Scientific Research Publishing

International Journal of Geosciences, 2023, 14, 150-186
https://www.scirp.org/journal/ijg
ISSN Online: 2156-8367
ISSN Print: 2156-8359

Wisdom and Geology, the North German Basin, and the Significance of Thrown Dices

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How to cite this paper: Brink, H.-J. (2023) Wisdom and Geology, the North German Basin, and the Significance of Thrown Dices. *International Journal of Geosciences*, **14**, 150-186.
https://doi.org/10.4236/ijg.2023.141008

Received: December 27, 2022
Accepted: January 28, 2023
Published: January 31, 2023

Abstract

For thousands of years, mankind is observing the surrounding nature. Often, they found no obvious clues for inexplicable and complex facts, leading to the belief that their wisdom was limited. This is in the majority of cases still true today, but based on hundreds of years of (geo-) scientific work some older thoughts can now be readjusted by combining newer geological, environmental, historical and philosophical clues. Facts about the development of the North German Basin are used to demonstrate the variability of geological systems and how these can be described by taking dice as a metaphor for ruling geological parameters. This includes all kinds of plate tectonically controlled basin forming processes, especially metamorphism of the lower crust due to a fixed mantle plume, basin filling processes with their galactic and lunar overprints, basin modifying tectonics due to internal (halokinesis, inversion) or external forces (one-sided loads at the surface due to mighty Delta sediments or glacial ice sheets) and geochemical reactions as a result of pressure and temperature changes in course of subsidence. Especially, the Rotliegend (Lower Permian) Gas Play is one of the possible illustrations of the entity of the North German Basin with its more than 70 - 90 independent parameters belonging to a global set of very complex hydrocarbon systems. Processes on Earth like the formation of systems of hydrocarbon fields as well as environmental systems (e.g. river systems, lakes, islands, sedimentary basins) are subordinated to the dices of nature and are steered invisibly by a selection of rules of the game that one understands as natural laws. The facts and remaining uncertainties as well as problems with subsurface-related processes (e.g. man-made tectonics, subsidence and uplift) guide the thoughts of engaged individuals on how to proceed wisely with limited predictability of challenges and dangers of a subsurface system. This work will be a trial to associate once more the natural sciences (geology) and the humanities (philosophy) for the benefit of both.

Keywords

North German Basin, Subsurface Problems, Geological Parameters, Wisdom, Thoughts, Dices

1. Introduction

During the last decades, many people became intensely sensitive to changes in their environment independently whether they are either humanly or naturally caused. This includes different kinds of geohazards related to the supply of essential energy resources from the subsurface like coal, oil, gas and heat. In this paper, some thoughts will be discussed about the geological subsurface, especially of the North German Basin, and about the related human wisdom and underground system properties, which can be metaphorically addressed by comparing them with thrown and then mathematically multiplying an undefined number of dices.

1.1. Examples of Subsurface Problems

Touching the geological subsurface at greater depths in densely populated countries like Germany, The Netherlands or the United States of America may have an important economic value, but can also lead to some unwished damages to human facilities at the surface. To predict those damages and find ways to prevent them remains an outstanding scientific task since people and politicians can hardly accept environmental harm due to the unsafe behaviour of responsible persons. A few examples of damages and conflicts demonstrate the problem. These are:

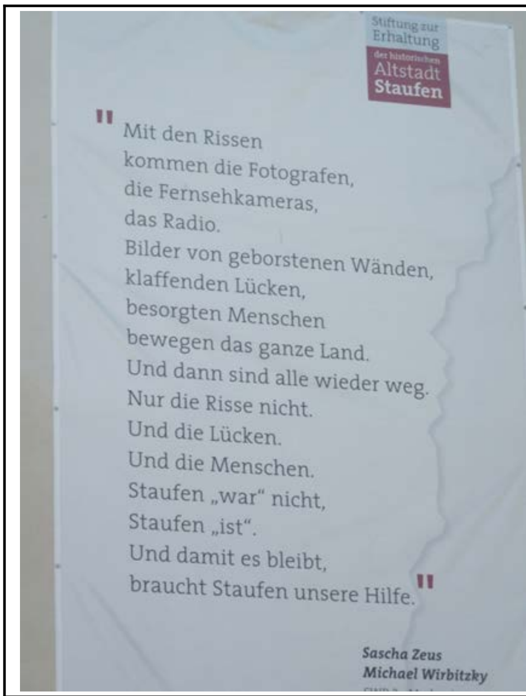
1.1.1. Staufen/Germany

"In September of 2007, seven geothermal wells were drilled adjacent to the 16th century town hall in the centre of Staufen im Breisgau (Upper Rhine Graben, Germany). This activity resulted in enormous structural damage to buildings as a function of four different geological parameters: artesian groundwater, two interacting karst formations, strong tectonization, and a swellable anhydrite formation. Some weeks after the termination of the drilling, uplift started, and reached a magnitude of approximately 26 cm in March 2010. About 250 buildings were involved, showing cracks (**Figure 1** and **Figure 2**), tilting, and other effects of the differential swelling movements beneath the foundations. Surface uplifts with rates up to 10 mm/month have been determined using high-resolution spaceborne radar data and radar interferometric techniques. Besides the uplift due to the swelling processes, future problems could arise from the fact that the gypsum formed from the swelled anhydrite is soluble in water. Thus, sinkholes and other karst-related phenomena may occur" [1].

1.1.2. Landau/Germany

Following reference [2], "several centimetres of uplift were observed extending

Figure 1. Cracks at a building in Staufen im Breisgau (Upper Rhine Graben, Germany, 2013).



With the rips
The photographers come,
the television cameras,
the radio.
Pictures of burst walls,
gaping gaps,
concerned people
motivate the whole country.
And then, all are again away.
Only the rips not.
And the gaps.
And the people.
Staufen "was" not,
Staufen "is".
And to remain,
Staufen needs our help.

Figure 2. Announcement at a wall in the city of Staufen, 2013 (Translation right side).

over a small area around the geothermal site of Landau (Upper Rhine Graben, Germany) artificially fracked by water treatment. This observation is based on the interpretation of a geodetic survey using radar satellite images of the Upper Rhine Graben recorded between April 2012 and April 2014. Observations are based on two data processing methods for synthetic aperture radar acquisitions: Synthetic Aperture Radar Interferometry (InSAR) and permanent scatterer InSAR (PS-InSAR) monitoring. The inferred time evolution shows that the displacement began in July 2013 and that the displacement rate reaches its maximum (about 16 cm/year) during the summer period (from July to September 2013). A surface displacement of 3.5 cm has been observed during this period" (**Figure 3**).

No similar subsurface reaction has been recorded during intensive fracking operations in North German gas fields in the last more than 50 years. Predictions for the North German Basin based on events in a different geological setting and vice versa appear to be without any wisdom.

1.1.3. Groningen/The Netherlands

1) Earthquakes

According to reference [3], "usually natural earthquakes do not occur in the northern part of the Netherlands. Yet, small earthquakes have frequently affected the area since the 1980s. For a long time, it was denied that these earthquakes were caused by the extraction of gas in the area and that these earthquakes could cause any damage. When more, and more severe, earthquakes struck the province of Groningen, these claims became unsustainable. In 2012, a relatively strong earthquake hit the area and the earthquakes became a national policy issue that threatened the legitimacy of the state. The crisis lingered on until 2018 when the national government finally realized that prolonged extraction

Figure 3. Surface cracks at the geothermal site of Landau (Upper Rhine Graben, Germany, 2015).

would cause a deep crisis and decided to terminate the extraction of gas well before the depletion of the field. They argue that this visible and enduring crisis was not recognized and sufficiently addressed because of a societal dependency on the extraction of gas. The crisis was actively suppressed by the main actors, which ultimately undermined the legitimacy of the gas production and the state".

2) Compaction and subsidence of the Groningen gas field

"The Groningen gas field has been produced since 1963 and production is currently expected to continue until 2080. The pressure decline in the field causes compaction in the reservoir which is observed as subsidence at the surface in the range of a few decimetres. Measured subsidence is characterized by a delay at the start of production" [4].

1.1.4. Oklahoma/USA

"Oklahoma is the site in the Midwest of the USA where wastewater injection is being carried out for disposal through a process in which the fluid is pumped into wells drilled deep into the subsurface. Those disposal activities may have caused the most powerful tremor ever recorded in Oklahoma, an earthquake with a magnitude of 5.7 near Prague in 2011 [5] [6]. The earthquake was recorded in about 17 federal states and caused damage in the epicentral region. It occurred in a sequence, with 2 earthquakes of M-w 5.0 and a prolific sequence of aftershocks. Significantly, this case indicates that decades-long lags between the commencement of fluid injection and the onset of induced earthquakes are possible".

1.1.5. Münsterland/Germany

As further subsurface-related problems naturally seeping hydrocarbons have been identified in course of the history. Sometimes gas has been religiously used in holy fires and oil seeps as a source for needful asphalt. Natural occurrences of leaking gas through the surface of the Earth are globally well-known [7]. The appearance of methane in the Münsterland area/Germany north of the mining area of the Ruhr district is a very familiar phenomenon [8]. The first documented findings come above all from the time of drilling coal wells in the outgoing 19th and early 20th century. Furthermore, methane accumulations in the groundwater and seeps at the day-surface of this region have been recognized in many cases. Especially, methane gas emissions from the groundwater are e.g. for a well-builder a considerable safety problem. Besides the appearance of burning gases in wells deflagrations have been recorded during the airing of pressure boilers. A first concrete analysis of methane in the groundwater proves top-contents of solved methane of up to 45 mg/l. Furthermore, methane concentrations from more than 75 Vol.-% became proven in pressure boilers of some house-well installations. The local people are aware of these problems and handle them with care. Carboniferous coal seams at greater depth are the source of the methane in the seeping Münsterland area as well as for the gas fields of the North German Basin still farther north. Thoughts to use those methane accumulations in the Münsterland area have been frequently made in the past, but up to now no commercial facility for extracting them has yet been realized.

Geological and technical knowledge and individual and societal wisdom combined may reflect the right step for solving the problems with subsurface processes. These problems are in many cases related to underground fluid transfer, including the generation of fluids through geochemical reactions, their migration and accumulation, and partly their circulation. In the Earth's history minerals at greater depths released water due to temperature and pressure-dependent metamorphism of the rocks and sourced opening fractures upwards with hydrothermal fillings like quartz and traces of gold, silver and other metals, which later became accessible at the surface due to tectonic uplift processes. Organic matter, deposited in a sedimentary basin, is released in course of a temperature and pressure-changing subsidence of hydrocarbons and inert gases like carbon dioxide and nitrogen. Depending on tectonic influences those fluids migrated through subsurface layers following possible pathways and gravitational forces and may once penetrate into the biosphere and atmosphere. Abundant water will act as solvent for different kinds of salt in rocks and may migrate through the subsurface system as well and enter the surface as brine. Additionally, depending on topographic and weather conditions meteoric water may contribute to a circulating subsurface fluid system, too.

Already, since the Bronze Age humans became able to identify, mine, handle, convert and use resources from the solid Earth. To develop this remarkable undertaking many observations and thoughts of individuals and the expectation of economic and military benefits were certainly the main drivers. The resources include near-surface ores of the metals gold, silver, iron, copper and tin and organic matter like asphalt as well as salt. A 3D or even a 4D understanding of the subsurface and its processes was only rudimentary possible by digging holes, caves, shafts and tunnels. Nevertheless, the distribution, quantity and quality of these resources remained a big question and were the cause of many unanswered thoughts. Insofar geology and wisdom became associated members of pillars of human life. This has already been written down in the Bronze and Iron Ages and is e.g. documented by the Job chapter of the bible.

1.2. Bronze Age Thoughts on Geology and Wisdom (Job/Bible)

The Bronze Age became an important milestone in course of the human evolution, when mankind started to think about the spirit of life and searched for a religious background, thereby linking among others wisdom vis-à-vis with geology.

In Job 28 or so they say:

Truly there is a mine for silver, and a place where gold is washed out.

Iron is taken out of the Earth, and stone is changed into brass by the fire.

Man puts an end to the dark, searching out to the farthest limit the stones of the deep places of the dark.

He makes a deep mine faraway from those living in the light of day; when they go about on the Earth, they have no knowledge of those who are under them, who are hanging far from men, twisting from side to side on a cord.

As for the Earth, bread comes out of it; but under its face it is turned up as if by fire.

Its stones are the place of sapphires, and it has dust of gold.

Man puts out his hand on the hard rock, overturning mountains by the roots.

He makes deep ways, cut through the rock, and his eye sees everything of value.

He keeps back the streams from flowing, and makes the secret things come out into the light.

But where may wisdom be seen? And where is the resting-place of knowledge?

