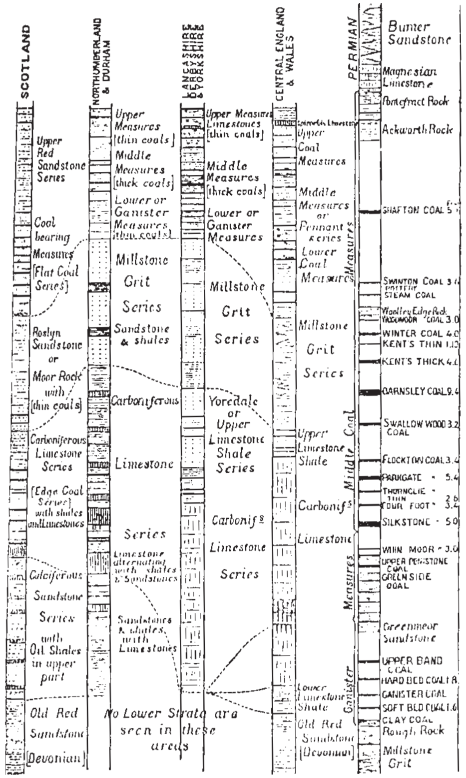

Fig. 13.1. Carboniferous strata in Britain

Why should coal seams be enclosed in these typically marine deposits? Why is coal relatively pure carbon, without much trace of any soil remains? Why are 'marine bands', deposits obviously derived from the sea [Rhodes, 1960], often found within the coal seams? Why are fossil mussel shells often associated with coal? Why are deposits of coal sometimes associated with salt beds?

These questions are even more perplexing when you take into account the relatively small amount of land surface which existed during the Carboniferous, if the approach used in this book is to be believed. Modern high-carbon deposits are being formed on land today, within our swamps and marshes (initially as peat), but their thickness is not great, especially after conversion and compression to a composition and density similar to that of coal.

An answer to some of these difficulties may be found in the following suggestion. Could it have been the case that these vast Coal Measure swamps existed, not on land, but on the surface of the sea? Was coal, and probably much of our oil and gas deposits, formed from material sinking to the floor of shallow seas, at a time when *all* seas were relatively shallow (because expansion had not then proceeded to the stage where ocean deeps existed)?

> *Proposition 13A*
> *Most coal deposits were produced by the conversion of plants which had grown up floating on the surface of the sea*

"Impossible!" would be the first response. How could the tall Coal Measure plants, clearly adjusted to fresh water, exist on the sea?

The Quaking Forests

A fascinating and unusual landscape feature can sometimes be encountered which is known as a Quaking Forest. You walk through the pine forests, and suddenly you notice that the trees are swaying, although there is no wind. They only sway where you are walking. The march of the Ents, perhaps, from Tolkien?

The explanation for a Quaking Forest is simple. It is a forest which has grown on top of a lake, on a layer of floating plant debris which has gradually accumulated and grown out from the original lake edge. This phenomenon is well known and accepted with some mangrove swamps, growing out from river banks, sometimes completely choking a river. But with a Quaking Forest, there is actually a pocket or lens of water left between the underside of the mass of plant roots and the solid mud which formed the bed of the lake.

It is like a layer of moss growing on the top of a waterbed – push your finger down into the top and the closer stems bend towards you. As you release your finger, or as waves travel out from where you pushed down, the stems bend and sway, back and forth.

It might be argued that the huge Carboniferous plants were too big to float on the surface of the sea, they would fall over. But, of course, the pines do it now in a Quaking Forest. And, in the densest, tallest, and most prolific rainforests of today, the root systems of the huge trees are surprisingly shallow. They resist falling over partly by developing buttresses, but more importantly through the shelter of their environment protecting them from winds. We have already seen, in Chapter 11, how the Carboniferous conditions were probably of dense, still air under an impenetrable cloud cover which would suppress air movements.

The Floating Swamps

The picture we are building up is perhaps not too different to the accepted swamp scenario, but with one vital difference — the swamps were not on land, but on the sea. This would explain much. It would explain why the coal seams are interleaved with marine sedimentary rocks, marine shell bands, and occasionally salt beds. It would explain the comparatively wide extent of coal deposits in the land-poor Carboniferous world. It would explain the low ash content of coals, if the plants they were derived from grew in the absence of soils.

How about the saltiness of the sea? We have already seen (Propositions 10I, 10J) that the salinity is likely to have increased continously up to the present time, so the seas would have been less salty during the Carboniferous than they are now. Moreover, it would be possible for a thick continuous mass of floating organic material to be saturated with fresh water, even though it was floating on salty water.

Fresh water is less dense than salt water, and under calm conditions it could easily happen that the floating plant layer, soaked in the rain which we have seen was probably falling continually, was stabilized enough so its fresh water did not mix with underlying more salty layers on which it floated. After all, that is not so very different from present conditions where a plant is growing in a soil, wet with fresh water, which overlies a deeper water table where the water is known to be salty.

If the scenario I have painted for the early days of life on Earth is correct, we are looking

then at a much smaller Earth, with less land than now, but also much less extensive seas. Instead of the rolling oceans of today, the seas would mostly be relatively shallow interdomain gulfs, perhaps none more than 100*km* across, and there would be no deep oceans.

Of course there could still be the conventional shore-line swamps, but these would be only a minor component, blending in continuously with the on-sea swamps. The latter would build up a thicker and thicker layer of plant material, the bottom part of which would break off periodically and sink down to the bottom of the sea. Or possibly whole floating islands could break off, like icebergs calving from a glacier, and later sink further out to sea. In these ways, in quiet times, very thick seams of what was to become coal could be accumulated.

When times were not so quiet, and domains were in active movement, the floating swamps might be washed or blown away. Newly-upraised land would erode and provide abundant sedimentary material to cover the coal. As the interdomain gulfs widened with Earth expansion, these sedimentary layers would be covered with the fine muds of more offshore areas, and perhaps the limestones of the still, warm seas.

> *Proposition 13B*
> *Coal deposits were laid down in the narrow and shallow interdomain gulfs produced by early Earth expansion*

The Petroleum Story

While coal was the energy mainstay in the early development of modern industry, petroleum is a latecomer in this respect, a child of the 20th Century. During this century it has moved from an energy source of little consequence to be the principal source of our needs. In the present context, petroleum can be taken to include both oil-type sources which are liquid under normal temperatures and pressures, and natural gas.

Both types frequently occur together, often with the gas dissolved in the oil, often under very high pressure — helping to make a self-pumping ‘gusher’. Natural gas as a developed energy source is even newer than oil, dating back only to the 1950’s. Before this, the gas was usually regarded as an annoying byproduct which was burnt off or otherwise went to waste.

Of course there are instances of practical use of petroleum, dating far back into the past. Natural seepages of oil (asphalt and bitumen) were used in the Middle East by the Sumerians, Assyrians, and Babylonians some 5000 years ago, in building mortar, road construction, and ship caulking.

Petroleum is very commonly associated with salt, and as the use of deep drilled wells was once primarily for the extraction of brine (concentrated natural salt solutions), it has often figured as an unwanted discovery. This was the case with the early Chinese, who around 200BC drilled a 140*m* deep well to extract brine and were annoyed to get gas as well. Subsequently they worked out how to burn the gas and use it to evaporate the brine in making salt crystals.

Even the early work in the United States, where large-scale petroleum extraction was pioneered, had a similar history. In 1819 a well being bored for brine in Kentucky yielded so much black petroleum that it was abandoned in disgust. In 1829 another Kentucky brine well yielded a huge flow of several thousand tonnes of oil, most of which was wasted, although a little was bottled and sold for liniment (as ‘American oil’). It was not until 1859 that a well was bored specifically to extract petroleum, in Pennsylvania.

Formation of Petroleum

There are obvious similarities and links between petroleum and coal, and a number of obvious differences. Chemically, petroleum sources are principally hydrocarbons, compounds of carbon and hydrogen, whereas in coals much of the corresponding hydrogen has been eliminated. Both fossil fuel sources are essentially complex mixtures, with no two deposits chemically identical. Coal often has a much higher sulphur content than petroleum, and for this reason has lost favour for domestic use with increasing concern over air pollution.

Physically, petroleum sources are fluids whereas coal is a solid, and this has important consequences. As a fluid, petroleum can migrate, and the rocks from which it is extracted are often not the same as the ones in which it was formed. It also means that to be available for large-scale extraction, the petroleum must be ‘trapped’ in the rocks in some way, as with impermeable layers of clay, shale, or salt around it.

The reservoir rocks which hold the petroleum are mostly sandstones (59%) and limestones, including dolomites (40%), the same typical sedimentary rocks which were associated with coal. Less than 1% of the world’s oil has been found in fractured igneous or metamorphic rocks, which typically lack the pore or void space needed to be successful reservoir rocks.

There seems no doubt that, whatever their mode of formation, both coal and petroleum are essentially derived from the remains of living creatures. In Proposition 13A, I made the possibly novel suggestion that coal was formed from the remains of plants growing floating on the seas. It seems very likely that petroleum had a similar origin.

> *Proposition 13C*
> *Oil and gas deposits were formed from the remains of plants which had grown floating on the surface of the sea*

Amusingly enough, while the coal proposition in 13A may lead to outraged protests, the almost identical one for oil will not — it is close to the currently accepted view. This is that the major source of petroleum was floating plankton, minute marine plant and animal organisms, which grew in shallow seas.

Fuller details of the reasons for concluding that petroleum has an organic origin, and that its major source was marine plankton, are given in the Encyclopaedia Britannica article on Petroleum [Britannica/ 14 :164-175]. The paragraph on the origin of petroleum concludes “In spite of the great amount of scientific research ... there remain many unresolved questions regarding its origin”.

It does seem possible that, even though Proposition 13C can be regarded as the accepted view, the floating plankton source idea may need modification in two ways. The first is to suggest that what are regarded as ‘land’ plants formed an important, or even the principal, source of the petroleum material. In other words, these plants grew on floating mats on the

sea, just as suggested for the coal deposits. And the remains of plants which are accepted as being of ‘land’ types are not uncommon in some petroleum deposits.

The second point has more implications; this is the suggestion that the floating mats of material were essentially continuous, forming closed capping layers over the surface of the sea. While these layers may not have been as thick and ‘trafficable’ as the coal ones, able to support quite tall trees, they still may have been able to effectively seal off the underlying sea from the atmosphere and from normal evaporative processes.

> *Proposition 13D*
> *The floating layers of plants which provided the source material for petroleum and coal were able to seal off significant areas of the seas and prevent normal evaporation*

If this Proposition is found to be valid, it has considerable implications for the formation of both fossil fuels and for salt. It is not disputed that the formation of fossil fuels from organic materials needs anaerobic conditions, those where oxygen is lacking. This is because the actual conversion is done by anaerobic bacteria which can only function where there is no oxygen — these are the organisms responsible for production of marsh gas (methane) from bogs, which lack oxygen under their surfaces.

Clearly sealing off the surface of a shallow sea with organic material would allow its water to become completely anaerobic and enable the conversion of plant remains under the surface to coal and petroleum.

> *Proposition 13E*
> *Seas sealed from the atmosphere with a floating organic layer would become anaerobic and foster the conversion of organic material to fossil fuels*

It has always been assumed that rock salt deposits, which are sometimes of great thickness, were formed by conventional evaporation of water from the surface of enclosed lakes or seas. This may well be the case, but it is also possible that they were formed from sealed seas.

If domain movement caused the uplift of a sealed-sea area, or some other change occurred to reduce the rain falling on such an area, it would be expected that the water in the sea would be gradually diminished and would disappear. Even if the floating plant layer was completely dead, water would continuously rise through the sponge-like layer and be evaporated, leaving the salt behind. Once a certain salt concentration was reached, the special properties of such salt solutions for holding thermal inversion layers could accelerate this process, leading to the formation of thick salt layers beneath the organic seal.

> *Proposition 13F*
> *Some salt deposits were formed by the elimination of water from sealed-sea areas*

Of course this suggestion does match in with the observed association of salt with coal and petroleum deposits.

The Age of Fossil Fuels

We have seen that most black coal deposits were formed in the Carboniferous, with some in the Permian, in the last two periods of the Paleozoic. Most petroleum deposits are found in the rocks of the Mesozoic (63%) and Cenozoic (29%), with only 8% in Paleozoic rocks and almost none in the Precambrian.

Of course petroleum is known to migrate from its strata of accumulation, but these figures do fit in well with Expanding Earth scenarios and other suggestions already made. Coal deposits are mostly in current land areas, whereas oil and gas fields are increasingly being developed on offshore areas, on the continental shelves. In the modern deep ocean beds, which are comparatively young, under 200*my* old, no fossil fuel deposits at all are found.

The inference is that the fossil fuel deposits were laid down at the bottoms of the deepest seas which then existed.

> *Proposition 13G*
> *Fossil fuel deposits were formed at the bottoms of the deepest seas which then existed, from plant sources floating on those seas*

The scenario is this. In Paleozoic times, the only seas which existed were fairly shallow and lying in the new interdomain gulfs, and it was in these that the coal plants were dumped. With increasing Earth Expansion, these areas are now mostly above sealevel. As expansion continued into the Mesozoic, new and lower interdomain gulfs opened up. It was into these that most of the petroleum plants were deposited, and it is these areas which are today mostly lower and at continental-shelf level.

Advancement into the Cenozoic saw the development of the modern deep ocean basins, and with this, changes in conditions to largely eliminate fossil fuel formation. The great floating plant mats died off, unable to survive in the blustery open ocean conditions, increasing salinity, and reduced carbon-dioxide content of the air. Their disappearance meant that the anaerobic conditions needed for plant conversion could no longer be attained in the ever-deepening seas.

The Matter of Sulphur

A minor point mentioned above was that coal deposits often have high sulphur contents, which makes them less suitable than oil or gas for domestic use, because the suphur can lead to air pollution.

Evidence which we have seen so far gives us an explanation for this difference. It seems likely that there was much more sulphur in the air in Paleozoic times, and this too, like the ammonia and methane, was largely eliminated by the start of the Mesozoic.

> *Proposition 13H*
> *The Paleozoic atmosphere originally contained much more sulphur compounds, which were largely eliminated by the start of the Mesozoic*

In the primeval atmosphere, sulphur was likely to have been present as hydrogen sulphide, the gas which gives the smell to rotten eggs. This is likely to have been converted to sulphur dioxide, the most common oxide of sulphur, by the start of the Paleozoic (when free oxygen became plentiful).

Both hydrogen sulphide (molecular weight 34) and sulphur dioxide (*mw*=64) are relatively heavy gases (see Table 11). Because of this, they are not likely to have been appreciably lost into space, but instead incorporated into sulphate sedimentary rocks when the right chemical conditions arose.

CHAPTER 14

GEOPROSPECTING AND MINERAL RICHES

“Gold is where you find it”
— Old Prospectors’ saying

Geoprospecting

In Chapter 13 we saw how deposits of ‘fossil fuels’ — the high-carbon minerals derived from plants remains — may have been associated with the seas and gulfs formed as the topmost domains of the Earth’s crust split apart during Earth expansion.

In this chapter we will look further at this, and also at how other mineral deposits were formed, the relationship of these processes to Earth expansion, and the practical application of this information to the discovery and exploitation of mineral riches.

Exploration geologists and prospectors have worked out many techniques for finding deposits of useful minerals. Most of these are based on knowledge of the rock types and formations with which particular minerals are associated — say gold being often found in quartz veins, oil in folded layers of sedimentary sandstone, and so on.

It is then a matter of working out where in the world the favourable rock types are to be found — and this has been surveyed in fair detail for most of the world’s accessible land surface — and applying more detailed tests to specific areas. Considerable help in recent years has been had from satellite observation data, but at some stage it is always necessary to start work on the actual ground. The ultimate test for occurrence of a mineral is that quoted at the head of this chapter.

We have seen that the analyses of plant distributions covered earlier in this book can be coupled with conventional geological approaches to enable reconstruction of the pre-expansion positions of different Earth domains.

For minerals formed early in the Earth’s history, or derived from the ancient rocks formed then, we can use as a ‘first-try’ prospecting method a global approach which we can call ‘Geoprospecting’.

As an example, if we know that the northwest part of Western Australia was once positioned against the eastern coast of Africa, we can look to see whether the minerals already known for that part of Africa are to be found also in Australia.

We already know this to be true for many minerals. Gold was an early example. The only major deposits of crocidolite, a blue asbestos mineral, are found in South Africa, principally in the Transvaal, and in Western Australia in the Hamersley Ranges. It seems likely that these two deposits were once physically linked as part of a huge basin of banded ironstone, laid down when the Earth still had a reducing atmosphere, well back before the 1000*my* era.

In the last few years we have seen the discovery and development of large deposits of diamonds in the Kimberley region in the north of W.A. These parallel the deposits found in southern and eastern Africa. Perhaps the next major discovery in W.A. will be of platinum

deposits, to parallel those already known from southern Africa*.

Of course this ‘Geoprospecting’ technique can be applied to domains anywhere in the world, provided that the pre-expansion neighboring domains are accurately identified.

The Location of Coal Deposits

The techniques for locating fossil fuels are different to those for many other minerals, because the fossil fuels were formed in the later years of the Earth, when expansion had already begun to have major effects on the surface conformation. And, of course, since these minerals are derived from living organisms, they could not be produced until the relevant life forms had come into being, some 200-600*my* ago.

In Chapter 13 the suggestion was put forward that many of our coal deposits have originated, not from land plants in the ordinary sense, but from floating forests on the surface of the sea (Proposition 13A). It was further suggested that these deposits were formed by the plant material sinking to the bottoms of the seas of those days, which were then much smaller and more shallow than now.

Most of our coal was laid down in the Paleozoic, and it appears from the patterns of change which have emerged from our study of Earth expansion that those former seabeds have now been superseded by new, deeper ones as the Earth opened up. These domain splittings, and the accompanying falls in sealevel, have left the majority of the Paleozoic seabeds up on dry land.

We might therefore expect to find coal in the interdomain gulfs created in the earlier days of the rupturing of the holodomain, the complete cap of continental rock which once covered the whole Earth. And the observed pattern fits in quite well with this. We have already noted how some particularly thick coal seams are to be found in the south of France and in northern India. Both these areas are ones which very probably lay on the Tethyan Girdle, the first major interdomain gulf which resulted from splitting the holodomain along the Equator into Gondwanaland and Laurasia.

Of course there are many major coal deposits, as in Australia and South Africa, which have nothing to do with the Tethyan Girdle. But they may well have been formed in other early domain splittings, and the whole thing can in fact be regarded as a two-way street. The observed presence of coal deposits implies the site of an early domain split, and conversely, prospecting for additional coal deposits should concentrate on areas where early domain splits may have taken place.

> *Proposition 14A*
> *Paleozoic coal deposits identify the sites of Paleozoic or earlier interdomain gulfs, and unlocated coal deposits should be looked for at such sites*

Prospecting for Oil and Gas

We have seen that the conditions for deposition of oil and gas were probably similar to those for coal. However, the petroleum deposits were produced at a generally later date, with

*Since announced; see page 60 of The West Australian of 1988 November 30.

the majority in the Mesozoic. Therefore these deposits are most likely to be located in the vicinity of domain gulfs which formed as the Earth expanded during the Mesozoic and earlier.

Again this scenario ties in quite well with the observed facts. Many of the major oil deposits are located on the Tethyan Girdle, including those of Texas, Venezuela, Mexico, North Africa, and the huge fields of the Middle East. The latter are illuminating in that they are now mostly quite distant from the major oceans, but represent a former major seafloor area which disappeared when Arabia, perhaps then still attached to other parts of Gondwanaland, was pushed up against Laurasia.

The fact that petroleum deposits have, as often as not, migrated from their strata of formation does not destroy this reasoning, it only implies that the possibility of migration must be kept in mind in evaluating any particular case. Of course even a fluid cannot migrate through an impermeable layer, and in the immense thicknesses found in the Mesozoic strata, measuring many thousands of metres, the probabilities are that the petroleum will encounter some form or other of trap before it has moved a very great distance.

We therefore end up with a similar proposition for petroleum as for coal, with a difference only in the age, and consequently location, of the seabeds involved.

Proposition 14B

Petroleum deposits identify the sites of Mesozoic or earlier interdomain gulfs, and unlocated deposits should be looked for at such sites

This Proposition is in accord with the fact that rich oil and gas deposits are often found on the continental shelves, at lower levels relative to coal, at the bottoms of presumed interdomain gulfs formed subsequent to those containing coal.

Field examination of this point may help sort out the question of where the Laurasia-Gondwanaland division should be drawn in the southeast Asia-China area. The plant distribution evidence tends to suggest this should be roughly east-west along the mountains of south China, which would imply the possibility of significant fossil fuel deposits there.

