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ALBERT EINSTEIN, WORLD OF DICES AND HYDROCARBON SYSTEM ANALYSIS

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ABSTRACT

Albert Einstein, Caesar and others have used dices as a metaphor for risks and probabilities; indirectly reverting to the experience human kind may have with natural processes in its environment contemporarily with human evolution. It will be shown for example by concentrating on the exploration of hydrocarbons that the rules of a dice-game can be used to better understand the importance of the number of ruling parameters (dices), in this case geological parameters. Especially the Rotliegend Gas Play of the North German Basin belongs to the very complex hydrocarbon systems with more than 70 independent parameters. The Dutch Rotliegend Play for comparison can be characterized by only 10 parameters and is therefore of a simple type. 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 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. The complexity of a system as well as the variedness of its "members" that may be found in anthropogenic systems as well (different properties in thinking, self-reflection, feedback-capabilities, combative and ambitious behavior of individuals with the target to climb upwards in a ranking matrix) is decided by the number of the influencing parameters, represented by dices. Like in a dice-game the exploration of hydrocarbons is unsolvable connected to luck and bad-luck, coincidence and necessity, and to past and future.

Contribution/Originality: It will be specified that the complexity of hydrocarbon systems and their geological unknowns (parameters) can be estimated by comparing them with the product of an adequate number of casted dices. The discovery rate of oil and gas fields appears strongly related to the complexity of a system and makes this study original. The study allows comparing different hydrocarbon systems and delivers an impression how much work has to be done to evaluate all systems independently and how many (unknown) geological parameters (dices) have to be assumed. Low parameter systems are certainly easy to explore. High parameter ones require a high amount of money and effort.

1. INTRODUCTION

After he had broken the backbone of the Celtic Gaul and had plundered it like a casino, Gaius Julius Caesar crossed with the words of "alea iacta est" ("the dice has been cast") the Rubikon river on January 10, 49 b.c. despite the existing law, that no Roman commander could approach Rome with armed troops. Caesar's famous quota refers to the irreversible infringement (the dice is now outside of all control, on the other hand on the risks of the action (the dice can be cast on each arbitrary side). He was conscious that he would need luck beside the stolen Celtic treasures in order to defeat his opponents in Rome. So, the election of the dice as symbol of it was clear and unambiguous. Surely, he assigned in the run-up to the decision a success likelihood that didn't tend against zero. Whether he applied also a forecast-ritual as usually among the Romans and fathomed heavenly signs (lightning and thunders) or the bird-flight, or let produce an oracle from the guts of victim-animals, is not passed on.

Maybe also the Roman commander Publius Quinctilius Varus has a similar intention, as he moved against the ancient Germans with one eighth of the Roman total-army about 2000 years ago, 9 a.c., into a battle with a historic defeat in the Teutoburg forest. Whether the ancient Germans had asked for a traditional oracle their priestesses, who enjoyed big respect among them because of their reliable prognoses, is unknown.

The fight and risk-willingness of the ancient Germans must have been very high and was according to historic sources also a component of their way of life. Tacitus reports in Germania 24 about their dice passion that they remarkably paid homage to "the dice-game in full soberness", as if it was about a serious business. This attitude to the luck-game has hardly dropped off in later times, even if sometimes the soberness remained outdoors: by 1220/30 a.c., it is expressed in the medieval age songs of "Carmina Burana":

"Some play dice, some guzzle,
Others make a noise, scream, and brawl.
Those, that began a game,
May move nude away;
Others may a mantle win,
Others in a sack may leave.
No one thinks about the hour of death,
"Bacchus", the Roman God of wine, is worth the dice-round."

Particular decisions become also prepared in the present modern day and age, e.g. in the exploration for hydrocarbons, with the rules of a dice-game, if the estimation of risks is demanded and likelihoods should be predicted. That the one or other prognosis rather resembles an oracle on that occasion often lies on inadequate geoscientific data-quantity and their analysis in the nature of that matter.

If the human being plays dice so gladly and pays homage to the risk and coincidence until to the own downfall, which also found an expression in the art many times and let Las Vegas and Monte Carlo bloom, what does he signalize with such a behavior? Does he reflect unconsciously on processes in nature that his life as well as the life of all others possibly appears as a dice-game for himself and the entire community? This attitude may at least being symbolized in some sacral-buildings like the cloister-church of Cottbus/Germany from 1303 a.c. with a dice falling down from the heaven painted at the outside wall.

However, Albert Einstein generally disagreed by repeating his famous quota that God doesn't play dice in the universe. Einstein was the coincidence in the micro-cosmos, which got a protruding meaning in quantum-physics, however, supremely unpleasant. The divine curiosity and the playfulness of the doing handicrafts and brooding researcher were for him the hidden fundament of the technical achievements of his time as well as the constructive imagination of the technical inventor. Should the playfulness of the human-being be an expression of nature and we share it today with Caesar, the ancient Germans and their descendants and with many other nations and their people on earth and now also with all researchers, dice-game-similar processes may also be suspected in the present "recognizable" environment and on all scales of the macro-cosmos, certainly under maintenance of the natural laws. Let's avert the gaze from the "big success", our blue planet, evolved after processes related to

- Incubation of heavier elements within exploding proto-stars up to the geological significant uranium, in a suitable galaxy with its important spiral arms and
- With suitable sun and
- A suitable distance,

- With suitable size and
- Suitable composition and heat-history,
- Under in-relationship of the biological evolution and
- Under influence of a big moon, whose exceptional formation is narrowly interconnected with that of the earth,
- Along a large geological time-axis playfully self-regulating and live-promoting and
- Changing intermittently and episodically.

Let's turn towards the backs of Julius Caesar, the ancient Germans and Albert Einstein and let's direct our attention into the world of the lognormality of the geoscientific environment and to the analysis of hydrocarbon systems and their Field Size Distributions (FSD). It will be specified that the complexity of hydrocarbon systems and their geological unknowns (parameters) can be estimated by comparing them with the product of an adequate number of casted dices. The discovery rate of oil and gas fields appears strongly related to the complexity of a system and makes this study original. The study allows comparing different hydrocarbon systems and delivers an impression how much work has to be done to evaluate all systems independently and how many (unknown) geological parameters (dices) have to be assumed. Low parameter systems are certainly easy to explore. High parameter ones require a high amount of money and effort.

2. FIELD SIZE DISTRIBUTION (FSD)

2.1. 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 (Brink, 2002; Brink, 2003), each of which can be assigned to a standardized system) are no exceptions in this approach. Like many other systems of the inorganic but also organic nature Figure 1 as well as systems in the societal area (Megill, 1977), they show a Gaussian or lognormal distribution of their single elements, if each system is divided into classification units and the number per unit via the classification quantity (normal or logarithmic) are graphically displayed.

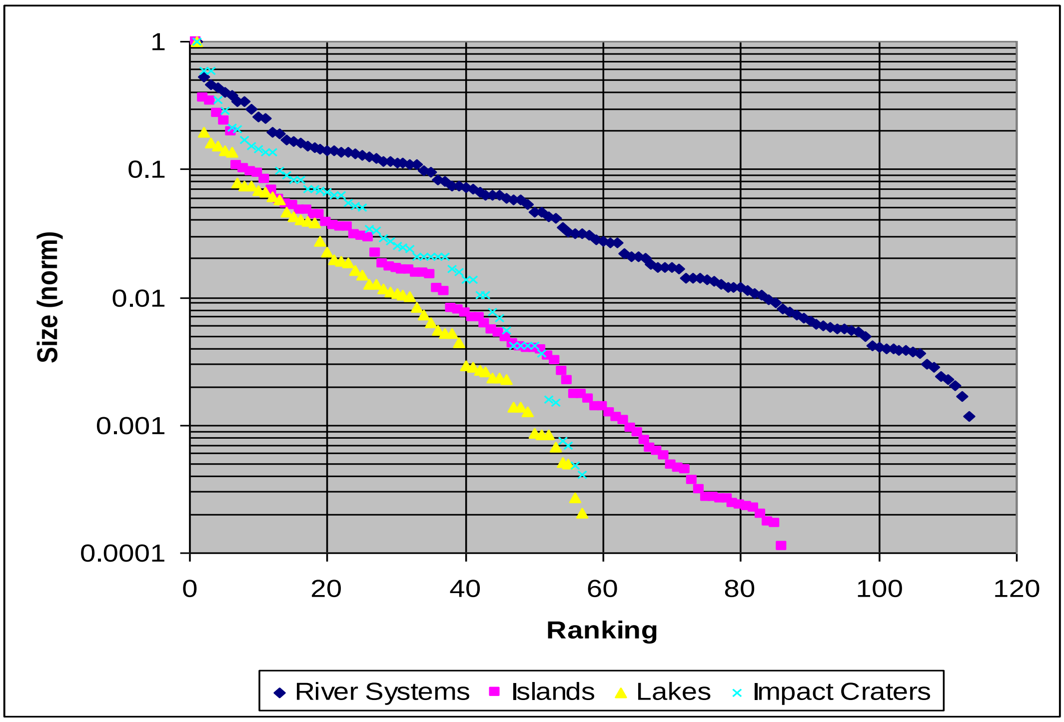


Figure 1. Lognormal behaviour of natural systems on Earth (modified from Brink (2003)).

