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).

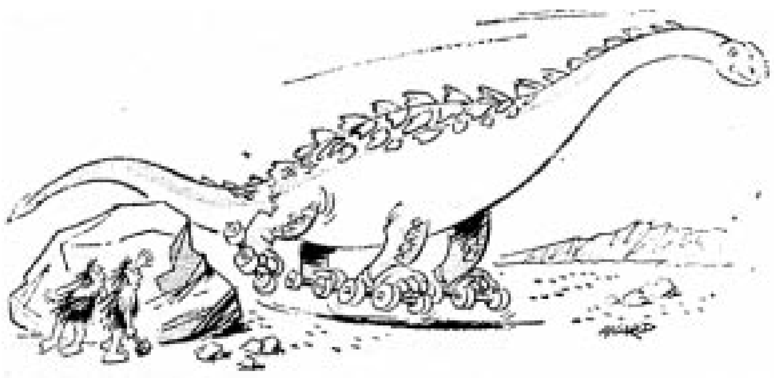

Fig. 12.2. "Are you sure their brains are only the size of peas?"
[Charig, 1979]

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.

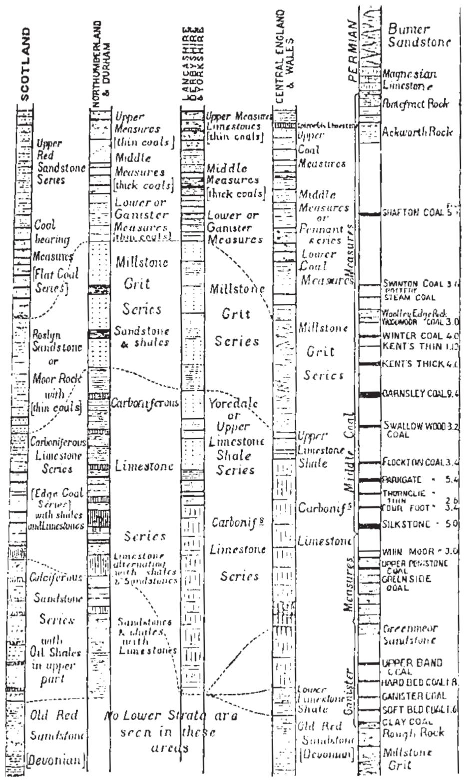

Fig. 13.1. Carboniferous strata in Britain

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.

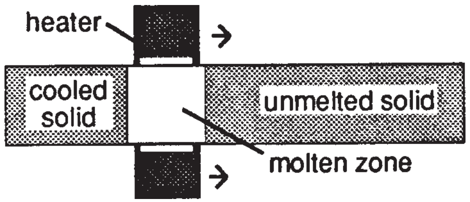

Fig. 14.1. The zone refining technique

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