But the evidence is not conclusive, the border could be much further south. Indonesia has significant reserves of both oil and coal in Borneo, Australia has much oil and gas in its Northwest Shelf and could have significant reserves beneath the Gulf of Carpentaria. And then again there may have been so much domain and microdomain mingling as to make any present-day line virtually meaningless.

Zone Melting and Ore Deposits

We have already seen (Chapter 8) that considerable heat would have been generated through Domain Rubbing, as adjacent domains moved relative to one another. The nature of these movements, and consequently of the heat generated, leads to an interesting implication for the formation of mineral ore deposits.

In recent years, a number of useful new techniques have been developed for the refining of mineral ores and other materials to produce products of great purity. In particular the zone

refining technique (Fig. 14.1), one of the group of zone melting methods, has enabled the production of such things as the high-purity silicon wafers used in computers. The purity levels obtained are well beyond those available from any other method presently known.

In one zone refining method, a slab of the metal or compound to be refined is placed in a trough along which a heating ring can be passed in a slow and regular manner. The heating ring is activated at one end of the trough and enough heat applied to melt the disc of the material immediately within the ring. The ring is then moved slowly towards the other end of the trough.

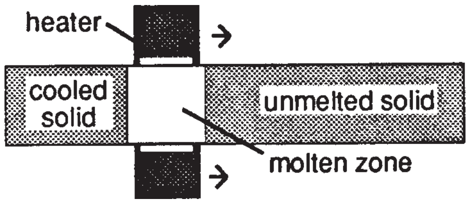

Fig. 14.1. The zone refining technique

As it moves, sufficient heat is applied in the ring to melt the new material moving under the ring, while the previously-molten material left behind cools and solidifies. The ring is gradually moved to the other end of the trough and the heat turned off, as one cycle of refining is finished.

What this process does is to dissolve minor impurities in the liquid zone as it reaches them, and continue to carry the impurities in the liquid zone as this moves to the other end of the trough. At the end of the cycle, the impurities have been partly removed from the main body of material and left in concentrated form at the far end of the trough.

It is normal to pass a material through a number of cycles, each of which improves the purity a little more. At the end of the process, the end of the bar of material containing the impurities is cut off, leaving a slab of material of very high purity.

There are many versions and modifications of this process. The slab can be replaced with a vertical cylinder of material, clamped at both ends, with the heating ring moving up or down, and with no trough or other support. In this case the thin ring of molten material is held in place between the solid portions purely by the surface tension of the liquid material. There may be a chain of heating rings, chasing each other along the trough, and far enough apart to permit solidification of the bar between one ring and the next.

The technique will also vary considerably according to the melting point of the material being used and the purpose of the work. In some cases, it is the ‘impurity’ which is wanted — the rest of the bar is thrown away. In other cases, a material may be purposely ‘doped’ with an impurity which is spread through it evenly by introducing it at the beginning of the bar.

The method can be applied to a range of minerals, metals, gemstones, and even plastics. Whether it will work or not, in any particular case, depends on the physical and chemical relationships involved in the solution behaviour of the main material and the impurities.

The Formation of Precious Ore Deposits

The modes of formation of gold, silver, and other precious metals and gemstones have always been subject to uncertainty. Because the elements involved are, by their nature, rare, it is obvious that they have somehow become more concentrated from a medium in which they were originally much more diluted.

There are satisfactory physical explanations for the formation of more common ores. The vast iron ore deposits of the Precambrian, for example, were almost certainly produced by simple precipitation of iron compounds washed into the sea. Salt beds were produced by evaporation of water from seas and lakes which had accumulated the salt dissolved by rain.

Some deposits originated through the action of life — we have already seen this to be the case for the fossil fuels. Deposits of native sulphur may also have a biological origin.

However, virtually all primary deposits of precious metals, their ores, and gemstones are intimately associated with igneous rocks. Their mode of occurrence is consistent with the views that great temperatures and pressures have been involved. Where did these temperatures and pressures come from?

The conventional view is that the heat came from inside the Earth, and the pressure from the weight of overlying rocks. I have suggested in this book that the Earth is not especially hot inside, and perhaps never was, but instead that the heat involved in volcanos and geothermal processes of every kind comes from the friction of domain rubbing.

It seems only reasonable that this frictional process is the source of the heat needed to make these precious metal and gem deposits. It also seems very reasonable that the interaction of the domains is at least one source, and possibly the major source, of the high pressures involved.

> *Proposition 14C*
> *Precious metal and gemstone occurrences were produced through processes involving the frictional heat and high pressures generated by domain rubbing*

This Proposition is supported by the observation that gold and gemstone deposits are much more commonly associated with 'long' mountains such as the Andes, themselves generated by domain rubbing (Proposition 8C), than with the 'fat' mountains such as the Himalayas which are presumed to result from domain impact.

Moreover, the essentially localized nature of the heat produced by domain rubbing gives a much more satisfactory explanation for the localized nature of precious ore deposits. These are hard to explain on the basis of heat diffusing or being carried up from some vast internal reservoir beneath the Earth.

There is another interesting feature of domain movements, which leads to quite a different aspect when you look at the heat of ore formation. These movements are not continuous, they go in discrete steps. We call these domain movements earthquakes.

Earthquakes as a class are not rare, there may be over a million of them occurring somewhere on Earth each year. The vast majority are very faint and only detectable by instruments, only one or two out of the million may cause public concern. But on and on they go, these Earth-twitches, all in all representing a gigantic amount of energy release.

And there is the likely cause of precious ore genesis. Active domain rubbing sites can be viewed as gigantic zone-refining factories, concentrating the precious ores as wave after wave of heat comes through from twitch after twitch.

> *Proposition 14D*
> *Precious metal and gemstone ore deposits are formed by a natural zone-refining process, with the heat needed stemming from the friction of earth-twitches as domain edges rub*

The Uses of Domainography

All the areas of mineral exploitation that we have looked at in this chapter — geoprospecting, the location of coal, oil, and other fossil fuels, and the formation of precious ores — are all facets of the field of domainography. This field of study, which started from observations of where different nut trees were to be found in different parts of the world, clearly has an immense but still uncharted usefulness for the world's industry and commerce.

Later we shall look more closely at implications for other aspects of the interaction of mankind, and of life in general, with these ponderous processes going on in the Earth. But first we will move off the Earth itself, and have a brief look at the rest of the Universe.

CHAPTER 15

THE MOON AND THE PLANETS

"So many worlds, so much to do,
so little done, such things to be"
— *Tennyson*

Nine known major planets rotate around our sun, and most of these planets themselves have other satellites rotating around them, some as big as the smaller planets. In addition the solar system has a huge number of smaller bodies, planetoids or asteroids, most of which lie in the 'Asteroid Belt' between Mars and Jupiter. These asteroids are usually assumed to be the remains of a tenth planet which broke up at some time in the past.

These other members of the solar system are of interest to us, in examining what has happened in the history of our Earth, for two main reasons. Firstly, whatever forces caused Earth expansion will almost certainly hold sway elsewhere in the Universe, and the other planets may show evidence of these forces. Secondly, as the other planets vary greatly in size and distance from the sun, they provide a range of models from which we can draw information on general planetary conditions (particularly atmospheres), which will help us explain why the present conditions on our planet are as they are.

The Sun's Family

Table 15 (mostly from [Academic, 1987]) gives some details of the planets of the solar system, including Earth, and of some of the major natural satellites. The most important factors to focus on are size, distance from the sun, atmosphere (if any), and escape velocity.

Our knowledge of the other members of the solar system is continually being improved, especially by data from the American and Russian space probes, but the general picture is clear. The planets are usually divided into two groups.

The Inner Planets

The first group, the innermost four of Mercury, Venus, Earth, and Mars, are usually called the Inner Planets. All have some similarity to Earth, but also many differences. Earth is the largest, but Venus is almost as large; Mercury is the smallest. Venus has a much denser atmosphere than Earth, Mars a much thinner one, Mercury none. Earth has a single large satellite (the Moon), Mars has two tiny ones, the other two have none.

The two natural satellites of Mars are the subject of one of the strangest puzzles in scientific history. Small, irregular lumps of rock — even the biggest, Phobos, is less than 14*km* long on its largest axis — both of them are smaller than Rottnest. Both are close in to the planet, Phobos so close that it goes round Mars in under 8 hours, less than Mars' 25-hour day, and so it rises in the West and sets in the East. These are very unusual objects.

These tiny, close-in moons were not discovered till 1877, when they were picked up by the American astronomer Asaph Hall. Such a late discovery can be understood, the satellites'

Table 15. Planets and major satellites of our Solar System

Planet Satellites	Mass (E=1)	Radius (km)	Surface gravity (E=1)	Density g/cc	Escape velocity (km/sec)	Distance from Sun (E=1)	Surface temperature (°C)	Atmosphere Pressure (E=1)	Atmosphere Gases
Mercury 0	0.055	2 439	0.37	5.41	4.25	0.39	200	0	--
Venus 0	0.815	6 051	0.88	5.25	10.4	0.72	470	90	CO_2,N_2
Earth 1	1.000	6 378	1.00	5.50	11.2	1.00	20	1.0	N_2,O_2,H_2O
Moon	0.013	1 738	0.16	3.35			0	0	--
Mars 2	0.107	3 393	0.38	3.91	5.02	1.52	-40	.007	CO_2,N_2,Ar
Jupiter 16+	317.9	71 398	2.54	1.24	59.6	5.20	-140	--	H_2,He, CH_4,NH_3
Io	0.015	1 815	0.18				-120		
Europa	0.008	1 569	0.13						
Ganymede	0.025	2 631	0.14						
Callisto	0.018	2 400	0.12						
Saturn 17+	95.18	60 330	1.15	0.62	35.5	9.54	-170	--	H_2,He
Titan	0.023	2 575						1.6	N_2,Ar,CH_4
Uranus 15+	14.54	26 200	1.17	1.24	21.3	19.18	--	--	H_2,He
Neptune 2+	17.07	25 225	1.18	1.61	23.3	30.06	--	--	H_2,He
Triton	0.022	1 750						0.1	N_2,CH_4
Pluto 1	0.022	1 145	--	2.06	1.3	39.44	--	--	CH_4
Charon	-	?640							

small size and closeness to the planet making them undetectable until telescopes were improved enough. How, then, can we explain the relatively accurate description of these two satellites, given in Jonathon Swift's 'Gulliver's Travels', published more than 150 years previously, in 1726?

Although nowadays regarded as a children's book, 'Gulliver's Travels' was, in fact, a bitter political satire on the society of Swift's times. In the third voyage, Gulliver describes the island of Laputa, inhabited by scientists and able to float in the air, its position controlled by a giant natural magnet. The island is described in some detail — its thickness (300 yards), its area (10,000 acres, about twice that of Rottnest), its drainage system — a typical microdomain!

Gulliver notes that the astronomers of Laputa had much better telescopes than those known in Swift's day, and that "they have likewise discovered two lesser stars, or satellites, which revolve about Mars; whereof the innermost is distant from the centre of the primary planet exactly three of his diameters, and the outermost, five; the former revolves in the space of ten hours, and the latter in twenty-one and a half".

It seems quite beyond the bounds of chance for these very unusual objects to have been predicted, so accurately and so far ahead of time, almost as an aside in a satirical novel. On this occasion, the formulation of a suitable Proposition will be left as an exercise for the reader.

The Giant Planets

The second group, the Outer Planets, includes the so-called Gas Giants — Jupiter, Saturn, Uranus, and Neptune — and the outermost known planet, Pluto. The gas giants are much more massive than Earth, have enormously dense atmospheres, and multiple satellites, more of which come to light with each new flypast. Most of these satellites are small, but Jupiter has four huge ones, and Saturn and Neptune have a huge one each; two of these satellites are bigger than Mercury, the planet closest to the Sun.

Pluto is the odd man out as far as the Outer Planets are concerned. Very distant, and still not investigated in detail by any space probe, it is much more imperfectly known than the rest. In size it is similar to a large asteroid, but it has one comparatively large satellite, of half its own radius. Although it is, on average, the planet farthest from the Sun, its orbit is appreciably elliptical, and it is currently inside the orbit of Neptune. It has been suggested that it is an escaped gas-giant moon or errant asteroid, or has some other exceptional mode of formation.

For the whole solar system, the Sun is far and away the most significant source of heat and other energy, and the planets closer to the sun than Earth are much hotter, while the outer ones are much colder. This has a major effect on their atmospheres — materials which are atmospheric gases on Earth may be liquids, or even solids, on the outermost planets.

Atmospheres of the Planets

The atmospheres of the planets differ very considerably, both in composition and in mass or density, but we will see that, with one exception, they do fit into a general pattern. The exception is Earth itself.

In Chapter 11 it was shown that the two most important properties of an atmospheric gas molecule, from the viewpoint of this book, were its molecular weight and its temperature. When we need to tie in these properties with the conditions on a particular planet, we need also to consider the mass of the planet, the main determinant of its escape velocity.

Jupiter is easily the most massive of the planets, more than 300 times heavier than Earth. Its escape velocity is so high it is easily able to retain even hydrogen and helium, the lightest gases, and in fact almost all of its enormous atmosphere consists of these gases — a reflection of their high relative abundance in the Universe. However, Jupiter's atmosphere also contains some readily detectable carbon and nitrogen gases such as methane and ammonia.

As Jupiter is a long way from the sun, it is also very cold. This cold, and the immense amount of its atmosphere, means that compounds which are gases in its outer atmosphere may be liquids or even solids lower down, under the huge pressures (perhaps many millions of atmospheres).

As yet we do not know where the solid surface begins, and whether this surface is of the same rocky nature as those of the inner planets, or is frozen atmosphere. The low density given for Jupiter in Table 15, 1.24 as opposed to the 5.50 for Earth, reflects the fact that this density is calculated for the whole planet, including its atmospheric components.

It seems likely that Jupiter's atmosphere is probably little changed from its primeval state, as far as composition is concerned. We can work from the assumption that the primeval atmospheres of all the planets were similar in composition to that of Jupiter now.

> *Proposition 15A*
> *The primeval atmospheres of all the planets had a similar composition to that of Jupiter now*

The actual present composition of Jupiter's atmosphere, at least the outer parts accessible to measurement, is about 90% hydrogen and 10% helium. The other gases present, such as compounds of nitrogen, oxygen, and carbon with hydrogen, make up less than 1% altogether.

The other three gas giants, Saturn, Uranus, and Neptune, follow the Jupiter pattern quite closely. All have high escape velocities, and as they are further out and so even colder than Jupiter, all their atmospheric gases, even the lightest ones, are moving too slowly to be lost to space. Their only difference is that some are cold enough to turn compounds which are gases in Jupiter's atmosphere into liquids or solids — ultimately leaving only hydrogen and helium, which both have low molecular weights (2 and 4) and a very low liquefaction temperature.

> *Proposition 15B*
> *Saturn, Uranus, and Neptune have similar 'primeval' atmospheres to Jupiter, except that they have less of the heavier atmospheric components due to freezing or liquefying out*

Information on Pluto's atmosphere is very uncertain, but it may have a very thin one consisting only of a little methane and possibly some neon. Pluto is so light that these heavier gases would only be retained at all because the intense cold would slow them right down.

Atmospheres of the Inner Planets

When we move from the Outer to the Inner planets, the picture changes completely. Each of the inner planets has a clearly-defined rocky surface, while their atmospheres have all been markedly changed from the primeval pattern, but in different ways.

Mars is the second smallest of the inner planets. Further out from the Sun than Earth, and hence colder, it has been able to retain only a residual atmosphere, less than one-hundredth of the pressure of that on Earth. This very thin atmosphere is believed to include about 95% carbon dioxide (molecular weight 44), 2.7% nitrogen (28), and 1.6% argon (40).

These figures are actually just about what we might expect. Because of the relatively small mass of Mars, and so fairly low escape velocity, all the lighter gases would be lost quite quickly. Hydrogen and helium, with molecular weights of 2 and 4, would go immediately. The next lightest gases, methane (16), ammonia (17), and water vapour (18), could hang on long enough for partial conversion into nitrogen (28) and carbon dioxide(44); anything not converted to these two heavier gases would be lost. Argon, an inert, heavy gas, would be largely retained, too heavy to be lost and too unreactive to be converted.

In contrast to Earth, Mars has an atmosphere with virtually no oxygen, which it could retain (*mw*=32), presumably because it has never been exposed to extensive oxygen generation through biological processes (Proposition 11E). The ratio of nitrogen to argon in Mars' atmosphere is instructive; Earth has a ratio of about 83.9, Mars has one of about 1.7. It seems clear that Mars has lost much more of its original nitrogen than Earth, purely because Mars itself is lighter, and medium-weight gases such as nitrogen are less able to be retained than heavier ones such as argon.

> *Proposition 15C*
> *Mars has lost much more of its atmospheric nitrogen than Earth because of its lower escape velocity*

In fact, if we assume as a first approximation that both planets once had the same nitrogen-argon ratio, and Earth has kept all its argon and nitrogen, while Mars has kept its argon but lost some of its nitrogen, the actual percentage lost turns out to be 98.7%. If all this nitrogen was restored to Mars' atmosphere, it would increase its atmospheric pressure by a factor of over 30, bringing it up to about a fifth of Earth's. This seems on the right track.

Moving now to the planet closest in to the Sun, Mercury, here we have an extremely hot, quite small planet. The complete lack of atmosphere is to be expected — even the heaviest gases would be boiled off quite quickly.

Venus the Mysterious

Venus is the most interesting of all the planets from our present viewpoint. Until the middle of the 1900s, Venus was very much a mystery planet. It is perpetually shrouded in thick clouds, so that the surface, and how far it lay beneath the clouds, was completely unknown. Even the time it took to rotate on its axis was not known. This left the field open for suggestions that Venus was a lush tropical swamp, perhaps inhabited by dinosaurs.

Data from the Venus probes, and from radar studies, have now given us a clearer picture of what turns out to be a very harsh and hostile environment. At the surface, which is is a typical rocky one like the other inner planets, pressures average around 90 times those of Earth. There are no seas, negligible free water in fact. The very dense atmosphere consists of about 96% carbon dioxide and about 3.5% nitrogen.

Venus is only a little smaller than Earth, with a slightly lower escape velocity, 10.4 instead of 11.2. It is closer to the Sun, and much hotter — surface temperatures around 450°C have been recorded by the probes. This temperature is actually higher than that on the surface of Mercury, which is even closer in.

Why should this be so? This high atmospheric temperature is usually ascribed to a sort of 'Greenhouse Effect', particularly because of all the carbon dioxide present. I believe this view is mistaken, not because we should expect higher temperatures at the bottom of thicker atmospheres (although this is true), but mostly because of the reflection-radiation ratio. We will throw more light on this matter when we come to look at the Greenhouse effect on Earth, in Chapter 17.

We will return to the matter of the mass or pressure of the atmosphere on Venus. Other things being equal, we would expect Venus to have a similar atmospheric pressure to Earth, or slightly less, because of its smaller size and higher temperature. Why does it have this exceptionally thick atmosphere?

There are two main parts to the answer. The first is that it is not Venus which has the exceptional atmosphere, it is Earth. Venus is the typical planet, Earth is out of line. Both planets have sufficient mass to retain most gases of medium weight or above. It will be interesting to see if the nitrogen-argon ratio on Venus is similar to that on Earth, as we would expect. The big difference is that Venus has not experienced the massive deposition of carbon dioxide into solid forms which took place on Earth (Proposition 11J). This in itself indicates that Venus has never developed any type of life capable of driving such a carbon-extraction process.

If all the carbon dioxide were removed from its atmosphere, Venus would experience a drop in atmospheric pressure by at least 96% — actually a bit more as carbon dioxide is heavier than nitrogen — and this would bring it down to between 2 and 3 Earth atmospheres. Again we are on the right track.

> *Proposition 15D*
> *Venus has a much higher atmospheric pressure than Earth because it has never experienced massive carbon deposition from its atmosphere*

Even so, this new figure is still rather higher than we would expect — it should be less than Earth. There is a minor point in that, as Venus has no seas the 'surface' pressure is comparable to that on Earth at the ocean bottom with the water removed, but this really makes very little difference. For the second part of the answer we will need to return to Earth itself.

The Earth and the Moon

The Earth/Moon system is actually close to being what is called a double planet. The Moon has about one eightieth of the mass of the Earth, and is roughly 400,000 km away. As a first approximation, the centre of gravity of the system therefore lies about one-eightieth of the way along a line from the centre of the Earth to the centre of the Moon.

