The Convection Cell System of Earth‘s Mantle
Heat transfer within the Earth and how it is revealed on its surface

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# Table of Contents

Figures: ......................................................................................................................... 4

Preface ............................................................................................................................... 6

Part I - From the core of the Earth to the crust .............................................................. 9

Chapter 1 - Background of the theory ........................................................................... 10

1.1. The model based on Earth’s layers ...................................................................... 10

1.2. Referring to physics: Rayleigh-Bénard convection and Coriolis effect ............ 12

1.3. Francis Bacon, Alfred Wegener, Harry Hess and many others .................... 14

1.4. The current cell system proposed by Harry Hess ............................................ 15

1.5. Description of a system ....................................................................................... 17

Chapter 2 - Dimensions of a cross section of the convection cells ......................... 19

2.1. The ‘core’ of this analysis ................................................................................. 19

2.2. The similarities and dissimilarities between atmosphere, ocean and mantle ...... 22

2.3. The current system ............................................................................................. 25

2.4. Height and breadth of convection cells ............................................................. 27

2.5. The 410 km discontinuity and the convection cells ........................................ 31

Chapter 3 - The 410 km and 670 km discontinuities .................................................... 33

3.1. Uppermost cells of the asthenosphere ............................................................... 33

3.2. The structure of the upper layers ...................................................................... 40

3.3. Convection cells compared with the upper layers ......................................... 41

Chapter 4 - The shape of the convection cell system .................................................... 44

4.1. The Coriolis Effect on the convection cells ...................................................... 45

4.2. The diameter of the circular horizontal flow on a perfect sphere .................... 46

4.3. The average diameter of horizontal circulation .............................................. 50

4.4. The basic horizontal model ............................................................................. 52

4.5. The equation of the world map of convection cells ......................................... 54

4.6. Differentiation of the equation of flow to find the direction along the cells .... 55

4.7. Degree of accuracy .............................................................................................. 57

Chapter 5 – MORB and OIB ......................................................................................... 61

5.1. MORB and OIB layers ...................................................................................... 62

5.2. The individual sections of essentially circular horizontal flow ....................... 64

5.3. Flow in current cells: east-west component due to convection and north-south component due to secondary horizontal flow ........................................ 66
10.5 The South Iceland Seismic Zone (SISZ) ................................................................. 127
10.6. Explanation of the orientation of fractures within the SISZ ......................... 129
10.7. Seismic areas in general .................................................................................... 131
10.9. The volcanic zones ............................................................................................ 137
10.11. The 64th latitude ............................................................................................ 139
10.10. The longitude axis of Öræfajökull – Kverkfjöll – Theistareykir ..................... 141
10.11. The mirrored location and morphology of the two Sneafell volcanoes .......... 142
10.12. An example of a fault in Iceland .................................................................... 146
10.13. Bedrock boundaries ....................................................................................... 147
10.14. The eruption of Holuhraun ............................................................................ 148
Chapter 11 - Tectonic drift .................................................................................... 151
11.1. Tectonic drift of Iceland ................................................................................... 151
11.2. The division line between the American and European plates through Iceland .... 153
11.3. Why does the drift direction follow the lines? ............................................... 157
11.4. Tectonic drift of the whole world ................................................................... 158
11.5. Grid of reference ............................................................................................. 159
11.6. The tectonic drift of Iceland reversed ............................................................... 161
11.7. The continental microplate extending from Jan Mayen to Öræfajökull ........... 163
Chapter 12 - Back to the beginning with the ‘Ocean Basins’ ................................... 164
12.1. Pinpointing the regional and local systems .................................................... 164
12.2. Zooming in on Iceland and then zooming out .............................................. 166
12.3. Ocean ridges around Iceland ........................................................................... 167
12.4. Pulsing of activity along the Reykjanes Ridge .............................................. 168
12.5. Taking more examples .................................................................................... 170
Proof? ..................................................................................................................... 174
Appendix 1: Basic model compared with world map ............................................. 177
The convection system of Earth’s mantle and how heat is conveyed to the surface .... 183
Works Cited ............................................................................................................ 184
Some other useful material at hand during writing: .............................................. 185
Figures:

Figure 1: Earth’s layers drawn to scale with circles representing location of convection cells
Figure 2: A schematic drawing of the current system along the equatorial plane.
Figure 3: A drawing by Antonio Snider Pelligrini (1858).
Figure 4: Hess’ drawing of convection cells.
Figure 5: Layering and convection cells.
Figure 6: A 3D sketch of the current cells as if cut along the equator line.
Figure 7: Surface Ocean Currents.
Figure 8: The Global Conveyor Belt.
Figure 9: The six main division lines of the system.
Figure 10: The point corresponding to the conditions within the mantle if the conditions were balanced, as explained by Manneville (Manneville 2010).
Figure 11: A convection cell with equal height and breadth.
Figure 12: The arrangement of lines necessary to calculate the thickness of the uppermost convection cells.
Figure 13: The 290 km interval between convection cells of lower mantle and the tectonic plates.
Figure 14: The trigonometry used to find the dimensions of the uppermost convection cells.
Figure 15: The 410 km and 670 km discontinuities and the convection cell system.
Figure 16: The convection cell model with small cells of 2 uppermost layers included.
Figure 17: Cross section of equator plane according to vertical arrangement of cells and the small convection rolls layers of 410-670 km depth included.
Figure 18: The upper layers of the Earth.
Figure 19: Convective cells of the asthenosphere and upper mantle.
Figure 20: According to Smet et al. (1999) the mantle is less depleted below 250 km.
Figure 21: How a horizontal circle on a rotating sphere will match with the sphere’s radius.
Figure 22: The calculated dimensions of horizontal flow circle of convection rolls.
Figure 23: A sketch of the horizontal shape of the convection cell system.
Figure 24: The big mantle cells shown underneath in red and the OIB-layer (blue) and the uppermost MORB layer (also red).
Figure 25: A convection cell map with the central line of the North Atlantic marked red.
Figure 26: A drawing representing the alignment of MORB layer convection cells.
Figure 27: The MORB and OIB layers.
Figure 28: The rise in conductivity around 1,300°C is mainly due to the fact that the mantle becomes transparent to radiation at high temperature.
Figure 29: Radiation from outer layers of the Earth heating the core.
Figure 30: The Munroe effect.
Figure 31: How the Munroe effect leads to a jetstream of molten material from convection cells.
Figure 32: How the flow due to Munroe effect cuts through the ductile part of the lithosphere.
Figure 33: A schematic cross section of the effect of main lower mantle Munroe line having effect on the smaller cells above, strengthening a number of Munroe lines of the asthenosphere.
Figure 34: A typical polygon of tectonic plate, formed by convection cells.
Figure 35: An example of how OIB type of magma enters a tectonic plate polygon.
Figure 36: The convection cells shown in the cross section between points A and B above drawn with thicker lines. Point B is on Öræfajökull volcano.
Figure 37: A section of convection rolls shown under Iceland. Munroe lines drawn on map.
Figure 38: Overview of heat flow through Earth’s crust as presented at the website www.mantelplume.org.
Figure 39: The northern intersection zone between hemispheric and polar lines.
Figure 40: Intersection zone structure of convection cells.
Figure 41: World map. Difference of hemispheric and polar cells pointed out.
Figure 42: The convection rolls become thinner as MORB- and OIB-layers originated from north and south intersect each other at these latitudes.
Figure 43: Drawing to scale, tilted 26°. Diagram of intersection zone between hemispheric and polar convection rolls.
Figure 44: Maintenance of circular convection along stress axis perpendicular to rotation axis of the Earth.
Figure 45: How convection cells and pattern of land mass and ocean along equator fit together.
Figure 46: Distance spans 30° over S-America along equator .......................................................... 94
Figure 47: Distance spans 60° over Atlantic Ocean along equator .................................................... 94
Figure 48: Distance spans 30° from west coast of Africa to Great Rift Valley .................................... 95
Figure 49: Distance spans 60° from Great Rift Valley to coast of Indonesia ...................................... 95
Figure 50: The distance from the east coast of Indonesia to the west coast along equator spans 30° ... 96
Figure 51: Pointing out the land vs. ocean pattern along equator ..................................................... 96
Figure 52: A cross section of the equator line showing how the three main ocean ridges of the Pacific, Atlantic and Indian Ocean are distributed on equator .......................................................... 97
Figure 53: The coherence between convection cells and divisions of tectonic features along equator ... 98
Figure 54: The intersection point of large convection cells beneath Africa ....................................... 99
Figure 55: Clarifying the regular division of 30° along equator on a world map ................................. 101
Figure 56: Adjusting the geophysical model to surface features ....................................................... 102
Figure 57: A world map showing twelve division lines around the globe ........................................ 103
Figure 58: Iceland put into context with the horizontal model ......................................................... 104
Figure 59: The world system, including some hot spots ................................................................. 105
Figure 60: The N-Atlantic part of a fully drawn model ................................................................. 105
Figure 61: How Hawaii and Iceland are located in context with lines 120° apart from each other ..... 107
Figure 62: The North Atlantic’s pattern ......................................................................................... 109
Figure 63: The topography of Kamchatka follows exactly the calculated value of direction .......... 111
Figure 64: The formula (Equation 6) fits exactly to ÚKV on this map and Kamchatka ....................... 112
Figure 65: A simplified comparison between map and formula for Tjörnes Fracture Zone .............. 113
Figure 66: The Pacific Plate underthrusting the Australian plate .................................................... 115
Figure 67: The Cameroon line compared to calculations with Equation 8 ....................................... 116
Figure 68: The hemispheric convection cells pattern over Iceland ............................................... 120
Figure 69: The polar convection cell systems pattern over Iceland ............................................... 120
Figure 70: The Icelandic grid of convection cells ......................................................................... 121
Figure 71: Famous places of volcanic zones coincide with intersection points ............................. 122
Figure 72: Comparing geothermal activity and the convection cell grid ....................................... 124
Figure 73: As can be pointed out with a few arrows, most low temperature areas in Iceland are found within distinct polygons .......................................................... 126
Figure 74: The South Iceland Seismic Zone .................................................................................... 127
Figure 75: A geological map of Snæfellsnes with inserted lines for directions of convection cells ... 133
Figure 76: Reykjaness examined with direct and secondary calculations ........................................ 134
Figure 77: Map showing tectonic framework of Iceland. Drawing: Leó Torfason ............................... 134
Figure 78: The 64th parallel being the central line of the transition zone ....................................... 139
Figure 79: The N-S axis from Óræfajökull to Theystareykir due to polygon arrangement ............ 141
Figure 80: Detailed maps, of the two Snæfell volcanoes, put side by side ....................................... 142
Figure 81: Formula shows direction of important faults ............................................................... 146
Figure 82: The earthquake map from the Icelandic Met Office .................................................... 148
Figure 83: A map showing the location of Laki and Eldgjá fissures ............................................... 150
Figure 84: Comparing the convection cells of 64°N and the division line between the tectonic plates .............................................................................................................. 155
Figure 85: The drift of the tectonic plates (from the Internet) ........................................................ 158
Figure 86: How Eurasia and N-America rotate in opposite ways (from the Internet) .................... 159
Figure 87: Resemblance between polar cells and continental microplate between Iceland and Jan Mayen .......................................................... 163
Figure 88: The tectonic resemblance between Hekla and Trondheim, 30° apart ......................... 171
Figure 89: Juan de Funca with calculated direction ............................................................... 172
Preface

In this essay a step forward is presented for geoscience in general of a 3D model of the convection cells of Earth’s mantle. The position of convection cells within the Earth’s mantle is derived and thereby opening up the possibility of calculations in addition to exploration all over the world. Before, no one would think that the orientation of the volcanic zones in Iceland could be calculated according to rather simple preconditions. Now it has become a reality. The convection cell system of the Earth’s mantle can be analyzed quite accurately, greatly increasing our understanding of geology. This essay is in many ways a continuation of the article “History of Ocean Basins”, written by Harry Hess in 1962. He called his writings “geopoetry” but his arguments were accurate enough to be taken seriously. His ideas about convection in the mantle are quite interesting; in fact, they are the same as worked on in this book. I am of the opinion that I have derived many of the details of the system that was described in general by Hess. The model of the convection cell system here presented is based on calculations, again based on physics and geophysical measurements. To make each step during the derivation as clear as possible, I will try to combine drawings with explanations and refer to measurements and physics when possible. This is at the edge of what is known, written with the purpose to push the horizon of what is understandable further. After a decade and a half of studying this, I am fully aware that this is a big step forward.

The most intriguing drawing is the one showing how the thickness of the outer core and the mantle fits to a regular pattern of circular convective cells, where each cell has the same diameter as the inner core. “Seeing is believing”, so at first I suggest the reader should look at that picture. That is the ‘most simple’ aspect, comparable to noticing that the coastlines of Africa and South America fit together. When the convection cell system has been derived from that basic pattern, geology becomes much simpler in many ways to comprehend, and one can even look at it and say: “Of course!”

Trying to keep to the basics and simple predictions, it is emphasized here that the two basic factors of this analysis of the inner structure of Earth are the flow of heat from the core on one hand and the rotation around its axis on the other hand. A wealth of geophysical data can then be adhered to, finding out the most important features characterizing the Earth’s structure.

The first set of geophysical data is the depth of Earth’s layers. The main clue,
then pursued throughout this book, is that the thickness of the mantle provides the exact space for twelve convection cells with equal height and breadth, which happens, due to the proportions of the circular form, to be the same as the diameter of the inner core. A match is found between the height and breadth for six current cells in the outer core of the Earth and twelve in the lower mantle. The key to this match is that the so-called D’ layer, also called the Gutenberg discontinuity at the core-mantle boundary (abbreviated as CMB), provides an intersection zone between the convection cells of the inner core and the lower mantle respectively. Pursuing this possibility did prove to be very convincing. In this essay a comprehensive analysis is carried out of the match between the thickness of the layers of the Earth and a system of convective current cells with identical height and breadth.

The consistency between layers, cells and physics is striking and the implications are pursued systematically. Referring to geophysics, the convective system of the Earth’s mantle can be expected to occur under balanced conditions, so that their height and width tend to be almost identical according to the so-called Rayleigh-Bénard convection as shown in chapter 2. The convection cells of this kind should form rolls, one at the side of another. The Coriolis effect then makes these current rolls curve in a regular way. A special attention is made to horizontal vectors of particle movement that according to relevant formulas. Two layers are then found within the upper mantle (see chapter 4).

The article is divided into two main parts. The former part is about a three-dimensional model of convective cells and the latter part is about how the system shows itself at the surface, especially in Iceland. After deriving the convection cell system from Earth’s center and upwards, the model can be easily verified by detecting tectonic, topographic and volcanic features and comparing those findings with previous analysis. It becomes a manifold proof of the existence of a regular system causing manifold consistency between physics, geophysical data and maps of the surface.

After noticing that a system of identical convective cells exactly fits to the layering of the Earth, much work still had to be done, solving one part after another of the problem how mantle material circulates inside the Earth. The result is indeed an amazing picture that shows how mathematics of the sphere are coherent with a comprehensive convective system. It has of course horizontal and vertical components of a nature that has made it possible to hide this system for many decades, even though it is in many ways obvious once it has been detected.
When introducing something one has been obsessed with for many years, it is tempting to assume that the reader will look at every detail with the same enthusiasm as oneself. I will deliberately try to avoid that, though, and concentrate on explaining what I believe to be basically a correct idea. The choice between introducing a piece of work like this with an article or a book is difficult to make, but in the end the form of the book was picked because of how wide the scope is that is dealt with.

A poster representing this system was exhibited at the GEORG Geothermal Workshop 2016 held at Grand Hotel in Reykjavik and is reprinted here.
Part I - From the core of the Earth to the crust
Chapter 1 - Background of the theory

The very base of the theory is as simple as this: *The diameter of each convection cell within the lower part of the mantle is the same as the diameter of the inner core.*

Pursuing the implications of that possibility becomes material for this book, which is divided into two rather independent parts; the former dealing with the preconditions and geophysics involved and the latter showing examples of how the convection cell system within the Earth is revealed on the surface.

1.1. The model based on Earth’s layers

Looking at a drawing of the layers of the Earth, one can at once see some degree of regularity. It requires, however, some effort to see whether this regularity is just a coincidence or not. The fact is that a regular convective cell system can be drawn so that it fits into the layering of the Earth. Ever since I did first draw the picture of how a simple pattern of circles fits into the layers, I have been working on deriving the system of convection cells within the Earth. The work proved to be very rewarding and I am convinced that knowledge of the system here presented is useful, making many aspects of geosciences more understandable and providing solutions to important questions. The model of convection cells can be difficult to describe only with words because of many reasons, one of them that English is not my first language, another that the system is basically quite simple so it should not need to be described with many words. Still I have decided to have the discussion rather lengthy, using more words than strictly necessary. I think it is very important that new thinking can be introduced into the field of geosciences and it is worth it to write a few more pages than strictly necessary in order to make it easier to comprehend what is explained here. There are so many essays and books that can be referred to dealing with this subject and it is hard to withstand the temptation to include much text written by others. But the main aspect here is logic, and then there are rules to follow not always inherent in everyday speech. Preconditions are followed by judgment, and that provides a base for discussion. By referring to the physical rules that govern the shape and behavior of the convective cells of the mantle, a comprehensive picture of the interior of the Earth can be revealed. The most obvious aspect of this system is that the diameter of the core is the same as the diameter of each circle representing a convection cell of the lower mantle. The consistency is so accurate that one feels
obliged to follow up on this and see whether there are more clues indicating that the main convective cell system of Earth’s interior is based on this pattern (Þorðbjarnarson 2000):

Figure 1: Earth’s layers drawn to scale with circles representing convection cells

As the convectons cells should be arranged on top of each other at equator, the drawing can be represented as such:

This is a very convenient way to represent convection cells with the same height and breadth. The actual flow lines are different. This picture can be represented here at the very beginning because the sooner the reader can become accustomed with it the better. The scientific explanations for this are then dealt with in the essay, showing that this is actually the form to be expected. The circles approximating the convection cells have to fit into distinct layers.
1.2. Referring to physics: Rayleigh-Bénard convection and Coriolis effect.

What is new in this book is organization of measurements made by others, referring to physical laws that have been known for a long time. This analysis of convection cells within the Earth is based on physics, for instance Rayleigh-Bénard convection and the Coriolis effect. Geophysical measurements, particularly of the depth of Earth’s layers, provide the other set of preconditions used for this work. Accordingly, the study has those three basic aspects:

1. The layers of the Earth fit to a regular system of convective cells. The system is consistent with pure physics, namely the tendency of these big and slowly turning convective cells to have the same height and breadth, called Bénard convection (Manneville 2010). More specifically, in Manneville’s study of convection between solid plates, it is referred to as RB convection, where ‘R’ stands for Rayleigh and ‘B’ for Bénard.

2. The location of individual parts of the convective cell system of the mantle is found according to the Coriolis effect (Paldor and Killworth 1988). The apparent pathway of every moving particle connected to the Earth is affected by the Coriolis effect, and that is dealt with in this book.

3. Explanations of various geological phenomena derived from the convection cell system should be found. The system reveals itself all over the world and can for instance be used to explain the geological framework of Iceland in much detail.

A number of indications, geological and topographical, make up a picture revealing a system that can eventually be derived and explained. I will try to examine a number of geologic phenomena in context with this system of convective cells within the mantle. This includes an insight into the history of tectonic drift etc. The GPS technology has improved our understanding of tectonic drift and that makes it easier to compare the effects of the convective cells on the movement of the tectonic plates.

In this way, a vertical aspect indicates the existence of the system here described, that is the thickness of the layers. The reasons for convection cells to have identical width and breadth are explained and they are likely to appear (Manneville 2010). In the second half of this book more emphasis is laid on the surface. The horizontal aspect of the system reveals itself in many topographical features, which
together add weight to the analysis of the convective cell system as here described. For instance, a pattern of 30°, 60°, 30°, 60°, 30° between land mass and ocean appears along equator, exactly where the Coriolis effect is zero. That cannot be a coincidence, because statistics show us that out of a circle of 360° it is virtually impossible to get such a regular sequence randomly, so it proofs that a systematic arrangement within the Earth does exist.

Figure 2: A schematic drawing of the current system along the equatorial plane.

The dynamics of tectonic drift are also included, because vectors derived from the measurements made by the National Land Survey of Iceland (ISN93 and ISN2004) (Valsson 2008) show resemblance to the convection cell system here described.

When these geophysical, topographical and dynamic factors are combined, the probability arises that a myriad of geological phenomena hitherto not explained can be dealt with by using this model.
1.3. Francis Bacon, Alfred Wegener, Harry Hess and many others

The content of this essay is an extension of what is hitherto known about certain geological aspects. It does not in any way conflict with established theories of tectonic drift. Because of the relation of this essay with tectonic drift science, one should mention the history of development of that field of science. When the coast of Africa and South America had been mapped five centuries ago, people immediately noticed that the two coastlines did fit together and theories about the drift of continents appeared. Francis Bacon was the first to draw attention to this in writing in 1620 by assuming this was probably “no coincidence” (Grand 1988). Drawings were made showing these continents together as by Snider-Pellegrini in 18581.

![Figure 3: A drawing by Antonio Snider Pellegrini (1858)](http://courses.science.fau.edu/~rjordan/phy1931/WEGENER/VG05.gif)

An important step was taken one century ago by Alfred Wegener, a meteorologist who analyzed the gliding directions of glaciers in former times. He could show that the gliding paths did fit to a formerly unified landmass of all the continents. In this way he could trace the sequence and direction of tectonic drift quite accurately (Stanley, 1999). He also pointed out other geological and biological facts that supported a theory of tectonic drift.

Harry Hess’ description of ocean floor spreading is the prerequisite of this essay, emphasizing the role of mid ocean ridges (Hess, 1962). All these three steps were taken on the foundations of new mapping and measurements. This history of development of science is very fascinating and it sounds strange to endeavor to add another chapter to it. As this history has been recited in many books and articles, I will only mention it here briefly. But I recommend that those who are interested in science read the whole story about the achievement of Alfred Wegener.

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1 http://courses.science.fau.edu/~rjordan/phy1931/WEGENER/VG05.gif
1.4. The current cell system proposed by Harry Hess

In the essay, *History of Ocean Basins* (Hess 1962), that changed the mind of many scientists, the main emphasis is laid on the geology of the ocean. Hess knew the bottom of the ocean well, when most other geologists were probably more land-bound. The Mid-Atlantic Ridge is probably the most convincing example of convection within the mantle:

The Mid-Atlantic Ridge is truly median because each side of the convecting cell is moving away from the crest at the same velocity, ca. 1 cm/yr. a more acceptable mechanism is derived for continental drift whereby continents ride passively on convecting mantle instead of having to plow through oceanic crust.

Then Hess considers the shape and dimensions of these convecting cells:

Vening Meinesz (1959) analyzed the spherical harmonics of the Earth’s topography up to the thirty-first order. The peak shown in the values from the third to fifth harmonic would correlate very nicely with mantle-sized convection currents; cells would have the approximate diameter of 3000 to 6000 km in cross section (the other horizontal dimension might be 10,000 to 20,0000 km, giving them a banana-like shape).

Hess’s general description of the convection cell system is remarkably similar to the one described in some detail in the following chapters of this book. To make a simple comparison, let’s look at some figures. According to the main postulate used in this essay, a convective cell of the lower mantle has the diameter of about 2,500 km, then covering a stretch of land above at equator from east to west of 3,333 km (that is probably what Hess meant with diameter of 3,000 to 6,000 km in cross section). The length of a semicircular convection cell between equator and 64°N can
be said to be of the order of 10,000 km, just as foresaid by Hess, and it is combined with a mirror shaped convection cell at the other hemisphere, giving the horizontal dimension of 20,000 km. The basic dimensions and shape of the system are all to be found in the said essay from 1962. In this book, all this is simply calculated to get the accurate figures. The search for a more complex situation, based on hot-spots, location of ridges and subduction zones, seems to be the reason for that the system here described has not been derived before on the basis of Hess’s description.
1.5. Description of a system

The main purpose of writing this essay, describing the system of convective cells of Earth’s mantle and core, is to show how regular parameters in Earth’s interior are found behind the more complex situation of the surface. Regularity is found to be the rule, and that is a precondition that is firmly based on physics and logic. Conditions prevalent for billions of years, found within a regularly formed globe which rotates in a very predictable way should show some degree of regular arrangement.