There is no need to say anything about coral or crystal; and the value of wisdom is greater than that of pearls.

The topaz of Ethiopia is not equal to it, and it may not be valued with the best gold.

From where then does wisdom come, and where is the resting-place of knowledge?

God has knowledge of the way to it, and of its resting-place;

For his eyes go to the ends of the Earth, and he sees everything under heaven.

When he made a weight for the wind, measuring out the waters;

When he made a law for the rain, and a way for the thunder-flames;

Then he saw it, and put it on record; he gave it its fixed form, searching it out completely.

And he said to man, truly the fear of the Lord is wisdom, and to keep from evil is the way to knowledge.

1.3. Wisdom and Thoughts

However, e.g. philosophical, religious, scientific or economic thoughts evolve under dispute with concurring ideas. To keep they secret and do not share them with other individuals, can safe a political life as valued by a 200 years old German folksong:

Thoughts are free, who can guess them,
they flee past like night-time shadows.
No one can know them, no hunter can kill it.
It remains: The thoughts are free!
(https://lyricstranslate.com/).

but with the dead of the owner the thought vanishes possibly for ever from Earth. Despite of imaginable negative reactions, wisdom can grow only when thoughts are being communicated and published, independent of their present value. Religious and other bonds have to be overcome, as the stories of Copernicus (1473-1543) and Galileo (1564-1641) demonstrate clearly. However, to enlarge wisdom common sense on all social levels is still required, taking Goethe's (1749-1832) quota on philosophers (Faust II) with their usual volume of thoughts into account:

Where the "ghosts" all find their place,
The Philosopher can show his face.
To please you with his art and favour,
He'll make you a dozen, any flavour.
(https://www.poetryintranslation.com/PITBR/German/FaustIIActIIScenesItoIV.php#Act_II_Scene_IV).

Yet, despite of such critic important thoughts are surely contributed e.g. by Voltaire (1694-1778) in his philosophical masterpiece "Candide: or, All for the Best (1759)". After surviving the epochal earthquake of Lisbon 1755 including tsunami and fire and many other Job-like life threatening and catastrophic events Candide finally moved to a place where he could cultivate a small area of land, and per wisdom, the work alone keeps him "free of three great evils: boredom, vice, and poverty" by ignoring philosophical thoughts stating that all including damaging earthquakes turned out for the best by necessity. The shaking of the subsurface of Lisbon and the subsequent damages with historical consequences became the reason for a long lasting scientific and religious dispute on Neptunism and Volcanism as drivers of the geology of and life on Earth (a.o.: Friedrich Wilhelm Heinrich Alexander Von Humboldt (1769-1859), Johann Wolfgang Von Goethe (1749-1832), Arnold Constantin Peter Franz Von Lasaulx (1839-1886), Christian Leopold Von Buch (1774-1853)).

According to the thoughts above, enhancing and communicating the knowledge on the subsurface should at least have the potential to enlarge special wisdoms and confine many questionable philosophers' "ghosts". This will be done now with a short extract about the subsurface of the North German Basin as an example of knowledge. The basin has been investigated since centuries. This may lead to the conclusion that wisdom and the rules of casted dices are strongly connected, that Einstein's quota "God does not throw dice" is neither a valid statement for the micro, nor for the macro-cosmos and that many natural processes on Earth and most likely also in the Universe can be assumed as controlled by the rules of thrown dices.

1.4. Lognormal Behavior of Nature

Natural objects comparable to one another are often sorted according to their size or other characteristics and subjected to a "ranking order" this way. Geological formations at the Earth's surface like islands, drainage systems, or even impact craters [9] [10] can be assigned to a standardized system. They are no exceptions in this approach. Like many other systems of the inorganic but also organic nature (**Figure 4**) as well as systems in the societal area [11] show a Gaussian or lognormal distribution of their single members, if each system is divided

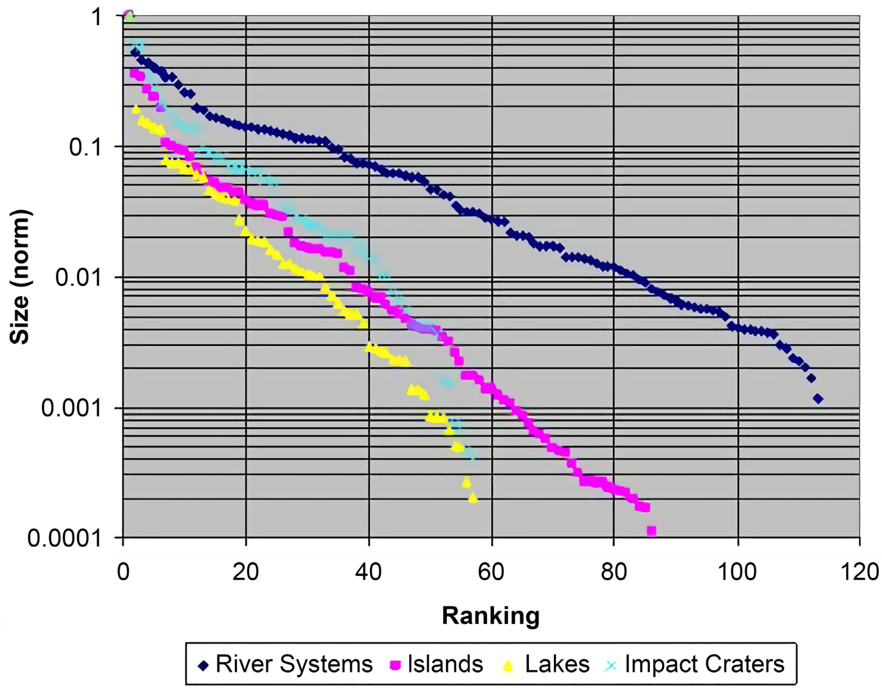


Figure 4. Lognormal behaviour of natural systems on Earth (modified from [9]).

into classification units and the number per unit via the classification quantity (normal or logarithmic) are graphically displayed.

In cumulative representation (integration), the Gauss error distribution curve or Gaussian bell curve becomes approximately linear in the central region. With a too small number of elements, the selection and correlation of classification quantities becomes difficult, if not even impossible. If single elements belonging to a natural system are sorted and ranked e.g. according to their size and the logarithms of their values are plotted vs. their rank, a linear relation between logarithmic quantity and position within the sequence becomes obvious in many cases (exponential factor). This representation corresponds approximately with the Gaussian cumulative (integral) lognormal distribution. The statistical quantities of this integral relation like standard deviation and the P15 and P85 probability values bear a mathematical relation to the derivable exponential factor. The quotient of standard deviation "σ" (sigma) and the number of single elements encompassed by "σ" is approximately proportional to the exponential factor (**Figure 5**).

The field size distributions of hydrocarbon systems of the Earth behave mainly in a lognormal manner (see below). Risks and profitability of exploration projects that contain a larger number of prospects can be estimated via the analysis of prospect size distributions [12].

2. North German Basin (NGB)

As documented for the Southern Permian Basin and the North German Basin therein (**Figures 6-8**) its hydrocarbon systems show lognormal distributions like

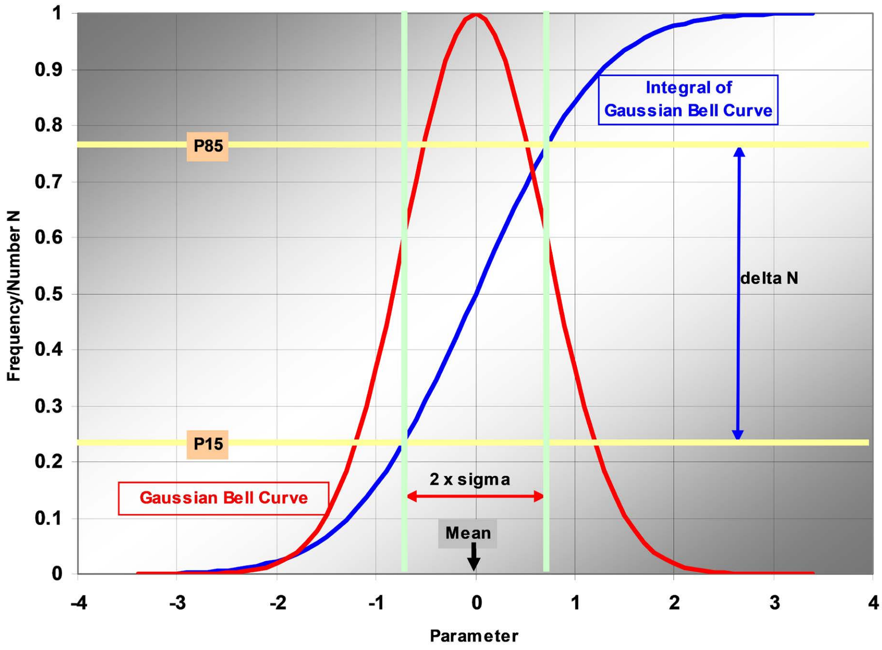


Figure 5. Gaussian bell curve parameters.

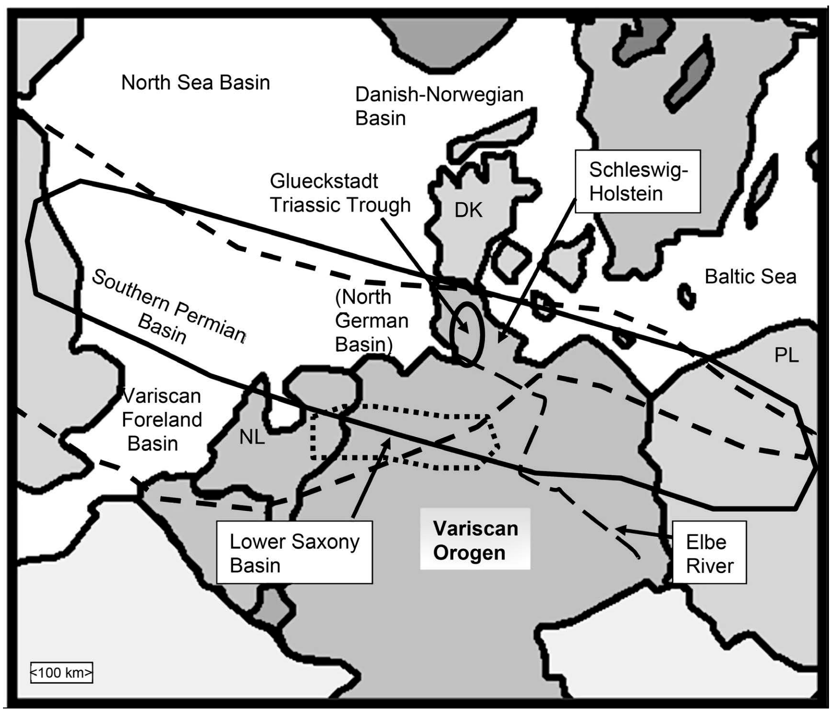


Figure 6. The Central European Basin System (CEBS) (sketched) with the Variscan Foreland Basin (dashed lines), the Southern Permian Basin (continuous line), the Lower Saxony Basin (dotted line) and the North Sea Basin (reference: North Sea coast line). Additional geological features are the North German Basin as the central part of the Southern Permian Basin, the Glueckstadt Triassic Trough, the Danish-Norwegian (Northern Permian) Basin, and the Variscan Orogen. As geographical features Schleswig-Holstein, the Elbe River, the Baltic Sea, and the states of The Netherlands (NL), Denmark (DK) and Poland (PL) are marked. "Undistorted" scale as reference for the distorted maps below. Use coast lines for orientation!