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 2.

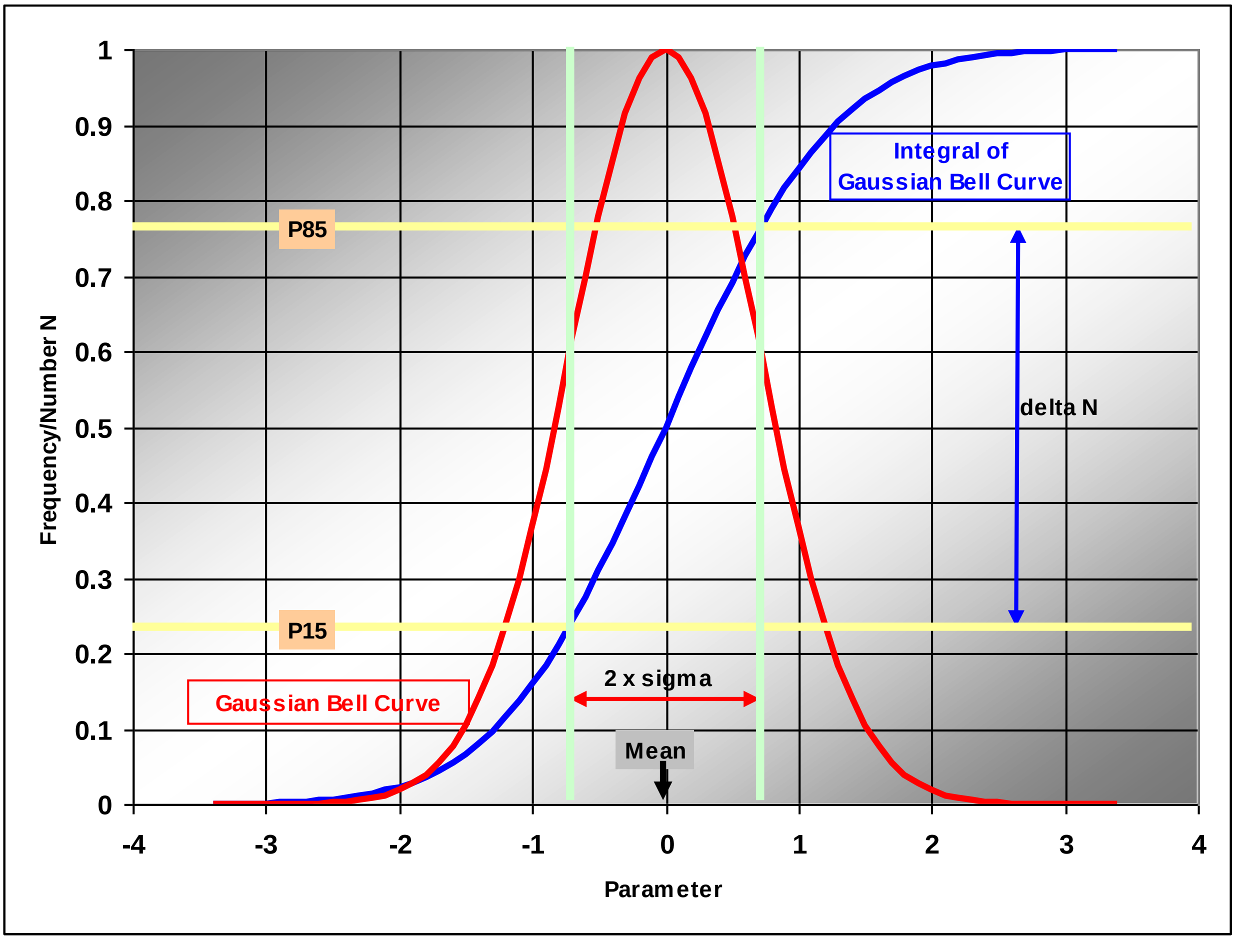


Figure 2. Gaussian bell curve parameters.

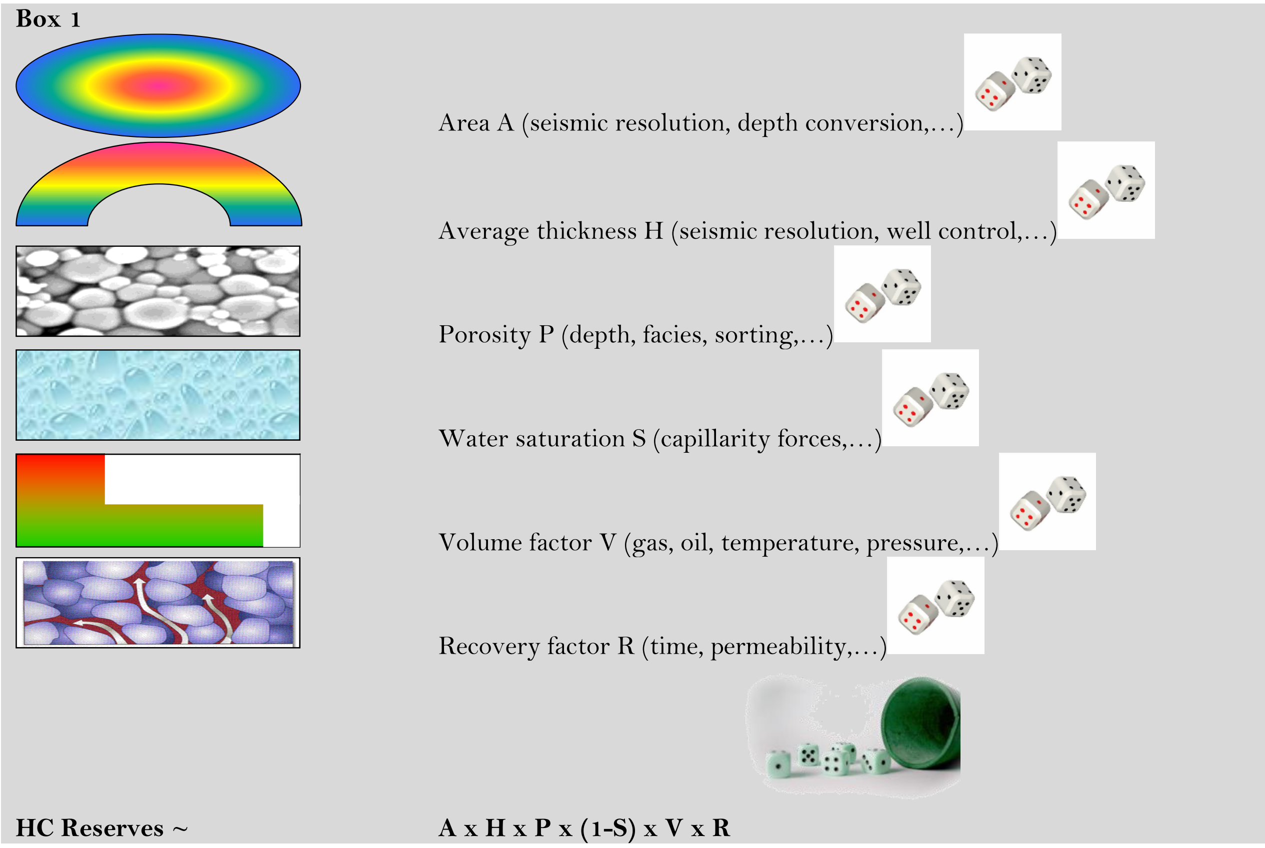
The field size distributions of hydrocarbon systems of the earth behave mainly in a lognormal manner (see below). Risks and profitability of exploration projects that contain a larger number of prospects can be estimated via the analysis of prospect size distributions (Megill, 1979).

2.2. Monte Carlo Analysis of Multiplicative Systems

Each oil accumulation belonging to a hydrocarbon system of oil fields is obviously characterized by its reserves. These reserves are determined by multiplication of factors that are related to closure area, reservoir thickness, structure height and associated geometric correction factors, net portion of the reservoir, its porosity, water saturation, and temperature- and pressure-dependent volume factors of stored hydrocarbons (Box 1). Normally, most of the parameters are independent of each other and are subject to a certain range. These ranges only allow approximations when calculating the precise reserves. When the reserves of a prospect are estimated, the estimated ranges of the single parameters are simulated using random generators, then random products are generated, and a representative mean is determined from the frequency distributions of the results. The distribution of the random products can be simply approximated via the result of a game of dice, in which each dice represents an independent parameter. For example, if 4 dices, each of which has 6 surfaces, are thrown 100 times and the 4 numbers from each throw are multiplied, a graphically linear relation in a lognormal representation can be observed.

If the experiment is repeated with dices that have a larger number of surfaces, the single products get larger, the linear trend, however, remains conserved with the same slope in the lognormal representation. This changes if the number of dices is changed. With an increasing number of dices, the slope increases in the chosen representation of the lognormal distribution and the exponential factor in the mathematical approach increases with it Figure 3.

Since the applied game of dice provides the same probability for each surface number and, this way, a rectangle distribution, while in nature, however, the Gaussian distribution curve rather applies to single parameters, an accordingly modified dice experiment shows that the slope decreases in the chosen lognormal representation when changing from rectangle to normal distribution. To realize a larger slope in a normal distribution of single parameters, the number of parameters (dices) has to be increased in such a case. The parameters that determine a single object also determine the whole system composed of these single objects. Field size distributions should thus reveal something about the sedimentary basins that house them as well.