Starting with an indication that the cells of the outer core and the lower part of the mantle have the same diameter as the inner core, more and more evidence is piled up for the same result. Also, some common sense can be applied. The mantle is very thick and convection has taken place for a long time, leading to the notion that conditions must have achieved a very balanced state (Walzer 1971). The fact that the proposed convective cells with the same diameter as the inner core would fit exactly into the layers of the Earth can be regarded literally as the “core” of this analysis. The layers of Earth have been measured quite accurately and everyone can check how circles can be drawn into them, representing convective cells with equal height and breadth. There are also reasons for the physical tendency of the convective cells within the Earth to have these dimensions (Manneville 2010).

The achievement of Harry Hess who in 1962 established the theory of the effects of ocean ridges and the resulting seafloor spreading is fundamental to understand the inner structure of Earth. He reasoned that convection in the mantle did move the tectonic plates as new material was constantly added to the ocean ridges (Hess, 1962). In this essay, an attempt is made to develop this idea further and describe the whole system of convection in the core and mantle of the Earth.

The idea of convective cells with currents reaching directly from core to surface has been presented many times. This is a description of different theories of that sort and speculates about connection between layering and convection (McBirney 1993):

The mantle is thought to turn over slowly, transferring heat generated in the core and in the mantle itself to the asthenosphere and the lithosphere. The temperature within any convecting horizon is probably close to an adiabatic gradient. That is to say, the heat content of the rocks remains nearly constant while temperature varies with pressure, much as it does in the earth’s atmosphere, where the temperature decreases as air rises and expands but increases as it descends and is compressed. And just as the
temperature of air is buffered by the heat absorbed or released when minerals melt, crystallize, or change their crystalline structure in response to changes in pressure.

[Two] conceptions of the mantle [are] consistent with these principles. In one, the entire mantle convects as a single unit, while in the other the upper and lower mantle convect as essentially separate systems.

In this analysis, the second option is the obvious choice, that there are separate systems found, because the size of the convection cells of the lower part of the mantle is fixed as the same as the diameter of the inner core. In many textbooks, the lower mantle is defined as the layer between 670 and 2700 km. In this book, as will be explained later, we should allow ourselves to think differently and consider that the transition zone between the lower and upper mantle is found at the depth of about 410 km.
Chapter 2 - Dimensions of a cross section of the convection cells

Here we begin with the simple picture of the Earth as it was cut into two parts along equator. Each aspect is explained in more detail throughout the book, what reasons are behind it and how it affects our environment.

2.1. The ‘core’ of this analysis

The scale drawing of mantle and core shows that a system of circular convection cells would exactly fit into the layers. It has been shown that the convection cells within the Earth’s mantle should most likely be approximated with circles (Walzer 1971). The radius of the inner core is measured to be 1,221 km. According to that we can draw the basic convection cell system of the outer core and lower mantle very easily.

The drawing is based on this data (Allen 1983) (Cristopherson 1992) (Francis 2000):

<table>
<thead>
<tr>
<th>Lithosphere and asthenosphere</th>
<th>0-250 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition zone</td>
<td>250 km</td>
</tr>
<tr>
<td>Olivine gives way to spinel</td>
<td>410 km</td>
</tr>
<tr>
<td>Lower mantle</td>
<td>670 – 2,700 km</td>
</tr>
<tr>
<td>Gutenberg layer</td>
<td>2,700 – 2,890 km</td>
</tr>
<tr>
<td>Outer core</td>
<td>2,900 – 5,150 km</td>
</tr>
<tr>
<td>Inner core</td>
<td>5,150 – 6,371 km</td>
</tr>
</tbody>
</table>

Here this will be reversed, so, instead of showing the depth of each layer, we can think of the center of the Earth as orego and then look at the distances to each layer above.

Then the table looks like that:

| Inner core                    | 0 - 1,221 km  |
| Outer core                    | 1,221 - 3,481 km |
| Gutenberg layer               | 3,481 - 3,671 km |
| Mantle to the depth of 410 km | 3,671 - 5,961 km |
| 120 and 410 km discontinuities| 5,961 - 6,251 km |
| Tectonic plates to surface    | 6,251 - 6,371 km |

A current cell system, drawn in accordance with physical preconditions (Walzer 1971) fits within this layering, with a match to the transition layer between mantle and outer core (the Gutenberg discontinuity).
The layers of Earth's interior and convection cell system at equator

The layering of the Earth according to seismic data.
The convection cell system as it should appear at equator.

The convection cell system as it should appear at equator.

The figure shows how the layers and the convection cell system fit together. The crust itself is barely visible in the drawing. The line marking the uppermost level of the large current cell system is at the depth of about 410 km. There is another division line between layers at 670 km not shown in the picture, as it most likely only represents changes in the structure of minerals at the relevant pressure that results in different speed of seismic waves (Foulger 2010). At the depth of about 410 km olivine takes on a dense spinel-like structure and at 670 km an even denser form with the structure of perovskite (McBirney 1993). Unlike the shift around 670 km of depth, the 410 km depth layer may represent a change in chemical composition as well as change in structure (Foulger 2010). The changes of form of olivine and this convection model combine at 410 km from surface. At around 2700-2900 km depth, there is the well-known Gutenberg layer. The drawing shows that the convection cells of outer core and mantle intersect each other exactly at that zone. Down below at the surface of the inner core, a similar transition layer is found.
This is a very convincing match between geophysical measurements and physical law that tell us that convective cells under conditions like these tend to have the same height and breadth (Manneville 2010). Therefore, one must assume that this phenomenal “fit” is hardly a coincidence, and it has to be analyzed thoroughly.
2.2. The similarities and dissimilarities between atmosphere, ocean and mantle

Before taking the next step from the 2D section through equator to a 3D model of the entire Earth, it is good to consider first what is commonly known and accepted about comparable systems in nature. The analogy between atmosphere, ocean and mantle makes it easier to work on this analysis of the convection cell system of the mantle, but to do that a clear distinction has to be made between ‘thermal’ and ‘rotational’ aspects of the effects governing the movement of each particle. It must be made clear that the thermal aspect is different, while the rotational factor is the same. The ocean currents must provide an analogy a bit closer to the mantle because the heat capacity per unit of volume is much larger. So, can we distinguish clearly between the rotational and thermal aspects of the atmosphere and the ocean? Yes of course, and we are going to do the same with the current flow within the Earth’s mantle.

The atmosphere and ocean current systems are often looked at mainly as horizontal, while we start here looking at a vertical section of the convection cells of the Earth’s mantle. A further investigation shows that the analysis of the horizontal plane of the convection cell system leads us to a picture that resembles both the weather and the ocean currents.
By learning about the sea currents, it becomes easier to derive the mantle currents. The main difference is the fact that within the Earth heat is evenly distributed between latitudes. It is good to have the conveyor belt of the ocean in mind, especially when reading Chapter 4 - The shape of the convection cell system.

This book is meant to be a real contribution to geosciences. Scientific work has many sides, and the one that appears here is rather rarely applied. The accumulated work of many others is used to derive one holistic framework. The term ‘proof’ and thereby ‘disprovable’ then comes to mind. The book actually provides
both quantitative and qualitative proofs, and anyone can come up with data and calculations to deny the existence of the system described here. The ‘fit’ between a convection system, where the cells have equal height and breadth on one hand and geophysical data on the other hand of the layers of Earth, can of course not by itself be seen as a proof of the existence of the said system. It still includes the possibility of coincidence or another cause than prescribed here. It is just the beginning of manifold analysis which can be reviewed by anyone according to ever accumulating data on the layers of the Earth and better knowledge of the physics of convection cells. When a rule found in an article about physics\(^1\) is in accordance with geophysical data\(^2\), there is a good reason to consider it further and carry out the analysis necessary to see whether it leads to some new results or not. In this case it did lead to a very convincing model of the convection cells within the mantle. The analysis following this simple drawing of the convection current system is not complex, with one preposition\(^3\) that is not even new\(^4\). Here it can be pointed out that when many different phenomena can be related to a simple preposition, then in the end it can be accepted as a model reliable enough to be used on scientific grounds.

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1 Manneville (2000) explains the conditions for convection cells to form with equal height and breadth that can be approximated in a drawing with circles.
2 Many textbooks provide information about the depth of Earth’s layers; outer core, mantle, etc.
3 The preposition is that the convection cells should have the same diameter as the inner core.
4 This is put forward as a preposition by Uwe Walzer (1971).
2.3. The current system

Describing this convection cell system must begin with the cross section of the Earth showing its main layers drawn to scale with a pattern of circles added. Each circle has the same diameter as the inner core. This is how the dimensions of the convection cells can be approximated (Walzer 1971) as will be explained later in more detail.

Those textbooks covering the basic aspects of physics generally include description of the three ways heat is transferred; that is by radiation, conduction and convection (Condon and Hugh 1967). All of these three factors are important understanding how heat is conveyed within the Earth, although the main emphasis is laid on convection. Starting from a two-dimensional picture of the current system of the mantle, a three-dimensional model also has to be developed. First, it is best to describe the picture with a few words. There are 12 current cells of the lower mantle, and therefore there are 6 ascending currents of magma that flow between them and 6 descending ones. To be able to see the system in 3-D, the shape of the cells has to be defined. There should be a way to trace those 12 lines of ascending and descending currents on the surface of Earth.

240 convective cells of the upper mantle and the asthenosphere are also drawn. In this article, surface mapping based on this current system will be done to a certain degree of accuracy. First, we must be able to visualize the shape of the current cells. A vertical cross section can only show the current cells to be circular at equator. When looking at a vertical cross section of a convection current cell either north or south of equator, it must of course be elliptical of shape, in order to fill the layers of the Earth, but still fit to the more limited space of northern and southern latitudes to east and west.
Figure 9: The six main division lines of the system.
2.4. Height and breadth of convection cells

Logic leads us to the conclusion that the conditions within the mantle of the Earth should be balanced. It can be done by referring to the time involved, more than 4 billion years, the size of the Earth, and the relatively calm situation on Earth’s surface. It indicates that a stable system of heat transfer from the radioactive elements through the surface of the Earth must exist. This is a prerequisite for a system of heat flow with as little frictional factors\(^1\) as possible.

The starting point of this all is the pattern of circular convection cells with the same diameter as the core. As often mentioned before, the clue that leads us to this path of analysis is the fact that the diameter of the core has the same length as the thickness of the outer core including the Gutenberg layer. Proceeding with that simple investigation we find out that the diameter of the core is also the same as that of the mantle from 410 to 2,900 km.

Geophysics should also lead us to look for that kind of situation, because referring to the Bénard convection (Manneville 2010) (Walzer 1971) (Paldor and Killworth 1988), regular systems of material flow occur under balanced conditions\(^2\). Considering the uniform conditions within a convective cell and the time span involved a situation of equal force of upwelling and resistance is very likely to occur. That would be a scientific precondition for the convective cells of equal height and breadth.

It is a big coincidence that at the same time as this model is made, a theoretical base is provided, showing the exact conditions that must exist in the mantle to match with the myriad of indications leading to this model of the convection cell model.

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\(^1\) The concept *frictional factor* is used here as a term describing conditions which would be contrary to a perfectly balanced, dynamic system.

\(^2\) This concept, balanced conditions within a system of material flow, refers to mutual equality, such as buoyancy vs viscosity, so that there should be no factors found accelerating or slowing down the current dynamic state of the relevant system.
The graph below gives insight into the relevant calculations (Manneville 2000).

At the lowermost point on line B the convection cells become almost perfectly of the same height and breadth. The resulting convection is as shown below:

The regularity of this system has a base in physics as the expected diameter of the convection cells is half the so called critical wave-length $\lambda_c = 2\pi / k_c$ where $k_c$ is very close to $\pi$ (Manneville 2010).

The pictures show the circumstances expected to be found within the Earth for

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1 From Manneville (2000).
various reasons, such as the equilibrium conditions than can be expected (Walzer 1971) and the perfect fit of convection currents with equal height and breadth with the layering of the Earth.

The conditions prevalent within such a system of material flow have been analyzed in detail and defined as RB convection (Manneville 2010), where ‘R’ stands for Rayleigh and ‘B’ for Bénard. Manneville’s description (e.g. chapter 2 of his essay, named *RB convection at threshold*) should at best be included here as a whole. In that chapter Manneville explains the preconditions needed for circular convection rolls to appear. Those preconditions are, generally speaking defined as stress free and no-slip conditions. Manneville shows the two marginal stability curves for stress-free (A) and no-slip (B) velocity boundary conditions and isothermal plates (infinitely large conductivity):

A straightforward calculation from the Boussinesq equations (1-4) and boundary condition (6) yields the marginal stability condition:

$$R_m(k) = \frac{(k^2 + \pi^2)^3}{k^2}$$

Where $k$ is the length of the horizontal wave-vector $k_h$. The curve is displayed in Fig. 3, together with that corresponding to the more realistic no-slip velocity boundary condition (5) obtained by Pellew & Southwell (1940). The minimum of each curve defines the corresponding threshold above which convection sets in, $R_c = 27 \pi^4/4 \approx 657.5$ and $R_c \approx 1708$ for stress-free and no-slip conditions respectively. The expected diameter of the expected convection cells is half the critical wave-length $\lambda_c = 2\pi/kc$. In the no-slip case $kc \approx 3.12$ which make the predicted diameter very close to the height of the cell.

To connect this theoretical value further with reality, it is explained why it is often the case that height and breadth of convective rolls become the same (Manneville 2010):

As the Rayleigh number exceeds the threshold value, part of the heat is transported by convection which decreases the potential for instability, while thermal diffusion and viscous friction increases due to the horizontal gradients implied by the modulation. This explains that the amplitude of the motions saturates beyond threshold. For rolls, the bifurcation turns out to be supercritical, i.e. behaves continuously in the vicinity of the threshold and the system builds up a well defined steady pattern.

To convince ourselves more about the possibility that the convective currents
have the basic nature of being circular, I will also refer to Uwe Walzer (1971). He does present several ideas in a systematic way about how the convective cells of the Earth might be distributed. In the summary of the article it is made quite clear that the convection must be highly regular (Walzer 1971):

Here it is essential, for the reason of symmetry, that the current system has a degree of regularity as high as possible and is modified only in the upper part, mainly due to the distribution of continents and oceans.

The pattern used in this essay does not appear in the work of Uwe Walzer, probably because he does not let the convection layers intersect each other. Still, the consistency between a system of this kind with the topography of the Earth leads him to the conclusion that its existence is proved in a quantitative way, as “the system yields the seismic discontinuities of the Earth’s mantle as a secondary product”.
2.5. The 410 km discontinuity and the convection cells

A) Calculations according to mathematically perfect circles and sphere:

With simple precondition at hand, simple calculations can be very convincing. This is true for the math used to calculate the dimensions of the upper convection cells, just below the tectonic plates. The geophysical data is quite accurate, so simple trigonometry leads to accurate conclusions.

![Diagram of convection cells](image)

Figure 12: The arrangement of lines necessary to calculate the thickness of the uppermost convection cells.

The angle between A and B is 15° by definition, that is 1/24 parts of a circle. A calculation according to perfect circular currents with the same diameter as the inner core can then be made. The length of the long line A (from center to the top of the upper most circle) is derived from sections B, C and D in this way:

\[ A = (\cos 15°)B + (\cos 15°)C + D \]

It is obvious that \( A = (\cos 15°)B + (\cos 15°)C + D \) and \( B = C \).

\[ A = 4^*(\cos 15°)(1221) + 1221 = 5,938 \]

Distance from cell to surface of Earth: \( 6,371 \text{ km} - 5,938 \text{ km} = 433 \text{ km} \)
**B) Calculation according to convection cell shape and geoid form:**

This approximation with circles gives us a result very close to the measured layers. But to be accurate the elongation factor must be applied for calculating the dimensions of the convection cells ($\pi/3.12$) (Manneville 2010) on one hand and the geoid form of the Earth should be taken into account on the other hand.

Putting the elongation factor into the formula, still retaining unchanged value of the radius of the core gives:

$$A = 4^\ast(\cos15^\circ)(1221^\ast(\pi/3.12)) + 1221 = 5,971$$

(The value of D now stands for the inner core.)

At equator the Earth’s radius is 6,378 km\(^1\) so that gives:

$$6,378 – 5,971 = 407 \text{ km}$$

This is so close to the measured value of a discontinuity at 410 km depth, that according to common sense it is reasonable to keep on with the analysis, keeping in mind the possibility that the preconditions of the existence of the 410 km discontinuity are actually regular convection cells.

The result is very convincing for the equator cross section. The geoid form and the convection cell currents should not be in conflict with each other at any latitude. That can be achieved if the rotation of the convection cells follows, fully or to a certain extent, the rotational plane of the Earth. Then the elongation axis of the cells is perpendicular to Earth’s rotation axis, enabling the convection cells to fit into the geoid form. At the poles the Earth’s radius is 6,356 km, and that can be compared with a situation where the elongation factor should be no longer detectible on the surface, giving the distance from Earth’s center of 5,938 km. This gives: $6,356 – 5,938 = 418 \text{ km}$

This figure is also amazingly close to the measured depth of the discontinuity. Anyway, the depth of the 410 km discontinuity is not everywhere measured to be exactly at 410 km depth (Foulger 2010). The calculations are convincing enough to suggest that a mechanism exists to avoid conflict between the shape of the convection cells described here and the geoid form of the Earth. In fact, those two should fit exactly together as no energy should be lost by the convection cells by adapting their shape to the geoid.

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\(^1\) Wikipedia
Chapter 3 - The 410 km and 670 km discontinuities

The convective cell system above the 410 km discontinuity can be seen as most important to analyze in detail as it is close to the surface where we live. The lower and much bigger current cells are easily detected, as described in chapter 2 and is dealt with also in chapter 7. That can in turn lead us on the track of those upper cells. Without that regular system of large convection cells it would be hard to know where the uppermost system should begin. As we simply have the diameter of the core as a reference for the whole construction of the model described in this book, simple logic leads to focusing on the interval between the depth of 410 and 120 km, whereas convection is not expected to take place in the crustal part of the mantle above 120 km (Francis 2000).

3.1. Uppermost cells of the asthenosphere

In this section the asthenosphere is examined. The current cells of the upper mantle must also be identified. The upper mantle current cells can be found in a similar way as the big current cells of the lower mantle and the outer core. Drawing the vertical cells, it can be seen that the uppermost 410 km are out of reach of the lower mantle currents.\(^1\) The number of convection cells can be calculated according to certain postulates as is done in this book. The results can then be compared with geological and geographical material. Indications of the dimensions of the uppermost current cells are first found on the surface. Mapping in Iceland, with the directions of the system already at hand, gives us one line every 1.5 degrees from east to west. That gives us 240 cells around the Earth. Searching for space for these cells is easy. According to measurements (Cristopherson 1992), a transition zone is found at a depth of about 250 km. A convection layer is found lower, or at 120 km. This is explained in this way (Francis 2000):

Plate tectonics concerns lithospheric plates, rather than drifting continents. Within the rigid lithosphere, heat is transferred to the surface by conduction and temperature increases progressively with depth. At a depth of about 120 km, the temperature reaches about 1350°C, rocks are no longer rigid, heat is

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\(^1\) The definition of lower mantle below 670 km is ignored to adhere better to the preposition used here that the lower mantle currents have the same diameter as the inner core.
transferred by convection, so temperature increases much less rapidly with depth. It is convenient to define the boundary between lithosphere and asthenosphere at the intersection between the two thermal gradients.

This is the precondition for pinpointing the upper limit of the convection cell system at the depth of 120 km. What is above is essentially a rigid plate, divided though into brittle and ductile parts divided with the well known Moho layer. This provides about 290 km of free space for convection within the upper mantle and the asthenosphere. This is what is found according to measurements.

Of course I stick to the measured thickness of the layers close to the crust when considering the real arrangement of convection cells there within. One of the reasons why I look into the possibility of exactly that space is filled with regular convection cells is that is this picture;

Figure 13: The 290 km interval between convection cells of lower mantle and the tectonic plates.
Looking at this consistency, that is the Gutenberg layer fits to the mathematical intersection of convection cells of equal height and breadth, one can succumb to the temptation to search for the same kind of regularity within the remaining gap between 120 and 410 km, that is the preconditions of perfectly balanced physical circumstances (Walzer 1971) are retained.

Simple trigonometry is adequate to find out the basic dimensions of the cells within this ‘gap’, (see drawing below for explanation). Petrology leads us to look for two layers, as is dealt with in other chapters, one for MORB and the other for OIB (McBirney 1993). There are many reasons for considering that two rather similar layers should be found within the gap between the large cells of the mantle and the tectonic plates. One is the necessity for horizontal circulation, which can be explained if there are two different layers found within the said boundaries.
A double layer with intersection zone can be calculated by drawing a triangle with the sides a, b and c, where the angle between a and b is 90°. Line c passes through the center of two identical circular convective cells. The length of c is by definition twice that of b. At surface of flat layers this gives the interval:

\[(2b)^2 = b^2 + a^2; \quad (2b)^2 - b^2 = 290; \quad 3b^2 = 290^2; \quad b = 167.4 \text{ km}\]

With a=290, we get \(b=167.4\), \(c=325\). And: \(40,000 \text{ km} / 167.4 \approx 239\)

The number has to be divisible with 12, so there should be 240 convection cells in one layer, each with its center at the depth of approximately 194 km (see below).

Some simple calculations have to be made according to this Figure 14. The Earth’s circumference is at the depth of about approximately:

\[(120 \text{ km} + (\cos30^\circ(167/2)) \approx 194 \text{ km}\]

\[2 \times \pi \times (6,371 - 194) \approx 38,811 \text{ km}.\]

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\(^1\) Note that the circles represent dimensions, not flow lines. Also, the upper circles enter the tectonic plate for mathematical clarity, in order to make the dimensions of the triangle clear (c = 2b). When curvature of Earth is taken into account in Figure 15, the uppermost cells are not intersecting the ductile layer of the tectonic plate.
The diameter of a cell divided with the calculated circumference of the layer at this depth gives:

$$\frac{38,811 \text{ km}}{240} \approx 162 \text{ km}.$$  

Then the flat layer model has to be laid behind in order to see how the 410 km and 670 km discontinuities fit to the convection cell model. The length from 410 km to 670 km is 250 km, 30 km less than the 290 km from ductile layer to 410 km discontinuity. Another system of 240 convection cells in each layer would fit there as well. The diameter of the cells becomes smaller as the circumference becomes smaller:

<table>
<thead>
<tr>
<th>Approximate radius of cells in upper layers:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer 1: 162 km</td>
</tr>
<tr>
<td>Layer 2: 158 km</td>
</tr>
<tr>
<td>Layer 3: 154 km</td>
</tr>
<tr>
<td>Layer 4: 150 km</td>
</tr>
</tbody>
</table>

The resulting section showing the curve of Earth’s surface and the 410 and 670 km discontinuities becomes like that:

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**Figure 15:** The 410 km and 670 km discontinuities and the convection cell system.
As the larger cells move very slowly, the possibility of a secondary convection within them between the 410 and 670 km discontinuities can take place. The level of accuracy is of course limited, for instance not including inherent elongation (Manneville 2010).

It is not necessary here to go into more details with the mathematics for more accuracy, as the purpose of the calculation in this section is to find a proportion of whole numbers. This result gives 20 smaller cells in a layer above each of the large 12 cells of the lower mantle. Figure 16 has then been derived with both the large cells and the smaller cells above:

![Figure 16: The convection cell model with small cells of 2 uppermost layers included.](image)

A more complicated picture does emerge if the convection cells of the zone between the 410 km and 670 km discontinuities are included. A flow line model is then more appropriate than the dimension model\(^1\) above.