The present radius of the Earth is about 6,400 km, so the centre of gravity lies only about 1,400 km below the surface, only one-fifth of the way down to the centre. If the centre of gravity was actually above the surface, then the Earth/Moon system would conform to the true definition of a double planet.

Now for the crunch. Some 300-400 million years ago, the Earth's radius was perhaps half what it is now, say around 3,200 km. If the Earth and the Moon had the same separation and masses as they have now, they would have formed a true double planet, with a centre of gravity some 1,800 km above the Earth's surface!

In actual fact, it appears quite likely that the Moon was once quite a lot closer to the Earth, but even so there is clearly scope for a double planet situation to have applied in the past. In a double planet, the two components tend to share atmospheres, especially if their mutual centre of gravity lies within the normal atmosphere of one component (and this is *more* likely if the Moon was once closer to the Earth).

Of course the centre of gravity is not the point at which the gravitational forces acting on a gas molecule between two bodies cancel out, but these two locations are linked. We can get a better feel for the situation by looking at another mind model.

Interaction between Gravity Wells

Figure 15.1 is a development of the 'gravity well' model shown for the Earth in Figure 11.1. The original model was simplified. That model, a cross-section of a funnel shape lying in a flat plain, only considered the Earth in isolation.

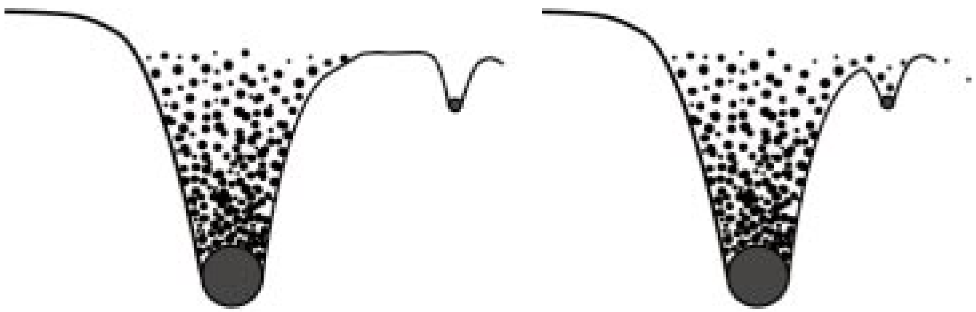

Fig. 15.1. Gravity wells for separated (left) and close (right) Earth-Moon systems

We can think of the gravity-well surface as being a huge flat sheet of very thin rubber. The Earth is then a heavy ball-bearing which is placed on the sheet and stretches it downwards to form the well shape.

We can extend this model by taking the Sun into account. The Sun is enormously heavier than the Earth, but is a long way away. We can think of the Sun as having its own gravity well, formed by a much heavier ball, placed a long way off on the rubber sheet. The Earth and its own tiny gravity well lies out towards the edge of the Sun's well, where its slope has become quite shallow. The Earth stays at the same distance from the Sun because it is running round the Sun, and holds its position on the sloping well-wall like a wall-of-death motorcyclist.

The first diagram in Figure 15.1 shows the gravity wells for the Earth and the Moon when they are fairly widely separated. The Moon lies high up in the Earth's gravity well and does not distort its shape much. That is close to the present situation.

The second diagram shows the Earth and the Moon much closer together. Their gravity wells are more merged together, with the rim of the Earth well 'dented' down, and so allowing atmospheric gases to overflow more easily. And, most important, the situation gives these gases greater scope to escape from the Earth-Moon system altogether, even though they may still remain within the Sun's immensely wider gravity well, elsewhere in the solar system.

In this way, at some stage of the Earth's history, a lot of its atmosphere is likely to have leaked off via the Moon. With its much smaller escape velocity, the Moon would have been unable to hold this atmosphere — of the solar system moons, only Saturn's giant moon Titan is able to hold a significant atmosphere, and Titan is much more massive and colder than our Moon. So here is a possible explanation for the fact that Earth has a thinner atmosphere than Venus even when carbon deposition is allowed for — Earth has a massive moon, while Venus has none.

> *Proposition 15E*
>
> *Earth has lost atmosphere through leakage via the Moon, especially when the Earth's radius was smaller and a double-planet situation was approached*

Life in the Universe

The vast rubber sheet in which the Sun's gravity well lies is part of an even vaster one extending over our whole Galaxy, and beyond that to other galaxies and to the remote ends of the Universe — if it has ends.

A question which has fascinated people ever since the existence of other planets was known is whether life, especially intelligent life, exists elsewhere in the Universe. Many views, ranging from the serious (such as Asimov [1979]) to the crazy, have been put forward.

So far no really positive evidence has emerged, and I will not be venturing a Proposition here. But we can note that the fact that no other planet in our solar system except Earth has an atmosphere containing much free oxygen, and that I have suggested that this oxygen originates only through the action of life. All the planets have immense reserves of oxygen in their rocky cores, oxygen is the most common element there, so it is not a question of unavailability.

Earth is also the only planet in the solar system with significant surface reserves of water. Water is made up of hydrogen and oxygen, and all the planets appear to have started off with huge reserves of hydrogen. Free hydrogen is easily lost except from the more massive planets. Water vapour can be retained by the middle-range planets, but this is always subject to breakdown in the outer atmosphere through the action of cosmic rays. The resulting hydrogen would be easily lost, and the oxygen retained, or reacted with methane to form carbon dioxide in a hydrocarbon-rich atmosphere.

In Asimov's book he tries to work out the probability of intelligent life existing elsewhere in the Universe, on making various assumptions as to the mode of formation of stars and planets, and the probability of occurrence of given conditions, whether normal or unusual. It does seem that our Earth is unusual. Earth life is believed to have originated in the water, and water is not common elsewhere in the solar system.

But perhaps the most unusual feature of Earth is its relatively large moon, unique among the inner planets. We have seen how the presence of the Moon may have affected the Earth's atmosphere, and we may wonder if the Moon may have been a crucial element in the formation of life on Earth. If so, it lessens the likelihood that life has arisen elsewhere, if the Earth-Moon system is truly very unusual.

The Expanding Planets

The Earth-Moon system may or may not be unusual, but there is nothing to suggest that it is not subject to the same physical laws as the rest of the Solar System, or indeed the rest of the Universe. We can therefore expect that if the Earth has expanded in the past, the same forces will have acted on the other planets, and evidence of this may be found on these planets.

In fact evidence of global changes of this sort were looked for on the other planets back in the days when Continental Drift was coming into its own, much earlier in the century. At that time, knowledge on the surfaces of the other members of the Solar System was quite sparse. What knowledge existed came entirely from telescope observations, and the only other world within proper reach of the telescope was one face of the Moon (the Moon always keeps the same face turned to Earth).

The Moon did show apparent evidence of volcanic activity, or at least of igneous rock flows, but its most prominent features were the huge impact craters which covered much of the visible surface. Further afield, the two closest planets were Venus, completely cloud-covered and enigmatic, and Mars.

Mars lies at the aggravating limit of resolution from Earth-based telescopes. Some surface details can be made out, but it was impossible to say for certain what they represented. At the beginning of this century, the American astronomer Percival Lowell was a strong advocate of the theory that a series of lines just barely visible on Mars was a network of canals containing irrigation water used by the inhabitants.

The advent of the space probes changed all this. Actual landings of remote-controlled vehicles have been made on both Venus and Mars, and even some simple analyses of rocks made. We have photographs of these rocky surfaces. Radar scans of the surface of Venus have given increasing information on its terrain. The surface of Mars has been mapped in fair detail from orbiting spacecraft.

Tiny Mercury, very close to the sun and for this reason very difficult to observe, is still not known in any detail. It does have a number of prominent surface features, mostly impact craters. To date, however, most of the relevant evidence has come from the two closest and best-studied planets, Venus and Mars.

Expansion on Venus

As the evidence accumulates, it lends increasing support to the view that the other planets are behaving similarly to Earth. Venus, similar in size to Earth, has a clear distribution of raised ‘continents’ and wide, flat ‘seabeds’, although of course the latter do not contain any water. And the interesting thing is that the ‘seabeds’ cover about 70% of the planet [Cambridge, 1985] — the same as on Earth.

At first the radar resolution was not good enough to show searched-for features similar to the midocean ridges of Earth, but these have now been found. An article in Scientific American [Fractured, 1986] describes these, crossing the Aphrodite Terra continent on the equator of Venus. It appears that a long fracture zone, very similar to our midocean ridges, stretches at least two-thirds of the way across Aphrodite Terra, and possibly runs right round the planet in its equatorial zone.

Of course, in the article this evidence is looked at from the conventional viewpoint, with no regard for an expanding Venus. The interior of Venus is assumed to be heated by radioactive decay, and the ‘midocean’ feature due to convective upwelling of hot rock. The author comments that “If new lithosphere is created near the Venusian equator, then old lithosphere must be destroyed by subduction near the poles, but so far no evidence of a subduction zone has been found”. Surprise, surprise.

It seems clear that the same type of domain movement as on Earth is occurring on Venus. However, the fact that the first prominent domain-boundary features observed on Venus run in an equatorial direction, while those on Earth run mostly north-south, may indicate that the Venus feature shows an earlier stage of expansion, perhaps similar to the Tethyan Girdle which earlier existed on Earth.

> *Proposition 15F*
> *Expansion of Venus is occurring in a similar way to Earth expansion, but may be at an earlier stage of development*

This slightly earlier stage of development may be expected, since Venus is somewhat smaller than Earth. This will be looked at again in the next Chapter.

Our Little Brother Mars

Although it is not the planet which is physically most comparable to Earth, Mars, the Red Planet, is perhaps the least hostile as far as human life is concerned. It is the only place we know of where a man might live with no more apparatus than a breathing mask and an insulating suit.

The Red Planet is red because of the colour of its terrain — waterless, eroded, and swept by thin winds able to support an occasional dust storm. Almost certainly the red rocks and dust are ‘rusty’ iron oxide colours, as in many Earth deserts. There is ample oxygen there, trapped in the rocks, but virtually none left in the atmosphere.

The terrain of Mars is not a featureless plain, but has a huge array of structural features, including giant volcanic calderas. The highest of these, Nix Olympica, is 25*km* high. But easily the most prominent topographic feature is a huge equatorial canyon, some 5000*km* long and with an average depth of 6*km*. Known as Valles Marineris (Figure 15.2), this great equatorial gash is the site of three out of the four largest volcanic calderas on Mars.

Incredibly enough, this vast canyon has been interpreted as evidence of former water erosion on Mars — after all, that was what caused Earth’s Grand Canyon, wasn’t it? No matter that water cannot exist on Mars (the air pressure is too low to allow liquid water). No matter that volcanos stand in a line along this feature.

In the light of evidence already given in this book, it seems obvious that Mars is in the early stages of planetary expansion, and that the Valles Marineris rift is part of a Tethyan Girdle in process of formation round the planet’s equator.

> *Proposition 15G*
> *Expansion of Mars is occurring in a similar way to Earth expansion, but is at a much earlier stage of development, with an Equatorial Girdle just emerging*

In Vulcan's Realm

In Chapter 8 we looked at the formation of volcanos on Earth, and concluded that these were locally-produced phenomena caused by domain-edge rubbing, and did not stem from any inner heat of the planet. We have seen that volcanos exist elsewhere in the Solar System, off Earth, and we can ask how they fit in with the theories put forward.

The most spectacular volcanos in our Solar System do not exist on any of the planets. They occur on Io, the innermost of Jupiter's four giant moons. Images from the space probes have shown huge eruptions from Io's surface, visible as giant plumes leaping up from the edge of the moon's disc.

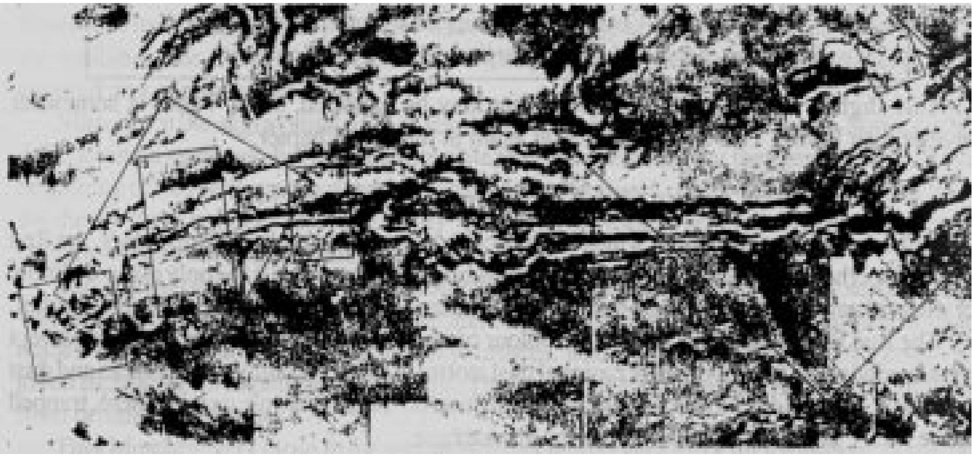

Fig. 15.2. The great equatorial canyon of Mars, Valles Marineris [Cambridge,1985]

Researchers have accepted the obvious fact that Io's volcanos have no connection with primeval internal heat welling up from its interior, and ascribed them to the effects on the surface of gravitational forces, caused by its giant companion, Jupiter. This view could be rephrased by saying that crustal movements on Io cause its volcanos — perhaps the same might apply on Mars, Venus, Mercury, the Moon, and even Earth?

This concludes our examination of the planets. Much remains to be discovered about them, but at present it can be said that they are known to contain nothing contradicting the ideas expressed here, and a great deal to support them. We can now move on to the *reasons* for the behaviour we have noted in the Earth and the other planets.

CHAPTER 16

THE COSMIC ENGINES

"The Universe: a wonderful and immense engine"
— George Santayana

Here is perhaps the place to look at some of the possible underlying reasons for the behaviour of the Earth in its past history of expansion and movement. As usual, I will venture forth with a number of Propositions. But it should be emphasized that these are in a separate class from those which have gone before.

The Propositions previously set out are generally attempts to explain *observed data*. Ones in this chapter mostly suggest mechanisms. Even if all the mechanisms suggested here should later be discredited, this does not affect the earlier Propositions.

PART 1 — DOMAIN MOVEMENT

In Chapter 5 we saw that there was clear evidence of movements of parts of the Earth's crust relative to one another — already accepted as 'Continental Drift' and 'terranes' — and that it also appears that smaller parts (microdomains) have moved bigger distances relative to larger ones. Moreover, it appears that the direction of movement has been strongly away from the equator. We will first look more closely at a possible reason for this result.

The Fugitive Domains

We have seen that the earlier Continental Drift theories and the later Expanding Earth concept are not mutually exclusive, one is a more developed case of the other. It is clear that pieces of the crust do actually move relative to one another on the surface of the Earth, as in the case of India colliding with northern Asia. Even though the Earth is expanding, these domains are not completely passive subjects of the expansion occurring beneath them; they do actually move.

What drives the movement of these domains? Earlier we have seen that the suggestions of 'convection cells', with floating land masses being pushed aside by uprising currents of hot rock, are just not supported by any real evidence. So what causes the movement?

The explanation lies, I believe, in the principle of conservation of momentum. If a body (or a group of bodies) is in motion, its momentum (the figure got by multiplying its mass by its velocity), remains constant or 'conserved' in spite of events it undergoes.

If a series of flat bodies is connected loosely to the surface of a rotating sphere, and that sphere expands under them, what would we expect to happen to the flat bodies?

If the underlying expanding sphere continues to rotate at the same angular rate (same number of revolutions per day), and to a first approximation we can take this to be the case with the Earth in the recent geological past, then 'floating' land masses originally situated near the equator may be expected to move away, towards the poles, so that their momentum remains the same.

This is because if the rate of rotation is the same, the actual velocity of a point on the Earth's equator must increase in direct proportion to its radius if it expands. A floating body may be expected to move away from the equator with a sort of 'centrifugal force', towards a latitude where the surface velocity is the same as in its original position.

> *Proposition 16A*
> *Domain flight away from the equator occurs on an expanding Earth in an effort to conserve the momentum of the individual domains*

This suggestion could be tested physically, for example with magnetized discs sliding on the lubricated surface of a metal sphere, or theoretically, through computer simulation.

There are some other factors to consider here. One is the the point that smaller domains appear to have moved longer distances than larger ones. The other is the actual position of the Equator from time to time.

Effect of Domain Size on Movement

Evidence has been given that the microdomains and smaller domains have moved greater distances than larger domains to which they were once attached (Proposition 5H). The reasons for this are not entirely clear.

One possible line of reasoning is based on momentum conservation. A large domain extending right over the equator will have a centre of gravity on, or fairly close to, the equator. If the effect of momentum conservation is to cause movement away from the equator, such movements will be balanced or minimized by the fact that the two halves of the domain are pulling in opposite directions. Of course this only holds while the domain stays in one piece.

On the other hand, a microdomain on the outer edge of such an equatorial megadomain will have its centre of gravity some way from the equator, and the effects of 'centrifugal flight' will be greater. Also, close to the equator the Earth's surface is close to parallel with its axis, so there will be a difference in the degree of change in momentum with radius expansion, compared to a domain in middle latitudes (Figure 16.1).

In this diagram, a microdomain M is shown attached to a large equatorial domain D on an unexpanded Earth, and in various positions relative to D on an Earth of larger radius.

On the expanded Earth, M1 is the position of the microdomain if it remains attached to D. However, we would expect that if it broke away from D and just kept its own position relative to the underlying core it would have appeared to 'move' relative to D, down to M2. If the expanded sphere continued to rotate at the same speed as the unexpanded one, then to move to a position where its rotational speed and momentum were preserved, the microdomain would have to travel right down to M3.

There other considerations. As already noted (Proposition 7F), it seems that domain flight becomes less marked or disappears altogether as the Poles are approached. We have also seen (Proposition 5K) that domain flight may be affected by the gravitational influence of adjacent large domains. There is also a philosophical consideration.

If the Earth is expanding, and smaller domains are ending up further from the Equator than

previously adjacent larger domains, this situation could be viewed as larger domains *moving further from the Poles* than smaller ones. This is an alternative model which deserves consideration. However, it is a model which does not seem as satisfactory as the one already looked at, in that it does not explain the preponderance of equator-pointing peninsulas, or the apparent large shifts of isolated islands such as Iceland.

Domain Blocking

Whatever the basic mechanisms involved in domain movement, whenever you look at the position of a particular area, the important factor may just be one of physical blocking of movement. The Italian, Iberian, and Indian peninsulas are clear examples of domains which were moving north but whose movement was stopped when they ran into larger domains.

The highest large area on Earth is the Tibetan Plateau, which stands more than 4*km* above sealevel. This domain is reasonably central in the east Asian landmass. Rather than being pushed up, as is usually assumed for high areas, it may be that this plateau never had the chance to slide down; while other parts of the holodomain may have slid away into hollows created by Earth expansion, this may have happened to have been blocked from movement by adjacent domains.

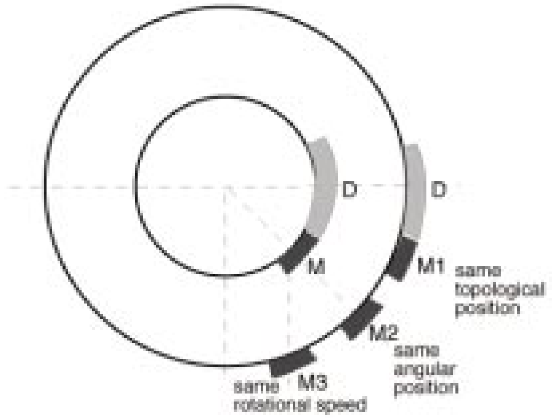

Fig. 16.1. Changes in momentum at different latitudes

It is usually assumed that India, breaking off from the Gondwanan continent low in the south, travelled a long way north before colliding with Laurasia. In fact, it is possible that the Indian megadomain was never more than a few hundred kilometres from Laurasia, so that the relative movement leading to creation of the Himalayas was only of this order, and the long 'skid marks' down the Indian Ocean actually represent the Earth expanding away under India. We have seen, in Chapter 5, that the Himalayas could have been formed from only 2-3*km* of domain material pushed together, so the actual 'run up' of India to the impact need not have been very long.

Thickness of Domains

At the end of Chapter 9 we arrived at a picture of the Earth (Fig. 9.2) in which the old broad, massive 'tectonic plates', extending down some 100*km* or more in the 'lithosphere', were replaced by a mass of smaller domains and sub-domains beneath them, of very varying thicknesses.

Another feature of the old 'tectonic plate' approach was the idea that these huge plates were floating on a layer of liquid rock within the Earth, like icebergs in the ocean. I have suggested that there is no such liquid layer. I also strongly suspect that actual calculations of the influence of any such liquid layer on movements would show them to be quite insignificant. It is as if the demolishers of an office tower on a hill would expect quite different results from a controlled implosion according to whether it had been raining or not.