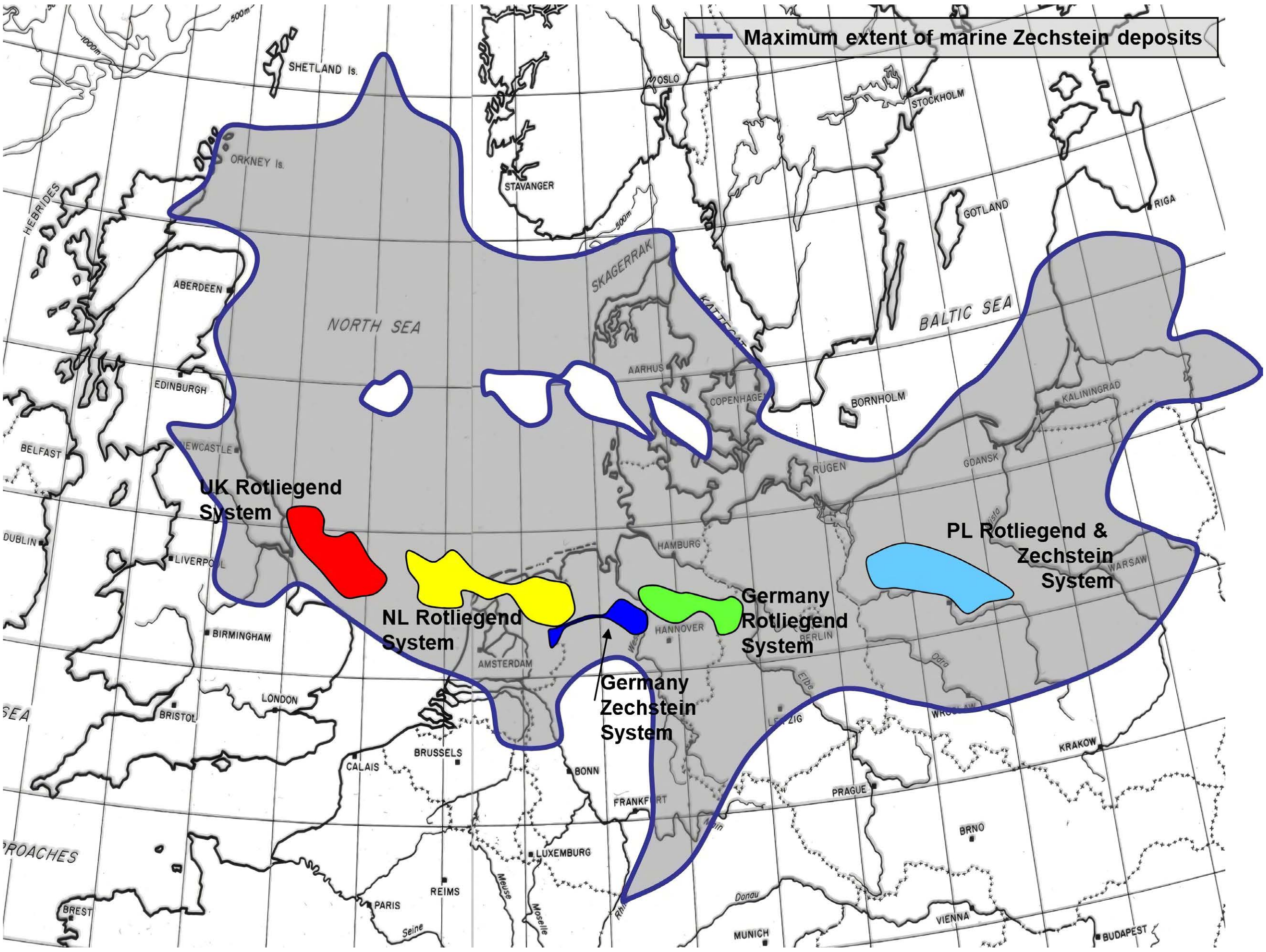


Figure 7. Gas systems of the Southern Permian Basin and their main areal extent (Basin outline after [13]). Geographical projection. Scale shown in **Figure 6**.

many other oil and gas systems worldwide. Each field size is the product of many independent geological and fluidal parameters. The ranking of those products can easily be compared with the ranking of products of a large number of thrown dices (**Figure 9**), where each dice may represent a geological unknown.

The number of parameters or dices determines the slope of the lognormal distribution of the products. A gentle slope points to a low number of unknowns, a steep slope to a high number. As the number of geological and geophysical methods for gathering independent data sets is always limited, complex hydrocarbon systems remain under-determined in all stages of their exploration. This leaves the growth of knowledge and the amount of wisdom below a satisfying level of predictability, which requires the assumption of low to high risks and wisdom alone can't finally satisfactorily help.

Within the North German Basin as part of the Southern Permian Basin and the Central European Basin System (CEBS) as well as in many prolific sedimentary basins on Earth hydrocarbons have been generated at greater depths in course of the time and migrated gravity driven subsequently towards the surface. They were accumulated in reservoir rocks, when sealing features (layers, faults,

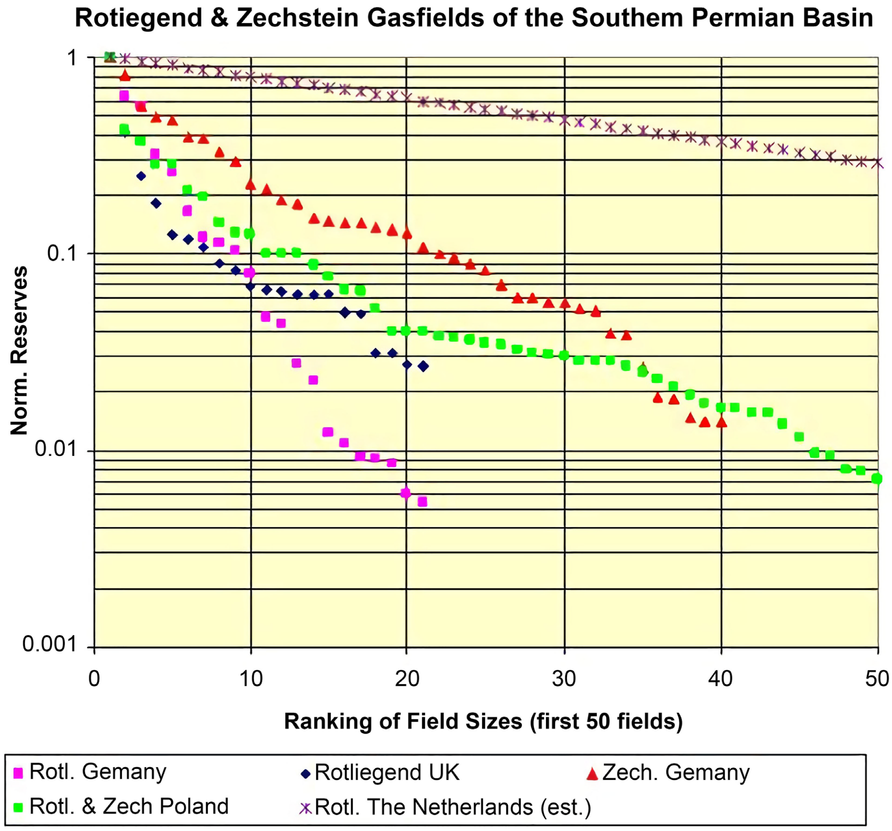


Figure 8. Field size distributions of the Southern Permian Basin gas systems with the gas systems of the North German Basin as part of it (Zechstein Germany and Rotliegend Germany) [14].

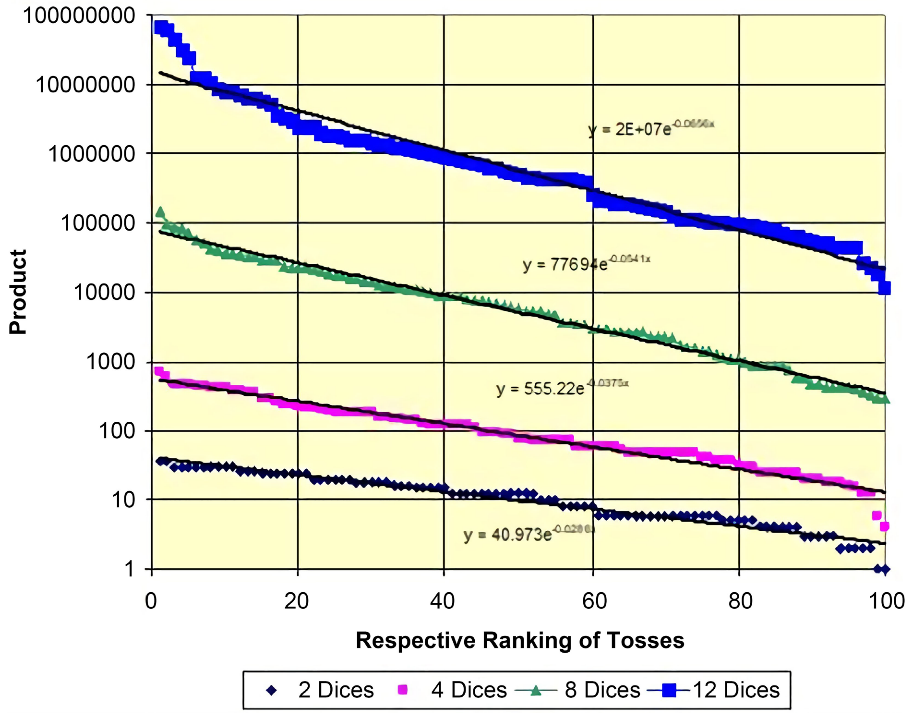


Figure 9. Throwing of variable numbers of dices [14].

salt stocks, etc.) hampered the further migration. The evolving accumulation size or field size distribution reflects a system that is governed by geological conditions (parameters) of the housing sedimentary basin. Such basins can't be investigated by digging holes, shafts, tunnels or caves alone like the people of the Bronze Age tried locally. On a regional or global basis highly sophisticated geophysical methods have to be applied. They deliver the knowledge for today's people to gather data about the subsurface, enlarge thereby the special wisdom on the history of the Earth, and find the distributed hidden treasures like oil and gas.

The North German Basin can be seen as an equivalent for hybrid, multicycle, polyphase, complex and stacked continental basins inclosing multi-parameter hydrocarbon systems. These hydrocarbon systems with their variable number of parameters (geological conditions vis-à-vis a world of dices) may act as an example of a macroscopic play of dices despite Einstein's quota and reflect essential properties of

- Basin forming tectonics describable through geological "dices" like plate tectonic conditions, subsidence rates, thermal heat flows (e.g. related to thermal effects of plumes that rise from the Earth's core-mantle boundary and the subsequent rock volume changes due to metamorphism of the middle and lower crust [15] [16]), basin size and basin age;
- Sedimentary fills governed by geological "dices" like celestially overprinted climate control through astronomical cycles with different periods and phase shifts [14] [17], climate zones dependent on latitudinal plate tectonic positions, sea level fluctuations, erosion of nearby or faraway mountain ranges, all kinds of biological activities (source rocks, carbonates), river systems and continental location;
- Modifying tectonics on local and regional scales with geological "dices" like halokinesis, rifting, thrusting, inversion tectonics, different kinds of faulting [14] [17] and fluid re-distributions due to regional inversions and regional dipping through one-sided differential loads (e.g. by mighty deltaic river systems and glaciations) [14];
- And geochemical reactions under geo-laboratory conditions as geological "dices" due to subsidence dependent severe temperature and pressure changes that affect the generation, migration and accumulation of hydrocarbons, the porosity and permeability of reservoir rocks, and the sealing capacity of overlying layers, tectonic faults or adjacent salt plugs.

The natural gas stored in the reservoir layers of the North German Basin comes mainly from the coal beds of the Carboniferous (see [18] [19]), which have experienced a burial history in Northwest Germany (Cimmerian inversion included) as portrayed in **Figure 10** in a generalized manner [19] [20]. The details of this burial history are the causes of the bimodal distribution of two subsequent natural gas generation phases whereat both phases can be characterized by their differences in the amounts of carbon and nitrogen isotopes [18] [19].

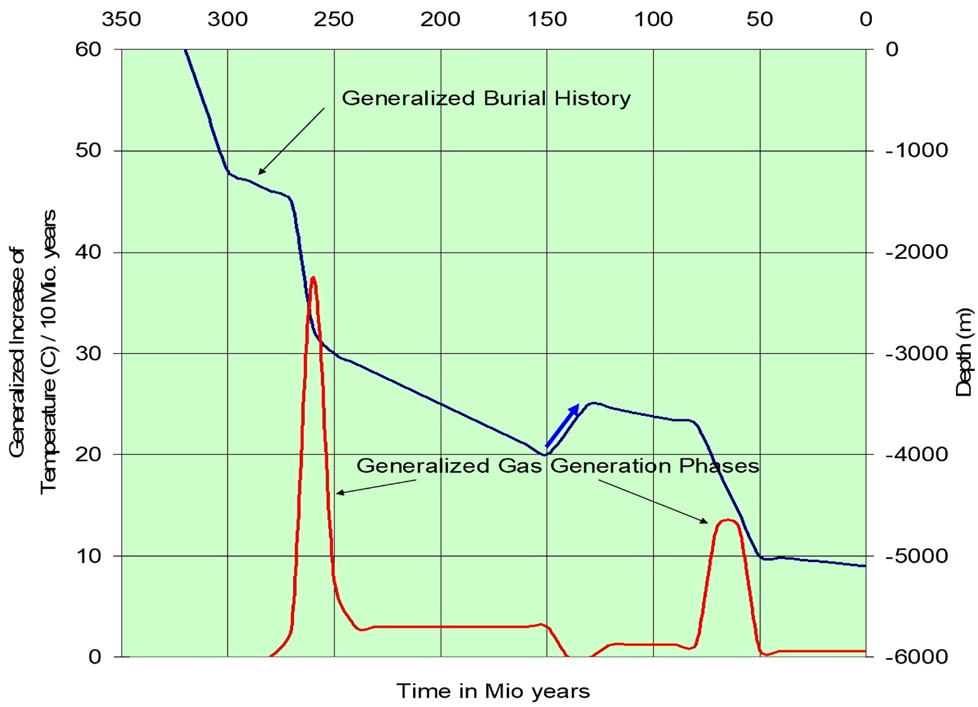


Figure 10. Generalized gas generation phases of the North German Basin [21], Cimmerian inversion indicated (blue arrow).