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\(^1\) The dimension model includes nly circles to indicate the hight and breadth of each cell. A flow line
The Convection Cell System should be arranged close to this drawing. Along equator the cells are directly above each other. Convection rolls at depth from 410-670 km follow the main flow of lower mantle.

Figure 17: Cross section of equator plane according to vertical arrangement of cells and the small convection rolls layers of 410-670 km depth included.
3.2. The structure of the upper layers

The structure of the layers below the crust and the crustal part of the mantle is represented in different ways, but with the convection cell system in mind a clear picture emerges.

![Diagram of Earth's layers](image)

**Figure 18: The upper layers of the Earth.**

The lithosphere consists of different layers, especially a brittle crust and a ductile layer where convection does not occur to any significant extent. The role of this ductile layer is important in regulating the distance from the brittle crust down to the uppermost convection layer. With this information at hand, the vertical mapping of the current system of the layers of Earth can be basically completed.

Note that at equator the cells should be located directly above each other. The intersection zone should be constantly changing shape but retaining the same balance between outer core and mantle.
3.3. Convection cells compared with the upper layers

Emphasis on mathematics of the previous section and measurement in this section can be compared as two points of view. It is now time to draw a picture of the convection cells below the crust and show how they resemble the main features of the layers as detected with geophysical measurements.

The layering close to Earth’s surface is drawn here. The drawing spans 30° of equator. The lithosphere layer can drift on the asthenosphere. Discontinuities are found at a depth of 410 km, where olivine gives way to spinel and at 670 km where spinel gives way to perovskite (Francis 2000). The 410 km discontinuity is focused on here as the convection cell system fits to it, and no indication is found that the 670 km discontinuity resembles difference of chemical composition (Foulger 2010). The 670 km transition zone still fits as a continuation of the system of convection cells of the asthenosphere as shown in previous section. The double aspect of explanation of layering, that structural change of minerals due to pressure occurs at certain depth coincide with the convection cell pattern, is nothing to worry about.

A theoretic transition zone is added around the depth of 265 km (that is, according to the simplest calculation, right in between 120 km and 410 km, and the relevant transition layer should be around 20 km thick). A theoretic transition layer appears, mathematically calculated here as close to 15 km thick, found at the depth between about 255 and 270 km. It has been shown that above 250 km the mantle is more depleted of materials than below that depth, according to Smet (1999). Smet does divide the crust and upper mantle into four layers, $H_c$ from 0-16 km, lower part

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1 The simple trigonometry used to find the dimensions of the upper most cells cannot be used here directly, because the lower cells form an inner, and a little bit smaller circle, the convection cells being smaller as well.
of crust, \( H_l \) from 16-50 km, \textit{depleted mantle} from 50 – 250 km and \textit{undepleted mantle} from 250-670 km. The heat flow for those layers is: \( H_c = 4.13 \mu \text{Wm}^{-3} \), \( H_l = 0.9 \mu \text{Wm}^{-3} \), \( H_d = 0.04 \mu \text{Wm}^{-3} \), og \( H_u = 0.09 \mu \text{Wm}^{-3} \).

Figure 20: According to Smet et al. (1999) the mantle is less depleted below 250 km\(^1\).

This indicates strongly that two sets of convection cells are divided at around the depth of 250 km. It is consistent with the analysis here; as it is right in between 120 km where adiabatic heat gradient replaces the higher gradient of the tectonic plates (Francis 2000) and the uppermost surface of the big convective cells of the lower mantle at 410 km.

The convection cell system under the lithosphere maintains an identical pattern throughout the globe. Constant flow means that it cannot stop anywhere! A comprehensive system of a complete circulation of mantle material is a necessity, and to achieve that the different layers must have some arrangement that makes adjustments possible to guarantee a steady flow in any relevant direction. The only way to achieve this is an “exchange system” of magma that allows the correct

\(^1\) J.H. de Smet et al. / Lithos 48 (1999) 153-170
allocation of material throughout the globe. A kind of intersection is therefore necessary, large enough for the convection units to overlap properly. That can be used to find the exact dimensions of the total system, both vertically and horizontally so that a complete “3D” version of the convection cell system of the Earth’s interior emerges.

Consistency is important in science, and here it counts for the transition zone in between individual layers of convection cells. The Gutenberg layer is in the description of this book regarded as a larger version of the transition layer measured to be close to the depth of 250 km. It can be concluded that a double set of convection cells, each with diameter of about 160 km, fits into the measured layering of Earth.
Chapter 4 - The shape of the convection cell system

To be able to come up with a reasonable model of the whole convection cell system of the Earth from the two poles to equator, one has to trace the path from equator where the conditions show themselves most clearly. Besides that, the uppermost layers between 410 km and 120 km of depth have to be dealt with in considerable detail.

The information derived in last chapter shows that the 240 convection cells within the asthenosphere span 1.5 degrees, along each latitude, all around the Earth (as $360°/240 = 1.5°$). The uppermost convection cell system can thereby be indicated with grid of parallel, curved lines, drawn on a geographical map, always maintaining the distance of 1.5 degrees from each other from east to west. When the location of these cells has been found, a basic model for the uppermost regular convective cells is thereby established. In the latter part of this essay, the regional example of Iceland is given to show how the pattern marked by that system explains the distribution of geothermal sites all over the country. To start the horizontal mapping on the surface, based on the vertical mapping of the layers of Earth, some physical rules must be reviewed.
4.1. The Coriolis Effect on the convection cells

The main reason for the curving of the current cells is the Coriolis Effect (Condon and Hugh 1967). To understand the preconditions for the shape of the convection cell system, a study of the Coriolis Effect is necessary. Here we mainly keep in mind two aspects of the Coriolis Effect affecting the path of a particle moving in the Earth; for vertical movement on one hand and horizontal movement on the other. This is the same as we find in weather systems and ocean currents, where we find systems similar in scale as in the interior of the Earth. The analogy between weather systems and the mantle currents is important to quickly understand the dimensions of the system, especially the division between the arctic and temperate zones. The ocean currents can be of help in other ways to understand the upper most layers between 120 to 410 km of depth. The ocean currents can namely be divided into surface and bottom currents, often crossing each other.

In all these cases, for wind, ocean and mantle currents, it is necessary to understand the Coriolis Effect. In the interior however, we have to deal with vertical movements on a much bigger scale than in the air and the oceans.

As the magma from the interior ascends, it must shift westward relative to the crust. Similarly, the mantle descending towards the core must shift eastward relative to the crust. Horizontal flow and vertical flow must then be in harmony with each other, and the horizontal component of the flow is therefore equally important as the vertical component when analyzing the shape of the total system.

As will be shown in the next section, the study of Coriolis effect on moving particles makes it possible to accurately calculate the dimensions of the convection cells within the mantle.
4.2. The diameter of the circular horizontal flow on a perfect sphere

By using the atmosphere and ocean as a reference it becomes easier to understand the shape and dimensions of the convection cells within the mantle. This problem is actually solved according to this (Paldor and Killworth 1988):

Inertia currents are characterized by the simplest possible dynamics; no forces whatsoever act on any element of fluid. Under the assumptions of zero pressure gradient, no friction or boundary effects, and that buoyancy forces suitably cancel, a two-dimensional inertial motion on a geopotential surface will occur. The length scale associated with such a flow is quite large, as no retarding forces obstruct the propagation of a fluid element, and is usually of the order of the earth’s radius.

This gives the scientific preconditions necessary to search for a mathematical equation to calculate the dimensions of the circle of horizontal flow. It is understood that there is a connection between earth’s radius and the radius of flow under the given preconditions. The horizontal flow will be centered on equator, forming a mirrored pattern of circular shapes. Each circle in that pattern will therefore by definition of this model be centered at latitude where the diameter from east to west is exactly the radius of the Earth. It is a logical and inherent precondition.

To find other points of reference, it can be reasoned that two other points on the circle are found at equator exactly 30° apart. Horizontal circulation to north and south, based originally on convection currents that are to a large extent vertical, must show consistency with the triggering system\(^1\) of heat flow. Therefore, horizontal circulation starting between two large cells of the lower mantle should end at the other side of the same convection cell\(^2\). Just from a logical side, the main flow upwards should be met with the main flow down again to maintain a circulation. This pattern will be continuous around the Earth, with the flow direction, if seen on a World Map, generally from west to east. Having these preconditions, the pattern of horizontal circulation can be calculated by using a square grid where the sides of each square stand for one degree of latitude and longitude respectively.

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\(^1\) Keep in mind that radioactive material creates heat and the flow of mantle material is actually carrying the heat upwards.

\(^2\) See the *Teaching material*, added as appendix to this essay.
This is true for approximately the 32nd parallel as shown here:

Figure 21: How a horizontal circle on a rotating sphere will match with the sphere's radius.

Explanation:
On the graph, representing longitudes (arbitrary, that is 0° is not necessarily through Greenwich) and latitudes of the globe, a circle C is drawn with diameter D between the points A and B, intersecting the x-axis, that represents equator, at E 15° east of the y-axis) and F (15° west of the y-axis), thereby fulfilling the precondition of being 30° apart along equator. The two lines marked G and H are found with formula (a):

(I) \[ x = \pm \left( \frac{1}{\cos \phi} \right) \times 30 \]

\( \phi \) stands for latitude, or in this case the relevant value on the y-axis of the grid. The relevant lines intersect the x-axis (equator) at ±30, which by definition have the same distance between them as the radius of the sphere (i.e. the Earth).

These lines show how many degrees along each parallel fulfill the precondition of having the same distance (diameter) between them as the radius of the Earth. The purpose is to find the intersection points between the circle and the graph, where the intersection points also represent the diameter of the circle, thereby finding a circle that has the correct dimensions.

As a circle is defined as \( x^2 + y^2 = r^2 \), it is possible to combine the formulas for a circle and the one given above for the two points with the distance of Earth’s radius
between them. The formula used must fulfill the precondition that the circle crosses the x-axis at ±15. The formula fulfilling this resembles a triangle with 90° angle at the intersection of x- and y-axis with the side of the x-axis 15 units long, the y-axis side unknown and the long side consisting of formula (I) with the value of y unknown.

Then the basic formula for a triangle \((a^2 + b^2 = c^2)\) will be used here by replacing formula (I) for the side (c):

\[
(II) \quad x^2 + y^2 = \left(\frac{1}{\cos(y)}*30\right)^2
\]

That figure, for the parallel where the center is found of a circular path of horizontal flow on a perfect sphere is found by solving this equation:

\[
(III) \quad (\frac{30}{\cos(y)})^2 - y^2 - 15^2 = 0
\]

That is true for \(y \approx 32.066\); that is on the latitude 32°N and S.

**Figure 22:** The calculated dimensions of horizontal flow circle of convection rolls.

This is drawn on the figure above, showing how the arch (a large part of a circle) follows a path which can be calculated because of the relationship of Coriolis Effect with latitude of a rotating sphere. Two points on the circle are known on the equator line, giving an important prerequisite to draw the arch. The mathematics
leading to a final solution is solved because the diameter of the circle (arch) can be found along the central parallel.

‘So far so good.’ This is the calculated value for a perfect sphere. No other perfect circle than the one shown above with diameter D fulfills the prerequisites of intersecting points A and B besides having the same diameter as the Earth’s radius\(^1\).

But when dealing with nature the concept of degree of accuracy arises. Therefore, the closest we can get is to draw a circle around the 32\(^{nd}\) parallel Its center can be written as found to be located on the parallel 32.0°±0.1. Other factors than the mathematics of a perfect sphere, play a role, especially the geoid form of Earth.

There is another solution, as seen on figure 17, namely at about 18.5°N and S. From starting point at equator, the circle would end 60° to the east, providing a second amplitude to the precondition of circulation. The transition layer from 410 km and 670 km fit into that model, as they are an inherent part of the large convection cells.
4.3. The average diameter of horizontal circulation

The exact calculated value of the central latitudes for horizontal flow on a sphere is 32.066, but the last digits are dropped, first because they cannot be valid, second because it is reasonable that these horizontal circles are a little bit smaller on the surface of the globe than on a perfect mathematical sphere. The curvature to the north and south of equator is sharper than close to the poles, so if there is a difference due to the geoid form, it should make the here so called, hemispheric circles slightly smaller. The quotation referred to earlier (Paldor and Killworth 1988) could namely be put into words differently, so instead of saying that fluid would sway in a circle “of the order of the earth’s radius” we can say “in accordance with earth’s curvature”.

We thereby find that the span of the theoretic circle along the 32\textsuperscript{nd} parallel is

\[ \frac{1}{\cos(32)} \times 30 = 35.34 \text{ degree units} \]

The closest we get to find the answer according to this method gives the circle:

\[ (x)^2 + (y – 32)^2 = 35.34^2 \]

That is a diameter for horizontal flow of 2*35.34° ≈ 70.7°, or 70.7 units on the mathematical grid of squares for the degrees.

The diameter of a circle of the convection cell system (that covers 70.7° of the 32\textsuperscript{nd} latitude according to the calculations here) is of the order of the earth’s radius. Calculating backwards again, we find that along the 32\textsuperscript{nd} parallel, where the horizontal flow circles are supposed to be centered, the diameter of each circle is the same as the diameter of the Earth:

\[ (\cos32 \times 111.111 \text{km per degree}) \times 70.7 \text{ degrees} \times \frac{3}{\pi} \]

is equal to:

\[ 0.848 \times 111.111 \times 70.7 \times \frac{3}{\pi} = 6,360 \text{ km} \]

The diameter of the Earth is about 6371 km on the average, close enough to be within the range of accuracy of this calculation. Even though there is an accurate

\footnote{en.wikipedia.org/wiki/Geoid}
formula to calculate the theoretical value of the diameter of the horizontal circle on a mathematically perfect sphere, some uncertainty is to be expected when confronting the real world. What is most important is that this confirms to the statement that “the length scale of such a flow is usually of the order of the earth’s radius” (Paldor and Killworth 1988). Referring to the time scale involved and the observation indicating that a Rayleigh-Bénard type of convection is taking place in a state of perfect stability between buoyancy and viscosity, there is also a reason to state that all the conditions for flow mentioned above (Paldor and Killworth 1988) are fulfilled. Thereby there are reasons to consider that the diameter of the circle of the convection cells is the same as (of the order of) the radius of the Earth, as calculated here.

Even though it is very close to evidence found in nature, other factors, especially the geoid form of the Earth has still not been taken into account.

For elaborating on this we should use a geoid model. Looking up in Wikipedia for Earth’s radius\(^1\), this information is obtained:

The distance from the Earth’s center to a point on the spheroid surface at geodetic latitude \(\varphi\) is:

\[
R = R(\varphi) = \sqrt{\frac{(a^2 \cos \varphi)^2 + (b^2 \sin \varphi)^2}{(a \cos \varphi)^2 + (b \sin \varphi)^2}}
\]

Where \(a\) and \(b\) are the equatorial radius and the polar radius, respectively.

\[a = \text{Equatorial radius (6,378 km)}\]
\[b = \text{Polar radius (6,357 km)}\]

This formula gives the geoid radius for the Earth at the 32\(^{nd}\) parallel as 6,371 km, almost accurately the average radius. The parallel found as central for the horizontal circulation of the convection rolls is thereby also the point where the average radius of the Earth is found. As we are dealing with circular paths, the effects of changes of curvature on the way should be more or less ruled out in the end. Therefore, perfect circles are used with its center at the latitudes of 32.0°N and S. The question about the accuracy or validity of these calculations will be dealt with in the last section of this chapter.

\(^{1}\) Earth radius - Wikipedia, the free encyclopedia.htm
4.4. The basic horizontal model

As things are kept simple in this book, the system is approximated with circles. The whole system can be mapped accurately with the help of a map where degrees of latitude and longitude serve as units in a grid of squares. (Each degree of latitude is drawn of the same length as each degree of longitude to maintain a circular drawing in spite of deviation caused by the geoid form of the Earth.) A circular path is then drawn for the horizontal shape of the Coriolis Cells. The center of the cells is found along the 32nd parallel North and South, called the hemispheric lines. A second type of cells is found at the poles, called the polar lines. The center for those lines can be found at an imaginary 96° N and S. These lines are arranged in a way so that there is always 1.5° free space between them (along each latitude).

Figure 23: A sketch of the horizontal shape of the convection cell system.

1 The same horizontal curvature is maintained everywhere according to Earth's curvature.
2 These are dealt with in more detail in the next section.
The result is a harmonic system providing the necessary possibilities for circulation of mantle material and magma found in the Earth. To draw the surface system on a world scale, 240 circles, for the parallel 240 convection rolls, are drawn from East to West for the North Pole, North Hemisphere, South Hemisphere and South Pole, all together 960 circles and semicircles to complete the picture! This model is defined mathematically, as approximated with circles, in the next section.
4.5. The equation of the world map of convection cells

In previous sections, two layers between 120–410 km of depth, one approximately from about 120-265 km and the other from 265 km to 410 km have been introduced. These layers are again divided into polar and hemispheric parts, which will be mathematically defined in this section.

The equation of a circle is \( x^2 + y^2 = r^2 \) in a rectangular system with a center at the point orego, (0,0). The point orego of the global grid of longitudes and latitudes, (0,0) is located where equator crosses 0° of latitude. As the center of the so called hemispheric circles are found on the line \( y=32 \), (equivalent to the 32nd parallel N and S), the formula for the two sets of circles located between equator and 67.3° N and S can be defined.

The equation for circular approximation for edges of hemispheric convection rolls is:

**Equation 1**  \[(x - C_n)^2 + (y - 32)^2 = 35.34^2\]

Where \( C_n = \{-178.7, -177.2, -175.7, \ldots, -0.2, 1.3, 2.8, \ldots, 179.8\} \) for n from 1 to 240. 

\((C_n + x)\) represents longitude (both N and S, respectively) and \( y \) latitude. The points of \( C_n \) are found 1.5 degrees apart around the globe.

The correspondent formula for the division lines between convection cells at the poles, that is from close to the 61st parallels to the North pole and the South pole respectively is:

**Equation 2**  \[(x - C_n)^2 + (y - 96)^2 = 35.34^2\]

Where \( C_n = \{-178.7, -177.2, -175.7, \ldots, -0.2, 1.3, 2.8, \ldots, 179.8\} \) for n from 1 to 120.

Equation 2 is the same as Equation 1 except for that the center of each circle is now found along the line \( y = 96 \) in the rectangular grid.

Now a system of convection cells can be drawn from center of the Earth up to the crust and from the South Pole to the North Pole.
4.6. Differentiation of the equation of flow to find the direction along the cells

To find the main directions of convection cell rolls at any place on the Earth, another formula can be derived, based on derivation of the circle:

In a regular quadratic grid with center at $(x,y) = (0,0)$, the slope $(a)$ of the tangent to a circle at a given coordinate is:

\[ a = -(x/y) \]

And the angle $(\gamma)$ given in degrees from x-axis (from west) is:

\[ \gamma = \arctan(a) \]

For the spherical form, the intervals between values on the x-axis are shortened by $\cos(\phi)$, where $\phi$ is the latitude. Therefore ‘\(y\)’ is multiplied with $\cos(\phi)$ for correction. When the rectangular grid of squares, where degrees of latitude and longitude are drawn of equal length, is substituted with the spherical grid of longitudes and latitudes, the formula showing the correct direction anywhere on the surface of the globe becomes:

\[ \arctan \left[ -(x/y)(1/\cos\phi) \right] \]

Where $\phi$ is the latitude (works both for northern and southern latitudes). This gives the correct angle between the convection cell roll and west.

A formula for direction $(\alpha)$ for hemispheric convection cell rolls can then be found, and for polar lines $(\beta)$. As directions on a map are usually referred to as compared with north rather than west, we subtract the outcome of Equation 5 from $90^\circ$. As the convection cell system is always symmetrical around a north-south axis, two different directions are found with a single calculation, both East and West of North.
For the hemispheric lines, from equator to the just above the 67th parallel, both for directions $N\alpha^\circ W$ and $N\alpha^\circ E$, formula (6) is applied:

Equation 6\[\alpha = 90^\circ - \arctan \left\{ \left[ (35.34^2 - (\varphi - 32)^2) \right]^{0.5} / (\varphi - 32) \right\} (1/\cos \varphi) \]

From close to the 61st parallel to the North Pole the directions $\pm \beta^\circ$ from N are given by Equation 7:

Equation 7\[\beta = 90^\circ - \arctan \left\{ \left[ (35.34^2 - (\varphi - 96)^2) \right]^{0.5} / (\varphi - 96) \right\} (1/\cos \varphi) \]

The same formulas are applied, in the same way, for the Southern hemisphere as for the Northern hemisphere.

For the lower cells of transition zone, this equation can be applied:

Equation 8\[\gamma = 90^\circ - \arctan \left\{ \left[ (35.34^2 - (\varphi - 18.5)^2) \right]^{0.5} / (\varphi - 18.5) \right\} (1/\cos \varphi) \]

As this equation applies to convection cells very deep below, they are seldom traced on the surface. The lower layer, adjacent to the 670 km discontinuity must cross equator in the middle, that is 30° apart from the crossings at each side over equator for the convection cells just below the 410 km discontinuity.

The remaining questions are obvious. How does this continue? Vertically there are probably more ‘inner convection cells’, and horizontally as well. The complete system can be worked out rather easily. Preconditions of physics, geophysical measurements, and real circumstances on the surface should then be pursued carefully.
4.7. Degree of accuracy

To emphasize on the fact that this is a limited mathematical model based on references found in scientific articles and books, the question of accuracy is dealt with here. The preconditions used to find the dimensions of the horizontal circles of the convection cells are, as so many other things in this essay, quite simple. Having three, or as in this case four, points of reference on a regular grid, an accurate circle can be drawn. A confirmation of the validity of that dimension is found by referring to the central latitudinal diameter of the circle having the same length as the radius of the Earth. The latitude of the horizontal circle can be calculated by combining two simple equations. Mathematically there is therefore an infinite degree of accuracy to be acquired.

Here we are dealing with nature, though, and it is necessary to assess the inaccuracy involved quantitatively (maybe also reluctantly). First let us review the theoretical framework. The points of reference for drawing a circle, on a grid of squares representing degrees of latitude and longitude, are 30° apart on the equator line. Also notice that a string along between two reference points of equator is equal to the radius of the Earth (60° apart). Therefore, we can draw two lines from equator, keeping the distance equivalent of Earth’s radius (60° apart), and combine it with a circle intersecting equator 30° apart. At approximately the 32nd parallel a match between Earth’s radius and central diameter of the horizontal circle is found, of which the calculated radius has the length of 35.34 units. (These ‘units’ here are for instance equivalent to 35.34 decimal degrees of the global grid of longitude and latitude.)

The circular shape appears because in the state of equilibrium of the mantle, the horizontally flowing imaginary particle along a convection roll only changes its path according to difference in rotation speed. The centrifugal force plays no role at all. Therefore, the curvature always maintains the form of a circle on a map where the shortening of circles of latitude are made up for by lengthening them with \(1/\cos\phi\), where \(\phi\) stands for latitude, as they converge by \(\cos\phi\) from equator towards the poles.

As the maps used are drawn so that degrees of latitude and longitude appear as squares, it is also convenient to speak about corresponding units of length. A unit in this case is then the same for one degree to any of the four main directions, and that providing the unit vector for any other direction as well. The digits of value in the number of 35.34 are of course too many. Still that value is given as a calculated figure
according to certain parameters (as if the center of the horizontal circle was found accurately at 32.00°N and S, which is probably not the case). The shape of the circle has its deviations, due to the geoid form. The center of the circle is not exactly at the 32nd parallel, just very close to it, so it can be written in decimal degrees as 32.0±0.1 to include the accuracy level. That is the order of accuracy possible to achieve with the methods used here. The mean radius of that circle should be given as 35.3±0.1, although it is also subject to a trajectory of the geoid surface, giving rise to another type of uncertainty. The necessary information to achieve more accuracy is readily available from many sources.