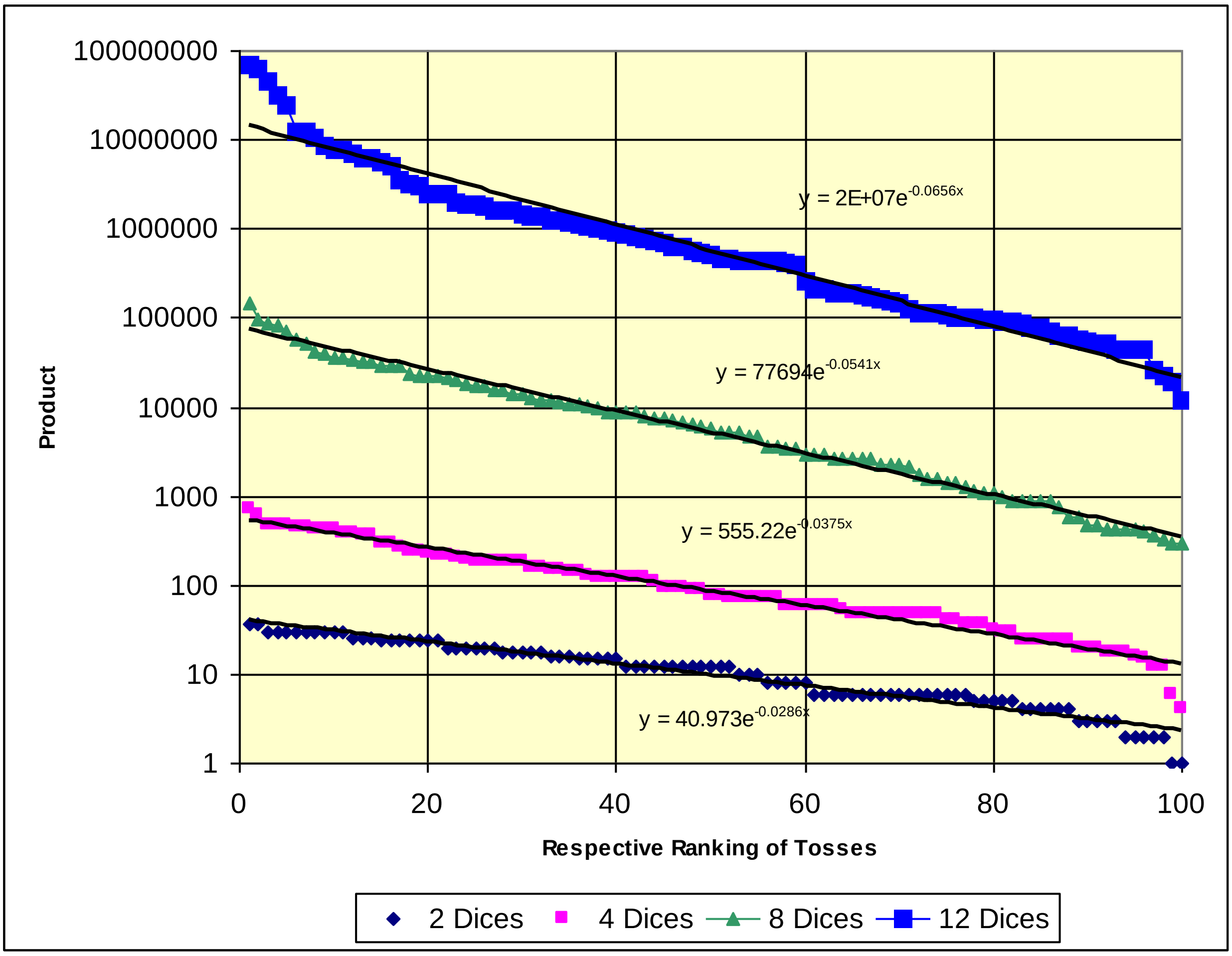


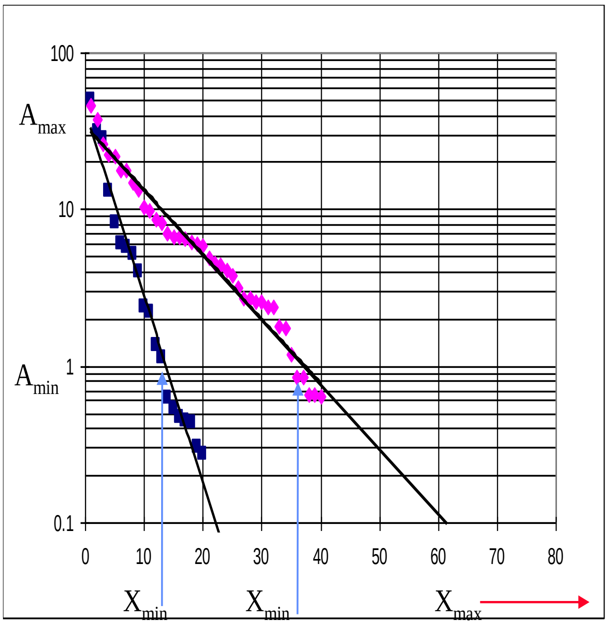
Figure 3. Tossing of variable numbers of dices.

The exponential alpha values determined for analyzed hydrocarbon systems and the minimal number of important parameters estimated from them proves the differences between analyzed hydrocarbon systems explicitly Figure 4. An estimation of the number of important (geological) parameters of a hydrocarbon system can be obtained by deducting it from the described dice experiment (Brink, 2000).

Figure 4. Relation between the number of dices and the exponential factor of the multiplicative lognormal distribution of 100 tosses with 6 face dices.

2.3. Discovery Rate

Via a mathematical simplification, a relation between the exponential alpha factor and the discovery rate of a hydrocarbon system can be derived Figure 5. When Amax is the largest field, Amin the smallest still profitable find, Xmin the number of fields, and Xmax the number of exploration wells, the discovery rate becomes reciprocally proportional to the product of the exponential factor (of distribution) and Xmax and directly proportional to the logarithm of Amax over Amin.



$$X_{min} = \text{No of Fields} > 1 \text{ BCM}$$

$$X_{max} = \text{No of Exploration Wells}$$

$$\text{Discovery Rate (DR)} = X_{min}/X_{max}$$

$$\text{Sequence of Fields: } A_{max} * \exp^{(-ax)}$$

$$A_{min}/A_{max} = \exp^{-aX_{min}}$$

$$X_{min} = 1/a * \ln(A_{max}/A_{min})$$

$$DR = \ln(A_{max}/A_{min}) /(a * X_{max})$$

Figure 5. Discovery rate (DR) and field size distribution (Brink, 2000).

3. HYDROCARBON SYSTEMS OF THE CENTRAL EUROPEAN BASIN SYSTEM (CEBS) AND OTHER BASINS

3.1. Comparison of Selected Hydrocarbon Systems

According to Klemme (1983), field size distributions (FSD) can be used for the classification of sedimentary basins. Normally, they display lognormal behavior and represent multiplicative systems, in which the number of parameters, whose multiplication leads to a field quantity, is represented by the steepness of the lognormal graph (linear approximation of the Gaussian integral). It can be shown by applying general rules of dice and their transformation into a simple approximation ('Monte Carlo inversion') that the more independent parameters (e.g. number of dices) are involved, the steeper the graph of a log-normal distribution is, e.g. for a large number of casts (Brink, 2000; Megill, 1977; Megill, 1979). For example, the size of a discovered oil or gas field can be determined by multiplication of its geometric dimensions like area and reservoir thickness, its porosity and water saturation as well as by other factors. In addition, the probable size of an oil or gas prospect can be estimated by assuming a range of numbers for those parameters and choosing e.g. the mean of a set of independent 'Monte Carlo' runs as an estimate of the most likely case.

Using an estimate of the number of relevant parameters derived via the simple 'Monte Carlo inversion' (Brink, 2000), comparisons of the field size distributions of Zechstein and Rotliegend gas fields of the Southern Permian Basin indicate different geologic complexities and, in addition, different commercial discovery probabilities. Depending on the absolute field sizes, the higher the complexity, the smaller the discovery rate will be.

The normalized gas field distributions (Salzwedel gas field excluded) in the Permian reservoirs of the Northern German Basin show a very complex Rotliegend system with a large number of independent parameters and a less complex Zechstein system. Within the Rotliegend, the British hydrocarbon system (Brink, 2010) is simpler than the

German system (Brink, 2002). A comparison of the field size distribution of the Permian fields in Poland (Zechstein and Rotliegend reservoirs together are part of one system (Bandlowa, 1998) with the German Zechstein and Rotliegend indicates an intermediate complexity that lies in between the two German distributions Figure 6.

The Dutch system of Rotliegend fields is even simpler than the British one. Extracting the necessary information from Van De Weerd (2004) and the Ministry of Economic Affairs (2002), an estimated FSD for the Rotliegend fields in the Netherlands can be derived (Box 2). In this case, the giant Groningen field has to be excluded from the field size distribution at first, as it represents a basin wide anomaly. The remaining 50 largest Rotliegend fields have a spread of a few 10's of billions cubic meters, leading to a relatively small increment between neighboring field sizes. The differences between the single regionally divided systems of the Southern Permian Basin Figure 7 are shaped considerably by the different reservoir and structure parameter distributions as well as by the variations of generation and migration of hydrocarbons due to the area dependent complex burial and thermal histories. The spread of differences may possibly define a further classification method for basins.