The geological history of the global sedimentary basin system, imaged for a significant time by the North German Basin, can be used at least for the Phanerozoic period as one record for studying selectively the evolution of the Earth. This will be described in more detail further below.

Obviously, it isn't possible to investigate all geological "dices" independently like it is performed in experimental physics, where in an experiment one parameter of a system is a variable and all others remain constant. To investigate the complexity of an Earth's system with its very large numbers of different variables, obviously a different way for the determination of ruling parameters has to be used.

By using the field size distribution concept and following the rules of the dice-game the characteristics of the North German Basin are compared with several other important hydrocarbon bearing basins on Earth (West Siberian and Timan Pechora Basins (Russia), the Dniepr-Donets Basin (Ukraine), and the Sirte Basin (Libya)). Especially the Rotliegend Gas Play of the North German Basin belongs to the very complex hydrocarbon systems with more than 70 - 90 independent and majoritarian unknown parameters. The Dutch Rotliegend Play for comparison can be characterized by about 10 parameters and is therefore of a simple type.

2.1. Basin Forming Tectonics

Some authors understand the origin of the Southern Permian Basin and the North German Basin therein as a result of rift processes of the crust (transtensional pull-apart-basin, Bachmann and Grosse 1989); others relate it to predominantly convergent wrench tectonics, slab detachment, and thermal thinning of the mantle-lithosphere. This would involve destabilization of the crust-mantle boundary during the Stephanian/Early Permian tectono-magmatic pulse [13] [22] [23] [24] [25]. According to reference [26], the Southern Permian Basin subsided in response to thermal relaxation of the lithosphere and its sedimentary loading during late Early Permian to Mid-Jurassic times, overprinted by the development of Triassic grabens and the Late Cretaceous to Tertiary inversion tectonics.

The North German Basin as the central part of the Southern Permian Basin positioned at the southern fringe of the Baltic shield has been an area of major subsidence at least since Late Proterozoic times. This long lasting process was episodically interrupted by orogenic phases, which are related to collisions of continents, terranes and micro plates due to plate tectonic activity. In Phanerozoic times, important orogenic phases involving the development of accretionary wedges in the greater basin area are the Caledonian (about 420 My) and Variscan (about 300 My) events.

Prior to the development of the North German (Permian) Basin proper (NGB), the underlying central European accreted crust [27] became altered by magmatic intrusions and volcanic extrusions. This important thermal event, an increase of heat flow during Late Stephanian and Early Permian, is reported by many authors (e.g. [13]).

The contemporary rifting that occurred during this event comprises a set of Early Rotliegend (Autunian) N-S striking grabens, more or less orthogonal to the basin axis [28]. This differs from model predictions: for crustal stretching, the development of a graben system or pull-apart-basin should be parallel to the axis of the basin prior to further basin evolution ("Steer Head Tectonics") [13] [22] [29] [30] [31].

The thermal anomaly in Stephanian/Early Permian times is estimated to have lasted for some 25 My (~300 - 275 My). Metamorphic processes must have taken place in the lower crust, resulting in increasing rock densities and the subsequent decrease of rock volume (**Figure 11**) [15] [32]. With an average reaction velocity of approximately 1 cm per 1000 years of these metamorphic processes effecting the lower crust, the above period of 25 Million years, for which a substantial sedimentary record is missing within the North German Basin, was necessary to develop an initial topographic depression of about 250 m depth. This topographic depression was subsequently filled with erosional products e.g. of the nearby Variscan Orogen. The load of these sediments and the ongoing metamorphic processes in the lower crust could have become the driving forces for the developing sedimentary basin. According to reference [15] volume reduction processes resulting from metamorphism can explain roughly 30% of the subsidence; the remaining 70% are related to sedimentary load. Therefore, the thermal anomaly, which became active about 25 Million years before the basin subsidence rate increased rapidly in late Rotliegend time, is most likely the first order

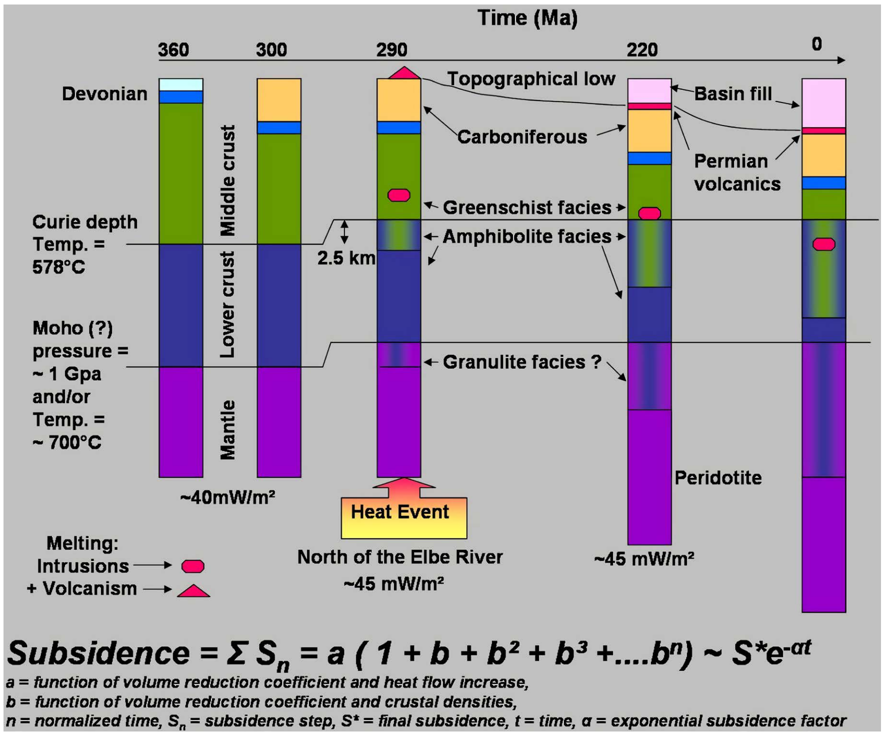


Figure 11. Relationship between metamorphism and subsidence processes of a young (accretionary) crust under the influence of a heat flow anomaly [15] [32].

force. The tectonic reaction would then be of secondary order. The thermal anomaly that affected the crust of the North German Basin in Permian times can be linked speculatively to a hot spot track of a mantle plume (Figure 11) that has been originated most likely from the Earth's core-mantle boundary. Incidentally, due to continental drift the present day Tibesti hotspot in Northern Africa is located where the North German Variscan Foreland Basin as substratum of the developing NGB was positioned during Early Permian. At least one further plume (Eifel hot spot?) may have overprinted the North German Basin during the ongoing continental drift in Mesozoic to Quaternary times [32].

That the North German Basin is not an exception in the above outlined sense can be demonstrated through the analysis of further large sedimentary basins. Examples are the West Siberian Basin as well as the Gulf of Mexico Basin. A close link between the evolution of the West Siberian Basin and a mantle plume that generated the Siberian basaltic traps has also been considered [32] [33]. For the Gulf of Mexico tectonic, subsidence and depositional history, hotspot tracks and the related mantle plume have been investigated by [34]. Other basins with indications for effective mantle plumes are the Sichuan Basin (China), the Timan Pechora Basin (Russia), the Dniepr-Donets Basin (Ukraine), the Sirte Basin (Libya), the North Sea Basin and the Michigan Basin (USA) [16]. Further investigations are necessary to confirm the hypothesis that mantle plumes/hot spots may be accountable for the development of prolific hydrocarbon bearing basins.

In the North German Basin, the present day base of the Post-Silurian Phanerozoic sediments is estimated to be at a depth of 10 - 15 km. A thick sequence of Proterozoic and Early Phanerozoic metasediments can be assumed to lie underneath, imbricated during the Caledonian orogeny in an accretionary wedge, which is, speculatively, merged with the microplates of Eastern Avalonia [17]. These deeply buried and metamorphically transformed Proterozoic and Early Phanerozoic rocks, penetrated by magmatic intrusions, now form the middle and lower portions of the crust (**Figure 12**).

Processes that have resulted in the evolution of this sedimentary basin must also have contemporaneously affected these deeper layers of the crust. Thus, basin development and property changes of the middle and lower crust below are linked to each other. Alteration processes include metamorphism, fluid release, partial melting, volcanism, transformation between brittle and ductile behaviour, and pressure build up.

Finally, the initial increase of the heat flow and the subsequent metamorphic reactions in the middle and lower crust (and upper mantle) lead to subsidence with exponential character as e.g. shown in this study for the Timan Pechora and Dniepr-Donets Basins (**Figure 13** and **Figure 14**). Based on the exponential subsidence history of selected sedimentary basins half-life times of each basin evolution can be estimated (**Table 1**). According to its exponential behaviour a basin reaches 50% of its final subsidence after its half-life time.

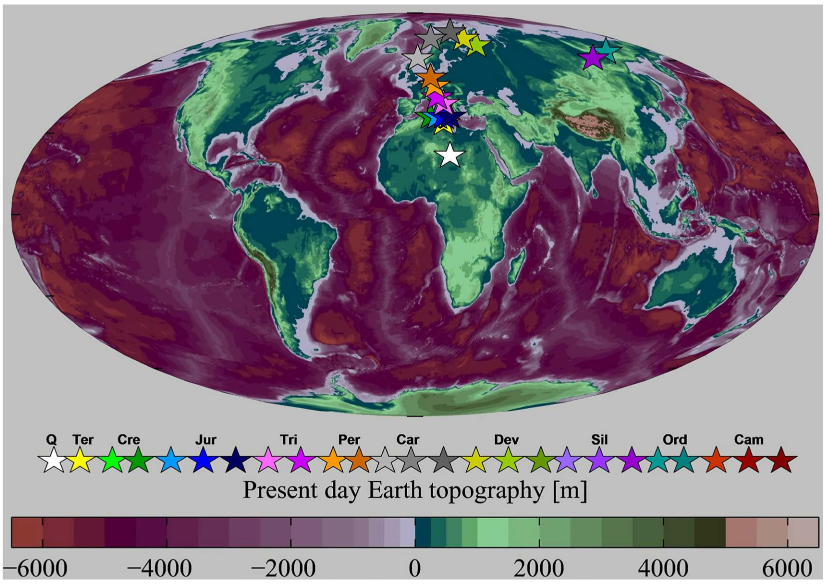


Figure 12. Trajectory of the (stable) Tibesti Hotspot (colored stars) on drifted continental plates (present day projection) during the Phanerozoic. The related mantle plume is interpreted here as the cause of origin of some hydrocarbon bearing basins that are mentioned in this study (Devonian: Timan-Pechora Basin (Russia), Permian: North German Basin, and Jurassic-Tertiary: Sirte Basin (Northern Africa)). Background map: Modified present day Earth altimetry and bathymetry at 15 minute horizontal resolution. Derived from the National Geophysical Data Center's Terrain Base, Digital Terrain Model (v1.0) (National Centers for Environmental Information, NOAA, TerrainBase Digi). Date: 7 March 2007. Source: English Wikipedia. Author: Plumbago. Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License.

Table 1. Selected hydrocarbon systems, their start of subsidence, representative (maximum) subsidence, and half-life times as well as their FSD exponential decay coefficient and geometric series attribute, and the estimated number of "unknowns" (a.o. data from [37] [38] [39]).