There is a reason, though, to believe that 32° is even closer to the real parallel of the centers of the circles than the calculated value for the sphere of 32.066° indicates. Now remember that the distance from Earth’s center to the poles is about 1/300 shorter\(^1\) than to the surface at equator. So we can make these points:

1) The curvature of Earth is sharper at southern latitudes, and if the lines sway accordingly (Paldor and Killworth 1988), the radius between equator and 67° will be a bit smaller than that on a perfect sphere.

2) Talking about a circle is convenient, but still inaccurate; it is an arch where 30° of the circle are missing along equator.

3) The shortening of the radius of circle will be less than 1/300, closer to the order of 1/500 making it more realistic to simply omit the last digits of 32.066° and use the 32nd parallel N and S directly.

Another source of uncertainty is the location of the center of each circle on the 32nd parallel on the east to west axis. That can namely not be calculated with a formula like other aspects of the system. Some geologically distinct locations can be used for pinpointing the centers used to draw the said circles; Hawaii, Iceland, the coastal points at equator etc., so an accuracy level of a tenth of a degree should be easily achievable. The figure for the first circle is then given here in Equation 1 and Equation 2 as -178.7±0.1, compared to the longitude of Greenwich as zero.

The accuracy of location of the center of each circle and its radius, besides following the form of the geoid, has its limits, but the purpose of this essay is essentially to describe the theory, not to give countless examples of ‘fits’ or reach a very high degree of accuracy locating the convection cells. Therefore, when reading

\(^1\) Wikipedia
this essay, discrepancy between a theoretical, strictly mathematical grid of the convection cell system drawn on maps and the real physical world must be kept in mind.

These calculations can only become accurate if the curvature of the Earth is followed, because that is what the moving particle\(^1\) can ‘detect’ and follow exactly. This includes that the circle is curving a little bit more sharply between equator and 32°N and S than from 32° to 67.3°. Actually, all of that sharpening of curvature (compared with a perfect sphere) should have been realized at 32°, replaced by flattening north of 32°N and south of 32°S. The relevant discrepancy is close to the order of 1/500, so the approximation of a circle is used throughout the book.

Those calculations, necessary to trace a convection cell accurately, are not made here, only a direct calculation for a perfect sphere with a level of uncertainty when referring to the real world. The figure of 35.34 for the radius of a circle is used as a mathematical reference for a long side of a right triangle where the other sides are 32.0 and 15.0 units long, respectively. This inconsistency is hopefully excused. It can be argued that the radius of curvature for the horizontal circle is slightly larger than the figure used here north of 32°N and S, and slightly smaller closer to equator. That would move the central latitude of the diameter of the horizontal convection cell circles closer to 31.9°N and 31.9°S. The exact mathematics of horizontal Coriolis path of the geoid will hopefully be worked out in the future.

It is of great importance to have a formula to refer to when looking into the geology anywhere in the world. It provides the directions of the convection cells at any latitude and can thereby make it easier to understand the tectonic framework of an area.

The basic form of the current system is circular. It is amazing to be able to calculate the direction of major faults all over the world with the same formula (given in section 4.6, *Differentiation of the equation of flow to find the direction* along the cells). That formula is of course subject to the uncertainty level of the calculations and measurements it is based on.

The way of thinking about geology and geophysics introduced here might seem quite new, but it is in harmony with the steps taken during the last century. The step taken to admit tectonic drift was a lot bigger than to accept the model described here of the convection cells within the Earth. If we can realize in what way the mantle behaves, geology becomes in many ways easier to comprehend once the basic system

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\(^1\) The concept *moving particle* refers here to an infinitesimally small unit within material of fluid state.
of mantle currents has been mapped.

What makes it possible to find a reasonable equation is the fact that the deviation resulting from the Coriolis Effect (Condon and Hugh 1967) varies proportionally to \( \cos \phi \), where \( \phi \) is the latitude. A map of squares (for degrees of longitudes and latitudes) rules out the deviation, simplifying the drawings as a perfect circle will then approximate the horizontal path of a moving particle.
Chapter 5 – MORB and OIB

Having direct calculations to rely on, based on geophysical measurements, it is possible to derive the dimensions of the convection cell system of the asthenosphere and the mantle of the Earth. Petrology provides very important information as well about the inner structure of the Earth. In this chapter the difference between MORB and OIB will be considered.

MORB and OIB are of course petrological concepts, based on two types of rock found on the surface. But it is clear that those two types come from two sources of magma found around the globe (Foulger, 2010). According to this analysis the two candidates for these types of magma are the upper and lower layer of convective cells found between 120 km and 410 km below Earth’s surface.
5.1. MORB and OIB layers

To further clarify the two upper most layers between 120 km and 410 km below Earth’s surface, these two pictures are shown together, with the same horizontal circle marked specially, one in 3D and the other two dimensional:

![Figure 24: The big mantle cells shown underneath in red and the OIB-layer (blue) and the uppermost MORB layer (also red). Drawing by Jón Leósson.](image)

And for comparison:

![Figure 25: A convection cell map with the central line of the North Atlantic marked red.](image)

Having defined the convection cell model mathematically it is time to look at its functions in more detail, especially the upper most layers, presumed to stand for the origins of two different kinds of magma, often referred to as MORB and OIB. For that purpose, a 3D picture was drawn showing how the convection rolls form a pattern, side by side around the globe.
The small cells of the so called hemispheric system are shown here, the polar cells omitted to achieve more clarity. In the 3D picture, red semicircles of the upper layer and a blue semicircles of the lower layer fit together end to end to form one circle. The combination of MORB and OIB circulating in that way is essential for the system. The volume of material flowing horizontally according to this system is of course limited, otherwise there would be little difference between the composition of MORB and OIB.

A circle with an arrow head is drawn in the picture to indicate the flow direction of an imaginary particle along one convection roll circle, first along the red, upper ones, to the north, and then to the south along a blue, lower convection roll. The rolls of the two layers are connected and therefore ensure continuous circulation.

The pattern that emerges on the next picture is the result of putting circles side by side, each representing the edge of one convection cell of the asthenosphere and upper most mantle.

One circle has here been distinguished with red color as it is a circle drawn according to Equation 1,

\[(x - (-4.7))^2 + (y - 32)^2 = 35.34^2\]

This particular circle divides the Atlantic Ocean exactly in the middle at equator and it also marks the western edge of the Eastern Volcanic Zone in Iceland (see Chapter 10 - Iceland).

The accuracy of this system is surprising at first, but several reasons can be pointed out for it.
5.2. The individual sections of essentially circular horizontal flow

Up to now the circular appearance of the horizontal flow has been described and the relevant calculations made. A model can then be mathematically presented of the convection cell system. But looking at the horizontal system of the two layers between 120 and 410 km of depth, it is obvious that the system is composed of semicircles which are connected. Different sections of the rolls, here called hemispheric and polar sections, find their counterparts end-to-end at equator and 64°N and S, so that a picture of a continuous aspect of the convection cells can be drawn.

The basic shape of uppermost current cells looks like this when traced from pole to pole. This is therefore the appearance of what is referred to here as the MORB-layer. This brings to light how hemispheric convection rolls are connected to polar convection rolls. The few lines representing convection cells are drawn for explanatory purpose only, not to scale. For a full scale drawing of the MORB-layer, 240 lines like these should be drawn side by side on a globe. Under this layer, the so called OIB-layer is found, which can be drawn by mirroring each line of this picture.

The generalized sketch shows what the uppermost layer of the current cells looks like. The main curves have their center close to the 32nd parallel. Also note the shift to polar sections around the 64th parallel, where the so called intersection zones are located.

These intersection zones are essential to regulate the system. The magma material flowing horizontally along the lines can be redistributed at these intersection
zones. Mathematics of the circle helps to understand how this system works. The semicircles of a polar convection roll have a tangent point with its counterpart of the hemispheric roll, allowing exchange of material. The tangent points appear when dealing with the mathematical model of the convection system. At equator the tangent points actually become horizontal connections, besides opening up possibility of connection between layers, but at 64°N and S the tangent points show only connections between different layers.
5.3. Flow in current cells: east-west component due to convection and north-south component due to secondary horizontal flow

As every enthusiast of geology is aware of, tectonic drift did add much to our understanding of geological processes. Common sense tells us that it must be due to the flow of material within the mantle and asthenosphere. The first clue ever was the separation of Africa and S-America, and looking at this model here it fits very well to two rolls circulating against each other, one to the east and the other to the west. The rolls affect the plates in some way so they follow the cooling, upper part of the convection cells. But another kind of flow is inherent in the system, namely along the rolls in the direction from pole to equator and from equator to pole.

According to this model of the convection cells, circulation of magma within the Earth is very regular. A special attention should be given to the flow of the uppermost part of the mantle, just below the lithosphere. That should affect geology of the surface most. Here we have to distinguish between the flow making up the vertical sections of the convection cells to the east and west on one hand and the horizontal flow along the rolls on the other hand. A consistency must of course be found between horizontal and vertical flow.

It is obvious that MORB is found above the OIB source of magma (Davies 1999), but it has also to be figured out which semicircle is that of MORB and which is associated with the OIB convection rolls. Luckily, one of the main features of the Earth shows quite clearly that a flow towards the north in the MORB-layer along the Mid Atlantic Ridge must take place. It can be detected because the shape of the Mid-Atlantic Ridge, especially the Reykjanes Ridge, must follow the MORB layer. It is basically shaped like an ‘S’, centered at equator, and according to the Coriolis Effect a flowing particle following that path must be heading northwards (Condon and Hugh 1967).

To elaborate on this, the polar areas have to be mentioned. The MORB convection rolls there have the opposite pattern, showing horizontal flow to the south, as will be dealt with later.

This trend seems to have been prevalent for a long time. In fact for the last 500 million years, the continents have been moving northward (Stanley 1998).
5.4. Horizontal circulation

As shown in the previous section, the asthenosphere cells must have a horizontal flow component. The material is carried northwards along a normal shaped current cell up to about 67°N. This is probably the layer where material for MORB is originated. It provides the oceanic ridges with basalt. The two sources for MORB and OIB are clearly distinguished (Davies 1999):

Since MORBs are rather clearly derived from the shallowest mantle, as will be discussed in more detail later, the OIBs are by implication sampling deeper parts of the mantle.

Under the “MORB layer”, a reservoir for the OIB material is found. The reverse shaped system and the layer below 250 km depth is a candidate for the source of OIB.

The asthenosphere cells are drawn in the figure. It can be reasoned that the upper more

cells represent the normal shaped curves, and the lower more cells represent the reverse lines (as drawn on the world map).

The systems are eventually all connected at the interconnection zones at the polar circles and equator, so that they can all be traced as an integrated system. Some exchange of material then occurs between the different types (for instance from MORB to OIB or from hemispheric to polar sections of convective cells) at the intersection zones close to equator and polar circle. An important conclusion must be made according to this, that there is a regular system of circulation of material found in the Earth.
Chapter 6 - Radiation and the Munroe effect

Essentially, this essay is about heat flow, and that can be in the form of the flow of mass, conduction and radiation. Finding the root of what is examined is thought to be interesting and often proves to be useful as well. When teaching geology, at least in Iceland, the student is required to understand that the inner forces of the Earth are fueled by radioactive material. But there seems to be another piece in that puzzle that probably all of us have overlooked so far. My father, Thorbjörn A. Fridriksson, pointed out that a very essential part of understanding the heat flow with radiation within the Earth seems to be missing. A theory about how radiation from the crust and crustal part of the mantle heats the core and how the core then emits that heat again with convection, is apparently not available.

6.1. The role of radiation

Although many must be of the opinion that the content of this essay is quite radical, additional topic has to be added in an effort to understand better how heat is transported within the Earth. The fact, that most radioactive material is within the lithosphere or close to it, at the same time as the heat originates from the core of the Earth has caused a lot of trouble for scientists. I have not seen it written, but it must seem strange that the core is so much hotter than the mantle when the radioactive material responsible for a big proportion of the heat within the Earth is found far above.

As a result, many of them probably suspect that the heat still found in the core must be largely due to the condensing of the Earth 4.6 billion years ago.

Therefore, a graph is presented as an argument for a form of heat flow that seems to be neglected in all geological literature. According to this graph, showing how transparent the mantle must be to radiation, the radiation must flow easily from the upper mantle all the way to the core. The inner core receives this radiation and is heated in that way and then the heat is transferred upwards again mainly with convection currents, first through the outer core and then the mantle.
Figure 28: The rise in conductivity around 1,300°C is mainly due to the fact that the mantle becomes transparent to radiation at high temperature\(^1\).

As known from sources about the distribution of various elements in different layers of the Earth, most radioactive elements are found in the mantle or even in the crust and very little in the core itself. The radiation can then be directed towards the core from the upper layers.

Figure 29: Radiation from outer layers of the Earth heating the core.

\(^1\) As can be seen in the picture, this graph is from Murase and Mc Birney, 1973, Geol. Soc. Amer. Bull., 84:3563-3592. Note the high value of peridotite on y-axis, rising steeply with temperature getting close to what is found in the mantle. The conductivity can only be expected to rise further, one factor being the absolute transparency for radiation. The Earth is therefore illuminated inside, very much like a light bulb inside, of these wavelengths. The result is constant heating of the inner core absorbing the radiation.
When speaking about how that heat is transferred from the core we must consider how it got there in the first place. This looks similar to the way heat is transferred to the surface of the Earth from the Sun by light, and then either carried away by long wave radiation or heating of the air. David A. Rothery writes on the web-site encyclopedia.com (viewed 9/4/2011) a good description of the three main radioactive elements within the Earth:

Only three radioactive elements occur within the Earth in sufficient abundance and release enough heat per decay event to be significant contributors to radioactive heat production. These are uranium, thorium, and potassium. Uranium has two radioactive isotopes (uranium-235 (\(^{235}\text{U}\)) and uranium-238 (\(^{238}\text{U}\))); thorium and potassium have one each (thorium-232 (\(^{232}\text{Th}\)) and potassium-40 (\(^{40}\text{K}\))). Each so-called heat-producing isotope decays at a different rate, so that the total rate of radioactive heat generation has declined and the relative importance of each isotope has varied over time (Fig. 1). Potassium-40 has remained the most important heat-producing isotope throughout the Earth's history, but uranium-235, which has the fastest decay rate (or shortest half-life), and now makes the smallest contribution of the four, was the second biggest contributor during the Earth's first half-billion years.

The radioactive elements are mostly distributed within the top layers of the Earth, but heat is constantly dispersing from the core with convection. The radiation from the upper layers through the mantle and to the core seems to have been neglected in the literature of geology, but my father, Thorbjörn A. Fridriksson, did point out that according to McBirney’s graph of transparency of the mantle the core is constantly being heated by the radiation from the uppermost layers of the Earth.
6.2. The Munroe Effect.

It would be very difficult to maintain a flow of magma into the brittle part of the crust from the asthenosphere if it was not for the Munroe effect. The flow is governed by the Munroe effect discovered in 1888 by Professor Charles E. Munroe. A cone emitting energy symmetrically inwards into another type of material will result in melting it and forming a self-regulating, comparatively narrow, jet of the said molten material directed outwards from the cone (Munroe 1943).

The convection cells carry heat to their upper more parts, emitting heat in the form of radiation. This results in an upward flow of magma through a narrow path, guided by radiation.
Two convection cells, A and B, with flow lines which together form a cone leading to Munroe effect to take place with a line of ascending molten magma.

![Diagram of convection cells and Munroe line](image)

**Figure 31**: How the Munroe effect leads to a jetstream of molten material from convection cells.

Again my father, Thorbjörn A. Fridriksson noticed that this natural phenomenon should arise as two regularly shaped convection cells rotate one against another, releasing radiation as the temperature of the material changes.

The two cells at each side of the Munroe line contribute to the constant heating of the vertical magma flow, further enhanced by Munroe effect within the walls of the Munroe line itself. The wideness of the Munroe line can probably be calculated, but a first guess is that is that the inner ascending flow can be around half a meter wide.

The flow within a Munroe line has vertical and horizontal components. The vertical component is obvious from the description, but horizontal flow along those lines is also an important factor. As has been shown, the system leads to a constant flow to the north in the uppermost hemispheric cells, and the horizontal flow of the Munroe lines must be in accordance with the Coriolis effect as well.

The magma walls cut the ductile part of the lithosphere into small pieces. How far up these Munroe walls reach must be quite different from one place to another. It can most easily be estimated where they penetrate magma chambers, pumping magma constantly into them.
In the drawing it is shown how the magma flow cuts up through the lithosphere. A very special case of geology strongly indicates that the ductile part of the crust is ‘cut’ with a high degree of accuracy with Munroe lines of the kind here described.

The Munroe effect can hardly continuously form a long wall along the edges between the convection cells, they can rather be described as ‘flames’, reaching up and migrating along the convection cell edges. The best example of such migration of major Munroe effect flame is along the Reykjanes Ridge, moving south about 25 cm each year (Jones, White og MacLennan 2002). The flame propagates in the opposite direction of general flow of magma, because the turning to the right is consistent with movement to the north according to the Coriolis effect. Now the intersection zone between individual layers, in this case the intersection zone of the MORB and OIB layers at the depth of around 260 km (see next chapter) should be reshaping constantly, from consisting predominantly of circular MORB convection cell above to that of the OIB convection cell below. A fully recovered section of a pair of MORB convection rolls should form a stronger Munroe line, resulting in enhanced volcanic activity. This pulsing activity of the Reykjanes Ridge is therefore essentially of vertical nature, as the propagation of Munroe effect magma flames is opposite to that of vertical flow.

There is a strong indication that the seismic zone of the Southern Lowlands of Iceland (South Iceland Seismic Zone or SISZ) is framed within a diamond shaped area marked by the lines in between convection cells. This is further dealt with in chapter 11.
6.3. The function of the Munroe-lines

A Munroe lines is probably the most surprising aspect of the system described in this book. It should be possible to detect a Munroe-line with geophysical measurements, but they must be narrow and mainly found below the brittle part of the crust. The Munroe lines extending into the lithosphere

![Figure 33: A schematic cross section of the effect of main lower mantle Munroe line having effect on the smaller cells above, strengthening a number of Munroe lines of the asthenosphere.](image)

The Munroe lines are of two types, MORB and OIB, referring to petrology. The reason why OIB is often found on islands and MORB appears mainly along ocean ridges can then be explained:

Imagine a diamond-shaped polygon cut into its shape by two parallel MORB-lines and similarly two parallel OIB-lines. The OIB-magma has a longer way to go, but according to the rules about stand-off for Munroe effect (Munroe 1943) it is not a hindrance.

The next drawings show examples of the combined result of Munroe lines of different types (MORB and OIB) cutting through the lithosphere.
Figure 34: A typical polygon of tectonic plate, formed by convection cells.

This is the basic pattern found over a big part of the world. Therefore, another picture is added showing how these circumstances can lead to the formation of a volcanic island with rock formation of a type referred to as OIB.

Figure 35: An example of how OIB type of magma enters a tectonic plate polygon.
Along ridges, on the contrary, the MORB jets form dykes parallel to the ridge. The formations of volcanic islands with OIB and that of ocean floor along ridges are therefore two aspects of the same forces.

In Iceland, practically all functions of the Munroe line system can be found. At Hekla volcano, for instance, the MORB and OIB lines merge into one. In fact, it is necessary to go through the next chapters comparing model with reality to have the necessary background to see all the different possibilities which emerge. The first step, though, for those familiar with conditions in Iceland, is probably to have a look at this cross section:

![Cross Section Diagram](image)

A simplified cross section from points A to B of the conditions leading to the formation of the West Volcanic Zone (WVZ), Central Volcanic Zone (CVZ) and the East Volcanic Zone (EVZ) of Iceland.

Figure 36: The convection cells shown in the cross section between points A and B above drawn with thicker lines. Point B is on Öræfajökull volcano.
Figure 37: A section of convection rolls shown under Iceland. Munroe lines drawn on map.

The cross section can also be shown in this way. Every layer of rolls leaves one set of Munroe lines within the tectonic plate. Over 1000°C hot lava can make its way to the surface only because of Munroe effect constantly carrying a flow into the brittle crust.
6.4. Horizontal transfer of heat within the mantle

At the Earth’s surface, heat transmitted from below is very unevenly distributed. The shear velocity variation of seismic waves from the relevant average value is only on the order of ±1.5% (Ritsema, van Heijst and Woodhouse 1999). How can the heat emitted from the surface be around 400 mW/m² in some areas¹ and virtually not detectable in others?

This can be explained with the combination of heat radiation within the Earth and the Munroe effect. The Munroe lines transfer heat effectively towards the crust, and if it is absorbed there the back-flow of the relevant Munroe-line will contain proportionally more crystalized material, absorbing heat radiation from the surroundings. The Munroe line is therefore maintained with extra input of energy if it meets with an ocean ridge above absorbing heat.

A map of the ocean ridges and the heat flow shows consistency with the convection cell model. Looking at equator, The East Pacific Ridge and the Indian Ocean Ridge are close to being equidistance from the center of the Atlantic Ocean. Much heat is emitted through those two ridges. They represent two of the six main ascending currents of the lower mantle. Thereby we have this basic picture²:

![Figure 38: Overview of heat flow through Earth's crust as presented at the website www.mantelplume.org.](image)

This large scale lateral flow of heat necessary to make this possible would hardly take place otherwise than with radiation within the Earth.

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¹ [www.mantleplumes.org](http://www.mantleplumes.org)
² [www.mantleplumes.org](http://www.mantleplumes.org)
Chapter 7 - Intersection zones of horizontal flow

An essential factor of understanding how the convection cell system works is that the whole system must constantly circulate smoothly, both regarding the vertical components of the convection current cells and the corresponding horizontal flow along the convection cell rolls. It turns out that intersection is an integral part of the convection cell system, and in turn is essential to stabilize it and indeed to make it work! We can then go on exploring some geological phenomena and explain them according to the current cell system shown on the world map. This is the key to make a model of the convection cells, showing in that way a resemblance to the distribution of the main volcanic and geothermal areas of the world. The circular shape of the convection cells is a result of the Coriolis Effect. The circulation is arranged in a way that provides not only a relatively uninterrupted flow, but also an exchange system for horizontally flowing magma.

7.1. Intersection Zones

When describing the basic pattern of the convection cells, the largest part consists of the so-called hemispheric rolls, which extend approximately from equator to the polar circle. Concentrating on the MORB layer it comes to an end when it reaches the point of pointing directly east-west. Similarly, the polar rolls come to an end around the 61st parallel. What is between becomes an intersection zone.

In the mathematical model of horizontal dimensions hemispheric and polar convection cells presented in this book (formulas (1) and (2)), the circles intersect each other at the interval between 60.7°N and 67.3°N. This is probably the most complex aspect of the system, but instead it is probably better detectable there, that is in Iceland. After applying the formulas (1) and (2) to insert the circles on a World Map, the volcanic zones of Iceland provide a basis to ‘zoom in’ on the complex grid appearing out of four sets of lines, showing immediately resemblance to many aspects of the tectonic system. It is actually possible to use this system to perceive an amazing wealth of details in Iceland. The map is more complex than for most other countries because it has both hemispheric lines and polar lines.
In this figure, the conditions of the intersection zone are shown.
The red line represents N0 according to the world identification system.
This line is quite dominant and its polar section goes through the Jan Mayen area.
7.2. MORB and OIB layers connection within the intersection zones

When studying the intersection zone between the hemispheric and polar current rolls, the emphasis is laid on horizontal flow of a particle within it to understand how it works. A MORB roll eventually reaches its northern boundary at around 67.3°N, pointing directly to the east. Exactly at that location, down below, there is the end of an OIB roll, pointing directly to the west. The result is that of a perfect circle combined of two semicircles of MORB and OIB respectively.