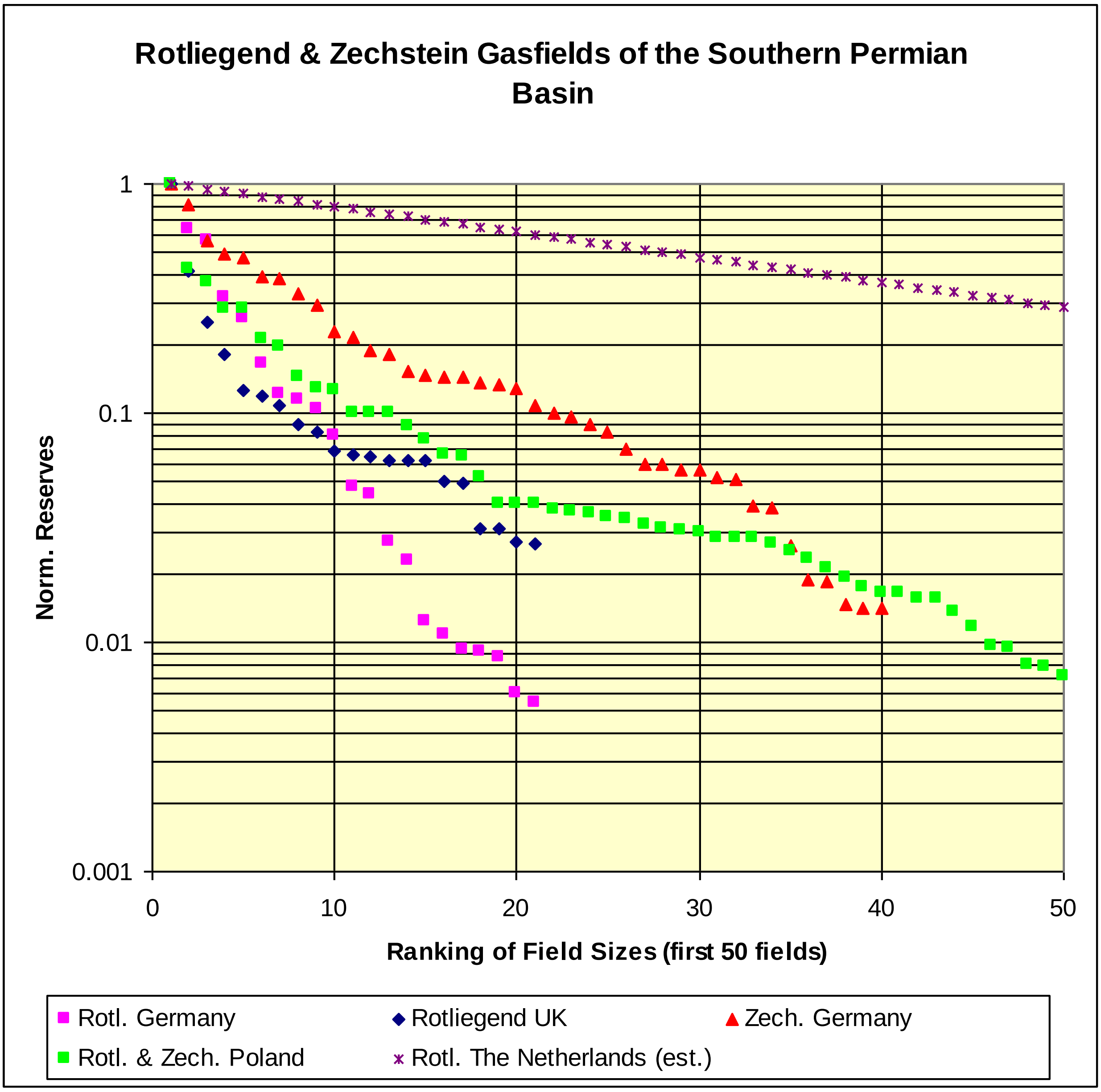


Figure 6. Field size distributions of the southern Permian basin gas systems.

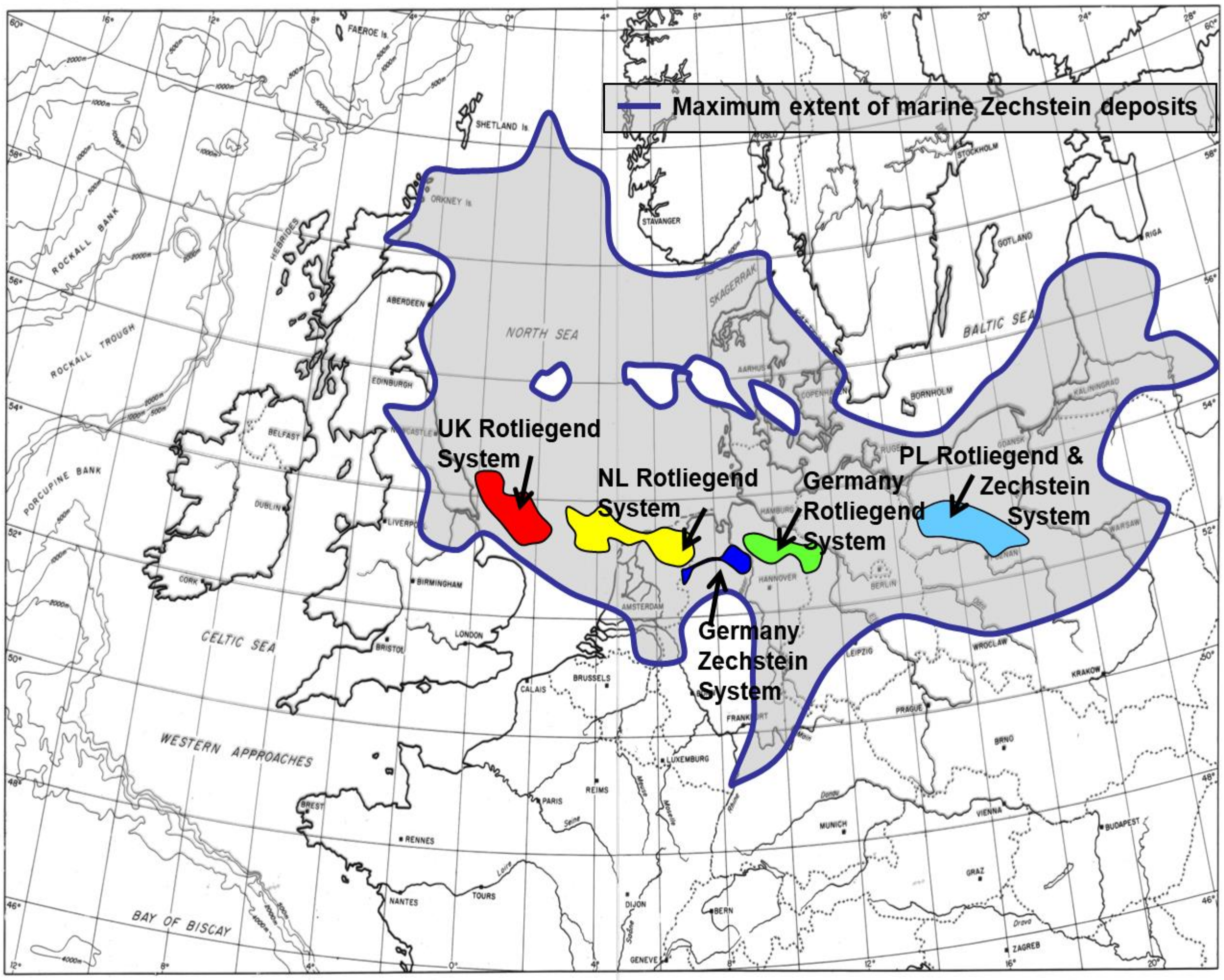


Figure 7. Gas systems of the Southern Permian Basin and their main areal extent (Basin outline after Ziegler (1990)).

Published data about the size or final total production of oilfields within the CEBS region exist e.g. for the Lower Saxony Basin (Binot, Gerling, Hiltmann, Kockel, & Wehner, 1993) and the Ekofisk region in the Central North Sea Graben (Cornford, 1994). Data on a very interesting distribution are available for the Niger delta (Thomas, 1995). As expected by following (Klemme, 1983) observation, the Nigerian delta basin is characterized by a low dip in its lognormal field size distribution, while the continental rift basin of the North Sea around Ekofisk has a high lognormal dip and the Lower Saxony Basin (Betz, Führer, Greiner, & Plein, 1987), as part of the CEBS, shows an intermediate lognormal dip Figure 8.

Comparing the CEBS on the FSD-basis with some already mentioned basins requires publicly available data on their hydrocarbon systems, preferably for a more or less mature stage of exploration. Assuming lognormal distributions of discovered oil and gas fields per hydrocarbon system as generally observed, the analytical lognormal coefficients or discrete geometrical series attributes, respectively, can approximately be calculated, should essential information on the total reserves, the number of fields, some field sizes and their ranking within the system be available.