Basin	Start of Subsidence in Million Years	Representative Maximum Subsidence S* (m)	Half life in Million Years	Exponential Factor "a"	Exponential Decay Coefficient *α*	Geometric Series Attribute	Estimated Number of Ruling Independent Parameters
North German (Rotl.) Basin	290	5500	70	0.0100	2.640E−01	0.77	70 - 90
North German (Zech) Basin	290	5500	70	0.0100	0.0949	0.91	40
West Siberian Basin Gas	230	5500	55	0.0120	0.3147	0.73	115
West Siberian Basin Oil	230	5500	55	0.0120	0.2107	0.81	75
Timan-Pechora Oil & Gas	515	8200	115	0.0065	0.0726	0.93	20
Donets Oil & Gas	385	3100	35	0.0130	0.3011	0.74	110
Sirte Central Carbonates Oil & Gas	144	5000	50	0.0110	0.0943	0.91	40
Sirte South East Clastics Oil & Gas	144	5000	50	0.0110	0.2357	0.79	85

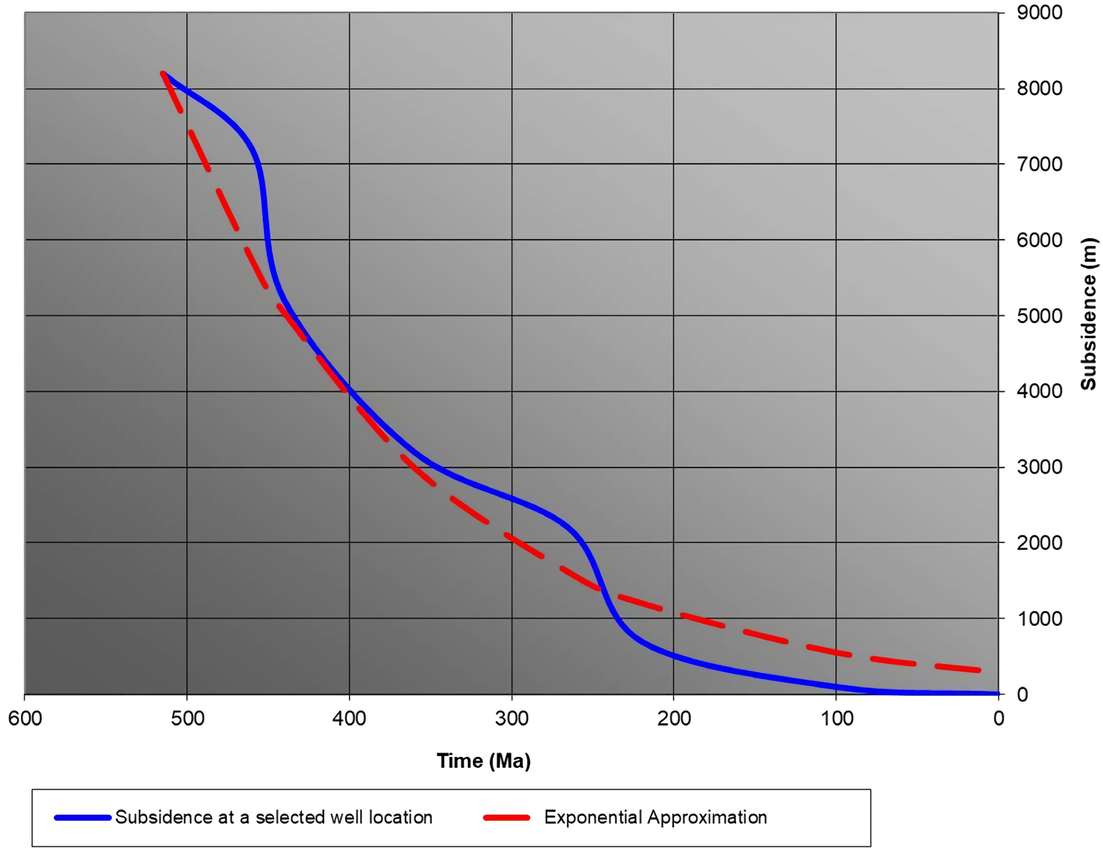


Figure 13. Tectonic subsidence of the Timan-Pechora Basin (northeastern European Russia) (after [35]) and the representative exponential approximation by taking metamorphism of the lower crust as dominant process of basin evolution into account. For mathematical reasons vertical scale adjusted to total subsidence depth as base level (=0 m).

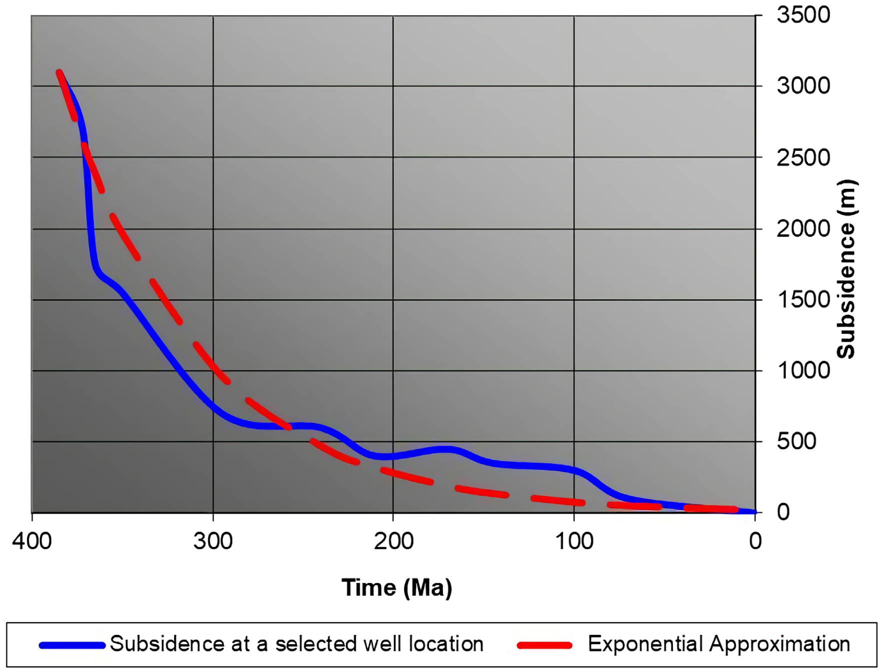


Figure 14. Tectonic subsidence of the Dniepr-Donets Basin (after [36]) and the representative exponential approximation by taking metamorphism of the lower crust as dominant process of basin evolution into account. For mathematical reasons vertical scale adjusted to total subsidence depth as base level (=0 m).

A weak inverse relationship between the internal complexity of a basin based on its hydrocarbon system (estimated number of ruling independent parameters) and the half life time of the basin history could be established (Figure 15) by using data gathered from the North German Basin, some Russian/Ukrainian basins and the Sirte Basin in Northern Africa (Table 1). This observation can be interpreted in the sense that rapidly subsiding basins most likely react internally by a complex sedimentation pattern during the filling processes and by the development of a dense pattern of tectonic faults. Slowly subsiding basins on the other hand should therefore be characterized by a gentler tectonic disturbance and by more homogeneous filling processes. According to [40] the five discussed basins belong either to the "Continental Multicycle Basin Type" or to the "Continental Rifted Basin Type". Whether the half-life time of a basin and its type are somehow related, has still to be proved.

Four of the above and below mentioned basins, the West Siberia Basin, the Gulf of Mexico Basin, the North Sea Basin (Northwest European Shelf Basin) and the Vienna Basin (see Figure 16), belong to a subset of fourteen basins with "mega" Petroleum Systems involving Upper Jurassic Source Rocks [41]. They contain one-fourth of the world's discovered petroleum. Not surprisingly, their Basin Size Distribution as well as their Hydrocarbon Potential Distribution shows a lognormal behaviour (Figure 17). The Basin Size Distribution is certainly multiplicatively governed by factors like duration and size of an initial heat flow anomaly, rock properties of the affected crust as well as metamorphic

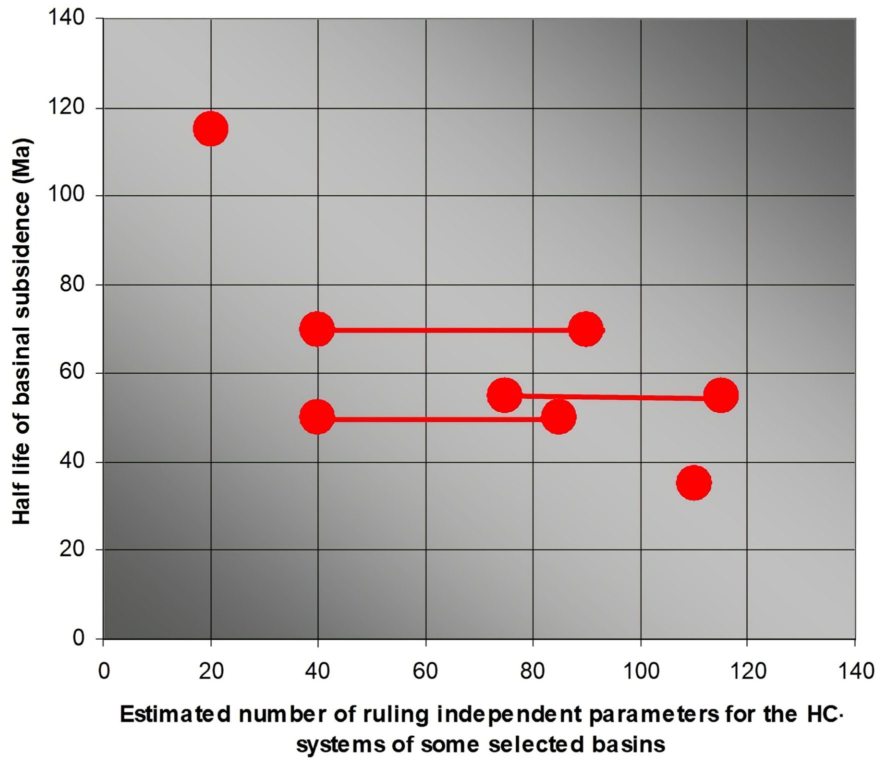


Figure 15. Weak inverse relationship between the internal complexity of a basin based on its hydrocarbon system (estimated number of ruling independent parameters) and the half-life time of the basin history. A rapid subsidence (short half-life) most likely leads to hydrocarbon systems with a higher number of ruling parameters. Data from Table 1. Bars connect values for the same basin, which HC-system is additionally subdivided by oil and gas.

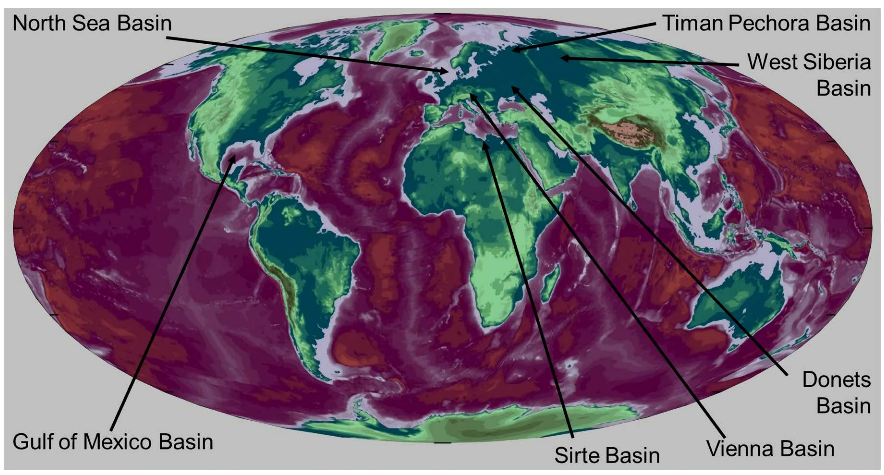


Figure 16. Locations of some mentioned basins. Background modified (National Centers for Environmental Information, NOAA, TerrainBase Digi). Source: English Wikipedia. Author: Plumbago.

processes therein, tectonic stress fields, positions within the migrating tectonic plates, conditions during sedimentation e.g. as function of sea-level variations and erosion of nearby mountain ranges, densities of deposited sediments (e.g.