Whatever, the tectonic plate idea assumes more or less uniform-thickness massive plates everywhere on the Earth. The domain approach does not. It is possible that the smaller microdomains, such as Rottnest, may be, like Laputa, only a few hundred metres or less thick.

What this implies is that these surface microdomains may be moving quite unsuspectedly, like snails on a slab of rock, without creating any obvious effects such as heating or rock metamorphism. The slab of rock may itself be inching its way downhill as soil is washed away under it, and the whole hillside may be part of a microdomain moving over a larger subdomain.

> *Proposition 16B*
> *Microdomains may be moving independently on underlying domains which are themselves in motion*

This Proposition is at the stage where it could be verified by careful actual measurements of relative movements; surveying instruments have now been developed which are just about capable of this level of accuracy. Let us revert briefly to the quotation about Rottnest which appeared at the head of Chapter 2. We have already shown how the earth movements suggested by the plant relationships in that quotation do appear to actually occur; now we can see their speed.

The basement limestone rocks on which Rottnest is situated are believed to be about 1.5*my* old. If Rottnest has moved 300*km* south in this period, simple calculation shows the average rate of movement to have been 20*cm/yr*. This is quite a large amount, which should be easily detectable with properly-designed measurements.

Of course, Rottnest may not be currently moving at all, it may be blocked on its undersea pedestal. The basement rock on which it moved could be above or below the level assumed, and hence of different age, and the reference point on the coast from which the 300*km* was measured could itself be moving, although variations here tend to increase the calculated speed rather than reduce them. Whatever, if the domain movements suggested actually exist, it should be possible to observe and measure them somewhere.

The Position of the Equator

There is quite a lot of geological evidence (e.g. [Carey, 1987]) that the position of the Earth's equator has varied somewhat in the past. This is not a new thought, such suggestions predate even the development of Continental Drift ideas. And of course the reasoning in this book makes the equatorial position almost a philosophical question — if domains and subdomains are moving freely about the Earth, like people milling in a crowd, what relevance is there in a line drawn across this crowd at some arbitrary point in the past?

There is, in fact, some relevance. We have seen, in the phenomenon of domain flight, that these movements have apparently been away from the equator of the time when movement

began. It has been suggested that when the split of the Holodomain into Laurasia and Gondwanaland occurred, this took place along the equator of that day. The Tethyan Girdle formed round the Earth by that event has had a strong influence on the Earth's subsequent history.

It is very obvious that the distribution of land between the northern and southern hemispheres is currently quite uneven, with far more in the north than in the south. This reflects the fact that the old Tethyan equator ran along a line between domains which is mostly much further north relative to its original position. As the jostling domains have moved to different extents, the line has become rather broken up, but appears most northernly in the Mediterranean, at about 35°N, and most southernly around southeast Asia.

In Table 6 there was a list of families suggested as originating in Laurasia, and of ones from Gondwanaland. There were far more in the Gondwanan section, presumably because more intense evolution occurs in the tropics, and almost all the current tropics were once part of Gondwanaland. Much more of Laurasia has ended up in cold polar regions where the opportunity for development is much poorer.

> *Proposition 16C*
> *More modern species are of Gondwanan origin than Laurasian because species development is more marked in the tropics, which are mostly parts of Gondwanaland*

The reason for the uneven distribution of land in the two hemispheres is not clear at present. It could be pure chance. However, there is another unevenness, more recent than the Tethyan one, which is happening because of the opening up of the Pacific Ocean.

The Pacific is very large, covering around a third of the entire Earth's surface, and it has opened up relatively recently and quickly. As a result, the hemisphere centered on a point in the South Pacific off New Zealand contains only 15% of the Earth's land surface. This does suggest that there have been at least two episodes of unevenness of domain redistribution, and that their cause is not related to the Earth's spin, as the Pacific episode has affected both hemispheres more or less equally.

There is some suggestion from plant family distributions of different early equator positions. In particular, the layout of the cycads (Fig. 4.13) leads to speculation about an equator which once dipped down towards southern Africa and Australia then up again to the Americas. The cycads are much older than the other plant groups featured, and could have originated under different conditions — but more evidence is needed on this one.

The Final Answer

As almost all of the concepts of domainography have only now been introduced with this book, it is not reasonable to expect that the whole field can be advanced to the stage of giving final answers in one go. In particular, much more detailed calculation is needed of the parts amenable to mathematical analysis. For the moment we must be content with pointing out that such calculations can be made.

In this work, we also need to keep in mind at every stage whether the assumptions used are justified. For example, it was assumed above, as a first approximation, that the Earth is rotating at the same rate as it did in the past. In fact there is evidence that the rate of spin is slowing down.

Most of this evidence comes from studies of growth patterns in fossil corals. Some of these show patterns, similar to the growth rings in trees, but with one ‘ring’ for each day rather than year. They indicate that in the past, the Earth had more than 400 days in a year.

This is usually taken to mean that the Earth turned more quickly on its axis in those days (an alternative, that the Earth took longer to go round the Sun, is much less likely). The implications of all the matters raised are going to need a lot of exploring!

Part 2 — Within the Planet

In Chapter 9 we had a good look inside the Earth, and a number of Propositions were made which differed greatly from accepted views. We can now go to develop some of these, and see some of the mechanisms for change which they imply. The first area to look at is the Earth’s inner structure and composition.

Phase Changes and Density

Working from the conventionally-accepted data and figures given in Fig. 9.1, we arrived at a new scenario for the inner structure of the Earth. The idea that the Earth’s density increases from the surface to the core, and does so through a number of abrupt changes or discontinuities as well as gradually, was not disputed. The idea that the Earth’s temperature increases regularly towards the core, reaching several thousand degrees at the centre, was rejected. The idea that our planet has an iron-rich core was rejected. The observation that the upper layers of the Earth’s crust are the source of heat which rises to the surface is undisputed, and a source for this heat was suggested.

The density of the Earth’s inner substance is believed to increase from an average of around 2.7 at the surface to around 13.6 at the centre. The density of iron metal is around 7.9, and of its oxides and compounds a good deal less, so this density of itself gives no explanation for the high value at the Earth’s centre. I have put forward part of an explanation (Proposition 9D), in suggesting that the density discontinuities are due to phase changes in the Earth’s substance caused by the great pressures. We can make the picture more explicit.

It seems reasonable to suggest that the entire reason for density increasing as you approach the Earth’s centre is that the rock substance is progressively more compressed as the weight of the overlying layers gets larger. At certain threshold pressures, the substance will undergo a specific rearrangement, a phase change. Between these key pressures, the substance will become progressively more compressed and hence of higher density, but stay in the same phase.

> *Proposition 16D*
> *Both the progressive and the abrupt increases in density encountered on approaching the Earth’s centre are due to the increasing pressure of the overlying material*

If, then, the increase in density towards the centre is purely the outcome of the increasing pressure, this raises another possibility, concerning the *composition* of the Earth’s substance. We have abandoned the iron core, we have suggested that the density discontinuities are due to pressure thresholds. We are left with nothing which necessarily requires the composition of the Earth substance to change with depth. The simple conclusion — and we will see in the next Chapter that we should always take the simplest way — is that it does not change.

> *Proposition 16E*
> *The composition of the Earth’s solid substance is more or less uniform from the centre to the surface*

Of course this Proposition does not apply to the Domainosphere, the outer layer of the Earth where, as we have seen, the interaction of domains has led to segregation of components. This segregation has occurred directly, through domain rubbing and natural zone-refining (Propositions 14C, 14D). It has occurred indirectly, through domain uplift or land exposure, by erosion and leaching of rock components. And it has occurred biologically, through the action of life, as in the formation of fossil fuels.

What the Proposition suggests is that the *primeval* composition of the Earth’s solid material was uniform. Only in the Domainosphere, the top 500*km* or so where domainographic processes are active, has this uniformity of composition been disturbed.

But hold on a minute — what about the Sial and the Sima layers, described at the start of Chapter 9, which are known to differ in chemical composition? Let us look more closely at these.

The Sial and the Sima

The Sial is the lighter layer of rock (density 2.7) which forms the majority of the Earth’s continents. It is discontinuous, up to about 30*km* thick below the continents, but grading away to nothing at their edge. The Sima is slightly denser (2.9), is exposed at the deeper ocean beds, and is believed to underlie the Sial where the latter exists. The situation, as conventionally accepted, was illustrated in Figure 9.1.

Table 16. Percentage oxide composition of Sial and Sima

	Silicon SiO_2	Aluminium Al_2O_3	Iron Fe_2O_3+FeO	Calcium CaO	Magnesium MgO	Other —
SIAL	69	14	4	—	—	13
SIMA	48	15	11	11	9	6

Both layers consist essentially of igneous rocks, although of course both may be overlaid by sedimentary or metamorphic ones. These rocks are not of a fixed composition, but both are basically made up of metal silicates — compounds of silicon and oxygen with various metals. Where the two differ is in their respective contents of the metals.

It is conventional to represent the compositions in terms of the oxides of the elements. Table 16 (based on [Physical, 1977]) shows the approximate percentage compositions of the Sima and the Sial in this form.

It should be noted that these are average compositions. Most igneous rocks fall fairly easily into one group or the other, but it is possible to find examples which grade from one type into the other.

The main differences are that the Sial has much more silica, less iron, and almost none of the calcium and magnesium of the Sima. Iron and calcium are considerably heavier than silicon, and the higher proportion of these in the Sima accounts for its higher density.

The conventional view is that the Sial, being lighter, floated out and condensed first in the early days of the Earth, when it was all molten. Conventionally, also, the heat which currently flows out of the Earth was believed to come, at least in part, from this 'primeval' heat. I have already suggested (Proposition 9F) that the idea that the Earth now has a hot core is wrong. I have also suggested (Proposition 8E) that igneous rocks are all produced locally, from domain rubbing, and do not well up from deep inside the Earth.

If we put all these points together, we end up with a scenario very different to the conventional one. This leads to a number of important propositions, the first of which concerns the Sial and the Sima. It seems likely that the Sial was never formed separately to the Sima, but instead represents only worked-over and re-melted Sima.

> *Proposition 16F*
> *The acidic igneous rocks classed as Sial have been derived by the re-melting of worked-over and leached basic Sima rocks*

This Proposition explains the occurrence of the iron-rich ore beds formed in the early, Precambrian era, and the calcium- and magnesium-rich deposits (limestones) of the Paleozoic and later eras. It also explains the silica-rich deposits (sands and sandstones) of all ages. The implication is that the Sima is the 'primeval' rock, which, as already suggested, extends throughout the Earth.

> *Proposition 16G*
> *Rock of 'Sima-type' composition has extended throughout the Earth since it was first formed, and has only been modified near to the surface by domainographic processes*

An implication of this (which can be tested) is that the average composition of all rocks, sedimentary, metamorphic, and igneous, in the upper layers above the Sima, should when summed together be identical to that of the Sima (after allowing for the mainly atmosphere-derived components such as carbon).

Heat and the Earth

If we do not need the inner Earth to be molten to explain such things as floating tectonic plates, heat rising to the surface, or segregation of the Sial or other layers, then we might as well assume that it never was molten.

> *Proposition 16H*
> *The Earth was never molten*

Instead, in the absence of a better story, we can take it that the primeval Earth accumulated at a temperature not too different to now. After all, if the Earth condensed from part of a solar-system wide disc of gas, as one proposal has it, there is no need to assume this gas was hot. Even if the Earth was formed from material thrown out from the hot Sun, this material could radiate heat freely, and need not still be hot by the time it reached Earth's orbit. If the material was very fine, close to the molecular level, the concept 'heat' in fact means nothing; heat is a measure of the interaction of particles close enough to interact.

The same reasoning applies also to the other planets of the Solar System.

Composition of the Other Planets

In Table 15, values were given for the densities of the planets and major moons of the Solar System. There are some conclusions to be drawn from these densities.

The density values given for the Outer Planets and most of their moons are irrelevant, because those values include unknown proportions of atmospheric components, whether as gas, liquid, or solid. The only values we can use here are for the large bodies with known rocky surfaces, that is, the four Inner Planets and our own Moon.

In order of decreasing size of planet, these values are: Earth - 5.50; Venus - 5.25; Mars - 3.91; Mercury - 5.41; and Moon - 3.35. There is a clear progression here, with the smaller bodies having lower densities — the only hiccup is with Mercury. Notice also that as the bodies get smaller, their densities approach those of the upper few hundred kilometres of Earth, 2.7-3.3 (see Figure 9.1).

It seems worth examining the proposition that all the rocky planets, and probably the rocky cores of the giant planets, are made up of Sima-type material like Earth, which material shows the same compression and increase in density with depth as on Earth.

> *Proposition 16I*
> *All the Solar System planets and major moons have rocky centres made up of the same Sima-type material as Earth, subject to the same increase in density with depth*

The situation is best illustrated by noting the radius of the planet or moon and imagining it superimposed on the higher layers of the Earth shown in Figure 9.1, with the surfaces matching. Thus our Moon, with a radius of 1738*km*, would extend down to halfway down the Lower Mantle, with a density at its centre of between 4.3 and 5.5, and one at its surface of around 2.7. The fit with the actual average density of 3.34 is really quite good, particularly when you allow for the fact that more of a sphere's volume is closer to its surface than its centre (seven-eighths is above the half-radius mark, only one-eighth below).

Mars, with a radius of 3393*km*, would extend on Fig. 9.1 some way into the Outer Core, with a small part of its volume having a density of 10.0-12.3. Again this looks as if it fits in quite well with an average density of 3.95. Probably this area would benefit from detailed and careful calculations.

As to the apparent Mercury hiccup, which causes it to vary from the pattern, there are a number of possibilities. One is that there are exceptional circumstances with Mercury which cause it to vary from the pattern This may well be the case, although I cannot think of any reasons at the moment.

Another possibility is that there may be errors in the quoted figures. For example, in the case of Mercury, the mass may be somewhat in error. Usually planetary masses are calculated, with good accuracy, from observations of the orbits of their moons. Mercury does not have a moon, and it is also so close to the Sun it is difficult to make good observations. The mass may therefore be in error; earlier figures havein fact suggested that its mass was higher, with a density more than that of Earth. From the general sequence, we would expect Mercury to have a density of about 3.6. Time will tell what the real position is.

At least at the moment, the evidence available favours the suggestion in Proposition 16I. If, in fact, the rocky components of all the planets are made up of very similar material, it also seems likely that all the planets were formed in the same event and at the same time.

> *Proposition 16J*
> *All the Solar System planets were formed in the same event and at the same time*

Before leaving this area, we should look more closely at the phase changes in the Sima material, and their role in planetary expansion.

Sima Phase Changes and Expansion

In Figure 9.1, the values shown for the density of the Earth's substance vary from 2.7 at the surface to 13.6 at the core. There are a number of abrupt changes or discontinuities, the biggest being at the Mantle/Core boundary, where the density leaps from 5.5 to 10.0.

Is it possible to compress rock with a 'natural' density of around 2.9 to one of 10.0 or more? The answer is yes, if the pressures are great enough. There may be two quite different stages in this compression.

Many substances will alter to denser phases, when high pressures are applied, by rearrangement of their crystal lattice structures. For example, of the two main forms of the element carbon, the normal-pressure one is graphite, which has a density of 2.25. All the atoms are packed in flat sheets, with some separation beween the sheets. These sheets give graphite

its ability to slip and lubricate, and also its ability to conduct electricity.

On the other hand, diamond is a 'frozen' high-pressure form of carbon. Its density is 3.52, more than 50% higher than graphite, and its atoms are all interlocked in a compact, three-dimensional construction. This structure gives diamond its great hardness.

We can number the Sima phases from I to V downwards from the surface, with I being the crustal phase, II and III the upper and lower Mantle, and IV and V the outer and inner Core. It seems possible that the densities for phases I-III, up to 5.5, could be achieved by appropriate crystal lattice structure rearrangements. But the leap to 10.0 looks less possible.

However, under very great pressures, matter can be compressed to an enormous degree, not by lattice rearrangements, but by actually crushing down the atoms themselves. Material crushed in this manner is called 'degenerate matter', and its density may be truly enormous. The example usually quoted is that of degenerate matter in the heart of 'black dwarf' stars, where one matchbox full would weigh more than our Earth.

A possible explanation for the high density of the phase IV and V Sima is that it consists of the lowest grades of degenerate matter.

> *Proposition 16K*
> *At the Mantle/Core boundary, phase III normal-matter Sima changes to phase IV degenerate-matter Sima*

This Proposition is not in conflict with an observed feature of the Mantle/Core boundary. Below this boundary, in the upper Core, earthquake waves behave similarly to what they do in liquid, while above it they do not. For this reason, the outer Core has been assumed to be liquid in the past. It now seems quite possible that this liquid-mimicking behaviour is a feature of phase IV degenerate matter. Certainly, at the enormous pressures involved, the normal concepts associated with 'liquid' and 'solid' begin to lose meaning.

It is worth pointing out that if the Earth once had half its current radius, for the same mass, its density would average eight times as much — that is the ratio of the two volumes of the current and unexpanded spheres. This density, around 44.16 instead of the current 5.52, would have to involve the use of degenerate matter. It is far higher than the density of the the most compact normal substances known, the densest element being osmium, at 22.59.

It is also now clear that the mechanism for planetary expansion involves changes in the planet's inner phases, progressively from denser to less dense forms.

> *Proposition 16L*
> *Planetary expansion occurs via the conversion of higher-density Sima phases into lower-density ones*

In some senses this is another way of looking at Proposition 9E, on the change in position of density discontinuities with pressure. It provides a mechanism for planetary expansion, but not a reason. For that, we must look at the next section.

Part 3 — Gravity Rules, OK?

Heating in the Earth

In Chapter 9 we looked at the question of the heat which flows from the Earth, and concluded (Proposition 9G) that it was mainly derived from the frictional heat of domain rubbing. We will now look at this area again, a bit more closely.

Proposition 9G is all right as it stands, but it does not explain everything. Heat flows up from beneath the Earth's surface even in places where the domains are not apparently active, where it is tectonically quiet. Of course the average sub-ground temperatures are higher in places where the domains are currently shifting — in fact close studies of these temperatures would be a good way to trace domain boundaries — but we still need a mechanism for the spread of the frictional heat throughout the rest of the Earth's surface.

This mechanism is to be found in earthquake waves. We already know that these travel throughout the body of the Earth — our knowledge of the Earth's interior is based on a sudy of these waves. And we have seen, in Chapter 14, that around a million earthquakes occur on our planet each year. This number is fairly arbitrary; if we took into account weaker and weaker earth-twitches, the number would be two, ten, or a hundred million.

It seems obvious that it is these vibrational waves which carry the heat energy derived from domainographic processes throughout the Earth.

> *Proposition 16M*
> *Heat derived from domain movements in the Domainosphere is distributed around the Earth by earthquake waves*

Heat is itself a form of vibrational energy, so the transfer of this energy from the earthquake waves would be quite normal. Where, in the Earth's upper layers, is the energy originally produced? This must be in the area of active domains, in what I have called the Domainosphere. This is the same as the area in which earthquakes are active, from the surface down to about 700*km* below.

Here is another area where the current treatment gives an improved explanation of observed facts. In the old tectonic-plate idea, these plates were assumed to be about 100*km* thick, and floating at this depth on a mushy or semi-liquid layer called the Aesthenosphere (Fig. 9.1). Movement of these plates has been suggested as the cause of shallower earthquakes, but till now there has been no accepted cause of origin for the deeper ones.

As the Earth expands, the effects will be most apparent near to the surface, where most of the volume lies. Setting the Domainosphere to 700*km* deep is arbitrary, that is just the level where domainographic activities have faded away close to nothing.

We can, however, try to identify a band in the Domainosphere where activity, and hence temperature, is highest. We have good information on the depths and strengths of larger earthquakes which have occurred over many years. If we assume as a first approximation that the Domainosphere's maximum activity band lies at the same depth over the whole Earth, its position can be found by summing together the energies of these earthquakes at the different depths, and seeing where the energy level is highest.

> *Proposition 16N*
> *The Domainosphere has a maximum activity band, with a position derivable from measurements of earthquake depths and energies*

It seems that the position of this band must be more than 10*km* down, because measured temperatures from oilwells increase to this sort of depth. Presumably underneath the band, and right down to the centre of the Earth, the temperature should be fairly uniform and close to that of the activity band — there is nowhere for the heat to escape to — at least in parts where the concept of temperature still has meaning.