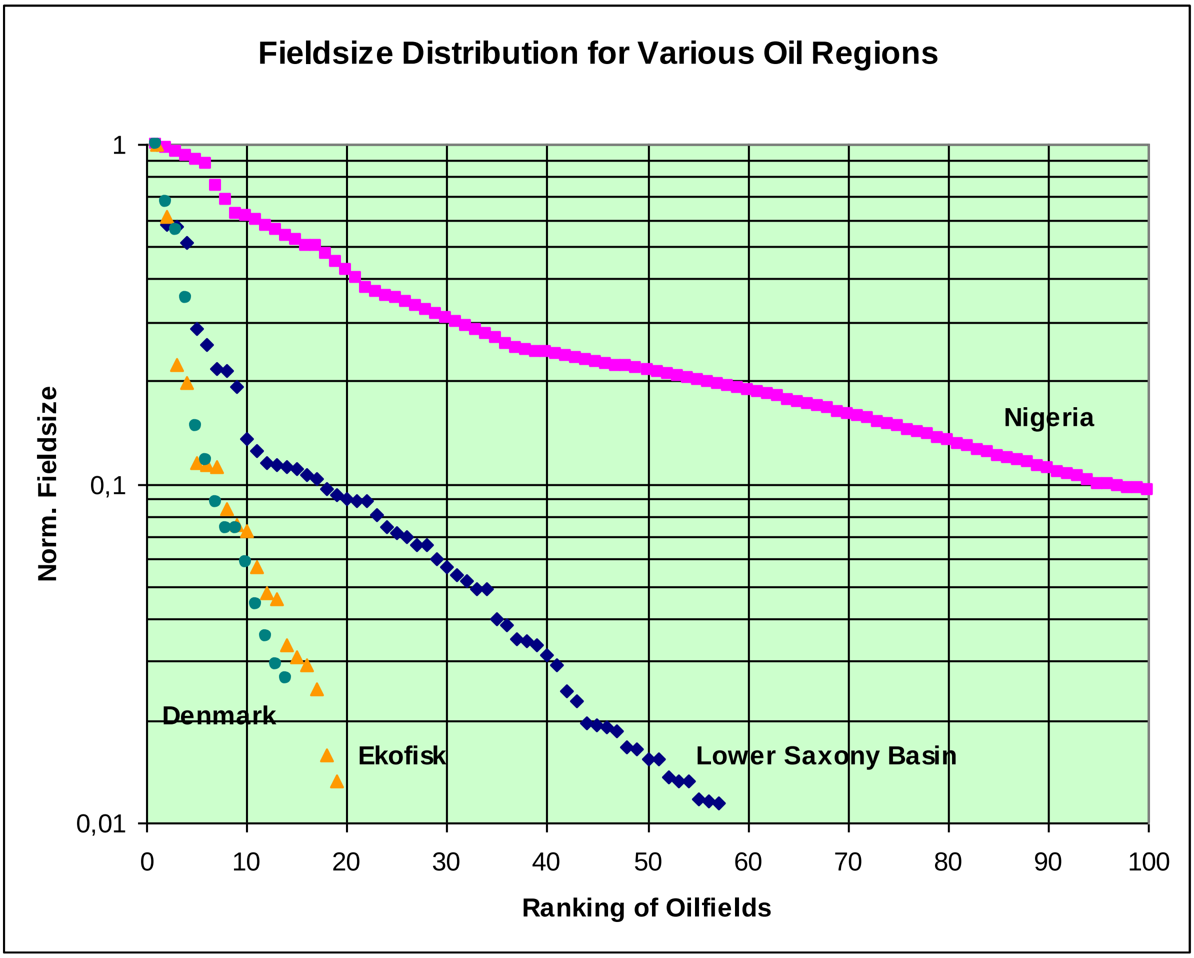


Figure 8. Field size distributions of some selected oil systems.

This data can be extracted for the West Siberia Basin (Ulmishek, 2003), the Timan-Pechora Basin (Lindquist, 1999), the Dnieper-Donets Basin (Ulmishek, 2001), and the Sirte Basin (Ahlbrandt, 2001). The normalized FSDs for the hydrocarbon systems of these basins are displayed in Figure 9. For each hydrocarbon system, the quotient of the sizes of two adjacent ranked members within the field size distribution is assumed constant (declining geometric series, exponential decay). However, applying this concept to field sizes in an early stage of exploration can certainly lead to a wrong characterization of a hydrocarbon system. In those cases, it will be helpful to use prospect size distributions, adjusted to the expected discovery rate by taking similar hydrocarbon systems for calibration purposes.

A compilation of the coefficients of the evaluated hydrocarbon systems is presented in Table 1. In the fourth column, an estimate is given for the number of ruling independent parameters for each system, following the 'Monte Carlo inversion' approach as outlined by Brink (2000). Following this classification, simple systems with less than 20 independent parameters are certainly the Rotliegend Gas System in the Netherlands, the Oil System in Nigeria, and the Timan-Pechora Oil & Gas system. Germany Rotliegend Gas, North Sea Ekofisk Oil, Sirte South East Oil & Gas, Donets Oil & Gas, and the two West Siberia Oil and Gas systems, all with more than 70 independent parameters, can be characterized as complex to very complex. All the others are moderately complex.

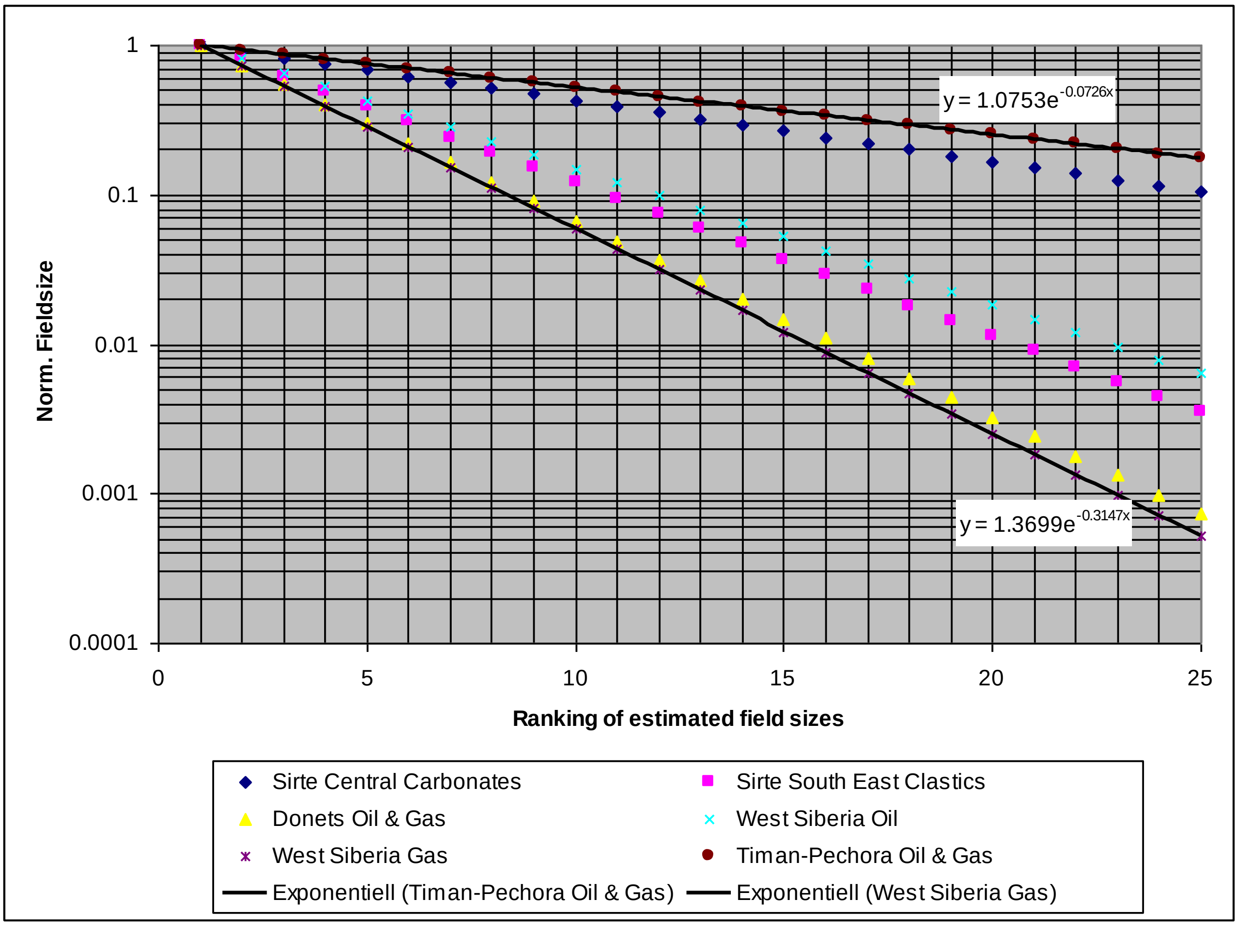


Figure 9. Estimated Field Size Distributions of some selected important gas & oil systems.