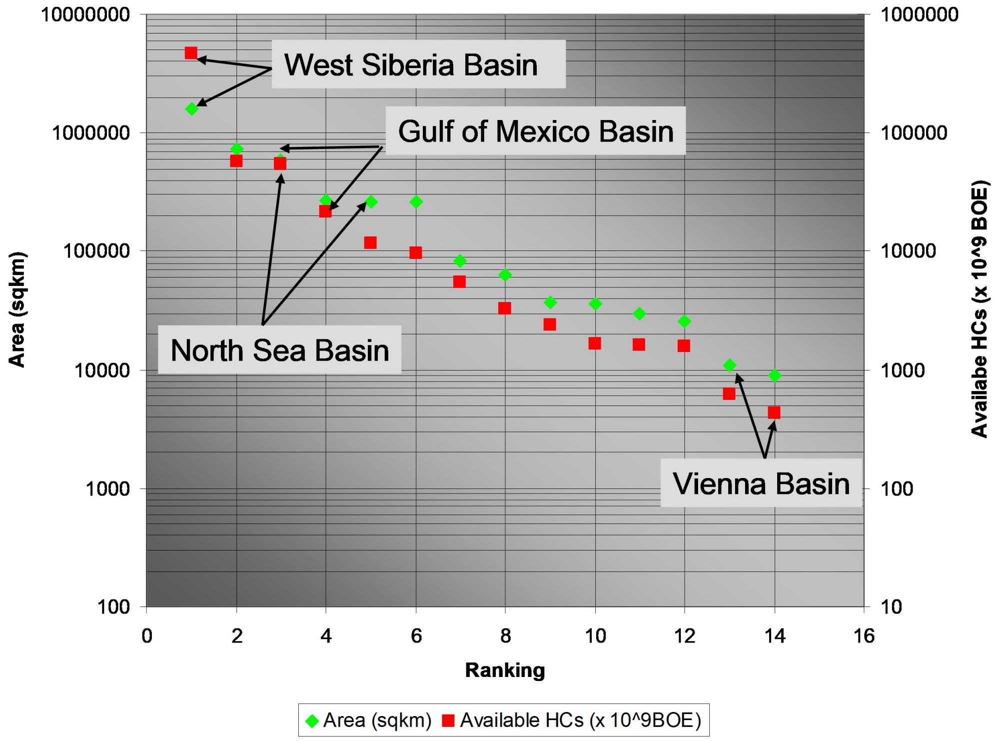


Figure 17. Basin size distribution and hydrocarbon potential distribution of fourteen basins with "mega" Petroleum Systems involving Upper Jurassic Source Rocks (after [41]).

light salt vs. heavy carbonates), and much more. The Hydrocarbon Potential Distribution may be affected additionally by basin specific internal processes, which include processes like petroleum generation, migration and accumulation, whereas other factors may become less important.

2.2. Basin Filling Affected by Depositional Cycles and Sequences

The development of a sedimentary load of clastics within a basin requires a high orogenic relief in the vicinity and conditions supporting effective erosion, combined with a transportation system of rivers, wind and sea currents. During the Early Permian (Rotliegend), the sources for the clastic sedimentary fill of the North German Basin were the Baltic Shield towards the North and the Variscan Orogen towards the South [13]. Surprisingly, during the Zechstein (Late Permian), only minor amounts of clastic sediments were deposited in the basin, which was in the meantime flooded by the ocean. Instead, hundreds of meters of chemical sediments like anhydrite, carbonate, and salt filled the depocenter, indicating that the Variscan orogen in Central Europe could not further act as a dominant sedimentary source.

In the sedimentary fill of the North German Basin and in the fill of the underlying Variscan foredeep, the geologic history of the CEBS has been recorded since the Devonian with periods of marine and continental environments (Figure 18). The filling of these two sedimentary basins was mainly governed by global sea level variations that are presumably belonging to a feedback system of

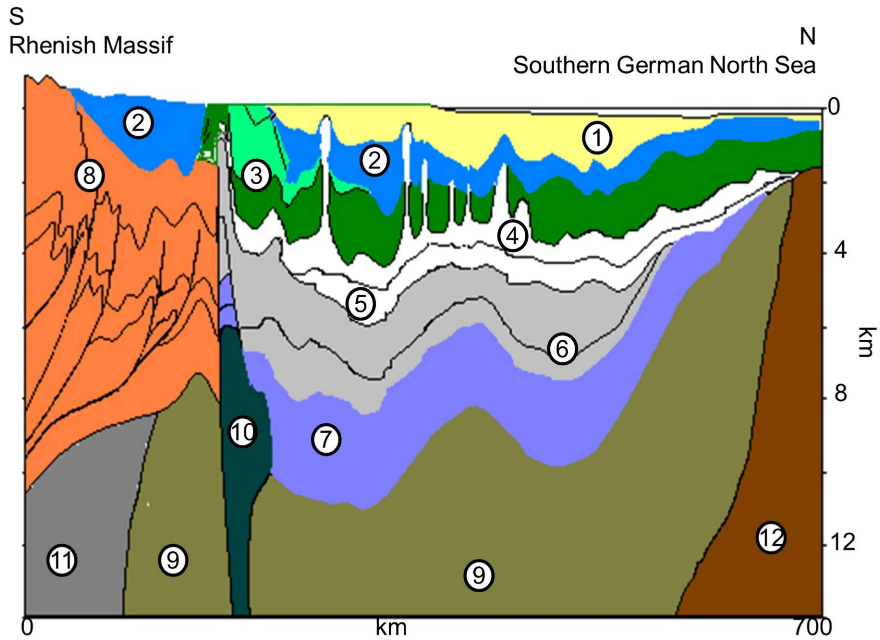


Figure 18. Generalized structural and facies cross-section through the North German Basin, from the Rhenish Massif in the South towards the Ringköping-Fünen-High in the North, modified from [13]. 1: Tertiary, clastics; 2: Upper Cretaceous, predominantly carbonates; 3: Triassic to Lower Cretaceous, predominantly clastics; 4: Upper Permian: predominantly evaporites; 5: Lower Permian, predominantly volcanics and clastics; 6: Upper Carboniferous, predominantly clastics; 7: Devonian to Lower Carboniferous: predominantly carbonates; 8: Rhenish Massif (Variscan Orogen), predominantly Paleozoic clastics; 9: Caledonian basement, predominantly accreted Silurian to Proterozoic clastics; 10: questionable Intrusion, Bramscher Massif; 11: Rhenohercynian basement; 12: Ringköping-Fünen High, Pre-Cambrian basement.

geodynamic cycles on long time scales (periodicity of about 300 Million years, including a.o. the cycle of the area extent of ancient mountain chains, **Figure 19**):

In Devonian and Early Carboniferous times, when the area was located south of the equator [42] [43], marine carbonates and black shales with some source rock potential dominated the lithological column.

This was followed by more continental and deltaic clastic deposits including Westphalian coals as later source rocks and evaporites in an approximately equatorial position during Late Carboniferous to Triassic times, but interrupted by short marine phases e.g. with the deposition of Zechstein salt.

In Jurassic and Cretaceous times at a location significantly further north of the equator, a marine environment yielded again to the deposition of shallow marine clastics and thick layers of carbonates.

Since the beginning of the Tertiary, continental to deltaic clastic deposition prevails again.

This feedback system is possibly subject to lunar control and the influence of

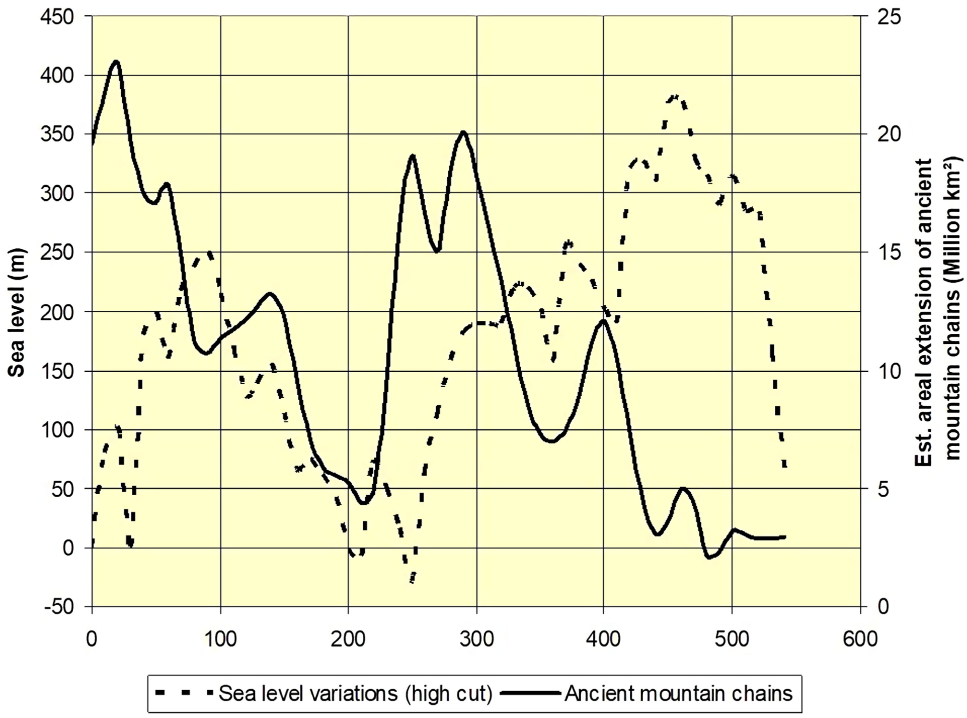


Figure 19. Geodynamic cycles: e.g. seal level variations (high cut), which led to periodic changes of tidal dissipation and Earth rotation, and the area extension of ancient mountain chains, which erosion led time-delayed to the filling of sedimentary basins [44] [45].

the properties of the spiral arms of the Milky Way [44] [45]. The geodynamic cycles become collaterally modulated by shorter cycles and sequences that are partly also controlled by celestial forces. An example of very short time scale cycles has been observed within Lower Permian Rotliegend aeolian deposits, a very important reservoir facies within the CEBS. Modeling those deposits and comparing the results with recent and ancient observations [46] confirmed that the most important parameters of the depositional environment are the rainfall, which controls deposition during wet times, and wind velocity, which controls deposition and erosion during dry times. Rainfall and wind variations are dependent on altering glaciations of the pole areas, which are predominantly affected by the major orbital cycles, the eccentricity with periodicities of 100 ka and 400 ka, the obliquity with 40 ka, and the precession with 19 ka, respectively 23 ka (Milancovic cycles) (see [47]). During the Permian, icecap expansions/contractions with corresponding increasing and decreasing high-pressure systems had their effect on lower-latitude climate belts. In case of icecap expansion, the climate belt contracted, resulting in an increase of average wind velocity at trade wind latitudes and subsequently supporting aeolian erosion.

The seven million years long period of the also very important Upper Permian Zechstein is characterized by seven cycles and many ancillary sequences (e.g. [48]). The length of the cycles Z1 to Z7 decreases with time beginning with 2 My for Z1, 1.5 My for Z2 and Z3, and roughly 0.5 My for Z4 to Z7 each (Stratigraphic Table of Germany, STD 2002). These oscillations represent low-frequency modulations of the Milankovic cycles. Therefore, they are also celestial drivers of the climate and its related sedimentation. Long-period astronomical forcing of the climate with similar periodicities as recorded in the glacio-eustatic sealevel variations of the Zechstein sea has also been described for other Phanerozoic epochs, e.g. for the Miocene [49] [50].

2.3. Basin Modifying Tectonics

In the North German Basin, extensional tectonic forces have interchanged with compressional ones, sometimes in a transversal regime, resulting in (wrench-) faulting, thrusting, folding, halokinesis, and inversion. Frequently, these forces affected the same area repeatedly, which led to a very complex structural pattern within the sedimentary pile. Quite often, the rock pile seems to have a memory, which effected the development of younger geological events. This means that geological anomalies within the younger strata may have had a preceding geological event during the time of deposition of strata today at greater depths. One example is the development of the Mesozoic Lower Saxony Basin just on top of the Upper Carboniferous depocenter, and a hypothetical mafic intrusion of Cretaceous age beneath [51]. Not only an interaction between the lower and middle crust and the development of the CEBS can be assumed, interactions between the individual stacked basins that ensemble the CEBS have also to be considered. The very thick Rotliegend and Zechstein evaporites (in total up to 4 km), which acted locally as tectonic detachment layers, resulted in an interaction being indistinguishable. However, the pre-salt structural setting interfered with the post-salt setting, since the distribution of salt plugs followed most likely old pre-Permian structural elements. In the following the salt stock development and several further aspects with exploration significance, especially effects on fluid re-distributions, will be briefly discussed.

2.3.1. General Investigations on Salt Plugs in Northern Germany

Salt plugs and their structural development represent a dominant part in the subsurface of northern Germany (**Figure 20**). Many commercial applications are linked to the effects of salt tectonics, e.g. salt plugs are a source of raw material for different salts and many oil accumulations are closely associated with the development of salt plugs [52]. Moreover, gas deposits were explored at the base of salt plugs (see [53]). The functional dependence of the individual northern German salt structures on salt stock families was outlined by [54] and their history was described by [55]. Reference [56] introduced the term halokinesis (**Figure 21**). In the explanations of the formation of salt plugs and the development of salt plug families, these authors presumed density instabilities for the North German area between underlying light salt und overlying heavy sediments to be the major force of the buoyancy driven halokinetic processes.