Looking further into the system of the horizontal intersection zone, the 64th parallel plays an important role in an exchange of moving particles from hemispheric to polar convection rolls. The reason is that the intersection lines have a tangent point at that latitude where, as can be expected, the rolls of both systems have exactly the same direction. That, again, can explain the shift of direction of tectonic drift exactly there in Iceland, because conditions for exchanging moving particles, still within a framework of undisrupted Coriolis effect, is found there.

This results in a perfect circle, within a grid of squares representing degrees of latitude and longitude, of MORB and OIB semicircles combined, covering 30° from east to west both at equator and 64°N (and of course 64°S as well). That circle is centred around a point on the 32nd parallel, where, in turn, the diameter of the circle is exactly the same as the radius of the Earth. That dimension can be expected according to Paldor (1988).
7.3. The layers of the horizontal intersection zones

To maintain the path of a particle moving according to the Coriolis effect, where the conditions are balanced according to various conditions (Paldor and Killworth 1988), the horizontal intersection zones must have four layers. Therefore there should be at around 60.7°N a division line where the rolls double themselves. To be a bit concrete, let’s visualize a roll within the MORB layer from its top to bottom, with a vertical diameter of about 160 km. North of 60.7°N there are two layers of rolls within the MORB layer, with a vertical diameter of about 80 km. The dimension of the doubled cells remains unchanged, but the effect of all of the four layers is found on the surface, making the conditions at the latitudes of intersection zones more complicated than elsewhere.

![Diagram of convection cells]

**Figure 40: Intersection zone structure of convection cells.**

The conversion of one layer into two at the latitudes of 60.7° and 67.3° respectively is object to special analysis. How a thicker roll to the south ‘crawls’ either under or over a thinner one from the north and visa versa is subject to a lot of speculation. A manifestation of how the horizontal flow works within the transition zone is found in the rather recent measurements of tectonic drift (ISNET 2004).
7.4. The intersection zones between 60.7° and 67.3°

As it was possible to calculate directly the dimensions of the hemispheric rolls described, here a more straight-forward method is used to introduce another aspect of the total convection cell system. Hemispheric rolls have the horizontal dimensions of the cells, covering theoretically 70.7 degrees from east to west along the 32nd parallel, and extending approximately from equator to 67.3°N with a mirror image from equator to 67.3°S. More accurate calculations can of course be made with the geoid form.

The name used for so called polar cells, is here introduced to distinguish them from hemispheric cells, also called polar and hemispheric rolls. First reviewing a few points about the hemispheric rolls, the finding of the central location of a horizontal circle at around the 32nd latitude implies that it has a northern limit. If we turn to mathematics, calculation shows a northernmost limit at 67.34°N. On the other hand, the system has a southern limit at equator. The 64th latitude plays an important role, as can be seen on the world map here, comparable mathematically to that of equator! The 64th latitude, provides an exchange system between both layers (vertical exchange) and different sections (horizontal exchange) of the globe. The other section here is of course found north of the 64th parallel, shaped according to the same preconditions as the hemispheric circle between equator and 67.3°. These conditions are found in the same way (although mirrored) in the North and the South Hemisphere around the poles.

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Figure 41: World map. Difference of hemispheric and polar cells pointed out.
Figure 42: The convection rolls become thinner as MORB- and OIB-layers originated from north and south intersect each other at these latitudes.

To elaborate further on the intersection zone, it should be taken into consideration that the function of horizontal flow within the convecting rolls is doubled on the average:
The original balance with cells in proportion 3.14 units perpendicular to rotation axis (therefore being the height according strain axis of convection cells as explained earlier) and 3.12 units wide is now altered. At 64°N a new balance is acquired resulting in vertical cells, so the strain axis should be along the line from Earth’s center to the surface. Where the cells become thinnest, horizontal flow will be dominating over the convection factor according to this analysis.

The special condition within the horizontal transition zone, in turn, can be used to estimate the relative flow volume of the vertical convection per time unit on one hand and the horizontal flow volume per time unit on the other hand. The first guess is that those two vectors of flow direction are equal. Therefore, the perpendicular line to the rotation axis of the Earth of a convection cell at 64°N would look as half the height compared to width. South of 60.7° and north of 67.3°N the proportion of the cells is the same as everywhere else on the globe outside the intersection zone, i.e. of equal height and breadth in the plane of Earth’s rotation.

The transition is here presented according to the known fact that more heat is measured above 61°N than south of that parallel (Foulger 2010). Therefore, it is reasoned that the polar convection rolls convey more heat than the hemispheric cells.
at that latitude. The material of the polar cells should be lighter and be found above the upper hemispheric cells in the intersection zone.

All this implies that conditions are a bit special in the areas from the 61st to the 67th degrees of latitude. There is indeed more heat flow found north of the 61st parallel than south of it (Foulger 2010), and that is in accordance with the observation that the convection rolls in the latitudes of the intersection zone have an axis of rotation independent from (not perpendicular to) the rotation axis of the Earth.

It should be noted that the division plane between the polar and hemispheric cells is almost perpendicular to the rotation axis of the Earth. Considering the stress alignment factor of $\pi/3.12$ as dealt with in chapter 2.4, it provides conditions of balance between the convection process and the centrifugal force.

7.5. Is there something special about the polar areas?
The different conditions found in the polar regions of North and South can be related to the opposite directions of main feeding into the polar cell system. The horizontal flow direction under both the Arctic Ocean and Antarctica must be mainly southwards, resulting in an ocean prevailing around the North Pole and landmass being kept around the South Pole.

The areas involved around the poles are comparatively rather small, and the width of the convection cells is approaching zero. Still, the mathematical grid of equal squares for each latitude and longitude is just as valid there as anywhere else. If anyone is surprised that an ocean has a tendency to prevail at the North Pole and landmass at the South Pole, then one has to be warned that there is more to come, for instance, as will be pointed out later, the western volcanic zone of the Gakkel Ridge in the Arctic Ocean can be traced to the volcanic zones in Iceland over 2,000 km away!
7.5. The intersection parallel of equator

At equator the shift between the two hemispheres has a crucial effect on the convection cells system. An example can be taken of northward flow crossing equator from south to north, causing a horizontally moving particle crossing this border line to change its apparent tendency to turn to the left in the south and start turning to the right in the north. This does cause strong constrains on the system of the equator line, clearly showing themselves with distribution of ocean floor and land mass respectively.

Equator can be called a line of transition. A particle surpassing the equator line cannot keep on swaying in the same direction, but must either turn to the other direction horizontally or shift to the other layer and turn back. This seems to result in the very strict restrictions exactly along equator, resulting in a regular pattern of land mass versus the ocean. At equator there is transition taking place of similar kind as what takes place along 64°N and S.

The tangent points between the circles extending from the South and the North on the equator line are on the same longitudes as their counterparts along the 64th parallels. Therefore, a particle that is from its own point of view always following a straight line, can undisturbed pass from one hemisphere to the other. The difference is found in the fact that no doubling of layers in the system occurs at equator as in the other intersection zones around 64°N and 64°S.
7.6. Vertical view, versus view along plane of rotation

A vertical view appears as perpendicular section (cross section) compared with Earth’s surface, while a view along plane of rotation is always perpendicular to Earth’s axis of rotation. These two types of cross sections have to be dealt with here.

When physical law predict almost equal height and breadth of the convection cells, should that form only be found along equator? Of course, that form of flow should be retained everywhere. What maintains this pattern is the persistence of circular lines of flow perpendicular to the Earth’s axis of rotation.

The system is most clearly detected and understood for the section at equator. To realize a 3D-model much more work has to be done. For instance, at 60° North or South, the wideness of the current cells is only half of their depth. Then the convective currents must be twice as thick as they are wide. This is a bit harder to visualize than the regular circular pattern of the equator. Still, in the plane of Earth’s rotation, a circular pattern is retained. In a slice along a parallel, similar to the one shown when the Earth has been cut into two parts along equator, the individual flow lines of the cells appear as circular. A section like that looks the same as that of equator. It can be explained mathematically whereas the width of a cell as seen perpendicular to the surface shrinks by \( \cos \varphi \) where \( \varphi \) is the degree of latitude. The main direction of centrifugal force is found directly away from the rotation axis of the Earth, and therefore that also becomes the elongation axis of the flow lines of the convection cells. That is the mechanism for the geoid and the convection cells to perfectly fit together.

As can be seen on the drawing there are more factors to cope with if the exact direction of flow is to be derived on each latitude, because the cells have some span from north to south as seen perpendicular to the rotation axis. The equalization of height (\( \cos \varphi \) for latitude) and breadth (\( \cos \varphi \) for axis of rotation) is simply the first approximation in order to understand how the convection cells match with the geoid form.
Figure 44: Maintainance of circular convection along stresss axis perpendicular to rotation axis of the Earth.

Looking from above (parallel to the rotation axis), the cross section perpendicular to the rotation axis of the flow lines of a convection roll appears circular at the latitudes of both A and B. The angle between a plane of latitude and vertical line to the surface is \( \phi \) in both cases, and thereby the length diminishes by \( \cos \phi \), so those two factors eliminate each other and that explains why the circular shape of the flow lines compared to the rotation axis of the Earth is retained on a slice of other parallels. This is also in accordance with the shape of the geoid, because the elongated axis of the cells is no longer perpendicular to the surface, resulting in conformity between convection cells elongated according to balanced conditions (as explained before they are therefore elongated vertically by \( \pi/3.12 \)) and the geoid shape of the Earth.
7.7. Conclusion

At the end of this part of the book, it is time to speculate on theories about the inner structure of the Earth. Tectonic drift is observed on daily basis with modern technology and it is also common knowledge that scientists claim that convection currents of the mantle of the Earth initiate the drift.

As there are many things discussed in this essay, we have to keep in mind that the preconditions are simple. They are based on the fact that circular currents with the same radius as the inner core would fit exactly to the layers of outer core and mantle at the equator plane. Everything else is just an attempt to work out how the whole system looks like.

The inner structure of the globe has been measured according to seismic data. The innermost core is thought to be solid, surrounded by the outer core that is in liquid state. The mantle above is solid, but still in plastic form because of high temperature. Therefore, currents can be found in the mantle (McBirney 1993). As the mantle is quite homogenous of composition, thickness and temperature (as it has adiabatic temperature gradient), a regular system of currents should also be expected.
Part II - How does the system reveal itself?
Chapter 8 - The distribution of land mass along equator

The division between the two parts of the book is made clear here for some reasons. Giving examples how theory about the inner structure of the Earth is radically different from the exercise of logic to trace the convection cell system literally from the core up to the surface, referring to geophysical data, physical law and experimental conclusions.

But we should not neglect the fact that geological mapping is also of scientific nature. The reader should actually be able to read this book beginning with this chapter, because here again we reveal just as quickly as before the size of the big cells within the mantle of the Earth. The distribution of land mass along equator is very convincing, showing the existence of the big convection cells in the mantle with the same diameter as the inner core. It is even in some ways more clarifying than the fact that the thickness of the outer core and the layers of the mantle fit together. Perhaps some people can have some doubt about the analysis according to the diameter of the core in Part I of this book, and maybe someone is not sure about the deduction of a convection cell system responsible for the regular distribution of land mass along equator here in Part II, but when those two different aspects fall into one then it becomes difficult to deny the theory.

South America covers 30°, the Atlantic Ocean 60°, Africa to The Rift Valley 30°, Rift Valley to Indonesia 60°, Indonesia 30°, Pacific Ocean 150°. Now we can keep on.
8.1. A “fit”

The resemblance between the convective cells and the thickness of the layers of the Earth is something very obvious to geologists trained in looking at sections of different layers. But just about anyone is trained to look at the world map and therefore is able to see at a glance the remarkable consistency we find along the equator. That is a good help to show the dimensions of the convective cells of the lower mantle. This is almost as stunning as the fit between the coasts of S-America and Africa.

Looking at equator has scientific value, because there the horizontal Coriolis Effect is zero. In addition to that, the Coriolis Effect works in opposite ways to the north and south of equator. Thus we make accurate measurements accurately on the line of equator. It is useful for taking the step from deriving the model of the convection cells over to looking at surface features that somehow fit to the whole system, but here it is especially important because it can be predicted by referring to physical law that conditions might be special there. Also, equator is where we start out because there we have the coincidence of the underlying cells having all dimensions exactly in harmony with the layering of the Earth.

The result is shocking, as the distribution is perfectly regular. And what is more, the regularity fits perfectly to 12 underlying convection cells.

![Figure 45: How convection cells and pattern of land mass and ocean along equator fit together^1.](http://www.gfd-dennou.org/arch/de1)

The circles on the map have the same diameter as the inner core. As can be so simply pointed out, the continents fit to every detail of the underlying mantle convection cells. This distribution does reveal the system in such a fantastic way, that I would like to have a special written book about it, pictures from the main locations and information about the geological framework and history. Here I can only try to elaborate on this point by making use of Google Earth.

8.2. Measurements along equator

To make use of the pattern of landmass and ocean along equator, a thorough research on the geological and geophysical conditions at every coastal area on the parallel have to be made. The pattern is unbelievably clear and accurate, yet it is in no way easy to work with in detail. To look at the predicted pattern of convection cells appearing on the surface is just amazing.

Here is the first picture drawn on the base of Google Earth map of the Globe along the equator line. The yellow line is available in the tool kit of Google Earth to make measurements.

![Image of Google Earth map with yellow line along equator]

Figure 46: Distance spans 30° over S-America along equator.

It is precisely covering 30° of the circumference of the Earth. Just that would be a coincidence worth looking further into, but other measurements distract us more. First the distance between S-America and Africa along equator.

![Image of Google Earth map with yellow line along equator]

Figure 47: Distance spans 60° over Atlantic Ocean along equator.

The distance between S-America and Africa is 60°, showing where two
convection cells, each having a diameter equivalent to 30° of the relevant circumference of the Earth, lie underneath. Again I have to thank Google to provide this excellent tool to measure distance and the yellow line for connecting the two points here. Hundreds of years ago people became suspicious because the coastlines did fit together, but it fits together in more ways than just coast to coast. The Mid Atlantic Ridge takes a turn along equator, so it is easy to say that here we have a pattern of Ridge in the middle and then the two coasts 30° away along equator.

As the big convective cells of the lower mantle are expected to span over exactly 30° each, this is a remarkable coincidence. But this pattern of the equator circle where its sections are divisible by 30° is found around the Globe. The West coast of Africa to the eastern part of the Great Rift Valley of the continent are also separated by 30°. Here it is drawn on a map:

![Figure 48: Distance spans 30° from west coast of Africa to Great Rift Valley.](image)

Again, the span from the same point of the Great Rift Valley to the coast of Indonesia is exactly 60°, as shown here:

![Figure 49: Distance spans 60° from Great Rift Valley to coast of Indonesia.](image)

The last picture shows that the distance between the West coast and the East
coast of Indonesia along equator is likewise 30°.

Figure 50: The distance from the east coast of Indonesia to the west coast along equator spans 30°.

So we have a pattern of 30, 60, 30, 60 and 30 degrees! The Atlantic Ocean and the Indian Ocean therefore both have a pair of convective cells underneath, whereas each continent is found above one single cell. The Pacific Ocean is of course in this pattern with 150° width, that is equivalent to the span of five convective cells.

As this pattern can not be overly emphasized, a simple 3D-drawing is added here:

Figure 51: Pointing out the land vs. ocean pattern along equator.
8.3. The ocean ridges at equator

In addition to the land / ocean pattern, there is an almost identically clear pattern of ocean ridges on the line of equator. It looks like this:

![Diagram of ocean ridges](image)

As can be seen from the cross section, both the Indian Ocean and the Pacific Ocean ridges seem to be over converging mantle currents, but looking at the upper most currents of the asthenosphere the currents immediately below the ridges are divergent, flowing from the center of the ridge to east and west respectively.

Here the absolute regularity found of the 30-60-30-60-30 pattern is not found, but it shows a remarkable consistency with the model of the convection cell system. The fact that this is all found along the single line of equator is quite extraordinary. It must be added, as this is not just a game of words here, that what seems to be a bit irregular, that is the ridge of the Pacific does not form 90° with the center of the Atlantic, would be corrected if it was not for special circumstances at a triple point at the Cocos-Nazca spreading axis and the Pacific plate.

Accordingly, it can be argued that a pattern of 30° is detectable around the globe at equator; the eastern edge of Pacific Plate – west coast of South America –

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1Inserted picture from www.HEAT AND CONVECTION IN THE EARTH.htm
east coast of South America – center of Atlantic Ocean – west coast of Africa – Great Rift Valley – center of Indian Ocean – west coast of Indonesia – east coast of Indonesia. That makes 8 x 30° in a row, or 240° out of 360°. Only 120° extending over the Pacific Plate remain somehow intact according to my knowledge.

Figure 53: The coherence between convection cells and divisions of tectonic features along equator.

The resulting picture of looking at the main features of equator is almost complete. The remaining three lines not showing some strong indications of their presence at equator are the ones extending from Japan, the Bearing Strait and Hawaii respectively.

These indications of a regular convection cell system give us a new start. This is pointed out in addition to the more scientific analysis of the previous chapters. Therefore, In this chapter, certain circumstances are described in order to compare them with the model which is based on the most simple calculations according to geophysical data readily available in basic textbooks and on open internet sites.

We are so lucky that these stepstones along equator are close to whole numbers, namely 50°W, 20°W, 10°E, 40°E, 70°E, 100°E and 130°E. The discrepancies are then to be dealt with in each case, as the proof of a systematic cause for this distribution is obvious to everyone.
8.3. Has the pattern along equator hitherto been hidden?

There must be some reason for that I have not seen this pattern along the equator line mentioned in any article or book, and I can try to explain it according to common sense.

Reason no. 1: There are small exceptions within this pattern, especially in Africa. The line of $30^\circ$ over the continent is not from coast to coast, but from the Gabon Estuary on the west coast to the eastern most part of the Great Rift Valley system where the Somalian plate is divided from the main part of the African plate. As something can be expected to be happening underneath the Great Rift Valley, this seems to be the exception that proves the rule. The fact that from the Great Rift Valley to the coast of Indonesia the distance of exactly $60^\circ$ is found confirms this further.

Figure 54: The intersection point of large convection cells beneath Africa.
Reason no. 2: Because tectonic drift is a continuous process, this was not the pattern in the past and it will somehow change in the future as the drift will proceed! It is not easy to keep two factors in mind at the same time, namely continuous tectonic drift and a constrained tectonic drift taking these twelve points along equator into account. As with Wegener, the more he looked into the geology of the fit between the coastlines of Africa and S-America, the more convinced he became. The same applies here.

Reason no. 3: Indonesia does not really look like a continent. Therefore, a pattern of three whole landmasses covering 30° opposed to two oceans covering exactly 60° does not appear with full clarity on a geographical map. Here, geology and geography do not tell the same story.

Reason no. 4: The coastlines of both S-America and Indonesia are oriented either to the NE or NW so they appear quite skewed on a map. That means that only slightly to the north or to the south of equator there is an entirely new pattern found that has nothing to do with regularity. Understandably, when looking briefly at the world map, it is easy to lose the track of the narrow equator line, exactly where the Coriolis force is zero.

Reason no. 5: The Mid-Atlantic Ridge is somewhat continuously E-W oriented along equator, the system of ridges in the Indian Ocean is double and the edge of the Pacific Plate makes a turn just south of equator. All of this makes it difficult to compare the ocean ridges with the pattern of land mass and ocean along equator at a single glance.

Reason no. 6: At first there does not seem to be any reason to look especially for any pattern at the equator line, but when considering the special physical circumstances where the Coriolis effect is zero, there is a reason to look for a special pattern exactly on the line of equator.
Figure 55: Clarifying the regular division of 30° along equator on a world map.

This picture is of course clear enough to manifest the pattern along equator. The thought - how was it before and how will it be later – even leads people to deny this pattern, somehow not to look at it. Later, it will not disturb people, because the connection between this current pattern and the long-term development of patterns along equator will be made clear.
Chapter 9 - The World Map

With a double manifestation of the existence of the convection cell system and the exact location along equator at hand, mapping the system for the whole world is the next step.

9.1. Preconditions to trace the system to the north and south

Obviously, there is a reason to believe that 12 convection cells, each covering 30° of the equator line, are responsible for the distribution of land mass there. And there is no need for a low aim. The location of the continents, the history of their drift, the pattern of hot spots, etc., should become quite natural when seen in this context. To clarify this, examples on different scales are given to show how this system gives us an opportunity to approach all these phenomena in a more focused way.

As we have examined the geophysical evidence and the basic physical rules behind the system of convective cells of Earth’s mantle, we can explore the system on the surface. First, the global scale shows major hot spots and helps us to trace the major dynamics of tectonic drift. Second, for Iceland a second view of how the hemispheric and polar sections can intersect one another is necessary. In this way we see the location of the main volcanic areas of Iceland. Third, a map of Iceland with the pattern of upper mantle convection cells shows the location of the main volcanic sites, and the high- and low-temperature areas throughout the country.

Figure 56: Adjusting the geophysical model to surface features.
9.2. Global view

Iceland and Hawaii are clearly both strong hot spots. They are probably the strongest hot spots in the world and are often mentioned at the same time in books about geology. With the model of convection cells at hand, the location of those hot spots can be explained. The reason is simply that they are separated by four convective cells of the lower mantle. This is one of many factors that show the shape of the convection cells. The horizontal radius of the current cells can be detected from this, although several factors had to be taken into account until the correct size of the horizontal circles of the convection cell system was found. That had to be worked out step by step for a long time, but the result is that each hemispheric cell forms a circle in a square grid of longitude and latitude, with midpoint at 32°, extending to 67° and 3° into the other hemisphere. How the general system can be drawn on a word map is shown below.

Figure 57: A world map showing twelve division lines around the globe

The picture above shows how the generalized horizontal system shows itself on a world map. By ‘zooming in’ on Iceland the picture becomes so accurate that drawing on the metric scale becomes more appropriate than rough sketching. Of course the total system should be drawn here, but an A4 piece of paper is too small for it.
Iceland is a very distinct place geologically speaking. It is located on the
Atlantic Ridge and over an ascending vertical current of magma as well. But here we
have to go into some detail regarding the polar ends of the current cells (from 60.7°N-
90°N and 60.7°S-90°S) and the hemispheric parts of the cells, (from equator to
67.3°N and 67.3°S). The shape of the arc from the equator north towards Iceland is
the arc of a circle, drawn on a map with equal distance for each degree with the centre
of the circle at 32°N. The radius therefore spans approximately from 32°N to 67.3°N
and 3.3°S. On the map here presented, the polar section has the same curve as the
hemispheric section. The same rule is applied for the Southern hemisphere.

Figure 58: Iceland put into context with the horizontal model.
On the map there are 24 S-shaped lines and 24 mirror-shaped lines showing the form of the system. All together there are 240 S-shaped lines, shown on the more detailed maps. The convection cells are numbered. For this world map, the lines at the edges of the convective cells are shown, and also the lines at the middle of the cells. This is a perfectly regular system. Those familiar with the geology of an area should try to compare it with this model. Final examination has to take more factors into account. A part of a full scale model looks like that:
9.3. Connection between Iceland and Hawaii

Irvine (1989) points out that the hot spots of Iceland and Hawaii form almost exactly 90° with the Earth’s center. He therefore reasons that this might indicate a regular pattern of the mantle. The Icelandic geologist Kristjan Saemundsson pointed this article out to me in 2010 as an example of a comprehensive model of the interior of the Earth. According to the convection cell system described here, the 90° angle between Hawaii and Iceland is a result of two regular angles, first 120° along the 64th parallel from an Icelandic convection cell to one extending from Hawaii, and then about 45° of longitude to the south along that arch. This results in this coincidence. As Irvine (1989) says:

In view, of the prominence of Hawaii and Iceland as global hot spots, this 90° relationship seems more than coincidence, and the proposition explored here is that it is a direct reflection of the Earth’s convection structure.