The CEBS as one composed entity contains a variable set of simple to complex hydrocarbon systems within its Permian Gas Reservoirs. Despite a high complexity, the commercial discovery rate for the West Siberian fields is most likely high, since the rate is dependent on the absolute field sizes as well.

Table 1. Selected hydrocarbon systems, their FSD exponential decay coefficient and geometric series attribute, and the estimated number of 'unknowns'.

Hydrocarbon System	Exponential Decay Coefficient α	Geometric Series Attribute k = exp(-α)	Estimated Number of Ruling Independent Parameters
Germany Rotliegend Gas	0.264	0.77	90
UK Rotliegend Gas	0.134	0.87	50
NL Rotliegend Gas	0.0253	0.98	10
PL Zechstein & Rotliegend Gas	0.0843	0.92	30
Germany Zechstein Gas	0.0949	0.91	40
Germany LSB Oil	0.0827	0.92	30
North Sea Ekofisk Oil	0.2143	0.81	75
Nigeria Oil	0.0211	0.98	10
Sirte Central Carbonates Oil & Gas	0.0943	0.91	40
Sirte South East Clastics Oil & Gas	0.2357	0.79	85
Donets Oil & Gas	0.3011	0.74	110
West Siberia Oil	0.2107	0.81	75
West Siberia Gas	0.3147	0.73	115
Timan-Pechora Oil & Gas	0.0726	0.93	20

Box 2

Geometrical series: $A_n = A_1 * k^{n-1}$ (n = 1,2,..) ~ $A_0 * e^{-\alpha n}$ (n=0,1,), $\ln(k) = -\alpha$, Sum $S_n = A_1/(1-k)$ for n -> ∞

Abbreviations: BB = Billion (10^9) Barrel, BBOE = Billion Barrel Oil Equivalent, TCF = Trillion Cubic Feet

Sirte Central Carbonates O&G:	9 fields > 0.5 BB, 28 fields > 0.1 BB, 19 fields: 0.5 – 0.1 BB, A_{10} = 0.5 BB, A_{28} = 0.1 BB, $A_{10}/A_{28} = 5 = k^9/k^{27} = k^{-18}$, $k^{-1} = \sqrt[18]{5}$, >> k = 0.91
Sirte Southeast Clastics O&G:	Sum ~ 21 BB, A_1 = 4.5 BB, >> k = 0.79
Donets Oil & Gas:	Sum ~ 11.5 BBOE, A_1 = 18 TCF = 2.94 BBOE, >> k = 0.74
West Siberian Oil:	Sum ~ 144 BB, A_1 = 27 BB, >> k = 0.81
West Siberian Gas:	Sum ~ 1300 TCF, A_1 = 350 TCF, >> k = 0.73
Timan-Pechora Oil & Gas:	Sum (n = 4 – 223) ~ 14 BBOE, A_4 ~ 1 BBOE (A_1 ~ 3 BBOE, sum A_1 - A_3 = 6 BBOE, >> k = 0.93
NL Rotliegend Gas:	Sum (without Groningen) ~ $1624*10^9m^3$, Rotliegend (70%) = $1134*10^9m^3$, No. of fields w/o Groningen = 352, small fields (< $2*10^9m^3$) = 184 with approx. $184*10^9m^3$ (Rotliegend 70 % = $129*10^9m^3$), No. of Rotliegend fields larger than 2* 10^9m^3 = ~ 120 (70% of 168 fields > $2*10^9m^3$), Rotliegend reserves = 1134 – 120 = 1005 (10^9m^3), 70 fields 2-6 (10^9m^3) ~ 4(Ø)*70 = 280 (10^9m^3), >>50 fields > $6*10^9m^3$ = 725(10^9m^3) ~ $A_1/(1-k)$, with A_{50} ~6 >> A_1 ~ approx. 25 and k = 0.98

The analysis of the general basin development of the CEBS and its classification will become more complicated should essential events during its evolution require a substantially different view that is not addressed in the current basin classification systems. One of these essential events is certainly the origin of the Southern Permian Basin.

Between the Ems and Weser rivers in Northwest Germany, natural gas is exploited from two reservoir rocks of the Late Permian basal Zechstein carbonate and the Early Triassic Middle Buntsandstein lying on top of each other whereat the location of the fields is nearly congruent Figure 10 (Plein, 1985; Reinicke, 2002). East of the Weser River, gas is found in the sandstones of the Early Permian Rotliegend. Zechstein und Rotliegend plays experience some similarities. Both reservoirs are charged by Carboniferous coals and sealed by Zechstein evaporates. Additionally, their burial histories are quite similar. As obvious from the map of Figure 10, no Buntsandstein gas fields are present east of the Weser River. Either the Zechstein evaporates have been a perfect seal for the Rotliegend reservoirs underneath for a very long period of time or discharged Rotliegend gas has migrated into still undetected traps or escaped directly to the surface.

3.2. Natural Gas Fields in Northwest Germany

West of the Weser River, where Zechstein and Buntsandstein gas fields are more or less stacked on each other, a genetic connection appears obvious, even if the natural gas is contaminated by sulphurous compounds in Zechstein but not in Buntsandstein. Both reservoirs are sealed up by superimposed salt layers. The natural gas stored in them comes mainly from the coal beds of the Carboniferous (see (Gerling, Kockel, & Krull, 1999; Schoell, 1984)), which have experienced a burial history in Northwest Germany (Cimmerian inversion included) as portrayed in Figure 11 in a generalized manner (Gerling et al., 1999; Neunzert, Gaupp, & Littke, 1996).

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 (Gerling et al., 1999; Schoell, 1984). From the amounts of natural gas already produced in the meantime [Zechstein > 120 billion m3, Buntsandtein > 80 billion m3 (Kosinowski, Porth, & Sedlacek, 1997)], added to the estimated remaining reserves [Zechstein ~ 130 billion m3 (~ 39% of the total reserves), Buntsandstein ~ 30 billion m3 (~ 10%) (Pasternak, 1999)], separately for both reservoirs in each case, a Zechstein – Buntsandstein ratio of ~ 2.3 of the total reserves can be calculated. On the assumption that the recovery factors are comparable for both reservoirs, this value also applies to the total amounts of the stored natural gas.

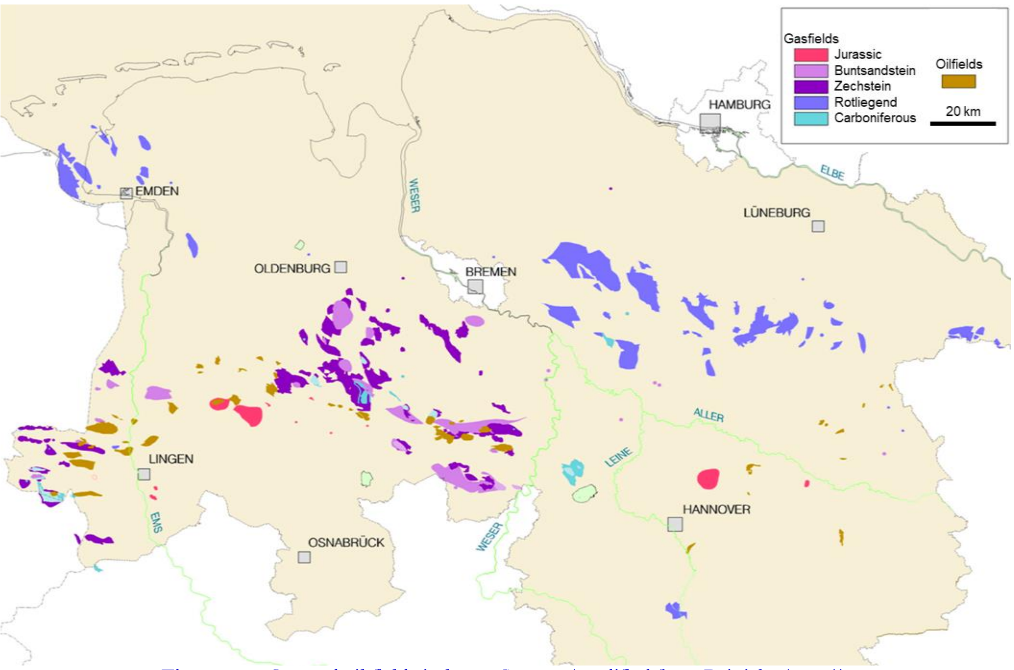


Figure 10. Gas and oil fields in lower Saxony (modified from Reinicke (2002)).