This assumption was already theoretically investigated in the early past by [58] and, using analogue experiments, by [59]. There are new concepts of salt tectonics, e.g. by [60] for general concepts and [61] for NW Germany. However,

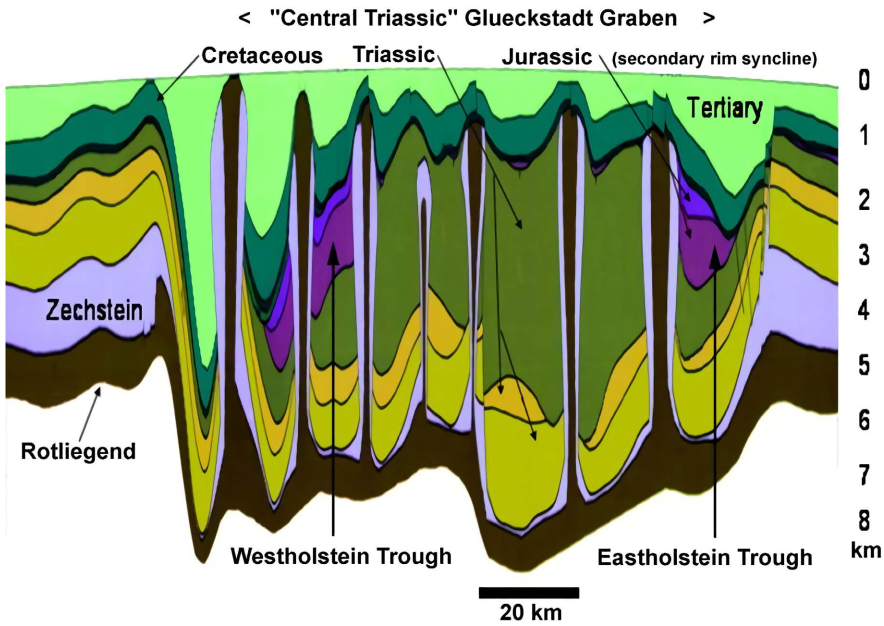


Figure 20. W-E cross section in Schleswig-Holstein with a salt stock family (modified from [57]).

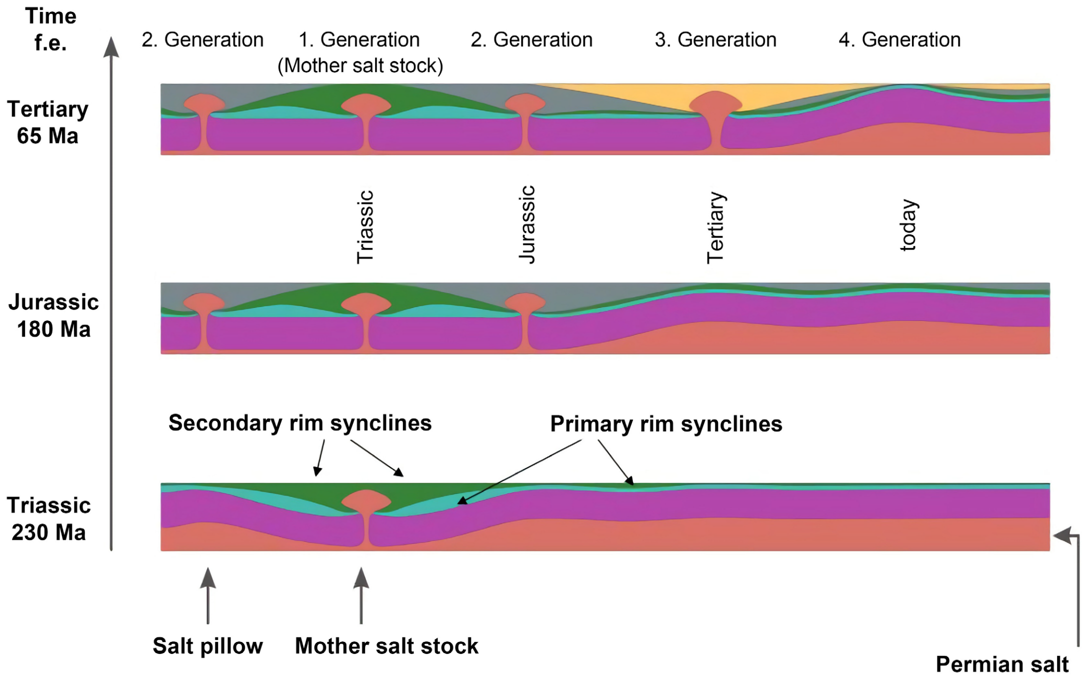


Figure 21. Concept of the evolution of a salt stock family (modified from [54]).

for the particular part of the greater East Holstein Trough area, the evolution of salt stock families was not yet revisited. Though, processing and interpretation of seismic reflection lines, gravity data, and density logs in boreholes raised severe doubts about the validity of this undoubtedly brilliant concept, at least for the early stages (*i.e.* Lower Triassic, Buntsandstein) of the halokinesis in Northern Germany. References [62] [63] [64] [65] reported several non-supporting observations of this concept:

1) Within the North German Basin compressive "flower structures" were observed in seismic data at locations where previously salt plugs were assumed. This observation was further verified by drilling.

2) At the northern termination of the Glueckstadt Graben, a positive residual gravity anomaly at a location of a presumed salt plug had required a reinvestigation by modern seismic data and was finally proved to be a "flower structure" of Early Triassic times.

3) A salt plug in the Glueckstadt Graben center, which was interpreted to be a member of the so-called "two-story" salt structures with a core of Rotliegend salt (Early Permian) and flanks of Zechstein salt (Late Permian) (see [57]), had to be redefined as a Late Triassic (Keuper) salt structure.

4) Halokinesis during the Early Triassic (Buntsandstein) was certainly not governed by buoyancy since the rock density of the young and uncompacted Buntsandstein layer was most likely lower than the density of the underlying Permian salt.

What has happened to the Permian salt then? It should be noted here that presently no method appears to be available to distinguish core samples of either Rotliegend salt or Keuper salt without any further information. Due to these doubts concerning the role of the primary dome in the Glueckstadt Graben, a salt dome of the second generation has been revisited and radically re-interpreted by [66] [67].

2.3.2. Cimmerian Inversion

The general exponentially developing subsidence of the CEBS that is expressed by a sedimentary "layer cake" mode with decreasing thicknesses as function of time, is modulated on different scales by "short" time tectonic events. These events include the development of a number of Triassic rift grabens, Jurassic grabens and troughs and a basin wide Cimmerian inversion of hundreds of meters. Similar to tilting through differential loads by the Eridanos River delta and the ice age glaciers (see below) and its effect on fluid migration, the Jurassic uplift event (Cimmerian Inversion) could have also resulted in a re-distribution of fluids in the subsurface of Northwest Germany and the surrounding areas at that time. Based on subsidence analyses of many wells, carried out for basin modelling studies, uplift amounts between 500 m (Schleswig-Holstein wells [68]), 800 - 1000 m (Northwest Germany wells [19] [69]), 200 - 1700 m (majority of Dutch wells onshore and offshore [70] [71]) and up to 3000 m (Groningen gas field [72]) can be estimated. The distribution of these amounts points to an uplift centre around the position of the present day Groningen gas field by taking regional maps of the Netherlands also into account [73]. A relative excess inversion of up to 2000 meters could have "suctioned" a large amount of hydrocarbons also from present day Northwest Germany, explaining the "early fill" of the Groningen gas field in Jurassic times (**Figure 22**). Reference [74] interpreted the age of the finest Illite fraction of the Groningen field as the time at which Illite

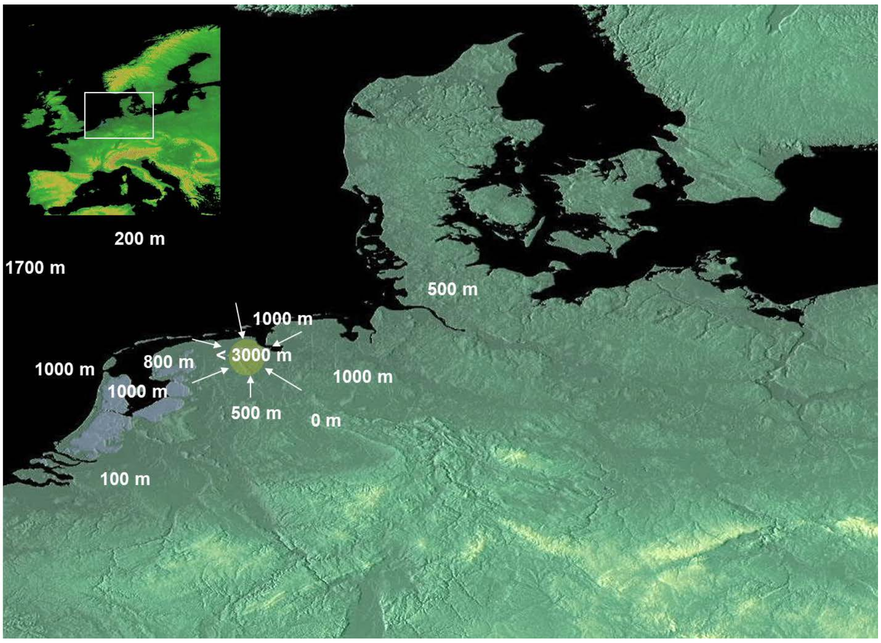


Figure 22. Amounts of uplift (m) during the Late Jurassic Cimmerian Inversion in Northwest Germany and surrounding areas. Scale: distorted. "Undistorted" scale shown in **Figure 6**.

formation ceased due to gas emplacement. Their results may indicate that gas emplacement in the Groningen field commenced prior to 150 Ma and continued for 30 million years until at least 120 Ma. Renewed charge due to young subsidence supplied additional volumes during the Late Tertiary.

2.3.3. Miocene Eridanos River System

During the Neogene, tilting of the subsurface took place on a regional scale due to differential loads, temporarily leading to a density driven re-distribution of fluids. A significant event is certainly the massive infilling (up to 1000 m thickness) of the North Sea basin by the so-called Eridanos river system [75] [76] [77]), named after the river-god who was the son of Oceanus and Tethys. In the Greek mythology, he is generally considered as a river of the West. During the deposition, the water depth of the depocenter decreased from about 160 m to about 60 m [74] and had never been 500 m or more in that time as commonly stated. Foraminifer as well as the dinocyst assemblages display this general shallowing upward trend over the entire succession from a deep neritic towards a shallow neritic and finally non-marine setting [78]. The Eridanos fluvio-deltaic system, draining most of northeastern Europe, developed during the Late Cenozoic as a result of simultaneous uplift of the Fennoscandian shield and accelerated subsidence in the North Sea Basin [75]. It transported large amounts of erosional products from the south (e.g. erosion of the inverted Lower Saxony Basin) and across the Baltic Sea, which were subsequently deposited in an extended delta system (**Figure 23** and **Figure 24**). The load of these sediments led to an additional local subsidence that resulted in a tilting of the MMU (Mid Miocene Unconformity) dipping towards the east/southeast with a relative uplift in the west

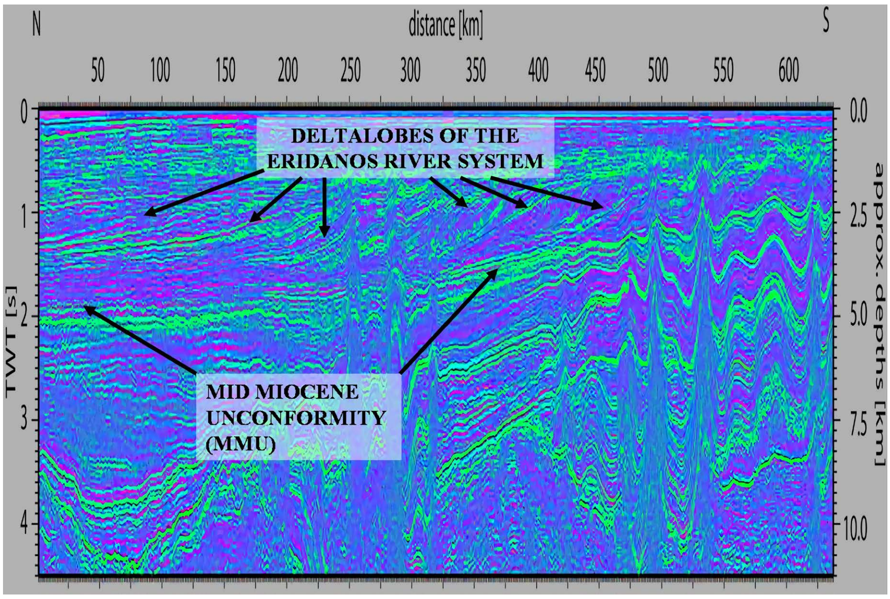


Figure 23. Time-migrated reflection seismic profile across the German sector of the North Sea running from the Panhandle region towards the island of Helgoland (data from TGS Nopec) (modified from [80]).