As the relative location of those two hot spots was regarded as unchanged over time, Irvin looks at this coincidence as a result of a fixed system of convection within the Earth. Irvin’s idea is exactly what is pursued in this book.

The location of the continents and various phenomena can be explained according to the location of the current cells, as seen here, on global, regional and local scales. The first points of reference are Iceland and Hawaii as common sense says those places are located over ascending currents. The third ascending current of the same is found at Indonesia.

These three locations, Iceland, Hawaii and Indonesia make the starting geographical points to find the dimensions of the ‘horizontal’ plane of the convection cell system. With the assistance of geophysics, a high level of accuracy can be achieved in constructing a model of the convection rolls, as described in previous chapters.
The world map has inserted circles, showing the convection cell lines 30° apart from each other. Now we zoom in on Hawaii and Iceland:

![World map with convection cell lines and dots for Hawaii volcanoes](image)

Figure 61: How Hawaii and Iceland are located in context with lines 120° apart from each other.

The dots for Hawaii show the location of currently active volcanoes. As this zooming in on Hawaii shows, the volcanoes are more and less arranged in the same direction as the main line of the convection system. The zooming in on Iceland shows a line responsible for the volcanoes Katla, Grímsvötn, Kverkfjöll and close to Bárðarbunga caldera, and passes through the area of western Vatnajökull glacier, usually pointed out as the hot spot of Iceland.
Both lines, for Hawaii and Iceland, are acquired from Equation 1 on page 54:

\[(x^2 - C_n) + (y^2 - 32) = 35.34\]

Where \(C_n = -123.2\) for Hawaii and \(C_n = -3.2\) for Iceland

\(x\) represents longitude and \(y\) latitude on a rectangular grid.

This tells us much about the consistency of the system. As shown before, the parameters used are calculated according to certain preconditions, and the reasons for using these preconditions can be explained logically and by referring to relevant books and articles.

One more point to make about the relationship between Hawaii and Iceland. The fixity of the so called hot spots is not as rigid as thought before (Foulger 2010), but according to this convection cell model there is a fixed relationship between the strong lines of the convection lines along which the melting anomalies of Iceland and Hawaii occur. The hot spot of Hawaii seems to have moved recently a bit southwards along a line between convection cells!

In the same way a 120° interval along latitudinal lines is found between Iceland and Indonesia which is a source for another study.
9.4. The North Atlantic

Referring to what was previously said about equator; the 64th parallel has a similar position in the system although the Coriolis effect is of course not zero there. What is similar is that two parts of the convection cell system meet there\(^1\). Therefore there is still a reason to look for a pattern there similar to equator. Actually there are some clues, like that the distance from the volcanic zone in Iceland (let us pinpoint it at Hekla volcano) and the coast of Norway at the 64th parallel is approximately 30°. Besides that, the Bering Strait is located at the ‘correct place’ according to the large convection cells, as two large cells meet under it. The picture below shows how the convection cells make up a basic grid for the North Atlantic.

\[\text{Figure 62: The North Atlantic ‘s pattern}\]

From S-America (1) to Africa (2): approximately 60°. Coast of Norway at 64°N (3) on the same longitude as Africa (2). From Norway (3) to the ‘icecoast’ of W-Greenland (4): 60°. Hekla (5) and Mid Atlantic Ridge crossing equator (6) are on the same latitude.

\(^1\) At equator: The N-hemispheric and S-hemispheric convection cells meet there. At the 64th parallel: The hemispheric and polar convection cells meet there. In mathematical terms, the derivatives of the curves of the two systems within a grid of latitude and latitude are the same at those latitudes.
A brief look at the 64th N parallel, it has characteristics similar to equator whereas it is the middle of a transition zone. The 30° distance from the Hekla volcanic system to the coast of Norway is a fact, and it is also the first thing to look after at the 64th parallel, considering the 30° and 60° pattern at equator.

To emphasize the basics, it should be pointed out that Hekla is at the same longitude as the center of the Atlantic Ocean at equator.

In this way a pattern for the North Atlantic emerges, where, Hekla, the coast of Norway at 64°N, the center of the Atlantic Ocean at 0° latitude and the coasts of S-America and Africa at 0° are playing the key roles.

Again, there is an exception to look into, this time in the case of Greenland. The ice cap makes the conditions there obscure. Greenland and Norway (64th parallel) and S-America and Africa (equator), should be seen as a square, but clearly the east coast of Greenland is farther to the east. The point is at the border line between ice and mountains of W-Greenland, which is also to be noticed. The Hekla-Norway-Africa-Mid Atlantic Ridge-S-America squared pattern is enough for us for a while. This ‘square’ also fits to the general pattern along equator as a whole. If the glacier of Greenland was lifted, the central areas would become filled with sea water. So weather or not the NW point of the N-Atlantic square is at a coastline or not is a matter of discussion.

An interesting manifestation is the existence of Crymostygius thingvallensis (Kristjansson og Svararsson 2002), a kind of freshwater shrimp found in Thingvellir in Iceland. It might be the remains of ‘old distribution’. It is clear that it survived the ice age, but it might also even be older than the land, indicating that rifts have been found in the area for much longer time than we usually connect with the formation of Iceland. An exact analysis of the total convection cell system leads to the conclusion that Thingvellir is on the same longitude as the exact center of the Atlantic Ocean at equator, and the 64th parallel is the northern mathematical counterpart to equator, located above the main division line between the large convection cells of the lower mantle. So perhaps an animal is one of the big ‘proofs’ showing the properties of the convection cell system.
9.5. Kamchatka and Iceland compared

The topography of Kamchatka also has a very decisive linear form, and of course the volcanism there is well known. The reason for the volcanic activity is in a way opposite to that in Iceland, so it is interesting that the same formula can be applied to get exactly the correct direction following the chain of mountains, the division between mountains and lowlands etc.

Figure 63: The topography of Kamchatka follows exactly the calculated value of direction\(^1\).

The inserted lines in Figure 63 are calculated according to \( \varphi = 57^\circ \) for hemispheric convection cells\(^2\). The result is N28.6\(^\circ\)E, shown with line A for each drawing, which fits perfectly to the peninsula. The adjacent Alpha Fracture Zone is perpendicular to the Kuril-Kamchatka Trench and thereby to the tectonic framework and topographical trend of the peninsula. The angle is close to being half the calculated value for the latitude, as shown by line B, thereby oriented N58.2\(^\circ\)W. The half angle value is added because it repeatedly found under similar circumstances.

\(^{1}\) Map sources: http://www.kscnet.ru/ivs/bibl/sotrudn/puz/Kamchatka.files/KamchatkaFig1_500.gif and http://en.wikipedia.org/wiki/Kamchatka_Peninsula

\(^{2}\) Equation 6, page 50.
The reason is partly explained with the conditions of the SISZ (see 10.5 The South Iceland Seismic Zone (SISZ)) and partly by comparing the Reykjanes and Snæfellsnes peninsulas in Iceland (see section 10.8.).

**South Iceland:**
Here is another example of a calculated orientation which proves to be in accordance with real circumstances.

The inserted line is drawn according to formula (7) for polar lines at 64.1°, at the centre of the lake Langisjór in Iceland. The tuff mountains around the lake clearly have the same direction as predicted with the formula for polar cells, namely N42.5°E.

![Figure 64: The formula (Equation 6) fits exactly to EVZ on this map and Kamchatka.](http://www.vatnajokulstjodgardur.is/english/hiking/langisjor/)

Langisjór has the same trend as the surrounding EVZ, shown in this essay to fit into the convection cell system in general. It is therefore not anything new, showing the lake Langisjór in particular. After reading about Kamchatka it is interesting to see that the same set of formulas can obviously be used for both Iceland and Kamchatka, and in fact any area in the world.

In these latitudes, the polar and hemispheric cells have very similar trends so it can be difficult or even impossible to distinguish between them. Then petrology is one

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1 Map source: [http://www.vatnajokulstjodgardur.is/english/hiking/langisjor/](http://www.vatnajokulstjodgardur.is/english/hiking/langisjor/)
key to find out about the source effecting the surface at each area. It does not to be emphasized that at the surface of the Earth, even the direct effects of the simple convection cells become somewhat complicated. The four layers between Iceland make up a grid of lines that all together form a pattern that works as a holistic system. It has therefore to be studied as such, how polygons work etc.

Going still a bit farther north, now we use exactly the same formula as for Kamchatka, the hemispheric formula, for the North Iceland Seismic Zone.

As previously mentioned, the direction of convection cell rolls can be calculated. The direction is also that of the Munroe lines, that have a huge effect on the topography. A good example of this is the Tjörnes fracture zone (or North Iceland Seismic Zone) out of the North coast of Iceland. When plotted on a map, the epicenters of earthquakes clearly form a line of the same direction as the convection cells. Using formula (6) for the latitude 66°10’:

\[ \alpha = N61°12’W. \]

The fact that the same formula can be used to calculate the direction of the Tjörnes Fracture Zone north of Iceland and the Kamchatka peninsula is a curiosity. Also, the same kind of approach repeats itself, as the faults themselves have the same direction as the formula gives. At Tjörnes, the epicenters of earthquakes are also distributed in the same way as the formula predicts.

Figure 65: A simplified comparison between map\(^1\) and formula for Tjörnes Fracture Zone.

\(^1\) Map source: [http://www.norvol.hi.is/~thora/ondvegi_frett.html](http://www.norvol.hi.is/~thora/ondvegi_frett.html)
This seems to fit quite well; the inserted line is parallel to the zone. It is not enough though to see a line and employ the formula, or in this case one of the two relevant formulas, to see whether the tectonic or topographic phenomena show signs of direct impact from the convection cell system or not. The conditions at the TFZ are a bit complex though and dealt with at two other places in this essay.
9.6. Trenches

As shown on page 31 and thereafter, the 410 and 670 km discontinuities fit into the convection cell system as described here. A special field of study is the interaction between tectonic plates and the convection cells immediately below. Earthquakes are measured around trenches, mainly found around the Pacific Ocean, down to 670 km below Earth’s surface, as the tectonic plates slide downwards. A random example is taken here, simply the first choice of Google when searching for a tectonic trench, the Havre Trouat about 180°E and 20-30°S.

This provides a base for endless study. A downwards convecting pair of cells ‘swallows’ the tectonic plate, and the upwards convection to the east causes tension. Then the plate sways concave through one convection cell of layer 2 (here sometimes referred to as the OIB layer), and then in a convex way after penetrating the 410 km discontinuity. The convex swaying can be anticipated at this location. At the latitude 30°S, two large convection cells of lower mantle meet, providing upwards flow, eventually dividing to east and west, so the ‘mantle wind’ of the 410-670 km zone where the tail of the subducted plate is found, is to the west.

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9.6. The Cameroon line

The Cameroon line is hard to explain and rather special because it crosses both sea bottom and mainland. The direction does not fit into the main framework of MORB and OIB convection cell layers as described here. But it fits perfectly to the other amplitude of convection cells of the transition zone between 410 and 670 km.

![Map of the Cameroon line](image.png)

**Figure 67: The Cameroon line compared to calculations with Equation 8†**

This is an important addition to the study of the convection cells, especially petrological issues. A line is inserted for the center of convection cell system at 18.5°S.

The petrology is quite special, and the fact that a hot spot seems to have been stationary under the Oku are for 66 million years². Most hot spots seem to be stationary relative to each other, but this one might follow the movement of the large convection cell, as the transition cells below the 410 km discontinuity follow its rotation.

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† Map from: islandbiodiversityrace.wildlifedirect.org
² en.wikipedia.org/wiki/Cameroon_line
9.7. The Arctic

Just like the mathematical grid of latitudes and longitudes of the globe itself, the convection cell system has its physical limits at the two poles. The area becomes more and more limited close to the 90th degree which is of course only one, infinitely small, point. Is there anything exceptional then with the system around the poles? The first answer must be no, the system adheres to the same rules all the way, even though its dimensions approach zero at the poles.

Now we use one of the methods used in geology, namely follow a particle on its way. A moving particle in this environment follows a straight line, appearing to curve according to the Coriolis effect. It is easier to considering the horizontal flow of magma within what we call the hemispheric part of the convection cell system. A particle flowing there can find its way along the MORB lines from equator to the north up to the transition zone between the 61st and 67th parallel where it shifts to OIB lines to carry on along the same circular path, always appearing to turn to the right, south to equator again, entering the south hemisphere where it appears to turn left.

It would be easy to just repeat this story for the Arctic part of the system. A particle flows with the MORB layer to the Pole where it must be able to find a tangent point with an OIB line to flow back. The grid of convective rolls becomes so tight close to the pole that there must be plenty of opportunities for an exchange system to work there, allowing a particle to maintain its horizontal path (straight line according to its own relative point of view) accurately enough. That is the easy way out, according to common sense.

Now we prepare to follow a mathematical particle flowing along the Arctic system, extending from around 60.7°N to 90°N. The reader must be reminded to distinguish between mathematics and reality, because, as the formula for the polar lines of the convection cell system shows, the center for the horizontal flow within the polar cell system is on a theoretical latitude of 96°N (and 96°S). In this case mathematics and reality can only make sense if the particle is allowed to pass the infinitely small point of the pole itself, over to the opposite side of the globe, flowing directly southwards at the 84th parallel, then forming ‘hubs’ at the 78th parallel.

Does the system then have an end there? This is a special case, but we should not forget the larger convection cells below. The flow from the North Pole must find its way farther to the south with the larger cells underneath. It is indeed in accordance with the shape of those large cells, swaying in one way that only allows southward
flow along it. At the South Pole, an opposite situation emerges, allowing exchange of material from the lower part of the mantle to the upper layers.

This means that the situation at the poles is indeed a little bit special. Therefore we can look for special circumstances there, which might be in some way opposite or mirroring from one side of the Earth to the other. To elaborate a bit on this analysis we should have a look at the Arctic Ocean and Antarctica and have them compared. The result raises more questions than it answers. The fact that the Arctic Ocean has similar shape as Antarctica becomes a curiosity, because the same forces (although mirrored) might be at work shaping and locating the coastlines in the areas between the 84th and 78th parallel N and S.

Mirror it and then turn it 180° would be my advice to see if the theory about opposite effects of the convection cell system for the Arctic and Antarctica was somehow reflected in real and observable circumstances. The comparison here does not rule out that possibility.
Chapter 10 - Iceland

I am of course more familiar with the geology of Iceland than other parts of the world. The Icelandic volcanoes are difficult to count and geothermal activity is found in practically all parts of the country. The geological settings are described in many textbooks so there is no need to go to the basics here. Comparing the framework set by the Coriolis effect for the convection rolls with a map of Iceland shows amazing consistency. It is hard to know where to begin and even harder to know where to end providing examples of how all the dynamic aspects of geology, tectonic, volcanic, geothermal, etc., appear as secondary products of the convection cell system. Iceland is being pulled apart, and about a quarter of the total area is within volcanic zones, mainly distributed from the SW to the NE. The effects from down below are, as can be expected, most clearly detected in those areas being torn apart. The 64th parallel shows this very clearly with a lot of volcanic activity, much of which is concentrated on critical points of the convection cell system.
10.1. The hemispheric and polar lines over Iceland

As mentioned before, there are four layers of convection cells below Iceland within the interval of 120-410 km, two of them due to convection rolls extending from equator to 67.3°N. These rolls make up a pattern as shown on the map below.

![Figure 68: The hemispheric convection cells pattern over Iceland.](image)

In the same way, convection rolls extend from the North Pole south to 60.7°N, covering Iceland with another set of lines.

![Figure 69: The polar convection cell systems pattern over Iceland.](image)
All four sets of rolls make up this pattern:

Figure 70: The Icelandic grid of convection cells.

This pattern can be extended all over the world. It has its foundations in the geophysical data about the layers of the Earth and the physics of convection cell behaviour. The geology of the whole world, not only Iceland, can then be explored by referring to this grid.
10.2. A pattern of distribution of the most active sites

Even though Iceland is known for its volcanoes and hot springs, the number of very famous sites, even among Icelanders themselves, has some limits. Let us begin with a map showing resemblance between some of the most prominent volcanic and geothermal sites of the country and the system.

![Figure 71: Famous places of volcanic zones coincide with intersection points](image)

These are not just some of the famous active areas in Iceland; all the most active ones are there. It is as simple as that to show that a general system, derived from geophysical data, physical laws and geographical maps, explains the geological settings in Iceland.

We cannot, though, leave the case after looking only briefly into it. There are more details; volcanic sites, seismic zones and geothermal areas that should be compared carefully with the convection cell system.

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1 Map base from Náttúrufræðistofnun.
A parallel pattern can be pointed out for the northern half of Iceland within the tight pattern of polygons.

Those who are familiar with the geology of these places can tell that most of the major areas of the area are pointed out. In the next chapter a map with dots representing geothermal sites is used to further clarify the relationship between the convection cell system and distribution of geothermal and volcanic activity in Iceland.
10.3. High temperature geothermal areas

The grid can of course be compared with maps with all kinds of background information. One is that of geothermal areas. It has been obvious that the high temperature areas are only found within the volcanic zones where magma occasionally finds its way through the crust towards the surface. The volcanic zones show a continuous pattern themselves. As there are many clues that the grid shaped by convection rolls underneath plays an important role, one becomes curious whether the lines as drawn according to the convection cell system is somehow consistent with the location of high temperature areas. Obviously the high temperature areas tend to be located either on the lines or close to them.

![Figure 72: Comparing geothermal activity and the convection cell grid.](image)

Here, on the geological map of Orkustofnun (Jarðfræðikortaf Íslandi 1:500.000 jarðhiti), it appears in detail how the system is coherent with the distribution of the main active areas in Iceland. The high temperature areas show resemblance with the lines. It is coherent with the assumption that magma is carried up through the crust with the Munroe effect along these lines. The lines refer to the edges of convection cell rolls at more than a 100 km depth, not directly to the surface, although they are drawn on the top of a topographical map.
It is apparent that the high temperature areas are large enough to extend for some distance away from the related line. This is most apparent for the large area of Hellisheidi, around 30 km east of Reykjavik. Secondly, some areas do not cross any line, so can that be contradictory to the theory? The answer is that magma travels easily horizontally within the crust, and the high temperature areas are found within areas literally torn apart, making way for horizontal flow just as vertical flow. The largest high temperature area in Iceland, of Torfajökull, does not cross a line, but is found to the NE of a Munroe line which is the main candidate for providing magma to it from the interior of the Earth. It is not controversial that the following processes (of petrology just as well as rheology) result in a huge high temperature area within one of the most active polygon of the convection cell system grid.

Dotted lines cover almost all the high temperature areas within reasonable distance. This can be compared with the coverage of the border line between Europe and America (see page 128).
10.4. Low temperature geothermal areas

The low temperature areas also show resemblance to the grid, but in another way. The grid shaped by the convection rolls makes up a pattern of areas, here referred to as ‘grid polygon area’ or simply as a polygon, often diamond-shaped. The border lines also seem to divide areas with different degree of concentration of low temperature areas. This is a logical resemblance considering the nature of these geothermal areas. It is assumed here that the ductile base of every grid area is cut asunder from its neighboring grid areas by Munroe lines, resulting in different conditions of pressure due to the tectonic drift. Therefore each of the grid areas break up in a rather unified way, that lead to different conditions, either favorable or not for low temperature areas to appear. Therefore the hot springs should tend to appear randomly over the whole grid polygon area concerned.

Figure 73: As can be pointed out with a few arrows, most low temperature areas in Iceland are found within distinct polygons.
10.5 The South Iceland Seismic Zone (SISZ)

As a student, I worked for professor Páll Einarsson measuring the earthquake faults in the South Iceland Seismic Zone. I was impressed by the fact that the underlying faults seemed to point directly N-S (Einarsson, 2001). The system of symmetric convection cells can explain that. In the figure of the South Iceland Seismic Zone (SISZ) it can be seen how the faults of the main seismic area, responsible for some main sequences of earthquakes that occur in Iceland.

Many features of Iceland coincide with the pattern of the current cell model, but this one is very special. That area has already been identified as a small separate tectonic plate (with slightly different “borders”) and on that plate a major earthquake zone is found (Sigmundsson & Einarsson, 1996). Within the convection cell grid, the SISZ fits into a distinct polygon area as shown on the next picture.

![Figure 74: The South Iceland Seismic Zone](image)
This is consistent with that the main (deepest) NS faults are created by a rupture of ductile material by confining pressure of 45° angle, as can be shown with the application of Mohr’s circle (Plujim & Marshak, 1997). The size and shape of the area reveals itself with the earthquake zone that can be mapped from the surface. When I was working at the mapping of the area, my conclusion was that one NS-oriented fault was found with about 715 m interval around the 64th parallel all the way from Hekla volcano to the town of Hveragerdi. The sides must somehow be cut so that the tectonic drift can exert pressure on the area in the correct way. The best explanation for this is that Munroe-lines have cut the ductile part of the plates asunder.

Roth (2004) on page 1314, defines the area where strong events occur as extending approximately from 21.2°W, 63.9°N to 19.7°W, 63.9°N. These coordinates happen to be within the east and west corners of the grid area framing the Southern Lowlands. The three factors combined, N-S fractures, Mohr’s circle and the length of the zone together require pressure induced from a diamond-shaped frame with corners at the two coordinates of approximately 21.2°W, 63.9°N to 19.7°W, 63.9°N to form the South Iceland Seismic Zone.

This can actually be taken as a qualitative proof of the existence of the underlying system, comparable to the quantitative proof provided by the combined consistency between the layers of the earth and a regular convection cell pattern and the distance between the continents along the equator line.
10.6. Explanation of the orientation of fractures within the SISZ

As the Southern Lowlands are probably the area in Iceland that I am most familiar with, I should elaborate a bit on how the earthquake fractures have formed and why they tend to be NS-oriented. In the model here discussed of convection rolls and the related Munroe lines, the ductile part under the SISZ is cut away from the surrounding grid areas like a diamond-shaped piece of cheese. All the four sides are oriented 45° from north as can be calculated with the formulas given in chapter 7.

We must keep in mind that a plate is 120 km thick, only the uppermost 10-20 km, in this case, are brittle. The fractures appearing on the surface are therefore a bit different from the ones below. In the SISZ they tend to be oriented to the NE and SW, forming side stepping segments over the deeper fault.
By tracing the fractures, often many kilometers, the NS-direction of the faults underneath can be derived.

A ductile crust (tectonic plate), under perfectly balanced conditions, should break up at a 45° angle to the direction of pressure. In the SISZ this seems to fit perfectly to what is observed. I believe this can be used as reference to find accurately the central line between the polar and hemispheric parts of the convection cell system. According to Roth (200$) that would be 63.9°N, but here we stick to the 64th parallel as the central line, with the estimated accuracy of 64.0±0.1.

Again, it must be stressed that there is a difference between the brittle uppermost 10 km and the 110 km underneath which are ductile. The perfect bookshelf arrangement is only prevalent within the ductile environment and above that it can only resemble it to a certain extent. Most researchers will therefore find the system irregular and the faults striking slightly NE-SW.
10.7. Seismic areas in general

After looking into the features of the SISZ, it must be compared with the other main earthquake zone of Iceland, the Tjörnes Fracture Zone, out of the North Coast. The Tjörnes Fracture Zone shows a more complex pattern. It is basically double or triple and very apparent on the cumulative map of epicenters shown here.

![The earthquake zones](http://www2.vedur.is/media/jar/myndasafn/frodleikur/medium/jardskjalftakort-GG_94-00_is.gif) (viewed 10.11.2012)


The epicenters in the North at the Tjörnes Fracture Zone follow the hemispheric lines very closely. Earthquakes tend to have their origins within certain squares. It is in accordance with the notion that below the brittle crust there is a pattern of Munroe lines, leading to the isolation of individual grid polygons, resulting in tension in the brittle crust above that in some areas starts to break, causing earthquakes. Remember, this is nature at work, the tectonic drift tearing Iceland apart, and simultaneously finding a way to adhere to the fabric of polygons.