Ultimately, all the domainographic energy stems from gravitational forces. A simple mind model of Earth Expansion is that the crust splits apart under the expansionist forces and top material falls down the split to fill it, with the potential energy given up by the falling material providing the source of heat. However, there are other models, for processes which are not quite as simple. We will pass on now to one of these.

The Moon Masseur

In Chapter 15 we looked at the Earth-Moon system, and saw that the double-planet situation which existed or was approached there may have led to the loss of much atmosphere (Proposition 15D). This close coupling between our planet and our moon has a further implication.

We saw that the centre of gravity of the system formed by our planet and its moon lies some 1400*km* below the surface, or around 5000*km* above the actual centre, of the Earth. Now this point is obviously not fixed in the Earth. Instead, it moves around the Earth as the planet rotates, staying always on the line joining the centres of gravity of the two bodies.

The gravitational attraction of the Moon has a very noticeable effect on our lives. Together with the attraction of the Sun, it controls the tides. The Moon is both much closer to the Earth and much lighter than the Sun, and the outcome of these two opposing influences is that the Moon has a little more than twice the effect of the Sun on tides. Tides have greatly influenced biological matters on Earth, as well as physical ones, and have set 'biological clocks' which are still ticking millions of years later, as in the menstrual periods of women.

There is a lot of energy in tidal movements, and commercial tide-power stations have been built in some parts of the world. Ultimately this energy is mostly derived from the rotational energy of the Earth, which is tending to slow down to present the same face to the Moon, as the Moon now does to the Earth.

Tidal energy, like most forms of energy, ends up as heat, so one effect of the tides is to heat up the oceans. But there are other tides. One is the tide of the atmosphere, the reason why weather patterns tend to move from west to east, and this also must result in some heating of the atmosphere.

But a far greater tide is the tide of the solid Earth. Every day, the Earth-Moon centre of gravity travels more than 30,000*km* round inside the Earth, at that depth of 1400*km* below the surface. The gravitational forces act like a giant fist, massaging the ball of the Earth. Because the solid Earth is hugely more massive than its oceans or atmosphere, even a small effect will release a lot of energy from this massage, and this energy will also appear as heat.

> *Proposition 16O*
> *The Earth is being continually heated up by gravitational massage exerted on its mass by the Moon*

It should be possible to calculate the amount of heat released in this way. It may or may not be significant compared to the energy released by Earth expansion. However, the forces involved are by no means minor, we know that they have been able to stop the rotations of planets and moons in their tracks.

As far as the Earth is concerned, the heating happens because its rotating gravitational system with the Moon is 'lopsided'. This point is true for when the rest of the Universe is considered, too.

The Lopsided Universe

As already mentioned, the Sun also has an effect on tidal processes in the Earth, if a lesser one than that due to the moon. As the Earth rotates each day, the Sun attempts to raise tides, not only in the seas and the atmosphere, but also in the solid Earth. The straining of the Earth's inner substance towards the direction of the Sun may be very small, but will still add up, and again contribute to 'tidal heating'.

Gravity reaches right throughout the Universe. As the Solar System is not at the centre of our local galaxy, but out towards the rim, the sum of the gravitational pulls of all the stars in this galaxy will also be lopsided, and have its effect on the Earth. The effect may be extremely tiny, but even so, over periods of billions of years, it may produce a measurable result.

Killed by an Apple

Another matter which will be affected by changes in the Earth's radius is its surface gravity. If the Earth had half its present radius but still the same mass, the gravitational force at its surface would be about four times as great as it is now, other things being equal. This is because gravitational forces decrease as the square of the distance.

A variation of this sort would have many effects on the Earth, for example erosion would be more active, stable mountain slopes would not be as steep (that is why Mars has a mountain twice as high as Earth, its surface gravity is lower), and taller plants and animals would be less feasible. Against this, the atmosphere would be drawn in closer to the surface, making it much denser and able to buoy up tall plants. Here is a further reason for assuming a much denser atmosphere on the early Earth.

According to legend, Isaac Newton first developed the theory of gravitation when he thought about what had caused an apple on a tree he was sitting under to fall on his head. If

gravity was four times higher, he might not have been in any condition to think afterwards.

When the rule for the variation of gravity with distance was mentioned above, the rider 'other things being equal' was added. It is possible that they weren't equal.

The Gravitational Constant and the Nuclear Strong Force

Just over 50 years ago, the Nobel Prize-winning physicist P.A.M. Dirac published a paper [Dirac, 1938] which suggested a number of basic relationships existed between the fundamental physical constants of the Universe. In particular, he suggested that these 'constants' were not actually fixed, but varied with the age of the Universe. Among these constants was included the gravitational constant, G, which defines the amount of gravitational attraction between two bodies of given mass and separation.

The effect of Dirac's Proposition was that G was decreasing in size with time, and so the gravitational forces holding together a body such as the Earth were also decreasing as time went on. Dirac was active at a time when the currently-accepted ideas of an expanding Universe were being worked out. Whether the relationships and numbers suggested by Dirac are 'true' or not, it does seem at least feasible that, in a Universe held together by gravity, the fundamental forces of gravity might alter as the Universe expanded.

Variation in the gravitational constant would also have many other effects, for example the planets would be expected to move out further from the Sun under weaker gravity. This would make them receive much less radiation from the Sun, unless there was some compensating effect, and get much colder. I know of no evidence to support such an occurrence.

Another, possibly more likely, cause concerns the Nuclear Strong Force, or some other force responsible for holding atoms together. A reduction in the strength of one of these forces, which are of relatively recent discovery and were not known when Dirac was active, might cause atoms to expand in average size. This need have no connection with gravity, and could explain planetary expansion without any changes in planetary orbits.

Here then is a possible root cause for the expansion observed in the Earth and our neighbouring planets.

> *Proposition 16P*
> *Planetary expansion has occurred because the nuclear forces acting between the components of the planet have become weaker as time progressed*

Of course, making such a bold assumption as that the fundamental constants of the Universe may vary with time really is opening a huge can of worms. So much of modern science depends on the assumption that some things really are permanently fixed. Once one starts questioning whether the rate of decay of a given radioactive substance, or the speed of light in a vacuum, or the rate of progression of time, are fixed quantities, the resulting chaos is more one of philosophy than of science. We will not venture further into these heavily mined areas, but instead will now sit back and review the ground already covered.

CHAPTER 17

LOOKING BACK: THE FINAL SYNTHESIS

Entia non sunt multiplicanda praeter necessitatem (Don't make a Big Deal out of it)
— William of Occam (died 1347)

And so, at the end of a long and perhaps tortuous journey, we look back down on the landscape travelled through, and try and view it as a whole. This may be difficult; the ground we have covered has been very diverse.

A possible criticism of this book is that it is too discursive, too rambling, covering too many unconnected topics. I would have to accept, with Propositions ranging everywhere from control of weeds to changes in the constants of the Universe, that the matters dealt with have been exceptionally varied. But that is the nature of the beast.

This book is a work of synthesis. At the head of Chapter 7, I quoted Sharr's call for us to move from an Age of Analysis to an Age of Synthesis. I have heeded this call, and this book is the result.

The essence of synthesis is that it draws from a number of disparate areas. In doing this, I have not hesitated to use written and other sources of every nature, whether learned periodicals, popular encyclopedias, newspaper articles, phone calls to local companies, television programmes, or science fiction magazines. Everything is grist to the mill, and that includes one thing especially — personal observation of what is going on in the world.

It may be appropriate for a work of analysis to be erected purely on carefully verified results published in refereed professional journals, but synthesis requires a wider range. Most important of all, it must not just put facts and opinions from different areas together, it must question the underlying, unquestioned, and even unrealized assumptions propping up those analytical edifices.

In this final chapter I will summarize what has gone before, in three parts. The first will deal with the physical nature of the Earth, and the second with its biological nature. These are the two great branches of the 'hard sciences', and cover the bulk of the material in this book.

The third part covers the interaction of Man and other intelligences with the first two parts, falling into the branch of 'soft' or social sciences. Some of the Propositions I have put forward may cause a degree of upheaval in the hard sciences, and it is a purpose of this book to do so. Not for the sake of upheaval in itself, but because we should always examine new propositions in the hard sciences, with a critical but unbiased approach, and let them stand or fall on their merits.

If the technique of synthesis works in the hard sciences, one may ask whether it will work also in the soft ones. I believe it could. While there are many fallacies and false assumptions rife in the hard sciences, there are probably far more in the soft ones. In the third part I will put a toe into the shark-packed sea of economics, politics, law, and psychology, but no more than a toe — any more would need a book of its own.

In what follows, to save repeating cautions at every stage, it will be assumed that the Propositions referred to at any given point are 'true'. All are, in fact, only working hypotheses to be picked apart, and it would be astonishing if all were accepted. But this is a case where the reader can decide.

Many scientific theories need a specialist knowledge of the field in order for them to be judged; the ones presented here do not. This book does not contain a single equation or complex formula; any intelligent reader can decide for themselves whether the Propositions I have put forward make sense or not. The synthesis has been built on a broad foundation of the sort of information available in any public library, and is not hard to check. Here goes.

SUMMARY 1
What's Happening: The Physical Earth

We have seen that the Earth has been in a state of continual flux ever since it first existed. Formed from a mass of material at the same time as the rest of the planets of the Solar System, that material separated into three parts — solid, liquid, and gas.

The solid Earth has remained uniform and unchanged in composition except at its surface, but has been subject to regular expansion, which has caused at least a doubling in its radius. This expansion has been a basic factor in the changes which have occurred on the Earth's surface and above and below this surface.

The Atmosphere

The atmosphere has been subjected to complete reworking during the Earth's history. Most of its original hydrogen was lost into space, only that combined with other elements being retained. The early atmosphere included no free oxygen, but did include large amounts of the carbon-containing gases methane and carbon dioxide. Almost all of these have since been withdrawn from the atmosphere to make organic-based fossil fuel rocks or carbonate rocks, mostly in two great sequences of deposition.

The early atmosphere was much denser than the modern one, resulting in much more humid and more uniform conditions over the whole Earth. The surface may have been shielded from space by a thick permanent cloud cover until around the beginning of the Cenozoic.

The Oceans

Oceans have existed since the early history of the Earth, but their nature and extent has altered considerably. Most of their water has been derived from the rocks under the surface, and has been continually released by domainographic processes. This water has more than replaced the water lost to space.

Originally, in the early days of limited expansion and a smaller Earth, the waters covered most of the Earth and substantial land did not emerge until the Paleozoic. Sea areas were relatively shallow and modern deep ocean beds did not begin to be formed until the Mesozoic.

The early seas contained fresher water than modern ones. While water has been released from the rocks exposed as expansion has proceeded, this release has not quite been enough to keep pace with filling the new low areas formed, and hence both the total area and the proportional area of land to sea on the planet have increased with time.

Domainographic processes have continually raised and lowered individual areas of the surface, and current sea-land boundaries have no relationship with those in the past. All the modern deep ocean beds are new surface, while most current land and continental-shelf areas consist of much older surface.

The Land

The Earth's current land surfaces are all remnant 'mesas' of older surface. As the Earth has expanded, creating first the continental shelves and then the modern deep ocean beds, these mesas have become separated in the expansion.

The whole of the upper 700*km* or so of the Earth's surface, the Domainosphere, consists of a complex aggregate of lumps of rock of every size, from close to subcontinental size downwards. These 'domains' exist with varying thicknesses and at varying levels from the surface down, similar to a drystone wall.

Continuing expansion has resulted in continual movement and fracture of these domains. The heat generated by these movements is the principal source of the Earth's heat. This heat is responsible for the local formation of igneous rocks, for volcanoes, and for all 'geothermal' processes.

Domains are also subject to movement away from the equator in an effort to conserve momentum on an expanding Earth. This domain flight is most marked with smaller domains, but it is modified by blocking with other domains and by the gravitational attraction of nearby large domain aggregates.

Domain movements and adjustments, recognized as earthquakes, are responsible for the formation of mountains of two main types. 'Fat' mountains are formed by impact between domains. 'Long' mountains are formed by rubbing domains, which slide against each other's edges.

The energy released by domain movements is distributed throughout the Earth by earthquake waves, and eventually ends up as heat. Temperatures inside the Earth do not increase continuously as the core is approached, but only up to the 'maximum activity band' in the Domainosphere, the level where domainographic processes are most active. The Earth is also subject to gravitational massage by the Moon and other parts of the Universe, which also releases energy which ends up as heat.

The Surface of the Land

The original composition of the rocks at the Earth's surface was the same as that throughout the Earth. Forces of erosion and chemical and biological change have redistributed and sorted this surface material to create differentiated rocks and mineral ores, some of which include material withdrawn from the atmosphere.

These differentiating forces have 'leached' certain of the heavier metals from the original

upper-level rocks, and some of these rocks have been reworked by domainographic processes to give Sial-type igneous rocks. Domain movements have also been responsible for the creation of precious-metal and gemstone ores through natural 'zone-refining' processes.

Summary 2
What's Happening: The Living Earth

As with the physical Earth, the complex of living creatures and their interactions with the Earth which we call the Biosphere has been in a state of continual flux ever since life first evolved. Life itself has been responsible for major changes in the physical conditions on our planet. It has been responsible for the development of the free-oxygen atmosphere upon which all higher life depends. It has withdrawn much of the carbon from the atmosphere, and deposited quite a lot of it in the rocks as fossil fuels and shell beds.

The pace of change as regards individual species has been enormously faster than generally recognized, with a continual turnover and change such that species half-lives are only of the order of one million years. The 'isocon envelopes' or ecological-condition niche boundaries within which individual species live are being continually shifted as a result of domainographic processes. These shifts have promoted the rapid changes in species.

The Isocons

On the other hand, the rates of natural spread of species have been far slower than usually assumed, averaging not more than one metre per year. In most cases, natural extension of the isocons has been limited by physical boundaries such as the change from land to sea.

Isocon boundaries frequently coincide with domain edges, as the physical changes associated with the edges are often the strongest factors in setting the limits to the associated ecological-conditions niche. Movement of domains has therefore often caused movement of isocon envelopes, and hence an apparent 'spread' of a species. Usually the apparent spread caused by domain movement has far exceeded the 'natural' spread caused by seed dispersion processes.

This feature has been particularly the case in more recent geological history, during the Cenozoic, when the increasing proportion of sea on the surface of the Earth has meant that land domains have become increasingly isolated. It has also become more important as the Earth has expanded and increased its surface, allowing more scope for greater domain flight as blocking factors decrease.

Fragmentation of the land in this way, plus a decrease in the uniformity of climatic conditions because of atmospheric changes, has led to a great increase in the number and range of available isocon envelopes. This is turn has resulted in a large increase in the number of extant species at any given time during the Cenozoic, especially on land.

Biological Dependence of Isocons

While the positions of isocon envelopes are strongly dependent on physical conditions, they are also dependent on biological ones, on other forms of life. This is demonstrated most clearly in the animal kingdom. Animals are dependent on plant-controlled aspects of their environment to a much greater extent than plants are dependent on animals.

The two major control aspects are food and habitat. The majority of animals eat plants as their major food source. Those that do not, the carnivores, are only one or possibly two steps away — their prey is usually a herbivore. Obviously a herbivore isocon must be contained within the isocons of plant species providing suitable food for the herbivore species.

Like plants, animal species have become adapted to the physical conditions of their isocons, but often these physical conditions are themselves strongly modified by plants. Many jungle animals could not survive in the open plains without trees, while a plains-adapted animal such as the bison could not survive in the jungle.

There is also a reverse dependence, but a less obvious one. It is not usually one of nutrition — although some plant species are dependent on animal droppings for this — but more often one of reproduction and of species continuance.

In particular, many plant species are dependent on insects or other animal vectors for pollination, and of course without pollination, there are no more seeds and the species may die out. Some flowers are utterly dependent for pollination on a single animal species, for example a moth with an especially long tongue, or a bird with a very long, thin beak. The incredible variety and complexity of plant-animal interactions in pollination is well covered in Bristow [1978].

The Birds and the Bees — and the Cassowaries

The development of pollination mechanisms is a fascinating and complex study which can yield inferences about the general history of the Earth. The flower-insect mechanism with which we are most familiar is of middle age, and developed largely during the earlier part of the Cenozoic.

Earlier plants, especially the more lowly ones, were usually dependent on pollen transportation by localised, non-animal means, such as in drops of water falling from leaves and splashing. Later plants developed the use of wind for pollination, and this mechanism is mostly restricted to the more recently-evolved species. It does suggest that winds of the type we now regard as normal were not common in the earlier days of the Earth.

Generally speaking, domains with a preponderance of insect-pollinated flowering plants among their flora became separated during the Cenozoic. This is true of Australia, which has the largest flowering plants of the world in its eucalypts, and which possesses an exceptionally rich flora of this type.

On the other hand, the great grasslands of the world, and their cereal derivatives such as wheat and rice, are more typical of the great Laurasian continents of the Northern Hemisphere. The same is true of the great pine forests of the world. Both these ‘mega-isocon envelopes’ are representative of wind-pollinated species.

Animals are also very important in the dispersal of the seeds of plants, especially plants which we regard as fruit or nut producers. In fact, the most common reason why plants have evolved to yield attractive edible fruits or nuts is so that they can take advantage of seed

dispersal by animals.

As with pollination, each fruit species distributed by animals has a target group which it relies on for this purpose, and the nature of the target group determines the nature of the fruit. Small fruits, especially berries, ‘expect’ to be distributed by birds. They have evolved to be small enough for birds to handle, and usually have tiny seeds which ‘expect’ to pass through the bird unharmed and be deposited in the fertilizer-pack bird droppings.

Larger fruits and nuts depend on larger animals. Sapucaia nuts, from South America, are produced in huge ready-made pots with lids (Figure 17.1); they are distributed by monkeys, who grab handfuls of nuts from the pots, and invariably lose some as they move back to base. Oak forests are partly regenerated from the acorn caches of squirrels, buried or hidden near the ground and then forgotten.

Fruits with large seeds depend on large animals for their distribution, especially if the seed is likely to be passed whole through the animal’s digestive tract. Elephants are noted fruit lovers, devouring the sweet marula fruits of southern Africa, and voiding the large edible nuts. Gorillas are also noted fruit eaters. In Australia, the attractive red quandong fruits have round stones which pass easily through the emu — that is one recommended germination method! And the huge Davidson plum of the Queensland rainforests (*Davidsonia pruriens*) is believed distributed by cassowaries.

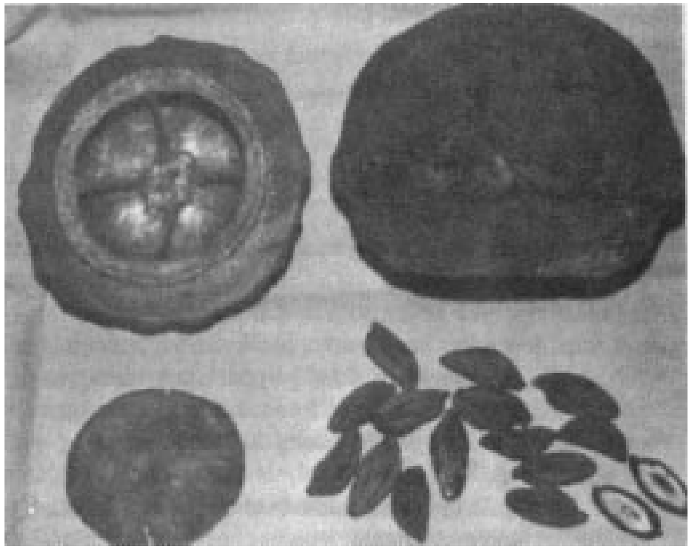

Fig. 17.1. Sapucaia pots and nuts (Lecythis species)

There are some deductions to be made here. Most of the large fruit-loving animals are of Gondwanan origin. This is probably because most of the tropics are also Gondwanan, and it is these areas which provide the dense tree cover which is optimum to support communities of large animals. Hence large fruits evolved mostly in Gondwanaland, where they could find distributing animals. This appears to be the reason why the Asimina is the largest native fruit in North America (Chapter 7); it is a Gondwanan migrant.

Of course, as well as plants being dependent on animals, and animals on plants, species in each of these groups are also dependent on other species within the group. The more complicated the ecology, the greater the number of species interacting — we are only at the earliest stages of beginning to understand all the interconnecting factors, all the overlapping isocons.

Another deduction concerns the establishment or introduction of a 'new' crop — one which is not native to the area of cultivation. All too often, the crop is considered in isolation, without regard to the complex of other-species isocons which it needs for good growth and ability to survive in the presence of pests. Elsewhere [Noël, 1988] I have dealt with this area in more detail. In the present context, it will be apparent that the need to move other, 'symbiotic' isocons at the same time is a basic reason for the slow natural spread of plants (Proposition 2A).