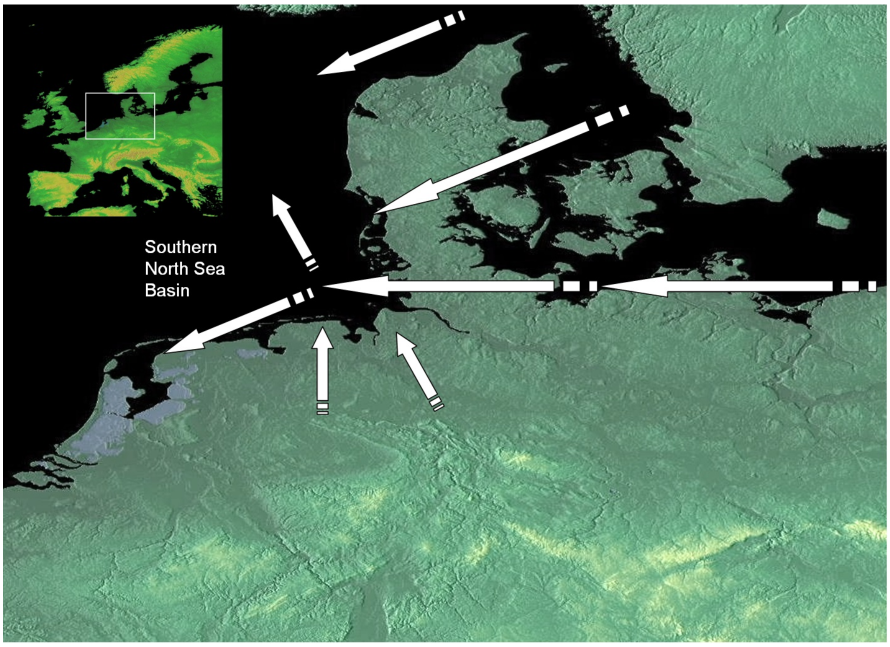


Figure 24. The so-called Miocene Eridanos river system (modified from [75]). Scale: distorted. "Undistorted" scale shown in Figure 6.

of up to <800 m (**Figure 25**). At Mid Pleistocene level, the entire southern depocenter of the North Sea basin was filled up and the tilting of the MMU was more or less leveled. During the MMU-successional Tertiary times only minor variations of the epeirogenic subsidence in the range of less than 100 m each occurred in the southern North Sea Basin [79], most likely with an insignificant influence on the re-distribution of subsurface fluids.

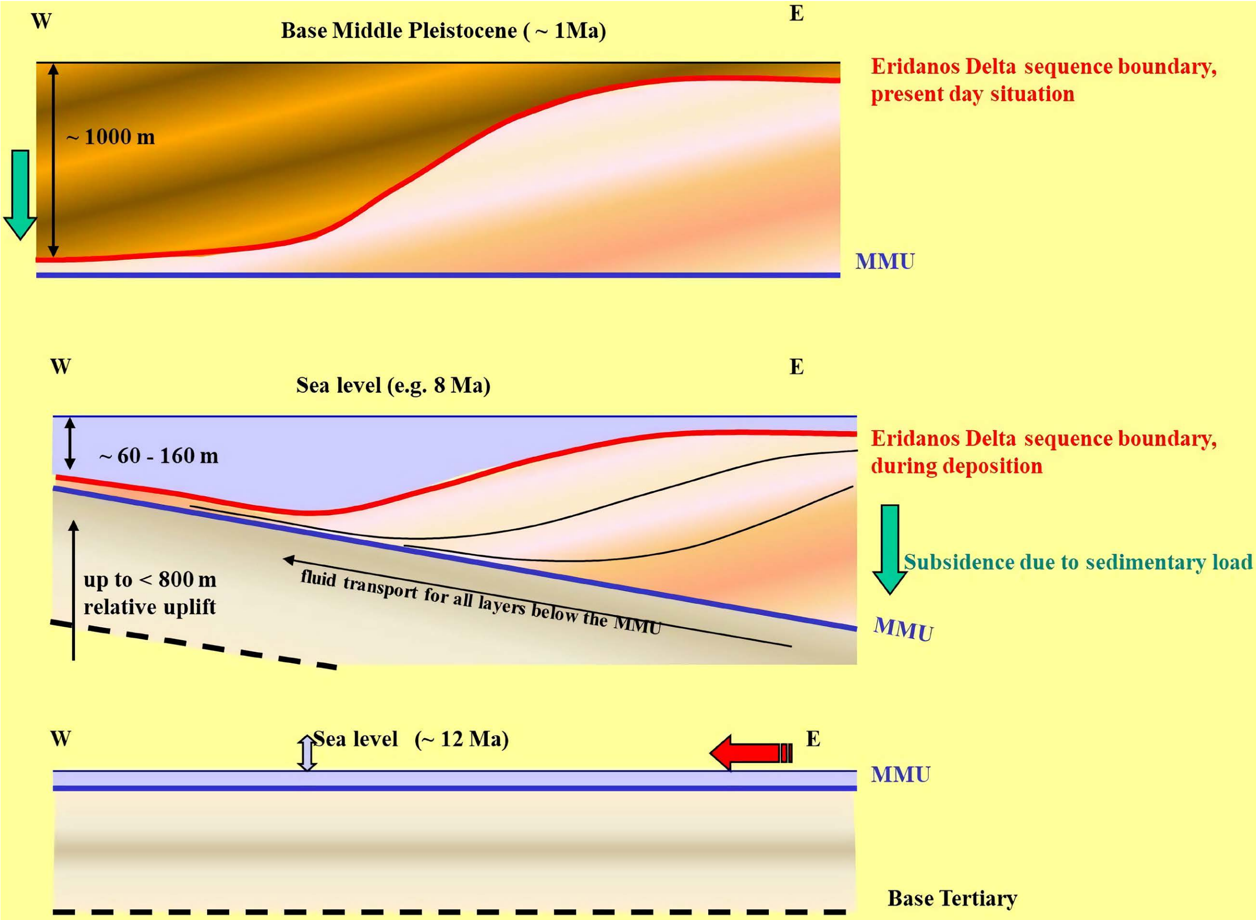


Figure 25. Sketch of the sedimentary load development of the Eridanos Delta in the southern North Sea Basin. A load of about 1000 m of sedimentary rocks led to an additional local subsidence that resulted in tilting of the MMU (Mid Miocene Unconformity) and the rock pile below dipping upward towards the west with a relative uplift of up to <800 m.

2.3.4. Pleistocene Glaciations

The later succeeding sequence of the celestially enforced Pleistocene glaciations (Figure 26) with up to 3000 m thick ice-sheets may have had similar effects as what is observed at the frontal areas of the glaciers, depending on the rheological properties of the crust and the time frame. Below the ice loads of different ages, depressions of the substrate in the range of some hundreds of meters were possible, reducing to zero in the ice-free areas. Within the last 0.6 My, several glaciations affected the North German Basin like a sequence of pulses, which originated from Fennoscandia in the northeast and tilting the subsurface by their loads periodically upward towards south/southwest, locally pumping fluids within the subsurface away from the glacial fronts.

3. Wisdom and Geology

The missing wisdom as outlined for the North German Basin is part of the macrocosmic uncertainty and belongs to the essentials of life on Earth. Since many natural systems can be described as assembled through a game with dices, Einstein's (1879-1955), quota that "God does not throw dice" is invalid on the macroscopic

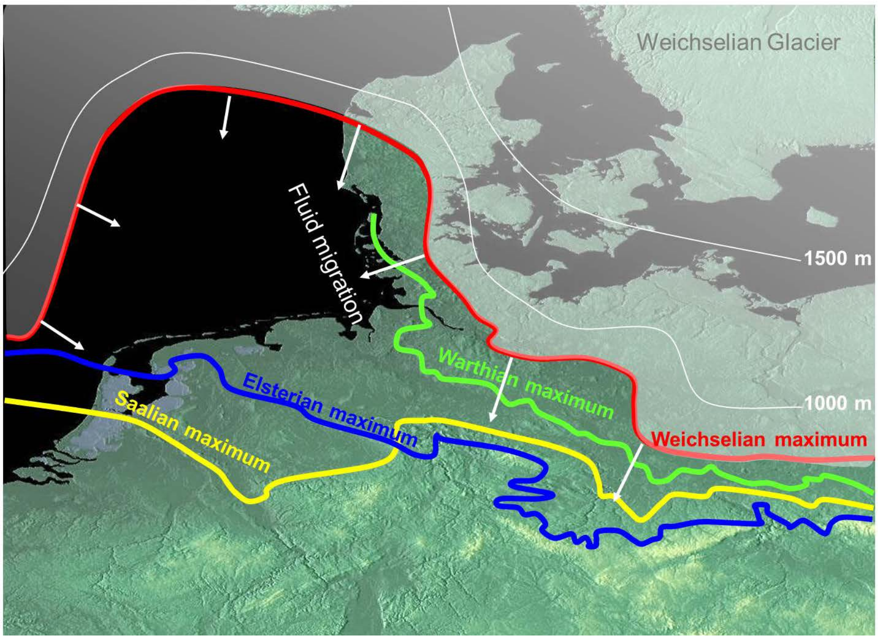


Figure 26. Sketch of Northern Germany and neighboring areas with the maximum extent of the Weichselian, Warthian, Saalian and Elsterian glaciations (for precise details see e.g. [81]), isopachs of the Weichselian glacier, and Weichselian fluid migration vectors in the subsurface (white arrows). Depending on the tilt of the subsurface layers, these vectors may have been effective. Scale: distorted. "Undistorted" scale shown in **Figure 6**.

scale as well [82]. On the microscopic scale the invalidity has already been proved by quantum mechanics (e.g. Heisenberg (1901-1976)). This limits the chance to find the absolute wisdom for everybody. Wisdom becomes depending on processes similar to a throw of dices. The best of all worlds like Leibniz (1646-1716) stated and Voltaire tried to falsify with his satire "Candide" underlies the rules of dice, too. In this sense, both, Job's geology and wisdom contain uncertainties, independent from their religious meaning. Subsurface problems may also be part of the overall uncertainties. Finally, in the sense of the above mentioned thoughts wisdom may include the acceptance that members of many natural and social systems are thrown together ensembles and Einstein's quota does apply neither for the past nor for the future.

Wisdom alone, an important issue for philosophers already in Bronze Age times and understood as an association with a restricted knowledge of geology (source: Job 28/bible), may be an inadequate intellectual human tool, since uncertainties as an essential part of any system cannot be overcome adequately. Their existence belongs unremovable to the human wisdom about life and nature. This may meaningfully bond the philosophers' "ghosts" as used satirically in literature and guide politicians in their decisions.

4. Conclusions

Philosophical thoughts and metaphors from the Bronze Age and the last few centuries about wisdom, geology, uncertainties, catastrophic events and the rule of dice as well as on the other hand, a technical description of the evolution of the North German Basin as an example of scientific knowledge have been used to associate the natural sciences (geology) and the humanities (philosophy) once more for a broader understanding of both within the society.

Under a geoscientific view, this is documented by subsurface hydrocarbon systems as well as by the global distribution e.g. of river systems, lakes, islands, and sedimentary basins. All these systems are subordinated to the dice of nature like in a Casino and are steered invisibly by a selection of rules of the game that one understands as natural laws. To support a better understanding of the effect of an outnumbered amount of variables of a system, the use of geological "dices" of the North German Basin, which controlled the development of this system, has been intensely delineated and may lead to an increase of related wisdom. It may help people in their thoughts and decisions, knowing that uncertainties are essentials of the surrounding life and nature. The North German Basin shouldn't, therefore, be seen as a hoard of trouble. The complexity of a system as well as the variedness of its "members" and the limits of predictability is guided by the number of influencing parameters, representable by dice. Obviously, the rules of the game are part of the growing human wisdom and should be mentioned as often as necessary.

Environmental harm due to natural or manmade geohazards requires a deeper understanding in the technical and philosophical sense for all acting people. Technically: as much as possible scientific facts have to be presented to the public to enhance the necessary trust; philosophically, to value historic experiences of realities and uncertainties as constant companions of mankind. Very important is a substantial handling of all uncertainties, risks and probabilities. They can easily be described with the casting of dice like the people already practiced playfully for thousands of years. That life on Earth and many environmental natural processes behave like the throw of dice is certainly an important feeling of many individuals at least since the Bronze Age.

To give some outlooks to offer guidance for further study, more astronomical and biological (evolution of life) clues could be included, and a deeper philosophical discussion about the ruling of the world of dice would be valuable.

Acknowledgements

The author would like to thank the anonymous reviewer for the valuable suggestions, the team of Scirp for the professional handling of this paper, and Ludwig Meyer as well as Renate Galley-Brink, who provided him a less informed reader of the *Bible*, an important indication of the Bronze Age thoughts documented in the Job chapter. Many uncited authors, who have contributed important but not mentioned thoughts, have already been valued by the author in previous here cited articles.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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