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1 [http://www2.vedur.is/media/jar/myndasafn/frodleikur/medium/jardskjalftakort-GG_94-00_is.gif](http://www2.vedur.is/media/jar/myndasafn/frodleikur/medium/jardskjalftakort-GG_94-00_is.gif) (viewed 10.11.2012)
10.8. Secondary calculations: EW- and NS-axis and ‘half angle’ trends

The volcanic zone of Snæfellsnes peninsula brings up a new aspect which is quite common though. It is an example of a simple secondary calculation, where the formula for direction of the convection cells is applied, but then the number of degrees found either compared to a NS-axis or an EW-axis is divided with two.

In this way the Snæfellsnes Ljósufjöll Volcanic System (with a calculated vector marked as ‘A’ through it). Here we go through the calculations with Equation 6 (on page 56) the formula for hemispheric lines where \( \varphi = 65 \), as Snæfellsnes is on the 65\(^{\text{th}}\) latitude. This gives N47.8°W.

To compare with EW-axis we get 90 - 47.8 = 42.2 and that divided with 2 is 21.1°
The direction of the volcanic zone is then 90 – 21.1 = N68.9°W

The Snæfellsnes peninsula has a pattern of fractures perpendicular to the volcanic fault lines of Ljósufjöll. The orientation of these fractures is in accordance with a direct calculation of the convection cells.
Here the calculated vectors are shown, A for the volcanic system, B is in accordance with hemispheric lines and C with polar lines. The presence of an EW-axis extending from the center of the country is well known.

Figure 75: A geological map of Snæfellsnes with inserted lines for directions of convection cells.

Secondary calculations for faults and fractures can be applied in many cases, showing consistency that once again proves the importance of the basic system. The South Iceland Seismic Zone is a similar case of secondary calculations, with interplay of the edges of a diamond-shaped square. On Snæfellsnes a similar interplay is found. The angle between the hemispheric OIB convection cells and the EW-axis is found, and the faults of the volcanic zone have exactly half that angle.

For the Reykjanes Peninsula, the same pattern is repeated, that is principal structures follow the primary calculated trend. The volcanic system follows a trend of half the angle, that is of a secondary calculation. The local trend follows that of the MORB hemispheric convection cells. The volcanic system considered here is that of Krýsuvík, marked K on original map, and coincides with A, inserted by the author for comparison with Snæfellsnes).

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1 Map: www.eldjallasafn.is/e/snaefellsnes.html
These two areas, Reykjanes and Snæfellsnes are therefore comparable, even though they are, at least in the mind of the author, of a quite different nature, mainly because the former is a spreading zone and the latter not. Still, a comparison like that becomes understandable by referring to the whole system described.

Here down below, an old map showing the main features of Iceland’s tectonic framework is added for comparing Reykjanes and Snæfellsnes.

On this map the existence of a fault zone throughout most of the center of the country is shown from east to west, indicating a underlying structural feature. I have traced more faults farther to the east on this EW-axis through the center. In the West
of Iceland the fault zone combines with the volcanic zone of Snæfellnes. Similarly, faults are found on Reykjanes that can be said to be a continuation of the SISZ, from east to west, also coexisting with the volcanic zone of Reykjanes.

Secondary calculation also applies for the Tjörnes Fracture Zone, also referred to as the North Iceland Seismic Zone. The map drawn by Hjörleifur Sveinbjörnsson shows various directions of faultlines, all of which fit into the convection cell system’s primary or secondary calculations. First let us have a look at the basic map of measured orientation of faultlines.

Then vectors representing hemispheric convection cells fit exactly to the Husavik – Flatey fault.
The diversity of the faults gives an excellent opportunity to use the set of calculable and predictable directions inherent in the convection cell system. Three different calculation methods are used in this small area.

Calculated trends for the fault systems marked A, B, C and D:

A: Hemispheric, primary on 66°N, direction N55.1°W
B: Hemispheric, secondary on 66.2°N, direction N72.5°W
C: Polar, primary on 66.1°N, direction N32.7°E
D: Hemispheric, primary on 66.2°N, direction N57.1°W

In addition, there are faults clearly oriented NS. As previously shown, the distribution of epicenters clearly does match the grid appearing when the division lines of all convection cell pairs are drawn on a map. This rather detailed map showing the main faults shows an even clearer resemblance.

The directions mainly found in the mega-tectonics directly connected with the convection cell system can be summed up. The tendency of the tectonic framework is first to be aligned parallel to the convection rolls. Also, EW- and NS-axis tends to form within the polygons. These lines of weaknesses in the crust then may lead to fracturing along a line forming half the angle of the Munroe lines to the EW- or NS-axis.
10.9. The volcanic zones

Perhaps the clearest resemblance between the world wide system of convective cells shows with the ‘zoomed in’ picture appearing of Iceland is that of the volcanic zones. The orientation and location of the volcanic zones follows exactly the lines formed by the convection cell grid. In addition to all other evidence, it is a remarkable coincidence that the volcanic zones are literally ‘drawn’ by the combined grid of all the division lines between the underlying convection cells. The area in the southern part of Iceland separating the two volcanic zones, often referred to as the Western Volcanic Zone and the Eastern Volcanic Zone can be explained according to the system of convection cells. As explained before, pressure is exerted to the individual polygons, so that they are either compressed or pulled apart. The tectonic drift to east and west in Iceland therefore results in breaking up certain polygons, together forming the volcanic zones.

The yellow colour shows volcanic systems that also fit astonishingly well to the pattern of convective cells.

The most obvious part is the WVZ and EVZ, but the North Volcanic Zone follows a NS-oriented axis also determined by the system. Two volcanic systems are not drawn on this map, namely those of Snæfellsnes and Öræfajökull. The
Snaefellsnes Volcanic Zone in the West of Iceland can also not be associated with the polygons just in a blink of an eye, but with the consistency of the WVZ and EVZ at hand we should not give up that easily. After all, geology and geophysics are not always that easy.

A long-term question about why new volcanic zones appear every 7 million years or so in ‘jumps’ can easily be answered according to this pattern with simple reasoning. The pull around the WVZ causes pressure on the next polygons to the east and west. Therefore, magma cannot ascend through opening faults or fractures there. As the tectonic drift is faster to the west than the east, in the end (after 7 million years) the next polygon farther to the east starts being likewise pulled apart, also causing pressure on the polygon in between the two volcanic systems.
10.11. The 64th latitude

The latitude of 64° is of special importance, because it is the center of the horizontal intersection zone of the convection cell system. There are in fact four volcanic zones found in context with the 64th parallel, those of Reykjanes, the West Volcanic Zone, East Volcanic Zone and the Öræfajökull Volcanic Zone. On the map below there are some special places pointed out. Outside the volcanic zones, nothing special appears, as expected, except the SISZ which is dealt with in a special chapter.

Figure 78: The 64th parallel being the central line of the transition zone.
The horizontal circles are tangent to each other on the 64th parallel. Therefore polygons do not appear there in the same way as on other latitudes. Of course each of those tangential points deserves special attention. The appearance of each of those points is totally different in each case. The resemblance is rather clear though between the site of Hekla and Öræfajökull as both are volcanoes exactly on the sets of tangential points. All the four layers below of the upper mantle and asthenosphere can then combine their forces to make a volcano above.

Öræfajökull is also on a NS-axis of volcanic and geothermal sites, as shown in the next section, besides being on the same latitude as the mirroring axis of tectonic drift of the North Volcanic Zone of Iceland as shown in section 10.10. The longitude axis of Öræfajökull – Kverkfjöll – Theistareykir. Hekla is on a NS-axis providing the mirror image for the Atlantic Ocean at equator, besides being on the mirror axis for Snæfellsjökull and Snæfell (section 10.11. The mirrored location and morphology of the two Snaefell volcanoes).

In addition to these features on the 64th parallel along the volcanic zones of Iceland, the distance from the Hekla system to the coast of Norway spans 30°, and the span along the same latitude from the Hekla system to the Bering Strait is exactly 150°. These things might seem trivial, but all this information is needed to tell the whole story. There is a reason, based on mathematics (see page 50), to search for consistency along 64°N, and we find that the Eurasian continent spans 180° along that parallel!
The consistency between lines and location of the two main volcanic zones in the South of Iceland, here abbreviated as WVZ and EVZ is very clear. Even the small Öræfajökull Volcanic Zone (ÖVZ) fits readily in as around an intersection point on the 64th latitude. It should therefore be enough at this stage to point that out in context with so many other things and let it stay as one of many standing points for even acquiring a quantitative proof for the convection cell system. But obviously the volcanic zone in the North (NVZ) is not literally marked by lines at each side. It looks much more confusing and the sides of the volcanic systems (as well as those of the volcanic zone) are often found in the middle of a polygon. Is the theory then a mess?

This is nature at work, different segments of the wide and complex border line between the American and Eurasian tectonic plates have different qualities, some obvious, some hidden. In this case there is an obvious consistency between the lines and polygons on one side and the volcanic zone on the other. This symmetry around the axis of a single longitude, that also is a central axis through the endpoints of a set of polygons, is a very convincing aspect of consistency between reality and the theory here described.

This feature can also be compared with the map showing the distribution of volcanic and geothermal sites related to small polygons, and with the map showing the directions of tectonic drift, making the importance of this axis clearer.
10.11. The mirrored location and morphology of the two Sneafell volcanoes

There are two mountains in Iceland, both originally called Snaefell, now known as Snaefellsjökull and Snaefell. They appear like mirror images of each other, in exactly the same (only mirrored) context of the current cell system.

Figure 80: Detailed maps, of the two Snaefell volcanoes, put side by side.

The dotted vertical lines of the upper map show that the volcanoes are mirrored around the famous volcano Hekla. The symmetry is like if you turned your hands, held the wrists together, and looked at the two palms showing up. The peaks of the two mountains have the same latitude. These mountains are quite unique in Iceland, geologically speaking, located at the western and eastern extremes of recent volcanic activity. This mirroring of Icelandic geology becomes even clearer when looking into the tectonic drift, as will be done in chapter 12.
The whole system is so integrated that the location of Hekla can be compared with the very center of the Atlantic Ocean at equator. Therefore we can also look for symmetry around Hekla within Iceland, found so perfectly with the two Snæfells. The double nature of symmetry found as a logical consequence of the forces underneath is another brick into the building of proof for the convection cell system in general.

The EW and NW axis.
The volcanic systems within divergent rift zones.

The volcanic systems outside the divergent rift zones.

It is an interesting fact that there is a NS axis found from Eyjafjallajökull through the central Þjófadalir point extending exactly the same distance to the island.
Drangey in Skagafjörður. It has been found to be less than 700,000 years old, formed within a volcanic zone which became active at the same time as the modern Snæfellsnes volcanic zone about 2 million years ago. It became inactive after more than a million years, but the location is absolutely coherent with the other three volcanic areas outside rift zones. The degree of accuracy is marvelous.

How the old volcanic zone of Drangey fits into the pattern of systems outside rift zones.

The activity of the Snæfellsnes peninsula has been difficult to understand because it is far away from the areas where the rift of the Mid Atlantic Ridge goes through Iceland. As for the main volcanic zones in Iceland, the direction of rifts is to the north-east, but at Snæfellsnes the direction is north-west (Jóhannesson 1982). When thinking of the conditions there as the mirror image of what is found in the eastern half of Iceland, these things become more understandable. This knowledge can even prove to be useful, as is indicated in the next section.
10.12. An example of a fault in Iceland

Icelanders are known for utilization of geothermal energy, and in many areas hot water is not easily found. It was after hard work of many experts of both geology and drilling that a fault was found on the Snæfellsnes peninsula of West Iceland that could provide water for the neighbouring town of Stykkishólmur. The fault was of course mapped and provided as an example in textbooks about how geothermal heat can be found after drilling a series of holes measuring temperature gradient in an area.

![Diagram showing fault direction](image)

**Figure 81: Formula shows direction of important faults.**

The direction of the fault fits exactly into the system of convection rolls, providing a little bit of data. If enough examples like this are collected, then they could be used as a quantitative proof that a regular system of the kind described in this book does exist.

It is a new kind of thinking, being able to calculate the direction of the most important faults. But it works. The author of this book even located a geothermal site not far away from this site, at Skógarströnd area, making use of this model.
10.13. Bedrock boundaries

When compared to a tectonic map of Iceland with the relevant types of bedrock marked with different colours, certain features appear. Upper and middle Miocene bedrock is always marked outlined by the convection cell system. These boundaries are mainly found at the Western Fjords Peninsula, and indications of conformity with the system are found in other areas as well. It is difficult to point out any single reason for this conformity. As the underlying forces shape the land and direct the tectonic drift, many features coincide with the outlines of the system.

Erosion has wiped out arbitrary outlines of this old rock, so it is exposed according to the underlying forces. Compared to many other big features, this might seem as a trivial coincidence, not even a very clear one, but still I find this worth pointing out.
10.14. The eruption of Holuhraun

The eruption of Holuhraun, is very well monitored and documented, and the distances magma did flow underground, forming a 45 km long dyke (Sigmundsson 2014), are on the scale of the relevant polygon. All the directions involved show consistency with the system of convection cells as described in this essay. Following the path of this dyke formation becomes clear when referring to the framework of Munroe lines. Inserted, drawn lines have calculated directions.

Caldera of Bárdarbunga  Site of eruption

(1) SE  (2) NE  (4) Secondary direction (formula/2)

Figure 82: The earthquake map from the Icelandic Met Office1.

The information provided by this map is not accurate enough to show individual short segments, but the general outlines appear clearly. Following short segments too closely might even conceal the consistency with the polygon of the surrounding convection cell border lines.

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1 Preliminary analysed data by the SIL seismic monitoring group of the Icelandic Meteorological Office. Date of delivery from the data bank: 14. September 2014.
Description of the propagation of the dyke along four main segments (shown in brackets in):

1. First kilometers form a SE oriented segment, parallel to the relevant sides of the polygon.
2. After turning to the NW, a long segment is formed along the direction of the hemispheric line, marking the outer limits of the polygon, until the dyke reached the EW-axis of the polygon.
3. Then it made a turn to the left, to form a segment almost directly to the north. The dyke then came to a halt when it met with the Munroe line border of a hemispheric line along the NE-side of the polygon.
4. Between the hemispheric and polar Munroe lines of the NE-side, the dyke did propagate in a rather straight line, crossing the outer more polar line by a few kilometers until the eruption began.

Earthquakes have then propagated (pulsing) from the vicinity of the point where the polar line and the dyke intersect towards the eruption site 1.

It is interesting that extra inflow of magma from an unknown source has been prevalent since about a week after the dyke started to form (Sigmundsson 2014). It coincides with the event of the dyke crossing the Munroe lines. Besides that, the eruption produces unusually much of \( \text{SO}_2 \), which might indicate a deeper source of magma than most often encountered. Therefore, the dyke, after travelling about 40 km, might encounter hot magma from below, be heated and erupt as a result of that. The material of the dyke must be diffracted to some extent after the long journey. If this is correct, the double qualities of the magma should be detectable, so this piece of theory can be proven to be false or true.

Comparing model and measured data, the immediate correlation is the directions the locations of earthquakes form on the map. Lines are drawn according to calculated directions of deep faults due to the convection system. The NW-SE orientation is shown at two locations, according to the polar set of lines. At first, the magma did flow away from the caldera to the SE. Then it makes a turn to NE, according to the surrounding hemispheric lines, all the way to the next Munroe line extending from the

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1 Observed by looking at a video (Bárðarbunga 16/08 – 23/09 2014) processed by the Icelandic Met Office; Preliminary analysed data by the SIL seismic monitoring group of the Icelandic Meterological Office (17.12.2014).
Kverkfjöll area. When the magma did surpass the line it also shifted direction to half the original angle from North. Then the magma keeps on, finally crossing another line forming the polygon.

Then we come to the most important part, namely the eruption itself. When the magma is close to the said Munroe line, the eruption starts in the Holuhraun lava field. It indicates that the magma did affect the border line of the polygon, initiating an extra inflow of lava, heating it up from below and finally causing eruption at that location. The earthquakes extending from Askja right now also indicate the same process, on a much smaller scale, and that could lead to an eruption close to the mountain Herðubreið.

This is consistent with what happened in the Laki eruption in 1783. The magma forming a dyke did flow all the way from Grimsvötn caldera, but close to Laki is the line forming the relevant polygon. In that case, two lines coexist, because it is close to 64°N as explained in the former chapter. As in Holuhraun, the eruption started close to the line forming the polygon. When this type of dyke forming event occurs, it is therefore reasonable to anticipate eruption to take place when the dyke propagating from a caldera intersects a Munroe line as described here.

The Eldgjá line of craters from 934 clearly also cross the polygon in a similar way from the Katla caldera.

Figure 83: A map showing the location of Laki and Eldgjá fissures.
Chapter 11 - Tectonic drift

Since the 1960’s, the knowledge about tectonic drift has added considerably to our understanding of geosciences in general. In this essay nothing is really changed or added to our knowledge about ridges and trenches, what is done here is simply comparing the convection cell system and what is known about tectonic drift.

11.1. Tectonic drift of Iceland

A correlation is apparent between the polar convection lines and tectonic drift of Iceland. The East of Iceland is drifting to the North-East and the West is drifting to the North-West (Guðmundur Þór Valsson 2007). The directions of drift vectors at the same latitude of the Eastern and Western parts (maximum eastward and westward trend approaching the grid) are accurately symmetrical. For instance, at the 66th latitude the direction is about 33 degrees West and East of North. The velocity of the drift is about 2.2 centimeters per year of the western part and approximately 1.7 centimeters per year of the eastern part. This information was a surprise to many scientists, already used to think about the more traditional figure of the order of 1 centimeter each year approximately to East and West.

One of the most spectacular results of the measurements is the mirroring of direction of drift vectors in the West and East respectively. Of course the mirror effect found around the Reykjanes Ridge for instance of magnetic lines was known before and many textbooks relate that fact with convection cells driving the tectonic drift equally to both sides. But this mirroring of directions related to northward drift was something new, so new that it is still not known by many geologists when this is written. It is not easy to see any logical reason for this symmetry, until you look at the drift vectors in context with the convection cell system as a whole.
The tectonic drift of Iceland\(^1\) and the polar convection cells

Two vectors of symmetric drift directions pointed out with inserted arrows

The drift vectors tend to be aligned parallel to the grid lines of the convection cells outside the main volcanic zones. The two inserted arrows point at vectors on the same parallel. Obviously the deviation from north for both vectors is the same, just one pointing east of north while the other is directed west from north.

Again, a general resemblance is apparent between system and direct measurements. This should be an opportunity to try to understand how tectonic drift works in more detail than before.

\(^{1}\) Map: (Guðmundur Þór Valsson 2007)
11.2. The division line between the American and European plates through Iceland

With this in hand we can again go into some details regarding Iceland, showing where the theoretical line between the two tectonic plates of North America and Eurasia meet. It looks like this:

![Theoretic border line between the N-American and Eurasian tectonic plates](image)

This line clearly follows the pattern and can be divided into seven main sections:

1) The Reykjanes Ridge follows a line to the corner of a polygon.

2) Two polygons between the main part of the Reykjanes ridge and the SISZ polygon. At the SW- corner of Iceland the arbitrary forces of tectonic drift seem to be take over, as a sort of a jump is taken from the Reykjanes Ridge to the East Volcanic Zone. The Reykjanes polygon is of a different nature than the nearby SISZ polygon, as it has a series of volcanic systems, somehow making it possible for the border line to bend and follow a SW-path out to the Atlantic Ocean, until it fits again properly into the pattern of the convection cell system with the Reykjanes Ridge.

3) The SISZ polygon and the nearby EVZ polygon have an axis through their center in a straight line from east to west. The seismic and volcanic faults and fissures do the same job, with an eastern end close to the Laki crater.

4) From Laki again there is a line through two polygons making up one section of the border line, through the Grímsvötn area up to Kverkfjöll.
5) From Kverkfjöll there is a border line directly to the north to Öxarfjörður. The northern end is manifold, because the Tjörnes Seismic Zone or the North Iceland Seismic Zone is dependent on at least three

6) The North Iceland Seismic Zone covers the jump from the NVZ to the Kolbeinsey Ridge. The Kolbeinsey Ridge can be traced farther to the south, close to the opening of Eyjafjörður as seen here:

http://www.earth-of-fire.com/page-8786992.html

The Kolbeinsey ridge reaches to the shores of the Tröllaskagi peninsula. Similarly, the NVZ extends as far north as the northern most peninsula of Iceland. One border line between the tectonic plates of N-America and Eurasia is therefore oversimplification. A more complete drawing looks like this, and it is still oversimplifying the conditions to a large extent.

The rift zones and seismic zones dividing the N-American and the Eurasian tectonic plates
An analysis of the direction of the small convection rolls shows that under the Reykjanes there must be an upwelling line. What is confusing at first is the result that upwelling of large cells does not result in upwelling close to surface at the 64° parallel. The upwelling takes place in the two lines of small cells at each side of the division line of large cells below. The divergent lines of the upper most cells play a crucial role in the division because they have direct contact with the tectonic plate.

Figure 84: Comparing the convection cells of 64°N and the division line between the tectonic plates.

With the analysis leading to the perfect consistency of upper convection cells at 64°N, there is a basis to speculate about the jump from the Reykjanes Ridge over to Hekla and the eastern side of the Eastern Volcanic Zone (EVZ).

1. The cells extending from equator lose influence as being lower than the polar cells, and when balance of thickness of the cells is acquired at 64°, the polar cells become dominant. The thicker crust leads to the fact that a rift valley is
not developed as on the Reykjanes Ridge, but the entire width span of the cell over western Vatnajökull becomes a rift zone.

2. As vertical component is important of convection cells in these latitudes, the tendency to develop a ridge above the upwelling line west of the main division line of deeper mantle is reversed. The divergent line is actually extending from Hekla, but the tectonic drift border extends from the eastern edge of the EVZ.

3. When influenced by ordinary conditions north of the transition zone, the tendency to develop a ridge west of the main division line of lower mantle is also the ruling factor.

4. At the crossings of the main lines of northern and southern flow, the convection currents aligned NW-SE affect the total outcome of balance between upwards and downwards currents. The polar currents have a net downwards flow, leading to tendency to choose the inner circle for stronger upwelling, but at the latitude of Iceland within the transition zone the net upward flow of the uppermost cells becomes positive. This leads to the jump from the Kolbeinsey Ridge to the other side of the main line of lower mantle to Theystareykir to Krafla and from there to Hekla.
11.3. Why does the drift direction follow the lines?

The tectonic drift of Iceland follows certain lines of the grid shaped by the convection cell system of the mantle. It is therefore tempting to think about some kind of horizontal flow along these lines. The convection rolls should not be forgotten, though, because the power necessary to move the plate is found there. The direction is also perpendicular to the rolls. Then there is one question to answer: The rolls rotate against each other, so should the horizontal effect on the tectonic plate above them not be evened out as one roll is working against the other? To answer this question, a few factors must first be reviewed. Below the small rolls there are the big convection cells which clearly affect continental drift. Also we have to keep in mind that horizontal flow must also exist as well as the essentially vertical flow directly involved in convection only. The horizontal flow can be viewed as an ‘excess flow’ that can easily affect the final outcome of many convection rolls working against each other.

Another thing to have in mind is that the ductile part of the tectonic plates, and even at some places the brittle part to some extent, is cut asunder by Munroe lines, making adjustments easier for the plate as it moves and encounters ever-changing conditions. That also counts as a factor determining the direction of tectonic drift. That might explain why the direction seems, in Iceland, to follow the lines rather than being perpendicular to rolls. The constant rearrangement of polygons along Munroe lines must also allow tectonic drift to go on steadily without causing as much tension as otherwise would build up within the moving plates.