So far we have looked at the effect on the isocons of physical factors, such as domain movement, and of biological factors, such as food cycles and pollination and seed dispersal mechanisms. Now we move on to the last and most complicated group of factors — those based on intelligence.

Summary 3
What's Happening: The Intelligent Earth

We have seen that the physical changes in the Earth represented by domainographic processes have had a very strong influence on the isocons, the ecological-niche boundaries of living creatures. We have also seen that these isocons are also very much interrelated, with one species dependent upon many others. So the biological influence is also large.

We have also seen that these physical and biological influences have been hugely overshadowed, negated, or made irrelevant by the third great factor — the actions of man. These actions have changed the face of the Earth beyond recognition, in many cases wreaking great devastation. In the final analysis, the physical and biological factors have stood by helpless, or been swept aside, in the face of the intelligence factor.

Using his power of thought, Man has become master of the planet. But it cannot be said that this mastery has been a very benevolent one, as each day passes the planet moves closer to self-destruction; with increasing power has come the ability to inflict greater and greater harm. But there is increasing hope, hope that the species *Homo sapiens* is maturing. This is not a physical or a biological maturing, but one of the mind. And so we stand today in the Age of Decision, within which the race will stand or fall, and with it the Earth.

Man and the Environment

Evidence already given in this book has shown how Man has caused huge changes in the environment ever since he evolved as an intelligent being. We are accustomed to the idea that modern technological civilization has caused such changes, but the idea that these changes began perhaps 100,000 years ago may be something of a jolt.

Of course these early changes were not intended — most of the harmful changes in the environment made by Man have been quite unintentional — but they have been nonetheless profound. It seems that our huge deserts and vast savannahs and grasslands were actually

caused by Man's actions. It is lucky that that the great mutability of species has allowed plants and animals to rapidly evolve and partially adapt to and compensate for these changes.

Degradation or elimination of habitat is the most obvious sign of environmental decline — the forests are changed into fields, the forest-based isocons vanish, and with them their associated species. Other changes are less obvious, but no less destructive in the long term. Quandongs still grow throughout Western Australia, but their distribution agent, the emu, is banished to the back blocks. Will the quandong survive? Will the Davidson Plum survive in Queensland, even in its preserved rainforest environment, once tourist pressures restrict the movement of cassowaries, or cause their numbers to tail off altogether?

Ironically enough, this degradation of the land had as its basic cause the urge to make the land fruitful, through the development of agriculture. Of the three great branches of agriculture, two of them, stock raising and field crops, are very often destructive of the environment. They need not be, but they both require careful monitoring and holding back if the damage is to be avoided. And even when farmers are aware of this, economic competition and the realities of the marketplace — and, ultimately, land degradation itself — often force their hand or force them, or their children, off the land.

Trees and the Environment

Only the third great branch of agriculture, that of tree cropping, is essentially beneficial to the environment. As I have described elsewhere [Noël, 1985b], this can be explained logically and reasonably in terms of the efficiencies of the different approaches in the use of light, land, water, and people. There are also some philosophical grounds.

Trees — and this word is used here to mean the whole class of perennial woody plants — are by their nature equalizers. They have evolved to live through all the seasons and through all the cycles of years, through years of high rainfall and drought, through hot years and cold. When the grass is gone, the cattleman may need to move his stock to other pastures, but the trees withstand. When the rains do not come, the wheat farmer will not plant, but the trees grow on. They smooth the benefits of land use out through the years, trimming off the peaks and using them to fill the troughs. They are essential for sustainable, long-term agriculture.

Such agriculture should not be based on trees alone, but on a thoughtfully integrated combination of tree crops, field crops, and stock raising, a sort of planned synthetic ecology. People whose traditions stem from Europe are accustomed to the idea that their food comes from the wheatfields and the cattle pastures, and need to look back before the two centuries of industrial development to realize how important tree crops were to their ancestors. In these two centuries, a huge hole developed in their tradition of land use, a hole which was largely filled by importation of goods from other 'less-developed' countries.

In some of these 'less-developed' countries, the traditional tree-based economies have disappeared under the influence of western ideas, in others they have hung on and may well prove to be the superior system in the end. When examined closely, an 'unsophisticated' swidden or slash-and-burn system such as that used in New Guinea is revealed to have astonishing complexity, subtlety, efficiency, and durability — no wonder it has been used with success for more than a thousand years.

Such systems are good ‘natural’ examples of integrated tree-field-animal ecologies in which man participates as a vital fourth factor. We are only just beginning to appreciate the interlocking of the isocons and microecologies involved. In another place [Noël, 1988], I have tried to show how biennial bearing in fruit trees can be explained by study of just such a system, involving the wild pigs, nut trees, and people of Borneo. It is vital that we attain not just a knowledge, but also an understanding, of the workings of such systems if life on our planet is to continue.

The Greenhouse Effect — Reality or Hoax?

The Greenhouse effect is currently a matter of worldwide public concern. The fact that people everywhere are now vitally concerned with matters such as this is a very desirable thing. But I will attempt to show that our knowledge of this matter is limited, our understanding is very small, our proposals are timid and restrained, and our concern is misplaced. The current near-panic has all the hallmarks of a ‘manufactured’ crisis.

> *Proposition 17A*
> *Concern over the ‘Greenhouse Effect’ is misplaced, and represents a ‘manufactured’ crisis*

What are the facts behind the Greenhouse Effect? The main feature is that the amount of carbon dioxide in the Earth’s atmosphere has increased over the last two hundred years or so, almost certainly as a result of industrial and agricultural activities, and appears to be increasing still. In fact, it appears to be as high now as it has ever been in the last 100,000 years or so. More recently the concentrations of the natural gases methane and nitrous oxide, and of manufactured gases called chlorofluorocarbons, have also increased. That is pretty well the extent of the facts.

The carbon dioxide data is mostly derived from studies of the composition of air bubbles trapped in glaciers of different ages, and I would not argue with these results. It is the conclusions and deductions made from the data which should be questioned.

Some dire predictions have certainly been made about the effects of the Effect. Foremost among these is that the increasing level of carbon dioxide in the atmosphere will trap more of the Earth’s heat (whether generated here or received from the Sun), causing world-wide increases in temperature. This will lead to partial melting of the polar icecaps, and hence increases in sealevels and flooding of coastal areas. Widespread changes in weather patterns have also been predicted, sometimes with increased frequency of storms.

Proposed actions to counteract these predicted bad effects have ranged from the sensible down to the trivial and ludicrous. Sensible ones have included the widespread planting of more trees, to tie up more of the carbon dioxide in the atmosphere — we have seen that that is a good idea anyway, from both environmental and economic viewpoints.

Trivial recommendations I have seen in print include such gems as “switch off lights when not in use”. Perhaps the most ludicrous one, stemming from the W.A. Greenhouse ’88 Conference supported by our State Government, was to “Identity and proscribe Greenhouse activities in light of existing laws”. Such an action, if carried through literally, would mean the immediate end of all life on Earth.

Some Carbon Dioxide Background

The carbon dioxide position is at once far worse and far better than is generally appreciated. The main sources identified for the Earth’s increasing atmospheric carbon dioxide content are the burning of fossil fuels and the clearing of forests.

Both these sources are very significant. As we have seen from Chapter 13, the use of fossil fuels is putting back into the atmosphere carbon which has been ‘frozen’ for millions of years, many deposits dating back to Paleozoic times. The amount of carbon ‘frozen’ in standing forests is also very large, but while it can be treated as being transferred continously from one plant to the next in a ‘steady-state’ forest, it does not matter. It is only when standing forests are cleared that it becomes a factor.

Table 17. Carbon on the Earth

Position	Mass*
Atmosphere	
Pre-industrial (1860)	1.0
Modern (1987)	1.3
Biosphere	
Above ground	0.9
Soil organic matter	2.8
In seas	
Dissolved in seas	65
Dead in seas	1.8
In sedimentary rocks	
Carbonate rocks	67 000
Fossil organic matter	27 000
Potential ‘fossil fuel’	14

*In units of 575 billion tonnes carbon equivalent

Let us put some figures to this picture. A dense, tall forested area will contain around 500 tonnes of plant material per hectare above ground. Obviously this figure will vary according to the nature of the forest, and scrubby open forests will contain less, but this gives us some sort of handle to work from. A field crop will typically hold only a few tonnes of plant material above ground when fully grown, and nothing at all outside the growing season. A pasture cover will typically have less than a tonne per hectare.

Both the field and the pasture plants will have much more water and less carbon in them than the woody plants of the forests, so as a rough figure we can assume that replacing forests by field crops or pasture reduces the carbon held to under 1% of the original figure. At the accuracy we are working at, we can assume it has all gone.

> *Proposition 17B*
> *Changing land use from forest to field crop or pasture reduces the amount of ‘frozen’ carbon to negligible levels*

In Table 17, mostly taken from Beckmann [1988], there is a figure for the carbon contained in the total estimated deposits of fossil fuel on the Earth. If this figure is divided by the total land area of the Earth, it gives a result which, coincidentally, is about the same as the forest — 500 tonnes per hectare. This figure takes no account of such factors as the extensive fossil fuel reserves under the sea, the many geological areas where fossil fuel deposits are lacking, or the fact that forest plant material is not all carbon, but it is another handle to use on the problem.

> *Proposition 17C*
> *Fossil fuel deposits in the ground have the same magnitude of 'frozen' carbon per hectare as a dense forest, on an Earth-wide average*

There are lessons to be learned from this comparison. First, it is much quicker, easier, and cheaper to clear forest than to extract fossil fuels from beneath the Earth, and so this forest clearance has had a much more immediate effect on the environment than burning fossil fuels. Most of our forests are already gone, but we are a still a long way from using up all our fossil fuels, in spite of widespread gloomy predictions to the contrary.

In the 1970's we had the Oil Crisis, and I was surprised at the antagonistic response from some quarters at that time when I went on public record with a contrary-to-usual view. I pointed out that similar gloomy predictions, of the Earth running out of fossil fuels or other mineral resources within 20, 10, or five years had been made many times before in the past, dating back to the mid 1800's. All such predictions had proved false.

In hindsight, we can see that the Oil Crisis was also a 'manufactured' crisis, and current worries relate to oil gluts instead of shortages. The paradoxic reality appears to be that mineral resources are not, in practice, finite; what happens when one 'standard' resource runs thin is that another is found to substitute for it, often one quite unappreciated at the time. For example, if there is X amount of fossil fuel deposits on Earth, there is some 2000X of other fossilized organic matter which is still untapped (Table 17).

The relevance of all this is that it is the forests, not the fossil fuels, which are both the danger and the potential salvation. Most of our forests are already gone. The position is seen to be even worse when it is remembered that Man has been clearing the world's forests, intentionally and accidentally, not for one or two centuries but for tens of thousands of years. Primitive man changed whole landscapes, whole climates. Even so, we can still restore the health of the Earth, with the use of ecologies and economies in which tree crops are no longer the forgotten Third Component of agricultural land use.

Salinity and Trees

There is another aspect of land degradation which is the subject of increasing public concern, especially in Western Australia, and that is loss of useful land through salinization. Salt is regarded as the Great Enemy at the moment.

Nowhere is that more true than in Australia, particularly Western Australia. In a recent article entitled "White Death: How Salt is Decimating the Country", Julian Cribb [1989b] reports how this State is losing the use of a massive 20,000*ha* of agricultural land each year through soil salinization.

Tree planting has been widely promoted as a means to combat soil salinization here. The

basis of this measure is said to be that trees use up water and keep the water table, which is often saline, low. If the trees are cleared, the water table rises, and salt comes to the surface, eventually in sufficient amounts to kill most vegetation.

The fact that tree clearing can cause soil salinization has been well documented. However, most analyses of the situation ignore a basic factor — the salt content of the trees.

Far from being a poison, salt is in fact an essential component of the blood of most animals, and the sap of most plants. In animals, the right concentration of salts in the blood is essential for many bodily functions. In plants, the basic mechanism by which plants take up water through their roots, osmosis, is dependent on having a higher concentration of salt in the cells than that outside.

Different plants are able to function with different salt contents, but a rough working figure can be taken as 1%. One percent of the 500*t/ha* of forest growth is 5*t/ha* of salt. Spread 5 tonnes of salt over a hectare of field crop or pasture, and you are sure to kill it. Yet the same amount is a normal feature of a hectare of forest. The forest 'freezes' the salt, just as it does carbon.

> *Proposition 17D*
> *In contrast to field crops and pastures, permanent tree-based ecologies handle high per-hectare amounts of salt without difficulty*

Industrial Carbon Dioxide

We have seen that forest clearing and the burning of fossil fuels, much of it in industry, are the main activities responsible for the increase in atmospheric carbon dioxide. But there are many other industrial activities which may also make a significant contribution.

One of these areas is the use of cement, concrete, and mortar. Calcareous mortars based on lime produced by burning limestone have been used at least since Roman times. Burning the limestone releases carbon dioxide. However, as the older types of mortar harden, they do this mostly by absorption of carbon dioxide from the air.

This is not the case with modern cements, produced by burning limestone together with clay. Carbon dioxide is released in the burning, but the resulting cements harden by chemical reactions to produce complex calcium silicates. Only a little carbon dioxide is subsequently absorbed. The now widespread use of cement and concrete is relatively new, much less than a hundred years old. It may figure significantly in the overall carbon dioxide cycle.

Many industrial and mineral refining processes release large amounts of acid gases into the air. The phenomenon of 'Acid Rains' is another pressing matter of environmental concern, particularly in Europe, where natural vegetation has suffered or been killed over large areas. These acid rains attack the carbonates in building limestones and cements, or in exposed natural limestone outcrops, again releasing carbon dioxide.

Manufacturers can be forced to neutralize acidic flue gases before release into the atmosphere, and this does eliminate damage to buildings. But the neutralization process is invariably based on using limestone materials, which therefore releases carbon dioxide sooner rather than later.

The very widespread practice in farming, of adding ground limestone to acid soils to improve their pH, also causes significant release. Every 100*t* of limestone used in this way gives out 44*t* of carbon dioxide.

The position looks grimmer and grimmer. But before shooting ourselves, let us look and see whether it really matters, or whether what we would actually be doing is to shoot ourselves in the foot.

Carbon Dioxide — Killer or Nutrient?

The first thing to look at is whether the higher concentration of carbon dioxide is, in itself, good or bad, or indeed of any relevance. The background is this. We saw in Chapter 11 that in earlier geological times, the amount of carbon dioxide in the atmosphere was enormously greater than now, when it it is really only at trace level (Proposition 11J).

We also saw (e.g. Beckmann [1988]) that modern plants are CO_2-hungry, chasing ever-decreasing amounts of the gas in the atmosphere. In fact, a relatively recent event in plant evolution appears to be the development of species able to use a photosynthesis path called the C4 cycle, which improves the efficency of photosynthesis in low-CO_2 situations. Plants with this C4 ability have a strong advantage in many environments, and have become known both for their high biomass conversion abilities (as with sugar cane) and their ability to outgrow non-C4 species and become powerful weeds.

Whether or not plants use the C4 mechanism, increasing CO_2 availability is now accepted as benefitting plant growth. In fact, Julian Cribb [1989], in an article headed "Farm Bonanza on the Horizon", reports a prediction that Australia's agricultural production levels could rise by up to one-third — a very significant amount — just because of the stimulus to plant growth from increased carbon dioxide levels (both Cribb's and Beckmann's articles are mostly based on work done by Roger Gifford of CSIRO). Usefully enough, the improvement is likely to be most marked in some of our hottest and most arid areas (Figure 17.2).

So there appears little doubt that increasing CO_2 levels in the atmosphere will, in fact, be of benefit to us. Let us now go on to see whether we can expect to continue to enjoy these benefits.

Balancing the Books: Gains and Losses

So far we have only looked at where the carbon dioxide in the atmosphere is coming from. If we are to get a balanced view of the position, it is vital that we also see where it is going to.

We already know that our plant cover contains a lot of carbon. Plants give out CO_2 as well as taking it in — they do this mostly at night, which is why trees grow mostly at night — but if the plant cover is at a steady state then decay and growth within the biosphere cancels out changes in carbon dioxide content.

If we plant more trees, and we have good reasons why we should do this anyway, we can expect to take some extra of the CO_2 out of the atmosphere and 'freeze' it in plant carbon. How far could we take this process, how much could we take out?

We saw above that a complete dense forest cover over the whole of the Earth's surface would represent a similar amount of 'frozen' carbon as that in all fossil fuel deposits. Let us assume for the sake of calculation that these amounts are the same.

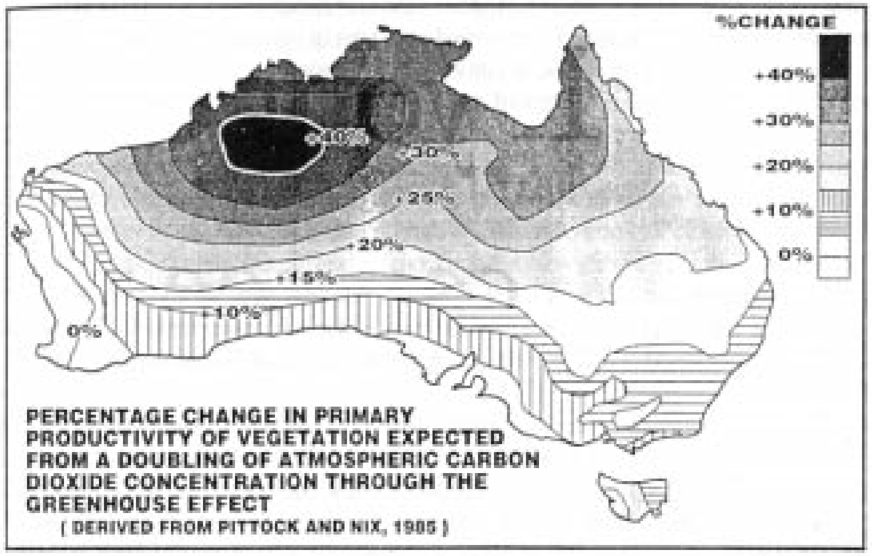

Figure 17.2 [Cribb, 1989]

If we again look at Table 17, we can see that the atmosphere currently holds 1.3 units, while the fossil fuel stands at 14 units. Above-ground carbon in plants and other living matter amounts to 0.9 units. To cover the world with trees, we would need to find another 13.1 units, much more than the total in the atmosphere! Where could it come from?

There is another way of looking at all this. Forests are the normal 'climax' vegetation of an area left undisturbed by man, and perhaps also by grazing animals. This is because a forest ecology is, as we have seen, more efficient than any other. There are good grounds, historical and otherwise, for granting that the Earth's forest cover was once far more extensive than it is now. If it once averaged out at even half a full cover, that is 7 units, where has it all gone to now?

With 0.9 units in the current above-ground biosphere, there is an extra 6.1 units to account for. We know that the atmosphere has gained 0.3 units since 1860, but even if the whole of the 1.3 units in the atmosphere had come from early tree clearing (which is obviously impossible since plants could not have functioned with *no* carbon dioxide in the atmosphere), that still leaves a massive 4.8 units to find. Clearly there is something wrong.

The explanation lies in a simple and obvious fact. Carbon dioxide is being withdrawn from the atmosphere continuously by other agencies apart from plant growth. When we look at it more closely, we find that these agencies may far outstrip the plant factor. Most involve the freezing of carbon as carbonates.

> *Proposition 17E*
> *Removal of carbon dioxide from the air as carbonates has had a greater impact than its removal as plant organic matter*

From Table 17 we can see the importance of the carbonate issue. Instead of talking about one, two, or 20 carbon units, we are concerned with tens of thousands of them. There are two main routes by which CO_2 in the air is converted to carbonates.

One is in the shells and skeletons of animals, particularly marine animals. Some quite massive limestone beds are known to consist almost entirely of mollusc shells, so the cumulative effect is quite powerful. Even more important are the coral reefs, again consisting mostly of carbonates. Australia's Great Barrier Reef has *grown* into position, and in so doing has frozen uncountable billions of tonnes of carbon into solid rock.

The second route is by direct precipitation from carbon dioxide dissolved in the sea. Many limestones contain some obvious shell remains, but the bulk of the material is fairly amorphous rock which could have been formed without any involvement of life processes. It has been said that limestone is currently being deposited on the bed of the Caribbean today, in this way.

What it comes down to is that carbon trapping by plants above ground is competing against carbon trapping under the sea by marine creatures and direct chemical processes, and the latter usually win. Once formed under the sea, carbonate rocks are subject to little attack, whereas plant material — whether still alive, as standing trees, or preserved as timber buildings or great libraries on paper — is continually liable to decay and burning.