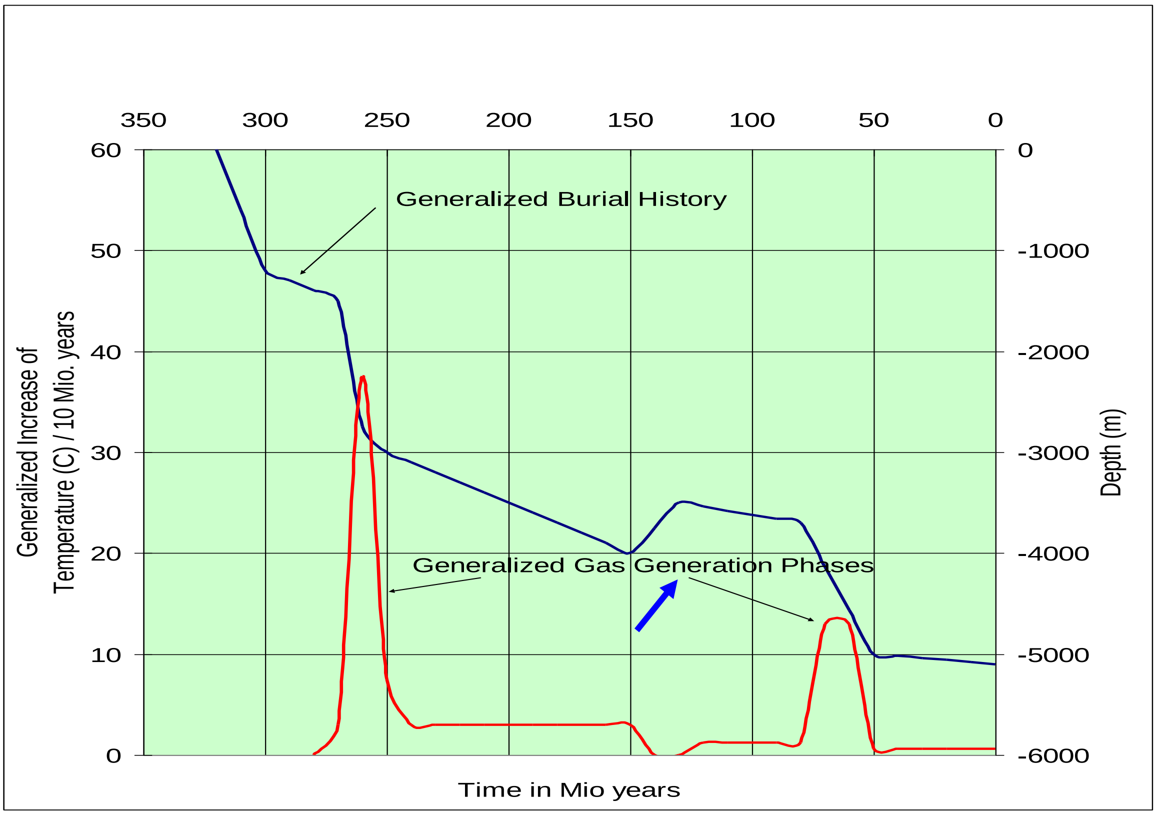


Figure 11. Generalized gas generation phases of the North German Basin (Brink, 2002), Cimmerian inversion indicated (blue arrow).

3.3. Zechstein-Buntsandstein Hydrocarbon System

Under the assumption of a relatively fast proceeding natural gas generation phase in the coals of the Upper Carboniferous and an almost immediately following charge of the Zechstein reservoirs, the Zechstein will subsequently discharge exponentially according to the Miller (1992) , whereas the half-life is still unknown for the time being. This discharge certainly will not proceed continually, but will be geared to tectonic processes as it is also observed today in the Circum-Pacific zone and the Alpine fold-belt (Wilson, Monaghan, Osanik, Price, & Rogers, 1974). Even if it does not completely consider the processes probably running episodically, it is being attempted here, in a generalizing manner, to depict a discontinuously proceeding discharge mathematically via an exponential curve. The discharge of the Zechstein will lead to the charge of the Buntsandstein reservoirs lying above it, whereby a part neglected here possibly reaches the earth's surface directly. The charge of the Buntsandstein does not happen in a short time for this reason, but drags on for a longer period. The discharge process of Buntsandstein starts simultaneously with the charge. To keep the possible mathematical complexity limited, it is assumed that the Middle Buntsandstein (because of its sealing by a salt layer (Rötsalz)) has a half-life comparable to the Zechstein. The mathematical approach for the Zechstein discharge, the Buntsandstein filling rate, the Buntsandstein reserves, and the Buntsandstein discharge is displayed in Figure 12. The curves were calculated numerically as function of the half-life and interpolated for the values lying in between. From the ratio of the time-dependent filling quantities of Zechstein and Buntsandstein, one can determine how today values and the half-life of the Zechstein-Buntsandstein system relate to one another Figure 13. From the observation presented above, that the last generation phase and filling happened in Northwest Germany about 50 million years ago, one can conclude a half-life of about 60 million years. This value is twice as much as the global value of about 30 million years for crude oil. In this case, the larger fugacity of natural gas probably gets more than balanced through the excellent properties of the salts in Northwest Germany in sealing fluids. If the deduced value also applies to the first generation phase of ~ 240 million years ago, there would only be remainders of the first methane filling of less than 10% contained in the Zechstein reservoirs. The value for the Buntsandstein reservoirs would probably be ~30%, which might contribute to the slightly different gas and isotope composition of these gases. If the reserves specified above get reduced by the amount of the first filling phase, a proportion between Zechstein and Buntsandtein gas of 225/80 = 2.8 results for the second filling phase, which would only cause an insignificant change of the half-life according to the analysis of Figure 13. If the Buntsandstein fields genetically relate to those of the Zechstein lying below, as it is assumed here, and if one regards them as multiplicative system in their entirety, sorted by size, their field size distribution has to point to a higher complexity compared to Zechstein as well. Additional parameters dependent on the Zechstein discharge define their reserve amounts (Brink, 2000). The field size distributions of both reservoirs presented in Figure 14 confirm this assumption, because, compared to Zechstein, the Buntsandstein indicates a considerably higher, complexity symbolizing slope in the lognormal presentation – here in a selection of larger fields (Kosinowski et al., 1997).

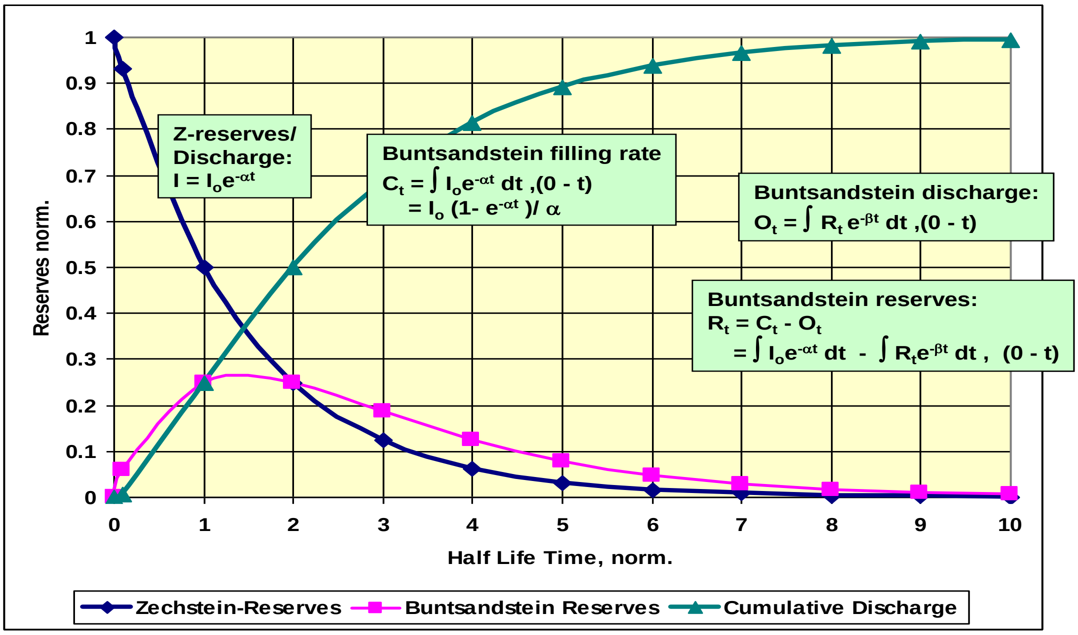


Figure 12. Normalized gas reserves, Zechstein discharge, Buntsandstein charge/discharge.