There are of course more questions, as always arise when working at a special example like Iceland. What about the rest of the world? Is tectonic drift always found to be along lines of the convection cell grid, or sometimes along lines and sometimes perpendicular to them? That question looks like a bit hard to answer, but the simple answer is ‘no’. The small example given previously of the SISZ shows that sometimes there are secondary features derived from the basic effects of the combination of plate tectonics and convection rolls. Once dealing with the surface everything becomes far more diversified than down in the mantle and the asthenosphere. Instead, the surface can be measured and observed directly, so the challenge is to work out the context between underlying forces and the geological and tectonic situation in any specific area. Geologists and geophysicists have had to do that before and have to keep on with it, even though this theory might be a contribution to make things look a bit more systematic than before.
11.4. Tectonic drift of the whole world

I once went to the institution of Landmælingar Íslands to learn about the drift of the country to the north. There I was told that it came as a surprise, but they could not find anything wrong with neither measurements nor processing of data. The country was actually drifting more to the north than to any other direction. Previously I had only thought about how the country widens up 2 cm a year, and in addition to that tried to understand how the country was probably drifting as a whole westwards relative to the hot spot, presumed to be located under the Vatnajökull glacier.

In this context we should look at the “big picture” of tectonic drift according to GPS-measurements all over the world. The north component of tectonic drift measured clearly fits nicely into it.

Figure 85: The drift of the tectonic plates (from the Internet).

Comparing the tectonic drift measured in Iceland with that of the whole world, the
The main point of interest is the rather obvious fact that the tectonic plates of Eurasia and that of N-America rotate against each other in a rather symmetric way. The smaller N-American plate rotates within a shorter radius. We are lucky enough to have a part of the starting areas for this measured in Iceland, as it is in fact a part of the Mid Atlantic Ridge. The simplified map below makes it easier to see why the directions of tectonic drift in Iceland can be the same as the alignment of the convection cell system.

![Map of tectonic drift](http://www.geologyin.com/2015/03/driving-forces-of-plate-motion.html)

**Figure 86:** How Eurasia and N-America rotate in opposite ways

The tectonic drift is shown here with arrows emphasizing the continuation of Icelandic vectors and the semi-symmetric rotation of the N-American and Eurasian tectonic plates.

11.5. Grid of reference

The results of these GPS measurements of tectonic drift show that Iceland is actually moving to the north and it means that each point of it is drifting closer to the
North Pole and farther away from equator. Besides that, the measurements of movement to the east and west are framed with reference points elsewhere in the world. This is quite different than the traditional thinking of Iceland simply ‘widening up’. A grid of reference for locating a point on the globe has been a real issue for centuries, but that counts especially for pinpointing the longitudes. The latitudes can more easily be correlated to the poles and equator, and therefore can the tectonic drift component to the north not be disputed at all.
11.6. The tectonic drift of Iceland reversed

To see how the pieces of Iceland have drifted apart, the measured vectors can be used to reverse the direction and see what has happened during the last 10 million years or so. Symbolic arrows are drawn on the map below indicating where the two main parts of the oldest rock in Iceland is originated from.

Basic map with polar cell grid

Direction of drift (ignoring velocity)

Old bedrock puzzle

Approximate position of the oldest bedrock about 10 million years ago according to present tectonic drift velocity and directions
Then, maybe clumsily, the parts can be put together in an attempt to map Iceland as it was about 10 million years ago. Of course there was more land around, especially north of the bedrock shown on the ‘old map’, now part of the bottom of the ocean. This is somewhat different from the result when the various parts are pulled together directly from west and east.
11.7. The continental microplate extending from Jan Mayen to Öræfajökull

It has been found that Öræfajökull provides magma partly derived from mainland crust.\(^1\) The crust below eastern Iceland is up to 32 km thick (Torsvik 2015) and following a convection cell from Öræfajökull to Jan Mayen.

Figure 87: Resemblance between polar cells and continental microplate between Iceland and Jan Mayen.

The microplate obviously follows a polar line of the convection cell system. Likewise, the path of the hot spot shows certain resemblance, especially if certain aspects of tectonic drift are taken into account.

Only with the information at hand that zircon has been found in Öræfajökull lava does not necessarily indicate that mainland crust extends all the way under the mountain, but a southwards mantle current along the convection cell found extending from Jan Mayen may carry material from the piece of mainland crust found there.

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\(^1\) Forskning.no/2015/03/sunket-kontinent
Chapter 12 - Back to the beginning with the ‘Ocean Basins’

Harry Hess (1962) wrote about the ocean basins an article where a convection cell system of the kind analyzed here is described. He said this was ‘geopoetry’, but poetry is in high esteem in Iceland, where we learn to say: “Half my fatherland is the ocean.” Likewise, the geology of Iceland is close to what we find at the “ocean basins”, quite unlike what is usually found on a mainland. It is therefore not a coincidence that Iceland provides a special opportunity to derive the convection cell system of the mantle in general.

12.1. Pinpointing the regional and local systems

The dimensions of this system have been calculated according to a carefully chosen reference points, based on scientific measurements. The result is a grid of lines representing the edges of convection rolls within the Earth, where each line is continuous from the North Pole to the South Pole.

A special type of map is ideal for tracing the lines used here, with a fixed length between each degree of latitude and longitude. Not only hot springs help to find the exact orientation of those current lines, but also many features appear because of weaknesses in the crust like waterfalls and earthquake faults, etc. As pointed out before, equator provides a good opportunity for pinpointing the convection cell system on a grand scale, because along it the Atlantic spans exactly 60°, the African continent 30°, the Indian Ocean 60° the Indonesian islands 30° and the Pacific Ocean 150°. This is one of many facts that coincides perfectly all other aspects of the system of convection cells. The 30, 60, 30, 60, 30 pattern would be enough, but there is more to notice here. The Icelandic volcanic system, for instance, is directly north of the centre of the Atlantic Ocean at equator, and a mathematical formula, based on physical preconditions, can connect these two points of the same longitude; one on equator, the other at 64°N. The relevant points on the coasts of equator must therefore be at important locations.

On the world map it can be seen how the coastline of the continents at these equator points is located at the meetings of mantle current cells. All this might sound complex, even after reading all the previous chapters, but it makes up one holistic
framework. Besides a few geological points for reference, this world system of convection cells is based exclusively on mathematical rules. Several locations in Iceland can be used to locate the system, and from there, the whole world system can be traced. And remember, even though Iceland is land, geographically speaking, Iceland resembles the ocean floor geologically.
12.2. Zooming in on Iceland and then zooming out

The system forms a regular, symmetrical pattern. In Iceland the network of lines becomes very tight, forming numerous polygons. The size of the convection cell polygons can vary considerably, from over 2000 km$^2$ to only a few square kilometers. An exception is the tangent points on the 64$^{th}$ parallel, theoretically infinitely small points. The areas on and around very small polygons are often quite active.

When first learning about the geology of Iceland, we are told about the rift of the Mid-Atlantic Ridge extending right through Iceland from south-west to north-east. But volcanoes and geothermal areas in Iceland do not follow this pattern entirely. Some very famous sites are located inside or very close to small plates within the pattern that emerges on the surface as a result of the alignment of convection cells below. In this book it has been analyzed how we can go step by step from information about the Earth’s layers to a detailed map of the related grid formed by convection currents in Iceland.

The grid of Iceland can be extended over the whole world

As mentioned before, we can zoom in on Iceland with the convection cell grid. What appears then is an especially clear picture of the interplay between surface and interior of the Earth. This we can again use to go the same way back and derive the World System from that of Iceland. I have to admit that it does not seem to be necessary at all, but both induction and deduction are used here to clarify things.
12.3. Ocean ridges around Iceland

The Reykjanes Ridge provides an example of how a single line of the convection cell grid system follows one feature for a thousand kilometers. In fact, by simply drawing a line along the ridge and extending it further, the system as here derived would start to show itself. So if the grid fits well to various conditions in Iceland, the Reykjanes Ridge becomes the largest individual feature to fit perfectly to the convection cell system.

The Reykjanes Ridge is a very good example to investigate further, because the magnetism of its rocks at each side show clearly how it has developed, and the so called V-shaped ridges associated with it tell a further story about the volcanic activity along it.

The inserted map is for comparison, showing the measured position of the Reykjanes Ridge. (Source: http://www.mantleplumes.org/Disclosure.html, (viewed 02/06/2012)).

Note: The two straight lines are parallel with the same length. This consistency extends all along the red line.

The Reykjanes ridge has the same orientation as the convection cell system
12.4. Pulsing of activity along the Reykjanes Ridge

One particular question that arises in these studies is how different layers of the Earth intersect with another. That must be one of the reasons why this system seems to have remained hidden for a century. The CMB or D’ layer or Gutenberg layer has been the main threshold. Let us have a look at the original picture of the vertical current system again:

![Diagram of vertical current system](image)

The thickness of the intersection zone (Gutenberg layer) becomes a natural consequence of the general system, because it fits to the mathematical intersection of circles with the same diameter as the inner core. This is another coincidence between geophysical measurement and this convection cell model that is hard to neglect. Still it also has to be explained. The layers cannot really coexist at the same place at the same time. The explanation must be pulsing of the cells. There are indications found at the surface of the Earth, on the bottom of the oceans, that such pulsing really takes place. The V-shaped ridges at the Reykjanes ridge show that pulses of volcanic activity move along the ridge towards the SW.

Pulsing must both occur within the convection cells and the Munroe lines between them. Therefore regular V-shaped formations on this large scale can be found.
This Google image shows the location of the Reykjanes Ridge and the V-shaped ridges quite clearly. It appears as a straight line (drawn), but below is a map, based on degrees of latitude and longitude of equal length, where a line at the same location is curved. That line follows the convection cell system in a very exact way. The convection cell system follows the Reykjanes Ridge to the south at 57°N and 33°W.

The speed of propagation along the ridge is 200-250 mm yr\(^{-1}\) (Jones, White og MacLennan 2002). The whole convective cell system must be pulsing all the time to give way for a counterpart in an intersection zone. At the same time, Munroe lines pulse and thereby show the tracks of propagation.

Considering that the pulses travel the opposite direction as the vertical flow according to the Coriolis grid, they must be originated in vertical components of the system. In the intersection layers, for instance between the MORB and OIB layers, one type of convection roll must constantly be giving way to the other within it. The vertical displacement of this convection cell interaction mechanism should be in the opposite direction with the flow, for energy conserving reasons. Therefore the V-shaped ridges also indicate that the MORB-layer contains mantle material flowing to the north.
12.5. Taking more examples.

The proper Reykjanes Ridge originates from the south corner of a polygon which has its center aligned along the 64th parallel. We can use this opportunity to mention the importance of this. The 64th parallel has a key position within this system. Actually it has the same role as equator from a certain point of view. It is the central line of the intersection zone between polar convection cells of the upper mantle and asthenosphere and the corresponding hemispheric convection cells.

It all fits to Iceland according to its latitudes, and the ocean around it. But there are more countries at the same latitudes as Iceland. These belong to the mainland with a thicker crust and no volcanoes. Can we expect any consistency between the grid of the convection cells and the mainland? Once again the answer is yes. The pattern of rivers, fjords and coastlines resembles the pattern of the grid lines to an extent not to be overlooked. The simple map is here provided for reference.

The small square at the coast of Norway at 64th parallel is exactly 30° away from Hekla.

Iceland and Norway.
The resemblance between Hekla and the corresponding point in Norway is literally striking. The orientation of the tectonic features is exactly the same, that is N60°E! The Munroe lines are oriented N44°E, so this is obviously a secondary direction. What is important is the fact that the orientation is exactly the same. It is difficult to explain why the faults of Hekla do not have the same direction as the volcanic system in general, which is about N45°E, but the same underlying reason is probably revealing itself by directing the glaciers of Norway exactly along the same direction as Hekla, namely N60°E.

Figure 88: The tectonic resemblance between Hekla and Trondheim, 30° apart.

The resemblance is obvious, for those two places on the same latitude, 30° apart.
Some examples of how formula complies with maps.

This simplified map of the Faroe Islands is enough to show that a line drawn N37°W according to the formula for the direction of hemispheric convection cell at the 62°N parallel. It is the best fit for the main features through the islands. Looking further into the geological, especially tectonic conditions, two fracture zones (Westray Fault Zone and Brynhild Fault Zone) with this orientation are responsible for the topography showing immediately a high degree of consistency with this calculated direction.

Figure 89: Juan de Funca with calculated direction

1 http://jgs.lyellcollection.org/content/168/1/27/F1.large.jpg
2 http://www.pmel.noaa.gov/pubs/outstand/embl1429/figures.shtml
Just to mention one simple example of how the formula works, take a rather random example from 45°N, giving the direction of N16°E for Juan de Fuca. It immediately shows accurate resemblance. There are endless examples to show how the convection cell system is shaping the Earth’s surface. The evidence piles up just endlessly.
Proof?

This analysis of a model of Earth’s interior is here to stay. The evidence of a regular system as is represented in this book is overwhelming. It is in one way simple, because one just has to understand what convection is, but it has another side of complexity, considering the combination of geophysical data and topographic and geological features etc. This is something new and can be used to explain many different things and is therefore difficult for anyone to swallow in one piece.

Reviewing how the dimensions of the convection cell system within the Earth were derived, these were the main steps:

**VERTICAL**
1) Convection rolls with the diameter of inner core fit into Earth’s layers.
2) Two layers of convection rolls fit between the depth 120 and 410 km.

**HORIZONTAL – (latitudinal)**
3) The diameter of the horizontal circle extending from equator found.
4) The polar systems derived.
5) The intersection zones around the 64th parallels analyzed.

**HORIZONTAL – longitudinal**
6) The exact center of each horizontal circle found by referring to geographical features.

Everyone wants to see how the system is revealed on the surface. Just to mention some concrete examples: The volcanic zones along with the Reykjanes Ridge show direct resemblance to that system. The distribution of land mass along equator where the Coriolis effect is zero is just as convincing as anything can be. The distribution of volcanic sites in Iceland, particularly Mt. Hekla and Mt. Öraefajökull along with many others show how the system is revealed at the surface. Until now we have not been used to have such a detailed model of what is happening within each layer of the Earth.

First of all, Coriolis effect, transparency of radiation, Munroe effect and Bénard type of convection are all factors contributing to a holistic picture of how heat is transferred within the Earth. The thinking of Irvine (1989) is also quite logical, that
is the extremely long time involved contributes to stabilize the system so that a balance between buoyancy and gravity is achieved, resulting in Bénard convection as formerly mentioned. The research I took part in on the South Iceland Seismic Zone with my professor, Pall Einarsson, also convinced me that similar balanced conditions prevail in the ductile part of the tectonic plates, so that the pressure induced by the tectonic drift exactly balances the tolerance of the ductile material. Therefore the Mohr’s circle shows that the earthquake fissures should make 45° angle to the pressure. All this can be easily deduced when referring to lines formed by the Munroe effect of the convective current system cutting up through the plates, governing the direction of pressure on the square forming the Southern Lowlands of Iceland.

The direction of tectonic drift measured globally with GPS technology is the same as that of the convection current cells, providing information which is probably closest to a typical scientific proof of the existence of the convection cell system described here as can possibly be achieved in large scale geosciences of this kind. First of all, though, no one can deny that a system of convective cells with equal height and breadth fits into the measured layers of the Earth. After noticing that, it was just a piece of work to draw and describe a model of the total system of Bénard convection cells of Earth’s outer core and mantle and the Munroe lines reaching up into the tectonic plates. The picture of radiation from the upper layers heating the core is an extra bonus adding to our understanding of the transfer of heat within the Earth.

As for the question: “Can we prove this?” I have to answer yes. What has been written here is enough to convince everyone who reads it. Still I know many will deny it, and in fact I would appreciate every denial if it only was based on scientific grounds. The convective cell theory is built on strong foundations. It makes up a holistic picture where each part strengthens the other parts, explaining natural phenomena that otherwise would be hard to even talk about, like the distribution of land mass on the equator line. It would be embarrassing for everyone not to allow himself to understand such details of the appearance of our world, just because we are maybe reluctant to accept some very simple logic. As there is only one precondition to everything in this study, namely that the convection cells have the same height and breadth, then that has to be disproved before anything else in this essay is actually disproved. I am very well aware of all possibilities of inaccurate logic, information, calculations and measurements found in this essay. Everyone can see that this material can be dealt with in a more sophisticated way, making graphics with the newest drawing programs, making use of high quality maps etc., but it is not necessary in
order to show that this convection cell system exists. That is: One has to point out specific preconditions, calculations or examples and ask how they make sense.

To be able to write this essay, of course I have to rely on the work of other people. One book that inspired me to finish this work and publish it is ‘Plates vs Plumes – A geological Controversy’ by Gillian R. Foulger. Probably the most common idea about mantle plumes is that of hot mantle column, maybe with a diameter of the order of 100 km, rising from deep within the Earth towards its crust, being responsible for uplift in that area, geothermal activity and volcanism. In that book, Foulger shows that mantle plumes of that nature do not seem to exist at all, so a new understanding of the so called hot spots or ‘melting anomalies’ is needed.

Since Foulger was convinced that Iceland has actually no continuous plume from the lower mantle to the crust, she writes (Foulger 2010):

Since that moment I have worked to see for myself whether such an hypothesis can stand – that Iceland does not owe its volcanism to a deep mantle plume but to processes rooted at shallow depth. And if such an hypothesis can stand for Iceland, can it also stand for other places traditionally assumed to be underlain by plumes.

These processes rooted at shallow depth are there, but derived from processes below 120 km of depth. After reading this book, I hope that an idea about how heat from radioactive material is transferred to the core with radiation, moves back again with convection, and at the same time the heat starts radiating out from the convection cells, resulting in Munroe effect bringing molten magma up into the tectonic plates, providing heat and material for a sequence of events within the crust, leading for instance to geothermal and volcanic activity.
Appendix 1: Basic model compared with world map

To make it easier for the reader can follow how the drawings are made in this book and what is meant by hemispheric and polar cells, some ‘teaching material’ is added in this section, showing step by step how the convection cell rolls are marked on a geographical map. Here we focus on the two layers of convection cell rolls found at the depth in between 120 - 410 km below Earth’s surface.

This row of pictures shows in an easy way some features of the system by connecting them with an arrow to a map.

Explanation – 01: A “MORB-line” extending from equator to 67.34°N. MORB- and OIB-lines represent convection cells within two different layers between 120 km to 410 km below the Earth’s surface.

Explanation – 02: An “OIB-line”, extending from 67.34°N to equator.
Explanation – 03: The two semicircular paths of explanation 01 and 02 put together end-to-end at the 67.3°N parallel. In this way, the convection rolls of the two layers between 120 and 410 km, form a circle. The circle ends with a head of an arrow, indicating the horizontal flow direction of a particle. A particle flowing all this way is then presumed to have been carried within the upper layer from equator to 67.4°N, and then with the lower layer back to equator.

Explanation – 04: The particle now keeps on over equator, immediately turning to the left. It keeps on within an OIB-layer all the way south to 67.3°S. The arrowhead indicates the horizontal flow direction. From that point the particle will have to be carried with the MORB-layer towards equator.
Explanation – 05: Here is the path of a horizontally flowing particle within the system traced all around the world. It can flow endlessly like this, swaying from our point of view, but directly from its own point of view, a difference explained by the rules of the Coriolis effect. Dotted lines show the longitude where the convection roll drawn here passes over equator. Adding 20 circulation paths (every 1.5° of longitude) shows total hemispheric system.

Explanation – 06: Many parallel curved lines together, width not to scale, showing parallel MORB-convection cells. This is identical to explanation 01.
Explanation – 07: Many parallel convection cells drawn together, responsible for horizontal flow to the south. Here it is called the OIB-layer, found directly below the MORB-layer.

Explanation – 08: The features of explanation drawings 06 and 07 are combined here. The lines, marking convection cells in the upper and lower layers, put together on a map, form a pattern like the one shown here. This drawing is for clarity only, the cells not to scale, just to make further reading easier. Note the pattern of diamond-shaped polygons.
Explanation – 09: A few lines representing polar convection rolls inserted to the World Map. In the same way as explained for the hemispheric lines, there is another layer under this one. The polar lines are then dealt with separately. Drawing more teaching material like this is important, as following step by step the paths of convection cells makes it easier to understand the system as a whole.

Explanation – 10: A fully filled map with all the circles drawn 1.5° apart looks like this. One circle (actually two semicircles) has been pointed out specially.
The convection system of Earth’s mantle and how heat is conveyed to the surface
Steingrimur Thorbjarnarson and Thorbjörn Armann Fridriksson

The preconditions
The layers of the Earth shown drawn to scale. Circles of the same diameter as the inner core fit into the diagram. The match is due to physics, whereas the mantle, under balanced conditions, should form convection cells equally high and wide.

The Gutenberg layer
The Gutenberg layer is here considered to be an intersection between the core and the mantle.

Measurements and physics
The layers of Earth drawn according to scale. The circles are drawn to represent Bénard type of convection.

3D drawing of the system according to the difference of angular velocity from one infinite step of latitude to the other, resulting in a curvature with diameter of the order of Earth’s radius.

Vertical heat flow:
- Radiation towards core
- Convection from core
- Munroe effect through crust

These three types of flow are shown here:

Radiation within the Earth

Convection from core towards crust

Munroe effect

Horizontal paths:
Found for 240 parallel rolls covering the Earth underneath the crust. One of those paths is shown here:

Radiation towards core

Convection from core towards crust

Munroe effect

Endless Coriolis derived path

The grid resulting from 4 layers of convection rolls under Iceland

Why north-south fractures?

The South Iceland Seismic Zone can be explained by referring to the grid formed by the layers of convection rolls.

World map

The grid is absolutely regular and possible to zoom in to analyse all kinds of tectonic features and geological phenomena and explain them thoroughly.

Iceland is located within an intersection zone of the polar and hemispheric parts of the total convection cell system. From the basic system drawn here, the grid under Iceland is derived. This grid can be referred to explaining the basics of the geology of Iceland.
The convection system of Earth’s mantle and how heat is conveyed to the surface

Abstract

A new method to calculate the direction of basic tectonic features of different latitudes is introduced. The interplay of convection cells of the Earth’s mantle and the Coriolis effect makes possible to take this step from measurements to calculations. Two basic preconditions make it possible to trace the convection cells within the mantle. First, according to physical law, convective mantle under balanced conditions shall have equal height and width. Second, the layers of the Earth have exactly the thickness that fit to convection cells with equal height and breadth. Along the convection cells, horizontal flow must occur, also following perfectly balanced Coriolis governed path. It follows the curvature of the Earth, resulting in a circle with the same diameter as Earth’s radius. Therefore, just to take an example, the directions of the volcanic zones of Iceland have been calculated in a very simple way.

The convection cells can then be mapped accurately for each convection layer respectively. Each layer affects the surface independently, and the effects can be traced on the surface. As a result of the mapping procedure is a grid that appears all over the world from the South Pole to the North Pole. This includes of course a map of the grid over Iceland which can be studied individually. Iceland is remarkably geologically active compared with most other areas, and that activity can be compared with the convection cell system underneath. The convection cells are found to form rolls convecting side by side, and the grid lines are drawn along the rolls to show their positions. These grid lines are also of special interest because they represent the middle zone of convective upwelling or downwelling.

The study has taken almost two decades, taking into account many different aspects of physics not necessarily mentioned in geological literature. The flow of heat was traced from core to surface, resulting in a very convincing model showing remarkable consistency with surface features. This was checked by Þorbjörn Ármann Friðriksson, according to the science of radiation. His findings explain why the core of the Earth remains much hotter than the mantle. By referring to the so-called Munroe Effect he also explained how magma can flow up through the tectonic plates to the surface.

With all the heat flow process from beginning to end clarified, the distribution of volcanoes, geothermal areas, earthquake zones and topography in general can be understood in much more detail than hitherto thought possible. This will lead geology to become more a science of calculations than before. The novelty of this approach is tremendous, and necessary for us to get a holistic picture of heat flow within the Earth.

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Some other useful material at hand during writing:


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