So the wheel has come full circle. Instead of the perceived excess of carbon dioxide in the air, we have a shortage. There isn't enough in the air to restore our forests. If we frantically pump some more in by burning up our fossil fuels, the molluscs and corals will grab most of it, and never give it back.

> *Proposition 17F*
> *The Earth is suffering from a carbon dioxide shortage in the air, not an excess*

It seems that the most accessible source for the carbon dioxide we need is the carbonate deposits, whether on land or under the sea. But all this arose from concern about another matter, about the Earth heating up due to the Greenhouse Effect. Where do we stand on the heat balance?

Heat Trapping in the Earth

It seems to me that a quite unnecessarily alarmist attitude is being taken in regard to possible heating up of the Earth. It is a good thing that the matter should be looked at in detail, but that certainly does not mean throwing logic and reasoning to the winds.

What are the facts in this matter? It is claimed that the Earth has heated up by an average of about half a degree during the present century, or perhaps the last fifty years. It is claimed that this heating is due to the accumulation of carbon dioxide and other 'Greenhouse' gases, due to Man's activities over the last century or so. Are these claims fact?

There does seem to be little doubt that increasing CO_2 content in the air will tend to heighten its ability to trap heat. As to the half-degree rise in the Earth's temperature, that is really not

too much above the degree of accuracy of measurement, but we may as well assume that it is true too. Now we can look at the conclusions which have been drawn from these assumptions, but first we should look at the balance sheet of the Heat Budget of the Earth.

Sources of Heat in the Biosphere

We have already seen that domainographic and gravitational processes within the Earth have contributed to the heat we experience in the biosphere. We know also that most of our heat comes, and has always come, from the Sun. In considering the importance of the Greenhouse Effect, what we are most concerned with is things we think we can influence, in particular heat generated by the activities of Man.

Man has always used artificial heat generation, ever since he first found out how to make fire — that is nothing new. However, since the development of modern technology the amounts of heat produced have increased. Concern with the Greenhouse Effect has caused people to look at ways in which Man's output of heat into the biosphere could be limited or reduced.

Most of the energy we use ends up as heat, but we need to distinguish between energy sources which are neutral as far as the Earth's energy budget is concerned, and ones which add to the heat of the biosphere above the level which would occur if we had not intervened. Budget-neutral sources include hydroelectricity, wind power, tidal power, and direct use of solar energy. In all these we are only temporarily diverting energy which would have turned into heat anyway; how long the diversion lasts depends on the use which we make of the energy source.

There are other 'benign' energy sources, some of which have never been tapped. In an earlier article [Noël, 1983] I have suggested a more efficient technique for trapping solar energy, and also pointed out ways of using two untapped sources. These are the electrical energy of thunderstorms, and the potential energy of rain.

Both these sources could be very major — one good thunderstorm is said to release as much energy as many atomic bombs. As far as I know, no-one has even estimated the energy available from rainfall potential energy, but with a fall of around 1000*m* available, compared to the 10 or so metres in a conventional hydroelectric plant, the amount must be huge.

Budget-negative sources are the ones we are currently worried about, ones which add extra heat to the biosphere rather than borrow it temporarily. Of course this group includes burning of fossil fuels (provided our budget runs over a hundred years or so, rather than many millions). Interestingly enough, it also includes at least the greater part of nuclear power generation.

Early nuclear power generators used a naturally-radioactive isotope of uranium, uranium-235, as their power source. To some degree this is a 'neutral' source, since some of the uranium-235 would decay anyway and give off heat, even if it were still in its original deposit in the Earth. But most of the power in modern nuclear reactors comes from the conversion of naturally non-fissionable forms of uranium and thorium into fissionable isotopes, and this is energy which would not be released except for our actions. This applies to current fission methods of nuclear power generation; the hoped-for 'clean' power from hydrogen fusion is entirely budget-negative.

> *Proposition 17G*
> *Use of nuclear power in place of burning fossil fuels would not reduce the heat added to the biosphere*

As well as the budget-neutral and budget-negative activities, there are some which are budget-positive, in that they tie up heat energy in some solid form, usually chemically. This is the case, of course, with plant photosynthesis, which ties up solar energy as plant carbohydrates. In this respect, nuclear power is *worse* than fossil fuel burning, because the latter at least releases carbon dioxide which will aid the budget-positive process of photosynthesis.

Having kicked this matter of heating around a bit, we are now in a position to ask whether any of it really matters at all. To answer this, we once again need to put some figures on the situation.

The Big Heat Budget

What are the relative sizes of these heat inputs and outputs? In looking at very large quantities of heat, it is common to measure heat in Q-units (1*Q* is equal to 10^{18} BTUs, or about 10^{21} joules).

Differing estimates of the Earth's total stocks of fossil fuels range between about 40 and 200*Q*. We have been using these for well over a century, and although current rates are higher than ever, we are probably still not injecting more than 2-3*Q* of heat into the biosphere each year. The potential reserves of fissionable nuclear fuels are much higher than for fossil fuels, but even so we are not actually using as much each year. A figure of 5*Q/yr* for Man's budget-negative injection of heat into the biosphere is probably well on the high side.

Such a figure pales into complete insignificance when placed against the heat the Earth receives from the Sun, which is about 5000*Q/yr*. Hold up one square metre of surface at right angles to the Sun, out in Earth orbit, and it receives the equivalent of 1.8 horsepower or 1.3*kW* of radiant energy — enough to drive an average air-conditioner.

Not all the energy sent by the Sun is absorbed by the Earth, about 30% is reflected back into space. This isolates one of the crucial factors. If the amount of heat reflected increased by only 1% (say with the average reflectance rising from 30.3 to 30.6%), this would slough off another 50*Q/yr*, some ten times the most Man is adding. Our fuel-use activities are irrelevant in the face of this factor.

> *Proposition 17H*
> *Man's influence on the amount of heat added to the biosphere is insignificant compared to the effects of small variations in reflected solar radiation*

With all this heat coming from the Sun, why don't we just heat up and vaporize? This is the other side of the energy balance — the Earth is itself radiating heat off into space. We move on now to look at the effect of small changes in this balance.

The Ice Ages

Over the last million or so years, during the Pleistocene period, the Earth has been subjected to a number of glaciations, during which ice sheets advanced from the Poles and covered what are now temperate areas. At their maximum, the ice sheets may have covered three times the area of the current polar ice sheets [Americana/ 14:698], and may have been up to 3*km* thick in parts.

There is also evidence of much earlier ice ages, as in the Permo-Carboniferous periods and at the end of the Precambrian, in the form of 'tillite' rocks of these ages. Tillites are typically produced by glacial action. These older glaciations formed part of the evidence used to support the Continental Drift theory, and they could be worth re-examining in the light of domainographic movements.

The Pleistocene glaciations were not a single episode, but consisted of a number of advances and retreats, often with interglacial periods believed to have had similar climatic conditions to now. These periods of glaciation and retreat were quite rapid on the geological timescale, measured in only tens of thousands of years. Obviously they caused appreciable movements in the isocons, with whole populations and ecologies moving quite rapidly back and forth.

The last glaciation ended only about 10,000 years ago, around the beginning of recorded history (8000 BC). The question arises whether the Earth is currently still approaching the middle of an interglacial period. If so, the observed half-degree temperature rise could just be a natural part of the cycle, unrelated to Man's recent activities. It could also be part of some other short-term cycle of unspecified origin, and could slip back again in the next hundred years.

The reasons for the cycles of glaciation and retreat are not well understood. Factors which have been suggested as involved include variations in radiation from the Sun, wobbling of the Earth's motion in orbit (such wobbling really does occur), running into interstellar dust clouds, changes in climate due to mountain building activities and injection of volcanic dust into the atmosphere, and various 'greenhouse' effects involving carbon dioxide buildup. However, the Encyclopedia Americana article cited does conclude with the words "At any rate, it is remarkable that ice ages, which are among the best-known geolological phenomena, are so little understood".

From what we have seen above, it seems that a reasonable explanation lies in consideration of the amount of the Sun's heat reflected from the Earth. The important feature is the colour of the surface. White objects are good reflectors, and poor radiators, while black surfaces are bad reflectors and good radiators.

Venus and Earth

We can get a better feel for the position on Earth if we slip back briefly to look again at Venus. Venus is in an extreme position. With its dense cover of white clouds, it is a brilliant object, reflecting about 59% of the Sun's light. This is almost twice the Earth's value of around 30% — and it also demonstrates how greatly the reflectivity of Earth could alter.

In Chapter 15 we noted that Venus has a very high average surface temperature, around 470°C, and that this has been ascribed to a sort of 'super-Greenhouse effect' because of the dense carbon dioxide atmosphere of the planet. In fact Venus has a hotter surface than Mercury, much further in, which averages somewhere around 200°C.

We noted above that white objects are poor radiators as well as being good reflectors. I suspect that the reason why Venus has such an exceptionally hot surface is that it is such a poor radiator. It reflects close to 60% of the Sun's light, much more than Mercury (only about 7%), so on this count it would be expected to be cooler than Mercury. What keeps it hot is that it cannot radiate off the heat it does absorb.

There is a fundamental difference between the processes of solar light absorption and planetary radiation. The first occurs only on the side of the planet facing the sun, while the latter occurs all over. We will see the importance of this shortly.

On Earth, both the polar icecaps and the high clouds appear white when viewed from space. It seems possible that it is the complex interplay between these two large-scale surface features which is responsible for the hot-cold oscillations involved in ice ages and glaciations. The icecaps receive and reflect little solar radiation, because they are almost in line with the Sun's rays. Dense cloud cover is unusual at the poles, so the ice is the dominant reflecting and radiating medium there.

On the other hand, in the tropics dense cloud cover is quite common and icesheets are unusual, so cloud is the dominating reflecting and radiating surface. This cloud is subject to the full force of the Sun's rays, as it is almost perpendicular to them (Figure 17.3).

What happens when, for some reason or another, part of the icecap starts to melt? The position is quite complex. At the edge of the icecap, darker rock is exposed. This is a poorer reflector, but receives little radiation anyway. As it is darker, it will radiate better, and so rather more heat will be lost from the Earth (for the same surface temperature and reflectance, the Earth radiates equally in all directions).

On the other hand, the melting icecaps and the temporary higher temperature which caused the melting are likely to create a higher degree of cloud cover, especially at the tropics. These extra clouds will reflect back more of the intense equatorial Sun's rays, giving a cooling effect. On the other hand, being whiter, these clouds will radiate less heat off into space at night. Also, these clouds, being higher up, will be cooler than the ground surface under them, and on this count the Earth will be retaining more heat.

When the temperate mid-latitudes are considered, all these effects are competing in complex ways, tied in with the inclinations to the Sun's surface. Even the slopes of mountain ranges come into it, and as there is more land in the northern hemisphere than in the southern, and more mountains able to support glaciers, even the hemispheres are differently affected. Then there is the fact that the Earth's orbit round the Sun is an ellipse, not a circle, and it is closer to the Sun in the southern summer.....

Without attempting to provide a detailed explanation of this situation, it is clearly one which is complex enough, and which has the elements of short-term positive feedback, long-term boundary conditions, and buffer capacities in the air, sea, and land, to hold the reasons for the observed behaviour of glaciations and ice ages.

> *Proposition 17I*
>
> *Cycles of ice ages and glaciations have their origin in the complex interplay of reflection and radiation from the Earth's clouds and icecaps*

This then leads us to an interesting thought. If reflection and radiation are such powerful influences in determining the temperature of our planet, might we not use them to control these temperatures as we wish?

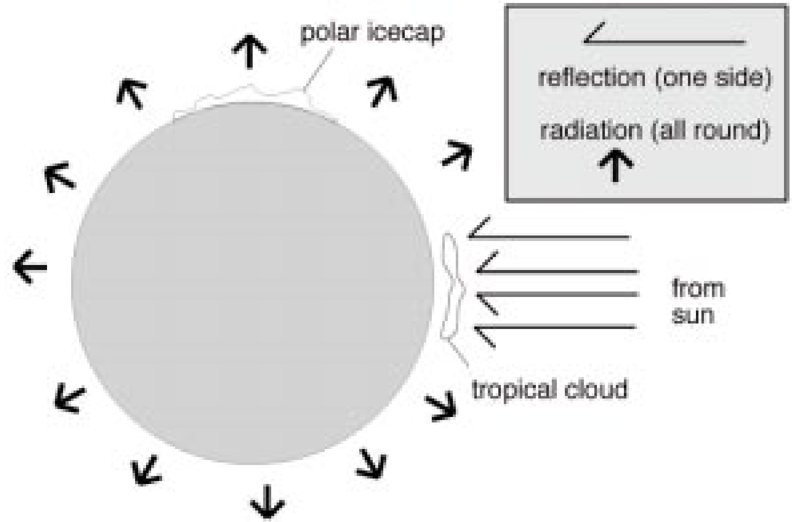

Fig. 17.3. Ice caps, tropical clouds, the Sun's rays, and Earth radiation

In fact, in the earlier article where I suggested the untapped sources of budget-neutral energy [Noël, 1983], I also suggested the same mechanisms could be used for climate control. Rafts of black vacuum balloons, or of balloons with black sheets suspended between them, would be poor reflectors and good radiators. If sited up at the poles, they would cool the Earth down, if near the Equator, they would cause it to heat up.

Silvery-coloured balloons would have the opposite effect. Moreover, the effect could be varied between one place and the next, so we could heat up the poles and cool off the tropics in this way if we wished. Or heat up the seas, and cool the land.

So, if we are really concerned about the mean temperature of our planet, would it not be more sensible to look at this or other reflection/radiation mechanisms, rather than fiddle with use of fossil fuels in a way likely to be quite inconsequential in the real scale of effects?

> *Proposition 17J*
> *The temperature of the Earth or of parts of it could be conveniently controlled through the use of artificial reflection and radiation surfaces supported by devices such as vacuum balloons*

We have now touched on the effects of varying carbon dioxide levels and the consequences of temperature variations on our planet. The last major dire prediction stemming from the Greenhouse Effect concerns varying sea levels.

Sealevel Changes

Once again, there is a case for considering current predictions about sealevel changes to be unduly alarmist.

In Chapter 10, when we first looked at the oceans, it was pointed out that with the evidence we had seen, comparing the positions of a piece of land relative to sealevel at different times in geological history was close to meaningless (Proposition 10A). Even in relatively recent geological times, the fact that a beach-type rock deposit formed one million years ago now stands 10*m* above local sealevel does not mean that general sealevels were 10*m* higher then.

Any extreme predictions of very rapid rises in sealevel with 'Greenhouse Effect' heating should be treated with reserve. For example, it has been predicted [Polar, 1989] that with rising sealevels, the South Pacific countries of Kiribati and Tuvalu will disappear completely under the water within the next 20 years. This is a very alarmist statement.

Many quoted measurements will, in fact, be inaccurate. Even when they are accurate, they are not necessarily meaningful. A recent television programme on the Greenhouse Effect concluded with the words "... during the last 50 years, measurements have shown a rise in sealevel along the Atlantic coast of the United States of 30*cm*. Along the Pacific coast, there has been a rise of 10*cm*".

There is clearly something wrong here. If the Greenhouse Effect really caused a rise of 30*cm* on one coast, why only a third of the rise on the other? Is it not more likely that any such rises are mixed in with domainographic changes in land levels of the same or greater effect?

It is undeniable that in an otherwise unchanged world, melting of the polar icecaps will cause a rise in average sealevels. But is the world otherwise unchanged? There are various places where ice melted or evaporated off the icecaps could be stored, as in more extensive clouds or circulating in the atmosphere, or even in higher average water tables — who has checked all those? Even long-term atmospheric pressure variations in particular parts of the globe could influence apparent average sealevels.

Nevertheless, in spite of all the above, it is quite possible, or even likely, that average sealevels have risen somewhat over the last hundred years or so. The points to be made are that any such changes are really quite small, usually much less than daily tidal variations or possible domainographic uplifts, and that there may well be compensating mechanisms

operating which will slow down or neutralize the effects of such changes. The Earth is tougher than is often claimed.

In addition, even if sealevels do rise somewhat, will it really have much effect? In Holland, more than a third of the current land surface is already below sealevel. Around the Caspian Sea, an area bigger than Britain is below sealevel. There are also large depressions below sealevel in China, North Africa, and Australia.

It comes down to a balance between rainfall and evaporation. Once again, trees can help. Since it is known that planting trees can lower the water table, they could clearly help to keep land below sealevel dry. Maybe we do not have to worry, after all.

> *Proposition 17K*
> *Excessive concern over possible rises in average sealevel is unwarranted*

Occam's Razor

We have come to the end of our review of the physical, biological, and mental processes operating on our Earth, now and in the past. Many of the concepts I have put forward will be new to the reader. So far I have done most of the thinking — but now the ball passes to you, the reader. Does what I have suggested make sense? Is it consistent, does it hold together? Can some of the suggestions be tested by experiment?

At the head of this chapter I quoted the analytical tool produced by the brilliant 14th century English thinker William of Occam, the 'Invincible Doctor'. This is a tool for making decisions on which of alternative theories or proposals should be chosen. It is known as 'Occam's Razor'.

The literal translation of the original Latin is "Entities should not be multiplied more than is necessary". The somewhat looser version commonly used in the scientific field is "If you are faced with a choice between two alternative explanations of a phenomenon, you should choose the least complicated one". Some more colloquial renderings might be "Don't make a Big Deal out of it", or even, "Keep it Simple, Stupid!".

I suggest to the reader that the approaches I have used and the explanations I have given have been simple ones. There has been no retreat into complex mathematics or obscure jargon, you are perfectly capable of deciding for yourself if what I have said makes sense — you don't have to take any other expert's word!

Undoubtedly the matters covered have been very diverse in every sense. But they do all relate together — every topic came in naturally as we made step after step through the Universe — and they do form a cohesive whole.

Even so, if many of the Propositions I have put forward come to be accepted, that does not mean every one of them is 'true'. In science, we try to represent parts of the Universe in theories, laws, and mind models. If these give the best, and simplest, explanation to date of what is observed, they can be taken as 'true'.

As they pass from the stage of a bright idea in one individual's mind through to being an entrenched and undisputed part of the racial mentality, part of the ‘conventional wisdom’, these concepts must be open to reexamination at every stage and at any time. Occasionally a deeply-rooted concept becomes completely overturned, it is no longer ‘true’. But more often it is shown that the original concept remains true, but not as universally as assumed. This is what happened when Einstein modified Newton’s gravitational laws with his relativity theory — Newton remained true for most purposes, but not in every possible circumstance.

Planetary Housekeeping

Both of the words ‘economy’ and ‘ecology’ have as their linguistic root the sense of ‘housekeeping’. In a very real sense, what we have looked at in this last part of the book is housekeeping on a planetary scale. We have recognized that Man’s unthinking or unknowing actions in the past have caused upheaval in the house.

But I hope to have shown that if we review the position critically, we really do have the tools to clean up our house and restore it to proper order. There only remains the question as to whether we have the desire and the will to do so.

Childhood’s End?

In 1953 Arthur C. Clarke, the inventor of the Communications Satellite (but better known as a science-fiction author), published a novel with the title ‘Childhood’s End’. In it he postulated a time in the future when the human race came of age — when it matured not physically, not in individual mentalities, but as a society as a whole, as a single group mentality.

There are hopeful grounds for believing that Man is coming of age. I admit to being an optimist, but even a pessimist would have to admit that our global concern for the planet we occupy has improved out of all recognition in recent years. Even the words we use had to be invented or redefined for our use; we have to have words for a concept before we can talk about it and develop it.

Ninety years ago, the word ‘ecology’ was spelled ‘oecology’, and had a much more restricted meaning than now, concerned with interrelationships within individual animal and plant groups — “Thus, parasitism, socialism, and nest-building are prominent in the scope of oecology” is how one old dictionary describes it.

Fifty years ago the word had virtually disappeared from use, any thoughts in the area falling in the ambit of ‘environmental studies’. It is only in the last 20 or 30 years — within the lifetimes of most of my readers today — that ‘ecology’ has come into common use in its modern sense. With the word comes the thought and the appreciation.

Now governments in Australia and the rest of the world, governments of every political persuasion, are beginning to mobilize to create ecological improvement. The need for widespread tree planting and tackling problems of soil degradation is being recognized globally, and action has commenced. Julian Grill, Western Australia’s Minister for Agriculture, was able to announce recently that our farmers are now planting more trees than are being cleared for the first time in history.

Along with the widespread new appreciation of the importance of ecological matters have

come other hopeful signs. The threat of nuclear war has receded somewhat; the cardboard patriotism of the early part of the century has gone. We are starting to regard ourselves as Citizens of Earth, with a responsibility for the whole planet, not just our own backyard.