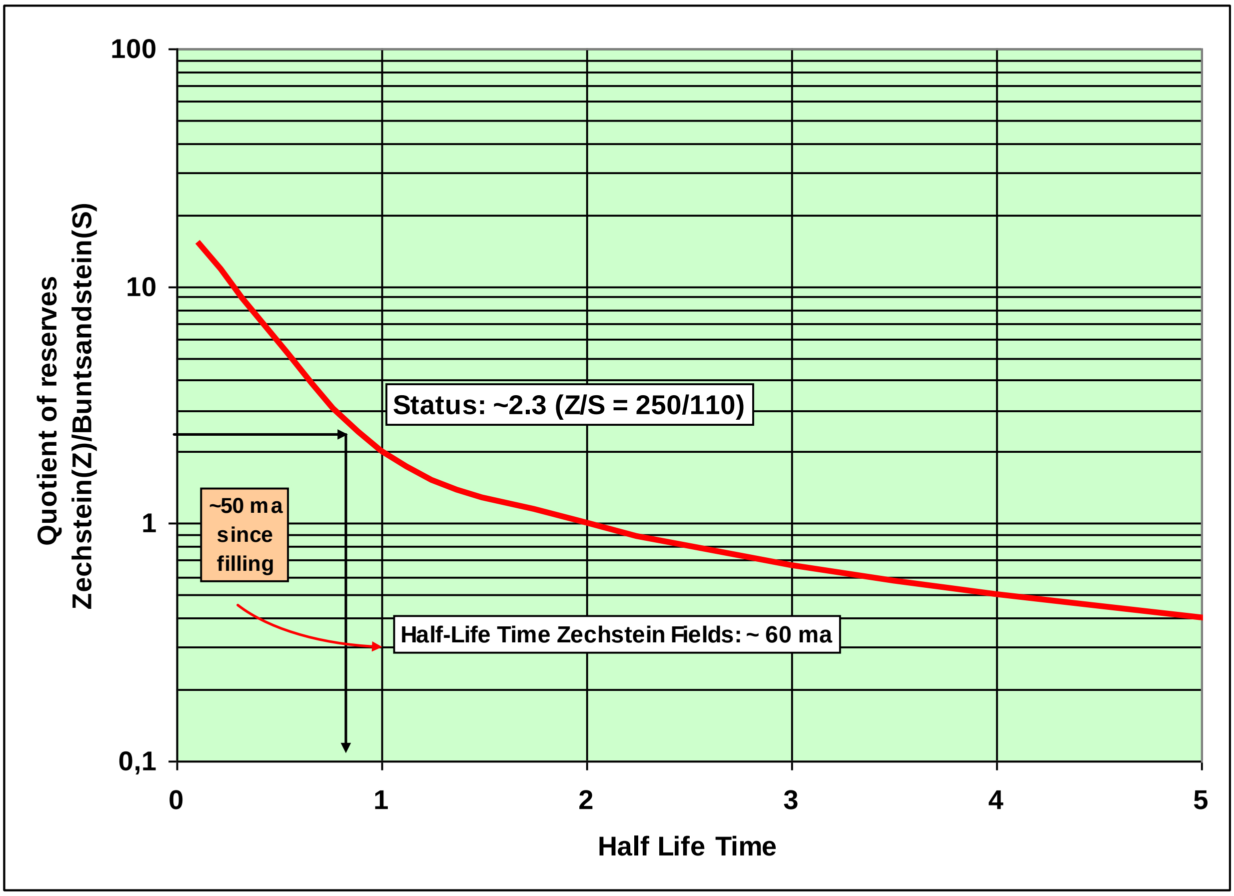


Figure 13. Quotient of Zechstein and Buntsandstein reserves vs. Half-Life Time.

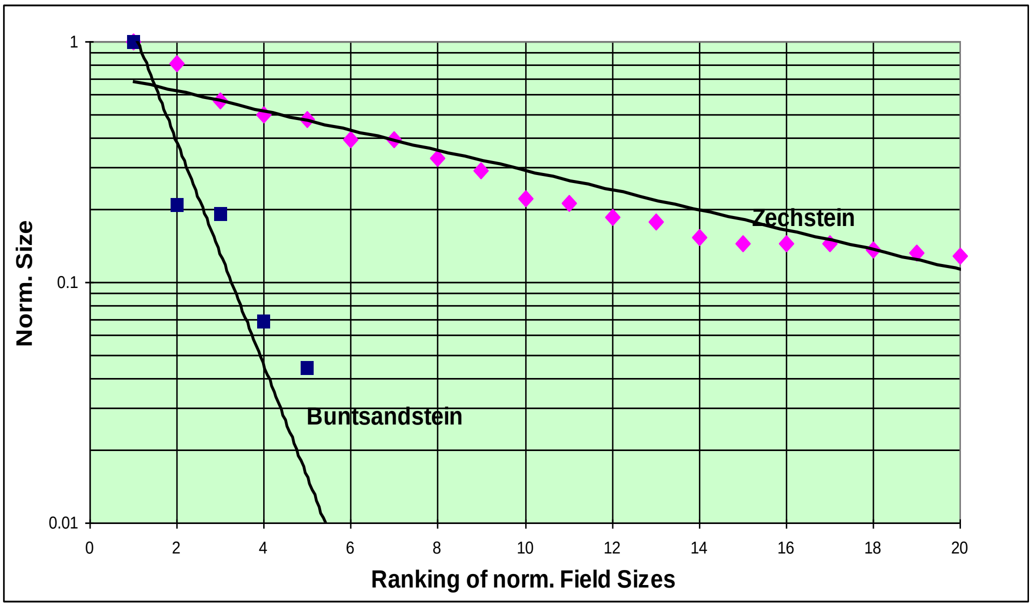


Figure 14. Field size distributions of Zechstein and Buntsandstein gas fields in Northwest Germany.

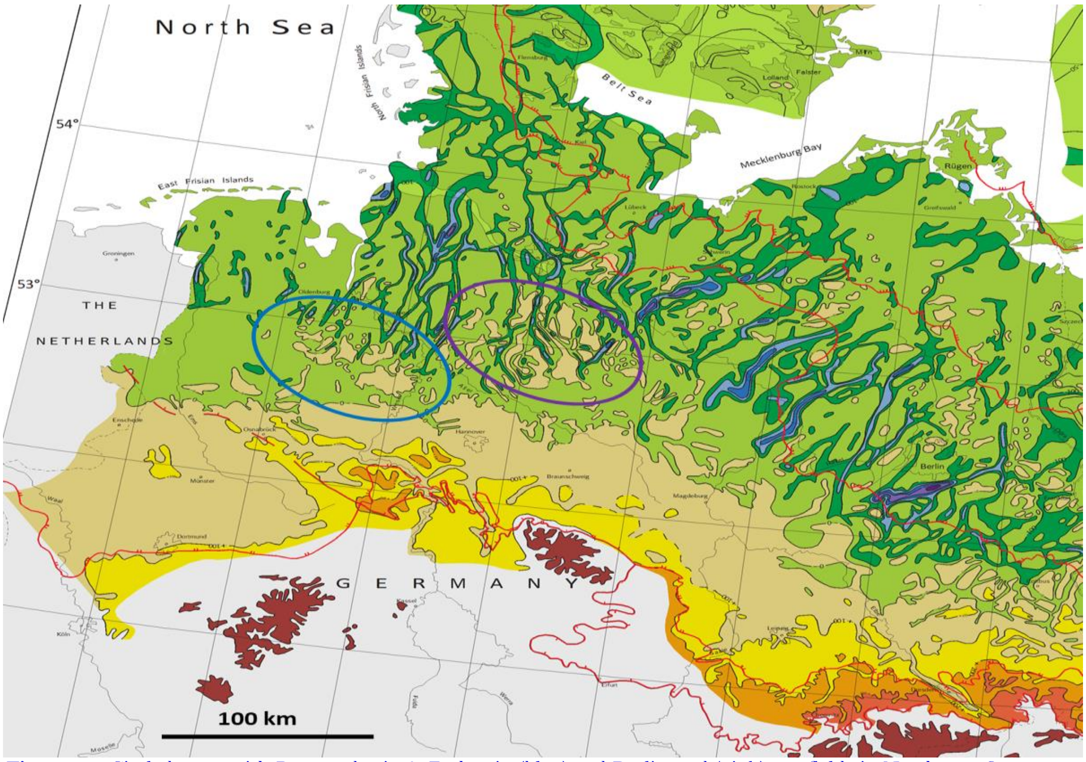


Figure 15. Circled areas with Buntsandstein & Zechstein (blue) and Rotliegend (pink) gas fields in Northwest Germany (see Figure 10) and cut-out of the Quaternary base map after (Geological Survey of Brandenburg, 1998) (green to blue colours: deep, brown to yellow colours: high).

Zechstein and Rotliegend Play areas are characterized by a Quaternary base above sea level, pointing to a very recent uplift, and possibly as fore bulge in front of the ice age glaciers coming from the Northeast Figure 15. This may have resulted in a concentration effect for migrating gas in very young times including a possible discharge of former peripheral accumulations. Since the last gas generation peak occurred at the end of the Cretaceous (Figure 11), no relationship may exist between the timing of generation and the accumulation in the 'recently' uplifted area. A similar uplift during the successive Tertiary could not be verified.

4. CONCLUSION

The CEBS may act as an analogue for hybrid, multicycle, polyphase, complex and stacked continental basins containing multi-parameter hydrocarbon systems. These hydrocarbon systems with their variable number of parameters (world of dices) may act as an example of a macroscopic play with dices despite Einstein's quota and reflect essential properties of

- Basin forming tectonics, e.g. related to thermal effects of plumes that rise from the Earth's core-mantle boundary (subsequent rock volume change due to metamorphism of the middle and lower crust) (Brink, 2005; Brink, 2009),
- Celestially overprinted sedimentary fills (e.g. by climate control through astronomical cycles with different periods and phase shifts) (Brink, 2006; Brink, 2015),
- Modifying tectonics on local and regional scales (e.g. halokinesis, rifting, inversion tectonics) (Brink, 2010; Brink, 2021) with
- Fluid re-distributions due to differential loads (e.g. by glaciations and a mighty deltaic river system) (Brink, 2010),
- And geo-laboratory conditions.

The geological history of the global sedimentary basin system, imaged for a significant time by the CEBS, can be used at least for the Phanerozoic period as one record for studying the evolution of the Earth.

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 independent parameters. The Dutch Rotliegend Play for comparison can be characterized by only 10 parameters and is therefore of a simple type.

Epilogue

Thales:

(J.W.v.Goethe, Faust II)

Nature with all her living, flowing powers
Was never bound by day and night and hours.
By rule she fashions every form, and hence
In great things too there is no violence.

Translation by George Madison Priest

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