All over the world, there are hopeful signs of political maturing. The number of dictatorships is falling, the great Communist powers have opened out to the world, beginning to see political dogma as just one of the tools available in the development of society, and not the aim and purpose of society.

The Other Earth Intelligences

The increasing maturity with which we are handling relationships between human societies has been accompanied by a pleasing increase in the maturity of our views towards other Earth creatures of high intelligence. No longer is there indiscriminate hunting of the whales. These, with their highly-developed social behaviour and their elaborate oral histories are now recognized as creatures of comparable intellect to ourselves.

Only Japan, Iceland, and Norway still kill whales, under the guise of scientific research, but in reality for economic reasons. “They eat too many fish” was the opinion of a minister in the Icelandic Government. The enormity of their crime can be appreciated if one of these nations was to start killing off Eskimos for economic reasons — “They eat too many fish”.

The elephant, the gorilla, the orang-outan — all are receiving much more enlightened treatment by man, opening up a new chapter in cross-species social interaction. And the interaction is not all one way.

On the coast of Western Australia, at a place called Monkey Mia, the dolphins appear to have opened up their first Consulate to the Human Race. Their consuls arrive for extended tours of duty, interact with the humans in a very tolerant way, and might even be conducting their own experiments in getting to know us. The public concern shown for the health and sanitation conditions of this Dolphin Consulate would have been unthinkable even 25 years ago — the thought would never have entered our consciousness. But if we work at it, the dolphins may upgrade their station to full Embassy status.

Tools of Higher Learning

In many ways this maturing has been due to the physical facilities afforded by the new communications networks which are based on Clarke’s satellites. When we can see for ourselves what is happening all over the world, we can truly appreciate the global picture. Communication is all-important. In a real sense, Clarke has helped to make the scenario he depicted in ‘Childhood’s End’ come true through his invention of the communication satellite.

We are also developing other techniques, other tools of higher learning, to assist in bringing our race closer to maturity. One such tool is the synthesis technique used in this book. Another is the development of Memetics — a method of tracing the propagation of ideas and attitudes through society, using the same concepts as those applied to the study of epidemics [Henson, 1987]. There will be many more such tools, the important thing is that we are beginning to appreciate their potential value.

In this book I have applied the technique of synthesis to the physical world. The same technique can be applied to the social world. This is not the place to do that , but I will extract one tiny part of such a synthesis — that is, that the structure of a society is not made up just of the people within it, but also of the links between those individuals.

Perhaps over half of the ‘mass’ of a society lies in its communications, its knowledge, its techniques. During the past the emphasis of work and wealth generation has moved inexorably over from the primary industries of farming and mining, through the secondary ones of manufacturing and distribution, and on to the tertiary ‘service’ industries of finance, education, and tourism. Can we look forward to a quaternary level which will supersede all these in importance, as the Earth’s races mature?

We can re-make the Earth. It is impossible to restore the Earth to what it was a hundred, a thousand, a million years ago. It would be pointless to do so. But, armed with the new tools of a maturing society, mental as well as physical tools, we can make the Earth a more pleasant and fruitful planet, and hopefully avoid the fate which may have overtaken the Ostrich Dinosaurs.

> *Proposition 17L*
>
> *We* ***can*** *re-make the Earth*

POSTSCRIPT: SITTING BACK ON THE SOFA

“Why must I be the planetary rebel?” he asked the Flopglopple.

“Perhaps you are like me”, said the Flopglopple. “You enjoy stirring things up”.

“But I don’t. I like smoothing things over. I like my feet high up on a sofa, eating peanuts”.

“Nonetheless, you are not like the other botanists”, said the Flopglopple. “I have always known this about you”.

—Kotzwinkle [1985]: E.T., the Book of the Green Planet

Postscript

In some sense, I didn’t write this book; it wrote itself. Or perhaps the book used me to make itself known. Like E.T., I have not sought to stir things up and produce controversial theories, but was the innocent victim of circumstances which just dumped huge piles of evidence in front of me and said “Be honest now, what is the only thing all this can mean?”.

Another way of looking at it would be to say I have been the producer and director of a play, having been given the raw script, written in rocks and genes, and told to put it up in a form suitable for presentation to the public. Who was the playwright? Perhaps the Earth itself.

It has been a fascinating and absorbing job, taking up the loose leaves of each new Act, and turning them over to find surprise after subtle surprise lurking within. I hope that you, the reader, will have found some pleasure and utility from my efforts to Let the Earth Speak.

— David Noël

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COLLECTED PROPOSITIONS

(In order of presentation)

Proposition 2A: Actual rates of spread of plants are usually much less than the potential rates of spread implied by the dispersion mechanisms operating for an individual seed

Proposition 2B: Plant and animal species do not expand their range because they are unable to overcome ecological pressure from other species already occupying their ecological niches

Proposition 2C: Weeds may be controllable through manipulation of their microecological surroundings, rather than through direct attack by sprays or cultivation.

Proposition 2D: The total genetic constitution of a species is subject to continual alteration, particularly if external conditions are changing

Proposition 2E: In the absence of ecological pressure, a species diverges into two species roughly every million years

Proposition 2F: Species tend to die out when the ecological niches in which they exist are eliminated, and this elimination is promoted by continuing changes in external factors such as climate and sea-level

Proposition 2G: Changes in external conditions increase rates of natural selection and evolution

Proposition 2H: No species can maintain its genetic identity for long periods, more than around ten million years

Proposition 2I: The half-life of a species is approximately one million years.

Proposition 3A: Plants in the same genus must have had common ancestors, and these ancestors must have existed within a single area

Proposition 3B: The convection-current mechanism for continental drift lacks any supporting evidence or plausible basis, and is completely wrong

Proposition 3C: The subduction theory lacks supporting evidence and plausibility, and is completely wrong

Proposition 4A: Plant families tend to be identifiable either with Gondwanaland or with Laurasia

Proposition 4B: Plant distributions are evidence that the Expanding Earth proposition represents the situation better than the simple Continental Drift theory

Proposition 4C: The Pacific Ocean is a relatively recent formation, and was largely created after the initial formation of the Atlantic Ocean

Proposition 4D: Gondwanaland included much of southeast Asia and southern China

Proposition 4E: The Earth's current continents were once all joined together to completely cover the surface of a much smaller sphere, which has since expanded

Proposition 5A: A tectonic plate is not a real entity in any permanent sense, but only the area within an arbitrary assembly of more or less active parts of domain boundaries

Proposition 5B: Antarctica is not a real continent, but an assembly of islands, with a land area probably totalling no more than half the 14 million square kilometres usually assumed

Proposition 5C: The former megadomains of Laurasia and Gondwanaland had the same surface areas

Proposition 5D: The first major event in Earth expansion was the splitting of the holodomain in half, along the Equator, to form the two megadomains of Laurasia and Gondwanaland

Proposition 5E: The Equatorial Split which created the two megadomains of Laurasia and Gondwanaland was notable for the first surface exposure of underlying 'oceanic' material, as the overlying continental material was thinned out by past expansion

Proposition 5F: Fossils of warmer-climate plants found in areas with colder climates may have been carried there by domain movement

Proposition 5G: All areas of the Earth sciences which implicitly assume a fixed Earth must be subject to detailed reconsideration in the light of possible domain movements

Proposition 5H: In the movement of domains during Earth expansion and continental drift, smaller domains have moved relatively further from the Equator than larger ones

Proposition 5I: Peninsulas point south in the northern hemisphere, and north in the southern hemisphere, because they were formed by island microdomains moving away from the Equator and joining with other domains

Proposition 5J: Terranes are random lots of microdomains which have accreted to larger domains

Proposition 5K: Bands of microdomains are shuffling away from the Equator along the sides of continents, particularly the west coasts of South and North America and the east coasts of Australia and Africa

Proposition 5L: Microdomain movement directly away from the Equator may be somewhat distorted by the gravitational influence of adjacent megadomains

Proposition 5M: None of the present continents is a simple megadomain, all show evidence of accretion, microdomain shuffle belts, or domain re-seaming

Proposition 5N: In making Earth-expansion reconstructions, domain boundaries should be taken as the present sea-level or abutment boundaries, ignoring continental shelves

Proposition 5O: The boundaries of domains have been modified by shifts of only a few kilometres as a result of erosional and impact forces in their past.

Proposition 6A: Many cases of plants assumed to introduced to have been introduced by man, to explain their occurrence, are as readily naturally explicable through expanding-Earth principles

Proposition 6B: Actual rates of spread of animals are usually much less than the potential rates of spread implied by the mobilities of individual animals

Proposition 6C: Marsupials evolved in the Australian and South American domains when these were in contact, and were not cut back to these areas because of competition from 'more evolved' creatures

Proposition 6D: The majority of marine creatures are ecologically restricted to shallow off-shore waters, and so inhabit long ecological strips of relatively small area

Proposition 7A: In the early part of the current (Cenozoic) era, 50-70my ago, the immediate ancestors of most of our current plant genera were evolving out

Proposition 7B: This evolution took place in one or more 'equatorial bands' of physically interlinked domains extending right round the Earth, with easy spread of species along the bands

Proposition 7C: The climatic conditions in these equatorial bands were closer to those of currently temperate areas than to modern tropical ones

Proposition 7D: Typical 'tropical' plant families are of relatively recent origin, less than about 50my old

Proposition 7E: The match of a plant's current distribution pattern with other local isocons gives evidence of whether or not the plant was introduced by man

Proposition 7F: Propositions relating to equatorial flight of domains may lose validity at high latitudes

Proposition 7G: Northern Europe has a relatively low level of plant diversity because much of it was cleared of living plants through the action of glaciers

Proposition 7H: Ice-age glaciers were not centered on the North Pole, but had an area of influence displaced over into northern Europe

Proposition 8A: All mountains have been created through the interaction of domains

Proposition 8B: 'Fat' mountains have been created by domain impacts

Proposition 8C: 'Long' mountains have been created by domain rubbing

Proposition 8D: Volcanos are created by the friction between rubbing domains

Proposition 8E: Igneous rocks are produced locally, through domain rubbing, and not from a 'primeval' Earth source:

Proposition 8F: All geothermal phenomena obtain their heat components from domain rubbing

Proposition 8G: Metamorphic rocks are formed by the heat and pressure produced by rubbing domain edges

Proposition 8H: Earthquakes are the relative movements of adjacent domains

Proposition 8I: Domains are three-dimensional objects of varying thicknesses, and the surface domains which are directly observable may be underlain by other domain-type structures

Proposition 8J: It should be possible to calculate where and when earthquakes will occur, once fuller data on the domains involved is known

Proposition 8K: 'Hot Spots' in the Earth are artefacts created by domain edge movements, and not real phenomena

Proposition 9A: The Moho discontinuity represents a phase change boundary where the rocks are changing their phase in response to increasing pressure

Proposition 9B: The position of the Moho will change as the pressure of overlying rock changes in consequence of domain movement

Proposition 9C: The Earth does not have an iron-rich core

Proposition 9D: The four discontinuities marking the boundaries between the Earth's Crust, Upper Mantle, Lower Mantle, Outer Core, and Inner Core are all due to pressure-induced phase changes

Proposition 9E: All the density discontinuities within the Earth may be expected to change position as internal pressures change with Earth expansion

Proposition 9F: The core of the Earth is not especially hot

Proposition 9G: The principal source of the heat observed to flow from the depths of the Earth is friction from movement of domains, including deeper domains

Proposition 10A: Most observations and deductions on the position of sealevel relative to particular points on land today are meaningless when applied to general sealevels in the past

Proposition 10B: In earlier ages the Earth had a smaller total volume of water on its surface

Proposition 10C: The first substantial land appeared above the sea around 400 million years ago

Proposition 10D: Water is being added to the Earth's hydosphere from internal materials brought into the active domain zone by Earth expansion

Proposition 10E: The average annual fall in mean world sealevel as a result of Earth expansion is of the order of one hundredth of a millimetre per year

Proposition 10F: The average annual fall in mean world sealevel as a result of loss of water to space is also of the order of a hundredth of a millimetre per year

Proposition 10G: Most of man's evolution took place in a semi-aquatic environment, and rising sealevels have concealed most of the fossil evidence for this evolution

Proposition 10H: Geological and biological evidence explained in the past by hypothesized land bridges may be more readily explicable through domain movements

Proposition 10I: The average salinity of seawater has increased continuously for at least the last 400my

Proposition 10J: Land creatures first evolved, around 400my ago, from sea creatures adapted to seawater much fresher than that of today

Proposition 11A: The composition of the Earth's atmosphere has changed very markedly at different times in the past, and present and early compositions are completely different.

Proposition 11B: Light atmospheric gases are much more likely to be lost from Earth into space than heavy gases

Proposition 11C: Part of the temperature increase observed in going down mines stems from the same basis of atmosphere gas physics as that causing a fall in temperature with increasing altitude

Proposition 11D: The primeval Earth was never molten or at a particularly high temperature

Proposition 11E: The Precambrian-Cambrian boundary marks the time when free oxygen first became common in the atmosphere and permitted the development of oxygen-breathing life

Proposition 11F: With the development of free oxygen in the air above the seas, changes occurred in the composition of substances dissolved in them

Proposition 11G: Atmospheric ammonia was converted to nitrogen, and methane to carbon dioxide, during the course of the Paleozoic

Proposition 11H: The Paleozoic-Mesozoic boundary was marked by the disappearance of methane and ammonia as major atmospheric components, and the appearance of carbon dioxide and nitrogen in their place

Proposition 11I: Atmospheric changes at the Paleozoic-Mesozoic boundary caused a switch in the state of the seas from being weakly alkaline to weakly acidic

Proposition 11J: The Mezozoic-Cenozoic

boundary marks the time at which carbon dioxide levels in the atmosphere had fallen to trace levels

Proposition 11K: Atmospheric pressures were very much higher on Earth in the past, because carbon now present in the rocks was formerly present in the air as atmospheric gases

Proposition 11L: Atmospheric pressures were also higher in the past because the same amount of atmosphere was present on a much smaller Earth

Proposition 11M: The amount of water vapour held in the Earth's atmosphere during Paleozoic and Mesozoic times was much greater than now.

Proposition 11N: The Earth was completely shrouded in clouds at all times during the Paleozoic and the Mesozoic

Proposition 11O: Conditions necessary for atmospheric nitrogen fixing by thunderbolts were not always present in past eras

Proposition 12A: Dinosaurs as a class are not extinct, they were only early forms of modern birds and mammals. Mass extinction was limited to larger forms of these classes

Proposition 12B: Extinctions of creatures weighing over about 40kg in the last 100,000 years were mostly due to the activities of man

Proposition 12C: Countries with economies having extensive integrated tree-based industries enjoy much more stable economic and environmental conditions than those without

Proposition 12D: Man's actions over the last 100,000 years have caused major changes in the composition of animal and plant species

Proposition 12E: At the end of the Cretaceous, a species of Ornithomimid developed intelligence and civilization , caused the mass extinction of large animals associated with this, then wiped itself out in a nuclear war

Proposition 12F: Changes in external conditions close to the Mesozoic-Cenozoic boundary adversely affected the thermodynamics of biochemical /biophysical processes dependent on body size and caused the extinction of creatures heavier than about 40kg

Proposition 13A: Most coal deposits were produced by the conversion of plants which had grown up floating on the surface of the sea

Proposition 13B: Coal deposits were laid down in the narrow and shallow interdomain gulfs produced by early Earth expansion

Proposition 13C: Oil and gas deposits were formed from the remains of plants which had grown floating on the surface of the sea

Proposition 13D: The floating layers of plants which provided the source material for petroleum and coal were able to seal off significant areas of the seas and prevent normal evaporation

Proposition 13E: Seas sealed from the atmosphere with a floating organic layer would become anaerobic and foster the conversion of organic material to fossil fuels

Proposition 13F: Some salt deposits were formed by the elimination of water from sealed-sea areas

Proposition 13G: Fossil fuel deposits were formed at the bottoms of the deepest seas which then existed, from plant sources floating on those seas

Proposition 13H: The Paleozoic atmosphere originally contained much more sulphur compounds, which were largely eliminated by the start of the Mesozoic

Proposition 14A: Paleozoic coal deposits identify the sites of Paleozoic or earlier interdomain gulfs, and unlocated coal deposits should be looked for at such sites

Proposition 14B: Petroleum deposits identify the sites of Mesozoic or earlier interdomain gulfs, and unlocated deposits should be looked for at such sites

Proposition 14C: Precious metal and gemstone occurrences were produced through processes involving the frictional heat and high pressures generated by domain rubbing

Proposition 14D: Precious metal and gemstone ore deposits are formed by a natural zone-refining process, with the heat needed stemming from the friction of earthtwitches as domain edges rub

Proposition 15A: The primeval atmospheres of all the planets had a similar composition to that of Jupiter now

Proposition 15B: Saturn, Uranus, and Neptune have similar 'primeval' atmospheres to Jupiter, except that they have less of the heavier atmospheric components due to freezing or liquefying out

Proposition 15C: Mars has lost much more of its atmospheric nitrogen than Earth because of its lower escape velocity

Proposition 15D: Venus has a much higher atmospheric pressure than Earth because it has never experienced massive carbon deposition from its atmosphere

Proposition 15E: Earth has lost atmosphere through leakage via the Moon, especially when the Earth's radius was smaller and a double-planet situation was approached

Proposition 15F: Expansion of Venus is occurring in a similar way to Earth expansion, but may be at an earlier stage of development

Proposition 15H: Expansion of Mars is occurring in a similar way to Earth expansion, but is at a much earlier stage of development, with an Equatorial Girdle just emerging

Proposition 16A: Domain flight away from the equator occurs on an expanding Earth in an effort to conserve the momentum of the individual domains

Proposition 16B: Microdomains may be moving independently on underlying domains which are themselves in motion

Proposition 16C: More modern species are of Gondwanan origin than Laurasian because species development is more marked in the tropics, which are mostly parts of Gondwanaland

Proposition 16D: Both the progressive and the abrupt increases in density encountered on approaching the Earth's centre are due to the increasing pressure of the overlying material

Proposition 16E: The composition of the Earth's solid substance is more or less uniform from the centre to the surface

Proposition 16F: The acidic igneous rocks classed as Sial have been derived by the remelting of worked-over and leached basic Sima rocks

Proposition 16G: Rock of 'Sima-type' composition has extended throughout the Earth since it was first formed, and has only been modified near to the surface by domainographic processes

Proposition 16H: The Earth was never molten

Proposition 16I: All the Solar System planets and major moons have rocky centres made up of the same Sima-type material as Earth, subject to the same increase in density with depth

Proposition 16J: All the Solar System planets were formed in the same event and at the same time

Proposition 16K: At the Mantle/Core boundary, phase III normal-matter Sima changes to phase IV degenerate-matter Sima

Proposition 16L: Planetary expansion occurs via the conversion of higher-density Sima phases into lower-density ones

Proposition 16M: Heat derived from domain movements in the Domainosphere is distributed around the Earth by earthquake waves

Proposition 16N: The Domainosphere has a maximum activity band, with a position derivable from measurements of earthquake depths and energies

Proposition 16O: The Earth is being continually heated up by gravitational massage exerted on its mass by the Moon

Proposition 16P: Planetary expansion has occurred because the nuclear forces acting between the components of the planet have become weaker as time progressed

Proposition 17A: Concern over the ‘Greenhouse Effect’ is misplaced, and represents a ‘manufactured’ crisis

Proposition 17B: Changing land use from forest to field crop or pasture reduces the amount of ‘frozen’ carbon to negligible levels

Proposition 17C: Fossil fuel deposits in the ground have the same magnitude of ‘frozen’ carbon per hectare as a dense forest, on an Earth-wide average

Proposition 17D: In contrast to field crops and pastures, permanent tree-based ecologies handle high per-hectare amounts of salt without difficulty

Proposition 17E: Removal of carbon dioxide from the air as carbonates has had a greater impact than its removal as plant organic matter

Proposition 17F: The Earth is suffering from a carbon dioxide shortage in the air, not an excess

Proposition 17G: Use of nuclear power in place of burning fossil fuels would not reduce the heat added to the biosphere

Proposition 17H: Man’s influence on the amount of heat added to the biosphere are insignificant compared to the effects of small variations in reflected solar radiation

Proposition 17I: Cycles of ice ages and glaciations have their origin in the complex interplay of reflection and radiation from the Earth’s clouds and icecaps

Proposition 17J: The temperature of the Earth or of parts of it could be conveniently controlled through the use of artificial reflection and radiation surfaces supported by devices such as vacuum balloons

Proposition 17K: Excessive concern over possible rises in average sealevel is unwarranted

Proposition 17L: We **can** re-make the Earth